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;