the launch vehicle has a land or water impact. These procedures must include the following provisions:

(1) Evacuation and rescue of members of the public, to include modeling the dispersion and movement of toxic plumes, identification of areas at risk, and communication with local government authorities;

(2) Extinguishing fires;

(3) Securing impact areas to ensure that personnel and the public are evacuated, and ensure that no unauthorized personnel or members of the public enter, and to preserve evidence; and

(4) Ensuring public safety from hazardous debris, such as plans for recovery and salvage of launch vehicle debris and safe disposal of hazardous materials.

§ 417.417 Propellants and explosives.

(a) A launch operator must comply with the explosive safety criteria in part 420 of this chapter.

(b) A launch operator must ensure that:

(1) The explosive site plan satisfies part 420 of this chapter;

(2) Only those explosive facilities and launch points addressed in the explosive site plan are used and only for their intended purpose; and

(3) The total net explosive weight for each explosive hazard facility and launch point must not exceed the maximum net explosive weight limit indicated on the explosive site plan for each location.

(c) A launch operator must establish, maintain, and perform procedures that ensure public safety for the receipt, storage, handling, inspection, test, and disposal of explosives.

(d) A launch operator must establish and maintain each procedural system control to prevent inadvertent initiation of propellants and explosives. These controls must include the following:

(1) Protect ordnance systems from stray energy through methods of bonding, grounding, and shielding, and controlling radio frequency radiation sources in a radio frequency radiation exclusion area. A launch operator must determine the vulnerability of its electro-explosive devices and systems to radio frequency radiation and establish radio frequency radiation power limits or radio frequency radiation exclusion areas as required by the launch site operator or to ensure safety.

(2) Keep ordnance safety devices, as required by § 417.409, in place until the launch complex is cleared as part of the final launch countdown. No members of the public may re-enter the complex until each safety device is reestablished.

(3) Do not allow heat and spark or flame producing devices in an explosive or propellant facility without written approval and oversight from a launch operator's safety organization.

(4) Do not allow static producing materials in close proximity to solid or liquid propellants, electro-explosive devices, or systems containing flammable liquids.

(5) Use fire safety measures including:

(i) Elimination or reduction of flammable and combustible materials;

(ii) Elimination or reduction of ignition sources;

(iii) Fire and smoke detection systems;

(iv) Safe means of egress; and

(v) Timely fire suppression response.

(6) Include lightning protection on each facility used to store or process explosives to prevent inadvertent initiation of propellants and explosives due to lightning unless the facility complies with the lightning protection criteria of § 420.71 of this part.

(e) A launch operator, in the event of an emergency, must perform the accident investigation plan as defined in § 417.111(h).

APPENDIX A TO PART 417—FLIGHT SAFETY ANALYSIS METHODOLOGIES AND PRODUCTS FOR A LAUNCH VEHICLE FLOWN WITH A FLIGHT SAFETY SYSTEM

A417.1 SCOPE

The requirements of this appendix apply to the methods for performing the flight safety analysis required by § 417.107(f) and subpart C of this part. The methodologies contained in this appendix provide an acceptable means of satisfying the requirements of subpart C and provide a standard and a measure of fidelity against which the FAA will measure any proposed alternative analysis approach. This appendix also identifies the analysis products that a launch operator must file with the FAA as required by §417.203(e).

A417.3 APPLICABILITY

The requirements of this appendix apply to a launch operator and the launch operator's flight safety analysis unless the launch operator clearly and convincingly demonstrates that an alternative approach provides an equivalent level of safety. If a Federal launch range performs the launch operator's analysis, §417.203(d) applies. Section A417.33 applies to the flight of any unguided suborbital launch vehicle that uses a wind-weighting safety system. All other sections of this appendix apply to the flight of any launch vehicle required to use a flight safety system as required by §417.107(a). For any alternative flight safety system approved by the FAA as required by §417.301(b), the FAA will determine the applicability of this appendix during the licensing process.

A417.5 GENERAL

A launch operator's flight safety analysis must satisfy the requirements for public risk management and the requirements for the compatibility of the input and output of dependent analyses of §417.205.

A417.7 TRAJECTORY

(a) *General.* A flight safety analysis must include a trajectory analysis that satisfies the requirements of §417.207. This section applies to the computation of each of the trajectories required by §417.207 and to each trajectory analysis product that a launch operator must file with the FAA as required by §417.203(e).

(b) *Wind standards.* A trajectory analysis must incorporate wind data in accordance with the following:

(1) For each launch, a trajectory analysis must produce ''with-wind'' launch vehicle trajectories pursuant to paragraph (f)(6) of this section and do so using composite wind profiles for the month that the launch will take place or composite wind profiles that are as severe or more severe than the winds for the month that the launch will take place.

(2) A composite wind profile used for the trajectory analysis must have a cumulative percentile frequency that represents wind conditions that are at least as severe as the worst wind conditions under which flight would be attempted for purposes of achieving the launch operator's mission. These worst wind conditions must account for the launch vehicle's ability to operate normally in the presence of wind and accommodate any flight safety limit constraints.

(c) *Nominal trajectory.* A trajectory analysis must produce a nominal trajectory that describes a launch vehicle's flight path, position and velocity, where all vehicle aerodynamic parameters are as expected, all vehicle internal and external systems perform exactly as planned, and no external perturbing influences other than atmospheric drag and gravity affect the launch vehicle.

(d) *Dispersed trajectories.* A trajectory analysis must produce the following dispersed trajectories and describe the distribution of a launch vehicle's position and velocity as a function of winds and performance error parameters in the uprange, downrange, left-crossrange and right-crossrange directions.

(1) *Three-sigma maximum and minimum performance trajectories.* A trajectory analysis must produce a three-sigma maximum performance trajectory that provides the maximum downrange distance of the instantaneous impact point for any given time after lift-off. A trajectory analysis must produce a three-sigma minimum performance trajectory that provides the minimum downrange distance of the instantaneous impact point for any given time after lift-off. For any time after lift-off, the instantaneous impact point dispersion of a normally performing launch vehicle must lie between the extremes achieved at that time after lift-off by the three-sigma maximum and three-sigma minimum performance trajectories. The three-sigma maximum and minimum performance trajectories must account for wind and performance error parameter distributions as follows:

(i) For each three-sigma maximum and minimum performance trajectory, the analysis must use composite head wind and composite tail wind profiles that represent the worst wind conditions under which a launch would be attempted as required by paragraph (b) of this section.

(ii) Each three-sigma maximum and minimum performance trajectory must account for all launch vehicle performance error parameters identified as required by paragraph (f)(1) of this section that have an effect upon instantaneous impact point range.

(2) *Three-sigma left and right lateral trajectories.* A trajectory analysis must produce a three-sigma left lateral trajectory that provides the maximum left crossrange distance of the instantaneous impact point for any time after lift-off. A trajectory analysis must produce a three-sigma right lateral trajectory that provides the maximum right crossrange distance of the instantaneous impact point for any time after lift-off. For any time after lift-off, the instantaneous impact point dispersion of a normally performing launch vehicle must lie between the extremes achieved at that time after liftoff by the three-sigma left lateral and three-sigma right lateral performance trajectories. The three-sigma lateral performance trajectories must account for wind and performance error parameter distributions as follows:

(i) In producing each left and right lateral trajectory, the analysis must use composite left and composite right lateral-wind profiles that represent the worst wind conditions under which a launch would be attempted as required by paragraph (b) of this section.

(ii) The three-sigma left and right lateral trajectories must account for all launch vehicle performance error parameters identified as required by paragraph (f)(1) of this section that have an effect on the lateral deviation of the instantaneous impact point.

(3) *Fuel-exhaustion trajectory.* A trajectory analysis must produce a fuel-exhaustion trajectory for the launch of any launch vehicle with a final suborbital stage that will terminate thrust nominally without burning to fuel exhaustion. The analysis must produce the trajectory that would occur if the planned thrust termination of the final suborbital stage did not occur. The analysis must produce a fuel-exhaustion trajectory that extends either the nominal trajectory taken through fuel exhaustion of the last suborbital stage or the three-sigma maximum trajectory taken through fuel exhaustion of the last suborbital stage, whichever produces an instantaneous impact point with the greatest range for any time after liftoff.

(e) *Straight-up trajectory.* A trajectory analysis must produce a straight-up trajectory that begins at the planned time of ignition, and that simulates a malfunction that causes the launch vehicle to fly in a vertical or near vertical direction above the launch point. A straight-up trajectory must last no less than the sum of the straight-up time determined as required by section A417.15 plus the duration of a potential malfunction turn determined as required by section A417.9(b)(2).

(f) *Analysis process and computations.* A trajectory analysis must produce each three-sigma trajectory required by this appendix using a six-degree-of-freedom trajectory model and an analysis method, such as root sum-square or Monte Carlo, that accounts for all individual launch vehicle performance error parameters that contribute to the dispersion of the launch vehicle's instantaneous impact point.

(1) A trajectory analysis must identify all launch vehicle performance error parameters and each parameter's distribution to account for all launch vehicle performance variations and any external forces that can cause offsets from the nominal trajectory during normal flight. A trajectory analysis must account for, but need not be limited to, the following performance error parameters:

(i) Thrust;

(ii) Thrust misalignment;

(iii) Specific impulse;

(iv) Weight;

(v) Variation in firing times of the stages;

(vi) Fuel flow rates;

(vii) Contributions from the guidance, navigation, and control systems;

(ix) Steering misalignment; and

(x) Winds.

(2) Each three-sigma trajectory must account for the effects of wind from liftoff through the point in flight where the launch vehicle attains an altitude where wind no longer affects the launch vehicle.

(g) *Trajectory analysis products.* The products of a trajectory analysis that a launch operator must file with the FAA include the following:

(1) *Assumptions and procedures.* A description of all assumptions, procedures and models, including the six-degrees-of-freedom model, used in deriving each trajectory.

(2) *Three-sigma launch vehicle performance error parameters.* A description of each three-sigma performance error parameter accounted for by the trajectory analysis and a description of each parameter's distribution determined as required by paragraph (f)(1) of this section.

(3) *Wind profile.* A graph and tabular listing of each wind profile used in performing the trajectory analysis as required by paragraph (b)(1) of this section and the worst case winds required by paragraph (b)(2) of this section. The graph and tabular wind data must provide wind magnitude and direction as a function of altitude for the air space regions from the Earth's surface to 100,000 feet in altitude for the area intersected by the launch vehicle trajectory. Altitude intervals must not exceed 5000 feet.

(4) *Launch azimuth.* The azimuthal direction of the trajectory's ''X-axis'' at liftoff measured clockwise in degrees from true north.

(5) *Launch point.* Identification and location of the proposed launch point, including its name, geodetic latitude, geodetic longitude, and geodetic height.

(6) *Reference ellipsoid.* The name of the reference ellipsoid used by the trajectory analysis to approximate the average curvature of the Earth and the following information about the model:

(i) Length of semi-major axis;

(ii) Length of semi-minor axis;

(iii) Flattening parameter;

(iv) Eccentricity;

(v) Gravitational parameter;

(vi) Angular velocity of the Earth at the equator; and

(vii) If the reference ellipsoid is not a WGS–84 ellipsoidal Earth model, the equations that convert the filed ellipsoid information to the WGS–84 ellipsoid.

(7) *Temporal trajectory items.* A launch operator must provide the following temporal trajectory data for time intervals not in excess of one second and for the discrete time points that correspond to each jettison, ignition, burnout, and thrust termination of each stage. If any stage burn time lasts less

than four seconds, the time intervals must not exceed 0.2 seconds. The launch operator must provide the temporal trajectory data from launch up to a point in flight when effective thrust of the final stage terminates, or to thrust termination of the stage or burn that places the vehicle in orbit. For an unguided sub-orbital launch vehicle flown with a flight safety system, the launch operator must provide these data for each nominal quadrant launcher elevation angle and payload weight. The launch operator must provide these data on paper in text format and electronically in ASCII text, space delimited format. The launch operator must provide an electronic ''read-me'' file that identifies the data and their units of measure in the individual disk files.

(i) *Trajectory time-after-liftoff.* A launch operator must provide trajectory time-after liftoff measured from first motion of the first thrusting stage of the launch vehicle. The tabulated data must identify the first motion time as T–0 and as the ''0.0'' time point on the trajectory.

(ii) *Launch vehicle direction cosines.* A launch operator must provide the direction cosines of the roll axis, pitch axis, and yaw axis of the launch vehicle. The roll axis is a line identical to the launch vehicle's longitudinal axis with its origin at the nominal center of gravity positive towards the vehicle nose. The roll plane is normal to the roll axis at the vehicle's nominal center of gravity. The yaw axis and the pitch axis are any two orthogonal axes lying in the roll plane. The launch operator must provide roll, pitch and yaw axes of right-handed systems so that, when looking along the roll axis toward the nose, a clockwise rotation around the roll axis will send the pitch axis toward the yaw axis. The right-handed system must be oriented so that the yaw axis is positive in the downrange direction while in the vertical position (roll axis upward from surface) or positive at an angle of 180 degrees to the downrange direction. The axis may be related to the vehicle's normal orientation with respect to the vehicle's trajectory but, once defined, remain fixed with respect to the vehicle's body. The launch operator must indicate the positive direction of the yaw axis chosen. The analysis products must present the direction cosines using the EFG reference system described in paragraph (g)(7)(iv) of this section.

(iii) *X, Y, Z, XD, YD, ZD trajectory coordinates.* A launch operator must provide the launch vehicle position coordinates (X, Y, Z) and velocity magnitudes (XD, YD, ZD) referenced to an orthogonal, Earth-fixed, right-handed coordinate system. The XY plane must be tangent to the ellipsoidal Earth at the origin, which must coincide with the launch point. The positive X-axis must coincide with the launch azimuth. The positive Z-axis must be directed away from the ellipsoidal Earth. The Y-axis must be positive to the left looking downrange.

(iv) *E, F, G, ED, FD, GD trajectory coordinates.* A launch operator must provide the launch vehicle position coordinates (E, F, G) and velocity magnitudes (ED, FD, GD) referenced to an orthogonal, Earth fixed, Earth centered, right-handed coordinate system. The origin of the EFG system must be at the center of the reference ellipsoid. The E and F axes must lie in the plane of the equator and the G-axis coincides with the rotational axis of the Earth. The E-axis must be positive through 0° East longitude (Greenwich Meridian), the F-axis positive through 90' East longitude, and the G-axis positive through the North Pole. This system must be non-inertial and rotate with the Earth.

(v) *Resultant Earth-fixed velocity.* A launch operator must provide the square root of the sum of the squares of the XD, YD, and ZD components of the trajectory state vector.

(vi) *Path angle of velocity vector.* A launch operator must provide the angle between the local horizontal plane and the velocity vector measured positive upward from the local horizontal. The local horizontal must be a plane tangent to the ellipsoidal Earth at the sub-vehicle point.

(vii) *Sub-vehicle point.* A launch operator must provide sub-vehicle point coordinates that include present position geodetic latitude and present position longitude. These coordinates must be at each trajectory time on the surface of the ellipsoidal Earth model and located at the intersection of the line normal to the ellipsoid and passing through the launch vehicle center of gravity.

(viii) *Altitude.* A launch operator must provide the distance from the sub-vehicle point to the launch vehicle's center of gravity.

(ix) *Present position arc-range.* A launch operator must provide the distance measured along the surface of the reference ellipsoid, from the launch point to the sub-vehicle point.

(x) *Total weight.* A launch operator must provide the sum of the inert and propellant weights for each time point on the trajectory.

(xi) *Total vacuum thrust.* A launch operator must provide the total vacuum thrust for each time point on the trajectory.

(xii) *Instantaneous impact point data.* A launch operator must provide instantaneous impact point geodetic latitude, instantaneous impact point longitude, instantaneous impact point arc-range, and time to instantaneous impact. The instantaneous impact point arc-range must consist of the distance, measured along the surface of the reference ellipsoid, from the launch point to the instantaneous impact point. For each point on the trajectory, the time to instantaneous impact must consist of the vacuum flight time remaining until impact if all thrust were terminated at the time point on the trajectory.

(xiii) *Normal trajectory distribution.* A launch operator must provide a description of the distribution of the dispersed trajectories required under paragraph (d) of this section, such as the elements of covariance matrices for the launch vehicle position coordinates and velocity component magnitudes.

A417.9 MALFUNCTION TURN

(a) *General.* A flight safety analysis must include a malfunction turn analysis that satisfies the requirements of §417.209. This section applies to the computation of the malfunction turns and the production of turn data required by §417.209 and to the malfunction turn analysis products that a launch operator must file with the FAA as required by §417.203(e).

(b) *Malfunction turn analysis constraints.* The following constraints apply to a malfunction turn analysis:

(1) The analysis must produce malfunction turns that start at a given malfunction start time. The turn must last no less than 12 seconds. These duration limits apply regardless of whether or not the vehicle would breakup or tumble before the prescribed duration of the turn.

(2) A malfunction turn analysis must account for the thrusting periods of flight along a nominal trajectory beginning at first motion until thrust termination of the final thrusting stage or until the launch vehicle achieves orbit, whichever occurs first.

(3) A malfunction turn must consist of a 90-degree turn or a turn in both the pitch and yaw planes that would produce the largest deviation from the nominal instantaneous impact point of which the launch vehicle is capable at any time during the malfunction turn as required by paragraph (d) of this section.

(4) The first malfunction turn must start at liftoff. The analysis must account for subsequent malfunction turns initiated at regular nominal trajectory time intervals not to exceed four seconds.

(5) A malfunction turn analysis must produce malfunction turn data for time intervals of no less than one second over the duration of each malfunction turn.

(6) The analysis must assume that the launch vehicle performance is nominal up to the point of the malfunction that produces the turn.

(7) A malfunction turn analysis must not account for the effects of gravity.

(8) A malfunction turn analysis must ensure the tumble turn envelope curve maintains a positive slope throughout the malfunction turn duration as illustrated in figure A417.9–1. When calculating a tumble turn for an aerodynamically unstable launch vehicle, in the high aerodynamic region it often turns out that no matter how small the initial deflection of the rocket engine, the airframe tumbles through 180 degrees, or one-half cycle, in less time than the required turn duration period. In such a case, the analysis must use a 90-degree turn as the malfunction turn.

(c) *Failure modes.* A malfunction turn analysis must account for the significant failure modes that result in a thrust vector offset from the nominal state. If a malfunction turn at a malfunction start time can occur as a function of more than one failure mode, the analysis must account for the failure mode that causes the most rapid and largest launch vehicle instantaneous impact point deviation.

(d) *Type of malfunction turn.* A malfunction turn analysis must establish the maximum turning capability of a launch vehicle's velocity vector during each malfunction turn by accounting for a 90-degree turn to estimate the vehicle's turning capability or by accounting for trim turns and tumble turns in both the pitch and yaw planes to establish the vehicle's turning capability. When establishing the turning capability of a launch vehicle's velocity vector, the analysis must account for each turn as follows:

(1) *90-degree turn.* A 90-degree turn must constitute a turn produced at the malfunction start time by instantaneously re-directing and maintaining the vehicle's thrust at 90 degrees to the velocity vector, without regard for how this situation can be brought about.

(2) *Pitch turn.* A pitch turn must constitute the angle turned by the launch vehicle's total velocity vector in the pitch-plane. The velocity vector's pitch-plane must be the two dimensional surface that includes the launch vehicle's yaw-axis and the launch vehicle's roll-axis.

(3) *Yaw turn.* A yaw turn must constitute the angle turned by the launch vehicle's total velocity vector in the lateral plane. The velocity vector's lateral plane must be the two dimensional surface that includes the launch vehicle's pitch axis and the launch vehicle's total velocity.

(4) *Trim turn.* A trim turn must constitute a turn where a launch vehicle's thrust moment balances the aerodynamic moment while a constant rotation rate is imparted to the launch vehicle's longitudinal axis. The analysis must account for a maximum-rate trim turn made at or near the greatest angle of attack that can be maintained while the aerodynamic moment is balanced by the thrust moment, whether the vehicle is stable or unstable.

(5) *Tumble turn.* A tumble turn must constitute a turn that results if the launch vehicle's airframe rotates in an uncontrolled fashion, at an angular rate that is brought about by a thrust vector offset angle, and if the offset angle is held constant throughout

the turn. The analysis must account for a series of tumble turns, each turn with a different thrust vector offset angle, that are plotted on the same graph for each malfunction start time.

(6) *Turn envelope.* A turn envelope must constitute a curve on a tumble turn graph that has tangent points to each individual tumble turn curve computed for each malfunction start time. The curve must envelope the actual tumble turn curves to predict tumble turn angles for each area between the calculated turn curves. Figure A417.9–1 depicts a series of tumble turn curves and the tumble turn envelope curve.

(7) *Malfunction turn capabilities.* When not using a 90-degree turn, a malfunction turn analysis must establish the launch vehicle maximum turning capability as required by the following malfunction turn constraints:

(i) *Launch vehicle stable at all angles of attack.* If a launch vehicle is so stable that the maximum thrust moment that the vehicle could experience cannot produce tumbling, but produces a maximum-rate trim turn at some angle of attack less than 90 degrees, the analysis must produce a series of trim turns, including the maximum-rate trim turn, by varying the initial thrust vector offset at the beginning of the turn. If the maximum thrust moment results in a maximum-rate trim turn at some angle of attack greater than 90 degrees, the analysis must produce a series of trim turns for angles of attack up to and including 90 degrees.

(ii) *Launch vehicle aerodynamically unstable at all angles of attack.* If flying a trim turn is not possible even for a period of only a few seconds, the malfunction turn analysis need only establish tumble turns. Otherwise, the malfunction turn analysis must establish a series of trim turns, including the maximum-rate trim turn, and the family of tumble turns.

(iii) *Launch vehicle unstable at low angles of attack but stable at some higher angles of attack.* If large engine deflections result in tumbling, and small engine deflections do not, the analysis must produce a series of trim and tumble turns as required by paragraph (d)(7)(ii) of this section for launch vehicles aerodynamically unstable at all angles of attack. If both large and small constant engine deflections result in tumbling, regardless of how small the deflection might be, the analysis must account for the malfunction turn capabilities achieved at the stability angle of attack, assuming no upsetting thrust moment, and must account for the turns achieved by a tumbling vehicle.

(e) *Malfunction turn analysis products.* The products of a malfunction turn analysis that a launch operator must file with the FAA include:

(1) A description of the assumptions, techniques, and equations used in deriving the malfunction turns.

(2) A set of sample calculations for at least one flight hazard area malfunction start time and one downrange malfunction start time. The sample computation for the downrange malfunction must start at a time at least 50 seconds after the flight hazard area malfunction start time or at the time of nominal thrust termination of the final stage minus the malfunction turn duration.

(3) A launch operator must file malfunction turn data in electronic tabular and graphic formats. The graphs must use scale factors such that the plotting and reading accuracy do not degrade the accuracy of the data. For each malfunction turn start time, a graph must use the same time scales for the malfunction velocity vector turn angle and malfunction velocity magnitude plot pairs. A launch operator must provide tabular listings of the data used to generate the graphs in digital ASCII file format. A launch operator must file the data items required in this paragraph for each malfunction start time and for time intervals that do not exceed one second for the duration of each malfunction turn.

(i) *Velocity turn angle graphs.* A launch operator must file a velocity turn angle graph for each malfunction start time. For each velocity turn angle graph, the ordinate axis must represent the total angle turned by the velocity vector, and the abscissa axis must represent the time duration of the turn and must show increments not to exceed one second. The series of tumble turns must include the envelope of all tumble turn curves. The tumble turn envelope must represent the tumble turn capability for all possible constant thrust vector offset angles. Each tumble turn curve selected to define the envelope must appear on the same graph as the envelope. A launch operator must file a series of trim turn curves for representative values of thrust vector offset. The series of trim turn curves must include the maximum rate trim turn. Figure A417.9–1 depicts an example family of tumble turn curves and the tumble turn velocity vector envelope.

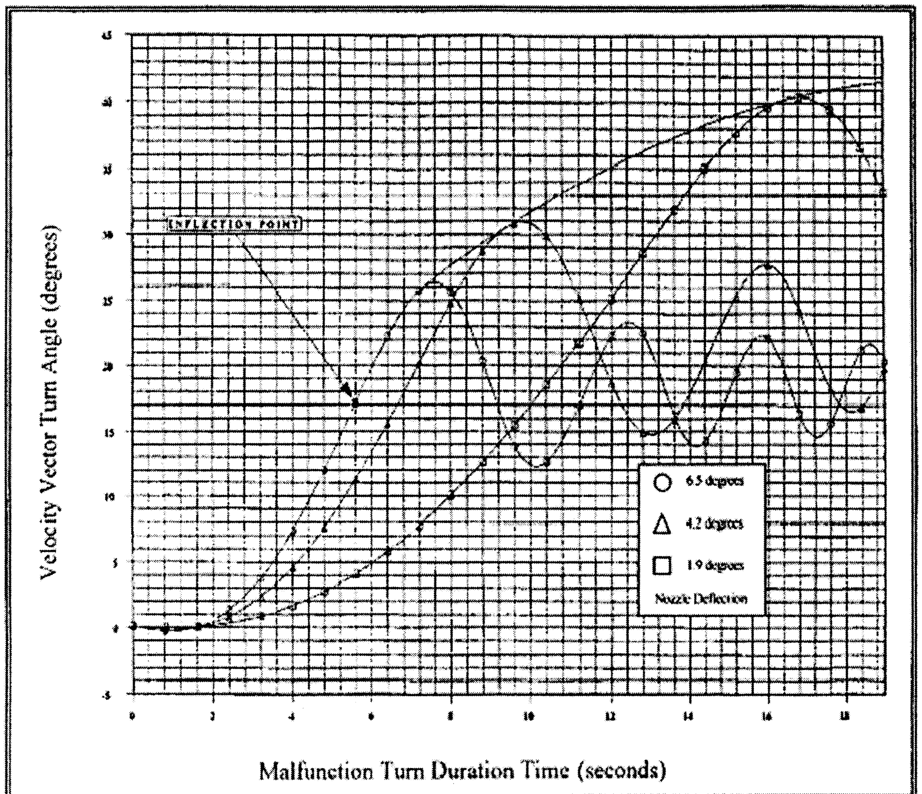

Figure A417.9-1, Example Tumble Turn Velocity Vector Turn Angle Graph.

(ii) *Velocity magnitude graphs.* A launch operator must file a velocity magnitude graph for each malfunction start time. For each malfunction velocity magnitude graph, the ordinate axis must represent the magnitude of the velocity vector and the abscissa axis must represent the time duration of the turn. Each graph must show the abscissa divided into increments not to exceed one second. Each graph must show the total velocity magnitude plotted as a function of time starting with the malfunction start time for each thrust vector offset used to define the corresponding velocity turn-angle curve. A launch operator must provide a corresponding velocity magnitude curve for each velocity tumble turn angle curve and each velocity trim-turn angle curve. For each individual tumble turn curve selected to define the tumble turn envelope, the corresponding velocity magnitude graph must show the individual tumble turn curve's point of tangency to the envelope. The point of tangency must consist of the point where the tumble turn envelope is tangent to an individual tumble turn curve produced with a discrete thrust vector offset angle. A launch operator must transpose the points of tangency to the velocity magnitude curves by plotting a point on the velocity magnitude curve at the same time point where tangency occurs on the corresponding velocity tumble-turn angle curve. Figure A417.9–2 depicts an example tumble turn velocity magnitude curve.

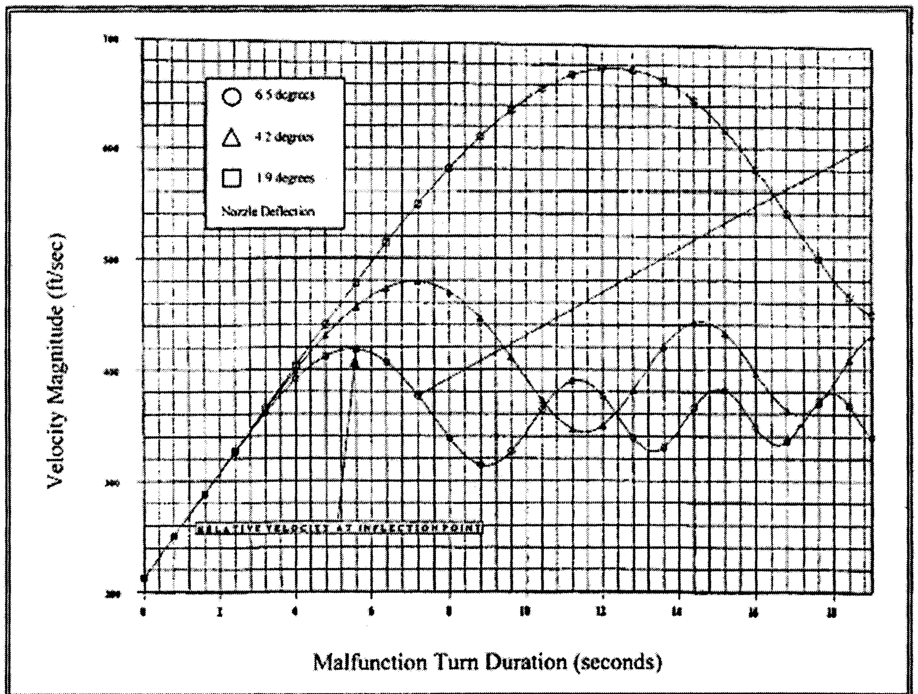

Figure A417.9-2, Illustrative Tumble Turn Velocity Magnitude Graph.

(iii) *Vehicle orientation.* The launch operator must file tabular or graphical data for the vehicle orientation in the form of roll, pitch, and yaw angular orientation of the vehicle longitudinal axis as a function of time into the turn for each turn initiation time. Angular orientation of a launch vehicle's longitudinal axis is illustrated in figures A417.9–3 and A417.9–4.

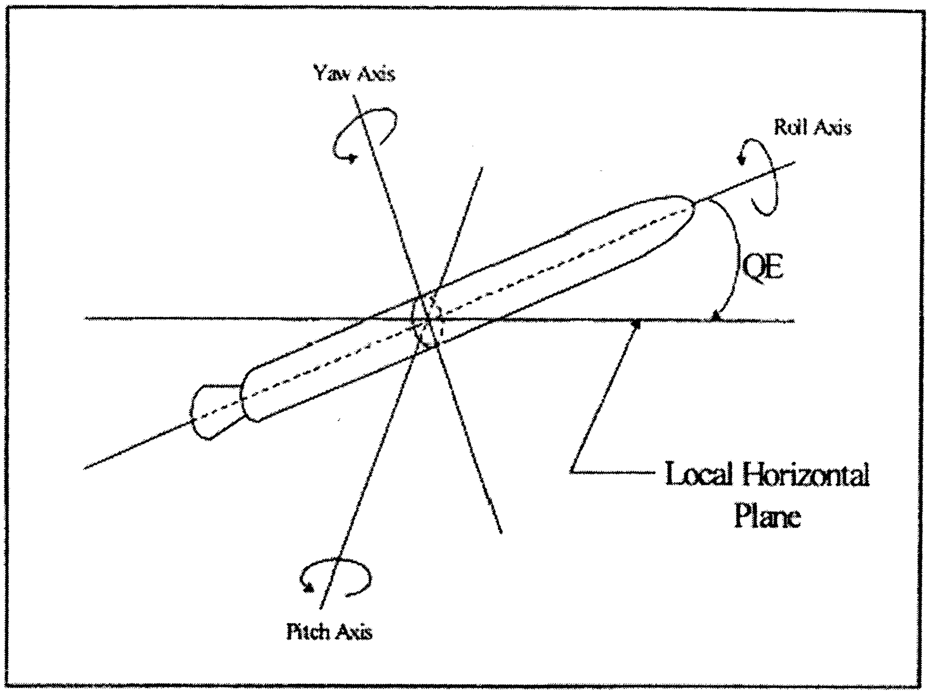

Figure A417.9-3, Illustrative Longitudinal Axis Quadrant Elevation (QE)

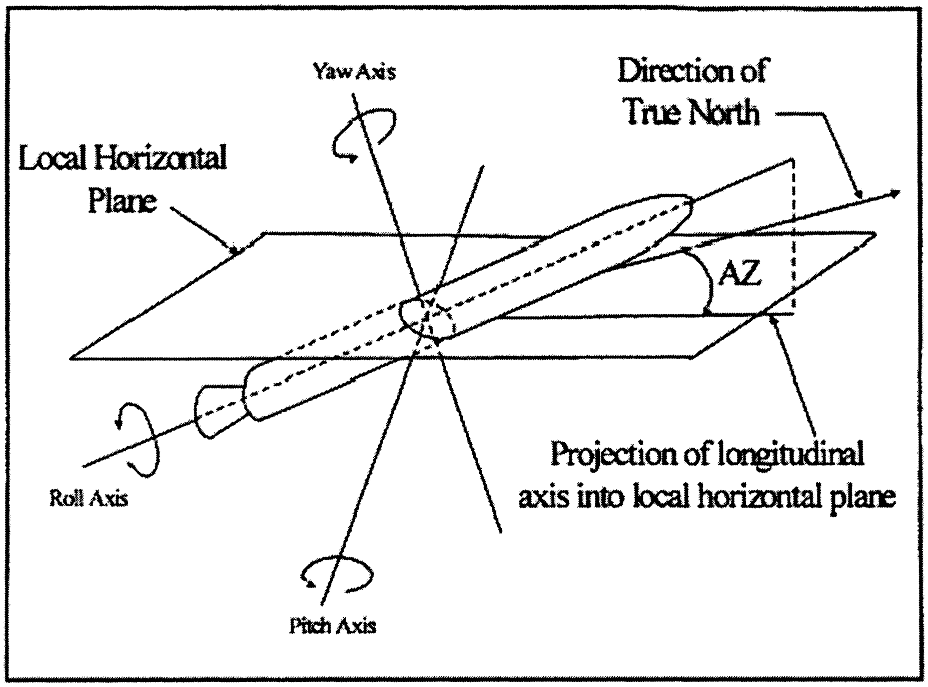

Figure A417.9-4, Illustrative Longitudinal Axis Azimuth (AZ)

(iv) *Onset conditions.* A launch operator must provide launch vehicle state information for each malfunction start time. This state data must include the launch vehicle thrust, weight, velocity magnitude and pad-centered topocentric X, Y, Z, XD, YD, ZD state vector.

(v) *Breakup information.* A launch operator must specify whether its launch vehicle will remain intact throughout each malfunction turn. If the launch vehicle will break up during a turn, the launch operator must identify the time for launch vehicle breakup on each velocity magnitude graph. The launch operator must show the time into the turn at which vehicle breakup would occur as either a specific value or a probability distribution for time until breakup.

(vi) *Inflection point.* A launch operator must identify the inflection point on each tumble turn envelope curve and maximum rate trim turn curve for each malfunction start time as illustrated in figure A417.9–1. The inflection point marks the point in time during the turn where the slope of the curve stops increasing and begins to decrease or, in other words, the point were the concavity of the curve changes from concave up to concave down. The inflection point on a malfunction turn curve must identify the time in the malfunction turn that the launch vehicle body achieves a 90-degree rotation from the nominal position. On a tumble turn curve the inflection point must represent the start of the launch vehicle tumble.

A417.11 DEBRIS

(a) *General.* A flight safety analysis must include a debris analysis that satisfies the requirements of § 417.211. This section applies to the debris data required by § 417.211 and the debris analysis products that a launch operator must file with the FAA as required by § 417.203(e).

(b) *Debris analysis constraints.* A debris analysis must produce the debris model described in paragraph (c) of this section. The analysis must account for all launch vehicle debris fragments, individually or in groupings of fragments called classes. The characteristics of each debris fragment represented by a class must be similar enough to the characteristics of all the other debris fragments represented by that class that all the debris fragments of the class can be described by a single set of characteristics. Paragraph (c)(10) of this section applies when establishing a debris class. A debris model must describe the physical, aerodynamic, and harmful characteristics of each debris fragment either individually or as a member of a class. A debris model must consist of lists of individual debris or debris classes for each cause of breakup and any planned jettison of debris, launch vehicle components, or payload. A debris analysis must account for:

(1) Launch vehicle breakup caused by the activation of any flight termination system. The analysis must account for:

(i) The effects of debris produced when flight termination system activation destroys an intact malfunctioning vehicle.

(ii) Spontaneous breakup of the launch vehicle, if the breakup is assisted by the action of any inadvertent separation destruct system.

(iii) The effects of debris produced by the activation of any flight termination system after inadvertent breakup of the launch vehicle.

(2) Debris due to any malfunction where forces on the launch vehicle may exceed the launch vehicle's structural integrity limits.

(3) The immediate post-breakup or jettison environment of the launch vehicle debris, and any change in debris characteristics over time from launch vehicle breakup or jettison until debris impact.

(4) The impact overpressure, fragmentation, and secondary debris effects of any confined or unconfined solid propellant chunks and fueled components containing either liquid or solid propellants that could survive to impact, as a function of vehicle malfunction time.

(5) The effects of impact of the intact vehicle as a function of failure time. The intact impact debris analysis must identify the trinitrotoluene (TNT) yield of impact explosions, and the numbers of fragments projected from all such explosions, including non-launch vehicle ejecta and the blast overpressure radius. The analysis must use a model for TNT yield of impact explosion that accounts for the propellant weight at impact, the impact speed, the orientation of the propellant, and the impacted surface material.

(c) *Debris model.* A debris analysis must produce a model of the debris resulting from planned jettison and from unplanned breakup of a launch vehicle for use as input to other analyses, such as establishing flight safety limits and hazard areas and performing debris risk, toxic, and blast analyses. A launch operator's debris model must satisfy the following:

(1) *Debris fragments.* A debris model must provide the debris fragment data required by this section for the launch vehicle flight from the planned ignition time until the launch vehicle achieves orbital velocity for an orbital launch. For a sub-orbital launch, the debris model must provide the debris fragment data required by this section for the launch vehicle flight from the planned ignition time until impact of the last thrusting stage. A debris model must provide debris fragment data for the number of time periods sufficient to meet the requirements for smooth and continuous contours used to define hazard areas as required by section A417.23.

(2) *Inert fragments.* A debris model must identify all inert fragments that are not volatile and that do not burn or explode under normal and malfunction conditions. A debris model must identify all inert fragments for each breakup time during flight corresponding to a critical event when the fragment catalog is significantly changed by the event. Critical events include staging, payload fairing jettison, and other normal hardware jettison activities.

(3) *Explosive and non-explosive propellant fragments.* A debris model must identify all propellant fragments that are explosive or non-explosive upon impact. The debris model must describe each propellant fragment as a function of time, from the time of breakup through ballistic free-fall to impact. The debris model must describe the characteristics of each fragment, including its origin on the launch vehicle, representative dimensions and weight at the time of breakup and at the time of impact. For any fragment identified as an un-contained or contained propellant fragment, whether explosive or non-explosive, the debris model must identify whether or not it burns during free fall, and provide the consumption rate during free fall. The debris model must identify:

(i) Solid propellant that is exposed directly to the atmosphere and that burns but does not explode upon impact as ''un-contained non-explosive solid propellant.''

(ii) Solid or liquid propellant that is enclosed in a container, such as a motor case or pressure vessel, and that burns but does not explode upon impact as ''contained non-explosive propellant.''

(iii) Solid or liquid propellant that is enclosed in a container, such as a motor case or pressure vessel, and that explodes upon impact as ''contained explosive propellant fragment.''

(iv) Solid propellant that is exposed directly to the atmosphere and that explodes upon impact as ''un-contained explosive solid propellant fragment.''

(4) *Other non-inert debris fragments.* In addition to the explosive and flammable fragments required by paragraph (c)(3) of this section, a debris model must identify any other non-inert debris fragments, such as toxic or radioactive fragments, that present any other hazards to the public.

(5) *Fragment weight.* At each modeled breakup time, the individual fragment weights must approximately add up to the

sum total weight of inert material in the vehicle and the weight of contained liquid propellants and solid propellants that are not consumed in the initial breakup or conflagration.

(6) *Fragment imparted velocity.* A debris model must identify the maximum velocity imparted to each fragment due to potential explosion or pressure rupture. When accounting for imparted velocity, a debris model must:

(i) Use a Maxwellian distribution with the specified maximum value equal to the 97th percentile; or

(ii) Identify the distribution, and must state whether or not the specified maximum value is a fixed value with no uncertainty.

(7) *Fragment projected area.* A debris model must include each of the axial, transverse, and mean tumbling areas of each fragment. If the fragment may stabilize under normal or malfunction conditions, the debris model must also provide the projected area normal to the drag force.

(8) *Fragment ballistic coefficient.* A debris model must include the axial, transverse, and tumble orientation ballistic coefficient for each fragment's projected area as required by paragraph (c)(7) of this section.

(9) *Debris fragment count.* A debris model must include the total number of each type of fragment required by paragraphs (c)(2), (c)(3), and (c)(4) of this section and created by a malfunction.

(10) *Fragment classes.* A debris model must categorize each malfunction debris fragment into classes where the characteristics of the mean fragment in each class conservatively represent every fragment in the class. The model must define fragment classes for fragments whose characteristics are similar enough to be described and treated by a single average set of characteristics. A debris class must categorize debris by each of the following characteristics, and may include any other useful characteristics:

(i) The type of fragment, defined by paragraphs (c)(2), (c)(3), and (c)(4) of this section. All fragments within a class must be the same type, such as inert or explosive.

(ii) Debris subsonic ballistic coefficient (β_{sub}). The difference between the smallest $\log10(\beta_{sub})$ value and the largest $\log10(\beta_{sub})$ value in a class must not exceed 0.5, except for fragments with β_{sub} less than or equal to three. Fragments with β_{sub} less than or equal to three may be grouped within a class.

(iii) Breakup-imparted velocity (ΔV). A debris model must categorize fragments as a function of the range of ΔV for the fragments within a class and the class's median subsonic ballistic coefficient. For each class, the debris model must keep the ratio of the maximum breakup-imparted velocity (ΔV_{max}) to minimum breakup-imparted velocity (ΔV_{min}) within the following bound:

$$\frac{\Delta V_{max}}{\Delta V_{min}} < \frac{5}{2 + \log_{10}\left(\beta'_{sub}\right)}$$

Where: β'_{sub} is the median subsonic ballistic coefficient for the fragments in a class.

(d) *Debris analysis products.* The products of a debris analysis that a launch operator must file with the FAA include:

(1) *Debris model.* The launch operator's debris model that satisfies the requirements of this section.

(2) *Fragment description.* A description of the fragments contained in the launch operator's debris model. The description must identify the fragment as a launch vehicle part or component, describe its shape, representative dimensions, and may include drawings of the fragment.

(3) *Intact impact TNT yield.* For an intact impact of a launch vehicle, for each failure time, a launch operator must identify the TNT yield of each impact explosion and blast overpressure hazard radius.

(4) *Fragment class data.* The class name, the range of values for each parameter used to categorize fragments within a fragment class, and the number of fragments in any fragment class established as required by paragraph (c)(10) of this section.

(5) *Ballistic coefficient.* The mean ballistic coefficient (β) and plus and minus three-sigma values of the β for each fragment class. A launch operator must provide graphs of the coefficient of drag (C_d) as a function of Mach number for the nominal and three-sigma β variations for each fragment shape. The launch operator must label each graph with the shape represented by the curve and reference area used to develop the curve. A launch operator must provide a C_d vs. Mach curve for any axial, transverse, and tumble orientations for any fragment that will not stabilize during free-fall conditions. For any fragment that may stabilize during free-fall, a launch operator must provide C_d vs. Mach curves for the stability angle of attack. If the angle of attack where the fragment stabilizes is other than zero degrees, a launch operator must provide both the coefficient of lift (C_L) vs. Mach number and the C_d vs. Mach number curves. The launch operator must provide the equations for each C_d vs. Mach curve.

(6) *Pre-flight propellant weight.* The initial preflight weight of solid and liquid propellant for each launch vehicle component that contains solid or liquid propellant.

(7) *Normal propellant consumption.* The nominal and plus and minus three-sigma solid and liquid propellant consumption rate, and pre-malfunction consumption rate for each component that contains solid or liquid propellant.

(8) *Fragment weight.* The mean and plus and minus three-sigma weight of each fragment or fragment class.

(9) *Projected area.* The mean and plus and minus three-sigma axial, transverse, and tumbling areas for each fragment or fragment class. This information is not required for those fragment classes classified as burning propellant classes under section A417.25(b)(8).

(10) *Imparted velocities.* The maximum incremental velocity imparted to each fragment class created by flight termination system activation, or explosive or overpressure loads at breakup. The launch operator must identify the velocity distribution as Maxwellian or must define the distribution, including whether or not the specified maximum value is a fixed value with no uncertainty.

(11) *Fragment type.* The fragment type for each fragment established as required by paragraphs (c)(2), (c)(3), and (c)(4) of this section.

(12) *Origin.* The part of the launch vehicle from which each fragment originated.

(13) *Burning propellant classes.* The propellant consumption rate for those fragments that burn during free-fall.

(14) *Contained propellant fragments, explosive or non-explosive.* For contained propellant fragments, whether explosive or non-explosive, a launch operator must provide the initial weight of contained propellant and the consumption rate during free-fall. The initial weight of the propellant in a contained propellant fragment is the weight of the propellant before any of the propellant is consumed by normal vehicle operation or failure of the launch vehicle.

(15) *Solid propellant fragment snuff-out pressure.* The ambient pressure and the pressure at the surface of a solid propellant fragment, in pounds per square inch, required to sustain a solid propellant fragment's combustion during free-fall.

(16) *Other non-inert debris fragments.* For each non-inert debris fragment identified as required by paragraph (c)(4) of this section, a launch operator must describe the diffusion, dispersion, deposition, radiation, and other hazard exposure characteristics used to determine the effective casualty area required by paragraph (d)(13) of this section.

(17) *Residual thrust dispersion.* For each thrusting or non-thrusting stage having residual thrust capability following a launch vehicle malfunction, a launch operator must provide either the total residual impulse imparted or the full-residual thrust as a function of breakup time. For any stage not capable of thrust after a launch vehicle malfunction, a launch operator must provide the conditions under which the stage is no longer capable of thrust. For each stage that can be ignited as a result of a launch vehicle malfunction on a lower stage, a launch operator must identify the effects and duration of the potential thrust, and the maximum deviation of the instantaneous impact point, which can be brought about by the thrust. A launch operator must provide the explosion effects of all remaining fuels, pressurized tanks, and remaining stages, particularly with respect to ignition or detonation of upper stages if the flight termination system is activated during the burning period of a lower stage.

A417.13 FLIGHT SAFETY LIMITS.

(a) *General.* A flight safety analysis must include a flight safety limits analysis that satisfies the requirements of §417.213. This section applies to the computation of the flight safety limits and identifying the location of populated or other protected areas as required by §417.213 and to the analysis products that the launch operator must file with the FAA as required by §417.203(e).

(b) *Flight safety limits constraints.* The analysis must establish flight safety limits as follows:

(1) Flight safety limits must account for potential malfunction of a launch vehicle during the time from launch vehicle first motion through flight until the planned safe flight state determined as required by section A417.19.

(2) For a flight termination at any time during launch vehicle flight, the impact limit lines must:

(i) Represent no less than the extent of the debris impact dispersion for all debris fragments with a ballistic coefficient greater than or equal to three; and

(ii) Ensure that the debris impact area on the Earth's surface that is bounded by the debris impact dispersion in the uprange, downrange and crossrange directions does not extend to any populated or other protected area.

(3) Each debris impact area determined by a flight safety limits analysis must be offset in a direction away from populated or other protected areas. The size of the offset must account for all parameters that may contribute to the impact dispersion. The parameters must include:

(i) Launch vehicle malfunction turn capabilities.

(ii) Effective casualty area produced as required by section A417.25(b)(8).

(iii) All delays in the identification of a launch vehicle malfunction.

(iv) Malfunction imparted velocities, including any velocity imparted to vehicle fragments by breakup.

(v) Wind effects on the malfunctioning vehicle and falling debris.

(vi) Residual thrust remaining after flight termination.

(vii) Launch vehicle guidance and performance errors.

(viii) Lift and drag forces on the malfunctioning vehicle and falling debris including variations in drag predictions of fragments and debris.

(ix) All hardware and software delays during implementation of flight termination.

(x) All debris impact location uncertainties caused by conditions prior to, and after, activation of the flight termination system.

(xi) Any other impact dispersion parameters peculiar to the launch vehicle.

(xii) All uncertainty due to map error and launch vehicle tracking error.

(c) *Risk management*. The requirements for public risk management of §417.205(a) apply to a flight safety limits analysis. When employing risk assessment, the analysis must establish flight safety limits that satisfy paragraph (b) of this section, account for the products of the debris risk analysis performed as required by section A417.25, and ensure that any risk to the public satisfies the public risk criteria of §417.107(b). When employing hazard isolation, the analysis must establish flight safety limits in accordance with the following:

(1) The flight safety limits must account for the maximum deviation impact locations for the most wind sensitive debris fragment with a minimum of 11 ft-lbs of kinetic energy at impact.

(2) The maximum deviation impact location of the debris identified in paragraph (c)(1) of this section for each trajectory time must account for the three-sigma impact location for the maximum deviation flight, and the launch day wind conditions that produce the maximum ballistic wind for that debris.

(3) The maximum deviation flight must account for the instantaneous impact point, of the debris identified in paragraph (c)(1) of this section at breakup, that is closest to a protected area and the maximum ballistic wind directed from the breakup point toward that protected area.

(d) *Flight safety limits analysis products*. The products of a flight safety limits analysis that a launch operator must file with the FAA include:

(1) A description of each method used to develop and implement the flight safety limits. The description must include equations and example computations used in the flight safety limits analysis.

(2) A description of how each analysis method meets the analysis requirements and constraints of this section, including how the method produces a worst-case scenario for each impact dispersion area.

(3) A description of how the results of the analysis are used to protect populated and other protected areas.

(4) A graphic depiction or series of depictions of the flight safety limits, the launch point, all launch site boundaries, surrounding geographic area, all protected area boundaries, and the nominal and three-sigma launch vehicle instantaneous impact point ground traces from liftoff to orbital insertion or the end of flight. Each depiction must have labeled geodetic latitude and longitude lines. Each depiction must show the flight safety limits at trajectory time intervals sufficient to depict the mission success margin between the flight safety limits and the protected areas. The launch vehicle trajectory instantaneous impact points must be plotted with sufficient frequency to provide a conformal representation of the launch vehicle's instantaneous impact point ground trace curvature.

(5) A tabular description of the flight safety limits, including the geodetic latitude and longitude for any flight safety limit. The table must contain quantitative values that define flight safety limits. Each quantitative value must be rounded to the number of significant digits that can be determined from the uncertainty of the measurement device used to determine the flight safety limits and must be limited to a maximum of six decimal places.

(6) A map error table of direction and scale distortions as a function of distance from the point of tangency from a parallel of true scale and true direction or from a meridian of true scale and true direction. A launch operator must provide a table of tracking error as a function of downrange distance from the launch point for each tracking station used to make flight safety control decisions. A launch operator must file a description of the method, showing equations and sample calculations, used to determine the tracking error. The table must contain the map and tracking error data points within 100 nautical miles of the reference point at an interval of one data point every 10 nautical miles, including the reference point. The table must contain map and tracking error data points beyond 100 nautical miles from the reference point at an interval of one data point every 100 nautical miles out to a distance that includes all populated or other areas protected by the flight safety limits.

(7) A launch operator must provide the equations used for geodetic datum conversions and one sample calculation for converting the geodetic latitude and longitude coordinates between the datum ellipsoids used. A launch operator must provide any equations used for range and bearing computations between geodetic coordinates and one sample calculation.

A417.15 STRAIGHT-UP TIME

(a) *General*. A flight safety analysis must include a straight-up time analysis that satisfies the requirements of §417.215. This section applies to the computation of straight-up time as required by §417.215 and to the analysis products that the launch operator must file with the FAA as required by

§417.203(e). The analysis must establish a straight-up time as the latest time-after-lift-off, assuming a launch vehicle malfunctioned and flew in a vertical or near vertical direction above the launch point, at which activation of the launch vehicle's flight termination system or breakup of the launch vehicle would not cause hazardous debris or critical overpressure to affect any populated or other protected area.

(b) *Straight-up time constraints.* A straight-up time analysis must account for the following:

(1) Launch vehicle trajectory. The analysis must use the straight-up trajectory determined as required by section A417.7(e).

(2) Sources of debris impact dispersion. The analysis must use the sources described in section A417.13(b)(3)(iii) through (xii).

(c) *Straight-up time analysis products.* The products of a straight-up-time analysis that a launch operator must file with the FAA include:

(1) The straight-up-time.

(2) A description of the methodology used to determine straight-up time.

A417.17 OVERFLIGHT GATE

(a) *General.* The flight safety analysis for a launch that involves flight over a populated or other protected area must include an overflight gate analysis that satisfies the requirements of §417.217. This section applies to determining a gate as required by §417.217 and the analysis products that the launch operator must file with the FAA as required by §417.203(e). The analysis must determine the portion, referred to as a gate, of a flight safety limit, through which a launch vehicle's tracking representation will be allowed to proceed without flight termination.

(b) *Overflight gate analysis constraints.* The following analysis constraints apply to a gate analysis.

(1) For each gate in a flight safety limit, all the criteria used for determining whether to allow passage through the gate or to terminate flight at the gate must use all the same launch vehicle flight status parameters as the criteria used for determining whether to terminate flight at a flight safety limit. For example, if the flight safety limits are a function of instantaneous impact point location, the criteria for determining whether to allow passage through a gate in the flight safety limit must also be a function of instantaneous impact point location. Likewise, if the flight safety limits are a function of drag impact point, the gate criteria must also be a function of drag impact point.

(2) When establishing a gate in a flight safety limit, the analysis must ensure that the launch vehicle flight satisfies the flight safety requirements of §417.107.

(3) For each established gate, the analysis must account for:

(i) All launch vehicle tracking and map errors.

(ii) All launch vehicle plus and minus three-sigma trajectory limits.

(iii) All debris impact dispersions.

(4) The width of a gate must restrict a launch vehicle's normal trajectory ground trace.

(c) *Overflight gate analysis products.* The products of a gate analysis that a launch operator must file with the FAA include:

(1) A description of the methodology used to establish each gate.

(2) A description of the tracking representation.

(3) A tabular description of the input data.

(4) Example analysis computations performed to determine a gate. If a launch involves more than one gate and the same methodology is used to determine each gate, the launch operator need only file the computations for one of the gates.

(5) A graphic depiction of each gate. A launch operator must provide a depiction or depictions showing flight safety limits, protected area outlines, nominal and 3-sigma left and right trajectory ground traces, protected area overflight regions, and predicted impact dispersion about the three-sigma trajectories within the gate. Each depiction must show latitude and longitude grid lines, gate latitude and longitude labels, and the map scale.

A417.19 DATA LOSS FLIGHT TIME AND PLANNED SAFE FLIGHT STATE

(a) *General.* A flight safety analysis must include a data loss flight time analysis that satisfies the requirements of §417.219. This section applies to the computation of data loss flight times and the planned safe flight state required by §417.219, and to the analysis products that the launch operator must file with the FAA as required by §417.203(e).

(b) *Planned safe flight state.* The analysis must establish a planned safe flight state for a launch as follows:

(1) For a suborbital launch, the analysis must determine a planned safe flight state as the nominal state vector after liftoff that a launch vehicle's hazardous debris impact dispersion can no longer reach any protected area.

(2) For an orbital launch where the launch vehicle's instantaneous impact point does not traverse a protected area prior to reaching orbit, the analysis must establish the planned safe flight state as the time after liftoff that the launch vehicle's hazardous debris impact dispersion can no longer reach any protected area or orbital insertion, whichever occurs first.

(3) For an orbital launch where a gate permits overflight of a protected area and where orbital insertion occurs after reaching the gate, the analysis must determine the planned safe flight state as the time after

liftoff when the time for the launch vehicle's instantaneous impact point to reach the gate is less than the time for the instantaneous impact point to reach any flight safety limit.

(4) The analysis must account for a malfunction that causes the launch vehicle to proceed from its position at the trajectory time being evaluated toward the closest flight safety limit and protected area.

(5) The analysis must account for the launch vehicle thrust vector that produces the highest instantaneous impact point range rate that the vehicle is capable of producing at the trajectory time being evaluated.

(c) *Data loss flight times.* For each launch vehicle trajectory time, from the predicted earliest launch vehicle tracking acquisition time until the planned safe flight state, the analysis must determine the data loss flight time as follows:

(1) The analysis must determine each data loss flight time as the minimum thrusting time for a launch vehicle to move from a normal trajectory position to a position where a flight termination would cause the malfunction debris impact dispersion to reach any protected area.

(2) A data loss flight time analysis must account for a malfunction that causes the launch vehicle to proceed from its position at the trajectory time being evaluated toward the closest flight safety limit and protected area.

(3) The analysis must account for the launch vehicle thrust vector that produces the highest instantaneous impact point range rate that the vehicle is capable of producing at the trajectory time being evaluated.

(4) Each data loss flight time must account for the system delays at the time of flight.

(5) The analysis must determine a data loss flight time for time increments that do not exceed one second along the launch vehicle nominal trajectory.

(d) *Products.* The products of a data loss flight time and planned safe flight state analysis that a launch operator must file include:

(1) A launch operator must describe the methodology used in its analysis, and identify all assumptions, techniques, input data, and equations used. A launch operator must file calculations performed for one data loss flight time in the vicinity of the launch site and one data loss flight time that is no less than 50 seconds later in the downrange area.

(2) A launch operator must file a graphical description or depictions of the flight safety limits, the launch point, the launch site boundaries, the surrounding geographic area, any protected areas, the planned safe flight state within any applicable scale requirements, latitude and longitude grid lines, and launch vehicle nominal and three-sigma instantaneous impact point ground traces from liftoff through orbital insertion for an orbital launch, and through final impact for a suborbital launch. Each graph must show any launch vehicle trajectory instantaneous impact points plotted with sufficient frequency to provide a conformal estimate of the launch vehicle's instantaneous impact point ground trace curvature. A launch operator must provide labeled latitude and longitude lines and the map scale on the depiction.

(3) A launch operator must provide a tabular description of each data loss flight time. The tabular description must include the malfunction start time and the geodetic latitude (positive north of the equator) and longitude (positive east of the Greenwich Meridian) coordinates of the intersection of the launch vehicle instantaneous impact point trajectory with the flight safety limit. The table must identify the first data lost flight time and planned safe flight state. The tabular description must include data loss flight times for trajectory time increments not to exceed one second.

A417.21 TIME DELAY

(a) *General.* A flight safety analysis must include a time delay analysis that satisfies the requirements of §417.221. This section applies to the computation of time delays associated with a flight safety system and other launch vehicle systems and operations as required by §417.221 and to the analysis products that the launch operator must file with the FAA as required by §417.203(e).

(b) *Time delay analysis constraints.* The analysis must account for all significant causes of time delay between the violation of a flight termination rule and the time when a flight safety system is capable of terminating flight as follows:

(1) The analysis must account for decision and reaction times, including variation in human response time, for flight safety official and other personnel that are part of a launch operator's flight safety system as defined by subpart D of this part.

(2) The analyses must determine the time delay inherent in any data, from any source, used by a flight safety official for making flight termination decisions.

(3) A time delay analysis must account for all significant causes of time delay, including data flow rates and reaction times, for hardware and software, including, but not limited to the following:

(i) *Tracking system.* A time delay analysis must account for time delays between the launch vehicle's current location and last known location and that are associated with the hardware and software that make up the launch vehicle tracking system, whether or not it is located on the launch vehicle, such as transmitters, receivers, decoders, encoders, modulators, circuitry and any encryption and decryption of data.

(ii) *Display systems.* A time delay analysis must account for delays associated with hardware and software that make up any display system used by a flight safety official to aid in making flight control decisions. A time delay analysis must also account for any manual operations requirements, tracking source selection, tracking data processing, flight safety limit computations, inherent display delays, meteorological data processing, automated or manual system configuration control, automated or manual process control, automated or manual mission discrete control, and automated or manual fail over decision control.

(iii) *Flight termination system and command control system.* A time delay analysis must account for delays and response times associated with flight termination system and command control system hardware and software, such as transmitters, decoders, encoders, modulators, relays and shutdown, arming and destruct devices, circuitry and any encryption and decryption of data.

(iv) *Software specific time delays.* A delay analysis must account for delays associated with any correlation of data performed by software, such as timing and sequencing; data filtering delays such as error correction, smoothing, editing, or tracking source selection; data transformation delays; and computation cycle time.

(4) A time delay analysis must determine the time delay plus and minus three-sigma values relative to the mean time delay.

(5) For use in any risk analysis, a time delay analysis must determine time delay distributions that account for the variance of time delays for potential launch vehicle failure, including but not limited to, the range of malfunction turn characteristics and the time of flight when the malfunction occurs.

(c) *Time delay analysis products.* The products of a time delay analysis that a launch operator must file include:

(1) A description of the methodology used to produce the time delay analysis.

(2) A schematic drawing that maps the flight safety official's data flow time delays from the start of a launch vehicle malfunction through the final commanded flight termination on the launch vehicle, including the flight safety official's decision and reaction time. The drawings must indicate major systems, subsystems, major software functions, and data routing.

(3) A tabular listing of each time delay source and its individual mean and plus and minus three-sigma contribution to the overall time delay. The table must provide all time delay values in milliseconds.

(4) The mean delay time and the plus and minus three-sigma values of the delay time relative to the mean value.

A417.23 FLIGHT HAZARD AREAS

(a) *General.* A flight safety analysis must include a flight hazard area analysis that satisfies the requirements of § 417.223. This section applies to the determination of flight hazard areas for orbital and suborbital launch vehicles that use a flight termination system to protect the public as required by § 417.223 and to the analysis products that the launch operator must file with the FAA as required by § 417.203(e). Requirements that apply to determining flight hazard areas for an unguided suborbital rocket that uses a wind-weighting safety system are contained in appendix C of this part.

(b) *Launch site flight hazard area.* A flight hazard area analysis must establish a launch site flight hazard area that encompasses the launch point and:

(1) If the flight safety analysis employs hazard isolation to establish flight safety limits as required by section A417.13(c), the launch site flight hazard area must encompass the flight safety limits.

(2) If the flight safety analysis does not employ hazard isolation to establish the flight safety limits, the launch site flight hazard area must encompass all hazard areas established as required by paragraphs (c) through (e) of this section.

(c) *Debris impact hazard area.* The analysis must establish a debris impact hazard area that accounts for the effects of impacting debris resulting from normal and malfunctioning launch vehicle flight, except for toxic effects, and accounts for potential impact locations of all debris fragments. The analysis must establish a debris hazard area as follows:

(1) An individual casualty contour that defines where the risk to an individual would exceed an expected casualty (Ec) criteria of 1 x 10 −6 if one person were assumed to be in the open and inside the contour during launch vehicle flight must bound a debris hazard area. The analysis must produce an individual casualty contour as follows:

(i) The analysis must account for the location of a hypothetical person, and must vary the location of the person to determine when the risk would exceed the Ec criteria of 1 x 10 −6. The analysis must count a person as a casualty when the person's location is subjected to any inert debris impact with a mean expected kinetic energy greater than or equal to 11 ft-lbs or a peak incident overpressure equal to or greater than 1.0 psi due to explosive debris impact. The analysis must determine the peak incident overpressure using the Kingery-Bulmash relationship, without regard to sheltering, reflections, or atmospheric effects.

(ii) The analysis must account for person locations that are no more than 1000 feet apart in the downrange direction and no more than 1000 feet apart in the crossrange direction to produce an individual casualty contour. For each person location, the analysis must sum the probabilities of casualty over all flight times for all debris groups.

(iii) An individual casualty contour must consist of curves that are smooth and continuous. To accomplish this, the analysis must vary the time interval between the trajectory times assessed so that each location of a debris impact point is less than one-half sigma of the downrange dispersion distance.

(2) The input for determining a debris impact hazard area must account for the results of the trajectory analysis required by section A417.7, the malfunction turn analysis required by section A417.9, and the debris analysis required by section A417.11 to define the impact locations of each class of debris established by the debris analysis, and the time delay analysis required by section A417.21.

(3) The analysis must account for the extent of the impact debris dispersions for each debris class produced by normal and malfunctioning launch vehicle flight at each trajectory time. The analysis must also account for how the vehicle breaks up, either by the flight termination system or by aerodynamic forces, if the different breakup may result in a different probability of existence for each debris class. A debris impact hazard area must account for each impacting debris fragment classified as required by section A417.11(c).

(4) The analysis must account for launch vehicle flight that exceeds a flight safety limit. The analysis must also account for trajectory conditions that maximize the mean debris impact distance during the flight safety system delay time determined as required by section A417.21 and account for a debris model that is representative of a flight termination or aerodynamic breakup. For each launch vehicle breakup event, the analysis must account for trajectory and breakup dispersions, variations in debris class characteristics, and debris dispersion due to any wind condition under which a launch would be attempted.

