RLV OPERATIONS & MAINTENANCE (O&M) WHITE PAPER,

INDUSTRY COMMENTS

Commercial Space Transportation Advisory Committee

(COMSTAC)

RLV Working Group

July 14, 2000

DRAFT

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EXECUTIVE SUMMARY

The Reusable Launch Vehicle (RLV) Operations & Maintenance (O&M) White Paper was presented to the COMSTAC RLV Working Group by Chuck Larsen, FAA/AST, on 20 October 1999. Chuck also presented a letter from Ms. Patti Grace Smith, Associate Administrator for Commercial Space Transportation to Steve Flajser, COMSTAC Chairman, requesting review of the document by the COMSTAC. Chuck in turn requested comments from all RLV WG members. He asked that all comments be sent to Bob Keltner, KST, who would incorporate them into a single report for presentation at the spring RLV WG meeting. Since there were a limited number available at the meeting and the paper was not available in a combined electronic format, members were asked to contact Bob to obtain additional copies. In the interim, considerable correspondence occurred among many in the group, discussing various aspects of the paper. As a result of these discussions, eight companies submitted comments formally. The comments, however, are a composite of ideas from many contributors within the group. Although comments from the Boeing Company, Long Beach, A9, do not address RLV operations and maintenance, but are a description of the Boeing approach to RLV certification, they have been included as an official submittal to the request for comments to the RLV O&M white paper.

The White Paper is included in its entirety with the exception of Attachments 1 and 2 that are not available in an electronic format. Attachment 1 is MSG-3, Airline/Manufacturer Maintenance Program Development Document prepared by the Air Transport Association of America. Attachment 2 is the presentation "Regulatory Medical Aspects of Manned Commercial Space Operations" prepared by the FAA Office of Aviation Medicine Civil Aeromedical Institute. Also included in this report is a copy of the referenced FAA letter and three letters of general interest from Working Group members that deserve wider circulation than the original correspondence. Since several sets of comments are new and were not included in the original draft, members are requested to review these new comments and provide corrections or remarks to Bob Keltner for incorporation in the final version.

FAA/AST LETTER

U.S. Department
of Transportation
Federal Aviation
Administration

800 Independence Ave., SW.
Washington D.C. 20591

OCT I 9 1999

Mr. Steven H. Flajser
Vice President, Space Systems
Loral Space and Communications Ltd.
1755 Jefferson Davis Highway, Suite 1007
Arlington, VA 22202

Dear Mr. Flajser,

The Office of the Associate Administrator for Commercial Space Transportation (AST) recently completed the enclosed White Paper on "Commercial Space Transportation Reusable Launch Vehicle Operations and Maintenance." AST conducted this study to examine what will be required of the emerging commercial reusable launch vehicle (RLV) industry from an operations and maintenance (O&M) standpoint to ensure RLV operations are safe to allow initial operations and *re-flight* of RLVs. There are seven main areas of consideration and concern that were examined for RLV O&M in this White Paper, as follows:

1) What parts of the existing FARs applicable to aircraft O&M can be utilized for commercial RLVs?
2) What new FARs will be required?
3) What regulatory safety guidelines need to be developed for this emerging industry to ensure public safety while new RLV O&M regulations are being developed?
4) What additional O&M requirements exist when humans are on board?
5) Can practices such as the Federal Aviation Administration's (FAA) designated examiners program be used on RLVs in a manner similar to the aviation arena?
6) What areas of research and development do the FAA and the industry need to focus -on to come up with an efficient means to conduct an RLV O&M program that maintains the requisite level of public safety?
7) What will be the requirements for an aerospace mechanic or repairman and how may they differ from an aviation mechanic or repairman?

Please review the enclosed document and provide your comments to AST by the next COMSTAC meeting in the spring of 2000. AST will use these comments, as appropriate, in efforts to develop draft regulations in the area of commercial RLV O&M.

Thank you for providing your insights and advice on this important FAA endeavor.

Sincerely,

Patricia G. Smith

Associate Administrator for Commercial Space

KNOWN LIST OF RECIPIENTS OF RLV O&M "WHITE PAPER"

Some attendees at the 20 February COMSTAC RLV WG meeting may have received copies of the FAA RLV O&M Requirements "white paper" at the meeting. Those who received copies by request following this meeting are listed below.

James Ballard,	United Space Alliance
David Brandt,	Lockheed Martin
Alan DeLuna,	United Space Alliance
Bill Findiesen,	Boeing Company
Jim French,	AIAA
Bill Gaubatz,	United Space Lines
George Gray,	Brevard Community College
Jeff Greason,	XCOR
Stephen Leonard,	International Space Brokers
Carl Meade,	Lockheed Martin
John Parker,	Lockheed Martin
Ron Schena,	Applied Science & Technology, Inc.
Marvin Williams,	Brevard Community College
Robert Wolf,	Pioneer Rocketplane
Edgar Zapata	NASA Kennedy Space Center

CORRESPONDENCE OF INTEREST

(E-mail from George Gray, Brevard Community College to Chuck Larsen, FAA/AST, 19 November 1999)

It is my understanding that currently FAA licenses launch sites and associated operations and not the technician. It is also my understanding that there is an advisory committee working on the requirements for technician licensing.

As the newly established manager of the Aerospace/Aviation Programs Office at Brevard Community College (BCC), I am responsible for developing an A.S. Spacecraft launch Technician (SLT) program. Because of our proximity to and our close and long standing relationship with the Kennedy Space Center and the Cape Canaveral Air Station we are in a great position to ascertain the educational requirements needed to support existing and future RLV and ELV operations.

We are in the process of forming an industry advisory committee which will include the United Space Alliance, Boeing, Lockheed and other firms directly related to training a productive and efficient workforce. It is imperative that BCC develop a curriculum that is realistic and endorsed by the Launch industry.

From the regulatory standpoint, it is just as important to ensure that our A.S. program integrates any licensing and/or certification requirements. To this end, it is respectfully requested that I be included as appropriate on any advisory committees or meetings that would assist us in developing a strong A.S. program. It is our intent to establish a program and begin classes next summer. Obviously, we would be very interested in any thoughts you may have as it relates to providing our course to the FAA and/or having an FAA instructor as part of our program. We are embarking on a program that hopefully will become the training center for Launch technicians in the US and abroad.

**(Letter from Spaceport Florida to
Florida State Senate Fiscal Policy Committee)**

Ms. Jane Hayes
Senate Fiscal Policy Committee
The Capitol, Room 201
Tallahassee, Florida 32399

Dear Ms. Hayes:
I understand that you are supporting the efforts of a joint committee to study workforce issues for the state. Our agency has been involved in various space-related workforce projects and I wanted to provide information to you on our experiences, particularly in the areas of technician-level training and certification, and practice-based education at the Cape Canaveral Spaceport.

Workforce Training & Certification

Several years ago, our agency proposed the development of a Community College-based technician training and certification program for the space launch industry. The concept is based on the successful A&P national certification system for aviation mechanics. This proposal was pursued in response to several industry concerns:

* Costly launch failures were increasingly attributed to human error during launch vehicle assembly and processing;
* Corporate consolidations revealed significant inconsistencies in industry approaches to workforce training;
* Minimum technician skill-levels were found to be different among multiple companies providing the same services; and
* Training represented an unusually high share of launch industry overhead, compared to other industries.

Together with Brevard Community College, whose service area includes the Cape Canaveral Spaceport, we proposed to work with industry, NASA and the Air Force to establish a broad technician-level training curriculum that would be taught by BCC. Students completing the curriculum would receive a state-level certification (established through our agency's regulatory rule-making authority). This would benefit the industry in several ways:

* Fewer launch failures would be attributable to human error;
* Launch insurance rates would likely be reduced;
* Overhead costs would decline for industry, NASA and the Air Force through externalized training services;
* Prospective employees would pay for their own training and certification, prior to being hired; and

* An increasingly homogenous, better-qualified workforce would support industry expansion, retention and recruitment.

Progress with this initiative has increased over the past two years, as BCC has added personnel and resources to support its development. (BCC's point of contact is George Gray at 321-632-1111, extension 63119.) Through the legislatively established Florida Space Research Institute, we have requested funding to continue to develop appropriate curriculum with industry. I believe that BCC has requested similar funding support for this very important project.

Practice-Based Education

The Spaceport Authority has facilitated an expanded university presence at the Cape Canaveral Spaceport, aimed at increasing university support for the industry's diversification. The university presence has also been beneficial by providing exciting opportunities for students and faculty to gain hands-on "practice-based" experience with actual space industry operations. Up to five engineering courses per semester are now taught at the spaceport, allowing students from several universities and colleges to gain a real-world advantage when they enter the workforce. A point of contact for these activities is Dr. Sam Durrance at the Florida Space Institute at 321-730-2601.

Another benefit of this university presence is found in the opportunities that it provides for faculty members to become problem solvers for industry. We can list multiple examples where industry has turned to their new university colleagues for on-the-spot advice and assistance. I cannot help but think that similar job site university programs would be beneficial for other industries in the state.

Overall, our agency's unique focus on space issues has allowed us to gather considerable expertise on the industry's needs and trends. The state might be well served by directing or empowering other agencies to focus on the state's other targeted industry sectors.

If you would like any additional information on these programs and concepts, please call me at 321-730-5301, extension 1105.

Sincerely,

Edward Ellegood
Director, Policy & Program Development
Spaceport Florida

(E-mail from Dr. Marvin Williams, Brevard Community College to Bob Keltner, KST, 12 January 2000)

We at Brevard Community College have been working for over five years to promote a Space Technician Certification program and I am very pleased to see an effort underway which could lead to the Certification System. Mr. Jim Ballard gave me a copy of your Working Group's efforts on the subject for review and I found it extremely interesting and positive. Brevard Community College has an A.S. Degree in Space Maintenance Technology which was designed as an introductory program to a full up certification program by governmental and private sector organizations. I have been employed by Brevard Community College (At KSC Office) for 6 years, having formerly served as the KSC-NASA Launch Operations Training and Certification Manager for 30 years. I think the working groups effort is on the right track and I sincerely believe the Technician Certification Program will be very beneficial to the Nation's Space Programs, especially for further insuring Safety in all operations.

White Paper on Commercial Space Transportation Reusable Launch Vehicle Operations and Maintenance

The infant commercial space transportation industry is embarking upon a transition from the use of primarily expendable launch vehicles (ELVs) to the use of reusable launch vehicles (RLVs) to deliver payloads to space. With the advent of RLVs into the launch vehicle arena comes new concerns and issues that were not present in the use of ELVs; namely, that of operations and maintenance (O&M) of reusable launch vehicles. This area is not new to the FAA, and an analogy may be drawn to aircraft which must comply with the applicable Federal Aviation Regulations (FARs) to ensure they are safe to fly over public, populated areas.

At present, the only launch vehicle that is operational and reusable, is the NASA Space Shuttle, a government owned and operated launch/reentry vehicle. Although much can be learned from the NASA experiences with Shuttle O&M, any commercial operation which employed the strict practices that NASA requires to certify the Shuttle would quickly be driven out of business. This paper will discuss the O&M considerations that the FAA should take into account when developing regulations for the operation and maintenance of an RLV. It will describe what an FAA inspector might look for when conducting an inspection of an RLV.

It is anticipated there will be many parallels between aviation industry O&M and future reusable launch vehicle industry practices. In addition, RLV O&M practices must account for the effects of the space environment and the reentry environment, which aircraft do not have to contend with. Other differences may include the importance of reducing the weight of the vehicle, and the levels of redundancy and the operational philosophy adopted (i.e. fail safe or fail operational) in systems such as avionics. Indeed, how this important area of RLV O&M evolves with the FAA developing regulations to ensure that RLVs are safe to re-fly, and the resultant costs to the industry to comply with these necessary regulations, may have a telling effect on the industry.

Areas of consideration and concern for RLV O&M include, but are not limited to the following; 1) how much of the existing FARs applicable to aircraft O&M can be utilized for the commercial RLVs?, 2) what new FARs will be required?, 3) what regulatory safety guidelines need to be developed for this emerging industry to ensure public safety while new RLV O&M regulations are being developed?, 4) what additional O&M requirements exist when humans are onboard?, 5) can practices such as the FAA’s designated examiners program be used on RLVs in a manner similar to the aviation arena?, 6) what areas of research and development do the FAA and the industry need to focus on to come up with an efficient means to conduct an RLV O&M program that maintains the requisite level of public safety?, 7) what will be the requirements for an aerospace mechanic or repairman and how may they differ from an aviation mechanic or repairman?

In an attempt to get some answers to these questions, let’s look at what a typical RLV consists of; namely, the hardware and software and firmware that is required to have a reusable launch vehicle. A typical RLV will have the following systems; 1) main propulsion (liquid and/or solid propellants), 2) avionics (including computers and guidance, navigation and control), 3) power including power distribution, 4) telemetry, tracking and control (TT&C), 5) thermal control (both active and passive), 6) electro-mechanical actuators (or hydraulics), 7) structure, 8) reaction control system, 9) orbital maneuvering system, 10) auxiliary power unit, 11) a flight safety system, and 12) for human spaceflight an environmental control and life support system (ECLSS). Since the RLV is designed to operate as an integrated system, all of the above major systems may have an effect on vehicle safety and, therefore, public safety and health. Since the integrated system may impact the public safety, the whole RLV will be looked at in terms of protecting the public health and safety.

How much of the existing FARs applicable to aircraft O&M can be utilized for commercial RLVs?

The following applicable regulations have been assessed for their applicability;

FAR Part 91 Subpart E - Maintenance, Preventive Maintenance and Alterations

FAR Part 43 – Maintenance, Preventive Maintenance, Rebuilding, and Alterations

FAR SUBCHAPTER D - AIRMEN Part 61 – Certification: Pilots, Flight Instructors, and Ground Instructors

Part 67 – Medical Standards and Certification

FAR Part 91 Subpart E (Maintenance, Preventive Maintenance and Alterations) cannot be used for most of the candidate RLVs according to the present FAR Part 91 section 91.1 Applicability. This specifically excludes unmanned rockets and refers to Part 101. Section 91.401 Applicability (a), states “This subpart prescribes rules governing the maintenance, preventive maintenance and alterations of U.S.-registered civil aircraft operating within or outside of the United States.” Presently, AST does not have registration authority. If these were part of Part 400 and included RLVs, then this could apply to an RLV maintenance program.

This subpart states in section 91.403 General (a) “The owner or operator of an aircraft is primarily responsible for maintaining that aircraft in an airworthy condition, including compliance with part 39 of this chapter.” Note: Part 39 is “Airworthiness Directives” Paragraph (b) states that “No person may perform maintenance, preventive maintenance, or alterations on an aircraft other than as prescribed in this subpart and other applicable regulations, including part 43 of this chapter.” Paragraph (c) states that “No person may operate an aircraft for which a manufacturer’s maintenance manual or instructions for continued airworthiness has been issued that contains an airworthiness limitations section unless the mandatory replacement times, inspection intervals, and related procedures set forth in an operations specification approved by the Administrator under part 121, 127 or 135 of this chapter or in accordance with an inspection program approved under section 91.409 (e) have been complied with.”

Note: Part 121 Certification and operations: Domestic, flag, and supplemental air carriers and commercial operators of large aircraft., Part 127 Certification and operations of scheduled air carriers with helicopters. (Part 127 was removed, effective 1-19-96), and Part 135 Air taxi operators and commercial operators. are particular parts of the FARs that deal with SUBCHAPTER G – AIR CARRIERS AND OPERATORS FOR COMPENSATION OR HIRE: CERTIFICATION AND OPERATIONS, Part 119 – Certification: Air Carriers and Commercial Operators. These sections may have to be revised extensively to be applicable for commercial RLVs. It may be better to do a whole new part for them, such as a Part 421 in the Commercial Space Transportation regulations. The removal of Part 127 was explained by the FAA as follows; rotocraft operators that previously operated under Part 127 are directed in Part 119.25 to conduct those operations under Part 135. Part 135 has been more recently updated and, therefore, provides a more appropriate level of safety for rotocraft operators than Part 127.

Section 91.405 Maintenance required it states "Each owner or operator of an aircraft—
Shall have that aircraft inspected as prescribed in subpart E of this part and shall between required inspections, except as provided in paragraph (c) of this section, have discrepancies repaired as prescribed in part 43 of this chapter;
Shall ensure that maintenance personnel make appropriate entries in the aircraft maintenance records indicating the aircraft has been approved for return to service;
Shall have any inoperative instrument or item of equipment permitted to be inoperative by section 91.213(d)(2) of this part repaired, replaced removed or inspected at the next required inspection; and
When listed discrepancies include inoperative instruments or equipment shall ensure that a placard has been installed as required by section 43.11 of this chapter."
Also, section 91.407 Operation after maintenance, preventive maintenance, rebuilding , or alteration. states that;
"(a) No person may operate any aircraft that has undergone maintenance, preventive maintenance, rebuilding or alteration unless--
It has been approved for return to service by a person authorized under section 43.7 of this chapter; and
The maintenance record entry required by section 43.9 or section 43.11, as applicable of this chapter has been made.
(b) No person may carry any person (other than crewmembers) in an aircraft that has been maintained, rebuilt, or altered in a manner that may have appreciably changed its flight characteristics, or substantially affected its

operation in flight until an appropriately rated pilot with at least a private pilot certificate flies the aircraft, makes an operational check of the maintenance performed or alteration made, and logs the flight in the aircraft records.
(c) The aircraft does not have to be flown as required by paragraph (b) of this section, if prior to flight, ground tests, inspection, or both show conclusively that the maintenance, preventive maintenance, rebuilding, or alteration has not appreciably changed the flight characteristics or substantially affected the flight operation of the aircraft." – Note: (b) and (c) above would apply only to piloted RLVs.

Finally, section 91.409 Inspection states that;
"(a) Except as provided in paragraph (c) of this section, no person may operate an aircraft unless, within the preceding 12 calendar months, it has had—
An annual inspection in accordance with part 43 of this chapter and has been approved for return to service by a person authorized by section 43.7 of this chapter; or
An inspection for the issuance of an airworthiness certificate in accordance with part 21 of this chapter.
No inspection performed under paragraph (b) of this section may be substituted for any inspection required by this paragraph unless it is performed by a person authorized to perform annual inspections and is entered as an "annual" inspection in the required maintenance records.
(b) Except as provided in paragraph (c) of this section, no person may operate an aircraft carrying any person (other than a crewmember) for hire, and no person may give flight instruction for hire in an aircraft which that person provides, unless within the preceding 100 hours of time in service the aircraft has received an annual or 100-hour inspection and has been approved for return to service in accordance with part 43 of this chapter or has received an inspection for the issuance of an airworthiness certificate in accordance with part 21 of this chapter. The 100-hour limitation may be exceeded by not more than 10 hours while en route to reach a place where the inspection can be done. The excess time used to reach a place where the inspection can be done must be included in computing the next 100 hours in service.
(c) Paragraphs (a) and (b) of this section do not apply to-
(1) An aircraft that carries a special flight permit, a current experimental certificate or a provisional airworthiness certificate;

(2) An aircraft inspected in accordance with an approved aircraft inspection program under part 125, 127, or 135 of this chapter and so identified by the registration number in the operations specifications of the certificate holder having the approved inspection program;
An aircraft subject to the requirements of paragraph (d) or (e) of this section; or
(4) Turbine-powered rotocraft when the operator elects to inspect that rotocraft in accordance with paragraph (e) of this section.
(d) *Progressive inspection.* Each registered owner or operator of an aircraft desiring to use a progressive inspection program must submit a written request to the FAA Flight Standards district office having jurisdiction over the area in which the applicant is located, and shall provide-
(1) A certified mechanic holding an inspection authorization, a certificated airframe repair station, or the manufacturer of the aircraft to supervise or conduct the progressive inspection;
(2) A current inspection procedures manual available and readily understandable to pilot and maintenance personnel containing in detail-
(i) An explanation of the progressive inspection, including the continuity of inspection responsibility, the making of reports, and the keeping of records and technical reference material;
(ii) An inspection schedule specifying the intervals in hours or days when routine and detailed inspections will be performed and including instructions for exceeding an inspection interval by not more than 10 hours while en route and for changing an inspection interval because of service experience;
(iii) Sample routine and detailed inspection forms and instructions for their use;
(3) Enough housing and equipment for necessary disassembly and proper inspection of the aircraft; and
(4) Appropriate current technical information for the aircraft.
The frequency and detail of the progressive inspection shall provide for the complete inspection of the aircraft within each 12 calendar months and be consistent with the manufacturer’s recommendations, field service experience, and the kind of operation in which the aircraft is engaged. The progressive inspection schedule must ensure that the aircraft at all times, will be airworthy and will conform to all applicable FAA aircraft specifications, type

certificate data sheets, airworthiness directives, and other approved data. If the progressive inspection is discontinued., the owner or operator shall immediately notify the local FAA Flight Standards district office, in writing, of the discontinuance. After the discontinuance, the first annual inspection under section 91.409(a)(1) is due within 12 calendar months after the last complete inspection of the aircraft under the progressive inspection. The 100-hour inspection under section 91.409(b) is due within 100 hours after that complete inspection. A complete inspection of the aircraft, for the purpose of determining when the annual and the 100-hour inspections are due, requires a detailed inspection of the aircraft and all its components in accordance with the progressive inspection. A routine inspection of the aircraft and a detailed inspection of several components is not considered to be a complete inspection.

