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Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Operations - Volume 2

Final Report

Prepared for
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Federal Aviation Administration
Associate Administrator for Commercial Space Transportation
AST-200 Licensing and Safety Division
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NOTICE

Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Operations - Volume 2

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Executive Summary

Development of commercial Reusable Launch Vehicles (RLVs) remains a great interest to many private companies. The appeal rests in an RLV's ability to support multiple mission types (e.g., cargo and "tourism") and amortized development costs over the life of the operational vehicle. Commercial RLV companies plan to use both existing and new technologies in the design/development of the vehicle. RLV Operations and Maintenance (O&M) practices have the potential to affect public safety; therefore, the FAA's Office of Commercial Space Transportation (FAA/AST) is in the process of developing guidelines for RLV O&M activities. These guidelines may be used in evaluating an RLV developer/operator's license application.

This Guideline Input and Technical Evaluation Report is intended to capture an initial set of Guideline Inputs (GIs) and Guideline Input Considerations (GICs) ordered around the various functions associated with RLV Operations. This volume is the second of five such volumes; the first volume addressed RLV Subsystems and the remaining 3 volumes address RLV Maintenance, Training, and Approval functions.

A total of 10 functions within two operational domains (Ground and Flight Operations) have been identified for development of guideline inputs. Each of these functions relate to one or more specific flight phases and includes sub-functions/tasks ranging from traditional aircraft-like operations, such as the scheduling of resources, to those more often associated with space operations such as performing COLA (Conjunction On Launch Assessment) analysis. The focus and intent of this Delivery Order 4 (DO4) effort has been to capture those tasks with potential public safety risks that should be considered relative to RLV operations. In order to ensure these guidelines have been considered, RTI proposes that a series of manuals be required as part of an RLV developer's final license application: Operations, Maintenance, Training, and Approval. These manuals would speak to the current requirements contained in the RLV Mission License Rule (14 CFR Part 431) and would also allow an RLV developer/operator to specify how they intend to address FAA/AST O&M Guidelines. In this way, the RLV developer/operator has the ability to stipulate which of these guidelines are relevant to their chosen vehicle design and ensures that public safety considerations associated with RLV operational tasks have been fully addressed.

In summary, the Guideline Inputs in this volume, and in the other four Guideline Input volumes, are intended to contribute to a common set of criteria by which the FAA and the industry can assess public safety aspects of RLV O&M processes. As the RLV industry matures, it is expected that additional guidelines will be developed; consequently, these Guideline Input volumes are considered to be living documents that will evolve as the RLV industry evolves.

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1.0 Introduction

Reusable Launch Vehicles (RLVs) will require guidelines and regulatory language to be developed for new approaches in both Operations and Maintenance (O&M). These approaches may have a direct effect on public safety where RLVs are being operated and maintained. This Guideline Input and Technical Evaluation Report is intended to capture an initial set of Guideline Inputs (GIs) and Guideline Input Considerations (GICs) ordered around the various functions associated with RLV Operations. This volume is the second of five such volumes; the first volume addressed RLV Subsystems and the remaining 3 volumes address RLV Maintenance, Training, and Approval Functions. The inputs identified in this volume, and in the other four Guideline Input volumes, are intended to contribute to a common set of criteria by which the FAA and the industry can assess public safety aspects of RLV O&M processes. As the RLV industry matures, it is expected that additional guidelines will be developed. Consequently, these Guideline Input volumes are considered to be living documents that will evolve as the RLV industry evolves.

1.1 Purpose

The purpose of this document is to provide basic Guideline Inputs/Considerations for RLV operations, as well as a top-level introduction of the pertinent RLV operations functions. In this context, "pertinent" operations are considered any activities associated with an RLV's ground and flight operations that have a potential to impact public safety. The functions identified here encompass activities associated with a variety of Concepts of Operations (CONOPS) being proposed by the industry.

1.2 Background

These Guideline Inputs are the result of a focused effort by FAA's Office of Commercial Space Transportation (FAA/AST) to facilitate a common understanding between both the regulator and the industry on what is expected from RLV operators and maintainers in order to ensure public safety. The creation of these Guideline Inputs was prompted by the response to an FAA/AST presentation of an RLV O&M White Paper to the Commercial Space Transportation Advisory Committee (COMSTAC) in October of 1999.

Industry feedback to that paper along with FAA-directed research activities led to the initiation of an information-only Rulemaking Project Record (RPR) intended to establish formal rules for RLV O&M. These Guideline Inputs represent an interim step toward a Notice of Proposed Rulemaking (NPRM) for RLV O&M and are intended to serve as a means by which those items requiring formalization as a rule can be identified and validated both by the FAA and by industry. However, it should be recognized that an NPRM would only be developed after the industry is sufficiently mature.

RTI used the Systems Functions and Procedural Items identified during the DO2 effort[1] as a starting point for DO3. It was determined that a general model was needed to place the Systems Functions and Procedural Items in context. A context diagram, Section 1.5, was developed to provide this contextual framework, as well as provide a way of marrying the O&M top-down analysis, being completed by RTI, with the bottom-up analysis, being accomplished internally within the FAA.

1.2.1 Statement of Understanding

A Statement of Understanding between the FAA and the RTI Team has been developed to govern each of the RLV O&M tasks. The following text presents the Statement of Understanding (SOU) developed for this effort under DO4:

> "The RTI Team will continue to support FAA/AST-100 in the development of RLV O&M guidelines and technical evaluation criteria.
>
> This task will build on the work done in the RLV O&M Top-Down Analyses performed under DO2 and DO3 of the reference contract. In particular, the RTI Team will develop material that will help FAA/AST-100 identify the O&M technical evaluation criteria and performance standards for safety-critical RLV subsystems and functions. In performing the specified work, particular attention will be made to any unique features, including proven and unproven RLV O&M activities, and their correlation to any historic lessons-learned in the Space Shuttle, airline and RLV research community.
>
> The outputs of this research (DO4) and the next research phase are to be presented in five RLV O&M Guideline Inputs and Technical Evaluation Report volumes: Subsystems -Volume 1, Operations - Volume 2, Maintenance - Volume 3, Training - Volume 4, and Approval - Volume 5.
>
> Under DO4, RTI will deliver the first two of these volumes: Subsystems - Volume 1 and Operations - Volume 2. The following list summarizes the specific topics that will be addressed under this DO:
>
> 1. Guideline inputs and rationale:
> The major RLV O&M subsystem and function safety items will be developed into guideline inputs along with the supporting rationale. These will be presented in a format approved by FAA/AST.
> 2. Further refinement of the Subsystem and Functional Decomposition:
> A number of modifications to the current Functional Decomposition diagrams have been identified including the need to add Functions for Contingency Operations, Vehicle Configuration Management, and Simulation Requirements to name just a few. The Functional Decomposition diagrams will be modified to reflect the functional refinements.
> 3. Continued data collection from the aviation and space domains:
> Continue to extract information from traditional aviation, the Space Shuttle, and other RLV programs in support of the guideline and technical evaluation criteria development.
> 4. Continued exploration of Special Topics:
> In previous Delivery Orders, certain topics were identified for further research such as inter/intra-agency coordination, human factors, design dependencies to name a few. These topics will be furthered as time allows in DO4."

1.3 Scope

The following Guideline Inputs are intended for use by the RLV Industry and the FAA's Office of Commercial Space Transportation in the preparation and evaluation of RLV license applications and O&M plans. The scope of these Guideline Inputs is bounded by the jurisdictional authority provided to the FAA by Congress 112 STAT. 2848 (Public Law 105-303-Oct. 28, 1998). Additionally, these Guideline Inputs do not affect or amend the content of the licensing rules, but rather are designed to help the FAA and RLV Industry jointly ensure the rules are both followed and applied in a consistent manner.

1.3.1 Guideline Input Philosophy

These Guideline Inputs have been developed to serve as a repository for best/recommended practices. It is expected that a portion of these practices will ultimately be formalized in a federal regulation that will govern the RLV Industry. Some inputs may have to be revised as newer technologies are developed and better procedures emerge as the industry matures.

A wide variety of sources were reviewed and analyzed to develop the content of these Guideline Inputs. Primary consideration was given to lessons-learned drawn from the aviation and space community. In some cases, these lessons are explicit and are clearly technology-independent public safety issues and thus could be written as a requirement. In these cases, Guideline Inputs (GIs) have been developed and the term "shall" is used. These GIs are numbered sequentially with an Operations prefix (e.g., The first Ground Operations Guideline Input Consideration is for the Conduct General Ground Operations Function and is numbered Conduct Gen Grd Ops GI-1.) It is reasonable to assume that these items will be included in any subsequent rule development governing RLV O&M.

In many cases, however, the lesson or issue being discussed is less clearly defined and sufficient experience or research is not available to validate the lesson or issue. Others are technology dependent and only apply to a narrow set of RLV concepts. For these cases, Guideline Input Considerations (GICs) have been developed and the term "should" is used. These GICs are numbered sequentially with an Operation Function prefix (e.g., the first Ground Operations Guideline Input Consideration is for the Conduct General Ground Operations Function and is numbered Conduct Gen Grd Ops GIC-1.) While these are candidates for inclusion in any subsequent rulemaking, it is reasonable to assume that further work may be needed before such a rule is promulgated.

Please note that there are many other safety issues that an RLV operator needs to consider for the safety of operators and technicians; FAA/AST is currently charged with only public safety concerns. Further, no delineation of when and how rules would be applied was made in these considerations. Some of these guidelines may be considered during the licensing stage while others may be considered as repeated launches are executed for the same vehicle under the launch license.

Within the following sections, Occupational Safety and Health Administration (OSHA) appears in many of the Inter/Intra Agency Issues subsections. Although OSHA is concerned with worker, the authors of this document are of the opinion that jurisdictional issues need to be addressed for cases where a worker safety situation escalates into a public safety concern.

1.3.2 Suggestion Form

It should be noted that these Guideline Inputs are expected to evolve as the industry matures and additional data becomes available, either from research or through actual flight activity. The reader is encouraged to share their experiences and knowledge through use of the Suggestion Form in Appendix B: RLV Guideline Input Suggestion Form. It is the FAA's intent to periodically review these Guideline Inputs to ensure they are current, particularly with respect to issues that are technology dependent.

1.4 Relationship to RLV Licensing

The impetus for this effort was to provide a common set of criteria related to O&M that could be used by FAA/AST to evaluate RLV developer/operator license applications. The Guideline Inputs and the related Guideline Input Considerations contained in this volume are focused on operations with particular emphasis placed on issues unique to the function being addressed and could pose a risk to the public if not followed. RLV developer/operators are expected to explain how each of these Guidelines is satisfied for their particular vehicle design.

In DO2, the RTI team proposed a formal set of readiness reviews, one for operations and one for maintenance. In addition, the concept of Instructions for Continued Flight-worthiness (ICF) and an Operations or Flight Manual was introduced. The reviews were intended to be focused activities within the context of the overall mission readiness review required by the RLV licensing rule. The Operations Manual was designed to lend form to the mission operational requirements while the ICF filled a gap in the current licensing description by addressing those considerations for turnaround of an RLV and preparation for subsequent flights. Since its introduction, the FAA has adopted the term Maintenance Program Plan in place of ICF.

The RTI Team believes that to further clarify the licensing rule and to better align with the proposed guideline structure, two additional data items should be provided to AST by the RLV developer/operator for review. These two items are a Training Manual and an Approval Manual. Note that this data can easily be packaged as part of the Maintenance Program Plan and Operations Manual, if the license applicant so chooses, provided that the data is clearly identified. The four documents, taken together, will allow individual RLV developer/operators to address the Guideline Inputs and Considerations contained in this volume and the three other functional volumes along with the subsystem volume for their specific vehicle. At the same time, the use of a common set of Guidelines will help FAA/AST evaluate the appropriateness and completeness of the provided data in a uniform manner.

1.5 Subsystem and Functional Context

Functional Guideline Inputs have been developed for those activities associated with operations and maintenance, as well as the related areas of training and approval. Figure 1 illustrates how these relate to one another and where they fit in the broader scope of RLV licensing, approvals, and RLV development. It should be noted this effort considers only the items to the right of the vertical line in Figure 1. This is highlighted in Figure 2.

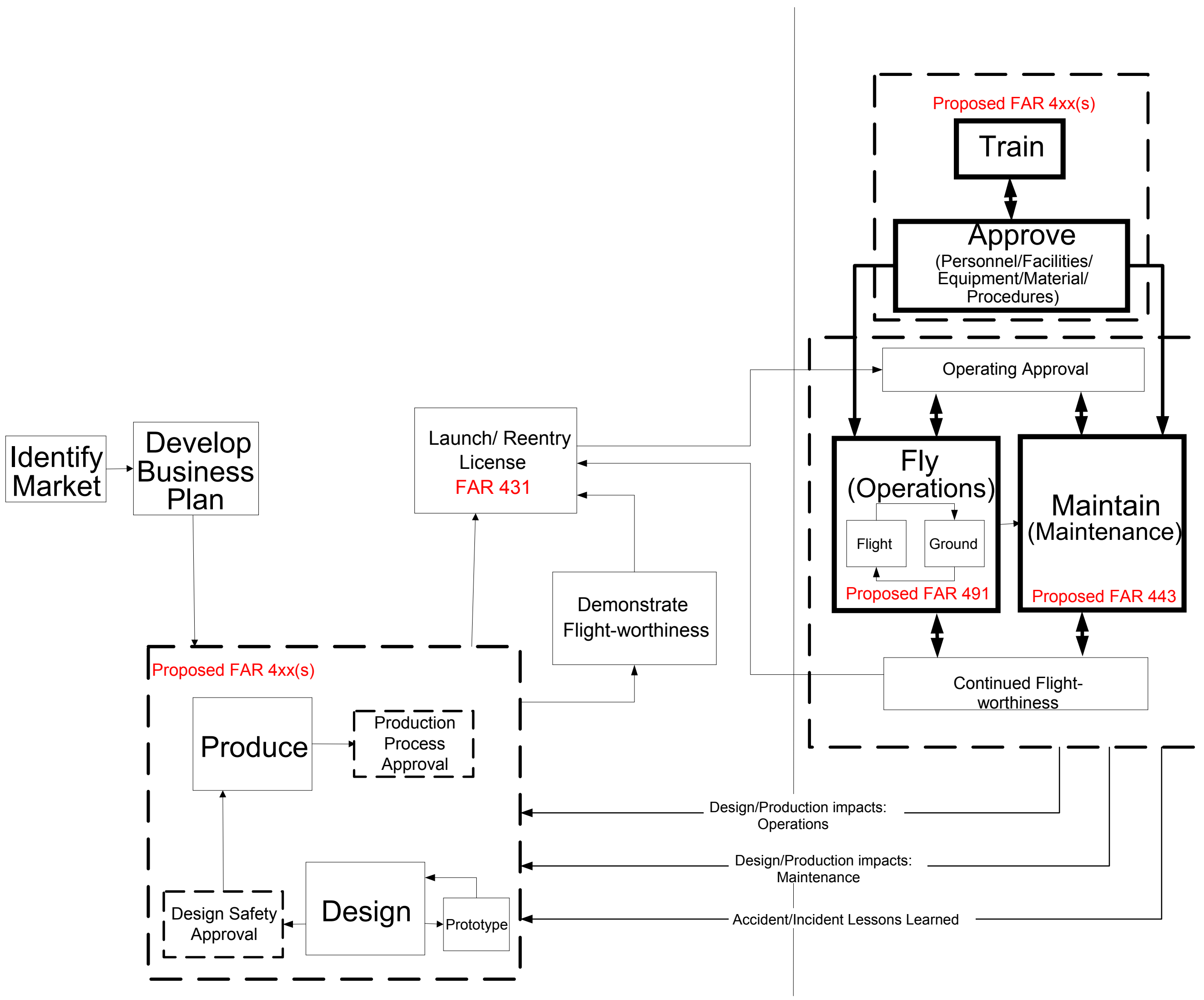

Figure 1 RLV Context Diagram

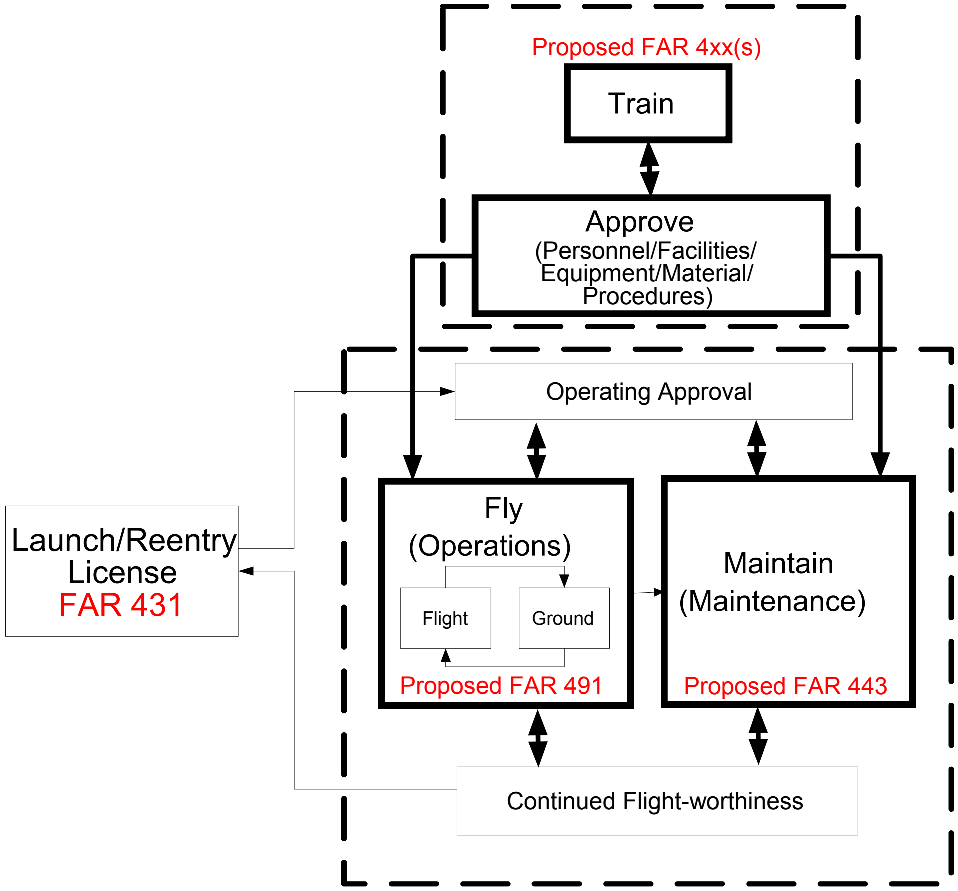

Figure 2 RLV O&M Context

It should also be noted that this top-down analysis is being supplemented by a bottom-up analysis effort being conducted by the FAA. The two efforts taken together are intended to serve as the basis for guidance development in the area of RLV O&M, see Figure 3.

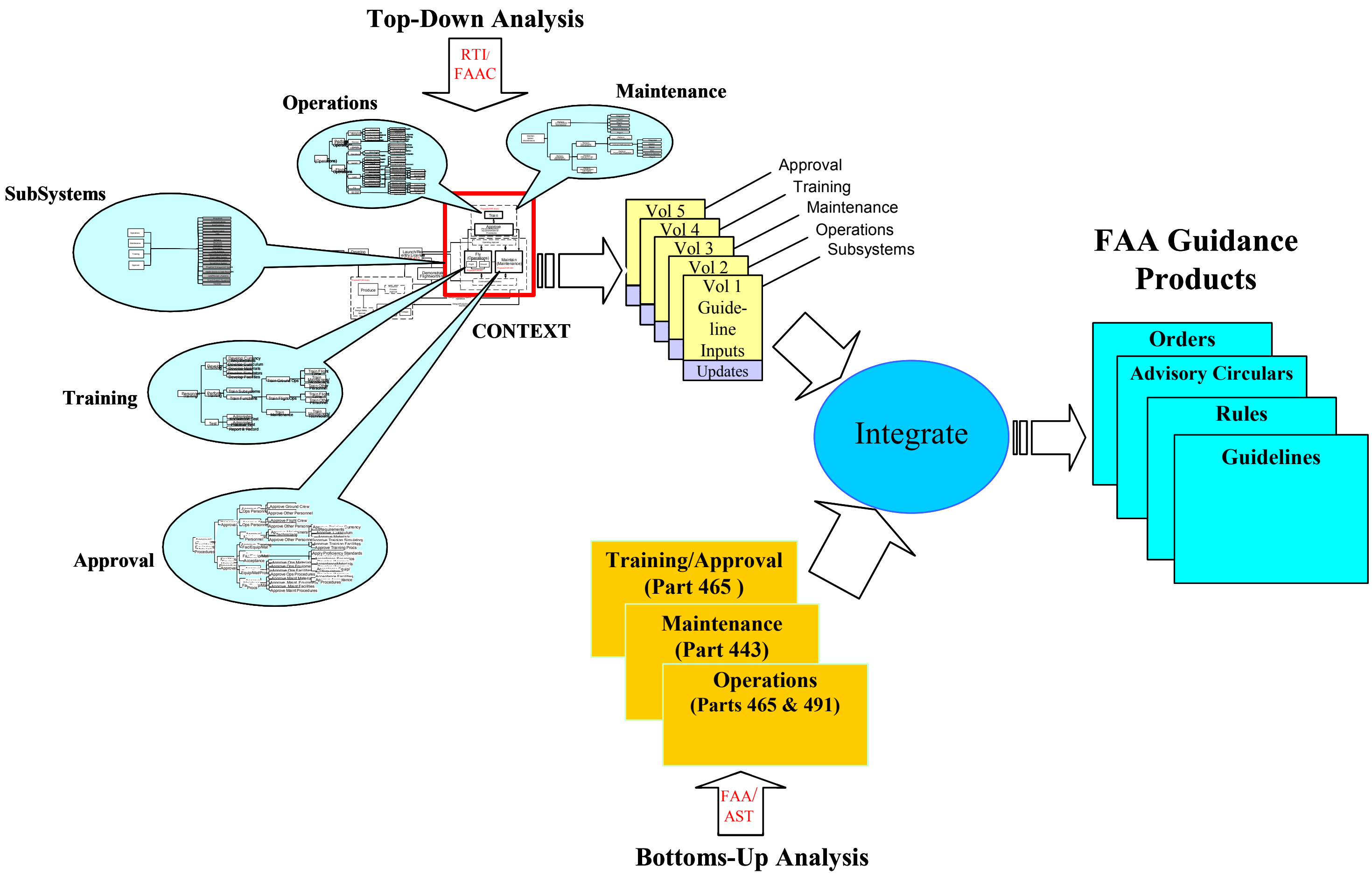

Figure 3 Guidance Document Process

As shown in Figure 3, the ultimate product of this activity is expected to be one or more guidance documents from the FAA. The FAA has realized that given the current level of maturity within the commercial RLV industry, the best approach to take in the near-term is the production of guidelines that can be employed by both the FAA and industry to evaluate proposed RLV's O&M activities on public safety. With this in mind, the top-down analysis has been organized around a 'divide and conquer' approach where individual subsystems and functions are examined for their potential contribution to public safety.

