A Tailored Concept of Operations for NASA LSP Integrated Operations

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Abstract

An integral part of the Systems Engineering process is the creation of a Concept of Operations (ConOps) for a given system, with the ConOps initially established early in the system design process and evolved as the system definition and design matures. As Integration Engineers in NASA's Launch Services Program (LSP) at Kennedy Space Center (KSC), our job is to manage the interface requirements for all the robotic space missions that come to our Program for a Launch Service. LSP procures and manages a launch service from one of our many commercial Launch Vehicle Contractors (LVCs) and these commercial companies are then responsible for developing the Interface Control Document (ICD), the verification of the requirements in that document, and all the services pertaining to integrating the spacecraft and launching it into orbit. However, one of the systems engineering tools that have not been employed within LSP to date is a Concept of Operations. The goal of this project is to research the format and content that goes into these various aerospace industry ConOps and tailor the format and content into template form, so the template may be used as an engineering tool for spacecraft integration with future LSP procured launch services.

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1.0 EXAMINATION OF A CONCEPT OF OPERATIONS

1.1 Terminology

The first step in tailoring an established standard or body of work for a specific task is to completely understand the original intent of that material. What is a Concept of Operations? The first recorded use of a ConOps document was in the paper by R.J. Lano, "A Structured Approach for Operational Concept Formulation" TRW SS-80-002, TRW Defense and Space Systems Group in 1980 (IEEE, 2007). With over 36 years of ConOps history under our collective belts it would only be logical to conclude that the term ConOps has a very universally accepted meaning. However, if you ask systems engineers today for a definition of a ConOps you will get a wide variety of responses, with each individual answer heavily slanted toward the type of work or systems with which each particular systems engineer is working. Sometimes a single diagram will be referred to as a ConOps and other times a rather lengthy and detailed document. NASA's Lifecycle, Processes and Systems Engineering course (APPEL-LPSE, 2011) describes an Operations Concept as having a variety of common names at each level:

At the System Level:

- Concept of Operations (CONOPS) Document
- Operational Concept Document
- Context of Operations Statement

At the Configuration Level:

- User's Manual
- Operator's Manual

At the Component Level:

- Design Description

There are many "official" definitions of a Concept of Operations, so this paper will start by acknowledging these definitions and will then establish a working definition for the specific ConOps that is being tailored for the Launch Services Program.

There are two main terms that are associated with a Concept of Operations that are often used interchangeably:

- Concept of Operations (ConOps)

- Operational Concept (OpsCon)

In reality, these two terms have very different meanings and these two distinct meanings from ISO/EEC/IEEE 29148 referenced below are used consistently by ANSI/AIAA, ISO/DEC/IEEE, and the Department of Defense (as cited in Walden, 2015).

ConOps description according to the INCOSE Systems Engineering Handbook Version 4 (as cited in Walden, 2015):

"*The ConOps, at the organization level, addresses the leadership*'s *intended way of operating the organization. It may refer to the use of one or more systems, as black boxes, to forward the organization*'s *goals and objectives. The ConOps document describes the organization*'s *assumptions or intent in regard to an overall operation or series of operations of the business with using the system to be developed, existing systems, and possible future systems. This document is frequently embodied in long-range strategic plans and annual operational plans. The ConOps document serves as a basis for the organization to direct the overall characteristics of the future business and systems, for the project to understand its background, and for the users of ISO/EEC/IEEE 29148 to implement the stakeholder requirements elicitation.*"

Operational Concept (OpsCon) description according to the INCOSE Systems Engineering Handbook Version 4 (as cited in Walden, 2015):

"*A System Operational Concept (OpsCon) document describes what the system will do (not how it will do it) and why (rationale). An OpsCon is a user-oriented document that describes system characteristics of the to-be-delivered system from the user*'s *viewpoint. The OpsCon document is used to communicate overall quantitative and qualitative system characteristics to the acquirer, user, supplier and other organizational elements.*"

From these two established and rather well accepted definitions the following conclusions can be made. The ConOps is more focused on the operational aspects of the system in question, while the OpsCon is a higher-level document that is focused more on general function (what the system will do) in the terms of the end user. Since the purpose of tailoring a Concept of Operations for use by NASA's Launch Services Program is operationally focused and will be used to convey the technical operations of integrating a spacecraft with the launch vehicle, the formal definition above for a ConOps is more applicable. From this point forward in the paper the terms Concept of Operations and ConOps will be used interchangeably and will generally refer to the above INCOSE cited definition of a ConOps.

1.2 Defining a Concept of Operations

Now that the general terminology associated with the term ConOps has been established for this paper, the next step is to go into a more thorough definition for a ConOps. A Concept of Operations can have many uses and can therefore have a wide variety of meanings. The first example to consider is the definition by the Department of Defense from the Dictionary of Military and Associated Terms ("DOD Dictionary of Military and Associated Terms", 2002):

"*A verbal or graphic statement that clearly and concisely expresses what the joint force commander intends to accomplish and how it will be done using available resources. The concept is designed to give an overall picture of the operation. Also called commander's concept or CONOPS.*"

The "Applied Space Systems Engineering" book (Larson, 2009) is another good source for a concise definition of a Concept of Operations:

"*A good concept of operations verbally and graphically reflects stakeholders' expectations, so it becomes a platform for validating the system's architecture and technical requirements.*"

Notice that both definitions use the terms "verbal" and "graphic", meaning that a ConOps should use both words and pictures to convey the content to the audience. The Applied Space Systems Engineering definition also goes on to say that a ConOps is a "platform for validating the system's architecture and technical requirements." As systems engineers, we are relatively good at writing requirements and these requirements almost always end up in a dedicated requirements document. This requirements document is all too often devoid, or at best, sparsely populated with figures and diagrams. Requirements documents are meant to be very specific, so it is left up to the ConOps to paint the high-level or "overall picture of the operation" to which the DOD definition refers. The DOD and Applied Space Systems Engineering definitions very clearly establish the following attributes for a ConOps:

- Verbal and graphical
- Overall picture of the operations
- A platform for validating the system's architecture and technical requirements
- A concise expression of what must be accomplished by the system

The Applied Space Systems Engineering book also cites the following as the purpose behind establishing a ConOps (as cited in Larson, 2009):

- Describe the system's operational characteristics

- Help users, customers, implementers, architects, testers, and managers understand system goals
- Form a basis for long-range operations planning
- Guide how system definition documents, such as system and interface specifications, develop
- Describe how the user's organization and mission relate to the system

The final professional source that should be considered for establishing a vision for what a tailored LSP ConOps should entail is the NASA Systems Engineering Handbook. The definition that NASA uses in the handbook is very similar to definitions referenced above, but the handbook provides some additional characteristics that are worth consideration (NASA Systems Engineering Handbook, 2007):

"*The ConOps is an important driver in the system requirements and therefore must be considered early in the system design processes. Thinking through the ConOps and use cases often reveals requirements and design functions that might otherwise be overlooked.*"

The key attributes from the NASA Systems Engineering Handbook for the LSP ConOps are the following:

- Must be established early in the system design process
- Should consider all aspects of operations including integration, test and launch through disposal
- Must include operational scenarios that are dynamic in nature, covering various modes and mode transitions with the key component being the inclusion of interactions with external interfaces

The first two items listed above that were taken from the NASA Systems Engineering Handbook are very important for the Preliminary LSP ConOps. Establishing the ConOps early in the design process is something that will require some proactive effort by LSP. The normal timeline for LSP to get involved is near the spacecraft CDR, which is not early the spacecraft design process. Therefore, this guidance will drive LSP into an earlier engagement with our spacecraft customer. Considering all aspects of operations is also really critical for an LSP ConOps. LSP is considered the agency experts when it comes to expendable launch vehicles, so LSP tends to focus on the launch vehicle. However, the spacecraft and other operational and external entities can be just as important as the launch vehicle in these operations.

The above professional references will serve as the foundation for the key attributes and characteristics of the LSP ConOps. However, before tailoring all of these inputs for the purposes of the LSP, the Launch Services Program and more specifically the integration function within LSP must be explained.

2.0 A SUMMARY OF LAUNCH SERVICES

2.1 The Role of LSP Within NASA

NASA's Launch Services Program is often referred to as "Earth's Bridge to Space," because LSP procures and manages the launch services for all NASA and NASA-sponsored payloads that seek to utilize an Expendable Launch Vehicle (ELV) to reach space. The "NASAfacts" pamphlet (NASA, 2012) on LSP does a good job of concisely describing LSP's role:

"*The Launch Services Program is responsible for NASA oversight of the launch service including launch vehicle engineering and manufacturing, launch operations and countdown management, and providing added quality and mission assurance in lieu of the requirement for the launch service provider to obtain a commercial launch license.*"

The Launch Services Program is located at Kennedy Space Center in Cape Canaveral, Florida and is a NASA Program operated under the Human Exploration and Operations (HEO) Mission Directorate. NASA LSP has four main goals (Launch Services Program, 2012):

Goal 1: Maximize Mission Success

Maximize mission success and achieve mission excellence for all missions.

Goal 2: Assure Long-Term Launch Services

Assure services by providing end-to-end and advisory service expertise for NASA science, Exploration, U.S. Government, and Government sponsored missions.

Goal 3: Promote Evolution of a U.S. Commercial Space Launch Market

Promote the evolution of a U.S. Commercial Space Launch Market through continued relationship development with customers and stakeholders as well as the continual enhancement of policy, contracts, and launch service products and services.

Goal 4: Continually Enhance LSP's Core Capabilities

Enhance the Launch Services Program Core Capabilities by monitoring the Program's performance assessment tools and measures, relationships with customer and stakeholders, workforce, LSP policy and contracts, and products and services.

Goal 1, maximize mission success, and Goal 4, continually enhance LSP's core capabilities, are the two goals that are advanced the most by the tailoring and development of a Concept of Operations for use with NASA LSP-managed launch services. LSP does more than just procure and manage the launch service. NASA looks to LSP to be the agency experts with respect to expendable launch vehicles and one of the ways that LSP leverages that expertise is through Independent Verification and Validation (IV&V). Some of the independent analyses performed by LSP are used to support the closure of verifications of launch vehicle interface requirements, which are contained in the launch vehicle contractor's Interface Control Document (ICD). NASA LSP maintains both insight and oversight of our launch vehicle contractors. There are two main tasks associated with managing an expendable launch vehicle launch service, maintaining insight and oversight of the launch vehicle itself (the hardware and the processes used on that hardware) and the process of integrating a payload/spacecraft onto that launch vehicle via a launch service. LSP has two separate groups of Systems Engineers that lead these tasks. The Vehicle Systems Engineers (VSEs) are mainly involved with the launch vehicle hardware, while the Integration Engineers (IEs) are focused on the spacecraft/payload customer and all the interfaces and integrated operations that are involved between the spacecraft and the launch vehicle. The focus of the tailored LSP ConOps is integrated operations, which is any operation or activity that involves both spacecraft and launch vehicle hardware or personnel.

2.2 The NASA Spacecraft Mission Lifecycle

Before going any further into explaining LSP integrated operations it is important to understand LSP's primary customer...the spacecraft. NASA has a very well defined process for taking a spacecraft mission from concept to flight, and the timeline for that process plays into the strategy for developing a tailored ConOps for LSP integrated operations. The NASA Space Flight Program and Project Management Requirements 7120.5E defines the typical review schedule for a NASA spacecraft project (7120.5E, 2012):

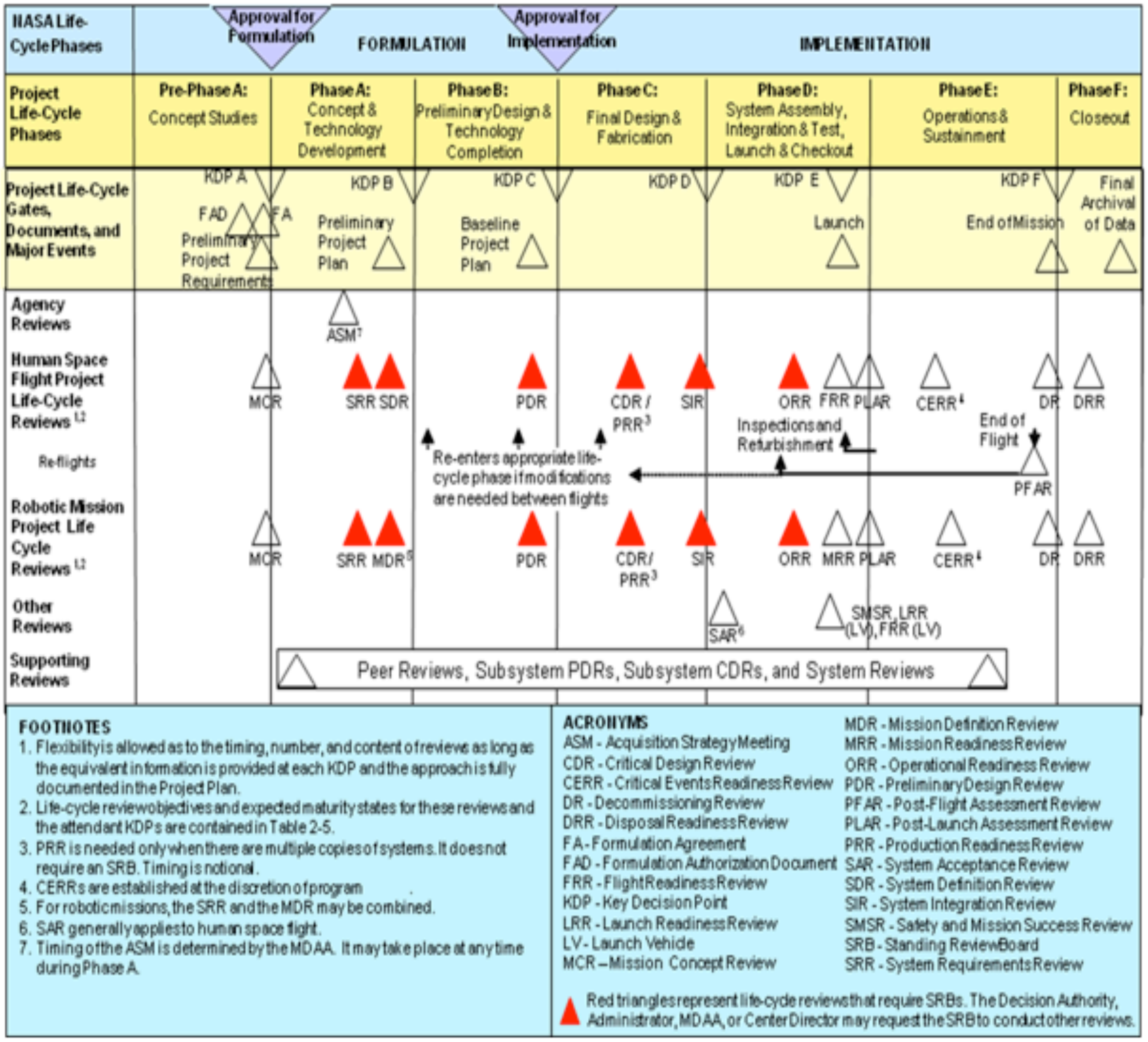

Figure 1: NASA Project Life Cycle

2.3 The LSP Mission Life Cycle

LSP begins supporting the spacecraft very early, pre-Phase A, as part of our advanced mission support function. Most of this support is related to providing basic launch vehicle feasibility information for some of the early mission architecture trades. LSP will also support spacecraft milestone reviews such as SRR and PDR, where high-level requirements can be allocated down to the launch vehicle before a specific launch vehicle/launch service has been selected through the procurement process. LSP has a business process that documents all the major interactions and support functions that LSP has with its spacecraft customers. This business process is called the Launch Services Program (LSP) Business Operating Success Strategies (BOSS). Within the BOSS, the entire timeframe for LSP interaction is captured in a high level schedule called the Mission Life Cycle (BOSS, 2011):

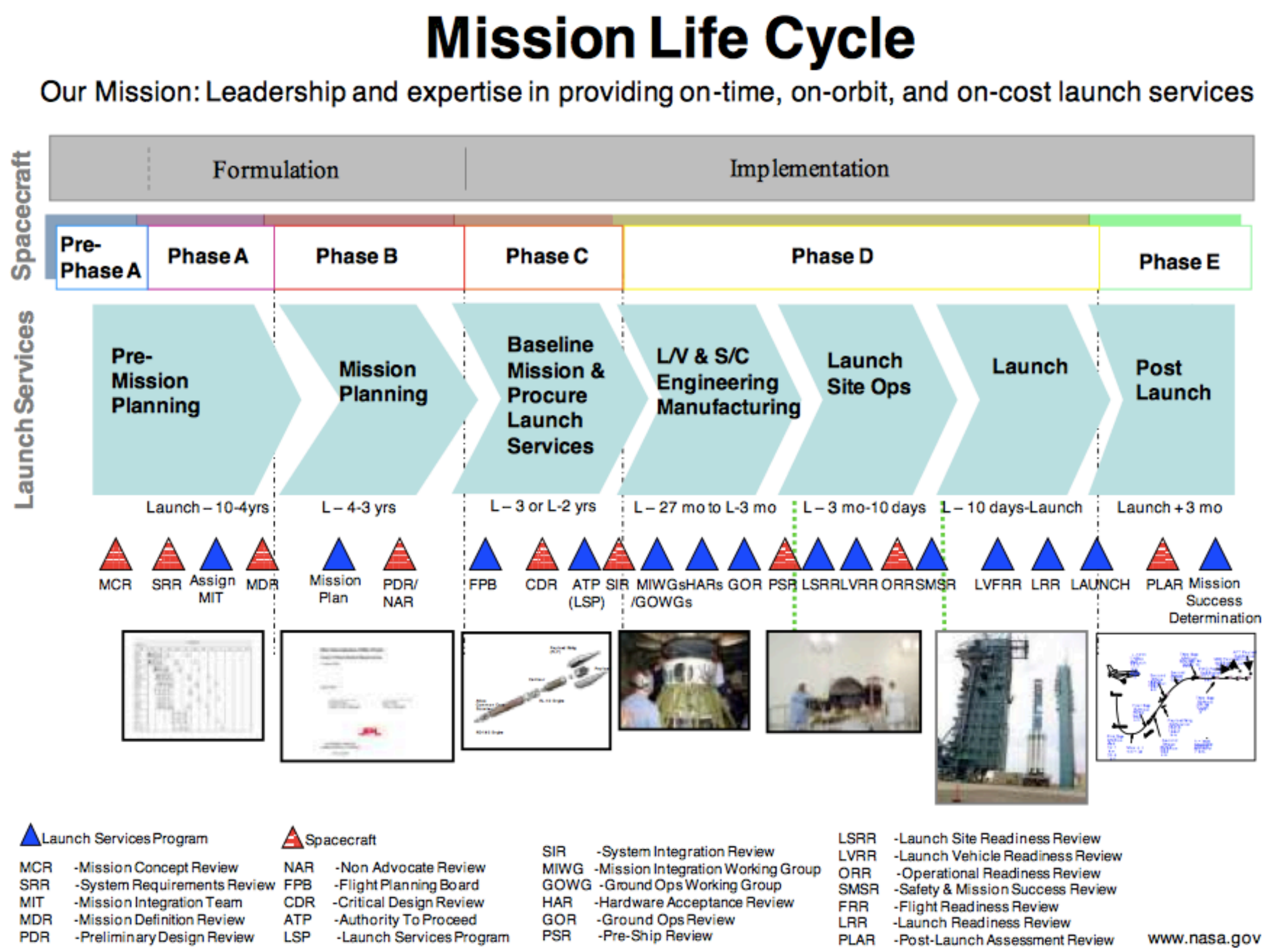

Figure 2: LSP Mission Life Cycle

The LSP Mission Life Cycle is not meant to line up exactly with the standard spacecraft project life cycle in 7120.5E as some spacecraft project mission milestones can vary slightly (spacecraft review dates are notional). But the major launch services milestones and the spacecraft phases shown in Figure 2 are meant to stay lock step. The main thing to notice in the LSP Mission Life Cycle is that the procurement of the launch service takes place after spacecraft PDR (and sometimes before and sometimes slightly after spacecraft CDR in Phase C).

