

NASA Cube Satellite Technical Development Materials: Guidebooks, Manuals, and Templates to Create Better Hardware and Successful Projects

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Agenda



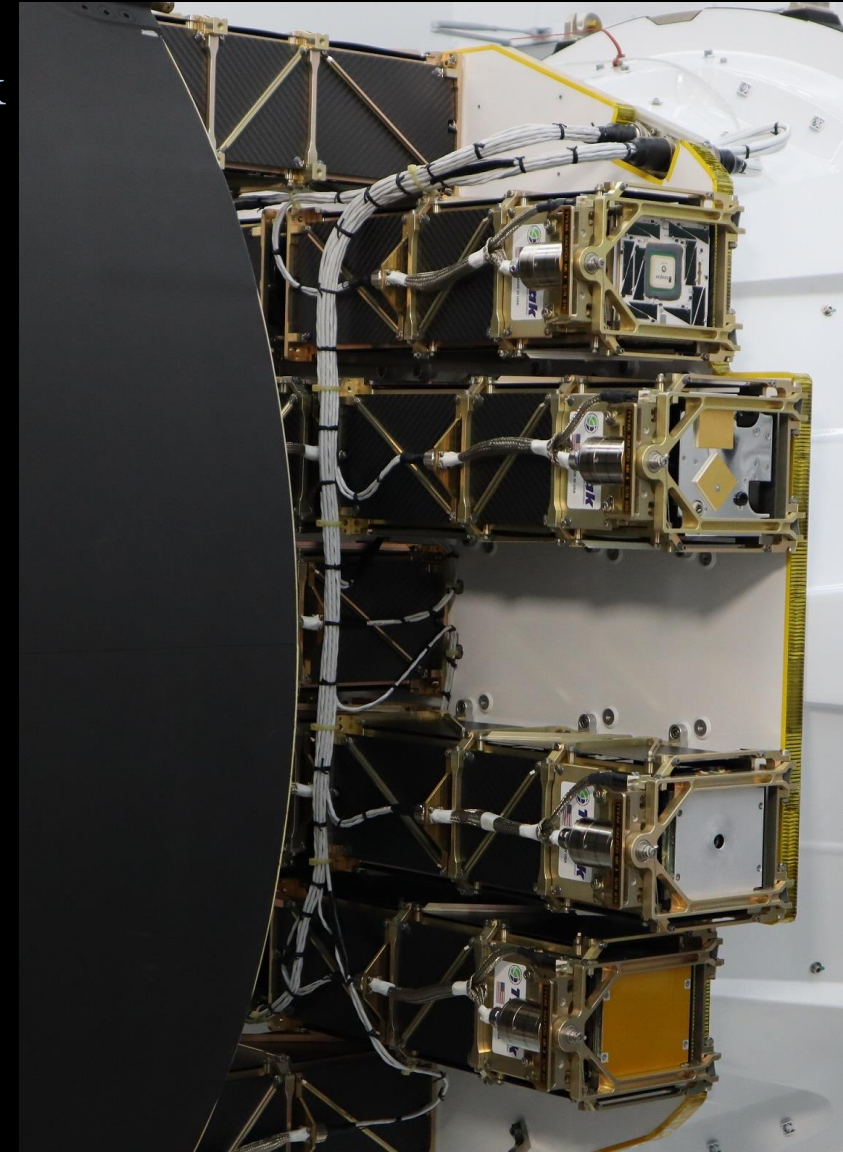
- The Small Spacecraft Technology Program Guidebook for NASA Procedural Requirement (NPR) 7120.8 is a top-level document to guide project management approaches to NPR 7120.8 NASA Research and Technology Program and Project Management Requirements
- SST Program Documents contain both technical manuals and document templates
 - Technical guides for R&D technical areas
 - Project document templates with lessons learned and references

7120.8 vs. 7120.5 Management Processes

- Process:
 - 7120.5 – Well-defined process with low tolerance for risk
 - 7120.8 – Heavy on select engineering processes and high tolerances for risk
- Schedule:
 - 7120.8 – Takes about 2 years
 - 7120.5 – Takes 10-20 years