The following sections describe each top-level function and major sub-functions; provides definitions for each function and sub-functions; and provides a brief treatment of the major public-safety considerations for each function. It should be noted that the functions depicted and discussed are presented in terms of requiring an action, hence the term function. This is in contrast to the subsystems that are addressed in Volume 1 which are hardware related.

2.0 Operations Decomposition

Figure 4 provides the functional decomposition for RLV Operations as developed in DO4. Operations is divided into the Ground Operations and Flight Operations Domains that are subsequently divided into a number of functions, the majority of which relate to one or more specific flight phase. These functions include necessary RLV operation tasks leading to and including launch, orbit/sub-orbit, and return.

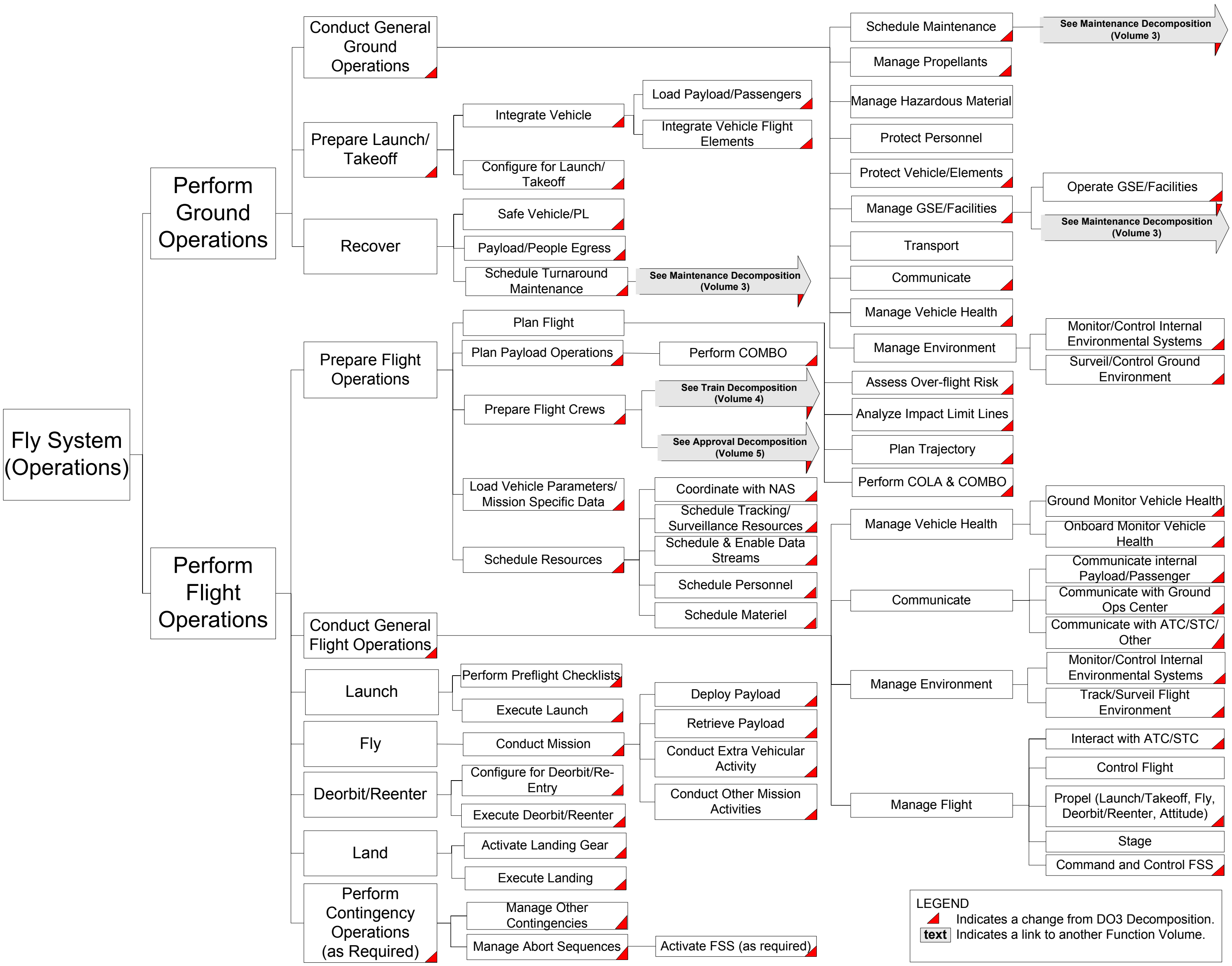

Figure 4 Operations Functional Decomposition

The results of CFR reviews, as well as the initial data collected during the DO2, DO3, and DO4 efforts, were used as a starting point for deriving these functions. RTI then collected and analyzed several references to further characterize

Operations. DO3 presented the first functional decomposition of RLV Operations Functions. These have been further analyzed and refined here in DO4. While many functions remain the same between DO3 and DO4, there are several new sub-functions and reorganizations. See Appendix C: Traceability of Operations Function Decomposition for function and sub-function traceability from the DO3 Operations Decomposition to the DO4 Operations Decomposition as reflected in Figure 4.

Definitions of Operations Functions have been drawn from already existing FAA rules where available. Where no FAA definition exists, definitions have been pulled from industry documentation with preference given to NASA and DoD publications. In some cases, standard definitions drawn from Webster's New Unabridged Twentieth Century Dictionary, 2nd edition have been used.

Section 1.0 presents Guideline Inputs for general topics covering the Operations Function. Section 4.0 and subsequent of this report provide a detailed treatment of Ground and Flight Operations Guideline Input Considerations (GICs), and Guideline Inputs (GIs).

3.0 General Operations Guideline Input

The following are Guideline Inputs (GIs) that were developed to reflect those tasks or procedures that are general in nature and apply to RLV Operations at an operational architecture level.

General Ops GI - 1. RLV Operator Concept of Operations
Guideline Input RLV operators shall develop a Concept of Operations (CONOPS) document for each vehicle type.
Rationale RLV design concepts are widely different. To account for these differences, each RLV operator must provide a document that describes the operator's intent and/or assumptions in regard to the overall RLV operation. While the CONOPS will typically be put into practice through procedural manuals developed by the RLV operator (e.g., the Operations Manual), the CONOPS will be used for additional clarity of purpose. Specifically, it will highlight to the FAA general assumptions/intent that may affect public safety; and, in a global sense, it will provide FAA the necessary insight into the following items of interest: 1. How the RLV operations will be integrated into the National Airspace System. 2. How the RLV operations will integrate into the launch/takeoff site. 3. What inter/intra agency (both local and federal) coordination that will be required. 4. General safety and environmental hazard potentials.

General Ops GI - 2. Operations Manual

Guideline Input

RLV operators shall develop and operate the RLV in compliance with the vehicle's Operations Manual.

Rationale

Since many RLV concepts include ground-breaking/novel technologies, there is minimal commonality amongst the concepts and their commensurate operational procedures. This lack of commonality thwarts the development of common technology-specific approval/certification guidelines; therefore, each RLV operator shall provide an Operations Manual for consideration by the approval authorities (FAA/AST).

This manual will provide the operating characteristics and limitations associated with the RLV across all possible configurations. Additionally, the Operations Manual will contain the nominal and off-nominal operational procedures for the FAA-approved RLV design.

Minimally, the following items should be included in the Operations Manual:

1. List of safety critical RLV sub-systems and GSE/Facilities
2. Ground and flight operational procedures
3. Propellant types and storage requirements
4. Hazardous material types and handling procedures
5. Engine/motor ignition/operation sequence of events
6. Checklists for normal and contingency operations
7. Communications plan

General Ops GI - 3. Statement of Compliance

Guideline Input

RLV operators shall attest on a Statement of Compliance for each RLV that it will be operated in accordance with the FAA-approved Operations Manual for that vehicle design.

Rationale

Since RLV designs are markedly different, new, and novel; there is minimal commonality that can lead to technology specific approval guidelines. The referenced Operations Manual will contain the FAA-approved operating procedures and vehicle-unique limitations. The RLV operator must operate the vehicle in compliance with the Operations Manual to ensure safe operations during ground and flight.

General Ops GI - 4. Nonstandard Operational Procedures

Guideline Input

If operational methods, tools or techniques to be used are other than what is specified in the Operations Manual, the RLV operator shall perform, and submit to FAA, a safety assessment that demonstrates that the deviation will not pose additional risk to public safety.

Rationale

Since RLV designs are new and novel, it is expected that operational procedures will evolve over time. Rather than requiring a complete resubmission of the Operations Manual, the FAA may approve changes to the Operations Manual in a structured, configuration-control-like method.

4.0 Perform Ground Operations

The Perform Ground Operations Domain is divided into three major functions: Conduct General Ground Operations, Prepare Launch/Takeoff, and Recover the RLV after a flight. Ground operations include all hardware processing activities on the ground associated with preparing the RLV for flight and recovering the vehicle/cargo/people post-flight.

The following sections provide a general discussion, Guideline Input Considerations (GICs), and Guideline Inputs (GIs) for each top-level Ground Operations Function and its major sub-functions Figure 5.

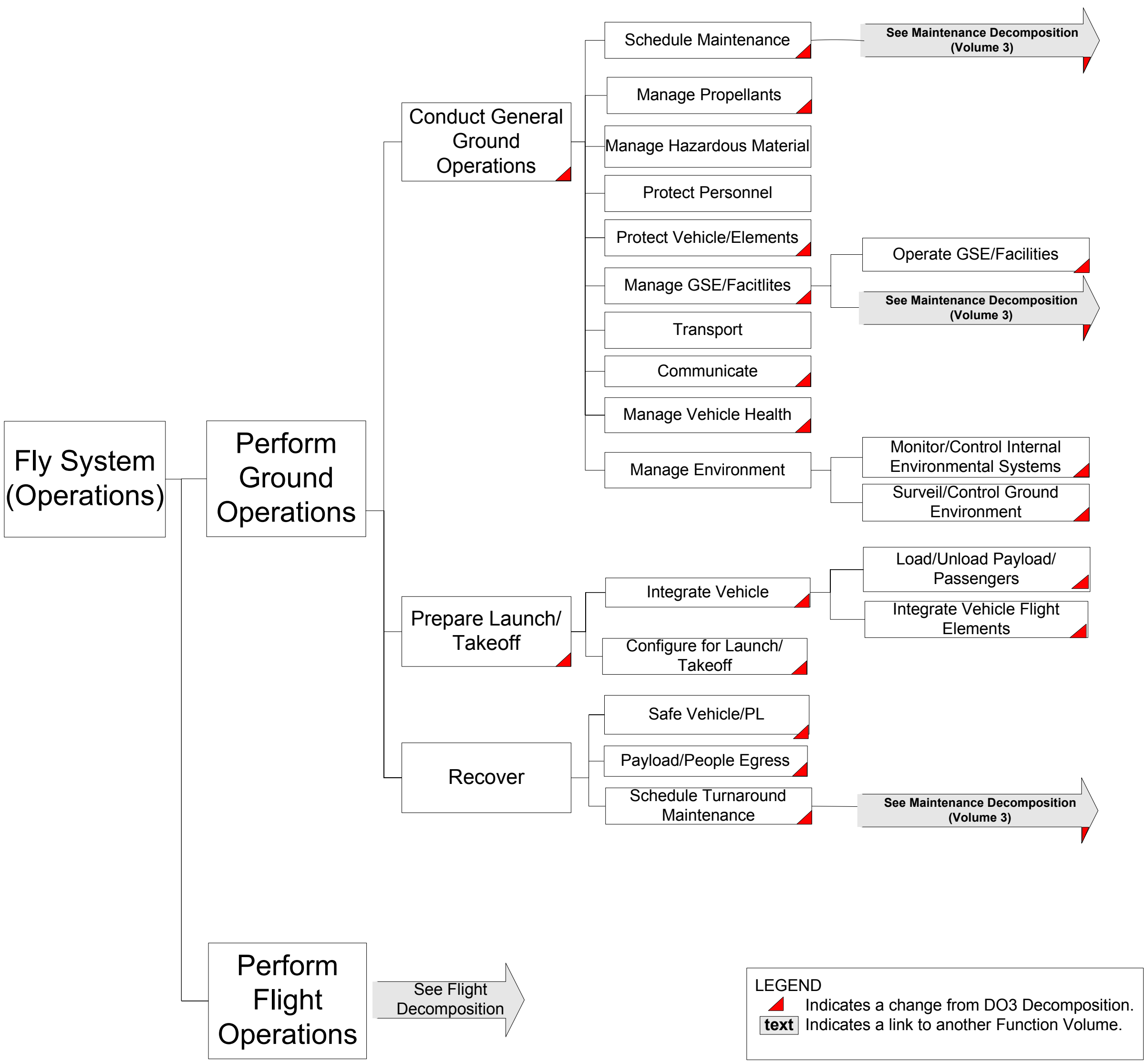

Figure 5 Ground Operations Decomposition

4.1 Conduct General Ground Operations

The Conduct General Ground Operations Function consists of those tasks, procedures, and sub-functions common to all ground operations of the Prepare Launch/Takeoff and Recover Functions. The RLV operator and/or the launch/takeoff site operator will typically conduct these tasks. The sub-functions graphically displayed in Figure 5 are defined in Table 1 below.

Table 1 Conduct General Ground Operations Definitions

<table>
<tr><td rowspan="2">Schedule Maintenance</td><td colspan="2">[Operations → Conduct General Ground Operations → Schedule Maintenance]</td></tr>
<tr><td colspan="2">The Schedule Maintenance Sub-function consists of the scheduling of repair-type maintenance on the vehicle during ground operations, but is not the actual maintenance. Note: this sub-function links to and references the Maintenance Functional Decomposition Diagram found in Volume 3-Maintenance.</td></tr>
<tr><td rowspan="2">Manage Propellants</td><td colspan="2">[Operations → Conduct General Ground Operations → Manage Propellants]</td></tr>
<tr><td colspan="2">During ground operations, the Manage Propellants Sub-function includes all aspects of storage, loading, and unloading of the propellants in a safe manner.</td></tr>
<tr><td rowspan="2">Manage Hazardous Material</td><td colspan="2">[Operations → Conduct General Ground Operations → Manage Hazardous Material)</td></tr>
<tr><td colspan="2">The Manage Hazardous Material Sub-function includes the procedures and tasks necessary for the safe storage, use, and loading/unloading of all hazardous material, other than propellants.</td></tr>
<tr><td rowspan="2">Protect Personnel</td><td colspan="2">[Operations → Conduct General Ground Operations → Protect Personnel]</td></tr>
<tr><td colspan="2">The Protect Personnel Sub-function includes those procedures and tasks necessary to ensure the safety of ground operations personnel, the crew and the passengers during ground preparation of an RLV. Potential risks include physical, chemical, and nuclear hazards.</td></tr>
<tr><td rowspan="2">Protect Vehicle/Elements</td><td colspan="2">[Operations → Conduct General Ground Operations→ Protect Vehicle/Elements]</td></tr>
<tr><td colspan="2">The Protect Vehicle/Elements Sub-function includes the procedures, and tasks necessary to ensure the RLV is protected from illegitimate treatment (e.g., terrorist attacks).</td></tr>
<tr><td rowspan="6">Manage GSE/Facilities</td><td colspan="2">[Operations → Conduct General Ground Operations→ Manage GSE/Facilities]</td></tr>
<tr><td colspan="2">The Manage Ground Support Equipment (GSE)/Facilities Sub-function includes the tasks performed to ensure that the GSE/Facilities are available when needed and meet operational requirements. This sub-function provides for the safe operation of and scheduling of needed repairs for the GSE/facilities.</td></tr>
<tr><td rowspan="2">Operate GSE/Facilities</td><td>[Operations → Conduct General Ground Operations→ Manage GSE/Facilities →Operate GSE/Facilities]</td></tr>
<tr><td>The Operate GSE/Facilities Sub-function includes the tasks and procedures for the safe operation of RLV equipment/facilities on the ground.</td></tr>
<tr><td rowspan="2">Maintenance Functional Decomposition Diagram</td><td>[Operations → Conduct General Ground Operations → Operate GSE/Facilities→ Maintenance Functional Decomposition Diagram]</td></tr>
<tr><td>This sub-function is a pointer to the maintenance functional decomposition diagram. This diagram depicts those functions associated with performing both scheduled and un-scheduled maintenance on GSE and facilities. See Volume 3- Maintenance of this series of documents.</td></tr>
</table>

Transport	[Operations → Conduct General Ground Operations→ Transport]	
	The Transport Sub-function is the movement of the RLV itself and any associated equipment, materials, cargo, or crew to/from the integration facility, launch site, landing site, servicing site, or egress facility.	
Communicate	[Operations → Conduct General Ground Operations→ Communicate]	
	The Communicate Sub-function is the exchange of data/information between RLV operations & maintenance entities, the transfer of information from/to the RLV itself during ground operations.	
Manage Vehicle Health	[Operations → Conduct General Ground Operations→ Manage Vehicle Health]	
	The Manage Vehicle Health Sub-function consists of verifying and controlling the operational status of all critical RLV systems.	
Manage Environment	[Operations → Conduct General Ground Operations→ Manage Environment]	
	The Manage Environment Sub-function addresses all aspects associated with monitoring and controlling the environment both on-board and off-board the RLV during ground operations.	
	Monitor/Control Internal Environmental Systems	[Operations → Conduct General Ground Operations→ Manage Environment→ Monitor/Control Internal Environmental Systems]
		The Monitor/Control Internal Environmental Systems Sub-function includes the procedures and tasks necessary to ensure the environmental systems on-board the RLV are functioning and have adequate consumables/non-consumables.
	Surveil/Control Ground Environment	[Operations → Conduct General Ground Operations→ Manage Environment→ Surveil/Control Ground Environment]
		The Surveil/Control Ground Environment Sub-function consists of the tasks and procedures used to monitor the RLV and its external environment during ground operations.

4.1.1 General Discussion

The tasks, procedures, and sub-functions associated with general ground operations are further explained in this section.

Schedule Maintenance

The Schedule Maintenance Sub-function is the set of tasks and procedures that are required to ensure that an out-of-spec safety-critical component or subsystem of the RLV are scheduled to be repaired prior to RLV integration/flight. While RLV maintenance is not an Operations Function, this sub-function ensures scheduling of repair actions during ground operations.

Manage Propellants

The Manage Propellants Sub-function addresses the operational procedures necessary to ensure RLV propellants (solids and liquids) are stored in a safe manner and monitored for compliance to operational specifications. Safety issues associated with the storage of propellants are defined by the type of propellant and are mitigated by the implementation of various federally mandated risk mitigation techniques/standards (e.g., Quantity Distance (Q-D) requirements and storage compatibility requirements).

This sub-function also provides for the safe transfer of liquid propellants between propellant storage tanks and the RLV (Note: solid motor propellant loading is performed during the manufacture of the solid motor element and is not considered part of this sub-function). When a fueling operation is ongoing, multiple regulations, standards, and operational procedures must be complied with to ensure a safe process (safe for the operations personnel, the public, and the environment).

This sub-function utilizes the Propellant Management, Ground Support Equipment (GSE), and the Facilities Subsystems. A key safety issue associated with this sub-function is the detection of leaks in these subsystems. Considerable effort has been put into developing techniques, tools, and strategies for identifying leaks in propellant feed systems; however, there is significant work that still needs to be done. For example, in 1999 the Linear Aerospike SR-71 Experiment (LASRE) was cancelled "because leak detection techniques were unable to verify that oxygen levels could be maintained below flammability limits."[2] This is not simply a hardware issue; but also an operational procedures issue associated with this sub-function.

Manage Hazardous Material

Hazardous material is generally defined as a substance or material in a quantity or form that may pose an unreasonable risk to health and safety, or property. 14 CFR Part 401.5 defines hazardous materials as those identified in 49 CFR 172.101.

In addition to the general handling of hazardous materials, this sub-function includes the removal, remediation, and disposal of hazardous materials, soils, debris, waste, etc., using personnel and equipment in such a way that will minimize endangerment to health, life, or property.

For working conditions and protective gear, OSHA guidelines are applicable for all human handlers; EPA rules will address environmental issues; and HAZMAT rules govern transport of these materials. The National Fire Protection Association (NFPA) diamond is commonly used to communicate general hazard contents. These NFPA diamonds are commonly located inside the main entrance of buildings to inform occupants; on the outside of the main entrance door to inform emergency response workers; at the perimeter fence entrance to inform the general public, and on hazardous products themselves.

Protect Personnel

Ensuring the safety of ground operations personnel, the crew, and passengers during ground preparation of the RLV starts with the identification of hazardous/potentially-hazardous operations, followed by the appropriate procedure development and use of protective equipment. This sub-function includes the operation of personnel protection equipment (e.g., goggles, ear protectors, Self-Contained Atmospheric Protective Ensemble (SCAPE) suits), and the execution of procedures designed to mitigate risk during ground operations.

Protect Vehicle/Elements

The need to ensure the security of the RLV and its flight elements is two-fold. First, there is the general need for the operator to protect its assets. This clearly is not a public safety issue. However, the second need is attached to Homeland Security. Through intelligence data, the launch industry (in particular the Space Shuttle) was identified as an Al Qaeda target.[3] This information, and the events of attacks on the United States that occurred on September 11, 2001, emphasize our nation's airports and launch sites as high-profile targets.

A recent 5-page Homeland Security Department internal advisory memo recommended that aviation security officials increase security beyond existing security directives and emergency amendments issued by the Transportation Security Administration. Existing directives focus on the passenger side of the airport, where pre-gate security screening is done. Specifically, the memo advised officials to tighten ramp security, where the catering, cleaning, fueling, and maintenance of aircraft take place. "Secure unattended aircraft to prevent unauthorized use," the memo recommends as one of several additional protective measures.[4] In addition to the concern for "unauthorized use" of an RLV, the "explosive potential" of an RLV may be of even greater concern to public safety.

Manage GSE/Facilities

Many of the circumstances under which RLV ground personnel will be operating GSE/facilities will involve hazardous procedures (e.g., fueling the RLV and/or the payload). Thus, awareness of RLV GSE/Facilities operational status has public safety implications. Monitoring GSE/Facility health is a means of verifying the operational status. This will enable ground support personnel to detect functional failures/degraded performance and determine the impact of a failure on the safety of ground support operations. Additionally, ground support personnel will be able to identify the need to schedule maintenance and repair actions for GSE and facilities.

The safe operation of GSE/Facilities also includes the checkout of all tools/devices/facilities prior to use and GSE/facilities security procedures. The Concept of Operations and the Operations Manual should identify the procedures that will be used to ensure that the operational capabilities of RLV GSE and facilities have not been compromised. Chapters five and six of the Eastern and Western Range Regulation 127-1 provide insight into the requirements and procedures employed at the Eastern and Western range to ensure the safe operations of GSE/facilities[5].

Transport
This sub-function involves the movement of the integrated RLV, individual flight elements, cargo, crew/passengers, propellants, and all other materials. The RLV may be able to move on its own ability such as an aircraft does when taxiing around the airport or it may require piggyback transportation such as on an aircraft or ground crawler.