(e) *Large airplanes (to which part 125 is not applicable), turbojet multiengine airplane, turbopropeller-powered multiengine airplane, and turbine-powered rotocraft*. No person may operate a large airplane, turbojet multiengine airplane, turbopropeller-powered multiengine airplane, or turbine-powered rotocraft unless the replacement times for life-limited parts specified the aircraft specifications, type data sheets, or other documents approved by the Administrator are complied with and the airplane or turbine-powered rotocraft, including the airframe, engines, propellers, rotors, appliances, survival equipment, and emergency equipment is inspected in accordance with an inspection program selected under the provisions of paragraph (f) of this section, except that, the owner or operator of a turbine-powered rotocraft may elect to use the inspection provisions of section 91.409(a), (b), (c), or (d) in lieu of an inspection option of 91.409(f).

(f)*Selection of inspection program under paragraph (e) of this section.* The registered owner or operator of each airplane or turbine-powered rotocraft described in paragraph (e) of this section must select, identify in the aircraft maintenance records, and use one of the following programs for the inspection of the aircraft:

(1) A continuous airworthiness inspection program that is part of a continuous airworthiness maintenance program currently in use by a person holding an air carrier operating certificate or an operating certificate issued under part 121, 127, or 135 of this chapter and operating that make and model aircraft under part 121 of this chapter or operating that make and model under part 135 of this

chapter and maintaining it under 135.411(a)(2) of this chapter.

(2)An approved aircraft inspection program approved under section 135.419 of this chapter and currently in use by a person holding an operating certificate issued under part 135 of this chapter.

(3)A current inspection program recommended by the manufacturer.

(4)Any other inspection program established by the registered owner or operator of that airplane or turbine-powered rotocraft and approved by the Administrator under paragraph (g) of this section. However, the Administrator may require revision of this inspection program in accordance with the provisions of section 91.415.

Each operator shall include in the selected program the name and address of the person responsible for scheduling the inspections required by the program and make a copy of that program available to the person performing inspections on the aircraft and, upon request, to the Administrator.

(g)*Inspection program approved under paragraph (e) of this section*. Each operator of an airplane or turbine-powered rotocraft desiring to establish or change an approved inspection program under paragraph (f)(4) of this section must submit the program for approval to the local FAA Flight Standards district office having jurisdiction over the area in which the aircraft is based. The program must be in writing and include at least the following information

(1)Instructions and procedures for the conduct of inspections for the particular make and model airplane or turbine-powered rotocraft, including necessary tests and checks. The instructions and procedures must set forth in detail the parts and areas of the airframe, engines, propellers, rotors, and appliances, including survival and emergency equipment to be inspected.

(2)A schedule for performing the inspections that must be performed under the program expressed in terms of the time in service, calendar time, number of system operations or any combination of these.

(h)*Changes from one inspection program to another*. When an operator changes from one inspection program under paragraph (f) of this section to another, the time in service, calendar times, or cycles of operation accumulated under the previous program must be applied in determining inspection due times under the new program." – <u>Note: section 91.409, though pertaining primarily to piloted</u>

aircraft, could be made applicable to autonomous RLVs with no humans on board. However, it may be better to use this as a model for developing a new Part 491 in the Commercial Space Transportation section.

Part 91 leads to Part 43 – Maintenance, Preventive Maintenance, Rebuilding, and Alterations This part is applicable to the following;
Section 43.1 Applicability –
"(a) Except as provided in paragraph (b) of this section, this part prescribes rules governing the maintenance, preventive maintenance, rebuilding, and alteration of any-
(1)Aircraft having a U.S. airworthiness certificate:
(2)Foreign-registered civil aircraft used in common carriage or carriage of mail under the provisions of Part 121, 127, or 135 of this chapter; and
(3)Airframe, aircraft engines, propellers, appliances, and component parts of such aircraft.
(b)This part does not apply to any aircraft for which an experimental airworthiness certificate has been issued, unless a different kind of airworthiness certificate had previously been issued for that aircraft."

Now, assuming that this can be made applicable to RLVs, or used as a model to develop a new Part 443 in the Commercial Space Transportation section, the primary sections called out in Part 91 applicable to RLVs in Part 43 are as follows;

Section 43.7 Persons authorized to approve aircraft, airframes, aircraft engines, propellers, appliances, or component parts for return to service after maintenance, preventive maintenance, rebuilding, or alteration.
"(a)Except as provided in this section and section 43.17, no person other than the Administrator may approve an aircraft, airframe, aircraft engine, propeller, appliance, or component part for return to service after it has undergone maintenance, preventive maintenance, rebuilding, or alteration.
(b)The holder of a mechanic certificate or an inspection authorization may approve an aircraft, airframe, aircraft engine, propeller, appliance, or component part for return to service as provided in Part 65 of this chapter." Note: See Part 65 discussion after question 7) later.
"(c)The holder of a repair station certificate may approve an aircraft, airframe, aircraft engine, propeller,

appliance, or component part for return to service as provided in Part 145 of this chapter.
(d)A manufacturer may approve for return to service any aircraft, airframe, aircraft engine, propeller, appliance, or component part which that manufacturer has worked on under 43.3(j). However, except for minor alterations, the work must have been done in accordance with technical data approved by the Administrator.
(e)The holder of an air carrier operating certificate or an operating certificate issued under Part 121, 127, or 135 of this chapter, as applicable.
(f)A person holding at least a private pilot certificate may approve an aircraft for return to service after performing preventive maintenance under the provisions of section 43.3(g)"

It is expected that each RLV company will have its own maintenance procedures and inspection criteria and processes. However, the Air Transport Association has developed a document that is an appendix to the FAA Inspector's Handbook 8300.10 entitled "Airline/Manufacturer Maintenance Program Development Document MSG-3, Revision 2", dated September 12, 1993 (see attachment 1). This may be a good model for the RLV companies to follow to tailor their maintenance programs to treat items that are safety related separately from those that are simply an economic consideration. This could be helpful to an inspector who could then concentrate on the maintenance items that are strictly safety related.

For RLV operations with pilots, FAR SUBCHAPTER D - AIRMEN Part 61 – Certification: Pilots, Flight Instructors, and Ground Instructors may be utilized by adding requirements for RLV Certificates and Ratings. Of course, the title of the subchapter would have to be appropriately modified to include "Spacemen", or some other appropriate term to show that these people will be operating their vehicles in space as well as in air. Section 61.1 Applicability and Definitions (a) states " This part prescribes:
(1) The requirements for issuing pilot, flight instructor, and ground instructor certificates and ratings; the conditions under which those certificates and ratings are necessary; and the privileges and limitations of those certificates and ratings.
(2) The requirements for issuing pilot, flight instructor, and ground instructor authorizations; the conditions under

which those authorizations are necessary; and the privileges and limitations of those authorizations.
(3) The requirements for issuing pilot, flight instructor, and ground instructor certificates and ratings for persons who have taken courses approved by the Administrator under other parts of this chapter."
Section 61.1 (b) lists a number of definitions applicable to this Part and appropriate RLV definitions would need to be added.
Section 61.2 Certification of foreign pilots, flight instructors, and ground instructors would be applicable after adding requirements for RLV Certificates and Ratings.
Section 61.3 Requirement for certificates, ratings, and authorizations. states that
"(a) *Pilot Certificate*. A person may not act as pilot in command or in any other capacity as a required pilot flight crewmember of a civil aircraft of U.S. registry, unless that person has a valid pilot certificate or special purpose pilot authorization issued under this part in that person's physical possession or readily accessible in the aircraft when exercising the privileges of that pilot certificate or authorization. However, when that aircraft is operated in a foreign country, a current pilot license issued by that country in which the aircraft is operated may be used.
(b) *Required pilot certificate for operating a foreign-registered aircraft*. A person may not act as pilot in command or in any other capacity as a required pilot flight crewmember of a civil aircraft of foreign registry within the United States, unless that person's pilot certificate:
(1) Is valid and in that person's physical possession or readily accessible in the aircraft when exercising the privileges of that pilot certificate; and
(2) Has been issued under this part, or has been issued or validated by the country in which the aircraft is registered.
(c) *Medical certificate*. (1) Except as provided in paragraph (c)(2) of this section, a person may not act as a pilot in command or in any other capacity as a required pilot flight crewmember of an aircraft, under a certificate issued to that person under this part, unless that person has been issued a current and appropriate medical certificate that has been issued under part 67 of this chapter, or other documentation acceptable to the Administrator, which is in that person's physical possession or readily accessible in the aircraft.

(2) A person is not required to met the requirements of paragraph (c)(1) of this section if that person-
(i) Is exercising the privileges of a student pilot certificate while seeking a pilot certificate with a glider category rating or balloon class rating;
(ii) Is holding a pilot certificate with a balloon class rating and is piloting or providing training in a balloon as appropriate;
(iii) Is holding a pilot certificate or flight instructor certificate with a glider category rating, and is piloting or providing training in a glider, as appropriate;
(iv) Except as provided in paragraph (c)(2)(iii) of this section, is exercising the privileges of a flight instructor certificate, provided the person is not acting as a pilot in command or as a required pilot flight crewmember;
(v) Is exercising the privileges of a ground instructor certificate;
(vi) Is operating an aircraft within a foreign country using a pilot license issued by that country and possess evidence of current medical qualifications for that license; or
(vii) Is operating an aircraft with a U.S. pilot certificate, issued on the basis of a foreign pilot license, issued under section 61.75 of this part, and holds a current medical certificate issued by the foreign country that issued the foreign pilot license, which is in that person's physical possession or readily accessible in the aircraft when exercising the privileges of that airman certificate."
Note – the remainder of this section 61.3 would be applicable to RLVs as appropriate, under the following major headings; (d) *Flight instructor certificate*, (e) *Instrument rating*, (f) *Category II pilot authorization*, (g)*Category III pilot authorization*, (h) *Category A aircraft pilot authorization*, (i) *Ground instructor certificate*, (j) *Age limitation for certain operations*, (k)*Special purpose pilot authorization*, (l) *Inspection of certificate*.
All other sections in this Section 61.5 Certificates and ratings issued under this part., would have to be modified to include the new RLV certificates and ratings, as appropriate.

For piloted RLVs, Part 67 – Medical Standards and Certification would apply with appropriate additions to reflect RLV medical requirements. Section 67.1

Applicability., states that “This part prescribes the medical standards and certification procedures for issuing medical certificates for airmen and for remaining eligible for a medical certificate.”
Section 67.3 Issue., States that “Except as provided in section 67.5, a person who meets the medical standards prescribed in this part, based on medical examination and evaluation of the person’s history and condition is entitled to an appropriate medical certificate.”
Section 67.5 Certification of foreign airmen., states that “A person who is neither a United States Citizen nor a resident alien is issued a certificate under this part, outside the United States, only when the Administrator finds that the certificate is needed for operations of a U.S.-registered aircraft.”
Finally, section 67.7 Access to the National Driver Register., states that “At the time of application for a certificate issued under this part, each person who applies for a medical certificate shall execute an express consent form authorizing the Administrator to request the chief driver licensing official of any state designated by the Administrator to transmit information contained in the National Driver Register about the person to the Administrator. The Administrator shall make information received from the National Driver Register, if any, available on request to the person for review and written comment.”

This section would also be applicable, as it allows the Administrator to get information on prospective pilots regarding any record of DWI or DUI violations. However, the remainder of this Part 67 would need to be modified or have a new subpart or FAR Part developed to cover the aspects of applying the unique medical standards required for spacemen, as either crew or passengers (see discussion under Question 2, later).

Much of the existing FARs for aircraft can be utilized for commercial RLVs. However, there must be changes made to make the existing FARs applicable and it is probably easier, and it makes more sense, to use the existing FARs as a model and to develop a new Part 461 regulations in the Commercial Space Transportation section to adequately cover RLV Operations and Maintenance.

2) What new FARs may be required to be developed?

There are no FARs that deal with unmanned air vehicles (UAVs), although some draft guidelines have been developed. It seems that RLVs are advancing at a pace that will outstrip the publication of UAV rules. Therefore, it appears that at least two new FARs will need to be developed, namely: 1) uncrewed RLV operations and 2) crewed RLV operations (also, this FAR may have a subset for passengers, or possibly a third new FAR would need to be created). In preliminary discussions with Flight Standards (AFS-200, Gene Kirkendall), it appears there is a need for a FAR Part 421, similar to FAR Parts 121, and 135, but applicable specifically to RLVs.

FAR Part 67 may either need extensive revision or a new FAR Part 467 to handle the certification of Spacepersons according to newly developed medical standards the Office of Aviation Medicine is drafting presently. Attachment 2 is a presentation on “Regulatory Medical Aspects of Manned Commercial Space Operations” that the Director of the Civil Aeromedical Institute of the FAA developed and it shows many of the areas that must be considered and the questions that must be answered in the development of such regulations.

What regulatory safety guidelines need to be developed for this emerging industry to ensure public safety while new RLV O&M regulations are being developed?

The FAA does not have certification authority over reusable launch vehicles, so the evaluation of the operations and maintenance procedures and people performing them will be handled under the authority of the Associate Administrator for Commercial Space Transportation (AST) licensing of launch and reentry vehicles’ operations. Thus, until standards are developed, as used on the airplane side of the FAA, to certify aircraft and airmen, AST will review each applicant on a case by case basis in these areas, using the FARs for aircraft as a guide. AST needs to develop guidelines in this area, similar to the draft RLV flight safety guidelines that were developed last year and utilized for industry guidance in developing their applications for RLV licensing. The Commercial Space Transportation Advisory Committee (COMSTAC) RLV Working Group could be a valuable source of information on developing RLV O&M guidelines. It is recommended that they be asked to give their advice on what are important considerations for RLV O&M guidelines. Another good source of information may be the Space Shuttle Maintenance and Operations procedures. The Shuttle has been in operation for over 18 years now, and it has developed a remarkable record for safe flight because of its strict adherence to its O&M procedures and processes, and through its lessons learned data base that gets added to each flight. This aspect will be explored by AST through our MOU with NASA on cooperation in future space flight technology research and development. Of the eleven Objectives AST developed as Interim Safety Guidance for Reusable Launch Vehicles that was discussed at a Public Meeting on February 11th, there was only one guideline concerning RLV maintenance issues. It was as follows:

“Objective 11: Preflight Inspection and Checkout
Prior to each flight, RLVs should undergo system monitoring, inspection and checkout to ensure that all critical systems are functioning within intended parameters and are not otherwise impaired or degraded.

Discussion:

Due to the inherent risks of operating RLV’s, it is necessary to verify that all launch and reentry safety critical systems are functioning properly prior to launch. This type of pre-operations verification and checkout has been a standard practice in the aircraft and space launch industries since their inception. Even for test flights, it is important for safety to ensure the systems are functioning properly before each flight. The purpose of test flights is to demonstrate and measure the performance and functioning of key systems. Such information may not be of great value if the condition of the system being tested is not clear. Such information will provide valuable documentation on how the critical systems hold up to the flight environment and the cycling of loads on the vehicle due to reusability. Unanticipated problems may be uncovered during this process which, if not corrected, might lead to serious public health and safety consequences. The vehicle developer and operator should define a preflight validation and checkout process/procedure that meets the intent of this objective.”

The issues associated with RLV operations and maintenance to assure safe flight that a review of the FARs bring to light, such as; 1) what are the right maintenance intervals for a particular RLV design for its operational environment?, 2) what maintenance procedures are acceptable to the FAA?, 3) who has approval authority over the RLV maintenance procedures?, 4) are different systems on different maintenance schedules? These and many other questions will need to be answered to issue any more guidelines on this subject.

What is the effect on RLV O&M requirements if humans are onboard?

The effect of having crew and or passengers onboard an RLV will make O&M requirements more stringent. Many of the considerations brought out in the medical certification requirements presentation in attachment 2 speak to this. The certification of ground personnel to perform the O&M procedures may be more stringent for flights of RLVs with human occupants than for pure cargo flights, as different skills may be involved in the evaluation of a cargo only RLV versus a crewed and/or passenger flight of an RLV. Another important factor with humans onboard affecting the O&M requirements will be the extent that they are part of the RLV flight safety system (FSS). If humans play a part in ensuring the FSS operates adequately in an off nominal situation, then the emphasis on O&M requirements for environmental control and life support systems (ECLSS) and redundancy (e.g. such as two crewmen, who are thoroughly trained and checked out to perform required safety functions and emergency procedures to effect a safe abort) will take on added importance.

Can innovative practices such as the FAA's designee program be used on RLV's the same as it is being used in the aviation arena?

These programs have had a lot to offer on the aviation side of the FAA. AST is studying whether it makes sense to employ them in commercial space transportation areas. NASA and its contractors have already been exploring this for Space Shuttle O&M activities on the West Coast, in Palmdale, CA, where the Orbiter undergoes periodic overhaul and major maintenance and alterations. They have an effort underway to define preliminary requirements for an equivalent Designated Manufacturing Inspection Representative, including defining all documentation. As the Shuttle approaches 20 years of service, the potential for unplanned downtime increases. NASA's study, as discussed below, looked at all areas for designees. The

FAA Airworthiness Assurance Task Force has identified five structural initiatives that would be the cornerstone of its aging airplane program. These initiatives are: 1) structural modifications, 2) corrosion prevention and control, 3) supplemental structural inspections, 4) structural repair assessment repair requirements, and 5) structural maintenance program requirements. In addition, human factors in heavy maintenance facilities are being studied to determine if any additional safety requirements may be needed. NASA's goal is through analysis of FAA studies, current Government Mandatory Inspection Points (GMIPs) will be reviewed and refreshed to assure these inspections address all critical areas for continued service of the Shuttle.