2.4 LSP Integration Engineering Functions

As stated previously, the primary focus of the LSP IE is the integration of the spacecraft with the launch vehicle. The LSP IE gets involved when reviewing the spacecraft Announcement of Opportunities and during spacecraft early mission feasibility studies and then again in support of some of the early spacecraft milestone reviews like SRR and PDR. Integration Engineering is also heavily involved with the development of the spacecraft Interface Requirements Document (IRD), where spacecraft to launch vehicle interface requirements are documented. The IRD is then used as an input into the launch services procurement process (which takes place in Phase C as shown in Figure 2). The spacecraft interface requirements from the spacecraft IRD are tailored down into a concise set of interface requirements that form a significant portion of the Request For Proposal (RFP) that is released for potential launch vehicle contractors to bid against as part of the competitive launch service procurement. Once a launch vehicle has been selected, the standard mission integration cycle begins. During mission integration LSP, the spacecraft project and the launch vehicle provider work together to start developing the mission ICD (which includes not only writing the interface requirements but the verification plans as well), performing the standard set of analyses that the launch vehicle provider runs to support the mission, planning for and executing spacecraft standalone tests that close out launch vehicle verifications and planning for and executing integrated operations. Figure 3 is a LSP Functional Architecture that has been tailored specifically for major functions that are supported by LSP Integration Engineering and shows in graphical form the activities just described.

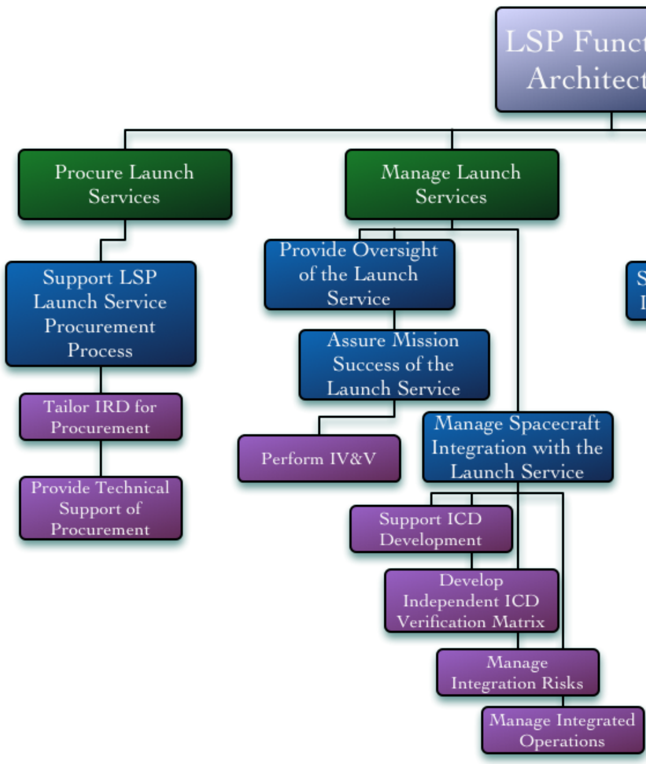

Figure 3: LSP IE Functional Architecture

LSP Integration Engineering is involved with four main functions: Procure Launch Services, Manage Launch Services, Support Spacecraft Advanced Mission Planning and Satisfy Agency-Wide Space Transportation Requirements. The main function that has the most to gain from the establishment of an LSP ConOps is the Manage Launch Services function, which is the activity where all the spacecraft integrated operations take place. But the other three functions will benefit from a ConOps as well.

The Satisfy Agency-Wide Space Transportation Requirements function has two sub-functions, certifying new launch systems and supporting Announcement of Opportunities (AO) proposal evaluations. An AO is one of the official mechanisms used to competitively compete spacecraft mission concepts. NASA uses experts from across the agency to help evaluate and rate these mission proposals and then the top concepts are funded to begin the first stages of mission development. Integration Engineering is one group that evaluates these proposals to ensure the mission concept and all the infrastructure and operations needed to support the mission concept are feasible. Establishing an LSP ConOps would help these concept mission teams better understand the operational aspects of their mission and identify and resolve concept weaknesses. The other sub-function, new launch system certification is a very small support task for Integration Engineering. Most launch vehicle certification activities are performed by individual discipline experts and then integrated by LSP's VSEs, who are the systems engineers responsible for launch vehicle systems engineering. Integration Engineering only gets involved with vehicle certification from the perspective of evaluating the spacecraft interfaces and vehicle environments since it is Integration Engineering that will be responsible for managing the integration of spacecraft with this new launch system.

The Support Advanced Mission Planning function has four sub-functions, but the support spacecraft IRD development function is the only function of the four that has any direct link to an LSP ConOps. As the spacecraft project continues to develop their requirements and flow them down to the next lower level, the requirements flow down eventually reaches the launch service. The spacecraft IRD is where all the interface requirements with the launch service are documented. LSP is heavily involved with the spacecraft team when this requirements document is developed to ensure that all the interfaces are properly identified and that they are consistent with the known capabilities of the existing fleet of launch vehicles.

The next major function is to procure launch services. When it comes time for LSP to procure a launch service, the spacecraft IRD is tailored down to what eventually becomes the requirements document that is put out for our launch vehicle contractors to bid on as part of the competitive procurement. If all of the requirements from the spacecraft IRD were included in the Request For Proposal (RFP), the procurement process would be a very time intensive and expensive activity. By streamlining the interface requirement down to just the requirements that are either unique to that particular spacecraft mission or are potential cost drivers for the launch service, LSP is able to focus the procurement process on the critical items. A ConOps would help both the spacecraft Project and LSP better identify operationally driven interface requirements (which can often be missed until later in the integration cycle) as well as help with the process of identifying mission unique requirements.

The final function is the management of the launch service. This starts in earnest after the launch service is awarded and the standard integration is kicked-off around L-36 months (Phase C in Figure 2) and continues until after launch when the mission success determination is made. Oversight of the launch service is mostly a contractual or management function and is supported from a technical aspect by the Integration Engineering function. One of the primary ways that LSP provides mission assurance is with IV&V. Some of the IV&V that is performed by LSP directly supports spacecraft test operations that involve launch vehicle personnel and/or hardware. Both the spacecraft project and NASA as an agency rely on LSP to provide this IV&V function and identifying where this fits into planned spacecraft activities (as an input or piece of support information for an environmental test, for example) is something that should be included in a ConOps. The final sub-function, managing spacecraft integration with the launch service, has a large number of sub-functions that will benefit from the existence of an LSP ConOps. This spacecraft integration sub-function is where the spacecraft integration takes place and has the most to gain from this new LSP ConOps.

3.0 CONOPS PROJECT SCOPE

3.1 Launch Services Boundaries

The scope of launch services is best explained with the use of a context diagram.

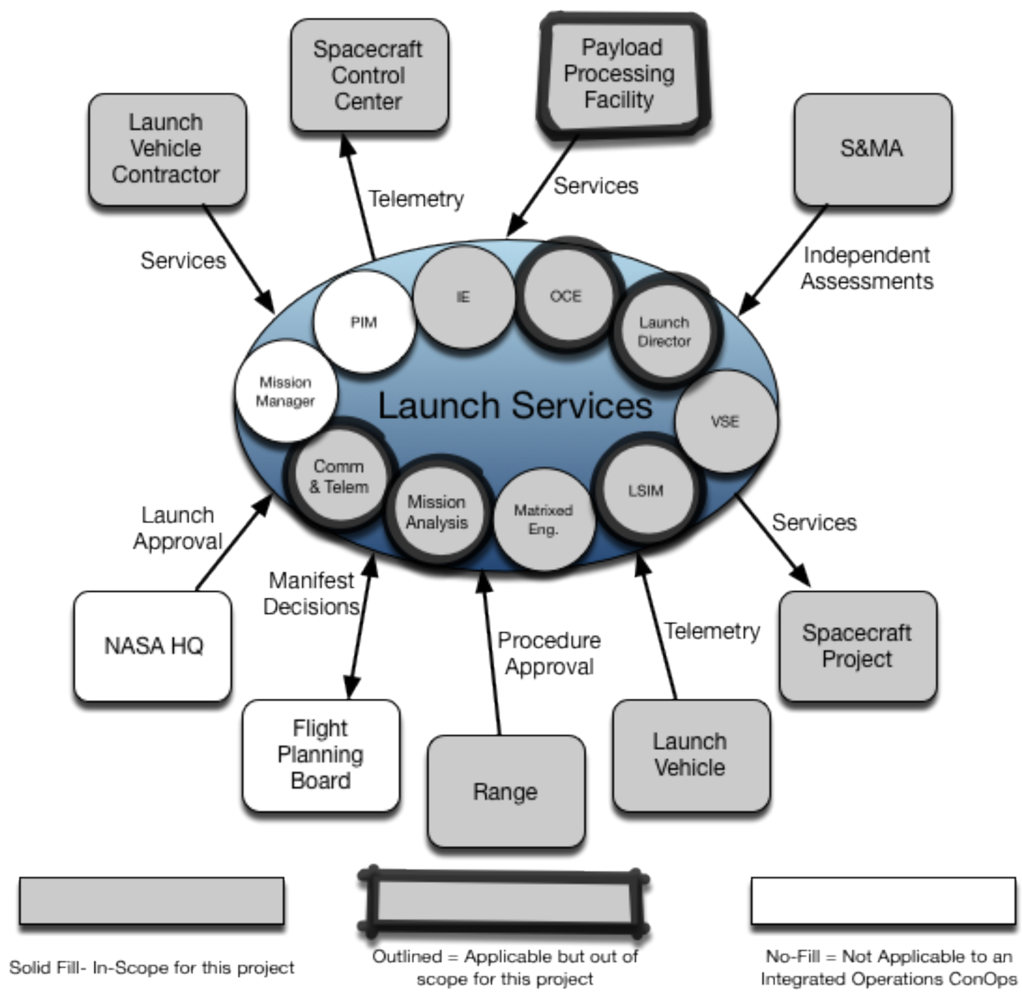

Figure 4: Launch Services Context Diagram

As illustrated in Figure 4, LSP interacts with many different entities. The small circles within the Launch Services oval are groups that are part of Launch Services (some are physically part of the Program and some are matrixed engineering support). Some of these entities do not come into play with respect to the LSP Integrated Operations ConOps, like the Flight Planning Board and NASA Headquarters (HQ). The prime interfaces for LSP are our spacecraft customer, the launch vehicle contractor and the payload processing facility (which is put on contract by the LSP Launch Site Integration Manager (LSIM) for our spacecraft customer). The LSIM, the Payload Processing Facility (PPF) and Communication and Telemetry are all very important aspects of the LSP ConOps but are not within the defined scope of this project. Formal coordination is required with the LSIM group within LSP and the time constraints of this project precluded having the formal reviews necessary to include their operations and scope with this first version of the ConOps. Communication and Telemetry is another very crucial service that LSP provides to our spacecraft customers that is within the scope of our ConOps but will have to be coordinated and included as future work.

3.2 ConOps Development Timing

As quoted earlier from the NASA Systems Engineering Handbook, the ConOps must be developed early in the system development cycle. For a NASA mission, early development is pre-Phase A and Phase A while there are still alternative mission concepts being evaluated. The critical time period for LSP to start collaborating on a high-level Integrated ConOps would be once the Spacecraft Project team has been fully formed to start developing a baseline mission concept. Prior to this time there would not be enough technical expertise on the Spacecraft Project team to support the level of technical rigor needed to populate a meaningful ConOps. However, Phase A is early with respect to the launch service. LSP does not procure launch services for a Spacecraft Project until around L-36 months, or Phase C. Therefore, if the ConOps were delayed until a launch vehicle were selected then the Spacecraft Project would already be in Phase C and would have completed their Critical Design Review (CDR). After the completion of the CDR the spacecraft begins full-scale production. This is too late to develop a ConOps if one of your main purposes is to capture missing operationally driven requirements that have the potential to change significant portions of the spacecraft design. But if the ConOps is developed in Phase A, the launch vehicle has not been selected yet. Without knowing the specific launch vehicle, the details of the integrated operations are still somewhat fluid and undefined. The obvious solution is to develop two separate ConOps. One ConOps in Phase A to support early mission design efforts and the solidification of interface requirements for the launch services procurement, and one in Phase C once the launch vehicle has been selected to support development of the mission Interface Requirements Document (ICD).

3.3 The Phased ConOps Development Approach

Now that it has been established that two separate ConOps are required in order to realize all of the benefits that a ConOps afforded, a schedule for when these two separate products will be developed and a strategy for how the first ConOps will evolve into the second is required. In order to develop a schedule, the key activities and milestones that drive that schedule need to be identified:

- L-5 to 6 Years: Phase A (when the spacecraft team begins to fully form)
- L-4 to 5 Years: LSP assigns the Mission Integration Team (MIT)
- L-3 to 4 Years: LSP Procures the Launch Service
- L-3 Years: Spacecraft CDR
- L-27 to 34 Months: Standard LSP Mission Integration Begins
- L-24 Months: Mission ICD Development Begins - Authority to Proceed (ATP)
- L-18 Months: Baseline Mission ICD is Released

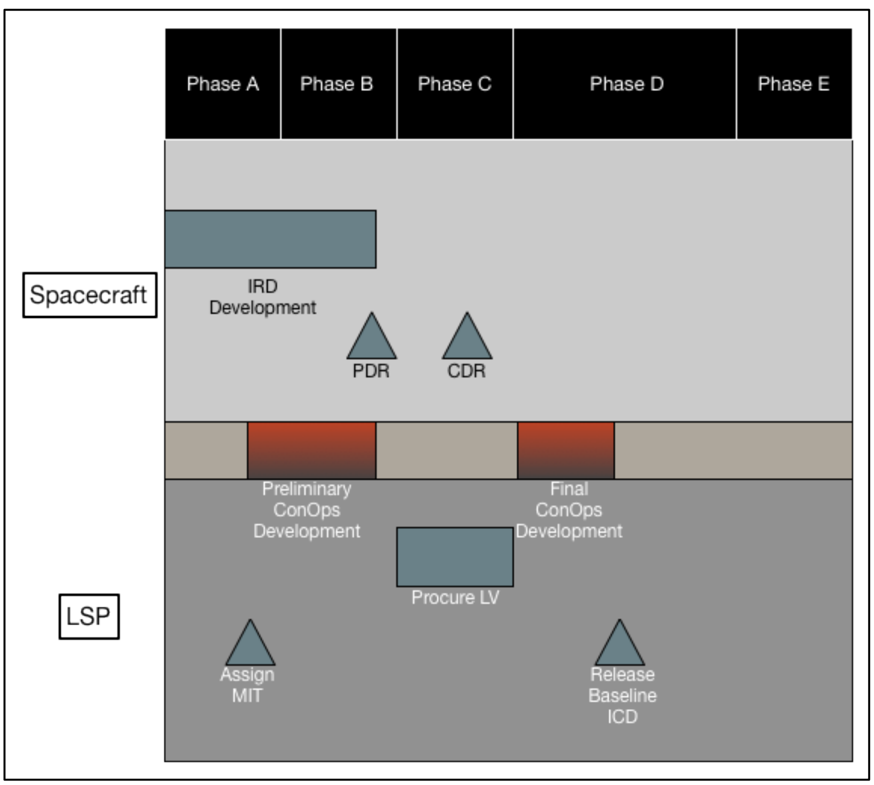

Figure 5: ConOps Development Schedule

The key drivers for development of the early 'Preliminary ConOps" is primarily the LSP procurement of the launch service, but the spacecraft development of their Interface Requirements Document (IRD) leading into their PDR is also a large driver for the timing of the early ConOps development. If the early ConOps can be developed in parallel with the spacecraft IRD then revisions to the IRD can be avoided and the spacecraft team can be that much more prepared for their PDR milestone review. This timing also gets the early ConOps done well ahead of the launch vehicle procurement activity. The later launch vehicle specific "Final ConOps" development can't start until the procurement of the launch service is complete at around L-30 months, but needs to be complete before the launch vehicle contractor delivers the Baseline ICD at around L-18 months. As depicted in Figure 5, there will be two separate ConOps documents. The Preliminary ConOps will be developed very early in the mission planning phases just as the LSP MIT is assigned and when the spacecraft has started staffing a full team to ramp up their IRD development efforts. This Preliminary ConOps will then be complete in time to support the spacecraft PDR, the launch vehicle procurement and the spacecraft CDR. Once the launch vehicle has been selected, the Final ConOps develop will begin. The Final ConOps will start with the content of the Preliminary ConOps but will built on it based on the specifics of the launch vehicle with which the spacecraft will be integrated. The Final ConOps development time will need to take place in a window of about 6-12 months (in order to be completed in time to support ICD development), much shorter than the 12-18 months afforded to the Early ConOps development. The Full ConOps development will take place in parallel with the ICD development efforts and will conclude when the Baseline ICD is released at approximately L-18 months. The primary focus of this paper going forward is going to be the Preliminary ConOps, but since the Final ConOps will be built from the Preliminary most of the paper is applicable to it as well.

