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Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Training - Volume 4

Final Report

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Department of Transportation
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Associate Administrator for Commercial Space Transportation
AST-200 Licensing and Safety Division
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Reusable Launch Vehicle Operations and Maintenance Guideline Inputs and Technical Evaluation Report: Training - Volume 4

Final Report

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Executive Summary

Development of commercial Reusable Launch Vehicles (RLVs) continues to be of great interest to many private companies. Returnable vehicles allow return from space of such things as people and experiments. The appeal rests in an RLV's ability to support multiple mission types (e.g., cargo and "tourism") and amortize 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 a launch system. RLV Operations and Maintenance (O&M) of new launch systems have the potential to affect public safety; therefore, the Federal Aviation Administration'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 to evaluate an RLV developer's/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) specific to the various functions associated with RLV training, for any RLV concept, large or small, orbital or suborbital. This volume is the fourth of five such volumes; the first volume addressed RLV Subsystems; the second, RLV Operations; the third, Maintenance; and the final volume addresses RLV O&M Approval functions.

A total of four functions within the training domain have been identified for development of training guideline inputs. Each of these functions relate to a unique set of sub-functions for RLV training. The focus and intent of this task, Order (0002), has been to capture potential public safety risks that should be considered relative to RLV training. In order to ensure these guidelines have been considered by the RLV developer/operator, RTI proposes that a series of manuals be required as part of the final license application: Operations, Maintenance, Training, and Approval. These manuals would allow an RLV developer/operator to specify how they intend to address FAA/AST O&M Guidelines and the current requirements contained in the RLV Mission License Rule (14 CFR Part 431). In this way, the RLV developer/operator has the ability to stipulate which of these guidelines are relevant to their vehicle design and ensures that public safety considerations associated with RLV O&M tasks, such as those in this Training volume, 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 RLV industry can assess public safety aspects of RLV O&M processes. As the industry matures, it is expected that additional guidelines will be developed. These Guideline Input volumes are considered to be living documents that will be developed as the RLV industry matures.

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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) centered around the various functions associated with RLV training, for any RLV concept, large or small, orbital or suborbital. This volume is the fourth of five such volumes: the first volume addresses RLV Subsystems; the second, RLV Operations; third, Maintenance; and the remaining volume addresses RLV Approval Functions. The inputs identified in this volume, and in the other four Guideline Input volumes, contribute to a common set of criteria by which the FAA and the RLV 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, making these 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 training, as well as a top-level introduction of the pertinent RLV training functions. The intent is for these Guideline Inputs/Considerations to be general enough to be applicable for any RLV concept, large or small, orbital or suborbital. In this context, “pertinent” training is considered any activity associated with RLV systems training development, actual training tasks for ground and operations personnel, testing, and reporting/recording that has a potential to impact public safety. The functions identified here encompass activities associated with a variety of Concept of Operations (CONOPS) being proposed by the industry.

1.2 Background

These Guideline Inputs are the result of a focused effort by Federal Aviation Administration’s Office of Commercial Space Transportation (FAA/AST) to facilitate a common understanding between both regulator and industry on what is expected from RLV Operators 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[1].

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 RLV industry is sufficiently mature.

RTI used the Systems Functions and Procedural Items identified during previous FAA tasking[2] as a starting point. It was determined that a general model was needed to place the Systems Functions and Procedural Items in context. These have been further developed in a subsequent tasking and now in this Order 0002. A context diagram, Figure 1 in Section 1.5, was developed to provide this contextual framework, as well as provide a means 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 (SOU) between the FAA and the RTI Team has been developed to govern each of the RLV O&M tasks. The following text presents the SOU developed for this effort:

> "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 accomplished in the RLV O&M Top-Down Analyses performed under DO2 and DO3 and complement the RLV O&M Guidelines developed under DO4 of the reference contract. In particular, the RTI Team will develop material to aid FAA/AST-100 identify the O&M technical evaluation criteria and performance standards for safety-critical RLV maintenance, training, and approval 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.
>
> Under Order 0002, RTI will deliver the final guideline input volumes: Maintenance - Volume 3, Training – Volume 4, and Approval - Volume 5.
>
> The following summarizes specific topics that will be addressed:
>
> 1. Guideline inputs and rationale:
>   The major RLV O&M subsystem and function safety items, as they pertain to the subject volumes, will be developed into guideline inputs along with the supporting rationale. These will be presented in the format approved by FAA/AST under DO4.
> 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 .The Functional Decomposition diagrams will be modified to reflect the functional refinements, as required.
> 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."

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 commercial 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 commercial RLV Industry. Some inputs may be revisited as newer technologies are developed and better procedures emerge as the industry matures.

Training is needed in almost every facet of RLV O&M. While much of this training is expected to include many of the same topics addressed in traditional aviation training, there are numerous new technologies and subsystems that will require RLV-specific training. The FAA is expected to formulate these guidelines to serve as a basis for evaluating training to be employed by RLV developers and operators to ensure their appropriateness and completeness in addressing issues that may affect public safety.

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 a Training Function prefix (e.g., the first Develop Training Guideline Input is numbered Dev Training 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 evaluated 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 a Training Function prefix (e.g., the first Dev Training Guideline Input Consideration is numbered Dev Training GIC-1.) While these are candidates for inclusion in any subsequent rulemaking, it is reasonable to assume that further work may be required.

Please note that there are many additional safety issues that an RLV Operator should consider for the safety of trainers and students; FAA/AST is only currently charged with public safety concerns. Further, no delineation of when and how rules would be applied is made in these considerations. Some guidelines may be considered during the licensing stage while others may be considered as repeated launches are executed for the same RLV under a specific launch license.

Within the following sections, the Occupational Safety and Health Administration (OSHA) is highlighted in many of the Inter/Intra Agency Considerations subsections. Although OSHA is concerned with worker safety and not the general public, the authors of this document believe 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 or operator license applications. While training may be considered less important than to operations and maintenance from a public safety perspective; it is the basis on which safe operations and maintenance is conducted. The Guideline Inputs and the related Guideline Input Considerations contained in this volume are focused on RLV training with particular emphasis placed on issues unique to the function being addressed. Failure to follow these guidelines could pose a potential risk to the public. RLV developers and operators are expected to explain how each Guideline is satisfied for their particular vehicle design.

In a previous tasking, the RTI team proposed a formal set of readiness reviews, one for operations and one for maintenance. In addition, the concepts of Instructions for Continued Flight-worthiness (ICF) and an Operations or Flight Manual were introduced. The reviews were intended to be focused activities within the context of the overall mission readiness review required by the RLV licensing rule.

RTI 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 or operator for review. These two items are a Training

Manual and an Approval Manual. The Training Manual implements the requirements and guidance that are documented in the RLV Operator's Training Plan. The Training Plan is considered by RTI to be similar in scope and breadth to the Concept of Operations and Maintenance Program Plan. Note that this data can be packaged as part of the Operations Manual, the Maintenance Manual, a combined document, or as individual documents. This is at the discretion of the RLV Operator, provided that the data is clearly identified. The four documents (Operations Manual, Maintenance Manual, Training Manual, and Approval Manual), taken together, will allow individual RLV developers/operators to address FAA/AST Guidelines. At the same time, the use of a common set of manuals 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 four areas relate to one another and where they fit into the broader scope of RLV licensing, approvals, and RLV development. It should be noted that this effort considers only the items to the right of the vertical line in Figure 1. This relationship is highlighted in Figure 2.