Far Part 183 – Representatives of the Administrator, spells out the requirements for these types of personnel. In section 183.1 Scope., it states that "This part describes the requirements for designating private persons to act as representatives of the Administrator in examining, inspecting, and testing persons and aircraft for the purpose of issuing airman and aircraft certificates. In addition, it states the privileges of those representatives and prescribes rules for their exercising of those privileges."

The advantages of having a designated representative of the administrator to do things such as inspections and verifications is that the FAA does not have to plan for, get approved and expend its own resources to do these activities. Instead it utilizes either company employees or contract personnel to do them. However, a disadvantage is the potential for conflict of interest, as the company employee or contract personnel is getting paid by the company to do the activities, so there is always the potential for pressure "to pass things" or "overlook" things that otherwise might have been noticed and caught if the inspections were performed directly by the FAA. These potential problems seem to have been handled adequately by the aircraft side of the FAA, as there is widespread use of these representatives to help relieve the burden on FAA resources directly, with no apparent impact on safety. If appropriate modifications were made to this part, it could be made applicable to RLVs. However, it may make more sense to establish a "Part 4XX" in the Commercial Space Transportation section to develop such regulations and to use Part 183 as a model.

What areas of research and development do the FAA and the industry need to focus on to come up with an efficient means to conduct an RLV O&M program that maintains the requisite level of public safety?

In addition to research on all of the systems in a typical RLV as outlined at the first of this paper, a critical research area for ensuring safety of flight and efficient operations is the area of “vehicle health monitoring” (VHM) or sometimes referred to as “integrated vehicle health monitoring” (IVHM). Other areas of R&D that need to be pursued are the reliability of new Flight Safety Systems (FSS) that do not employ destruct charges, but employ other means to bring about a safe abort (e.g. the FSS for X-33 and for X-34, as well as for potential commercial RLV applicants). Still other areas of R&D technology that need to be explored include software for emergency landings and tools and methodologies to predict safe space/air corridors to allow for the co-existence of launch/reentry vehicles and airplanes and rotocraft.

What will be the requirements for an aerospace mechanic or repairman and how will they differ form an aviation mechanic or repairman?

Attachment 3 is a letter that discusses a proposal for creation of FAA certificates and ratings for aerospace maintenance technicians that offers a different perspective and provides some additional items for consideration.

PART 65-CERTIFICATION: AIRMEN OTHER THAN FLIGHT CREWMEMBERS, spells out the requirements for Mechanics in Subpart D, and for Repairmen in Subpart E. The sections of Subpart D that are applicable to an Aerospace Mechanic who would be authorized to work on RLVs, are shown in attachment 4. They would need appropriate modifications to accommodate the specific requirements of an RLV configuration. These specific requirements include the differences in technologies involved in the powerplants (jet versus rocket engines), avionics designs, life support systems (where human occupants are involved on RLVs).

The sections of Subpart E that are applicable to an Aerospace Repairman who would be authorized to work on RLVs, are shown in attachment 5. They would need appropriate modifications to accommodate the specific requirements of an RLV configuration. These specific requirements include the differences between aircraft and launch vehicle repair, including disciplines of powerplants, avionics, materials' fastening techniques and capabilities to operate machinery in the rocket manufacturing versus the aircraft industry.

USA
United Space Alliance

Date: 1-25-99

(Name, organization. Internal Address) *(Name, Organization, Internal Address, Phone)*

To: SF0C FLIGHT OPERATIONS From:

Subject: Proposed creation of FAA certificates and ratings for aerospace maintenance technicians.

Aerospace technicians work all aspects of the aerospace environment, perform tasks vastly different from those performed in aviation maintenance environments, and are affected by training and recent experience requirements that are substantially more extensive than those affecting other FAA regulated maintenance industries. The highly complex and technical field of contemporary aerospace maintenance requires substantially more than the manual skills typically associated with many facets of the aviation maintenance industry. There is an increasing complexity of training and experience requirements affecting aerospace maintenance technicians today.

1. Currently there is no training requirement to give aerospace maintenance technicians entry level experience and skills necessary for work involving different types of aerospace vehicles that employ new technology.

2. Because of the rapid acceleration of technological advances, the ability of the new aerospace technician to master this new technology without enhanced training is becoming exceedingly difficult.

3. More preparation and training are required to meet higher levels of qualification that the aerospace maintenance industry demands.

Therefore we recommend that the FAA develop the means necessary to train aerospace maintenance technicians to a level of expertise beyond the level of a licensed aircraft mechanic, which is the highest level of expertise currently available. This training should be required also to ensure that aerospace technicians possess the necessary skills to maintain the sophisticated aerospace vehicles that are in service today and in the future. In recognition of the increasing complexity and integrated nature of the systems found in expendable and reusable launch vehicles there is the proposal to create aerospace maintenance technician certification and licensing. FAA licensing thru testing defines the entry level types of skills necessary to maintain the complex aerospace vehicles and more accurately reflects the level of professionalism in the aerospace industry. There are other reasons for this change:

1. An effort to upgrade the level of maintenance proficiency in the aerospace industry.

2. Establishment of basic competency requirements for all aerospace maintenance technicians working in NASA, Air Force Space Command, and private commercial space operations.

3. Consolidate and clarify all certification training and experience requirements for aerospace maintenance technicians.

4. Establish training requirements that would enhance the technical capabilities of and increase the level of professionalism among aerospace maintenance technicians.

5. Provide essential demographic information that could be used to disseminate vital aerospace safety and training information thereby enhancing aerospace safety.

6. Development of a system with enhancements in training methods that would have a positive and significant affect on all aspects of aerospace maintenance operations.

7. Development of a system for granting additional privileges and limitations for aerospace maintenance technicians.

Because of new FAA aviation regulation developments affecting licensed aircraft mechanics, manpower needs that were previously met by personnel trained in the aviation industry, may not be able to meet future needs. These new requirements will prohibit the licensed aircraft mechanic from exercising the privileges of his certificate if the individual is not actively engaged in the aviation industry. Once the mechanic is listed as inactive by the FAA, a series of punishing regulatory requirements in the form of retraining requirements and fees must be met before the FAA would restore the mechanic's authority to return an aircraft to service thru maintenance activities. This factor will be a well known fact and highly discouraging for any licensed aircraft mechanic presently employed in aerospace or having future considerations for employment in the industry. The loss of personnel with FAA aircraft maintenance training, as a source of entry level knowledge and experience requirements, would leave the aerospace industry more vulnerable to deterioration of core competency requirements. These requirements are needed to conduct aerospace launch processes in a safe and effective manner. This will promote a need to develop a system to establish entry level skills with the consistency and reliability that aviation maintenance training requirements have provided in the past.

Attachment 4

SUBPART D – MECHANICS

Section 65.71 Eligibility requirements: General.

"(a) To be eligible for a mechanic certificate and associated ratings a person must-

(1) Be at least 18 years of age;

(2) Be able to read, write, speak, and understand the English language, or in the case of an applicant who does not meet this requirement and is employed outside of the United States by a U.S. air carrier have his certificate endorsed "Valid only outside the United States";

(3) Have passed all the prescribed tests within a period of 24 months; and

(4) Comply with the sections of this subpart that apply to the rating he seeks.

(b) A certificated mechanic who applies for an additional rating must meet the requirements of section 65.77 and, within a period of 24 months pass the tests prescribed by sections 65.75 and 65.79 for the additional rating sought.

Section 65.73 Ratings

(a) The following ratings are issued under this subpart;

(1) Airframe.

(2) Powerplant.

(b) A mechanic certificate with an aircraft or aircraft engine rating, or both, that was issued before, and was valid on June 15, 1952, is equal to a mechanic certificate with an airframe or powerplant rating, or both as the case may be, and may be exchanged for such a corresponding certificate and rating or ratings.

Section 65.75 Knowledge requirements.

(a) Each applicant for a mechanic certificate or rating must, after meeting the applicable experience requirements of section 65.77, pass a written test covering the construction and maintenance of aircraft appropriate to the rating he seeks, the regulations in this subpart, and the applicable provisions of parts 43 and 91 of this chapter. The basic principles covering the installation and maintenance of propellers are included in the powerplant test.

(b) The applicant must pass each section of the test before applying for oral and practical tests prescribed by section 65.79. A report of the written test is sent to the applicant.

Section 65.77 Experience requirements.

Each applicant for a mechanic certificate or rating must present either an appropriate graduation certificate or certificate of completion from a certificated aviation maintenance technician school or documentary evidence, satisfactory to the Administrator, of-

(a)At least 18 months of practical experience with the procedures, practices, materials, tools, machine tools, and equipment generally used in constructing, maintaining, or altering airframes, or powerplants appropriate to the rating sought; or

(b)At least 30 months of practical experience concurrently performing the duties appropriate to both the airframe and powerplant ratings.

Section 65.79 Skill requirements.

Each applicant for a mechanic certificate or rating must pass an oral and a practical test on the rating he seeks. The tests cover the applicant's basic skill in performing practical projects on the subjects covered by the written test for that rating. An applicant for a powerplant rating must show his ability to make satisfactory minor repairs to, and minor alterations of, propellers.

Section 65.80 Certified aviation maintenance technician school students.

Whenever an aviation maintenance technician school certified under part 147 of this chapter shows to an FAA inspector that any of its students has made satisfactory progress at the school and is prepared to take the oral and practical tests prescribed by section 65.79, that student may take those tests during the final subjects of his training in the approved curriculum, before he meets the applicable experience requirements of section 65.77 and before he passes each section of the written test prescribed by section 65.75.

Section 65.81 General privileges and limitations.

(a)A certified mechanic may perform or supervise the maintenance, preventive maintenance, or alteration of an aircraft or appliance, or a part thereof, for which he is rated (but excluding major repairs to, and major alterations of, propellers, and any repair to, or alteration of, instruments) and may perform additional duties in accordance with sections 65.85, 65.87, and 65.95. However, he may not supervise the maintenance, preventive maintenance, or alteration of, or approve and return to service, any aircraft or appliance, or part thereof, for which he is rated unless he has satisfactorily performed that work concerned at an earlier date. If he has not so performed that work at an earlier date he may show his ability to do it by performing it to the satisfaction of the Administrator or under the direct supervision of a certificated and appropriately rated mechanic, or a certificated repairman, who has had previous experience in the specific operation concerned.

(b) A certificated mechanic may not exercise the privileges of his certificate and rating unless he understands the current instructions of the manufacturer, and the maintenance manuals, of the specific operation concerned.

Section 65.83 Recent experience requirements.

A certified mechanic may not exercise the privileges of his certificate and rating unless, within the preceding 24 months-

(a) The Administrator has found that he is able to do that work; or

(b) He has, for at least 6 months-

(1)Served as a mechanic under his certificate and rating;

(2)Technically supervised other mechanics;

(3)Supervised, in an executive capacity, the maintenance or alteration of aircraft; or

(4)Been engaged in any combination of paragraph (b) (1), (2), or (3) of this section.

Section 65.85 Airframe rating; additional privileges.

A certified mechanic with an airframe rating may approve and return to service an airframe, or any related part or appliance, after he has performed, supervised, or inspected its maintenance or alteration(excluding major repairs and major alterations). In addition he may perform the 100-hour inspection required by part 91 of this chapter on an airframe, or any related part or appliance, and approve and return it to service.

Section 65.87 Powerplant rating; additional privileges.

A certificated mechanic with a powerplant rating may approve and return to service a powerplant or propeller or any related part or appliance, after he has performed, supervised, or inspected its maintenance or alteration (excluding major repairs and major alterations). In addition, he may perform the 100-hour inspection required by part 91 of this chapter on a powerplant or propeller, or any part thereof, and approve and return it to service.

Section 65.89 Display of certificate

Each person who holds a mechanic certificate shall keep it within the immediate area where he normally exercises the privileges of the certificate and shall present it for inspection upon the request of the Administrator or an authorized representative of the National Transportation Safety board, or any Federal, State, or local law enforcement officer.

Section 65.91 Inspection authorization.

(a)An application for an inspection authorization is made on a form and in a manner prescribed by the Administrator.
(b)An applicant who meets the requirements of this section is entitled to an inspection authorization.
(c)To be eligible for an inspection authorization, an applicant must-
(1)Hold a currently effective mechanic certificate with both an airframe rating and a powerplant rating, each of which is currently effective and has been in effect for at least 3 years;
(2)Have been actively engaged, for at least the 2-year period before the date he applies in maintaining aircraft certificated and maintained in accordance with this chapter;
(3)Have a fixed base of operations at which he may be located in person or by telephone during a normal working week but it need not be the place where he will exercise his inspection authority;
(4)Have available to him the equipment, facilities, and inspection data necessary to properly inspect airframes, powerplants, propellers, or any relate art or appliance; and
(5)Pass a written test on his ability to inspect according to safety standards for returning aircraft to service after major repairs and major alterations and annual and progressive inspections performed under part 43 of this chapter.
An applicant who fails the test prescribed in paragraph (c)(5) of this section may not apply for retesting until at least 90 days after the date he failed the test.

Section 65.92 Inspection authorization: Duration

(a)Each inspection authorization expires on March 31 of each year. However, the holder may exercise the privileges of that authorization only while he holds a currently effective mechanic certificate with both a currently effective airframe rating and a currently effective powerplant rating.
(b)An inspection authorization ceases to be effective whenever any of the following occurs;
(1)The authorization is surrendered, suspended, or revoked.
(2)The holder no longer has a fixed base of operation.
(3)The holder no longer has the equipment, facilities, and inspection data required by section 65.91(c)(3) and (4) for issuance of his authorization.
(c)The holder of an inspection authorization that is suspended or revoked shall, upon the Administrator’s request, return it to the Administrator.

Section 65.93 Inspection authorization: Renewal.

To be eligible for renewal of an inspection authorization for a 1-year period an applicant must present evidence annually, during the month of March, at an FAA Flight Standards District Office that the applicant still meets the requirements of section 65.91(c)(1) through (4) and must show that, during the current period that the applicant held the inspection authorization, the applicant-

(1)Has performed at least one annual inspection for each 90 days that the applicant held the current authority; or

(2)Has performed inspections of at least two major repairs or major alterations for each 90 days that the applicant held the current authority; or

(3)Has performed or supervised and approved at least one progressive inspection in accordance with standards prescribed by the Administrator; or

(4)Has attended and successfully completed a refresher course, acceptable to the Administrator, of not less than 8 hours of instruction during the 12-month period preceding the application for renewal; or

(5)Has passed an oral test by an FAA inspector to determine that the applicant's knowledge of applicable regulations and standards is current.

(b)The holder of an inspection authorization that has been in effect for less than 90 days before the expiration date need not comply with paragraphs (a)(1) through (5) of this section.

Section 65.95 Inspection authorization: Privileges and limitations.

(a)The holder of an inspection authorization may-

(1)Inspect and approve for return to service any aircraft or related part or appliance (except any aircraft maintained in accordance with a continuous airworthiness program under part 121 or 127 of this chapter) after a major repair or major alteration to it in accordance with part 43 [New} of this chapter, if the work was dopne in accordance with technical data approved by the Administrator; and

(2)Perform an annual or perform or supervise a progressive inspection according to sections 43.13 and 43.15 of this chapter.

(b)When he exercises the privileges of an inspection authorization the holder shall keep it available for inspection by the aircraft owner, the mechanic submitting the aircraft, repair, or alteration for approval (if any), and shall present it upon the request of the Administrator or an authorized representative of the National

Transportation Safety Board, or of any Federal, State, or local law enforcement officer.

(c)If the holder of an inspection authorization changes his fixed base of operation, he may not exercise the privileges of the authorization until he has notified the FAA Flight Standards District Office or International Field Office for the area in which the new base is located, in writing, of the change.

Attachment 5

Subpart E-Repairman

Section 65.101 Eligibility requirements: General.

(a)to be eligible for a repairman certificate a person must-

(1)Be at least 18 years of age;

(2)Be specially qualified to perform maintenance on aircraft or components thereof, appropriate to the job for which he is employed;

(3)Be employed for a specific job requiring those special qualifications by a certified repair station, or by a certified air carrier, that is required by its operating certificate or approved operations specifications to provide a continuous airworthiness maintenance program according to its maintenance manuals;

(4)Be recommended for certification by his employer, to the satisfaction of the Administrator, as able to satisfactorily maintain aircraft or components, appropriate to the job for which he is employed;

(5)Have either-

(i)At least 18 months of practical experience in the procedures, practices, inspection methods, materials, tools, machine tools, and equipment generally used in the maintenance duties of the specific job for which the person is to be employed and certified; or

(ii)Completed formal training that is acceptable to the Administrator and is specifically designed to qualify the applicant for the job on which the applicant is to be employed; and

(6)Be able to read, write, speak, and understand the English language, or, in the case of an applicant who does not meet this requirement and who is employed outside the United States by a certificated repair station, a certificated U.S. commercial operator, or a certificated U.S. air carrier, described in paragraph (c) of this section, have his certificate endorsed “Valid only outside the United States.”

(b)This section does not apply to the issuance of repairman certificates (experimental aircraft builder) under section 65.104.

Section 65.103 Repairman certificate: Privileges and limitations.

(a)A certificated repairman may perform or supervise the maintenance, preventive maintenance, or alteration of aircraft or aircraft components appropriate to the job for which the repairman was employed and certificated, but only in connection with duties for the certificate holder by whom the repairman was employed and recommended.

(b)A certificated repairman may not perform or supervise duties under the repairman certificate unless the repairman understands the current instructions of the certificate holder by whom the repairman is employed and the manufacturer’s instructions for continued airworthiness relating to the specific operations concerned.

Section 65.104 Repairman certificate-experimental aircraft builder-Eligibility, privileges and limitations.

(a)To be eligible for repairman certificate (experimental aircraft builder), an individual must-

(1)Be at least 18 years of age;

(2)Be the primary builder of the aircraft to which the privileges of the certificate are applicable;

(3)Show to the satisfaction of the Administrator that the individual has the requisite skill to determine whether the aircraft is in a condition for safe operations; and

(4)be a citizen of the United States or an individual citizen of a foreign country who has lawfully been admitted for permanent residence in the United States.

(b)The holder of a repairman certificate (experimental aircraft builder) may perform condition inspections on the aircraft constructed by the holder in accordance with the operating limitations of that aircraft.

(c)Section 65.103 does not apply to the holder of a repairman certificate (experimental aircraft builder) while performing under that certificate.

Section 65.105 Display of certificate.

Each person who holds a repairman certificate shall keep it within the immediate area where he normally exercises the privileges of the certificate and shall present it for inspection upon the request of the Administrator or an authorized representative of the National Transportation Safety Board, or of any Federal, State, or local law enforcement officer.

A.1 COMMENTS OF KELLY SPACE & TECHNOLOGY, INC. (KST), REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

(Concurred by George Gray, Brevard Community College)
(Concurred by ASTI with minor exceptions noted in section A.8)

(KST's initial comments were in mark-ups mailed to early recipients and concurred by George Gray of Brevard Community College and Ron Schena of ASTI. These comments immediately follow.)

Introductory matter:
Page 2, Add the following to listed systems; Propellant Transfer System, Control Surfaces.
Page 2, Qualify the type of Flight Safety System.
Page 2, What is the difference between the Reaction Control System and the Orbital Maneuvering System?
Page 2, Some RLVs will have Landing Gear.
Page 3, FAR Part 91, first paragraph, next to last sentence, Change "registration" to "regulation".
Page 3, FAR Part 91, second paragraph, second sentence, typo, Change "is" to "in".
Page 4, first paragraph, Change "rotocraft" to "rotorcraft", (2) places.
Page 7, (e), This sentence does not address rocket-powered craft. Change "rotocraft" to "rotorcraft", (1) place.
Page 12, first paragraph, (2), typo, Change "met" to "meet".
Page 18, second paragraph, last sentence, Add words to describe this as an integrated Air Traffic Control system.
Page 18, Part 65, first paragraph, Add the following unique or different systems: TT&C; Thermal Control; Reaction Control System or Orbital Maneuvering System.