Transport is multi-modal (i.e. land, sea, or air). The Department Of Transportation (DOT) regulates and inspects the movement of hazardous materials along any of these transportation routes. For example, the DOT Federal Railroad Administration (DOT/FRA) inspects the following: piping, valves, and fittings; enclosures/protective housings; pressure relief devices; and safety systems for any hazardous material shipments. DOT also regulates proximity and isolation measures between chemicals that may react to produce hazardous materials if they are transported together.

Communicate
In order to operate the equipment and facilities associated with RLV ground processing, support personnel must be provided information in a timely manner, while working in a variety of environments (e.g., loud or under varying weather conditions). This communication may be autonomous, automated and/or human initiated, and it may be in the form of voice, data, or imagery. This sub-function addresses the procedures used to query/assess/provide information to or from a data repository/archive and between ground operations personnel.

Manage Vehicle Health
The purpose of managing the health of the RLV during ground operations focuses on the detection and mitigation of RLV functional failures and degraded performance that may affect public safety during ground operations or later in flight. To detect functional failures or degraded performance, parameters indicating the status of various RLV systems must be monitored (e.g., voltages, pressures, temperatures, etc.). This data is then used to identify specific maintenance/repair activities that need to be scheduled during the ground-processing phase and/or to modify the ground processing sequence. This data may also be used to establish trend/history information on the vehicle’s systems to aid in future troubleshooting or for modification to ground operational procedures. Patterns in this trend/history data may also result in updating scheduled maintenance intervals, as well as equipment to be serviced during these intervals.

Manage Environment
This sub-function includes the monitoring and control of RLV internal environmental systems; ground operations safety zones (e.g., Quantity-Distance (Q-D) explosive separation); RLV personnel and payload security; and vehicle traffic proximity to the RLV in flight.

The internal environment, referenced in this sub-function, is constrained to the necessary environment for people and/or equipment/payload on-board an RLV. The "necessary" environment includes atmospheric conditions, life support, and shielding from hazardous environments. Atmospheric conditions to monitor and control include temperature, pressure, and composition (e.g., humidity, and O_2/CO_2 levels). Life support includes a supply of breathable air; the provision and treatment of water, and other consumables; as well as waste management. Hazardous environments to shield from include both natural (e.g., lightening protection) and induced (e.g., contamination) during ground operations.

To surveil and control the ground environment external to the RLV during ground operations is the detection, tracking, characterization, and control of the RLV, other vehicles, people, and weather phenomena for the purpose of conducting ground operations in a safe and secure manner. Surveillance may be accomplished by visual, aural, electronic, and photographic, or other means. The control task includes both the monitoring and enforcement of safety zones; personnel and equipment security procedures; and ground traffic proximity requirements.

4.1.2 Guideline Input Considerations

The following Guideline Input Considerations (GICs) have been identified for the Conduct General Ground Operations Sub-function:

General

Conduct Gen Grd Ops GIC - 1. Hazardous lifting operations should be conducted without risk to public safety.

Conduct Gen Grd Ops GIC - 2. General OSHA requirements relative to the operation of GSE should be followed.

Conduct Gen Grd Ops GIC - 3. Equipment and facility management programs should ensure calibration, security, and environmental controls are maintained.

Conduct Gen Grd Ops GIC - 4. Scheduled maintenance should ensure the RLV is returned to flight-worthiness condition and critical safety components are fully mission capable.

Conduct Gen Grd Ops GIC - 5. Inventories of hazardous material should be conducted at least annually and conditions of materials in storage assessed at least monthly, and those determined to be unsuitable for use should be removed from active inventory and disposed of per HAZMAT and EPA requirements.

Conduct Gen Grd Ops GIC - 6. Contamination control of the vehicle should be conducted during processing, transport and at the launch point.

Schedule Maintenance

Conduct Gen Grd Ops GIC - 7. If repair/maintenance items occur more frequently than allowed for in the routine maintenance schedule, then routine maintenance checks for these failing items should be added.

Conduct Gen Grd Ops GIC - 8. Any maintenance activity must be compared with the flight-worthiness status requirements of the RLV and, if necessary, an out-of-service notification should be disseminated.

Manage Propellants

Conduct Gen Grd Ops GIC - 9. Connection of the propellant lines should be performed to produce no leaks.

Conduct Gen Grd Ops GIC - 10. Rigorous leak checks should be incorporated in the operational procedures associated with this sub-function.

Conduct Gen Grd Ops GIC - 11. During vehicle fueling, engine propellant line valves should be closed to mitigate leaks, spillage, or mixing of propellants.

Conduct Gen Grd Ops GIC - 12. Ground storage of propellants should be conducted per Parts 420.65-420.69 of 14 CFR, Chapter III.

Conduct Gen Grd Ops GIC - 13. During hazardous hypergol propellant operations, RLV operations personnel should wear a Propellant Handlers Ensemble (PHE) similar to that used at KSC and Vandenberg Air Force Base (VAFB)[6] to protect personnel.

Conduct Gen Grd Ops GIC - 14. Propellant storage risk should be mitigated by the implementation of Quantity Distance (Q-D) requirements based upon federal regulations.

Manage Hazardous Material

Conduct Gen Grd Ops GIC - 15. RLV operators should have a Material Safety Data Sheet (MSDS) for each hazardous chemical used. The MSDS is a detailed information bulletin that describes the physical and chemical properties, health hazards, routes of exposure, precautions for safe handling, first-aid procedures, and emergency control measures associated with the material.

Conduct Gen Grd Ops GIC - 16. Storage, use, and disposal of hazardous materials should comply with Federal and State regulations and address the requirements for release prevention, countermeasures, and contingency planning.

Conduct Gen Grd Ops GIC - 17. The RLV operator should document the approved safe distance (e.g., Q-D) required for any hazardous materials used during ground processing of the RLV.

Conduct Gen Grd Ops GIC - 18. Inventories of hazardous material should be conducted at least annually and conditions of materials in storage assessed at least monthly. Those materials determined to be unsuitable for use should be removed from the active inventory and disposed per appropriate federal and state regulations.

Conduct Gen Grd Ops GIC - 19. Procedures for hazardous material handling should be addressed as part of the operational readiness review and should be of sufficient detail to ensure public safety is maintained.

Protect Personnel

Conduct Gen Grd Ops GIC - 20. An RLV operator should mitigate emergency conditions that may result in the:

1. Inability to detect and control contamination of life support consumables.
2. Lack of life support consumables or lack of ability to supply these consumables (e.g., lack of breathable air, or availability of fluids).
3. Inability to detect a malfunctioning or inoperative fire protection or explosion suppressant system.
4. Inability to mitigate exposure to toxic materials or flammables.
5. Inability to mitigate exposure to radiation.
6. Inability to maintain controlled pressurization.
7. Inability to maintain controlled temperature.
8. Inability to supply independent emergency life-support for the crew in case of loss of life support for the rest of the vehicle.

Protect Vehicle/Elements

Conduct Gen Grd Ops GIC - 21. The RLV operator should ensure the security of the RLV and its components, including protection against unintended commands.

Operate GSE/Facilities

Conduct Gen Grd Ops GIC - 22. An indication of a malfunction during hazardous processing may include a reduction in the quality of air in a facility; therefore, RLV ground operations personnel should continuously monitor facility air quality parameters during hazardous processing.

Conduct Gen Grd Ops GIC - 23. Fuel storage failure should not place the public at risk.

Conduct Gen Grd Ops GIC - 24. The interface of safety critical systems (including the RLV health management system) with GSE and facilities should be verified and monitored at all times during ground operations.

Conduct Gen Grd Ops GIC - 25. A Failure Modes and Effects Analysis (FMEA) for "as built" GSE should be performed.

Transport

Conduct Gen Grd Ops GIC - 26. Contamination control of the vehicle should be conducted during all transport activities.

Conduct Gen Grd Ops GIC - 27. Any potential chemical or physical (pressure) reactions between the RLV/ components /payload/other materials and transport equipment should be assessed for potential public safety implications.

Communicate

Conduct Gen Grd Ops GIC - 28. The following communications elements should be analyzed for safety implications during ground operations: Data Rates, Latency, Bit Error Rates, Frequency, Bandwidth, and Distance.

Manage Vehicle Health

Conduct Gen Grd Ops GIC - 29. During ground operations any anomalous vehicle health information that affects the flight-worthiness status of the vehicle should be communicated to the FAA. If health monitors/managers fail in disseminating a degrading situation in a timely manner, the safety of the public may be compromised.

Manage Environment

Conduct Gen Grd Ops GIC - 30. Area surveillance should include the detection of people and vehicles in those land or sea areas where normal or malfunction-generated toxic and/or debris hazards may exist as a result of ground operations.

Conduct Gen Grd Ops GIC - 31. Weather surveillance should be conducted in the ground operations area to warn of impending out-of-limit weather conditions (e.g., lightening).

Conduct Gen Grd Ops GIC - 32. The RLV operator should monitor both the internal and external RLV environments for any fire, explosion and environmental hazards.

Conduct Gen Grd Ops GIC - 33. General area surveillance should alert the ground operations personnel of any conditions that may subject flight hardware to out-of-specification environments.

Conduct Gen Grd Ops GIC - 34. A clean operations environment should be maintained to ensure proper operation of RLV subsystems (e.g., contamination of hydraulic systems by water, dust, dirt, fragments of paint, etc., may lead to malfunction, or wire insulation exposed to fluids or conditions may cause electrical fires).

Conduct Gen Grd Ops GIC - 35. Internal RLV environmental monitoring should include:

a. Breathable air
b. Pressure
c. Temperature
d. Water supply for consumption and hygiene
e. Shielding from electro-magnetic energy from space
f. Waste removal
g. Carbon dioxide removal
h. Food
i. Shielding of humans from chemical, biological, or radiation hazards that may be present in payload cargo
j. Vibration requirements
k. Acoustic requirements
l. Gravitational acceleration (within tolerance for humans)
m. Fire Detection, Suppression and Extinction

4.1.2.1 Inter/Intra Agency

The following Conduct General Ground Operations Function inter/intra agency considerations were identified:

1. Handling and transportation of hazardous materials are ruled by DOT Hazardous Material regulations. The process for handling hazardous materials during the Recover function is similar to that accomplished during Conduct Ground Operations. Similar standards such as those from OSHA and DOT should be employed. A key consideration would be to determine if propellant residuals could be re-used or recycled to minimize propellant-waste generation.
2. Venting and disposal of hazardous materials are ruled by EPA regulations. The Environmental Protection Agency addresses disposal of hazardous materials.
3. DOT coordination should occur with appropriate rail, air, and roadway transportation offices for safe practices and regulations associated with the transportation of hazardous materials on public routes.
4. The North American Emergency Response Guidebook provides guidance on handling hazardous materials. It cross-references shipping names, UN numbers (United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labeling of Chemicals) and DOT labels with emergency response procedures. It is available from the U.S. Department of Transportation, Research and Special Programs Administration. Additionally, the Department

of Transportation publishes a Hazardous Materials Table in Section 101 of Part 172, Title 49 of the Code of Federal Regulations.

5. Federal Communication Commission (FCC) coordination should occur for all frequency assignments used in RLV operations, particularly those employed in emergencies.
6. The State Department should be notified for international coordination of tracking and surveillance stations.
7. The Department of Defense Explosive Safety Board (ESB) may provide a source of lessons learned for FAA/AST for conducting RLV safety evaluations, storage of propellants, and chemical agents.[7]
8. National Fire Protection Agency (NFPA) coordination will be required for procedure development to ensure that fire safety and mitigation procedures are in place for launch/takeoff preparations.

4.1.3 Guideline Recommendations

Conduct Gen Grd Ops GI - 1. **Hazardous Materials Handling**
Guideline Input The RLV operator shall develop and use procedures for handling hazardous materials that comply with federal, state, and local regulations and laws.
Rationale Hazard protections associated with the operation of GSE and facilities will comply with local spaceport or spaceport operator directives and specific Federal guidelines such as Occupational Safety and Health Administration (OSHA), Department Of Transportation, and Environmental Protection Agency. These federal guidelines and industry standards should be specified as compliance documents. Additionally, new materials and chemicals that are introduced may not be listed in any of the traditional standards or guidelines. Since these new materials and chemicals may pose a risk to the public and/or generate hazardous waste in the form of air and water pollutants, the RLV operator must show compliance with the intent of federal, state, and local laws, standards, and guidelines.

Conduct Gen Grd Ops GI - 2.	**Monitoring Operability of Safety Critical Systems During Ground Operations**

Guideline Input

The RLV operator shall monitor the operational status of all safety critical systems while performing ground operations.

Rationale

Safety critical systems are those systems previously identified in the Operations Manual that if a malfunction or failure occurs will have immediate affect to public safety. Monitoring these safety critical systems will allow the RLV operator the ability to prevent, troubleshoot, and safely operate these systems. The state/condition data for vehicle systems, GSE, and facilities must be communicated to the appropriate operations centers to ensure the ability to determine the status of the safety critical systems.

Conduct Gen Grd Ops GI - 3. **Personnel Protection During Hazardous Operations**

Guideline Input

The RLV ground operations personnel shall comply with local state, Occupational Safety and Health Administration (OSHA), Department Of Transportation, and Environmental Protection Agency guidelines during the performance of hazardous operations.

Rationale

The requirement to ensure that ground personnel are protected during hazardous operations affects public safety in a two ways:

1. Should one of these individuals be incapacitated during a hazardous operation, their ability to perform contingency procedures during an accident could be compromised.
2. Should they become incapacitated during the performance of a safety critical procedure, they could cause an accident with public safety implications.

Conduct Gen Grd Ops GI - 4. **Ground Operations Hazard Analysis and Mitigation Planning**

Guideline Input

An RLV operator shall perform a hazard analysis and develop appropriate mitigation procedures for those operations that may cause an unacceptable risk to the public.

Rationale

RLV ground operations activities must be assessed to determine specific processes/procedures that require hazard analysis/mitigation. The following is a minimal list for hazard analysis:

1. Chemical or physical (pressure) reactions between hardware elements
2. Collisions during handling
3. Exposure to environmental elements such as vibration and/or thermal conditions that may cause problems (e.g., the Challenger and Columbia accidents)
4. Environmental hazards such as hazardous fluid spills

Hazard analyses ascertain the potential repercussions for a plausible mishap/malfunction. Once the hazard/repercussion is understood, a mitigation action must be developed.

The mitigation action may be the development/modification of operational procedures that, by default, completely neutralize the hazard (e.g., limiting access to hazardous areas). Alternatively, a mitigation action/procedure may only reduce the potential for injuries or death due to mishaps/malfunctions to an "acceptable" level.

Conduct Gen Grd Ops GI - 5. **GSE Test and Evaluation**

Guideline Input

The RLV operator shall provide to the FAA:

1. GSE Test and Evaluation Plan
2. Documentation of each GSE inspection and test for hazardous operations equipment

Rationale

This Test and Evaluation Plan must be used, by the operator, to demonstrate the operability of the RLV Ground Support Equipment (GSE) that is directly involved in operations that may impact public safety during any phase of RLV operations. The GSE Test and Evaluation Plan must include the following as a minimum:

1. A list and description of the GSE that is directly involved in operations that may impact public safety during any phase of RLV operations
2. Written procedures for the test/checkout (including the evaluation criteria) of these safety-critical GSE
3. Frequency at which the test/checkout will occur
4. Reference to written procedures for the operation of the subject GSE
5. Reference to the appropriate contingency/emergency procedures that protect the public in the event of a GSE malfunction
6. Reference to the skill level/title of the personnel who may operate this GSE along with any certification standards that may apply

Some examples of GSE that this guideline applies to include: Flight Safety System (FSS) ground components, fuel carts, and hazardous material transporters.

The documentation shall identify the date of the inspection or test, the name of the person who performed the inspection or test, a unique identifier of the equipment on which the inspection or test was performed, a description of the inspection or test performed, and the results of the inspection or test.

Conduct Gen Grd Ops GI - 6. **Ground Operations Emergency Response Plans**

Guideline Input

A launch operator shall develop emergency response plans for potential ground operations hazard sources.

Rationale

The ultimate purpose of an emergency response plan is to ensure public safety in the event of a mishap during launch vehicle processing or flight. Emergency response plans (ERPs) are necessary for identifying potential emergencies and how to control, contain, and remove a hazard. ERPs will address handling requirements for hazardous materials, required personnel protection clothing/apparatus, and evacuation procedures for affected areas. An emergency response plan must identify emergency response personnel and their duties and describes the methods to be used to ensure public safety. An emergency response plan must define the process for providing assistance to any injured people and describe the methods used to control any hazards associated with a mishap. An emergency response plan must describe the types of emergency support required, equipment to be used, emergency response personnel and their qualifications, and any related agreements with any launch site operator and state, county, or local government agencies.

The following are a minimum that must be addressed in the ERP:

1. Firefighting
2. Explosive ordnance disposal
3. Chemical spill response
4. Medical support
5. Inadvertent release of radiological, corrosive, toxic, flammable, or cryogenic materials in hazardous quantities
6. Inadvertent activation of hazardous ordnance devices
7. Inadvertent ignition of flammable material
8. Inadvertent electrical shock/burns
9. Inadvertent deployment of appendages used in preparing the vehicle

Conduct Gen Grd Ops GI - 7. **Hazardous Substance Discharge**

Guideline Input

If a discharge of a hazardous substance occurs, a Hazardous Material Report (HMR) must be filed with the EPA.

Rationale

In addition to the reporting requirements of the HMR found in Sections 171.15 and 171.16 of Title 49, a discharge of a hazardous substance is subject to EPA reporting requirements at 40 CFR 302.6 and may be subject to the reporting requirements of the U.S. Coast Guard at 33 CFR 153.203.[8]

4.2 Prepare Launch/Takeoff

The Prepare Launch/Takeoff Function is defined as those tasks and procedures required to prepare the RLV hardware systems for launch/takeoff.

The sub-functions include integrating the vehicle elements and configuring the RLV hardware for launch/takeoff. The sub-functions are defined in Table 2.

Table 2 Prepare Launch/Takeoff Operations Definitions

Integrate Vehicle	*[Operations → Prepare Launch/Takeoff → Integrate Vehicle]* The Integrate Vehicle Sub-function involves all activities associated with the assembly and mating of RLV flight elements and the incorporation of cargo into the RLV (e.g., payload or passengers).	
	Load Payload/ People	*[Operations → Prepare Launch/Takeoff → Load Payload/People]* The Load Payload/People Sub-function encompasses the tasks and procedures to be performed to encapsulate and place Payloads and People (crew and passengers) on-board the RLV.
	Integrate Vehicle Flight Elements	*[Operations→Prepare Launch/Takeoff→Integrate Vehicle Flight Elements]* The Integrate Vehicle Flight Elements Sub-function consists of the tasks and procedures to assemble and mate RLV flight elements (e.g., orbit vehicle, boost stages, etc.).
Configure for Launch/Takeoff	*[Operations → Prepare Launch/Takeoff →Configure for Launch/Takeoff]* The Configure for Launch/Takeoff Sub-function includes the tasks and procedures to ensure the hardware of the RLV and its elements are configured for the mission's launch and flight operations.	

4.2.1 General Discussion

General

Launch/takeoff is defined as that point at which the RLV experiences first motion. Note: Takeoff is applicable to ascent from any angle whereas launch is applicable only to a vertical ascent.

Integrate Vehicle

Integration of the RLV will vary and be dependent on the type of RLV being operated. A Single Stage To Orbit (SSTO) vehicle will not require mating of stage elements, but may require the loading of payloads and people. Other RLV concepts may require multiple stages that must be assembled and mated to each other for launch and flight operations. A stage element is a self-propelled, separable element of the RLV. Staging an element of a vehicle refers to the shedding of no-longer-required structural mass (e.g., empty tanks). See Section 5.5 for the disposition of stages.

These assembly and mating operations are critical to the success and safety of the mission. Proper element alignment and assembly is required in order to ensure that the thrust vectors maintain positive flight control.

Several actions must occur during this function:

1. Electrical mating
2. Power transfer
3. Flight Safety System checks
4. RLV integrated test with umbilicals connected and disconnected
5. Thrust vector alignment verification
6. RLV umbilical connection as required

Some potential safety issues associated with integration of the vehicle are highlighted in Table 3.

Table 3 Vehicle Integration Safety

Servicing	Handling	Interfaces
• Contamination control • Maintain purges • Environmental issues	• Many lifts and moves of large, potentially hazardous elements • Multiple cranes • Fragile materials • Specialized equipment requiring certification • Specialized, one-time only training	• Use pyrotechnic separation • Verify interfaces/interconnects complete
NOTE: On the ground, compartments are purged to prevent accumulation of hazardous gases and to ensure that components are maintained at a safe temperature. There is also a potential for in-flight purges (e.g., the shuttle uses a helium purge to provide pressure for actuating engine valves during emergency pneumatic shutdown).		

Other tasks include configuring the payload in the payload bay or in other on-board compartments; boarding passengers; and preparing passengers for flight. The people, or passenger, compartment may be a type of payload container and standards may need to be developed for the "containers".

Configure for Launch/Takeoff

For vertical takeoff RLVs this sub-function includes the erecting of the RLV into the vertical takeoff position and for air-dropped/piggy-backed RLVs this will include the mating of the RLV to the carrier craft.

This sub-function also includes configuring the payload(s) into the proper state for the launch/takeoff environment: instituting the correct environmental controls and performing any necessary ordnance safing. Payload attitude thrusters and orbit insertion engines/motors will be configured for no operation during launch/takeoff and enabled at the proper time after orbit insertion takes place.

4.2.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Prepare Launch/Takeoff Sub-function:

General

Prepare Launch/TO GIC - 1. Communications should be adequate between ground operations personnel that are integrating the various stages of the vehicle and/or the payload to reduce risks of accidents/incidents.

Integrate Vehicle

Prepare Launch/TO GIC - 2. The payload should not present public safety risks due to radiation from Radioisotope-Thermoelectric Generators (RTG) or hazardous material.

Prepare Launch/TO GIC - 3. Proper environmental conditioning should be established and maintained for payloads and people.

Configure for Launch/Takeoff

Prepare Launch/TO GIC - 4. During Configure for Launch/Takeoff the on-board control system should be tested and the test results should be documented and verified to meet acceptance criteria.

Prepare Launch/TO GIC - 5. Electrical and piping connections should be verified.

Prepare Launch/TO GIC - 6. The propellant control and flow systems should be monitored for leaks.

Prepare Launch/TO GIC - 7. Proper operational characteristics of the pneumatics system should be checked using bleed air system indications.

4.2.2.1 Inter/Intra Agency

The following Prepare Launch/Takeoff Function inter/intra agency considerations were identified:

1. The Environmental Protection Agency should be consulted regarding sound/noise level issues that are associated with the launch of RLVs.
2. National Fire Protection Agency (NFPA) coordination will be required for procedure development to ensure that fire safety and mitigation procedures are in place for launch/takeoff preparations.