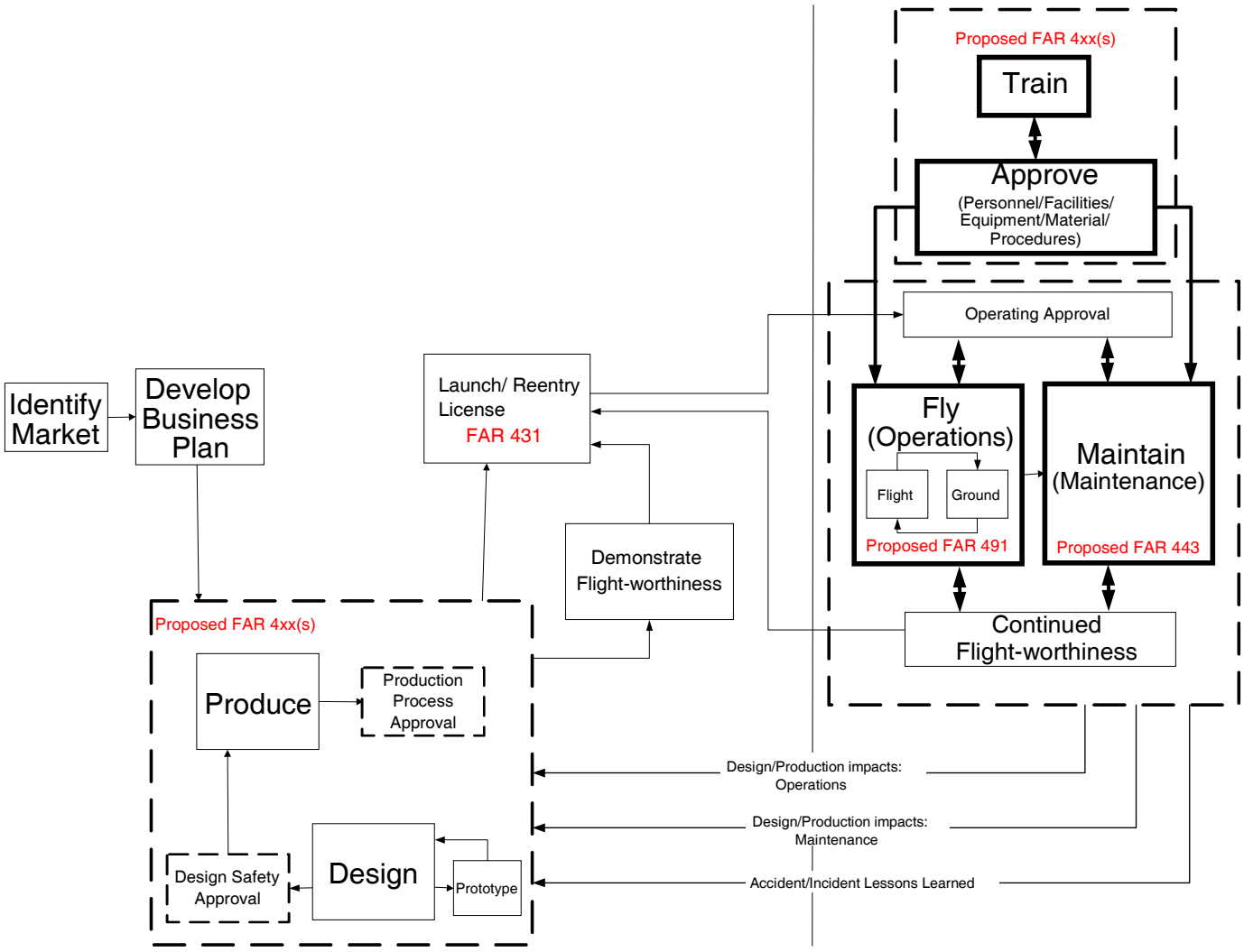

Figure 1 RLV Context Diagram

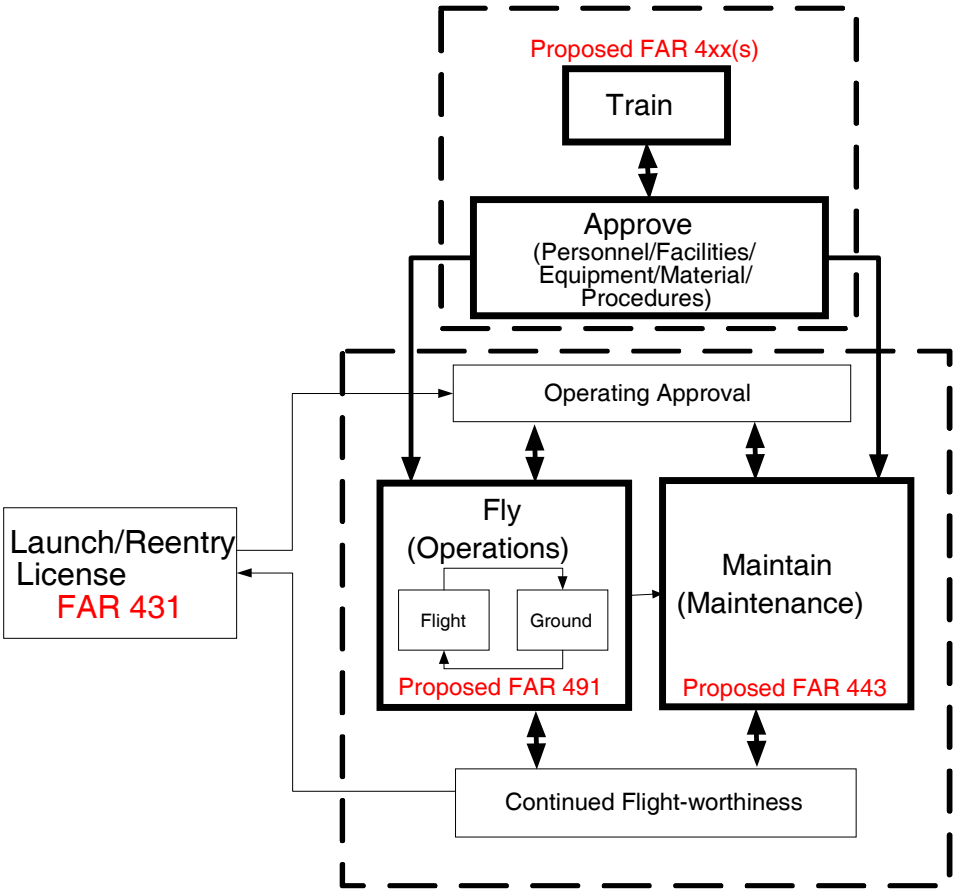

Figure 2 RLV O&M Context

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.