4.0 GROUND RULES & ASSUMPTIONS

4.1 Ground Rules

1. The scope of the LSP ConOps is limited to the area of responsibility of Integration Engineering within LSP. Other significant contributors to LSP Integrated Operations, like the LSIM, OCE, Launch Director, Payload Processing Facility and Communication and Telemetry, will require formal coordination and review as part of future work that is beyond the scope of this project.
2. This paper and the corresponding Preliminary ConOps Template in Appendix A are conceptual and will still need to be formalized with LSP before being put into use by LSP Integration Engineering and established as an LSP management product.
3. The Preliminary LSP ConOps will be launch vehicle agnostic, as this ConOps will be established before the launch vehicle has been procured by LSP.

4. The Preliminary LSP ConOps will use the term "Payload Processing Facility (PPF)" generically as LSP will not have a PPF on contract for the spacecraft project at the time the Preliminary LSP ConOps is established.
5. The content within this ConOps should not be a duplication of information contained in spacecraft or launch vehicle requirements documents. Specific values established in these requirements document should not be used, but instead a reference to these documents should be utilized. Specifying numeric values in the Preliminary ConOps would lead to unnecessary configuration management and versioning work that should be left to the more formal requirements documents.

4.2 Assumptions

1. The Spacecraft Project already has all the information needed to populate the LSP ConOps and no further engineering work is required (other than re-formatting).
2. The LSP Chief Engineer (LSP CE) delegates many tasks to the Integration Engineer for early mission planning, spacecraft I&T and integrated operations. For the purposes of this project it is assumed that the LSP CE is applicable but out of scope for this project due to the areas of responsibility pertaining to integrated operations being delegated to the integration engineer. Formal collaboration with the LSP Office of Chief Engineer is required future work before this ConOps can be used for LSP.
3. It is assumed that the LSP Integration Engineering group will take on the responsibility of configuration management of the LSP ConOps document for each of our missions. LSP Integration Engineering will adopt a similar configuration management process to that being currently used by the LSP Mission Analysis Division for their in-house models.

5.0 THE TAILORING PROCESS

5.1 Tailored LSP ConOps Characteristics

In Section 1.2 of this paper, key characteristics were identified from various industry standards and professional ConOps examples. These characteristics were then taken and examined within the context of the Integration Engineering functions described in the Launch Services Summary section (Section 2.0). The process for tailoring these characteristics was very simple and informal. Each key attribute was taken and modified in order to properly address the specific functions and culture that is inherent with how the Launch Services Program functions. These characteristics are applicable to both the early ConOps and the later ConOps developed once the launch vehicle has been selected. Each of the following tailored characteristics is immediately followed by rationale for why this characteristic is important to the LSP ConOps:

1. Will describe how the spacecraft and the LSP managed Launch Service will be operated during all integrated operations

Rationale: Each operation that includes some combination of spacecraft assets (hardware or personnel) and launch vehicle contractor assets (hardware or personnel) is considered an integrated operation. Operations can drive additional mission unique requirements that are not always apparent while developing an interface requirements document like an IRD or an ICD.

2. Will provide an overall picture of all the systems, facilities, processes and people that will be involved with integrated operations

Rationale: Graphical depictions of operations often reveal details and expectations that are difficult to convey in the form of written requirements. Graphical depictions of operations will act to supplement the spacecraft IRD, aid in the development of the launch vehicle contractor ICD and then be used to capture operational details that are not typically captured or appropriate for an ICD.

3. Will include an overview of the mission's science objectives and the operations that are carried out by the spacecraft to meet those objectives

Rationale: Spacecraft science objectives are the main driver for the mission. Spacecraft operations are required in order to carry out the mission and meet the science objectives. Spacecraft operations, even though most of them occur after separation from the launch vehicle, can flow requirements down to the launch service and the launch vehicle hardware. A good example of this is with contamination control requirements that are driven by science goals for a sample return mission. Identifying spacecraft mission operations that are directly linked to science objectives early in the mission development cycle can reduce the likelihood of inadequately flowing spacecraft operational requirements down to the launch vehicle.

4. Will be written from the perspective of the spacecraft customer, who is the end user of the Launch Service

Rationale: A ConOps is first a foremost a communication tool. In order to effectively communicate operational needs and expectations between the spacecraft customer and the launch vehicle contractor and to *ensure the customer needs are properly captured, the document should be written using terminology that is consistent with the spacecraft project.*

5. Will be utilized as a resource during the development of the ICD

Rationale: Graphical representations of operations are informational rich than written interface requirements, and up until this point, written interface requirements have been the source material for launch vehicle ICDs (i.e. leveraging from the spacecraft project IRD and the launch vehicle contractor's ICD template). By supplementing the ICD development with an already established ConOps we are less likely miss requirements or misinterpret them when creating the ICD.

6. Will be used to facilitate the capture of spacecraft customer expectations

Rationale: Operational details are not meant to be captured by an interface requirements document. Historically we have captured operational details and expectations in the form of operational working group telecons starting several weeks before planned integrated operations. Waiting that long until discussing and compiling operational details risks having large operational needs/requirements can go unidentified until it is too late to address before the time of the scheduled operation.

7. Should consider all aspects of operations that use launch vehicle hardware, launch vehicle contractor services/support and personnel and any activity that involves the Launch Services Program (IV&V, government furnished equipment, facilities and services). This should span all planned operations including integration, test and launch through disposal.

Rationale: Needs to encompass all operations that have the potential to drive additional launch vehicle support above and beyond the standard services called out in our NASA Launch Services (NLS) contract.

8. Will be launch vehicle agnostic

Rationale: The ConOps will be developed before the procurement of the launch service so that is can be used as a tool to ensure that all mission unique requirements (including operationally derived requirements) are identified before competing the launch service. Eventually the ConOps could also be used as an additional reference document provided along with the Request for Proposal (RFP) to the potential bidders for the launch service.

5.2 Tailoring Content for the LSP ConOps

The LSP ConOps is a concept of operations that will be unique for each and every spacecraft mission for which LSP manages a launch service. Each individual spacecraft will need to tailor the generic LSP ConOps template (see Appendix A) based on the specifics of that mission, but the template that will be presented and discussed in the following sections of this paper will be applicable to all future LSP missions.

Tailoring the content for the Early ConOps template is a six-step process:

1. Identify the LSP Functions that are applicable to the scope of the Integrated ConOps
2. Identify available spacecraft design artifacts that are available and applicable to integrated operations at the time of Early ConOps development in Phase A
3. Tailor standard industry ConOps content down to content that is relevant to the Early ConOps
4. Identify content generally part of LSP Launch Service procurement requirement documents
5. Identify key ConOps content in the NASA Systems Engineering Handbook
6. Map the full ConOps content from all the sources obtained from the previous 5 steps and the tailored LSP ConOps characteristics from Section 5.1

These six steps are described in detail below:

<u>Step 1: Identify Applicable LSP Functions</u>

The LSP IE Functional Architecture from Figure 3 was examined and compared against the scope and ConOps applicability in the Launch Services Context Diagram in Figure 4 and the result was the following functional applicability.

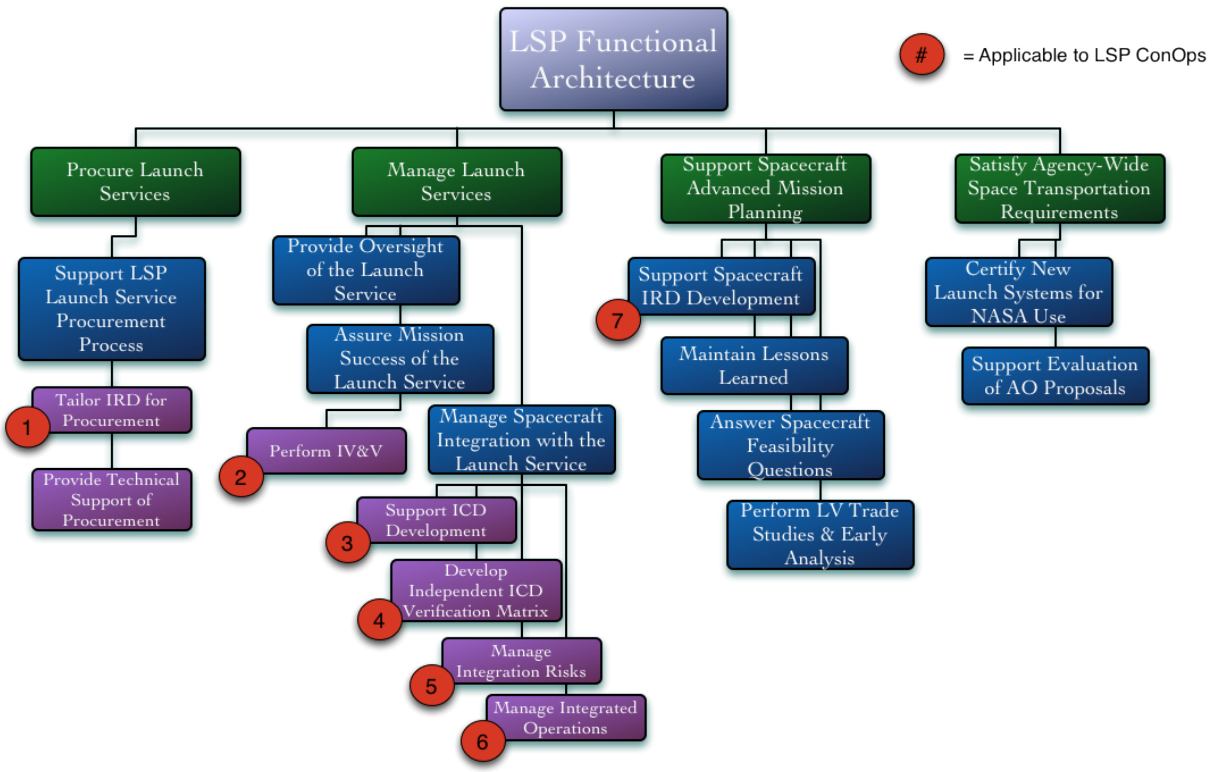

Figure 6: LSP ConOps Functional Applicability

Most of the applicability in Figure 6 is obvious, but a few of them are not. Two identified functions stand out and require further explanation: "Perform IV&V" and "Manage Integration Risks." These two functions are related because one of the main purposes for the existence of LSP is to provide an extra layer of assurance that the mission will be a success. This is accomplished by a combination of risk management and IV&V. LSP performs targeted IV&V on a mission-by-mission basis, performing the IV&V in areas that are unique or involve an increased level of complexity. These mission unique IV&V areas of interest are identified as part of our risk management process and the IV&V is carried out in conjunction with our independent verification of interface requirements. All of our interface requirements are linked back to either an operation or an environmental test, all of which are within the scope of a ConOps. Therefore it is imperative that the ConOps capture these risk management and IV&V activities within the context of the operations.

Step 2: Identify Available Spacecraft Design Artifacts

Available spacecraft design artifacts were identified from the NASA Project Life Cycle shown in Figure 1 and by referencing NASA System Engineering Processes and Requirements (NPR 7123.1A), which lists all of the content expected to be part of each major spacecraft milestone review (7123.1B, 2013).

Design Artifacts	MCR (NPR 7123.1A)	SRR (NPR 7123.1A)	PDR (NPR 7123.1A)	Ref # of Identified Applicable Content
Preliminary Mission De-scope Options	✔			
Preliminary Technical Plans to Achieve Next Phase	✔			
Defined Measures of Effectiveness (MOE) and Measures of Performance (MOP)	✔			**1**
Mission Goals and Objectives	✔			**2**
System Software Functionality Description		✔	✔	
Concept of Operations	✔	✔	✔	**3**
Mission Requirements Document		✔	✔	**4**
SEMP		✔	✔	
Risk Management Plan		✔	✔	

Design Artifacts	MCR (NPR 7123.1A)	SRR (NPR 7123.1A)	PDR (NPR 7123.1A)	Ref # of Identified Applicable Content
Schedule		✔	✔	**5**
Technology Development Maturity Assessment Plan		✔	✔	
Risk Assessment	✔	✔	✔	**6**
Concept life-cycle support strategies (Logistics, Manufacturing and Operation)	✔	✔	✔	**7**
Software Development Plan		✔	✔	
Document Tree		✔	✔	
Verification and validation approach	✔	✔		**8**
System Safety Analysis		✔	✔	
Analysis of Alternative Concepts	✔		✔	
System Safety and Mission Assurance Plan			✔	
Configuration Management Plan			✔	
System Architecture			✔	**9**

Table 1: Applicable Spacecraft Design Artifacts

Step 3: Tailor Industry Standard ConOps Content

There are a large number of example ConOps from which to choose, but only a few were selected for the basis of the content tailoring based on their recognition of being an "industry standard", their direct applicability due to a similar operating environment or because their structure was uniquely suited for the LSP ConOps need:

- IEEE Guide for Information Technology-System Definition-Concept of Operations (ConOps) Document (IEEE, 2007)
- ANSI/AIAA G-043A-2012 Guide to the Preparation of Operational Concept Documents (ANSI, 2012)
- Operational Concept Description (OCD)-Space and Naval Warfare Systems Command (DI-IPSC-81430A, 2000)
- Federal Highway Administration - California Division: Concept of Operations Template (Federal, 2016)

The IEEE and ANSI standards are both well respected and commonly used across the industry as the foundation for many ConOps, so it seemed appropriate to include them as part of the tailoring inputs. The Operational Concept Description (OCD) document and the Federal Highway Administration (FHA) - California Division: Concept of Operations Template are both examples of having a structure that was different than other ConOps but well suited for to their specific ConOps purpose. What follows is a table summarizing the main sections from each of these four documents with the last column of the table referencing back to the numbered Tailored LSP ConOps Characteristics listed in Section 5.1. Content from these four reference documents that relate heavily to the Tailored LSP ConOps Characteristics have been shaded and bolded in the table and will flow into the content structure for the LSP ConOps.

ANSI	Space and Naval Warfare Systems Command (DID: DI-IPSC-81430)	IEEE	California Division-FHA ConOps Template	LSP ConOps Content	Applicable LSP ConOps Char.
Scope: Identification	Scope	Scope	Purpose of the Document	**Purpose**	**1,2,4,5,6,7**
			Scope	**Scope**	**1,2,4,5,6,7,8**
Reference Documents	Reference Documents	Reference Documents	Referenced Documents	**Reference Documents**	**2,3,7**

ANSI	Space and Naval Warfare Systems Command (DID: DI-IPSC-81430)	IEEE	California Division-FHA ConOps Template	LSP ConOps Content	Applicable LSP ConOps Char.
Background information	Current system or situation	Current system or situation	Background	**Mission Goals & Objectives**	**1,3,4,6**
Existing systems and operations	Justification or nature of changes	Justification or nature of changes		**Operational Overview**	**1,2,3,4,6,7**
System Overview	Concept for a new or modified system	Concept for the proposed system	System Overview	**System Overview**	**1,2,3,4,6,7**
Other operational needs	Operational Scenarios	Operational Scenarios	Operational Environment	**Operational Environment**	**1,2,3,7,8**
	Summary of impacts	Summary of impacts	Operational Needs		
Analysis of the proposed system	Analysis of the proposed system	Analysis of the proposed system	Support Environment		
System Operational Scenarios	Summary of advantages		Operational Scenarios	**Operational Scenarios**	**1-8**
	Notes	Notes	Appendices	**Appendices**	
Acronyms, Abbreviations and Glossary			User-Oriented Operational Description	**Acronyms, Abbreviations and Glossary**	
			Concept of the Proposed System		

Table 2: LSP ConOps Tailored Content

Step 4: Identify Typical Procurement Requirement Document Content

Figure 7 below represents the main components of the tailored requirements that are part of the LSP launch service procurement process, similar in content to a spacecraft IRD or a launch vehicle contractor ICD but slightly more focused on just the critical, mission unique or cost driving requirements. This figure is the content that is critical to carrying out the procurement of the launch service.

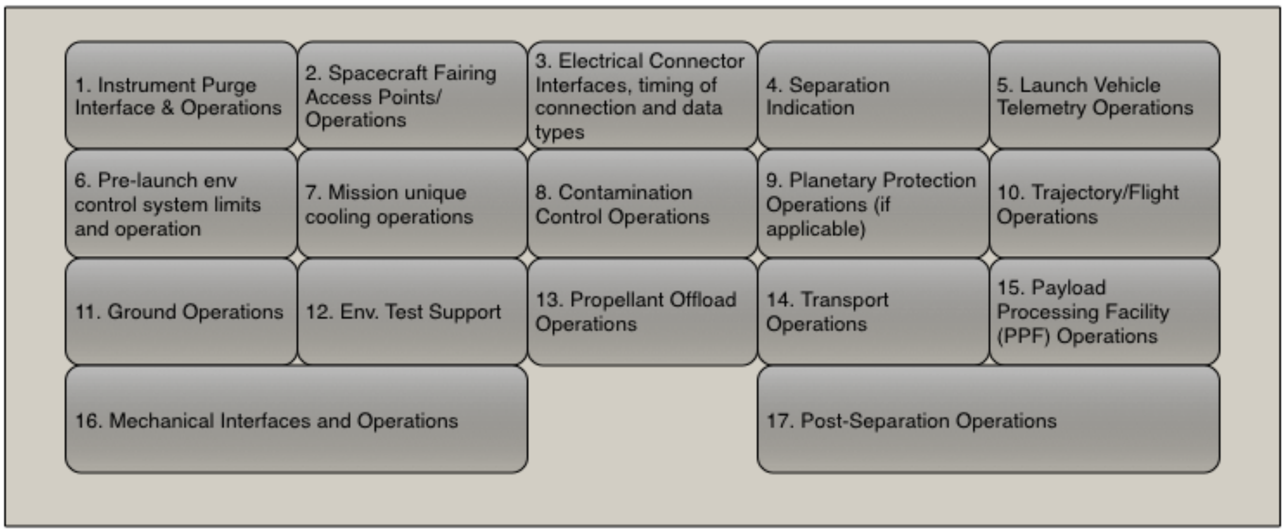

Figure 7: Typical LV Procurement Requirement Content

Step 5: Identify Key NASA SE Handbook Content

The NASA Systems Engineering Handbook (NASA Systems, 2007) is an excellent all-around reference for systems engineers. While the handbook does not devote a significant portion of its content to the topic of ConOps, it does contain some very valuable guidance on the content and format that should be considered when creating a Concept of Operations. Figure 8 depicts the content identified in the NASA Systems Engineering Handbook that is crucial for a ConOps to capture and effectively communicate.