Program Management Advantage for 7120.8 Tech Dev = Speed

7120.8 Timeline	Authority to Proceed		Project Approval		Project Implementation						
	Pre-Formulation		Formulation		Implementation						
	△	△	△	△	△	△	△	△	△	△	
	PPBE	Project Plan / Contract	PDA	CDA	MRR	ILC	Launch		Closeout		
Timeline	Max: L-60 months / Min: L-18 months		Max: L-36 months / Min: L-12 months				~ L + 4 months				
7120.5 Timeline	Approval for Formulation			Approval for Implementation			Implementation				
	Pre-Phase A:	Phase A:		Phase B:	Phase C:		Phase D:		Phase E:	Phase F:	
	Concept Studies	Concept and Tech Dev		Prelim Design	Final Design & Fab		Assembly, I&T, & Checkout		Ops & Sustainment	Closeout	
	△	△	△	△	△	△	△	△	△	△	△
Agency Reviews	MCR	SRR	PDR	CDR / PRR	SIR / SAR	ORR / FRR	Launch	CERR	PFAR	DR/DRR	
Timeline	L-10 years to L-3.5year			L-3.5 years to L-2.5 years		L-2 years to Launch		Launch to EOM			



Small Spacecraft Technology Program Guidebook



The SST Program Guidebook is comprised of a set of documents developed by the program to help guide and inform technology development projects under NASA Procedural Requirement (NPR)

7120.8

The guidebook:

- Provides an understanding of how NPR 7120.8 is defined utilized by the SST program.
- Informs the 3 types of SST projects:
 - SST-NC NASA Center
 - SST-PS Academia or Private Sector
 - SST-Space Demo



SST Program Guidebook - Project Cycle Phases



Key Decision Points (KDP) are “gates” – typically ATP and Closeout – that are managed by the SST program. Project reviews, called “Periodic Project Reviews” (PPRs) in NPR 7120.8, are managed by the project for the project. Spaceflight demos typically plan to run SRR/SDR, CDR, and MRR/FRR.

Phase	Activity	Output(s)
Pre-formulation	Preliminary planning (NPR 7120.8 Sect 4.2.5). Often omitted from SST projects which proceed from ATP	Scope, from SST Program
ATP (KDP)	SST approval of proposed project to enter Formulation Phase (NPR 7120.8 Sect 4.2.6)	Approval, Preliminary Project Plan
Formulation	NPR 7120.8 Sect 4.2.7	
Project Approval (KDP)	SST approval to enter Implementation Phase (NPR 7120.8 Sect 4.2.8)	Approval, Final Project Plan
Implementation	NPR 7120.8 Sect 4.2.9	Life cycle reviews per approved Project Plan
Continuation Assessments (if in plan/contract/grant, or upon subsequent direction)	NPR 7120.8 Sect 4.2.10.3	Continuation approval, if required
Independent Assessments (if required, or upon subsequent direction)	NPR 7120.8 Table 4-1	Independent assessments, if required
Status telecons, quad charts (for small lab demo projects)	NPR 7120.8 Sect. 4.2.10.2 informal reviews for lab projects	Quad charts (typical) as planned
SRR/SDR*** (large flight demo projects)	Internal review conducted by project. Tailored from NPR 7123.1 Appendix G-4	NPR 7123.1 success criteria, as in approved project plan
CDR*** (large flight demo projects)	Internal review conducted by project. Tailored from NPR 7123.1 Appendix G-7	NPR 7123.1 success criteria, as in approved project plan
MRR/FRR*** (large flight demo projects)	Internal review conducted by project. Tailored from NPR 7123.1 Appendix G-13	NPR 7123.1 success criteria, as in approved project plan
Closeout Review (KDP)	NPR 7120.8 Sect 4.2.11	Closeout Report, New Technology Report



SST Program Documents

Three guidebook documents provide guidance and lessons learned.

Drawing Document

Offers help on how start the documentation of drawings and outlines how to have a process to ensure reliability and quality of project team processes.