(5) The analysis must account for the probability of failure of each launch vehicle stage and the probability of existence of each debris class. The analysis must account for the probability of occurrence of each type of launch vehicle failure. The analysis must account for vehicle failure probabilities that vary depending on the time of flight.

(6) In addition to failure debris, the analysis must account for nominal jettisoned body debris impacts and the corresponding debris impact dispersions. The analysis must use a probability of occurrence of 1.0 for the planned debris fragments produced by normal separation events during flight.

(d) *Near-launch-point blast hazard area.* A flight hazard area analysis must define a blast overpressure hazard area as a circle extending from the launch point with a radius equal to the 1.0 psi overpressure distance produced by the equivalent TNT weight of the explosive capability of the vehicle. In addition, the analysis must establish a minimum near-pad blast hazard area to provide protection from hazardous fragments potentially propelled by an explosion. The analysis must account for the maximum possible total solid and liquid propellant explosive potential of the launch vehicle and any payload. The analysis must define a blast overpressure hazard area using the following equations:

$$R_{op} = 45 \cdot (NEW)^{1/3}$$

Where:

R_{op} is the over pressure distance in feet.

$NEW = W_E \cdot C$ (pounds).

W_E is the weight of the explosive in pounds.

C is the TNT equivalency coefficient of the propellant being evaluated. A launch operator must identify the TNT equivalency of each propellant on its launch vehicle including any payload. TNT equivalency data for common liquid propellants is provided in tables A417–1. Table A417–2 provides factors for converting gallons of specified liquid propellants to pounds.

(e) *Other hazards.* A flight hazard area analysis must identify any additional hazards, such as radioactive material, that may exist on the launch vehicle or payload. For each such hazard, the analysis must determine a hazard area that encompasses any debris impact point and its dispersion and includes an additional hazard radius that accounts for potential casualty due to the additional hazard. Analysis requirements for toxic release and far field blast overpressure are provided in § 417.27 and section A417.29, respectively.

(1) *Aircraft hazard areas.* The analysis must establish an aircraft hazard area for each planned debris impact for the issuance of notices to airmen as required by § 417.121(e). Each aircraft hazard area must encompass an air space region, from an altitude of 60,000 feet to impact on the Earth's surface, that contains the three-sigma drag impact dispersion.

(2) *Ship hazard areas.* The analysis must establish a ship hazard area for each planned debris impact for the issuance of notices to mariners as required by § 417.121(e). Each ship hazard area must encompass a surface region that contains the three-sigma drag impact dispersion.

(f) *Flight hazard area analysis products.* The products of a flight hazard area analysis that a launch operator must file with the FAA include:

(1) A chart that depicts the launch site flight hazard area, including its size and location.

(2) A chart that depicts each hazard area required by this section.

(3) A description of each hazard for which analysis was performed; the methodology used to compute each hazard area; and the debris classes for aerodynamic breakup of the launch vehicle and for flight termination. For each debris class, the launch operator must identify the number of debris fragments, the variation in ballistic coefficient, and the standard deviation of the debris dispersion.

(4) A chart that depicts each of the individual casualty contour.

(5) A description of the aircraft hazard area for each planned debris impact, the information to be published in a Notice to Airmen, and all information required as part of any agreement with the FAA ATC office having jurisdiction over the airspace through which flight will take place.

(6) A description of any ship hazard area for each planned debris impact and all information required in a Notice to Mariners.

(7) A description of the methodology used for determining each hazard area.

(8) A description of the hazard area operational controls and procedures to be implemented for flight.

TABLE A417-1. LIQUID PROPELLANT EXPLOSIVE EQUIVALENTS

Propellant combinations	TNT equivalents
LO_2/LH_2	The larger of $8W^{2/3}$ or 14% of W. Where W is the weight of LO_2/LH_2.
$LO_2/LH_2 + LO_2/RP\text{-}1$	Sum of (20% for $LO_2/RP\text{-}1$) the larger of $8W^{2/3}$ or 14% of W. Where W is the weight of LO_2/LH_2.
$LO_2/RP\text{-}1$	20% of W up to 500,000 pounds + 10% of W over 500,000 pounds. Where W is the weight of $LO_2/RP\text{-}1$.
N_2O_4/N_2H_4 (or UDMH or UDMH/N_2H_4 Mixture)	10% of W. Where W is the weight of the propellant.

TABLE A417-2. PROPELLANT HAZARD AND COMPATIBILITY GROUPINGS AND FACTORS TO BE USED WHEN CONVERTING GALLONS OF PROPELLANT INTO POUNDS

Propellant	Hazard group	Compatibility group	Pounds/gallon	^{0}F
Hydrogen Peroxide	II	A	11.6	68
Hydrazine	III	C	8.4	68
Liquid Hydrogen	III	C	0.59	-423
Liquid Oxygen	II	A	9.5	-297
Nitrogen Tetroxide	I	A	12.1	68
RP-1	I	C	6.8	68
UDMH	III	C	6.6	68
UDMH/Hydrazine	III	C	7.5	68

A417.25 DEBRIS RISK

(a) *General.* A flight safety analysis must include a debris risk analysis that satisfies the requirements of § 417.225. This section applies to the computation of the average number of casualties (E_c) to the collective members of debris hazards from the proposed flight of a launch vehicle as required by § 417.225 and to the analysis products that the launch operator must file with the FAA as required by § 417.203(e).

(b) *Debris risk analysis constraints.* The following constraints apply to a debris risk:

(1) A debris risk analysis must use valid risk analysis models that compute E_c as the summation over all trajectory time intervals from lift-off through orbital insertion of the products of the probability of each possible event and the casualty consequences due to debris impacts for each possible event.

(2) A debris risk analysis must account for the following populations:

(i) The overflight of populations located inside any flight safety limits.

(ii) All populations located within five-sigma left and right crossrange of a nominal trajectory instantaneous impact point ground trace and within five-sigma of each planned nominal debris impact.

(iii) Any planned overflight of the public within any gate overflight areas.

(iv) Any populations outside the flight safety limits identified as required by paragraph (b)(10) of this section.

(3) A debris risk analysis must account for both inert and explosive debris hazards produced from any impacting debris caused by normal and malfunctioning launch vehicle flight. The analysis must account for the debris classes determined by the debris analysis required by section A417.11. A debris risk analysis must account for any inert debris impact with mean expected kinetic energy at impact greater than or equal to 11 ft-lbs and peak incident overpressure of greater than or equal to 1.0 psi due to any explosive debris impact. The analysis must account for all debris hazards as a function of flight time.

(4) A debris risk analysis must account for debris impact points and dispersion for each class of debris as follows:

(i) A debris risk analysis must account for drag corrected impact points and dispersions for each class of impacting debris resulting from normal and malfunctioning launch vehicle flight as a function of trajectory time from lift-off through orbital insertion, including each planned impact, for an orbital launch, and through final impact for a suborbital launch.

(ii) The dispersion for each debris class must account for the position and velocity state vector dispersions at breakup, the variance produced by breakup imparted velocities, the effect of winds on both the ascent trajectory state vector at breakup and the descending debris piece impact location the variance produced by aerodynamic properties for each debris class, and any other dispersion variances.

(iii) A debris risk analysis must account for the survivability of debris fragments that are subject to reentry aerodynamic forces or heating. A debris class may be eliminated from the debris risk analysis if the launch operator demonstrates that the debris will not survive to impact.

(5) A debris risk analysis must account for launch vehicle failure probability. The following constraints apply:

(i) For flight safety analysis purposes, a failure occurs when a vehicle does not complete any phase of normal flight or exhibits the potential for the stage or its debris to impact the Earth or reenter the atmosphere during the mission or any future mission of similar vehicle capability. Also, either a launch incident or launch accident constitutes a failure.

(ii) For a launch vehicle with fewer than 2 flights completed, the analysis must use a reference value for the launch vehicle failure probability estimate equal to the upper limit of the 60% two-sided confidence limits of the binomial distribution for outcomes of all previous launches of vehicles developed and launched in similar circumstances. The FAA may adjust the failure probability estimate to account for the level of experience demonstrated by the launch operator and other factors that affects the probability of failure. The FAA may adjust the failure probability estimate for the second launch based on evidence obtained from the first flight of the vehicle.

(iii) For a launch vehicle with at least 2 flights completed, the analysis must use the reference value for the launch vehicle failure probability of Table A417–3 based on the outcomes of all previous launches of the vehicle. The FAA may adjust the failure probability estimate to account for evidence obtained from the flight history of the vehicle. The FAA may adjust the failure probability estimate to account for the nature of launch outcomes in the flight history of the vehicle, corrective actions taken in response to a failure of the vehicle, or other vehicle modifications that may affect reliability. The FAA may adjust the failure probability estimate to account for the demonstrated quality of the engineering approach to launch vehicle processing, meeting safety requirements in this part, and associated hazard mitigation. The analysis must use a final failure estimate within the confidence limits of Table A417–3.

(A) Values listed on the far left of Table A417–3 apply when no launch failures are experienced. Values on the far right apply when only launch failures are experienced. Values in between apply for flight histories that include both failures and successes.

(B) Reference values in Table A417–3 are shown in bold. The reference values are the median values between 60% two-sided confidence limits of the binomial distribution. For the special cases of zero or N failures in N launch attempts, the reference values may also be recognized as the median value between the 80% one-sided confidence limit of the binomial distribution and zero or one, respectively.

(C) Upper and lower confidence bounds in Table A417–3 are shown directly above and below each reference value. These confidence bounds are based on 60% two-sided confidence limits of the binomial distribution. For the special cases of zero or N failures in N launch attempts, the upper and lower confidence bounds are based on the 80% one-sided confidence limit, respectively.

Table A417-3. LAUNCH VEHICLE FAILURE PROBABILITY REFERENCE ESTIMATES AND CONFIDENCE BOUNDS of with Two or More Flights

Launch #									<--------Success			Failure ------->									
									.553		.894		1.00								
3									**.276**		**.50**		**.724**								
									.00		.106		.447								
								.415		.713		.928		1.00							
4								**.208**		**.392**		**.608**		**.792**							
								.00		.072		.287		.585							
							.331		.582		.788		.946		1.00						
5							**.166**		**.318**		**.50**		**.682**		**.834**						
							.00		.054		.212		.418		.669						
						.275		.49		.673		.831		.956		1.00					
6						**.138**		**.267**		**.421**		**.579**		**.733**		**.862**					
						.00		.044		.169		.327		.51		.725					
					.235		.422		.585		.731		.86		.963		1.00				
7					**.118**		**.229**		**.363**		**.50**		**.637**		**.771**		**.882**				
					.00		.037		.14		.269		.415		.578		.765				
				.205		.371		.517		.65		.772		.88		.969		1.00			
8				**.103**		**.201**		**.318**		**.439**		**.561**		**.682**		**.799**		**.897**			
				.00		.031		.12		.228		.35		.483		.629		.795			
			.182		.33		.462		.584		.697		.801		.896		.972		1.00		
9			**.091**		**.179**		**.283**		**.391**		**.50**		**.609**		**.717**		**.821**		**.909**		
			.00		.028		.104		.199		.303		.416		.538		.67		.818		
		.164		.298		.418		.529		.634		.732		.824		.907		.976		1.00	
10		**.082**		**.161**		**.255**		**.352**		**.451**		**.549**		**.648**		**.745**		**.839**		**.918**	
		.00		.024		.093		.176		.268		.366		.471		.582		.702		.836	
	.149		.271		.381		.484		.581		.673		.761		.842		.917		.978		1.00
11	**.074**		**.147**		**.232**		**.321**		**.41**		**.50**		**.59**		**.679**		**.768**		**.853**		**.926**
	.00		.022		.083		.158		.239		.327		.419		.516		.619		.729		.851

(6) A debris risk analysis must account for the dwell time of the instantaneous impact point ground trace over each populated or protected area being evaluated.

(7) A debris risk analysis must account for the three-sigma instantaneous impact point trajectory variations in left-crossrange, right-crossrange, uprange, and downrange as

a function of trajectory time, due to launch vehicle performance variations as determined by the trajectory analysis performed as required by section A417.7.

(8) A debris risk analysis must account for the effective casualty area as a function of launch vehicle flight time for all impacting debris generated from a catastrophic launch vehicle malfunction event or a planned impact event. The effective casualty area must account for both payload and vehicle systems and subsystems debris. The effective casualty area must account for all debris fragments determined as part of a launch operator's debris analysis as required by section A417.11. The effective casualty area for each explosive debris fragment must account for a 1.0 psi blast overpressure radius and the projected debris effects for all potentially explosive debris. The effective casualty area for each inert debris fragment must:

(i) Account for bounce, skip, slide, and splatter effects; or

(ii) Equal seven times the maximum projected area of the fragment.

(9) A debris risk analysis must account for current population density data obtained from a current population database for the region being evaluated or by estimating the current population using exponential population growth rate equations applied to the most current historical data available. The population model must define population centers that are similar enough to be described and treated as a single average set of characteristics without degrading the accuracy of the debris risk estimate.

(10) For a launch vehicle that uses a flight safety system, a debris risk analysis must account for the collective risk to any populations outside the flight safety limits during flight, including people who will be at any public launch viewing area during flight. For such populations, in addition to the constraints of paragraphs (b)(1) through (b)(9) of this section, a launch operator's debris risk analysis must account for the following:

(i) The probability of a launch vehicle failure that would result in debris impact in protected areas outside the flight safety limits.

(ii) The failure probability of the launch operator's flight safety system. A flight safety system failure rate of 0.002 may be used if the flight safety system complies with the flight safety system requirements of subpart D of this part. For an alternate flight safety system approved as required by §417.107(a)(3), the launch operator must demonstrate the validity of the probability of failure through the licensing process.

(iii) Current population density data and population projections for the day and time of flight for the areas outside the flight safety limits.

(c) *Debris risk analysis products.* The products of a debris risk analysis that a launch operator must file with the FAA include:

(1) A debris risk analysis report that provides the analysis input data, probabilistic risk determination methods, sample computations, and text or graphical charts that characterize the public risk to geographical areas for each launch.

(2) Geographic data showing:

(i) The launch vehicle nominal, five-sigma left-crossrange and five-sigma right-crossrange instantaneous impact point ground traces;

(ii) All exclusion zones relative to the instantaneous impact point ground traces; and

(iii) All populated areas included in the debris risk analysis.

(3) A discussion of each launch vehicle failure scenario accounted for in the analysis and the probability of occurrence, which may vary with flight time, for each failure scenario. This information must include failure scenarios where a launch vehicle:

(i) Flies within normal limits until some malfunction causes spontaneous breakup or results in a commanded flight termination;

(ii) Experiences malfunction turns; and

(iii) Flight safety system fails to function.

(4) A population model applicable to the launch overflight regions that contains the following: region identification, location of the center of each population center by geodetic latitude and longitude, total area, number of persons in each population center, and a description of the shelter characteristics within the population center.

(5) A description of the launch vehicle, including general information concerning the nature and purpose of the launch and an overview of the launch vehicle, including a scaled diagram of the general arrangement and dimensions of the vehicle. A launch operator's debris risk analysis products may reference other documentation filed with the FAA containing this information. The description must include:

(i) Weights and dimensions of each stage.

(ii) Weights and dimensions of any booster motors attached.

(iii) The types of fuel used in each stage and booster.

(iv) Weights and dimensions of all interstage adapters and skirts.

(v) Payload dimensions, materials, construction, and any payload fuel; payload fairing construction, materials, and dimensions; and any non-inert components or materials that add to the effective casualty area of the debris, such as radioactive or toxic materials or high-pressure vessels.

(6) A typical sequence of events showing times of ignition, cutoff, burnout, and jettison of each stage, firing of any ullage rockets, and starting and ending times of coast periods and control modes.

(7) The following information for each launch vehicle motor:

(i) Propellant type and composition;

(ii) Thrust profile;

(iii) Propellant weight and total motor weight as a function of time;

(iv) A description of each nozzle and steering mechanism;

(v) For solid rocket motors, internal pressure and average propellant thickness, or borehole radius, as a function of time;

(vi) Maximum impact point deviations as a function of failure time during destruct system delays. Burn rate as a function of ambient pressure;

(vii) A discussion of whether a commanded destruct could ignite a non-thrusting motor, and if so, under what conditions; and

(viii) Nozzle exit and entrance areas.

(8) The launch vehicle's launch and failure history, including a summary of past vehicle performance. For a new vehicle with little or no flight history, a launch operator must provide all known data on similar vehicles that include:

(i) Identification of the launches that have occurred;

(ii) Launch date, location, and direction of each launch;

(iii) The number of launches that performed normally;

(iv) Behavior and impact location of each abnormal experience;

(v) The time, altitude, and nature of each malfunction; and

(vi) Descriptions of corrective actions taken, including changes in vehicle design, flight termination, and guidance and control hardware and software.

(9) The values of probability of impact (P_I) and expected casualty (E_c) for each populated area.

A417.27 Toxic release hazard analysis

A flight safety analysis must include a toxic release hazard analysis that satisfies the requirements of §417.227. A launch operator's toxic release hazard analysis must satisfy the methodology requirements of appendix I of this part. A launch operator must file the analysis products identified in appendix I of this part as required by §417.203(e).

A417.29 Far field blast overpressure effects analysis

(a) *General.* A flight safety analysis must include a far field blast overpressure effects hazard analysis that satisfies the requirements of §417.229. This section applies to the computation of far field blast overpressure effects from the proposed flight of a launch vehicle as required by §417.229 and to the analysis products that the launch operator must file with the FAA as required by §417.203(e). The analysis must account for distant focus overpressure and any overpressure enhancement to establish the potential for broken windows due to peak incident overpressures below 1.0 psi and related casualties due to falling or projected glass shards. The analysis must employ either paragraph (b) of this section or the risk analysis of paragraph (c) of this section.

(b) *Far field blast overpressure hazard analysis.* Unless an analysis satisfies the requirements of paragraph (c) of this section a far field blast overpressure hazard analysis must satisfy the following:

(1) Explosive yield factors. The analysis must use explosive yield factor curves for each type or class of solid or liquid propellant used by the launch vehicle. Each explosive yield factor curve must be based on the most accurate explosive yield data for the corresponding type or class of solid or liquid propellant based on empirical data or computational modeling.

(2) Establish the maximum credible explosive yield. The analysis must establish the maximum credible explosive yield resulting from normal and malfunctioning launch vehicle flight. The explosive yield must account for impact mass and velocity of impact on the Earth's surface. The analysis must account for explosive yield expressed as a TNT equivalent for peak overpressure.

(3) Characterize the population exposed to the hazard. The analysis must demonstrate whether any population centers are vulnerable to a distant focus overpressure hazard using the methodology provided by section 6.3.2.4 of the American National Standard Institute's ANSI S2.20–1983, ''Estimating Air Blast Characteristics for Single Point Explosions in Air with a Guide to Evaluation of Atmospheric Propagation and Effects'' and as follows:

(i) For the purposes of this analysis, a population center must include any area outside the launch site and not under the launch operator's control that contains an exposed site. An exposed site includes any structure that may be occupied by human beings, and that has at least one window, but does not include automobiles, airplanes, and waterborne vessels. The analysis must account for the most recent census information on each population center. The analysis must treat any exposed site for which no census information is available, or the census information indicates a population equal to or less than four persons, as a 'single residence.'

(ii) The analysis must identify the distance between the location of the maximum credible impact explosion and the location of each population center potentially exposed. Unless the location of the potential explosion site is limited to a defined region, the analysis must account for the distance between the potential explosion site and a population center as the minimum distance between any point within the region contained by the flight safety limits and the nearest exposed site within the population center.

(iii) The analysis must account for all weather conditions optimized for a distant focus overpressure hazard by applying an atmospheric blast ''focus factor'' (F) of 5.

(iv) The analysis must determine, using the methodology of section 6.3.2.4 of ANSI S2.20–1983, for each a population center, whether the maximum credible explosive yield of a launch meets, exceeds or is less than the ''no damage yield limit,'' of the population center. If the maximum credible explosive yield is less than the ''no damage yield limit'' for all exposed sites, the remaining requirements of this section do not apply. If the maximum credible explosive yield meets or exceeds the ''no damage yield limit'' for a population center then that population center is vulnerable to far field blast overpressure from the launch and the requirements of paragraphs (b)(4) and (b)(5) of this section apply.

(4) Estimate the quantity of broken windows. The analysis must use a focus factor of 5 and the methods provided by ANSI S2.20–1983 to estimate the number of potential broken windows within each population center determined to be vulnerable to the distant focus overpressure hazard as required by paragraph (b)(3) of this section.

(5) Determine and implement measures necessary to prevent distant focus overpressure from breaking windows. For each population center that is vulnerable to far field blast overpressure from a launch, the analysis must identify mitigation measures to protect the public from serious injury from broken windows and the flight commit criteria of §417.113(b) needed to enforce the mitigation measures. A launch operator's mitigation measures must include one or more of the following:

(i) Apply a minimum 4-millimeter thick anti-shatter film to all exposed sites where the maximum credible yield exceeds the ''no damage yield limit.''

(ii) Evacuate the exposed public to a location that is not vulnerable to the distant focus overpressure hazard at least two hours prior to the planned flight time.

(iii) If, as required by paragraph (b)(4) of this section, the analysis predicts that less than 20 windows will break, advise the public of the potential for glass breakage.

(c) *Far field blast overpressure risk analysis.* If a launch operator does not employ paragraph (b) of this section to perform a far field overpressure hazard analysis, the launch operator must conduct a risk analysis that demonstrates that the launch will be conducted in accordance with the public risk criteria of §417.107(b).

(d) *Far field blast overpressure effect products.* The products of a far field blast overpressure analysis that a launch operator must file with the FAA include:

(1) A description of the methodology used to produce the far field blast overpressure analysis results, a tabular description of the analysis input data, and a description of any far field blast overpressure mitigation measures implemented.

(2) For any far field blast overpressure risk analysis, an example set of the analysis computations.

(3) The values for the maximum credible explosive yield as a function of time of flight.

(4) The distance between the potential explosion location and any population center vulnerable to the far field blast overpressure hazard. For each population center, the launch operator must identify the exposed populations by location and number of people.

(5) Any mitigation measures established to protect the public from far field blast overpressure hazards and any flight commit criteria established to ensure the mitigation measures are enforced.

A417.31 COLLISION AVOIDANCE

(a) *General.* A flight safety analysis must include a collision avoidance analysis that satisfies the requirements of §417.231. This section applies to a launch operator obtaining a collision avoidance assessment from United States Strategic Command as required by §417.231 and to the analysis products that the launch operator must file with the FAA as required by §417.203(e). United States Strategic Command refers to a collision avoidance analysis for a space launch as a conjunction on launch assessment.

(b) *Analysis constraints.* A launch operator must satisfy the following when obtaining and implementing the results of a collision avoidance analysis:

(1) A launch operator must provide United States Strategic Command with the launch window and trajectory data needed to perform a collision avoidance analysis for a launch as required by paragraph (c) of this section, at least 15 days before the first attempt at flight. The FAA will identify a launch operator to United States Strategic Command as part of issuing a license and provide a launch operator with current United States Strategic Command contact information.

(2) A launch operator must obtain a collision avoidance analysis performed by United States Strategic Command 6 hours before the beginning of a launch window.

(3) A launch operator may use a collision avoidance analysis for 12 hours from the time that United States Strategic Command determines the state vectors of the manned or mannable orbiting objects. If a launch operator needs an updated collision avoidance analysis due to a launch delay, the launch operator must file the request with United States Strategic Command at least 12 hours

prior to the beginning of the new launch window.

(4) For every 90 minutes, or portion of 90 minutes, that pass between the time United States Strategic Command last determined the state vectors of the orbiting objects, a launch operator must expand each wait in a launch window by subtracting 15 seconds from the start of the wait in the launch window and adding 15 seconds to the end of the wait in the launch window. A launch operator must incorporate all the resulting waits in the launch window into its flight commit criteria established as required by § 417.113.

(c) *Information required.* A launch operator must prepare a collision avoidance analysis worksheet for each launch using a standardized format that contains the input data required by this paragraph. A launch operator must file the input data with United States Strategic Command for the purposes of completing a collision avoidance analysis. A launch operator must file the input data with the FAA as part of the license application process as required by § 415.115 of this chapter.

(1) *Launch information.* A launch operator must file the following launch information:

(i) *Mission name.* A mnemonic given to the launch vehicle/payload combination identifying the launch mission from all others.

(ii) *Segment number.* A segment is defined as a launch vehicle stage or payload after the thrusting portion of its flight has ended. This includes the jettison or deployment of any stage or payload. A launch operator must provide a separate worksheet for each segment. For each segment, a launch operator must determine the ''vector at injection'' as defined by paragraph (c)(5) of this section. The data must present each segment number as a sequence number relative to the total number of segments for a launch, such as ''1 of 5.''

(iii) *Launch window.* The launch window opening and closing times in Greenwich Mean Time (referred to as ZULU time) and the Julian dates for each scheduled launch attempt.

(2) *Point of contact.* The person or office within a launch operator's organization that collects, analyzes, and distributes collision avoidance analysis results.

(3) *Collision avoidance analysis analysis results transmission medium.* A launch operator must identify the transmission medium, such as voice, FAX, or e-mail, for receiving results from United States Strategic Command.

(4) *Requestor launch operator needs.* A launch operator must indicate the types of analysis output formats required for establishing flight commit criteria for a launch:

(i) *Waits.* All the times within the launch window during which flight must not be initiated.

(ii) *Windows.* All the times within an overall launch window during which flight may be initiated.

(5) *Vector at injection.* A launch operator must identify the vector at injection for each segment. ''Vector at injection'' identifies the position and velocity of all orbital or suborbital segments after the thrust for a segment has ended.

(i) *Epoch.* The epoch time, in Greenwich Mean Time (GMT), of the expected launch vehicle liftoff time.

(ii) *Position and velocity.* The position coordinates in the EFG coordinate system measured in kilometers and the EFG components measured in kilometers per second, of each launch vehicle stage or payload after any burnout, jettison, or deployment.

(6) *Time of powered flight.* The elapsed time in seconds, from liftoff to arrival at the launch vehicle vector at injection. The input data must include the time of powered flight for each stage or jettisoned component measured from liftoff.

(7) *Time span for launch window file (LWF).* A launch operator must provide the following information regarding its launch window:

(i) *Launch window.* The launch window measured in minutes from the initial proposed liftoff time.

(ii) *Time of powered flight.* The time provided as required by paragraph (c)(6) of this section measured in minutes rounded up to the nearest integer minute.

(iii) *Screen duration.* The time duration, after all thrusting periods of flight have ended, that a collision avoidance analysis must screen for potential conjunctions with manned or mannable orbital objects. Screen duration is measured in minutes and must be greater than or equal to 100 minutes for an orbital launch.

(iv) *Extra pad.* An additional period of time for collision avoidance analysis screening to ensure the entire first orbit is screened for potential conjunctions with manned or mannable orbital objects. This time must be 10 minutes unless otherwise specified by United States Strategic Command.

(v) *Total.* The summation total of the time spans provided as required by paragraphs (c)(7)(i) through (c)(7)(iv) expressed in minutes.

(8) *Screening.* A launch operator must select spherical or ellipsoidal screening as defined in this paragraph for determining any conjunction. The default must be the spherical screening method using an avoidance radius of 200 kilometers for manned or mannable orbiting objects. If the launch operator requests screening for any unmanned or unmannable objects, the default must be the spherical screening method using a miss distance of 25 kilometers.

(i) *Spherical screening.* Spherical screening utilizes an impact exclusion sphere centered on each orbiting object's center-of-mass to determine any conjunction. A launch operator must specify the avoidance radius for manned or mannable objects and for any unmanned or unmannable objects if the launch operator elects to perform the analysis for unmanned or unmannable objects.

(ii) *Ellipsoidal screening*. Ellipsoidal screening utilizes an impact exclusion ellipsoid of revolution centered on the orbiting object's center-of-mass to determine any conjunction. A launch operator must provide input in the UVW coordinate system in kilometers. The launch operator must provide delta–U measured in the radial-track direction, delta–V measured in the in-track direction, and delta–W measured in the cross-track direction.

(9) *Orbiting objects to evaluate*. A launch operator must identify the orbiting objects to be included in the analysis.

(10) *Deliverable schedule/need dates*. A launch operator must identify the times before flight, referred to as ''L-times,'' for which the launch operator requests a collision avoidance analysis.

(d) *Collision avoidance assessment products*. A launch operator must file its collision avoidance analysis products as required by § 417.203(e) and must include the input data required by paragraph (c) of this section. A launch operator must incorporate the result of the collision avoidance analysis into its flight commit criteria established as required by § 417.113.

APPENDIX B TO PART 417—FLIGHT HAZARD AREA ANALYSIS FOR AIRCRAFT AND SHIP PROTECTION

B417.1 SCOPE

This appendix contains requirements to establish aircraft hazard areas, ship hazard areas, and land impact hazard areas. The methodologies contained in this appendix represent an acceptable means of satisfying the requirements of § 417.107 and § 417.223 as they pertain to ship, aircraft, and land hazard areas. This appendix provides a standard and a measure of fidelity against which the FAA will measure any proposed alternative approaches. Requirements for a launch operator's implementation of a hazard area are contained in §§ 417.121(e) and (f).

B417.3 HAZARD AREA NOTIFICATIONS AND SURVEILLANCE

(a) A launch operator must ensure the following notifications have been made and adhered to at launch:

(1) A Notice to Airmen (NOTAM) must be issued for every aircraft hazard area identified as required by sections B417.5 and B417.7. The NOTAM must be effective no less than thirty minutes prior to flight and effective until no sooner than thirty minutes after the air space volume requested by the NOTAM can no longer be affected by the launch vehicle or its potential hazardous effects.

(2) A Notice to Mariners (NOTMAR) must be issued for every ship hazard area identified as required by sections B417.5 and B417.7. The NOTMAR must be effective no less than thirty minutes prior to flight and effective until no sooner than thirty minutes after the area requested by the NOTMAR can no longer be affected by the launch vehicle or its potential hazardous effects.

(3) All local officials and landowners adjacent to any hazard area must be notified of the flight schedule no less than two days prior to the flight of the launch vehicle.

(b) A launch operator must survey each of the following hazard areas:

(1) Each launch site hazard area;

(2) Each aircraft hazard area in the vicinity of the launch site; and

(3) Each ship hazard area in the vicinity of the launch site.

B417.5 LAUNCH SITE HAZARD AREA

(a) *General*. A launch operator must perform a launch site hazard area analysis that protects the public, aircraft, and ships from the hazardous activities in the vicinity of the launch site. The launch operator must evacuate and monitor each launch site hazard area to ensure compliance with §§ 417.107(b)(2) and (b)(3).

(b) *Launch site hazard area analysis input*. A launch site hazard area must encompass no less than the following:

(1) Each land hazard area in the vicinity of the launch site calculated as required by section B417.13;

(2) Each ship hazard area in the vicinity of the launch site calculated as required by section B417.11(c); and

(3) The aircraft hazard area in the vicinity of the launch site calculated as required by section B417.9(c).

B417.7 DOWNRANGE HAZARD AREAS

(a) *General*. A launch operator must perform a downrange hazard area analysis that protects the public, aircraft, and ships from the hazardous activities in the vicinity of each scheduled impact location.

(b) *Downrange hazard areas analysis input*. A launch hazard area must bound no less than the following:

(1) The aircraft hazard area in the vicinity of each planned impact location calculated as required by section B417.9(d);

(2) The ship hazard area in the vicinity of each planned water impact location calculated as required by section B417.11(d); and

(3) The land hazard area in the vicinity of each planned land impact location calculated as required by section B417.13.

B417.9 AIRCRAFT HAZARD AREAS ANALYSIS

(a) *General.* A launch operator must perform an aircraft hazard areas analysis as required by §417.223(b). A launch operator's aircraft hazard areas analysis must determine the aircraft hazard area in the vicinity of the launch site and the aircraft hazard area in the vicinity of each planned impact location as required by this section.

(b) *Aircraft hazard areas analysis input.* A launch operator must account for the following inputs to determine the aircraft hazard areas:

(1) The trajectory analysis performed as required by section A417.7 or section C417.3; and

(2) The debris risk analysis performed as required by section A417.25 or section C417.9.

(c) *Methodology for computing an aircraft hazard area in the vicinity of the launch site.* An aircraft hazard area analysis must determine an aircraft hazard area that encompasses the launch point from the surface of the Earth to an altitude of 100,000 ft MSL and wholly contains the launch vehicle's normal trajectory plus five nautical miles in every radial direction. A launch operator must calculate an aircraft hazard area in the vicinity of the launch site as follows:

(1) Using the trajectory analysis performed as required by section A417.7 or section C417.3, select all data locations where the vehicle's nominal altitude, or positional component on the z-axis, is less than and equal to 100,000 ft MSL.

(2) From the data locations representing the dispersed trajectories calculated as required by section A417.7(d) or section C417.3(f) and modified to incorporate a 5 nm buffer as required by paragraph (c)(1) of this section for the data locations selected below a nominal altitude of 100,000 ft MSL as required by paragraph (c)(1) of this section, select the location that is the farthest left-hand crossrange, the location that is the farthest right-hand crossrange, the location that is the farthest downrange, and the location that is the farthest uprange.

(3) Construct a box in the xy plane that includes two lines parallel to the azimuth, two lines perpendicular to the azimuth, and contains the four locations selected as required by paragraph (c)(2) of this section.

(4) Extend the box constructed as required by paragraph (c)(3) of this section from the surface of the Earth to an infinite altitude.

(d) *Methodology for computing an aircraft hazard area in the vicinity of each planned impact location.* A launch operator must determine an aircraft hazard area in the vicinity of each planned impact location from the surface of the Earth to an altitude of 100,000 ft MSL that wholly contains the launch vehicle's calculated impact dispersion with a 5 nm buffer and the normal trajectory. A launch operator must compute an aircraft hazard area in the vicinity of each planned impact location as follows:

(1) The analysis must calculate a three-sigma dispersion ellipse by determining the three-sigma impact limit around a planned impact location.

(2) Taking the three-sigma dispersion ellipse calculated as required by paragraph (d)(1) of this section, plot a co-centric ellipse in the xy plane where the major and minor axes are 10nm longer than the major and minor axes of the three-sigma dispersion ellipse.

(3) Extend the ellipse calculated as required by paragraph (d)(2) of this section from the surface to an infinite altitude.

(4) Using the trajectory that predicts the instantaneous impact locations required in section A417.7(g)(7)(xii) or section C417.3(d), find the location on the trajectory where the vehicle's nominal altitude is predicted to be 100,000 ft MSL.

(5) At the trajectory time where the altitude is represented as 100,000 ft MSL, select the corresponding points from the normal trajectory dispersion that are the farthest uprange, downrange, right crossrange, and left crossrange relative to the nominal trajectory.

(6) Construct a box in the xy plane that includes two lines parallel to the azimuth, two lines perpendicular to the azimuth, and contains the points selected as required by paragraph (d)(5) of this section and the nominal impact point.

(7) Extend the box constructed as required by paragraph (d)(6) of this section from the surface of the Earth to an infinite altitude.

(8) Construct a volume, the aircraft hazard area, that encompasses the volumes calculated as required by paragraphs (d)(3) and (d)(7) of this section.

B417.11 SHIP HAZARD AREAS ANALYSIS

(a) *General.* A flight hazard area analysis must establish ship hazard areas bound by the 1×10^{-5} ship impact contour in the vicinity of the launch site and the vehicle's three-sigma dispersion limit plus a 5 nm buffer in the vicinity of a planned, downrange impact location.

(b) *Ship hazard area analysis input.* A launch operator must account for the following inputs to determine the ship hazard areas:

(1) The trajectory analysis performed as required by section A417.7 or section C417.3;

(2) For a launch vehicle flown with a flight safety system, the malfunction turn analysis required by section A417.9;

(3) The debris analysis required by section A417.11 or section C417.7 to define the impact locations of each class of debris established by the debris analysis;

(4) For a launch vehicle flown with a flight safety system, the time delay analysis required by section A417.21; and

(5) The debris risk analysis performed as required by section A417.25 or section C417.9.

(c) *Methodology for computing ship hazard areas in the vicinity of the launch site.* The analysis must establish the ship-hit contours as follows:

(1) A ship-hit contour must account for the size of the largest ship that could be located in the ship hazard area. The analysis must demonstrate that the ship size used represents the largest ship that could be present in the ship hazard area or, if the ship size is unknown, the analysis must use a ship size of 120,000 square feet.

(2) The analysis must first calculate the probability of impacting the reference ship selected as required by paragraph (c)(1) of this section at the location of interest. From the location of interest, move the ship away from the launch location along a single radial until the probability that debris is present at that location multiplied by the probability that a ship is at that location is less than or equal to 1×10^{-5}. When calculating the probability of impacting a ship, an impact occurs when:

(i) The analysis predicts that inert debris will directly impact the vessel with a mean expected kinetic energy at impact greater than or equal to 11 ft-lbs; or

(ii) The analysis predicts the peak incident overpressure at the reference vessel will be greater than or equal to 1.0 psi due to any explosive debris impact.

(3) The analysis must account for:

(i) The variance in winds;

(ii) The aerodynamic properties of the debris;

(iii) The variance in velocity of the debris;

(iv) Guidance and performance errors;

(v) The type of vehicle breakup, either by any flight termination system or by aerodynamic forces that may result in different debris characteristics; and

(vi) Debris impact dispersion resulting from vehicle breakup and the malfunction turn capabilities of the launch vehicle.

(4) Repeat the process outlined in paragraph (c)(2) of this section while varying the radial direction until enough locations are found where the reference ship's probability of impact is less than or equal to 1×10^{-5} such that connecting each location will result in a smooth and continuous contour.

(d) *Methodology for computing ship hazard areas in the vicinity of each planned water impact location.* A launch operator must compute a ship hazard area in the vicinity of each planned impact location as required by the following:

(1) The analysis must calculate a three-sigma dispersion ellipse by determining the three-sigma impact limit around a planned impact location.

(2) Taking the three-sigma dispersion ellipse calculated as required by paragraph (d)(1) of this section, plot a co-centric ellipse in the xy plane where the major and minor axes are 10 nm longer than the major and minor axes of the three-sigma dispersion ellipse.

B417.13 Land hazard areas analysis

(a) *General.* A flight hazard area analysis must establish land hazard areas in the vicinity of the launch site and land hazard areas in the vicinity of each land impact location to ensure that the probability of a member of the public being struck by debris satisfies the probability threshold of 1×10^{-6} required by §417.107(b) and to determine exclusion areas that may require entry control and surveillance prior to initiation of flight. The analysis must establish a land impact hazard area that accounts for the effects of impacting debris resulting from normal and malfunctioning launch vehicle flight, except for toxic effects, and accounts for potential impact locations of all debris fragments. The land hazard area must encompass all individual casualty contours and the near-launch-point blast hazard area calculated as required by paragraph (c) of this section. A launch operator may initiate flight only if no member of the public is present within the land hazard area.

(b) *Land hazard areas analysis input.* A land hazard analysis must account for the following inputs to determine the land hazard area:

(1) The trajectory analysis performed as required by section A417.7 or section C417.3;

(2) For a launch vehicle flown with a flight safety system, the malfunction turn analysis required by section A417.9;

(3) The debris analysis required by section A417.11 or section C417.7 to define the impact locations of each class of debris established by the debris analysis;

(4) For a launch vehicle flown with a flight safety system, the time delay analysis required by section A417.21; and

(5) The debris risk analysis performed as required by section A417.25 or section C417.9.

(c) *Methodology for computing land hazard areas in the vicinity of the launch site and in the vicinity of each planned land impact location.* The analysis must establish a land hazard area as follows:

(1) Each land hazard area must completely encompass all individual casualty contours that define where the risk to an individual would exceed the expected casualty (E_c) criteria of 1×10^{-6} if one person were assumed to be in the open and inside the contour during launch vehicle flight. The analysis must produce an individual casualty contour as follows:

(i) The analysis must account for the location of a hypothetical person, and must vary the location of the person to determine when the risk would exceed the E_c criteria of 1×10^{-6}. The analysis must count a person as a casualty when the person's location is subjected to any inert debris impact with a mean expected kinetic energy greater than or equal to 11 ft-lbs or a peak incident overpressure equal to or greater than 1.0 psi due to explosive debris impact. The analysis must determine the peak incident overpressure using the Kingery-Bulmash relationship, without regard to sheltering, reflections, or atmospheric effects.

(ii) The analysis must account for all person locations that are no more than 1000 feet apart in the downrange direction and no more than 1000 feet apart in the crossrange direction to produce an individual casualty contour. For each person location, the analysis must sum all the probabilities of casualty over all flight times for all debris groups.

(iii) An individual casualty contour must consist of curves that are smooth and continuous. To accomplish this, the analysis must vary the time interval between each trajectory time assessed so that each location of a debris impact point is less than one-half sigma of the downrange dispersion distance.

(2) The input for determining a land impact hazard area must account for the following in order to define the impact locations of each class of debris established by the debris analysis and the time delay analysis required by section A417.21 for a launch vehicle flown with a flight safety system:

(i) The results of the trajectory analysis required by section A417.7 or section C417.3;

(ii) The malfunction turn analysis required by section A417.9 for a launch vehicle flown with a flight safety system; and

(iii) The debris analysis required by section A417.11 or section C417.7.

(3) The analysis must account for the extent of the impact debris dispersions for each debris class produced by normal and malfunctioning launch vehicle flight at each trajectory time. The analysis must also account for how the vehicle breaks up, either by any flight termination system or by aerodynamic forces, if the different breakup may result in a different probability of existence for each debris class. A land impact hazard area must account for each impacting debris fragment classified as required by section A417.11(c) or section C417.7.

(4) For a launch vehicle flown with a flight safety system, the analysis must account for launch vehicle flight that exceeds a flight safety limit. The analysis must also account for trajectory conditions that maximize the mean debris impact distance during the flight safety system delay time determined as required by section A417.21 and account for a debris model that is representative of a flight termination or aerodynamic breakup.

(5) For each launch vehicle breakup event, the analysis must account for trajectory and breakup dispersions, variations in debris class characteristics, and debris dispersion due to any wind condition under which a launch would be attempted.

(6) The analysis must account for the probability of failure of each launch vehicle stage and the probability of existence of each debris class. The analysis must account for the probability of occurrence of each type of launch vehicle failure. The analysis must account for each vehicle failure probabilities that vary depending on the time of flight.

(7) In addition to failure debris, the analysis must account for nominal jettisoned body debris impacts and the corresponding debris impact dispersions. The analysis must use a probability of occurrence of 1.0 for the planned debris fragments produced by normal separation events during flight.

(d) *Near-launch-point blast hazard area.* A land hazard area analysis must define a blast overpressure hazard area as a circle extending from the launch point with a radius equal to the 1.0 psi overpressure distance produced by the equivalent TNT weight of the explosive capability of the vehicle. In addition, the analysis must establish a minimum near-launch point blast hazard area to provide protection from hazardous fragments potentially propelled by an explosion. The analysis must account for the maximum possible total solid and liquid propellant explosive potential of the launch vehicle and any payload. The analysis must define a blast overpressure hazard area using the following equations:

$R_{op} = 45 \cdot (NEW)^{1/3}$

Where:

R_{op} is the over pressure distance in feet.
NEW = $W_E \cdot C$ (pounds).
W_E is the weight of the explosive in pounds.
C is the TNT equivalency coefficient of the propellant being evaluated. A launch operator must identify the TNT equivalency of each propellant on its launch vehicle including any payload. TNT equivalency data for common liquid propellants is provided in tables A417–1. Table A417–2 provides factors for converting gallons of specified liquid propellants to pounds.

(e) *Other hazards.* A flight hazard area analysis must identify any additional hazards, such as radioactive material, that may exist on the launch vehicle or payload. For each such hazard, the analysis must determine a hazard area that encompasses any debris impact point and its dispersion and includes an additional hazard radius that accounts for potential casualty due to the additional hazard. Analysis requirements for toxic release and far field blast overpressure are provided in sections A417.27 and A417.29, respectively.

(f) *Land impact dispersion ellipses.* A land impact hazard area must contain the land impact dispersion ellipse for each planned land impact. A launch operator must compute a land impact dispersion ellipse in the vicinity of each planned land impact location as follows:

(1) The analysis must calculate a one-sigma dispersion ellipse by determining the one-sigma impact limit around a planned impact location.

(2) Taking the one-sigma dispersion ellipse calculated as required by paragraph (f)(1) of this section, plot a co-centric ellipse in the xy plane where the major and minor axes are 10nm longer than the major and minor axes of the one-sigma dispersion ellipse.

APPENDIX C TO PART 417—FLIGHT SAFETY ANALYSIS METHODOLOGIES AND PRODUCTS FOR AN UNGUIDED SUBORBITAL LAUNCH VEHICLE FLOWN WITH A WIND WEIGHTING SAFETY SYSTEM

C417.1 GENERAL

(a) This appendix contains methodologies for performing the flight safety analysis required for the launch of an unguided suborbital launch vehicle flown with a wind weighting safety system, except for the hazard area analysis required by § 417.107, which is covered in appendix B of this part. This appendix includes methodologies for a trajectory analysis, wind weighting analysis, debris analysis, debris risk analysis, and a collision avoidance analysis.

(b) The requirements of this appendix apply to a launch operator and the launch operator's flight safety analysis unless the launch operator clearly and convincingly demonstrates that an alternative approach provides an equivalent level of safety.

(c) A launch operator must:

(1) Perform a flight safety analysis to determine the launch parameters and conditions under which an unguided suborbital launch vehicle may be flown using a wind weighting safety system as required by § 417.233.

(2) When conducting the flight safety analysis, comply with the safety criteria and operational requirements contained in § 417.125; and

(3) Conduct the flight safety analysis for an unguided suborbital launch vehicle using the methodologies of this appendix and appendix B of this part unless the launch operator demonstrates, in accordance with § 406.3(b), through the licensing process, that an alternate method provides an equivalent level of fidelity.

C417.3 TRAJECTORY ANALYSIS

(a) *General*. A launch operator must perform a trajectory analysis for the flight of an unguided suborbital launch vehicle to determine:

(1) The launch vehicle's nominal trajectory;

(2) Each nominal drag impact point; and

(3) Each potential three-sigma dispersion about each nominal drag impact point.

(b) *Definitions*. A launch operator must employ the following definitions when determining an unguided suborbital launch vehicle's trajectory and drag impact points:

(1) *Drag impact point* means the intersection of a predicted ballistic trajectory of an unguided suborbital launch vehicle stage or other impacting component with the Earth's surface. A drag impact point reflects the effects of atmospheric influences as a function of drag forces and mach number.

(2) *Maximum range trajectory* means an optimized trajectory, extended through fuel exhaustion of each stage, to achieve a maximum downrange drag impact point.

(3) *Nominal trajectory* means the trajectory that an unguided suborbital launch vehicle will fly if all rocket aerodynamic parameters are as expected without error, all rocket internal and external systems perform exactly as planned, and there are no external perturbing influences, such as winds, other than atmospheric drag and gravity.

(4) *Normal flight* means all possible trajectories of a properly performing unguided suborbital launch vehicle whose drag impact point location does not deviate from its nominal location more than three sigma in each of the uprange, downrange, left crossrange, or right crossrange directions.

(5) *Performance error parameter* means a quantifiable perturbing force that contributes to the dispersion of a drag impact point in the uprange, downrange, and cross-range directions of an unguided suborbital launch vehicle stage or other impacting launch vehicle component. Performance error parameters for the launch of an unguided suborbital launch vehicle reflect rocket performance variations and any external forces that can cause offsets from the nominal trajectory during normal flight. Performance error parameters include thrust, thrust misalignment, specific impulse, weight, variation in firing times of the stages, fuel flow rates, contributions from the wind weighting safety system employed, and winds.

(c) *Input*. A trajectory analysis requires the input necessary to produce a six-degree-of-freedom trajectory. A launch operator must use each of the following as inputs to the trajectory computations:

(1) Launcher data, as follows—

(i) Geodetic latitude and longitude;

(ii) Height above sea level;

(iii) All location errors; and

(iv) Launch azimuth and elevation.

(2) Reference ellipsoidal Earth model, as follows—

(i) Name of the Earth model employed;

(ii) Semi-major axis;

(iii) Semi-minor axis;

(iv) Eccentricity;

(v) Flattening parameter;

(vi) Gravitational parameter;

(vii) Rotation angular velocity;

(viii) Gravitational harmonic constants; and

(ix) Mass of the Earth.

(3) *Vehicle characteristics for each stage.* A launch operator must identify the following for each stage of an unguided suborbital launch vehicle's flight:

(i) Nozzle exit area of each stage.

(ii) Distance from the rocket nose-tip to the nozzle exit for each stage.

(iii) Reference drag area and reference diameter of the rocket including any payload for each stage of flight.

(iv) Thrust as a function of time.

(v) Propellant weight as a function of time.

(vi) Coefficient of drag as a function of mach number.

(vii) Distance from the rocket nose-tip to center of gravity as a function of time.

(viii) Yaw moment of inertia as a function of time.

(ix) Pitch moment of inertia as a function of time.

(x) Pitch damping coefficient as a function of mach number.

(xi) Aerodynamic damping coefficient as a function of mach number.

(xii) Normal force coefficient as a function of mach number.

(xiii) Distance from the rocket nose-tip to center of pressure as a function of mach number.

(xiv) Axial force coefficient as a function of mach number.

(xv) Roll rate as a function of time.

(xvi) Gross mass of each stage.

(xvii) Burnout mass of each stage.

(xviii) Vacuum thrust.

(xix) Vacuum specific impulse.

(xx) Stage dimensions.

(xxi) Weight of each spent stage.

(xxii) Payload mass properties.

(xxiii) Nominal launch elevation and azimuth.

(4) *Launch events.* Each stage ignition times, each stage burn time, and each stage separation time, referenced to ignition time of first stage.

(5) *Atmosphere.* Density as a function of altitude, pressure as a function of altitude, speed of sound as a function of altitude, temperature as a function of altitude.

(6) *Wind errors.* Error in measurement of wind direction as a function of altitude and wind magnitude as a function of altitude, wind forecast error, such as error due to time delay from wind measurement to launch.

(d) *Methodology for determining the nominal trajectory and nominal drag impact points.* A launch operator must employ the steps in paragraphs (d)(1)–(d)(3) of this section to determine the nominal trajectory and the nominal drag impact point locations for each impacting rocket stage and component:

(1) A launch operator must identify each performance error parameter associated with the unguided suborbital launch vehicle's design and operation and the value for each parameter that reflect nominal rocket performance. A launch operator must identify each performance error parameter's distribution to account for all launch vehicle performance variations and any external forces that can cause offsets from the nominal trajectory during normal flight. These performance error parameters include thrust misalignment, thrust variation, weight variation, fin misalignment, impulse variation, aerodynamic drag variation, staging timing variation, stage separation-force variation, drag error, uncompensated wind, launcher elevation angle error, launcher azimuth angle error, launcher tip-off, and launcher location error.

(2) A launch operator must perform a no-wind trajectory simulation using a six-degrees-of-freedom (6–DOF) trajectory simulation with all performance error parameters set to their nominal values to determine the impact point of each stage or component. The 6–DOF trajectory simulation must provide rocket position translation along three axes of an orthogonal Earth-centered coordinate system and rocket orientation in roll, pitch and yaw. The 6–DOF trajectory simulation must compute each translation and orientation in response to forces and moments internal and external to the rocket including all the effects of the input data required by paragraph (c) of this section. A launch operator may incorporate the following assumptions in a 6–DOF trajectory simulation:

(i) The airframe may be treated as a rigid body.

(ii) The airframe may have a plane of symmetry coinciding with the vertical plane of reference.

(iii) The vehicle may have aerodynamic symmetry in roll.

(iv) The airframe may have six degrees-of-freedom.

(v) The aerodynamic forces and moments may be functions of mach number and may be linear with small flow incidence angles of attack.

(3) A launch operator must tabulate the geodetic latitude and longitude of the launch vehicle's nominal drag impact point as a function of trajectory time and the final nominal drag impact point of each planned impacting stage or component.

(e) *Methodology for determining maximum downrange drag impact points.* A launch operator must compute the maximum possible downrange drag impact point for each launch vehicle stage and impacting component. A launch operator must use the nominal drag impact point methodology, as defined by paragraph (d) of this section, modified to optimize the unguided suborbital launch vehicle's performance and flight profile to create the conditions for a maximum downrange drag impact point, including fuel exhaustion for each stage and impacting component.

(f) *Methodology for computing drag impact point dispersions.* A launch operator must employ the steps in paragraphs (f)(1)–(f)(3) of this section when determining the dispersions in terms of drag impact point distance standard deviations in uprange, downrange, and crossrange direction from the nominal drag impact point location for each stage and impacting component:

(1) For each stage of flight, a launch operator must identify the plus and minus one-sigma values for each performance error parameter identified as required by paragraph (d)(1) of this section (i.e., nominal value plus one standard deviation and nominal value minus one standard deviation). A launch operator must determine the dispersion in downrange, uprange, and left and right crossrange for each impacting stage and component. A launch operator may either perform a Monte Carlo analysis that accounts for the distribution of each performance error parameter or determine the dispersion by a root-sum-square method under paragraph (f)(2) of this section.

(2) When using a root-sum-square method to determine dispersion, a launch operator must determine the deviations for a given stage by evaluating the deviations produced in that stage due to the performance errors in that stage and all preceding stages of the launch vehicle as illustrated in Table C417–1, and by computing the square root of the sum of the squares of each deviation caused by each performance error parameter's one sigma dispersion for each stage in each of the right crossrange, left crossrange, uprange and downrange directions. A launch operator must evaluate the performance errors for one stage at a time, with the performance of all subsequent stages assumed to be nominal. A launch operator's root-sum-square method must incorporate the following requirements:

Table C417-1, Illustrative simulation runs required to determine drag impact point dispersions for a three stage launch vehicle.

Trajectory Simulation Runs Stage Performance Error Parameters	Dispersion Being Determined		
	Stage 1	Stage 2	Stage 3
Stage 1 errors	X[(1)]	-	-
Stage 1 errors, Stage 2 nominal	-	X	-
Stage 1 nominal, Stage 2 errors	-	X	-
Stage 1 errors, Stage 2 nominal, Stage 3 nominal	-	-	X
Stage 1 nominal, Stage 2 errors, Stage 3 nominal	-	-	X
Stage 1 nominal, Stage 2 nominal, Stage 3 errors	-	-	X

(1) An X in a given stage column means that the noted simulation runs are required to determine the dispersion for that stage.

(i) With the 6-DOF trajectory simulation used to determine nominal drag impact points as required by paragraph (d) of this section, perform a series of trajectory simulation runs for each stage and planned ejected debris, such as a fairing, payload, or other component, and, for each simulation, model only one performance error parameter set to either its plus or minus one-sigma value. For a given simulation run, set all other performance error parameters to their nominal values. Continue until achieving a trajectory simulation run for each plus one-sigma performance error parameter value and each minus one-sigma performance error parameter value for the stage or the planned ejected debris being evaluated. For each trajectory simulation run and for each impact being evaluated, tabulate the downrange, uprange, left crossrange, and right crossrange drag impact point distance deviations measured from the nominal drag impact point location for that stage or planned debris.

(ii) For uprange, downrange, right crossrange, and left crossrange, compute the square root of the sum of the squares of the distance deviations in each direction. The square root of the sum of the squares distance value for each direction represents the one-sigma drag impact point dispersion in that direction. For a multiple stage rocket, perform the first stage series of simulation runs with all subsequent stage performance error parameters set to their nominal value. Tabulate the uprange, downrange, right crossrange, and left crossrange distance deviations from the nominal impact for each subsequent drag impact point location caused by the first stage one-sigma performance error parameter. Use these deviations in determining the total drag impact point dispersions for the subsequent stage impacts as described in paragraph (f)(2)(iii) of this section.

(iii) For each subsequent stage impact of an unguided suborbital launch vehicle, determine the one-sigma impact dispersions by first determining the one-sigma distance deviations for that stage impact caused by each preceding stage as described in paragraph (f)(2)(ii) of this section. Then perform a series of simulation runs and tabulate the uprange, downrange, right crossrange, and left crossrange drag impact point distance deviations as described in paragraph (f)(2)(i) of this section for that stage's one-sigma performance error parameter values with the preceding stage performance parameters set to nominal values. For each uprange, downrange, right crossrange, and left crossrange direction, compute the square root of the sum of the squares of the stage impact distance deviations due to that stage's and each preceding stage's one-sigma performance error parameter values. This square root of the sum of the squares distance value for each direction represents the total one-sigma drag impact point dispersion in that direction for the nominal drag impact point location of that stage. Use these deviations when determining the total drag impact point dispersions for the subsequent stage impacts.

(3) A launch operator must determine a three-sigma dispersion area for each impacting stage or component as an ellipse that is centered at the nominal drag impact point location and has semi-major and semi-minor axes along the uprange, downrange, left crossrange, and right crossrange axes. The length of each axis must be three times as large as the total one-sigma drag impact point dispersions in each direction.

(g) *Trajectory analysis products for a suborbital launch vehicle.* A launch operator must file the following products of a trajectory analysis for an unguided suborbital launch vehicle with the FAA as required by §417.203(e):

(1) A description of the process that the launch operator used for performing the trajectory analysis, including the number of simulation runs and the process for any Monte Carlo analysis performed.

(2) A description of all assumptions and procedures the launch operator used in deriving each of the performance error parameters and their standard deviations.

(3) Launch point origin data: name, geodetic latitude (+N), longitude (+E), geodetic height, and launch azimuth measured clockwise from true north.

(4) Name of reference ellipsoid Earth model used. If a launch operator employs a reference ellipsoid Earth model other than WGS–84, Department of Defense World Geodetic System, Military Standard 2401 (Jan. 11, 1994), the launch operator must identify the semi-major axis, semi-minor axis, eccentricity, flattening parameter, gravitational parameter, rotation angular velocity, gravitational harmonic constants (e.g., J2, J3, J4), and mass of Earth.

(5) If a launch operator converts latitude and longitude coordinates between different ellipsoidal Earth models to complete a trajectory analysis, the launch operator must file the equations for geodetic datum conversions and a sample calculation for converting the geodetic latitude and longitude coordinates between the models employed.

(6) A launch operator must file tabular data that lists each performance error parameter used in the trajectory computations and each performance error parameter's plus and minus one-sigma values. If the launch operator employs a Monte Carlo analysis method for determining the dispersions about the nominal drag impact point, the tabular data must list the total one-sigma drag impact point distance deviations in each direction for each impacting stage and component. If the launch operator employs the square root of the sum of the squares method of paragraph (f)(2) of this section, the tabular data must include the one-sigma

drag impact point distance deviations in each direction due to each one-sigma performance error parameter value for each impacting stage and component.

(7) A launch operator must file a graphical depiction showing geographical landmasses and the nominal and maximum range trajectories from liftoff until impact of the final stage. The graphical depiction must plot trajectory points in time intervals of no greater than one second during thrusting flight and for times corresponding to ignition, thrust termination or burnout, and separation of each stage or impacting body. If there are less than four seconds between stage separation or other jettison events, a launch operator must reduce the time intervals between plotted trajectory points to 0.2 seconds or less. The graphical depiction must show total launch vehicle velocity as a function of time, present-position ground-range as a function of time, altitude above the reference ellipsoid as a function of time, and the static stability margin as a function of time.

(8) A launch operator must file tabular data that describes the nominal and maximum range trajectories from liftoff until impact of the final stage. The tabular data must include the time after liftoff, altitude above the reference ellipsoid, present position ground range, and total launch vehicle velocity for ignition, burnout, separation, booster apogee, and booster impact of each stage or impacting body. The launch operator must file the tabular data for the same time intervals required by paragraph (g)(7) of this section.

(9) A launch operator must file a graphical depiction showing all geographical landmasses and the unguided suborbital launch vehicle's drag impact point for the nominal trajectory, the maximum impact range boundary, and the three-sigma drag impact point dispersion area for each impacting stage or component. The graphical depiction must show the following in relationship to each other: The nominal trajectory, a circle whose radius represents the range to the farthest downrange impact point that results from the maximum range trajectory, and the three-sigma drag impact point dispersions for each impacting stage and component.

(10) A launch operator must file tabular data that describes the nominal trajectory, the maximum impact range boundary, and each three-sigma drag impact point dispersion area. The tabular data must include the geodetic latitude (positive north of the equator) and longitude (positive east of the Greenwich Meridian) of each point describing the nominal drag impact point positions, the maximum range circle, and each three-sigma impact dispersion area boundary. Each three-sigma dispersion area must be described by no less than 20 coordinate pairs. All coordinates must be rounded to the fourth decimal point.

C417.5 WIND WEIGHTING ANALYSIS

(a) *General.* As part of a wind weighting safety system, a launch operator must perform a wind weighting analysis to determine launcher azimuth and elevation settings that correct for the windcocking and wind-drift effects on an unguided suborbital launch vehicle due to forecasted winds in the airspace region of flight. A launch operator's wind weighting safety system and its operation must comply with §417.125(c). The launch azimuth and elevation settings resulting from a launch operator's wind weighting analysis must produce a trajectory, under actual wind conditions, that results in a final stage drag impact point that is the same as the final stage's nominal drag impact point determined according to section C417.3(d).

(b) *Wind weighting analysis constraints.*

(1) A launch operator's wind weighting analysis must:

(i) Account for the winds in the airspace region through which the rocket will fly. A launch operator's wind weighting safety system must include an operational method of determining the wind direction and wind magnitude at all altitudes that the rocket will reach up to the maximum altitude defined by dispersion analysis as required by section C417.3.

(ii) Account for all errors due to the methods used to measure the winds in the airspace region of the launch, delay associated with wind measurement, and the method used to model the effects of winds. The resulting sum of these error components must be no greater than those used as the wind error dispersion parameter in the launch vehicle trajectory analysis performed as required by section C417.3.

(iii) Account for the dispersion of all impacting debris, including any uncorrected wind error accounted for in the trajectory analysis performed as required by section C417.3.

(iv) Establish flight commit criteria that are a function of the analysis and operational methods employed and reflect the maximum wind velocities and wind variability for which the results of the wind weighting analysis are valid.

(v) Account for the wind effects during each thrusting phase of an unguided suborbital launch vehicle's flight and each ballistic phase of each rocket stage and component until burnout of the last stage.

(vi) Determine the impact point location for any parachute recovery of a stage or component or the launch operator must perform a wind drift analysis to determine the parachute impact point location.

(2) A launch operator must perform a wind weighting analysis using a six-degrees-of-

freedom (6–DOF) trajectory simulation that targets an impact point using an iterative process. The 6–DOF simulation must account for launch day wind direction and wind magnitude as a function of altitude.

(3) A launch operator must perform a wind weighting analysis using a computer program or other method of editing wind data, recording the time the data was obtained, and recording the balloon number or identification of any other measurement device used for each wind altitude layer.

(c) *Methodology for performing a wind weighting analysis.* A launch operator's method for performing a wind weighting analysis on the day of flight must account for the following:

(1) A launch operator must measure the winds on the day of flight to determine wind velocity and direction. A launch operator's process for measuring winds must provide wind data that is consistent with any assumptions made in the launch operator's trajectory and drag impact point dispersion analysis, as required by section C417.3, regarding the actual wind data available on the day of flight. Wind measurements must be made at altitude increments such that the maximum correction between any two measurements does not exceed 5%. Winds must be measured from the ground level at the launch point to a maximum altitude that is consistent with the launch operator's drag impact point dispersion analysis. The maximum wind measurement altitude must be that necessary to account for 99% of the wind effect on the impact dispersion point. A launch operator's wind measuring process must employ the use of balloons and radar tracking or balloons fitted with a Global Positioning System transceiver, and must account for the following:

(i) Measure winds from ground level to an altitude of at least that necessary to account for 99% of the wind effect on the impact dispersion point within six hours before flight and after any weather front passes the launch site before liftoff. Repeat a wind measurement up to the maximum altitude whenever a wind measurement, for any given altitude, from a later balloon release is not consistent with a wind measurement, for the same altitude, from an earlier balloon release.

(ii) Measure winds from ground level to an altitude of at least that necessary to account for 95% of the wind effect on the impact dispersion point within four hours before flight and after any weather front passes the launch site before liftoff. Repeat a wind measurement to the 95% wind effect altitude whenever a wind measurement, for any given altitude, from a later lower altitude balloon release is not consistent with the wind measurement, for the same altitude, from the 95% wind effect altitude balloon release.

(iii) Measure winds from ground level to an altitude of no less than that necessary to account for 80% of the wind effect on the impact dispersion point twice within 30 minutes of liftoff. Use the first measurement to set launcher azimuth and elevation, and the second measurement to verify the first measurement data.

(2) A launch operator must perform runs of the 6–DOF trajectory simulation using the flight day measured winds as input and targeting for the nominal final stage drag impact point. In an iterative process, vary the launcher elevation angle and azimuth angle settings for each simulation run until the nominal final stage impact point is achieved. The launch operator must use the resulting launcher elevation angle and azimuth angle settings to correct for the flight day winds. The launch operator must not initiate flight unless the launcher elevation angle and azimuth angle settings after wind weighting are in accordance with the following:

(i) The launcher elevation angle setting resulting from the wind weighting analysis must not exceed ± 5° from the nominal launcher elevation angle setting and must not exceed a total of 86° for a proven launch vehicle, and 84° for an unproven launch vehicle. A launch operator's nominal launcher elevation angle setting must be as required by §417.125(c)(3).