4.2.3 Guideline Recommendations

Prepare Launch/TO GI - 1. **Flight Readiness Approval**
Guideline Input RLV operators shall obtain Flight Readiness Approval from the FAA prior to launch/takeoff.
Rationale The Flight Readiness Approval will certify that the RLV is ready for launch/takeoff and flight. This approval will be obtained via a Flight Readiness Review. The Flight Readiness Review will approve the final flight plan, ensure coordination and integration with the NAS is complete and abort sites are available and ready. Additionally, the Flight Readiness Review will ensure that the RLV, crew, and payload/people are ready for flight (i.e., meet the relevant safety requirements).

Prepare Launch/TO GI - 2. **Payload Integration Safety**

Guideline Input

A Payload Safety Analysis shall be performed and submitted for consideration to the Flight Readiness Review authorities.

Rationale

For payloads containing hazardous materials, the integration/assembly of the payload must be conducted using appropriate precautions and special handling procedures. Certain payloads may contain material (e.g., propellants such as hydrazine) that if not handled or treated properly will impact public safety directly. Additionally, there may be operations or materials associated with the payload that may damage the RLV and subsequently cause breakup of the RLV over populated areas. Certain payload materials, such as Radioisotope Thermoelectric Generators (RTGs), must be handled according to EPA requirements to ensure no radiation hazard is present. Toxic and flammable materials must be characterized and their risk mitigated. Additionally, adequate environmental conditioning must be provided during the assembly and integration of the payload. NASA's Guidelines For The Preparation Of Payload Flight Safety Data Packages And Hazard Reports For Payloads Using The Space Shuttle contains additional guidance for these issues.[9]

4.3 Recover

The Recover Function is defined as those sub-functions, tasks, and procedures required to retrieve and safe the RLV and/or any of its flight elements (e.g., the Shuttle's Solid Rocket Motors (SRM)), payload, and people after landing, for subsequent turnaround maintenance, assembly, and integration[10].

The sub-functions unique to recovery include safing the vehicle and payload, unloading the payload and/or passengers; and scheduling turnaround maintenance. These sub-functions are defined in Table 4.

Table 4 Recover Operations Definitions

Safe Vehicle/PL		*[Operations → Recover→ Safe Vehicle/PL]* The Safe Vehicle/PL Sub-function involves the procedures and tasks required to ensure mechanical, electrical, and environmental conditions (e.g., hazardous materials) are nominal, secure, and safe for egress and servicing. This may include purging of propellant tanks or neutralizing hazardous material.
Payload/People Egress		*[Operations → Recover→ Payload/People Egress]* The Payload/People Egress Sub-function entails the tasks and procedures for the off-loading of the payload and/or passengers during Recover Operations.
Schedule Turnaround Maintenance		*[Operations → Recover → Schedule Turnaround Maintenance]* The Schedule Turnaround Maintenance Sub-function consists of those activities that are required to schedule the RLV for Turnaround Maintenance to return the RLV to flight-worthiness status. The Maintenance Function performs the turnaround maintenance tasks.
	Maintenance Functional Decomposition Diagram	*[Operations → Recover → Schedule Turnaround Maintenance→ Maintenance Functional Decomposition Diagram]* The Maintenance Functional Decomposition outlines maintenance functions for performing Scheduled and Un-Scheduled Maintenance to return the RLV to flight-worthiness status. See Volume 3, Maintenance, of this document.

4.3.1 General Discussion

General

The Recover Function starts immediately after Landing. Procedures will be required for both nominal and emergency landing sites. Since it will be necessary to know its exact landing location, some form of beacon capability may be needed in the event of an emergency. For example, system recovery aids such as chaff, dye markers, flashing lights, smoke, radar reflective parachutes, or GPS locator beacons may be employed to aid in recovery.

Safe Vehicle/PL

Safing the RLV and payload during the recovery process first involves determining the status of the vehicle and then neutralizing any hazards found present. This may require that the ground team wear protective gear similar to a self-contained atmospheric protective ensemble (SCAPE) suit in order to protect them from toxic chemicals. It may also be necessary to have a remote sensing capability to ensure the atmosphere in the vicinity of the spacecraft is not hazardous or explosive prior to allowing the ground team to approach the vehicle.

The following excerpt from the Shuttle mission profile presents procedures used during Shuttle recovery operations[11]:

> A ground support equipment air-conditioning purge unit is attached so cool air can be directed through the orbiter's aft fuselage, payload bay, forward fuselage, wings, vertical stabilizer, and orbital maneuvering system/reaction control system pods to dissipate the heat of entry. A second ground support equipment ground-cooling unit is connected to the Freon coolant loops to provide cooling for the flight crew and avionics during the post landing and system checks.
>
> In the event of propellant leaks, a wind machine truck carrying a large fan may be moved into the area to create a turbulent airflow that will break up gas concentrations and reduce the potential for an explosion. The Shuttle fuel cells remain powered up. The flight crew will then exit the spacecraft, and a ground crew will power down the spacecraft.

Nominal mission hazards may include: purging/venting propellant tanks and ordnance safing.

Payload/People Egress

Off loading of the payload and/or passengers will likely be handled in a manner similar to aircraft (i.e. at the final destination versus the exact landing point) provided there are no hazards on-board. If there are hazards on-board, getting the vehicle to a state "safe enough" to off-load passengers and crew will take priority.

Once the off-loading of passengers and/or payload occurs, the RLV may be scheduled for any necessary maintenance and repair prior to the next mission.

Schedule Turnaround Maintenance

The Recover Sub-function ends once the Turnaround Maintenance Function begins. See Volume 3 – Maintenance of this document.

4.3.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Recover Sub-function:

General

Recover GIC - 1. No air and water pollutants should be released during the Recover operation.

Recover GIC - 2. Critical communication of location data and vehicle state data (i.e. safety critical system status) should be continued after landing and on through the recovery operation.

Safe Vehicle/PL

Recover GIC - 3. Potentially hazardous RLV subsystems should have the ability to autonomously return to a safe condition.

Recover GIC - 4. In the event of an expected hazardous environment (e.g., it is known that a payload will contain hazardous materials at landing), procedures should have been developed during the mission/flight-planning phase to ensure protection of the public, the crew, and any passengers during the recovery operation.

Payload/People Egress

Recover GIC - 5. Anomalous egress should be managed with contingency procedures.

Recover GIC - 6. Life support and environmental control should be provided and monitored for payload and people egress from the RLV.

Schedule Turnaround Maintenance

Recover GIC - 7. Post-flight replenishment, maintenance, repair, or testing of a life support system should ensure the primary and backup systems are operating within specifications prior to re-certification for flight.

4.3.2.1Inter/Intra Agency

The following Recover Function inter/intra agency considerations were identified:

1. Handling and transportation of hazardous materials are ruled by DOT Hazardous Material regulations. The process for handling hazardous materials during the Recover function is similar to that accomplished during Conduct Ground Operations. Similar standards such as those from OSHA and DOT should be employed. A key consideration would be to determine if propellant residuals could be re-used or recycled to minimize propellant-waste generation.
2. Venting and disposal of hazardous materials are ruled by EPA regulations. The Environmental Protection Agency addresses disposal of hazardous materials.
3. During recovery, real-time coordination, data sharing, and situational awareness between the RLV Flight Crew, RLV operator, and the NAS Air Traffic Control (ATC) system should occur. Air Traffic Control (ATC)/Space Traffic Control (STC) includes Aerospace Traffic Control Operator (ATCO). These functions provide the ground movement and flight traffic control to ensure safety.

4. FCC coordination should occur for all frequency assignments used in RLV operations, particularly those employed in emergencies.
5. The State Department should be notified for international coordination of recovery operations that occur on foreign soil or non-international waters.
6. The Department of Defense Explosive Safety Board (ESB) may provide a source of lessons learned for FAA/AST for conducting RLV safety evaluations, storage of propellants, and chemical agents.[12]
7. National Fire Protection Agency (NFPA) coordination will be required for procedure development to ensure that fire safety and mitigation procedures are in place for recovery operations.

4.3.3 Guideline Recommendations

Recover GI - 1.	**RLV Safety Critical Systems Monitoring During Recovery**
Guideline Input During recovery operations, RLV safety critical systems shall be monitored to ensure all systems are functioning nominally.	
Rationale During recovery, the status of safety critical systems on-board the RLV and/or the payload will need to be communicated to ground operations personnel. Therefore, continuous monitoring of these safety critical systems must be performed in the nominal recovery operation and contingency procedures will address how ground operations personnel will determine the status of safety critical systems prior to performing operations (e.g., leak testing, remote sensing, etc.). RLV safety critical system data may also be used to trend historical data on the vehicle's systems to identify off-nominal parameters in the event of an anomaly. Safety critical system data may also highlight additional maintenance activities that need to be performed during the Turnaround Maintenance function.	

Recover GI - 2. **Recovery Hazardous Procedures**

Guideline Input

The RLV Operations Manual shall provide operation procedures for hazardous Recovery conditions.

Rationale

During Recovery, hazardous condition procedures will be defined in the planning phase. Hazards may be managed with nominal and contingency procedures. There may exist conditions of an expected hazardous environment (e.g., a payload with hazardous commodities). These are known in advance to have a potential to impact safety. These procedures are necessary in order to protect the public, the crew, and passengers.

5.0 Flight Operations

The Flight Operations Domain covers the entire flight regime from flight planning through the vehicle coming to rest as well as contingency operations, see Figure 6. The major elements are derived from the phases of flight: flight preparation, launch (or takeoff), flight, reentry, and landing.

Flight operations, as defined here, encompasses all planning, analysis, and performance associated with the actual flight of the RLV as opposed to ground operations that involve flight readiness preparations for the vehicle.

The following sections provide Guideline Inputs for each Flight Operation Sub-function. Where appropriate, interrelationships with other functions are discussed.

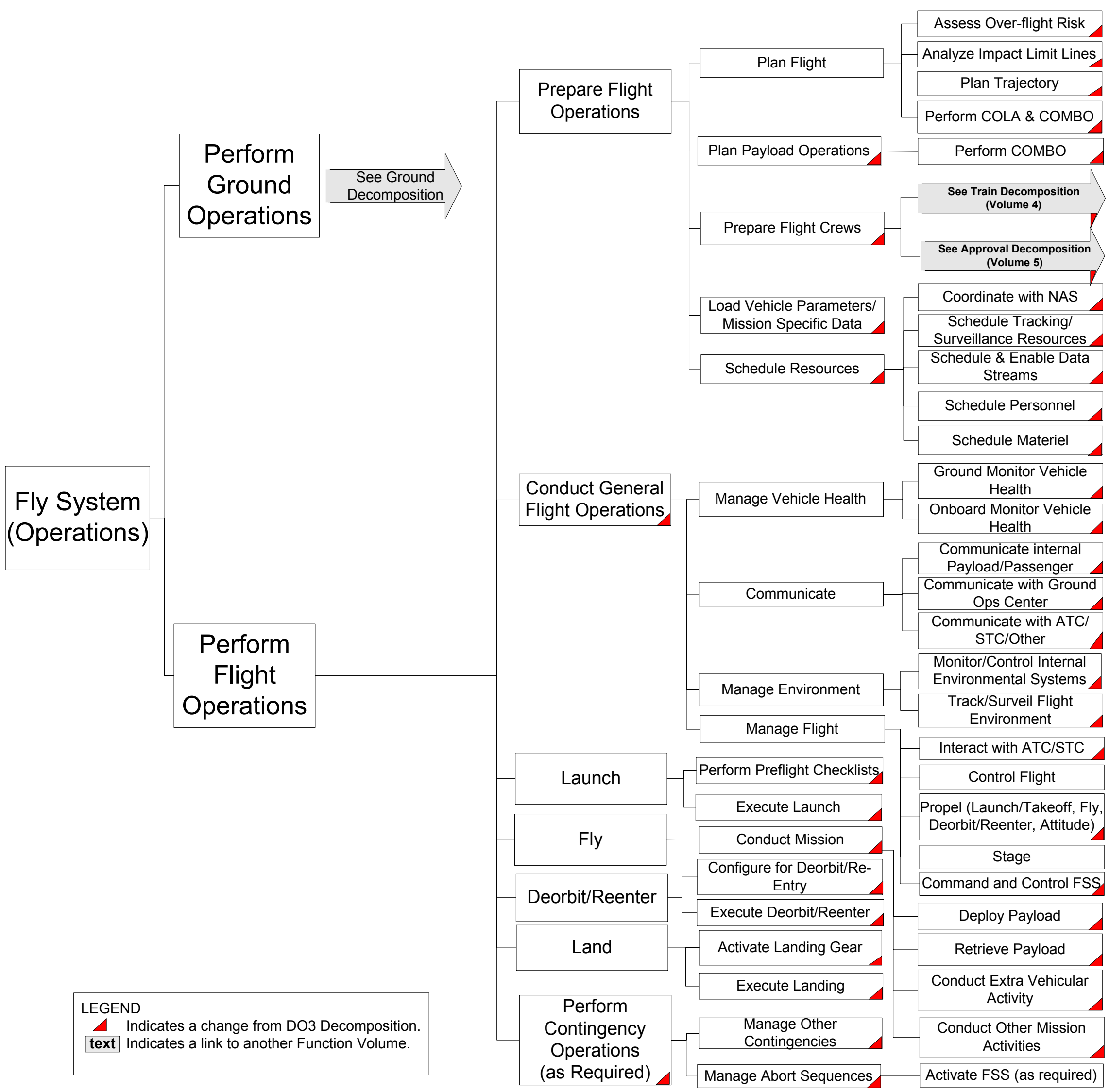

Figure 6 Flight Operations Functional Decomposition

5.1 Prepare Flight Operations

The Prepare Flight Operations Function encompasses all planning, analysis, and performance tasks and procedures associated with actual launch and flight of the RLV as opposed to ground operations ensuring the vehicle is flight ready. The sub-functions are defined in Table 5.

Table 5 Prepare Flight Operations Definitions

Plan Flight	*[Operations→Perform Flight Operations→Prepare Flight Operations→Plan Flight]* The Plan Flight Sub-function includes the assessment of risk, the definition of Impact Limit Lines (ILL) or equivalent, optimization of the RLV trajectory/flight plan, and interaction with external agencies. Note: Trajectory/Flight Plan encompasses the ascent and descent of flight to and from the mission altitude.	
	Assess Over-flight Risk	*[Operations→Perform Flight Operations→Prepare Flight Operations→Plan Flight→ Assess Over-flight Risk]* The Assess Over-Flight Risk is the set of tasks and procedures to identify and quantify the risk associated with the flight of an RLV over populated areas.
	Analyze Impact Limit Lines	*[Operations→Perform Flight Operations→Prepare Flight Operations→Plan Flight→Analyze Impact Limit Lines]* The Analyze Impact Limit Lines (ILLs) Sub-function includes the tasks and procedures to establish the launch and downrange areas to be protected from impact of debris.
	Plan Trajectory	*[Operations→Perform Flight Operations→Prepare Flight Operations→Plan Flight→ Plan Trajectory]* The Plan Trajectory Sub-function involves identifying the optimum trajectory to accomplish the mission of the flight within safety constraints.
	Perform COLA & COMBO	*[Operations→Perform Flight Operations→Prepare Flight Operations→Plan Flight→ Perform COLA & COMBO]* The Perform COLA & COMBO Analysis Sub-function involves calculating the Conjunction On Launch Assessment (COLA) and Calculation Of Miss Between Orbits (COMBO) to assess the potential for conflict with orbiting spacecraft and debris during flight operations.
Plan Payload Operations	*[Operations→Perform Flight Operations→Prepare Flight Operations→Plan Payload Operations]* The Plan Payload Operation Sub-function includes the tasks required to plan for the payload to accomplish its purpose, including orbit selection, launch window evaluation, power and fuel budgeting, deployment, return (potentially), communication, etc.	
	Perform COMBO	*[Operations→Perform Flight Operations→Prepare Flight Operations→Plan Plan Operations →Perform COMBO]* Calculation Of Miss Between Orbits (COMBO) analyses are performed during the mission-planning phase when the mission requires a station change or on-orbit maneuver. This COMBO analysis assesses the potential for conflict with other orbiting spacecraft and debris during flight operations.

Prepare Flight Crews		*[Operations→Perform Flight Operations→Prepare Flight Operations→Prepare Flight Crews]* Preparing the flight crews includes medical evaluations, psychological evaluations, as well as mission training, RLV crew training and approval.
	Train Functional Decomposition	*[Operations→Perform Flight Operations→Prepare Flight Operations→Prepare Flight Crews→ Train Functional Decomposition]* The Training Functional Decomposition outlines general and mission-specific training functions required for Flight Crew readiness preparation. See Volume 4, Training, of this document.
	Approve Functional Decomposition	*[Operations→Perform Flight Operations→Prepare Flight Operations→Prepare Flight Crews→ Approve Functional Decomposition]* The Approval Functional Decomposition outlines medical/psychological evaluation and training approval functions required for Flight Crew readiness status. See Volume 5, Approval, of this document.
Load Vehicle Parameters/ Mission Specific Data		*[Operations→Perform Flight Operations→Prepare Flight Operations→ Load Vehicle Parameters/Mission Specific Data]* The Load Vehicle Parameters/Mission Specific Data Sub-function includes the tasks and procedures necessary to load (transfer) configuration data and software packages required for the RLV mission.
Schedule Resources		*[Operations → Perform Flight Operations→Prepare Flight Operations → Schedule Resources]* The Schedule Resources Sub-function includes the tasks and procedures for scheduling of various resource elements in order to prepare for launch/takeoff, flight, landing, and recovery.
	Coordinate with NAS	*[Operations → Perform Flight Operations→Prepare Flight Operations → Schedule Resources→Coordinate with NAS]* The Coordinate with NAS Sub-function consists of tasks and procedures necessary to coordinate with entities such as the Aerospace Traffic Control Operator (ATCO) for the scheduling of airspace and over-flight.
	Schedule Tracking/Surveillance Resources	*[Operations → Perform Flight Operations→Prepare Flight Operations → Schedule Resources→Schedule Tracking/Surveillance Resources]* The Schedule Tracking/Surveillance Resources Sub-function involves the scheduling of RLV operator and launch/takeoff/landing/recovery site tracking assets as well as NAS resources.
	Schedule & Enable Data Streams	*[Operations → Perform Flight Operations→Prepare Flight Operations → Schedule Resources→Schedule&Enable Data Streams]* The Schedule & Enable Data Streams includes the tasks and procedures required to reserve, schedule, and activate RLV data communications streams for voice, telemetry, or video.
	Schedule Personnel	*[Operations → Perform Flight Operations→Prepare Flight Operations → Schedule Resources→Schedule Personnel]* The Schedule Personnel Sub-function includes the scheduling of flight and ground support personnel to ensure safety during all flight phases.
	Schedule Materiel	*[Operations → Perform Flight Operations→Prepare Flight Operations → Schedule Resources→Schedule Materiel]* The Schedule Materiel Sub-function includes tasks required to schedule materiel such as ground equipment, transportation equipment, loading and cargo handling equipment, as well as consumable and non-consumable items.

5.1.1 General Discussion

General

Prepare Flight Operations is accomplished in advance of and up to Launch/Takeoff of an RLV. Usually alternate flight plans are prepared so that there are choices available for different launch/takeoff windows. It is expected that elements of the flight plan will include orbit insertion points, calculation of ILLs, results of COLA/COMBO, and trajectory calculations. It is recognized that these may be reaccomplished during a flight, particularly in light of off-nominal conditions encountered during the flight.

Prepare Flight Operations is the responsibility of the RLV operator. Certain elements of flight planning may be accomplished by a third-party or as a government activity (such as NORAD), similar to the flight planning support that is provided by Flight Service Stations (FSS) in traditional aviation.

Prepare Flight Operations activities are required to ensure that potential impacts on public safety have been considered throughout the mission/flight, and the appropriate coordination has been accomplished (see Figure 7). Following the positive control model used in Air Traffic Control (ATC), it is through the flight plan that the RLV flight is integrated with other users of the airspace. Correct calculation of the trajectory and consideration of other craft and orbital debris reduce the chances of a mishap during the flight. Finally, the vehicle monitoring performed during this function helps ensure that the vehicle is properly prepared to be able to execute the intended flight plan.

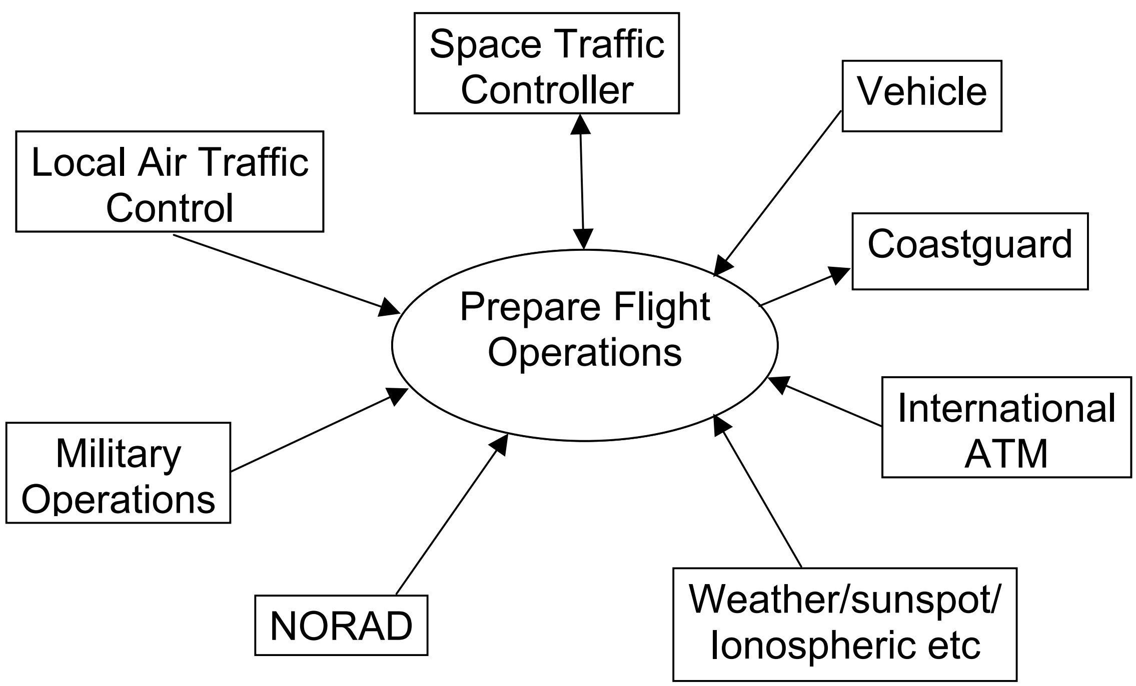

Figure 7 Prepare Flight Operations Coordination

Prepare Flight Operations activities may be accomplished at an RLV operator's facility, the serving spaceport, a government facility, or at a contractor's facility engaged in providing flight support. Future CONOPS may require all or part of planning/re-planning be done on-board the RLV.

The Prepare Flight Operations Sub-function is the last gate to verify the vehicle and the crew are capable of safely accomplishing the mission. Effects of miscalculation, bad planning or use of wrong data may result in collision on launch, collision with debris, or landing at a site that does not support such landing. Such mishaps can cause the vehicle to become uncontrolled or to breakup over populated areas.