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- 1. Purpose
- 2. Scope
- 3. Roles and Responsibilities
- 3.1 Chief Engineer
- 3.2 Project Manager
- 3.3 Lead Engineer
- 3.4 Design Engineer
- 3.5 Drafter
- 3.6 Checker
- 3.7 Writer
- 3.8 Manufacturing Engineer / Welding Engineer
- 3.9 Quality Control
- 3.10 Purchasing and Quality Assurance
- 3.11 Safety
- 3.12 Assembly
- 3.13 Testing
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- 5. Training
- 6. GD&T
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- 7. Reviews
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Appendix A: Applicable Documents, Reference Documents, Websites

1. Purpose
This Small Spacecraft Technology Program (SSTP) Technical Drawing Control Program Plan (TDCPP) defines the requirements, processes, and implementation of technical drawing organizations, programs, and projects.

This plan is based on the American Society of Mechanical Engineers (ASME) industry standard guidelines and best practices regarding achieving a highly detailed drawing with Geometric Dimensioning and Tolerancing (GD&T) implementation. It defines the part in question but establishes intent with the manufacturing consideration.

In this TDCPP, all mandatory actions (i.e., requirements) are denoted by the state term "shall." The terms "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice, and is recommended, but not required, "will" denote a requirement, and "are/is" denote descriptive material.

This plan defines "Technical Drawing" as any working engineering drawing in any form, three-dimensional Computer Aided Design (CAD) model files are not drawings and shall not be used in place of technical drawings.

All document citations are assumed to be the latest version unless otherwise specified. Reference documents, helpful resources, definitions, and acronyms are provided in the Appendix.

2. Scope
The following SSTP TDCPP is a guide for projects and programs that are working on the Small Spacecraft Technology Program. This TDCPP is for the projects that are working on the Small Spacecraft Technology Program. Risk tolerance of research and technology development projects is typically higher in contrast to NPR 7120.5 Spaceflight Programs science or exploration programs. For further definitions on these practices, see the [Technology Program Guidebook for Technology Development Projects](#).

3. Roles and Responsibilities
Some of these roles and responsibilities will have crossover between each other and the size and scope of the project. Each role must have a minimum experience and qualifications with experience must have a senior / mentor to check their work.

3.1 Chief Engineer
Responsible for: Oversight of overall compliance of project, reviews and approves drawings and the institution's procedural requirements.

3.2 Project Manager
Responsible for: Planning and implementation of high-level activities, ensuring schedule, cost, safety, and environmental requirements, and have applicable certificates / training for work on hand, and support as necessary.

3.3 Lead Engineer
Responsible for: Oversight of overall day-to-day project activities and authority / approver on drawing requirement and operation compliance.