(ii) The launcher azimuth angle setting resulting from the wind weighting analysis must not exceed +30° from the nominal launcher azimuth angle setting unless the launch operator demonstrates clearly and convincingly, through the licensing process, that its unguided suborbital launch vehicle has a low sensitivity to high wind speeds, and the launch operator's wind weighting analysis and wind measuring process provide an equivalent level of safety.

(3) Using the trajectory produced in paragraph (c)(2) of this section, for each intermediate stage and planned ejected component, a launch operator must compute the impact point that results from wind drift by performing a run of the 6-DOF trajectory simulation with the launcher angles determined in paragraph (c)(2) of this section and the flight day winds from liftoff until the burnout time or ejection time of the stage or ejected component. The resulting impact point(s) must be accounted for when performing flight day ship-hit operations defined in section B417.11(c).

(4) If a parachute is used for any stage or component, a launch operator must determine the wind drifted impact point of the stage or component using a trajectory simulation that incorporates modeling for the change in aerodynamics at parachute ejection. Perform this simulation run in addition to any simulation of spent stages without parachutes.

(5) A launch operator must verify that the launcher elevation angle and azimuth angle settings at the time of liftoff are the same as required by the wind weighting analysis.

(6) A launch operator must monitor and verify that any wind variations and maximum wind limits at the time of liftoff are within the flight commit criteria established according to §417.113(c).

(7) A launch operator must generate output data from its wind weighting analysis for each impacting stage or component in printed, plotted, or computer medium format. This data must include:

(i) Launch day wind measurement data, including magnitude and direction.

(ii) The results of each computer run made using the launch day wind measurement data, including but not limited to, launcher settings, and impact locations for each stage or component.

(iii) Final launcher settings recorded.

(d) *Wind weighting analysis products.* The products of a launch operator's wind weighting analysis filed with the FAA as required by §417.203(e) must include the following:

(1) A launch operator must file a description of its wind weighting analysis methods, including its method and schedule of determining wind speed and wind direction for each altitude layer.

(2) A launch operator must file a description of its wind weighting safety system and identify all equipment used to perform the wind weighting analysis, such as any wind towers, balloons, or Global Positioning System wind measurement system employed and the type of trajectory simulation employed.

(3) A launch operator must file a sample wind weighting analysis using actual or statistical winds for the launch area and provide samples of the output required by paragraph (c)(7) of this section.

C417.7 DEBRIS ANALYSIS

(a) *General.* A flight safety analysis must include a debris analysis that satisfies the requirements of §417.211. This section applies to the debris data required by §417.211 and the debris analysis products that a launch operator must file with the FAA as required by §417.203(e).

(b) *Debris analysis constraints.* A debris analysis must produce the debris model described in paragraph (c) of this section. The analysis must account for all launch vehicle debris fragments, individually or in groupings of fragments called classes. The characteristics of each debris fragment represented by a class must be similar enough to the characteristics of all the other debris fragments represented by that class that all the debris fragments of the class can be described by a single set of characteristics. Paragraph (c)(10) of this section applies when establishing a debris class. A debris model must describe the physical, aerodynamic, and harmful characteristics of each debris fragment either individually or as a member of a class. A debris model must consist of lists of individual debris or debris classes for each cause of breakup and any planned jettison of debris, launch vehicle components, or payload. A debris analysis must account for:

(1) Debris due to any malfunction where forces on the launch vehicle may exceed the launch vehicle's structural integrity limits.

(2) The immediate post-breakup or jettison environment of the launch vehicle debris, and any change in debris characteristics over time from launch vehicle breakup or jettison until debris impact.

(3) The impact overpressure, fragmentation, and secondary debris effects of any confined or unconfined solid propellant chunks and fueled components containing either liquid or solid propellants that could survive to impact, as a function of vehicle malfunction time.

(4) The effects of impact of the intact vehicle as a function of failure time. The intact impact debris analysis must identify the trinitrotoluene (TNT) yield of impact explosions, and the numbers of fragments projected from all such explosions, including non-launch vehicle ejecta and the blast overpressure radius. The analysis must use a model for TNT yield of impact explosion that accounts for the propellant weight at impact, the impact speed, the orientation of the propellant, and the impacted surface material.

(c) *Debris model.* A debris analysis must produce a model of the debris resulting from planned jettison and from unplanned breakup of a launch vehicle for use as input to other analyses, such as establishing hazard areas and performing debris risk and toxic analyses. A launch operator's debris model must satisfy the following:

(1) *Debris fragments.* A debris model must provide the debris fragment data required by this section for the launch vehicle flight from the planned ignition time until thrust termination of the last thrusting stage. A debris model must provide debris fragment data for the number of time periods sufficient to meet the requirements for smooth and continuous contours used to define hazard areas as required by appendix B of this part.

(2) *Inert fragments.* A debris model must identify all inert fragments that are not volatile and that do not burn or explode under normal and malfunction conditions. A debris model must identify all inert fragments for each breakup time during flight corresponding to a critical event when the fragment catalog is significantly changed by the event. Critical events include staging,

payload fairing jettison, and other normal hardware jettison activities.

(3) *Explosive and non-explosive propellant fragments.* A debris model must identify all propellant fragments that are explosive or non-explosive upon impact. The debris model must describe each propellant fragment as a function of time, from the time of breakup through ballistic free-fall to impact. The debris model must describe the characteristics of each fragment, including its origin on the launch vehicle, representative dimensions and weight at the time of breakup and at the time of impact. For any fragment identified as an un-contained or contained propellant fragment, whether explosive or non-explosive, the debris model must identify whether or not it burns during free fall, and provide the consumption rate during free fall. The debris model must identify:

(i) Solid propellant that is exposed directly to the atmosphere and that burns but does not explode upon impact as ''un-contained non-explosive solid propellant.''

(ii) Solid or liquid propellant that is enclosed in a container, such as a motor case or pressure vessel, and that burns but does not explode upon impact as ''contained non-explosive propellant.''

(iii) Solid or liquid propellant that is enclosed in a container, such as a motor case or pressure vessel, and that explodes upon impact as ''contained explosive propellant fragment.''

(iv) Solid propellant that is exposed directly to the atmosphere and that explodes upon impact as ''un-contained explosive solid propellant fragment.''

(4) *Other non-inert debris fragments.* In addition to the explosive and flammable fragments identified under paragraph (c)(3) of this section, a debris model must identify any other non-inert debris fragments, such as toxic or radioactive fragments, that present any other hazards to the public.

(5) *Fragment weight.* At each modeled breakup time, the individual fragment weights must approximately add up to the sum total weight of inert material in the vehicle and the weight of contained liquid propellants and solid propellants that are not consumed in the initial breakup or conflagration.

(6) *Fragment imparted velocity.* A debris model must identify the maximum velocity imparted to each fragment due to potential explosion or pressure rupture. When accounting for imparted velocity, a debris model must:

(i) Use a Maxwellian distribution with the specified maximum value equal to the 97th percentile; or

(ii) Identify the distribution, and state whether or not the specified maximum value is a fixed value with no uncertainty.

(7) *Fragment projected area.* A debris model must include each of the axial, transverse, and mean tumbling areas of each fragment. If the fragment may stabilize under normal or malfunction conditions, the debris model must also provide the projected area normal to the drag force.

(8) *Fragment ballistic coefficient.* A debris model must include the axial, transverse, and tumble orientation ballistic coefficient for each fragment's projected area as required by paragraph (c)(7) of this section.

(9) *Debris fragment count.* A debris model must include the total number of each type of fragment required by paragraphs (c)(2), (c)(3), and (c)(4) of this section and created by a malfunction.

(10) *Fragment classes.* A debris model must categorize malfunction debris fragments into classes where the characteristics of the mean fragment in each class conservatively represent every fragment in the class. The model must define fragment classes for fragments whose characteristics are similar enough to be described and treated by a single average set of characteristics. A debris class must categorize debris by each of the following characteristics, and may include any other useful characteristics:

(i) The type of fragment, defined by paragraphs (c)(2), (c)(3), and (c)(4) of this section. All fragments within a class must be the same type, such as inert or explosive.

(ii) Debris subsonic ballistic coefficient (β_{sub}). The difference between the smallest $\log_{10}(\beta_{sub})$ value and the largest $\log_{10}(\beta_{sub})$ value in a class must not exceed 0.5, except for fragments with β_{sub} less than or equal to three. Fragments with β_{sub} less than or equal to three may be grouped within a class.

(iii) Breakup-imparted velocity (ΔV). A debris model must categorize fragments as a function of the range of ΔV for the fragments within a class and the class's median subsonic ballistic coefficient. For each class, the debris model must keep the ratio of the maximum breakup-imparted velocity (ΔV_{max}) to minimum breakup-imparted velocity (ΔV_{min}) within the following bound:

$$\frac{\Delta V_{max}}{\Delta V_{min}} < \frac{5}{2 + \log_{10}\left(\beta'_{sub}\right)}$$

Where:

β'_{sub} is the median subsonic ballistic coefficient for the fragments in a class.

(d) *Debris analysis products.* The products of a debris analysis that a launch operator must file with the FAA as required by §417.203(e) must include:

(1) *Debris model.* The launch operator's debris model that satisfies the requirements of this section.

(2) *Fragment description.* A description of the fragments contained in the launch operator's debris model. The description must identify the fragment as a launch vehicle

part or component, describe its shape, representative dimensions, and may include drawings of the fragment.

(3) *Intact impact TNT yield.* For an intact impact of a launch vehicle, for each failure time, a launch operator must identify the TNT yield of each impact explosion and blast overpressure hazard radius.

(4) *Fragment class data.* The class name, the range of values for each parameter used to categorize fragments within a fragment class, and the number of fragments in any fragment class established as required by paragraph (c)(10) of this section.

(5) *Ballistic coefficient.* The mean ballistic coefficient (β) and plus and minus three-sigma values of the β for each fragment class. A launch operator must provide graphs of the coefficient of drag (C_d) as a function of Mach number for the nominal and three-sigma β variations for each fragment shape. The launch operator must label each graph with the shape represented by the curve and reference area used to develop the curve. A launch operator must provide a C_d vs. Mach curve for any axial, transverse, and tumble orientations for any fragment that will not stabilize during free-fall conditions. For any fragment that may stabilize during free-fall, a launch operator must provide C_d vs. Mach curves for the stability angle of attack. If the angle of attack where the fragment stabilizes is other than zero degrees, a launch operator must provide both the coefficient of lift (C_L) vs. Mach number and the C_d vs. Mach number curves. The launch operator must provide the equations for each C_d vs. Mach curve.

(6) *Pre-flight propellant weight.* The initial preflight weight of solid and liquid propellant for each launch vehicle component that contains solid or liquid propellant.

(7) *Normal propellant consumption.* The nominal and plus and minus three-sigma solid and liquid propellant consumption rate, and pre-malfunction consumption rate for each component that contains solid or liquid propellant.

(8) *Fragment weight.* The mean and plus and minus three-sigma weight of each fragment or fragment class.

(9) *Projected area.* The mean and plus and minus three-sigma axial, transverse, and tumbling areas for each fragment or fragment class. This information is not required for those fragment classes classified as burning propellant classes under section A417.25(b)(8).

(10) *Imparted velocities.* The maximum incremental velocity imparted to each fragment class created by explosive or overpressure loads at breakup. The launch operator must identify the velocity distribution as Maxwellian or must define the distribution, including whether or not the specified maximum value is a fixed value with no uncertainty.

(11) *Fragment type.* The fragment type for each fragment established as required by paragraphs (c)(2), (c)(3), and (c)(4) of this section.

(12) *Origin.* The part of the launch vehicle from which each fragment originated.

(13) *Burning propellant classes.* The propellant consumption rate for those fragments that burn during free-fall.

(14) *Contained propellant fragments, explosive or non-explosive.* For contained propellant fragments, whether explosive or non-explosive, a launch operator must provide the initial weight of contained propellant and the consumption rate during free-fall. The initial weight of the propellant in a contained propellant fragment is the weight of the propellant before any of the propellant is consumed by normal vehicle operation or failure of the launch vehicle.

(15) *Solid propellant fragment snuff-out pressure.* The ambient pressure and the pressure at the surface of a solid propellant fragment, in pounds per square inch, required to sustain a solid propellant fragment's combustion during free-fall.

(16) *Other non-inert debris fragments.* For each non-inert debris fragment identified as required by paragraph (c)(4) of this section, a launch operator must describe the diffusion, dispersion, deposition, radiation, and other hazard exposure characteristics used to determine the effective casualty area required by paragraph (c)(9) of this section.

(17) *Residual thrust dispersion.* For each thrusting or non-thrusting stage having residual thrust capability following a launch vehicle malfunction, a launch operator must provide either the total residual impulse imparted or the full-residual thrust in foot-pounds as a function of breakup time. For any stage not capable of thrust after a launch vehicle malfunction, a launch operator must provide the conditions under which the stage is no longer capable of thrust. For each stage that can be ignited as a result of a launch vehicle malfunction on a lower stage, a launch operator must identify the effects and duration of the potential thrust, and the maximum deviation of the instantaneous impact point which can be brought about by the thrust.

C417.9 DEBRIS RISK

(a) *General.* A launch operator must perform a debris risk analysis that satisfies the requirements of §417.225. This section applies to the computation of the average number of casualties (E_c) to the collective members of the public exposed to inert and explosive debris hazards from the proposed flight of an unguided suborbital launch vehicle as required by §417.225 and to the analysis products that the launch operator must file with the FAA as required by §417.203(e).

(b) *Debris risk analysis constraints.* The following constraints apply to debris risk:

(1) A debris risk analysis must use valid risk analysis models that compute E_c as the summation over all trajectory time intervals from lift-off through impact of the products of the probability of each possible event and the casualty consequences due to debris impacts for each possible event.

(2) A debris risk analysis must account for the following populations:

(i) The overflight of populations located inside any flight hazard area.

(ii) All populations located within five-sigma left and right crossrange of a nominal trajectory instantaneous impact point ground trace and within five-sigma of each planned nominal debris impact.

(3) A debris risk analysis must account for both inert and explosive debris hazards produced from any impacting debris caused by normal and malfunctioning launch vehicle flight. The analysis must account for the debris classes determined by the debris analysis required by section A417.11. A debris risk analysis must account for any inert debris impact with mean expected kinetic energy at impact greater than or equal to 11 ft-lbs and peak incident overpressure of greater than or equal to 1.0 psi due to any explosive debris impact. The analysis must account for all debris hazards as a function of flight time.

(4) A debris risk analysis must account for debris impact points and dispersion for each class of debris in accordance with the following:

(i) A debris risk analysis must account for drag corrected impact points and dispersions for each class of impacting debris resulting from normal and malfunctioning launch vehicle flight as a function of trajectory time from lift-off through final impact.

(ii) The dispersion for each debris class must account for the position and velocity state vector dispersions at breakup, the variance produced by breakup imparted velocities, the effects of winds on both the ascent trajectory state vector at breakup and the descending debris piece impact location, the variance produced by aerodynamic properties for each debris class, and any other dispersion variances.

(iii) A debris risk analysis must account for the survivability of debris fragments that are subject to reentry aerodynamic forces or heating. A debris class may be eliminated from the debris risk analysis if the launch operator demonstrates that the debris will not survive to impact.

(5) A debris risk analysis must account for launch vehicle failure probability. The following constraints apply:

(i) For flight safety analysis purposes, a failure occurs when a vehicle does not complete any phase of normal flight or exhibits the potential for the stage or its debris to impact the Earth or reenter the atmosphere during the mission or any future mission of similar vehicle capability. Also, either a launch incident or launch accident constitutes a failure.

(ii) For a launch vehicle with fewer than 2 flights completed, the analysis must use a reference value for the launch vehicle failure probability estimate equal to the upper limit of the 60% two-sided confidence limits of the binomial distribution for outcomes of all previous launches of vehicles developed and launched in similar circumstances. The FAA may adjust the failure probability estimate to account for the level of experience demonstrated by the launch operator and other factors that affects the probability of failure. The FAA may adjust the failure probability estimate for the second launch based on evidence obtained from the first flight of the vehicle.

(iii) For a launch vehicle with at least 2 flights completed, the analysis must use the reference value for the launch vehicle failure probability of Table C417–2 based on the outcomes of all previous launches of the vehicle. The FAA may adjust the failure probability estimate to account for evidence obtained from the flight history of the vehicle. Failure probability estimate adjustments to the reference value may account for the nature of launch outcomes in the flight history of the vehicle, corrective actions taken in response to a failure of the vehicle, or other vehicle modifications that may affect reliability. The FAA may adjust the failure probability estimate to account for the demonstrated quality of the engineering approach to launch vehicle processing. The analysis must use a final failure estimate within the confidence limits of Table C417–2.

(A) Values listed on the far left of Table C417–2 apply when no launch failures are experienced. Values on the far right apply when only launch failures are experienced. Values in between apply for flight histories that include both failures and successes.

(B) Reference values in Table C417–2 are shown in bold. The reference values are the median values between 60% two-sided confidence limits of the binomial distribution. For the special cases of zero or N failures in N launch attempts, the reference values may also be recognized as the median value between the 80% one-sided confidence limit of the binomial distribution and zero or one, respectively.

(C) Upper and lower confidence bounds in Table C417–2 are shown directly above and below each reference value. These confidence bounds are based on 60% two-sided confidence limits of the binomial distribution. For the special cases of zero or N failures in N launch attempts, the upper and lower confidence bounds are based on the 80% one-sided confidence limit, respectively.

Table C417-2, Launch Vehicle Failure Probability Reference Estimates and Confidence Bounds of Launch Vehicles with Two or More Flights

Launch #									<--------Success			Failure ------->									
									.553		.894		1.00								
3									**.276**		**.50**		**.724**								
									.00		.106		.447								
								.415		.713		.928		1.00							
4								**.208**		**.392**		**.608**		**.792**							
								.00		.072		.287		.585							
							.331		.582		.788		.946		1.00						
5							**.166**		**.318**		**.50**		**.682**		**.834**						
							.00		.054		.212		.418		.669						
						.275		.49		.673		.831		.956		1.00					
6						**.138**		**.267**		**.421**		**.579**		**.733**		**.862**					
						.00		.044		.169		.327		.51		.725					
					.235		.422		.585		.731		.86		.963		1.00				
7					**.118**		**.229**		**.363**		**.50**		**.637**		**.771**		**.882**				
					.00		.037		.14		.269		.415		.578		.765				
				.205		.371		.517		.65		.772		.88		.969		1.00			
8				**.103**		**.201**		**.318**		**.439**		**.561**		**.682**		**.799**		**.897**			
				.00		.031		.12		.228		.35		.483		.629		.795			
			.182		.33		.462		.584		.697		.801		.896		.972		1.00		
9			**.091**		**.179**		**.283**		**.391**		**.50**		**.609**		**.717**		**.821**		**.909**		
			.00		.028		.104		.199		.303		.416		.538		.67		.818		
		.164		.298		.418		.529		.634		.732		.824		.907		.976		1.00	
10		**.082**		**.161**		**.255**		**.352**		**.451**		**.549**		**.648**		**.745**		**.839**		**.918**	
		.00		.024		.093		.176		.268		.366		.471		.582		.702		.836	
	.149		.271		.381		.484		.581		.673		.761		.842		.917		.978		1.00
11	**.074**		**.147**		**.232**		**.321**		**.41**		**.50**		**.59**		**.679**		**.768**		**.853**		**.926**
	.00		.022		.083		.158		.239		.327		.419		.516		.619		.729		.851

(6) A debris risk analysis must account for the dwell time of the instantaneous impact point ground trace over each populated or protected area being evaluated.

(7) A debris risk analysis must account for the three-sigma instantaneous impact point trajectory variations in left-crossrange, right-crossrange, uprange, and downrange as a function of trajectory time, due to launch vehicle performance variations as determined by the trajectory analysis performed as required by section C417.3.

(8) A debris risk analysis must account for the effective casualty area as a function of launch vehicle flight time for all impacting debris generated from a catastrophic launch vehicle malfunction event or a planned impact event. The effective casualty area must:

(i) Account for both payload and vehicle systems and subsystems debris;

(ii) Account for all debris fragments determined as part of a launch operator's debris analysis as required by section A417.11;

(iii) For each explosive debris fragment, account for a 1.0 psi blast overpressure radius and the projected debris effects for all potentially explosive debris; and

(iv) For each inert debris fragment, account for bounce, skip, slide, and splatter effects; or equal seven times the maximum projected area of the fragment.

(9) A debris risk analysis must account for current population density data obtained from a current population database for the region being evaluated or by estimating the current population using exponential population growth rate equations applied to the most current historical data available. The population model must define population centers that are similar enough to be described and treated as a single average set of characteristics without degrading the accuracy of the debris risk estimate.

(c) *Debris risk analysis products.* The products of a debris risk analysis that a launch operator must file with the FAA must include:

(1) A debris risk analysis report that provides the analysis input data, probabilistic risk determination methods, sample computations, and text or graphical charts that characterize the public risk to geographical areas for each launch.

(2) Geographic data showing:

(i) The launch vehicle nominal, five-sigma left-crossrange and five-sigma right-crossrange instantaneous impact point ground traces;

(ii) All exclusion zones relative to the instantaneous impact point ground traces; and

(iii) All populated areas included in the debris risk analysis.

(3) A discussion of each launch vehicle failure scenario accounted for in the analysis and the probability of occurrence, which may vary with flight time, for each failure scenario. This information must include failure scenarios where a launch vehicle:

(i) Flies within normal limits until some malfunction causes spontaneous breakup; and

(ii) Experiences malfunction turns.

(4) A population model applicable to the launch overflight regions that contains the following: Region identification, location of the center of each population center by geodetic latitude and longitude, total area, number of persons in each population center, and a description of the shelter characteristics within the population center.

(5) A description of the launch vehicle, including general information concerning the nature and purpose of the launch and an overview of the launch vehicle, including a scaled diagram of the general arrangement and dimensions of the vehicle. A launch operator's debris risk analysis products may reference other documentation filed with the FAA containing this information. The description must include:

(i) Weights and dimensions of each stage.

(ii) Weights and dimensions of any booster motors attached.

(iii) The types of fuel used in each stage and booster.

(iv) Weights and dimensions of all interstage adapters and skirts.

(v) Payload dimensions, materials, construction, and any payload fuel; payload fairing construction, materials, and dimensions; and any non-inert components or materials that add to the effective casualty area of the debris, such as radioactive or toxic materials or high-pressure vessels.

(6) A typical sequence of events showing times of ignition, cutoff, burnout, and jettison of each stage, firing of any ullage rockets, and starting and ending times of coast periods and control modes.

(7) The following information for each launch vehicle motor:

(i) Propellant type and composition;

(ii) Vacuum thrust profile;

(iii) Propellant weight and total motor weight as a function of time;

(iv) A description of each nozzle and steering mechanism;

(v) For solid rocket motors, internal pressure and average propellant thickness, or borehole radius, as a function of time;

(vi) Burn rate; and

(vii) Nozzle exit and entrance areas.

(8) The launch vehicle's launch and failure history, including a summary of past vehicle performance. For a new vehicle with little or no flight history, a launch operator must provide all known data on similar vehicles that include:

(i) Identification of the launches that have occurred;

(ii) Launch date, location, and direction of each launch;

(iii) The number of launches that performed normally;

(iv) Behavior and impact location of each abnormal experience;

(v) The time, altitude, and nature of each malfunction; and

(vi) Descriptions of corrective actions taken, including changes in vehicle design, flight termination, and guidance and control hardware and software.

(9) The values of probability of impact (PI) and expected casualty (Ec) for each populated area.

C417.11 COLLISION AVOIDANCE

(a) *General*. A flight safety analysis must include a collision avoidance analysis that satisfies the requirements of §417.231. This section applies to a launch operator obtaining a collision avoidance assessment from United States Strategic Command as required by §417.231 and to the analysis products that the launch operator must file with the FAA as required by §417.203(e). United States Strategic Command refers to a collision avoidance analysis for a space launch as a conjunction on launch assessment.

(b) *Analysis not required*. A collision avoidance analysis is not required if the maximum altitude attainable by the launch operator's unguided suborbital launch vehicle is less than the altitude of the lowest manned or mannable orbiting object. The maximum altitude attainable means an optimized trajectory, assuming 3-sigma maximum performance, extended through fuel exhaustion of each stage, to achieve a maximum altitude.

(c) *Analysis constraints*. A launch operator must satisfy the following when obtaining and implementing the results of a collision avoidance analysis:

(1) A launch operator must provide United States Strategic Command with the launch window and trajectory data needed to perform a collision avoidance analysis for a launch as required by paragraph (d) of this section, at least 15 days before the first attempt at flight. The FAA will identify a launch operator to United States Strategic Command as part of issuing a license and provide a launch operator with current United States Strategic Command contact information.

(2) A launch operator must obtain a collision avoidance analysis performed by United States Strategic Command 6 hours before the beginning of a launch window.

(3) A launch operator may use a collision avoidance analysis for 12 hours from the time that United States Strategic Command determines the state vectors of the manned or mannable orbiting objects. If a launch operator needs an updated collision avoidance analysis due to a launch delay, the launch operator must file the request with United States Strategic Command at least 12 hours prior to the beginning of the new launch window.

(4) For every 90 minutes, or portion of 90 minutes, that pass between the time United States Strategic Command last determined the state vectors of the orbiting objects, a launch operator must expand each wait in a

launch window by subtracting 15 seconds from the start of the wait in the launch window and adding 15 seconds to the end of the wait in the launch window. A launch operator must incorporate all the resulting waits in the launch window into its flight commit criteria established as required by §417.113.

(d) *Information required.* A launch operator must prepare a collision avoidance analysis worksheet for each launch using a standardized format that contains the input data required by this paragraph. A launch operator must file the input data with United States Strategic Command for the purposes of completing a collision avoidance analysis.

(1) *Launch information.* A launch operator must file the following launch information:

(i) *Mission name.* A mnemonic given to the launch vehicle/payload combination identifying the launch mission from all others.

(ii) *Segment number.* A segment is defined as a launch vehicle stage or payload after the thrusting portion of its flight has ended. This includes the jettison or deployment of any stage or payload. A launch operator must provide a separate worksheet for each segment. For each segment, a launch operator must determine the "vector at injection" as defined by paragraph (d)(5) of this section. The data must present each segment number as a sequence number relative to the total number of segments for a launch, such as "1 of 5."

(iii) *Launch window.* The launch window opening and closing times in Greenwich Mean Time (referred to as ZULU time) and the Julian dates for each scheduled launch attempt.

(2) *Point of contact.* The person or office within a launch operator's organization that collects, analyzes, and distributes collision avoidance analysis results.

(3) *Collision avoidance analysis results transmission medium.* A launch operator must identify the transmission medium, such as voice, FAX, or e-mail, for receiving results from United States Strategic Command.

(4) *Requestor launch operator needs.* A launch operator must indicate the types of analysis output formats required for establishing flight commit criteria for a launch:

(i) *Waits.* All the times within the launch window during which flight must not be initiated.

(ii) *Windows.* All the times within an overall launch window during which flight may be initiated.

(5) *Vector at injection.* A launch operator must identify the vector at injection for each segment. "Vector at injection" identifies the position and velocity of all orbital or suborbital segments after the thrust for a segment has ended.

(i) *Epoch.* The epoch time, in Greenwich Mean Time (GMT), of the expected launch vehicle liftoff time.

(ii) *Position and velocity.* The position coordinates in the EFG coordinate system measured in kilometers and the EFG components measured in kilometers per second, of each launch vehicle stage or payload after any burnout, jettison, or deployment.

(6) *Time of powered flight.* The elapsed time in seconds, from liftoff to arrival at the launch vehicle vector at injection. The input data must include the time of powered flight for each stage or jettisoned component measured from liftoff.

(7) *Time span for launch window file (LWF).* A launch operator must provide the following information regarding its launch window:

(i) *Launch window.* The launch window measured in minutes from the initial proposed liftoff time.

(ii) *Time of powered flight.* The time provided as required by paragraph (d)(6) of this section measured in minutes rounded up to the nearest integer minute.

(iii) *Screen duration.* The time duration, after all thrusting periods of flight have ended, that a collision avoidance analysis must screen for potential conjunctions with manned or mannable orbital objects. Screen duration is measured in minutes.

(iv) *Extra pad.* An additional period of time for collision avoidance analysis screening to ensure the entire trajectory time is screened for potential conjunctions with manned or mannable orbital objects. This time must be 10 minutes unless otherwise specified by United States Strategic Command.

(v) *Total.* The summation total of the time spans provided as required by paragraphs (d)(7)(i) through (d)(7)(iv) expressed in minutes.

(8) *Screening.* A launch operator must select spherical or ellipsoidal screening as defined in this paragraph for determining any conjunction. The default must be the spherical screening method using an avoidance radius of 200 kilometers for manned or mannable orbiting objects. If the launch operator requests screening for any unmanned or unmannable objects, the default must be the spherical screening method using a miss-distance of 25 kilometers.

(i) *Spherical screening.* Spherical screening utilizes an impact exclusion sphere centered on each orbiting object's center-of-mass to determine any conjunction. A launch operator must specify the avoidance radius for manned or mannable objects and for any unmanned or unmannable objects if the launch operator elects to perform the analysis for unmanned or unmannable objects.

(ii) *Ellipsoidal screening.* Ellipsoidal screening utilizes an impact exclusion ellipsoid of revolution centered on the orbiting object's center-of-mass to determine any conjunction. A launch operator must provide input in the UVW coordinate system in kilometers. The launch operator must provide delta-U measured in the radial-track direction, delta-V measured in the in-track direction, and delta-W measured in the cross-range direction.

(9) *Deliverable schedule/need dates*. A launch operator must identify the times before flight, referred to as ''L-times,'' for which the launch operator requests a collision avoidance analysis.

(e) *Collision avoidance assessment products*. A launch operator must file its collision avoidance analysis products as required by § 417.203(e) and must include the input data required by paragraph (d) of this section. A launch operator must incorporate the result of the collision avoidance analysis into its flight commit criteria established as required by § 417.113.

APPENDIX D TO PART 417—FLIGHT TERMINATION SYSTEMS, COMPONENTS, INSTALLATION, AND MONITORING

D417.1 GENERAL

This appendix applies to each flight termination system and the components that make up the system for each launch. Section 417.301 requires that a launch operator's flight safety system include a flight termination system that complies with this appendix. Section 417.301 also contains requirements that apply to a launch operator's demonstration of compliance with the requirements of this appendix.

D417.3 FLIGHT TERMINATION SYSTEM FUNCTIONAL REQUIREMENTS

(a) When a flight safety system terminates the flight of a vehicle because it has either violated a flight safety rule as defined in § 417.113 or the vehicle inadvertently separates or destructs as described in section D417.11, a flight termination system must:

(1) Render each propulsion system that has the capability of reaching a populated or other protected area, incapable of propulsion, without significant lateral or longitudinal deviation in the impact point. This includes each stage and any strap on motor or propulsion system that is part of any payload;

(2) Terminate the flight of any inadvertently or prematurely separated propulsion system capable of reaching a populated or other protected area;

(3) Destroy the pressure integrity of any solid propellant system to terminate all thrust or ensure that any residual thrust causes the propulsion system to tumble without significant lateral or longitudinal deviation in the impact point; and

(4) Disperse any liquid propellant, whether by rupturing the propellant tank or other equivalent method, and initiate burning of any toxic liquid propellant.

(b) A flight termination system must not cause any solid or liquid propellant to detonate.

(c) The flight termination of a propulsion system must not interfere with the flight termination of any other propulsion system.

D417.5 FLIGHT TERMINATION SYSTEM DESIGN

(a) *Reliability prediction*. A flight termination system must have a predicted reliability of 0.999 at a confidence level of 95 percent. A launch operator must demonstrate the system's predicted reliability by satisfying the requirements for system reliability analysis of § 417.309(b).

(b) *Single fault tolerance*. A flight termination system, including monitoring and checkout circuits, must not have a single failure point that would:

(1) Inhibit functioning of the system during flight; or

(2) Produce an inadvertent initiation of the system that would endanger the public.

(c) *Redundancy*. A flight termination system must use redundant components that are structurally, electrically, and mechanically separated. Each redundant component's mounting on a launch vehicle, including location or orientation, must ensure that any failure that will damage, destroy or otherwise inhibit the operation of one redundant component will not inhibit the operation of the other redundant component and will not inhibit functioning of the system. Each of the following exceptions applies:

(1) Any linear shaped charge need not be redundant if it initiates at both ends, and the initiation source for one end is not the same as the initiation source for the other end; or

(2) Any passive component such as an antenna or radio frequency coupler need not be redundant if it satisfies the requirements of this appendix.

(d) *System independence*. A flight termination system must operate independently of any other launch vehicle system. The failure of another launch vehicle system must not inhibit the functioning of a flight termination system. A flight termination system may share a component with another launch vehicle system, only if the launch operator demonstrates that sharing the component will not degrade the flight termination system's reliability. A flight termination system may share a connection with another system if the connection must exist to satisfy a flight termination system requirement, such as any connection needed to:

(1) Accomplish flight termination system arming and safing;

(2) Provide data to the telemetry system; or

(3) Accomplish any engine shut-down.

(e) *Performance specifications for components and parts*. Each flight termination system component and each part that can affect the reliability of a flight termination component during flight must have written performance specifications that show, and contain the details of, how the component or part satisfies the requirements of this appendix.

(f) *Ability to test.* A flight termination system, including each component and associated ground support and monitoring equipment, must satisfy the tests required by appendix E of this part.

(g) *Software safety critical functions.* The requirements of §417.123 apply to any computing system, software or firmware that is associated with a flight termination system and performs a software safety critical function as defined in §417.123.

(h) *Component storage, operating, and service life.* Each flight termination system component must have a specified storage life, operating life, and service life and must satisfy all of the following:

(1) Each component must satisfy all its performance specifications when subjected to the full length of its specified storage life, operating life, and service life; and

(2) A component's storage, operating, or service life must not expire before flight. A launch operator may extend an ordnance component's service life by satisfying the service life extension tests of appendix E of this part.

(i) *Consistency of components.* A launch operator must ensure that each flight component sample is manufactured using parts, materials, processes, quality controls, and procedures that are each consistent with the manufacture of each qualification test sample.

D417.7 Flight Termination System Environment Survivability

(a) *General.* A flight termination system, including all of its components, mounting hardware, cables, and wires, must each satisfy all of their performance specifications when subjected to each maximum predicted operating and non-operating environment and environmental design margin required by this appendix. As an alternative to subjecting the flight termination system to the maximum predicted environments and margin for each dynamic operating environment, such as vibration or shock, a flight termination system need only satisfy all its performance specifications when subjected to an environmental level greater than the level that would cause structural breakup of the launch vehicle.

(b) *Maximum predicted environments.* A launch operator must determine all maximum predicted non-operating and operating environments that a flight termination system, including each component, will experience before its safe flight state. This determination must be based on analysis, modeling, testing, or monitoring. Non-operating and operating environments include temperature, vibration, shock, acceleration, acoustic, and other environments that apply to a specific launch vehicle and launch site, such as humidity, salt fog, dust, fungus, explosive atmosphere, and electromagnetic energy. Both of the following apply:

(1) Each maximum predicted vibration, shock, and thermal environment for a flight termination system component must include a margin that accounts for the uncertainty due to flight-to-flight variability and any analytical uncertainty. For a launch vehicle configuration for which there have been fewer than three flights, the margin must be no less than plus 3 dB for vibration, plus 4.5 dB for shock, and plus and minus 11 °C for thermal range; and

(2) For a launch vehicle configuration for which there have been fewer than three flights, a launch operator must monitor flight environments at as many locations within the launch vehicle as needed to verify the maximum predicted flight environments for each flight termination system component. An exception is that the launch operator may obtain empirical shock environment data through ground testing. A launch operator must adjust each maximum predicted flight environment for any future launch to account for all data obtained through monitoring.

(c) *Thermal environment.* A component must satisfy all its performance specifications when exposed to preflight and flight thermal cycle environments. A thermal cycle must begin with the component at ambient temperature. The cycle must continue as the component is heated or cooled to achieve the required dwell time at one extreme of the required thermal range, then to achieve the required dwell time at the other extreme, and then back to ambient temperature. Each cycle, including all dwell times, must be continuous without interruption by any other period of heating or cooling. Paragraphs (c)(2) through (c)(6) of this section identify the required thermal range for each component. A thermal cycle must include no less than a one-hour dwell time at each temperature extreme. The thermal rate of change between the extremes must be no less than the maximum predicted thermal rate of change or 1 °C per minute, whichever is greater. For an ordnance device, the thermal cycle must include no less than a two-hour dwell time at each temperature extreme. The thermal rate of change between the extremes for an ordnance device must be no less than the maximum predicted thermal rate of change or 3 °C per minute, whichever is greater.

(1) *Acceptance-number of thermal cycles.* For each component, the acceptance-number of thermal cycles must be no less than eight thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing and flight, including all launch delays

and recycling, rounded up to the nearest whole number, whichever is greater.

(2) *Passive components*. A passive component must satisfy all its performance specifications when subjected to:

(i) The acceptance-number of thermal cycles from one extreme of the maximum predicted thermal range to the other extreme; and

(ii) Three times the acceptance-number of thermal cycles from the lower of −34 °C or the predicted lowest temperature minus 10 °C, to the higher of 71 °C or the predicted highest temperature plus 10 °C.

(3) *Electronic components*. An electronic flight termination system component, including any component that contains an active electronic piece-part such as a microcircuit, transistor, or diode must satisfy all its performance specifications when subjected to:

(i) The sum of ten thermal cycles and the acceptance-number of thermal cycles from one extreme of the maximum predicted thermal range to the other extreme; and

(ii) Three times the acceptance-number of thermal cycles from the lower of −34 °C or the predicted lowest temperature minus 10 °C, to the higher of 71 °C or the predicted highest temperature plus 10 °C.

(4) *Power source thermal design*. A flight termination system power source, including any battery, must satisfy all its performance specifications when exposed to preflight and flight thermal environments. The power source must satisfy the following:

(i) A silver zinc battery must satisfy all its performance specifications when subjected to the acceptance-number of thermal cycles from 10 °C lower than the lowest temperature of the battery's maximum predicted temperature range to 10 °C higher than the highest temperature of the range. An exception is that each thermal cycle may range from 5.5 °C lower than the lowest temperature of the battery's maximum predicted temperature range to 10 °C higher than the highest temperature of the range if the launch operator monitors the battery's operating temperature on the launch vehicle with an accuracy of no less than ±1.5 °C.

(ii) A nickel cadmium battery must satisfy all its performance specifications when subjected to three times the acceptance-number of thermal cycles from the lower of −20 °C or the predicted lowest temperature minus 10 °C, to the higher of 40 °C or the predicted highest temperature plus 10 °C.

(iii) Any other power source must satisfy all its performance specifications when subjected to three times the acceptance-number of thermal cycles from 10 °C lower than the lowest temperature of the maximum predicted temperature range to 10 °C higher the highest temperature of the range.

(5) *Electro-mechanical safe-and-arm devices with internal explosives*. A safe-and-arm device must satisfy all its performance specifications when subjected to:

(i) The acceptance-number of thermal cycles from one extreme of the maximum predicted thermal range to the other extreme; and

(ii) Three times the acceptance-number of thermal cycles from the lower of −34 °C or the predicted lowest temperature minus 10 °C, to the higher of 71 °C or the predicted highest temperature plus 10 °C.

(6) *Ordnance thermal design*. An ordnance device and any associated hardware must satisfy all its performance specifications when subjected to the acceptance-number of thermal cycles from the lower of −54 °C or the predicted lowest temperature minus 10 °C, to the higher of 71 °C or the predicted highest temperature plus 10 °C. Each cycle must include a two-hour dwell time at each temperature extreme and a thermal rate of change between the extremes must be no less than the maximum predicted thermal rate of change or 3 °C per minute, whichever is greater.

(d) *Random vibration*. A component must satisfy all its performance specifications when exposed to a composite vibration level profile consisting of the higher of 6 dB above the maximum predicted flight random vibration level or a 12.2Grms workmanship screening level, across the 20 Hz to 2000 Hz spectrum of the two levels. The component must satisfy all its performance specifications when exposed to three times the maximum predicted random vibration duration time or three minutes per axis, whichever is greater, on each of three mutually perpendicular axes and for all frequencies from 20 Hz to 2000 Hz.

(e) *Sinusoidal vibration*. A component must satisfy all its performance specifications when exposed to 6 dB above the maximum predicted flight sinusoidal vibration level. The component must satisfy all its performance specifications when exposed to three times the maximum predicted sinusoidal vibration duration time on each of three mutually perpendicular axes and for all frequencies from 50% lower than the predicted lowest frequency to 50% higher than the predicted highest frequency. The sweep rate must be no greater than one-third the maximum predicted sweep rate on each of the three axes.

(f) *Transportation vibration*. A component must satisfy all its performance specifications when exposed to 6 dB above the maximum predicted transportation vibration level to be experienced when the component is in the configuration in which it is transported, for three times the maximum predicted transportation exposure time. A component must also satisfy all its performance specifications when exposed to the workmanship screening vibration levels and duration required by section E417.9(f).

(g) *Pyrotechnic shock*.

(1) A flight termination system component must satisfy all its performance specifications when exposed to the greater of:

(i) A force of 6 dB above the maximum predicted pyrotechnic shock level to be experienced during flight with a shock frequency response range from 100 Hz to 10,000 Hz; or

(ii) The minimum breakup qualification shock levels and frequencies required by Table E417.11–2 of appendix E of this part.

(2) A component must satisfy all its performance specifications after it experiences a total of 18 shocks consisting of three shocks in each direction, positive and negative, for each of three mutually perpendicular axes.

(h) *Transportation shock.* A flight termination system component must satisfy all its performance specifications after being exposed to the maximum predicted shock to be experienced during transportation while in the configuration in which it is packed for transport.

(i) *Bench handling shock.* A flight termination system component must satisfy all its performance specifications after being exposed to the maximum predicted shock to be experienced during handling in its unpacked configuration.

(j) *Acceleration environment.* A flight termination system component must satisfy all its performance specifications when exposed to launch vehicle breakup acceleration levels or twice the maximum predicted flight acceleration levels, whichever is greater. The component must satisfy all its performance specifications when exposed to three times the maximum predicted acceleration duration for each of three mutually perpendicular axes.

(k) *Acoustic environment.* A flight termination system component must satisfy all its performance specifications when exposed to 6 dB above the maximum predicted sound pressure level. The component must satisfy all its performance specifications when exposed to three times the maximum predicted sound pressure duration time or three minutes, whichever is greater for each of three mutually perpendicular axes. The frequency must range from 20 Hz to 2000 Hz.

(l) *Other environments.* A flight termination system component must satisfy all its performance specifications after experiencing any other environment that it could experience during transportation, storage, preflight processing, or preflight system testing. Such environments include storage temperature, humidity, salt fog, fine sand, fungus, explosive atmosphere, and electromagnetic energy environments.

D417.9 COMMAND DESTRUCT SYSTEM

(a) A flight termination system must include a command destruct system that is initiated by radio command and satisfies the requirements of this section.

(b) A command destruct system must have its radio frequency components on or above the last launch vehicle stage capable of reaching a populated or other protected area before the planned safe flight state for the launch.

(c) The initiation of a command destruct system must result in accomplishing all the flight termination system functions of section D417.3.

(d) At any point along the nominal trajectory from liftoff until no longer required by §417.107, a command destruct system must operate with a radio frequency input signal that has an electromagnetic field intensity of 12 dB below the intensity provided by the command transmitter system under nominal conditions over 95 percent of the radiation sphere surrounding the launch vehicle.

(e) A command destruct system must survive the breakup of the launch vehicle until the system accomplishes all its flight termination functions or until breakup of the vehicle, including the use of any automatic or inadvertent separation destruct system, accomplishes the required flight termination.

(f) A command destruct system must receive and process a valid flight termination system arm command before accepting a flight termination system destruct command.

(g) For any liquid propellant, a command destruct system must allow a flight safety official to non-destructively shut down any thrusting liquid engine by command before destroying the launch vehicle.

D417.11 AUTOMATIC OR INADVERTENT SEPARATION DESTRUCT SYSTEM

(a) A flight termination system must include an automatic or inadvertent separation destruct system for each stage or strap-on motor capable of reaching a protected area before the planned safe flight state for each launch if the stage or strap-on motor does not possess a complete command destruct system. Any automatic or inadvertent separation destruct system must satisfy the requirements of this section.

(b) The initiation of an automatic or inadvertent separation destruct system must accomplish all flight termination system functions of section D417.3 that apply to the stage or strap-on motor on which it is installed.

(c) An inadvertent separation destruct system must activate when it senses any launch vehicle breakup or premature separation of the stage or strap-on motor on which the inadvertent separation destruct system is located.

(d) A launch operator must locate an automatic or inadvertent separation destruct system so that it will survive launch vehicle breakup until the system activates and accomplishes all its flight termination functions.

(e) For any electrically initiated automatic or inadvertent separation destruct system, each power source that supplies energy to initiate the destruct ordnance must be on the same stage or strap-on motor as the system.

D417.13 FLIGHT TERMINATION SYSTEM SAFING AND ARMING

(a) *General.* A flight termination system must provide for safing and arming of all flight termination system ordnance through the use of a mechanical barrier or other positive means of interrupting power to each of the ordnance firing circuits to prevent inadvertent initiation of ordnance.

(b) *Flight termination system arming.* A flight termination system must provide for each flight termination system ordnance initiation device or arming device to be armed and all electronic flight termination system components to be turned on before arming any launch vehicle or payload propulsion ignition circuits. For a launch where propulsive ignition occurs after first motion of the launch vehicle, the system must include an ignition interlock that prevents the arming of any launch vehicle or payload propulsion ignition circuit unless all flight termination system ordnance initiation devices and arming devices are armed and all electronic flight termination system components are turned on.

(c) *Preflight safing.* A flight termination system must provide for remote and redundant safing of all flight termination system ordnance before flight and during any launch abort or recycle operation.

(d) *In-flight safing.* Any safing of flight termination system ordnance during flight must satisfy all of the following:

(1) Any onboard launch vehicle hardware or software used to automatically safe flight termination system ordnance must be single fault tolerant against inadvertent safing. Any automatic safing must satisfy all of the following:

(i) Any automatic safing must occur only when the flight of the launch vehicle satisfies the safing criteria for no less than two different safing parameters or conditions, such as time of flight, propellant depletion, acceleration, or altitude. The safing criteria for each different safing parameter or condition must ensure that the flight termination system on a stage or strap-on-motor can only be safed once the stage or strap-on motor attains orbit or can no longer reach a populated or other protected area;

(ii) Any automatic safing must ensure that all flight termination system ordnance initiation devices and arming devices remain armed and all electronic flight termination system components remain powered during flight until the requirements of paragraph (d)(1)(i) of this section are satisfied and the system is safed; and

(iii) If operation of the launch vehicle could result in satisfaction of the safing criteria for one of the two safing parameters or conditions before normal thrust termination of the stage or strap-on motor to which the parameter or condition applies, the launch operator must demonstrate that the greatest remaining thrust, assuming a three-sigma maximum engine performance, cannot result in the stage or strap-on motor reaching a populated or other protected area;

(2) If a radio command safes a flight termination system, the command control system used for in-flight safing must be single fault tolerant against inadvertent transmission of a safing command under § 417.303(d).

D417.15 FLIGHT TERMINATION SYSTEM INSTALLATION

(a) A launch operator must establish and implement written procedures to ensure that all flight termination system components are installed on a launch vehicle according to the qualified flight termination system design. The procedures must ensure that:

(1) The installation of all flight termination system mechanical interfaces is complete;

(2) Installation personnel use calibrated tools to install ordnance when a specific standoff distance is necessary to ensure that the ordnance has the desired effect on the material it is designed to cut or otherwise destroy; and

(3) Each person involved is qualified for each task that person is to perform.

(b) Flight termination system installation procedures must include:

(1) A description of each task to be performed, each facility to be used, and each hazard involved;

(2) A checklist of tools and equipment required;

(3) A list of personnel required for performing each task;

(4) Step-by-step directions written with sufficient detail for a qualified person to perform each task;

(5) Identification of any tolerances that must be met during the installation; and

(6) Steps for inspection of installed flight termination system components, including quality assurance oversight procedures.

(c) The personnel performing a flight termination system installation procedure must signify that the procedure is accomplished, and record the outcome and any data verifying successful installation.

D417.17 FLIGHT TERMINATION SYSTEM MONITORING

(a) A flight termination system must interface with the launch vehicle's telemetry system to provide the data that the flight safety system crew needs to evaluate the health and status of the flight termination system prior to and during flight.

(b) The telemetry data must include:

(1) Signal strength for each command destruct receiver;

(2) Whether the power to each electronic flight termination system component is on or off;

(3) Status of output commands for each command destruct receiver and each automatic or inadvertent separation destruct system;

(4) Safe or arm status of each safe-and-arm device of sections D417.35 and D417.39;

(5) Voltage for each flight termination system battery;

(6) Current for each flight termination system battery;

(7) Status of any electrical inhibit at the system level that is critical to the operation of a flight termination system and is not otherwise identified by this appendix;

(8) Status of any exploding bridgewire firing unit, including arm input, power level, firing capacitor charge level, and trigger capacitor charge level;

(9) Temperature of each flight termination system battery, whether monitored at each battery or in the immediate vicinity of each battery so that each battery's temperature can be derived; and

(10) Status of each switch used to provide power to a flight termination system, including any switch used to change from an external power source to an internal power source.

D417.19 FLIGHT TERMINATION SYSTEM ELECTRICAL COMPONENTS AND ELECTRONIC CIRCUITRY

(a) *General.* All flight termination system electrical components and electronic circuitry must satisfy the requirements of this section.

(b) *Electronic piece-parts.* Each electronic piece-part that can affect the reliability of an electrical component or electronic circuitry during flight must satisfy § 417.309(b)(2) of this part.

(c) *Over and under input voltage protection.* A flight termination system component must satisfy all its performance specifications and not sustain any damage when subjected to a maximum input voltage of no less than the maximum open circuit voltage of the component's power source. The component must satisfy all its performance specifications and not sustain any damage when subjected to a minimum input voltage of no greater than the minimum loaded voltage of the component's power source.

(d) *Series-redundant circuit.* A flight termination system component that uses a series-redundant branch in a firing circuit to satisfy the prohibition against a single failure point must possess one or more monitoring circuits or test points for verifying the integrity of each series-redundant branch after assembly and during testing.

(e) *Power control and switching.* In the event of an input power dropout, a power control or switching circuit, including any solid-state power transfer switch and arm-and-enable circuit must not change state for 50 milliseconds or more. Any electromechanical, solid-state, or relay component used in a flight termination system firing circuit must be capable of delivering the maximum firing current for no less than 10 times the duration of the intended firing pulse.

(f) *Circuit isolation, shielding, and grounding.* The circuitry of a flight termination system component must be shielded, filtered, grounded, or otherwise isolated to preclude any energy sources, internal or external to the launch vehicle, such as electromagnetic energy, static electricity, or stray electrical currents, from causing interference that would inhibit the flight termination system from functioning or cause an undesired output of the system. An electrical firing circuit must have a single-point ground connection directly to the power source only.

(g) *Circuit protection.* Any circuit protection provided within a flight termination system must satisfy all of the following:

(1) Electronic circuitry must not contain protection devices, such as fuses, except as allowed by paragraph (g)(2) of this section. A destruct circuit may employ current limiting resistors;

(2) Any electronic circuit designed to shut down or disable a launch vehicle engine and that interfaces with a launch vehicle function must use one or more devices, such as fuses, circuit breakers, or limiting resistors, to protect against over-current, including any direct short; and

(3) The design of a flight termination system output circuit that interfaces with another launch vehicle circuit must prevent any launch vehicle circuit failure from disabling or degrading the flight termination system's performance.

(h) *Repetitive functioning.* Each circuit, element, component, and subsystem of a flight termination system must satisfy all its performance specifications when subjected to repetitive functioning for five times the expected number of cycles required for all acceptance testing, checkout, and operations, including re-tests caused by schedule or other delays.

(i) *Watchdog circuits.* A flight termination system or component must not use a watchdog circuit that automatically shuts down or disables circuitry during flight.

(j) *Self-test capability.* If a flight termination system component uses a microprocessor, the component and the microprocessor must perform self-tests, detect errors, and relay the results through telemetry during flight to the launch operator. The execution of a self-test must not inhibit the intended processing function of the unit or cause any output to change.

(k) *Electromagnetic interference protection*. The design of a flight termination system component must eliminate the possibility of the maximum predicted electromagnetic interference emissions or susceptibilities, whether conducted or radiated, from affecting the component's performance. A component's electromagnetic interference susceptibility level must ensure that the component satisfies all its performance specifications when subjected to the maximum predicted emission levels of all other launch vehicle components and external sources to which the component would be exposed.

(l) *Ordnance initiator circuits*. An ordnance initiator circuit that is part of a flight termination system must satisfy all of the following:

(1) An ordnance initiator circuit must deliver an operating current of no less than 150% of the initiator's all-fire qualification current level when operating at the lowest battery voltage and under the worse case system tolerances allowed by the system design limits;

(2) For a low voltage ordnance initiator with an electro-explosive device that initiates at less than 50 volts, the initiator's circuitry must limit the power at each associated electro-explosive device that could be produced by an electromagnetic environment to a level at least 20 dB below the pin-to-pin direct current no-fire power of the electro-explosive device; and

(3) For a high voltage ordnance initiator that initiates ordnance at greater than 1,000 volts, the initiator must include safe-and-arm plugs that interrupt power to the main initiator's charging circuits, such as the trigger and output capacitors. A high voltage initiator's circuitry must ensure that the power that could be produced at the initiator's command input by an electromagnetic environment is no greater than 20 dB below the initiator's firing level.

D417.21 FLIGHT TERMINATION SYSTEM MONITOR CIRCUITS

(a) Each parameter measurement made by a monitor circuit must show the status of the parameter.

(b) Each monitor circuit must be independent of any firing circuit. A monitor, control, or checkout circuit must not share a connector with a firing circuit.

(c) A monitor circuit must not route through a safe-and-arm plug.

(d) Any monitor current in an electro-explosive device system firing line must not exceed one-tenth of the no-fire current of the electro-explosive device.

(e) Resolution, accuracy, and data rates for each monitoring circuit must provide for detecting whether performance specifications are satisfied and detecting any out-of-family conditions.

D417.23 FLIGHT TERMINATION SYSTEM ORDNANCE TRAIN

(a) An ordnance train must consist of all components responsible for initiation, transfer, and output of an explosive charge. Ordnance train components must include, initiators, energy transfer lines, boosters, explosive manifolds, and destruct charges.

(b) The reliability of an ordnance train to initiate ordnance, including the ability to propagate a charge across any ordnance interface, must be 0.999 at a 95% confidence level.

(c) The decomposition, cook-off, sublimation, auto-ignition, and melting temperatures of all flight termination system ordnance must be no less than 30(C higher than the maximum predicted environmental temperature to which the material will be exposed during storage, handling, installation, transportation, and flight.

(d) An ordnance train must include initiation devices that can be connected or removed from the destruct charge. The design of an ordnance train must provide for easy access to the initiation devices.

D417.25 RADIO FREQUENCY RECEIVING SYSTEM

(a) *General*. A radio frequency receiving system must include each flight termination system antenna, radio frequency coupler, any radio frequency cable, or other passive device used to connect a flight termination system antenna to a command receiver decoder. The system must deliver command control system radio frequency energy that satisfies all its performance specifications to each flight termination system command receiver decoder when subjected to performance degradation caused by command control system transmitter variations, launch vehicle flight conditions, and flight termination system hardware performance variations.

(b) *Sensitivity*. A radio frequency receiving system must provide command signals to each command receiver decoder at an electromagnetic field intensity of no less than 12dB above the level required for reliable receiver operation. The system must satisfy the 12-dB margin over 95% of the antenna radiation sphere surrounding the launch vehicle and must account for command control system radio frequency transmitter characteristics, airborne system characteristics including antenna gain, path loses due to plume or flame attenuation, and vehicle trajectory. For each launch, the system must satisfy the 12-dB margin at any point along the nominal trajectory until the planned safe flight state for the launch.

(c) *Antenna*. All of the following apply to each flight termination system antenna:

(1) A flight termination system antenna must have a radio frequency bandwidth that is no less than two times the total combined maximum tolerances of all applicable radio frequency performance factors. The performance factors must include frequency modulation deviation, command control transmitter inaccuracies, and variations in hardware performance during thermal and dynamic environments;

(2) A launch operator must treat any thermal protection used on a flight termination system antenna as part of the antenna; and

(3) A flight termination system antenna must be compatible with the command control system transmitting equipment.

(d) *Radio frequency coupler.* A flight termination system must use a passive radio frequency coupler to combine radio frequency signals inputs from each flight termination system antenna and distribute the required signal level to each command receiver. A radio frequency coupler must satisfy all of the following:

(1) A radio frequency coupler must prevent any single point failure in one redundant command receiver or antenna from affecting any other redundant command receiver or antenna by providing isolation between each port. An open or short circuit in one redundant command destruct receiver or antenna path must not prevent the functioning of the other command destruct receiver or antenna path;

(2) Each input port must be isolated from all other input ports;

(3) Each output port must be isolated from all other output ports; and

(4) A radio frequency coupler must provide for a radio frequency bandwidth that exceeds two times the total combined maximum tolerances of all applicable radio frequency performance factors. The performance factors must include frequency modulation deviation of multiple tones, command control transmitter inaccuracies, and variations in hardware performance during thermal and dynamic environments.

D417.27 ELECTRONIC COMPONENTS

(a) *General.* The requirements in this section apply to each electronic component that contains piece-part circuitry and is part of a flight termination system, including each command receiver decoder. Each piece-part used in an electronic component must satisfy § 417.309(b)(2) of this part.

(b) *Response time.* Each electronic component's response time must be such that the total flight termination system response time, from receipt of a destruct command sequence to initiation of destruct output, is less than or equal to the response time used in the time delay analysis required by § 417.221.

(c) *Wire and connectors.* All wire and connectors used in an electronic component must satisfy section D417.31.

(d) *Adjustment.* An electronic component must not require any adjustment after successful completion of acceptance testing.

(e) *Self-test.* The design of an electronic component that uses a microprocessor must provide for the component to perform a self-test, detect errors, and relay the results through telemetry during flight to the launch operator. The execution of a self-test must not inhibit the intended processing function of the unit or cause any output to change state.

(f) *Electronic component repetitive functioning.* An electronic component, including all its circuitry and parts, must satisfy all its performance specifications when subjected to repetitive functioning for five times the total expected number of cycles required for acceptance tests, preflight tests, and flight operations, including potential retests due to schedule delays.

(g) *Acquisition of test data.* The test requirements of appendix E of this part apply to all electronic components. Each electronic component must allow for separate component testing and the recording of parameters that verify its functional performance, including the status of any command output, during testing.

(h) *Warm-up time.* The warm-up time that an electronic component needs to ensure reliable operation must be no greater than the warm-up time that is incorporated into the preflight testing of appendix E of this part.

(i) *Electronic component circuit protection.* An electronic component must include circuit protection for power and control circuitry, including switching circuitry. The circuit protection must ensure that the component satisfies all its performance specifications when subjected to launch processing and flight environments. An electronic component's circuit protection must satisfy all of the following:

(1) Circuit protection must provide for an electronic component to satisfy all its performance specifications when subjected to the open circuit voltage of the component's power source for no less than twice the expected duration and when subjected to the minimum input voltage of the loaded voltage of the power source for no less than twice the expected duration;

(2) In the event of an input power dropout, any control or switching circuit critical to the reliable operation of a component, including solid-state power transfer switches, must not change state for at least 50 milliseconds;

(3) An electronic component must not use a watchdog circuit that automatically shuts down or disables the component during flight;

(4) An electronic component must satisfy all its performance specifications when any of its monitoring circuits or nondestruct output ports are subjected to a short circuit or the highest positive or negative voltage capable of being supplied by the monitor batteries or other power supplies where the voltage lasts for no less than five minutes; and

(5) An electronic component must satisfy all its performance specifications when subjected to any undetectable reverse polarity voltage that can occur during launch processing for no less than five minutes.

(j) *Electromagnetic interference susceptibility*. The design of an electronic component must eliminate the possibility of electromagnetic interference or modulated or unmodulated radio frequency emissions from affecting the component's performance. These electromagnetic interference and radio frequency environments include emissions or susceptibilities, whether conducted or radiated.

(1) The susceptibility level of an electronic component must be below the emissions of all other launch vehicle components and external transmitters.

(2) Any electromagnetic emissions from an electronic component must not be at a level that would affect the performance of other flight termination system components.

(3) An electronic component must not produce any inadvertent command output and must satisfy all its performance specifications when subjected to external radio frequency sources and modulation schemes to which the component could be subjected prior to and during flight.

(k) *Output functions and monitoring*. An electronic component must provide for all of the following output functions and monitoring:

(1) Each series redundant branch in any firing circuit of an electronic component that prevents a single failure point from issuing a destruct output must include a monitoring circuit or test points that verify the integrity of each redundant branch after assembly;

(2) Any piece-part used in a firing circuit must have the capacity to output at least 1.5 times the maximum firing current for no less than 10 times the duration of the maximum firing pulse;

(3) An electronic component's destruct output circuit and all its parts must deliver the required output power to the intended output load while operating with any input voltage that is within the component's input power operational design limits;

(4) An electronic component must include monitoring circuits that provide for monitoring the health and performance of the component including the status of any command output; and

(5) The maximum leakage current through an electronic component's destruct output port must:

(i) Not degrade the performance of downstream circuitry;

(ii) Be 20 dB lower than the level that could degrade the performance of any downstream ordnance initiation system or component, such as any electro-explosive device; and

(iii) Be 20 dB lower than the level that could result in inadvertent initiation of any downstream ordnance.

D417.29 COMMAND RECEIVER DECODER

(a) *General*. Each command receiver decoder must:

(1) Receive radio frequency energy from the command control system through the radio frequency receiving system and interpret, process, and send commands to the flight termination system;

(2) Be compatible with the command control system transmitting equipment;

(3) Satisfy the requirements of section D417.27 for all electronic components;

(4) Satisfy all its performance specifications and reliably process a command signal when subjected to command control system transmitting equipment tolerances and flight generated signal degradation, including:

(i) Locally induced radio frequency noise sources;

(ii) Vehicle plume;

(iii) The maximum predicted noise-floor;

(iv) Command transmitter performance variations; and

(v) Launch vehicle trajectory.

(b) *Tone-based radio frequency processing*. Each tone-based command receiver decoder must satisfy all of the following for all preflight and flight environments:

(1) *Decoder channel deviation*. A receiver decoder must reliably process the intended tone deviated signal at the minimum and maximum number of expected tones. The receiver decoder must satisfy all its performance specifications when subjected to:

(i) Plus and minus 3 KHz per tone; or

(ii) A nominal tone deviation plus twice the maximum and minus half the minimum of the total combined tolerances of all applicable radio frequency performance factors, whichever range is greater.

(2) *Operational bandwidth*.

(i) The receiver decoder's operational bandwidth must be no less than plus and minus 45 KHz and must ensure that the receiver decoder satisfies all its performance specifications at:

(A) Twice the worst-case command control system transmitter radio frequency shift;

(B) Doppler shifts of the carrier center frequency; and

(C) Shifts in flight hardware center frequency during flight at the manufacturer guaranteed receiver sensitivity.

(ii) The operational bandwidth must account for tone deviation and the receiver sensitivity must not vary by more than 3dB across the bandwidth.

(3) *Radio frequency dynamic range.* The receiver decoder must satisfy all its performance specifications when subjected to the variations of the radio frequency input signal level that will occur during checkout and flight. The receiver decoder must output all commands with input from the radio frequency threshold level up to:

(i) The maximum radio frequency level that it will experience from the command control system transmitter during checkout and flight plus a 3-dB margin; or

(ii) 13 dBm, whichever is greater.

(4) *Capture ratio.* For each launch, the receiver decoder's design must ensure that no transmitter with less than 80% of the power of the command transmitter system for the launch, could capture or interfere with the receiver decoder.

(5) *Radio frequency level monitor.* (i) The receiver decoder must include a monitoring circuit that accurately monitors and outputs the strength of the radio frequency input signal during flight.

(ii) The output of the monitor circuit must be directly related and proportional to the strength of the radio frequency input signal from the threshold level to saturation.

(iii) The dynamic range of the radio frequency input from threshold to saturation must be no less than 50 dB. The monitor circuit output amplitude from threshold to saturation must have a corresponding range of 18 dB or greater.

(iv) The monitor output signal level must be compatible with vehicle telemetry system interfaces and provide a maximum response time of 100 ms.

(v) The slope of the monitor circuit output must not change polarity.