The amount of automation in the Prepare Flight Operations Sub-functions depends upon the specific RLV design. For example, on one end of the spectrum, RLV planning could be totally autonomous and flight operations personnel simply monitor the preparations for flight. In most cases, the flight operations personnel on the ground and the flight crew will have shared functions in both planning and monitoring.

Plan Flight

During the flight-planning phase, it is necessary to perform risk analyses to determine acceptable times and locations to "fly". Debris analysis is the process whereby inert, explosive and other debris resulting from an RLV malfunction, and from any planned jettison of vehicle components, are identified. In addition to the quantity of debris, each piece of debris has an associated impact/casualty area that is used to determine potential risk to the public as a result of either planned or unplanned debris impact.

Impact Limit Lines (ILLs) are established to define the landmass areas to be protected. Significant debris pieces that could cause property damage and personal injury from malfunctioning launch vehicles must be contained inside the ILLs. In the case of an RLV with a vertical launch profile, the types of failure modes that are traditionally examined include: explosion on the launch pad, loss of control at liftoff, straight-up flight, on-trajectory breakup, malfunction turn, thrust termination, and unplanned jettison of components. Other RLV flight profiles will require risk metrics suitable to their intended trajectory.

The Assess Over-flight Risk Sub-function includes the calculation of the expected casualty, E_C (casualty expectation), and the individual hit probability for aircraft or ships, (P_i), associated with both planned jettison components and unplanned debris impacts. Risk metrics are calculated throughout the launch trajectory by computing the probability of failure at any given time; determining the potential failure modes, debris types, and energies; propagating the debris using wind and aerodynamic models; and estimating casualties for the debris type, the affected area, shelter types, and population densities exposed to the risk. The types of failure modes that are traditionally examined include: on-trajectory breakup, malfunction turn, thrust termination and unplanned jettison of components.

Two risk "types" include:

1. P_I = probability of impact or "hit"
2. E_C = casualty expectation

Three contributions to risk are:

1. Inert debris impacts
2. Overpressures from explosive impacts
3. Projected debris from explosive impacts

The following data are used in these analyses:

1. Detailed description of entire vehicle, mission, and payload
2. Nominal and dispersed three-sigma trajectories
3. Velocity turn data (for nominal trajectory only)[1]
4. Vehicle breakup and destruct debris catalog
5. FSS functionality and effects description (if applicable)
6. Wind data (historical)
7. Impact limit lines
8. Facilities and population in launch, landing and abort site areas
9. Downrange population centers

RLV operators will need to determine what, if any, assumptions can and should be made in assessing the risk for a particular flight. Considerations include:

1. Instantaneous turn to any attitude is possible or use physical limitations on turn rates
2. No debris is consumed by heat during reentry or apply debris survivability algorithms
3. No populations are sheltered or apply sheltering models.

[1] "The turn data shall describe the turning capability of the vehicle velocity vector as a function of thrust vector offset or other parameters characterizing the turns. This information is used to determine how fast a vehicle or, more exactly, a vehicle impact point can deviate from the nominal if a malfunction occurs. Velocity vector turn data is required only for the thrusting periods from launch up to a point in flight where effective thrust of the final stage has terminated or to thrust termination of that stage or burn that places the vehicle in orbit. In determining the maximum turn capability of a vehicle, the usual procedure is to consider both trim turns and tumble turns, in both the pitch and yaw planes." (Reference: Eastern and Western Range 127-1-Appendix 2B)

FAA/AST is conducting research to develop a document to establish casualty expectation analysis for RLVs. Per a briefing given at the October, 2003 COMSTAC meeting, this effort will result in a tabular lookup handbook allowing the industry a first-hand estimation of the casualty expectation for the reentry phase of the flight.

Planning a trajectory involves many tradeoffs. An optimum trajectory would include meeting mission objectives with minimum impact to NAS traffic and maximum fuel efficiency, while ensuring public safety.

COLA analysis compares the planned RLV ascent flight path, or trajectory, to space traffic data in orbit to detect potential collisions. COMBO analysis compares the rest of the planned RLV flight, including deorbit/reentry, to space traffic data to ensure the planned flight satisfies the vehicle proximity separation requirements. NORAD (North American Aerospace Defense Command) provides the space traffic data used in these analyses. The separation criteria established for manned spacecraft is 200 km (108 nm) separation between man-rated vehicles and/or satellites.[13] This separation requirement is in all directions, so analysts model this as a 200 km sphere around the vehicle.

Plan Mission
COMBO analysis is also used to compute the “real-time” separation between spacecraft in orbit. Generally, it is a collision avoidance activity; however, there have been instances where a conflict has been detected and resolved by the relocation of another spacecraft. The same manned spacecraft separation criteria applied during the Plan Flight Sub-function is applicable on-orbit.

Prepare Flight Crews
This sub-function includes the training and approval of ground and on-board flight crews, and is presented here for operations functional decomposition accuracy only. See Volume 4 - Training and Volume 5 - Approval of this document for additional information.

Load Vehicle Parameters/ Mission Specific Data
Each RLV mission will require its unique set of data and software for safe space flight. During the Load Vehicle Parameters/Mission Specific Data Sub-function the software for the Flight Control, Flight Safety and Avionics Subsystems are configured for launch/takeoff and flight with the proper trajectory data, abort sequences, nominal flight control, communications links, etc. Additionally, the Health Monitor and Data Recording Subsystem will be placed on-line and the groundside of these subsystems will be configured for commanding and telemetry.

Schedule Resources
Resources considered in this sub-function include scheduling of ground and flight personnel; materiel (e.g. consumables required for the mission); ground

communication and data links; ground infrastructure necessary for flight safety (e.g. surveillance systems); and interactions with external systems such as the National Air Space (NAS). Elements associated with NAS include: flight corridor access and deconfliction, tracking asset scheduling, and communications links for data streams.

Additionally, the ATCO (Aerospace Traffic Control Operator) is coordinated with to ensure airspace reservation and notification to aviators of potential in-flight hazards associated with the atmospheric flight of the RLV, and the Coast Guard for notification to mariners of potential over-flight hazards during RLV flight. These can include optical, radar, inertial navigation systems, or GPS system.

This function will evolve based on the particular CONOPS the FAA finalizes as well as that of the operator's. Interaction with ATC and STC will change over time based on the implementation of the integration of RLVs into the NAS as mentioned in the DO2 report.[14]

5.1.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Prepare Flight Operations Sub-function:

General

Prepare Flt Ops GIC - 1. Anomalous conditions for safety-critical systems should be identified.

Prepare Flt Ops GIC - 2. Consideration should be given for specific issues/events coincident with the flight such as:

1. Increased sun spot activity that could affect on-board systems
2. Temporary Flight Restrictions (TFR) or other unique Special Use Airspace (SUA) issues including large-scale special events (e.g., Olympics, Air shows)
3. Predicted meteorological events such as hurricanes
4. Other environmental issues such as seasonal bird migration paths or known volcanic activity
5. On-orbit activities of other spacecraft (e.g., laser emissions)

Prepare Flt Ops GIC - 3. There are three aspects to these Prepare Flight Operations functions that should be addressed regardless of the level of automation or the spread of responsibilities between the flight crew and ground flight controllers:

1. Planning (timelines, configuration and interfaces)

2. Procedures (How to and who does what)
3. Performance (vehicle capabilities, operational constraints (including equipment, human and payload constraints), normal and contingency activities)

Prepare Flt Ops GIC - 4. The communications plan should be developed in such a way as to take advantage of “free flight” tools and infrastructure that are currently in evolution.

Plan Flight

Prepare Flt Ops GIC - 5. Trajectory data should be as accurate as possible as this greatly impacts final risk calculations.

Prepare Flt Ops GIC - 6. In order to maintain the fidelity of the model, updated/most current data should be used to for debris catalogs, debris survivability issues, malfunction turn data, probability of failure, population models.

Prepare Flt Ops GIC - 7. NORAD data should be current.

Prepare Flt Ops GIC - 8. ILLs require that the launch hazard area should be defined if applicable.

Prepare Flt Ops GIC - 9. Planning should include alternate landing sites and landing constraints.

Prepare Flt Ops GIC - 10. When planning RF tests in different facilities, pathfinder tests should be conducted to minimize loss in measurement precision or to eliminate the need for extensive workarounds.

Plan Mission

Prepare Flt Ops GIC - 11. Prior to a mission, mission analysts should determine the trajectory and desired attitude profile that will satisfy all the mission and safety requirements.

Prepare Flight Crews

Prepare Flt Ops GIC - 12. Flight crew training should be adequate for planning, monitoring, and operations functions.

Prepare Flt Ops GIC - 13. Ground crew training should include planning, monitoring, and operations functions to ensure full flight responsibility or contingent operations.

Prepare Flt Ops GIC - 14. Planning of ground control operations, task definitions, and mission requirements should include procedure to ensure crew alertness to possible emergency situations.

Prepare Flt Ops GIC - 15. If any data is to be changed in flight, flight crew should be trained also in updating/testing these parameters.

Load Vehicle Parameters/Mission Specific Data

Prepare Flt Ops GIC - 16. Any software loaded that has the opportunity to introduce errors should be formally verified.

Prepare Flt Ops GIC - 17. Mission planning data (flight plans, interface with flight management systems, processing of any commands from the ground) should be available to flight and ground crews for review/reload.

Schedule Resources

Prepare Flt Ops GIC - 18. Shared resources should be assigned and reserved based on proper priority between various contending functions.

Prepare Flt Ops GIC - 19. If NAS flight conflict detection/collision avoidance with aircraft is not employed, integration with NAS should use a just-in-time SUA reservation technique.

Prepare Flt Ops GIC - 20. Adequate supplies for purposes of life support and sustaining normal human functions during the mission should be carefully planned, and must incorporate the provisioning for planned, and contingency extra-vehicular crew activities.

5.1.2.1 Inter/Intra Agency

The following Prepare Flight Operations Function inter/intra agency considerations were identified:

1. There may be bilateral or other understandings required between different countries in allowing a flight through a foreign airspace as well as over-flight risks. While planning a flight for both a normal flight and for contingencies, an established protocol for recognizing alternate spaceports should be developed. The US State Department should be coordinated with regarding these flights.
2. During prep-for-launch/takeoff operations, coordination with NORAD (for COLA and COMBO) and with ATM for planning should occur.
3. During the launch/takeoff/ascent/deorbit/reentry and landing portions of flight, real-time coordination, data sharing, and situational awareness between the RLV operator and the NAS Air Traffic Control (ATC) system should occur for NAS integration (i.e., Special Use Airspace (SUA) reservation, and Notices to Airmen (NOTAMs)).

4. In conjunction with item 3 above, coordination with the Coast Guard should occur regarding Notices to Mariners (NOTMARs) for those launches which occur over bodies of water with marine traffic.
5. Communications frequency usage must be compliant with Federal Communications Commission (FCC) regulations.
6. There should be a function for space traffic similar to that of the International Civil Aviation Organization (ICAO). Presently, the State Department is instrumental in coordinating over-flight of foreign countries. However, there is need for a unifying influence, in certain areas, for the development of a code of international space traffic law. It is a function of ICAO to facilitate the adoption of international air law instruments and to promote their general acceptance. So far international air law instruments have been adopted under the Organization's auspices involving such varied subjects as the international recognition of property rights in aircraft, damage done by aircraft to third parties on the surface, the liability of the air carrier to its passengers, crimes committed on-board aircraft, marking of plastic explosives for detection and unlawful interference with civil aviation.

5.1.3 Guideline Recommendations

Prepare Flt Ops GI - 1. Operational Readiness Review

Guideline Input

The RLV operator shall conduct an Operational Readiness Review (ORR) in order to receive FAA/AST approval for flight operations.

Rationale

There are two types of ORRs envisioned: an ORR associated with an RLV operator in general and an ORR associated with a particular “flight”. This guideline addresses the latter. The purpose of this review is to communicate and document that risks associated with RLV O&M have been adequately identified and mitigated in order to ensure public safety requirements are met.

The Operational Readiness Review shall include, but is not limited to the following items:

1. Flight Plan (including alternate landing sites, SUA considerations, and ATM coordination).
2. COLA/COMBO, ILL, and over-flight risk assessment results for the particular flight.
3. Vehicle health/maintenance records showing compliance with the RLV Maintenance Program Plan
4. Documentation that supports the presence of essential equipage on-board the vehicle.
5. Ground and Flight crew training/availability documentation.
6. Environmental impacts of launch/takeoff, landing, and recovery operations.

The Space Shuttle Program has established a Flight Readiness Review (FRR). The FRR, is held approximately two weeks prior to launch, and is a comprehensive review of all activities/elements necessary for the safe and successful conduct of shuttle operations from prelaunch through post–landing and recovery operations. The readiness of the Space Shuttle vehicle, flight crew, and payloads is determined at this review. A signed Certification of Flight Readiness ensures that all work elements have successfully completed their Flight Preparation Processes.[15]

Prepare Flt Ops GI - 2. **Prepare Flight Plan**

Guideline Input

RLV operator shall file a flight plan.

Rationale

An improperly filed or missing flight plan may result in a public safety hazard since ATC may be unaware of the RLV's intended flight or predicted trajectory. This may lead to a collision avoidance problem and possible collision jeopardizing passengers on-board the RLV and the public on the ground.

Prepare Flt Ops GI - 3. **In-Flight Hazard Mitigation Planning**

Guideline Input

A launch operator shall develop flight operations plans and procedures for crew response to alerts/warnings for potential hazardous conditions.

Rationale

The complex design and system inter-dependencies of a launch vehicle and its payload demand detailed analysis to identify credible failure events and careful planning to develop plans for mitigating the effects of a mishap/malfunction. In-flight failure response plans require special attention to ensure there is no conflict between the continued operation of the RLV and the mitigation of a safety concern. In-flight hazard mitigation planning is essential to mission success and may help to reduce the launch vehicle's probability of failure. Most safety critical systems may not be immediately accessible to the crew for visual/tactile detection of potential hazards. Therefore, alerts and warnings must be present to signal the crew that a potential safety hazard exists and that action is necessary to mitigate the hazard. For each credible failure event a crew response plan is required and will document in detail each step necessary to mitigate a potential safety hazard.

Such potential hazardous conditions include:

1. Anomalies in cargo element(s) hazardous operations
2. Fire detection
3. Degradation of RLV safety critical functions by payload
4. Radiation detection
5. Collision/contact between different payloads or payload with RLV whether within the bay or during deployment
6. Failures of safety critical functions due to interaction with payload systems
7. Distraction during safety critical flight activities due to payload system(s) requirements
8. Degraded (uncontrollable) reentry capability due to payload system(s) requirements
9. Inadvertent and unsafe reactions due to temperature or pressure requirements for payload element(s)
10. Inadvertent reactions between payload and planned mission operations that may result in putting the flight into jeopardy
11. Potential adverse payload operations affecting other payload elements or the structure of the vehicle

5.2 Conduct General Flight Operations

The Conduct General Flight Operations Function encompasses the performance of all necessary sub-functions, tasks, and procedures common to all flight operations of the Launch, Fly, Deorbit/Reentry, Land, and Contingency Functions. The RLV operator, in conjunction with the launch/takeoff site operator, will typically conduct these tasks.

These operations include managing the health of the RLV; managing the atmospheric environment on-board the RLV; ensuring safety of flight; managing the flight controls; interacting with air and space traffic management; communicating voice and data; and flight of the vehicle. The sub-functions are defined in Table 6.

Table 6 Conduct General Flight Operations Definitions

Manage Vehicle Health	*[Operations→Perform Flight Operations→Conduct General Flight Operations→Manage Vehicle Health]*	
	The Manage Vehicle Health Sub-function consists of verifying and controlling the operational status of all critical RLV systems.	
	Ground Monitor Vehicle Health	*[Operations→Perform Flight Operations→ Conduct General Flight Operations →Manage Vehicle Health→ Ground Monitor Vehicle Health]*
		The Ground Monitor Vehicle Health Sub-function utilizes ground assets through telemetry to monitor and command links to manage the RLV's state of health during flight.
	On-board Monitor Vehicle Health	*[Operations→Perform Flight Operations→Conduct General Flight Operations→Manage Vehicle Health→On-board Monitor Vehicle Health]*
		The On-board Monitor Vehicle Health Sub-function utilizes RLV on-board assets to monitor and manage the RLV's state of health during flight.
Communicate	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Communicate]*	
	The Communicate Sub-function includes the tasks and procedures to exchange data/information within the RLV; between the RLV and ground O&M entities; and between all ground O&M entities.	
	Communicate Internal Payload /Passengers	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Communicate→ Communicate Internal Payload /Passengers]*
		The Communicate Internal Payload/Passengers Sub-function encompasses the tasks and procedures necessary for the Flight Crew to perform voice, data, or imagery communications both two-way and one-way with the payload or passengers.
	Communicate with Ground Ops Center	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Communicate→ Communicate with Ground Ops Center]*
		The Communicate with Ground Ops Center Sub-function includes the tasks and procedures for the RLV, autonomously, or the Flight Crew, manually, to send/receive data, voice, or imagery to the Operations Center. This includes telemetry and commands.
	Communicate with ATC/STC/Other	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Communicate→ Communicate with ATC/STC]*
		The Communicate with ATC/STC/Other Sub-function includes the tasks and procedures to exchange information (data, voice, and video) from the RLV and Ground Ops Center with ATC/STC and other entities.

Manage Environment	*[Operations→Perform Flight Operations→ Conduct General Flight Operations →Manage Environment]* The Manage Environment Sub-function addresses all aspects associated with monitoring and controlling the environment both on-board and off-board the RLV during flight operations.	
	Monitor/Control Internal Environmental Systems	*[Operations→Perform Flight Operations→ Conduct General Flight Operations →Manage Environment→ Monitor/Control Internal Environmental Systems]* The Monitor/Control Internal Environmental Systems Sub-function includes the procedures and tasks necessary to manage the internal environmental systems: Crew Systems, Payload/People Systems, Environmental Systems, and utilizes the Health Managers.
	Track/ Surveil Flight Environment	*[Operations→Perform Flight Operations→ Conduct General Flight Operations →Manage Environment→ Track/Surveil Flight Environment]* The Track/Surveil Flight Environment Sub-function consists of the process of monitoring the location and movements of the RLV and objects in the RLV's surrounding space.
Manage Flight	*[Operations → Perform Flight Operations→ Conduct General Flight Operations →Manage Flight]* The Manage Flight Sub-function is the set of sub-functions that manage all aspects surrounding the actual flight environment: controlling the RLV using propulsion or flight control surfaces, coordination with traffic controllers, staging, and commanding the vehicle FSS.	
	Interact with ATC/STC	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Manage Flight→ Interact with ATC/STC]* The Interact with ATC/STC Sub-function consists of the tasks and procedures for coordinating flight plans and flight paths through the NAS with ATM resources.
	Control Flight	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Manage Flight→ Control Flight]* The Control Flight Sub-function consists of the tasks and procedures that specifically direct the RLV with particular references to changes in attitude and speed.
	Propel (Lift-Off/Takeoff, Fly, Deorbit/Reenter, Attitude)	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Manage Flight→ Propel (Lift-Off/Takeoff, Fly, Deorbit/Reenter, Attitude)]* The Propel Sub-function is the set of procedures and tasks to impart or change the motion of the RLV via the propulsion subsystem.
	Stage	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Manage Flight→ Stage]* The Stage Sub-function is the act/procedure of jettisoning no longer required structural mass (e.g., empty tanks and "spent" engines).
	Command and Control FSS	*[Operations → Perform Flight Operations→ Conduct General Flight Operations → Manage Flight→ Command and Control FSS]* The Command and Control FSS Sub-function consists of the procedures to activate, command, and control all Flight Safety System elements.

5.2.1 General Discussion

General

The detailed operations of the Conduct General Flight Operation Function will depend on the RLV operator's vehicle CONOPS and the FAA Integrated NAS CONOPS. These two CONOPS will work in unison to provide the requisite operation procedures for launch, flight, deorbit/reentry, and landing.

Manage Vehicle Health

The RLV is monitored to establish trend/historical data on the RLV's safety critical subsystems for off-nominal verification checks in the event of an anomaly. Trend/historical data will also help to identify unscheduled maintenance activities that need to be performed. Patterns in such data may also result in updating scheduled maintenance intervals, as well as equipment to be serviced during these intervals.

Communicate

Communication may be autonomous, automated, and/or human initiated, and it may be in the form of voice, data, or imagery. It involves both two-way and one-way data and information transmission and reception using the electromagnetic spectrum. Typically in manned space flight there is both verbal and data communications. In addition, the Flight Crew may be required to send or receive data pertinent to the payload.

The implementation of communications will evolve based on the particular CONOPS the FAA finalizes and the operator's CONOPS. Interaction with ATC and STC will change over time based on the implementation of the integration of RLVs into the NAS as mentioned in the DO2 report.[16]

There is a specific safety consideration during the reentry phase of flight involving communications, notably the communications blackout during reentry due to ionization plasma surrounding the vehicle preventing communications to and from the ground or space assets.

Manage Environment

Monitor/Control Internal Environmental Systems

Managing Internal Environment Sub-function includes the procedures and tasks necessary to ensure the environmental subsystems are functioning and have adequate consumables/non-consumables required for the flight. Internal environment subsystems are constrained to those used to provide the necessary life support to sustain living occupants on-board an RLV. These internal environmental subsystems also shield occupants from hazardous environments both natural and induced, throughout its entire flight regime. See Subsystems Volume 1 of this document. These systems may include atmospheric control (temperature, pressure, humidity, contamination, and composition (e.g., O_2 and CO_2 levels)) and supply of breathable atmosphere, water treatment, and waste management.

Track/Surveil Flight Environment

In addition to the internal environment management, there are also several elements regarding the management of the external environment: tracking, surveiling, and COLA/COMBO analyses. Tracking may be done using an optical, radar, inertial navigation system or GPS system. Tracking data is used to compare actual and nominal flight trajectories, verify performance in conjunction with telemetry, and identify violations of flight safety limits.

During on-orbit operations, COMBO computes the “real-time” separation between vehicles in orbit and identifies when a station change or on-orbit maneuver is required to avoid collision. Additionally, before de-orbit, a COMBO analysis is performed to ensure the safe de-orbit of an RLV and/or payload.

In general, surveil means to subject to surveillance and it is the systematic observation of the aerospace environment by visual, aural, electronic, photographic or other means. It includes the detection, characterization, and observation of aircraft, ships, space vehicles, other vehicles, people, and weather phenomena for the purpose of conducting flight operations in a safe and efficient manner.

Surveilling encompasses the collision avoidance of space assets and debris while leaving the atmosphere to achieve orbit or sub-orbit; on-orbit or in sub-orbit; and entering the atmosphere. Surveilling also encompasses the utilization of the ATC for passage through the NAS. Of primary concern are any operations or natural occurrences that may affect the safety of the RLV and hence the possible breakup over populated areas.

During the Deorbit/Reenter Function, Manage Environment includes the management of shielding the occupants from hazardous environments both natural and induced.

During Deorbit/Reenter and Land, the Track/Surveil Flight Environment Sub-function ensures the RLV’s state vector is known and provides input for collision avoidance of space assets and debris while deorbit and reentering the atmosphere.