Maintenance Program Development Document, MSG-3, Revision 2 (Attachment 1):
Second page, This caveat looks like good wording for the AIAA guidance documents.
Third page, Create similar document titled "Commercial Space Transportation (CST) Reusable Launch Vehicle (RLV) Developer/Operator Maintenance Program Development Document"

Regulatory Medical Aspects of Manned Commercial Space Operations (Attachment (2):
Second chart, last bullet, April 1999, Is this document now available?
Third chart, second bullet, states "all occupants". Note that requirements are different for passengers and crew.
Third chart, last bullet, states "passengers". Medical standards are not required for aircraft passengers, why space vehicles? Will this be an insurance issue?
Sixth chart, first bullet, typo, "takeoff" is one word. "reentry" should be added to acceleration profile.
Seventh chart, second bullet, Add "pressure".

Eighth chart, first bullet, Add "pressure".
Eighth chart, last bullet, typo, "fire-retardant" is hyphenated.
Ninth chart, second bullet, Add "psychosis"
Eleventh chart, second bullet, Add "radioactive"
Twelfth chart, first bullet, Change to read, "Protection against all weather elements, i.e. lightning, rain, hail, snow, etc."
Twelfth chart, second bullet, typo, "takeoff" is one word.
Fourteenth chart, first bullet, states, "and passengers". Medical certification should not be required for passengers.
Fifteenth chart, first paragraph, states, "and passengers". Medical certification should not be required for passengers.
Twentieth chart, 4), first bullet, typo, "takeoff" is one word.
Twentieth chart, Insert second bullet, "Type of reentry"
Twenty-third chart, second bullet, states, "and passengers". Waivers should not be applicable to passengers.
Twenty-fifth chart, states "and passengers". Medical exams should not be required for passengers.
Twenty-sixth chart, first bullet, states, "or a passenger" Medical decisions should not be required for passengers.

(Following are additional comments provided by KST for Revision A)

1. **How much of the existing FARs applicable to aircraft O&M can be utilized for commercial RLVs?**
2. **What new FARs may be required to be developed?**

KST has articulated clearly the company position regarding licensing versus certification since the inception of the RLV Working Group. That position contends that the only reasonable approach to regulation of the commercial space transportation as a new and evolving industry is a licensing regime that will ensure public safety without threatening the very survival of that industry. As proponents of certification state in their own rationale, the aviation industry certification process has evolved over a period of 90 years. KST, and most of the other RLV developers, have proposed and continue to propose that the regulatory process evolve from a licensing to a certification regime as the industry matures.

One of the most perplexing aspects of the “certify now” position is proposing the modification of existing aircraft FARs to accommodate RLVs. Conversation with virtually anyone involved with aircraft certification reveals the unfortunate schedule impact of the certification process upon not only new aircraft but also upon aircraft modifications. It should be the goal of all those involved in an evolving RLV certification process to reduce these timeliness to a more reasonable period. Were “aircraft like” certification to be imposed upon RLVs at the outset, the impact upon the industry would be fatal.

3. What regulatory safety guidelines need to be developed for this emerging industry to ensure public safety while new RLV O&M regulations are being developed?

The COMSTAC RLV Working Group Final Report on RLV Licensing Approaches, concurred by nine companies involved in the development of RLVs, proposed a flexible licensing regime that would allow each developer to propose a licensing approach best suited to the developer's concept. This approach would take into account the safety guidelines established by FAA/AST and would require approval by FAA/AST to obtain a launch and reentry license. The initial safety guidelines proposed by FAA/AST received extensive review and comment by the RLV industry in both the interim and final reports.

One area requiring significant oversight by the FAA during development of new RLV regulations is that of vehicle refurbishment and re-processing between flights. It is the opinion of KST that refurbishment between flights is of particular concern. Those areas of the aerodynamic surfaces subjected to the high temperatures of reentry must be inspected thoroughly to ensure integrity of Thermal Protection Systems. If necessary, the protective surface must be repaired or replaced. Vehicle re-processing between flights must be assessed carefully to minimize reprocessing requirements while ensuring safety of flight.

4. What is the effect on RLV O&M requirements if humans are on board?

Experience to date has proven that piloted vehicles are considerably more reliable than UAVs. Having a pilot in the loop lends the added flexibility that no automated system, including the current state of artificial intelligence can match. Although it is true that additional systems are involved to provide life support, the requirement for greater stringency in processing other vehicle systems is not obvious. While downplayed by advocates of "certification now," the economic incentive of recovering the space vehicle is a very powerful motivator. The availability of a pilot in the loop simply enhances the probability of safe recovery.

5. Can innovative practices such as the FAA designee program be used on RLVs the same as it is being used in the aviation arena?

KST agrees that a designee program may be appropriate for commercial space transportation as well, with this cautionary note. It is imperative that the CST designee be properly conditioned for the new role and not be "contaminated" by the traditional aircraft certification process. KST has been concerned for some time that the aircraft certification side of the FAA would be solicited by AST to "help" in the RLV certification process due to a lack of AST personnel. This "help" would be as counter-productive as modifying existing FARs to accommodate RLVs.

6. What areas of research and development do the FAA and industry need to focus on to come up with an efficient means to conduct an RLV O&M program that maintains the requisite level of public safety?

KST agrees that development of accurate IVHM systems would greatly benefit RLV operations. Another fruitful area of research noted in the white paper is non-destructive flight safety systems. The KST approach is to use the pilot in the loop to fly to an alternate-landing site or, worst case, to an acceptable impact location. Another beneficial area that the FAA is currently pursuing is that of a truly integrated Air Traffic Control system. This is of benefit to all concepts from VTVL to HTHL. In KST's opinion, piloted vehicles are much more amenable to integration into the existing NAS.

7. What will be the requirements for an aerospace mechanic or repairman and how will they differ from an aviation mechanic or repairman?

It is KST's opinion that the RLV industry should take advantage of the existing skill capabilities and enhance those capabilities where appropriate. For the aerospace mechanic or repairman, the skill levels of the currently licensed aviation mechanic or repairman would require the following enhancements as a minimum:

- Rocket engines
- Life Support Systems
- Thermal Protection Systems
- Reaction Control Systems

A.2 COMMENTS OF LOCKHEED MARTIN SKUNK WORKS, X-33/RLV PROGRAM, REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

(Concurred by Kelly Space & Technology, Inc.)
(Concurred, with minor reservations, by XCOR Aerospace)

Should RLVs use MSG-3?
We are in support of the philosophy outlined in MSG-3. We believe that it is the direction that the RLV industry should go. However, the historically paper intensive methodology used to implement MSG needs to be modernized to utilize a user-friendly, automated method. Many of the airlines and the commercial airframe builders have already done this successfully. The X-33 program has attempted to prototype an automated database that takes you through similar decision gates, but accomplishes it in an easy to interface fashion. Because it is an 'X' program with a limited number of flights, we have not attempted to capture all of the elements required for a commercial or military aircraft. Obviously, either the scope of our prototype will need to be expanded for a fully functional RLV system, or one of the existing systems developed commercially would need to be adapted to RLVs.

What are the true needs of the mechanics?
Within our industry the technicians must be trained and certified to a corporate standard before they are permitted to work on a vehicle. Additionally, they must be periodically recertified. This process would be continued with RLVs. LM's diverse corporate base and teaming arrangement provides the basic skills mix, knowledge, and training to deal with all vehicle systems.

It is not required to have an A&P certificate to build an aircraft (Boeing 777) or launch vehicle (Titan rocket), to build, maintain or modify the space shuttle main engines, to maintain or modify the space shuttle, or to maintain or modify the military aircraft of the US Armed Forces. Lockheed Martin Company will be the designer, builder, owner, and operator of our RLV; the technicians that built it will be the same people that will maintain it. In reviewing other precedents and according to the exclusions in the FAA guidelines and requirements our mechanics should not be required to have an A&P certificate.

Additionally, from our perspective there is no need for a higher aerospace tech grade. The experience base of the aircraft and space technicians is current with the requirements of an RLV. The training of a crew systems tech for an F-16 LOX system covers the majority of issues that training a LOX propellant system tech for the External Tank at LMMSS (materials compatibility, cleanliness, work hazards). The avionics system requirements for the shuttle are no more complicated than for other redundant systems that are out there and flying today. In fact because of the age of the shuttle, many contemporary aircraft systems reflect newer technology and are more complicated. In some cases the state-of-the-art work being performed in aircraft is beyond the needs of space systems. Few single systems are as large as the Boeing 777 video entertainment system (over 2000 LRUs, and 2,500,000 lines of software). The majority of work to be performed on an RLV is still wrench turning and electrical troubleshooting. Any line mechanic can inspect a wire harness for chafing and fix abrasion damage.

Expand the scope of existing documents to include RLVs or write parallel sections for RLVs?

We will be willing to work with the FAA on each section individually. There are merits to both approaches. To a large extent it depends on how some of the other questions are answered. One of the most significant questions is who will own/operate the RLVs of the future. The FARs already provide exclusions for work being performed by the OEM. Is there a viable case where there will be an RLV operator that is not the government or the OEM? If not, then the required revisions to the FARs may be dramatically reduced.

(Further comments by XCOR Aerospace)

Strongly concur that work done by OEMs has a different character than work done by independent operating organizations, and that OEM workers do not need A&P certification to develop RLVs.

A.3 COMMENTS OF SPACE ACCESS, REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

(Strong non-concurrence by XCOR Aerospace. Specific XCOR comments follow Space Access comments on page 38.)
(Non-concurred by Kelly Space & technology, Inc. (KST))

One premise of the document is the statement, "commercial operations which employed the strict practices that NASA requires to certify the Shuttle would quickly be driven out of business." Space Access would like to offer a different conclusion based on the fact we find the highest cost of any commercial business is the cost of unreliability and unsafe practices. Because the Space Shuttle was ultimately designed and built to less strict criteria than airworthiness standards existing for a commercial aircraft transport, NASA must adhere to strict practices to insure the safety of the crew. The premise of any Reusable Launch Vehicle (RLV) is reuse, and, specifically for the next generation RLVs, the more often reused the cheaper the life cycle cost. If any system or vehicle is not reused, due to failure or loss, the cost of replacement, or the cost of insurance to enable replacement, is prohibitive and that cost will drive commercial operations out of business, not the cost of strict practices. If the government insured its vehicles they would find this cost to far outweigh the already high cost of maintenance. What is true about the statement is the commercial goal to significantly reduce the cost of operations and maintenance for any future space transportation system.

The first area of consideration discussed was, "how much of the existing FARs applicable to aircraft O&M can be utilized for the commercial RLVs?" The first example given states, "FAR Part 91 Subpart E (Maintenance, Preventive Maintenance and Alterations) cannot be used for most of the candidate RLVs." This leads the reader to believe that the writer is advocating FARs not be used because of a specific statements that directs unmanned rockets to Part 101. In fact several valid examples are given where the FARs appear to be very applicable and the final conclusion stated is, "Much of the existing FARs for aircraft can be utilized for commercial RLVs." The exercise is left to the reader to determine what the applicable FARs might be. Space Access advocates the use of the entire FAR system not just the implementation of unique parts. Space Access believes the whole (FARs) system is greater than the sum of the parts (FAR Part 91 for example) since each piece of the FAR system relies on the assumptions, direction and experience from all the other pieces in regulating the complex and risky business of aviation. To just say airmen, like a pilot, must be licensed or certified to perform duties (FAR part 61) does not cover the complexities of how that person must get the applicable experience and knowledge. That experience only comes from a certified instructor operating certified aircraft in authorized areas with approved weather conditions and in accordance with approved guidelines and standards for each piece of this puzzle. To merely pick any small part of the system will certainly have some positive effect but not the same total effect as incorporating all existing guidance and only deleting those areas superseded by better or new guidance for areas not already covered. In Space Access's view the FARs are a compilation of over 90 years of aviation experience paid for by the trials and tribulation of private and commercial enterprises. This total package of guidance, information and technical knowledge has produced the safest form of public transportation in place in the world today. The extension of the aviation infrastructure and capabilities out into space is the only way any company will survive commercially in what might otherwise be a cost prohibitive venture. As stated above, strict practices will be a must to insure the ultimate safe reuse of future space transportation systems as the only cost effective means of developing and operating RLVs.

Space Access agrees that FARs for unmanned air vehicles (UAVs) and for certification of space persons must be developed. However, these areas are not new, since human space flight started in the early 1960s under NASA and unmanned vehicles are becoming almost a daily operation in the Department of Defense. The lessons learned from these agencies, NASA and DoD, must be incorporated into new Federal Space or Aerospace Regulations. The wheel need not be invented again, just gather applicable guidance and consolidate it into a single source document.

The FAA AST office can use the guidelines and licensing documents developed above, until Congress codifies them into law when the industry is ready for full certification. The modeling of future space business, like existing aviation business, should help the industry not hurt it, as aviation is a multi-billion dollar revenue generating industry today. Consideration for streamlining processes and reducing paperwork or busywork must always be done. With no clear evidence to support new methodology or techniques, existing methods and standards should be used to the maximum extent possible.

Space Access wants to reinforce, and the document seems clear, that having crew or passengers onboard an RLV will require more stringent requirements than for unmanned vehicles. The FAA must give serious consideration for total safety before any passenger for hire service is established.

Space Access agrees that the concept of an FAA designee program should be considered, but that caution is advisable before implementing any such program. The FAA AST should look back at the historical experience as to when this program became beneficial to the government and industry. Implement the program at the time in maturity that makes sense based on the experience in aviation.

Space Access believes the FAA should limit research and development activities to those directly impacting the FAA's ability to monitor and validate safe vehicle development and operations. The commercial market forces have always responded to commercial demands and will develop new vehicle health monitoring systems if they are required for efficient commercial operations, so the FAA should not do this type activity. However, the FAA should definitely pursue things like, "tools and methodologies to predict safe space/air corridors to allow the co-existence of launch/reentry vehicles and airplanes and rotorcraft." The airspace control issue is critical to safe operations and no individual or commercial company can take on that role, so the FAA must develop these capabilities and determine priorities and procedures for complex operations as they do today for aviation.

The last question asked is, "what will be the requirements for an aerospace mechanic or repairman and how will they differ from an aviation mechanic or repairman." Space Access agrees in total with the attached letter proposing creation of FAA certificates and ratings for aerospace maintenance technicians. This is another crucial part of the total FAR package such that without qualified and certified people to perform the correct maintenance activities the safe operation of existing aviation systems would rapidly cease. This rating and certification process emerged over many years and the safety and reliability of future space transportations systems cannot be assured without such a program. The use of existing guidelines should be adopted where possible and then modified as experience is gained in commercial operations such as at United Space Alliance (USA). The letter request from USA is a clear example of where cost efficient commercial operation is made better by implementation of additional government regulation or guidance instead of deleting appropriate guidance. The proper training and certification of aerospace employees will make future space transportation operations and maintenance reliable and safe thus enabling the industry not hindering progress.

(Further comments by XCOR Aerospace)

Obviously, XCOR has a significant difference of opinion from Space Access LLC regarding the desirability (or even possibility) of wholesale adoption of the existing aircraft FARs to RLVs verbatim. The common point between the Space Access and XCOR position is the desirability of learning as much as possible from the successful history of aviation in the creation of an RLV industry. Obviously, it is in the self-interest of any company seeking to create a new type of vehicle to carefully study the lessons of previous vehicles. Our experience has been that applicable lessons can be found widely scattered in the prior art, and that almost every innovation considered for RLVs has some prior art, some in operating hardware, some merely in prior analyses, which can be a valuable point of departure. Our fundamental difference of opinion can be traced to Space Access' opinion that "the FARs are a compilation of over 90 years of aviation experience". This is not how we view the FARs. Instead, we believe the FARs (14CFR 1 to 14CFR 139), are regulations, which codify "best practices" derived from experience FOR A SPECIFIC TYPE OF VEHICLE. Attempting to distill the total experience of aviation to 1700 pages would be an impossible task, one that the FARs make no pretense of attempting. By limiting narrowly the scope of regulation, the FARs have attempted to codify "best practices" applicable ONLY within their intended field. As a result of this process, the existing FARs deliberately and properly ignore a great deal of aviation experience from other fields (which may be more relevant to some RLV concepts), and make many simplifying assumptions which may well be irrelevant to various RLV concepts. The notion of adopting the existing FARs, such as Part 25, verbatim is refuted by carefully examining the contents. An examination of FAR Part 25, for example, reveals that it applies only to HTHL lifting vehicles, turbojet or propeller powered, with flight limited within the atmosphere. As a further practical matter, flight under the existing FARs is effectively limited to subsonic flight by FAR 91.817. Even if the supersonic limitation were waived under FAR 91 appendix B, any supersonic capable aircraft would find it extremely difficult to comply with the dynamic stability requirements of FAR 25.181(b) - and, in fact, the rich history of supersonic aircraft is replete with successful and safe aircraft which do not meet the requirements of FAR 25.181(b) regarding Dutch roll. Instead, most supersonic aircraft limit the period of Dutch roll to long periods which pilots find tolerable (or largely unnoticeable), a criteria not documented in the FARs. This is an example of the deliberately narrowed focus of the FARs - which do not embody the rich knowledge base of satisfactory flying qualities of supersonic aircraft, for the simple reason that a large body of civil supersonic aircraft do not exist. Exo-atmospheric flight under the existing airplane FARs is clearly not allowed, since at all times indicated airspeed must be kept above the minimum control speed defined in FAR 25.149 in order to ensure effectiveness of the aerodynamic controls. Exo-atmospheric flight requires differentiating between the "low altitude" stall region experienced in low speed atmospheric flight, and the "high altitude" stall region experienced when a high velocity vehicle runs out of dynamic pressure due to decreased atmospheric density with extreme altitude. Exo-atmospheric flight will require new practices to be established, which can and should draw on the wealth of experience with this regime (in vehicles such as the U.S. Space Shuttle, X-15, ASSET, PRIME/X-23/X-24 and NF-104 programs, and the Spiral/BOR-4 program from the former Soviet Union). For example, meaningful criteria for the authority of a reaction control system need to be established, to avoid a repeat of incidents such as the NF-104 crash caused by a "dead zone" of dynamic pressure where the aerodynamic controls lost effectiveness but the reaction control system was not yet effective. The existing airplane FARs do not speak to this regime of operation at all, simply forbidding it by disallowing operation below Vmc. Rotorcraft face analogous restrictions within their relevant FARs. Verbatim adoption of the FARs would also require certification of power plants under part 33. We have carefully examined FAR 33 and see no possible way in which a rocket engine could be certificated under it as written, since FAR 33 explicitly restricts itself to turbine or reciprocating engines. While it is certainly conceivable that a concept employing an advanced air breathing engine could operate under the FARs as written, we do not think eliminating rocket propulsion from consideration for RLVs is a prudent course, since the past experience with space transportation systems relies exclusively on rocket engines. FAR part 25 makes the implicit assumption that the vehicle engines can be throttled deeply enough to permit stabilized level powered flight. While some RLV concepts may be able to achieve this, many others cannot - nor is the relevance of this flight regime to a typical RLV flight profile clear. Many RLV concepts operate in a climbing or descending mode when in atmospheric flight with comparatively little level atmospheric flight, and would be more meaningfully evaluated in a stabilized powered climb or stabilized un-powered glide. However, strict application of FAR 25.145(c) and 25.331(c), to pick just two examples, is not possible unless the aircraft can attain steady level flight. Many other conflicts between the existing FARs and the operating characteristics of RLVs exist. The above examples are merely a few selected to illustrate the difficulties of adopting the existing FARs verbatim for RLV application. Note that nothing in the XCOR position prevents a company from operation under the existing FARs if they find it advantageous to do so. If an RLV restricts itself to subsonic HTHL operation, flight within the atmosphere, and employs multiple deeply throttling engines, it may well be possible to operate within the aircraft- oriented FAR regime. For vehicles departing from these properties, either extensive waivers will be required (which is not a viable long-term regulatory regime), or the FARs would need to be modified to incorporate the new vehicles (which would burden aviation regulations with RLV oriented material), or new FARs under part 400 will need to be crafted. The common core of agreement between XCOR and Space Access can probably be found by adopting the SPIRIT of the FARs, rather than the letter. While the detailed wording of the FARs is frequently inapplicable to RLVs, it is usually possible to examine the relevant FAR point by point and ask "what is the *reason* for this rule?" Then one can determine whether that reason applies to the vehicle in question. If it does, a design requirement usually results, which may or may not be identical to the design requirement applied to subsonic HTHL atmospheric air breathing vehicles. We have found this approach useful in developing a starting point for design requirements - but only a starting point, for as illustrated above, there are many areas of RLV design requirements which must be drawn from other sources. To summarize, wholesale application of the FARs, verbatim, to RLVs is, in our view:

* Not possible due to the differences in flight regime, power plant, and vehicle characteristics (even for very "airplane like" concepts)
* Not desirable due to the many portions of the existing FARs which are inapplicable and unnecessary for RLVs
* Not, in itself, sufficient to ensure a safe vehicle even if the inapplicable sections were waived, since important characteristics of an RLV flight regime are not even considered in the existing FARs.