(6) *Radio frequency threshold sensitivity.* The receiver decoder's threshold sensitivity must satisfy its performance specifications and be repeatable within a tolerance of plus and minus 3 dB, to demonstrate in-family performance.

(7) *Noise level margin.* The receiver decoder's guaranteed input sensitivity must be no less than 6 dB higher than the maximum predicted noise-floor.

(8) *Voltage standing wave ratio.* All radio frequency losses within the receiver decoder interface to the antenna system must satisfy the 12–dB margin of §417.9(d) and be repeatable to demonstrate in-family performance. The radio frequency receiving system and the impedance of the receiver decoder must match.

(9) *Decoder channel bandwidth.* The receiver decoder must provide for reliable recognition of the command signal when subjected to variations in ground transmitter tone frequency and frequency modulation deviation variations. The command receiver must satisfy all its performance specifications within the specified tone filter frequency bandwidth using a frequency modulation tone deviation from 2 dB to 20 dB above the measured threshold level.

(10) *Tone balance.* Any secure receiver decoder must reliably decode a valid command with an amplitude imbalance between two tones within the same message.

(11) *Message timing.* Any secure receiver decoder must function reliably when subjected to errors in timing caused by ground transmitter tolerances. The receiver decoder must process commands at twice the maximum and one-half the minimum timing specification of the ground system.

(12) *Check tone.* The receiver decoder must decode a tone, such as a pilot tone or check tone, which is representative of link and command closure and provide a telemetry output indicating whether the tone is decoded. The presence or absence of this tone signal must have no effect on a command receiver decoder's command processing and output capability.

(c) *Inadvertent command output.* A command receiver decoder must satisfy all of the following to ensure that it does not provide an output other than when it receives a valid command.

(1) *Dynamic stability.* The receiver decoder must not produce an inadvertent output when subjected to a radio frequency input short-circuit, open-circuit, or changes in input voltage standing wave ratio.

(2) *Out of band rejection.* The receiver decoder must not degrade in performance nor respond when subjected to any out-of-band vehicle or ground transmitter source that could be encountered from liftoff to the no-longer endanger time. The receiver decoder must not respond to frequencies, from 10 MHz to 1000 MHz except at the receiver specified operational bandwidth. The receiver decoder's radio frequency rejection of out of band signals must provide a minimum of 60 dB beyond eight times the maximum specified operational bandwidth. These frequencies must include all expected interfering transmitting sources using a minimum bandwidth of 20% of each transmitter center frequency, receiver image frequencies and harmonics of the assigned center frequency.

(3) *Decoder channel bandwidth rejection.* The receiver decoder must distinguish between tones that are capable of inhibiting or inadvertently issuing an output command. Each tone filter must not respond to another tone outside the specified tone filter frequency bandwidth using an FM tone deviation from 2 dB to 20 dB above the measured threshold level.

(4) *Adjacent tone decoder channel rejection.* The receiver decoder must not be inhibited or inadvertently issue an output command when subjected to any over-modulation of adjacent tones. The tone decoder channels must not respond to adjacent frequency modulation-modulated tone channels when they are modulated with a minimum of 150% of the expected tone deviation.

(5) *Logic sequence.* Each tone sequence used for arm and destruct must protect against inadvertent or unintentional destruct actions.

(6) *Destruct sequence.* The receiver decoder must provide a Destruct command only if preceded by a valid Arm command.

(7) *Receiver abnormal logic.* The receiver decoder must not respond to any combination of tones or tone pairs other than the correct command sequence.

(8) *Noise immunity.* The receiver decoder must not respond to a frequency modulated white noise radio frequency input that has a minimum frequency modulated deviation of 12 dB above the measured threshold deviation.

(9) *Tone drop.* The receiver decoder must not respond to a valid command output when one tone in the sequence is dropped.

(10) *Amplitude modulation rejection.* The receiver decoder must not respond to any tone or modulated input at 50% and 100% amplitude modulated noise when subjected to the maximum pre-flight and flight input power levels.

(11) *Decoder channel deviation rejection.* The receiver decoder must not inadvertently trigger on frequency modulated noise. The receiver decoder must not respond to tone modulations 10 dB below the nominal tone modulation or lower.

D417.31 WIRING AND CONNECTORS

(a) All wiring, including any cable and all connectors, that interface with any flight termination system component must provide for the component, wiring, and connectors to satisfy the qualification tests required by appendix E of this part.

(b) Each connector that interfaces with a flight termination system component must protect against electrical dropout and ensure electrical continuity as needed to ensure the component satisfies all its performance specifications.

(c) All wiring and connectors must have shielding that ensures the flight termination system satisfies all its performance specifications and will not experience an inadvertent destruct output when subjected to electromagnetic interference levels 20 dB greater than the greatest electromagnetic interference induced by launch vehicle and launch site systems.

(d) The dielectric withstanding voltage between mutually insulated portions of any component part must provide for the component to function at the component's rated voltage and satisfy all its performance specifications when subjected to any momentary over-potentials that could normally occur, such as due to switching or surge.

(e) The insulation resistance between mutually insulated portions of any component must provide for the component to function at its rated voltage. Any insulation material must satisfy all its performance specifications when subjected to workmanship, heat, dirt, oxidation, or loss of volatile material.

(f) The insulation resistance between wire shields and conductors, and between each connector pin must withstand a minimum workmanship voltage of at least 1,500 volts, direct current, or 150 percent of the rated output voltage, whichever is greater.

(g) If any wiring or connector will experience loads with continuous duty cycles of 100 seconds or greater, that wiring or connector, including each connector pin, must have a capacity of 150% of the design load. If any wiring or connector will experience loads that last less than 100 seconds, all wiring and insulation must provide a design margin greater than the wire insulation temperature specification.

(h) All wiring, including any cable or connector, must satisfy all its performance specifications when subjected to the pull force required by section E417.9(j) and any additional handling environment that the component could experience undetected.

(i) Redundant circuits that can affect a flight termination system's reliability during flight must not share any wiring harness or connector with each other.

(j) For any connector or pin connection that is not functionally tested once connected as part of a flight termination system or component, the design of the connector or pin connection must eliminate the possibility of a bent pin, mismating, or misalignment.

(k) The design of a flight termination system component must prevent undetectable damage or overstress from occurring as the result of a bent connector pin. An inadvertent initiation must not occur if a bent connector pin:

(1) Makes unintended contact with another pin;

(2) Makes unintended contact with the case of the connector or component; or

(3) Produces an open circuit.

(l) Each connector that can affect a flight termination system component's reliability during flight must satisfy the requirements of § 417.309(b)(2) of this part.

(m) All connectors must positively lock to prevent inadvertent disconnection during launch vehicle processing and flight.

(n) The installation of all wiring, including any cable, must protect against abrasion and crimping of the wiring.

D417.33 BATTERIES

(a) *Capacity*. A flight termination system battery must have a manufacturer-specified capacity of no less than the sum total amp-hour and pulse capacity needed for:

(1) Any self discharge;

(2) All load and activation checks;

(3) All launch countdown checks;

(4) Any potential hold time;

(5) Any potential number of preflight retests due to potential schedule delays including the number of potential launch attempts that the battery could experience before it would have to be replaced;

(6) Two arm and two destruct command loads at the end of the flight; and

(7) A flight capacity of no less than 150% of the capacity needed to support a normal flight from liftoff to the planned safe flight state. For a launch vehicle that uses solid propellant, the flight capacity must be no less than a 30-minute hang-fire hold time.

(b) *Electrical characteristics*. A flight termination system battery, under all load conditions, including line loss, must have all the following electrical characteristics:

(1) The manufacturer specified minimum voltage must be no less than the minimum acceptance test voltage that satisfies the electrical component acceptance tests of appendix E of this part. For a battery used in a pulse application to fire an electro-explosive device, the manufacturer specified minimum voltage must be no less than the minimum qualification test voltage that satisfies the electro-explosive device qualification tests of appendix E of this part;

(2) A battery that provides power to an electro-explosive device initiator, including to any initiator fired simultaneously with another initiator, must:

(i) Deliver 150% of each electro-explosive device's all-fire current at the qualification test level. The battery must deliver the current to each ordnance initiator at the lowest system battery voltage;

(ii) Have a current pulse that lasts ten times longer than the duration required to initiate the electro-explosive device or a minimum workmanship screening level of 200 milliseconds, whichever is greater; and

(iii) Have a pulse capacity of no less than twice the expected number of arm and destruct command sets planned to occur during launch vehicle processing, preflight flight termination system end-to-end tests, plus flight commands including load checks, conditioning, and firing of initiators;

(3) The design of a battery and any activation procedures must ensure uniform cell voltage after activation. Activation must include any battery conditioning needed to ensure uniform cell voltage, such as peroxide removal or nickel cadmium preparation; and

(4) The design of a battery or the system using the battery must protect against undetectable damage to the battery from any reverse polarity, shorting, overcharging, thermal runaway, or overpressure.

(c) *Service and storage life*. The service and storage life of a flight termination system battery must satisfy all of the following:

(1) A flight termination system battery must have a total activated service life that provides for the battery to meet the capacity and electrical characteristics required by paragraphs (a) and (b) of this section; and

(2) A flight termination system battery must have a specified storage life. The battery must satisfy the activated service life requirement of paragraph (c)(1) of this section after experiencing its storage life, whether stored in an activated or inactivated state.

(d) *Monitoring capability*. A battery or the system that uses the battery must provide for monitoring the status of the battery voltage and current. The monitoring must be sufficient to detect the smallest change in voltage or current that would indicate any health problem with each battery. Monitoring accuracy must be consistent with the minimum and maximum voltage and current limits used for launch countdown. The design of a battery that requires heating or cooling to sustain performance must provide for monitoring the battery's temperature with a resolution of 0.5 °C.

(e) *Battery identification*. Each battery must have an attached permanent label with the component name, type of construction (including chemistry), manufacturer identification, part number, lot and serial number, date of manufacture, and storage life.

(f) *Battery temperature control*. Any battery heater must ensure even temperature regulation of all battery cells.

(g) *Silver zinc batteries*. Any silver zinc battery that is part of a flight termination system must satisfy all of the following:

(1) A silver zinc battery must consist of cells assembled from electrode plates that are manufactured together and without interruption;

(2) The design of a silver zinc battery must allow activation of each individual cell within the battery;

(3) For any silver zinc battery that may vent electrolyte mist as part of normal operations, the battery must satisfy all its performance specifications for pin-to-case and pin-to-pin resistances after the battery experiences the maximum normal venting;

(4) The design of a silver zinc battery and its cells must allow for the qualification, acceptance, and storage life extension testing required by appendix E of this part. A launch operator must ensure sufficient batteries and cells are available from the same lot to accomplish the required testing;

(5) Each silver zinc battery must have attached, no less than one additional cell from the same production lot, with the same lot

date code, as the cells in the battery for use in cell acceptance verification tests. The cell must remain attached to the battery from the time of assembly until performance of the acceptance tests to ensure that the additional cell is subjected to all the same environments as the complete battery;

(6) The design of a silver zinc battery must permit voltage monitoring of each cell during open circuit voltage and load tests of the battery; and

(7) All cell and battery parts and materials and manufacturing parts, materials, and processes must undergo configuration control that ensures that each cell and battery has repeatable in-family performance unless each cell and battery undergoes lot testing that demonstrates repeatable in-family performance. The launch operator must identify and implement any lot testing that replaces configuration control.

(h) *Rechargeable cells and batteries*.

(1) Any rechargeable battery or cell that is part of a flight termination system must satisfy all the requirements of this section for each charge-discharge cycle.

(2) With the exception of any silver zinc battery, a rechargeable battery must satisfy all its performance specifications for five times the number of operating charge and discharge cycles expected of the battery throughout its life, including all acceptance testing, preflight testing, and flight. A silver zinc rechargeable battery must satisfy all its performance specifications for each operating charge-discharge cycle expected of the battery throughout its life, including all acceptance testing, preflight testing, and flight.

(3) A rechargeable battery must consist of cells from the same production lot. For a battery that consists of commercially produced nickel cadmium cells, each cell must be from the same production lot of no less than three thousand cells that are manufactured without interruption.

(4) The design of a silver zinc or commercial nickel cadmium battery and each of its cells must allow for the qualification and acceptance tests required by appendix E of this part. A launch operator must ensure sufficient batteries and cells are available to accomplish the required testing. A launch operator must identify and implement design and test requirements for any other type of rechargeable battery proposed for use as part of a flight safety system.

(i) *Commercial nickel cadmium cells and batteries*. Any nickel cadmium battery that uses one or more commercially produced nickel cadmium cells and is part of a flight termination system must satisfy each of the following to demonstrate that each cell or battery satisfies all its performance specifications:

(1) The battery or cell must have repeatable capacity and voltage performance. Capacity must be repeatable within one percent for each charge and discharge cycle.

(2) Any battery or cell venting device must ensure that the battery or cell does not experience a loss of structural integrity or create a hazardous condition when subjected to electrical discharge, charging and short-circuit conditions.

(3) The battery or cell must retain its charge and provide its required capacity, including the required capacity margin, from the final charge used prior to launch to the planned safe flight state during flight at the maximum pre-launch and flight temperature. The cell or battery must not self-discharge more than 10% of its fully charged capacity after 72 hours at ambient temperature.

(4) The design of the battery must prevent current leakage from pin-to-pin or pin-to-case from creating undesired events or battery self-discharge. Pin-to-pin and pin-to-case resistances must be repeatable so that measurements of pin-to-pin and pin-to-case resistances can establish in-family performance and determine whether all battery wiring and connectors are installed according to the manufacturer's design specifications.

(5) The battery or battery case must be sealed to the required leak rate and not loose structural integrity or create a hazardous condition when subjected to the predicted operating conditions plus all required margins including any battery short-circuit. The battery or battery case must maintain its structural integrity when subjected to no less than 1.5 times the greatest operating pressure differential that could occur under qualification testing, preflight, or flight conditions.

(6) Any battery voltage, current, or temperature monitoring circuit that is part of the battery must have resolution, accuracy, and data rates that all for detecting whether the performance specifications are satisfied and detecting any out-of-family conditions.

(7) Any battery heater circuit, including any thermostat must ensure that all cells are heated uniformly and must allow for repeatable battery performance that satisfies all the battery's performance specifications. Any heating must ensure that cells are not overstressed due to excessive temperature. The thermostat tolerances must ensure that the battery remains within its thermal design limits.

(8) The battery or cell must satisfy all its electrical performance specifications and be in-family while subjected to all pre-flight and flight environments, including hot and cold temperature, and all required electrical loads at the beginning, middle, and end of its manufacturer specified capacity.

D417.35 ELECTRO-MECHANICAL SAFE-AND-ARM DEVICES WITH AN INTERNAL ELECTRO-EXPLOSIVE DEVICE

(a) This section applies to any electro-mechanical safe-and-arm device that has an internal electro-explosive device and is part of a flight termination system. A safe-and-arm device must provide for safing and arming of the flight termination system ordnance to satisfy section D417.13.

(b) A safe-and-arm device in the arm position must remain in the arm position and satisfy all its performance specifications when subjected to the design environmental levels determined under section D417.7.

(c) All wiring and connectors used in a safe-and-arm device must satisfy section D417.31.

(d) Each piece-part that is used in the firing circuit of a safe-and-arm device and that can affect the reliability of the device during flight must satisfy §417.309(b)(2) of this part.

(e) A safe-and-arm device's internal electro-explosive device must satisfy the requirements for an ordnance initiator of section D417.41.

(f) A safe-and-arm device must not require any adjustment throughout its service life.

(g) A safe-and-arm device's internal electrical firing circuitry, such as wiring, connectors, and switch deck contacts, must satisfy all its performance specifications when subjected to an electrical current pulse with an energy level of no less than 150% of the internal electro-explosive device's all-fire energy level for 10 times as long as the all-fire pulse lasts. A safe-and-arm device must deliver this firing pulse to the internal electro-explosive device without any dropout that could affect the electro-explosive device's performance when subjected to the design environmental levels.

(h) A safe-and-arm device must satisfy all its performance specifications after being exposed to the handling drop required by section E417.9(k) and any additional transportation, handling, or installation environment that the device could experience undetected.

(i) A safe-and-arm device must not initiate and must allow for safe disposal after experiencing the abnormal drop required by section E417.9(l).

(j) When a safe-and-arm device's electro-explosive device is initiated, the safe- and arm-device's body must not fragment, regardless of whether the explosive transfer system is connected or not.

(k) When dual electro-explosive devices are used within a single safe-and-arm device, the design must ensure that one electro-explosive device does not affect the performance of the other electro-explosive device.

(l) A safe-and-arm device must satisfy all its performance specifications when subjected to no less than five times the total number of safe and arm cycles required for the combination of all acceptance tests, preflight tests, and flight operations, including an allowance for potential re-tests due to schedule changes.

(m) The design of a safe-and-arm device must allow for separate component testing and recording of parameters that verify its functional performance , and the status of any command output during the tests required by section E417.25.

(n) A safe-and-arm device must be environmentally sealed to the equivalent of 10^{-4} scc/sec of helium at one atmosphere differential or the device must provide other means of withstanding non-operating environments, such as salt-fog and humidity, experienced during storage, transportation and preflight testing.

(o) The safing of a safe-and-arm device must satisfy all of the following:

(1) While in the safe position, a safe-and-arm device must protect each internal electro-explosive device from any condition that could degrade the electro-explosive device's performance and prevent inadvertent initiation during transportation, storage, preflight testing, and any preflight fault conditions.

(2) While in the safe position, a safe-and-arm device's electrical input firing circuit must prevent degradation in performance or inadvertent initiation of the electro-explosive device when the safe-and-arm device is subjected to any external energy source, such as static discharge, radio frequency energy, or firing voltage.

(3) While in the safe position, a safe-and-arm device must prevent the initiation of its internal electro-explosive device and any other ordnance train component, with a reliability of 0.999 at a 95% confidence level.

(4) A safe-and-arm device must satisfy all its performance specifications when in the safe position and subjected to the continuous operational arming voltage required by section E417.25(d).

(5) A safe-and-arm device must not initiate its electro-explosive device or any other ordnance train component when locked in the safe position and subjected to the continuous operational arming voltage required by section E417.25(e)(3).

(6) A safe-and-arm device must have a visual display of its status on the device and remote display of the status when the device is in the safe position. When transitioning from the arm to safe position, the safe indication must not appear unless the position of the safe-and-arm device has progressed more than 50% beyond the no-fire transition motion.

(7) A safe-and-arm device must have a remote means of moving its rotor or barrier to the safe position from any rotor or barrier position.

(8) A safe-and-arm device must have a manual means of moving its rotor or barrier to the safe position.

(9) A safe-and-arm device must have a safing interlock that prevents movement from the safe position to the arm position while operational arming current is being applied. The interlock must have a means of positively locking into place and must allow for verification of proper functioning. The interlock removal design or procedure must eliminate the possibility of accidental disconnection of the interlock.

(p) The arming of a safe-and-arm device must satisfy all of the following:

(1) When a safe-and-arm device is in the arm position, all ordnance interfaces, such as electro-explosive device, rotor charge, and explosive transfer system components must align with one another to ensure propagation of the explosive charge with a reliability of 0.999 at a 95% confidence level;

(2) When in the arm position, the greatest energy supplied to a safe-and-arm device's electro-explosive device from electronic circuit leakage and radio frequency energy must be no greater than 20 dB below the guaranteed no-fire level of the electro-explosive device;

(3) A safe-and-arm device must have a visual display of its status on the device and provide for remote display of the status when the device is in the arm position. The arm indication must not appear unless the safe-and-arm device is armed as required by paragraph (o)(1) of this section; and

(4) A safe-and-arm device must provide for remote arming of the device.

D417.37 EXPLODING BRIDGEWIRE FIRING UNIT

(a) *General.* This section applies to any exploding bridgewire firing unit that is part of a flight termination system. An exploding bridgewire firing unit must provide for safing and arming of the flight termination system ordnance to satisfy section D417.13. An exploding bridgewire firing unit must satisfy the requirements for electronic components of section D417.29.

(b) *Charging and discharging.* An exploding bridgewire firing unit must have a remote means of charging and discharging of the unit's firing capacitor and an external means of positively interrupting the firing capacitor charging voltage.

(c) *Input command processing.* An exploding bridgewire firing unit's electrical input processing circuitry must satisfy all of the following:

(1) An exploding bridgewire firing unit's input circuitry must function, when subjected to the greatest potential electromagnetic interference noise environments, without inadvertently triggering;

(2) In the firing circuit of an exploding bridgewire firing unit, all series redundant branches that prevent any single failure point from issuing a destruct output must include monitoring circuits or test points for verifying the integrity of each redundant branch after assembly;

(3) The unit input trigger circuitry of an exploding bridgewire firing unit must maintain a minimum 20 dB margin between the threshold trigger level and the worst-case noise environment;

(4) An exploding bridgewire firing unit must have a minimum trigger sensitivity that provides for the unit to fire at 6 dB lower in amplitude and one-half the duration of the worst-case trigger signal that the unit could receive during flight;

(5) In the event of a power dropout, any control or switching circuit critical to the reliable operation of an exploding bridgewire firing unit, including solid-state power transfer switches, must not change state for 50 milliseconds or more; and

(6) An exploding bridgewire firing unit's response time must satisfy all its performance specifications for the range of input trigger signals from the specified minimum trigger signal amplitude and duration to the specified maximum trigger signal amplitude and duration.

(d) *High voltage output.* An exploding bridgewire firing unit's high voltage discharge circuit must satisfy all of the following:

(1) An exploding bridgewire firing unit must include circuits for capacitor charging, bleeding, charge interruption, and triggering;

(2) An exploding bridgewire firing unit must have a single fault tolerant capacitor discharge capability;

(3) An exploding bridgewire firing unit must deliver a voltage to the exploding bridgewire that is no less than 50% greater than the exploding bridgewire's minimum all-fire voltage, not including transmission losses, at the unit's worst-case high and low arming voltages;

(4) The design of an exploding bridgewire firing unit must prevent corona and arcing on internal and external high voltage circuitry;

(5) An exploding bridgewire firing unit must satisfy all its performance specifications at the worst-case high and low arm voltages that could be delivered during flight; and

(6) Any high energy trigger circuit used to initiate exploding bridgewire firing unit's main firing capacitor must deliver an output signal of no less than a 50% voltage margin above the nominal voltage threshold level.

(e) *Output monitors.* The monitoring circuits of an exploding bridgewire firing unit must provide the data for real-time checkout and determination of the firing unit's acceptability for flight. The monitored data must include the voltage level of all high voltage capacitors and the arming power to the firing unit.

D417.39 ORDNANCE INTERRUPTER SAFE-AND-ARM DEVICE WITHOUT AN ELECTRO-EXPLOSIVE DEVICE

(a) This section applies to any ordnance interrupter safe-and-arm device that does not have an internal electro-explosive device and is part of a flight termination system. An ordnance interrupter must provide for safing and arming of the flight termination system ordnance to satisfy section D417.13.

(b) An ordnance interrupter must remain in the armed position and satisfy all its performance specifications when subjected to the design environmental levels determined according to section D417.7.

(c) An ordnance interrupter must not require adjustment throughout its service life.

(d) An ordnance interrupter must satisfy all its performance specifications after experiencing any transportation, handling, or installation environment that the device could experience undetected.

(e) An ordnance interrupter that uses ordnance rotor leads must not initiate and must allow for safe disposal after experiencing the worst-case drop and resulting impact that it could experience during storage, transportation, or installation.

(f) An ordnance interrupter must satisfy all of its performance specifications when subjected to repetitive functioning for five times the expected number of arming cycles required for acceptance testing, preflight checkout, and flight operations, including an allowance for re-tests due to potential schedule delays.

(g) An ordnance interrupter must not fragment during ordnance initiation.

(h) The design of a flight termination system must protect an ordnance interrupter from conditions that could degrade its performance or cause inadvertent initiation during transportation, storage, installation, preflight testing, and potential preflight fault conditions. Safing of an ordnance interrupter must satisfy all of the following:

(1) While in the safe position, an ordnance interrupter must prevent the functioning of an ordnance train with a reliability of 0.999 at a 95% confidence level;

(2) When locked in the safe position, an ordnance interrupter must prevent initiation of an ordnance train. The ordnance interrupter must satisfy all its performance specification when locked in the safe position and subjected to the continuous operational arming voltage required by section E417.29(j);

(3) An ordnance interrupter must not initiate its electro-explosive device or any other ordnance train component when locked in the safe position and subjected to the continuous operational arming voltage required by section E417.29(e)(3);

(4) An ordnance interrupter must have a manual and a remote means of safing from any rotor or barrier position;

(5) An ordnance interrupter must have a visual display of the status on the device and provide for remote display of the status when the ordnance interrupter is in the safe position; and

(6) An ordnance interrupter must include a safing interlock that prevents the interrupter from moving from the safe position to the arm position when subjected to an operational arming current. A safing interlock must have a means of positively locking into place and a means of verifying proper function of the interlock. A safing interlock and any related operation procedure must eliminate the possibility of inadvertent disconnection of the interlock.

(i) Arming of an ordnance interrupter must satisfy all of the following:

(1) An ordnance interrupter is armed when all ordnance interfaces, such as a donor explosive transfer system, rotor charge, and acceptor explosive transfer system are aligned with one another to propagate the explosive charge with a reliability of 0.999 at a 95% confidence level;

(2) An ordnance interrupter must have a visual display of the status on the device and provide for remote display of the status when the ordnance interrupter is in the arm position; and

(3) An ordnance interrupter must provide for remote arming of the interrupter.

D417.41 ORDNANCE INITIATORS

(a) This section applies to any low-voltage electro-explosive device that is part of a flight termination system or high-voltage exploding bridgewire ordnance initiator that is part of a flight termination system. An ordnance initiator must use electrical energy to trigger an explosive charge that initiates the flight termination system ordnance.

(b) An ordnance initiator must have a manufacturer-specified all-fire energy level. When the all-fire energy level is applied, the ordnance initiator must fire with a reliability of no less than 0.999 at a 95 percent confidence level.

(c) An ordnance initiator must have a specified no-fire energy level. An ordnance initiator must not fire when exposed to continuous application of the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level. An ordnance initiator must satisfy all its performance specifications when subjected to continuous application of the no-fire energy level.

(d) The lowest temperature at which an ordnance initiator would experience autoignition, sublimation, or melting or in any other way experience degradation in performance must be no less than 30 °C higher than the highest temperature that the initiator could experience prior to or during flight.

(e) An ordnance initiator must not fire, and must satisfy all its performance specifications when subjected to the maximum expected electrostatic discharge that it could experience from personnel or conductive surfaces. An ordnance initiator must not fire, and must satisfy all its performance specifications when subjected to workmanship discharges of no less than a 25-kV, 500-pF pin-to-pin discharge through a 5-kΩ resistor and a 25-kV, 500-pF pin-to-case discharge with no resistor.

(f) An ordnance initiator must not initiate and must satisfy all its performance specifications when exposed to stray electrical current that is at a 20-dB margin greater than the greatest stray electrical current that the ordnance initiator could experience prior to or during flight. When determining the 20-dB margin, a launch operator must account for all potential sources of stray electrical current, including leakage current from other electronic components and radio frequency induced electrical current.

(g) An ordnance initiator must satisfy all its performance specification after being exposed to the tensile load required by section E417.9(j), the handling drop required by section E417.9(k), and any additional transportation, handling, or installation environment that the device could experience undetected.

(h) An ordnance initiator must not initiate and must allow for safe disposal after experiencing the abnormal drop required by section E417.9(l).

(i) An ordnance initiator must be hermetically sealed to the equivalent of 5×10^{-6} scc/sec of helium at one atmosphere pressure differential.

(j) The insulation resistance between mutually insulated points must ensure that an ordnance initiator satisfies all its performance specifications when subjected to the greater of twice the maximum applied voltage during testing and flight or a workmanship voltage of no less than 500 volts. The insulation material must satisfy all its performance specifications when exposed to workmanship, heat, dirt, oxidation, and any additional expected environment.

D417.43 EXPLODING BRIDGEWIRE

(a) This section applies to any exploding bridgewire that is part of a flight termination system. An exploding bridgewire must use high-voltage electrical energy of 50 volts or greater to trigger an explosive charge that initiates the flight termination system ordnance.

(b) An exploding bridgewire must satisfy the ordnance initiator requirements of section D417.41.

(c) An exploding bridgewire's electrical circuitry, such as connectors, pins, wiring and header assembly, must transmit an all-fire pulse at a level 50% greater than the lowest exploding bridgewire firing unit's operational firing voltage. This must include allowances for effects such as corona and arcing of a flight configured exploding bridgewire exposed to altitude, thermal vacuum, salt-fog, and humidity environments.

(d) An exploding bridgewire must not fragment during ordnance initiation.

(e) All exploding bridgewire connector pins must withstand the tension and compression loads required by section E417.9(j).

D417.45 PERCUSSION-ACTIVATED DEVICE

(a) This section applies to any percussion-activated device that is part of a flight termination system. A percussion-activated device must use mechanical energy to trigger an explosive charge that initiates the flight termination system ordnance.

(b) A percussion-activated device's lanyard pull system must have a protective cover or other feature that prevents inadvertent pulling of the lanyard.

(c) A percussion-activated device must not fragment upon initiation.

(d) A percussion-activated device must have a guaranteed no-fire pull force of no less than twice the largest inadvertent pull force that the device could experience:

(1) Any time prior to flight that the safing interlock of paragraph (o) of this section is not in place; or

(2) During flight.

(e) A percussion-activated device must not initiate when pulled with its maximum no-fire pull force and then released with a reliability of no less than 0.999 at a 95% confidence level.

(f) A percussion-activated device must have a primer all-fire energy level, including spring constant and pull distance that ensures initiation, with a reliability of no less than 0.999 at a 95% confidence level when subjected to preflight and flight environments.

(g) A percussion-activated device must deliver an operational impact force to the primer of no less than twice the all-fire energy level.

(h) A percussion-activated device's primer must initiate and must satisfy all its performance specifications when subjected to two times the operational impact energy or four times the all-fire impact energy level.

(i) A percussion-activated device's reliability must satisfy its performance specifications when subjected to a no-fire pull force and then released.

(j) The lowest temperature at which a percussion-activated device would experience autoignition, sublimation, or melting, or in any other way not satisfy its performance specifications, must be no less than 30 °C higher than the highest temperature that the percussion-activated device could experience prior to or during flight.

(k) A percussion-activated device must satisfy all its performance specifications after experiencing the handling drop required by section E417.9(k) and any additional transportation, handling, or installation environment that the device could experience undetected.

(l) A percussion-activated device's ordnance must be hermetically sealed to the equivalent of 5×10^{-6} scc/sec of helium at one atmosphere differential.

(m) A percussion-activated device's structural and firing components must withstand 500 percent of the largest pull or jerk force that the device could experience during breakup of the launch vehicle.

(n) A percussion-activated device must not initiate and must allow for safe disposal after experiencing the abnormal drop required by section E417.9(l).

(o) A percussion-activated device must include a safing interlock, such as a safing pin, that provides a physical means of preventing the percussion-activated device assembly from pulling more than 50% of the guaranteed no-fire pull distance. The following apply to a safing interlock:

(1) A safing interlock must positively lock into place and must have a means of verifying proper function of the interlock.

(2) A safing interlock must eliminate the possibility of inadvertent disconnection or removal of the interlock should a pre-load condition exist on the lanyard unless the device provides a visual or other means of verifying that there is no load on the lanyard.

(3) A safing interlock, when in place, must prevent initiation of the percussion actuated device when subjected to twice the greatest possible inadvertent pull force that could be experienced during launch processing.

D417.47 EXPLOSIVE TRANSFER SYSTEM

(a) This section applies to any explosive transfer system that is part of a flight termination system. An explosive transfer system must transmit an explosive charge from an initiation source, such as an ordnance initiator, to other flight termination system ordnance such as a destruct charge.

(b) Ordnance used in an explosive transfer system must consist of a secondary explosive. An exception to this is any transition component that contains a primary explosive that is fully contained within the transition component. Any transition component that contains a primary explosive must be no more sensitive to inadvertent detonation than a secondary explosive.

(c) An explosive transfer system, including all donor, acceptor, and transition charges and components must transfer an explosive charge with a reliability of no less than 0.999 at a 95% confidence level.

(d) An explosive transfer system must satisfy all its performance specifications with the smallest bend radius that it is subjected to when installed in its flight configuration.

(e) All explosive transfer connectors must positively lock in place and provide for verification of proper connection through visual inspection.

(f) Each explosive transfer system component must satisfy all its performance specifications when subjected to the tensile load required by section E417.9(j).

(g) An explosive transfer system must satisfy all its performance specifications after experiencing the handling drop required by section E417.9(k) and any additional transportation, handling, or installation environment that the system could experience undetected.

(h) An explosive transfer system must not initiate and must allow for safe disposal after experiencing the abnormal drop required by section E417.9(l).

(i) An explosive transfer system must be hermetically sealed to the equivalent of 5×10^{-6} scc/sec of helium at one atmosphere pressure differential.

D417.49 DESTRUCT CHARGE

(a) This section applies to any destruct charge that is part of a flight termination system. A destruct charge must sever or penetrate a launch vehicle component or payload, such as a propellant tank or motor casing, to accomplish a flight termination function.

(b) A destruct charge must use a secondary explosive.

(c) When initiated, a destruct charge acceptor, where applicable, or main charge must ensure the transfer of the explosive charge with a reliability of 0.999 at a 95% confidence level.

(d) Initiation of a destruct charge must result in a flight termination system action in accordance with the flight termination system functional requirements of §417.303.

(e) A destruct charge must sever or penetrate 150% of the thickness of the material that must be severed or penetrated in order for the destruct charge to accomplish its intended flight termination function. A destruct charge, when initiated to terminate the flight of a launch vehicle, must not detonate any launch vehicle or payload propellant.

(f) Each destruct charge and associated fitting must satisfy all its performance specifications when subjected to the tensile load required by section E417.9(j).

(g) A destruct charge must satisfy all its performance specifications after experiencing the handling drop required by section E417.9(k) and any additional transportation, handling, or installation environment that the charge could experience undetected.

(h) A destruct charge must not initiate and must allow for safe disposal after experiencing the abnormal drop required by section E417.9(l).

(i) A destruct charge must be hermetically sealed to the equivalent of 5×10^{-6} scc/sec of helium at one atmosphere pressure differential.

D417.51 VIBRATION AND SHOCK ISOLATORS

(a) This section applies to any vibration or shock isolator that is part of a flight safety system. A vibration or shock isolator must ensure the environmental survivability of a flight termination system component by reducing the vibration or shock levels that the component experiences during flight.

(b) A vibration or shock isolator must have repeatable natural frequency and resonant amplification parameters when subjected to flight environments.

(c) An isolator must account for all effects that could cause variations in repeatability, including acceleration preloads, temperature, component mass, and vibration level variations.

(d) A vibration or shock isolator must satisfy all of its performance specifications when subjected to the qualification test environments for each component that is mounted on the isolator.

(e) All components mounted on a vibration or shock isolator must withstand the environments introduced by isolator amplification. In addition, all component interface hardware, such as connectors, cables, and grounding straps, must withstand any added deflection introduced by an isolator.

D417.53 MISCELLANEOUS COMPONENTS

(a) This section applies to any miscellaneous flight termination system component that is not specifically identified by this appendix.

(b) A miscellaneous component must satisfy all its performance specifications when subjected to the non-operating and operating environments of section D417.3.

(c) The design of a miscellaneous component must provide for the component to be tested in accordance with appendix E of this part.

(d) A launch operator must identify any additional requirements that apply to any new or unique component and demonstrate that those requirements ensure the reliability of the component.

APPENDIX E TO PART 417—FLIGHT TERMINATION SYSTEM TESTING AND ANALYSIS

E417.1 GENERAL

(a) *Scope and compliance.* This appendix contains requirements for tests and analyses that apply to all flight termination systems and the components that make up each flight termination system. Section 417.301 requires that a launch operator's flight safety system employ a flight termination system that complies with this appendix. Section 417.301 also contains requirements that apply to a launch operator's demonstration of compliance with the requirement of this appendix. A launch operator must employ on its launch vehicle only those flight termination system components that satisfy the requirements of this appendix.

(b) *Component tests and analyses.* A component must satisfy each test or analysis required by any table of this appendix to demonstrate that the component satisfies all its performance specifications when subjected to non-operating and operating environments. A launch operator must identify and implement any additional test or analysis for any new technology or any unique application of an existing technology.

(c) *Test plans.* Each test of a component, subsystem, or system must follow a written plan that specifies the test parameters, including pass/fail criteria, and a testing sequence that satisfy the requirements of this appendix. For any component that is used for more than one flight, the test plan must provide for component reuse qualification, refurbishment, and acceptance as required by section E417.7(g). The test plan must include any alternate procedures for testing a component when it is in place on the launch vehicle.

(d) *Test failures.* If a test of a component results in a failure, the component does not satisfy the test requirement. Each of the following is a test failure:

(1) Any component sample that does not satisfy a performance specification;

(2) Any failure to accomplish a test objective;

(3) Any component sample with a test result that indicates that the component is out-of-family when compared to other samples of the component, even if the component satisfies other test criteria;

(4) Any unexpected change in the performance of a component sample occurring at any time during testing;

(5) Any component sample that exhibits any sign that a part is stressed beyond its design limit, such as a cracked circuit board, bent clamps, worn part, or loose connector or screw, even if the component passes the final functional test;

(6) When component examination shows any defect that could adversely affect the component's performance;

(7) Any discontinuity or dropout in a measured performance parameter that could prevent the component from satisfying a performance specification;

(8) Any inadvertent output; or

(9) Any indication of internal component damage.

(e) *Failure analysis.* In the event of a test failure, the test item, procedures and equipment must undergo a written failure analysis. The failure analysis must identify the cause of the failure, the mechanism of the failure, and isolate the failure to the smallest replaceable item or items and ensure that there are no generic design, workmanship, or process problems with other flight components of similar configuration.

(f) *Test tolerances.* Each test must apply to the nominal values specified by this appendix tolerances that satisfy the following:

(1) The tolerance of any measurement taken during a functional test must provide the accuracy needed to detect any out-of-family or out-of-specification anomaly.

(2) An environmental level, such as for vibration or temperature, used to satisfy a component test requirement of this appendix must include the environment design margin required by appendix D of this part. The environmental level must account for any test equipment tolerance to ensure that the component experiences the required margin.

(g) *Test equipment.* All equipment used during environmental testing must provide for the test item to experience the required environmental test levels. Any test fixture used to simultaneously test multiple component samples must ensure that each component sample, at each mounting location on the fixture experiences each required environmental test level. Any difference in a qualification or acceptance test fixture or cable must undergo an evaluation to ensure that flight hardware is not subjected to stresses greater than that which the unit experiences during qualification.

(h) *Rework and repair of components.* Components that fail a test may undergo rework and repair and must then complete the failed test and each remaining test. If a repair requires disassembly of the component or soldering operations, the component must repeat any test necessary to demonstrate that the repair corrected the original anomaly and did not cause other damage. The total number of acceptance tests experienced by a repaired component must not exceed the environments for which the component is qualified.

(i) *Test and analysis reports.* A launch operator must prepare or obtain one or more written reports that:

(1) Describe all flight termination system test results and test conditions;

(2) Describe any analysis performed instead of testing;

(3) Identify, by serial number or other identification, each test result that applies to each system or component;

(4) Describe any family performance data to be used for comparison to any subsequent test of a component or system;

(5) Describe all performance parameter measurements made during component testing for comparison to each previous and subsequent test to identify any performance variations that may indicate a potential workmanship or other defect that could lead to a failure of the component during flight; and

(6) Identify any test failure or anomaly, including any variation from an established performance baseline, with a description of the failure or anomaly, each corrective action taken, and all results of additional tests.

E417.3 Component Test and Analysis Tables

(a) *General.* This section applies to each test and analysis table of this appendix. Each component or system that is identified by a table must satisfy each test or analysis identified by the table. Each component or system must satisfy a test by undergoing and passing the test as described in the paragraph that the table lists. In cases where the listed paragraph allows a test or analysis, any analysis must satisfy any specific requirement listed in the paragraph and must demonstrate one of the following:

(1) The test environment does not apply to the component;

(2) The test environment does not degrade the component's performance; or

(3) Another test or combination of tests that the component undergoes places equal or greater stress on the component than the test in question.

(b) *Test sequence.* A component or system must undergo each test in the same order as the table identifies the test. A launch operator may deviate from the test sequence if the launch operator demonstrates that another order will detect any component anomaly that could occur during testing.

(c) *Quantity of sample components tested.*

(1) For a new component, each table identifies the quantity of component samples that must undergo each test identified by the table.

(2) A launch operator may test fewer samples than the quantity identified for a new component if the launch operator demonstrates one of the following:

(i) That the component has experienced comparable environmental tests; or

(ii) The component is similar to a design that has experienced comparable environmental tests.

(3) Any component that a launch operator uses for any comparison to a new component must have undergone all the environmental tests required for the new component to develop cumulative effects.

(d) *Performance verification tests.* Each performance verification test identified by any table of this appendix must satisfy all of the following:

(1) Each test must measure one or more of a component or system's performance parameters to demonstrate that the component or system satisfies all its performance specifications;

(2) The component must undergo each test:

(i) Before the component is exposed to each test environment; and

(ii) After the component is exposed to the test environment to identify any performance degradation due to the environment; and

(3) Any electronic component must undergo each performance verification test at:

(i) The lowest operating voltage;

(ii) Nominal operating voltage; and

(iii) Highest operating voltage that the component could experience during preflight and flight operations.

(e) *Abbreviated performance verification tests.* Each abbreviated performance verification test required by any table of this appendix must satisfy all of the following:

(1) Each test must exercise all of a component's functions that are critical to a flight termination system's performance during flight

(i) while the component is subjected to each test environment; or,

(ii) for short duration environments such as shock, before and after each test;

(2) Each test must measure a sampling of the component's critical performance parameters while the component is subjected to each test environment to demonstrate that the component satisfies all its performance specifications; and

(3) Any electronic component must undergo each abbreviated performance verification test at the component's nominal operating voltage.

(f) *Status-of-health tests.* Each status-of-health test required by any table of this appendix must satisfy all of the following:

(1) Each test must measure one or more critical performance parameter to demonstrate that a component or system satisfies all its performance specifications;

(2) The critical performance parameters must include those parameters that act as an indicator of an internal anomaly that a functional performance test might not detect; and

(3) Each test must compare the results to any previous test results to identify any degradation in performance.

E417.5 COMPONENT EXAMINATION

(a) *General.* This section applies to each component examination identified by any table of this appendix. Each component examination must identify any manufacturing defect that the performance tests might not detect. The presence of a defect that could adversely affect the component's performance constitutes a failure.

(b) *Visual examination.* A visual examination must verify that good workmanship was employed during manufacture of a component and that the component is free of any physical defect that could adversely affect performance. A visual examination may include the use of optical magnification, mirrors, or specific lighting, such as ultraviolet illumination.

(c) *Dimension measurement.* A dimension measurement of a component must verify that the component satisfies all its dimensional specifications.

(d) *Weight measurement.* A weight measurement of a component must verify that the component satisfies its weight specification.

(e) *Identification check.* An identification check of a component must verify that the component has one or more identification tags that contain information that allows for configuration control and tracing of the component.

(f) *X-ray and N-ray examination.* An X-ray or N-ray examination of a component must have a resolution that allows detailed inspection of the internal parts of the component and must identify any internal anomalous condition. The examination must include enough photographs, taken from different angles, to allow complete coverage of the component's internal parts. When utilized as a recurring inspection technique to accept production hardware, the examination must use the same set of angles for each sample of a component to allow for comparison. A certified technician must evaluate X-ray and N-ray photographs.

(g) *Internal inspection.* An internal inspection of a component must demonstrate that there is no wear or damage, including any internal wear or damage, to the component that could adversely affect its performance after exposure to any test environment. An internal inspection must satisfy all of the following:

(1) All internal components and subassemblies, such as circuit board traces, internal connectors, welds, screws, clamps, electronic piece parts, battery cell plates and separators, and mechanical subassemblies must undergo examination to satisfy this paragraph using an inspection method such as a magnifying lens or radiographic inspection;

(2) For a component that can be disassembled, the component must undergo complete disassembly to the point needed to satisfy this paragraph; and

(3) For a component that cannot be disassembled, such as an antenna, potted component, or welded structure, the component must undergo any special procedures needed to satisfy this paragraph, such as depotting the component, cutting the component into cross-sections, or radiographic inspection.

(h) *Leakage.* A leakage test must demonstrate that a component's seal satisfies all its performance specifications before and after the component is subjected to any test environment as follows:

(1) The test must have the resolution and sample rate to demonstrate that the component's leak rate is no greater than its design limit.

(2) For an electronic component, the test must demonstrate a leak rate of no greater than the equivalent of 10^{-4} standard cubic centimeters/second (scc/sec) of helium.

(3) For an ordnance component, the test must demonstrate a leak rate of no greater than the equivalent of 5×10^{-6} scc/sec of helium.

E417.7 QUALIFICATION TESTING AND ANALYSIS

(a) This section applies to each qualification non-operating and operating test or analysis identified by any table of this appendix. A qualification test or analysis must demonstrate that a component will satisfy all its performance specifications when subjected to the design environmental levels required by section D417.7.

(b) Before a component sample undergoes a qualification environmental test, the component sample must pass all the required acceptance tests.

(c) A component must undergo each qualification test in a flight representative configuration, with all flight representative hardware such as connectors, cables, and any cable clamps, and with all attachment hardware, such as dynamic isolators, brackets and bolts, as part of that flight representative configuration.

(d) A component must undergo re-qualification tests if there is a change in the design of the component or if the environmental levels to which it will be exposed exceed the levels for which the component is qualified. A component must undergo requalification if the manufacturer's location, parts, materials, or processes have changed since the previous qualification. A change in the name of the manufacturer as a result of a sale does not require re-qualification if the personnel, factory location or the parts, material and processes remain unchanged since the last component qualification. The extent of any re-qualification tests must be the same as the initial qualification tests except where paragraph (f) of this section applies.

(e) A launch operator must not use for flight any component sample that has been subjected to a qualification test environment.

(f) A launch operator may reduce the testing required to qualify or re-qualify a component's design through qualification by similarity to tests performed on identical or similar hardware. To qualify component ''A'' based on similarity to component ''B'' that has already been qualified for use, a launch operator must demonstrate that all of the following conditions are satisfied:

(1) ''B'' must have been qualified through testing, not by similarity;

(2) The environments encountered by ''B'' during its qualification or flight history must have been equal to or more severe than the qualification environments required for ''A;''

(3) ''A'' must be a minor variation of ''B.'' The demonstration that A is a minor variation of B must account for all of the following:

(i) Any difference in weight, mechanical configuration, thermal effects, or dynamic response;

(ii) Any change in piece-part quality level; and

(iii) Any addition or subtraction of an electronic piece-part, moving part, ceramic or glass part, crystal, magnetic device, or power conversion or distribution equipment;

(4) ''A'' and ''B'' must perform the same functions, with ''A'' having equivalent or better capability; and

(5) The same manufacturer must produce ''A'' and ''B'' in the same location using identical tools and manufacturing processes;

(g) For any flight termination system component used for more than one flight, the component qualification tests must demonstrate that the component satisfies all its performance specifications when subjected to:

(1) Each qualification test environment; and

(2) The total number of exposures to each maximum predicted environment for the total number of flights.

E417.9 QUALIFICATION NON-OPERATING ENVIRONMENTS

(a) *General*. This section applies to each qualification non-operating environment test or analysis identified by any table of this appendix. A qualification non-operating test or analysis must demonstrate that a component satisfies all its performance specifications when subjected to each maximum predicted non-operating environment that the component could experience, including all storage, transportation, and installation environments.

(b) *Storage temperature*. A storage temperature test or analysis must demonstrate that a component will satisfy all its performance specifications when subjected to the maximum predicted high and low temperatures, thermal cycles, and dwell-times at the high and low temperatures that the component could experience under storage conditions as follows:

(1) Any storage temperature test must subject the component to the range of temperatures from 10 °C lower than the maximum predicted storage thermal range to 10 °C higher. The rate of change from one thermal extreme to the other must be no less than the maximum predicted thermal rate of

change. All thermal dwell-times and thermal cycles must be no less than those of the maximum predicted storage environment.

(2) Any analysis must demonstrate that the qualification operating thermal cycle environment is more severe than the storage thermal environment by satisfying one of the following:

(i) The analysis must include thermal fatigue equivalence calculations that demonstrate that the large change in temperature for a few thermal cycles experienced during flight is a more severe environment than the relatively small change in temperature for many thermal cycles that would be experienced during storage; or

(ii) The analysis must demonstrate that the component's operating qualification thermal cycle range encompasses –34 °C to 71 °C and that any temperature variation that the component experiences during storage does not exceed 22 °C.

(c) *High-temperature storage of ordnance.* A component may undergo a high-temperature storage test to extend the service-life of an ordnance component production lot from one year to three or five years as permitted by any test table of this appendix. The test must demonstrate that each component sample satisfies all its performance specifications after being subjected to +71 °C and 40 to 60 percent relative humidity for no less than 30 days each.

(d) *Transportation shock.* A transportation shock test or analysis must demonstrate that a component satisfies all its performance specifications after being subjected to the maximum predicted transportation induced shock levels that the component could experience when transported in its transported configuration. Any analysis must demonstrate that the qualification operating shock environment is more severe than the transportation shock environment.

(e) *Bench handling shock.* A bench handling shock test must demonstrate that a component satisfies all its performance specifications after being subjected to maximum predicted bench handling induced shock levels. The test must include, for each orientation that could occur during servicing; a drop from the maximum predicted handling height onto a representative surface.

(f) *Transportation vibration.* A transportation vibration test or analysis must demonstrate that a component satisfies all its performance specifications after being subjected to a maximum predicted transportation-induced vibration level when transported in its transportation configuration as follows:

(1) Any transportation vibration test must subject a component to vibration in three mutually perpendicular axes for 60 minutes per axis. The test must subject each axis to the following vibration profile:

(i) 0.01500 g^2/Hz at 10 Hz to 40 Hz;

(ii) 0.01500 g^2/Hz at 40 Hz to 0.00015 g^2/Hz at 500 Hz; and

(iii) If the component is resonant below 10 Hz, the test vibration profile must extend to the lowest resonant frequency.

(2) Any analysis must demonstrate that the qualification operating vibration environment is more severe than the transportation vibration environment. The analysis must include vibration fatigue equivalence calculations that demonstrate that the high vibration levels with short duration experienced during flight creates a more severe environment than the relatively low-vibration levels with long duration that would be experienced during transportation.

(g) *Fungus resistance.* A fungus resistance test or analysis must demonstrate that a component satisfies all its performance specifications after being subjected to a fungal growth environment. Any analysis must demonstrate that all unsealed and exposed surfaces do not contain nutrient materials for fungus.

(h) *Salt fog.* For a component that will be exposed to salt fog, a salt fog test or analysis must demonstrate that the component satisfies all its performance specifications after being subjected to the effects of a moist, salt-laden atmosphere. The test or analysis must demonstrate the ability of all externally exposed surfaces to withstand a salt-fog environment. The test or analysis must demonstrate the ability of each internal part of a component to withstand a salt-fog environment unless the component is environmentally sealed, and acceptance testing verifies that the seal works.

(i) *Fine sand.* For a component that will be exposed to fine sand or dust, a fine sand test or analysis must demonstrate that the component satisfies all its performance specifications after being subjected to the effects of dust or fine sand particles that may penetrate into cracks, crevices, bearings and joints. The test or analysis must demonstrate the ability of all externally exposed surfaces to withstand a fine sand environment. The test or analysis must demonstrate the ability of each internal part of a component to withstand a fine sand environment unless the component is environmentally sealed and acceptance testing verifies that the seal works.

(j) *Tensile load.* A tensile load test must demonstrate that a component satisfies all its performance specifications after being exposed to tensile and compression loads of no less than twice the maximum predicted level during transportation and installation. In addition, the test load must satisfy one of the following where applicable:

(1) For an explosive transfer system and its associated fittings, a pull of no less than 100 pounds unless the launch operator establishes procedural controls or tests that prevent or detect mishandling;

(2) For a destruct charge and its associated fittings, a pull of no less than 50 pounds;

(3) For a flight radio frequency connector, a pull of no less than one-half the manufacturer specified limit;

(4) For an electro-explosive device wire, a pull of no less than 18 pounds; or

(5) For an electrical pin of an exploding bridgewire device, no less than an 18-pound force in axial and compression modes.

(k) *Handling drop of ordnance.* A handling drop test must demonstrate that an ordnance component satisfies all its performance specifications after experiencing the more severe of the following:

(1) The maximum predicted drop and resulting impact that could occur and go undetected during storage, transportation, or installation; or

(2) A six-foot drop onto a representative surface in any orientation that could occur during storage, transportation, or installation.

(l) *Abnormal drop of ordnance.* An abnormal drop test must demonstrate that an ordnance component does not initiate and allows for safe disposal after experiencing the maximum predicted drop and resulting impact onto a representative surface in any orientation, that could occur during storage, transportation, or installation. The component need not function after this drop.

E417.11 QUALIFICATION OPERATING ENVIRONMENTS

(a) *General.* This section applies to each qualification operating environment test or analysis identified by any table of this appendix. A qualification operating environment test must demonstrate that a component satisfies all of its performance specifications when subjected to each qualification operating environment including each physical environment that the component will experience during acceptance testing, launch countdown, and flight. The test must employ each margin required by this section.

(b) *Qualification sinusoidal vibration.* (1) A qualification sinusoidal vibration test or analysis of a component must demonstrate that the component and each connection to any item that attaches to the component satisfy all their performance specifications when subjected to the qualification sinusoidal vibration environment. The attached items must include any vibration or shock isolator, grounding strap, bracket, explosive transfer system, or cable to the first tie-down. Any cable that interfaces with the component during any test must be representative of the cable used for flight.

(2) The qualification sinusoidal vibration environment must be no less than 6dB greater than the maximum predicted sinusoidal vibration environment for no less than three times the maximum predicted duration.

(3) The sinusoidal frequency must range from 50% lower than the maximum predicted frequency range to 50% higher than the maximum predicted frequency range.

(4) Any test must satisfy all of the following:

(i) The test must subject each of three mutually perpendicular axes of the component to the qualification sinusoidal vibration environment, one axis at a time. For each axis, the duration of the vibration must be no less than three times the maximum predicted sinusoidal vibration duration.

(ii) The sinusoidal sweep rate must be no greater than one-third the maximum predicted sweep rate;

(iii) The sinusoidal vibration test amplitude must have an accuracy of ±10%; and

(iv) For any component that uses one or more shock or vibration isolators, the component must undergo the test mounted on its isolator or isolators as a unit. Each isolator must satisfy the requirements of section E417.35.

(5) Any analysis must demonstrate that the qualification random vibration environment of paragraph (c) of this section encompasses the qualification sinusoidal vibration environment.

(c) *Qualification random vibration.* (1) A qualification random vibration test of a component must demonstrate that the component and each connection to any item that attaches to the component satisfy all their performance specifications when subjected to the qualification random vibration environment. The attached items must include any isolator, grounding strap, bracket, explosive transfer system, or cable to the first tie-down. Any cable that interfaces with the component during any test must be representative of the cable used for flight.

(2) For each component required by this appendix to undergo 100% acceptance testing, the minimum qualification random vibration environment must be no less than a 3 dB margin greater than the maximum acceptance random vibration test environment for all frequencies from 20 Hz to 2,000 Hz. The minimum and maximum test environments must account for all the test tolerances to ensure that the test maintains the 3 dB margin.

(3) For each component that is not required by this appendix to undergo 100% acceptance testing, the minimum qualification random vibration environment must be no less than a 4.5–dB margin greater than the greater of the maximum predicted random vibration environment or the minimum workmanship test levels of table E417.11–1 for all frequencies from 20 Hz to 2000 Hz. The minimum qualification test environment must account for all the test tolerances to ensure that the test maintains the 4.5 dB margin.

(4) If a component is mounted on one or more shock or vibration isolators during flight, the component must undergo the qualification random vibration test while hard-mounted or isolator-mounted as follows:

(i) Any qualification random vibration test with the component hard-mounted must subject the component to a qualification random vibration environment that:

(A) Accounts for the isolator attenuation and amplification due to the maximum predicted operating random vibration environment, including any thermal effects and acceleration pre-load performance variability, and adds a 1.5 dB margin to account for any isolator attenuation variability;

(B) Adds the required qualification random vibration margin of paragraph (c)(1) or (c)(2) of this section after accounting for the isolator effects of paragraph (c)(4)(i)(A) of this section and accounts for all tolerances that apply to the isolator's performance specifications to ensure that the qualification test margin is maintained; and

(C) Is no less than the minimum workmanship screening qualification random vibration level of table E417.11–1.

(ii) Any qualification random vibration test with the component isolator-mounted must:

(A) Use an isolator or isolators that passed the tests required by section E417.35;

(B) Have an input to each isolator of no less than the required qualification random vibration environment of paragraph (c)(1) or (c)(2) of this section; and

(C) Subject the component to no less than the minimum workmanship screening qualification random vibration level of table E417.11–1. If the isolator or isolators prevent the component from experiencing the minimum workmanship level, the component must undergo a test while hard-mounted that subjects the component to the workmanship level.

(5) The test must subject each component sample to the qualification random vibration environment in each of three mutually perpendicular axes. For each axis, the test must last three times as long as the acceptance test duration or a minimum workmanship qualification duration of 180 seconds, whichever is greater.

(6) For a component sample that must experience the acceptance random vibration environment before it experiences the qualification random vibration environment, such as a command receiver decoder, the test must use the same configuration and methods for the acceptance and qualification environments.

(7) If the duration of the qualification random vibration environment leaves insufficient time to complete any required performance verification test while the component is subjected to the full qualification environment, the test must continue at no less than the acceptance random vibration environment. The test need only continue for the additional time needed to complete the performance verification test.

(8) The test must continuously monitor and record all performance and status-of-health parameters while the component is subjected to the qualification environment. This monitoring must have a sample rate that will detect any component performance degradation. Any electrical component must undergo the test while subjected to its nominal operating voltage.

(9) A launch operator may substitute a random vibration test for another required dynamic test, such as acceleration, acoustic, or sinusoidal vibration if the launch operator demonstrates that the forces, displacements, and test duration imparted on a component during the random vibration test are no less severe than the other test environment.

Table E417.11-1, Minimum Workmanship

Power Spectral Density for Qualification Random Vibration Testing

Frequency Range (Hz)	Minimum Power Spectral Density
20	0.021 g^2/Hz
20-150	3 dB/octave slope
150-600	0.16 g^2/Hz
600-2000	-6 dB/octave slope
2000	0.014 g^2/Hz
Overall G_{rms} = 12.2	

(d) *Qualification acoustic.* (1) A qualification acoustic vibration test or analysis of a component must demonstrate that the component and each connection to any item that attaches to the component satisfy all their performance specifications when subjected to the qualification acoustic vibration environment. The attached items must include any isolator, grounding strap, bracket, explosive transfer system, or cable to the first tie-down. Any cable that interfaces with the component during any test must be representative of the cable used for flight.

(2) For each component required by this appendix to undergo 100% acoustic acceptance testing, the minimum qualification acoustic vibration environment must be greater than the maximum acceptance acoustic vibration test environment for all frequencies from 20 Hz to 2000 Hz. The minimum and maximum test environments must account for all the test tolerances to ensure that the test maintains a positive margin between the minimum qualification environment and the maximum acceptance environment. For each acoustic vibration test required by this appendix to have a tolerance of ±3 dB, the qualification test level must be 6 dB greater than the acceptance test level.

(3) For each component that is not required by this appendix to undergo 100% acceptance testing, such as ordnance, the minimum qualification acoustic vibration environment must be no less than a 3 dB margin greater than the maximum predicted acoustic vibration environment or a minimum workmanship screening test level of 144 dBA for all frequencies from 20 Hz to 2000 Hz. The minimum qualification test environment must account for all the test tolerances to ensure that the test maintains the 3 dB margin. For each acoustic vibration test required by this appendix to have a tolerance of ±3.0 dB, the qualification test level must be 6 dB greater than the greater of the maximum predicted environment or the minimum workmanship test level.

(4) For any component that uses one or more shock or vibration isolators during flight, the component must undergo any qualification acoustic vibration test mounted on its isolator or isolators as a unit. Each isolator must satisfy the test requirements of section E417.35.

(5) Any test must continuously monitor and record all performance and status-of-health parameters while the component is subjected to the qualification environment. This monitoring must have a sample rate that will detect any component performance degradation.

(6) Any analysis must demonstrate that the qualification random vibration test environment of paragraph (c) of this section encompasses the qualification acoustic vibration environment. The analysis must demonstrate that the qualification random vibration environment is more severe than the

qualification acoustic vibration environment. The analysis must account for all peak vibration levels and durations.

(e) *Qualification shock.* (1) A qualification shock test of a component must demonstrate that the component and each connection to any item that attaches to the component satisfies all their performance specifications when subjected to the qualification shock environment. The attached items must include any isolator, grounding strap, bracket, explosive transfer system, or cable to the first tie-down. Any cable that interfaces with the component during the test must be representative of the cable used for flight.

(2) The minimum qualification shock environment must be no less than a 3 dB margin plus the greater of the maximum predicted environment or the minimum breakup levels identified in table E417.11–2 for all frequencies from 100 Hz to 10000 Hz. The minimum qualification test environment must account for all the test tolerances to ensure that the test maintains the 3dB margin. For a shock test required by this appendix to have a ±3 dB tolerance, the qualification test environment must be 6 dB greater than the greater of the maximum predicted shock environment or the minimum breakup test level.

(3) The test must subject the component simultaneously to a shock transient and all the required frequencies.

(4) The test must subject each component to three shocks in each direction along each of the three orthogonal axes.

(5) The shock must last as long as the maximum predicted shock event.

(6) The test must continuously monitor each component's critical performance parameters for any discontinuity or inadvertent output while the component is subjected to the shock environment.

(7) The test must continuously monitor and record all performance and status-of-health parameters while the component is subjected to the qualification environment. This monitoring must have a sample rate of once every millisecond or better.

(8) For any component that uses one or more shock or vibration isolators during flight, the component must undergo the qualification shock test mounted on its isolator or isolators. Each isolator must satisfy the test requirements of section E417.35.

Table E417.11-2, Minimum Breakup Qualification Shock Levels

Frequency Range (Hz)	Minimum Acceleration Spectral Density
100	100 G
2000	1300 G
10000	1300 G
Q (Resonant Amplification Factor) = 10	

(f) *Qualification acceleration.* (1) A qualification acceleration test or analysis of a component must demonstrate that the component and each connection to any item that attaches to the component satisfy all their performance specifications when subjected to the qualification acceleration environment. The attached items must include any isolator, grounding strap, bracket, explosive transfer system, or cable to the first tie-down. Any cable that interfaces with the component during any test must be representative of the cable used for flight.

(2) The qualification acceleration test environment must be no less than 200% greater than the maximum predicted acceleration environment.

(3) The qualification acceleration must last three times as long as the maximum predicted environment lasts in each direction for each of the three orthogonal axes.

(4) For any test, if the test tolerance is more than ±10%, the qualification acceleration test environment of paragraph (f)(1) of this section must account for the test tolerance to ensure that the test maintains the

200% margin between the minimum qualification acceleration test and the maximum predicted environment.

(5) Any analysis must demonstrate that the qualification operating random vibration test required by paragraph (c) of this section encompasses the qualification acceleration environment. The analysis must demonstrate that the qualification random vibration environment is equal to or more severe than the qualification acceleration environment. The analysis must account for the peak vibration and acceleration levels and durations.

(6) Any test must continuously monitor and record all performance and status-of-health parameters while the component is subjected to the qualification environment. This monitoring must have a sample rate that will detect any component performance degradation.

(7) For any component that uses one or more shock and vibration isolators during flight, the component must undergo any qualification acceleration test mounted on its isolator or isolators. Each isolator must satisfy the test requirements of section E417.35.

(g) *Qualification humidity*. A qualification humidity test or analysis must demonstrate that a component satisfies all its performance specifications when subjected to the maximum predicted relative humidity environment that the component could experience when stored, transported, or installed as follows:

(1) The test or analysis must demonstrate the ability of all externally exposed surfaces to withstand the maximum predicted relative humidity environment.

(2) The test or analysis must demonstrate the ability of each internal part of a component to withstand the maximum predicted relative humidity environment unless the component is environmentally sealed and an acceptance test demonstrates that the seal works.

(3) Each test must satisfy all of the following:

(i) The test must subject the component to no less than four thermal cycles while the component is exposed to a relative humidity of no less than 95%;

(ii) The test must measure each electrical performance parameter at the cold and hot temperatures during the first, middle and last thermal cycles; and

(iii) The test must continuously measure and record all performance and status-of-health parameters with a resolution and sample rate that will detect any component performance degradation throughout each thermal cycle.