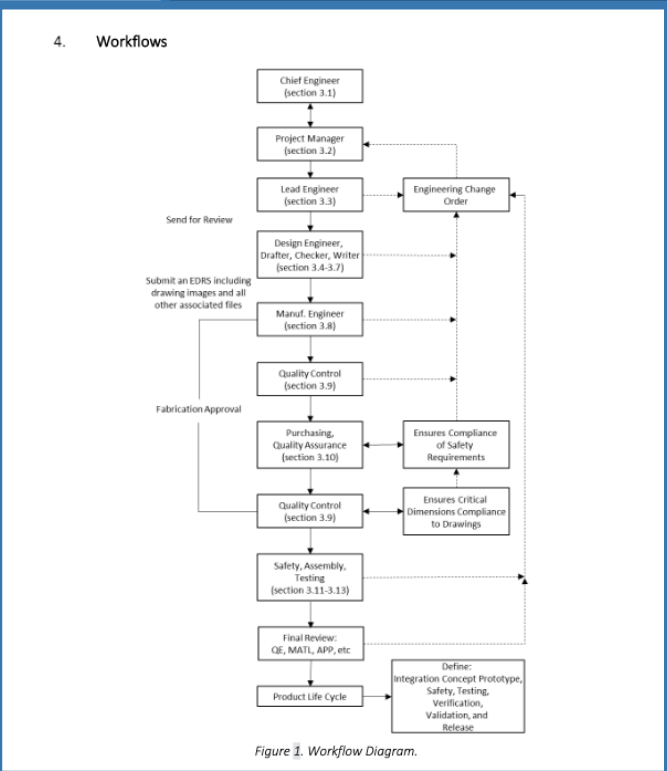
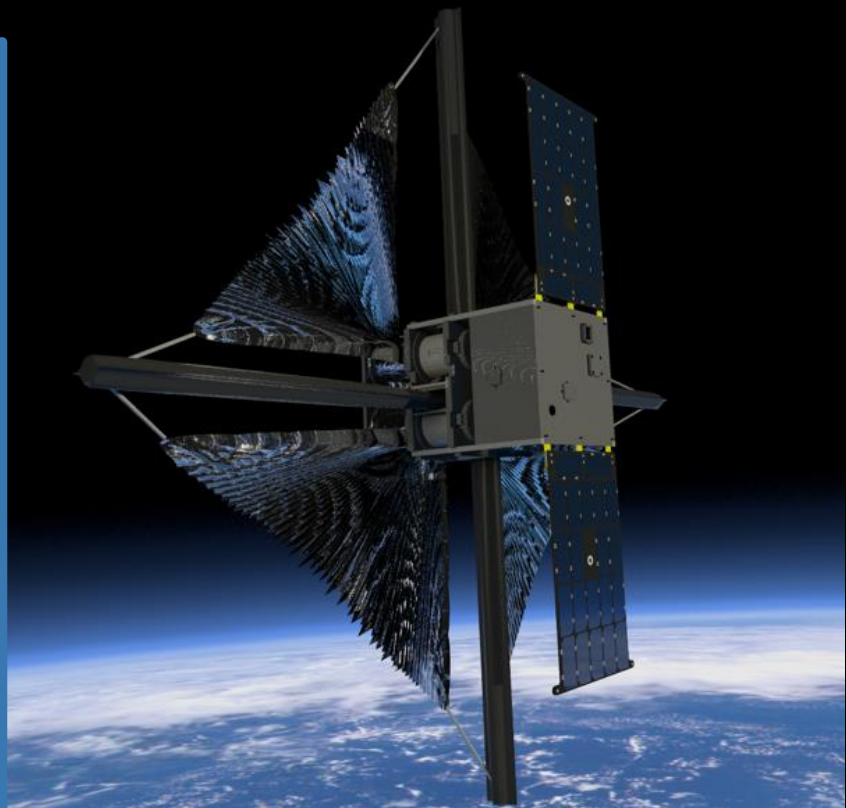


Figure 1. Workflow Diagram.





SST Program Documents

SPACE Printed Circuit Board

Provides lessons learned from experts in the field regarding how to start to document, process, design, and ensure reliability and quality in project PCB processes.

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Assembly Requirements	16
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5.3 Managing the Process	16
6. Inspecting and Awaiting Quality	16

High-Risk Novice Approach

Setting: This is your first-ever space-application PCB and one of your first PCB design start somewhere, and this is honestly not a bad place to start. You are allowed a h before you need to move on to better designs.

Project Criteria: 3-month ISS LEO Orbit (no radiation considerations), IPC Class-2 (f standard)

Your block diagram may look like:

- COTS microcontroller breakout board
 - A common way to get around the intricate design of a fine-pitched buy a breakout board and solder that board to a larger custom PCB peripherals and other bits you need.
- Discrete component peripherals
 - A handful of ICs and passives to implement some controls or other
- Power converter module
 - An integrated-inductor module to supply your board that keeps size eliminating design time and multiple parts.

Your parts selection process is likely:

- COTS microcontroller breakout board
 - Whichever board Sparkfun or Adafruit has in stock that physically
- Discrete component peripherals
 - Whatever a Digi-key, Mouser, or Arrow search returns that meets requirements.
- Buck converter module
 - Utilizing the Texas Instruments online calculator.