However, XCOR firmly believes that many elements of the existing FARs can serve as a valuable starting point for setting design criteria for RLVs, if applied with judgment and a careful eye towards their relevance to the RLV design problem. For example, the structural factors of safety recommended in FAR Part 25 subpart (c) represent an excellent starting point in setting design requirements for "aircraft like" HTHL vehicles we have examined. We also believe that many valuable lessons from the aviation knowledge base exist to be tapped which lie outside the FARs. Synthesizing the requirements for the design of safe and reliable vehicles is a task each of the entrants in the RLV industry must face. Appealing to the aircraft FARs can assist us but cannot relieve us of this task. As an additional note, XCOR wishes to draw attention to the excellent series of NASA special publications SP-8001 through SP-8099. These represent an attempt by NASA to capture design requirements drawn from NASA experience with the Mercury, Gemini, and Apollo programs - a database with substantial relevance to the RLV flight regime, and a source of considerable assistance in developing RLV design requirements. Like the FARs, these design requirements have to be critically examined for their applicability to a given vehicle, but also like the FARs, they contain much valuable material for entrants seeking design requirements appropriate for a given RLV.

A.4 COMMENTS OF UNITED SPACE ALLIANCE, REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

(Concurred, by XCOR Aerospace)

(Comments of Vela Technology Development, Inc. added to Rocket Engine Curriculum, page 45)

(Further comments by XCOR Aerospace)

While we think the following comments do indeed form an excellent training outline for personnel, for reasons explained in our original comments, we oppose creation of an independent "aerospace technician" rating at this time. Of course, opposing such a rating for FAA regulatory purposes in no way deters companies such as United Space Alliance from creating training programs tailored to their needs.

RLV OPERATIONS AND MAINTENANCE

The root cause of aerospace industry difficulties has been human factors related incidents and discrepancies in the information that we provide the industry personnel. Many of these lessons learned from industrialized standards in the aviation industry can be used to eliminate the aerospace industries need to create new standards at a high cost, in a untimely manner. The primary risk mitigation element used in the commercial aviation industry is providing all the information available to the person performing the work or the end user. This information comes in the form of nationally available formal training programs, maintenance manuals, illustrated parts catalogs, wiring diagrams and other technical data in a user friendly technical writing format. This factor provides for a knowledgeable , skilled work force with readily available user friendly data. The reason we need to move towards a skill based cultural change shift, is that we can no longer afford rule based operations and the high cost of doing business that is associated with them. In an aerospace industry that is currently dependent on using multifunctional, cross trained technical personnel, capable of performing multiple tasks by themselves with minimal work documentation, developing compatible industrialized standards is an essential factor for operations and maintenance.

STATEMENT ON EXAMPLE CURRICULUM PROFILE FOR AEROSPACE MAINTENANCE TECHNICIANS

This is strictly a profile or model curriculum based on the Federal Aviation Administration, Federal Air Regulation Part 147 Airframe and Powerplant mechanic's, Aviation Maintenance Technician School curriculum. This model is for reference and comment only to achieve a mature document through participation by interested parties and is not by any means a finished product. Many variables have to be considered wholly to achieve this goal. Participants should include the following: Shuttle Flight Operations contractors, all other interested RLV manufacturers, future RLV manufacturers, ELV manufacturers, future ELV manufacturers, launch site operations contractors, interested and launch site operations personnel including; engineering staff, training staff, and other interested support staff members.

APPENDIX B TO AST PART 147
Space-frame and Propulsion Curriculum Subjects

A. BASIC ELECTRICITY

1. Calculate and measure capacitance and inductance.
2. Calculate and measure electrical power.
3. Measure voltage, current, resistance and continuity.
4. Determine the relationship of voltage, current and resistance in electrical circuits.
5. Read and interpret space vehicle electrical circuit diagrams, including solid state devices and logic functions.
6. Inspect and service batteries.

B. SPACECRAFT DRAWINGS

7. Use space vehicle drawings, symbols and system schematics.
8. Draw sketches of repairs and alterations.
9. Use blueprint information.
10. Use graphs and charts.

C. WEIGHT AND BALANCE.

11. Weigh space vehicle.
12. Perform complete weight and balance check and record data.

D. FLUID LINES AND FITTINGS

13. Fabricate and install rigid and flexible fluid lines.

E. MATERIALS AND PROCESSES

14. Identify and select appropriate nondestructive testing methods.
15. Perform dye penetrant, eddy current, ultrasonic, and magnetic particle inspections.
16. Perform basic heat-treating processes.
17. Identify and select space vehicle hardware and materials.
18. Inspect and check welds.
19. Perform precision measurements.

F. GSE TO VEHICLE GROUND OPERATIONS / SERVICING

20. Vehicle ground operations, transport, safing, securing.
21. Identify and select fuels and propellants.

G. CLEANING AND CORROSION CONTROL

22. Identify and select cleaning materials.
23. Inspect identify remove and treat vehicle corrosion and perform vehicle cleaning.

H. MATHEMATICS

24. Extract roots and raise numbers to a given power.
25. Determine areas and volumes of various geometrical shapes.
26. Solve ratio, proportion and percentage problems.
27. Perform algebraic operations involving addition, subtraction, multiplication and division of positive and negative numbers.

I. LAUNCH PROCESSING, MAINTENANCE FORMS AND RECORDS

28. Write descriptions of work performed including vehicle discrepancies and corrective actions using typical vehicle maintenance records.
29. Complete required maintenance forms, records and inspection reports.

J. BASIC PHYSICS

30. Use and understand the principles of simple machines; sound, fluid, and heat dynamics; basic aerodynamics; vehicle structures; and theory of flight and launch trajectories.
31. Demonstrate ability to read, comprehend and apply information contained in manufacturing, vehicle maintenance specifications, data sheets, manuals, publications, and related FAA regulations.
32. Read technical data.

L. MAINTENANCE TECHNICIANS PRIVILEGES AND LIMITATIONS

33. Exercise technicians privileges within the limitations prescribed by AST part 65.

APPENDIX B TO AST PART 147
Space-frame and Propulsion Curriculum Subjects

SPACE-FRAME STRUCTURES

A. SHEET METAL AND NON-METALLIC STRUCTURES

1. Select, install, and remove special fasteners for metallic, bonded, and composite structures.
2. Inspect bonded structures.
3. Inspect, test and repair fiberglass, plastics, honeycomb, composite and laminated primary and secondary structures.
4. Inspect, check, service and repair windows, doors and interior furnishings.
5. Inspect and repair sheet metal structures.
6. Install conventional rivets.
7. Form, lay out and bend sheet metal.

B. WELDING

8. Weld magnesium and titanium.
9. Solder stainless steel.
10. Fabricate tubular structures.
11. Solder, braze, gas-weld, and arc-weld steel.
12. Weld aluminum and stainless steel.

C. ASSEMBLY AND RIGGING

13. Rig rotary wing vehicles.
14. Rig fixed wing vehicles.
15. Check alignment of structures.
16. Assemble vehicle components including flight control surfaces.
17. Balance, rig and inspect movable primary and secondary control surfaces.
18. Jack space vehicle.

II. SPACE-FRAME SYSTEMS AND COMPONENTS

A. SPACE VEHICLE LANDING GEAR SYSTEMS

19. Inspect, check, service and repair landing gear and pad retraction systems, shock struts, brakes, wheels, tires and steering systems.

B. HYDRAULIC AND PNEUMATIC POWER SYSTEMS

20. Repair hydraulic and pneumatic power system components.
21. Identify and select hydraulic fluids.
22. Inspect, check, service, troubleshoot and repair hydraulic and pneumatic power systems.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

23. Inspect, check, troubleshoot, service, and repair atmospheric revitalization systems, N2/O2 storage and supply systems, cabin pressurization / depressurization systems, atmospheric monitoring / CO2 sensing system.
24. Inspect, check, troubleshoot, service, and repair water / coolant loop systems.

SPACE VEHICLE INDICATING AND RECORDING SYSTEMS

25. Inspect, check, service, troubleshoot and repair electronic flight instrument systems and both mechanical and electrical heading, speed, altitude, temperature, pressure and position indicating systems to include the use of built-in test equipment.
26. Install instruments and perform a static pressure system leak test.

COMMUNICATION AND TRACKING SYSTEMS

27. Inspect, check and troubleshoot auto flight ascent thrust vector control systems and aerosurface control systems.
28. Inspect, check and service space vehicle electronic communication and navigation / tracking systems, including audio distribution systems, UHF air traffic control communication, S-band, KU-band, telemetry control systems, heads up display system and integrated data processing systems.
29. Inspect and repair antenna electronic equipment installations.

APPENDIX B TO AST PART 147
Space-frame and Propulsion Curriculum Subjects

SPACE VEHICLE FUEL AND PROPELLANT SYSTEMS

30. Leak check / system operational check of propellant manifolds, valves, pneumatic systems and RTLS dump systems.
31. Check propellant cross-feed and off-load system.
32. Inspect, check, and repair propellant loading systems including GSE.
33. Repair propellant system components.
34. Inspect and repair propellant quantity indicating systems.
35. Troubleshoot, service and repair propellant temperature and pressure sensing systems.
36. Inspect, check, service, troubleshoot and repair space vehicle propulsion systems.

SPACE VEHICLE ELECTRICAL SYSTEMS

38. Repair and inspect vehicle electrical system components; crimp and spice wiring to manufacturer's specifications; repair pins and receptacle conductors of vehicle connectors.
39. Install, check and service vehicle electrical wiring, controls, switches, indicators and protective devices.
40. Inspect, check, troubleshoot, service and repair alternating and direct current electrical systems.
41. Inspect, check, service, troubleshoot and repair mechanical generator systems and PRSD electrical generation systems.

POSITION AND WARNING SYSTEMS

42. Inspect, check and service speed and configuration warning systems, electrical brake controls, and anti-skid systems.
43. Inspect, check, troubleshoot and service landing gear position indicating and warning systems.

HAZARDOUS GAS INDICATING AND FIRE PROTECTION SYSTEMS

44. Inspect, check, and service hazardous gas, smoke and carbon monoxide detection systems.
45. Inspect, check, service, troubleshoot and repair vehicle hazardous gas, fire detection and extinguishing systems.

I. PROPULSION SYSTEM THEORY AND MAINTENANCE

A. ROCKET ENGINES
(*Further comments by VELA Technology Development, Inc.)*

(Also need to address engines that use propellants which are neither inert, hypergolic nor cryogenic, such as hydrogen peroxide, hydrazine, nitromethane, nitrous oxide and propane.)

46. Remove and install inert gas rocket motors, valves, quick disconnect fittings and leak check.
47. Remove and install hypergolic rocket motors, valves, quick disconnect fittings and leak check.
48. Remove and install cryogenic rocket motors, pre-valves, re-circulation pumps, flow control valves, quick disconnect fittings and perform mass spectrometer leak checks and testing.
49. Test and checkout of propellant inert gas pressurization system regulators, valves, actuators and quick disconnect fittings.

B. TURBINE ENGINES

50. Overhaul turbine engine.
51. Inspect, check, service and repair turbine engines and turbine engine installations.
52. Install, troubleshoot and remove turbine engines.

C. PROPULSION SYSTEM INSPECTION

53. Perform power plant conformity and flight worthiness inspections.

APPENDIX B TO AST PART 147
Space-frame and Propulsion Curriculum Subjects

II. PROPULSION SYSTEMS AND COMPONENTS

A. ENGINE INSTRUMENTATION SYSTEMS

54. Troubleshoot, service and repair electrical and mechanical fluid rate-of-flow instrumentation systems.
55. Inspect, service, troubleshoot and repair electrical and mechanical engine temperature, pressure and RPM instrumentation systems.

B. ENGINE FIRE PROTECTION SYSTEMS

56. Inspect, check, service, troubleshoot and repair engine fire detection and extinguishing systems.

C. ENGINE ELECTRICAL SYSTEMS

57. Repair and replacement of engine electrical system components.
58. Install, check and service engine electrical wiring, controls, switches, indicators and protective devices.

D. LUBRICATION SYSTEMS

59. Identify and select lubricants.
60. Repair engine lubrication system components.
61. Inspect, check, service, troubleshoot and repair engine lubrication systems.

E. IGNITION AND STARTING SYSTEMS

62. Inspect, service, troubleshoot and repair rocket and turbine engine ignition systems.
63. Operation, checkout and leak check of rocket engine pre-start conditioning, re-pressurization and vent systems.
64. Inspect, service, troubleshoot and repair turbine engine electrical starting systems.
65. Inspect, service, troubleshoot and repair turbine engine pneumatic starting systems.

F. FUEL AND PROPELLANT METERING SYSTEMS

66. Troubleshoot and adjust rocket and turbine engine fuel / propellant metering systems, electronic engine fuel controls and rocket main engine controllers.
67. Repair engine fuel and propellant metering components.
68. Flow meter and mass spectrometer decay and leak checks on propellant system components.
69. Inspect, check, service, troubleshoot and repair turbine engine fuel metering systems.

G. ENGINE FUEL AND PROPELLANT SYSTEMS

70. Repair engine fuel and propellant system components.
71. Inspect, check, service, troubleshoot and repair engine fuel and propellant systems.

H. ENGINE AIR-FLOW SYSTEMS

72. Inspect, check, service and repair engine ice and rain control systems.
73. Inspect, check, service, troubleshoot and repair heat exchangers turbine engine airflow systems and temperature control systems.

I. ENGINE COOLING AND HEATING SYSTEMS

74. Repair power head heater systems and engine cooling system components.
75. Inspect, check, troubleshoot service and repair engine cooling and heating system components.

J. ROCKET AND TURBINE EXHAUST AND REVERSER SYSTEMS

76. Repair engine exhaust nozzle and system components.
77. Inspect, check, troubleshoot, service, and repair engine exhaust and thrust vector control systems.
78. Troubleshoot and repair engine thrust reverser systems and related components.

APPENDIX B TO AST PART 147
Space-frame and Propulsion Curriculum Subjects

M. AUXILIARY POWER UNITS

79. Inspect, check, service and troubleshoot jet engine and hypergolic auxiliary power units.
80. Repair, replacement, mass spectrometer and pressure decay check of hypergolic APU system components.

N. SOLID PROPELLANT AND PYROTECHNIC SYSTEMS

81. Installation, safing and testing of solid propellant and pyrotechnic components.
82. Expendable launch vehicle stacking, separation and payload shroud component installation and handling.

A.5 COMMENTS OF XCOR AEROSPACE, REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS
(Concurred by Kelly Space & Technology, Inc., with exception of item 5)
(Concurred by Vela Technology Development, Inc.)

XCOR Aerospace Position Paper on RLV Operations & Maintenance Regulations

A response to the "White Paper on Commercial Space Transportation Reusable Launch Vehicle Operations and Maintenance"

GENERAL COMMENTS

The phrase "Reusable Launch Vehicles" (RLV) is a catch-all term covering a range of vehicles from small suborbital rocket aircraft to massive heavy-lift vehicles such as the Shuttle or the proposed Venture Star craft. The white paper on O&M requirements correctly points out that the operations and maintenance practices of reusable craft impact public safety, and are therefore appropriate areas for the FAA to weigh the need for regulation.

We agree enthusiastically with the comment on page one of the white paper "any commercial operation which employed the strict practices that NASA requires to certify the Shuttle would quickly be driven out of business". We could not agree more. The comments on the relative applicability (or lack thereof) of existing FARs we generally agree with, except as indicated.

1) DISCUSSION OF APPLICABLE FARS

On page four (4), we agree with the recommendation that it would be better to do a whole new regulation part covering operator certification. We believe that regulations in this area are premature -- but when the time is right, we should begin these regulations with a "clean sheet" approach, Similarly, on page nine (9) we agree that section 91.409 could serve as a model for a new part 491. However, we believe these regulations are premature as well. Note that when the time for a "part 491" does come, the "100 hour" inspection will have to be changed to reflect more appropriate criteria, such as so many launch/reentry cycles, as time on-orbit has a very different character than time in powered flight. We do not believe that a meaningful set of requirements in this area can evolve until after the industry has matured sufficiently to allow vehicle certification -- a milestone that is a long way off.

On page 10, we agree that inspection criteria and maintenance procedures will have to be specific to each RLV company (vehicles such as TGV Rockets MICHELLE-B and Lockheed-Martin's VentureStar could hardly be more different in maintenance requirements). Naturally, the FAA can and should consider the existence of documented inspection and maintenance procedures in a launch operator application for an RLV. We agree that the ATA document "MSG-3" could serve as a useful sample for an RLV company preparing its own inspection and maintenance procedures, but it can only be a model, not a prescription, The remaining existing FARs discussed, part 61 and 67, we will discuss below, under "Personnel Qualifications".

2) NEW FARS TO DEVELOP

In the longer term, we agree with the need for a new body of "operating" regulations, analogous to part 121 and 135, but we do not see any need for such regulation until vehicle certification is possible. As long as each launch or class of launch must be licensed, the licensing process protects public safety. When the FAA is ready to allow essentially unrestricted operation of "proven" vehicles, then and only then is regulation to determine safe operating practices required. If that is contemplated, XCOR Aerospace would welcome the development of operator licensing analogous to part 121. We do not see how to develop such regulations meaningfully until several different RLVs have demonstrated the ability to operate routinely and profitably, and therefore developed a more applicable experience base. We will comment on the UAV applicability under "Personnel Qualifications"

On revising or replacing part 67, we strongly suggest that additional medical qualifications be added only in the presence of clear and convincing evidence that they are required. For this reason, we would recommend adding a section to part 67 (which need not, and should not, be an "extensive revision), describing the few additional medical qualifications needed for space crew. (I coin here the term "space crew" by analogy to "aircrew", since the term "spacepersons" used in the white paper is very clumsy).