(h) *Qualification thermal cycle*. A qualification thermal cycle test must demonstrate that a component satisfies all its performance specifications when subjected to the qualification thermal cycle environment as follows:

(1) *Electronic components*. For any command receiver decoder or other electronic component that contains piece-part circuitry, such as microcircuits, transistors, diodes and relays, a qualification thermal cycle test must satisfy all of the following:

(i) The qualification thermal cycle environment must range from 10 °C above the acceptance test high temperature to 10 °C below the acceptance test low temperature;

(ii) The test must subject a component to no less than three times the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles must satisfy section E417.13(d)(1). For each cycle, the dwell-time at each of the high and low temperatures must last long enough for the component to achieve internal thermal equilibrium and must last no less than one hour. The test must begin each dwell-time at each high and low temperature with the component turned off. The component must remain off until the temperature stabilizes. Once the temperature stabilizes, the component must be turned on and the test must complete each dwell-time with the component turned on;

(iii) When heating or cooling the component, the temperature must change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater;

(iv) The test must measure all performance parameters with the component powered at its low and high operating voltages when the component is at ambient temperature before beginning the first thermal cycle and after completing the last cycle. The test must measure all performance parameters with the component powered at its low and high operating voltages when the component is at the high and low temperatures during the first, middle, and last thermal dwell cycles; and

(v) The test must continuously monitor and record all critical performance and status-of-health parameters during all cycles and thermal transitions and with the component operating at its nominal operating voltage. The monitoring and recording must have a resolution and sample rate that will detect any component performance degradation.

(2) *Passive components*. For any passive component that does not contain an active electronic piece-part, such as a radio frequency antenna, coupler, or cable, a qualification thermal cycle test must satisfy all of the following:

(i) The qualification thermal cycle environment must range from 10 °C above the acceptance test high temperature to 10 °C below the acceptance test low temperature;

(ii) The test must subject a component to no less than three times the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles must satisfy section E417.13(d)(1). For each cycle, the dwell-time at each high and low temperature must last long enough for the component to achieve internal thermal equilibrium and must last no less than one hour;

(iii) When heating or cooling the component, the temperature must change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater;

(iv) The test must measure all performance parameters when the component is at ambient temperature before beginning the first thermal cycle and after completing the last cycle. The test must measure all performance parameters when the component is at the high and low temperatures during the first, middle, and last thermal cycles; and

(v) The test must continuously monitor and record all critical performance and status-of-health parameters with a resolution and sample rate that will detect any component performance degradation during all cycles and thermal transitions.

(3) *Safe-and-Arm Devices.* For any electromechanical safe-and-arm device with an internal explosive, a qualification thermal cycle test must satisfy all of the following:

(i) The qualification thermal cycle must range from 10 °C above the acceptance test high temperature to 10 °C below the acceptance test low temperature;

(ii) The test must subject the component to no less than three times the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles must satisfy section E417.13(d)(1). For each cycle, the dwell-time at each high and low temperature must last long enough for the component to achieve internal thermal equilibrium and must last no less than one hour;

(iii) When heating or cooling the component, the temperature must change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater;

(iv) The test must measure all performance parameters when the component is at ambient temperature before beginning the first thermal cycle. The test must measure all performance parameters when the component is at the high and low temperatures during the first, middle, and last thermal cycles. The test must measure all performance parameters when the component is at ambient temperature after completing the last cycle; and

(v) The test must continuously monitor and record all critical performance and status-of-health parameters during all temperature cycles and transitions using a resolution and sample rate that will detect any component performance degradation.

(4) *Ordnance components.* For any ordnance component, a qualification thermal cycle test must satisfy all of the following:

(i) The qualification thermal cycle must range from 10 °C above the predicted highest temperature, or 71 °C, whichever is higher, to 10 °C below the predicted lowest temperature, or −54 °C, whichever is lower;

(ii) The test must subject each ordnance component to no less than the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles must satisfy section E417.13(d)(1). For an ordnance component that is used inside a safe-and-arm device, the test must subject the component to three times the acceptance-number of thermal cycles. For each cycle, the dwell-time at each high and low temperature must last long enough for the component to achieve internal thermal equilibrium and must last no less than two hours; and

(iii) When heating or cooling the component, the temperature must change at an average rate of 3 °C per minute or the maximum predicted rate, whichever is greater.

(i) *Qualification thermal vacuum.* A qualification thermal vacuum test or analysis must demonstrate that a component satisfies all its performance specifications, including structural integrity, when subjected to the qualification thermal vacuum environment as follows:

(1) The qualification thermal vacuum environment must satisfy all of the following:

(i) The thermal vacuum pressure gradient must equal or exceed the maximum predicted rate of altitude change that the component will experience during flight;

(ii) The final vacuum dwell-time must last long enough for the component to achieve pressure equilibrium and equal or exceed the greater of the maximum predicted dwell-time or 12 hours;

(iii) During the final vacuum dwell-time, the environment must include no less than three times the maximum predicted number of thermal cycles; and

(iv) Each thermal cycle must range from 10 °C above the acceptance thermal vacuum range, to 10 °C below the acceptance thermal vacuum range. The acceptance thermal vacuum temperature range is described in section E417.13(e);

(2) Any test must satisfy all of the following:

(i) The test must measure all performance parameters with the component powered at its low and high operating voltages when the component is at ambient temperature before beginning the first thermal cycle and after completing the last cycle;

(ii) The test must measure all performance parameters while the component is powered at its low and high operating voltages when the component is at the high and low temperatures during the first, middle and last thermal cycles;

(iii) The test must continuously monitor and record all critical performance and status-of-health parameters during chamber pressure reduction and the final vacuum dwell-time, with the component at its high operating voltage and using a resolution and sample rate that will detect any component performance degradation; and

(3) Any analysis must satisfy all of the following:

(i) For any low voltage component of less than 50 volts, the analysis must demonstrate that the component is not susceptible to corona, arcing, or structural failure; and

(ii) For any high voltage component of 50 volts or greater, the component must undergo a thermal vacuum test unless the component is environmentally sealed and the analysis demonstrates that any low voltage externally exposed part is not susceptible to corona, arcing, or structural failure. A component with any high voltage externally exposed part of 50 volts or greater must undergo a thermal vacuum test.

(j) *Electromagnetic interference and electromagnetic compatibility*. An electromagnetic interference and electromagnetic compatibility test must demonstrate that a component satisfies all its performance specifications when subjected to radiated or conducted emissions from all flight vehicle systems and external ground transmitter sources. In addition, the test must demonstrate that the component does not radiate or conduct electromagnetic interference that would degrade the performance of any other flight termination system component.

(k) *Explosive atmosphere*. An explosive atmosphere test or analysis must demonstrate that a component is capable of operating in an explosive atmosphere without creating an explosion or that the component is not used in an explosive environment.

E417.13 ACCEPTANCE TESTING AND ANALYSIS

(a) *General*. This section applies to each acceptance test or analysis identified by any table of this appendix. An acceptance test or analysis must demonstrate that a component does not have any material or workmanship defect that could adversely affect the component's performance and that the component satisfies all its performance specifications when subjected to each acceptance environment, including each workmanship and maximum predicted operating environment.

(1) An acceptance test of a component must subject the component to one or more of the component's maximum predicted environments as determined under section D417.7. An acceptance test must not subject a component to a force or environment that is not tested during qualification testing.

(2) Each component sample that is intended for flight must undergo each acceptance test identified by any table of this appendix. A single-use component, such as ordnance or a battery, must undergo the production lot sample acceptance tests identified by any tables of this appendix.

(3) If a launch vehicle uses a previously flown and recovered flight termination system component, the component must undergo one or more reuse acceptance tests before each next flight to demonstrate that the component still satisfies all its performance specifications when subjected to each maximum predicted environment. Each reuse acceptance test must be the same as the initial acceptance test for the component's first flight. Each reuse acceptance test must follow a written component reuse qualification, refurbishment, and acceptance plan and procedures. Each acceptance reuse test must compare performance parameter measurements taken during the test to all previous acceptance test measurements to ensure that the data show no trends that indicate any degradation in performance that could prevent the component from satisfying all its performance specifications during flight.

(4) Each acceptance test of a component must use test tolerances that are consistent with the test tolerances used by each qualification test of the component.

(b) *Acceptance random vibration*. An acceptance random vibration test must demonstrate that a component satisfies all its performance specifications when exposed to the acceptance random vibration environment as follows:

(1) The acceptance random vibration environment must equal or exceed the greater of the maximum predicted random vibration level or the minimum workmanship acceptance test level of table E417.13–1, for all frequencies from 20 Hz to 2000 Hz, in each of three mutually perpendicular axes.

(2) For each axis, the vibration must last the greater of three times the maximum predicted duration or a minimum workmanship screening level of 60 seconds.

(3) For a component sample that undergoes qualification testing and must experience the acceptance environment before it experiences the qualification environment, such as a command receiver decoder, the test must use the same configuration and methods for the acceptance and qualification random vibration environments. An acceptance random vibration test of a flight component sample must use a configuration and method that is representative of the component's qualification tests to ensure that the requirements of paragraph (a) of this section are satisfied.

(4) For any component that is mounted on one or more vibration or shock isolators during flight, the component must undergo the acceptance random vibration test in the

same isolator-mounted configuration or hard-mounted configuration as the component's qualification random vibration test as follows:

(i) Any hard-mounted acceptance random vibration test must subject the component to an acceptance random vibration environment that:

(A) Accounts for the isolator attenuation and amplification due to the maximum predicted operating random vibration environment, including any thermal effects and acceleration pre-load performance variability, and adds a 1.5 dB margin to account for any isolator attenuation variability; and

(B) Is no less than the minimum workmanship screening acceptance random vibration level of table E417.13–1.

(ii) Any isolator-mounted acceptance random vibration test must:

(A) Use an isolator or isolators that passed the tests required by section E417.35;

(B) Have an input to each isolator of no less than the required acceptance random vibration environment of paragraphs (b)(1) and (b)(2) of this section; and

(C) Subject the component to no less than the minimum workmanship screening acceptance random vibration level of table E417.13–1. If the isolator or isolators prevent the component from experiencing the minimum workmanship level, the component must undergo a hard-mount test that subjects the component to the workmanship level.

(5) If the duration of the acceptance random vibration environment leaves insufficient time to complete any required performance verification test while the component is subjected to the full acceptance environment, the test must continue at no lower than 6 dB below the acceptance environment. The test need only continue for the additional time needed to complete the performance verification test.

(6) The test must continuously monitor all performance and status-of-health parameters with any electrical component at its nominal operating voltage. This monitoring must have a sample rate that will detect any component performance degradation.

Table E417.13-1, Minimum Workmanship

Power Spectral Density for Acceptance Random Vibration

Frequency Range	Minimum Power Spectral Density
20	0.0053 g^2/Hz
20-150	3 dB/Octave Slope
150-600	0.04 g^2/Hz
600-2000	-6 dB/Octave Slope
2000	0.0036 g^2/Hz
Overall G_{rms} = 6.1	

(c) *Acceptance acoustic vibration.* An acceptance acoustic vibration test or analysis must demonstrate that a component satisfies all its performance specifications when exposed to the acceptance acoustic vibration environment as follows:

(1) The acceptance acoustic vibration environment must satisfy all of the following:

(i) The vibration level must equal or exceed the maximum predicted acoustic level for all frequencies from 20 Hz to 2,000 Hz in each of three mutually perpendicular axes; and

(ii) For each axis, the vibration must last the maximum predicted duration or 60 seconds, whichever is greater.

(2) Any test must satisfy all of the following:

(i) The test must continuously monitor all performance and status-of-health parameters with any electrical component at its nominal operating voltage. This monitoring must have a sample rate that will detect any component performance degradation; and

(ii) If the duration of the acceptance acoustic vibration environment leaves insufficient time to complete any required performance verification test while the component is subjected to the full acceptance environment, the test must continue at no lower than 6 dB below the acceptance environment. The test need only continue for the additional time needed to complete the performance verification test.

(3) Any analysis must demonstrate that the acceptance random vibration environment of paragraph (b) of this section encompasses the acceptance acoustic vibration environment. The analysis must demonstrate that the peak acceptance random vibration levels and duration are equal to or are more severe than the acceptance acoustic vibration environment.

(d) *Acceptance thermal cycle.* An acceptance thermal cycle test of a component must demonstrate that the component satisfies all its performance specifications when exposed to the acceptance thermal cycle environment as follows:

(1) *Acceptance-number of thermal cycles.* The acceptance-number of thermal cycles for a component means the number of thermal cycles that the component must experience during the test. The test must subject each component to no less than the greater of eight thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing and flight, including all launch delays and recycling, rounded up to the nearest whole number.

(2) *Electronic components.* For any electronic component, an acceptance thermal cycle test must satisfy all of the following:

(i) The acceptance thermal cycle environment must range from the higher of the maximum predicted environment high temperature or 61 °C workmanship screening level, to the lower of the predicted low temperature or a −24 °C workmanship screening level.

(ii) The test must subject a component to no fewer than 10 plus the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles must satisfy this paragraph. For each cycle, the dwell-time at each high and low temperature must last long enough for the component to achieve internal thermal equilibrium and must last no less than one hour. The test must begin each dwell-time at each high and low temperature with the component turned off. The component must remain off until the temperature stabilizes. Once the temperature stabilizes, the test must complete each dwell-time with the component turned on.

(iii) When heating or cooling the component, the temperature must change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater.

(iv) The test must measure all performance parameters with the component powered at its low and high operating voltages when the component is at ambient temperature before beginning the first thermal cycle and after completing the last cycle.

(v) The test must measure all performance parameters with the component at its low and high operating voltages when the component is at the high and low temperatures during the first, middle, and last thermal cycles.

(vi) The test must continuously monitor and record all critical performance and status-of-health parameters during all cycles and thermal transitions and with the component at its nominal operating voltage. The monitoring and recording must have a resolution and sample rate that will detect any component performance degradation.

(3) *Passive components.* For any passive component that does not contain any active electronic piece-part, such as any radio frequency antenna, coupler, or cable, an acceptance thermal cycle test must satisfy all of the following:

(i) Unless otherwise noted, the acceptance thermal cycle environment must range from the higher of the maximum predicted environment high temperature or a 61 °C workmanship screening temperature, to the lower of the predicted lowest temperature or a −24 °C workmanship screening temperature;

(ii) The test must subject a component to no fewer than the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles must satisfy this paragraph. For each cycle, the dwell-time at each high and low temperature must last long enough for the component to achieve internal thermal equilibrium and must last no less than one hour;

(iii) When heating or cooling the component, the temperature must change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater;

(iv) The test must measure all performance parameters when the component is at ambient temperature before beginning the first thermal cycle and after completing the last cycle;

(v) The test must measure all performance parameters when the component is at the high and low temperatures during the first, middle, and last thermal cycles; and

(vi) The test must continuously monitor and record all critical performance and status-of-health parameters throughout each thermal cycle with a resolution and sample rate that will detect any component performance degradation.

(4) *Safe-and-arm devices.* For any electromechanical safe-and-arm device with an internal explosive, an acceptance thermal cycle test must satisfy all of the following:

(i) The acceptance thermal cycle environment must range from the higher of the maximum predicted environment high temperature or the minimum workmanship screening temperature of 61 °C to the lower of the predicted lowest temperature or the minimum workmanship screening temperature of −24 °C.

(ii) The test must subject a component to no fewer than the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles must satisfy this paragraph. For each cycle, the dwell-time at each high and low temperature must last long enough for the component to achieve internal thermal equilibrium and must last no less than one hour.

(iii) When heating or cooling the component, the temperature must change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater.

(iv) The test must measure all performance parameters when the component is at ambient temperature before beginning the first thermal cycle and after completing the last cycle.

(v) The test must measure all performance parameters including each critical electrical parameter, when the component is at the high and low temperatures during the first, middle, and last thermal cycles.

(vi) The test must continuously monitor and record all critical performance and status-of-health parameters throughout each thermal cycle with a resolution and sample rate that will detect whether the component satisfies all its performance specifications.

(e) *Acceptance thermal vacuum.* An acceptance thermal vacuum test or analysis must demonstrate that a component satisfies all its performance specifications when exposed to the acceptance thermal vacuum environment as follows:

(1) The acceptance thermal vacuum environment must satisfy all of the following:

(i) The thermal vacuum pressure gradient must equal or exceed the maximum predicted rate of altitude change that the component will experience during flight. The pressure gradient must allow for no less than ten minutes for reduction of chamber pressure at the pressure zone from ambient pressure to 20 Pascal;

(ii) The final vacuum dwell-time must last long enough for the component to achieve pressure equilibrium and must last no less than the maximum predicted dwell-time or 12 hours, whichever is greater;

(iii) During the final vacuum dwell-time, the environment must include no less than the maximum predicted number of thermal cycles; and

(iv) Each thermal cycle must range from the higher of the maximum predicted environment high temperature or the workmanship screening high temperature of 61 °C, to the lower of the predicted low temperature or the workmanship screening low temperature of −24 °C.

(2) Any test must satisfy all of the following:

(i) The test must measure all performance parameters with the component powered at its low and high operating voltages when the component is at ambient temperature before beginning the first thermal cycle and after completing the last cycle.

(ii) The test must measure all performance parameters with the component powered at its low and high operating voltages when the component is at the high and low temperatures during the first, middle, and last thermal cycles; and

(iii) The test must continuously monitor all critical performance and status-of-health parameters during chamber pressure reduction and during the final vacuum dwell-time with the component at its high operating voltage. This monitoring must have a resolution and sample rate that will detect any component performance degradation.

(3) Any analysis must satisfy all of the following:

(i) For any low voltage component of less than 50 volts, any analysis must demonstrate that the component is not susceptible to corona, arcing, or structural failure; and

(ii) Any high voltage component of 50 volts or greater must undergo a thermal vacuum test unless the component is environmentally sealed and the analysis demonstrates that any low voltage externally exposed part of less than 50 volts is not susceptible to corona, arcing, or structural failure. A component with any high voltage externally exposed part must undergo an acceptance thermal vacuum test.

(f) *Tensile loads.* An acceptance tensile load test of a component must demonstrate that the component is not damaged and satisfies all its performance specifications after experiencing twice the maximum predicted pull-force that the component could experience before, during, or after installation.

E417.15 Ordnance service-life extension testing

(a) *General.* This section applies to each service-life extension test of an ordnance component that is identified by any table of this appendix. A service-life extension test must demonstrate that an ordnance component will satisfy all its performance specifications when subjected to non-operating and operating environments throughout its initial service-life and throughout any extension to the service-life. An ordnance component must undergo a service-life extension test to extend its service-life if its initial service-life and any previous extension will expire before the component is used for flight.

(b) *Service-life*. An ordnance component must undergo any service-life extension test before the component's initial service-life expires and again before each service-life extension expires. The initial service-life of an ordnance component, including any component that contains ordnance or is used to directly initiate ordnance, must start upon completion of the initial production lot sample acceptance tests and must include both storage time and time after installation until completion of flight. The test tables of this appendix identify the options for the length of any service-life extension for each type of ordnance component.

(c) *Test samples*. The tables of this appendix identify the number of ordnance component samples that must undergo any service-life extension test. Each component sample must be:

(i) From the same production lot;

(ii) Consist of identical parts and materials;

(iii) Manufactured through identical processes; and

(iv) Stored with the flight ordnance component or in an environment that duplicates the storage conditions of the flight ordnance component.

E417.17 RADIO FREQUENCY RECEIVING SYSTEM

(a) *General*. (1) This section applies to a radio frequency receiving system, which includes each flight termination system antenna and radio frequency coupler and any radio frequency cable or other passive device used to connect a flight termination system antenna to a command receiver.

(2) The components of a radio frequency receiving system must satisfy each test or analysis identified by any table of this section to demonstrate that:

(i) The system is capable of delivering command control system radio frequency energy to each flight termination system receiver; and

(ii) The system satisfies all its performance specifications when subjected to each non-operating and operating environment and any performance degradation source. Such sources include any command control system transmitter variation, non-nominal launch vehicle flight condition, and flight termination system performance variation.

Table E417.17-1

Radio frequency receiving system Acceptance	Section E417.13	Quantity Tested		
		Cable	Coupler	Antenna
Component Examination:	E417.5			
Visual Examination	E417.5(b)	100%	100%	100%
Dimension Measurement	E417.5(c)	100%	100%	100%
Identification Check	E417.5(e)	100%	100%	100%
Performance Verification:	E417.3(d)			
Status-of-Health [(1)]	E417.17(b)	-	-	100%
Link Performance [(1)]	E417.17(c)	100%	100%	-
Isolation [(1)]	E417.17(d)	-	100%	-
Abbreviated Antenna Pattern	E417.17(g)	-	-	100%
Abbreviated Performance Verification:	E417.3(e)			
Abbreviated Status-of-health [(2)]	E417.17(e)	100%	100%	100%
Operating Environment Tests:	E417.13			
Thermal Cycling	E417.13(d)	100%	100%	100%
Acoustic	E417.13(c)	-	100%	100%
Random Vibration	E417.13(b)	-	100%	100%
Tensile Load	E417.13(f)	100%	-	-
Abbreviated Antenna Pattern	E417.17(g)	-	-	100%

[(1)] A component must undergo this test before the first and after the last operating environment test.

[(2)] A component must undergo this test during each operating environment test.

Table E417.17-2

Radio frequency receiving system Qualification	Section E417.7	Quantity Tested [6]		
		Cable X=3	Coupler X=3	Antenna X=3
Acceptance Tests [1]	Table E417.17-1	X	X	X
Antenna Pattern [2]	E417.17(f)	X	X	X
Abbreviated Antenna Pattern	E417.17(g)	-	-	X
Performance Verification:	E417.3(d)			
Status-of-Health [3]	E417.17(b)	-	-	X
Link Performance [3]	E417.17(c)	X	X	-
Isolation [3]	E417.17(d)	-	X	-
Non-Operating Environment Tests:	E417.9			
Storage Temperature	E417.9(b)	X	X	X
Transportation Shock	E417.9(d)	X	X	X
Bench Handling Shock	E417.9(e)	X	X	X
Transportation Vibration	E417.9(f)	X	X	X
Fungus Resistance	E417.9(g)	1	1	1
Salt Fog	E417.9(h)	1	1	1
Fine Sand	E417.9(i)	1	1	1
Abbreviated Performance Verification:	E417.3(e)			
Abbreviated Status-of-Health [4]	E417.17(e)	X	X	X
Operating Environment Tests:	E417.11			

Thermal Cycling [5]	E417.11(h)	X	X	X
Humidity [5]	E417.11(g)	X	X	X
Acceleration [5]	E417.11(f)	X	X	X
Shock [5]	E417.11(e)	X	X	X
Sinusoidal Vibration [5]	E417.11(b)	X	X	X
Acoustic [5]	E417.11(d)	X	X	X
Random Vibration [5]	E417.11(c)	X	X	X
Tensile Load	E417.9(j)	X	-	-
Abbreviated Antenna Pattern	E417.17(g)	-	-	X
Internal Inspection	E417.5(g)	-	X	X

(1) Each sample component to undergo qualification testing must first successfully complete all acceptance tests identified by table E417.17-1 of this section.

(2) The radio frequency receiving system, including the antenna, radio frequency cables, and radio frequency coupler must undergo this test.

(3) A component must undergo this test before the first and after the last non-operating environment test and before the first and after the last operating environment test.

(4) A component must undergo this test during the operating environment tests.

(5) A component must undergo this test with flight radio frequency cables attached in the flight representative configuration.

(6) The same three sample components must undergo each test designated with an X. For a test designated with a quantity of less than three, each sample component tested must be one of the original three sample components.

(b) *Status-of-health.* A status-of-health test of a radio frequency receiving system must satisfy section E417.3(f) and include antenna voltage standing wave ratio testing that measures the assigned operating frequency at the high and low frequencies of the operating bandwidth to verify that the antenna satisfies all its performance specifications.

(c) *Link performance.* A link performance test of a radio frequency component or subsystem must demonstrate that the component or subsystem satisfies all its performance specifications when subjected to performance degradation caused by ground transmitter variations and non-nominal vehicle flight. This must include demonstrating all of the following:

(1) The radio frequency receiving system provides command signals to each command destruct receiver at an electromagnetic field intensity of 12 dB above the level required for reliable receiver operation over 95% of the antenna radiation sphere surrounding the launch vehicle;

(2) The radio frequency coupler insertion loss and voltage standing wave ratio at the assigned operating frequency and at the high and low frequencies of the operating bandwidth satisfy all their performance specifications; and

(3) The cable insertion loss at the assigned operating frequency and at the high and low frequencies of the operating bandwidth satisfies all its performance specifications.

(d) *Isolation*. An isolation test of a radio frequency receiving system must demonstrate that each of the system's radio frequency couplers isolate the redundant antennas and receiver decoders from one another. The test must demonstrate that an open or short-circuit in one string of the redundant system, antenna or receiver decoder, will not prevent functioning of the other side of the redundant system. The test must demonstrate that the system satisfies all its performance specifications for isolation and is in-family.

(e) *Abbreviated status-of-health*. An abbreviated status-of health test of a radio frequency receiving system component must determine any internal anomaly while the component is under environmental stress conditions. The test must include continuous monitoring of the voltage standing wave ratio and any other critical performance parameter that indicates an internal anomaly during environmental testing to detect any variations in amplitude. Any amplitude variation constitutes a test failure. The monitoring must have a sample rate that will detect any component performance degradation.

(f) *Antenna pattern*. An antenna pattern test must demonstrate that the radiation gain pattern of the entire radio frequency receiving system, including the antenna, radio frequency cables, and radio frequency coupler will satisfy all the system's performance specifications during vehicle flight. This must include all of the following:

(1) The test must determine the radiation gain pattern around the launch vehicle and demonstrate that the system is capable of providing command signals to each command receiver decoder with electromagnetic field intensity at a 12 dB link margin above the level required for reliable receiver operation. The test must demonstrate the 12–dB margin over 95 percent of the antenna radiation sphere surrounding the launch vehicle.

(2) All test conditions must emulate flight conditions, including ground transmitter polarization, using a simulated flight vehicle and a flight configured radio frequency command destruct system.

(3) The test must measure the radiation gain for 360 degrees around the launch vehicle in degree increments that are small enough to identify any deep pattern null and to verify that the required 12 dB link margin is maintained throughout flight. Each degree increment must not exceed two degrees.

(4) The test must generate each antenna pattern in a data format that is compatible with the format needed to perform the flight safety system radio frequency link analysis required by § 417.329(h).

(g) *Abbreviated antenna pattern*. An abbreviated antenna pattern test must determine any antenna pattern changes that might have occurred due to damage to an antenna resulting from exposure to test environments. This must include all of the following:

(1) The antenna must undergo the test before and after exposure to the qualification or acceptance test environments.

(2) The test must use a standard ground plane test fixture. The test configuration need not generate antenna pattern data that is representative of the actual system-level patterns.

(3) The test must include gain measurements in the 0° and 90° plane vectors and a conical cut at 80°.

E417.19 COMMAND RECEIVER DECODER

(a) *General*. A command receiver decoder must satisfy each test or analysis identified by any table of this section to demonstrate that the receiver decoder satisfies all its performance specifications when subjected to each non-operating and operating environment and any command control system transmitter variation.

Table E417.19-1

Command Receiver Decoder Acceptance	Section E417.13	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Identification Check	E417.5(e)	100%
Performance Verification:	E417.3(d)	
Status-of-health (1)	E417.19(b)	100%
Functional Performance (1)	E417.19(c)	100%
Radio Frequency Processing (1)	E417.19(e)	100%
Inadvertent Command Output	E417.19(f)	
Logic Sequence (1)	E417.19(f)(5)	100%
Destruct Sequence (1)	E417.19(f)(6)	100%
Receiver Abnormal Logic (1)	E417.19(f)(7)	100%
Tone Drop (1)	E417.19(f)(9)	100%
AM Rejection (1)	E417.19(f)(10)	100%
Decoder Channel Deviation Rejection (1)	E417.19(f)(11)	100%
Abbreviated Performance Verification:	E417.3(e)	
Input Current Monitor (2)	E417.19(g)	100%
Output Functions (2)	E417.19(h)	100%
Radio Frequency Level Monitor (2)	E417.19(i)	100%
Thermal Performance (3)	E417.19(j)	100%
Operating Environment Tests:	E417.13	

Thermal Cycling	E417.13(d)	100%
Thermal Vacuum	E417.13(e)	100%
Acoustic	E417.13(c)	100%
Random Vibration	E417.13(b)	100%
Leakage [4]	E417.5(h)	100%

(1) A component must undergo this test before the first and after the last operating environment test.

(2) A component must undergo this test during the vibration and acoustic operating environments.

(3) A component must undergo this test during the operating thermal cycle and thermal vacuum environments.

(4) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.19-2

Command Receiver Decoder Qualification	Section E417.7	Quantity [5] Tested X=3
Acceptance Tests and Analyses [1]	Table E417.19-1	X
Performance Verification:	E417.3(d)	
Status-of-health [2]	E417.19(b)	X
Functional Performance [2]	E417.19(c)	X
Radio Frequency Processing [2]	E417.19(e)	X
Inadvertent Command Output [2]	E417.19(f)(1)-(11)	X
Non-Operating Environment Tests:	E417.9	
Storage Temperature	E417.9(b)	X
Transportation Shock	E417.9(d)	X
Bench Handling Shock	E417.9(e)	X
Transportation Vibration	E417.9(f)	X
Fungus Resistance	E417.9(g)	1
Salt Fog	E417.9(h)	1
Fine Sand	E417.9(i)	1
Abbreviated Performance Verification:	E417.3(e)	
Input Current Monitor [3]	E417.19(g)	X
Output Functions [3]	E417.19(h)	X
Radio Frequency Level Monitor [3]	E417.19(i)	X
Thermal Performance [4]	E417.19(j)	X
Operating Environment Tests:	E417.11	

Thermal Cycling	E417.11(h)	X
Humidity	E417.11(g)	X
Thermal Vacuum	E417.11(i)	X
Acceleration	E417.11(f)	X
Shock	E417.11(e)	X
Sinusoidal Vibration	E417.11(b)	X
Acoustic	E417.11(d)	X
Random Vibration	E417.11(c)	X
Electromagnetic Interference and Compatibility	E417.11(j)	2
Explosive Atmosphere	E417.11(k)	1
Leakage [(6)]	E417.5(h)	X
Circuit Protection Test	E417.19(d)	X
Internal Inspection	E417.5(g)	X

(1) Each sample component to undergo qualification testing must first successfully complete all applicable acceptance tests.

(2) A component must undergo this test before the first and after the last non-operating environment test and before the first and after the last operating environment test.

(3) A component must undergo this test during shock, acceleration, and vibration testing.

(4) A component must undergo this test during operating thermal cycle and thermal vacuum testing.

(5) The same three sample components must undergo each test designated with an X. For a test designated with a quantity of less than three, each sample component tested must be one of the original three sample components.

(6) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

(b) *Status-of-health.* A status-of-health test of a command receiver decoder must satisfy section E417.3(f) and must measure each pin-to-pin and pin-to-case resistance, input current, voltage standing wave ratio, and radio frequency threshold sensitivity. Each measurement must demonstrate that all wiring and connectors are installed according to the manufacturer's design. The test must demonstrate that each pin-to-pin and pin-to-case resistance satisfies its performance specification and is in-family.

(c) *Functional performance.* A functional performance test must demonstrate that a command receiver decoder satisfies all the requirements for an electronic component of section D417.27 that apply to the receiver decoder. This test must:

(1) *Response time.* Demonstrate that the receiver decoder satisfies all its performance specifications for response time, from receipt of destruct sequence to initiation of destruct output;

(2) *Input current.* Monitor the input current into the receiver decoder to demonstrate reliable functioning of all internal components. The test must demonstrate that the receiver decoder's electrical characteristics satisfy all its performance specifications and are in-family;

(3) *Leakage current.* Demonstrate that the maximum leakage current through any command output port is at a level that cannot degrade performance of down-string electrical or ordnance initiation systems or result in an unsafe condition. The test must demonstrate no less than a 20–dB safety margin between the receiver leakage output and the lowest level that could degrade performance of down-string electrical or ordnance initiation systems or result in an unsafe condition;

(4) *Output Functions.* Function all receiver outputs to demonstrate that all the output performance specifications are satisfied. The test must include drawing the expected current at the receiver's low, nominal and high input specified voltages using output impedances that simulate the flight-configured load. The test must demonstrate that a command receiver is capable of simultaneously outputting arm, destruct, and check channel signals; and

(5) *Warm Up Time.* Demonstrate that the receiver decoder satisfies all its performance specifications after being powered for the manufacturer specified warm-up time.

(d) *Circuit protection.* A circuit protection test must demonstrate that a receiver decoder's circuit protection provides for the receiver decoder to satisfy all its performance specifications when subjected to any improper launch processing, abnormal flight condition, or any non-flight termination system vehicle component failure. This test must:

(1) *Abnormal voltage.* Demonstrate that any circuit protection allows the receiver decoder to satisfy all its performance specifications when powered with the open circuit voltage of the receiver decoder's power source for no less than twice the expected duration of the open circuit voltage and then when powered with the minimum input voltage of the loaded voltage of the power source for no less than twice the expected duration of the loaded voltage. The test must also demonstrate that the receiver decoder satisfies all its performance specifications when subjected to increasing voltage from zero volts to the nominal voltage and then decreasing voltage from nominal back to zero;

(2) *Power dropout.* Demonstrate that, in the event of an input power dropout, any control or switching circuit that contributes to the reliable operation of a receiver decoder, including solid-state power transfer switches, does not change state for 50 milliseconds or more;

(3) *Watchdog circuits.* Demonstrate that any watchdog circuit satisfies all its performance specifications;

(4) *Output circuit protection.* Demonstrate that the receiver decoder's performance does not degrade when any of its monitoring circuits or non-destruct output ports are subjected to a short circuit or the highest positive or negative voltage capable of being supplied by the monitor batteries or other power supplies, for no less than five minutes;

(5) *Reverse polarity.* Demonstrate that the receiver decoder satisfies all of its performance specifications when subjected to a reverse polarity voltage that could occur before flight, for no less than five minutes; and

(6) *Memory.* Demonstrate by test or analysis that any memory device that is part of the receiver decoder satisfies all its performance specifications. The test or analysis must demonstrate that the data stored in memory is retained in accordance with the performance specifications. For any secure receiver decoder, the test or analysis must demonstrate that the command codes remain in memory for the specified time interval while the receiver decoder is not powered.

(e) *Radio frequency processing.*

(1) *General.* A radio frequency processing test must demonstrate that a receiver decoder's radio frequency processing satisfies all its performance specifications when subjected to command control system transmitting equipment tolerances and flight generated signal degradation. The environment must include locally induced radio frequency noise sources, vehicle plume, the maximum predicted noise-floor, ground transmitter performance variations, and abnormal launch vehicle flight.

(2) *Tone-based system.* For any tone-based system, a radio frequency processing test must demonstrate that the receiver decoder satisfies all the design requirements of section D417.29(b) of appendix D of this part and must satisfy all of the following;

(i) *Decoder channel deviation.* The test must demonstrate that the receiver decoder reliably processes the intended tone deviated signal at the minimum and maximum number of expected tones. The test must demonstrate that the receiver decoder satisfies all its performance specifications when subjected to a nominal tone deviation plus twice the maximum and minus half the minimum of the total combined tolerances of all applicable radio frequency performance factors. The tone deviation must be no less than ± 3 KHz per tone.

(ii) *Operational bandwidth.* The testing must demonstrate that the receiver decoder satisfies all its performance specifications at twice the worst-case command control system transmitter radio frequency shift, Doppler shifts of the carrier center frequency, and shifts in flight hardware center frequency during flight at the manufacturer guaranteed receiver sensitivity. The test must demonstrate an operational bandwidth of no less than ± 45KHz. The test must demonstrate that the operational bandwidth accounts for any tone deviation and that the receiver sensitivity does not vary by more than 3dB across the bandwidth.

(iii) *Radio frequency dynamic range.* The test must demonstrate that the receiver decoder satisfies all its performance specifications when subjected to variations of the radio frequency input signal level that it will experience during checkout and flight. The test must subject the receiver decoder to no less than five uniformly distributed radio frequency input levels. The test must demonstrate that the receiver outputs the destruct command from the radio frequency threshold level up to:

(A) The maximum radio frequency level that it will experience from the command control system transmitter during checkout and flight plus a 3 dB margin; or

(B) 13 dBm, whichever is greater.

(iv) *Capture ratio.* The test must demonstrate that the receiver cannot be captured by another transmitter with less than 80% of the power of the command transmitter system for the launch. The test must show that the application of any unmodulated radio frequency at a power level of up to 80% of the command control system transmitter's modulated carrier signal does not capture the receiver or interfere with a signal from the command control system.

(v) *Radio frequency monitor.* The test must demonstrate that the receiver decoder's monitoring circuit accurately monitors and outputs the strength of the radio frequency input signal and must satisfy all of the following:

(A) The test must show that the output of the monitor circuit is directly related and proportional to the strength of the radio frequency input signal from the threshold level to saturation.

(B) The dynamic range of the radio frequency input from the threshold level to saturation must be no less than 50 dB. The monitor circuit output from threshold to saturation must have a corresponding range that is greater than 18 dB.

(C) The test must perform periodic samples sufficient to demonstrate that the monitor satisfies all its performance specifications.

(D) The test must include the following radio frequency input levels: Quiescent; threshold; manufacturer guaranteed; beginning of saturation; and 13 dBm.

(E) The test must demonstrate that the slope of the monitor circuit output does not change polarity.

(vi) *Radio frequency threshold sensitivity.* The test must determine the radio frequency threshold sensitivity or each receiver decoder output command to demonstrate reliable radio frequency processing capability. The threshold sensitivity values must satisfy all their performance specifications, be repeatable, and be in-family. In-family performance may be met with a tolerance of ± dB.

(vii) *Noise level margin.* The test must demonstrate that the receiver decoder's guaranteed input sensitivity is no less than 6 dB higher than the maximum predicted noise-floor.

(viii) *Voltage standing wave ratio.* The test must demonstrate that any radio frequency losses within the receiver decoder interface to the antenna system satisfy the required 12 dB margin. The test must determine the radio frequency voltage standing wave ratio at the high, low, and assigned operating frequencies of the operating bandwidth and demonstrate that it satisfies its performance specifications and is in-family. The test must also demonstrate that the impedance of the radio frequency receiving system and the impedance of the receiver decoder are matched closely enough to ensure that the receiver decoder satisfies all its performance specifications.

(ix) *Decoder channel bandwidth.* The test must demonstrate that the receiver decoder provides for reliable recognition of any command signal when subjected to variations in ground transmitter tone frequency and frequency modulation deviation variations. The test must demonstrate that the receiver decoder satisfies all its performance specifications within the specified tone filter frequency bandwidth using a frequency modulated tone deviation from 2 dB to 20 dB above the measured threshold level.

(x) *Tone balance.* For any secure receiver decoder, the test must demonstrate that the receiver decoder can reliably decode a valid command with an amplitude imbalance between two tones within the same message.

(xi) *Message timing.* For any secure receiver decoder, the test must demonstrate that the receiver decoder functions reliably during any errors in timing caused by any ground transmitter tolerances. The test must demonstrate that the receiver decoder can process commands at twice the maximum and one-half the minimum timing specification of the ground system. These tolerances must include character dead-time, character on-time and inter-message dead-time.

(xii) *Check tone*. The test must demonstrate that the decoding and output of a tone, such as a pilot tone or check tone, is representative of link and command closure. The test must also demonstrate that the presence or absence of the tone signal will have no effect on the receiver decoder's command processing and output capability.

(xiii) *Self-test*. The test must demonstrate that the receiver decoder's self-test capability functions and satisfies all its performance specifications and does not inhibit functionality of the command destruct output. The test must include initiating the self-test while issuing valid command outputs.

(xiv) *Reset*. For any receiver decoder with a reset capability, the test must demonstrate that the reset will unlatch any command output that has been latched by a previous command.

(f) *Inadvertent command output*. Each of the following inadvertent command output tests must demonstrate that the receiver decoder does not provide an output other than when it receives a valid command.

(1) *Dynamic stability*. The test must demonstrate that the receiver decoder does not produce an inadvertent output when subjected to any radio frequency input short-circuit, open-circuit, or change in input voltage standing wave ratio.

(2) *Out of band rejection*. The test must demonstrate that the receiver decoder does not degrade in performance when subjected to any out-of-band vehicle or ground transmitter source that it could encounter from liftoff to the planned safe flight state. The test must ensure the receiver decoder does not respond to frequencies, from 10 MHz to 1000 MHz except at the receiver specified operational bandwidth. The test must demonstrate that the radio frequency rejection of out of band signals provides a minimum of 60 dB beyond eight times the maximum specified operational bandwidth. The test frequencies must include all expected interfering transmitting sources using a minimum bandwidth of 20% of each transmitter center frequency, receiver image frequencies and harmonics of the assigned center frequency.

(3) *Decoder channel bandwidth rejection*. The test must demonstrate that the receiver decoder rejects any out-of-band command tone frequency. The test must demonstrate that each tone filter will not respond to another tone outside the specified tone filter frequency bandwidth using a frequency modulated tone deviation from 2 dB to 20 dB above the measured threshold level.

(4) *Adjacent tone decoder channel rejection*. The test must demonstrate that none of the tone decoder channels responds to any adjacent frequency modulated tone channel when they are frequency modulated with a minimum of 150% of the expected tone deviation.

(5) *Logic sequence*. The test must demonstrate that the receiver issues the required commands when commanded and does not issue false commands during any abnormal logic sequence including issuing a destruct command prior to the arm command.

(6) *Destruct sequence*. The test must demonstrate that the receiver decoder requires two commanded steps to issue a destruct command. The test must demonstrate that the receiver processes an arm command as a prerequisite for the destruct command.

(7) *Receiver abnormal logic*. The test must demonstrate that the receiver decoder will not respond to any combination of tones or tone pairs other than the correct command sequence.

(8) *Noise immunity*. The test must demonstrate that a receiver decoder will not respond to a white noise frequency modulated radio frequency input at a minimum frequency modulated deviation of 12 dB above the measured threshold deviation.

(9) *Tone drop*. The test must demonstrate that the receiver decoder will not respond to a valid command output when one tone in the sequence is dropped.

(10) *Amplitude modulation rejection*. The test must demonstrate that the receiver decoder will not respond to any tone or amplitude modulated noise when subjected to maximum pre-flight and flight input power levels. An acceptance test must subject the receiver decoder to 50% amplitude modulation. A qualification test must subject the receiver decoder to 100% amplitude modulation.

(11) *Decoder channel deviation rejection*. The test must demonstrate that the receiver decoder does not inadvertently trigger on frequency-modulated noise. The test must demonstrate that the receiver decoder does not respond to tone modulations 10 dB below the nominal tone modulation.

(g) *Input current monitor*. An input current monitor test must continuously monitor command receiver decoder power input current during environmental stress conditions to detect any variation in amplitude. Any variation in input current indicates internal component damage and constitutes a test failure. Any fluctuation in nominal current draw when the command receiver decoder is in the steady state indicates internal component damage and constitutes a test failure.

(h) *Output functions*. An output functions test must subject the receiver decoder to the arm and destruct commands during environmental stress conditions and continuously monitor all command outputs to detect any variation in amplitude. Any variation in output level indicates internal component damage and constitutes a test failure.

(i) *Radio frequency level monitor*. A radio frequency level monitor test must subject a receiver decoder to the guaranteed radio frequency input power level during environmental stress conditions and continuously monitor the radio frequency level monitor, also known as radio frequency signal strength, signal strength telemetry output, or automatic gain control. Any unexpected fluctuations or dropout constitutes a test failure.

(j) *Thermal performance*. A thermal performance test must demonstrate that the receiver decoder satisfies all its performance specifications when subjected to operating and workmanship thermal environments. The receiver decoder must undergo the thermal performance test during a thermal cycle test and during a thermal vacuum test. The receiver decoder must undergo the thermal performance test at its low and high operating voltage while the receiver decoder is at the high and low temperatures during the first, middle, and last thermal cycles. The thermal performance test at each high and low temperature must include each of the following sub-tests of this section:

(1) Response time, paragraph (c)(1) of this section;

(2) Input current, paragraph (c)(2) of this section;

(3) Output functions, paragraph (c)(4) of this section;

(4) Decoder channel deviation, paragraph (e)(2)(i) of this section;

(5) Operational bandwidth, paragraph (e)(2)(ii) of this section;

(6) Radio frequency dynamic range, paragraph (e)(2)(iii) of this section;

(7) Capture ratio, paragraph (e)(2)(iv) of this section;

(8) Radio frequency monitor, paragraph (e)(2)(v) of this section;

(9) Message timing, paragraph (e)(2)(xi) of this section;

(10) Check tone, paragraph (e)(2)(xii) of this section; and

(11) Self test, paragraph (e)(2)(xiii) of this section.

E417.21 SILVER-ZINC BATTERIES

(a) *General*. This section applies to any silver-zinc battery that is part of a flight termination system. Any silver-zinc battery must satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all its performance specifications when subjected to each non-operating and operating environment.

Table E417.21-1

Manually Activated Silver-Zinc Battery Acceptance	Section E417.13(a)	Quantity Tested X= 100% of Batteries
Cell Capacity	E417.21(b)	Cell Sample [3]
500-Volt Insulation	E417.21(c)(1)	X
Proof Pressure	E417.21(d)	X
Electrolyte	E417.21(e)	X
Battery Mounting and Case Integrity [1]	E417.21(f)	X
Component Examination:	E417.5	
Visual Examination [2]	E417.5(b)	X
Dimension Measurement [2]	E417.5(c)	X
Identification Check [2]	E417.5(e)	X
Weight Measurement [2]	E417.5(d)	X
Pre-Activation [2]	E417.21(g)	X
Continuity and Isolation [2]	E417.21(c)(2)	X
Performance Verification:	E417.3(d)	
Monitoring Capability [2]	E417.21(h)	X
Heater Circuit Verification [2]	E417.21(i)	X
Coupon Cell Acceptance [2]	E417.21(r)	1 cell per flight battery
Activation [2]	E417.21(j)	X
No-load Voltage [2]	E417.21(c)(3)	X
Pin-to-case Isolation [2]	E417.21(c)(4)	X
Electrical Performance [2]	E417.21(k)	X
Pin-to-case Isolation [2]	E417.21(c)(4)	X
Battery Case Proof Pressure [2]	E417.21(d)(2)	X

(1) This test applies only to any battery with a mounting or case that contains a weld.

(2) A battery must undergo this test at the launch site just before installation.

(3) For each battery, no less than one cell that is representative of the cells that make up the battery must undergo this test. This test need not take place at the launch site.

Table E417.21-2

Manually Activated Silver-Zinc Battery Qualification	Section E417.7	Quantity Tested (4) Batteries X=3	Cells X=12
Cell Capacity	E417.21(b)	Cell Sample (7)	-
500-Volt Insulation	E417.21(c)(1)	X	-
Proof Pressure	E417.21(d)	X	X
Electrolyte	E417.21(e)	X	X
Battery Mounting and Case Integrity (1)	E417.21(f)	X	-
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Identification Check	E417.5(e)	X	X
Weight Measurement	E417.5(d)	X	X
Pre-Activation	E417.21(g)	X	X
Continuity and Isolation	E417.21(c)(2)	X	-
Non-Operating Environment Tests:	E417.9		
Storage Temperature	E417.9(b)	X	X
Transportation Shock	E417.9(d)	X	-
Bench Handling Shock	E417.9(e)	X	-
Transportation Vibration	E417.9(f)	X	-
Fungus Resistance	E417.9(g)	X	-
Salt Fog	E417.9(h)	X	-
Fine Sand	E417.9(i)	X	-
Performance Verification:	E417.3(d)		

Manually Activated Silver-Zinc Battery Qualification	Section E417.7	Quantity Tested [4]	
		Batteries X=3	Cells X=12
Monitoring Capability	E417.21(h)	X	X
Heater Circuit Verification	E417.21(i)	X	-
Activation	E417.21(j)	X	X
No-load Voltage	E417.21(c)(3)	X	X
Pin-to-case Isolation	E417.21(c)(4)	X	-
Electrical Performance	E417.21(k)	X	X
Battery Case Proof Pressure	E417.21(d)(2)	X	-

Operating Environment Tests:	E417.11		
Activated Stand Time	E417.21(l)	X	X
Pin-to-case Isolation	E417.21(c)(4)	X	-
Overcharge (6)	E417.21(m)	X	-
Charge-Discharge Cycles (6)	E417.21(n)	X	X
Humidity (5)	E417.11(g)	X	-
Acoustic (2) (3) (5)	E417.11(d)	X	-
Shock (3) (5)	E417.11(e)	X	-
Thermal Vacuum (2) (3) (5)	E417.11(i)	X	-
Acceleration (2) (3) (5)	E417.11(f)	X	-
Sinusoidal Vibration (2) (3) (5)	E417.11(b)	X	-
Random Vibration (2) (3) (5)	E417.11(c)	X	-
Thermal Cycle (2) (5)	E417.21(o)	X	X
Pin-to-case Isolation	E417.21(c)(4)	X	-
Electromagnetic Interference and Compatibility (5)	E417.11(j)	1	-
Explosive Atmosphere (5)	E417.11(k)	1	-
Performance Verification:	E417.3(d)		
Monitoring Capability	E417.21(h)	X	X
Heater Circuit Verification	E417.21(i)	X	-
Discharge and Pulse Capacity (5)	E417.21(p)	X	X
Pin-to-case Isolation	E417.21(c)(4)	X	X
Proof Pressure (5)	E417.21(d)	X	X
Internal Inspection (5)	E417.21(q)	X	X

(1) This test applies only to any battery that has a mounting or case that contains a weld.

(2) A battery or cell must undergo the electrical performance test of paragraph (k) of this section while the battery is under ambient conditions before the battery undergoes this operating environment test and again while the battery is subjected to the operating environment.

(3) This test must include continuous monitoring of the battery to verify that the required voltage regulation is maintained while supplying the required operating steady-state current. The monitoring must have a sample rate of once every 0.1 millisecond or better. Any dropout constitutes a test failure.

(4) The same three sample batteries must undergo each test designated with an X in that column and the same 12 sample cells must undergo each test designated with an X in that column. For tests designated with a quantity of less than three, each battery tested must be one of the original three sample batteries.

(5) Each battery or cell sample must undergo this test at the end of the wet stand time after the last operating charge.

(6) This test only applies if normal operation of the battery includes charging.

(7) For each of the three battery samples, no less than one cell that is representative of the cells that make up the battery must undergo this test. These cells, no less than three, are in addition to the 12 cells of the far right column.

Table E417.21-3

Silver-Zinc Battery Storage Life	Section	Quantity Tested X=2 Cells Per Year [(1)]
Proof Pressure	E417.21(d)	X
Electrolyte	E417.21(e)	X
Component Examination:	E417.5	
Visual Examination	E417.5(b)	X
Dimension Measurement	E417.5(c)	X
Identification Check	E417.5(e)	X
Weight Measurement	E417.5(d)	X
Performance Verification:	E417.3(d)	
Monitoring Capability	E417.21(h)	X
Activation	E417.21(j)	X
No-load Voltage	E417.21(c)(3)	X
Electrical Performance	E417.21(k)	X
Operating Environment Tests:	E417.11	
Activated Stand Time	E417.21(l)	X
Charge-Discharge Cycles [(2)]	E417.21(n)	X
Thermal Cycling [(3)] [(4)]	E417.21(o)	X
Discharge and Pulse Capacity [(4)]	E417.21(p)	X
Proof Pressure [(4)]	E417.21(d)	X
Internal Inspection [(4)]	E417.21(q)	X

(1) Two silver-zinc cells from the production lot used for qualification testing must undergo each test designated with an X, each year of the manufacturer's specified storage life, to demonstrate that they still satisfy their performance specifications.

(2) This test only applies if normal operation of the battery includes charging.

(3) Each cell must undergo the electrical performance test of paragraph (k) of this section under ambient conditions before the cell undergoes this operating environment test and again while the cell is subjected to the operating environment.

(4) Each cell sample must undergo this test at the end of the wet stand time after the last operating charge.

(b) *Cell capacity.*

(1) *Single electrical cycle.* For a sample silver-zinc cell from a battery that has only one charge-discharge cycle, a capacity test must satisfy all of the following:

(i) The cell must undergo activation that satisfies paragraph (j) of this section;

(ii) At the end of the manufacturer-specified wet stand time, the cell must undergo a discharge of the nameplate capacity;

(iii) The test must then subject the cell to the electrical performance test of paragraph (k) of this section using the qualification electrical load profile described in paragraph (k)(7)(ii) of this section;

(iv) The cell must then undergo a final discharge to determine the positive and negative plate capacity; and

(v) The test must demonstrate that each capacity satisfies the manufacturer's specification and is in-family.

(2) *Multiple electrical cycles.* For a silver-zinc cell from a battery that has more than one charge-discharge cycle, a capacity test must satisfy all of the following:

(i) The cell must undergo activation that satisfies paragraph (j) of this section;

(ii) The test must subject the cell to the maximum predicted number of charge-discharge cycles that the battery will experience during normal operations;

(iii) At the end of each cycle life after each charge, the test must satisfy all of the following:

(A) The cell must undergo a discharge of the manufacturer's nameplate capacity;

(B) The cell must then undergo the electrical performance test of paragraph (k) of this section using the qualification electrical load profile described in paragraph (k)(7)(ii) of this section; and

(C) The cell must then undergo a discharge to determine the positive plate capacity;

(iv) At the end of the cycle life of the last charge-discharge cycle, in addition to determining the positive plate capacity, the cell must undergo a discharge to determine the negative plate capacity; and

(v) The test must demonstrate that each capacity for each cycle satisfies the manufacturer's specification and is in-family.

(c) *Silver-zinc battery status-of-health tests.*

(1) *500-volt insulation.* A 500-volt insulation test of a silver-zinc battery must satisfy the status-of-health test requirements of section E417.3(f). The test must measure insulation resistance between mutually insulated pin-to-pin and pin-to-case points using a minimum 500-volt workmanship voltage prior to connecting any battery harness to the cells. The test must measure the continuity of the battery harness after completion of all wiring, but before battery activation to demonstrate that the insulation and continuity resistances satisfy their performance specifications.

(2) *Continuity and isolation.* A continuity and isolation test of a silver zinc battery must satisfy the status-of-health test requirements of section E417.3(f). The test must demonstrate that all battery wiring and connectors are installed according to the

manufacturer's specifications. The test must measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all its performance specifications and are in-family.

(3) *No-load voltage*. A no-load voltage test must satisfy the status-of-health test requirements of section E417.3(f). The test must demonstrate that each battery cell satisfies its performance specification for voltage without any load applied. A battery must undergo this test just after introduction of electrolyte to each cell, after electrical conditioning of the battery, before and after each electrical performance test and, for a flight battery, just before installation into the launch vehicle.

(4) *Pin-to-case isolation*. A pin-to-case isolation test must satisfy the status-of-health test requirements of section E417.3(f). The test must measure voltage isolation between each pin and the battery case to demonstrate that no current leakage path exists as a result of electrolyte leakage. This measurement must use a voltmeter with an internal resistance of no less than 100K ohms and have a resolution that detects any leakage current of 0.1 milliamps or greater.

(d) *Proof pressure*.

(1) *Cells*. Each individual cell or each cell within a battery must undergo pressurization to 1.5 times the worst case operating differential pressure or highest setting of the cell vent valve for no less than 15 seconds. The test must demonstrate that the leak rate satisfies its performance specification. After pressurization, each cell must remain sealed until activation. For a battery, the test must demonstrate the integrity of each cell seal when in the battery configuration.

(2) *Battery cases*. Each battery case must undergo pressurization to 1.5 times the worst case operating differential pressure for no less than 15 minutes. The test must demonstrate no loss of structural integrity and no hazardous condition. For any sealed battery, the test must demonstrate that the leak rate satisfies its performance specification.

(e) *Electrolyte*. A test of each electrolyte lot for battery activation must demonstrate that the electrolyte satisfies the manufacturer's specifications, including volume and concentration.

(f) *Battery mounting and case integrity*. A battery mounting and case integrity test must demonstrate that any welds in the battery's mounting hardware or case are free of workmanship defects using X-ray examination that satisfies section E417.5(f).

(g) *Pre-activation*. A pre-activation test must demonstrate that a battery or cell will not experience a loss of structural integrity or create a hazardous condition when subjected to predicted operating conditions and all required margins. This must include all of the following:

(1) The test must demonstrate that any battery or cell pressure relief device satisfies all its performance specifications;

(2) The test must exercise 100% of all pressure relief devices that can function repeatedly without degradation; and

(3) The test must demonstrate that each pressure relief device opens within ± 10% of its performance specification.

(h) *Monitoring capability*. A monitoring capability test must demonstrate that each device that monitors a silver-zinc battery's voltage, current, or temperature satisfies all its performance specifications.

(i) *Heater circuit verification*. A heater circuit verification test must demonstrate that any battery heater, including its control circuitry, satisfies all its performance specifications.

(j) *Activation*.

(1) The activation of a battery or cell must follow a procedure that is approved by the manufacturer and includes the manufacturer's activation steps.

(2) The activation procedure and equipment for acceptance testing must be equivalent to those used for qualification and storage life testing.

(3) The activation procedure must include verification that the electrolyte satisfies the manufacturer's specification for percentage of potassium hydroxide.

(4) The quantity of electrolyte for activation of the batteries and cells for any qualification test must satisfy all of the following:

(i) One of the three required qualification battery samples and six of the 12 required individual qualification cell samples must undergo activation with no less than the manufacturer specified maximum amount of electrolyte; and

(ii) One of the three required qualification battery samples and six of the 12 required individual qualification cell samples must undergo activation with no greater than the manufacturer specified minimum amount of electrolyte.

(k) *Electrical performance*. An electrical performance test must demonstrate that a battery or cell satisfies all its performance specifications and is in-family while the battery is subjected to the electrical load profile described in paragraph (k)(7) of this section and include all of the following:

(1) The test must demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer's specifications and is in family with previous test results;

(2) The test must monitor each of the battery or cell's critical electrical performance parameters; including voltage, current, and temperature, with a resolution and sample rate that detects any failure to satisfy a performance specification. For a battery, the

test must monitor the battery's performance parameters and the voltage of each cell within the battery. During the current pulse portion of the load profile, the voltage monitoring must have a sample rate of once every 0.1 millisecond or better;

(3) The test must measure a battery or cell's no-load voltage before and after the application of any load to the battery or cell;

(4) A silver-zinc battery or cell must undergo this test after the battery or cell is activated and after the manufacturer's specified soak period;

(5) The test must demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum acceptance voltage of each electronic component that the battery powers while the battery or cell is subjected to the steady state portion of the load profile;

(6) The test must demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum qualification voltage of each electronic component that the battery powers while the battery or cell is subjected to the pulse portion of the load profile; and

(7) The test load profile must satisfy one of the following:

(i) For acceptance testing, the load profile must begin with a steady-state flight load that lasts for no less than 180 seconds followed without interruption by a current pulse. The pulse width must be no less than 1.5 times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 100 milliseconds, whichever is greater. The pulse amplitude must be no less than 1.5 times the ordnance initiator qualification pulse amplitude. After the pulse, the acceptance load profile must end with the application of a steady-state flight load that lasts for no less than 15 seconds; or

(ii) For qualification testing or any storage life testing, the load profile must begin with a steady-state flight load that lasts for no less than 180 seconds followed by a current pulse. The pulse width must be no less than three times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds, whichever is greater. The pulse amplitude must be no less than 1.5 times the ordnance initiator qualification pulse amplitude. After the pulse, the qualification load profile must end with a steady-state flight load that lasts for no less than 15 seconds.

(l) *Activated stand time.* An activated stand time test must demonstrate that a silver-zinc battery or cell satisfies all its performance specifications after it is activated and subjected to the environments that the battery or cell will experience from the time it is activated until flight. This must include all of the following:

(1) The test environment must simulate the pre-flight battery or cell conditioning environments, including the launch vehicle installation environment;

(2) The test environment must simulate the worst case temperature exposure and any thermal cycling, such as due to any freezer storage, and any diurnal cycling on the launch vehicle;

(3) The test must measure the battery or cell's open-circuit voltage at the beginning and again at the end of the activated stand time to demonstrate that it satisfies its performance specifications; and

(4) The test must apply an electrical load to the battery or cell at the end of the activated stand time to demonstrate whether the battery or cell is in a peroxide or monoxide chemical state that satisfies its performance specifications before undergoing any other operating environmental test.

(m) *Overcharge.* An overcharge test only applies to a battery or cell that undergoes charging during normal operations. The test must demonstrate that the battery or cell satisfies all its performance specifications when subjected to an overcharge of no less than the manufacturer's specified overcharge limit using the nominal charging rate.

(n) *Charge-discharge cycles.* This test only applies to a battery or cell that undergoes charging during normal operations. The test must satisfy all of the following:

(1) The test must subject the battery or cell sample to the maximum predicted number of charge-discharge cycles that the battery or cell will experience during normal operations;

(2) After activation, each battery or cell sample must undergo three thermal cycles at the end of the first cycle life and three thermal cycles at the end of each cycle life after each intermediate charge before the final charge;

(3) During each set of three thermal cycles for each charge-discharge cycle, the test must satisfy the thermal cycle test requirements of paragraphs (o)(2)–(o)(5) of this section;

(4) For a battery, after the three thermal cycles for each charge-discharge cycle, the battery must undergo a pin-to-case isolation test that satisfies paragraph (c)(4) of this section;

(5) Each battery or cell must undergo a discharge of its nameplate capacity before each charge; and

(6) The battery or cell must undergo any further operating environment tests only after the final charge.

(o) *Thermal cycle.* A thermal cycle test must demonstrate that a silver-zinc battery or cell satisfies all its performance specifications when subjected to pre-flight thermal cycle environments, including acceptance testing, and flight thermal cycle environments. This must include all of the following:

(1) The test must subject the battery or cell to no less than the acceptance-number of thermal cycles that satisfies section E417.13(d)(1);

(2) The thermal cycle environment must satisfy all of the following:

(i) Each thermal cycle must range from 10 °C above the maximum predicted temperature range to 5.5 °C below. If the launch vehicle's telemetry system does not provide the battery's temperature before and during flight as described in section D417.17(b)(9), each thermal cycle must range from 10 °C above the maximum predicted temperature range to 10 °C below;

(ii) For each cycle, the dwell-time at each high and low temperature must last long enough for the battery or cell to achieve internal thermal equilibrium and must last no less than one hour; and

(iii) When heating and cooling the battery or cell, the temperature change at a rate that averages 1 °C per minute or the maximum predicted rate, whichever is greater;

(3) Each battery or cell must undergo the electrical performance test of paragraph (k) of this section when the battery or cell is at ambient temperature before beginning the first thermal cycle and after completing the last cycle;

(4) Each battery or cell must undergo the electrical performance test of paragraph (k) of this section, at the high and low temperatures during the first, middle and last thermal cycles; and

(5) The test must continuously monitor and record all critical performance and status-of-health parameters, including the battery or cell's open circuit voltage, during all thermal cycle dwell times and transitions with a resolution and sample rate that will detect any performance degradation.

(p) *Discharge and pulse capacity.* A discharge and pulse capacity test must demonstrate that a silver zinc battery or cell satisfies all its electrical performance specifications at the end of its specified capacity limit for the last operating charge and discharge cycle. The test must include all of the following:

(1) The battery or cell must undergo discharge at flight loads until the total capacity consumed during this discharge and during all previous qualification tests reaches the manufacturer's specified capacity.

(2) The test must demonstrate that the total amount of capacity consumed during the discharge test and all previous qualification tests satisfies the battery or cell's minimum performance specification.

(3) After satisfying paragraphs (p)(1) and (p)(2) of this section, the test must measure the battery or cell's no-load voltage and then apply a qualification load profile that satisfies all of the following:

(i) The load profile must begin with a steady state flight load for no less than 180 seconds followed by a current pulse;

(ii) The pulse width must be no less than three times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds; whichever is greater;

(iii) The pulse amplitude must be no less than 1.5 times the ordnance initiator qualification pulse amplitude; and

(iv) After the pulse, the qualification load profile must end with a steady state flight load that lasts for no less than 15 seconds.

(4) The test must monitor each of the battery or cell's critical electrical performance parameters; including voltage, current, and temperature, with a resolution and sample rate that detects any failure to satisfy a performance specification. For a battery, the test must monitor the battery's performance parameters and the voltage of each cell within the battery. During the current pulse portion of the load profile, the voltage monitoring must have sample rate that will detect any component performance degradation.

(5) The test must demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum acceptance voltage of each electronic component that the battery powers while the battery or cell is subjected to the steady state portion of the load profile.

(6) The test must demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum qualification voltage of each electronic component that the battery powers while the battery or cell is subjected to the pulse portion of the load profile.

(7) After satisfying paragraphs (p)(1) through (p)(6) of this section, the battery or cell must undergo a complete discharge and the test must demonstrate that the total silver plate capacity is in-family.