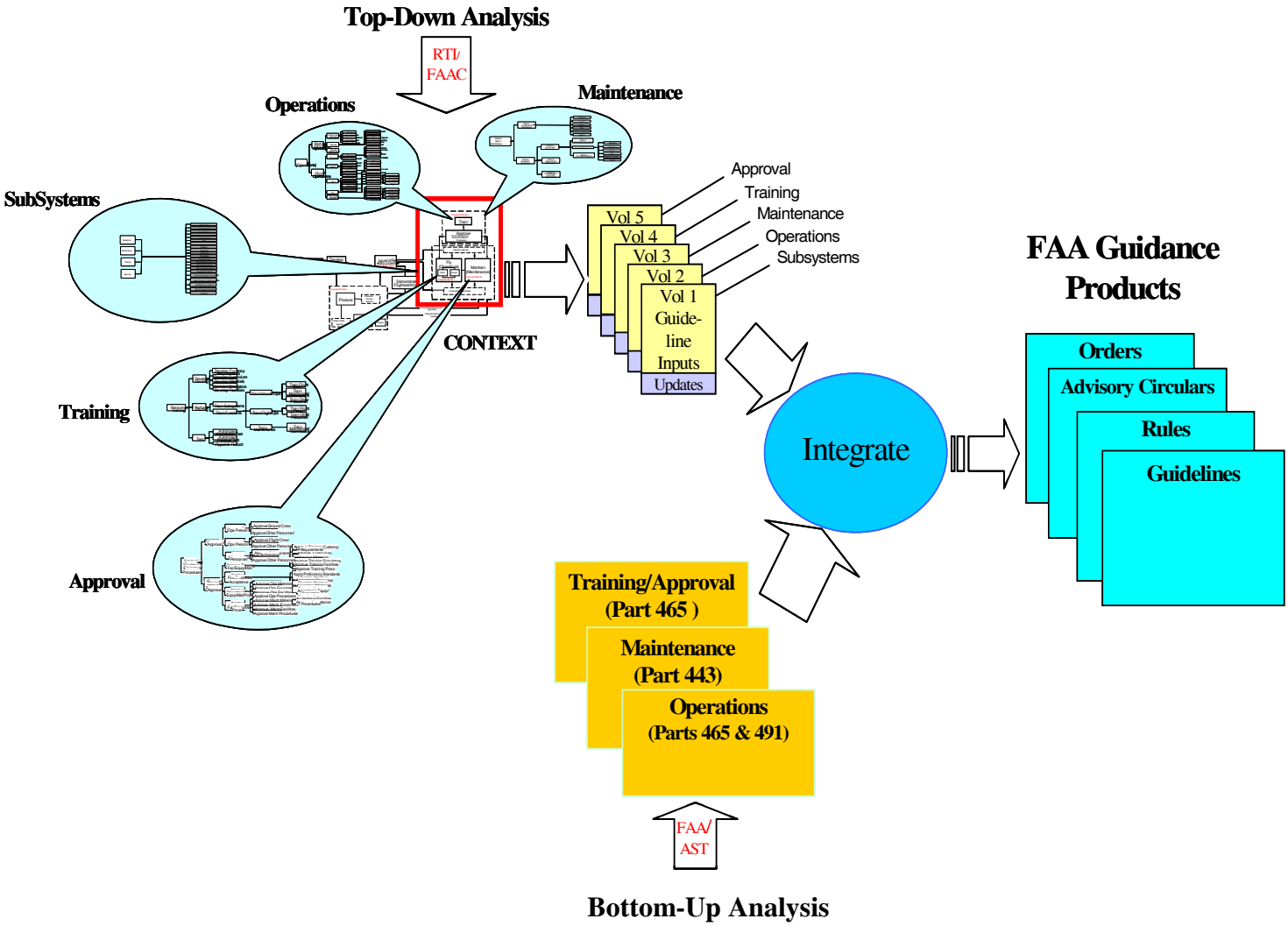

Figure 3 Guidance Document Process

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; provide definitions for each function and sub-function; 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 an action, hence the term "function".

2.0 Training Decomposition

Figure 4 displays the current RLV training functional decomposition. Training is broken into four major sub-functions: Develop Training, Perform Training, Test, and Record & report. The RLV Operator's Training Plan will document the training strategy for an individual RLV program vehicle type, see Section 3.0.

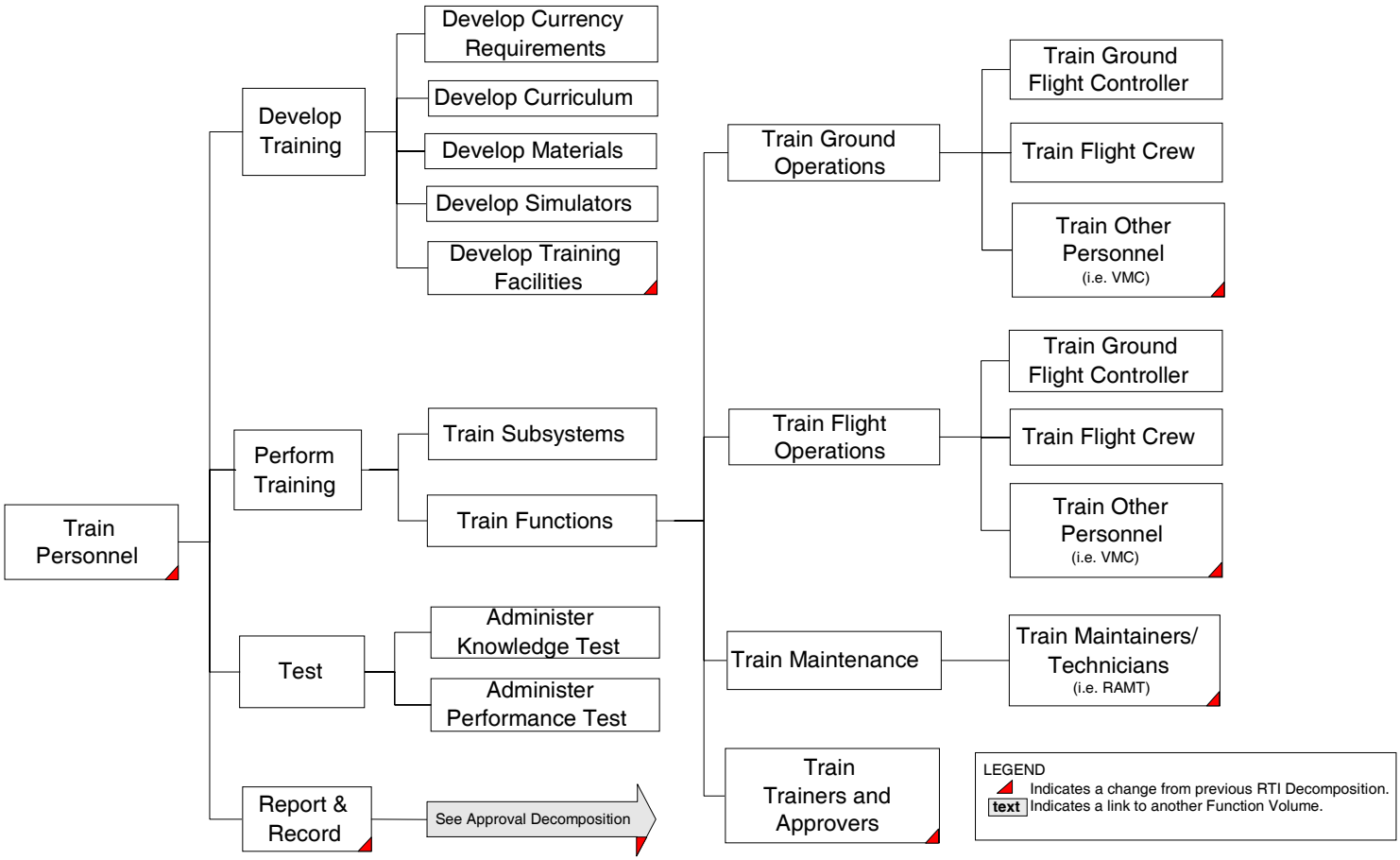

Figure 4 Training Functional Decomposition

The results of the CFR reviews, as well as the data collected during previous efforts, were used as a starting point for deriving these functions. RTI then collected and analyzed several references to further characterize training. Previous work presented the first functional decomposition of RLV Training Functions. These training functions and sub-functions have been further analyzed and refined in this task. While many functions remain the same, there are several new sub-functions and reorganization. See Appendix C: Traceability of Training Function Decomposition for function and sub-function traceability from the previous Training Decomposition to the current Training Decomposition.

3.0 General Training Guideline Recommendations

The following Guideline Inputs (GIs) were developed to reflect those tasks or procedures that are general in nature and apply to Train Personnel Function.

General Train GI - 1. RLV Operator Training Plan

Guideline Input

RLV Operators shall develop a Training Plan for each vehicle type.

Rationale

To account for the differences in RLV designs, each RLV Operator must provide a Training Plan that describes the operator's intent and/or assumptions relative to RLV training. This plan will include general strategies associated with developing training, performing the training, testing, and reporting/recording. This will include training tasks associated with ground operations, flight operations, maintenance, training, and approval. The Training Plan is comparable to the RLV Operator's Concept of Operations Document and Maintenance Program Plan.

Although the Training Plan will be implemented through a procedural Training Manual, the Training Plan's value to the FAA lies in the additional clarity of purpose it will provide. One recommendation from the Space Shuttle Challenger accident investigation was to ensure adequate technical training of flight crew as well as program management personnel.[3]

Specifically, it will highlight to the FAA general assumptions/intent that may affect public safety; and it will provide the FAA with necessary insight into the following items of interest:

1. General public safety assurance and environmental hazard mitigation
2. Inter/intra agency (both local and federal) coordination requirements
3. Logistical support that will be necessary for training of the RLV and its associated GSE/ facilities
4. Steps to take in developing non-nominal training procedures/environment
5. Training accreditation
6. Personnel training requirements
    a. schedule of recurring training
    b. "type-specific" training
7. Periodic update to account for new tasks required to be trained based on design changes or lessons-learned
8. Frequency and type of initial and recurring training tasks

General Train GI - 2. Training Manual

Guideline Input

RLV Operators shall develop an FAA/AST-approved vehicle-specific Training Manual.