Manage Flight

This function will evolve based on the particular CONOPS the FAA finalizes as well as that of the operator’s. Interaction with ATC and STC will change over time based on the implementation of the integration of RLVs into the NAS as mentioned in the DO2 report.[17]

Interact with ATC/STC

During RLV operations it will be necessary to coordinate and collaborate with multiple ATM agencies: ATC (Air Traffic Control) authorities to establish and maintain airspace reservation and NOTAMs of potential in-flight hazards associated with the launch/landing of the RLV; with STC (Space Traffic Control) authorities for on-orbit allocation; and with the Coast Guard for NOTMARs of over-flight hazards during launch/landing.

Ground traffic controllers are envisioned to be responsible for traffic control, scheduling, coordinating, and possibly tasks for RLV launch and landing. They also communicate vehicle specific information to other traffic controllers.

During the Launch, Deorbit/Reenter, and Land Functions, interaction with ATC/STC will utilize the Track/Surveil Sub-function, data and voice communication/coordination, and control of the RLV airspace.

Control Flight

During the Launch, Fly, Deorbit/Reenter, and Land Functions, the Control Flight Sub-function sends commands to the Flight Control Subsystem in order to orient the RLV, using the attitude engines and/or gimballing the main engines or using aerodynamic control surfaces in order to safely and successfully keep the RLV in the correct attitude and flight path.

Propel

The Propel Sub-function is directly related to and perhaps considered subordinate to Control Flight function.

The Launch Function will fire the main engines or motors in order to increase the velocity of the vehicle to achieve orbital velocity or the velocity required for a sub-orbital mission. The RLV may also be equipped with attitude control/station-keeping engines as well as main engines that may be gimbaled for flight control. Therefore the Propel Sub-function is also used during Launch for attitude control.

Used by the Fly Function, Propel will fire the orbit change engines or motors in order to change the velocity of the vehicle causing it to change orbit. The Propel Sub-function, during Fly, therefore is also the act of keeping attitude and station keeping. Managing the on-orbit flight operations include the nominal station keeping maneuvering, orbit change maneuvers and attitude adjustments. While not directly under the jurisdiction of FAA/AST these on-orbit operations are pertinent to the extent they affect public safety.

During Deorbit/Reenter, the Propel Sub-function acts by firing the Deorbit engines or motors in order to change the velocity of the vehicle causing it to follow a trajectory taking it out of its nominal orbit for a return to earth. The RLV may also be equipped with descent engines for the reentry part of the flight causing the vehicle to slow on reentry. Additionally, the Reaction Control System (RCS) engines may be utilized for proper orientation during Deorbit/Reenter flight regime.

For the Land Function, the Propel Sub-function is the act of firing the landing engines or motors in order to decrease the velocity of the vehicle for landing. The

RLV is also equipped with attitude control/station keeping engines. The Propel Sub-function, during Land in conjunction with aerodynamic surfaces while in the atmosphere, is also the act of keeping attitude while performing the landing maneuvers.

Stage

During Launch, Stage may include the fly-back of jettisoned RLV pieces.

Command and Control FSS

The FSS can include both non-destructive and destructive methods to “safe” the operation. The non-destruct methods involve commanding the vehicle to a safe configuration (e.g., expelling all hazardous materials prior to landing).

The destructive method has traditionally been referred to as the Range Safety System (RSS) or Flight Termination System (FTS). This system typically has two commands (arm and fire) transmitted from the ground station when a malfunctioning launch vehicle violates established flight safety limits. However, transmitting these two commands can be done simultaneously as seen in Sea Launch’s Thrust Termination System (TTS).

Current FAA/AST guidance defines FSS as “a system designed to limit or restrict the hazards to public health and safety and the safety of property presented by a launch vehicle or reentry vehicle while in flight by initiating and accomplishing a controlled ending to vehicle flight. A flight safety system may be destructive resulting in intentional break up of a vehicle or nondestructive, such as engine thrust termination enabling vehicle landing or safe abort capability.”[18]

It is envisioned that typically the FSS employment during an RLV Fly phase will involve non-explosive contingency operations. This is to minimize orbital debris.

During the Land Function the Flight Safety System (FSS) could involve the destructive method of FSS if it was warranted for public safety or it may involve the non-destructive methods in order to prevent a debris problem. FSS in the Land Function is intended to configure the vehicle to the safest state.

5.2.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Conduct General Flight Operations Function:

General

Conduct Gen Flight GIC - 1. Ground and flight crews should be adequately trained to assess:

1. Correctness of the displays of individual sensors
2. Correctness of the displays of data fusion from different sensors
3. Error messages

4. Corrective actions recommended in the Operations Manual.

Conduct Gen Flight GIC - 2. The flight crew or RLV operator should be adequately trained to react to a degraded situation presented by the health monitor/manager where human intervention is necessary.

Manage Vehicle Health

Conduct Gen Flight GIC - 3. During Conduct General Flight Operations, any anomalous vehicle health information should be shared with the FAA/ATC in case contingency-landing sites may be needed.

Conduct Gen Flight GIC - 4. If health monitors/managers fail in capturing degrading situations, or in making the situation known to the ground and/or flight crews in a timely manner, problems should be mitigated to bring the vehicle to a safe condition.

Communicate

Conduct Gen Flight GIC - 5. During any Operations Function the following key communications elements should be considered: Data Rates, Latency, Bit Error Rates, Frequency, Bandwidth, and Distance.

Manage Environment

Conduct Gen Flight GIC - 6. Surveillance hand-off should be positively confirmed so that contact with the RLV is maintained at all times while switching responsibility from one tracking/surveillance site to another.

Conduct Gen Flight GIC - 7. Environmental considerations should include:

1. Shielding of humans from chemical, biological or radiation hazards that may be present in payload cargo
2. Vibration requirements (vibration frequency dampened to levels tolerable to humans)
3. Acoustic requirements
4. Gravitational acceleration (within tolerance for humans)

Conduct Gen Flight GIC - 8. Operation and maintenance of Environmental Systems for human-rated vehicles should address all of the environmental factors for the specific mission.

Conduct Gen Flight GIC - 9. Internal Environmental Management should consider operability of:

1. Breathable air
2. Pressure
3. Thermal conditioning of environment
4. Water supply for consumption and hygiene
5. Shielding from electromagnetic energy from space
6. Waste removal
7. Carbon dioxide removal
8. Food
9. Shielding of humans from chemical, biological or radiation hazards that may be present in payload cargo
10. Vibration requirements
11. Acoustic requirements (less than the max tolerance for humans)
12. Gravitational acceleration (within tolerance for humans)
13. Fire Detection, Suppression and Extinction

Conduct Gen Flight GIC - 10. Weather surveillance should consist of radiosonde observations, radar tracking of weather balloons, radar, satellite IR and imagery.

Conduct Gen Flight GIC - 11. Future CONOPS should require that surveillance include on-orbit collision avoidance functions similar to COLA for pre-launch assessments and COMBO while on-orbit.

Conduct Gen Flight GIC - 12. Considerations for addressing surveillance during launch, recovery, and abort site operations are a current topic being discussed by the ARTWG Tracking and Surveillance Working Group[19]. These issues should include:

1. Latency and Update Rates
2. Position Accuracy
3. Degree of interoperability with FAA Space and Air Traffic Management System (SATMS)
4. Redundancy (hardware and data)
5. Weather Surveillance including forecasts, winds, catastrophic weather warnings, cloud ceilings, visibility, and lightning

6. Identification and Planning for abort sites
7. Definition of a Toxic Corridor (if applicable, based on propellants on-board)

Conduct Gen Flight GIC - 13. Hazardous materials (propellant on-board) should not be jettisoned or vented over populated areas.

Manage Flight

Conduct Gen Flight GIC - 14. For daily operations, ground command capability should be provided to power-up, power-down and reconfigure systems as required for turnaround.

Conduct Gen Flight GIC - 15. Flight Operations approval should ensure:

1. Crew should be approved for command generation
2. Procedures for Flight Safety should be approved
3. Hardware & software on the vehicle should be approved for flight-worthiness for safety

Conduct Gen Flight GIC - 16. Engine combustion stability and motor burn status should be monitored for compliance to Operations Manual of the RLV.

Conduct Gen Flight GIC - 17. The Flight Control system should operate with the propulsion system ensuring system reliability is maintained.

Conduct Gen Flight GIC - 18. Engines should be throttled as required.

Conduct Gen Flight GIC - 19. Activation of the reaction control engines should maintain proper vehicle attitude control as required.

Conduct Gen Flight GIC - 20. Checklists for normal as well as emergency Propulsion Subsystem situations should be approved for operations.

Conduct Gen Flight GIC - 21. Ground flight crew should be approved for FSS implementation.

Conduct Gen Flight GIC - 22. Flight safety consists of evaluating the Flight Safety System (FSS) prior to launch and should include monitoring the vehicle and environmental conditions during flight operations.

Conduct Gen Flight GIC - 23. Procedures for Flight Safety and Flight Termination should be approved.

5.2.2.1 Inter/Intra Agency

The following Conduct General Flight Operations Function inter/intra agency considerations were identified:

1. During prep-for-launch operations, coordination with NORAD (for COLA) and with ATM for planning should occur.
2. During the launch/takeoff/ascent/deorbit/reentry and landing portions of flight, real-time coordination, data sharing, and situational awareness between the RLV operator and the NAS Air Traffic Control (ATC) system should occur for NAS integration (i.e., Special Use Airspace (SUA) reservation, and Notices to Airmen (NOTAMs)) to include:
    a. Movement through and in the national airspace
    b. ATC for NAS integration
    c. ATC for flight corridor
    d. Military operators for coordination with military air/space traffic
    e. Coordination with the Coast Guard regarding Notices to Mariners (NOTMARs) for those launches/reentries that occur over bodies of water with marine traffic.
3. The fuels associated with the thrusting components may be hazardous - follow OSHA guidelines for all human handlers; follow EPA rules for environmental issues and HAZMAT rules for transport of these fluids.
4. The Federal Communications Commission (FCC) should be coordinated with for frequency allocation and non-interference issues for all flight phases.
5. There may be bilateral or other understandings required between different countries in allowing a flight through a foreign airspace as well as over-flight risks. While planning a flight for both a normal flight and for contingencies, an established protocol for recognizing alternate spaceports should be developed. The US State Department should be coordinated with regarding these.

5.2.3 Guideline Recommendations

Conduct Gen Flt Ops GI - 1. **Payload Environment Operations**
Guideline Input Operations and maintenance plans shall verify correct operation of payload interaction with RLV.
Rationale The environment of the payload must be maintained. Payload systems are integrated with the RLV controls as needed for the mission. For example, the payload may be a satellite that would be released at a certain position. This payload would have to be integrated with the devices that would make possible the release of the payload without collision risk to the vehicle.

Conduct Gen Flt Ops GI - 2. **Health Management**

Guideline Input

The RLV operator shall be able to monitor and control the RLV's health.

Rationale

The purpose of managing RLV subsystems includes: detection and mitigation of functional failures and degraded component performance to assess and prevent the impact of a failure on the safety of the RLV state and identification of maintenance actions required prior to the next flight. Managing the RLV's health is a safety critical operation performed during all flight operations. The RLV's subsystems health and integrity are monitored and may be transmitted to ground processing facilities in a mission control center. This involves data and voice communications. Automated capabilities within the health management subsystem or manually controllable capabilities may be utilized to maintain vehicle system operational integrity.

Uses for data from health monitors:

1. Automated vehicle ground checkout
2. On-board monitoring throughout both ground and flight ops
3. Automated approach and landing
4. Leak detection
5. Automated inspection of engines
6. Automated inspection of electromechanical actuators
7. Automated valve checkout
8. Automated checks of avionics
9. Automated checks of cables
10. Trend analysis of historical data and decision of maintenance actions
11. Automated propellant inspection

Conduct Gen Flt Ops GI - 3. **Air Traffic Management Communications**

Guideline Input

The RLV operator shall maintain two-way communications with Air Traffic Management (ATM) through all phases of RLV operations.

Rationale

During RLV operations it will be necessary to communicate with Air Traffic Management (ATM) entities. ATC (Air Traffic Control) will issue notifications to aviators (NOTAMs) of potential in-flight hazards and the Coast Guard for notification to mariners (NOTMARs) of potential over-flight hazards during launch/landing of the RLV.

Conduct Gen Flt Ops GI - 4. **COLA and COMBO Analyses**

Guideline Input

COLA and COMBO analyses shall be performed to ensure that there will not be a collision with on-orbit assets or space debris.

Rationale

This may entail the Tracking and Surveillance of the space environment in proximity to the RLV. Managing the RLV's environment will provide necessary data for the COLA and COMBO analyses. Additionally, micrometeoroid collisions will pose hazards to the RLV. For example, the Space Shuttle has suffered micrometeoroid collisions, which although not catastrophic, did cause significant damage that required replacement of the front view ports among others during turnaround processing for the next flight.[20]

Conduct Gen Flt Ops GI - 5. **Monitoring Operability of Safety Critical Systems During Flight Operations**

Guideline Input

The RLV operator shall monitor the operational status of all safety critical systems while performing all flight operations.

Rationale

Safety critical systems are those systems previously identified in the Operations Manual that if a malfunction or failure occurs will have an immediate affect on the integrity of the RLV thus impacting public safety. Monitoring these safety critical systems will allow the RLV operator the ability to prevent, troubleshoot, and safely operate these systems. The state/condition data for vehicle systems, GSE, and facilities must be communicated to the appropriate operations centers to ensure the ability to determine the status of the safety critical systems.

5.3 Launch

In 14 CFR 401, FAA/AST has defined Launch as the following: "Launch means to place or try to place a launch vehicle or reentry vehicle and any payload from Earth in a suborbital trajectory, in Earth orbit in outer space, or otherwise in outer space, and includes activities involved in the preparation of an RLV for flight, when those activities take place at a launch site in the United States. The term launch includes the flight of a launch vehicle and pre-flight ground operations beginning with the arrival of a launch vehicle or payload at a U.S. launch site. … For other orbital RLVs, flight ends upon completion of the first sustained, steady-state orbit of an RLV at its intended location."[21]

In this document, RTI examined individual functions; thus isolating the Launch Function in this section to mean the pre-flight validation that all systems are ready for launch and the actual launch of the RLV. These sub-functions are defined in Table 7.

Table 7 Launch Operations Definitions

Perform Preflight Checklists	*[Operations→Perform Flight Operations→Launch→Perform Preflight Checklists]* The Perform Preflight Checklists Sub-function is the set of tasks and procedures outlined in checklist form that are required to be performed as final checks for launch and for the actual launch.
Execute Launch	*[Operations→Perform Flight Operations→Launch→Execute Launch]* The Execute Launch Sub-function is the set of tasks and procedures required to manage the launch/takeoff operations of the RLV.

5.3.1 General Discussion

General

The Launch Function, as defined in this document, includes the procedures performed just prior to first motion of the RLV (similar to aircraft takeoff procedures), initiation of first motion and ascent to mission altitude. "Ascent to mission altitude" is the flight of the vehicle to the height of its suborbital trajectory or insertion into its mission orbit.

Perform Preflight Checklists

Just prior to executing launch, the Pre-Flight Checklist is conducted and all final preparation for the flight of the RLV occur. This final preparation is driven to some extent by the launch/takeoff method/configuration of the RLV.

If the vehicle utilizes a vertical takeoff, such as the Shuttle or Delta-Clipper (DC-X), the procedures that will be performed just prior to first motion may be similar to those used for rocket launches today including movement of gantries/mobile service towers and disconnection of servicing umbilicals (e.g., on-ground power, communications). Horizontal takeoff RLVs may have procedures not unlike those used for aircraft. Airborne launched RLVs such as SpaceShipOne and DaVinci will need pre-flight procedures that address launch requirements both on the launch platform and the RLV. Once the preflight checklist has been accomplished the RLV is cleared to execute launch/takeoff.

Execute Launch

After first motion occurs, the RLV is in the initial ascent phase of launch. During this period, functions that may occur include staging, communications, as well as the possibility to terminate the ascent by landing back at the takeoff site, an alternate abort site or activating the on-board flight safety system.

The detailed execute launch procedures of the RLV will depend on the RLV operator's vehicle-specific CONOPS; however, takeoff and initial ascent are among the most hazardous portions of space flight (re: Challenger accident in 1986, Titan IV 1993 and 1998). This is also analogous to safety critical phases of flight in the aviation domain. For example, ~20% of fatalities (~16% of accidents) in the Worldwide Commercial Jet Fleet between 1993 and 2002 occurred during the takeoff and initial climb phase of flight.[22] This is very significant considering takeoff and initial climb only account for ~2% of the total flight time for these vehicles.

5.3.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Launch Sub-function:

General

Launch GIC - 1. A ground-automated sequence should perform a system checkout without manual intervention. These should include:

1. Automated inspection of engines
2. Automated inspection of electromechanical actuators
3. Automated valve checkout
4. Automated checks of avionics
5. Automated checks of cables
6. Automated propellant inspection
7. Perform anti-skid brake inspections and check electrical power/pedal calibration integrity and hydraulic control valves

Perform Preflight Checklists

Launch GIC - 2. Preflight checklists should check the following environmental conditions and situation to ensure they are in nominal tolerances for launch:

1. Vehicle and ground support equipment are ready for launch

2. Cross-winds and upper level winds are within specifications
3. Weather (to include lightning) is within tolerance
4. Abort site(s) availability
5. Integration into the NAS has been cleared
6. Impact limit lines are defined and verified
7. Launch area surveillance is clear
8. Launch area safety areas are clear

Launch GIC - 3. The pre-flight checklist should include measures to verify adequate quantities of mitigation agents are available to the crew, pressure levels are within required limits, and shelf life extinction will not occur during the mission.

Launch GIC - 4. All communications, fuel, and instrumentation checks should be performed during the Perform Preflight Checklists.

Launch GIC - 5. If applicable, landing gear stowage should be identified as a critical process and, therefore, part of the preflight checklist.

Launch GIC - 6. Pre-launch engine and motor checklists should be performed.

Launch GIC - 7. Checks should be conducted for primary and backup life support systems.

Launch GIC - 8. Integrity of connections between the payload and the RLV should be maintained.

Launch GIC - 9. Chemicals used for fire suppression and explosion suppression should be checked for adequate pressure levels, and freshness.

Execute Launch

Launch GIC - 10. Checks of critical subsystem conditions should be performed during launch/ascent to ensure all systems are operating nominally. If non-nominal conditions occur, contingency and/or emergency procedures should be implemented and the status of flight should be communicated to NAS and RLV flight operators/controllers.

5.3.2.1 Inter/Intra Agency

The following Launch Function inter/intra agency considerations were identified:

1. During the launch portions of flight, real-time coordination, data sharing and situational awareness between the launch operator and the NAS Air Traffic Control (ATC) system shall occur.

2. The Federal Communications Commission (FCC) should be coordinated with for frequency allocation and non-interference issues for all flight phases.
3. The operation of, and fuels associated with, thrusting components may be hazardous. EPA rules for environmental issues, such as noise abatement as well as plume and exhaust impingement, should be adhered to.
4. There may be bilateral or other agreements required between different countries in allowing a flight through a foreign airspace as well as over-flight risks. While planning a flight for both a normal flight and for contingencies, an established protocol for recognizing alternate spaceports should be required. The US State Department should be coordinated with regarding these flights. Presently, the State Department is instrumental in coordinating over-flight of foreign countries.

5.3.3 Guideline Recommendations

Launch GI - 1. **Preflight Checklist Requirements**
Guideline Input As part of the Preflight Checklist, the RLV operator shall conduct a comprehensive test and checkout of safety critical subsystems to ensure flight-worthiness criteria have not been compromised.
Rationale Takeoff and initial ascent are among the most hazardous portions of space flight (re: Challenger accident in 1986, Titan IV 1993 and 1998). This is also analogous to safety critical phases of flight in the aviation domain. For example, ~20% of fatalities (~16% of accidents) in the Worldwide Commercial Jet Fleet between 1993 and 2002 occurred during the takeoff and initial climb phase of flight.[23] This is very significant considering takeoff and initial climb only account for ~2% of the total flight time for these vehicles.

Launch GI - 2. **Launch Safety Clear Zone Enforcement**

Guideline Input

RLV operator shall enforce the safety clear zone identified in the Ground Operations Hazard Analysis.

Rationale

The Ground Operations Hazard Analysis performed by the RLV operator and approved by the FAA identifies the limit/proximity criteria for acceptable public/non-mission essential personnel risk.

5.4 Fly

The Fly Function consists of the sub-functions, tasks, and procedures for conducting on-orbit or sub-orbital flight operations associated with what has traditionally been called the “mission”. In essence, it is the time during which the RLV fulfills its purpose for the flight.

Specific Fly Functions include Deploy Payload, Retrieve Payload, Conduct Extravehicular Activities, and Conduct Other Mission Activities. The sub-functions are defined in Table 8.

Table 8 Fly Operations Definitions

<table>
<tr><td rowspan="10">Conduct Mission</td><td colspan="2">[Operations→Perform Flight Operations→Fly→Conduct Mission]</td></tr>
<tr><td colspan="2">The Conduct Mission Sub-function, while not a direct RLV O&M public safety function, is included because it may impact overall RLV safety critical operations. Conduct Mission includes those sub-functions, tasks, and procedures required for the RLV operator to accomplish the desired goal and intent of the RLV flight. These may include deploying or retrieving a payload, conducting extra-vehicular activities, or other mission activities as required.</td></tr>
<tr><td rowspan="2">Deploy Payload</td><td>[Operations→Perform Flight Operations→Fly→Conduct Mission→ Deploy Payload]</td></tr>
<tr><td>The Deploy Payload Sub-function encompasses the tasks required to jettison, extend using a robotic arm, or “launching” the payload to the desired location for mission accomplishment.</td></tr>
<tr><td rowspan="2">Retrieve Payload</td><td>[Operations→Perform Flight Operations→Fly→Conduct Mission→ Retrieve Payload]</td></tr>
<tr><td>The Retrieve Payload Sub-function includes the tasks and procedures necessary to grab/recover, secure, and place the payload into a bay in the RLV.</td></tr>
<tr><td rowspan="2">Conduct Extra-vehicular Activity</td><td>[Operations→Perform Flight Operations→Fly→Conduct Mission→ Conduct Extra-vehicular Activity]</td></tr>
<tr><td>The Conduct Extravehicular Activities Sub-function includes the tasks and procedures for human activities performed external to the RLV while in flight.</td></tr>
<tr><td rowspan="2">Conduct Other Mission Activities</td><td>[Operations→Perform Flight Operations→Fly→Conduct Mission→ Conduct Other Mission Activities]</td></tr>
<tr><td>The Conduct Other Mission Activities Sub-function encompasses other mission specific tasks such as experiments on-board the RLV.</td></tr>
</table>

5.4.1 General Discussion

General

The Fly Function is the on-orbit or the lofted part of a sub-orbital launch. It is recognized that FAA/AST currently has no explicit on-orbit authority for this phase of flight; this material is presented for completeness and for how it affects reentry. However, there may be tasks, operations, or procedures performed on-orbit that may affect the deorbit and reentry of the RLV. These are items pertinent to FAA/AST as they may affect public safety.