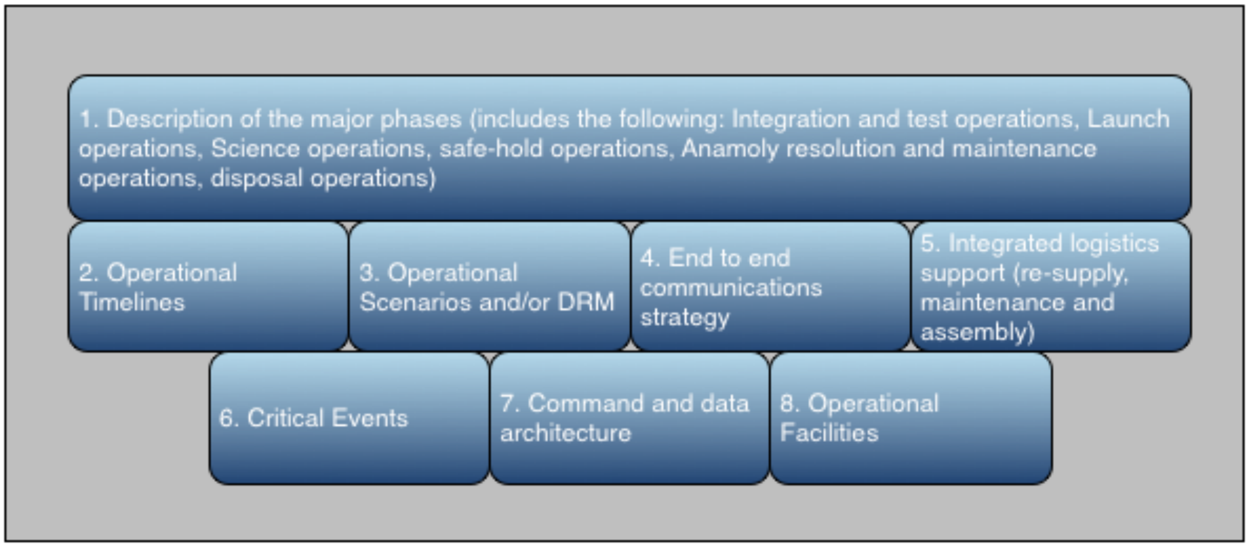

Figure 8: NASA SE Handbook Content

Step 6: Map Full Content From Previous 5 Steps

Table 3 represents the structure of the Preliminary LSP ConOps. The main content sections listed in the first column of the table were created by taking the content from Table 2 and consolidating that content down to a structure and sequence that made sense for how LSP provides services to our spacecraft customer. Those basic content types from Table 2 were then taken and compared against the following existing ConOps documents and NASA training materials and a common structure was created based on the author's judgment and background from working within LSP. The three main sources used for determining the final table of contents were:

- James Webb Space Telescope Operations Concept Document (JWST, 2014)
- Space Vehicle Operators Concept of Operations (Space, 2004)
- NASA Space Systems Engineering ConOps Training Module (Scoping, 2016)

This last remaining step for tailoring the ConOps content involves taking the tailored data and characteristics from steps 1, 2, 4 & 5 and the tailored LSP ConOps characteristics from Section 5.1 and mapping them into the proposed LSP ConOps table of contents in Table 3. The end result is a structure from which the template of the Preliminary LSP ConOps can be created. The numbers in each of the columns in Table 3 reference back to the reference numbers in figures and tables from steps 1, 2, 4 & 5.

LSP ConOps Content	LSP Functions	Spacecraft Design Artifacts	LV Procurement Requirements	NASA SE Handbook	Tailored LSP ConOps Characteristics
Purpose					1,2,4,5,6,7
Scope		1-9			1,2,4,5,6,7,8
Reference Documents	7	1-9			2,3,7
Mission Goals & Objectives	7	2,3,4		3,6,7	1,3,4,6
Operational Overview	3,7	2,3,8	1-17	1-8	1,2,3,4,6,7
System Overview	3,7	1,2,3,4,5,7,8,9	1-17		1,2,3,4,6,7
Operational Environment	1,2,3,6,7	3,4,7,8	1-17	1,3,5,8	1,2,3,7,8
Operational Scenarios	1-7	1, 3, 7, 8	1-17	1,3,4,5,8	1-8
Appendices					
Acronyms, Abbreviations and Glossary					

Table 3: Mapped Content for Preliminary LSP ConOps

6.0 TEMPLATE CONTENT GUIDANCE & EXAMPLES

Section 6.0 of this document goes through each of the sections defined in the template (see Appendix A) that has been established for the Preliminary LSP Concept of Operations for Integrated Operations. Each section of the template in Appendix A will be addressed in the following sections of this paper, explaining the purpose and expectations for each section complete with examples using the fictional FireSat mission as the example. Some FireSat mission example diagrams and figures will be referenced from already existing diagrams, but most diagrams will be reproduced in a scope and format suited for the LSP Preliminary Concept of Operations. In both cases, the original source material for FireSat diagrams will be cited. Each of the following sections will start with excepts of Table 3 that pertain to that given section, followed by an explanation of what is expected complete with example FireSat content.

Three different types of reference text is used throughout the LSP ConOps template in Appendix A:

[MISSION]:

This is a placeholder used throughout the document meant to be used with the Microsoft Word "Search and Replace" functionality. A simple search and replace can be performed on "[MISSION]" with the actual name of the mission replacing the "[MISSION]" term.

{Directions and references}:

This text is used throughout the document to provide instructions on how to use the template and to refer back to sections of this document for further guidance on the expected content and format. Once the ConOps template has been populated and is ready to be formalized, a search on all instances of "{" can be performed all these directions and references can be deleted.

Spacecraft Inputs:

The green text throughout the template is expected content within the template that the spacecraft Project is responsible to replacing with their mission specific inputs. After replacing this green placeholder text with mission specific content the text in the document should be reformatted as black text.

6.1 Template: Purpose & Scope

LSP ConOps Content	LSP Functions	Spacecraft Design Artifacts	LV Procurement Requirements	NASA SE Handbook	Tailored LSP ConOps Characteristics
Purpose					1,2,4,5,6,7
Scope		1-9			1,2,4,5,6,7,8

Table 4: Purpose and Scope Mapped Content

6.1.1 Template: Purpose & Scope - Purpose

This is the introductory section of the Preliminary LSP ConOps and as such it needs to clearly define the purpose behind establishing and maintaining two separate ConOps document (the Preliminary and the Final), how these two documents are related and the scope of the spacecraft operations that are covered. This is also the section of the document that explains the LSP unique characteristics; therefore the Tailored LSP ConOps Characteristics from Section 5.1 of this document is included. The final paragraph of this section introduces the concept of four separate phase of the integrated operations timeline (Early IV&V, Integration & Test, Launch and On-Orbit Ops), starting from early IV&V activities that occur before any spacecraft I&T is started and extending all the way through the end of spacecraft on-orbit operations. Each of theses four phases will be expanded upon in later sections of the ConOps template. Three of the four phases of this timeline and most of the sub-sections of the timeline were adopted from a NASA Space Systems Engineering Scoping & Concept of Operation (ConOps) Module (Scoping,2016).

6.1.2 Template: Purpose & Scope - Expectations

This section of the LSP ConOps template is completely populated, so there are no expectations for the spacecraft Project to provide any additional information for this section.

6.2 Template: Reference Documents

LSP ConOps Content	LSP Functions	Spacecraft Design Artifacts	LV Procurement Requirements	NASA SE Handbook	Tailored LSP ConOps Characteristics
Reference Documents	7	1-9			

Table 5: Reference Documents Mapped Content

6.2.1 Template: Reference Documents - Purpose

The mapped content to this section of the document comes from LSP's involvement in the spacecraft IRD development and from products that the spacecraft project should have produced in support of the major spacecraft design reviews leading up to this point in time; the SRR and the PDR. This Preliminary ConOps will not require all of the detail that the Final ConOps will, but it is still important that the full extent of the source spacecraft content be referenced.

LSP has a significant number of guides and processes that it utilizes throughout the mission lifecycle. Table 1 in the LSP ConOps template lists all of the LSP and NASA documents that are applicable in varying degrees to the development and implementation of LSP integrated spacecraft operations. These references will aid the spacecraft Project throughout the progression of operational concept development, planning and execution of these operations. Since this list of documents are for reference only, the specific versions of these documents and guides are not required for the table. It is assumed that the latest versions of these documents should always be used as reference material. If these were applicable documents then specific version information would be required.

6.2.2 Template: Reference Documents - Expectations

Each spacecraft Project prepares its own versions of design documents leading up to milestone reviews. Some spacecraft Projects are even taking a Model-Based Systems Engineering (MBSE) approach, which could replace some design documents with models or views produced from a model. The expected document placeholders in Table 1 of the template could take the form of a model or a section of the SRR or PDR presentation package. Spacecraft design review artifacts 1-9 and the corresponding placeholders in Table 1 are not meant to be all-inclusive, but rather a starting point. It is important that each spacecraft Project fully identify any design documents that could potentially be used to populate this ConOps or support the data within it. The spacecraft Project should also reference the guidance/requirements document they use for determining spacecraft testing levels and allocation of margins and budgets. For example, NASA Goddard Spaceflight Center (GSFC) has a document titled "Rules for the Design, Development, Verification, and Operation of Flight Systems" - GSFC-STD-1000 (Rules,2013), which establishes formal guidance for all GSFC managed missions. The Jet Propulsion Laboratory has a similar document titled "Design, Verification/Validation and Operations Principles for Flight Systems" document number D-17868 (Design,2016). Design, test, verification and operational guidance documents like this are important to include in the reference documents list as they can sometimes drive spacecraft testing levels in excess of launch vehicle driven environments and the source of those testing levels is important to understand.

6.3 Template: Mission Objectives

LSP ConOps Content	LSP Functions	Spacecraft Design Artifacts	LV Procurement Requirements	NASA SE Handbook	Tailored LSP ConOps Characteristics
Mission Goals & Objectives	7	2,3,4		3,6,7	1,3,4,6

Table 6: Mission Objectives Mapped Content

6.3.1 Template: Mission Objectives - Purpose

Mission objectives are by nature qualitative rather than quantitative. At the lower levels of engineering it is not uncommon for engineers to focus on the measurable technical details of a mission and lose sight of the bigger picture...the reason behind the quantitative engineering artifacts that drive mission requirements and constraints. Referring back to Section 5.1 of this document, the Tailored LSP, specifically characteristic 3:

"Will include an overview of the mission's science objectives and the operations that are carried out by the spacecraft to meet those objectives"

Operations should not be viewed without the proper context, in this case the mission objectives driving the need to perform the operations. Mission objectives can drive all kinds of operations, including but not limited to: additional integration and test operations, mission specific IV&V as risk mitigation, early launch vehicle interface testing and launch vehicle operational trailblazers. LSP has the advantage of being involved with a wide variety of missions and has accrued a significant amount of experience regarding integration operations and how they can often be driven by mission unique objectives. The inclusion of mission objectives along side the integrated operational concepts will increase the visibility into these objectives and decrease the likelihood of missing an operational opportunity to buy down risk or strengthen the operational verifications of interface requirements.

6.3.2 Template: Mission Objectives - Expectations

There are two main spacecraft Project inputs into the Mission Objectives portion of the Preliminary ConOps, a table of the mission objectives themselves as well a figure depicting "how" the objectives will be met operationally. The following is an example table showing the FireSat Mission Objectives, which was taken directly from the Space Mission Analysis and Design (SMAD) Third Edition (Wertz,1999).

FireSat Mission Objectives
Primary Objective: To detect, identify, and monitor forest fires throughout the United States, including Alaska and Hawaii, in near real time.
Secondary Objectives: To demonstrate to the public that positive action is underway to contain forest fires. To collect statistical data on the outbreak and growth of forest fires. To collect other forest management data.

Table 7: Example FireSat Mission Objectives

The second portion of the mission objectives section is a single high-level diagram depicting the operations of the spacecraft that will meet the objectives outlined in Table 7 above. There are a couple of approaches the spacecraft Project can take with respect to creating this figure. The first approach is to take an existing spacecraft mission ConOps diagram and overlay the primary and secondary objectives over this diagram, depicting where within the ConOps the objectives are being met by the mission operations. The second option is to create a new ConOps diagram specifically for this LSP Preliminary ConOps. This first option is the preferred option for depicting this link between the spacecraft operations and the mission objectives because it re-uses an already existing diagram. One of the goals of this Preliminary LSP ConOps is to keep the ConOps at a high level as to not drive any additional work for the spacecraft Project. At some point during the early stages of mission development there should have been a diagram created that depicts the high-level mission operations. If at all possible, use this existing diagram and overlay numbers on that diagram at each location where a mission operation is supporting one of the mission objectives. Then combine that annotated figure with a table that lists each of those numbered annotations along with a short description of how each annotated operation supports achieving the mission objectives. Figure 9 below is an example of a FireSat ConOps diagram created for the Stevens Institute of Technology Cost Effective Space Mission Operations (SDOE 637) class (Cost,2012) and then modified/annotated as described above.

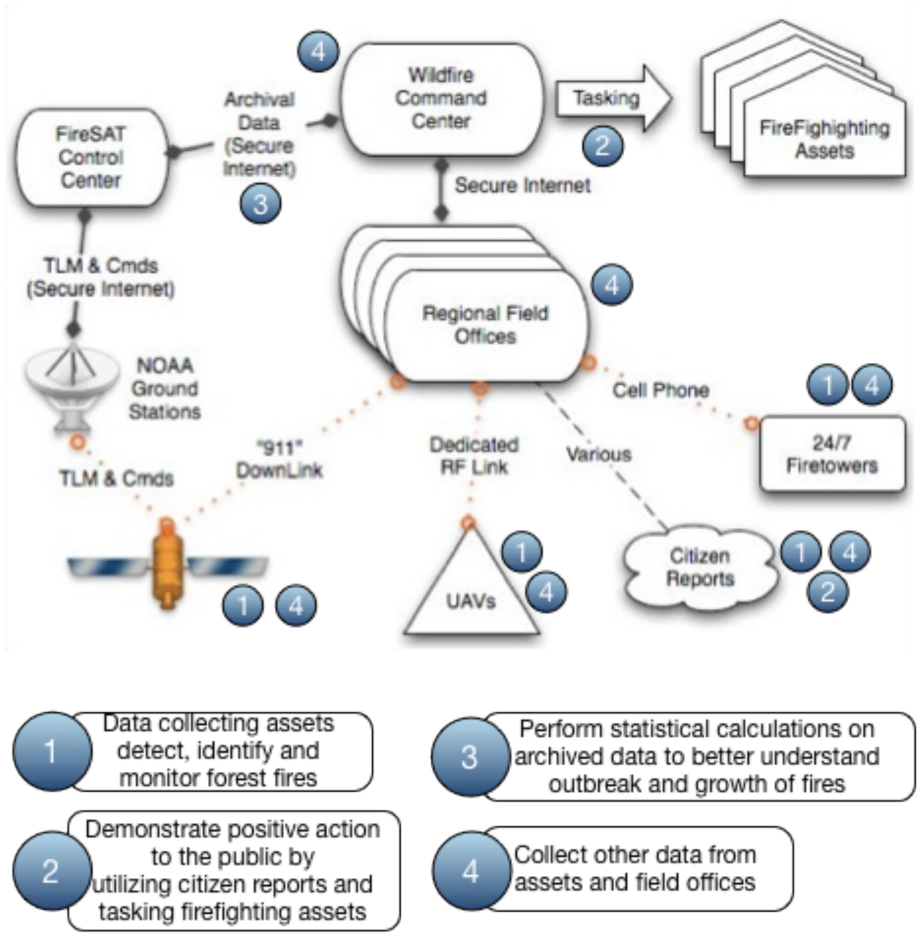

Figure 9: Example FireSat ConOps Objectives Diagram

The FireSat example figure above was used to show how an already existing figure (in this case a diagram in the paper materials for a Stevens Institute of Technology class - used with permission) was converted into a digital image, annotated and had a tabular set of descriptions added.

The purpose of having content like this in the LSP ConOps is to ensure that the entire integrated operations team (the spacecraft, LSP and the launch vehicle contractor) all understand how the operations of the spacecraft (even operations that occur well after spacecraft separation from the launch vehicle) contribute towards meeting mission objectives. There can be circumstances where operationally driven interfaces and requirements can be missed and we often have to rely on experts from all three of these teams to identify these subtle and easily missed requirements and expectations.

6.4 Template: Mission Architecture

LSP ConOps Content	LSP Functions	Spacecraft Design Artifacts	LV Procurement Requirements	NASA SE Handbook	Tailored LSP ConOps Characteristics
System Overview	3,7	1,2,3,4,5,7,8,9	1-17		1,2,3,4,6,7

Table 8: Mission Architecture Mapped Content

6.4.1 Template: Mission Architecture - Purpose

The main reason for having this mission architecture section in the LSP ConOps is to provide a context and depth to the mission's architecture that is not usually captured all in one place. Developing interface requirements documents like the spacecraft IRD and the launch service ICD require a certain amount of focused discipline on just the interfaces. However, there are times where non-interface items can drive IRD and ICD requirements (which is why LSP functions 3 and 7 are mapped into this section of the ConOps). For example, the decision for a spacecraft to isolate their sample return canister both in function and in form from the rest of the architecture may be driven by a contamination concern as well as a need to ensure the most critical portion of the mission has an appropriate level of redundancy. Even though the sample canister may be buried deep within the spacecraft, there are still interfaces between that system and the launch service. The sample canister may have some kind of software or hardware isolation built into it and those types of design isolation measures are typically analyzed from the launch vehicle perspective to ensure that launch vehicle flight time variability do not adversely impact the spacecraft. The relative location of the sample return canister can also be useful information if one of the spacecraft operations in the PPF is to access that canister. This operation could drive additional PPF requirements for increased cleanliness, gowning protocols, planetary protection hardware and tool cleanings and even personnel restrictions. While the mission architecture may not be a major consideration for operations and interfaces to the launch service, it is still a crucial design artifact that should be included in a concept of operations.

6.4.2 Template: Mission Architecture - Expectations

There are three main components to the mission architecture section of the ConOps:

- A figure depicting the mission architecture
- A figure depicting the spacecraft physical architecture

• A figure with the overall spacecraft physical components

As this Preliminary ConOps is established very early in the mission lifecycle, one important assumption from Section 4.2 of this paper is that the spacecraft Project already has all the information it needs to populate this Preliminary ConOps. Each of these three figures can be populated with mission design artifacts that have already been created in support of the mission's milestone reviews. If this Preliminary ConOps drove the creation of additional design artifacts it would significantly increase the likelihood that the ConOps itself would either not be completed or would be completed later in the mission lifecycle than optimal. So it is very important that the spacecraft Project is encourage to re-purpose existing diagrams and figures. The most effective way to demonstrate this concept of re-purposing existing diagrams is to use already existing FireSat spacecraft diagrams. The following three figures below are examples of a FireSat diagrams created for the Stevens Institute of Technology Designing Space Missions and Systems (SYS 632) class (Designing,2003) by Teaching Science and Technology Inc. (TSTI) and then combined and/or re-purposed as described above. These three figures are being used with permission from Teaching Science and Technology Inc. (TSTI) and the Stevens Institute of Technology.