Rationale

Since many RLV concepts include ground-breaking/novel technologies, there is minimal commonality between current industry training procedures and those required for specific RLV training procedures. This lack of commonality hinders the development of common technology-specific training approval/certification guidelines; therefore, each RLV Operator must develop a vehicle-specific Training Manual and provide it to FAA/AST for approval.

This manual will provide the training specifications and procedures associated with the specific RLV type and its GSE/facilities.

Minimally, the following items will be included in the Training Manual:

1. Safety critical RLV and GSE/Facilities sub-systems, operations, and maintenance training procedures for knowledge and performance based instruction
2. Hazardous material types and handling procedures during training
3. Testing criteria
    a. knowledge evaluation
    b. performance evaluation
4. Training documentation process to include feedback of lessons-learned
5. Training tools, test equipment, facility, and simulator identification and description for different training methods (i.e. on-the-job (OJT) training and “classroom” instruction)

4.0 Develop Training

The following sub-functions were developed to reflect those tasks or procedures that apply to the Develop Training activities. Table 1 highlights the general definitions for Develop Training Sub-functions.

Table 1 Develop Training Definitions

Develop Training	*[Train Personnel → Develop Training]*	
	Development of training is defined as development of currency requirements, curriculum, materials (including lesson plans, test materials, reports and records), simulators or other training devices, and adequacy requirements for facilities.	
	Develop Currency Requirements	*[Train Personnel → Develop Training→Develop Currency Requirements]*
		The Develop Currency Requirements sub-function is the set of tasks to assess: 1. Routine and non-routine portions of a job as to whether additional training is needed in certain knowledge and skill sets. 2. The adequacy of the training within a defined period as technology advances.
	Develop Curriculum	*[Train Personnel → Develop Training→Develop Curriculum]*
		The Develop Curriculum sub-function consists of the tasks to explore knowledge and skill sets required for a job and to develop a roadmap to instill the knowledge and skill sets in the students. Curricula need to be developed for initial, supplemental, recurrent, and remedial training.
	Develop Materials	*[Train Personnel → Develop Training→Develop Materials]*
		Materials in this document are defined as those items used for training purposes. Materials include classroom lesson plans, references, records, reports, tests, and performance evaluations.
	Develop Simulators	*[Train Personnel → Develop Training→Develop Simulators]*
		A simulator is an apparatus, or environment, that generates situations approximating actual or operational conditions. Simulation[4] is defined as system modeling and their operations using various means of representation.
	Develop Training Facilities	*[Train Personnel → Develop Training→Develop Training Facilities]*
		Facility is defined as the physical environment (e.g. buildings, classrooms…). In this context it is the environment in which training is accomplished.

4.1 General Discussion

Development of training includes an assessment of core job functions and skills to be taught during training. An assessment of safety implications of certain job functions and the corresponding training to mitigate risks must feed into the curriculum and materials. As technology advances, regulations change, or job functions are modified, these requirements must be revisited to assess appropriateness and completeness. In aviation, the FAA has imposed special training when safety concerns are being mitigated by procedural changes for pilots and air traffic controllers. Such training may also be formulated as supplemental training and absorbed into initial training going forward. Recurrent training may not be very different from initial training. Certain job functions that are not frequently used must be stressed in recurrent training. Supplemental training is offered when there is no change in the initial training but additional information needs to be conveyed; for example, a new instrument, new material or a new technique. Remedial training is offered when mistakes are found on the job. Such training may have to be customized to address a particular problem, lack of a specific skill, or lack of certain background knowledge.

The tasks, procedures, and sub-functions associated with the Develop Training Sub-function are further explained in this section. Training development requirements may be different for the four types of training: initial, recurrent, supplemental, and remedial. These training types pertain to ground operations personnel, flight operations personnel, maintainers, personnel providing training, and approval personnel.

Develop Currency Requirements

The FAA has specific aviation training currency requirements. These requirements can be applied globally to the aviation industry because this is a relatively mature industry. For RLVs, since this is a fast growing industry with many new innovations and ideas, it would be difficult to have an all-inclusive currency requirement at this time. The requirements could only be applied to a certain RLV concept because each RLV has its own design and safety issues and must be examined individually.

Develop Curriculum

Curriculum, in this context, is defined as the set of courses that will be used to train ground flight controllers, pilots/crew, maintainers/technicians, and other personnel as appropriate based on the RLV CONOPS. There are two types of curriculum defined by the FAA in 14 CFR –Chapter I- Part 142, Core Curriculum and Specialty Curriculum.

Core Curriculum consists of training in basic subjects important to a specific function; for example, all maintainers will learn how to use a basic set of tools. It does not include specialized training for tasks related to a specific rating such as maintenance training for a specific type of propulsion.

Specialty Curriculum is a set of courses that are designed to address training requirements unique for a specific type of RLV or a specific type of subsystem, etc. For example, Flight Crew Training for an HTHL may be very different from that for a VTVL.

Develop Materials

Course materials may be specific to an RLV and specific to job functions such as ground flight controller, flight crew, maintainers/technicians, and other personnel (e.g. trainers and approval personnel). These materials may include actual hardware, test equipment or other tangible tools. These materials are also expected to be specific for initial, supplemental, recurring, and remedial training. For example, supplemental training may be limited only to a new tool, technology or technique. Recurring training may be based on the frequency of usage of certain tools and techniques. Remedial training may be individualized to compensate for lack of knowledge or skills gained in the initial training. Materials used for remedial purposes would be tailored to individual needs.

Develop Simulators

Simulations are used in training personnel by creating a model such as a flight simulation for the flight crew. Situations that may be dangerous to a student, such as propulsion failures, may be simulated and the student may be taught to handle these situations before experiencing a real-world event. The strength of simulation is in its accuracy of representation of the real world. If the simulation is not close to reality, it may not be of much use in training.

Aviation simulators and flight training devices are covered in Aviation 14 CFRs 61, 141, and 142. FAA Flight Standards organization has the charter of assuring that airmen are properly trained. As part of their charter, they assure that the curricula, training devices and schools are qualified. The National Simulator Program (NSP) for the FAA is based in Atlanta, GA. This office is responsible for establishing simulation standards, qualification process, and a simulator QA process. Flight training devices are divided into levels depending upon the sophistication of its use. Simulators to train pilots on a specific cockpit have to be very sophisticated and accurate to represent a real life scenario. A generic simulator does not have to be exact in its details of the location of the controls. Rules on the qualification of these training devices depend upon the level of the device. There are also rules on the duration and rigor of training that is required on these devices.

Develop Training Facilities

Training facilities will house the training equipment and courseware, including simulators or other advanced training devices. Basically, it is the physical environment in which knowledge and performance lesson objectives are taught and tested.

4.2 Guideline Input Considerations

The following Guideline Input Considerations (GICs) have been identified for the Develop Training Sub-function:

Dev Training GIC - 1. Facilities and tools should present a realistic environment of the operation being provided to the trainee to ensure proper representation.

Dev Training GIC - 2. A set of spaceflight and RLV concept specific training requirements should be developed for each individual concept or application.

4.2.1 Inter/Intra Agency Considerations

The following Develop Training Sub-function inter/intra agency considerations were identified:

1. 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.
2. Federal Communication Commission (FCC) coordination should occur for all frequency assignments used in RLV training, particularly those employed in emergencies.
3. The Department of Defense Explosive Safety Board (ESB) should be consulted to provide a source of lessons learned to FAA/AST for conducting RLV safety evaluations, storage of propellants, and chemical agents.[5]

4.3 Guideline Recommendations

Dev Training GI - 1. Assess O & M Core Task Functions

Guideline Input
The RLV Operator shall perform an assessment of core operations and maintenance tasks as the basis for the design of their training curriculum.