The examination of medical factors (attachment 2 of the O&M White Paper) is very thorough, and lists all possible issues. It is important to keep some perspective on the possible risks, however. Combat aircraft have been conducting high-G maneuvers for decades, but only now is G-tolerance training in centrifuges beginning. It is important that additional medical qualifications for space crew are added incrementally, and only where clear evidence supports them. XCOR believes that centrifuge qualification and parabolic flight tests to test for space sickness MAY be desirable for safety-critical space crew, but even in these cases, the data is inconclusive. Since our market segment is in suborbital flight, the burden of regulations has to be judged against a lower-price, lower-margin market than satellite launch. We believe that the market availability of human centrifuge or parabolic zero-G flight services has something to do with the question of whether they should be included in medical certification of flight crew. If the market can supply these services to U.S. private companies affordably and reliably, it may be prudent to include them in pilot qualification. As a practical matter, XCOR Aerospace is not aware of ANY non-government organization offering parabolic zero-G flight services inside the U.S. today; we regard a requirement to procure services from NASA or from Russian providers as burdensome and too uncertain for business purposes. Similarly, we have not yet confirmed the availability of human centrifuges suitable for G-tolerance testing and training outside of government facilities. Until the market can supply these testing capabilities, we would oppose requiring them as preconditions for medical certification.

In the longer term, research on the acceleration limits suitable for the general public (not holding a flight medical certificate) would be welcome. Data on the tolerance of flight crew is well established and available from many publications. Other hazards identified in the attachment (vibration, noise, humidity, temperature, air quality, etc.), while by no means trivial, are well understood and already faced in other hostile environments (submarines, jet aircraft, etc.), where ample design experience in safe life support exists.

The long-term health risks of very low-level radiation exposure from cosmic radiation are not completely understood. It is POSSIBLE that this will eventually limit the fraction of the time that regular space crew can fly, but this is by no means certain. In any event, this does not pose a risk to the safety of the general public, since the hazard (if any) is from chronic exposure over a long period, not a problem that can incapacitate spacecrew during a single flight. Occupational risks are the concern of OSHA, rather than the FAA.

3) INTERIM GUIDELINES WHILE O&M REGULATIONS ARE DEVELOPED

We agree that FAA scrutiny during the licensing process is adequate until regulations evolve. Our discussion on "Personnel Qualifications" below is intended to assist the FAA in preparing safety guidelines to guide RLV license applicants in advance of regulations.

We strongly DISAGREE that the Space Shuttle Maintenance and Operations Procedures are a good source of information (as suggested on page 15). Rocket vehicles such as the U.S. X-1 and X-15, the French Mirage III with SEPR 841 and SEPR 844 rocket engine, or the British S.R. 53 have been successfully operated through many more flights than the Space Shuttle with procedures which were one to two ORDERS OF MAGNITUDE less complex than those of the Space Shuttle. (The Mirage III operated, under rocket power, in front-line service with air forces of several nations from 1961 through 1990). These are not usually thought of as sourcesof rocket operational experience, because no special disciplines were deemed necessary -- they were operated by aircraft technicians given additional training as needed to operate specialized systems.

We believe that O&M practices should evolve from these examples of past rocket vehicles with much more routine operations than the Space Shuttle has demonstrated.

The spirit of "Objective 11", requiring inspection and checkout of safety-critical systems prior to each flight, is an excellent guideline. The FAA could reasonably request that an operations & maintenance plan be submitted as part of the license application for a "launch operator" license covering many flights of an RLV. We recommend that the procedures for aircraft, rather than the Space Shuttle, be used as a guide.

4) WHAT IS THE EFFECT OF HAVING HUMANS ONBOARD?

We do not agree that public safety requires "more stringent" requirements for crewed RLVs than for autonomous or remotely-piloted RLVs. Since the primary mission of the FAA is to protect public safety, we question the tone of this whole section.

It is our technical opinion that the safety of the public is enhanced by piloted RLV operation. As for passengers, the industry has many milestones to meet before the "general public" will be carried as passengers. While we all hope to reach those milestones as quickly as possible, the surest way of delaying passenger operations is to increase the already-heavy regulatory burden by adding additional requirements for passenger-carrying vehicles.

We believe that the experience of aviation has been that manned vehicles are far *less* likely to endanger people on the ground than unmanned vehicles. In the absence of any government intervention, vehicle designers, builders, and operators are highly motivated to take greater care in the performance of their mission on manned vehicles than unmanned vehicles.

Therefore, we believe that having humans on board should carry no additional burdens for the launch license or O&M requirements in the near term, with one exception.

Certainly it is true that if humans are part of the flight safety system (which will be true for piloted RLVs), then the environmental and life support systems are now flight critical, and must have adequate reliability (or failing that, adequate redundancy) just as any other safety-critical system.

Even then, the mention of "two crewmen" seems odd. Single pilot general aviation aircraft are flown across populated areas in great numbers, without undue risk to public safety. The additional features of the space environment are not so profoundly different from aircraft as to require a new approach to safety (redundant crew). Particularly for suborbital flight, the only environmental factor different from aircraft (given a functioning life support system) is the acceleration environment. Crew tolerance to high accleration, and their performance in a high accleration environment, has been well characterized in the available literature.

Certainly, space adaptation syndrome ("space sickness") can degrade crew performance, and that factor must be designed for. Methods of screening for space adaptation system (microgravity parabolas) have not demonstrated good correlation to long-duration microgravity flight. However, true space adaptation syndrome takes substantial time to develop (hours), as distinguished from more
conventional motion sickness.

Single-pilot aircraft are flown by aircrew without any special screening for airsickness, and anecdotal evidence from pilots suggest that mission-critical functions can be performed even while suffering from motion sickness.

Suborbital trajectories generally do not have long microgravity exposures, and so the issue of longer-term space adaptation syndrome does not apply in this case. While not deemed necessary for single-pilot aircraft, it would be possible to screen aircrew for ordinary motion sickness.

Requirement for two aircrew, both with the ability to fly a piloted vehicle, significantly increases the minimum size of vehicle which can be designed for a given mission. That puts more "metal in the sky" for a given mission in return for mitigating a risk which, in aviation, has been demonstrated to be extremely small -- the chance of "aircrew failure". While the flight regime is new, we're still flying with the Mark I human pilot, whose reliability statistics are good, and whose life support requirements are well understood. Redundancy of components is only required to enhance reliability where the reliability of the individual components is low -- therefore, since pilot reliability is high, we do not see a requirement for redundant pilots.

5) USE OF A DESIGNEE PROGRAM

XCOR has no objection to a designee program; we think it makes sense.

6) NEW AREAS FOR RESEARCH

We believe that IVHM technologies are currently best developed by the RLV industry, due to the close relationship between appropriate monitoring techniques and the vehicle design.

Non-destructive Flight Safety Systems could be a useful area; XCOR Aerospace intends to address Flight Safety by pilot controlled flight to safe abort locations. It is possible that FAA research could help develop a standard code for predicting instantaneous impact point to assist pilots in flying abort trajectories (for piloted or remotely-piloted vehicles).

As mentioned above, additional research on the acceleration limits tolerated by the general public would be welcome.

The most useful area, and one which only the FAA can really tackle, is tools and methodologies to predict safe space/air corridors to allow for the co-existence of launch/reentry vehicles and airplanes and rotorcraft. Since our focus is on piloted vehicles, enhancing the pilot's awareness of the airspace by presenting him with real-time information about other air traffic and safe air corridors would be a TREMENDOUS operational enhancement. Without this capability, rocket aircraft will be able to fly only in remote areas with dedicated airspace. With a real-time "situational awareness" capability, rocket aircraft could be well integrated into the National Airspace System. We would recommend that FAA research focus in this area.

7) REQUIREMENTS FOR AEROSPACE MECHANIC

This discussion presents a philosophy which XCOR strongly disagrees with. Instead of commenting point by point, we present a complete discussion of the topic:

Operations & Maintenance Personnel Qualifications

This breaks down into two areas: mechanics and pilots.

Mechanics

Mechanics are responsible for the routine inspection and maintenance of aircraft and powerplants. It has been proposed by the United Space Alliance (attachment 3 to the O&M White Paper) that a new "aerospace technician"profession be created to serve as qualified personnel for this purpose, along with schools and FAA qualifying regulations. We disagree.

Today, there is no RLV industry. Many entrants, large and small, are trying to create such an industry, and the FAA is fostering this activity. The only semi-reusable launch vehicle in operation today is the Space Shuttle, operated by United Space Alliance as a contractor to NASA. This vehicle requires a very large workforce to operate and maintain -- a feature which every other RLV is trying to change. As a result of the large workforce, the situation today is:
* The overwhelming majority of the workforce with "aerospace" experience are working on ELVs or the Space Shuttle.
* Because both ELVs and the Space Shuttle have very large workforces, technicians working on them are very narrowly specialized.

By contrast, the newer generation of RLVs will call for mechanics with a much broader range of experience, capable of maintaining several different subsystems. We therefore believe that any attempt to create a NEW type of technician will inevitably draw heavily on ELV and Shuttle experience. XCOR personnel have previously tried to hire technicians and mechanics from this workforce, without success -- the degree of specialization rendered candidates' prior experience inapplicable to our needs.

No RLV is yet operating, and there will be a gap between the introduction to service of any proposed RLV and the time when it operates so routinely that training of new maintenance personnel can possibly be standardized. Therefore, XCOR Aerospace does not believe that regulations for maintenance personnel are yet appropriate. However, if the FAA regulations for RLV launch licensing allow for a dramatic reduction in licensing requirements for launches after a "qualification" period, then licensing for maintenance personnel may be appropriate. (Note that f repeated flights do NOT gain a substantial reduction in licensing burden, then the launch license presumably protects public safety adequately. Only if an RLV operator reaches a point where vehicle safety is proven by past record rather than analysis does it make sense to maintain safety by maintaining a "proven" vehicle)

If the FAA feels that near-term regulation of maintenance personnel IS appropriate, XCOR Aerospace STRONGLY recommends that these personnel be drawn from the existing pool of Airframe and Powerplant mechanics trained under the FAA aircraft regulations, with supplementary training where needed.

An examination of Advisory Circular 65-9A, 65-12A, and 65-15A, covering the training to be given to airframe and powerplant mechanics, shows that this material consists of widely applicable "basics" in good mechanical practice. Technicians are taught how to recognize good and bad welds, good and bad rivets, etc, as well as the basic operating principles of the systems involved.

Of course, no general curriculum such as this could possibly cover all the details of a given system. In that case, frequent reference is made in the Advisory Circular of the need to consult either official regulations or the manufacturer's instructions. Since certification regulations for RLVs do not exist (nor are likely to for some time), manufacturer's instructions will be the only place to turn.

Certainly, there are additional areas currently poorly covered by A&P training where an additional "rating" would be welcome. Composite structures (for aircraft or RLV's) is one such, and a "rocket rating" supplemental to a current powerplant mechanic is probably called for (as a side note, the existing "rocket mechanic" experience base is thinning rapidly as the mechanics of the 1950's and 1960's leave the workforce). But for the foreseeable future, these ratings should be SUPPLEMENTARY TO an Airframe or Powerplant mechanic rating, rather than replacing them.

If airframe and powerplant mechanics are used for RLV operation, a trained workforce with relevant work experience will be available for the RLV industry to draw from. To facilitate attracting trained personnel, XCOR recommends that the AIRCRAFT A&P regulations be modified, to make clear that an airframe or powerplant mechanic does not "lose currency" by working on a RLV. If the FAA feels that a standardized body of training exists in specific areas such as composite structures or rocket engines, they can create recognized supplemental certificates to cover these additional skill sets.

This approach allows for a phased, incremental approach to regulating RLV mechanics, appropriate to a developing industry. It also avoids burdening the new industry with the "corporate culture" and poorly relevant training drawn from the Space Shuttle or expendable launch vehicles. In the near term, a simple advisory circular stating that maintenance personnel qualifications are a factor in assessing Ec calculations during an RLV license, and that an A&P or equivalent level of qualification is presumed adequate, would get the ball rolling.

Pilots

In addition to mechanics, RLVs require vehicle operators. There is not yet agreement within the industry on a control philosophy for vehicle operation. Candidate approaches run the gamut from fully autonomous operation with ground-based flight termination, to fully piloted operation with no significant ground-based operation presence.

Safe operation on ground-controlled vehicles clearly requires skilled personnel; however, the lack of an established set of safe operating practices for remotely piloted air vehicles makes it difficult to discern the appropriate qualifications for such personnel. XCOR recommends that the qualification requirements for ground-based operators mirror, to the extent possible, the regulations evolved for the ground-based operators of remotely piloted air vehicles.

In our opinion, it is difficult to achieve an acceptable level of public safety with an autonomous RLV. That concern more properly is addressed in the launch license, however.

Piloted operation raises new challenges. What kind of pilot qualifications are appropriate for piloting a reusable launch vehicle? This is made MUCH more difficult by the wide range of vehicle types envisioned. The task of piloting a helicopter-landing vehicle such as Rotary Rocket Company's "Roton" is quite different from piloting a suborbital airplane-like X-Prize vehicle such as Bristol Spaceplanes' "Ascender", which is in turn quite different from a rocket-powered VTOL vehicle such as TGV Rockets' "MICHELLE-B".

In the opinion of XCOR Aerospace, this area deserves careful consideration. We believe public safety would be enhanced by a regulatory regime favorable to piloted vehicle operation -- yet a piloted vehicle with an unqualified pilot does not enhance safety.

At this stage of the RLV industry, a general "RLV pilot license" would be impossible, as there is not enough commonality between the different vehicle types. We recommend instead that the vehicle operators submit as part of their license application information describing the pilot qualification or training which will be used for their vehicle, and that the FAA take this into account as part of the license application -- remembering that the current charter of the FAA is to protect the safety of the general public, not the vehicle operator.

Some advisory examples of "acceptable" pilot training would of course help to guide the FAA and prospective applicants. Here is an example of a "generic" airplane-like suborbital vehicle, with Mach 5 peak velocity, operated at altitudes up to 400,000 feet. The vehicle takes off horizontally under rocket power and lands horizontally by gliding. In describing the type of pilot qualification program XCOR would propose for this vehicle, we are NOT proposing specific qualifications for other vehicles. Rather we are illustrating by example a PROCEDURE which we believe the FAA would follow, in each applicant's case, to determine acceptable pilot qualifications.

For such a vehicle, first we examine existing vehicles to see if a similar type exists. No current certificated vehicle with a similar flight behavior exists. We then look to past operational experience, and we find that the vehicle bears resemblance to the X-15 experimental vehicle during flight and landing, while takeoff resembles an afterburning takeoff of a jet fighter or takeoff with JATO units. Examining the pilot qualifications in the X-15 program, we see that the pilots:

* Had significant experience in supersonic jet aircraft
* Were given simulator training to gain experience in the handling qualities unique to the X-15 aircraft
* Practiced in sailplanes and in specially configured jet aircraft to master the glide landing of low L/D aircraft
* Held current medical certificates for jet aircraft flight

In addition, tests in a centrifuge were conducted to confirm pilots' ability to control the X-15 under the expected G-loads of ascent, but individual pilot qualification in a centrifuge was not conducted (this *may* have been a contributing factor in the loss of an X-15 on flight 191.
See Thompson, _At The Edge Of Space_, p. 260-261
In that incident, vertigo may have hampered the pilot's attempt to control a badly malfunctioning aircraft).

We would follow a similar procedure in pilot qualification for this hypothetical vehicle. Pilots would be required to:

* Have a current pilot medical certificate
* Be a current private or commercial pilot, with aircraft category ratings of turbojet-powered airplane and glider, as well as the holder of an airplane instrument rating.
* Demonstrate proficiency in a flight training device (flight simulator) in the unique handling properties of the new rocket aircraft, including unpowered landing procedures
* If practical and affordable, demonstrate ability to perform control tasks under appropriate G-loads in a human centrifuge

As a practical matter, these would be minimum qualifications only; early flights of the vehicle would be entrusted to pilots with substantial flight test experience in jet aircraft until the flying characteristics of the vehicle had been well demonstrated. However, the FAA should concern itself only with reasonable minimum qualifications.

Again, if a proposed rocket craft had radically different operating characteristics, it would of course require different qualifications. We believe that the principle of selecting those qualifications would be similar in such a case -- examine what existing or past vehicles had comparable flight characteristics (at least in part of the flight regime), and use proficiency in those vehicles as a prerequisite for flight.

Once several piloted RLVs have demonstrated operational safety, flight experience in those RLVs can be used as a criteria for similar RLV operation; this discussion only considers the current situation, where piloted RLVs (and hence experienced RLV pilots) do not exist.

A.6 COMMENTS OF THE BOEING COMPANY, REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

Reusable launch vehicles must be inherently robust to accommodate high utilization rates and rapid turnaround times with minimum maintenance, which implies a specified level of flightworthiness. A variety of factors contribute to flightworthiness, and several aspects have to be taken into account to ensure that an RLV will be flight-worthy throughout its complete life cycle, including: design, manufacture, structure and components testing, flight testing, acceptance, operation, development in service, and maintenance. However, once an RLV becomes operational, frequent reuse will demand the means and processes to ensure continued flightworthiness, just like commercial aircraft. These processes must accommodate troubleshooting and repair procedures, test and inspection criteria, return to service requirements, limits and restrictions, and system reconfiguration for failed system components. During the interim period between licensing and full certification, Boeing believes that the processes resident in MSG-3 will adequately address these factors. The MSG-3 standard, in fact, will help the RLV industry bridge the gap between ELV-like licensing and aircraft-like certification. The MSG-3 standard is inherently flexible, and has been employed successfully in O&M programs for nuclear power plants, submarines and many, many different types of commercial aircraft. Boeing, therefore, proposes that members of the RLV industry convene a panel to tailor the MSG-3 "recommended specifications" to a set of common processes and practices that will not only accommodate the present generation of RLVs, but will also drive the evolutionary advancement of an RLV-unique MSG concept. Such a concept would allow a "natural selection" of the appropriate aircraft O&M FARs for RLVs, key insight into how some O&M FARs may need to be revised, and identification of any new FARs that may be required. Furthermore, the licensing and certification of spacecraft-specialized technicians will be mandatory in the implementation of any RLV O&M program. A thorough understanding of the effects of the space environment on avionics, structures, propellants, lubricants, fluids and materials used for repair and replacement (not to mention a host of other items) cannot be minimized (or trivialized). Boeing, therefore, applauds the visionary efforts of Spaceport Florida and Brevard Community College to establish a broad technician-level spacecraft training program.

A.7 COMMENTS OF KISTLER AEROSPACE, REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS
(Concurred by Kelly Space & Technology, Inc.)

Introduction

The operations and maintenance practices for a Reusable Launch Vehicles (RLVs) are the backbone of safe, successful recurring flights. In regulating these practices, it is important to understand that commercial RLV operators are driven by their need to ensure the highest probability of vehicle return for reuse. RLV operators are driven by their own economic interests to emplace the safest and most effective ground operations and maintenance procedures.

In the broader picture, RLVs occupy a unique position in the spectrum of transportation systems. Analogies are routinely made to commercial aviation, expendable launch systems and the Space Shuttle, but none of these analogies fits perfectly, nor does any of them adequately cover the subject. While clearly these represent the starting point for any discussion of RLV O&M, any blanket proposition should be greeted with caution.

When faced with a similar uncertainty in the development of an RLV licensing regime, the COMSTAC RLV Working Group advocated a flexible approach to licensing that maintained safety while enabling the evolution of a more sophisticated regime commensurate with industry development. The goal was to maintain safety levels while fostering learning and innovation.

A similar philosophical posture would serve well in the development of RLV O&M regulations. We should keep in mind throughout that while safety and risk management are critical aspects of any RLV operation, our goal is to create an environment for learning and evolution.