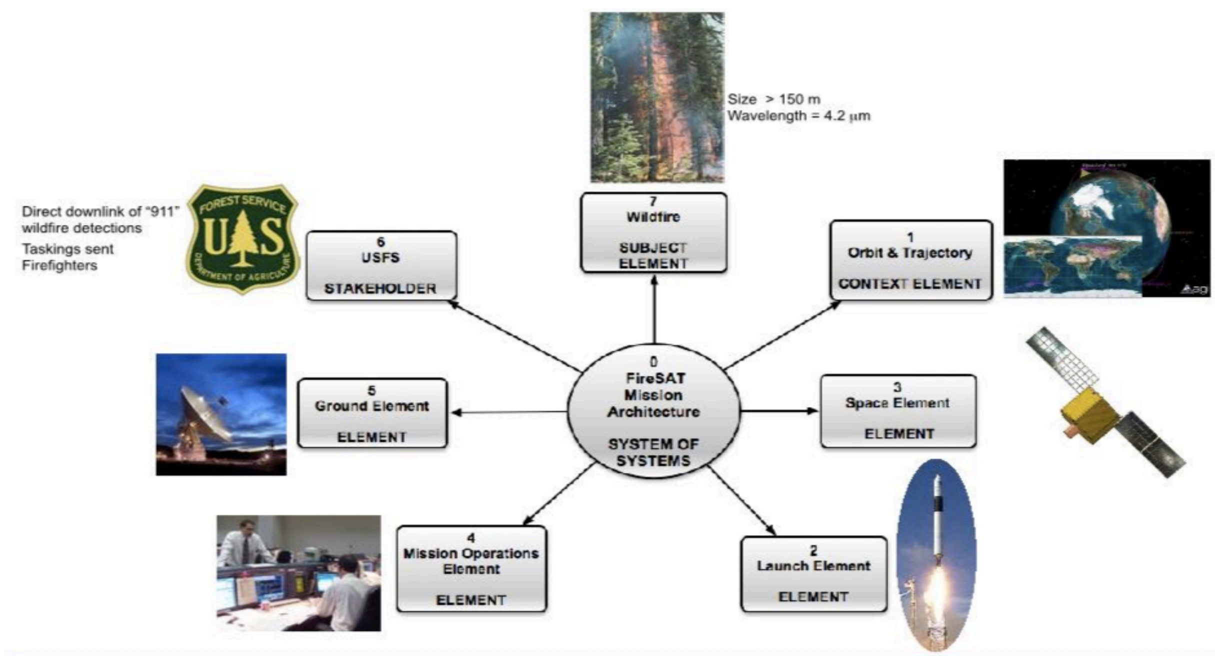

Figure 10: Example FireSat Mission Architecture

The main goal of the mission architecture is to portray all the major elements of the mission in one simple diagram. Notice that the FireSat example in Figure 10 includes a ground element (which can drive things like launch vehicle separation line of site with a particular ground station). The FireSat mission architecture also includes mission operations, external stakeholders like the US Forest Service, the subject of the science itself (wildfires), the space element and of course the primary subject of this ConOps...the launch element. It may be necessary for the spacecraft to show the mission architecture one more layer down from what is shown in the FireSat example in Figure 10. This can be accomplished by either a more detailed architecture figure or with simply the addition of a table at the bottom of the figure that details out a few of the elements under each of the graphically shown elements. This is something that will need to be determined on a mission-by-mission basis. If the subsequent physical architecture and spacecraft component diagrams are sufficient to explain the scope of the spacecraft mission with respect to the launch service than the existing example diagram's level of detail may be sufficient.

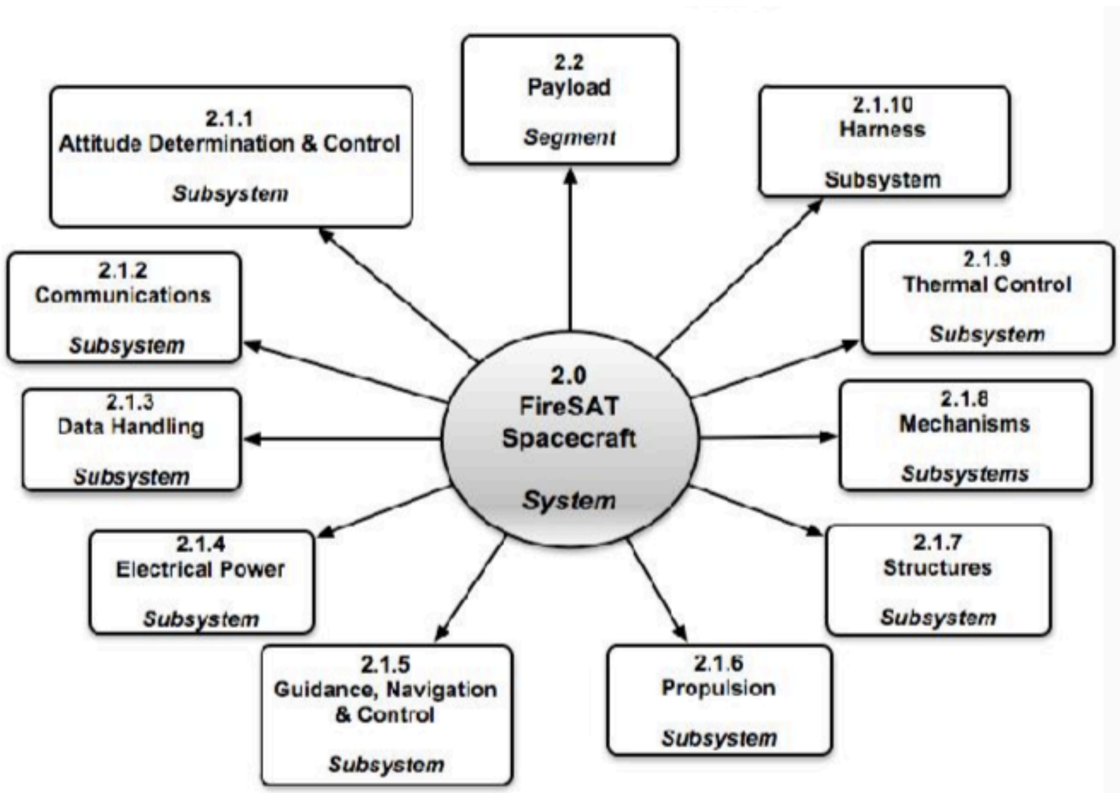

Figure 11: Example FireSat Physical Architecture

The physical architecture should be detailed enough to show the primary components that drive the science for the mission and the interfaces to the launch service. In the case of FireSat, the science is driven by the primary payload, which is a simple imaging element shown in context as part of the spacecraft physical component diagram in Figure 12. The primary interfaces to the launch service besides the payload in Figure 11 are the harness, thermal control, structures and electrical power subsystems. Just like with the mission architecture diagram, some mission may require more depth. This can be accomplished with either a more detailed diagram or ideally with just the addition of a table below the existing diagram with the pertinent next layer of detail required for the purpose of this ConOps.

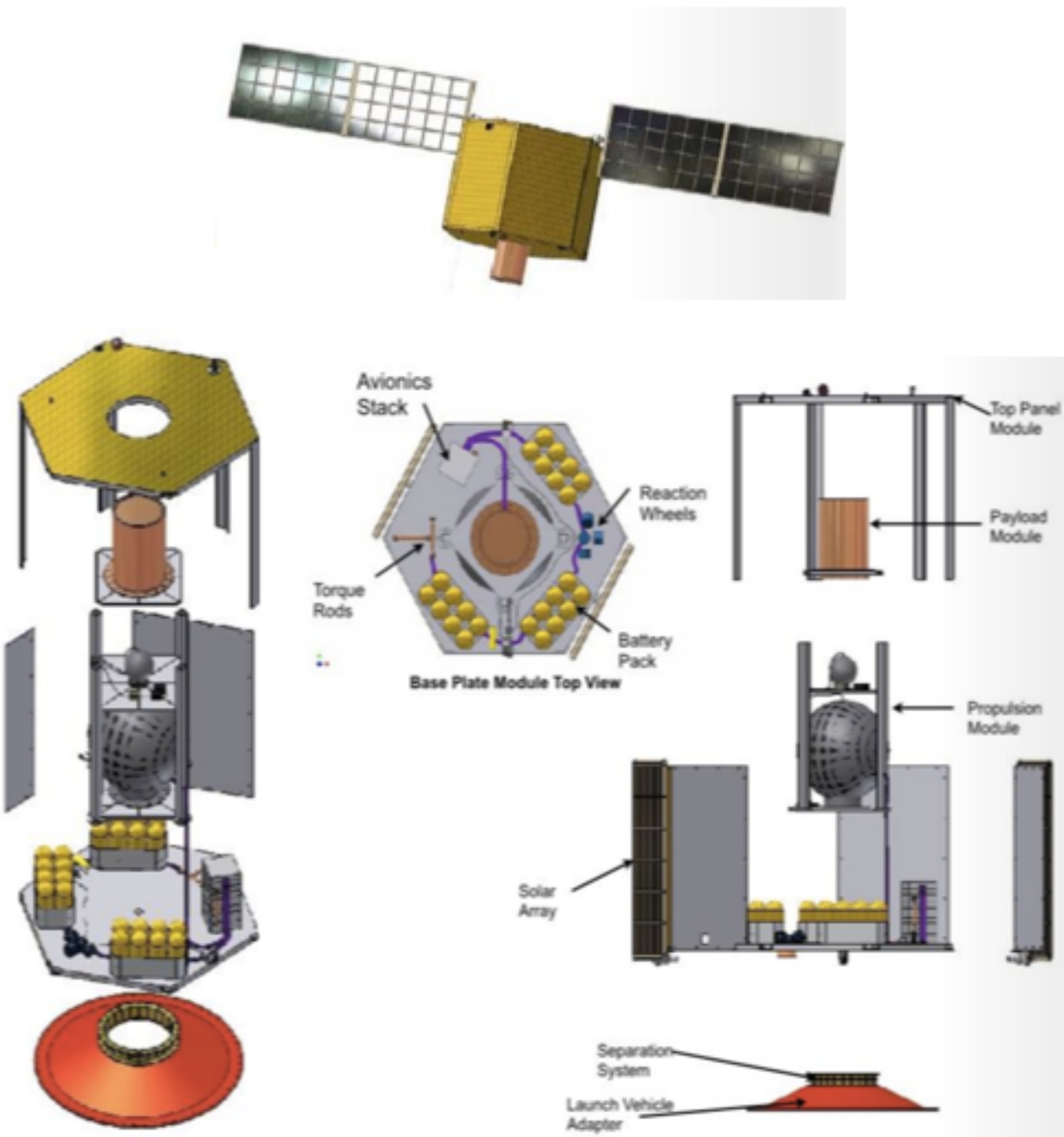

Figure 12: Example FireSat Spacecraft Component Diagram

Notice that the FireSat example spacecraft component diagram includes the main interface to the launch vehicle (the separation system), the location of the primary instrument/payload module and other major components like the propulsion module, avionics, attitude control and power elements. The combination of these three rather basic diagrams gives a very complete overview of the FireSat mission at a basic enough level such that it can be communicated quickly but with enough of the critical details such that the rest of the ConOps can reference this information and provide context to the operations detailed in subsequent sections.

6.5 Template: Integrated Operational Concepts

LSP ConOps Content	LSP Functions	Spacecraft Design Artifacts	LV Procurement Requirements	NASA SE Handbook	Tailored LSP ConOps Characteristics
Operational Overview	3,7	2,3,8	1-17	1-8	1,2,3,4,6,7
Operational Environment	1,2,3,6,7	3,4,7,8	1-17	1,3,5,8	1,2,3,7,8
Operational Scenarios	1-7	1, 3, 7, 8	1-17	1,3,4,5,8	1-8

Table 9: Integrated Operational Concepts Mapped Content

6.5.1 Template: LSP Early Analysis and IV&V

LSP perform a wide variety of early analysis (a subset of which is IV&V) as part of our own internal mission integration processes. Some of these IV&V activities are a means of independently verifying that the launch vehicle is providing the environments and performances specified in the mission ICD, while other IV&V activities are meant to benefit the spacecraft. As specified in Figure 4, Mission Analysis is in scope of this Preliminary LSP ConOps but out of scope of this project. Before the template can be finalized, LSP Integration Engineering needs to formalize the template with the LSP Mission Analysis Division. Until that occurs, the template in Appendix A will only have a placeholder table for the LSP Analytical IV&V. This section of the ConOps will be primarily populated by LSP, but the spacecraft Project may request or identify some mission unique analysis for LSP to perform on a mission-by-mission basis and those special IV&V cases would be listed in this section of the ConOps.

6.5.2 Template: Overall Integrated Operational Phases

This section of the ConOps is already pre-populated with its only purpose being to define the phases and sub-phases of the integrated operations.

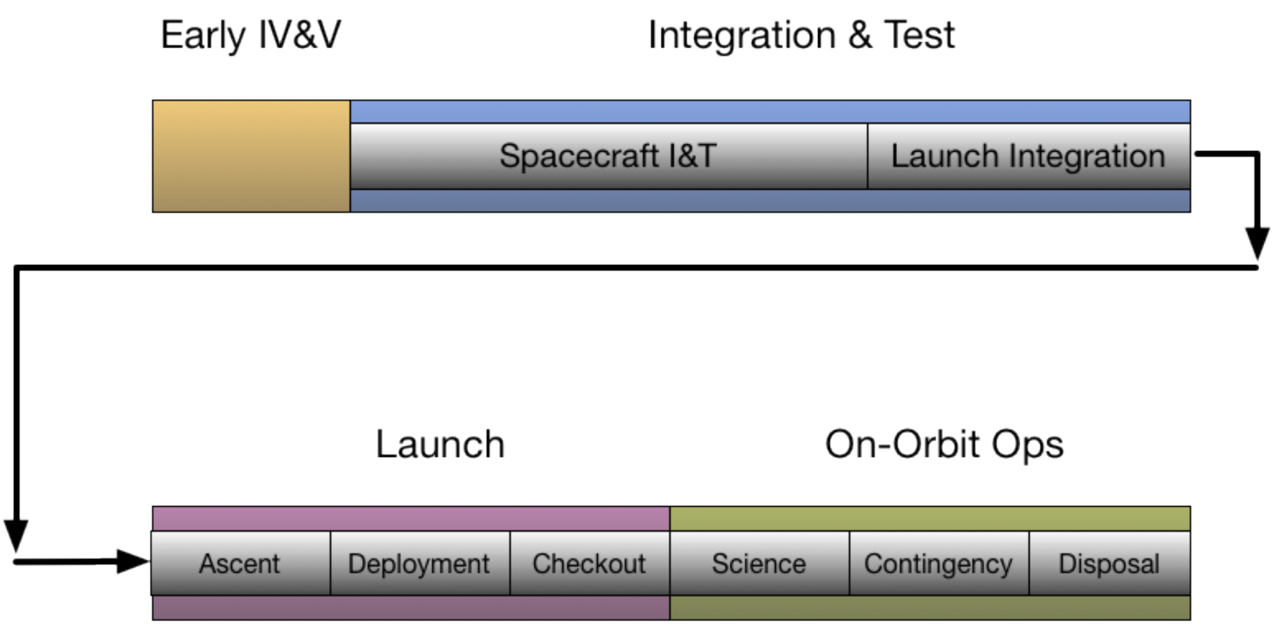

Figure 13: Integrated Operational Phases

Three of the four phases of this timeline and most of the sub-sections of the timeline were adopted from a NASA Space Systems Engineering Scoping & Concept of Operation (ConOps) Module (Scoping,2016). Early IV&V was a phase added at the beginning that is specific to LSP. Often there are early analyses like a trajectory feasibility analysis, an early coupled loads analysis or a fairing volume compatibility check that is performed to aid the spacecraft in early mission assessments and pre-operational scoping and planning. The Integration & Test phase contains two sub-phases, Spacecraft I&T and Launch Integration. These two sub-phases are shown in the Figure as being in serial, however they often times overlap. Most of the Spacecraft I&T is complete before the launch vehicle contractor begins the process of integration with the launch vehicle. But there are generally a few late tests and operations that the spacecraft performs after fairing encapsulation (like removal of power enable plugs or integration of a nuclear power source). For these reasons, the Launch Integration is part of the Integration & Test phase rather than the Launch Phase. The Launch phase begins at T-0 when the ascent phase of the mission begins. The On-Orbit phase begins after the initial checkout of the spacecraft systems are complete and the spacecraft begins normal mission operations (which can take weeks or months to complete depending on the mission).

6.5.3 Template: Operational Schedule

Section 5.3 of the Preliminary LSP ConOps has but a single table. That table is a summary of the approximate start time and duration of each integrated operation for the mission. The table is color coded to match the color used to indicate each major phase of integrated operations. The spacecraft Project inputs to this table are the names of all the operations, the approximate start date of the operation (in terms of months, days or hours before T-0) and the approximate duration of the operation. Some operations, particularly those operations starting with Launch Integration and forward, will need to be defined and scheduled after a launch vehicle has been procured. For this Preliminary ConOps it is recommended that major generic launch vehicle operations like transport to the launch pad, encapsulation and launch vehicle mate be captured so the spacecraft operations that take place around these launch vehicle operations can be planned in relation to them. Once the launch vehicle has been selected a more refined and complete set of launch vehicle specific operations will be included in the operation schedule in the Final LSP ConOps.

6.5.4 Template: Operational Personnel

Personnel are arguably one of the most important aspects of operations. Everyone involved in an operation has an important function that must be carried out in order to meet the objectives of the operation. This section of the ConOps is a reference section that identifies the key roles involved across all integrated operations and when available assigns a name to that role. If a particular role is carried out by a variety of people across the operations, it is acceptable to fill on those fields with "See Section 5.5 for details." The next section of the ConOps, Overview of Integrated Operations, will provide an overview of each integrated operation and part of that overview involves the personnel involved in each operation. For this Preliminary LSP ConOps the details of the operational chain of command are not included, but will be part of the Final LSP ConOps. At this early stage of the mission lifecycle the most important aspect of the chain of command is to establish the role within each organization that is the lead for each operation.