(q) *Internal inspection.* An internal inspection must identify any excessive wear or damage to a silver-zinc battery, including any of its cells, or an individual cell after the battery or cell is exposed to all the qualification test environments. An internal inspection must satisfy section E417.5(g) and include all of the following:

(1) An internal examination of any battery to verify that there was no movement of any component within the battery that could stress that component beyond its design limit during flight:

(2) An examination to verify the integrity of all cell and wiring interconnects.

(3) An examination to verify the integrity of all potting and shimming materials.

(4) The removal of all cells from the battery and examination of each cell for any physical damage.

(5) A destructive physical analysis to verify the integrity of all plate tab to cell terminal connections and the integrity of each plate and separator. For each battery sample required to undergo all the qualification tests, one cell from each corner and two cells from the middle of the battery must undergo the destructive physical analysis. For storage life testing, one of the two cells required to undergo all the storage life tests must undergo destructive physical analysis. The inspection must verify the integrity of each plate tab, identify any anomaly in each plate, including its color or shape, and identify any anomaly in each separator, including its condition, silver migration, and any oxalate crystals.

(6) A test that demonstrates that the zinc plate capacity of the cells satisfies the manufacturer's specification. For each battery sample required to undergo all the qualification tests, the test must determine the zinc plate capacity for three cells from the battery, other than the cells of paragraph (q)(5) of this section. For storage life testing, the test must determine the zinc plate capacity for one cell that is required to undergo all the storage life tests, other than the cell of paragraph (q)(5) of this section.

(r) *Coupon cell acceptance.* A coupon cell acceptance test must demonstrate that the silver zinc cells that make up a flight battery were manufactured the same as the qualification battery cells and satisfy all their performance specifications after being subjected to the environments that the battery experiences from the time of manufacture until activation and installation. This must include all of the following:

(1) One test cell that is from the same production lot as the flight battery, with the same lot date code as the cells in the flight battery, must undergo the test.

(2) The test cell must have been attached to the battery from the time of the manufacturer's acceptance test and have experienced the same non-operating environments as the battery.

(3) The test must occur immediately before activation of the flight battery.

(4) The test cell must undergo activation that satisfies paragraph (j) of this section.

(5) The test cell must undergo discharge at a moderate rate, using the manufacturer's specification, undergo two qualification load profiles of paragraph (k)(7)(ii) of this section at the nameplate capacity, and then undergo further discharge until the minimum manufacturer specified voltage is achieved. The test must demonstrate that the cell's amphour capacity and voltage characteristics satisfy all their performance specifications and are in-family.

(6) For a silver-zinc battery that will undergo charging during normal operations, the test cell must undergo the requirements of paragraph (r)(5) of this section for each qualification charge-discharge cycle. The test must demonstrate that the cell capacity and electrical characteristics satisfy all their performance specifications and are in family for each charge-discharge cycle.

E417.22 COMMERCIAL NICKEL-CADMIUM BATTERIES

(a) *General.* This section applies to any nickel-cadmium battery that uses one or more commercially produced nickel-cadmium cells and is part of a flight termination system.

(1) *Compliance.* Any commercial nickel-cadmium battery must satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all its performance specifications when subjected to each non-operating and operating environment.

(2) *Charging and discharging of nickel-cadmium batteries and cells.* Each test required by any table of this section that requires a nickel-cadmium battery or cell to undergo a charge or discharge must include all of the following:

(i) The rate of each charge or discharge must prevent any damage to the battery or cell and provide for the battery or cell's electrical characteristics to remain consistent. Unless otherwise specified, the charge or discharge rate used for qualification testing must be identical to the rate that the flight battery experiences during acceptance and preflight testing;

(ii) A discharge of a cell must subject the cell to the discharge rate until the cell voltage reaches no greater than 0.9 volt. A discharge of a battery, must subject the battery to the discharge rate until the battery voltage reaches no greater than 0.9 volt times the number of cells in the battery. Any discharge that results in a cell voltage below 0.9 volt must use a discharge rate that is slow enough to prevent cell damage or cell reversal. Each discharge must include monitoring of voltage, current, and time with sufficient resolution and sample rate to determine capacity and demonstrate that the battery or cell is in-family;

(iii) A charge of a battery or cell must satisfy the manufacturer's charging specifications and procedures. The charging input to the battery or cell must be no less than 160% of the manufacturer's specified capacity. The charge rate must not exceed C/10 unless the launch operator demonstrates that a higher charge rate does not damage the battery or cell and results in repeatable battery or cell performance. The cell voltage must not exceed 1.55 volts during charging to avoid creating a hydrogen gas explosion hazard; and

(iv) The test must monitor each of the battery or cell's critical electrical performance parameters with a resolution and sample rate to detect any failure to satisfy a performance specification. For a battery, the test must monitor the battery's performance parameters and those of each cell within the battery. During the current pulse portion of the load profile, the monitoring must have a resolution and sample rate that will detect any component performance degradation.

Table E417.22-1

Nickel-cadmium Cell Lot Acceptance [1]	Section	Quantity Tested
Cell Lot Acceptance: [2]		
Component Examination:	E417.5	
Visual Examination [3]	E417.5(b)	100%
Dimension Measurement [3]	E417.5(c)	100%
Identification Check [3]	E417.5(e)	100%
Cell Screening:		
Cell Reusable Venting Devices [3]	E417.22(b)(1)	100%
Cell Inspection and Preparation [3]	E417.22(c)	100%
Cell Conditioning [3]	E417.22(d)	100%
Cell Characterization [3]	E417.22(e)	100%
Charge Retention [3]	E417.22(f)	100%
Capacity and Overcharge at 0°C [3]	E417.22(g)	100%
Electrical Performance	E417.22(n)	100%
Cell leakage	E417.22(s)	100%
Lot Sample Tests:		
X-ray Inspection [4] [5]	E417.5(f)	Lot Sample [6]
Cell Non-Reusable Venting Devices [4]	E417.22(b)(2)	Lot Sample [6]
Post Acceptance Discharge and Storage	E417.22(h)	100% of Lot Remainder

(1) Each test that requires a nickel-cadmium cell to undergo a charge or discharge must satisfy paragraph (a)(2) of this section. Unless otherwise specified, each test must begin with the cell fully charged.

(2) All nickel-cadmium cells used in a qualification or flight battery must be from a production lot that has successfully passed each cell lot acceptance test required

by this table. A production lot must consist of cells that were manufactured in a single continuous production run using identical parts, materials, and processes. Each production lot must undergo the tests required by this table to ensure that the cells are consistent and will provide the required performance and to detect any manufacturer variation introduced into the lot of cells. A launch operator must ensure that all the results of the tests executed on each lot are entered into an engineering database to establish family characteristics and that those characteristics satisfy all the cell's performance specifications.

(3) For any cell sample that fails to pass this test, a launch operator may not use that cell sample in any further test or flight, but such a failure does not disqualify the remainder of the lot for use.

(4) If any cell sample fails to pass this test, a launch operator may not use the entire lot.

(5) This test only applies to any cell with multiple internal tabs. Any X-ray inspection must demonstrate tab integrity at 0^0 and 90^0.

(6) The lot sample quantity must be no less than five samples or 10% of the production lot; whichever is greater.

Table E417.22-2

Nickel-cadmium Battery Acceptance	Section E417.13(a)	Quantity Tested
Cell Lot Acceptance and Qualification Tests [2]	Table E417.22-1	100% of Cells
Component Examination (Complete Battery):	E417.5	
Visual Examination	E417.5(b)	100%
Weight Measurement	E417.5(d)	100%
Dimension Measurement	E417.5(c)	100%
Identification Check	E417.5(e)	100%
Battery Case Integrity [3]	E417.22(k)	100%
Charge Retention (Battery)	E417.22(f)	100%
Status-of-health	E417.22(j)	100%
Electrical Performance [4]	E417.22(n)	100%
Reusable Venting Devices (Battery Only)	E417.22(b)(1)	100%
Non-Reusable Venting Devices (Battery Only)	E417.22(b)(2)	Lot Sample [6]
Monitoring Capability	E417.22(l)	100%
Heater Circuit Verification	E417.22(m)	100%
Operating Environment Tests:	E417.11	
Acceptance Thermal Cycle	E417.22(o)	100%
Random Vibration [5]	E417.13(b)	100%
Charge Retention (Battery)	E417.22(f)	100%
Status-of-health	E417.22(j)	100%
Electrical Performance [4]	E417.22(n)	100%

Component Examination (Complete Battery):	E417.5	
Visual Examination	E417.5(b)	100%
Battery Case Integrity [3]	E417.22(k)	100%
Post acceptance discharge and storage	E417.22(h)	100%

(1) Each test that requires a nickel-cadmium battery to undergo a charge or discharge must satisfy paragraph (a)(2) of this section. Unless otherwise specified, each test must begin with the battery fully charged.

(2) All cells used in each qualification or flight battery must be from a production lot that has successfully passed the cell lot acceptance tests required by Table E417.22-1.

(3) This test is required only for any sealed battery.

(4) The battery must undergo an electrical performance test under ambient conditions before the first operating environment test and while the battery is subjected to each environment as required by each operating environment test.

(5) The battery must undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load during the random vibration environment. The monitoring must have a sample rate of once every 0.1-millisecond or better, and demonstrate that the voltage does not does experience any dropout.

(6) The lot sample quantity must be no less than five samples or 10% of the production lot, whichever is greater. The sample venting devices need not undergo this test in the battery assembly.

Table E417.22-3

Nickel-cadmium Battery and Cell Qualification [(1)] [(2)]	Section E417.7	Quantity Tested X = 3 Batteries
Battery Acceptance Tests [(3)]	Table E417.22-2	X
Non-Operating Environment Tests:	E417.9	
Storage Temperature	E417.9(b)	X
Transportation Shock	E417.9(d)	X
Bench Shock	E417.9(e)	1
Transportation Vibration	E417.9(f)	X
Fungus Resistance	E417.9(g)	1
Salt Fog	E417.9(h)	X
Charge Retention (Battery)	E417.22(f)	X
Electrical Performance [(4)]	E417.22(n)	X
Operating Environment Tests:	E417.11	
Sinusoidal Vibration [(5)]	E417.11(b)	X
Acoustic [(5)]	E417.11(d)	X
Shock [(5)]	E417.11(e)	X
Acceleration [(5)]	E417.11(f)	X
Humidity [(6)]	E417.11(g)	X
Qualification Thermal Cycle	E417.22(p)	X
Random Vibration [(5)]	E417.11(c)	X
Electromagnetic Interference and Compatibility	E417.11(j)	1

Status-of-health	E417.22(j)	X
Cycle Life	E417.22(i)	X
Electrical Performance [7]	E417.22(n)	X
Charge Retention	E417.22(f)	X
Operational Stand Time	E417.22(q)	2
Battery Case Integrity [8]	E417.22(k)	X
	E417.11(k)	1
Explosive Atmosphere	E417.22(r)	X
	E417.5(f)	5 cells
Internal Inspection		
X-ray Inspection [9]		

(1) Each new production lot of nickel-cadmium cells must satisfy all the qualification tests required by this table to demonstrate that any variation in parts, material, or processes between each production lot does not adversely affect cell performance. For each new cell production lot, three battery assemblies that are made up of cells from the lot must undergo each test required by this table to demonstrate that each battery and each cell satisfy all their performance specifications when in their packaged flight configuration.

(2) Each test that requires a nickel-cadmium battery to undergo a charge or discharge must satisfy paragraph (a)(2) of this section. Unless otherwise specified, each test must begin with the battery fully charged.

(3) Each qualification test battery must pass all the acceptance tests of table E417.22-2.

(4) The battery must undergo an electrical performance test under ambient conditions before the first operating environment test and while the battery is subjected to each environment as required by each operating environment test.

(5) The battery must undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load during the dynamic environment. The monitoring must have a sample rate of once every 0.1 millisecond or better; and demonstrate that the voltage does not experience any dropout.

(6) A battery must undergo a charge retention test that satisfies paragraph (f) of this section while the battery is exposed to the humidity environment and the test results must undergo comparison to previous charge retention test results to demonstrate that the humidity environment does not degrade battery capacity.

(7) Each battery must undergo an electrical performance test during the first three charge and discharge cycles, during every tenth cycle thereafter, and during the last three cycles.

(8) This test is only required for any sealed battery.

(9) This test is only required for any cell with multiple internal tabs. The test must demonstrate tab integrity at 0^0 and 90^0.

(b) *Venting devices.* A test of a battery or cell venting device must demonstrate that the battery or cell will not experience a loss of structural integrity or create a hazardous condition when subjected to any electrical discharge, charging, or short-circuit condition and satisfy the following paragraphs:

(1) *Reusable venting devices.* For a venting device that is capable of functioning repeatedly without degradation, such as a vent valve, the test must exercise the device and demonstrate that it satisfies all its performance specifications.

(2) *Non-reusable venting devices.* For a venting device that does not function repeatedly without degradation, such as a burst disc, the test must exercise a lot sample to demonstrate that the venting device satisfies all its performance specifications. The test must demonstrate that each device sample vents within ±10% of the manufacturer specified average vent pressure with a maximum vent pressure no higher than 350 pounds per square inch.

(c) *Cell inspection and preparation.* A cell inspection and preparation must:

(1) Record the manufacturer's lot-code;

(2) Demonstrate that the cell is clean and free of manufacturing defects;

(3) Use a chemical indicator to demonstrate that the cell has no leak; and

(4) Discharge each cell to no greater than 0.9 volt using a discharge rate that will not cause damage to the cell.

(d) *Cell conditioning.* Conditioning of a nickel-cadmium cell must stabilize the cell and ensure repeatable electrical performance throughout the cell's service-life. Conditioning of a cell must include both of the following:

(1) Before any testing, each cell must age for no less than 11 months after the manufacturer's lot date code to ensure consistent electrical performance of the cell for its entire service-life; and

(2) After aging, each cell must undergo a first charge at a charging rate of no greater than its capacity divided by 20 (C/20), to initialize the chemistry within the cell. Any battery stored for over one month after the first charge must undergo recharging at the same rate.

(e) *Cell characterization.* Characterization of a nickel-cadmium cell must stabilize the cell chemistry and determine the cell's capacity. A cell characterization must satisfy both of the following:

(1) Each cell must repeatedly undergo charge and discharge cycles until the capacities for three consecutive cycles agree to within 1% of each other; and

(2) During characterization, each cell must remain at a temperature of 20 °C ± 2 °C to ensure that the cell is not overstressed and to allow repeatable performance.

(f) *Charge retention.* A charge retention test must demonstrate that a nickel-cadmium battery or cell consistently retains its charge and provides its required capacity, including the required capacity margin, from the final charge used prior to flight to the end of flight. The test must satisfy the status-of-heath test requirements of § E417.3(f) and satisfy all of the following steps in the following order:

(1) The test must begin with the battery or cell fully charged. The battery or cell must undergo an immediate capacity discharge to develop a baseline capacity for comparison to its charge retention performance;

(2) The battery or cell must undergo complete charging and then storage at 20 °C ± 2 °C for 72 hours;

(3) The battery or cell must undergo discharging to determine its capacity; and

(4) The test must demonstrate that each cell or battery's capacity is greater than 90% of the baseline capacity of paragraph (f)(1) of this section and the test must demonstrate that the capacity retention is in-family.

(g) *Capacity and overcharge at 0 °C.* A 0 °C test of a nickel-cadmium cell must validate the cell's chemistry status-of-health and determine the cell's capacity when subjected to a high charge efficiency temperature. The test must include all of the following:

(1) Each cell must undergo repeated charge and discharge cycles at 0 °C ± 2 °C until all the capacities for three consecutive cycles agree to within 1% of each other; and

(2) After the charge and discharge cycles of paragraph (g)(1) of this section, each cell must undergo an inspection to demonstrate that it is not cracked.

(h) *Post acceptance discharge and storage.* Post acceptance discharge and storage of a nickel-cadmium battery or cell must prevent any damage that could affect electrical performance. This must include all of the following:

(1) Any battery must undergo discharge to a voltage between 0.05 volts and 0.9 volts to prevent cell reversal, allow safe handling, and minimize any aging degradation;

(2) Any individual cell must undergo discharge to no greater than 0.05 volts to allow safe handling and minimize any aging degradation;

(3) After the discharge, each battery or cell must undergo storage in an open circuit configuration and under storage conditions that protect against any performance degradation and are consistent with the qualification tests. This must include a storage temperature of no greater than 5 °C.

(i) *Cycle life.* A cycle life test of a nickel-cadmium cell or battery must demonstrate that the cell or battery satisfies all its performance specifications for no less than five times the number of operating charge and discharge cycles expected of the flight battery, including acceptance testing, pre-flight checkout, and flight.

(j) *Status-of-health.* A status-of-health test of a nickel-cadmium battery must satisfy section E417.3(f) and include continuity and isolation measurements that demonstrate that all battery wiring and connectors are installed according to the manufacturer's specifications. The test must also measure all pin-to-pin and pin-to-case resistances to demonstrate that each satisfies all its performance specifications and are in-family.

(k) *Battery case integrity.* A battery case integrity test of a sealed nickel-cadmium battery must demonstrate that the battery will not lose structural integrity or create a hazardous condition when subjected to all predicted operating conditions and all required margins and that the battery's leak rate satisfies all its performance specifications. This must include all of the following:

(1) The test must monitor the battery's pressure while subjecting the battery case to no less than 1.5 times the greatest operating pressure differential that could occur under qualification testing, pre-flight, or flight conditions;

(2) The pressure monitoring must have a resolution and sample rate that allows accurate determination of the battery's leak rate;

(3) The test must demonstrate that the battery's leak rate is no greater than the equivalent of 10^{-4} scc/sec of helium; and

(4) The battery must undergo examination to identify any condition that indicates that

the battery might loose structural integrity or create a hazardous condition.

(l) *Monitoring capability*. A monitoring capability test must demonstrate that each device that monitors a nickel-cadmium battery's voltage, current, or temperature satisfies all its performance specifications.

(m) *Heater circuit verification*. A heater circuit verification test must demonstrate that any battery heater, including its control circuitry, satisfies all its performance specifications.

(n) *Electrical performance*. An electrical performance test of a nickel-cadmium battery or cell must demonstrate that the battery or cell satisfies all its performance specifications and is in-family while the battery or cell is subjected to an acceptance or qualification electrical load profile. The test must also demonstrate that the battery or cell satisfies all its electrical performance specifications at the beginning, middle, and end of its specified preflight and flight capacity plus the required margin. The test must include and satisfy each of the following:

(1) The test must measure a battery or cell's no-load voltage before applying any load to ensure it is within the manufacturer's specification limits.

(2) The test must demonstrate that the battery or cell voltage does not violate the manufacturer's specification limits while the battery or cell is subjected to the steady-state flight load. The test must also demonstrate that the battery provides the minimum acceptance voltage of each electronic component that the battery powers.

(3) The test must demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer's specification. The test must demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum qualification voltage of each electronic component that the battery powers while the battery or cell is subjected to the pulse portion of the load profile. The test must subject the battery or cell to one of the following load profiles:

(i) For acceptance testing, the test load profile must satisfy all of the following:

(A) The load profile must begin with a steady-state flight load that lasts for no less than 180 seconds followed without interruption by a current pulse;

(B) The pulse width must be no less than 1.5 times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 100 milliseconds, whichever is greater;

(C) The pulse amplitude must be no less than 1.5 times the ordnance initiator qualification pulse amplitude; and

(D) After the pulse, the acceptance load profile must end with a steady state flight load that lasts for no less than 15 seconds.

(ii) For qualification testing, the test load profile must satisfy all of the following:

(A) The load profile must begin with a steady-state flight load that lasts for no less than 180 seconds followed by a current pulse;

(B) The pulse width must be no less than three times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds, whichever is greater;

(C) The pulse amplitude must be no less than 1.5 times the ordnance initiator qualification pulse amplitude; and

(D) After the pulse, the qualification load profile must end with a steady-state flight load that lasts for no less than 15 seconds.

(4) The test must repeat, satisfy, and accomplish paragraphs (n)(1)–(n)(3) of this section with the battery or cell at each of the following levels of charge-discharge and in the following order:

(A) Fully charged;

(B) After the battery or cell undergoes a discharge that removes 50% of the capacity required for launch and all required margins; and

(C) After the battery or cell undergoes a discharge that removes an additional 50% of the capacity required for launch.

(5) The test must subject the battery or cell the a final discharge that determines the remaining capacity. The test must demonstrate that the total capacity removed from the battery during all testing, including this final discharge, satisfies all the battery's performance specifications and is in-family.

(o) *Acceptance thermal cycle*. An acceptance thermal cycle test must demonstrate that a nickel-cadmium battery satisfies all it performance specifications when subjected to workmanship and maximum predicted thermal cycle environments. This must include each of the following:

(1) The acceptance-number of thermal cycles for a component means the number of thermal cycles that the component must experience during the acceptance thermal cycle test. The test must subject each component to no less than eight thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing and flight, including all launch delays and recycling, rounded up to the nearest whole number, whichever is greater.

(2) The acceptance thermal cycle high temperature must be a 30 °C workmanship screening level or the maximum predicted environment high temperature, whichever is higher. The acceptance thermal cycle low temperature must be a −24 °C workmanship screening temperature or the predicted environment low temperature, whichever is lower;

(3) When heating or cooling the battery during each cycle, the temperature must

change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater. The dwell time at each high and low temperature must be long enough for the battery to achieve internal thermal equilibrium and must be no less than one hour.

(4) The test must measure all of a battery's critical status-of-health parameters at the thermal extremes on all cycles and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery must undergo monitoring of its open circuit voltage throughout the test to demonstrate that it satisfies all its performance specifications throughout testing. The sample rate must be once every 10 seconds or more often.

(5) The battery must undergo an electrical performance test that satisfies paragraph (n) of this section while the battery is at the high, ambient, and low temperatures, during the first, middle, and last thermal cycles.

(6) If either the workmanship high or low temperature exceeds the battery's maximum predicted operating temperature range and the battery is not capable of passing the electrical performance test at the workmanship temperature, the battery may undergo the electrical performance test at an interim temperature during the cycle. This must include all of the following:

(i) Any interim high temperature must be no less than the maximum predicted high temperature;

(ii) Any interim low temperature must be no greater than the maximum predicted low temperature;

(iii) The dwell-time at any interim temperature must be long enough for the battery to reach thermal equilibrium; and

(iv) After any electrical performance test at an interim temperature, the thermal cycle must continue until the battery reaches its workmanship temperature.

(p) *Qualification thermal cycle.* A qualification thermal cycle test must demonstrate that a nickel-cadmium battery satisfies all its performance specifications when subjected to pre-flight, acceptance test, and flight thermal cycle environments. This must include each of the following:

(1) The test must subject the fully charged battery to no less than three times the acceptance-number of thermal cycles of paragraph (o)(1) of this section.

(2) The qualification thermal cycle high temperature must be a 40 °C workmanship screening level or the maximum predicted environment high temperature plus 10 °C, whichever is higher. The qualification thermal cycle low temperature must be a −34 °C workmanship screening temperature or the predicted environment low temperature minus 10 °C, whichever is lower.

(3) When heating or cooling the battery during each cycle, the temperature must change at an average rate of 1 °C per minute or the maximum predicted rate, whichever is greater. The dwell time at each high and low temperature must be long enough for the battery to achieve internal thermal equilibrium and must be no less than one hour.

(4) The test must measure the battery's critical status-of-health parameters at the thermal extremes on all cycles and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery must undergo monitoring of its open circuit voltage throughout the test to demonstrate that it satisfies all it performance specifications. The sample rate must be once every 10 seconds or more often.

(5) The battery must undergo an electrical performance test that satisfies paragraph (n) of this section while the battery is at the high, ambient, and low temperatures, during the first, middle, and last thermal cycles.

(6) If either the workmanship high or low temperature exceeds the battery's maximum predicted operating temperature range and the battery is not capable of passing the electrical performance test at the workmanship temperature, the battery may undergo the discharge and pulse capacity test at an interim temperature during the cycle. This must include all of the following:

(i) Any interim high temperature must be no less than the maximum predicted high temperature plus 10 °C;

(ii) Any interim low temperature must be no greater than the maximum predicted low temperature minus 10 °C;

(iii) The dwell-time at any interim temperature must last long enough for the battery to reach thermal equilibrium; and

(iv) After any electrical performance test at an interim temperature, the thermal cycle must continue to the workmanship temperature.

(q) *Operational stand time.* An operational stand time test must demonstrate that a nickel-cadmium battery will maintain its required capacity, including all required margins, from the final charge that the battery receives before flight until the planned safe flight state. This must include each of the following:

(1) The battery must undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity for comparison to the capacity after the battery experiences the operational stand time.

(2) The battery must undergo a charge to full capacity. The test must then subject the battery to the maximum predicted pre-flight temperature for the maximum operating stand time between final battery charging to the planned safe flight state while in an open circuit configuration. The maximum operating stand time must account for all launch processing and launch delay contingencies that could occur after the battery receives its final charge.

(3) After the maximum operating stand time has elapsed, the battery must undergo a capacity discharge to determine any capacity loss due to any self-discharge by comparing the operational stand time capacity with the baseline capacity in paragraph (q)(1) of this section.

(4) The test must demonstrate that the battery's capacity, including all required margins, and any loss in capacity due to the operational stand time satisfy all associated performance specifications.

(r) *Internal inspection.* An internal inspection of a nickel-cadmium battery must identify any excessive wear or damage to the battery, including any of its cells, after the battery is exposed to all the qualification test environments. An internal inspection must satisfy section E417.5(g) and include all of the following:

(1) An internal examination to verify that there was no movement of any component within the battery that stresses that component beyond its design limit;

(2) An examination to verify the integrity of all cell and wiring interconnects;

(3) An examination to verify the integrity of all potting and shimming materials;

(4) The removal of all cells from the battery and examination of each cell for any physical damage;

(5) A test with a chemical indicator to demonstrate that none of the cells leaked; and

(6) Destructive physical analysis of one cell from each corner and one cell from the middle of each battery that undergoes all the qualification tests. The destructive physical analysis must verify the integrity of all connections between all plate tabs and cell terminals, and the integrity of each plate and separator.

(s) *Cell leakage.* A leakage test of a cell must demonstrate the integrity of the cell case seal using one of the following approaches:

(1) *Leak test 1:*

(i) The test must measure each cell's weight to 0.001 grams to create a baseline for comparison.

(ii) The test must subject each cell, fully charged, to a vacuum of less than 10^{-2} torr for no less than 20 hours. While under vacuum, the cell must undergo charging at a C/20 rate. The test must control each cell's temperature to ensure that its does not exceed the cell's maximum predicted thermal environment.

(iii) The test must measure each cell's weight after the 20-hour vacuum and demonstrate that the cell does not experience a weight loss greater than three-sigma from the average weight loss for each cell in the lot.

(iv) Any cell that fails the weight-loss test of paragraph (h)(3) of this section must undergo cleaning and discharge. The cell must then undergo a full charge and then inspection with a chemical indicator. If the chemical indicator shows that the cell has a leak, a launch operator may not use the cell in any further test or flight.

(2) *Leak test 2:*

(i) The cell must develop greater than one atmosphere differential pressure during the 0 °C capacity and overcharge test of paragraph (g) of this section.

(ii) After the 0 °C capacity and overcharge test of paragraph (g) of this section, the cell must undergo a full charge and then inspection with a chemical indicator. If the chemical indicator shows that the cell has a leak, a launch operator may not use the cell in any further test or flight.

E417.23 MISCELLANEOUS COMPONENTS

This section applies to any component that is critical to the reliability of a flight termination system and is not otherwise identified by this appendix. This includes any new technology or any component that may be unique to the design of a launch vehicle, such as any auto-destruct box, current limiter, or timer. A miscellaneous component must satisfy each test or analysis identified by any table of this section to demonstrate that the component satisfies all its performance specifications when subjected to each non-operating and operating environment. For any new or unique component, the launch operator must identify any additional test requirements necessary to ensure its reliability.

Table E417.23-1

Miscellaneous Component Acceptance	Section E417.13(a)	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Identification Check	E417.5(e)	100%
Performance Verification [1]	E417.3(d)	100%
Abbreviated Performance Verification [2]	E417.3(e)	100%
Operating Environment Tests:	E417.13	
Thermal Cycling	E417.13(d)	100%
Thermal Vacuum	E417.13(e)	100%
Acoustic	E417.13(c)	100%
Random Vibration	E417.13(b)	100%
Leakage[3]	E417.5(h)	100%

(1) A component must undergo this test before the first and after the last operating environment test.

(2) A component must undergo this test during each operating environment test.

(3) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.23-2

Miscellaneous Component Qualification	**Section E417.11**	**Quantity [4] Tested**
		X=3
Acceptance Tests [1]	Table E417.23-1	X
Performance Verification [2]	E417.3(d)	X
Non-Operating Environment Tests:	E417.9	
Storage Temperature	E417.9(b)	X
Transportation Shock	E417.9(d)	X
Bench Handling Shock	E417.9(e)	X
Transportation Vibration	E417.9(f)	X
Fungus Resistance	E417.9(g)	1
Salt Fog	E417.9(h)	1
Fine Sand	E417.9(I)	1
Abbreviated Performance Verification [3]	E417.3(e)	X
Operating Environment Tests:	E417.11	

Thermal Cycling	E417.11(h)	X
Humidity	E417.11(g)	X
Thermal Vacuum	E417.11(i)	X
Acceleration	E417.11(f)	X
Shock	E417.11(e)	X
Sinusoidal Vibration	E417.11(b)	X
Acoustic	E417.11(d)	X
Random Vibration	E417.11(c)	X
Electromagnetic Interference and Compatibility	E417.11(j)	1
Explosive Atmosphere	E417.11(k)	1
Leakage (5)	E417.5(h)	X
Internal Inspection	E417.5(g)	X

(1) Each sample component to undergo qualification testing must first successfully complete all acceptance tests required by table E417.23-1.

(2) A component must undergo this test before the first and again after the last non-operating environment test and before the first and again after the last operating environment test.

(3) A component must undergo this test during each operating environment test.

(4) The same three sample components must undergo each test designated with an X. For a test designated with a quantity of less than three, each component tested must be one of the original three sample components.

(5) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

E417.25 SAFE-AND-ARM DEVICES, ELECTRO-EXPLOSIVE DEVICES, ROTOR LEADS, AND BOOSTER CHARGES

(a) *General.* This section applies to any safe-and-arm device that is part of a flight termination system, including each electro-explosive device, rotor lead, or booster charge used by the safe-and-arm device. Any safe-and-arm device, electro-explosive device, rotor lead, or booster charge must satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

Table E417.25-1

Safe-and-Arm Device Acceptance	Section E417.13(a)	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Identification Check	E417.5(e)	100%
Performance Verification:	E417.3(d)	
Safe-and-Arm Device Status-of-Health [(1)]	E417.25(b)	100%
Safety Tests:	E417.25(e)	
Manual Safing	E417.25 (e)(4)	100%
Safing-interlock test	E417.25 (e)(5)	100%
Abbreviated Performance Verification:	E417.3(e)	
Dynamic Performance [(2)]	E417.25(g)	100%
Thermal Performance [(2)]	E417.25(f)	100%
Operating Environment Tests:	E417.13	
Thermal Cycling	E417.13(d)	100%
Random Vibration	E417.13(b)	100%
X-ray	E417.5(f)	100%
Leakage [(3)]	E417.5(h)	100%

(1) A component must undergo this test before the first and after the last operating environment test.

(2) A component must undergo this test while it is subjected to each operating environment test.

(3) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.25-2

Safe-and-Arm Device Qualification	Section E417.7	Quantity Tested		
		X=1 [4]	X=6 [5]	X=3 [6]
Barrier Alignment	E417.25(o)			
Acceptance Tests [1]	Table E417.25-1	X	X	-
Safety Tests:	E417.25(e)			
Extended Stall	E417.25(e)(3)	X	-	-
Abnormal Drop	E417.9(l)	X	-	-
Containment	E417.25(e)(1)	-	-	1
Barrier Functionality	E417.25(e)(2)	-	-	2
Safing Verification	E417.25(e)(6)	-	X	-
Non-Operating Environment Tests:	E417.9			
Storage Temperature	E417.9(b)	-	X	-
Transportation Shock	E417.9(d)	-	X	-
Bench Handling shock	E417.9(e)	-	X	-
Transportation Vibration	E417.9(f)	-	X	-
Fungus Resistance	E417.9(g)	-	1	-
Salt Fog	E417.9(h)	-	1	-
Fine Sand	E417.9(I)	-	1	-
Handling Drop	E417.9(k)	-	X	-
Performance Verification:	E417.3(d)			
Safe-and-Arm Device Status-of-Health [2]	E417.25(b)		X	
Abbreviated Performance Verification:	E417.3(e)			

Safe-and-Arm Device Qualification	Section E417.7	Quantity Tested		
		X=1 (4)	X=6 (5)	X=3 (6)
Dynamic Performance (3)	E417.25(g)	-	X	-
Thermal Performance (3)	E417.25(f)	-	X	-
Operating Environment Tests:	E417.11			
Thermal Cycling	E417.11(h)	-	X	-
Humidity	E417.11(g)	-	X	-
Acceleration	E417.11(f)	-	X	-
Shock	E417.11(e)	-	X	-
Sinusoidal Vibration	E417.11(b)	-	X	-
Acoustic	E417.11(d)	-	X	-
Random Vibration	E417.11(c)	-	X	-
Explosive Atmosphere	E417.11(k)	-	X	-
Safe-and-Arm Transition	E417.25(c)	-	X	-
Stall	E417.25(d)	-	X	-

X-ray	E417.5(f)	-	X	-
Leakage [7]	E417.5(h)	-	X	-
Internal Inspection	E417.5(g)	-	2	-
Firing Tests:	E417.25(j)(1)			
Operating Current:	E417.25(j)(3)			
High-temperature	E417.25(j)(6)	-	2	-
Low-temperature	E417.25(j)(7)	-	2	-

(1) Each sample safe-and-arm device to undergo qualification testing must first successfully complete all acceptance tests required by table E417.25-1.

(2) A component must undergo this test before the first and after the last operating environment test.

(3) A component must undergo this test during each operating environment test.

(4) One safe-and-arm device must undergo the extended stall and abnormal drop tests designated with an X.

(5) The same six sample safe-and-arm devices must undergo each test designated with an X. For a test designated with a quantity of less than six, each safe-and-arm device tested must be one of the original six sample components.

(6) One safe-and-arm device must undergo the containment test and two safe-and-arm devices must under go the barrier functionality test. The safe-and-arm device samples used for these tests need not be flight safe-and-arm devices. The test samples must duplicate all dimensions of a flight safe-and-arm device, including gaps between explosive components, free-volume, and diaphragm thickness.

(7) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.25-3

Electro-explosive Device Lot Acceptance	Section	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Leakage	E417.5(h)	100%
X-ray and N-ray	E417.5(f)	100%
Performance Verification:	E417.3(d)	
Static Discharge	E417.25(i)	100%
Electro-explosive Device Status-of-Health	E417.25(h)	100%
Non-Operating Environment Tests and	E417.9	
Operating Environment Tests:	E417.11	
Thermal Cycling (1)	E417.11(h)	Lot Sample (3)
High-temperature Storage (2)	E417.9(c)	Lot Sample
Shock (1)	E417.11(e)	Lot Sample
Random Vibration (1)	E417.11(c)	Lot Sample
No Fire Verification	E417.25(p)	Lot Sample
Performance Verification:	E417.3(d)	
Status-of-Health	E417.25(h)	Lot Sample
Component Examination:	E415.5	
Visual Examination	E417.5(b)	Lot Sample
Leakage	E417.5(h)	Lot Sample
X-ray and N-ray	E417.5(f)	Lot Sample

Firing Tests:	E417.25(j)(1)	
Ambient-temperature:	E417.25(j)(5)	
All-Fire Current	E417.25(j)(2)	1/6 Lot Sample
Operating Current	E417.25(j)(3)	1/6 Lot Sample
High-temperature:	E417.25(j)(6)	
All-Fire Current	E417.25(j)(2)	1/6 Lot Sample
Operating Current	E417.25(j)(3)	1/6 Lot Sample
Low-temperature:	E417.25(j)(7)	
All-Fire Current	E417.25(j)(2)	1/6 Lot Sample
Operating Current	E417.25(j)(3)	1/6 Lot Sample

(1) This test must subject each electro-explosive device sample to the qualification environmental test level. For an electro-explosive device that is internal to a safe-and-arm device, the test level must be no less than the environment that the electro-explosive device experiences when installed and the safe-and-arm device is subjected to its qualification environment.

(2) A high-temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(3) The lot sample quantity must be no less than 10 percent of the production lot or 30 sample electro-explosive devices, whichever is greater.

Table E417.25-4

Electro-explosive Device	Section	Quantity Tested [5] X=				
		5	SS [6]	SS [7]	SS [8]	105
Component Examination:	E417.5					
Visual Examination	E417.5(b)	X	X	X	X	X
Dimension Measurement	E417.5(c)	X	X	X	X	X
Leakage	E417.5(h)	X	X	X	X	X
X-ray and N-ray	E417.5(f)	X	X	X	X	X
Performance Verification:	E417.3(d)					
Static Discharge	E417.25(i)	X	X	X	X	X
Electro-expl. Dev. Status-of-Health	E417.25(h)	X	X	X	X	X
Component Examination:	E417.5	X	X	X	X	X
Visual Examination	E417.5(b)	X	X	X	X	X
Dimension Measurement	E417.5(c)	X	X	X	X	X
Leakage	E417.5(h)	X	X	X	X	X
X-ray and N-ray	E417.5(f)	X	X	X	X	X
Radio Frequency Impedance	E417.25(k)	-	10	-	-	-
Radio Frequency Sensitivity	E417.25(l)	-	X	-	-	-
No-Fire Level	E417.25(m)	-	-	X	-	-
All-Fire Level	E417.25(n)	-	-	-	X	-
Non-Operating Environment Tests and	E417.9					

Electro-explosive Device Qualification [1]	**Section E417.7**	**Quantity Tested** [5] **X=**				
		5	**SS** [6]	**SS** [7]	**SS** [8]	**105**
Operating Environment Tests:	E417.11	-	-	-	-	X
Thermal Cycling [2]	E417.11(h)	-	-	-	-	30
High-temperature Storage [3]	E417.9(c)	-	-	-	-	X
Shock [2]	E417.11(e)	-	-	-	-	X
Random Vibration [2]	E417.11(c)	-	-	-	-	30
No-Fire Verification	E417.25(p)	-	-	-	-	30
Tensile Load [4]	E417.9(j)	X	-	-	-	-
Auto Ignition	E417.25(q)					
Performance Verification	E417.3(d)					
Static Discharge	E417.25(i)	-	-	-	-	X
Status-of-Health	E417.25(h)	-	-	-	-	X
Component Examination	E415.5					
Visual Examination	E417.5(b)	---	-	-	-	X
Leakage	E417.5(h)		-	-	-	X
X-ray and N-ray	E417.5(f)		-	-	-	X

Firing Tests:	E417.25(j)(1)					
Ambient-temperature:	E417.25(j)(5)					
All-Fire Current [9]	E417.25(j)(2)	-	-	-	-	15
Operating Current [9]	E417.25(j)(3)	-	-	-	-	15
22-Amps Current	E417.25(j)(4)	-	-	-	-	5
High-temperature:	E417.25(j)(6)					
All-Fire Current [9]	E417.25(j)(2)	-	-	-	-	15
Operating Current [9]	E417.25(j)(3)	-	-	-	-	15
22-Amps Current	E417.25(j)(4)	-	-	-	-	5
Low-temperature:	E417.25(j)(7)					
All-Fire Current [9]	E417.25(j)(2)	-	-	-	-	15
Operating Current [9]	E417.25(j)(3)	-	-	-	-	15
22-Amps Current	E417.25(j)(4)	-	-	-	-	5

(1) All sample electro-explosive devices to undergo qualification testing must be from a production lot that has passed the lot acceptance tests required by Table E417.25-3.

(2) This test must subject each electro-explosive device sample to the qualification environmental test level. For an electro-explosive device that is internal to a safe-and-arm device, the test level must be no less than the environment that the electro-explosive device experiences when installed in a safe-and-arm device subjected to the safe-and-arm device's qualification environment.

(3) A high-temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an

initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) This test is not required if any other test verifies that each electro-explosive device is not damaged during installation.

(5) For each column, the quantity required at the top of the column must be from the same production lot and must be subjected to each test designated with an X. For a test designated with a lessor quantity, each sample tested must be one of the original samples for that column.

(6) For the designated column, SS (statistical sample) must be the quantity of sample components needed to perform a statistical firing series to determine the radio frequency sensitivity of the electro-explosive device and must be no less than 10 samples. Each sample component must undergo each test designated with an X.

(7) For the designated column, SS must be the quantity of sample components needed to perform a statistical firing series to determine the electro-explosive device's no-fire energy level. Each sample component must undergo each test designated with an X.

(8) For the designated column, SS must be the quantity of sample components needed to perform a statistical firing series to determine the electro-explosive device's all-fire energy level. Each sample component must undergo each test designated with an X.

(9) All the electro-explosive device samples that undergo the high-temperature storage test, no-fire verification test, or tensile load test must be evenly distributed between each all-fire current and operating current firing test.

Table E417.25-5

Electro-explosive Device Service-life Extension [5]	Section E417.15	Quantity Tested [2] 1 Year [3] X=5	Quantity Tested [2] 3 Years [4] X=10
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Performance Verification:	E417.3(d)		
Static Discharge	E417.25(i)	X	X
Electro-explosive Device Status-of-Health	E417.25(h)	X	X
Non-Operating Environment Tests and	E417.9		
Operating Environment Tests:	E417.11		
Thermal Cycling [1]	E417.11(h)	X	X
High-temperature Storage	E417.9(c)	-	X
Shock [1]	E417.11(e)	X	X
Random Vibration [1]	E417.11(c)	X	X
Performance Verification:	E417.3(d)		
Electro-explosive Device Status-of-Health	E417.25(h)	X	X
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X

Firing Tests:	E417.25(j)(1)		
All-Fire Current:	E417.25(j)(2)		
Ambient-temperature	E417.25(j)(5)	1	3
High-temperature	E417.25(j)(6)	2	3
Low-temperature	E417.25(j)(7)	2	4

(1) This test must subject each electro-explosive device sample to the qualification environmental test level. For an electro-explosive device that is internal to a safe-and-arm device, the test level must be no less than the environment that the electro-explosive device experiences when installed in a safe-and-arm device subjected to the safe-and-arm device's qualification environment.

(2) For each column, the quantity of sample electro-explosive devices required at the top of the column must be from the same production lot and must undergo each test designated with an X. For a test designated with a lessor quantity, each electro-explosive device tested must be one of the original samples for that column.

(3) Five electro-explosive devices from the same lot must undergo the tests required by this column to extend the service-life of the remaining electro-explosive devices from the same lot for one year.

(4) Ten electro-explosive devices from the same lot must undergo the tests required by this column to extend the service-life of the remaining electro-explosive devices from the same lot for three years.

(5) In order to extend the service-life of an electro-explosive device, the device must undergo the tests required by the one-year column or the three-year column before the device's initial service-life or any previous service-life extension expires.

Table E417.25-6

Safe-and-Arm Rotor Lead and Booster Charge Lot Acceptance [(1)]	Section E417.13(a)	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Leakage	E417.5(h)	100%
X-ray and N-ray	E417.5(f)	100%
Non-Operating Environment Tests and	E417.9	
Operating Environment Tests:	E417.11	
Thermal Cycling [(2)]	E417.11(h)	Lot Sample [(4)]
High-temperature Storage [(3)]	E417.9(c)	Lot Sample
Component Examination:	E417.5	
Leakage	E417.5(h)	Lot Sample
X-ray and N-ray	E417.5(f)	Lot Sample
Firing Tests:	E417.25(j)(1)	
High-temperature	E417.25(j)(6)	½ Lot Sample [(5)]
Low-temperature	E417.25(j)(7)	½ Lot Sample [(6)]

(1) This table applies to any rotor lead or booster charge that is used by a safe-and-arm device.

(2) This test must subject each ordnance sample to the qualification environmental test level. For ordnance that is internal to a safe-and-arm device, the test level must be no less than the environment that the ordnance experiences when installed and the safe-and-arm device is subjected to its qualification environment.

(3) A lot will have an initial service-life of five years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) The lot sample quantity must be no less than 10 percent of the lot or nine sample units from the lot, whichever is greater.

(5) For this test, the quantity must be no less than one half the lot sample quantity rounded down to the nearest whole number.

(6) For this test, the quantity must be no less than one half the lot sample quantity rounded up to the nearest whole number.

Table E417.25-7

Safe-and-Arm Rotor Lead and Booster Charge Qualification [1]	**Section E417.7**	**Quantity** [4] **Tested X=21**
Component Examination:	E417.5	
Visual Examination	E417.5(b)	X
Dimension Measurement	E417.5(c)	X
Leakage	E417.5(h)	X
X-ray and N-ray	E417.5(f)	X
Non-Operating and Operating Environment Tests:	E417.9 E417.11	
Thermal Cycling [2]	E417.11(h)	X
High-temperature Storage [3]	E417.9(c)	10
Shock [2]	E417.11(e)	X
Random Vibration [2]	E417.11(c)	X
Component Examination:	E417.5	
X-ray and N-ray	E417.5(f)	X
Leakage	E417.5(h)	X
Firing Tests:	E417.25(j)(1)	
Ambient-temperature	E417.25(j)(5)	7
High-temperature	E417.25(j)(6)	7
Low-temperature	E417.25(j)(7)	7

(1) This table applies to any rotor lead or booster charge that is used by a safe-and-arm device.

(2) This test must subject each ordnance sample to the qualification environmental test level. For ordnance that is internal to a safe-and-arm device, the test level must be no less than the actual environment that the ordnance experiences when installed and the safe-and-arm device is subjected to its qualification environment.

(3) A lot will have an initial service-life of five years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) The same 21 sample components, from the same production lot, must undergo each test designated with an X. For a test designated with a quantity of less than 21, each component sample tested must be one of the original 21 samples.

Table E417.25-8

Safe-and-Arm Rotor Lead and Booster Charge Service-life Extension [1]	Section E417.15	Quantity Tested [3] 1 Year [4] X=5	5 Years [5] X=10
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Non-Operating and	E417.9		
Operating Environment Tests:	E417.11		
Thermal Cycling [2]	E417.11(h)	X	X
High-temperature Storage	E417.9(c)	-	X
Component Examination:	E417.5		
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Firing Tests:	E417.25(j)(1)		
High-temperature	E417.25(j)(6)	2	5
Low-temperature	E417.25(j)(7)	3	5

(1) This table applies to any rotor lead or booster charge that is used by a safe-and-arm device. In order to extend the service-life of a rotor lead or booster charge, the rotor lead or charge must undergo each test required by the one-year column or the five-year column before its initial service-life or any previous service-life extension expires.

(2) This test must subject each ordnance sample to the qualification environmental test level. For ordnance that is internal to a safe-and-arm device, the test level must be no less than the actual environment that the ordnance experiences when installed and the safe-and-arm device is subjected to its qualification environment.

(3) For each column, the quantity of sample components required at the top of the column must be from the same production lot and must undergo each test designated with an X. For a test designated with a lessor quantity, each component tested must be one of the original samples for that column.

(4) Five ordnance samples from the same lot must undergo the tests required by this column to extend the service-life of the remaining ordnance from the same lot for one year.

(5) Ten ordnance samples from the same lot must undergo the tests required by this column to extend the service-life of the remaining ordnance from the same lot for five years.

(b) *Safe-and-arm device status-of-health.* A safe-and-arm device status-of-health test must satisfy section E417.3(f). This must include measuring insulation resistance from pin-to-pin and pin-to-case, safe-and-arm transition time, and bridgewire resistance consistency through more than one safe-and-arm transition cycle.

(c) *Safe-and-arm transition.* This test must demonstrate that the safe-and-arm transition, such as rotational or sliding operation, satisfies all its performance specifications. This must include all of the following:

(1) The test must demonstrate that the safe-and-arm monitors accurately determine safe-and-arm transition and whether the safe-and-arm device is in the proper configuration;

(2) The test must demonstrate that a safe-and-arm device is not susceptible to inadvertent initiation or degradation in performance of the electro-explosive device during pre-flight processing; and

(3) The test must demonstrate the ability of a safe-and-arm device to satisfy all its performance specifications when subjected to five times the maximum predicted number of safe-to-arm and arm-to-safe cycles.

(d) *Stall.* A stall test must demonstrate that a safe-and-arm device satisfies all its performance specifications after being locked in its safe position and subjected to an operating arming voltage for the greater of:

(i) Five minutes; or

(ii) The maximum time that could occur inadvertently and the device still be used for flight.

(e) *Safety tests.* The following safety tests must demonstrate that a safe-and-arm device can be handled safely:

(1) *Containment.* A containment test must demonstrate that a safe-and-arm device will not fragment when any internal electro-explosive device or rotor charge is initiated. A safe-and-arm device must undergo the test in

the arm position and with any shipping cap or plug installed in each output port.

(2) *Barrier functionality*. A barrier functionality test must demonstrate that, when in the safe position, if a safe-and-arm device's internal electro-explosive device is initiated, the ordnance output will not propagate to an explosive transfer system. This demonstration must include all of the following:

(i) The test must consist of firings at high and low temperature extremes, the explosive transfer system must be configured for flight;

(ii) Each high-temperature firing must be initiated at the manufacturer specified high temperature or a 71 °C workmanship screening level, whichever is higher; and

(iii) Each low-temperature firing must be initiated at the manufacturer specified low temperature or a −54 °C workmanship screening level, whichever is lower.

(3) *Extended stall*. An extended stall test must demonstrate that a safe-and-arm device does not initiate when locked in its safe position and is subjected to a continuous operating arming voltage for the maximum predicted time that could occur accidentally or one hour, whichever is greater.

(4) *Manual safing*. A manual safing test must demonstrate that a safe-and-arm device can be manually safed in accordance with all its performance specifications.

(5) *Safing-interlock*. A safing-interlock test must demonstrate that when a safe-and-arm device's safing-interlock is in place and operational arming current is applied, the interlock prevents arming in accordance with all the interlock's performance specifications.

(6) *Safing verification*. A safing verification test must demonstrate that, while a safe-and-arm device is in the safe position, any internal electro-explosive device will not initiate if the safe-and-arm device input circuit is accidentally subjected to a firing voltage, such as from a command receiver or inadvertent separation destruct system output.

(f) *Thermal performance*. A thermal performance test must demonstrate that a safe-and-arm device satisfies all its performance specifications when subjected to operating and workmanship thermal environments. This demonstration must include all of the following:

(1) The safe-and-arm device must undergo the test while subjected to each required thermal environment;

(2) The test must continuously monitor the bridgewire continuity with the safe-and-arm device in its arm position to detect each and any variation in amplitude. Any variation in amplitude constitutes a test failure;

(3) The test must measure the bridgewire resistance for the first and last thermal cycle during the high and low temperature dwell times to demonstrate that the bridgewire resistance satisfies the manufacturer specification;

(4) The test must subject the safe-and-arm device to five safe-and-arm cycles and measure the bridgewire continuity during each cycle to demonstrate that the continuity is consistent; and

(5) The test must measure the safe-and-arm cycle time to demonstrate that it satisfies the manufacturer specification.

(g) *Dynamic performance*. A dynamic performance test must demonstrate that a safe-and-arm device satisfies all its performance specifications when subjected to the dynamic operational environments, such as vibration and shock. This demonstration must include all of the following:

(1) The safe-and-arm device must undergo the test while subjected to each required dynamic operational environment;

(2) The test must continuously monitor the bridgewire continuity with the safe-and-arm device in the arm position to detect each and any variation in amplitude. Any amplitude variation constitutes a test failure. The monitoring must have a sample rate that will detect any component performance degradation;

(3) The test must continuously monitor each safe-and-arm device monitor circuit to detect each and any variation in amplitude. Any variation in amplitude constitutes a test failure. This monitoring must have a sample rate that will detect any component performance degradation; and

(4) The test must continuously monitor the safe-and-arm device to demonstrate that it remains in the fully armed position throughout all dynamic environment testing.

(h) *Electro-explosive device status-of-health*. An electro-explosive device status of health test must satisfy section E417.3(f). The test must include measuring insulation resistance and bridgewire continuity.

(i) *Static discharge*. A static discharge test must demonstrate that an electro-explosive device can withstand an electrostatic discharge that it could experience from personnel or conductive surfaces without firing and still satisfy all its performance specifications. The test must subject the electro-explosive device to the greater of:

(1) A 25k-volt, 500-picofarad pin-to-pin discharge through a 5k-ohm resistor and a 25k-volt, 500-picofarad pin-to-case discharge with no resistor; or

(2) The maximum predicted pin-to-pin and pin-to-case electrostatic discharges.

(j) *Firing tests*.

(1) *General*. Each firing test of a safe-and-arm device, electro-explosive device, rotor lead, or booster charge must satisfy all of the following:

(i) The test must demonstrate the initiation and transfer of all ordnance charges and that the component does not fragment. For a safe-and-arm device that has more than one internal electro-explosive device, each firing test must also demonstrate that the initiation of one internal electro-explosive device does not adversely affect the performance of any other internal electro-explosive device;

(ii) The number of component samples that the test must fire and the test conditions, including firing current and temperature must satisfy each table of this section;

(iii) Before initiation, each component sample must experience the required temperature for enough time to achieve thermal equilibrium;

(iv) Each test must measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the output satisfies all its performance specifications; and

(v) Each test of a safe-and-arm device or electro-explosive device must subject each sample device to a current source that duplicates the operating output waveform and impedance of the flight current source. Each test of a rotor lead or booster charge must subject the component to an energy source that simulates the flight energy source.

(2) *All-fire current.* Each all-fire current test must subject each component sample to the manufacturer's specified all-fire current value.

(3) *Operating current.* Each operating current test must subject each component sample to the launch vehicle operating current value if known at the time of testing. If the operating current is unknown, the test must use no less than 200% of the all-fire current value.

(4) *22-amps current.* This test must subject each component sample to a firing current of 22 amps.

(5) *Ambient-temperature.* This test must initiate each ordnance sample while it is subjected to ambient-temperature.

(6) *High-temperature.* Each high-temperature test must initiate each ordnance sample while it is subjected to the qualification high-temperature level or a +71 °C workmanship screening level, whichever is higher.

(7) *Low-temperature.* Each low-temperature test must initiate each ordnance sample while it is subjected to the qualification low-temperature level or a −54 °C workmanship screening level, whichever is lower.

(k) *Radio frequency impedance.* This test must determine the radio frequency impedance of an electro-explosive device for use in any flight termination system radio frequency susceptibility analysis.

(l) *Radio frequency sensitivity.* This test must consist of a statistical firing series of electro-explosive device lot samples to determine the radio frequency no-fire energy level for the remainder of the lot. The firing series must determine the highest continuous radio frequency energy level to which the device can be subjected and not fire with a reliability of 0.999 at a 95% confidence level. Any demonstrated radio frequency no-fire energy level that is less than the level used in the flight termination system design and analysis constitutes a test failure.

(m) *No-fire energy level.* This test must consist of a statistical firing series of electro-explosive device lot samples to determine the no-fire energy level for the remainder of the lot. The firing series must determine the highest electrical energy level at which the device will not fire with a reliability of 0.999 at a 95% confidence level when subjected to a continuous current pulse. Any demonstrated no-fire energy level that is less than the no-fire energy level used in the flight termination system design and analysis constitutes a test failure.

(n) *All-fire energy level.* This test must consist of a statistical firing series of electro-explosive device lot samples to determine the all-fire energy level for the remainder of the lot. This firing series must determine the lowest electrical energy level at which the device will fire with a reliability of 0.999 at a 95% confidence level when subjected to a current pulse that simulates the launch vehicle flight termination system firing characteristics. Any demonstrated all-fire energy level that exceeds the all-fire energy level used in the flight termination system design and analysis constitutes a test failure.

(o) *Barrier alignment.* A barrier alignment test must consist of a statistical firing series of safe-and-arm device samples. The test must demonstrate that the device's safe to arm transition motion provides for ordnance initiation with a reliability of 0.999 at a 95% confidence level. The test must also demonstrate that the device's arm to safe transition motion provides for no ordnance initiation with a reliability of 0.999 at a 95% confidence level. This test may employ a reusable safe-and-arm subassembly that simulates the flight configuration.

(p) *No-fire verification.* This test must demonstrate that a flight configured electro-explosive device will not inadvertently initiate when exposed to the maximum predicted circuit leakage current and will still satisfy all its performance specifications. The test must subject each sample electro-explosive device to the greater of:

(1) The worst-case leakage current level and duration that could occur in an operating condition; or

(2) One amp/one watt for five minutes.

(q) *Auto-ignition.* This test must demonstrate that an electro-explosive device does not experience auto-ignition, sublimation, or melting when subjected to any high-temperature environment during handling, testing, storage, transportation, installation, or flight. The test must include all of the following:

(1) The test environment must be no less than 30 °C higher than the highest non-operating or operating temperature that the device could experience;

(2) The test must last the maximum predicted high-temperature duration or one hour, whichever is greater; and

(3) After exposure to the test environment, each sample device must undergo external and internal examination, including any dissection needed to identify any auto-ignition, sublimation, or melting.

E417.27 EXPLODING BRIDGEWIRE FIRING UNITS AND EXPLODING BRIDGEWIRES

(a) *General*. This section applies to any exploding bridgewire firing unit that is part of a flight termination system, including each exploding bridgewire that is used by the firing unit. Any firing unit or exploding bridgewire must satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

Table E417.27-1

Exploding Bridgewire Firing Unit Acceptance	Section E417.13	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Identification Check	E417.5(e)	100%
Performance Verification:	E417.3(d)	
Firing Unit Status-of-Health (1)	E417.27(b)	100%
Input Command Processing (1)	E417.27(c)	100%
High Voltage Circuitry (1)	E417.27(d)	100%
Output Monitoring (1)	E417.27(e)(1)	100%
Abbreviated Performance Verification:	E417.3(e)	
Abbreviated Status-of-Health (2)	E417.27(f)	100%
Abbreviated Command Processing (2)	E417.27(g)	100%
Output Monitoring (2)	E417.27(e)(2)	100%
Operating Environment Tests:	E417.13	
Thermal Cycling (3)	E417.13(d)	100%
Thermal Vacuum (3)	E417.13(e)	100%
Acoustic	E417.13(c)	100%
Random Vibration	E417.13(b)	100%
Leakage(4)	E417.5(h)	100%

(1) A component must undergo this test before the first and again after the last operating environment test.

(2) A component must undergo this test during each operating environment test.

(3) This test must include continuous monitoring of all abbreviated status-of-health parameters and output monitors during all thermal cycles and transitions.

(4) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.27-2

Exploding Bridgewire Firing Unit Qualification	**Section E417.7**	**Quantity Tested**		
		X=1	**X=1**	**X=1**
Acceptance Tests (1)	***Table E417.27-1***	X	X	X
Performance Verification:	E417.3(d)			
Firing Unit Status-of-Health (2)	E417.27(b)	X	X	X
Input Command Processing (2)	E417.27(c)	X	X	X
High Voltage Circuitry (2)	E417.27(d)	X	X	X
Abbreviated Performance Verification:	E417.3(e)			
Abbreviated Status-of-Health (3)	E417.27(f)	X	X	X
Abbreviated Command Processing (3)	E417.27(g)	X	X	X
Output Monitoring (3)	E417.27(e)(2)	X	X	X
Non-Operating Environment Tests:	E417.9			
Storage Temperature	E417.9(b)	X	X	X
Transportation Shock	E417.9(d)	X	X	X
Bench Handling Shock	E417.9(e)	X	X	X
Transportation Vibration	E417.9(f)	X	X	X
Fungus Resistance	E417.9(g)	X	-	-
Salt Fog	E417.9(h)	X	-	-
Fine Sand	E417.9(I)	X	-	-
Operating Environment Tests:	E417.11			

Thermal Cycling [4]	E417.11(h)	X	X	X
Humidity	E417.11(g)	X	X	X
Thermal Vacuum [4]	E417.11(i)	X	X	X
Acceleration	E417.11(f)	X	X	X
Shock	E417.11(e)	X	X	X
Sinusoidal Vibration	E417.11(b)	X	X	X
Acoustic	E417.11(d)	X	X	X
Random Vibration	E417.11(c)	X	X	X
Electromagnetic Interference and Compatibility	E417.11(j)	X	X	-
Explosive Atmosphere	E417.11(k)	-	X	-
Repetitive functioning	E417.27(i)	X	X	X
Circuit Protection	E417.27(h)	X	-	-
Leakage [5]	E417.5(h)	X	X	X
Internal Inspection	E417.5(g)	X	X	X

(1) Each qualification test component sample must successfully complete all acceptance tests before undergoing qualification testing.

(2) A component sample must undergo this test before the first and after the last environmental test.

(3) A component sample must undergo this test during each operating environment test.

(4) While undergoing this test, a component sample must undergo an abbreviated status-of-health test and output monitor test during all thermal cycles and transitions.

(5) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.27-3

Exploding Bridgewire Lot Acceptance	Section	Quantity Tested
Component Examination and	E417.5	
Performance Verification:	E417.3(d)	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Static Discharge	E417.27(j)	100%
Exploding Bridgewire Status-of-Health	E417.27(k)	100%
Safety Devices (1)	E417.27(l)	100%
Leakage	E417.5(h)	100%
X-ray and N-ray	E417.5(f)	100%
Non Operating Environment Tests and	E417.9	
Operating Environment Tests:	E417.11	
Thermal Cycling (2)	E417.11(h)	Lot Sample (4)
High-temperature Storage (3)	E417.9(c)	Lot Sample
Shock (2)	E417.11(e)	Lot Sample
Random Vibration (2)	E417.11(c)	Lot Sample
Component Examination and	E417.5	
Performance Verification:	E417.3(d)	
Exploding Bridgewire Status-of-health	E417.27(k)	Lot Sample
Safety Devices (1)	E417.27(l)	Lot Sample
Leakage	E417.5(h)	Lot Sample
X-ray and N-ray	E417.5(f)	Lot Sample

Firing Tests:	E417.27(m)(1)	
Ambient-temperature:	E417.27(m)(5)	
All-Fire Voltage	E417.27(m)(2)	1/6 Lot Sample
Operating Voltage	E417.27(m)(3)	1/6 Lot Sample
High-temperature:	E417.27(m)(6)	
All-Fire Voltage	E417.27(m)(2)	1/6 Lot Sample
Operating Voltage	E417.27(m)(3)	1/6 Lot Sample
Low-temperature:	E417.27(m)(7)	
All-Fire Voltage	E417.27(m)(2)	1/6 Lot Sample
Operating Voltage	E417.27(m)(3)	1/6 Lot Sample

(1) An exploding bridgewire must undergo this test only if it contains internal protection circuitry such as a spark gap.

(2) This test must subject a component sample to the qualification test environmental level.

(3) A high-temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) The lot sample quantity must be no less than 10 percent of the production lot or 30 sample exploding bridgewires; whichever is greater.

Table E417.27-4

Exploding Bridgewire Qualification	Section	Quantity Tested [4] X=				
		5	SS [5]	SS [6]	SS [7]	105
Lot Acceptance Tests [1]	Table E417.27-3					
Component Examination and	E417.5					
Performance Verification:	E417.3(d)	X	X	X	X	X
Visual Examination	E417.5(b)	X	X	X	X	X
Dimension Measurement	E417.5(c)	X	X	X	X	X
Static Discharge	E417.27(j)	X	X	X	X	X
Expl. Bridgewire Status-of-Health	E417.27(k)	X	X	X	X	X
Safety Devices [2]	E417.27(l)	X	X	X	X	X
Leakage	E417.5(h)	X	X	X	X	X
X-ray and N-ray	E417.5(f)					
Radio Frequency Impedance	E417.27(n)	-	10	-	-	-
Radio Frequency Sensitivity	E417.27(o)	-	X	-	-	-
No-Fire Energy Level	E417.27(p)	-	-	X	-	-
All-Fire Energy Level	E417.27(q)	-	-	-	X	-
Non-Operating Environment Tests and	E417.9					
Operating Environment Tests:	E417.11					

Exploding Bridgewire Qualification	Section	Quantity Tested (4) X=				
		5	SS (5)	SS (6)	SS (7)	105
Storage Temperature	E417.9(b)	-	-	-	-	X
Transportation Shock	E417.9(d)	-	-	-	-	X
Bench Handling Shock	E417.9(e)	-	-	-	-	X
Transportation Vibration	E417.9(f)	-	-	-	-	X
Fungus Resistance	E417.9(g)	-	-	-	-	5
Salt Fog	E417.9(h)	-	-	-	-	5
Fine Sand	E417.9(I)	-	-	-	-	5
Thermal Cycling	E417.11(h)	-	-	-	-	X
High-temperature Storage (3)	E417.9(c)	-	-	-	-	30
Shock	E417.11(e)	-	-	-	-	X
Random Vibration	E417.11(c)	-	-	-	-	X
Handling Drop	E417.9(k)	-	-	-	-	X
Tensile Load	E417.9(j)	X	-	-	-	-
Abnormal Drop	E417.9(l)	X	-	-	-	-
Auto Ignition	E417.27(r)	X	-	-	-	-
Component Examination and Performance Verification:	E417.5 E417.3(d)					
Expl. Bridgewire Status-of-health	E417.27(k)	-	-	-	-	X
Safety Devices (2)	E417.27(l)	-	-	-	-	X
Leakage	E417.5(h)	-	-	-	-	X
X-ray and N-ray	E417.5(f)	-	-	-	-	X

Firing Tests:	E417.27(m)(1)					
Ambient-temperature:	E417.27(m)(5)					
All-Fire Voltage	E417.27(m)(2)	-	-	-	-	15
Operating Voltage	E417.27(m)(3)	-	-	-	-	15
Twice-Operating Voltage	E417.27(m)(4)	-	-	-	-	5
High-temperature:	E417.27(m)(6)					
All-Fire Voltage	E417.27(m)(2)	-	-	-	-	15
Operating Voltage	E417.27(m)(3)	-	-	-	-	15
Twice-Operating Voltage	E417.27(m)(4)	-	-	-	-	5
Low-temperature:	E417.27(m)(7)					
All-Fire Voltage	E417.27(m)(2)	-	-	-	-	15
Operating Voltage	E417.27(m)(3)	-	-	-	-	15
Twice-Operating Voltage	E417.27(m)(4)	-	-	-	-	5

(1) All sample-exploding bridgewire samples used in qualification testing must be from a production lot that has passed the lot acceptance tests required by table E417.27-3.