Rationale
Assessments of safety implications of certain job/task functions and the corresponding training to mitigate risks must be implemented in the curriculum and materials. As technology advances, regulations change, or job functions are modified, these requirements must be revisited to assess appropriateness and completeness.

Curricula will ensure that the diverse requirements for learning a particular function are covered. For example, a maintainer should be trained in the specific specialization such as wiring and should be well versed in the safety implications of that job. Some subjects may require cross disciplines such as propulsion and propellant management. In such cases, the maintainer may require cross training in the overlapping disciplines.

In aviation, the FAA has imposed special training when safety concerns are being mitigated by procedural changes for pilots and air traffic controllers. Such training may also be formulated in the RLV industry as supplemental training and absorbed into initial training going forward.

Dev Training GI - 2. Training Currency Requirements

Guideline Input

The RLV Operator shall develop training currency requirements for all job functions/tasks and document same in the RLV Training Plan.

Rationale

Tasks that are not performed on a routine/regular basis with a certain frequency have a tendency to be forgotten. Personnel may forget certain procedures that may cause mistakes/errors causing or leading to incidents/accidents that could pose a risk to the public. Training currency requirements mitigate these potential lapses.

Recurrent training may not be very different from initial training. Certain job functions that are not frequently used must be stressed in recurrent training. Supplemental training is offered when there is no change in the initial training but additional information needs to be conveyed; for example, a new instrument, new material or a new technique. Remedial training is offered when mistakes are found on the job. Such training may have to be customized to address a particular problem, lack of a specific skill, or lack of certain background knowledge.

The currency requirements will be established with an interval between activity or training not to exceed a specified amount to be established between FAA/AST and the RLV Operator. These may eventually become industry standards.

Dev Training GI - 3. Curricula Updates

Guideline Input
Curricula shall be updated based on lessons-learned, changes in RLV design or configuration, or changes in operations and maintenance procedures.

Rationale
Curricula will be reevaluated when there is change in technology, existing regulations, operational/maintenance procedures, or when new tools are introduced for training. New methodologies and training approaches may drive curricula revisions as well. If outdated or incorrect technology is being taught; if obsolete guidance is being followed in class; or if the tools are not being correctly used, students may be prone to more incidents/accidents on the job. These changes may also affect the trainee's ability to make satisfactory real-time decisions.

Certain new technologies that will be introduced into RLVs may pose a risk to the public in how they are implemented, operated, and maintained. Training curricula provides the basis for ensuring operators and maintainers are trained in these technologies to prevent incidents/accidents posing a potential risk to the public. For example, as new composites are introduced, methods of handling these composites should be introduced into the curriculum as soon as practical.

Dev Training GI - 4. Simulator Fidelity

Guideline Input
Simulators used in training shall look, feel, and behave as closely as possible to the deployed operational equipment.

Rationale
The value of using simulators is their ability to present training close to what is expected in real-world situations on the job. The fidelity in simulations has a positive effect on job performance in accuracy and speed of performance. This mitigates possible confusion, improves reaction times in assessing anomalies, and decreases the possibility of an incident or accident.

Dev Training GI - 5. Passenger Training

Guideline Input
Spaceflight personnel training shall be developed and conducted for passengers on an RLV.

Rationale
This may be a much reduced set of requirements from that of the RLV's flight crew. However, just as in aviation, passenger safety training will mitigate risks to the public on board the RLV, and improve their ability to react to off-nominal conditions. This training will include items such as emergency situation training and use of safety equipment. Passenger preparedness will not only help mitigate passenger safety situations, but also may aid the flight crew during off-nominal events (e.g. flight abort scenario) that may escalate into a catastrophe.

5.0 Perform Training

The following sub-functions were developed to reflect those tasks or procedures applicable to RLV Perform Training activities. Table 2 outlines the general definitions for the Perform Training Sub-functions.

Table 2 Perform Training Definitions

Perform Training	*[Train Personnel → Preform Training]*			
	The Perform Training Sub-function is the process of training ground operations personnel, flight operations personnel, and maintenance personnel in their respective job.			
	Train Subsystems	*[Train Personnel → Preform Training→Train Subsystems]*		
		The Train Subsystems sub-function is defined as training the operations and maintenance personnel in related subsystem-specific subjects as needed for their respective job.		
	Train Functions	*[Train Personnel → Preform Training→Train Functions]*		
		The Train Functions sub-function is defined as training the operations and maintenance personnel in function-specific subjects as required for their respective jobs.		
		Train Ground Operations	*[Train Personnel → Preform Training→Train Functions→Train Ground Operations]*	
			The Train Ground Operations sub-function is defined as training the ground operations personnel: ground flight controllers, flight crew, maintenance/technicians, and other personnel. Other personnel includes trainers and approval personnel.	
			Train Ground Flight Controller	*[Train Personnel → Preform Training→Train Functions→Train Ground Operations→Train Ground Flight Controller]*
				The Train Ground Flight Controller sub-function under Train Ground Operations is defined as training the ground flight controllers for specific flight operation tasks that are performed on the ground.
			Train Flight Crew	*[Train Personnel → Preform Training→Train Functions→Train Ground Operations→Train Flight Crew]*
				The Train Flight Crew sub-function under Train Ground Operations is the training of the flight crew that is aboard the RLV conducting operations to understand the tasks being performed on the ground.
			Train Other Personnel (i.e. VMC)	*[Train Personnel → Preform Training→Train Functions→Train Ground Operations→Train Other Personnel (i.e. VMC)]*
				The Train Other Personnel sub-function under Train Ground Operations is defined as the training of flight operations personnel other than ground flight controller and flight crew for specific ground operations.

		Train Flight Operations	*[Train Personnel → Preform Training→Train Functions→Train Flight Operations]*	
			Train Flight Operations is defined as the training of Flight Operations personnel including ground flight controller, flight crew, and other personnel.	
			Train Ground Flight Controller	*[Train Personnel → Preform Training→Train Functions→Train Flight Operations→Train Ground Flight Controller]*
				The Train Ground Flight Controller sub-function under Train Flight Operations is defined as training ground flight controllers for specific flight operations.
			Train Flight Crew	*[Train Personnel → Preform Training→Train Functions→Train Flight Operations→Train Flight Crew]*
				The Train Flight Crew sub-function under Train Flight Operations is training the flight crew for flight operations. The on-board personnel in charge of and at the flight controls of an RLV are referred to as the flight crew.
			Train Other Personnel (i.e. VMC)	*[Train Personnel → Preform Training →Train Functions→Train Flight Operations →Train Other Personnel (i.e. ATC-O)]*
				The Train Other Personnel sub-function under Train Flight Operations is defined as training the flight operations personnel other than ground flight controller and flight crew for specific flight operations tasks. These personnel may include trainers and approval personnel in this area of expertise such as the Vehicle Mission Coordinator (VMC).
		Train Maintenance	*[Train Personnel → Preform Training→Train Functions→Train Flight Operations]*	
			The Train Maintenance sub-function is defined as the training of maintainers/ technicians.	
			Train Maintainers/ Technicians (i.e. RAMT)	*[Train Personnel → Preform Training→Train Functions→Train Maintenance→Train Maintainers/Technicains (i.e. RAMT)]*
				The Train Maintainers/ Technicians sub-function is defined as training the maintainers/technicians to work in a specialization on a specific RLV.
		Train Trainers and Approvers	*[Train Personnel → Preform Training→Train Functions→Train Approvers]*	
			The Train Trainers and Approvers sub-function is defined as additional special training for those in the capacity to train and approve procedures, requirements, material, operations, maintenance, and training to work in a specialization on a specific RLV.	

5.1 General Discussion

For aviation, the FAA encourages operators to be innovative and creative in training delivery methods and techniques. While the FAA Flight Standards Services Inspectors check for the appropriateness and depth of training, they use discretion and latitude in recognizing differences between operators in their training delivery. A similar approach would be beneficial for RLVs.