6.5.5 Template: Overview of Integrated Operations

This section of the ConOps contains the primary content for a concept of operations, information concerning the integrated operations. Since the Preliminary ConOps is developed early in the spacecraft mission integration cycle (in parallel with the spacecraft IRD development), the level of detail known about operations that are still several years in the future is relatively small. This is the reason for LSP having the strategy of developing two separate ConOps documents, a Preliminary ConOps to capture high level details that are known early on and then the Final ConOps (which is built onto the Preliminary ConOps structure) for when the launch vehicle has been selected and more details concerning integrated operations are known and are being actively developed. The purpose of attempting to populate a concept of operations (the Preliminary LSP ConOps) this early is to aid in establishing spacecraft IRD requirements and to help ensure that operationally driven requirements are identified before LSP procures the launch vehicle. Most spacecraft projects have a certain methodology for performing integration and test and also have at least a general concept of some of the mission unique drivers for how integrated operations will need to be performed with their particular spacecraft. It is these kinds of spacecraft project and mission unique aspects that should be captured as part of the Preliminary LSP ConOps. It is absolutely crucial that the LSP Preliminary ConOps not drive the spacecraft Project to perform any out of sequence work to support the ConOps development. The reason for this is quite simple. If the Preliminary LSP ConOps drives any significant amount of additional work/analysis/planning for the spacecraft Project then one of two things will happen. Either the spacecraft Project will be unable to support this need for additional work and the Preliminary LSP ConOps will not be created or the ConOps will be populated with information that is not accurate. Neither of these outcomes will result in a more complete development of the spacecraft IRD and a more complete capture of driving spacecraft requirements for the launch vehicle procurement. Therefore, it is a far better approach to acknowledge the lack of information and detail that is available in this early stage of spacecraft development and design the ConOps level of detail to match.

Each integrated operation in Section 5.5 of the Preliminary LSP ConOps template is expected to contain a single figure, an operational summary table (called a figure because a graphical element may optionally included) for each integrated operation. A graphic/figure can be added to the top of each of these summary tables if a there is a graphic available that aids in the high-level communication of the operation. If a graphic is part of the summary then it is recommended that the figure be broken into a “a” and a “b” section as was done for the one of the FireSat examples below.

Placeholder for the Spacecraft Operation Overview Figure (Optional)

Operation Name	
Start Date (L-#)	
Duration	
Facility Name & Location	
Lead Spacecraft Personnel	Role/Title: Name:
Lead Spacecraft Personnel	Role/Title: Name:
Lead LV Personnel	Role/Title: Name:
Major Spacecraft Components	
Major Launch Vehicle Components	
GFE	
Inputs and Preceding Operations	
Operational Objectives	
Operational Environment/Restrictions	
Timeline/Sequence	
Spacecraft Procedure Name(s)	
Launch Vehicle Procedure Name(s)	

Figure 14: Example Integrated Operations Summary Figure

The "Operation Overview Figure(s)" placeholder box at the top of the example figure in Figure 14 is an optional placeholder. It is not expected that every integrated operation summary figure contain a graphical figure above the table. However, sometimes a basic graphical representation of the operation is available and in those circumstances a picture can aid in communicating the intent of operation. Graphical figures should only be used if they are already available to ensure the Preliminary LSP ConOps does not drive any unnecessary work. The table below the placeholder for the graphic contains the following input fields:

Operation Name:

This is simply the name of the operation. If it is a spacecraft project driven operation then the spacecraft project most likely already has a standard name that is used for that operation. If the operation is primarily a launch vehicle driven operation, then for the Preliminary LSP ConOps the specific launch vehicle is not yet known and a generic operational name will need to be used (i.e. Transport to the Launch Pad, Launch Vehicle Adapter Mate, etc.).

Start Date:

The approximate start date for the operation should be specified in relation to the planned launch date (L-#), where "#" can be specified in years, months, weeks, days or hours. Operation dates tend to move around and so do launch dates, so an approximate date that is specified in relation to the generic event "launch" will prevent the need to continually update the ConOps to correct operational dates.

Duration:

This is the expected time the operation is expected to take and can be specified in hours, days, weeks or months.

Facility Name & Location:

Specify the name and location(s) in which the operation will take place. If the operation location is dependent on launch site or launch vehicle or facility and those details are not yet known, it is acceptable to put in a generic placeholder like "PPF near the launch site" or "launch vehicle contractor facility." Some facilities can drive additional constraints on the operation so the earlier a location can be determined the better.

Lead LSP Personnel:

Specify the operational lead from LSP that will be responsible for the operation. There can be more than one person specified in this field, just be sure to distinguish between multiple people with different roles/titles. Ensure that personnel, roles and titles are consistent with the information in Table 5 of the ConOps.

Lead Spacecraft Personnel:

Specify the operational lead from the spacecraft team that will be responsible for the operation. There can be more than one person specified in this field, just be sure to distinguish between multiple people with different roles/titles. Ensure that personnel, roles and titles are consistent with the information in Table 5 of the ConOps.

Lead LV Personnel:

Specify the operational lead from the launch vehicle contractor team that will be responsible for the operation. Even though the launch vehicle contractor is not known at the time the Preliminary ConOps is created, if there is a need for a specific launch vehicle personnel expertise at an operation it should be identified. There can be more than one person specified in this field, just be sure to distinguish between multiple people with different roles/titles.

Major Spacecraft Components:

The intent here is the list out the major spacecraft components that will be required for the operation. For example, if the operation is a spacecraft sine vibration test, then the spacecraft, some sort of an adapter that connects the spacecraft to the vibe table and the vibe table would be the major components the spacecraft project would be providing for the test. An all-inclusive list of components and tool is not required here. Identifying the major pieces of equipment early will help the team to identify potential component availability conflicts and resolve them early before they impact the operational schedule. **Spacecraft flight hardware utilized during the operation should be in bold font in the table.**

Major Launch Vehicle Components:

The intent here is the list out the major launch vehicle components that will be required for the operation. For example, if the operation is a spacecraft sine vibration test then the test launch vehicle adapter might be the major component the launch vehicle contractor would be responsible for providing for the test. An all-inclusive list of components and tool is not required here. Identifying the major pieces of equipment early will help the team to identify potential component availability conflicts and resolve them early before they impact the operational schedule. **Launch vehicle flight hardware utilized during the operation should be in bold font in the table.**

GFE:

Any government furnished equipment (whether it be ground support hardware, flight hardware, diagnostics equipment or tools) should be listed here. **GFE flight hardware utilized during the operation should be in bold font in the table.** Hardware provided by the launch vehicle contractor is not considered GFE.

Inputs and Preceding Operations

This field in the table is meant for any critical analytical products or LSP IV&V that may be used to help establish test levels or scope as well as any preceding operations whose results or activities flow into this operation. Identification of these critical inputs and dependencies will help the team to identify potential schedule drivers or conflicts early before they impact the operational schedule. If an LSP IV&V product is an input or driver to the operation then be sure to used the same naming convention used to identify that IV&V Table 3 and Table 4 of the ConOps template. Another typical an very critical activity that must take place before an integrated operation is the review of both spacecraft and launch vehicle procedures. This is a 3-way review (spacecraft, LSP and launch vehicle) and often times the launch vehicle must incorporate aspects of the spacecraft procedure into thier own and vice versa. Crane certifications and load cell calibrations are another common preceding activity to a major integrated operation and their completion can end up becoming constraint to the operation if they are not handled in a timely manner.

Operational Objectives

This field should contain either a short summary (1-2 sentences) of the objectives of the operation or a bulleted or numbered list of the high level objectives. If the objective is tied to the verification of an interface requirement or environment then that should be specified in the summary as well. Direct links to requirement verification numbers should not be used, as this would drive more updates to the ConOps in order to keep it up to date with evolving requirements documents.

Operational Environment/Restrictions

Any specific operational environmental needs or facility restrictions that may impact the operation should be listed here. For example, a highly contamination sensitive instrument is part of the operation and may require a certain level of cleanliness or restricts the number of personnel that can be part of the operation. Some facilities can have restrictions or protocols that can also impact operational planning. The purpose of including this information is so that all parties involved in the operation understand the potential impacts and have adequate time to prepare for them. The amount of information and level of detail provided in this field could vary greatly from operation to operations and from mission to mission.

Timeline/Sequence

The major parts or steps involved with the operation in the approximate order they are performed should be listed in a numbered list in this field. For example, if the operation requires equipment diagnostics or if major components need to be cleaned or assembled that level of activity should be included. This list is not meant to duplicate the level of detail that a procedure would have but instead should only contain a very short list of activities (5-10) that make up the bulk of the operation. The intent of specifying information is ensuring that all parties involved in the operation understand the high level activities involved. Timing and durations of activities are not needed, just the general sequence in which they occur.

Spacecraft Plan/Procedure Name(s)

The name of the spacecraft plan or procedure(s) that will be used should be specified here. If the exact name of the procedure is not known then a generic name can be used. If only a portion of a procedure is being used for the operation then that should be specified as well. The important thing to capture here is how the spacecraft project intends to formally document the procedures for this operation.

The Preliminary LSP ConOps template lists some potential operations under each phase and sub-phase in the document, but each spacecraft mission will vary in how many integrated operations they will need to include in this Preliminary ConOps. Below are four example integrated operation summary figures, three are for the fictional FireSat mission and one is for a fictional commercial satellite data delivery system called GigabitSat. The graphic used in the FireSat Fire Detection Scenario (Figure 17a) contains two graphics that were created for the Stevens Institute of Technology Cost Effective Space Mission Operations (SDOE 637) class (Cost,2012) by Teaching Science and Technology Inc. (TSTI) and then combined into a single image for use in this paper. These figures are being used with permission from the Stevens Institute of Technology and TSTI.

- FireSat Sine Vibration Testing (part of Spacecraft I&T)
- FireSat Payload Mate (part of Launch Integration)
- FireSat Fire Detection Scenario (part of Science Operations)
- GigabitSat Communications Architecture (part of Science Operations) (Flon, 2012)

Operation Name	FireSat Sine Vibration Test
Start Date	L-9 Months
Duration	1 Week
Facility Name & Location	FireSat Prime Contractor Test Facility / Denver, CO
Lead Spacecraft Personnel	Role/Title: Operational Test Lead Name: John Doe
Lead LSP Personnel	Role/Title: LSP IE Name: Skip Owens
Major Spacecraft Components	- **FireSat Spacecraft (with primary instrument)** - Spacecraft lift sling & dolly - Sine Vibration Table
Major Launch Vehicle Components	- Test payload adapter - Test clampband
GFE	None
Inputs and Preceding Operations	- Procedure Review & Integration - LVC FDLC Loads Cycle Results - LSP FDLC Coupled Loads IV&V
Operational Objectives	- Perform 3-axis sine vibration testing up to limits specified in the ICD - Verify spacecraft ability to sustain launch sine environments - Verify spacecraft workmanship
Operational Environment/Restrictions	- Class 10,000 (ISO 7) to protect instrument optics - Maximum personnel load of 15 with sine vibe table, spacecraft lift fixture and dolly in place (small test facility bay)
Timeline/Sequence	1. Install LV test payload adapter on sine vibe table 2. Lift spacecraft off of dolly 3. Mate spacecraft to LV test payload adapter 4. Perform x-axis testing 5. Perform y-axis testing 6. Perform z-axis testing
Spacecraft Plan/Procedure Name(s)	FireSat Sine Vibration Test Procedure

Figure 15: Example FireSat Sine Vibration Operation Summary

Operation Name	FireSat Payload Mate
Start Date	L-10 Days
Duration	1 Day
Facility Name & Location	Launch Site PPF (TBD)
Lead Spacecraft Personnel	Role/Title: Operational Test Lead Name: John Doe
Lead LSP Personnel	Role/Title: LSP IE Name: Skip Owens
Major Spacecraft Components	- **FireSat Spacecraft** - Spacecraft lift sling - Spacecraft dolly
Major Launch Vehicle Components	- **Flight payload adapter** - **Flight clampband**
GFE	None
Inputs and Preceding Operations	- Procedure Review & Integration - Spacecraft fueling - LV flight adapter shipment to launch site
Operational Objectives	- Verify flight mating surfaces - Verify mechanical and electrical mating interfaces - Mate spacecraft with the launch vehicle adapter
Operational Environment/Restrictions	- Class 10,000 (ISO 7) to protect instrument optics - Maximum personnel load of 25
Timeline/Sequence	1. Clean LV flight adapter 2. Secure flight adapter to facility floor 3. Lift spacecraft from dolly 4. Verify mating surfaces 5. Mate spacecraft to flight adapter 6. Verify mechanical and electrical interfaces
Spacecraft Plan/Procedure Name(s)	FireSat Payload Mate Procedure

Figure 16: Example FireSat Payload Mate Operation Summary

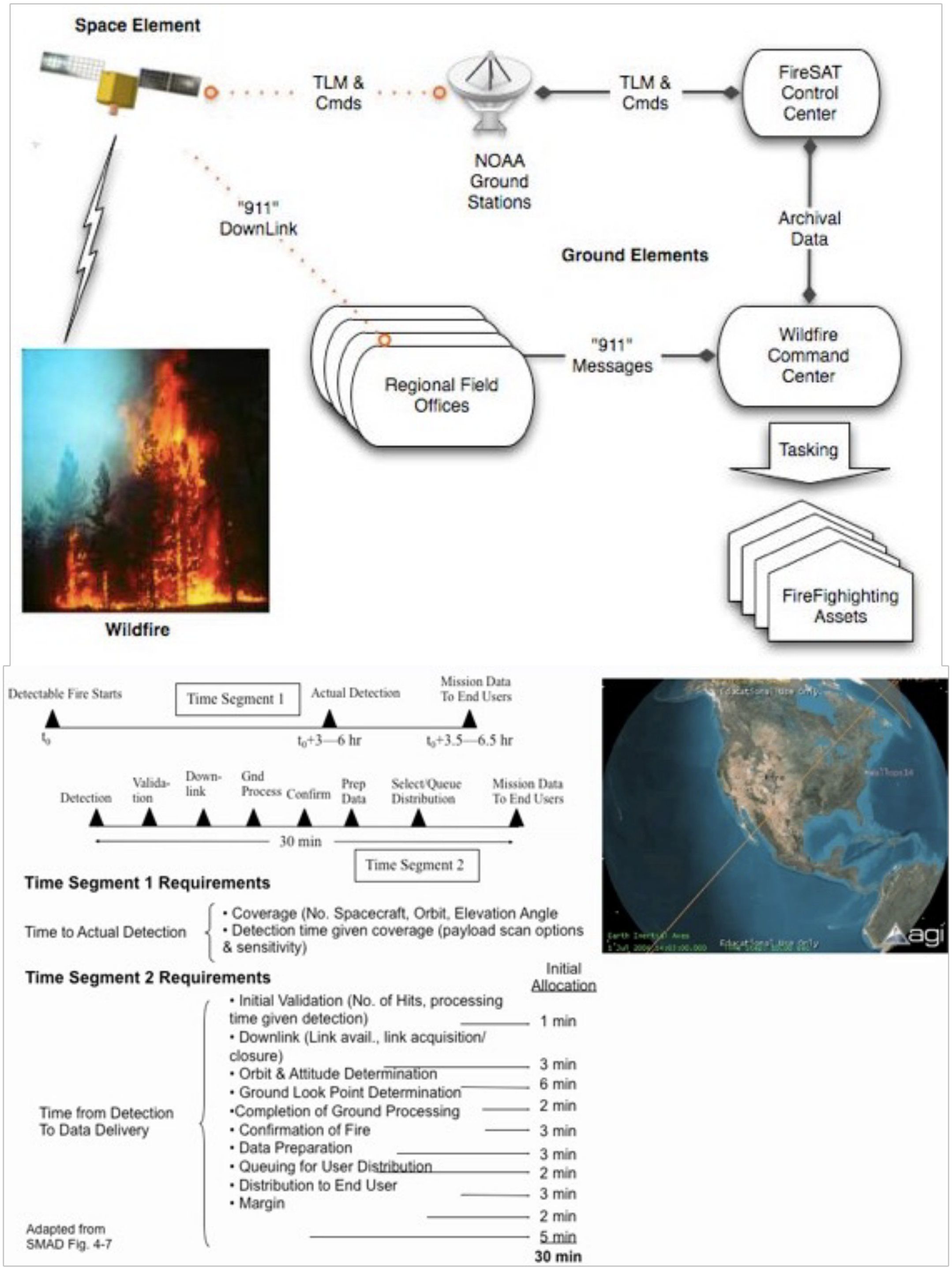

Figure 17a: Example FireSat Fire Detection Operation Summary

Operation Name	FireSat Fire Detection Operations
Start Date	L+30 Day
Duration	30 Minutes
Facility Name & Location	FireSat Operational Orbit
Lead Spacecraft Personnel	Role/Title: Science Operations Lead Name: Jane Doe
Major Spacecraft Components	- **FireSat Spacecraft** - NOAA Ground Stations - FireSat Control Center
Major Launch Vehicle Components	N/A
GFE	None
Inputs and Preceding Operations	- Spacecraft command validation - NOAA ground station pass/command upload
Operational Objectives	- Identify subject fires - Ground confirmation of fire
Operational Environment/Restrictions	- Min elevation angles for downlink - Maximum NOAA station pass duration - Detection to ground confirmation timing goal
Timeline/Sequence	1. Detect fire 2. Validate detection 3. Downlink data 4. Perform Attitude Determination 5. Ground Processing 6. Ground determination of fire
Spacecraft Plan/Procedure Name(s)	FireSat Fire Detection Data Validation Procedure FireSat Attitude Determination Procedure FireSat Ground Determination of Fire Procedure