The issues with this method are:

- COTS microcontroller breakout board
 - Almost guaranteed to be lead-free solder, likely uses resonators, and the parts used to assemble the board are of unknown quality and origin. The board is also fabricated of unknown materials to an unknown standard and assembled to an unknown standard. Some of these unknowns may be answered by phone calls and emails, but you are saving time at the expense of control and parts assurance. The board you are buying was designed to sit on a desk, not to get shot into space. e board is excited, your risk manager is not.
- Discrete component peripherals
 - Not paying attention to tolerances, thermal coefficients, and the manufacturer increases your failure risk. A cheap 5% resistor may vary too much and be permanently damaged from thermal cycling and cause a voltage divider to overshoot an input limit. Not reviewing the full datasheet for selected ICs may result in behaviors or requirements you did not expect or cannot support.

4.3 Circuits in Space

Some considerations to move you into orbit before you start designing schematics.

Radiation and a lack of convective cooling are two of the biggest immediate threats when moving to space electronics design. Resistor thermal coefficients, power ratings, deratings, package types, and efficiency are only a few elements that may need to be considered when working on projects destined for space application. Solder joints are mechanical structures subject to strain as the chip and board they hold together expand at different rates during thermal cycles. The resistor divider feedback circuit for a power supply must maintain a proper ratio when the board is at -20°C in the dark with the load turned off and at 40°C in the sun with all systems running. Meanwhile, radiation and heavy ion impacts on the MOSFETs, silicon, diodes, CMOS circuits, and other components may ultimately result in a malfunction of the device.

So how do you take all these factors into account and successfully design a board for space? The short answer is you simply cannot. For major projects where long-term reliability is key, an entire team of engineers will be dedicated to the electronics design, with support from other groups performing radiation testing, thermal testing, and just managing procurement and acceptance testing. By paying attention to small details and adjusting your practices, you can immensely improve your work and change a desktop design into a spaceflight-ready electronics package.

Some Tips and Tricks

Power Supplies:

Let's start with power. Linear regulators still have their circuits, but just about every microcontroller and other high-frequency supplies. Adapting your project to switcher intricacies is a best practice. Design Tips:

- Don't Boost when you can Buck and be careful of Buck-Boost. Buck-Boost can sometimes have odd behaviors when switching modes. If this causes your main processor to reset, you will have issues.
- Add jumpers to the output of each of your power supplies so they must be manually connected to their load. This will allow you to test a supply before it destroys an expensive part because of a misplaced feedback resistor.
- Keep switching frequencies low; around the 400kHz range should stay out of your GPS and satellite constellation

8. Appendix A: Technical Design Resources

NASA Small Spacecraft Systems Virtual Institute (S3VI) Space Mission Design Tools:

<https://www.nasa.gov/smallsat-institute/space-mission-design-tools>

A list of Open Source or Public NASA software to help with the development of small spacecraft missions.

<https://s3vi.ndc.nasa.gov/>

Searchable database of small spacecraft knowledge collected by S3VI.

Radiation Estimator and Component Databases:

R-Gentic Radiation Risk Tool:

<https://vanguard.isde.vanderbilt.edu/RGentic/>

https://nepp.nasa.gov/workshops/etw2021/talks/17-JUN-21_Thur/1345_Niederlander-Parts-selection-and-Radiation-Assessment_v2.pdf

A web-based tool that helps provide an initial estimate/understanding of possible radiation risks based on mission class, orbit, altitude, and mission lifetime. Generates estimated TID, SEE, and impact of aluminum shielding.

Goddard Space Flight Center Radiation Database:

<https://radhome.gsfc.nasa.gov/radhome/radatabase/radatabase.html>

Database of test data from component radiation testing performed by GSFC. Site also links to other databases and publications.

European Space Agency Radiation Reports Database:

<https://escies.org/labreport/radiationList>

<https://escies.org/webdocument/showArticle?id=119&groupid=6>



SST Program Documents



Radiation Guidebook

Serves as an educational and instructional document about radiation and the radiation effects that can cause satellite failures or damage. Provides resources to address questions when starting to build hardware and encountering designs where radiation is a consideration.