Conduct Mission

While four sub-functions have been identified for the Conduct Mission Sub-function, the Deploy and Retrieve Payload Sub-functions may have a direct affect on the safety of the RLV, passengers, and possibly the general public.

Deploying a payload may be accomplished in several ways. A jettison payload activity may return a payload through the atmosphere for scientific or commercial purposes. Extending the payload may place it in an orientation to achieve its mission, yet not separate it from physical control of the RLV. “Launching” the payload may involve igniting the boost stage of the payload to place it in its usable orbit. The risk to public safety must be assessed for these types of deployments.

The retrieval of a payload may involve safing and securing it within the RLV. Residual fuels may remain on-board the payload. The payload may additionally contain hazardous material. These conditions may pose a risk to public safety.

5.4.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Fly Sub-function:

General

Fly GIC - 1. Collision with orbital man-made objects or micrometeoroids while on orbit should be mitigated.

Fly GIC - 2. State vectors should be accurate for planning any maneuver.

Fly GIC - 3. Sufficient propellant should be available to deorbit and reenter.

Conduct Mission

Fly GIC - 4. Prior to a mission, mission analysts should determine the trajectory and desired attitude profile that will satisfy all the mission requirements.

5.4.2.1 Inter/Intra Agency

The following Fly Function inter/intra agency considerations were identified:

1. During the flight, real-time coordination, data sharing, and situational awareness between the launch operator and the NAS Air Traffic Control (ATC) system shall occur.
2. The Federal Communications Commission (FCC) should be coordinated with for frequency allocation and non-interference issues for all flight phases.
3. During flight operations, coordination with NORAD (for COLA and COMBO) and with ATM for planning should occur.
4. NASA should be consulted for COLA and COMBO interfaces for commercial launches under the Global Partnership Initiative.

5.4.3 Guideline Recommendations

Fly GI - 1. **On-orbit COMBO Analysis**
Guideline Input The COMBO analysis shall be reaccomplished on-orbit utilizing updated ephemeris data.
Rationale The initial COMBO analysis performed utilized propagated ephemeris of orbiting objects and the RLV's project flight path. Once on-orbit, the RLV's flight path is known and the orbiting object state vectors will have been updated. These two elements will allow a more accurate COMBO analysis for any on-orbit maneuvering. Additionally, this will also maintain the established 200km separation criteria for manned spacecraft.[24]

5.5 Deorbit/Reenter

The Deorbit/Reenter Function encompasses the performance of all necessary functions, tasks, and procedures that are performed to place the RLV on a trajectory which takes it out of its nominal orbit and brings it into the Earth's atmosphere. The sub-functions are defined in Table 9.

Table 9 Deorbit/Reenter Operations Definitions

Configure for Deorbit/Reentry	*[Operations→Perform Flight Operations→Deorbit/Reenter→Configure for Deorbit/Reentry]* The Configure for Deorbit/Reentry Sub-function includes the tasks and procedures necessary to prepare the RLV for a safe deorbit and reentry.
Execute Deorbit/Reentry	*[Operations→Perform Flight Operations→Launch→Manage Launch]* The Execute Deorbit/Reentry Sub-function is the set of tasks and procedures required to accomplish the deorbit/reentry operations of the RLV.

5.5.1 General Discussion

General

Deorbit procedures include orienting the RLV into the appropriate attitude (i.e., flight path angle) for deorbit and executing the deorbit burn that establishes the proper velocity and range conditions for reentry.

Reenter refers to the RLV entering the sensible atmosphere after deorbit. The sensible atmosphere is defined as the altitude at which the atmosphere offers measurable resistance to a body passing through it.

FAA guidance provides the following definition:

> Reenter; reentry means to return or attempt to return, purposefully, a reentry vehicle and its payload, if any, from Earth orbit or from outer space to Earth. The term ``reenter; reentry'' includes activities conducted in Earth orbit or outer space to determine reentry readiness and that are critical to ensuring public health and safety and the safety of property during reentry flight. The term ``reenter; reentry'' also includes activities conducted on the ground after vehicle landing on Earth to ensure the reentry vehicle does not pose a threat to public health and safety or the safety of property. [25]

Reentry actually occurs at the Earth's sensible atmosphere, approximately 400,000 feet above sea level. This point is called the reentry interface.

It should be noted that stages shed from an RLV must also deorbit/reenter safely. Stages on a fully reusable vehicle are flown back or returned to earth for reuse (e.g., the Space Shuttle's Solid Rocket Boosters (SRBs)). For partially reusable vehicles, stages may be expended. These expended stages must be returned to earth safely as is currently done with the Space Shuttle's external tank or placed into a safe orbit.

Configure for Deorbit/Reentry
Deorbiting an RLV assumes it is in a nominal orbit about the Earth. In order to return the RLV to Earth it must be removed from the nominal orbit and placed on a trajectory that allows the RLV to reenter the atmosphere. A change in velocity is used to accomplish this action. The RLV attitude is adjusted and refined to ensure proper alignment for the deorbit thruster burn and reentry angle.

Execute Deorbit/Reentry
This Deorbit maneuver is critical to the RLV since it places it on the trajectory to reenter the Earth's atmosphere exposing the vehicle to the most extreme thermal loads.

Various procedures/systems may be employed for reentry and are dependent on the RLV design. For example, the Thermal Protection Subsystem is critical during the reentry phase; however, the type of thermal protection employed varies amongst vehicle designs. Additionally, any bay doors and hatches must be closed and sealed to prevent reentry plasma leaks into the RLV that may cause vehicle breakup.

5.5.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Deorbit/Reenter Sub-function:

General

Deorbit/Reenter GIC - 1. Proper orientation and velocity to achieve safe deorbit and reentry should be maintained.

Deorbit/Reenter GIC - 2. Debris scattering should be mitigated in the event of vehicle breakup.

Deorbit/Reenter GIC - 3. Thermal and stress loads should be managed using appropriate flight controls and propulsion.

Deorbit/Reenter GIC - 4. Accuracy of the reentry trajectory data should be ensured in order to maintain a safe reentry.

Deorbit/Reenter GIC - 5. Fidelity of the flight and vehicle model should be updated (e.g., debris catalog, debris survivability issues, malfunction turn data, probability of failure, population models) and used for any deorbit/reentry planning/replanning.

Deorbit/Reenter GIC - 6. Communications blackout should be accounted for in the deorbit/reenter procedures.

Configure for Deorbit/Reentry

Deorbit/Reenter GIC - 7. Temperature data during reentry from sensors in the RLV subsurface should be monitored/archived. These data should be used as warnings for impending failure or may help to determine root causes of incidents and accidents.

Execute Deorbit/Reentry

Deorbit/Reenter GIC - 8. During the deorbit/reentry portions of flight, real-time coordination, data sharing, and situational awareness between the RLV operator and the NAS Air Traffic Control (ATC) system should occur.

Deorbit/Reenter GIC - 9. A ground command capability should be provided to execute deorbit/reentry.

Recommendations from the Columbia Accident Investigation Board[26]:

Deorbit/Reenter GIC - 10. An on-orbit Thermal Protection Subsystem inspection should be conducted early in flight.

5.5.2.1 Inter/Intra Agency

The following Deorbit/Reenter Function inter/intra agency considerations were identified:

1. There may be bilateral or other understandings required between different countries in allowing a flight through a foreign airspace as well as over-flight risks. While planning a flight for both a normal flight and for contingencies, an established protocol for recognizing alternate spaceports should be required. The US State Department should be coordinated with regarding these flights. Presently, the State Department is instrumental in coordinating over-flight of foreign countries.
2. During the deorbit/reentry portion of flight, real-time coordination, data sharing, and situational awareness between the RLV operator and the NAS Air Traffic Control (ATC) system should occur for NAS integration. (e.g., Special Use Airspace (SUA) reservation and Notices to Airmen (NOTAMs)).
3. Communications frequency usage must be compliant with Federal Communications Commission (FCC) regulations.

5.5.3 Guideline Recommendations

Deorbit/Reenter GI - 1. **Reentry Debris Risk Mitigation**
Guideline Input The RLV operator shall prevent/mitigate public risk associated with debris generated as the result of nominal RLV staging or the uncontrolled deorbit of the RLV/elements.
Rationale Debris hazard is a direct public safety concern. The United Nations General Assembly has established a multilateral policy for the safe deorbit and reentry of launch vehicle stages[27]. The United States has provided the following inputs for adoption: 1. Launch vehicle sub-orbital stages will be equipped with tracking aids to permit monitoring of trajectories and prediction of impact points. 2. Launch vehicle sub-orbital stages will be equipped with a remotely controlled engine shut-off and/or stage destruction capability, as appropriate, in order to prevent the descent of stages/or stage debris outside predefined safety limits. 3. The design of orbital stages will support the capability of being safely de-orbited or moved to a disposal orbit, as appropriate.

5.6 Land

The Land Function includes the performance of all necessary sub-functions, tasks, and procedures to return an RLV to earth on land or water.

The Land Function is the set of sub-functions employed after reentry to maneuver the RLV descent, final approach and landing. The specific Landing sub-functions include Activate Landing Gear and Execute Landing Sub-Functions. The sub-functions are defined in Table 10.

Table 10 Land Operations Definitions

Activate Landing Gear	*[Operations→Perform Flight Operations→Land→Activate Landing Mechanism]* The Activate Landing Gear Sub-function includes the tasks and procedures for deploying the landing mechanism(s) of the RLV.
Execute Landing	*[Operations→Perform Flight Operations→Launch→Manage Launch]* The Execute Landing Sub-function is the set of tasks and procedures required to perform the landing operations of the RLV.

5.6.1 General Discussion

General

Landing and recovery of the RLV are considered activities of reentry by the current FAA CFR 14 Part 400 series. However, it is considered here as a separate sub-function in order to categorize and partition public safety issues.

The landing method for an RLV is dependent on its design and flight configuration. The RLV may employ a horizontal or vertical orientation for landing. It may have multiple stages each of which lands in a different orientation or location.

Activate Landing Gear

If the vehicle lands horizontally the landing is likely to involve landing gear similar to the Shuttle or aircraft (e.g., wheels, brakes, aero-surfaces, drag chutes, etc.). Vertically landed RLVs, such as the Delta Clipper (DC-X), Rotary Rocket and Kistler K-1, employ aero-surfaces, parachutes and/or airbags.

Execute Landing

Continued monitoring and control of the landing gear will occur during the Execute Landing Sub-function. Additionally, if the selected landing site becomes unavailable/unattainable, the changes to the flight plan, based on the new landing site, will need to be calculated and communicated to the appropriate NAS and RLV operators/controllers.

5.6.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Land Function:

General

Land GIC - 1. A water landing should consider marine traffic especially when the vehicle is not under positive control (falling ballistically).

Activate Landing Mechanism

Land GIC - 2. Autonomous landing equipment should be monitored for sufficient power to fully actuate.

Execute Landing

Land GIC - 3. Abort site selection should be based on weather criteria, over-flight risk, and air traffic considerations.

5.6.2.1 Inter/Intra Agency

The following Land Function inter/intra agency considerations were identified:

1. There may be bilateral or other understandings required between different countries in allowing a landing on foreign soil due to an aborted landing. While planning a flight for both a normal flight and for contingencies, an established protocol for recognizing alternate spaceports should be required. The US State Department should be coordinated with regarding these flights. Presently, the State Department is instrumental in coordinating over-flight of foreign countries.
2. During landing, real-time coordination, data sharing, and situational awareness between the launch operator and the NAS Air Traffic Control (ATC) system shall occur.
3. The fuels associated with the thrusting components may be hazardous. EPA rules for environmental issues such as noise abatement as well as plume and exhaust impingement should be followed.

5.6.3 Guideline Recommendations

Parachute Landing
Guideline Input Parachute landing mechanisms shall be stable and maneuverable.
Rationale Any RLV that proposes a parachute landing system must address the following issues: Parachute landing gear must possess the proper porosity (the ratio of the volume of the materials pores to that of its solid content) selection for the parachute. The porosity selected for the parachute must ensure positive inflation stability and reasonable parachute flight stability. NASA research has indicated that too high a porosity value will lead to inflation instability and if the total porosity exceeds approximately 30% the parachute may fail to inflate at the local Mach number of 2.5[28]. Conversely if the parachute porosity is too low, violent oscillatory motions are observed during flight and these may have a de-stabilizing effect on the vehicle. Additionally, regarding the maneuverability of the parachute recovery system, FAA rules on powered parachutes should be examined/applied for the “maneuvered” parachute landing and recovery.

5.7 Perform Contingency Operations (as required)

The Perform Contingency Operations Function includes the sub-functions and tasks required to return the vehicle to a safe configuration and/or return the vehicle to the ground safely in response to anomalous situations/conditions. The sub-functions are defined in Table 11.

Table 11 Perform Contingency Operations Definitions

Manage Other Contingencies	*[Operations → Perform Flight Operations→ Perform Contingency Operations→Manage Other Contingencies]*
	The Manage Other Contingencies Sub-function consists of performing other contingency operations tasks, procedures, and activities as outlined in the Operations Manual for any other potential contingencies identified.
Manage Abort Sequences	*[Operations → Perform Flight Operations→ Perform Contingency Operations→Manage Abort Sequences]*
	The Manage Abort Sequences Sub-function consists of performing the required tasks, procedures, and activities as outlined in the Operations Manual for aborting the RLV's flight.

5.7.1 General Discussion

General

Abort sequences will vary due to their dependency on the RLV's CONOPS and design. They include abort on launch, return to the launch site, proceed to orbit once around and return, return to an alternate landing site, abort to orbit, abort from orbit, or abort during reentry and landing. Any type of abort is considered a contingency in this document.

FAA/AST makes a distinction between contingency and emergency aborts as follows:

> Contingency abort means cessation of vehicle flight during ascent or descent in a manner that does not jeopardize public health and safety and the safety of property, in accordance with mission rules and procedures. Contingency abort includes landing at an alternative location that has been designated as a contingency abort location in advance of vehicle flight.[29]
>
> Emergency abort means cessation of vehicle flight during ascent or descent in a manner that minimizes risk to public health and safety and the safety of property. Emergency abort involves failure of a vehicle, safety-critical system, or flight safety system such that contingency abort is not possible.[30]

Manage Abort Sequences

There are four types of intact aborts: abort to orbit (ATO), abort once around (AOA), transoceanic landing (TOL), and return to launch site (RTLS).

The ATO mode allows the vehicle to reach a temporary orbit that is potentially lower than the nominal orbit. This mode requires less performance and allows time to evaluate problems and then choose either an early deorbit maneuver or an orbital maneuver to raise the orbit and continue the mission.

The AOA is designed to allow the vehicle to fly once around the Earth and make a normal entry and landing. This mode generally involves two orbital maneuvering thrusting sequences, with the second sequence being a deorbit maneuver. The entry sequence would be similar to a normal entry.

The TOL mode is designed to permit an intact landing that may be accomplished via a ballistic trajectory, which does not require an orbital maneuvering system maneuver.

The RTLS mode involves flying downrange to dissipate propellant and then turning around under power to return directly to a landing at or near the launch site.

Manage Other Contingencies
In general, other contingencies may occur during the flight of the RLV. Responses to these contingencies will be documented in a set of contingency plans.

5.7.2 Guideline Input Considerations

The following Guideline Input Considerations have been identified for the Perform Contingency Sub-function:

General

Contingency GIC - 1. The RLV operator's contingency plans should consider vehicle limitations and crew limitations, if any; be executable within mission constraints if possible; provide as much protection to the public as possible.

Contingency GIC - 2. Provisions for contingency operations should be on-board the RLV at all times (e.g., fire/explosion suppression commodities). In order to ensure sufficient mitigation resources during the mission, the pre-flight checklist should include the verification that adequate quantities of mitigation agents are available to the crew.

Contingency GIC - 3. Contingency planning should include the necessary crew support commodities and equipment to allow the crew to survive an extended mission or make emergency repairs resulting from a mishap/malfunction.

Contingency GIC - 4. The RLV operator personnel should be trained, practice, and be evaluated on, flight operations contingency plans, and emergency/disaster preparedness procedures, per FAA-approved pass/fail criteria.

Contingency GIC - 5. During on-orbit operations any anomalous vehicle health information should be shared with the FAA/ATC in case contingency-landing sites may be needed.

Manage Abort Sequences

Contingency GIC - 6. On launch, abort procedures should account for deorbit and reentry.

Contingency GIC - 7. In an abort/emergency-landing scenario, there is a potential for hazardous materials to still be on-board the RLV. Contingency planning and procedures should address the handling and containment of any residual hazardous materials in such a manner as to maintain public safety.

Contingency GIC - 8. "The FAA should allow the developer to develop and test abort maneuvers and procedures in a simulated environment."[31]

Contingency GIC - 9. Contingency abort flight plans should be developed for reentry anomalies.

Manage Other Contingencies

Contingency GIC - 10. The RLV operator should develop contingency plans for the storage, use, and disposal of hazardous materials in the event of a mishap.

Contingency GIC - 11. The RLV operator should develop contingency/emergency procedures that protect the public in the event of a GSE malfunction.

Contingency GIC - 12. Contingency procedures should be developed for anomalous egress conditions.

5.7.2.1Inter/Intra Agency

The following Perform Contingency Operations Function inter/intra agency considerations were identified:

1. During contingency operations, coordination with NORAD (for COLA) and with ATM for planning should occur.
2. During any contingency operations, real-time coordination, data sharing and situational awareness between the launch operator and the NAS Air Traffic Control (ATC) system shall occur.

3. The Federal Communications Commission (FCC) should be coordinated with for frequency allocation and non-interference issues for all flight phases.
4. The National Airspace System (NAS) Air Traffic Management (ATM) should be coordinated with for:
    a. Movement through and in the national airspace
    b. ATC for NAS integration
    c. ATC for flight corridor
    d. Military operators for coordination with military air/space traffic
    e. Coastguard for marine traffic over-flight
5. The fuels associated with the thrusting components may be hazardous - follow OSHA guidelines for all human handlers; follow EPA rules for environmental issues and HAZMAT rules for plume and exhaust impingement.
6. There may be bilateral or other agreements required between different countries in allowing a flight through a foreign airspace as well as over-flight risks. While planning a flight for both a normal flight and for contingencies, an established protocol for recognizing alternate spaceports should be required. The US State Department should be coordinated with regarding these flights. Presently, the State Department is instrumental in coordinating over-flight of foreign countries.

5.7.3 Guideline Recommendations

Contingency GI - 1. **Contingency Planning**
Guideline Input The RLV operator shall develop contingency operations procedures and plans for failures identified in the ground and flight hazard analyses.
Rationale The complex design and system inter-dependencies of a launch vehicle and its payload demand detailed analysis to identify credible failure events and careful planning to develop procedures for mitigating the effects of that failure. Each credible failure event must have a mitigation response plan. In-flight failure mitigation response plans must ensure the desire to continue operation of the RLV does not conflict with the need to mitigate the risk. Most safety critical systems may not be immediately accessible to the crew for visual/tactile detection of potential hazards. Therefore, alerts and warnings must be present to signal the crew that a potential safety hazard exists. For each credible in-flight failure event a crew response plan is required. The crew response plan must document in detail each step necessary to mitigate the safety hazard. The use of crew response plans will decrease the probability for a potential hazard to escalate to an irrevocable catastrophic level. In-flight failures may result in a non-nominal mission timeline. Therefore, it is necessary for life support mission planning to account for contingency supplies. If the RLV payload includes human passengers, the contingency life-support supplies for the crew must be independent from those available to the passengers. This increases the likelihood of crew survival during contingency mitigation efforts and reduces the probability of a catastrophic failure due to loss of the crew.

Contingency GI - 2. **Contingency Landing Sites**

Guideline Input

The RLV operator shall develop contingency landing site plans and document them in the Operations Manual for abort scenarios.

Rationale

It is envisioned that in the event of a landing at an alternate site, a crew will move to the landing site to assist the flight crew in preparing the RLV for transport back to the home launch site. Some of the procedures that will need to be performed will be different from the nominal landing; therefore, there must an approved set of procedures for use by the RLV operations personnel.

Similar to Shuttle operations, for landings outside the U.S., RLV personnel at the contingency landing sites must, as a minimum, be trained on safe handling of the RLV with emphasis on crash rescue, returning the RLV to a safe status, and propellant conflagration prevention.