Figure 17b: Example FireSat Fire Detection Operation Summary

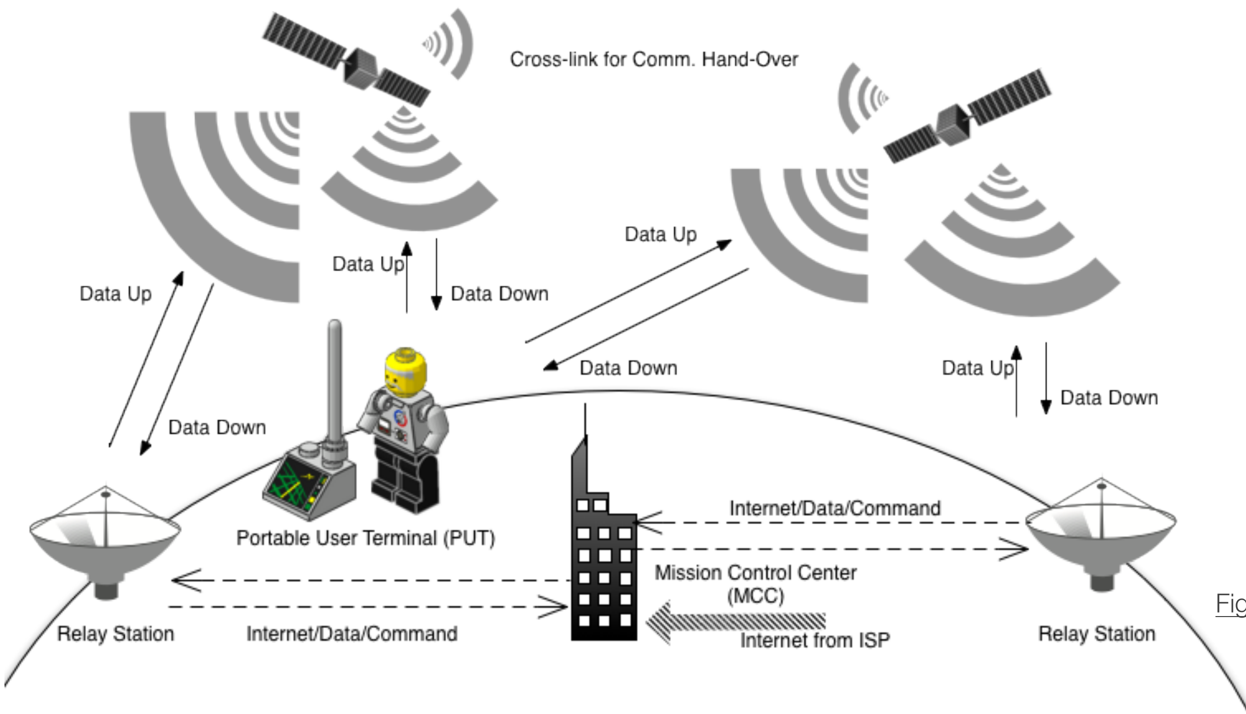

Figure 18a: Example GigabitSat Communication Architecture

Operation Name	GigabitSat Communications Architecture
Start Date	L+30 Day
Duration	Continuous 24/7 3-shift operations
Facility Name & Location	GigabitSat Operational Orbits
Lead Spacecraft Personnel	Role/Title: GigabitSat Operations Lead Name: Terry Byte
Major Spacecraft Components	- **GigabitSat Spacecraft Constellation** - Relay Stations - Portable User Terminals (PUTs) - Mission Control Center
Major Launch Vehicle Components	N/A
GFE	None
Inputs and Preceding Operations	- GigabitSat Acquisition of PUT signal - Portable User Terminal (PUT) Login
Operational Objectives	Provide Internet service to end user (PUT)
Operational Environment/Restrictions	- Min elevation angles for PUT acquisition - Maximum relay station pass duration
Timeline/Sequence	1. PUT acquires GigabitSat 2. PUT logs into service 3. GigabitSat provided data relay services 4. GigabitSat hangovers as needed
Spacecraft Plan/Procedure Name(s)	N/A

Figure 18b: Example GigabitSat Communication Architecture

7.0 CONFIGURATION MANAGEMENT

The ANSI/AIAA G-043A-2012 Guide to the Preparation of Operational Concept Documents (ANSI, 2012) recommends that the role of configuration management and change authority of a ConOps document be placed at the "lowest practical level." Since the LSP Integration Engineering group is establishing this LSP ConOps document, this group should also take responsibility for configuration management and change control. The LSP Mission Analysis Division already has a configuration management process in place for their analytical models using a SubVersion configuration management repository. LSP Integration Engineering will leverage from this existing process and capability to provide configuration management of both the Preliminary and Final LSP ConOps documents.

8.0 FUTURE WORK

As specified in Section 4.0 Ground Rules and Assumptions, the full-intended scope of the Preliminary LSP ConOps could not be undertaken as part of this project. Formal collaboration is still required with the following organizations before the Preliminary LSP ConOps template can be finalized and formalized with LSP Program Management:

- Formalize the LSP Analytical IV&V section of the ConOps with the LSP Mission Analysis Division
- Collaboration with the LSP LSIM Branch to identify the proper content to include from the LSIM management of the PPF contract and support contractor and all the standalone spacecraft activities that involve LSIM LSP support
- Work with the LSP Launch Directors to ensure launch operations and LSP involvement in manifest decisions are properly captured in both the Preliminary and Final LSP ConOps
- Integration of any communication and telemetry services and functions not already captured from ICD content that is provided by the LSP Communication & Telemetry group
- Formalize the LSP ConOps with the LSP Office of Chief Engineer (OCE)
- Work closely with our spacecraft customer community to ensure the scope and content of the Preliminary ConOps can be supported by the spacecraft projects in the timeframes specified

The previous section addressed configuration management, but more work is needed to define the process and mechanisms that will be used to allow both LSP and the spacecraft project to collaborate on the population of the Preliminary LSP ConOps template with mission data. A process for populating, base lining and updating the

Preliminary ConOps will need to be established by LSP and an efficient mechanism for collaboration should be put into place. Additionally, before the Preliminary LSP ConOps template is formalized with LSP Program Management, the template for the Final LSP ConOps should also be developed. The most efficient way to create the Final LSP ConOps after the launch vehicle has been selected and in parallel with the mission ICD development is to use the Preliminary LSP ConOps template as the starting point for the structure of the Final LSP ConOps. Some iteration in format and content may be required in order to achieve the right balance of minimizing the effort required to support the population of these documents while at the same time maximizing the return on investment (which is the strengthening of the formal products like the IRD, reduced IRD for launch vehicle procurement, ICD and operational procedures and plans).

ACKNOWLEDGMENTS

I would first like to acknowledge Norm Beck, who retired from LSP in early 2015 and was a strong supporter of the development of Concept of Operations for use with LSP managed launch services. Before starting this project in earnest I conducted an interview with Mr. Beck (Beck, 2016), which help me lay a foundation for the approach and scope I was going to take with developing the template for the Preliminary LSP ConOps. I would also like to thank Dr. Wiley Larson at the Stevens Institute of Technology and Teaching, Science and Technology (TSTI) who graciously allowed the re-use of FireSat figures from class materials as a demonstration of how a spacecraft project could use existing graphics to populate the Preliminary LSP ConOps. And finally I would like to thank the LSP Integration Engineering Branch for supporting this effort with numerous peer reviews that were conducted to transform this paper and the Preliminary LSP ConOps template into its final form for my SYS-800 masters project submission.

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DEFINITION OF TERMS

Name/Title/Term	Definition
Announcement of Opportunity (AO)	The formal announcement mechanism utilized by NASA to begin the process for allowing groups/organizations to propose a mission for NASA to fund through the early stages of development with the possibility of continuation of funding through flight.
Business Operating Success Strategies (BOSS)	The LSP Program's strategy for managing the business products related to launch services.
Critical Design Review (CDR)	The Critical Design Review is a spacecraft Project milestone review to evaluate the integrity of the program integrated design, including its projects and ground systems. To meet mission requirements with appropriate margins and acceptable risk within cost and schedule constraints. To determine if the integrated design is appropriately mature to continue with the final design and fabrication phase. (7120.5E, 2012)
Comm & Telem	LSP Communications and Telemetry is responsible for receiving and processing launch vehicle telemetry and other mission critical communications required to support LSP missions. Hangar AE on Cape Canaveral Air Force Station (CCAFS) is the primary facility used.

Name/Title/Term	Definition
Concept of Operations (ConOps)	*"The ConOps should consider all aspects of operations including integration, test, and launch through disposal. Typical information contained in the ConOps includes a description of the major phases; operation timelines; operational scenarios and/or DRM; end-to-end commu-nications strategy; command and data architecture; op-erational facilities; integrated logistic support (resupply, maintenance, and assembly); and critical events. The op-erational scenarios describe the dynamic view of the sys-tems' operations and include how the system is perceived to function throughout the various modes and mode transitions, including interactions with external inter-faces" (NASA Systems Engineering Handbook, 2007)*
Expendable Launch Vehicle (ELV)	A term used to describe a rocket built by a U.S. commercial organization that is built and used for a single flight
Federal Highway Administration (FHA)	The Federal Highway Administration is a division of the United States Department of Transportation that manages large road construction and infrastructure projects.
Government Furnished Equipment (GFE)	Any hardware owned and managed by the U.S. Government. Launch vehicle contractor hardware is not considered GFE.
Human Exploration & Operations (HEO)	The NASA headquarters mission directorate under which LSP is operated
Interface Control Document (ICD)	A requirements document that defines the interfaces between the spacecraft and the launch vehicle for an LSP managed launch service.
Interface Requirements Document (IRD)	A spacecraft interface requirements document that contains spacecraft to launch vehicle interface requirements.
IE (Integration Engineer)	LSP Integration Engineer, responsible for the technical integration of the spacecraft with the launch service

Name/Title/Term	Definition
Independent Verification & Validation (IV&V)	The process of independently testing, possibly under simulated conditions, to ensure that a finished product works as required and proving or demonstrating that a finished product meets design specifications and requirements (NASA, 2007).
Integrated Operations	Each operation that includes some combination of spacecraft assets (hardware or personnel) and launch vehicle contractor assets (hardware or personnel) is considered an integrated operation. LSP analytical IV&V is included in this as it involves LSP personnel and can be used by the spacecraft to design and/or scope spacecraft testing operations.
L- ("L Minus") / L+ ("L Plus")	Most scheduled deliverables or operations are defined as a certain time in relation to the scheduled launch day so that if/when the launch days moves the overall operations and deliverables tied to a point in time that is anchored to that movable launch date. "L Minus" times are typically specified in day, hours or months. For operations that take place after launch the term L+ "L Plus" is used.
Launch Director	LSP Launch Director is responsible for the planning, implementation and execution of the launch countdown for NASA
Launch Site Integration Manager (LSIM)	LSP LSIM is responsible for preparation of the payload processing facility, services and other equipment needed to support spacecraft processing at the launch site
MDR (Mission Definition Review)	Mission Definition Review is a spacecraft milestone review that covers the spacecraft mission architecture and the flow down of functional requirements to the mission elements (7120.5E, 2012)
MCR (Mission Concept Review)	Mission Concept Review is a spacecraft Project milestone review that covers the mission's primary objectives and overall mission concept (7120.5E, 2012)

Name/Title/Term	Definition
MIC (Mission Integration Coordinator)	LSP Mission Integration Coordinator provides the MIT with meeting scheduling and logistics support and aides in the transmission of mission data
Matrixed Eng Support	KSC engineering support matrixed to LSP to support in the areas of Mechanical, Mechanical Ground Support Equipment (MGSE), Electrical, Contamination Control and Materials and Processes (M&P)
Model-Based Systems Engineering (MBSE)	A model-centric approach to Systems Engineering, where models take the place or supplement the use of formal documentation and allow for linking of design artifacts in a way not possible with physical documents.
Mission Analysis	LSP technical experts in the areas of Flight Design, Flight Controls, Flight Software, EMI/EMC, Thermal, Loads, Stress/Strength, Fluids/Aero and Dynamic Environments
MIT (Mission Integration Team)	LSP Mission Integration Team is comprised of the MM, IE, LSIM, PIM and the MIC and is responsible for leading the overall integration and management of a mission's launch service
MM (Mission Manager)	LSP Mission Manager, responsible for overall management of a mission's launch service and the budget for that launch service
OCE (Office of Chief Engineer)	LSP Chief Engineer is the LSP technical authority
Operational Concept (OpsCon)	*"A System Operational Concept (OpsCon) document describes what the system will do (not how it will do it) and why (rationale). An OpsCon is a user-oriented document that describes system characteristics of the to-be-delivered system from the user's viewpoint. The OpsCon document is used to communicate overall quantitative and qualitative system characteristics to the acquirer, user, supplier and other organizational elements." (Walden, 2015)*

Name/Title/Term	Definition
Payload Processing Facility (PPF)	The facility near the launch site in which the spacecraft is processed and prepared for integration with the launch vehicle. This can either be a commercial or a government managed facility.
Preliminary Design Review (PDR)	The Preliminary Design Review is a spacecraft Project milestone review to evaluate the completeness/consistency of the planning, technical, cost, and schedule baselines developed during Formulation. To assess compliance of the preliminary design with applicable requirements and to determine if the project is sufficiently mature to begin Phase C. (7120.5E, 2012)
Program Integration Manager (PIM)	LSP contracting officer, responsible for contract execution with the launch vehicle contractor
Spacecraft Project	This refers to the entire organization responsible for the design, manufacture, management and operation of the spacecraft mission. This typically involves a NASA Center, a commercial contractor and a university partner.
System Requirements Review (SRR)	System Requirements Review is a spacecraft Project milestone review that covers the mission's functional and performance requirement definitions, the overall Project Plan and ensures the mission concept meets those requirements. (7120.5E, 2012)
T-0 (T-Zero)	The exact moment in time differs slightly from launch vehicle to launch vehicle but it is essentially the point in time the launch vehicle lifts off of the launch pad.
VSE (Vehicle System Engineer)	LSP VSE is the systems engineer responsible for launch vehicle system integration of the launch vehicle fleet

APPENDIX A: LSP CONOPS TEMPLATE

Double-Click the icon / image on the next page to open the template

National Aeronautics and Space Administration
John F. Kennedy Space Center, Florida
Launch Services Program

ELVL-2016-#######
Revision Basic
Month 2016

Preliminary LSP Concept of Operations for [MISSION] Integrated Operations

RECORD OF REVISIONS		
REV	**DESCRIPTION**	**DATE**
Basic	Basic Issue	# Month 2016

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{Template instructions:

1. *Perform a search a replace on every occurrence of "[MISSION]" and replace it with actual name of the mission.*
2. *Text within the "{…}" brackets are template instructions and refer to a document (see the first reference document in Section 2 of this document) that contains background information and references concerning this document.*
3. *All text within this document that is* green *is text that is expected spacecraft Project input. Replace this* green text *with mission specific information and return the text color to* black *and the font to* Arial un-italicized.
4. *Once the document is ready to be finalized, do a search for every occurrence of "{" and delete the text associated with the template help text within these brackets.}*

1.0 Purpose & Scope

{Refer to Section 6.1 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

The purpose of this document is to begin the process of defining the integrated operations for [MISSION]. Integrated operations are defined as any spacecraft activity that includes launch vehicle hardware, launch vehicle contractor personnel or LSP personnel (LSP personnel includes any IV&V that LSP may be performing in support of a spacecraft operation). LSP will maintain two separate Concept of Operations (ConOps) documents for [MISSION], this document, which is the "Preliminary" ConOps, and a second document called the "Final" ConOps. The Preliminary ConOps development should occur in parallel with the [MISSION] IRD development with main purposes of its completion being to support the [MISSION] PDR and the development of a tailored IRD for the LSP procurement of a launch service. The Final ConOps development starts after a launch vehicle has been selected and the mission integration activities have begun with the launch vehicle contractor. The Final ConOps development will aid in the development of the launch vehicle contractor mission ICD, aid in the development of interface requirement verifications, and serve as a guide for preparing for the mission's integrated operations.

The structure and content of this document have been designed with the following tailored LSP Concept of Operations characteristics in mind:

1. Will describe how the spacecraft and the LSP managed Launch Service will be operated during all integrated operations

Rationale: All operations that include some combination of spacecraft assets (hardware or personnel) and launch vehicle contractor assets (hardware or personnel) is considered an integrated operation. Operations can drive additional mission unique requirements that are not always apparent while developing an interface requirements document like an IRD or an ICD.

2. Will provide an overall picture of all the systems, facilities, processes and people that will be involved with integrated operations

Rationale: Graphical depictions of operations often reveal details and expectations that are difficult to convey in the form of written requirements. Graphically depicting operations will act to supplement the spacecraft IRD, aid in the development of the launch vehicle contractor ICD and then be used to capture operational details that are not typically captured or appropriate for an ICD.

3. Will include an overview of the mission's science objectives and the operations that are carried out by the spacecraft to meet those objectives

Rationale: Spacecraft science objectives are the main driver for the mission. Spacecraft operations are required in order to carry out the mission and meet the science objectives. Spacecraft operations, even though most of them occur after separation from the launch vehicle, can flow requirements down to the launch service and the launch vehicle hardware. Identifying spacecraft mission operations that are directly linked to science objectives early in the mission development cycle can reduce the likelihood of inadequately flowing spacecraft operational requirements down to the launch vehicle.

4. Will be written from the perspective of the spacecraft customer, who is the end user of the Launch Service

Rationale: A ConOps is first a foremost a communication tool. In order to effectively communicate operational needs and expectations between the spacecraft customer and the launch vehicle contractor and to ensure the customer needs are properly captured, the document should be written using terminology that is consistent with the spacecraft project.

5. Will be utilized as a resource during the development of the ICD

Rationale: Graphical representations of operations are more information ally rich than written interface requirements, and up until this point, written interface requirements have been the source material for launch vehicle ICDs (i.e. leveraging from the spacecraft project IRD and the launch vehicle contractor's ICD template). By supplementing the ICD development with an already established ConOps we are less likely miss requirements or misinterpret them when creating the ICD.

6. Will be used to facilitate the capture of spacecraft customer expectations

Rationale: Operational details are not meant to be captured by an interface requirements document. Historically we have captured operational details and expectations in the form of operational working group telecons starting several weeks before planned integrated operations. Waiting that long until discussing and compiling operational details risks having large operational needs/requirements go I identified until it is too late to address before the time of the schedule operation.

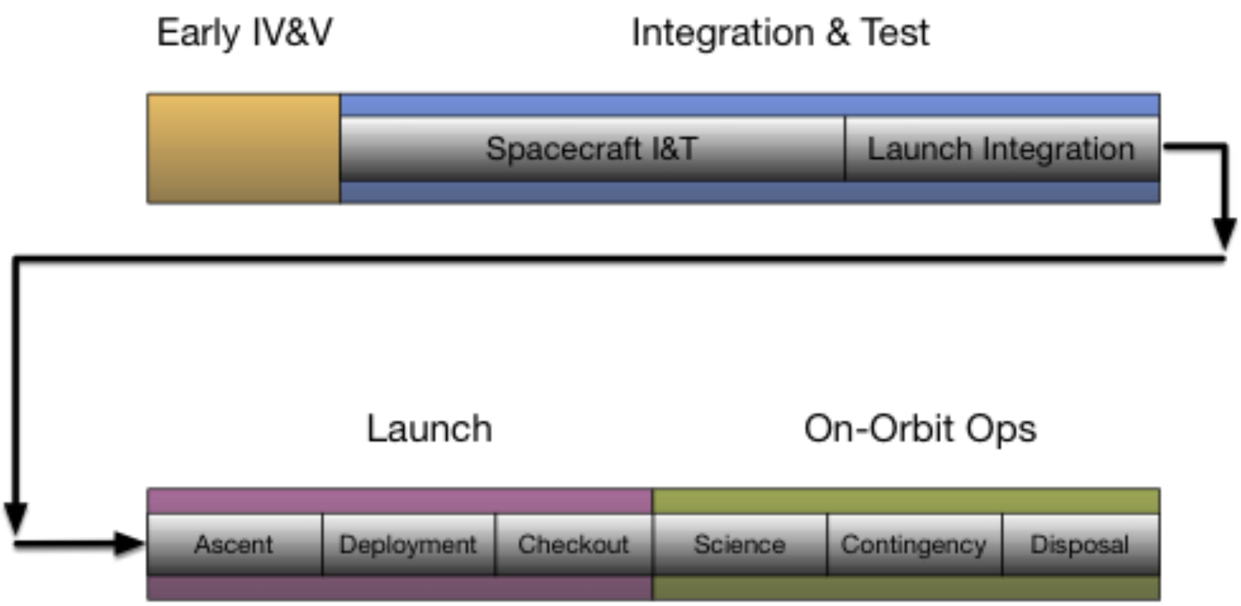
7. Should consider all aspects of operations that use launch vehicle hardware, launch vehicle contractor services/support and personnel and any activity that involves the Launch Services Program (IV&V, government furnished equipment, facilities and services). This should span all planned operations including integration, test and launch through disposal.