Applicability of the FARs

Kistler Aerospace believes that regardless of the stated or perceived applicability of various FARs to RLVs, it behooves the industry and the FAA to place any new rules for the regulation of RLVs under new FARs. While the existing FARs may serve as templates for the *organization* of new regulatory development, a 'clean sheet' approach to creating the *content* would yield the most feasible and coherent system of regulation for supporting an emerging RLV industry.

New Guidelines Development

The subject White Paper asks, "What regulatory safety guidelines need to be developed for this emerging industry to ensure public safety while new RLV O&M regulations are being developed?"

Kistler believes that the development of RLV O&M regulations is an evolutionary process. It is only through the active undertaking by developers to present their O&M processes to the FAA that, over time, a proper regulatory response will be identified. The FAA itself appears to recognize this when it writes as part of the discussion of this topic, "…AST will review each applicant on a case by case basis…"

In regard to RLV Operations and Maintenance, then, FAA guidelines at this early phase of the industry should focus on identifying and assessing processes rather than setting thresholds and conditions. For example, it is not clear that the "100 hour" inspection as mandated for aircraft would have any relevance to RLVs. It is further uncertain that *any* single inspection interval – 5 hours, 25 hours, 1000 hours – may be meaningfully applied to *all* RLVs.

In an earlier presentation to AST, Kistler pointed out that there are three fundamental questions that RLV launch license applicants need to answer. These questions could not be answered directly, but they initiate a set of lower level questions that may be directly supported with data.

The three fundamental questions are:

1. Is the vehicle designed to be safe?
2. Is the vehicle built as designed?
3. Is the vehicle operated safely?

The first two questions are outside the realm of the O&M White Paper. The third question, however, is relevant here and had three lower tier questions attached. They are:

1. Does vehicle processing maintain system integrity?
2. Are mechanisms in place for continued flight-worthiness?
3. Are mechanisms in place for a safe flight?

Does Vehicle Processing Maintain System Integrity?

Each RLV operator should have in place mechanisms to ascertain that any work done on the vehicle between flights was accomplished completely and correctly and did not detrimentally affect the system integrity. Such mechanisms may be as simple as a "check technician" inspecting another technician's work, or as sophisticated as an automated test and checkout system built into the vehicle.

The point here is that *the* process for maintaining system integrity is not mandated, but *a* process for maintaining system integrity is. Such a process would be presented to the FAA as part of the RLV licensing process.

Of ancillary interest in this discussion is the question of whether or not there is a need for an Aerospace Mechanics certificate. Kistler would answer this question in the negative.

A certificate program is useful when there is a substantive body of skills required of *all* technicians in an industry, and when those skills are being taught nowhere else. Kistler does not believe this is the case with the skills required to work on an RLV.

There are two categories of skills required of technicians working on RLVs, or on aircraft for that matter. They are Fundamental Skills and Manufacturer Training Skills. Fundamental Skills include such items as the reading of specifications, care and use of various tools and measurement equipment, and appropriate work and inspection techniques. Manufacturer Training Skills include all items unique to a given manufacturer's equipment.

Kistler believes that in the commercial aircraft industry, where design and materials are relatively consistent across the various manufacturers, Fundamental Skills constitute the bulk of a technician's useful training. In the RLV industry, however, where design, materials, fuel, and operational environments are so divergent, Manufacturer Training Skills, i.e. skills relevant only to the selected vehicle, are far more important. These diverse skills do not lend themselves to a certificate program.

Kistler believes that the Fundamental Skills required to operate the K-1 are already possessed by a large number of people in the population and are already being taught in various technical programs across the country. At the very most, then, hiring preference might be given to individuals already possessing an A&P certificate for aircraft maintenance. But Manufacturer Training Skills, skills that by definition are unique to the K-1, simply cannot be taught in generic certificate programs.

Are Mechanisms In Place for Continued Flight-worthiness?

Each RLV operator should have a process in place by which appropriate inspection and scheduled maintenance intervals may be identified and, as operational experience is gained, lengthened as appropriate.

It is worth noting once again that the length of inspection intervals, especially initial inspection intervals set at the start of operations, will be fully hardware dependent. Inspection intervals for off-the-shelf items such as Kistler's NK-33 engines will be known with greater certainty than inspection intervals for new development so long as it can be shown they are operating within their design envelope and environment.

Processes for safely exploring the parameters of a maintenance program and lengthening inspection intervals have already been developed. Fleet leader programs, problem reporting and correction systems (PRACAS) and failure reporting and correction systems (FRACAS) are all tools available for RLV operators. Once again, it is not important that *the* process for continued flight-worthiness be identified, but that *a* process be identified.

The Role of MSG-3

Any discussion of continued flight-worthiness gives rise to consideration of the applicability of MSG-3 to RLV O&M.

MSG-3 was developed by the aviation industry as a logical framework for assessing a system's maintenance needs and maintaining a system's "inherent levels of safety and reliability." It is a methodology for allocating maintenance resources. It attempts to do this without losing sight of the operator's need for cost-effective operations.

While MSG-3 is a candidate for adoption by any RLV operator developing a maintenance plan, it is worth noting what MSG-3 does not address.

- *MSG-3 does not directly identify the Maintenance Significant Items (MSIs) that will be subject to the program, nor does it provide a methodology for doing so.* It is left to the manufacturer to develop the initial set of MSIs.

- *MSG-3 does not identify appropriate initial inspection intervals for MSIs, nor does it provide a methodology for doing so.* Once again, this development is designated as a task for the manufacturer who presents the results to the regulatory authority.

In light of this, Kistler believes that a case-by-case approach to regulating RLVs at this juncture is the most appropriate approach. Depending upon the RLV concept and design, the maturity of the technology being used and the extent of COTS equipment incorporated, the MSI list and the initial inspection intervals will vary greatly.

Is the vehicle operated safely?

This question, while strictly speaking is part of an Operations and Maintenance discussion, is generally addressed as part of the System Safety Review. Such items as an Operations Safety Plan, an Accident Response Plan and the need and availability of emergency services may be presented in response to this question. It will be addressed no further in these comments.

Research and Development

The FAA recently signed an MOU with NASA for the development of commercial space technologies. In the first half of the last century NASA's predecessor agency, NACA, undertook the methodical characterization of airfoils to the benefit of the entire aviation industry. Under the referenced MOU, and in conjunction with FAA input, NASA could make a similar contribution to RLV O&M.

NASA, under FAA direction, could undertake the characterization of materials and components to facilitate the identification of commercially viable initial inspection intervals.

It is no secret that initial inspection intervals are conservative in nature. Given the novelty of the RLV environment, RLV operators may be forced into adopting overly conservative initial inspection intervals.

By conducting tests and demonstrations of generic materials and components, NASA would provide the RLV industry with critical tools for commercializing operations. Among the items characterized might be various composite materials, circuit boards, TPS materials, connectors, GPS and TDRSS receivers, various size valves, etc. Among the exposures might be mechanical load cycles, radiation, heating, acoustic loading, etc.

Clearly this presentation is only the germ of the seed of an idea, but a task force of specialists could rationally develop a matrix of characterizations to undertake. Previously developed data – from LDEF, STS and other programs – could be factored into the plan. NASA facilities at many centers could be utilized as well as STS and ISS if appropriate.

Kistler believes that such a characterization program, undertaken at government expense with FAA input and NASA execution, would be a service to the RLV community and yield a competitive advantage to American developers as these systems evolve.

A.8 COMMENTS OF APPLIED SCIENCE 7 TECHNOLOGY, INC. (ASTI), REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

(The following comments were made to the original draft, dated May 30, 2000. Page numbers in the original ASTI comments were revised to reflect the current revision.)

Overall ASTI agrees with a lot of the comments provided by "real stakeholders" in the commercial RLV industry. The following are comments to comments to clarify and/or take exception.

- Page vi thru ix: The letters from Florida don't appear to have addressed the mail as in providing comments to FAA/AST's draft white paper, but rather appear to be a proposal to FAA to be their school for spacecraft technicians.
- Page 30, Kelly Space & Technology Comments: Agree with all, but would change one Introductory Matter comment regarding RLV landing gear to "Most RLVs will have landing gear" instead of just "some".
- Page 34, third paragraph: The Shuttle example may not be appropriate since it is a Government system. Also I don't agree with the last sentence since Boeing 777 operators (United, Delta, etc.) are required to have an A&P, just as the Lockheed-Martin operator segment (VentureStar LLC) working on an operational system in commercial service should also be required to have a A&P.
- Page 36, second paragraph: I believe that using the current FAR certification process at this point in the RLV industry's development should be a corporate choice and not dictated. The full up certification process should be phased in over time as the industry matures and develops.
- Page 37, first full paragraph: NASA may be a good starting point but they still treat astronauts as "national resources/heroes" and in order to "pilot" a Shuttle one must be a test pilot.
- Page 42: This is a good baseline to start the development of a certification process to obtain additional ratings on an A&P cert/license for spacecraft mechanics. You should also add to the litany of folks to develop this curriculum aircraft developers, operators and maintainers to provide a more balanced perspective.
- Page 48, paragraph beginning "On page four": Rather than completely throwing out the existing FARs, they can be used effectively as models.
- Page 49, first paragraph under 2): The FAA has regulations and procedures in place to govern operations of restricted and experimental category aircraft, and something similar could be used for RLVs before they reach "essentially unrestricted operation".
- Page 50, second paragraph under 3): The Shuttle is a good source of data, but the use of the data must be tempered greatly. Another very good source would be the maintainability and operability data from the DC-X/XA flight tests since it was designed for operability.
- Page 51, third paragraph under 4): I believe the statement here is not entirely true from a business perspective since an unmanned/autonomous RLV operators will be very

motivated to ensure safety performance of their vehicles since any "disaster" would spell corporate disaster for the company.

- Page 51, fifth paragraph under 4): I would think that with passengers (not just crew as part the flight safety systems) on board a "spacecraft" life support systems would be critical to protect the "traveling (space) public".
- Page 51, sixth paragraph under 4): Single pilot military aircraft are also flown on a daily basis over populated areas.
- Page 51, eighth paragraph under 4): Space sickness anecdotal evidence can be obtained from the astronaut corps – there are multiple instances that can be related.
- Page 55, second full paragraph: I don't necessarily agree that an acceptable level of public safety ca be achieved with an autonomous RLV, however, I do agree that it is more appropriately addressed in the licensing process.

A.9 COMMENTS OF BOEING COMPANY, LONG BEACH, REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

Processes for the Development and Certification of Commercial Reusable Launch Vehicles

Scott Jackson and Walter S. Smith
The Boeing Company
Long Beach, California

Introduction. The risks and challenges associated with the development and certification of Reusable Launch Vehicles (RLVs) demand processes as rigorous as those for commercial aircraft in terms of risk (critical systems failures less than 10^9). We have had many decades of man-rated space vehicles that can provide a base of knowledge necessary for passenger operation. Future generations of RLVs will take advantage of the reliable-scheduled operations of present commercial aircraft. This body of knowledge will enable RLVs to operate commercially in a new environment, with new technologies, and with a new mission.

The Concept and Mission of a Reusable Launch Vehicle

The notion of a Reusable Launch Vehicle is, at the present time, broad. Fundamentally, it includes any vehicle which can take-off, exit the earth's atmosphere and land multiple times. Whether it will be able to and required to land at commercial airports is still to be defined.

The mission of a *commercial* RLV is similarly in the formative stage. Current plans envision early commercial RLVs primarily as cargo carriers. Thus, when technology has matured, the potential of paying passengers will be within the realm of possibility.

A historical parallel is the early government support of airmail to establish the commercial feasibilityof air travel considering the technology and projected uses available at the time.

Arguments for Certification

There are two methods for achieving government sanctions for launch, flight and return to the atmosphere, namely, licensing and certification. Licensing, the current method, is the permission on a flight-by-flight basis. Certification, the proposed future method, is government authority assuring that a vehicle *type* is safe, and that operations and production methods achieve prescribed standards.

The reasons most often advanced for certification, as opposed to licensing, of RLVs are as follows:

- Certification ensures the most rigorous methods are applied to assure public safety
- Certification assures that the safety standards are in place on a continuous basis rather than on a flight-by-flight basis
- Certification provides protection against second- and third-party liability

The economic soundness of these reasons is apparent: If a commercial enterprise wishes to launch RLVs on a regular basis, the cost and uncertain schedule effects of licensing would most likely be economically undesirable. A business analysis to support this hypothesis is an early goal. Stevens addresses the commercial aspect of RLVs.

Who Certifies?

The existing Federal Aviation Regulations recognize airworthiness regulations may not contain adequate or appropriate safety standards because of a novel or unusual design as defined in the Code of Federal Regulations (CFR), Section 14, Parts 11 and 21. Special Conditions are issued to establish as the Administrator finds necessary to establish a level of safety equivalent to that established in the regulations.

Congress established Commercial Space Transportation under Title 49 Transportation, subtitle IX in 1984. DOT assigned this responsibility to the FAA Office of the Associate Administrator for Commercial Space Transportation (AST) in 1984. The primary responsibility of this organization is to regulate the US commercial space transportation industry and license commercial space launches to protect public health and safety, safety of property, national security, and foreign policy interests of the U.S. The Office is also responsible for encouraging, facilitating, and promoting commercial launches by the private sector and for regulating non-federal or commercial launch sites.

The framework is in place. However, the approach should not be to replicate the existing FARs but to use the commercial certification experience as a template to apply to the space technology and environment.

This subject, however important, is outside the scope of this paper and is addressed by Herzfeld, et al. In addition, Rey discusses the legal aspects of liability and indemnification. This paper focuses on the actual methodology for evolving the *criteria* of certification for RLVs.

Procedures for Rule Making

The present certification process provides the procedure for making new rules to adapt to new conditions and to new technology. CFR, Section 14, Part 11, for example, states,

> "Any interested person may petition the Administrator to issue, amend, or repeal a rule whether or not it is a substantive rule with the meaning of §11.21, or for a temporary or permanent exemption from any rule issued by the [FAA] under statutory authority."

CFR, Section 14, Part 21 CFR states "For special classes of aircraft … for which airworthiness standards have not been issued … airworthiness criteria as the Administrator may find provide an equivalent level of safety…." Thus, new conditions or technology introduced by the RLV may generate new rules to handle the situation. A new rule under the rule making process is called Special Conditions. Following is an example of Special Conditions for the commercial certification of the Boeing MD-17.

Boeing Experience With Developing the Special Condition for Certification of the MD-17.

The MD-17 is a commercial derivative of the USAF C-17 aircraft. Among the novel features of the C-17 airplane is the use of powered lift to operate out of short airfields. Powered lift is developed by engine exhaust externally blown over the wing and flaps. A Special Condition was developed to maintain equivalent safety to existing aircraft while allowing different approach and takeoff speed margins.

The Roadmap for Development and Certification

The engineering framework for the new environment is documented in the standard ANSI/EIA 632, *Processes for the Engineering of a System* (1999) and in SAE Aerospace Recommended Practice (ARP) 4754, *Guidelines for the Certification of Highly-Integrated and Complex Aircraft Systems* (1996). These two documents together provide the roadmap for successful RLV development and certification.

Developments in Development and Certification Processes

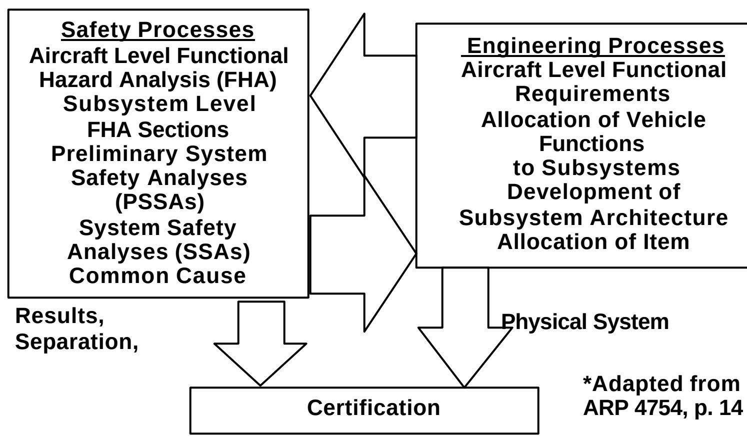
The core processes described in ANSI/EIA 632 require a rigorous development of the vehicle's mission, functions, requirements, solution alternatives and selection, and verification. These processes apply to the entire vehicle from its top-level system objectives to component performance and quality and include both safety and non-safety functions. ANSI/EIA 632 also addresses program planning, technical management, control processes, implementation, and any other factors which may affect its performance. The bottom line is rigor and thoroughness. The processes described in ANSI/EIA 632 complement and overlap the recommended certification processes described in ARP 4754, especially with respect to the functional breakdown and safety of the system.

ARP 4754, on the other hand, is certification focused. Traditional certification practices have employed the use of the historical knowledge of possible failure modes to assess possible functional failures. In particular, traditional functional hazard analysis (FHA) assumes that there are approximately 100 possible failure modes on any aircraft. This number is based entirely on historical evidence. The number of possible failure modes of an RLV is entirely unknown. ARP 4754 proposes an alternative, and more thorough approach, namely, to conduct an exhaustive functional analysis and breakdown of the functions of the vehicle, in this case, the RLV. That is, a functional architecture of the vehicle is developed which comprises all the functions of all the systems, subsystems, and components on the vehicle. From this functional breakdown a traditional Failure Modes and

Effects Analysis (FMEA) can be performed. This analysis will determine the criticality of each function, the consequences of the failure of the function, and what can be done to reduce the criticality of the function. A newly developed document *Guidelines for the Practice of Systems Engineering in the Commercial Aircraft Domain* (draft) by the International Council on Systems Engineering (INCOSE) Joint Commercial Aircraft Working Group (JCAWG) provides a template for the development of such a functional breakdown. In addition to the concentration on the functional breakdown, ARP 4754 recommends increased emphasis on the Common Cause Analysis (CCA) which determines how a single failure can be prevented from causing other failures.

In short, ARP 4754 shows how the system development processes, like those described in ANSI/EIA 632, can be integrated with the traditional safety processes to form a unified set of processes leading to more rigorous adherence of safety goals. The five system development processes identified by ARP 4754 are as follows: vehicle level functional requirements, allocation of vehicle functions to subsystems, development of subsystem architecture, allocation of item requirements to hardware and software, and system implementation. These processes are completely in line with the processes of ANSI/EIA 632. Secondly, ARP 4754 identifies five safety processes, as follows: vehicle level Functional Hazard Analysis (FHA), subsystem level FHA, Preliminary System Safety Analysis (PSSA), System Safety Analysis (SSA), and the Common Cause Analysis (CCA). This relationship is illustrated in Figure 1.
The use of the top-down functional analysis will be described later.

Figure 1. Relationship Between Engineering and Safety



Issues Which Drive the Design for Certification

Although there may be many development and safety issues associated with the RLV, there are several which are apparent. They are as follows:

Cabin Decompression. With regard to cabin decompression, the issue is whether the current levels of safety can be maintained. Although the criterion can be lowered, this option is not realistic or desirable. The alternatives are equally daunting. All design solutions involve considerable penalties, for example, double hulled vehicles, passengers in space suits, etc. A serious examination of this issue is required.

Space Debris. The most likely cause of cabin decompression is space debris. The basic task is to determine the debris diameter which will meet our probability requirement and design a structural protection against it.

Ground Noise. Ground noise reduction options are even more limited. Vehicle design can achieve only limited results. Other options include limiting the flight paths and ground points of landing.