While testing includes knowledge testing and performance testing, it is not clear what percentage of classroom training should be divided between the delivery of these instructions and hands on training.

Train Subsystems

Brevard Community College (BCC) has developed and implemented a new degree program in August 2001 called Aerospace Technology Science degree program. In conjunction with this program, BCC also developed a skills standard development process. This was in response to the status of the aerospace industry. The aerospace industry has an aging workforce. There are twice as many in the aerospace workforce over 60 as there are under 30. Additionally, there have been industry changes due to legislation such as the Commercial Space Act and the changes in the Export Control Act. Finally, societal changes in technology and cycle times of development have changed the aerospace workforce and its focus. This has been addressed by BCC by developing aerospace technical education partnerships, a two-year college degree program, and development of National Skills Standards for competencies. Their goal was to develop and implement a program to provide qualified, employable technicians for the future aerospace industry.

An executive steering group called the Aerospace Technology Advisory Committee (ATAC) oversees the program. It is made up of partnerships from the government, industry, and academia, see Table 3, ATAC Partners. The Program Plan consists of a five-year implementation. In 2000 their goal was to develop the Aerospace Technician Degree and obtain aerospace industry support for a National Skills Training Program. This led to the formation of the ATAC industry working group, the development of laboratories for teaching, and opening of a spaceport center facility at KSC.

Table 3 ATAC Partners

Government		Industry		Academia	
NASA	KSC	Boeing	Wyle	Astronauts Memorial Foundation (AMF)	Brevard Community College
45th Space Wing	National Science Foundation	United Space Alliance	Pratt & Whitney	Embry Riddle Aeronautical University	Florida Institute of Technology
Brevard Workforce Development Board	Federal Aviation Administration	Florida Aviation Aerospace Alliance	Bionetics	Florida Space Research Institute	Division of Community College (DCC)
Cape Canaveral Air Force Station	Southern Economic Development Center	Dynamac	Lockheed Martin	K-12	Florida Space Institute-University of Central Florida
Technology Research and Development Authority	Florida Space Authority	Harris	Delaware North Park Services (DNPS)	Community Colleges for Innovative Technology Transfer	
Enterprise Florida, Inc. (EFI)	Education Development Center	Command Control Technologies	NIDA Corporation		
		Space Gateway Support (SGS)	Indyne		

Train Functions
In contrast to subsystems, functions have a procedural nature, such as Analyze Impact Limit Lines.

Train Ground Operations
Ground operations personnel ready the vehicle for flight. Since different RLVs have very specific needs, it is envisioned that Ground Operations will be unique to each RLV with some common elements such as replenishing the consumables even though the list of consumables may also be different from one RLV to another.

Train Flight Operations
Flight operations personnel perform activities associated with launch through landing operations. They may be located either on-board the RLV or on the ground.

Train Maintenance
Since RLVs vary in the types of technology they are using, maintainers/technicians trained on a specific RLV cannot move to another RLV

without a certain amount of additional training and familiarization. Maintenance consists of turnaround, interval-driven, condition-based, scheduled and unscheduled maintenance. These activities may include preventive maintenance, replacement of defective parts and repair activities. RLV maintainers and technicians are also referred to as RLV Aerospace Maintenance Technicians (RMAT) by the FAA.

14 CFR 147, Aviation Maintenance Schools cover the FAA requirements for certification of schools. Facilities, equipment, materials, tools, instructors, and curricula are covered in these requirements. Operating rules for these schools include rules for enrollment, attendance, record keeping, certification awards, maintenance of the school facilities, maintenance of the curricula, and inspection.

Train Trainers and Approvers
Trainer and Approver training will be conducted in addition to the operations and maintenance personnel training.

In aviation, the FAA is responsible for training the inspectors (i.e. approvers) who perform certification activities. However, since there are a variety of RLV concepts, individual Approver training programs may be required.

5.2 Guideline Input Considerations

The following Guideline Input Considerations (GICs) have been identified for the Perform Training Sub-function:

Perf Train GIC - 1. The FAA should provide guidance on how the training program should be structured. Current FAA guidance for aviation training suggests that the training take into consideration individual differences in learning, forgetting and retention, habit formation, instructor's communication skills and different methods of teaching such as lecture, general discussion, demonstration-performance, and programmed instruction. This guidance also includes different methods for evaluating the students' progress, such as oral quizzing, written tests, and performance tests.

Perf Train GIC - 2. Pilot training, curricula, eligibility, and training equipment should be approved by the FAA. It is recognized that these items may be unique to individual RLV designs.

Perf Train GIC - 3. Propulsion and propellant management training should be skill or technology specific rather than engine specific.

5.2.1 Inter/Intra Agency Considerations

The following Perform Training Sub-function inter/intra agency considerations were identified:

1. The training of hazardous material handling may be a concern to OSHA and/or EPA.
2. 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.
3. Federal Communication Commission (FCC) coordination should occur for all frequency assignments used in RLV operations, particularly those employed in emergencies.
4. The Department of Defense Explosive Safety Board (ESB) should be consulted to provide a source of lessons learned for FAA/AST for conducting RLV safety evaluations, storage of propellants, and chemical agents.[5]

5.3 Guideline Recommendations

Perform Training GI - 1. Train Task Changes

Guideline Input

When new risks and/or safety-critical tasks are seen in the operation or maintenance of an RLV, the RLV Operator shall train personnel in the field and in the classroom based on the associated Safety Advisories until formal course material is available.

Rationale

Performance of training will be reevaluated when there is change in technology, change in existing regulations, when new tools are introduced for training, or when new risks are faced. New methodologies and training approaches may drive curricula revisions as well. If outdated or incorrect technology is being taught; if obsolete guidance is being followed in class; or if the tools are not being correctly used, students may be more prone to incidents/accidents on the job. The above changes may also affect the trainee's ability to make informed real-time decisions.

Perform Training GI - 2. Trainer Requirements

Guideline Input

Training programs shall be updated, and trainers shall be retrained when the school acquires new training tools.

Rationale

In addition to new curriculum, facilities, and simulator updates based on technology and procedure changes, trainers will also require updated training in order to teach the new material.

Perform Training GI - 3. Technician/Mechanic Training

Guideline Input

Technicians and mechanics shall be trained in specific technology areas.

Rationale

Some amount of experience and training is required for technicians and mechanics working on RLVs, particularly safety critical systems. The experience levels, and what skills and training may be substituted for this experience must be determined.

Perform Training GI - 4. Trainer/Approver Training

Guideline Input

Trainers and Approvers shall be trained in both RLV-specific areas and technical instructor and approval methodologies.

Rationale

In addition to being trained in RLV-specific skills, Trainers and Approvers must be able to communicate effectively and evaluate students in order to ensure that RLV personnel are prepared adequately.

6.0 Test

The following sub-functions were developed to reflect those tasks or procedures that are applicable to RLV Test activities. Table 4 highlights the general definitions for the Test Sub-functions.

Table 4 Test Definitions

Test	*[Train Personnel→Test]*	
	The Test Sub-function is defined as the administration of knowledge and performance measurements that demonstrate personnel have been trained adequately to perform their functions in a safe manner.	
	Administer Knowledge Test	*[Training Personnel→Test→Administer Knowledge Test]*
		The Administer Knowledge Test sub-function is defined as the administration of that part of the test that checks a student's competency and depth in the domain knowledge of subjects relevant to the job for which the student has been trained.
	Administer Performance Test	*[Training Personnel→Test→Administer Performance Test]*
		The Administer Performance Test sub-function is defined as the administration of that part of the test that checks a student's competency in the hands-on skill of the subjects that are relevant to the job for which the student has been trained.

6.1 General Discussion

The RLV industry is still in its infancy. There are many varied ideas for space flight being developed. There is no single concept of how all of these RLVs will be operated or maintained. These RLV concepts are so varied that no single knowledge or skill set can be defined as the standard required knowledge for personnel in different RLV organizations. Thus, no standard test is envisioned (e.g. no single test for pilots is adequate for all the different RLV concepts).