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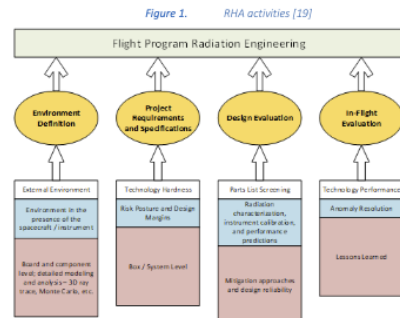
2 Radiation Hardness Assurance

Industry standards on radiation testing, guidelines on assurance methodologies, and bodies of knowledge for technology failure modes exist to aid in the engineering discipline of radiation effects on Electrical, Electronic and Electromechanical (EEE) components [1-5]. NASA does not currently have an Agency-level standard associated with the process of radiation hardness assurance (RHA) practices. RHA practices benefit from strict parts assurance standards through screening and part traceability in order to make use of available radiation test results [6-9]. In some small spacecraft instances, alternative component grades selected from automotive or industrial qualified products have been adopted for additional reliability/traceability but are not designed for space radiation environments [10]. Guidance for commercial-off-the-shelf (COTS) use exists with many caveats with regard to parts reliability, but the unique challenge associated with radiation effects is often not addressed in detail [10-12]. That said, missions that are Class D and below still benefit from RHA activities when adopting the use of COTS parts/subsystems that lack screening and/or traceability [10-16]. Therefore, the practices of RHA become an integral part of the design process for spacecraft regardless of the mission class or risk posture [17-24].

Why is radiation unique to Mission, Environment, Application and Lifetime (MEAL) [25]?

Radiation sources for spaceflight missions include free-space particles (Galactic Cosmic Rays; GCR), solar particles (protons and heavy ions), and trapped particles (protons and electrons) in planetary magnetic fields (e.g., Van Allen Belts around Earth). The effects of these contributors on spacecraft materials present challenges to active (e.g., semiconductors, transistors) and passive (e.g., basic components including antennas and sensors, and electromechanical components including cables and switches) electronic and electrical systems and can be grouped into two families: instantaneous or cumulative. Both have the potential to be catastrophic ranging from temporary malfunction to permanent device damage. The focus on this topic will only address active (e.g., semiconductor) devices. Single Event Effects (SEE) is an example of instantaneous effects where single ionizing particle interaction strike and deposit charges with varying impacts to the equipment. Cumulative effects is a result of repeated and long-term damage to the equipment and include total ionizing dose (TID) and total non-ionizing dose (TNID). In order to address these risks, RHA describes a process for analysis and assessment [17-24].

RHA consists of all activities undertaken to ensure that the electronics and materials of a space system perform to their design specifications throughout exposure to the mission space environment. RHA activities include defining the environment, deriving requirements, design evaluation, and in-flight evaluation (see Figure 1). Each of those activities have engineering problem sets that may require subject matter expertise, but there are straightforward efforts that have been adopted as state-of-the-art practice that either have publicly available tools or methodologies that introduce first principles to non-experts.



Parts criteria standards (radiation):