(2) An exploding bridgewire must undergo this test only if it contains internal protection circuitry such as a spark gap.

(3) A high-temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) For each column, the quantity required at the top of the column must be from the same production lot and must undergo each test designated with an X. For a test

designated with a lessor quantity, each sample exploding bridgewire tested must be one of the original samples for the column.

(5) The statistical sample (SS) must be the quantity of sample components needed to perform a statistical firing series to determine the radio frequency sensitivity of the exploding bridgewire. Each sample component must undergo each test designated with an X. The statistical sample quantity must be no less than 10 sample components, which is the minimum required to undergo the radio frequency impedance test.

(6) The statistical sample (SS) must be the quantity of sample components needed to perform a statistical firing series to determine the electro exploding bridgewire's no-fire energy level. Each sample component must undergo each test designated with an X.

(7) The statistical sample (SS) must be the quantity of sample components needed to perform a statistical firing series to determine the exploding bridgewire's all-fire energy level. Each sample component must undergo each test designated with an X.

Table E417.27-5

Exploding Bridgewire Service-life Extension (6)	**Section E417.15**	**Quantity Tested** (3) **1 Year** (4) **X=5**	**3 Years** (5) **X=10**
Component examination and Performance Verification:	E417.5 E417.3(d)		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Static Discharge	E417.27(j)	X	X
Exploding Bridgewire Status-of-Health	E417.27(k)	X	X
Safety Devices (2)	E417.27(l)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Non-Operating Environment Tests and Operating Environment Tests:	E417.9 E417.11		
Thermal Cycling (1)	E417.11(h)	X	X
High-temperature Storage	E417.9(c)	-	X
Shock (1)	E417.11(e)	X	X
Random Vibration (1)	E417.11(c)	X	X
Component examination and Performance Verification:	E417.5 E417.3(d)		
X-ray and N-ray	E417.5(f)	X	X
Exploding Bridgewire Status-of-Health	E417.27(k)	X	X
Safety Devices (2)	E417.27(l)	X	X
Leakage	E417.5(h)	X	X

Firing Tests:	E417.27(m)(1)		
All-Fire Voltage:	E417.27(m)(2)		
Ambient-temperature	E417.27(m)(5)	1	3
High-temperature	E417.27(m)(6)	2	3
Low-temperature	E417.27(m)(7)	2	4

(1) This test must subject each component sample to the qualification environmental level.

(2) An exploding bridgewire must undergo this test only it contains internal protection circuitry such as a spark gap.

(3) For each column, the component samples required at the top of the column must be from the same production lot and each component sample must undergo each test designated with an X. For a test designated with a lessor quantity, each sample exploding bridgewire tested must be one of the original samples for the column.

(4) Five exploding bridgewires from the same lot must undergo each test designated with an X to extend the service-life of the remaining exploding bridgewires from the same lot for one year.

(5) Ten exploding bridgewires from the same lot must undergo each test designated with an X to extend the service-life of the remaining exploding bridgewires from the same lot for three years.

(6) In order to extend an exploding bridgewire's service-life, the bridgewire must undergo the tests required by the one-year column or the three-year column before its initial service-life or any previous service-life extension expires.

(b) *Firing unit status-of-health.* A firing unit status-of-health test must satisfy section E417.3(f). This must include measuring input current, all pin-to-pin and pin-to-case resistances, trigger circuit threshold, capacitor charge time and arming time.

(c) *Input command processing.* An input command processing test must demonstrate that an exploding bridgewire firing unit's input trigger circuit satisfies all its performance specifications when subjected to any variation in input that it could experience during flight. The firing unit must undergo this test before the first and after the last environmental test to identify any degradation in performance due to any of the test environments. The test must demonstrate all of the following:

(1) The amplitude sensitivity of the firing unit trigger circuit provides margin over the worst-case trigger signal that could be delivered on the launch vehicle as follows:

(i) The firing unit triggers at 50% of the amplitude and 50% of the pulse duration of the lowest trigger signal that could be delivered during flight; and

(ii) The firing unit triggers at 120% amplitude and 120% of the pulse duration of the highest trigger signal that could be delivered during flight;

(2) The firing unit satisfies all its performance specifications when subjected to the maximum input voltage of the open circuit voltage of the power source, ground or airborne, and the minimum input voltage of the loaded voltage of the power source;

(3) Each control and switching circuit that is critical to the reliable operation of an exploding bridgewire firing unit does not change state when subjected to a minimum input power drop-out for a period of 50 milliseconds;

(4) The firing unit's response time satisfies all its performance specifications with input at the specified minimum and maximum vehicle supplied trigger signal; and

(5) If the firing unit has differential input, the unit satisfies all its performance specifications with all input combinations at the specified trigger amplitude input signals.

(d) *High voltage circuitry*. This test must demonstrate that a firing unit's high voltage circuitry satisfies all its performance specifications for initiating the exploding bridgewire when subjected to any variation in input that the circuitry could experience during flight. The firing unit must undergo the test before the first and after the last environmental test to identify any degradation in performance due to any of the test environments. The test must demonstrate all of the following:

(1) The firing unit satisfies all its performance specifications when subjected to the worst-case high and low arm voltages that it could experience during flight;

(2) The firing unit's charging and output circuitry has an output waveform, rise-time, and amplitude that delivers no less than a 50% voltage margin to the exploding bridgewire. The test must use the identical parameters, such as capacitor values and circuit and load impedance, as those used to provide the exploding bridgewire all-fire energy level;

(3) The firing unit does not experience any arcing or corona during high voltage discharge; and

(4) Each high-energy trigger circuit used to initiate the main firing capacitor has an output signal that delivers no less than a 50% voltage margin with an input to the circuit at the nominal trigger threshold level.

(e) *Output monitoring*. (1) An output monitoring test must measure the voltage of each high voltage capacitor and the arm power to a firing unit and demonstrate that it satisfies all its performance specifications.

(2) An output monitoring test conducted while the firing unit is subjected to an operating environment, must continuously monitor the voltage of each high voltage capacitor and the arm power to the firing unit to detect any variation in amplitude. Any amplitude variation constitutes a test failure. The monitoring must use a sample rate that will detect any component performance degradation.

(f) *Abbreviated status-of-health*. An abbreviated status-of-health test must measure all a firing unit's critical performance parameters while the unit is subjected to each required operating environment to identify any degradation in performance while exposed to each environment. This must include continuous monitoring of the firing unit's input to detect any variation in amplitude. Any amplitude variation constitutes a test failure. The monitoring must have a sample rate that will detect any component performance degradation.

(g) *Abbreviated command processing*. An abbreviated command processing test must exercise all of a firing unit's flight critical functions while the unit is subjected to each required operating environment. This must include subjecting the firing unit to the fire command throughout each environment while monitoring function time and the high voltage output waveform to demonstrate that each satisfies all its performance specifications.

(h) *Circuit protection*. A circuit protection test must demonstrate that any circuit protection allows a firing unit to satisfy all its performance specifications, when subjected to any improper launch processing, abnormal flight condition, or any failure of another launch vehicle component. The demonstration must include all of the following:

(1) Any circuit protection allows an exploding bridgewire firing unit to satisfy all its performance specifications when subjected to the maximum input voltage of the open circuit voltage of the unit's power source and when subjected to the minimum input voltage of the loaded voltage of the power source;

(2) In the event of an input power dropout, any control or switching circuit that contributes to the reliable operation of an exploding bridgewire firing unit, including solid-state power transfer switches, does not change state for at least 50 milliseconds;

(3) Any watchdog circuit satisfies all its performance specifications;

(4) The firing unit satisfies all its performance specifications when any of its monitoring circuits' output ports are subjected to

a short circuit or the highest positive or negative voltage capable of being supplied by the monitor batteries or other power supplies; and

(5) The firing unit satisfies all its performance specifications when subjected to any reverse polarity voltage that could occur during launch processing.

(i) *Repetitive functioning.* This test must demonstrate that a firing unit satisfies all its performance specifications when subjected to repetitive functioning for five times the worst-case number of cycles required for acceptance, checkout and operations, including any retest due to schedule delays.

(j) *Static discharge.* A static discharge test must demonstrate that an exploding bridgewire will not fire and satisfies all its performance specifications when subjected to any electrostatic discharge that it could experience from personnel or conductive surfaces. The test must subject an exploding bridgewire to the greater of:

(1) A 25k-volt, 500-picofarad pin-to-pin discharge through a 5k-ohm resistor and a 25k-volt, 500-picofarad pin-to-case discharge with no resistor; or

(2) The maximum predicted pin-to-pin and pin-to-case electrostatic discharge.

(k) *Exploding bridgewire status-of-health.* An exploding bridgewire status-of-health test must satisfy section E417.3(f). This must include measuring the bridgewire insulation resistance at operating voltage.

(l) *Safety devices.* This test must demonstrate that any protection circuitry that is internal to an exploding bridgewire, such as a spark gap, satisfies all its performance specifications and will not degrade the bridgewire's performance or reliability when exposed to the qualification environments. The test must include static gap breakdown, dynamic gap breakdown, and specification hold-off voltage under sustained exposure.

(m) *Firing tests*—(1) *General.* Each firing test of an exploding bridgewire must satisfy all of the following:

(i) Each test must demonstrate that the exploding bridgewire satisfies all its performance specifications when subjected to qualification stress conditions;

(ii) The number of exploding bridgewire samples that each test must fire and the test conditions, including firing voltage and temperature, must satisfy each table of this section;

(iii) Before initiation, each component sample must experience the required temperature for enough time to achieve thermal equilibrium;

(iv) Each test must subject each exploding bridgewire sample to a high voltage initiation source that duplicates the exploding bridgewire firing unit output waveform and impedance, including high voltage cabling; and

(v) Each test must measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the ordnance output satisfies all its performance specifications.

(2) *All-fire voltage.* Each all-fire voltage test must subject each exploding bridgewire sample to the manufacturer specified all-fire energy level for voltage, current, and pulse duration.

(3) *Operating voltage.* Each operating voltage test must subject each exploding bridgewire sample to the firing unit's manufacturer specified operating voltage, current, and pulse duration. If the operating energy is unknown, the test must use no less than 200% of the all-fire voltage.

(4) *Twice-operating voltage.* This test must subject each exploding bridgewire sample to 200% of the operating voltage.

(5) *Ambient-temperature.* This test must initiate each exploding bridgewire sample while at ambient temperature.

(6) *High-temperature.* Each high-temperature test must initiate each exploding bridgewire sample while it is subjected to the manufacturer specified high-temperature level or at a +71 °C workmanship screening level, whichever is higher.

(7) *Low-temperature.* Each low-temperature test must initiate each exploding bridgewire sample while it is subjected to the manufacturer specified low-temperature level or at a –54 °C workmanship screening level, whichever is lower.

(n) *Radio frequency impedance.* A radio frequency impedance test must determine an exploding bridgewire's radio frequency impedance for use in any system radio frequency susceptibility analysis.

(o) *Radio frequency sensitivity.* A radio frequency sensitivity test must consist of a statistical firing series of exploding bridgewire lot samples to determine the radio frequency sensitivity of the exploding bridgewire. The test must demonstrate that the radio frequency no-fire energy level does not exceed the level used in the flight termination system design and analysis.

(p) *No-fire energy level.* A no-fire energy level test must consist of a statistical firing series of exploding bridgewire lot samples to determine the highest electrical energy level at which the exploding bridgewire will not fire with a reliability of 0.999 with a 95% confidence level when subjected to a continuous current pulse. The test must demonstrate that the no-fire energy level is no less than the no-fire energy level used in the flight termination system design and analysis.

(q) *All-fire energy level.* An all-fire energy level test must consist of a statistical firing series of exploding bridgewire lot samples to determine the lowest electrical energy level at which the exploding bridgewire will fire with a reliability of 0.999 with a 95% confidence level when subjected to a current pulse simulating the firing unit output waveform and impedance characteristics. Each exploding bridgewire sample must be in its flight configuration, and must possess any internal safety devices, such as a spark gap, employed in the flight configuration. The test must demonstrate that the all-fire energy level does not exceed the all-fire energy level used in the flight termination system design and analysis.

(r) *Auto-ignition.* This test must demonstrate that an exploding bridgewire does not experience auto-ignition, sublimation, or melting when subjected to any high-temperature environment during handling, testing, storage, transportation, installation, or flight. The test must include all of the following:

(1) The test environment must be no less than 30 °C higher than the highest non-operating or operating temperature that the device could experience;

(2) The test duration must be the maximum predicted high-temperature duration or one hour, whichever is greater; and

(3) After exposure to the test environment, each exploding bridgewire sample must undergo external and internal examination, including any dissection needed to identify any auto-ignition, sublimation, or melting.

E417.29 Ordnance interrupter

(a) *General.* This section applies to any ordnance interrupter that is part of a flight termination system, including any rotor lead or booster charge that is used by the interrupter. Any ordnance interrupter, rotor lead, or booster charge must satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

Table E417.29-1

Ordnance Interrupter Acceptance	Section	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Identification Check	E417.5(e)	100%
Performance Verification:	E417.3(d)	
Status-of-Health [1]	E417.29(b)	100%
Safe-and-arm position monitor [1]	E417.29(c)	100%
Safety Tests:	E417.29(d)(1)	
Manual Safing	E417.29(d)(5)	100%
Safing-interlock	E417.29(d)(6)	100%
Abbreviated Performance Verification:	E417.3(e)	
Interrupter Abbreviated Performance [2]	E417.29(e)	100%
Operating Environment Tests:	E417.13	
Thermal Cycling	E417.13(d)	100%
Random Vibration	E417.13(b)	100%
X-ray	E417.5(f)	100%
Leakage [3]	E417.5(h)	100%

(1) A component must undergo this test before the first and again after the last environmental test.

(2) A component must undergo this test during each operating environment test.

(3) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.29-2

Ordnance Interrupter Qualification	Section	Quantity Tested X=		
		1	6	3
Barrier Alignment	E417.29(g)			
Acceptance Tests	Table E417.29-1	X	X	-
Safety Tests:	E417.29(d)(1)			
Extended Stall [(1)]	E417.29(d)(4)	X	-	-
Abnormal Drop [(1)]	E417.9(1)	X	-	-
Containment	E417.29(d)(2)	-	-	1
Barrier Functionality	E417.29(d)(3)			
High-temperature	E417.29(d)(3)(i)	-	-	1
Low-temperature	E417.29(d)(3)(ii)	-	-	1
Non-Operating Environment Tests:	E417.9			
Storage Temperature	E417.9(b)	-	X	-
Transportation Shock	E417.9(d)	-	X	-
Bench Handling	E417.9(e)	-	X	-
Transportation Vibration	E417.9 (f)	-	X	-
Fungus Resistance	E417.9(g)	-	1	-
Salt Fog	E417.9(h)	-	1	-
Fine Sand	E417.9(i)	-	1	-
Handling Drop	E417.9(k)	-	X	-
Performance Verification:	E417.3(d)			
Status-of-Health [(2)]	E417.29(b)		X	
Abbreviated Performance Verification:	E417.3(e)			

Interrupter Abbreviated Performance [3]	E417.29(e)		X	
Operating Environment Tests:	E417.11			
Thermal Cycling	E417.11(h)	-	X	-
Humidity	E417.11(g)	-	X	-
Acceleration	E417.11(f)	-	X	-
Shock	E417.11(e)	-	X	-
Sinusoidal Vibration	E417.11(b)	-	X	-
Acoustic	E417.11(d)	-	X	-
Random Vibration	E417.11(c)	-	X	-
Explosive Atmosphere	E417.11(k)	-	X	-
Repetitive Function	E417.29(h)	-	X	-
Stall	E417.29(I)	-	X	-
X-ray	E417.5(f)	-	X	-
Leakage [4]	E417.5(h)	-	X	-
Internal Inspection	E417.5(g)	-	2	-
Firing Tests:	E417.29(f)(1)			
High-temperature	E417.29(f)(3)	-	2	-
Low-temperature	E417.29(f)(4)	-	2	-
	I			

(1) This test is only required for an ordnance interrupter that uses a rotor or booster charge.

(2) A component must undergo this test before the first and again after the last operating environment test.

(3) A component must undergo this test during each operating environment test.

(4) An unsealed component that has successfully completed salt-fog, humidity, fungus resistance, and fine sand qualification tests need not undergo a leakage test.

Table E417.29-3

Ordnance Interrupter Rotor Lead and Booster Charge Acceptance [(1)]	**Section**	**Quantity Tested**
Non-Destructive Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Leakage	E417.5(h)	100%
X-ray and N-ray	E417.5(f)	100%
Non-Operating Environment Tests and	E417.9	
Operating Environment Tests:	E417.11	
Thermal Cycling [(2)]	E417.11(h)	Lot Sample [(4)]
High-temperature Storage [(3)]	E417.9(c)	Lot Sample
Component Examination:	E417.5	
Leakage	E417.5(h)	Lot Sample
X-ray and N-ray	E417.5(f)	Lot Sample
Firing Tests:	E417.29(f)(1)	
High-temperature	E417.29(f)(3)	½ Lot Sample
Low-temperature	E417.29(f)(4)	½ Lot Sample

(1) This table applies to any rotor lead or booster charge that is used by an ordnance interrupter.

(2) This test must subject the component to the qualification environmental test level. For a rotor lead or booster charge that is internal to an ordnance interrupter, the test level must be no less than the environment that the rotor lead or booster charge experiences when installed and the ordnance interrupter is subjected to the ordnance interrupter's qualification environment.

(3) A high-temperature storage test is optional. A lot will have an initial service-life of five years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) The lot sample quantity must be no less than 10 percent of the lot or 10 sample units, whichever is greater.

Table E417.29-4

Ordnance Interrupter Rotor Lead and Booster Charge Qualification [1]	Section E417.7	Quantity Tested X=21 [4]
Component Examination:	E417.5	
Visual Examination	E417.5(b)	X
Dimension Measurement	E417.5(c)	X
Leakage	E417.5(h)	X
X-ray and N-ray	E417.5(f)	X
Non-Operating and Operating Environment Tests:	E417.9 E417.11	
Thermal Cycling [2]	E417.11(h)	X
High-temperature Storage [3]	E417.9(c)	10
Shock [2]	E417.11(e)	X
Random Vibration [2]	E417.11(c)	X
Component Examination:	E417.5	
X-ray and N-ray	E417.5(f)	X
Leakage	E417.5(h)	X
Firing Tests:	E417.29(f)(1)	
Ambient-temperature	E417.29(f)(2)	7
High-temperature	E417.29(f)(3)	7
Low-temperature	E417.29(f)(4)	7

(1) This table applies to any rotor lead or booster charge that is used by an ordnance interrupter.

(2) This test must subject the component to the qualification environmental test level. For a rotor lead or booster charge that is internal to an ordnance interrupter, the

test level must be no less than the environment that the rotor lead or booster charge experiences when installed and the ordnance interrupter is subjected to the ordnance interrupter's qualification environment.

(3) A high-temperature storage test is optional. A lot will have an initial service-life of five years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) The same 21 sample components, from the same lot, must be subjected to each test designated with an X. For tests designated with a lessor quantity, each component tested must be one of the original 21 sample components.

Table E417.29-5

Ordnance Interrupter Rotor Lead and Booster Charge Service-life Extension [1]	**Section E417.15**	**Quantity Tested** [3]	
		1 Year [4] **X=5**	**5 Years** [5] **X=10**
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Non-Operating Environment Tests and	E417.9		
Operating Environment Tests:	E417.11		
Thermal Cycling [2]	E417.11(h)	X	X
High-temperature Storage	E417.9(c)	-	X
Component Examination:	E417.5		
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Firing Tests:	E417.29(f)(1)		
High-temperature	E417.29(f)(3)	2	5
Low-temperature	E417.29(f)(4)	3	5

(1) This table applies to any rotor lead or booster charge that is used by an ordnance interrupter. In order to extend a rotor lead or booster charge service live, the rotor lead or charge must undergo the tests required by the one-year column or the five-year column before its initial service-life or any previous service-life extension expires.

(2) This test must subject the component to the qualification environmental test levels. For a rotor lead or booster charge that is internal to an ordnance interrupter, the test level must be no less than the environment that the rotor lead or booster charge experiences when installed and the ordnance interrupter is subjected to ordnance interrupter's qualification environment.

(3) For each column, the quantity of sample components required at the top of the column must be from the same production lot and must undergo each test designated with an X. For a test designated with a lessor quantity, each component must be one of the original samples for that column.

(4) Five sample components from the same lot must undergo each test required by this column to extend the service-life of the remaining components from the same lot for one year.

(5) Ten components from the same lot must undergo each test required by this column to extend the service-life of the remaining components from the same lot for five years.

(b) *Status-of-health*. An ordnance interrupter status-of-health test must satisfy section E45417.3(f). This must include measuring the interrupter's safe-and-arm transition time.

(c) *Safe-and-arm position monitor*. This test must demonstrate all of the following:

(1) That an ordnance interrupter's safe-and-arm transition operation, such as rotation or sliding, satisfies all its performance specifications;

(2) That any ordnance interrupter-monitoring device can determine, before flight, if the ordnance interrupter is in the proper flight configuration;

(3) The presence of the arm indication when the ordnance interrupter is armed; and

(4) The presence of the safe indication when the ordnance interrupter is safed.

(d) *Safety tests*—(1) *General*. Each safety test must demonstrate that an ordnance interrupter is safe to handle and use on the launch vehicle.

(2) *Containment*. For any ordnance interrupter that has an internal rotor charge, a containment test must demonstrate that the interrupter will not fragment when the internal charge is initiated.

(3) *Barrier functionality*. A barrier functionality test must demonstrate that, when the ordnance interrupter is in the safe position, if the donor transfer line or the internal rotor charge is initiated, the ordnance output will not propagate to an explosive transfer system. The test must consist of firing tests at high- and low-temperature extremes with an explosive transfer system that simulates the flight configuration. The number of samples that the test must fire and the test conditions must satisfy each table of this section and all of the following:

(i) *High-temperature*. A high-temperature test must initiate each ordnance sample while it is subjected to no lower than the qualification high-temperature level or a 71 °C workmanship screening level, whichever is higher; and

(ii) *Low-temperature*. A low-temperature test must initiate each ordnance sample while it is subjected to no higher than the qualification low-temperature level or a −54 °C workmanship screening level, whichever is lower.

(4) *Extended stall*. For an ordnance interrupter with an internal rotor or booster charge, an extended stall test must demonstrate that the interrupter does not initiate when:

(i) Locked in its safe position; and

(ii) Subjected to a continuous operating arming voltage for the maximum predicted time that could occur accidentally or one hour, whichever is greater.

(5) *Manual safing*. A manual safing test must demonstrate that an ordnance interrupter can be manually safed.

(6) *Safing-interlock*. A safing-interlock test must demonstrate that when an ordnance interrupter's safing-interlock is in place and operating arming current is applied, the interlock prevents arming and satisfies any other performance specification of the interlock.

(e) *Interrupter abbreviated performance*. An interrupter abbreviated performance test must satisfy section E417.3(e). This must include continuous monitoring of the interrupter's arm monitoring circuit. An ordnance interrupter must undergo this test while armed.

(f) *Firing tests*. (1) General. A firing test of an ordnance interrupter, rotor lead, or booster charge must satisfy all of the following:

(i) The test must demonstrate that the initiation and output energy transfer of each ordnance charge satisfies all its performance specifications and that the component does not fragment;

(ii) The number of samples that the test must fire and the test conditions, including firing current and temperature, must satisfy each table of this section;

(iii) Before initiation, each component sample must experience the required temperature for enough time to achieve thermal equilibrium;

(iv) The test of an ordnance interrupter must simulate the flight configuration, including the explosive transfer system lines on the input and output;

(v) Each test of a rotor lead or booster charge must subject the component to an energy source that simulates the flight energy source;

(vi) Each test must measure each ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the output satisfies all its performance specifications; and

(vii) For a single interrupter that contains more than one firing path, the test must demonstrate that the initiation of one firing path does not adversely affect the performance of any other path.

(2) *Ambient-temperature*. This test must initiate each ordnance sample while it is at ambient temperature.

(3) *High-temperature*. A high-temperature test must initiate each ordnance sample while it is subjected to no lower than the qualification high-temperature level or a +71 °C workmanship level, whichever is higher.

(4) *Low-temperature*. A low-temperature test must initiate each ordnance sample while it is subjected to no higher than the qualification low-temperature level or a − 54 °C workmanship level, whichever is lower.

(g) *Barrier alignment*. A barrier alignment test must consist of a statistical firing series of ordnance interrupter samples. The test must demonstrate that the interrupter's safe to arm transition motion provides for ordnance initiation with a reliability of 0.999 at a 95% confidence level. The test must also demonstrate that the interrupter's arm to safe transition motion provides for no ordnance initiation with a reliability of 0.999 at a 95% confidence level. The test may employ a reusable ordnance interrupter subassembly that simulates the flight configuration.

(h) *Repetitive function*. A repetitive function test must demonstrate the ability of an ordnance interrupter to satisfy all its performance specifications when subjected to five times the maximum predicted number of safe-to-arm and arm-to-safe cycles.

(i) *Stall*. A stall test must demonstrate that an ordnance interrupter satisfies all its performance specifications after being locked in its safe position and subjected to an operating arming voltage for the greater of:

(1) Five minutes; or

(2) The maximum predicted time that could occur inadvertently and the interrupter would still be used for flight.

E417.31 Percussion-activated device (PAD)

(a) *General*. This section applies to any percussion-activated device that is part of a flight termination system, including any primer charge it uses. Any percussion-activated device or primer charge must satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

Table E417.31-1

Percussion-activated Device Lot Acceptance [1]	Section	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Identification Check	E417.5(e)	100%
Status-of-health	E417.31(c)	100%
Leakage	E417.5(h)	100%
X-ray and N-ray	E417.5(f)	100%
Non-Operating Environment Tests and	E417.9	
Operating Environment Tests:	E417.11	
Thermal Cycling [2]	E417.11(h)	Lot Sample[4]
High-temperature Storage: [3]	E417.9(c)	Lot Sample
Shock [2]	E417.11(e)	Lot Sample
Random Vibration [2]	E417.11(c)	Lot Sample
Component Examination:	E417.5	
Leakage	E417.5(h)	Lot Sample
Safety Tests	E417.31(b)	Lot Sample
X-ray and N-ray	E417.5(f)	Lot Sample
Percussion-activated Device Firing Tests:	E417.31(d)(1)	
Ambient-temperature	E417.31(d)(2)	1/3 of Lot Sample
High-temperature	E417.31(d)(3)	1/3 of Lot Sample
Low-temperature	E417.31(d)(4)	1/3 of Lot Sample

(1) The tests required by this table apply to a fully assembled percussion-activated device including all internal ordnance.

(2) This test must subject each percussion-activated device sample to the qualification environmental test level.

(3) A high-temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(4) The lot sample quantity must be no less than the greater of 10% of the lot or nine sample units.

Table E417.31-2

Percussion-activated Device Qualification	Section	Quantity Tested [2]	
		X=5	X=21
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Identification Check	E417.5(e)	X	X
Status-of-health	E417.31(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Safety Tests:	E417.31(b)(1)		
No-fire impact	E417.31(b)(2)	-	X
Safing-interlock Locking	E417.31(b)(3)	-	X
Safing-interlock Retention	E417.31(b)(4)	-	X
Non-Operating Environment Tests and	E417.9		
Operating Environment Tests:	E417.11		

Storage Temperature	E417.9(b)	-	X
Transportation Shock	E417.9(d)	-	X
Bench Handling	E417.9(e)	-	X
Transportation Vibration	E417.9(f)	-	X
Fungus Resistance	E417.9(g)	-	4
Salt Fog	E417.9(h)	-	4
Fine Sand	E417.9(I)	-	4
Handling Drop	E417.9(k)	-	X
Thermal Cycling	E417.11(h)	-	X
High-temperature Storage [(1)]	E417.9(c)	-	X
Humidity	E417.11(g)	-	4
Acceleration	E417.11(f)	-	X
Shock	E417.11(e)	-	X
Sinusoidal Vibration	E417.11(b)	-	X
Random Vibration	E417.11(c)	-	X
Abnormal Drop	E417.9(l)	1	-
Auto Ignition [(4)]	E417.31(g)	X	-
Component Examination:	E417.5		
Leakage	E417.5(h)	-	X
X-ray and N-ray	E417.5(f)	-	X
Internal Inspection	E417.5(g)	-	3 [(3)]
Percussion-activated Device Firing Tests:	E417.31(d)(1)		
Ambient-temperature	E417.31(d)(2)	-	6
High-temperature	E417.31(d)(3)	-	6
Low-temperature	E417.31(d)(4)	-	6

(1) A high-temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(2) For each column, the required quantity of sample components from the same lot must undergo each test designated with an X. For a test designated with a lessor quantity, each component tested must be one of the original samples for that column.

(3) One of the three disassembled sample components must be a sample that was subjected to all non-operating environment tests required by this table except for the abnormal drop test.

(4) An auto ignition test applies to any ordnance internal to a percussion-activated device. The ordnance may undergo the test in a subassembly.

Table E417.31-3

Percussion-activated Device Primer Charge Lot Acceptance [1]	Section	Quantity Tested	
Component Examination:	E417.5		
Visual Examination	E417.5(b)	100%	
Dimension Measurement	E417.5(c)	100%	
Leakage	E417.5(h)	100%	
X-ray and N-ray	E417.5(f)	100%	
Operating Environment Tests:	E417.11		
Thermal Cycle	E417.11(h)	Lot Sample [4]	-
Component Examination:	E417.5		
Visual Examination	E417.5(b)	Lot Sample	-
Dimension Measurement	E417.5(c)	Lot Sample	-
Leakage	E417.5(h)	Lot Sample	-
X-ray and N-ray	E417.5(f)	Lot Sample	-
Primer Charge Firing Tests:	E417.31(f)(1)		
All-Fire Impact:	E417.31(f)(2)		
High-temperature [2]	E417.31(f)(6)	½ Lot Sample	-
Low-temperature [2]	E417.31(f)(7)	½ Lot Sample	-
All-Fire [3]	E417.31(e)	-	Statistical Sample

(1) Each test required by this table applies to a primer charge before its installation in a percussion-activated device.

(2) This test must subject each sample primer charge to the all-fire impact determined by the statistical all-fire impact series required during the qualification testing of table E417.31-4.

(3) This test must demonstrate that the production lot is a representative sample of the all-fire baseline established during the qualification testing required by table E417.31-4.

(4) The lot sample quantity must be no less than the greater of 10% of the lot or 30 sample units.

Table E417.31-4

Percussion-activated Device Primer Charge Qualification	Section	Quantity Tested X=	
		Statistical Sample	105
Component Examination	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
All-Fire Energy Level	E417.31(e)	X	-
Operating Environmental Tests:	E417.11		
Thermal Cycling	E417.11(h)	-	X
Component Examination:	E417.5		
Leakage	E417.5(h)	-	X
X-ray and N-ray	E417.5(f)	-	X
Primer Charge Firing Tests:	E417.31(f)(1)		
Ambient-temperature:	E417.31(f)(5)		
All-Fire Impact (1)	E417.31(f)(2)	-	15
Operational Impact (2)	E417.31(f)(3)	-	15
200% Operational Impact	E417.31(f)(4)	-	5
High-temperature:	E417.31(f)(6)		
All-Fire Impact (1)	E417.31(f)(2)	-	15
Operational Impact (2)	E417.31(f)(3)	-	15
200% Operational Impact	E417.31(f)(4)	-	5

Low-temperature:	E417.31(f)(7)		
All-Fire Impact [(1)]	E417.31(f)(2)	-	15
Operational Impact [(2)]	E417.31(f)(3)	-	15
200% Operational Impact	E417.31(f)(4)	-	5

(1) This test must subject each sample primer charge to the all-fire impact determined by the statistical all-fire impact series required by this table.

(2) This test must subject each sample primer charge to no less than the operational impact that it would receive from the percussion-activated device assembly according to the device's performance specifications, or 200% of the all-fire impact; whichever is greater.

Table E417.31-5

Percussion-activated Device Service-life Extension (1)	Section	Quantity Tested (3) 1 Year (4) X=5	Quantity Tested (3) 3 Years (5) X=10
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Non-Operating Environmental Tests and	E417.9		
Operating Environmental Tests:	E417.11		
Thermal Cycling (2)	E417.11(h)	X	X
High-temperature Storage	E417.9(c)	-	X
Shock (2)	E417.11(e)	X	X
Random Vibration (2)	E417.11(c)	X	X
Component Examination:	E417.5		
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Percussion-activated Device Firing Tests:	E417.31(d)(1)		
High-temperature	E417.31(d)(3)	2	5
Low-temperature	E417.31(d)(4)	3	5

(1) Each test required by this table applies to a fully assembled percussion-activated device including all internal ordnance. In order to extend a percussion-activated device's service-life, the device must undergo the tests required by the one-year

column or the three-year column before its initial service-life or any previous service-life extension expires.

(2) This test must subject each sample percussion-activated device to the qualification environmental level.

(3) For each column, the quantity of sample components required at the top of the column must be from the same production lot and must undergo each test designated with an X. For a test designated with a lessor quantity, each sample component tested must be one of the original samples for that column.

(4) Five sample percussion-activated devices from the same lot must undergo each test required by this column to extend the service-life of remaining percussion-activated devices from the same lot for one year.

(5) Ten sample percussion-activated devices from the same lot must undergo each test required by this column to extend the service-life of remaining percussion-activated devices from the same lot for three years.

(b) *Safety tests*—(1) *General.* Each safety test must demonstrate that a percussion-activated device is safe to handle and use on the launch vehicle.

(2) *No-fire impact.* A no-fire impact test must demonstrate that a percussion-activated device, when pulled with the guaranteed no-fire pull force:

(i) Will not fire;

(ii) The device's primer initiation assembly will not disengage; and

(iii) The device will continue to satisfy all its performance specifications.

(3) *Safing-interlock locking.* A safing-interlock test must demonstrate that, a percussion-activated device, with its safing-interlock in place, will continue to satisfy all its performance specifications and the device's firing assembly will not move more than half the no-fire pull distance when subjected to the greater of:

(i) A 200-pound pull force;

(ii) The device's all-fire pull-force; or

(iii) Twice the worst-case pull force that the device can experience after it is installed on the vehicle.

(4) *Safing-interlock retention test.* A safing-interlock retention test must demonstrate that a percussion-activated device's safing-interlock is not removable when a no-fire pull or greater force is applied to the percussion-activated device lanyard. The test must also demonstrate that the force needed to remove the safing-interlock with the lanyard in an unloaded condition satisfies its performance specification.

(c) *Status-of-health.* A status-of-health test of a percussion-activated device must satisfy section E417.3(f). This test must include measuring the spring constant and firing pull distance.

(d) *Percussion-activated-device firing tests*—(1) *General.* Each firing test of a percussion-activated device must satisfy all of the following:

(i) The test must demonstrate that the device satisfies all its performance specifications when subjected to all qualification stress conditions;

(ii) The number of samples that the test must fire and the test conditions, including temperature, must satisfy each table of this section;

(iii) Before initiation, each component sample must experience the required temperature for enough time to achieve thermal equilibrium;

(iv) The test must subject the device to the manufacturer specified pull-force;

(v) The test must simulate the flight configuration, including the explosive transfer system lines on the output; and

(vi) The test must measure each ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the output satisfies all its performance specifications.

(2) *Ambient-temperature.* This test must initiate each ordnance sample while it is subjected to ambient temperature.

(3) *High-temperature.* A high-temperature test must initiate each ordnance sample while it is subjected to no lower than the qualification high-temperature level or a +71 °C workmanship screening level, whichever is higher.

(4) *Low-temperature.* A low-temperature test must initiate each ordnance sample while it is subjected to no higher than the qualification low-temperature level or a −54 °C workmanship screening level, whichever is lower.

(e) *All-fire energy level.* An all-fire energy level test must consist of a statistical firing series of primer charge lot samples to determine the lowest energy impact at which the primer will fire with a reliability of 0.999 at a 95% confidence level. The test must use a firing pin and configuration that is representative of the flight configuration.

(f) *Primer charge firing tests.* (1) *General.* Each firing test of a primer charge must satisfy all of the following:

(i) The test must demonstrate that the primer charge, including any booster charge or ordnance delay as an integral unit, satisfies all its performance specifications when subjected to all qualification stress conditions;

(ii) The number of samples that the test must fire and the test conditions, including impact energy and temperature, must satisfy each table of this section;

(iii) Before initiation, each component sample must experience the required temperature for enough time to achieve thermal equilibrium;

(iv) The test must use a firing pin and configuration that is representative of the flight configuration; and

(v) The test must measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the ordnance output satisfies all its performance specifications.

(2) *Ambient-temperature.* This test must initiate each ordnance sample while it is subjected to ambient temperature.

(3) *High-temperature.* A high-temperature test must initiate each ordnance sample while it is subjected to no lower than the qualification high-temperature level or a +71 °C workmanship screening level, whichever is higher.

(4) *Low-temperature.* A low-temperature test must initiate each ordnance sample while it is subjected to no higher than the qualification low-temperature level or a −54 °C workmanship screening level, whichever is lower.

(g) *Auto-ignition.* This test must demonstrate that any ordnance internal to a percussion-activated device does not experience auto-ignition, sublimation, or melting when subjected to any high-temperature environment during handling, testing, storage, transportation, installation, or flight. The test must include all of the following:

(1) The test environment must be no less than 30 °C higher than the highest non-operating or operating temperature that the device could experience;

(2) The test duration must be the maximum predicted high-temperature duration or one hour, whichever is greater; and

(3) After exposure to the test environment, each ordnance component must undergo external and internal examination, including any dissection needed to identify any auto-ignition, sublimation, or melting.

E417.33 EXPLOSIVE TRANSFER SYSTEM, ORDNANCE MANIFOLD, AND DESTRUCT CHARGE

(a) *General.* This section applies to any explosive transfer system, ordnance manifold, or destruct charge that is part of a flight termination system. Any explosive transfer system, ordnance manifold, or destruct charge must satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

Table E417.33-1

Explosive Transfer System, Ordnance Manifold and Destruct Charge Lot Acceptance	Section	Quantity Tested		
		Ordnance Manifolds (3) (4)	Explosive Transfer System (5)	Destruct Charges
Component Examination:	E417.5			
Visual Examination	E417.5(b)	100%	100%	100%
Dimension Measurement	E417.5(c)	100%	100%	100%
Leakage	E417.5(h)	100%	100%	100%
X-ray and N-ray	E417.5(f)	100%	100%	100%
Non-operating and Operating Environments:	E417.9 E417.11			
Thermal Cycling (1)	E417.9(c)	Lot Sample (6)	Lot Sample (6)	Lot Sample (6)
High-temperature Storage (2)	E417.11(h)	Lot Sample	Lot Sample	Lot Sample
Shock (1)	E417.11(e)	Lot Sample	Lot Sample	Lot Sample
Random Vibration (1)	E417.11(c)	Lot Sample	Lot Sample	Lot Sample
Tensile Load (7)	E417.9(j)	-	Lot Sample	Lot Sample
Component Examination:	E417.5			
X-ray and N-ray	E417.5(f)	Lot Sample	Lot Sample	Lot Sample
Leakage	E417.5(h)	Lot Sample	Lot Sample	Lot Sample
Firing Tests:	E417.33(b)(1)			
Ambient-temperature	E417.33(b)(2)	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample
High-temperature	E417.33(b)(3)	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample
Low-temperature	E417.33(b)(4)	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample

(1) This test must subject each sample component to the qualification environment.

(2) A high-temperature storage test is optional. A lot will have an initial service-life of five years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(3) Any inert manifold need only undergo visual examination and dimension measurement.

(4) The tests required by this column apply to any manifold that contains a booster charge. A fully assembled manifold, including any internal ordnance must undergo each test.

(5) The required quantity applies to each configuration of explosive transfer line end-tip.

(6) The lot sample quantity must be no less than 10 percent of the lot or nine sample units, whichever is greater.

(7) No less than one half the lot sample quantity must undergo a tensile load test after the operational environment tests. The remainder of the lot sample quantity may undergo the tensile load test before the operational environmental tests.

Table E417.33-2

Destruct Charge Qualification	Section	Quantity Tested			
		X=5	X=2	X=1	X=21
Component Examination:	E417.5				
Visual Examination	E417.5(b)	-	-	X	X
Dimension Measurement	E417.5(c)	-	-	X	X
Leakage	E417.5(h)	-	-	X	X
X-ray and N-ray	E417.5(f)	-	-	X	X
Non-Operating Environment Tests and Operating Environment Tests:	E417.9 E417.11				
Storage Temperature	E417.9(b)	-	-	-	4
Transportation Shock	E417.9(d)	-	-	-	4
Bench Handling	E417.9(e)	-	-	-	4
Transportation Vibration	E417.9(f)	-	-	-	4
Fungus Resistance	E417.9(g)	-	-	-	4
Salt Fog	E417.9(h)	-	-	-	4
Fine Sand	E417.9(i)	-	-	-	4
Thermal Cycling	E417.11(h)	-	-	-	X
High-temperature Storage (1)	E417.9(c)	-	-	-	10
Humidity	E417.11(g)	-	-	-	4
Acceleration	E417.11(f)	-	-	-	X
Shock	E417.11(e)	-	-	-	X
Sinusoidal Vibration	E417.11(b)	-	-	-	X
Random Vibration	E417.11(c)	-	-	-	X
Handling Drop	E417.9(k)	-	-	-	X
Abnormal Drop	E417.9(l)	-	-	X	-
Tensile Load	E417.9(j)	-	-	-	X

Component Examination:	E417.5				
Leakage	E417.5(h)	-	-	-	X
X-ray and N-ray	E417.5(f)	-	-	-	X
Penetration Margin Test	E417.33(c)	X	-	-	-
Propellant Detonation	E417.33(d)	-	X	-	-
Firing Tests:	E417.33(b)(1)				
Ambient-temperature	E417.33(b)(2)	-	-	-	7
High-temperature	E417.33(b)(3)	-	-	-	7
Low-temperature	E417.33(b)(4)	-	-	-	7

(1) A high-temperature storage test is optional. A lot will have an initial service-life of five years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

Table E417.33-3

Explosive Transfer System and Ordnance Manifold Qualification	Section	Quantity (3) (4) Tested	
		X=1	X=21
Component Examination	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Non-Operating Environment Test and Operating Environment Tests:	E417.9 E417.11		
Storage Temperature	E417.9(b)	-	4
Transportation Shock	E417.9(d)	-	4
Bench Handling	E417.9(e)	-	4
Transportation Vibration	E417.9(f)	-	4
Fungus Resistance	E417.9(g)	-	4
Salt Fog	E417.9(h)	-	4
Fine Sand	E417.9(I)	-	4
Thermal Cycling	E417.11(h)	-	X
High-temperature Storage (1)	E417.9(c)	-	10
Humidity	E417.11(g)	-	4
Acceleration (5)	E417.11(f)	-	X
Shock (2) (5)	E417.11(e)	-	X
Sinusoidal Vibration (2) (5)	E417.11(b)	-	X
Random Vibration (2) (5)	E417.11(c)	-	X
Handling Drop	E417.9(k)	-	X
Abnormal Drop	E417.9(l)	X	-
Tensile Load	E417.9(j)	-	X

Component Examination:	E417.5		
Leakage	E417.5(h)	-	X
X-ray and N-ray	E417.5(f)	-	X
Firing Tests:	E417.33(b)(1)		
Ambient-temperature	E417.33(b)(2)	-	7
High-temperature	E417.33(b)(3)	-	7
Low-temperature	E417.33(b)(4)	-	7

(1) A high-temperature storage test is optional. A lot will have an initial service-life of five years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(2) Any explosive transfer system must undergo this test attached to a dynamically equivalent test fixture that simulates each flight configured interface.

(3) The quantity of test samples required by the column applies to explosive transfer lines and explosive manifolds with internal ordnance.

(4) The required quantity applies for each configuration of explosive transfer line end-tip.

(5) Any explosive transfer system manifold must undergo this test with its explosive transfer system assembly attached.

Table E417.33-4

Explosive Transfer System, Explosive Manifold, and Destruct Charge Service-life Extension [1]	Section	Quantity Tested [3]	
		1 Year [4] X=5	5 Years [5] X=10
Component Examination:	E417.5		
Visual Examination	E417.5(b)	X	X
Dimension Measurement	E417.5(c)	X	X
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Non-Operating Environment Test and Operating Environment Tests:	E417.9 E417.11		
Thermal Cycling [2]	E417.11(h)	X	X
High-temperature Storage	E417.9(c)	-	X
Shock [2]	E417.11(e)	X	X
Random Vibration [2]	E417.11(c)	X	X
Tensile load	E417.9(j)	X	X
Component Examination:	E417.5		
Leakage	E417.5(h)	X	X
X-ray and N-ray	E417.5(f)	X	X
Firing Tests:	E417.33(b)(1)		
High-temperature	E417.33(b)(3)	2	5
Low-temperature	E417.33(b)(4)	3	5

(1) In order to extent an explosive transfer system, manifold, or destruct charge service-life, the component must undergo the tests required by the one-year column or the five-year column before its initial service-life or any previous service-life extension expires. For any explosive manifold with internal ordnance, the ordnance may undergo each test installed in the manifold or separately.

(2) This test must subject each sample component to the qualification environmental level.

(3) The quantity required by each column applies for each configuration of explosive transfer line end-tip. For each column, the quantity of sample components required at the top of the column must be from the same production lot and must undergo each test designated with an X. For a test designated with a lessor quantity, each sample component tested must be one of the original samples for that column.

(4) Five sample ordnance components from the same lot must undergo each test required by this column to extend the service-life of the remaining components from the same lot for one year.

(5) Ten sample ordnance components from the same lot must undergo each test required by this column to extend the service-life of the remaining components from the same lot for five years.

(b) *Firing tests*—(1) *General*. A firing test of an explosive transfer system, explosive manifold, or destruct charge must satisfy all of the following:

(i) The test must demonstrate that each ordnance sample satisfies all its performance specifications when subjected to all qualification stress conditions;

(ii) The number of samples that the test must fire and the test conditions, including temperature, must satisfy each table of this section;

(iii) Before initiation, each ordnance sample must experience the required temperature for enough time to achieve thermal equilibrium;

(iv) For any destruct charge, the test must initiate the charge against a witness plate to demonstrate that the charge satisfies all its performance specifications and is in-family;

(v) For any explosive transfer system component, the test must measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the ordnance output satisfies all its performance specifications; and

(vi) For any explosive manifold that contains ordnance, the test must initiate the ordnance using an explosive transfer system in a flight representative configuration.

(2) *Ambient-temperature*. This test must initiate each ordnance sample while it is subjected to ambient temperature.

(3) *High-temperature*. A high-temperature test must initiate each ordnance sample while it is subjected to no lower than the qualification high-temperature level or a +71 °C workmanship screening level, whichever is higher.

(4) *Low-temperature*. A low-temperature test must initiate each ordnance sample while it is subjected to no higher than the qualification low-temperature level or a −54 °C workmanship screening level, whichever is lower.

(c) *Penetration margin*. A penetration margin test must demonstrate a destruct charge's ability to accomplish its intended flight termination function, such as to destroy the pressure integrity of any solid propellant stage or motor or rupture any propellant tank. This must include penetrating no less than 150% of the thickness of the target material. Each test must also demonstrate that the charge is in-family by correlating equivalent penetration depth into a witness plate and comparing the results from each test.

(d) *Propellant detonation*. A propellant detonation test or analysis must demonstrate that a destruct charge will not detonate the propellant of its intended target.

E417.35 SHOCK AND VIBRATION ISOLATORS

(a) *General*. This section applies to any shock or vibration isolator that is part of a flight termination system. Any isolator must satisfy each test or analysis identified by table E417.35–1 to demonstrate that it has repeatable performance and is free of any workmanship defects.

Table E417.35-1

Shock and Vibration Isolator Acceptance (1)	Section	Quantity Tested
Component Examination:	E417.5	
Visual Examination	E417.5(b)	100%
Dimension Measurement	E417.5(c)	100%
Performance Verification Tests:	E417.3	
Load Deflection	E417.35(b)	100%
Status-of-Health	E417.35(c)	100%

(1) Each isolator must undergo the tests required by this table in a configuration that demonstrates whether isolator satisfies all its performance specifications. The test configuration need not be the flight configuration.

(b) *Load deflection.* A load deflection test must demonstrate the ability of a shock or vibration isolator to withstand the full-scale deflection expected during flight while satisfying all its performance specifications and that the isolator is in-family. This must include subjecting each isolator to varying deflection increments from the null position to the full-scale flight deflection and measuring the isolator's spring constant at each deflection increment.

(c) *Status-of-health.* A status-of-health test of a shock or vibration isolator must satisfy section E417.3(f). The test must include all of the following:

(1) The test must measure the isolator's natural frequency while the isolator is subjected to a random vibration or sinusoidal sweep vibration with amplitudes that are representative of the maximum predicted operating environment; and

(2) The test must measure the isolator's dynamic amplification value while the isolator is subjected to a random vibration or sinusoidal sweep vibration with amplitudes that are representative of the maximum predicted operating environment.

E417.37 ELECTRICAL CONNECTORS AND HARNESSES

(a) *General.* This section applies to any electrical connector or harness that is critical to the functioning of a flight termination system during flight, but is not otherwise part of a flight termination system component. Any electrical connector or harness must satisfy each test or analysis identified by table E417.37–1 of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

Table E417-37-1

Electrical Connector and Harness Qualification	Section	Quantity Tested X=2
Non Operating Environments:	E417.9	
Salt Fog [(1)]	E417.9(h)	X
Status-of-health	E417.37(b)	X
Operating Environments:	E417.11	
Humidity [(1)]	E417.11(g)	X
Shock [(2)]	E417.11(e)	X
Sinusoidal Vibration [(2)]	E417.11(b)	X
Random Vibration [(2)]	E417.11(c)	X
Status-of-health	E417.37(b)	X

(1) This test must measure each connector and cable pin to pin and pin-to-case resistance immediately after the connector or harness is subjected to the test environment.

(2) This test must continuously monitor connector and cable continuity using a sample rate of no less than once every millisecond.

(b) *Status-of-health.* A status-of-health test of a harness or connector must satisfy section E417.3(f). The test must include all of the following:

(1) The test must measure the dielectric withstanding voltage between mutually insulated portions of the harness or connector to demonstrate that the harness or connector satisfies all its performance specifications at its rated voltage and withstands any momentary over-potential due to switching, surge, or any other similar phenomena;

(2) The test must demonstrate that the insulation resistance between mutually insulated points is sufficient to ensure that the harness or connector satisfies all its performance specifications at its rated voltage and the insulation material is not damaged after the harness or connector is subjected to the qualification environments;

(3) The test must demonstrate the ability of the insulation resistance between each wire shield and harness or conductor and the insulation between each harness or connector pin to every other pin to withstand a minimum workmanship voltage of 500 VDC or 150% of the rated output voltage, whichever is greater; and

(4) The test must measure the resistance of any wire and harness insulation to demonstrate that it satisfies all its performance specifications.

E417.39 ORDNANCE INTERFACES AND MANIFOLD QUALIFICATION

(a) *General.* This section applies to any ordnance interface or manifold that is part of a flight termination system. Each ordnance interface or manifold must undergo a qualification test that demonstrates that the interface or manifold satisfies its performance specifications with a reliability of 0.999 at a 95% confidence level.

(b) *Interfaces.* A qualification test of an ordnance interface must demonstrate the interface's reliability. This must include all of the following:

(1) The test must use a simulated flight configured interface and test hardware that duplicate the geometry and volume of the firing system used on the launch vehicle; and

(2) The test must account for performance variability due to manufacturing and workmanship tolerances such as minimum gap, maximum gap, and axial and angular offset.

(c) *Detonation flier plate ordnance transfer systems.* A qualification test of a detonation flier plate ordnance transfer system composed of any component that has a charge or initiates a charge such as; electro-explosive devices, exploding bridgewires, ordnance delays, explosive transfer systems, destruct charges, and percussion-activated devices; must demonstrate the system's reliability using one of the following:

(1) A statistical firing series that varies critical performance parameters, including gap and axial and angular alignment, to ensure that ordnance initiation occurs across each flight configured interface with a reliability of 0.999 at a 95% confidence level;

(2) Firing 2994 flight units in a flight representative configuration to demonstrate that ordnance initiation occurs across each flight configured interface with a reliability of 0.999 at a 95% confidence level; or

(3) Firing all of the following units to demonstrate a gap margin that ensures ordnance initiation:

(i) Five units at four times the combined maximum system gap;

(ii) Five units at four times the combined maximum system axial misalignment;

(iii) Five units at four times the combined maximum system angular misalignment; and

(iv) Five units at 50% of the combined minimum system gap.

(d) *Deflagration and pressure sensitive ordnance transfer systems.* A qualification test of a deflagration or pressure sensitive ordnance transfer system composed of devices such as ordnance delays, electro-explosive system low energy end-tips, and percussion-activated device primers must demonstrate the system's reliability using one of the following:

(1) A statistical firing series that varies critical performance parameters, including gap interface, to ensure that ordnance initiation occurs across each flight configured interface;

(2) Firing 2994 flight units in a flight representative configuration to demonstrate that ordnance initiation occurs across each flight configured interface; or

(3) Firing all of the following units to demonstrate a significant gap margin:

(i) Five units using a 75% downloaded donor charge across the maximum gap; and

(ii) Five units using a 120% overloaded donor charge across the minimum gap.

E417.41 Flight termination system pre-flight testing

(a) *General.* A flight termination system, its subsystems, and components must undergo the pre-flight tests required by this section to demonstrate that the system will satisfy all its performance specifications during the countdown and launch vehicle flight. After successful completion of any pre-flight test, if the integrity of the system, subsystem, or component is compromised due to a configuration change or other event, such as a lightning strike or connector demate, the system, subsystem, or component must repeat the pre-flight test.

(b) *Pre-flight component tests.* A component must undergo one or more pre-flight tests at the launch site to detect any change in performance due to any shipping, storage, or other environments that may have affected performance after the component passed the acceptance tests. Each test must measure all the component's performance parameters and compare the measurements to the acceptance test performance baseline to identify any performance variations, including any out-of-family results, which may indicate potential defects that could result in an in-flight failure.

(c) *Silver-zinc batteries.* Any silver-zinc battery that is part of a flight termination system, must undergo the pre-flight activation and tests that table E417.21–1 identifies must take place just before installation on the launch vehicle. The time interval between pre-flight activation and flight must not exceed the battery's performance specification for activated stand time capability.

(d) *Nickel-cadmium batteries.* Any nickel-cadmium flight termination system battery must undergo pre-flight processing and testing before installation on the launch vehicle and the processing and testing must satisfy all of the following:

(1) Any pre-flight processing must be equivalent to that used during qualification testing to ensure the flight battery's performance is equivalent to that of the battery samples that passed the qualification tests;

(2) Each battery must undergo all of the following tests at ambient temperature no later than one year before the intended flight date and again no earlier than two weeks before the first flight attempt:

(i) A status-of-health test that satisfies section E417.22(j);

(ii) A charge retention test that satisfies section E417.22(f); and

(iii) An electrical performance test that satisfies section E417.22(n); and

(3) The test results from the battery acceptance tests of section E417.22 and the one-year and two-week pre-flight tests of paragraph (d)(2) of this section must undergo a comparison to demonstrate that the battery satisfies all its performance specifications.

The flight battery test data must undergo an evaluation to identify any out-of-family performance and to ensure that there is no degradation in electrical performance that indicates an age-related problem.

(4) In the event of a launch schedule slip, after six weeks has elapsed from a preflight test, the battery must undergo the test again no earlier than two weeks before the next launch attempt.

(e) *Pre-flight testing of a safe-and-arm device that has an internal electro-explosive device.* An internal electro-explosive device in a safe-and-arm device must undergo a pre-flight test that satisfies all of the following:

(1) The test must take place no earlier than 10 calendar days before the first flight attempt. If the flight is delayed more than 14 calendar days or the flight termination system configuration is broken or modified for any reason, such as to replace batteries, the device must undergo the test again no earlier than 10 calendar days before the next flight attempt. A launch operator may extend the time between the test and flight if the launch operator demonstrates that the electro-explosive device and its firing circuit will each satisfy all their performance specifications when subjected to the expected environments for the extended period of time;

(2) The test must include visual checks for signs of any physical defect or corrosion; and

(3) The test must include a continuity and resistance check of the electro-explosive device circuit while the safe-and-arm device is in the arm position and again while the device is in the safe position.

(f) *Pre-flight testing of an external electro-explosive device.* An external electro-explosive device that is part of a safe-and-arm device must undergo a pre-flight test that satisfies all of the following:

(1) The test must take place no earlier than 10 calendar days before the first flight attempt. If the flight is delayed more than 14 calendar days or the flight termination system configuration is broken or modified for any reason, such as to replace batteries, the device must undergo the test again no earlier than 10 calendar days before the next flight attempt. A launch operator may extend the time between the test and flight if the launch operator demonstrates that the electro-explosive device and its firing circuit will satisfy all their performance specifications when subjected to the expected environments for the extended period of time; and

(2) The test must include visual checks for signs of any physical defect or corrosion and a resistance check of the electro-explosive device.

(g) *Pre-flight testing of an exploding bridgewire.* An exploding bridgewire must undergo a pre-flight test that satisfies all of the following:

(1) The test must take place no earlier than 10 calendar days before the first flight attempt. If the flight is delayed more than 14 calendar days or the flight termination system configuration is broken or modified for any reason, such as to replace batteries, the exploding bridgewire must undergo the test again no earlier than 10 calendar days before the next flight attempt. A launch operator may extend the time between the test and flight if the launch operator demonstrates that the exploding bridgewire will satisfy all its performance specifications when subjected to the expected environments for the extended period of time.

(2) The test must verify the continuity of each bridgewire.

(3) Where applicable, the test must include a high voltage static test and a dynamic gap breakdown voltage test to demonstrate that any spark gap satisfies all its performance specifications.

(h) *Pre-flight testing for command receiver decoders and other electronic components.* (1) An electronic component, including any component that contains piece part circuitry, such as a command receiver decoder, must undergo a pre-flight test that satisfies all of the following:

(i) The test must take place no earlier than 180 calendar days before flight. If the 180-day period expires before flight, the launch operator must replace the component with one that meets the 180-day requirement or test the component in place on the launch vehicle. The test must satisfy the alternate procedures for testing the component on the launch vehicle contained in the test plan and procedures required by section E417.1(c); and

(ii) The component must undergo the test at ambient temperature. The test must measure all performance parameters measured during acceptance testing.

(2) A launch operator may substitute an acceptance test for a pre-flight test if the acceptance test is performed no earlier than 180 calendar days before flight.

(i) *Pre-flight subsystem and system level test.* A flight termination system must undergo the pre-flight subsystem and system level tests required by this paragraph after the system's components are installed on a launch vehicle to ensure proper operation of the final subsystem and system configurations. Each test must compare data obtained from the test to data from the pre-flight component tests and acceptance tests to demonstrate that there are no discrepancies indicating a flight reliability concern.

(1) *Radio frequency system pre-flight test.* All radio frequency systems must undergo a pre-flight test that satisfies all of the following:

(i) The test must demonstrate that the flight termination system antennas and associated radio frequency systems satisfy all their performance specifications once installed in their final flight configuration;

(ii) The test must measure the system's voltage standing wave ratio and demonstrate that any insertion losses are within the design limits;

(iii) The test must demonstrate that the radio frequency system, from each command control system transmitter antenna used for the first stage of flight to each command receiver satisfies all its performance specifications;

(iv) The test must occur no earlier than 90 days before flight; and

(v) The test must demonstrate the functions of each command receiver decoder and calibrate the automatic gain control signal strength curves, verify the threshold sensitivity for each command, and verify the operational bandwidth.

(2) *End-to-end test of a non-secure command receiver decoder system.* Any flight termination system that uses a non-secure command receiver decoder must undergo an end-to-end test of all flight termination system subsystems, including command destruct systems and inadvertent separation destruct systems. The test must satisfy all of the following:

(i) The test must take place no earlier than 72 hours before the first flight attempt. After the test, if the flight is delayed more than 14 calendar days or the flight termination system configuration is broken or modified for any reason, such as to replace batteries, the system must undergo the end-to-end test again no earlier than 72 hours before the next flight attempt;

(ii) The flight termination system, except for all ordnance initiation devices, must undergo the test in its final onboard launch vehicle configuration;

(iii) The test must use a destruct initiator simulator that satisfies § 417.307(h) in place of each flight initiator to demonstrate that the command destruct and inadvertent separation destruct systems deliver the required energy to initiate the flight termination system ordnance;

(iv) The flight termination system must undergo the test while powered by the batteries that the launch vehicle will use for flight. A flight termination system battery must not undergo recharging at any time during or after the end-to-end test. If the battery is recharged at any time before flight the system must undergo the end-to-end test again;

(v) The end-to-end test must exercise all command receiver decoder functions critical to flight termination system operation during flight, including the pilot or check tone, using the command control system transmitters in their flight configuration or other representative equipment;

(vi) The test must demonstrate that all primary and redundant flight termination system components, flight termination system circuits, and command control system transmitting equipment are operational; and

(vii) The test must exercise the triggering mechanism of all electrically initiated inadvertent separation destruct systems to demonstrate that each is operational.

(3) *Open-loop test of a non-secure command destruct system.* For each flight attempt, any flight termination system that uses a non-secure command receiver decoder must undergo an open-loop radio frequency test, no earlier than 60 minutes before the start of the launch window, to validate the entire radio frequency command destruct link. For each flight attempt, the flight safety system must undergo the test again after any break or change in the system configuration. The test must satisfy all of the following:

(i) The system must undergo the test with all flight termination system ordnance initiation devices in a safe condition;

(ii) Flight batteries must power all receiver decoders and other electronic components. The test must account for any warm-up time needed to ensure the reliable operation of electronic components;

(iii) The test must exercise the command receiver decoder arm function, including the pilot or check tone, using a command control transmitter in its flight configuration;

(iv) The test must demonstrate that each receiver decoder is operational and is compatible with the command control transmitter system; and

(v) Following successful completion of the open-loop test, if any receiver decoder is turned off or the transmitter system fails to continuously transmit the pilot or check tone, the flight termination system must undergo the open-loop test again before flight.

(4) *Initial open-loop test of a secure high-alphabet command destruct system.* Any flight termination system that uses a secure high-alphabet command receiver decoder must undergo an open-loop radio frequency test to demonstrate the integrity of the system between the command control transmitter system and launch vehicle radio frequency system from the antenna to the command receiver decoders. The test must satisfy all of the following:

(i) The test must occur before loading the secure flight code on to the command transmitting system and the command receiver decoders;

(ii) The test must use a non-secure code, also known as a maintenance code, loaded on to the command control transmitting system and the command receiver decoders;

(iii) Each command receiver decoder must be powered by either the ground or launch vehicle power sources;

(iv) The command control transmitter system must transmit, open-loop, all receiver decoder commands required for the flight termination system functions, including pilot or check tone to the vehicle;

(v) The test must demonstrate that each command receiver decoder receives, decodes and outputs each command sent by the command control system; and

(vi) The testing must demonstrate that all primary and redundant flight termination system components, flight termination system circuits, and command control system transmitting equipment are operational.