6.2 Guideline Input Considerations

The following Guideline Input Considerations (GICs) have been identified for the Test Sub-function:

Test GIC - 1. Testing of trainers and approvers should include testing for their particular RLV specialization (job) as well as testing as instructors or approvers.

Test GIC - 2. Requirements for a testing program should be developed to accommodate curriculum for initial and recurring training.

6.2.1 Inter/Intra Agency Considerations

The following Test Sub-function inter/intra agency considerations were identified:

1. It is possible that new chemicals and new materials may be introduced to support RLVs. DOT, OSHA, and EPA must be involved in formulating safe methods of transporting, handling, and using these chemicals. Formulation of test questions for these types of new chemicals and materials should be performed in cooperation with these agencies.

6.3 Guideline Recommendations

Test GI - 1. Post Training Testing

Guideline Input
Post training tests shall be conducted that demonstrate appropriate knowledge and skill levels were acquired.

Rationale
Testing is conducted in order to provide a means of determining and demonstrating the required knowledge and skills necessary to safely perform as an RLV operator, maintainer, trainer, or approver. Testing ensures that personnel are adequately trained which will mitigate risks in generating RLV incidents/accidents that may endanger the public. For all of the personnel to be trained, there are two parts to their training, namely, knowledge and hands-on skill (performance). Testing will include knowledge testing and performance testing.

Test GI - 2. Performance Test Safety

Guideline Input
Performance testing shall be performed in accordance with the FAA/AST approved RLV Operator Training Manual hazardous procedures.

Rationale
Tests should be a realistic representation of what personnel would do on the job. If the skill being evaluated requires an environment that may put the public at risk, the testing personnel must adhere to the hazardous procedures guidelines outlined in the RLV Operator Training Manual.

7.0 Record & Report

The following sub-functions were developed to reflect those tasks or procedures that are applicable to RLV Record and Report activities. Table 5 highlights the general definitions for the Record and Report Sub-functions.

Table 5 Record and Report Sub-function Definitions

Record & Report	*[Train Personnel→Record & Report]*	
	The Record and Report Function encompasses the tasks and procedures to record training documentation for each course, facility, simulator, and student. This information is used to improve training quality as well as pass the student on to the approval process.	
	Approval Functional Decomposition	*[Train Personnel→Record & Report→See Approval Decomposition]*
		The Approval Functional Decomposition outlines functions for performing approval activities associated with equipment, procedures, and personnel involved in maintenance activities. See Volume 5, Approval.

7.1 General Discussion

RLV training courses will have criteria by which the student's knowledge will be measured against. These include both task/performance based items as well as knowledge based items. The student's achievements and failures will be recorded to provide a complete record of their level of readiness for actual field work. Additionally, the RLV Operator may be required to provide records of use and revisions for course curriculum, training facilities, and training simulators to ensure the approved versions of these items are being used in the training of RLV personnel.

Reporting entails the endorsement of the training facility to the approval authority that the student is prepared to be evaluated for certification, licensing, or other approval mechanism.

7.2 Guideline Input Considerations

The following Guideline Input Considerations (GICs) have been identified for the Record and report Sub-function:

Record & Report GIC - 1. Training records should be recorded and made available for future tracking to ensure personnel have received the appropriate training for their position.

7.2.1 Inter/Intra Agency Considerations

The following Test Sub-function inter/intra agency considerations were identified:

1. 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.
2. Federal Communication Commission (FCC) coordination should occur for all frequency assignments used in RLV maintenance procedures, particularly those employed in emergencies.

3. The Department of Defense Explosive Safety Board (ESB) should be consulted to provide a source of lessons learned for FAA/AST for conducting RLV safety evaluations, storage of propellants, and chemical agents.[5]
4. National Fire Protection Agency (NFPA) coordination should be required for procedure development to ensure that fire safety and mitigation procedures are in place for maintenance.

7.3 Guideline Recommendations

Record & Report GI - 1. Training Completion Endorsement

Guideline Input
An authorized instructor shall log an endorsement in a student's training record that attests that the student has been found proficient in the learning objectives identified in the course curricula.

Rationale
Before personnel can be evaluated and determined to be qualified for their respective position, they must successfully complete position training. An endorsement from an authorized person will attest to the fact that personnel are ready for evaluation to be determined they are qualified.

The endorsement document records the results of training and will include the following information:

1. Name of the trainee
2. Name of the course
3. Make and model of the training equipment used
4. Trainee's prerequisite experience and course time completed
5. Trainee's performance on each lesson and the name of the instructor providing instruction
6. Date and result of each end-of-course performance test
7. Name of the evaluator conducting the test
8. Number of hours of additional training that was accomplished after any unsatisfactory performance test
9. Endorsement from authorized instructor
10. Recurring Training Records
11. Cross Training Records

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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
CBM	Condition-Based Maintenance
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 Procedure
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
MPP	Maintenance Program Plan
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
RMAT	RLV Aerospace Maintenance Technician
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
VOD	Vehicle Operator Dispatcher
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. 4 – Training
Sec: _____ Page: ____ Line: _____

[ ] Documentation Error (Format, punctuation, spelling)

[ ] Content Error

[ ] Enhancement or Refinement

Rationale (Describe the error or justification for enhancement):
_____
_____
_____

Proposed change (Attach marked up text or proposed rewrite):
_____
_____
_____

Please provide any general comments for improvements of this document:

_____
_____
_____
_____

Return completed form to:

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

Appendix C: Traceability of Training Function Decomposition

Figure 5 reflects the Training Functional Decomposition as developed for this effort. The following figure, Figure 6, reflects the Training Functional Decomposition as developed for a previous tasking effort. The subsequent table, Table 6, provides the sub-function level traceability between the two decompositions. The current decomposition was developed in preparation of a Functional Analysis.