Rationale: Needs to encompass all operations that have the potential to drive additional launch vehicle support above and beyond the standard services called out in our NASA Launch Services (NLS) contract.

8. Will be launch vehicle agnostic

Rationale: The ConOps will be developed before the procurement of the launch service so that is can be used as a tool to ensure that all mission unique requirements (including operationally derived requirements) are identified before competing the launch service. Eventually the ConOps could also be used as an additional reference document provided along with the Request for Proposal (RFP) to the potential bidders for the launch service.

The general scope of this Preliminary ConOps covers spacecraft integrated operations starting with spacecraft Integration and Test (I&T) (or even earlier if there are LSP IV&V activities like an early coupled loads analysis, a trajectory feasibility analysis or CAD model payload fairing compatibility analysis that LSP is asked to perform) and extends all the way though the end of spacecraft on-orbit operations (disposal operations). The four phases and their corresponding sub-phases depicted below in Figure 1, Early IV&V, Spacecraft I&T, Launch and On-Orbit Ops will be expanded upon and referenced throughout the LSP Concept of Operations.



Operational Phase	Sub-Phase	Entrance Trigger
Early IV&V	N/A	Pre-Phase A
Integration & Test		
	Spacecraft I&T	1st Spacecraft Integration/Test Op
	Launch Integration	Spacecraft Arrival at the Launch Site
Launch		
	Ascent	T-0
	Deployment	Spacecraft Separation
	Checkout	1st Spacecraft Checkout Operation
On-Orbit Ops		
	Science	Spacecraft is Deemed Operational
	Contingency	Anomaly is Encountered
	Disposal	All Mission Ops Completed

Figure 1: LSP Integrated ConOps Phases & Transitions

2.0 Reference Documents

{Refer to Section 6.2 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps. It is assumed that all reference documents refer to the most recently published version.}

Document Number (Use Latest Revision)	Document Title
ELVL-2016-#######	A Tailored LSP Concept of Operations
AFPCMAN 91-710	RANGE SAFETY USER REQUIREMENTS
NASA-STD-8719.24	NASA Expendable Launch Vehicle Payload Safety Requirements
LSP-P-332.03	Mission Approval Process
KDP-P-2403	Expendable Launch Vehicle (ELV) Launch Service Task Order (LSTO) Process
LSP-P-333.01	Launch Services Program Payload Processing Requirements and Launch Site Support Plan (LSSP) Development
LSP-UG-332.01	Guide for NASA Spacecraft Processing at the Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS)
LSP-UG-332.02	Guide for NASA Spacecraft Processing at Vandenberg Air Force Base
LSP-UG-331.01	LSP Review Process for Spacecraft Interface Requirements Document Development
LSP-UG-333.07	Interface Control Document (ICD) Development, Change & Approval Process
LSP-UG-333.11	Interface Control Document (ICD) Violation & Waiver Process
LSP-UG-333.08	LSP ICD Verification Process
LSP-UG-333.12	LV Integrated Procedure Distribution and Review
LSP-P-335.02	Mission Success Determination Process
SC Doc #	[MISSION] Measures of Effectiveness
SC Doc #	[MISSION] Goals & Objectives
SC Doc #	[MISSION] Concept of Operations
SC Doc #	[MISSION] IRD
SC Doc #	[MISSION] Schedule
SC Doc #	[MISSION] Risk
SC Doc #	[MISSION] Lifecycle Support Strategies (or logistics documentation)
SC Doc #	[MISSION] Verification & Validation Plan
SC Doc #	[MISSION] System Architecture
SC Doc #	Applicable Guidance Document on Testing, Margins and Budgets

Table 1: Reference Documents

3.0 Mission Objectives

{Refer to Section 6.3 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

[MISSION] Mission Objectives
Primary Objective: Enter primary objective here
Secondary Objectives: Enter 1st secondary objective here Enter 2nd secondary objective here Enter nth secondary objective here

Table 1: [MISSION] Mission Objectives

Placeholder for Operational Implementation of Mission Objectives Figure

Figure 2: [MISSION] Operational Implementation of Mission Objectives

4.0 Mission Architecture

{Refer to Section 6.4 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

Placeholder for the [MISSION] Mission Architecture Figure

Figure 3: [MISSION] Mission Architecture

Placeholder for the [MISSION] Physical Architecture Figure

Figure 4: [MISSION] Physical Architecture

Placeholder for the [MISSION] Spacecraft Components Figure

Figure 5: [MISSION] Spacecraft Components

5.0 Integrated Operational Concepts

{Refer to Section 6.5 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

This section of the Preliminary LSP ConOps covers all of the spacecraft integration operations with the launch service. Integrated operations for the purposes of this Preliminary LSP ConOps is defined as:

"All operations that include some combination of spacecraft assets (hardware or personnel), launch vehicle contractor assets (hardware or personnel) and LSP personnel is considered an integrated operation. LSP analytical IV&V is included in this as it involves LSP personnel and can be used by the spacecraft to design and/or scope spacecraft testing operations."

The following sections within Section 5.x of this ConOps are meant to define (at a high level) all of the anticipated integrated operations the [MISSION] spacecraft Project anticipates conducting with the NASA provided launch service. Section 5 has the following components:

- LSP Analytical IV&V: A complete list of all anticipated analytical IV&V LSP will perform for the [MISSION] mission
- Overall Integrated Operational Phases: A breakdown of the four main phases of integrated operations and all of the sub-phases within each major phase
- Operational Schedule: A tabular summary of all planned integrated operations with an approximate "L minus" timeframe and location specified for each

- Definition of Operations: A table that contains a short definition of each integrated operation
- Operational Personnel: A list of all spacecraft Project and LSP personnel that are anticipated to be part of integrated operations
- Overview of Integrated Operations: Each identified integrated operation gets its own sub-section in this section of the ConOps with a single Figure that graphically depicts the operation. Integrated Operations will be broken into the four main phases and sub-phases that are defined further in Section 5.2 of this ConOps.

5.1 LSP Early Analysis and IV&V

{Refer to Section 6.5.1 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

Analytical Discipline	Name of Analysis	Start Date	Duration
Mechanical			
Flight Design			
Flight Controls			
Thermal			
Loads			
Environments			
Fluids/Aero			
EMI/EMC			
Flight Software			
Electrical			

Table 3: LSP Analytical IV&V

5.2 Overall Operational Phases

{Refer to Section 6.5.2 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

The integrated operational phases and sub-phases will be defined using the structure in the figure below. It should be noted that IV&V can and will occur throughout the entire integrated operational phases below. Early IV&V is given its own phase because there are often analytical tasks that must be done before spacecraft integration and testing can begin.

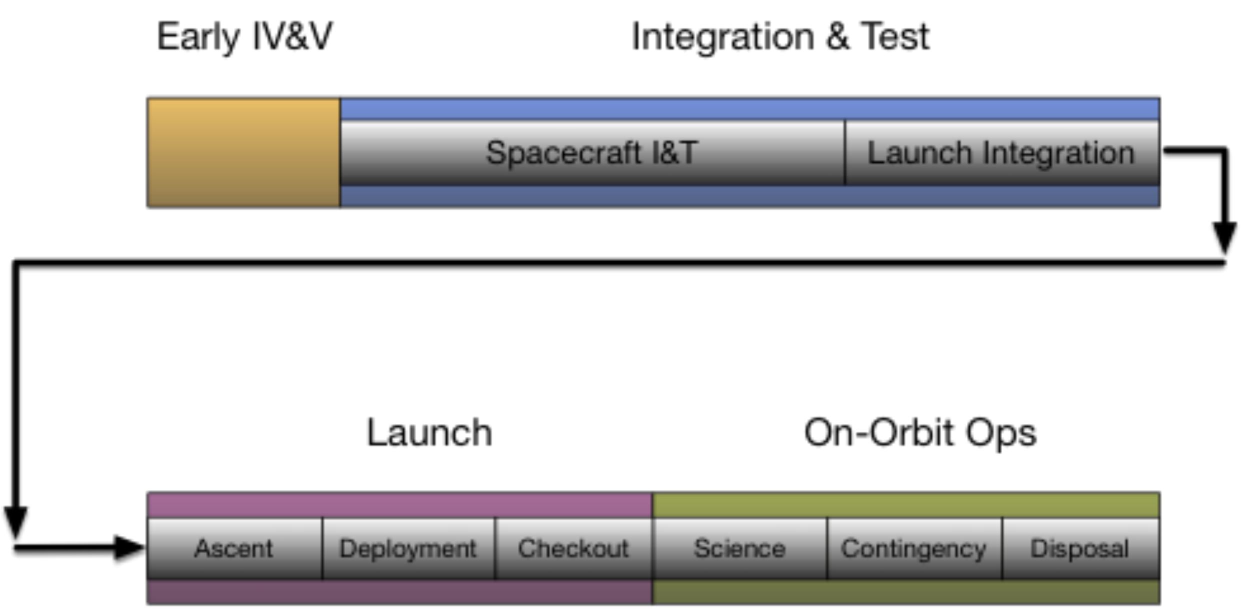


Figure 6: Integrated Operational Phases

5.3 Operational Schedule

{Refer to Section 6.5.3 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

Phase Name	Segment Name	Operation Name	Start Date (L- or L+ Yrs/Months/ Days/Hours)	Duration (days/wks/ months)
Early IV&V				
	N/A	IV&V #1		
	N/A	IV&V #n		
Integration & Test				
	Spacecraft I&T	1st I&T Op		
	Spacecraft I&T	nth I&T Op		
	Launch Integration	1st Integrated Op		
	Launch Integration	nth Integrated Op		
Launch				
	Ascent	1st Ascent Op		
	Ascent	nth Ascent Op		
	Deployment	1st Deploy Op		
	Deployment	nth Deploy Op		
	Checkout	1st Check-Out Op		
	Checkout	nth Check-Out Op		
On-Orbit Ops				
	Science	1st Science Op		
	Science	nth Science Op		
	Contingency	1st Contingency Op		
	Contingency	1st Contingency Op		
	Contingency	nth Contingency Op		
	Spacecraft Disposal	1st Disposal Op		
	Spacecraft Disposal	nth Disposal Op		

Table 4: Integrated Operations Schedule

5.4 Operational Personnel

{Refer to Section 6.5.4 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

Below is a list of spacecraft and LSP operational personnel will be involved in at least one of the planned integrated operations (this includes Early IV&V or any IV&V activity that is identified). Since the launch vehicle has not yet been selected there are no launch vehicle personnel to identify. If people have not been assigned to specific roles it is acceptable to insert only the Role/Title and add the name and contact information after the assignment has been made.

Role/Title	Name	Email	Work Phone #	Cell #
LSP Personnel				
LSP Integration Engineer (IE)				
LSP Backup IE				
LSP LSIM				
LSP LSSE				
LSP NSC	LSIM or LSSE	Console Position: NSC		
LSP Mechanical				
LSP Payload Elec.				
LSP Contamination				
LSP MGSE				
Spacecraft Personnel				
Title 1	Name 1	Email 1	Work #1	Cell #1
Title 2	Name 2	Email 2	Work #2	Cell #2
Title 3	Name 3	Email 3	Work #3	Cell #3
Title 4	Name 4	Email 4	Work #4	Cell #4

Table 5: Operational Personnel

5.5 Overview of Integrated Operations

{Refer to Section 6.5.5 of the document "A Tailored LSP Concept of Operations" for further instructions and background for this section of the ConOps}

The following sections of the Preliminary LSP ConOps are structured to match the phases and sub phases defined in Section 5.2. Each integrated operation that has been identified will have its own numbered sub-section within the phase and sub-phase to which it belongs. Within each integrated operation sub-section there will be a minimum of one summary table using the format established in the "A Tailored LSP Concept of Operations" document. A single figure or multiple figures can be added to the top of this summary table if required to help clarify the operation.

Placeholder for the [MISSION] Spacecraft Operation Overview Figure(s)

Operation Name	
Start Date (L - #)	
Duration	
Facility Name & Location	
Lead Spacecraft Personnel	Role/Title: Name:
Lead LSP Personnel	Role/Title: Name:
Lead LV Personnel	Role/Title: Name:
Major Spacecraft Components	• Hardware • **Flight Hardware in BOLD**
Major Launch Vehicle Components	• Hardware • **Flight Hardware in BOLD**
GFE	
Inputs and Preceding Operations	
Operation Objectives	
Operational Environment/Restrictions	
Timeline/Sequence	
Spacecraft Plan/Procedure Name(s)	

Figure 7: Example Integrated Operations Summary Figure

5.5.1 Integration & Test

5.5.1.1 Spacecraft I&T

{Examples of Spacecraft I&T Operations are:

- *Matchmate/Fit-Check*
- *Thermal Vac*
- *Sine Vibration*
- *Random Vibration*
- *Shock*
- *Acoustics*
- *Structural (Static and Modal)*
- *EMI/EMC}*

5.5.1.2 Launch Integration

{Examples of Spacecraft Launch Integration Operations are:

- *Transport to Launch Site*
- *Unloading Operations*
- *Functional Checks*
- *Propellant Loading*
- *Spin Balancing*
- *Weighing*
- *Mate to LV Adapter*
- *Encapsulation*
- *Transport to Launch Pad*
- *Mate to the Launch Vehicle*
- *Aliveness Testing*
- *Battery Charging*
- *Purge Connections*
- *Arming Pyrotechnic Devices*
- *Spacecraft Closeouts*
- *Lighting Re-Test*
- *Contingency Propellant Offload*
- *Hurricane Sheltering}*

5.5.2 Launch

5.5.2.1 Ascent

{Examples of Ascent Operations are:

- *Terminal Count*
- *Transfer to Internal Power*
- *Any Functions Initiated During Powered Flight}*

5.5.2.2 Deployment

{Examples of Deployment Operations are:

- *Null Separation Rates*
- *Deploy Solar Arrays*
- *Transmitter & Receiver Activations*
- *On-Orbit Instrument Cover Deployments*
- *Initial Data Downlink*
- *Initial Command Uplink*
- *Any Functions Initiated/Tied-To Launch Vehicle Separation}*

5.5.2.3 Checkout

{Examples of Checkout Operations are:

- *On-Orbit Aliveness Tests*
- *Instrument and Sensor Calibrations*
- *Any Pre-Operational Activities}*

5.5.3 On-Orbit Operations

5.5.3.1 Science Operations

{Examples of Science Operations are:

- *Collecting Science Data*
- *Communications Architecture*
- *Instrument and Sensor Calibrations*
- *Any Pre-Operational Activities}*

5.5.3.2 Contingency Operations

{Examples of Contingency Operations are:

- *Entering Safe Hold*
- *Exiting Safe Hold}*

5.5.3.3 Disposal Operations

{Examples of Disposal Operations are:

- *Launch Vehicle Post-Separation Operations*
  - *Post Separation Attitude and Orbit Adjustments*
  - *Maneuver to Disposal Orbit/Reentry*
  - *Launch Vehicle Passivation*
- *Spacecraft Passivation*
- *Spacecraft Maneuvering into Disposal Orbit}*

6.0 Acronyms & Abbreviations

Name/Title/Term	Definition
Environmental Control System (ECS)	A generic term used to describe the system or systems the launch vehicle contractor uses to maintain the fairing environment (temperature and relative humidity). ECS can also apply during transport from the PPF to the launch pad depending on the launch vehicle.
Government Furnished Equipment (GFE)	Any hardware owned and managed by the U.S. Government. Launch vehicle contractor hardware is not considered GFE.
Integrated Operations	All operations that include some combination of spacecraft assets (hardware or personnel), launch vehicle contractor assets (hardware or personnel) and LSP personnel is considered an integrated operation. LSP analytical IV&V is included in this as it involves LSP personnel and can be used by the spacecraft to design and/or scope spacecraft testing operations.
LSP Contamination	The LSP Contamination Engineer is responsible for contamination control of the launch service and the PPF operations at the launch site.
LSP Integration Engineer (IE)	The LSP Systems Engineer responsible for the integration of the spacecraft with the launch vehicle.
LSP Launch Site Integration Manager (LSIM)	The LSP engineer responsible for PPF operations and logistics. The LSIM manages the contract with the PPF and aids the spacecraft in standalone PPF operations and standalone spacecraft transportation operations like the initial spacecraft transport to the PPF from the factory.
LSP Mechanical	The LSP Mechanical engineer involved with early mechanical engineering IV&V and integrated mechanical operations such as match mate/fit check, flight mate, encapsulation and launch vehicle mate.
LSP Mechanical Ground Support Equipment (MGSE)	The LSP Mechanical engineer involved with ground support equipment including environmental control systems, purge systems, access platforms and transportation systems.
LSP Launch Site Support Engineer (LSSE)	The LSSE focuses on the technical aspects of the payload process facility to spacecraft interfaces and works closely with the LSP LSIM.
LSP Payload Electrical	The LSP Electrical engineer involved with launch vehicle to spacecraft electrical interfaces and operations.
LSP NSC	LSP NSC (NASA Spacecraft) is the console call sign for the NASA LSP personnel on console 24/7 while the spacecraft is powered on after leaving the PPF for the launch pad. LSP NSC is typically either the LSIM or LSSE. LSP NSC has the authority to request operational changes of the launch vehicle contractor (like ECS settings).
Matchmate/Fit Check	A generic term used to describe an early test of the

	physical mating surfaces between the spacecraft and the launch vehicle. Operation can also include purge and electrical interface checks as well. This risk reduction test is generally performed about 1-year before launch and can vary in scope on a mission-by-mission basis.
Payload Processing Facility (PPF)	The facility in which the spacecraft performs its final Integration & Test operations near the launch site. The PPF is typically used to start launch integration operations which is begun when the spacecraft is physically integrated with the first piece of launch vehicle flight hardware.
New Spacecraft Terms	Spacecraft Definitions

7.0 Configuration Management

All data associated with this validation effort have been checked in the SubVersion configuration management repository under MissionDocumentation\####### version ####.

Questions regarding this template can be directed to:

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