(5) *End-to-end test of a secure high-alphabet command destruct system.* Any flight termination system that uses a secure high-alphabet command receiver decoder must undergo an end-to-end test of all flight termination system subsystems, including command destruct systems and inadvertent separation destruct systems. The test must satisfy all of the following:

(i) The system must undergo the test no earlier than 72 hours before the first flight attempt. After the test, if the flight is delayed more than 14 calendar days or the flight termination system configuration is broken or modified for any reason, such as to replace batteries, the system must undergo the end-to-end tests again no earlier than 72 hours before the next flight attempt;

(ii) The system must undergo the test in a closed-loop configuration using the secure flight code;

(iii) The flight termination system, except for the ordnance initiation devices, must undergo the test in its final onboard launch vehicle configuration;

(iv) The test must use a destruct initiator simulator that satisfies §417.307(h) in place of each flight initiator to demonstrate that the command destruct and inadvertent separation destruct systems deliver the energy required to initiate the flight termination system ordnance;

(v) The flight termination system must undergo the test while powered by the batteries that the launch vehicle will use for flight. A flight termination system battery must not undergo recharging at any time during or after the end-to-end test. If the battery is recharged at any time before flight the system must undergo the end-to-end test again;

(vi) The test must exercise all command receiver decoder functions critical to flight termination system operation during flight, including the pilot or check tone, in a closed-loop test configuration using ground support testing equipment hardwired to the launch vehicle radio frequency receiving system;

(vii) The test must demonstrate that all primary and redundant launch vehicle flight termination system components and circuits are operational; and

(viii) The test must exercise the triggering mechanism of all electrically initiated inadvertent separation destruct systems to demonstrate that they are operational.

(6) *Abbreviated closed-loop test of a secure high-alphabet command destruct system.* Any flight termination system that uses a secure high-alphabet command receiver decoder must undergo an abbreviated closed-loop test if, due to a launch scrub or delay, more than 72 hours pass since the end-to-end test of paragraph (h)(5) of this section. The test must satisfy all of the following:

(i) The flight termination system must undergo the test in its final flight configuration with all flight destruct initiators connected and in a safe condition;

(ii) The test must occur just before launch support tower rollback or other similar final countdown event that suspends access to the launch vehicle;

(iii) Each command receiver decoder must undergo the test powered by the flight batteries;

(iv) The test must exercise all command receiver decoder functions critical to flight termination system operation during flight except the destruct function, including the pilot or check tone, in a closed-loop test configuration using ground support testing equipment hardwired to the launch vehicle radio frequency receiving system; and

(v) The test must demonstrate that the launch vehicle command destruct system, including each command receiver decoder and all batteries, is functioning properly.

(7) *Final open-loop test of a secure high-alphabet command destruct system.* Any flight termination system that uses a secure high-alphabet command receiver decoder must undergo a final open-loop radio frequency test no earlier than 60 minutes before flight, to validate the entire radio frequency command destruct link from the command control transmitting system to launch vehicle antenna. The test must satisfy all of the following:

(i) The flight termination system must undergo the test in its final flight configuration with all flight destruct initiators connected and in a safe condition;

(ii) Flight batteries must power all receiver decoders and other electronic components. The test must account for any warm-up time needed for reliable operation of the electronic components;

(iii) The test must exercise each command receiver decoder's self-test function including pilot or check tone using the command control system transmitters in their flight configuration;

(iv) The test must demonstrate that each receiver decoder is operational and compatible with the command control transmitter system; and

(v) Following successful completion of the open-loop test, if any command receiver decoder is turned off or the transmitter system fails to continuously transmit the pilot or check tone, the flight termination system must undergo the final open-loop test again before flight.

APPENDIX F TO PART 417 [RESERVED]

APPENDIX G TO PART 417—NATURAL AND TRIGGERED LIGHTNING FLIGHT COMMIT CRITERIA

G417.1 GENERAL

For purposes of this section, the requirement for any weather monitoring and measuring equipment needed to satisfy the lightning flight commit criteria limits the equipment to only that which is needed. Accordingly, the equipment could include a ground-based, or airborne field mill, or a weather radar, but may or may not be limited to those items. Certain equipment, such as a field mill, when utilized with the lightning flight commit criteria, may increase launch opportunities because of the ability to verify the electric field in any cloud within 5 nautical miles of the flight path. However, a field mill is not required in order to satisfy the lightning flight commit criteria.

(a) This appendix provides flight commit criteria to protect against natural lightning and lightning triggered by the flight of a launch vehicle. A launch operator must apply these criteria under §417.113 (c) for any launch vehicle that utilizes a flight safety system.

(b) The launch operator must employ:

(1) Any weather monitoring and measuring equipment needed to satisfy the lightning flight commit criteria.

(2) Any procedures needed to satisfy the lightning flight commit criteria.

(c) If a launch operator proposes any alternative lightning flight commit criteria, the launch operator must clearly and convincingly demonstrate that the alternative provides an equivalent level of safety.

G417.3 DEFINITIONS, EXPLANATIONS AND EXAMPLES

For the purpose of appendix G417:

Anvil cloud means a stratiform or fibrous cloud produced by the upper level outflow or blow-off from thunderstorms or convective clouds.

Associated means that two or more clouds are causally related to the same weather disturbance or are physically connected. Associated does not have to mean occurring at the same time. A cumulus cloud formed locally and a cirrus layer that is physically separated from that cumulus cloud and that is generated by a distant source are not associated, even if they occur over or near the launch point at the same time.

Bright band means an enhancement of radar reflectivity caused by frozen hydrometeors falling and beginning to melt at any altitude where the temperature is 0 degrees Celsius or warmer.

Cloud means a visible mass of water droplets or ice crystals produced by condensation of water vapor in the atmosphere.

Cloud edge means the visible boundary, including the sides, base, and top, of a cloud as seen by an observer. In the absence of a visible boundary as seen by an observer, the 0 dBZ radar reflectivity boundary defines a cloud edge.

Cloud layer means a vertically continuous array of clouds, not necessarily of the same type, whose bases are approximately at the same level.

Cumulonimbus cloud means any convective cloud with any part at an altitude where the temperature is colder than -20 degrees Celsius.

Debris cloud means any cloud, except an anvil cloud, that has become detached from a parent cumulonimbus cloud or thunderstorm, or that results from the decay of a parent cumulonimbus cloud or thunderstorm.

Disturbed Weather means a weather system where dynamical processes destabilize the air on a scale larger than the individual clouds or cells. Examples of disturbed weather include fronts and troughs.

Electric field measurement aloft means the magnitude of the instantaneous vector electric field (E) at a known position in the atmosphere, such as measured by a suitably instrumented, calibrated, and located airborne-field-mill aircraft.

Electric field measurement at the surface of Earth means the 1-minute arithmetic average of the vertical electric field (Ez) at the ground measured by a ground-based field mill. The polarity of the electric field is the same as that of the potential gradient; that is, the polarity of the field at Earth's surface is the same as the dominant charge overhead. An interpolation based on electric field contours is not a measurement for purposes of this appendix.

Field mill is a specific class of electric-field sensor that uses a moving, grounded conductor to induce a time-varying electric charge on one or more sensing elements in proportion to the ambient electrostatic field.

Flight path means the planned normal flight trajectory, including its vertical and horizontal uncertainties to include the sum of the wind effects and the three-sigma guidance and performance deviations.

Moderate precipitation means a precipitation rate of 0.1 inches/hr or a radar reflectivity factor of 30 dBZ.

Nontransparent means cloud cover is nontransparent if (1) forms seen through it are blurred, indistinct, or obscured; or (2) forms are seen distinctly only through breaks in the cloud cover. Clouds with a radar reflectivity factor of 0 dBZ or greater are also nontransparent.

Ohms/Square means the surface resistance in ohms when a measurement is made from an electrode on one surface extending the length of one side of a square of any size to an electrode on the same surface extending the length of the opposite side of the square. The resistance measured in this way is independent of the area of a square.

Precipitation means detectable rain, snow, hail, graupel, or sleet at the ground; virga, or a radar reflectivity factor greater than 18 dBZ at altitude.

Specified Volume means the volume bounded in the horizontal by vertical plane, perpendicular sides located 5.5 km (3 NM) north, east, south, and west of the point on the flight track, on the bottom by the 0 degree C level, and on the top by the upper extent of all clouds.

Thick cloud layer means one or more cloud layers whose combined vertical extent from the base of the bottom layer to the top of the uppermost layer exceeds a thickness of 4,500 feet. Cloud layers are combined with neighboring layers for determining total thickness only when they are physically connected by vertically continuous clouds, as, for example, when towering clouds in one layer contact or merge with clouds in a layer (or layers) above.

Thunderstorm means any convective cloud that produces lightning.

Transparent Cloud cover is transparent if objects above, including higher clouds, blue sky, and stars can be distinctly seen from below; or objects, including terrain, buildings, and lights on the ground, can be distinctly seen from above. Transparency is only defined for the visible wavelengths.

Triboelectrification means the transfer of electrical charge from ice particles to the launch vehicle when the ice particles rub the vehicle during impact.

Volume-Averaged, Height-Integrated Radar Reflectivity (units of dBZ-kilometers) means the product of the volume-averaged radar reflectivity and the average cloud thickness within a specified volume relative to a point along the flight track.

Within is a function word used to specify a distance in all directions (horizontal, vertical, and slant separation) between a cloud edge and a flight path. For example, ''within 10 nautical miles of a thunderstorm cloud'' means that there must be a 10 nautical mile margin between every part of a thunderstorm cloud and the flight path.

G417.5 LIGHTNING

(a) A launch operator must not initiate flight for 30 minutes after any type of lightning occurs in a thunderstorm if the flight path will carry the launch vehicle within 10 nautical miles of that thunderstorm.

(b) A launch operator must not initiate flight for 30 minutes after any type of lightning occurs within 10 nautical miles of the flight path unless:

(1) The cloud that produced the lightning is not within 10 nautical miles of the flight path;

(2) There is at least one working field mill within 5 nautical miles of each such lightning flash; and

(3) The absolute values of all electric field measurements made at the Earth's surface within 5 nautical miles of the flight path and at each field mill specified in paragraph (b)(2) of this section have been less than 1000 volts/meter for 15 minutes or longer.

(c) If a cumulus cloud remains 30 minutes after the last lightning occurs in a thunderstorm, section G417.7 applies. Sections G417.9 and G417.11 apply to any anvil or detached anvil clouds. Section G417.13 applies to debris clouds.

G417.7 CUMULUS CLOUDS

For the purposes of this section, ''cumulus clouds'' do not include altocumulus, cirrocumulus, or stratocumulus clouds.

(a) A launch operator must not initiate flight if the flight path will carry the launch vehicle within 10 nautical miles of any cumulus cloud that has a cloud top at an altitude where the temperature is colder than −20 degrees Celsius.

(b) A launch operator must not initiate flight if the flight path will carry the launch vehicle within 5 nautical miles of any cumulus cloud that has a cloud top at an altitude where the temperature is colder than −10 degrees Celsius.

(c) A launch operator must not initiate flight if the flight path will carry the launch vehicle through any cumulus cloud with its cloud top at an altitude where the temperature is colder than −5 degrees Celsius.

(d) A launch operator must not initiate flight if the flight path will carry the launch vehicle through any cumulus cloud that has a cloud top at an altitude where the temperature is between +5 degrees Celsius and −5 degrees Celsius unless:

(1) The cloud is not producing precipitation;

(2) The horizontal distance from the center of the cloud top to at least one working field mill is less than 2 nautical miles; and

(3) All electric field measurements made at the Earth's surface within 5 nautical miles of the flight path and at each field mill used as required by paragraph (d)(2) of this section have been between −100 volts/meter and +500 volts/meter for 15 minutes or longer.

G417.9 ATTACHED ANVIL CLOUDS

(a) A launch operator must not initiate flight if the flight path will carry the launch vehicle through, or within 10 nautical miles of, a nontransparent part of any attached anvil cloud for the first 30 minutes after the last lightning discharge in or from the parent cloud or anvil cloud.

(b) A launch operator must not initiate flight if the flight path will carry the launch vehicle through, or within 5 nautical miles of, a nontransparent part of any attached anvil cloud between 30 minutes and three hours after the last lightning discharge in or from the parent cloud or anvil cloud unless:

(1) The portion of the attached anvil cloud within 5 nautical miles of the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(2) The volume-averaged, height-integrated radar reflectivity is less than +33 dBZ-kft everywhere along the portion of the flight path where any part of the attached anvil cloud is within the volume.

(c) A launch operator must not initiate flight if the flight path will carry the launch vehicle through a nontransparent part of any attached anvil cloud more than 3 hours after the last lightning discharge in or from the parent cloud or anvil cloud unless:

(1) The portion of the attached anvil cloud within 5 nautical miles of the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(2) The volume-averaged, height-integrated radar reflectivity is less than +33 dBZ-kft everywhere along the portion of the flight path where any part of the attached anvil cloud is within the specified volume.

G417.11 Detached Anvil Clouds

For the purposes of this section, detached anvil clouds are never considered debris clouds.

(a) A launch operator must not initiate flight if the flight path will carry the launch vehicle through or within 10 nautical miles of a nontransparent part of a detached anvil cloud for the first 30 minutes after the last lightning discharge in or from the parent cloud or anvil cloud before detachment or after the last lightning discharge in or from the detached anvil cloud after detachment.

(b) A launch operator must not initiate flight if the flight path will carry the launch vehicle within 5 nautical miles of a nontransparent part of a detached anvil cloud between 30 minutes and 3 hours after the time of the last lightning discharge in or from the parent cloud or anvil cloud before detachment or after the last lightning discharge in or from the detached anvil cloud after detachment unless section (1) or (2) is satisfied:

(1) This section is satisfied if all three of the following conditions are met:

(i) There is at least one working field mill within 5 nautical miles of the detached anvil cloud; and

(ii) The absolute values of all electric field measurements at the surface within 5 nautical miles of the flight path and at each field mill specified in (1) above have been less than 1000 V/m for 15 minutes; and

(iii) The maximum radar return from any part of the detached anvil cloud within 5 nautical miles of the flight path has been less than 10 dBZ for 15 minutes.

(2) This section is satisfied if both of the following conditions are met:

(i) The portion of the detached anvil cloud within 5 nautical miles of the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(ii) The volume-averaged, height-integrated radar reflectivity is less than +33 dBZ-kft everywhere along the portion of the flight path where any part of the detached anvil cloud is within the specified volume.

(c) A launch operator must not initiate flight if the flight path will carry the launch vehicle through a nontransparent part of a detached anvil cloud unless Section (1) or (2) is satisfied.

(1) This section is satisfied if both of the following conditions are met:

(i) At least 4 hours have passed since the last lightning discharge in or from the detached anvil cloud; and

(ii) At least 3 hours have passed since the time that the anvil cloud is observed to be detached from the parent cloud.

(2) This section is satisfied if both of the following conditions are met.

(i) The portion of the detached anvil cloud within 5 nautical miles of the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(ii) The volume-averaged, height-integrated radar reflectivity is less than +33 dBZ-kft everywhere along the portion of the flight path where any part of the detached anvil cloud is within the specified volume.

G417.13 Debris Clouds

(a) A launch operator must not initiate flight if the flight path will carry the launch vehicle through any nontransparent part of a debris cloud for 3 hours after the debris cloud is observed to be detached from the parent cloud or after the debris cloud is observed to have formed from the decay of the parent cloud top to an altitude where the temperature is warmer than −10 degrees Celsius. The 3-hour period must begin again at the time of any lightning discharge in or from the debris cloud.

(b) A launch operator must not initiate flight if the flight path will carry the launch vehicle within 5 nautical miles of a nontransparent part of a debris cloud during the 3-hour period defined in paragraph (a) of this section, unless:

(1) There is at least one working field mill within 5 nautical miles of the debris cloud;

(2) The absolute values of all electric field measurements at the Earth's surface within 5 nautical miles of the flight path and measurements at each field mill employed required by paragraph (b)(1) of this section

have been less than 1000 volts/meter for 15 minutes or longer; and

(3) The maximum radar return from any part of the debris cloud within 5 nautical miles of the flight path has been less than 10 dBZ for 15 minutes or longer.

G417.15 DISTURBED WEATHER

(a) A launch operator must not initiate flight if the flight path will carry the launch vehicle through a nontransparent cloud associated with disturbed weather that has clouds with cloud tops at altitudes where the temperature is colder than 0 degrees Celsius and that contains, within 5 nautical miles of the flight path:

(1) Moderate or greater precipitation; or

(2) Evidence of melting precipitation such as a radar bright band.

G417.17 THICK CLOUD LAYERS

(a) A launch operator must not initiate flight if the flight path will carry the launch vehicle through a nontransparent part of a cloud layer that is:

(1) Greater than 4,500 feet thick and any part of the cloud layer along the flight path is located at an altitude where the temperature is between 0 degrees Celsius and −20 degrees Celsius; or

(2) Connected to a thick cloud layer that, within 5 nautical miles of the flight path, is greater than 4,500 feet thick and has any part located at any altitude where the temperature is between 0 degrees Celsius and −20 degrees Celsius.

(b) A launch operator need not apply the lightning commit criteria in paragraphs (a)(1) and (a)(2) of this section if the thick cloud layer is a cirriform cloud layer that has never been associated with convective clouds, is located only at temperatures of −15 degrees Celsius or colder, and shows no evidence of containing liquid water.

G417.19 SMOKE PLUMES

(a) A launch operator must not initiate flight if the flight path will carry the launch vehicle through any cumulus cloud that has developed from a smoke plume while the cloud is attached to the smoke plume, or for the first 60 minutes after the cumulus cloud is observed to be detached from the smoke plume.

(b) Section G417.7 applies to cumulus clouds that have formed above a fire but have been detached from the smoke plume for more than 60 minutes.

G417.21 SURFACE ELECTRIC FIELDS

(a) A launch operator must not initiate flight for 15 minutes after the absolute value of any electric field measurement at the Earth's surface within 5 nautical miles of the flight path has been greater than 1500 volts/meter.

(b) A launch operator must not initiate flight for 15 minutes after the absolute value of any electric field measurement at the Earth's surface within 5 nautical miles of the flight path has been greater than 1000 volts/meter unless:

(1) All clouds within 10 nautical miles of the flight path are transparent; or

(2) All nontransparent clouds within 10 nautical miles of the flight path have cloud tops at altitudes where the temperature is warmer than +5 degrees Celsius and have not been part of convective clouds that have cloud tops at altitudes where the temperature is colder than −10 degrees Celsius within the last 3 hours.

G417.23 TRIBOELECTRIFICATION

(a) A launch operator must not initiate flight if the flight path will go through any part of a cloud at an altitude where the temperature is colder than −10 degrees Celsius up to the altitude at which the launch vehicle's velocity exceeds 3000 feet/second; unless

(1) The launch vehicle is ''treated'' for surface electrification; or

(2) A launch operator demonstrates by test or analysis that electrostatic discharges on the surface of the launch vehicle caused by triboelectrification will not be hazardous to the launch vehicle or the spacecraft.

(b) A launch vehicle is treated for surface electrification if

(1) All surfaces of the launch vehicle susceptible to ice particle impact are such that the surface resistivity is less than 10^9 ohms/square; and

(2) All conductors on surfaces (including dielectric surfaces that have been treated with conductive coatings) are bonded to the launch vehicle by a resistance that is less than 10^5 ohms.

APPENDIX H TO PART 417 [RESERVED]

APPENDIX I TO PART 417—METHODOLOGIES FOR TOXIC RELEASE HAZARD ANALYSIS AND OPERATIONAL PROCEDURES

I417.1 GENERAL

This appendix provides methodologies for performing toxic release hazard analysis for the flight of a launch vehicle as required by §417.229 and for launch processing at a launch site in the United States as required by §417.407(f). The requirements of this appendix apply to a launch operator and the launch operator's toxic release hazard analysis unless the launch operator clearly and convincingly demonstrates that an alternative approach provides an equivalent level of safety.

I417.3 IDENTIFICATION OF NON-TOXIC AND TOXIC PROPELLANTS

(a) *General.* A launch operator's toxic release hazard analysis for launch vehicle flight (section I417.5) and for launch processing (section I417.7) must identify all propellants used for each launch and identify whether each propellant is toxic or non-toxic as required by this section.

(b) *Non-toxic exclusion.* A launch operator need not conduct a toxic release hazard analysis under this appendix for flight or launch processing if its launch vehicle, including all launch vehicle components and payloads, uses only those propellants listed in Table I417–1.

Table I417-1, Commonly Used Non-Toxic Propellants

Item	Chemical Name	Formula
1	Liquid Hydrogen	H_2
2	Liquid Oxygen	O_2
3	Kerosene (RP-1)	$CH_{1.96}$

(c) *Identification of toxic propellants.* A launch operator's toxic release hazard analysis for flight and for launch processing must identify all toxic propellants used for each launch, including all toxic propellants on all launch vehicle components and payloads. Table I417–2 lists commonly used toxic propellants and the associated toxic concentration thresholds used by the Federal launch ranges for controlling potential public exposure. The toxic concentration thresholds contained in Table I417–2 are peak exposure concentrations in parts per million (ppm). A launch operator must perform a toxic release hazard analysis to ensure that the public is not exposed to concentrations above the toxic concentration thresholds for each toxicant involved in a launch. A launch operator must use the toxic concentration thresholds contained in table I417–2 for those propellants. Any propellant not identified in table I417–1 or table I417–2 falls into the category of unique or uncommon propellants, such as those identified in table I417–3, which are toxic or produce toxic combustion by-products. Table I417.3 is not an exhaustive list of possible toxic propellants and combustion by-products. For a launch that uses any propellant listed in table I417–3 or any other unique propellant not listed, a launch operator must identify the chemical composition of the propellant and all combustion by-products and the release scenarios. A launch operator must determine the toxic concentration threshold in ppm for any uncommon toxic propellant or combustion by-product in accordance with the following:

(1) For a toxicant that has a level of concern (LOC) established by the U.S. Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), or Department of Transportation (DOT), a launch operator must use the LOC as the toxic concentration threshold for the toxic release hazard analysis except as required by paragraph (c)(2) of this section.

(2) If an EPA acute emergency guidance level (AEGL) exists for a toxicant and is more conservative than the LOC (that is, lower after reduction for duration of exposure), a launch operator must use the AEGL instead of the LOC as the toxic concentration threshold.

(3) A launch operator must use the EPA's Hazard Quotient/Hazard Index (HQ/HI) formulation to determine the toxic concentration threshold for mixtures of two or more toxicants.

(4) If a launch operator must determine a toxic concentration threshold for a toxicant for which an LOC has not been established, the launch operator must clearly and convincingly demonstrate through the licensing process that public exposure at the proposed toxic concentration threshold will not cause a casualty.

Table I417-2, Commonly Used Toxic Propellants

Chemical Name	**Formula**	**Toxic Concentration Threshold (ppm)**
Nitrogen Tetroxide	N_2O_4	4
Mixed Oxides of Nitrogen (MON)	NO, NO_2, N_2O_4	4
Nitric Acid	HNO_3	4
Hydrazine	N_2H_4	8
Monomethylhydrazine (MMH)	CH_3NHNH_2	5
Unsymmetrical Dimethylhydrazine (UDMH)	$(CH_3)_2NNH_2$	5
Ammonium Perchlorate/Aluminum	NH_3ClO_4/Al	10

Table I417-3, Uncommon Toxic Propellants and Combustion By-products

Item	Chemical Name	Formula	Toxic Concentration Threshold (ppm)
1	Fluorine	F_2	Determined according to section I417.3(c).
2	Hydrogen Fluoride	HF	
3	Potassium Perchlorate	$KClO_4$	
4	Lithium Perchlorate	$LiClO_4$	
5	Chlorine Oxides	Cl_2O, ClO_2, CL_2O_6, Cl_2O_7	
6	Chlorine Trifluoride	ClF_3	
7	Beryllium	Be	
8	Beryllium Borohydride	$Be(BH_4)_2$	
9	Boron	B	
10	Boron Trifluoride	BF_3	
11	Diborane	B_2H_6	
12	Pentaborane	B_5H_9	
13	Hexaborane	B_6H_{10}	
14	Aluminum Borohydride	$Al(BH_4)_3$	
15	Lithium Borohydride	$Li(BH_4)_2$	
16	Ammonia	NH_3	
17	Ammonium Nitrate	NH_4NO_3	
18	Ozone	O_3	
19	Methylamine	CH_3NH_2	

20	Ethylamine	$CH_3CH_2NHH_2$	
21	Triethylamine	$(C_2H_5)_3N$	
22	Ethylenediamine	$NH_2CH_2CH_2NH_2$	
23	Diethylenetriamine	$NH_2C_2H_4NHC_2H_4NH_2$	
24	Aniline	$C_6H_5NH_2$	
25	Monoethylaniline	$C_6H_5NHC_2H_5$	
26	Xylidine	$(CH_3)_2C_6H_3NH_3$	
27	Trimethylaluminum	$Al(CH_3)_3$	
28	Dimethylberyllium	$Be(CH_3)_2$	
29	Nitromethane	CH_3NO_2	
30	Tetranitromethane	$C(NO_2)_4$	
31	Nitroglycerine	$C_3H_5(ONO_2)_3$	
32	Butyl Mercaptan	$CH_3(CH_2)_2CH_2SH$	
33	Dimethyl Sulfide	$(CH_3)_2S$	
34	Tetraethyl Silicate	$(C_2H_5)_4SiO_4$	

I417.5 TOXIC RELEASE HAZARD ANALYSIS FOR LAUNCH VEHICLE FLIGHT

(a) *General.* For each launch, a launch operator's toxic release hazard analysis must determine all hazards to the public from any toxic release that will occur during the proposed flight of a launch vehicle or that would occur in the event of a flight mishap. A launch operator must use the results of the toxic release hazard analysis to establish for each launch, in accordance with §417.113(b), flight commit criteria that protect the public from a casualty arising out of any potential toxic release. A launch operator's toxic release hazard analysis must determine if toxic release can occur based on an evaluation of the propellants, launch vehicle materials, and estimated combustion products. This evaluation must account for both normal combustion products and the chemical composition of any unreacted propellants.

(b) *Evaluating toxic hazards for launch vehicle flight.* Each launch must satisfy either the exclusion requirements of section I417.3(b), the containment requirements of paragraph (c) of this section, or the statistical risk management requirements of paragraph (d) of this section, to prevent any casualty that could arise out of exposure to any toxic release.

(c) *Toxic containment for launch vehicle flight.* For a launch that uses any toxic propellant, a launch operator's toxic release hazard analysis must determine a hazard distance for each toxicant and a toxic hazard area for the launch. A hazard distance for a toxicant is the furthest distance from the launch point where toxic concentrations may be greater than the toxicant's toxic concentration threshold in the event of a release during flight. A launch operator must determine the toxic hazard distance for each toxicant as required by paragraphs (c)(1) and (c)(2) of this section. A toxic hazard area defines the region on the Earth's surface that may be exposed to toxic concentrations greater than any toxic concentration threshold of any toxicant involved in a launch in the event of a release during flight. A launch operator must determine a toxic hazard area in accordance with paragraph (c)(3) of this section. In order to achieve containment, a launch operator must evacuate the public from a toxic hazard area as required by paragraph (c)(4) of this section or employ meteorological constraints as required by paragraph (c)(5) of this section. A launch operator must determine the hazard distance for a quantity of toxic propellant and determine and implement a toxic hazard area for a launch as follows:

(1) *Hazard distances for common propellants*. Table I417–4 lists toxic hazard distances as a function of propellant quantity and toxic concentration threshold for commonly used propellants released from a catastrophic launch vehicle failure. Tables I417–10 and I417–11 list the hazard distance as a function of solid propellant mass for HC1 emissions during a launch vehicle failure and during normal flight for ammonium perchlorate based solid propellants. A launch operator must use the hazard distances corresponding to the toxic concentration thresholds established for a launch to determine the toxic hazard area for the launch in accordance with paragraph (c)(3) of this section.

(2) *Hazard distances for uncommon or unique propellants*. For a launch that involves any uncommon or unique propellant, a launch operator must determine the toxic hazard distance for each such propellant using an analysis methodology that accounts for the following worst case conditions:

(i) Surface wind speed of 2.9 knots with a wind speed increase of 1.0 knot per 1000 feet of altitude.

(ii) Surface temperature of 32 degrees Fahrenheit with a dry bulb temperature lapse rate of 13.7 degrees Fahrenheit per 1000 feet over the first 500 feet of altitude and a lapse rate of 3.0 degrees F per 1000 feet above 500 feet.

(iii) Directional wind shear of 2 degrees per 1000 feet of altitude.

(iv) Relative humidity of 50 percent.

(v) Capping temperature inversion at the thermally stabilized exhaust cloud center of mass altitude.

(vi) Worst case initial source term assuming instantaneous release of fully loaded propellant storage tanks or pressurized motor segments.

(vii) Worst case combustion or mixing ratios such that production of toxic chemical species is maximized within the bounds of reasonable uncertainties.

(viii) Evaluation of toxic hazards for both normal launch and vehicle abort failure modes.

Table I417-4

Hazard Distances from the Launch Point							
Quantity	Concentrations [ppm] and Hazard Distances [km]						
	NO_2 4 ppm[1]	**UDMH** 5 ppm[1]	**N_2H_4** 8 ppm[1]	**MMH** 5 ppm[1]	**NO** 4 ppm[1]	**HNO_3** 4 ppm[1]	**HCl[2]** 10 ppm[1]
[pounds]	[km]	[km]	[km]	[km]	[km]	[km]	[km]
100	8	4	3	5	9	8	0
300	14	8	7	9	17	15	0
500	18	10	8	12	20	19	0
1000	26	15	11	17	26	24	0
2000	36	19	13	21	33	31	0
3000	44	22	15	24	39	35	1
4000	47	24	16	27	42	39	2
5000	50	26	17	29	45	42	2
7500	58	30	20	35	52	48	2
10000	64	34	22	37	58	52	3
20000	78	42	27	47	71	66	4
30000	91	47	29	55	81	76	5
40000	99	52	31	59	88	81	5
50000	105	56	34	64	100	87	6
60000	111	59	35	67	104	92	7
70000	116	62	36	72	109	100	8
80000	123	64	37	74	114	104	9
90000	126	68	38	77	118	108	9
100000	130	69	39	79	122	111	10

125000	138	74	42	85	131	119	12
150000	145	78	44	95	138	125	13
175000	151	81	45	99	144	131	14
200000	160	88	47	103	156	136	16
250000	167	94	49	110	163	148	18
300000	175	99	50	117	171	155	21
350000	182	103	52	122	179	161	22
400000	189	107	53	128	186	167	25
450000	203	110	54	132	193	173	27
500000	207	114	57	136	196	178	28
750000	230	127	61	157	206	184	37
1000000	247	140	64	170	220	195	43

1 Indicates a toxic concentration threshold from Table I417-2.

2 HCL emissions from catastrophic launch vehicle failure.

(3) *Toxic hazard area.* Having determined the toxic hazard distance for each toxicant, a launch operator must determine the toxic hazard area for a launch as a circle centered at the launch point with a radius equal to the greatest toxic hazard distance determined as required by paragraphs (c)(1) and (c)(2) of this section, of all the toxicants involved in the launch. A launch operator does not have to satisfy paragraph (c)(3) of this section if:

(i) The launch operator demonstrates that there are no populated areas contained or partially contained within the toxic hazard area; and

(ii) The launch operator ensures that no member of the public is present within the toxic hazard area during preflight fueling, launch countdown, flight and immediate postflight operations at the launch site. To ensure the absence of the public, a launch operator must develop flight commit criteria and related provisions for implementation as part of the launch operator's flight safety plan and hazard area surveillance and clearance plan developed under §§417.111(b) and 417.111(j), respectively.

(4) *Evacuation of populated areas within a toxic hazard area.* For a launch where there is a populated area that is contained or partially contained within a toxic hazard area, the launch operator does not have to satisfy paragraph (c)(5) of this section if the launch operator evacuates all people from all populated areas at risk and ensures that no member of the public is present within the toxic hazard area during preflight fueling and flight. A launch operator must develop flight commit criteria and provisions for implementation of the evacuations as part of the launch operator's flight safety plan, hazard area surveillance and clearance plan, and local agreements and public coordination plan developed according to §§417.111(b), 417.111(j) and 417.111(i), respectively.

(5) *Flight meteorological constraints.* For a launch where there is a populated area that is contained or partially contained within a toxic hazard area and that will not be evacuated under paragraph (c)(4) of this section, the launch is exempt from any further requirements of this section if the launch operator constrains the flight of a launch vehicle to favorable wind conditions or during times when atmospheric conditions result in reduced toxic hazard distances such that any potentially affected populated area is outside the toxic hazard area. A launch operator must employ wind and other meteorological constraints as follows:

(i) When employing wind constraints, a launch operator must re-define the toxic hazard area by reducing the circular toxic hazard area determined under paragraph (c)(3) of this section to one or more arc segments that do not contain any populated area. Each arc segment toxic hazard area must have the same radius as the circular toxic hazard area and must be defined by a range of downwind bearings.

(ii) The launch operator must demonstrate that there are no populated areas within any arc segment toxic hazard area and that no member of the public is present within an arc segment toxic hazard area during preflight fueling, launch countdown, and immediate postflight operations at the launch site.

(iii) A launch operator must establish wind constraints to ensure that any winds present at the time of flight will transport any toxicant into an arc segment toxic hazard area and away from any populated area. For each arc segment toxic hazard area, the wind constraints must consist of a range of downwind bearings that are within the arc segment toxic hazard area and that provide a safety buffer, in both the clockwise and counterclockwise directions, that accounts for any uncertainty in the spatial and temporal variations of the transport winds. When determining the wind uncertainty, a launch operator must account for the variance of the mean wind directions derived from measurements of the winds through the first 6000 feet in altitude at the launch point. Each clockwise and counterclockwise safety buffer must be no less than 20 degrees of arc width within the arc segment toxic hazard area. A launch operator must ensure that the wind conditions at the time of flight satisfy the wind constraints. To accomplish this, a launch operator must monitor the launch site vertical profile of winds from the altitude of the launch point to no less than 6,000 feet above ground level. The launch operator must proceed with a launch only if all wind vectors within this vertical range satisfy the wind constraints. A launch operator must develop wind constraint flight commit criteria and implementation provisions as part of the launch operator's flight safety plan and its hazard area surveillance and clearance plan developed according to §§417.111(b) and 417.111(j), respectively.

(iv) A launch operator may reduce the radius of the circular toxic hazard area determined in accordance with paragraph (c)(3) of this section by imposing operational meteorological restrictions on specific parameters that mitigate potential toxic downwind concentrations levels at any potentially affected populated area to levels below the toxic concentration threshold of each toxicant in question. The launch operator must establish meteorological constraints to ensure that flight will be allowed to occur only if the specific meteorological conditions that would reduce the toxic hazard area exist and will continue to exist throughout the flight.

(d) *Statistical toxic risk management for flight.* If a launch that involves the use of a toxic propellant does not satisfy the containment requirements of paragraph (c) of this section, the launch operator must use statistical toxic risk management to protect public safety. For each such case, a launch operator must perform a toxic risk assessment and develop launch commit criteria that protect the public from unacceptable risk due to planned and potential toxic release. A launch operator must ensure that the resultant toxic risk meets the collective and individual risk criteria requirements contained in §417.107(b). A launch operator's toxic risk assessment must account for the following:

(1) All credible vehicle failure and non-failure modes, along with the consequent release and combustion of propellants and other vehicle combustible materials.

(2) All vehicle failure rates.

(3) The effect of positive or negative buoyancy on the rise or descent of each released toxicant.

(4) The influence of atmospheric physics on the transport and diffusion of each toxicant.

(5) Meteorological conditions at the time of launch.

(6) Population density, location, susceptibility (health categories) and sheltering for all populations within each potential toxic hazard area.

(7) Exposure duration and toxic propellant concentration or dosage that would result in casualty for all populations.

(e) *Flight toxic release hazard analysis products.* The products of a launch operator's toxic release hazard analysis for launch vehicle flight to be filed in accordance with §417.203(e) must include the following:

(1) For each launch, a listing of all propellants used on all launch vehicle components and any payloads.

(2) The chemical composition of each toxic propellant and all toxic combustion products.

(3) The quantities of each toxic propellant and all toxic combustion products involved in the launch.

(4) For each toxic propellant and combustion product, identification of the toxic concentration threshold used in the toxic risk analysis and a description of how the toxic concentration threshold was determined if other than specified in table I417.2.

(5) When using the toxic containment approach of paragraph (c) of this section:

(i) The hazard distance for each toxic propellant and combustion product and a description of how it was determined.

(ii) A graphic depiction of the toxic hazard area or areas.

(iii) A listing of any wind or other constraints on flight, and any plans for evacuation.

(iv) A description of how the launch operator determines real-time wind direction in relation to the launch site and any populated area and any other meteorological condition in order to implement constraints on flight or to implement evacuation plans.

(6) When using the statistical toxic risk management approach of paragraph (d) of this section:

(i) A description of the launch operator's toxic risk management process, including an explanation of how the launch operator ensures that any toxic risk from launch meets the toxic risk criteria of §417.107(b).

(ii) A listing of all models used.

(iii) A listing of all flight commit criteria that protect the public from unacceptable risk due to planned and potential toxic release.

(iv) A description of how the launch operator measures and displays real-time meteorological conditions in order to determine whether conditions at the time of flight are within the envelope of those used by the launch operator for toxic risk assessment and to develop flight commit criteria, or for use in any real-time physics models used to ensure compliance with the toxic flight commit criteria.

I417.7 TOXIC RELEASE HAZARD ANALYSIS FOR LAUNCH PROCESSING

(a) *General.* A launch operator must perform a toxic release hazard analysis to determine potential public hazards from toxic releases that will occur during normal launch processing and that will occur in the event of a mishap during launch processing. This section implements the ground safety requirements of §417.407(g). A launch operator must use the results of the toxic release hazard analysis to establish hazard controls for protecting the public. A launch operator must include the toxic release hazard analysis results in the ground safety plan as required by §417.111(c).

(b) *Process hazards analysis.* A launch operator must perform an analysis on all processes to identify toxic hazards and determine the potential for release of a toxic propellant. The analysis must account for the complexity of the process and must identify and evaluate the hazards and each hazard control involved in the process. An analysis that complies with 29 CFR 1910.119(e) satisfies paragraphs (b)(1) and (b)(2) of this section. A launch operator's process hazards analysis must include the following:

(1) Identify and evaluate each hazard of a process involving a toxic propellant using an analysis method, such as a failure mode and effects analysis or fault tree analysis.

(2) Describe:

(i) Each toxic hazard associated with the process and the potential for release of toxic propellants;

(ii) Each mishap or incident experienced which has a potential for catastrophic consequences;

(iii) Each engineering and administrative control applicable to each hazard and their interrelationships, such as application of detection methodologies to provide early warning of releases and evacuation of toxic hazard areas prior to conducting an operation that involves a toxicant;

(iv) Consequences of failure of engineering and administrative controls;

(v) Location of the source of the release;

(vi) All human factors;

(vii) Each opportunity for equipment malfunction or human error that can cause an accidental release;

(viii) Each safeguard used or needed to control each hazard or prevent equipment malfunctions or human error;

(ix) Each step or procedure needed to detect or monitor releases; and

(x) A qualitative evaluation of a range of the possible safety and health effects of failure of controls.

(3) The process hazards analysis must be updated for each launch. The launch operator must conduct a review of all the hazards associated with each process involving a toxic propellant for launch processing. The review must include inspection of equipment to determine whether the process is designed, fabricated, maintained, and operated according to the current process hazards analysis. A launch operator must revise a process hazards analysis to reflect changes in processes, types of toxic propellants stored or handled, or other aspects of a source of a potential toxic release that can affect the results of overall toxic release hazard analysis.

(4) The personnel who perform a process hazard analysis must possess expertise in engineering and process operations, and at least one person must have experience and knowledge specific to the process being evaluated. At least one person must be knowledgeable in the specific process hazard analysis methodology being used.

(5) A launch operator must resolve all recommendations resulting from a process hazards analysis in a timely manner prior to launch processing and the resolution must be documented. The documentation must identify each corrective action and include a written schedule of when any such actions are to be completed.

(c) *Evaluating toxic hazards of launch processing.* A launch operator must protect the public from each potential toxic hazard identified by the process hazards analysis required by paragraph (b) of this section, the exclusion requirements of section I417.3(b), the containment requirements of paragraph

(d) of this section, or the statistical risk management requirements of paragraph (l) of this section, to prevent any casualty that could arise out of exposure to any toxic release.

(d) *Toxic containment for launch processing.* A launch operator's toxic release hazard analysis must determine a toxic hazard area surrounding the potential release site for each toxic propellant based on the amount and toxicity of the propellant and the meteorological conditions involved. A launch operator must determine whether there are populated areas located within a toxic hazard area that satisfy paragraph (h) of this section. If necessary to achieve toxic containment, a launch operator must evacuate the public in order to satisfy paragraph (i) of this section or employ meteorological constraints that satisfy paragraph (j) of this section. A launch operator, in determining a toxic hazard area, must first perform a worst-case release scenario analysis that satisfies paragraph (e) of this section or a worst-case alternative release scenario analysis that satisfies paragraph (f) of this section for each process that involves a toxic propellant. The launch operator must then determine a toxic hazard distance for each process that satisfies paragraph (g) of this section.

(e) *Worst-case release scenario analysis.* A launch operator's worst-case release scenario analysis must account for the following:

(1) *Determination of worst-case release quantity.* A launch operator must determine the worst-case release quantity of a toxic propellant by selecting the greater of the following:

(i) For substances in a vessel, the greatest amount held in a single vessel, accounting for administrative controls that limit the maximum quantity; or

(ii) For toxic propellants in pipes, the greatest amount in a pipe, accounting for administrative controls that limit the maximum quantity.

(2) *Worst-case release scenario for toxic liquids.* A launch operator must determine the worst-case release scenario for a toxic liquid propellant as follows:

(i) A launch operator must assume that for toxic propellants that are normally liquids at ambient temperature, the quantity in the vessel or pipe, as determined in paragraph (e)(1) of this section, is spilled instantaneously to form a liquid pool.

(ii) The launch operator must determine surface area of the pool by assuming that the liquid spreads to one centimeter deep unless passive mitigation systems are in place that serve to contain the spill and limit the surface area. Where passive mitigation is in place, the launch operator must use the surface area of the contained liquid to calculate the volatilization rate.

(iii) If the release occurs on a surface that is not paved or smooth, the launch operator may account for actual surface characteristics.

(iv) The volatilization rate must account for the highest daily maximum temperature occurring in the past three years, the temperature of the substance in the vessel, and the concentration of the toxic propellants if the liquid spilled is a mixture or solution.

(v) The launch operator must determine rate of release to the air from the volatilization rate of the liquid pool. A launch operator must use either the methodology provided in the Risk Management Plan (RMP) Offsite Consequence Analysis Guidance, dated April 1999, available at *http:/www.epa.gov/swercepp/ap-ocgu.htm*, or an air dispersion modeling technique that satisfies paragraph (g) of this section.

(3) *Worst-case release scenario for toxic gases.* A launch operator must determine the worst-case release scenario for a toxic gas as follows:

(i) For toxic propellants that are normally gases at ambient temperature and handled as a gas or as a liquid under pressure, the launch operator must assume that the quantity in the vessel, or pipe, as determined in paragraph (e)(1) of this section, is released as a gas over 10 minutes. The launch operator must assume a release rate that is the total quantity divided by 10 unless passive mitigation systems are in place.

(ii) For gases handled as refrigerated liquids at ambient pressure, if the released toxic propellant is not contained by passive mitigation systems or if the contained pool would have a depth of 1 cm or less, the launch operator must assume that the toxic propellant is released as a gas in 10 minutes.

(iii) For gases handled as refrigerated liquids at ambient pressure, if the released toxic propellant is contained by passive mitigation systems in a pool with a depth greater than 1 cm, the launch operator must assume that the quantity in the vessel or pipe, as defined in paragraph (e)(1) of this section, is spilled instantaneously to form a liquid pool. The launch operator must calculate the volatilization rate at the boiling point of the toxic propellant and at the conditions defined in paragraph (e)(2) of this section.

(4) *Consideration of passive mitigation.* The launch operator must account for passive mitigation systems in the analysis of a worst case release scenario if the passive mitigation system is capable of withstanding the release event triggering the scenario and would function as intended.

(5) *Additional factors in selecting a worst-case scenario.* A launch operator's worst-case release scenario for a toxic propellant must account for each factor that would result in a greater toxic hazard distance, such as a smaller quantity of the toxic propellant than

required by paragraph (e)(1) of this section, that is handled at a higher process temperature or pressure.

(f) *Worst-case alternative release scenario analysis*. A launch operator's worst-case alternative release scenario analysis must account for the following:

(1) The worst-case release scenario for each toxic propellant and for each toxic propellant handling process;

(2) Each release event that is more likely to occur than the worst-case release scenario that is determined in paragraph (e) of this section;

(3) Each release scenario that exceeds a toxic concentration threshold at a distance that reaches the general public;

(4) Each potential transfer hose release due to splits or sudden hose uncoupling;

(5) Each potential process piping release from failures at flanges, joints, welds, valves, valve seals, and drain bleeds;

(6) Each potential process vessel or pump release due to cracks, seal failure, or drain, bleed, or plug failure;

(7) Each vessel overfilling and spill, or over pressurization and venting through relief valves or rupture disks;

(8) Shipping container mishandling and breakage or puncturing leading to a spill;

(9) Mishandling or dropping flight or ground hardware that contains toxic commodities;

(10) Each active and passive mitigation system provided they are capable of withstanding the event that triggered the release and would still be functional;

(11) History of each accident experienced by the launch operator involving the release of a toxic propellant; and

(12) Each failure scenario.

(g) *Toxic hazard distances for launch processing*. For each process involving a toxic propellant, a launch operator must perform an air dispersion analysis to determine the hazard distance for the worst-case release scenario or the worst-case alternative release scenario as determined under paragraphs (e) and (f) of this section. A launch operator must use either the methodology provided in the RMP Offsite Consequence Analysis Guidance, dated April 1999, or an air dispersion modeling technique that is applicable to the proposed launch. A launch operator's air dispersion modeling technique must account for the following analysis parameters:

(1) *Toxic concentration thresholds*. A launch operator must use the toxic concentration thresholds defined by section I417.3(c).

(2) *Wind speed and atmospheric stability class*. A launch operator, for the worst-case release analysis, must use a wind speed of 1.5 meters per second and atmospheric stability class F. If the launch operator demonstrates that local meteorological data applicable to the source of a toxic release show a higher wind minimum wind speed or less stable atmosphere during the three previous years, the launch operator may use these minimums. The launch operator, for analysis of the worst-case alternative scenario, must use statistical meteorological conditions for the location of the source.

(3) *Ambient temperature and humidity*. For a worst-case release scenario analysis of a toxic propellant, the launch operator must use the highest daily maximum temperature from the last three years and average humidity for the site, based on temperature and humidity data gathered at the source location or at a local meteorological station. For analysis of a worst-case alternative release scenario, the launch operator must use typical temperature and humidity data gathered at the source location or at a local meteorological station.

(4) *Height of release*. The launch operator must analyze the worst-case release of a toxic propellant assuming a ground level release. For a worst-case alternative scenario analysis of a toxic propellant, the release scenario may determine release height.

(5) *Surface roughness*. The launch operator must use either an urban or rural topography, as appropriate. Urban means that there are many obstacles in the immediate area; obstacles include buildings or trees. Rural means there are no buildings in the immediate area and the terrain is generally flat and unobstructed.

(6) *Dense or neutrally buoyant gases*. Models or tables used for dispersion analysis of a toxic propellant must account for gas density.

(7) *Temperature of release substance*. For a worst-case release scenario, the launch operator must account for the release of liquids other than gases liquefied by refrigeration at the highest daily maximum temperature, based on data for the previous three years appropriate to the source of the potential toxic release, or at process temperature, whichever is higher. For a worst-case alternative scenario, the launch operator may consider toxic propellants released at a process or ambient temperature that is appropriate for the scenario.

(h) *Toxic hazard areas for launch processing*. A launch operator, having determined the toxic hazard distance for the toxic concentration threshold for each toxic propellant involved in a process using either a worst-case release scenario or a worst-case alternative release scenario, must determine the toxic hazard area for the process as a circle centered at the potential release point with a radius equal to the greatest toxic hazard distance for the toxic propellants involved in the process. A launch operator does not have to satisfy this section if:

(1) There are no populated areas contained or partially contained within the toxic hazard area; and

(2) There is no member of the public present within the toxic hazard area during the process.

(i) *Evacuation of populated areas within a toxic hazard area.* For a process where there is a populated area that is contained or partially contained within the toxic hazard area, the launch processing operation does not have to satisfy this section if the launch operator evacuates the public from the populated area and ensures that no member of the public is present within the toxic hazard area during the operation. A launch operator must coordinate notification and evacuation procedures with the Local Emergency Planning Committee (LEPC) and ensure that notification and evacuation occurs according to its launch plans, including the launch operator's ground safety plan, hazard area surveillance and clearance plan, accident investigation plan, and local agreements and public coordination plan.

(j) *Meteorological constraints for launch processing.* For a launch processing operation with the potential for a toxic release where there is a populated area that is contained or partially contained within the toxic hazard area and that will not be evacuated as required by paragraph (i) of this section, the operation is exempt from further requirements in this section if the launch operator constrains the process to favorable wind conditions or during times when atmospheric conditions result in reduced toxic hazard distances such that the potentially affected populated area is outside the toxic hazard area. A launch operator must employ wind and other meteorological constraints that satisfy the following:

(1) A launch operator must limit a launch processing operation to times during which prevailing winds will transport a toxic release away from populated areas that would otherwise be at risk. If the mean wind speed during the operation is equal to or greater than four knots, the launch operator must re-define the toxic hazard area by reducing the circular toxic hazard area as determined in paragraph (h) of this section to one or more arc segments that do not contain a populated area. Each arc segment toxic hazard area must have the same radius as the circular toxic hazard area and must be defined by a range of downwind bearings. If the mean wind speed during the operation is less than four knots, the toxic hazard area for the operation must be the full 360-degree toxic hazard area as defined by paragraph (h) of this section. The total arc width of an arc segment hazard area for launch processing must be greater than or equal to 30 degrees. If the launch operator determines the standard deviation of the measured wind direction, the total arc width of an arc segment hazard area must include all azimuths within the mean measured wind direction plus three sigma and the mean measured wind direction minus three sigma; otherwise, the following apply for the conditions defined by the Pasquil-Gifford meteorological stability classes:

(i) For stable classes D–F, if the mean wind speed is less than 10 knots, the total arc width of the arc segment toxic hazard area must be no less than 90 degrees;

(ii) For stable classes D–F, if the mean wind speed is greater than or equal to 10 knots, the total arc width of the arc segment toxic hazard area must be no less than 45 degrees;

(iii) For neutral class C, the total arc width of the arc segment toxic hazard area must be no less than 60 degrees;

(iv) For slightly unstable class B, the total arc width of the arc segment toxic hazard area must be no less than 105 degrees; and

(v) For mostly unstable class A, the total arc width of the arc segment toxic hazard area must be no less than 150 degrees.

(2) The launch operator must ensure that there are no populated areas within an arc segment toxic hazard area and that no member of the public is present within an arc segment toxic hazard area during the process as defined by paragraph (i) of this section.

(3) A launch operator must establish wind constraints to ensure that winds present at the time of an operation will transport toxicants into an arc segment toxic hazard area and away from populated areas. For each arc segment toxic hazard area, the wind constraints must consist of a range of downwind bearings that are within the arc segment toxic hazard area and that provide a safety buffer, in both the clockwise and counterclockwise directions, that accounts for uncertainty in the spatial and temporal variations of the transport winds.

(4) A launch operator may reduce the radius of the circular toxic hazard area as determined under paragraph (h) of this section by imposing operational meteorological restrictions on specific parameters that mitigate potential toxic downwind concentrations levels at a potentially affected populated area to levels below the toxic concentration threshold of the toxicant in question. The launch operator must establish meteorological constraints to ensure that the operation will be allowed to occur only if the specific meteorological conditions that would reduce the toxic hazard area exist and will continue to exist throughout the operation, or the operation will be terminated.

(k) *Implementation of meteorological constraints.* A launch operator must use one or more of the following approaches to determine wind direction or other meteorological conditions in order to establish constraints on a launch processing operation or evacuate the populated area in a potential toxic hazard area:

(1) The launch operator must ensure that the wind conditions at the time of the process comply with the wind constraints used to define each arc segment toxic hazard area. The launch operator must monitor the vertical profile of winds at the potential toxic release site from ground level to an altitude of 10 meters or the maximum height above ground of the potential release, whichever is larger. The launch operator may proceed with a launch processing operation only if wind vectors meet the wind constraints used to define each arc segment toxic hazard area.

(2) A launch operator must monitor the specific meteorological parameters that affect toxic downwind concentrations at a potential toxic release site for a process and for the sphere of influence out to each populated area within the potential toxic hazard area as defined by paragraph (h) of this section. The launch operator must monitor spatial variations in the wind field that could affect the transport of toxic material between the potential release site and populated areas. The launch operator must acquire real-time meteorological data from sites between the potential release site and each populated area sufficient to demonstrate that the toxic hazard area, when adjusted to the spatial wind field variations, excludes populated areas. Meteorological parameters that affect toxic downwind concentrations from the potential release site and covering the sphere of influence out to the populated areas must fall within the conditions as determined in paragraph (j)(4) of this section. A launch operator must use one of the following methods to determine the meteorological conditions that will constrain a launch processing operation:

(i) A launch operator may employ real-time air dispersion models to determine the toxic hazard distance for the toxic concentration threshold and proximity of a toxicant to populated areas. A launch operator, when employing this method, must proceed with a launch processing operation only if real-time modeling of the potential release demonstrates that the toxic hazard distance would not reach populated areas. The launch operator's process for carrying out this method must include the use of an air dispersion modeling technique that complies with paragraph (g) of this section and providing real-time meteorological data for the sphere of influence around a potential toxic release site as input to the air dispersion model. The launch operator's process must also include a review of the meteorological conditions to identify changing conditions that could affect the toxic hazard distance for a toxic concentration threshold prior to proceeding with the operation.

(ii) A launch operator may use air dispersion modeling techniques to define the meteorological conditions that, when present, would prevent a toxic hazard distance for a toxic concentration threshold from reaching populated areas. The launch operator, when employing this method, must constrain the associated launch processing operation to be conducted only when the prescribed meteorological conditions exist. A launch operator's air dispersion modeling technique must comply with paragraph (g) of this section.

(l) *Statistical toxic risk management for launch processing.* The launch operator must use statistical toxic risk management to protect public safety if a process that involves the use of a toxic propellant does not satisfy the containment requirements of paragraph (d) of this section. A launch operator, for each such case, must perform a toxic risk assessment and develop criteria that protect the public from risks due to planned and potential toxic release. A launch operator must ensure that the resultant toxic risk meets the collective and individual risk criteria requirements defined in §417.107(b). A launch operator's toxic risk assessment must account for the following:

(1) All credible equipment failure and non-failure modes, along with the consequent release and combustion of toxic propellants;

(2) Equipment failure rates;

(3) The effect of positive or negative buoyancy on the rise or descent of the released toxic propellants;

(4) The influence of atmospheric physics on the transport and diffusion of toxic propellants released;

(5) Meteorological conditions at the time of the process;

(6) Population density, location, susceptibility (health categories) and sheltering for populations within each potential toxic hazard area; and

(7) Exposure duration and toxic propellant concentration or dosage that would result in casualty for populations.

(m) *Launch processing toxic release hazard analysis products.* The products of a launch operator's toxic release hazards analysis for launch processing must include the following:

(1) For each worst-case release scenario, a description of the vessel or pipeline and toxic propellant selected as the worst case for each process, assumptions and parameters used, and the rationale for selection of that scenario. Assumptions must include use of administrative controls and passive mitigation that were assumed to limit the quantity that could be released. The description must include the anticipated effect of the controls and mitigation on the release quantity and rate;

(2) For each worst-case alternative release scenario, a description of the scenario identified for each process, assumptions and parameters used, and the rationale for the selection of that scenario. Assumptions must include use of administrative controls and

passive mitigation that were assumed to limit the quantity that could be released. The description must include the anticipated effect of the controls and mitigation on the release quantity and rate;

(3) Estimated quantity released, release rate, and duration of release for each worst-case scenario and worst-case alternative scenario for each process;

(4) A description of the methodology used to determine the toxic hazard distance for each toxic concentration threshold;

(5) Data used to estimate off-site population receptors potentially affected; and

(6) The following data for each worst-case scenario and worst-case alternative release scenario:

(i) Chemical name;

(ii) Physical state;

(iii) Basis of results (provide model name if used, or other methodology);

(iv) Scenario (explosion, fire, toxic gas release, or liquid spill and vaporization);

(v) Quantity released in pounds;

(vi) Release rate;

(vii) Release duration;

(viii) Wind speed and atmospheric stability class;

(ix) Topography;

(x) Toxic hazard distance;

(xi) All members of the public within the toxic hazard distance;

(xii) Any passive mitigation considered; and

(xiii) Active mitigation considered (worst-case alternative release scenario only).

APPENDIX J TO PART 417—GROUND SAFETY ANALYSIS REPORT

J417.1 GENERAL

(a) This appendix provides the content and format requirements for a ground safety analysis report. A launch operator must perform a ground safety analysis as required by subpart E of part 417 and document the analysis in a ground safety analysis report that satisfies this appendix, as required by §417.402(d).

(b) A ground safety analysis report must contain hazard analyses that describe each hazard control, and describe a launch operator's hardware, software, and operations so that the FAA can assess the adequacy of the hazard analysis. A launch operator must document each hazard analysis on hazard analysis forms as required by §J417.3(d) and file each system and operation descriptions as a separate volume of the report.

(c) A ground safety analysis report must include a table of contents and provide definitions of any acronyms and unique terms used in the report.

(d) A launch operator's ground safety analysis report may reference other documents filed with the FAA that contain the information required by this appendix.

J417.3 GROUND SAFETY ANALYSIS REPORT CHAPTERS

(a) *Introduction.* A ground safety analysis report must include an introductory chapter that describes all administrative matters, such as purpose, scope, safety certification of personnel who performed any part of the analysis, and each special interest issue, such as a high-risk situation or potential non-compliance with any applicable FAA requirement.

(b) *Launch vehicle and operations summary.* A ground safety analysis report must include a chapter that provides general safety information about the vehicle and operations, including the payload and flight termination system. This chapter must serve as an executive summary of detailed information contained within the report.

(c) *Systems, subsystems, and operations information.* A ground safety analysis report must include a chapter that provides detailed safety information about each launch vehicle system, subsystem and operation and each associated interface. The data in this chapter must include the following:

(1) *Introduction.* A launch operator's ground safety analysis report must contain an introduction to its systems, subsystems, and operations information that serves as a roadmap and checklist to ensure all applicable items are covered. All flight and ground hardware must be identified with a reference to where the items are discussed in the document. All interfacing hardware and operations must be identified with a reference to where the items are discussed in the document. The introduction must identify interfaces between systems and operations and the boundaries that describe a system or operation.

(2) *Subsystem description.* For each hardware system identified in a ground safety analysis report as falling under one of the hazardous systems listed in paragraphs (c)(3), (c)(4) and (c)(5) of this section, the report must identify each of the hardware system's subsystems. A ground safety analysis report must describe each hazardous subsystem using the following format:

(i) General description including nomenclature, function, and a pictorial overview;

(ii) Technical operating description including text and figures describing how a subsystem works and any safety features and fault tolerance levels;

(iii) Each safety critical parameter, including those that demonstrate established system safety approaches that are not evident in the technical operating description or figures, such as factors of safety for structures and pressure vessels;

(iv) Each major component, including any part of a subsystem that must be technically described in order to understand the subsystem hazards. For a complex subsystem such as a propulsion subsystem, the ground safety analysis report must provide a majority of the detail of the subsystem including any figures at the major component level such as tanks, engines and vents. The presentation of figures in the report must progress in detail from broad overviews to narrowly focused figures. Each figure must have supporting text that explains what the figure is intended to illustrate;

(v) Ground operations and interfaces including interfaces with other launch vehicle and launch site subsystems. A ground safety analysis report must identify a launch operator's and launch site operator's hazard controls for all operations that are potentially hazardous to the public. The report must contain facility figures that illustrate where hazardous operations take place and must identify all areas where controlled access is employed as a hazard control; and

(vi) Hazard analysis summary of subsystem hazards that identifies each specific hazard and the threat to public safety. This summary must provide cross-references to the hazard analysis form required by paragraph (d) of this section and indicate the nature of the control, such as design margin, fault tolerance, or procedure.

(3) *Flight hardware.* For each stage of a launch vehicle, a ground safety analysis report must identify all flight hardware systems, using the following sectional format:

(i) Structural and mechanical systems;

(ii) Ordnance systems;

(iii) Propulsion and pressure systems;

(iv) Electrical and non-ionizing radiation systems; and

(v) Ionizing radiation sources and systems.

(4) *Ground hardware.* A ground safety analysis report must identify the launch operator's and launch site operator's ground hardware, including launch site and ground support equipment, that contains hazardous energy or materials, or that can affect flight hardware that contains hazardous energy or materials. A launch operator must identify all ground hardware by using the following sectional format:

(i) Structural and mechanical ground support and checkout systems;

(ii) Ordnance ground support and checkout systems;

(iii) Propulsion and pressure ground support and checkout systems;

(iv) Electrical and non-ionizing radiation ground support and checkout systems;

(v) Ionizing radiation ground support and checkout systems;

(vi) Hazardous materials; and

(vii) Support and checkout systems and any other safety equipment used to monitor or control a potential hazard not otherwise addressed above.

(5) *Flight safety system.* A ground safety analysis report must describe each hazard of inadvertent actuation of the launch operator's flight safety system, potential damage to the flight safety system during ground operations, and each hazard control that the launch operator will implement.

(6) *Hazardous materials.* A ground safety analysis report must:

(i) Identify each hazardous material used in all the launch operator's flight and ground systems, including the quantity and location of each material;

(ii) Contain a summary of the launch operator's approach for protecting the public from toxic plumes, including the toxic concentration thresholds used to control public exposure and a description of any related local agreements;

(iii) Describe any toxic plume model used to protect public safety and contain any algorithms used by the model; and

(iv) Include the products of the launch operator's toxic release hazard analysis for launch processing as defined by section I417.7(m) of appendix I of this part for each launch that involves the use of any toxic propellants.

(d) *Hazard analysis.* A ground safety analysis report must include a chapter containing a hazard analysis of the launch vehicle and launch vehicle processing and interfaces. The hazard analysis must identify each hazard and all hazard controls that the launch operator will implement. A ground safety analysis report must contain the results of the launch operator's hazard analysis of each system, subsystem, and operation using a standardized format that includes the items listed on the example hazard analysis form provided in figure J417–1 and that satisfies the following:

(1) *Introduction.* A ground safety analysis report must contain an introduction that serves as a roadmap and checklist to the launch operator's hazard analysis forms. A launch operator must identify all flight hardware, ground hardware, interfacing hardware, and operations with a reference to where the items are discussed in the ground safety analysis report. The introduction must explain how a launch operator presents its hazard analysis in terms of hazard identification numbers as identified in figure J417–1.

(2) *Analysis.* A launch operator may present each hazard on a separate form or consolidate hazards of a specific system, subsystem, component, or operation onto a single form. There must be at least one form for each hazardous subsystem and each hazardous subsystem operation. A launch operator must state which approach it has chosen in the introduction to the hazard analysis section. A launch operator must track each identified hazard control separately.

(3) *Numbering.* A launch operator must number each hazard analysis form with the applicable system or subsystem identified. A launch operator must number each line item

on a hazard analysis form with numbers and letters provided for multiple entries against an individual line item. A line item consists of a hardware or operation description and a hazard.

(4) *Hazard analysis data.* A hazard analysis form must contain or reference all information necessary to understand the relationship of a system, subsystem, component, or operation with a hazard cause, control, and verification.

(e) *Hazard analysis supporting data.* A ground safety analysis report must include data that supports the hazard analysis. If such data does not fit onto the hazard analysis form, a launch operator must provide the data in a supporting data chapter. This chapter must contain a table of contents and may reference other documents that contain supporting data.

PARTS 418–419 [RESERVED]

PART 420—LICENSE TO OPERATE A LAUNCH SITE

Subpart A—General

Sec.

Subpart B—Criteria and Information Requirements for Obtaining a License

Subpart C—License Terms and Conditions

Subpart D—Responsibilities of a Licensee

AUTHORITY: 49 U.S.C. 70101–70121.

SOURCE: Docket No. FAA–1999–5833, 65 FR 62861, Oct. 19, 2000, unless otherwise noted.

Subpart A—General

§ 420.1 Scope.

This part prescribes the information and demonstrations that must be provided to the FAA as part of a license application, the bases for license approval, license terms and conditions, and post-licensing requirements with which a licensee shall comply to remain licensed. Requirements for preparing a license application are contained in part 413 of this subchapter.

§ 420.3 Applicability.

This part applies to any person seeking a license to operate a launch site or to a person licensed under this part. A person operating a site that only supports amateur rocket activities, as defined in 14 CFR 401.5, does not need a license under this part to operate the site.

§ 420.5 Definitions.

For the purpose of this part.

Ballistic coefficient means the weight of an object divided by the quantity product of the coefficient of drag of the object and the area of the object.