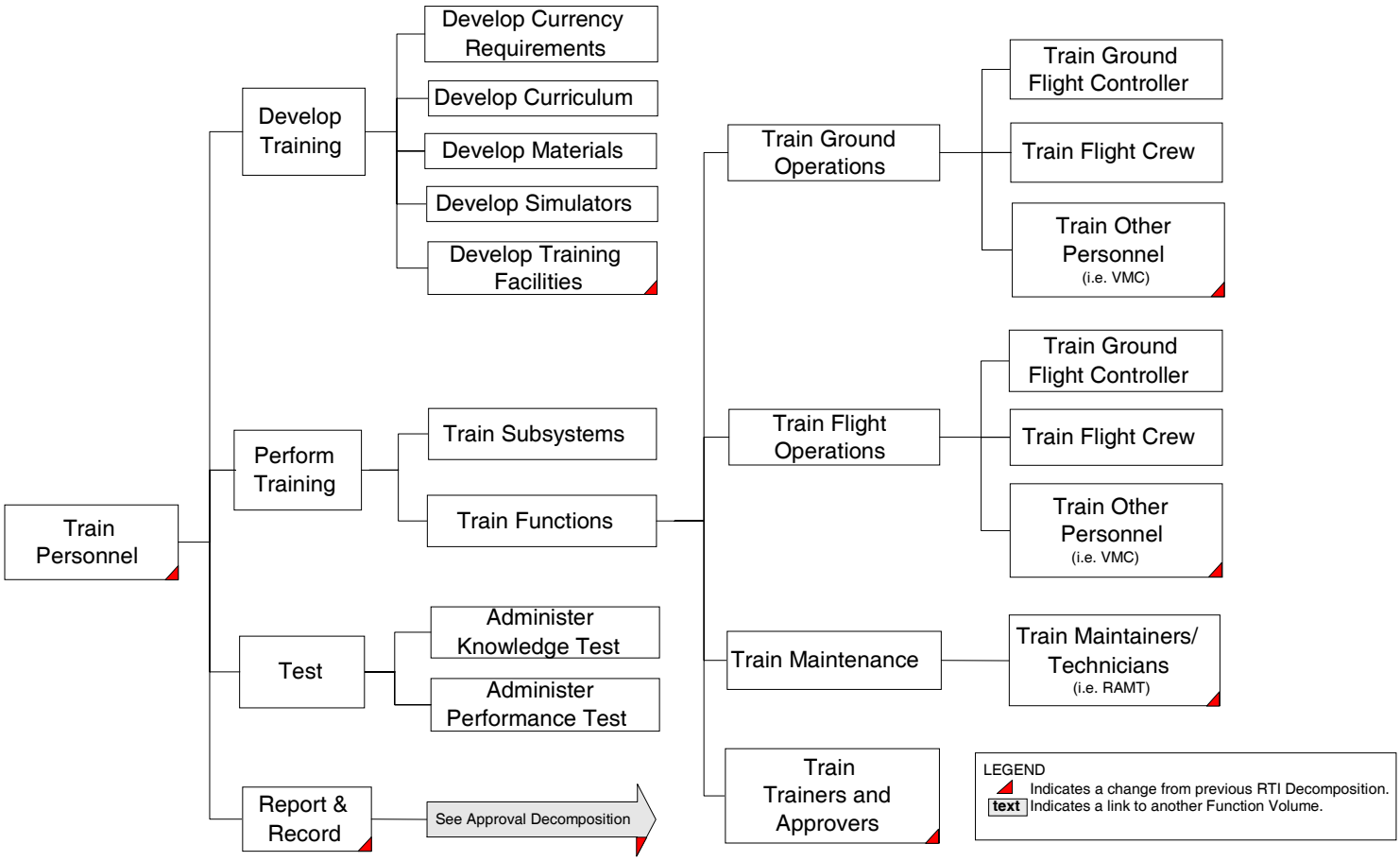

Figure 5 Current Training Functional Decomposition

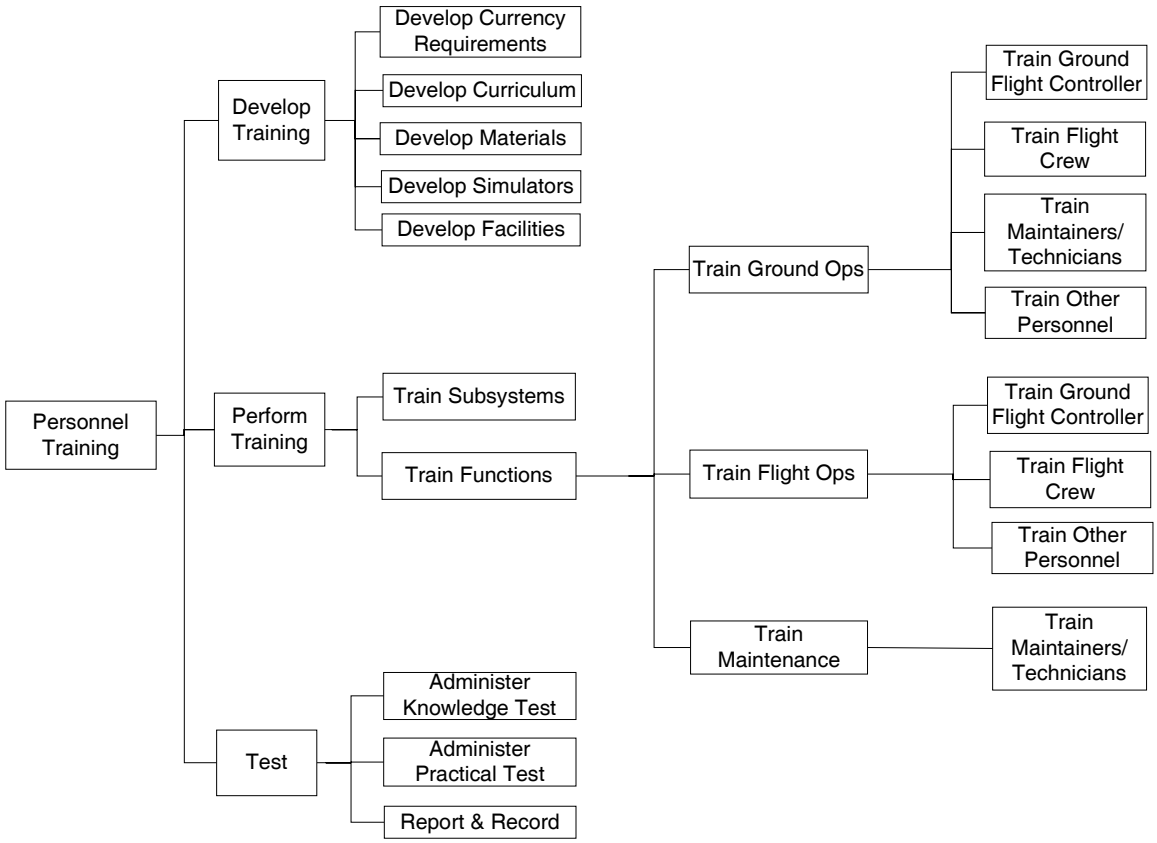

Figure 6 Previous Training Functional Decomposition

Table 6 Train Personnel Sub-Function Traceability

Indicates Same from Previous to Current	Indicates Move/Change from Previous to Current	Indicates New Sub-Function	Indicates no Previous to Current Correlation

Current Sub-Functions					Previous Sub-Functions				
High Level Function	**Second Level Sub-Function**	**Tertiary Sub-Function**	**Fourth Level Sub-unction**	**Change**	**High Level Function**	**Second Level Sub-Function**	**Tertiary Sub-Function**	**Fourth Level Sub-unction**	**Change**
Develop Training				Same	Personnel Training				Same
	Develop Currency Requirements			Same		Develop Currency Requirements			Same
	Develop Curriculum			Same		Develop Curriculum			Same
	Develop Materials			Same		Develop Materials			Same
	Develop Simulators			Same		Develop Simulators			Same
	Develop Training Facilities			Changed Name		Develop Facilities			Changed Name
Perform Training				Same	Perform Training				Same
	Train Subsystems			Same		Train Subsystems			Same
	Train Functions			Same		Train Functions			Same
		Train Ground Operations		Same			Train Ground Operations		Same
			Train Ground Flight Controller	Same				Train Ground Flight Controller	Same
			Train Flight Crew	Same				Train Flight Crew	Same
			Train Other Personnel (i.e. VMC)	Added Comment				Train Other Personnel	Added Comment
		Train Flight Operations		Same			Train Flight Operations		Same
			Train Ground Flight Controller	Same				Train Ground Flight Controller	Same
			Train Flight Crew	Same				Train Flight Crew	Same
			Train Other Personnel (i.e. VMC)	Added Comment				Train Other Personnel	Added Comment
		Train Maintenance		Same			Train Maintenance		Same
			Train Maintainers/Technicians (i.e. RAMT)	Added Comment				Train Maintainers/Technicians	Added Comment
		Train Trainers and Approvers		New					
Test				Same	Test				Same
	Administer Knowledge Test			Same		Administer Knowledge Test			Same
	Administer Performance Test			Renamed		Administer Practical Test			Renamed
	Record & Report			Renamed & Moved		Report & Record			Moved to Secondary Level
		See Approval Decomposition		New					

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Endnotes

[1] White Paper on Commercial Space Transportation Reusable Launch Vehicle Operations and Maintenance, FAA-AST, Chuck Larsen, October 1999

[2] Reusable Launch Vehicles Operations and Maintenance Top-Down Analysis Final Technical Report, RTI, September 30, 2002 (RTI Report No. 08087.002)

[3] Lessons Learned From Challenger Headquarters National Aeronautics And Space Administration Safety Division Office Of Safety, Reliability, Maintainability And Quality Assurance Washington, DC, February 1988

[4] Definition from Simulation Validation by Peter L. Knepeli and Deborah C. Arangno, IEEE Computer Society, 1993

[5] Department of Defense Explosive Safety Board, General Information-Functions, http://www.ddesb.pentagon.mil/function.html