Structural Integrity and Durability. To meet the severe environmental and mission requirements, advanced materials are envisioned. Performance and durability characteristics would have to be established for repeated flights. The environmental factors, not present in commercial aircraft, include solar radiation, molecular oxygen, and gamma radiation.

Fail-Safe Systems. To meet rigorous reliability requirements, flight controls and other systems made need as many as five levels of redundancy.

The Ascent Environment. The most critical

phase of flight is ascent. This is where the most energy must be expended and controlled. Failures happen in nanoseconds. Although failures are possible in orbit and in re-entry, ascent will be the driving phase for most of the system.

Propulsion Control. The propulsion control system is one of the least reliable systems besides the engines. Propellant lines can be 17 to 36 inches in diameter. This is one of the most difficult systems for achieving redundancy.

Propulsion Detonation. This one of the most challenging certification issues. Questions to be answered are: Could the probability of detonation meet the probabilistic criteria? How would personnel be protected in the event of a propulsion detonation? How would the personnel return to earth?

Medical Issues. The environment to which the personnel would be exposed is more severe than for commercial aircraft thus imposing limits on the types and physiology of crew and passengers. In addition to types of radiation mentioned above, there are the launch and re-entry g-loads.

Other Issues. Solutions for the abort requirements and emission control are also prime subjects for examination.

Failure Criteria and Certification Options

Meeting the criteria for certification may involve operational tradeoffs. The current criterion for risk to population is 30 x 10^{-7} for commercial aircraft. One way to achieve this criterion is to avoid population over-flight. The second option would be to increase the reliability of the spacecraft and limit over-flights to more sparsely populated areas. The last option would be to raise the reliability to current commercial aircraft standards.

The best solution will depend on the achievable reliability. Figure 2 shows the estimated reliability for various subsystems on the CS-1 (Clean Sheet Configuration Number 1) Low Orbital Vehicle with an RS 2100 stages-combustion liquid hydrogen/oxygen engine. This chart shows that that propulsion system is the reliability driver. This vehicle is estimated to result in one failure out of 1524 missions. It is expected that these results will improve with time and further development.

RLV Risk and Technology Management

Another essential process is risk management. Risks, especially safety risk, will be present due to the new environment, new technologies and a new mission. Basic risk reduction methods include a comprehensive testing and prototype program and reliance on proven technology especially from NASA programs.

Technology Approach. The NASA technology maturity criteria provide a method for the evaluation of technology maturity levels. As a general rule it is desirable to achieve a level 9 (flight proven) for technologies to be used on commercial RLVs.

The FAA has a history of dealing with the introduction of new technologies. Two examples are the introduction of the jet engine into commercial use in the 1950s and more recently the approval of powered lift for the MD-17, the commercial version of the Boeing C-17. The key question is: When will technologies be mature enough to be used in passenger flight on RLVs? More importantly, will the technology jumps be so much greater than in the past that different policies will be required?

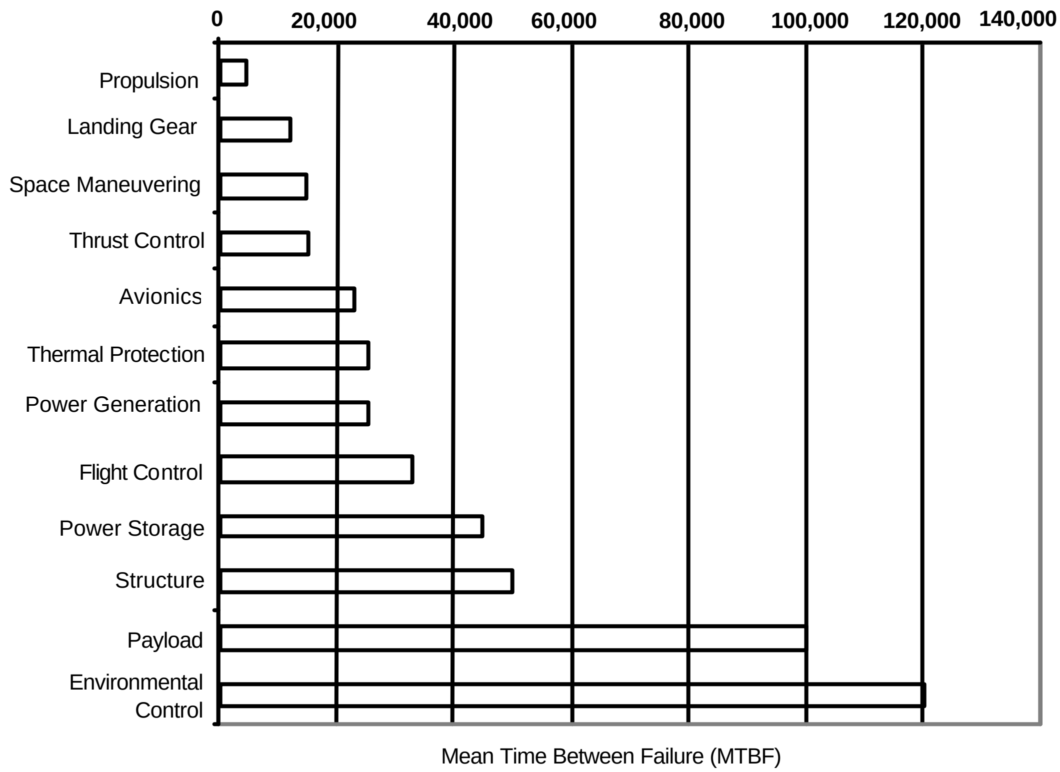
Current Boeing thinking envisions an incremental approach in which the RLV, first, takes advantage of NASA experience, and secondly, introduces new technologies on cargo missions while deferring passenger flights until these technologies have reached a significant degree of operational experience. As a rule, the policy can be stated as follows:

> *RLVs will employ new technologies only when they, first, provide significant performance benefit, and secondly, when they are mature enough for deployment.*

The second method of technical risk mitigation is the adoption of the top-down functional safety analysis described in ARP 4754, described and discussed later. Hence, two aspects of a future framework already exist, namely, present FAA policy for the introduction of technology, and secondly, the ARP 4754 approach to functional analysis. Whether further aspects need to be added remains to be seen.

The NASA Integrated Space Technology Program (ISTP) has identified 48 critical technologies which are broken down into the following ten categories:

Figure 2. CS-1 LOV RELIABILITY ESTIMATES (RS-2100 No Redundancy)



- Airframe and Mechanical
- Avionics
- Crew Systems
- Integrated Design, Manufacturing, Manufacturing, and Operations
- Integrated Propulsion
- Integrated Vehicle Health and Maintenance
    - Operations Architecture
    - Power and Actuation
    - Reliable Engine
    - Thermal Protection System

Cost Risk. Another key risk is cost risk. As a general principle, safety will always take precedence over cost. That is, the investment required to have successful missions will define the financial structure of the program. No commercial program can afford the expense of failures.

The Top-Down Functional Approach to RLV Safety

Traditionally, aircraft safety analysis has relied on a set of 100 functions which have been known, *by experience*, to be critical. The difference with the RLV is that the operating environment is so radically different from commercial aircraft that, on the one hand, many of these functions may have no relevance to space flight, and secondly, there may be functions important to the RLV not considered among the traditional set of 100 functions. While it is axiomatic that we will never know all the unknowns, the functional approach takes us closer to the goal of knowing all the unknowns.

Secondly, although some of these functions may be the same, the severity of the requirements associated with the function may be radically different. The function *Provide Cabin Pressurization*, for example, is important to both domains. As mentioned before, the difficulty in satisfying this function for the RLV is far greater than for commercial aircraft.

With respect to the top-down approach, the Joint Commercial Aircraft Work Group has proposed a set of seven top-level aircraft functions. The concept is, first, that these functions would be decomposed into hundreds of lower tier functions which would be a complete and detailed functional description of the entire aircraft, and secondly, that any lower-tier function could be traceable to these top-level functions. These seven top-level functions are as follows:

- Provide and Distribute Aircraft Communications and Data
- Plan, Generate and Control Aircraft Movement
- Provide Crew, Passenger and Cargo Environment and Services
- Detect and Analyze Aircraft Conditions for Flight
- Generate and Manage Aircraft Internal Power and Manage Aircraft Systems Materials
- Provide Airframe Movement and Attachment Support
- Provide Aircraft Containment and Internal Support

While all of these functions may not have direct analogues for the RLV, the concept is valid for the RLV. The sub-functions Provide Thrust and Provide Lift, for example, are subordinate to the second top-level function Plan, Generate and Control Aircraft Movement. It is doubtful whether Provide Protection Against Solar Radiation is on the present list of 100 functions. This example reinforces the contention that rigorous engineering processes, including an exhaustive definition of the environment and its impact on all vehicle components *and on the passengers and crew*, will be required.

Of the available literature, Zapata addresses the issue of technical certification criteria most thoroughly. That paper reinforces the point that the technical issues on the RLV will be radically different from traditional aircraft and that certification will require extensive testing and operational demonstration to achieve certification. It also supports the top-down approach by saying, “Higher level requirements lead to lower level requirements.” The point of this paper is that the methods used to identify those requirements must be more rigorous than before.

The Certification Approach

To realize their maximum potential, RLVs will need to function with the confines on an international regulatory framework and an established airworthiness code. Boeing believes that early second-generation RLVs will become catalysts for the certification of RLV-specific flightworthiness standards, and will validate these unique certification requirements through revenue-generation, operational flight-testing. The evolution of certified, commercial RLV operations within an international law and regulatory framework is depicted in Figure 3.

It is imperative to begin planning for the certification of advanced second-generation RLVs and beyond, well before theses systems are built and tested. First, such planning will initiate the process of removing a major source of marketing and financial risk from the development of these vehicles. Secondly, it will enable the industry to work with government regulators and speed the process of certification. Finally, it will allow the legal and regulatory process to interact with the design and manufacturing process of the vehicle. This interaction will, in turn, influence the final design and operational characteristics of the system – directly affecting the indemnification rates and, ultimately, the business case for the RLV enterprise.

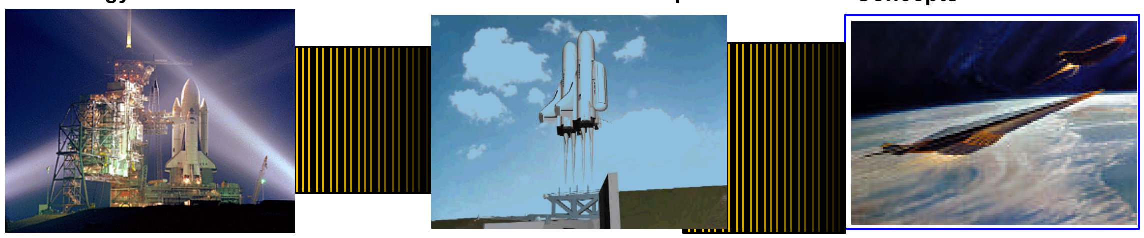
So then the question is what is the approach for establishing the rules of certification for an RLV? The present FARs consist of hundreds of such rules based on known failure modes and critical functions. The present approach builds on the history of rule making and at the same time accounts for the potential failure modes associated with the RLV. This approach consists of the following four steps:

Step 1 - Build on Present Failure Modes and Rules. Much can be learned from present failure modes and rules. It is not proposed that any present rules be adopted as-is without examination. This approach would be high risk. It is proposed, however, that the present rules be used as a point of departure for new RLV rules. It is proposed that each one of the present rules be examined in the light of the new mission and new environment, and that a new rule should be formulated to reflect the RLV operation.

As an example, 14 CFR 25.609 calls for adequate structure to survive all “weather conditions.” In the RLV case this rule would be modified to reflect the RLV environment including such effects as solar radiation and micrometeorites.

Figure 3. Evolving Commercial RLV Operations Within An International Law and Regulatory Framework

1st Generation Space Shuttle Technology | **2nd Generation Concepts** | **Future 3rd Generation Concepts**



- **Validation of Flightworthiness Criteria**
- **Time-Age-Cycle Data Collected From Operational Flights**

• Current Practice (Satisfies Space Law)
– Licensing on a Flight-by-Flight Basis
– Operations Limited to Coastal Launch Site With a Range
– No Overflight of Population Centers

• Needed Government Action
– Policy, Regulatory & Technology Transfer Guidance
– Liability Standards & Indemnification Req'ts
– Certification-Related Research & Development

• Future Practice (Satisfies Air Law & Space Law)
– Appropriate Legal Regime
– Like Commercial Aircraft
– Global Operations from Commercial Spaceports with Air Traffic Mgmt Interface
– Overflight of Population Centers

Step 2 - Perform the Top-Down Functional Analysis. The top-down functional analysis described above is designed to identify new and possibly critical functions unique to the RLV. A

vehicle with rocket engines may have functions such as Ignite Deorbit Thrusters which would be absent in commercial aircraft. For each of these functions a design would be created which would assure that these functions are performed in a reliable and adequate fashion.

Step 3 - Perform Exhaustive Analysis of NASA Shuttle Orbiter Data. It is expected that the NASA experience with lifting reentry will yield much data relative to potential failure modes and the associated rules which would come from them.

Step 4 – Validate RLV Flightworthiness Criteria. RLV flightworthiness derived from Steps 1 – 3 should be validated through time-age-cycle

data collected from operational flights (early second-generation systems) and government-sponsored certification research and development activities, before they become standards.

Hence, it is expected that these three steps will yield the most comprehensive set of rules for the certification and development of a successful RLV.

Conclusion

In summary, a commercial RLV program is a viable prospect providing the structure is in place to assure that safety standards required for certification are maintained. Furthermore, a new set of processes is needed to assure that these standards are met.

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Authors

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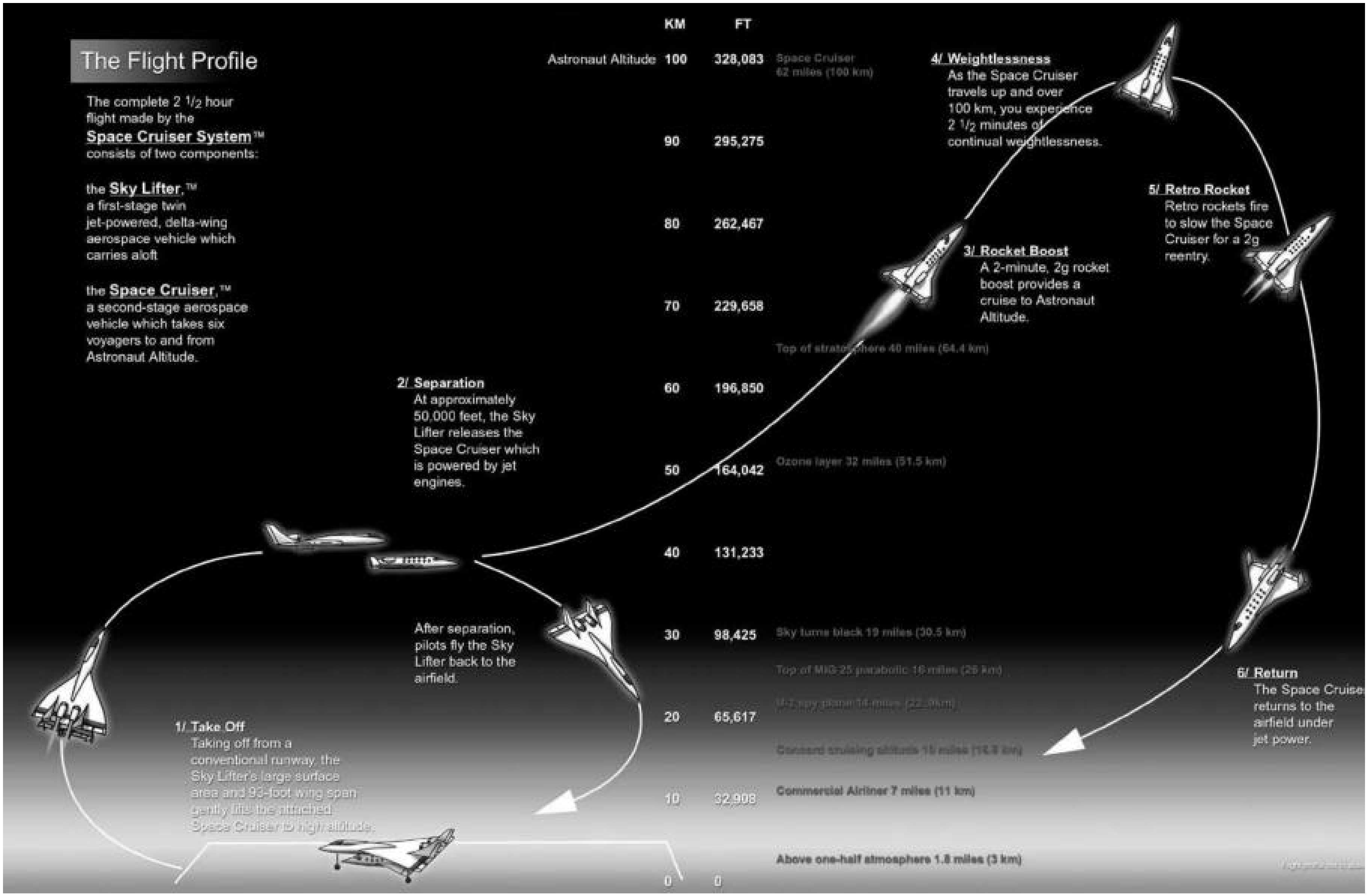
A.10 COMMENTS OF VELA TECHNOLOGY DEVELOPMENT, INC., REUSABLE LAUNCH VEHICLE OPERATIONS AND MAINTENANCE REQUIREMENTS

The following attachment is an illustration of the Space Cruiser flight operations profile. Details not shown in the illustration are as follows:

- Flight time from takeoff to launch point can be up to two hours, if requested by the Adventure Travel Partner.
- Reentry time down to 70,000 feet and subsonic speed is about 2 minutes.
- Windmill or electrical start of jet engines occurs at 35,000 feet.
- Up to 30 minutes supply of jet fuel.


The Flight Profile
The complete 2 1/2 hour flight made by the Space Cruiser System™ consists of two components:
the Sky Lifter,™ a first-stage twin jet-powered, delta-wing aerospace vehicle which carries aloft
the Space Cruiser,™ a second-stage aerospace vehicle which takes six voyagers to and from Astronaut Altitude.
KM
FT
Astronaut Altitude
100 328,083
90 295,275
80 262,467
70 229,658
60 196,850
50 164,042
40 131,233
30 98,425
20 65,617
10 32,908
0 0
Space Cruiser 62 miles (100 km)
Top of stratosphere 40 miles (64.4 km)
Ozone layer 32 miles (51.5 km)
Sky turns black 19 miles (30.5 km)
Top of MIG-25 parabolic 16 miles (26 km)
Commercial Airliner 7 miles (11 km)
Above one-half atmosphere 1.8 miles (3 km)
1/ Take Off
Taking off from a conventional runway, the Sky Lifter's large surface area and 93-foot wing span gently lifts the attached Space Cruiser to high altitude.
2/ Separation
At approximately 50,000 feet, the Sky Lifter releases the Space Cruiser which is powered by jet engines.
After separation, pilots fly the Sky Lifter back to the airfield.
3/ Rocket Boost
A 2-minute, 2g rocket boost provides a cruise to Astronaut Altitude.
4/ Weightlessness
As the Space Cruiser travels up and over 100 km, you experience 2 1/2 minutes of continual weightlessness.
5/ Retro Rocket
Retro rockets fire to slow the Space Cruiser for a 2g reentry.
6/ Return
The Space Cruise returns to the airfield under jet power.