Appendix A: Acronyms/Terminology

AAAF	Association Aéronautique et Astronautique de France
A&P	Airframe & Powerplant
A/C	Aircraft
AC	Advisory Circular
AD	Airworthiness Directive
ADIZ	Air Defense Information Zones
AETB	Alumina Enhanced Thermal Barrier
AFS	Aviation Flight Standards
AIAA	American Institute of Aeronautics and Astronautics
ALARA	As Low As Reasonably Achievable
AM	Amplitude Modulation
AMF	Astronauts Memorial Foundation
ANPRM	Advanced Notice of Proposed Rule Making
ANSI	American National Standards Institute
AOA	Abort Once Around
AOG	Airplane on Ground
APU	Auxiliary Power Unit
ARAC	Aviation Rulemaking Advisory Committee
ARC	Ames Research Center
ARF	Assembly and Refurbishment Facility
ARINC	Aeronautical Radio, Inc.
ARP	Aerospace Recommended Practice
ASEE	American Society for Engineering Education
ASICS	Application Specific Integrated Circuits
ASME	American Society of Mechanical Engineers
ASQ	American Society for Quality
AST	Office of the Associate Administrator for Commercial Space Transportation
ASTM	American Society for Testing and Materials
ASTWG	Advance Spaceport Technology Working Group
AWS	Aerospace Worthiness Standards
ATA	Air Transport Association
ATAC	Advanced Technology Advisory Committee
ATC	Air Traffic Control
ATM	Air Traffic Management
ATO	Abort to Orbit
ATOS	Air Transport Oversight System
ATSRAC	Aging Transport Systems Rule Making Advisory Committee

AVCS	Air Vehicle Control Station
BCSP	Board of Certified Safety Professionals
BFE	Buyer Furnished Equipment
BITE	Built In Test Equipment
BPSK	Bit Phase Shift Keying
CAA	Civil Aviation Authorities
CAM	Civil Aeronautics Manual
CAR	Code of Aviation Regulations
CASA	Civil Aviation Safety Authority
CASS	Continuous Analysis and Surveillance
CAST	Civil Aviation Safety Team
C-Band	Frequency range between 3.6 and 4.2 GHz
CCAFS	Cape Canaveral Air Force Station
CDR	Critical Design Review
CEI	Contract End Item
CEO	Chief Executive Officer
CFR	Code of Federal Regulations
CIL	Critical Items List
CINCSPACE	Commander In Chief, Space Command
CMR	Certification Maintenance Requirements
CO_2	Carbon Dioxide
COFR	Certificate of Flight Readiness
COLA	Conjunction On Launch Assessment or Collision Avoidance
COMBO	Computation of Miss Between Orbits
COMSTAC	Commercial Space Transportation Advisory Committee
CONOPS	Concept Of Operations
CONUS	Continental United States
CRM	Cockpit Resource Management
CRV	Crew Return/Rescue Vehicle
CVR	Cockpit Voice recorder
dB	Decibel
DACUM	Developing A Curriculum
DARPA	Defense Advanced Research Projects Agency
DCC	Division of Community College
DCN	Document Change Notice
DFRC	Dryden Flight Research Center
DMS	Docket Management System
DNPS	Delaware North Park Services
DO	Delivery Order
DoD	Department of Defense

DOF	Degrees of Freedom
DOT	Department of Transportation
E_c	Casualty Expectation
EIS	Environmental Impact Statement
EFI	Enterprise Florida, Inc.
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOM	End Of Mission
EPA	Environmental Protection Agency
ERP	Emergency Response Plan
ESA	European Space Agency
ESD	Electrostatic Discharge
ESMC	Eastern Space and Missile Center
ET	External Tank
ETMS	Enhanced Traffic Management System
ETOPS	Extended Twin (engines) Operations
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FCC	Federal Communications Commission
FHA	Functional Hazard Assessment
FL	Florida
FM	Frequency Modulation
FMEA	Failure Modes and Effects Analysis
FMEA/CIL	Failure Modes and Effects Analysis/Critical Items List
FMECA	Failure Modes, Effects, and Criticality Analysis
FMS	Flight Management System
FOCC	Flight Operations Control Center
FOQA	Flight Operations Quality Assurance
FR	Flight Recorder
FRCS	Forward Reaction Control System
FRR	Flight Readiness Review
FSDO	Flight Standards District Office
FSO	Flight Safety Officer
FSS	Flight Safety Systems
FTA	Fault Tree Analysis
FTD	Flight Training Devices
FTS	Flight Termination Systems
FY	Fiscal Year
G	Gravitation Acceleration at Sea Level

GLONASS	Global Orbiting Navigation Satellite System
GNC	Guidance, Navigation, Control
GNSS	Global Navigation Satellite System
GOR	Ground Operations Review
GPS	Global Positioning System
GRC	Glenn Research Center
GSE	Ground Support Equipment
GSO	Ground Safety Officer
GSRP	Ground Safety Review Panel
GSS	Ground Support System
HAZMAT	Hazardous Material
HBAT	Handbook Bulletin for Air Transportation
HCF	High Cycle Fatigue
HDTV	High Definition Television
HMI	Human-Machine Interface
HMF	Hypergolic Maintenance Facility
HMR	Hazardous Material Report
HRST	Highly Reusable Space Transportation
HTHL	Horizontal Take Off and Landing
HTVL	Horizontal Take Off and Vertical Landing
HW	Hardware
IASA	International Aviation Safety Assessment
ICA	Instructions for Continued Airworthiness
ICAO	International Civil Aviation Organization
ICF	Instructions for Continued Flight-worthiness
ICHM	Integrated Control and Health Management
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IFR	Instrument Flight Rules
ILL	Impact Limit Lines
ILS	Instrument Landing System
IMU	Inertial Measurement Unit
ISO	International Organization for Standardization
ISS	International Space Station
ITU	International Telecommunication Union
IVHM	Integrated Vehicle Health Monitoring

IV&V	Independent Validation and Verification
JAA	Joint Aviation Authorities
JAR_1	Joint Airworthiness Regulations
JAR_2	Joint Aviation Regulations
JAR-VLA	Joint Aviation Regulations-Very Light Airplanes
JROC	Joint Requirements Oversight Council
JSC	Johnson Space Center
Klb	Kilo Pound
Klbs	Kilo Pounds
KSC	Kennedy Space Center
Ku-Band	Frequency Range from 1.7 to 12.76 GHz
LA	Los Angeles
LCC	Launch Control Complex
LH2	Liquid Hydrogen
LOA	Letter of Agreement
LEO	Low Earth Orbit
LLC	Limited Liability Corporation
LOX	Liquid Oxygen
LRCS	Long-Range Communication System
LRU	Line Replaceable Units
MAKS	Multi-Purpose Aerospace System
MMEL	Master Minimum Equipment List
MEL	Minimum Equipment List
MLP	Mobile Launcher Platform
MMH	Monomethyl Hydrazine
MNPS	Minimum Navigation Performance Specifications Airspace
MRB	Maintenance Review Board
MRM	Maintenance Resource Management
MRO	Maintenance, and Repair, Overhaul
MSFC	Marshall Space Flight Center
MSG	Maintenance Steering Group
MSI	Maintenance Significant Items
MSL	Mean Sea Level
N/A	Not Applicable
NAI	National Aerospace Initiative
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASP	National Aerospace Plane
NAT	North Atlantic
NDE	Non Destructive Evaluations
NIDA	NIDA Corporation

NORAD	North American Aerospace Defense Command
NOTAM	Notice To Airmen
NOTMAR	Notice To Mariners
NPRM	Notice of Proposed Rulemaking
NSP	National Simulator Program
NSLD	NASA Shuttle Logistics Depot
NSTS	National Space Transportation System
NTSC	National Television System Committee
O_2	Oxygen
O&M	Operations and Maintenance
O&S	Operations and Supportability
OEI	One Engine Inactive
OEM	Original Equipment Manufacturer
OJT	On-the-Job Training
OMD	Operations and Maintenance Document
OMDP	Orbiter Maintenance Down Period
OMI	Operations and Maintenance Instructions
OMRS	Operations and Maintenance Requirements Specifications
OMRSD	Operations and Maintenance Requirements Specifications Document
OMS	Orbital Maneuvering System
OPF	Orbital Processing Facility
ORR	Orbiter Readiness Review
OSD/AF	Office of Scientific Development/Air Force
OSHA	Occupational Safety and Health Administration
OSI	Open Systems Interconnect
P_i	Probability of Impact
PAL	Phase Alternation Line
PCM	Pulse Code Modulation
PiC	Pilot in Command
PLC	Programmable Logic Controller
PMA	Parts Manufacturer Approval
PMD	Propellant Management Devices
PMI	Principle Maintenance Inspectors or Preventative Maintenance Inspection
PoC	Point of Contact
PRACA	Problem Reporting and Corrective Action
PRR	Payload Readiness Review

PSI	Pounds per Square Inch
PSRP	Payload Safety Review Panel
Pt.	Part
PVAT	Position, Velocity, Attitude, Time
Q-D	Quantity Distance
QD	Quick Disconnects
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RCM	Reliability Centered Maintenance
RCS	Reaction Control System
RF	Radio Frequency
RLV	Reusable Launch Vehicle
RNAV	Area Navigation
RPM	Revenue Passenger Mile
RPR	Rulemaking Project Record
RPSF	Rotation, Processing & Surge Facility
RSO	Range Safety Officer
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System
RTG	Radioisotope Thermoelectric Generator
RTI	Research Triangle Institute
RTLS	Return To Launch Site
RTS	Return To Service
RTV	Room Temperature Vulcanizing
RVT	Reusable Vehicle Test
SAE	Society of Automotive Engineers
SATMS	Space and Air Traffic Management System
SCAPE	Self-Contained Atmospheric Protective Ensemble
SDP	Safety Data Package
SDR	Service Difficulty Report
SFE	Supplier Furnished Equipment
SGS	Space Gateway Support
SIAT	Shuttle Independent Assessment Team
SLF	Shuttle Landing Facility
SLI	Space Launch Initiative
SME_1	Shuttle Main Engine
SME_2	Subject Matter Expert
S/N	Stock Number
SNPRM	Supplemental Notice of Proposed Rule Making
SOH	State of Health
SOP	Standard Operating Procedure
SPST	Space Propulsion Synergy Team
SRB	Solid Rocket Booster
SRD	Systems Requirements Document

SRM	Solid Rocket Motor
SRSO	Senior Range Safety Officer
SSA	System Safety Assessment
SSB	Single Side Band
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSTO	Single Stage To Orbit
SSV	Space Shuttle Vehicle
STC	Space Traffic Control
STS	Space Transportation System
SUA	Special Use Airspace
SUP	Suspected Unapproved Parts
SW	Software
TAL	Transoceanic Abort Landing
TBD	To Be Determined
TCAS	Traffic Alert and Collision Avoidance System
TOGA	Takeoff/Go-Around
TOL	Transoceanic Landing
TPS	Thermal Protection System
TSA	Transportation Security Administration
TSO	Technical Standard Order
TSOA	Technical Standard Order Authorization
TSPI	Time Space Position Information
TSTO	Two Stage To Orbit
TTS	Thrust Termination System
TVC	Thrust Vector Control
UAV	Unmanned Aerial Vehicle
US	United States
USAF	United States Air Force
USBI	United States Boosters, Inc.
USC	United States Code
VAB	Vehicle Assembly Building
VFC/MFC	Maximum Speed For Stability Characteristics
VDF/MDF	Demonstrated Flight Diving Speed
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omnidirectional Range (navigation system)
VSP	Vision Spaceport Program
VTHL	Vertical Take Off and Horizontal Landing
VTVL	Vertical Take Off and Landing
WSMC	Western Space and Missile Center
WWI	World War 1
Wx	Weather

Appendix B: RLV Guideline Input Suggestion Form

RLV Guideline Input Suggestion Form

Name: ___________________________ Company Name: _________________
Address: ____
City: _______________ State, Postal Code, Country: ____________________
Phone: __________________________ Date: ___________________________
Email: ____

Document: RLV O&M Guideline Inputs – Vol. 2 – Operations
Sec: ______ Page: ____ Line: _______

[ ] Documentation Error (Format, punctuation, spelling)

[ ] Content Error

[ ] Enhancement or Refinement

Rationale (Describe the error or justification for enhancement):
____
____
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Proposed change (Attach marked up text or proposed rewrite):
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____
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Please provide any general comments for improvements of this document:

____
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____
____

Return completed form to:

FAA/AST-100
RLV O&M
800 Independence Ave SW RM 331
Washington DC 20591

Appendix C: Traceability of Operations Function Decomposition

The following figure, Figure 8, reflects the Operations Functional Decomposition as developed for the DO3 effort. Figure 9 reflects the Operations Functional Decomposition as developed for this effort, DO4. The subsequent table, Table 12, provides the sub-function level traceability between the two decompositions. The DO4 decomposition was developed in preparation of a Functional Analysis.

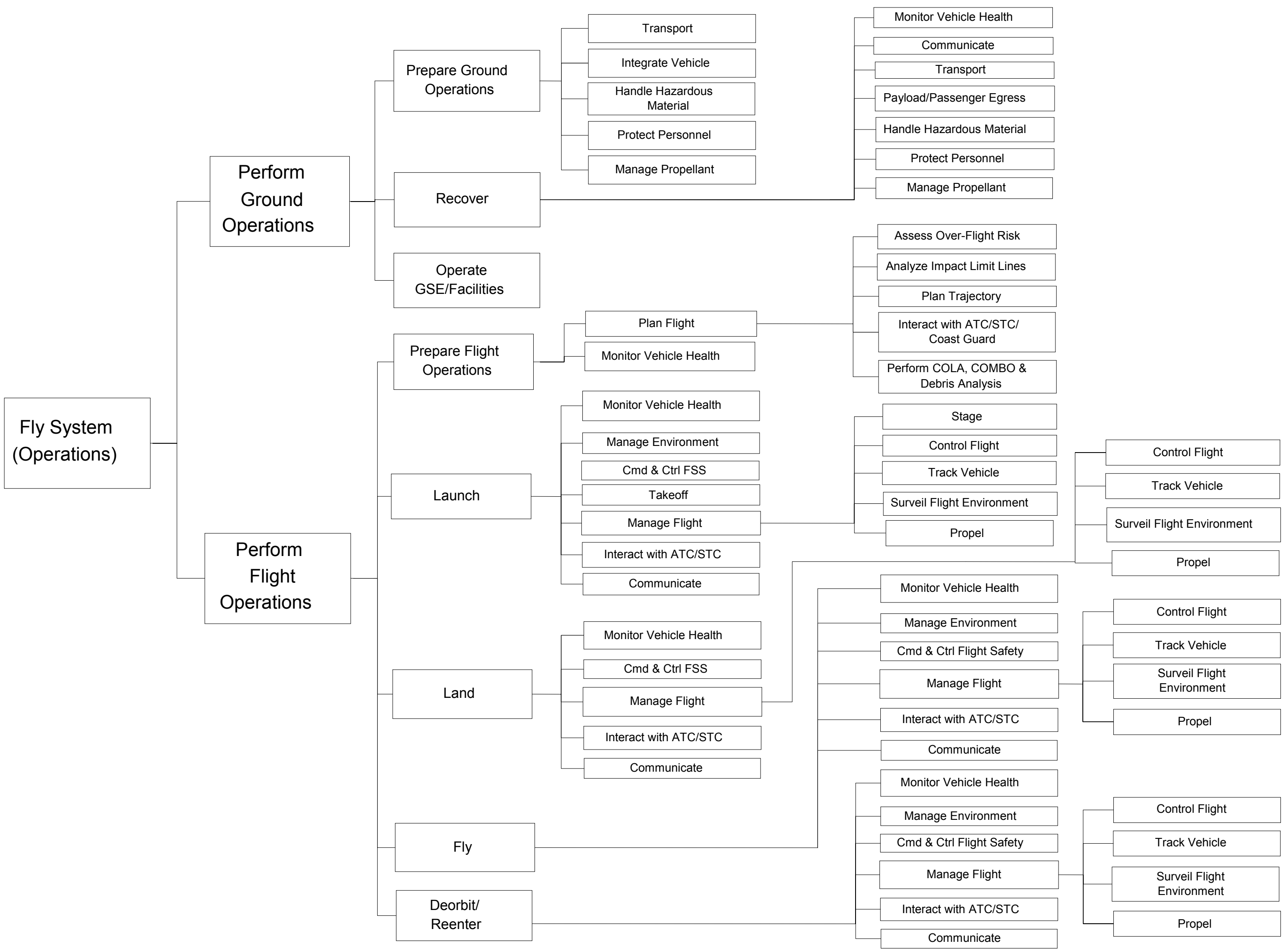

Figure 8 DO3 Operations Functional Decomposition

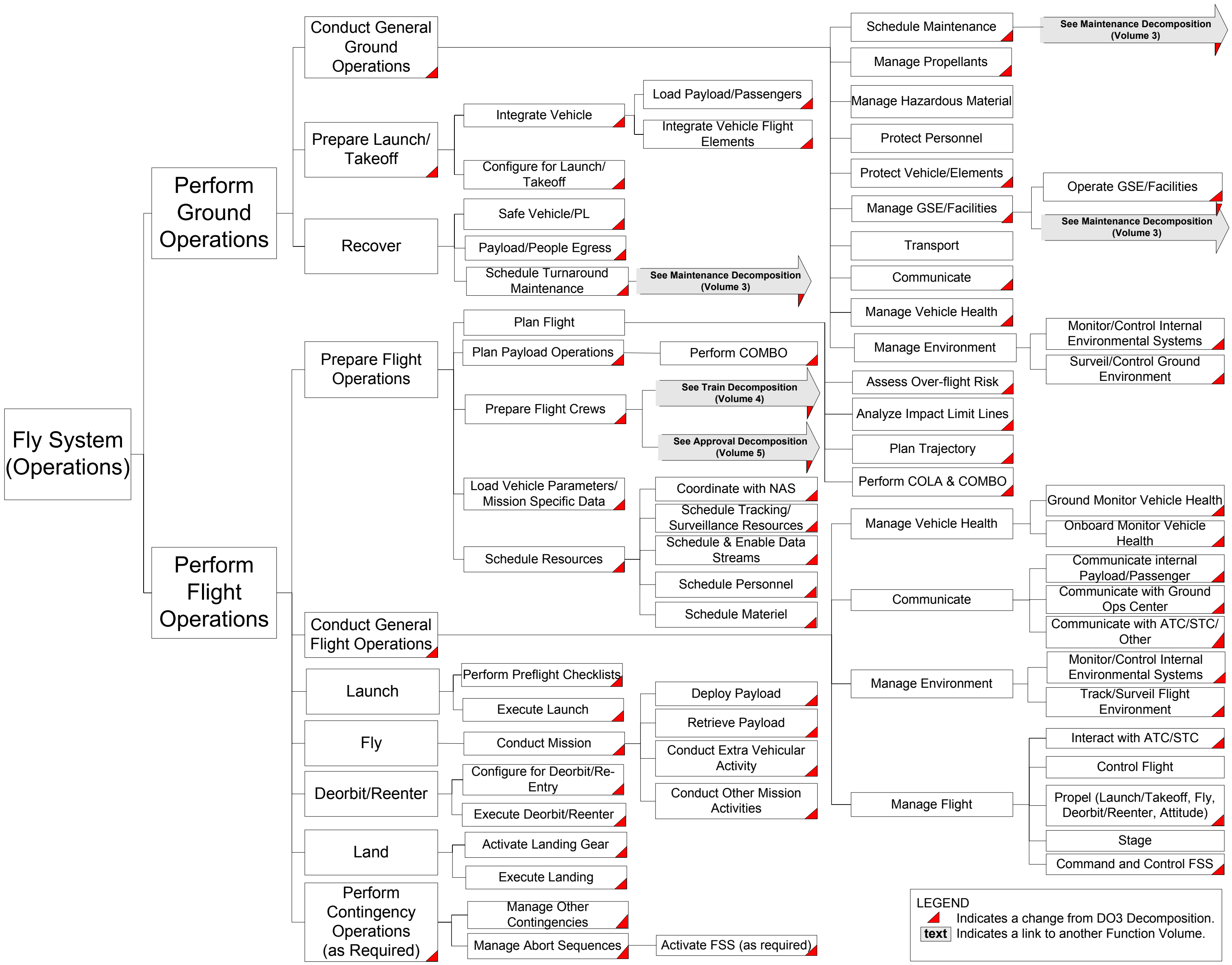

Figure 9 DO4 Operations Functional Decomposition

Table 12 Sub-Function Traceability

Indicates Same from DO3 to DO4	Indicates Move from DO3 to DO4	Indicates New Sub-Function	Indicates no DO3 to DO4 Correlation

DO4 Sub-Functions				DO3 Sub-Functions			
High Level Sub-Function	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**	**High Level Sub-Function**	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**
Ground Operations							
Conduct General Ground Operations			New Name	Prepare Ground Operations			Renamed
	Manage Propellant		Moved from Recover				
	Schedule Maintenance		New				
		Maintenance Functional Decomposition	New				
	Manage Hazardous Material		Same		Manage Hazardous Material		Same
	Protect Personnel		Same		Protect Personnel		Same
	Protect Vehicle/Elements		New				
	Manage GSE/Facilities		Moved to here from a higher level sub-function				
		Operate GSE/Facilities	New				
		Maintenance Functional Decomposition	New				
	Transport		Same		Transport		Same
	Communicate		New for this Sub-Function				
	Manage Vehicle Health		New for this Sub-Function				
	Manage Environment		New				
		Monitor/Control Internal Environmental Systems	New				
		Surveil/Control Ground Environment	New				
					Integrate Vehicle		Moved to Prepare Launch/Takeoff
					Manage Propellant		Moved to Prepare Launch/Takeoff
				Operate GSE/Facilities			Moved to here to lower level sub-function under Conduct General ground Operations

DO4 Sub-Functions				DO3 Sub-Functions			
High Level Sub-Function	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**	**High Level Sub-Function**	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**
Prepare Launch/Takeoff			New				
	Integrate Vehicle		Moved form Prepare Ground Operations				
		Load Payload/People	New				
		Integrate Vehicle Flight Elements	New				
	Configure for Launch/Takeoff		New				
Recover			Same	Recover			Same
	Safe Vehicle/PL		New		Payload/People Egress		Same, but incorporated into a larger safing function.
	Payload/People Egress		New				
	Schedule Turnaround Maintenance		New				
		Maintenance Functional Decomposition	New				
					Manage Propellant		Moved to Conduct General Ground Operations

DO4 Sub-Functions				DO3 Sub-Functions			
High Level Sub-Function	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**	**High Level Sub-Function**	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**
Flight Operations							
Prepare Flight Operations			Same	Prepare Flight Operations			Same
	Plan Flight		Same		Plan Flight		Same
		Assess Over-Flight Risk	Change			Assess Over-Flight Risk	Same
		Analyze Impact Limit Lines	Same			Analyze Impact Limit Lines	Same
		Plan Trajectory	Same			Plan Trajectory	Same
		Perform COLA & COMBO	Change			Perform COLA, COMBO & Debris Analysis	Same
	Plan Payload Operations		New				
		Perform COMBO	New				
	Prepare Flight Crews		New				
		Train Functional Decomposition	New				
		Approve Functional Decomposition	New				
	Load Vehicle Parameters/Mission Specific Data		New				
	Schedule Resources		New				
		Coordinate with NAS	New				
		Schedule Tracking/Surveillance Resources	New				
		Schedule & Enable Data Streams	New				
		Schedule Personnel	New				
		Schedule Materiel	New				
Conduct General Flight Operations			New				
	Manage Vehicle Health		Same, Manage changed from Monitor		Monitor Vehicle Health		Same, Monitor changed to Manage, was under Launch, Fly, Deorbit, and Land
		Ground Monitor Vehicle Health	New				
		On-board Monitor Vehicle Health	New				
	Communicate		Same		Communicate		Same, was under Launch, Fly, Deorbit, and Land
		Communicate Internal Payload/Passenger	New				
		Communicate with Ground Ops Center	New				
		Communicate with ATC/STC/Other	New				
	Manage Environment		Same		Manage Environment		Same, was under Launch, Fly, Deorbit, and Land
		Monitor/Control Internal Environmental Systems	New				

DO4 Sub-Functions				DO3 Sub-Functions			
High Level Sub-Function	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**	**High Level Sub-Function**	**Secondary Level Sub-Function**	**Tertiary Sub-Function**	**Change**
		Track/Surveil Flight Environment	New		Manage Flight	Track Vehicle and Surveil Flight Environment	Combined Track with Surveil, placed under Manage Environment from Manage Flight
	Manage Flight		Same		Manage Flight		Same, was under Launch, Fly, Deorbit, and Land
		Interact with ATC/STC	Moved from Secondary Level		Interact with ATC/STC		Moved to Tertiary Level
		Control Flight	Same		Manage Flight	Control Flight	Same, was under Launch, Fly, Deorbit, and Land
		Propel (Lift-Off/Takeoff, Fly, Deorbit/Reenter, Attitude)	Same, but this lists the propel types		Takeoff	Propel	Same, but this lists the propel types, was under Launch, Fly, Deorbit, and Land
		Stage	Same		Manage Flight	Stage	Same, was under Launch, Fly, Deorbit, and Land
		Command and Control FSS	Moved from Secondary Level		Command and Control FSS		Moved to Tertiary Level under Manage Flight
Launch			Same	Launch			Same
	Perform Preflight Checklists		New				
	Execute Launch		New				
Fly			Same	Fly			Same
	Conduct Mission		New				
		Deploy Payload	New				
		Retrieve Payload	New				
		Conduct Extravehicular Activities	New				
		Conduct Other Mission Activities	New				
Deorbit/Reenter			Same	Deorbit/Reenter			Same
	Configure for Deorbit/Reentry		New				
	Execute Deorbit/Reentry		New				
Land			Same	Land			Same
	Activate Landing Gear		New				
	Execute Landing		New				
Perform Contingency Operations (as required)			New				
	Manage Abort Sequences		New				
	Manage Other Contingencies		New				

Endnotes

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