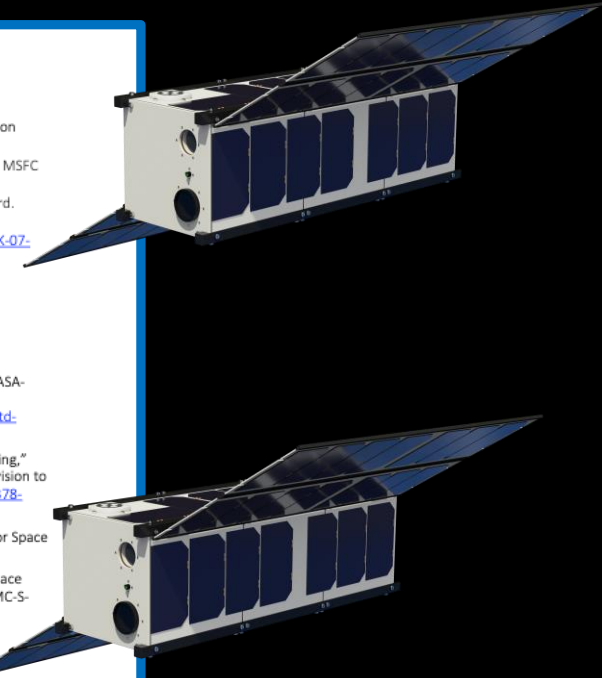
- NASA Office of Safety and Mission Assurance: Discipline-EEE Parts. <https://sma.nasa.gov/sma-disciplines/eee-parts>
- NASA Electronic Parts and Packaging Program. Electronic Radiation Characterization Project (ERC). <https://nepp.nasa.gov/pages/Radiation.cfm>
- MSFC Tech Standard -3012; EEE parts management and control requirements for MSFC space flight hardware. <https://neop.nasa.gov/files/26094/MSFC-STD-3012A.pdf>
- High energy/LET radiation EEE parts certification handbook. JSC technical standard. Projects using the VDBP to test electronics; deep space missions. <https://standards.nasa.gov/sites/default/files/standards/JSC/Baseline/0/JSC-HDBK-07-001.pdf>
- Standards for radiation effects testing: Jean-Marie Lauenstien (GSFC). <https://ntrs.nasa.gov/api/citations/20150011462/downloads/20150011462.pdf>

Parts criteria standards (not radiation):

- "Electrical, Electronic, and Electromechanical (EEE) Parts Assurance Standard," NASA-STD-8739.10, June 13, 2017. <https://standards.nasa.gov/sites/default/files/standards/NASA/Baseline/0/nasa-std-873910.pdf>
- Sahu, K., "Instructions for EEE Parts Selection, Screening, Qualification, and Derating," EEE-INST-002, NASA/TP—2003-212242, (2003, original document; April 2008, revision to incorporate addendum 1). https://nepp.nasa.gov/docuuploads/FE852B88-36AF-4378-A05B2C084B5EE2CC/EEE-INST-002_add1.pdf
- "Space Product Assurance Derating - EEE Components," European Cooperation for Space Standardization, ECSS-Q-5T-30-11C Rev 2, June 23, 2021.
- "Technical Requirements for Electronic Parts, Materials, and Processes used in Space Vehicles," USAF Space Command, Space and Missile Systems Center Standard, SMC-S-010, April 12, 2013. <https://aops.dtic.mil/sti/pdfs/AD1112325.pdf>

COTS focused documents:

- "Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions – Phase I Report," NESC Final Report NESC-RP-19-01490, October 27, 2020. <https://ntrs.nasa.gov/api/citations/20210015032/downloads/TM-20205011579.pdf>
- Ladbury, R., "Strategies for SEE Hardness Assurance: From Buy-It-And-Fly-It to Bullet Proof," presented at the 2017 IEEE Nuclear and Space Radiation Effects Conference (NSREC), New Orleans, LA, July 17-21, 2017. <https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170006865.pdf>
- "Guideline for the Selection of COTS Electronic Parts in Radiation Environments" JPL Publication 19-9. <https://hdl.handle.net/2014/51837>
- Valinia, A., "The Role of SmallSats in Scientific Exploration and Commercialization of Space". <https://ntrs.nasa.gov/citations/20190002568>



SST Program Documents - PMP Template



Project Management Plan

- Easy to digested document
- Contains PMP examples and outlines technical content that the plans need to have.

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3.2 Project Background and Project Opportunity

{High level overview regarding project and/or program background including definition of opportunities utilized} {Insert description; consider what opportunities this project takes advantage of or high-level problems this project hopes to solve. Include history of project technologies and/or systems.}

3.3 Goals, Objectives, and Metrics

{Explain goals, objectives, and metrics. Utilize tables and conform to relevant internal / external documents.} The {Project Name} goals are to mature payloads through the {XX programs} and realize rapid, transformative, and affordable mission capabilities. *{Add more as necessary}*

The {Project Name} technology demonstration success criteria and metrics are {Insert description}

The {Project Name} project series contributes to the {XX Program} strategic goals and objectives (Table 1) and success criteria (Table 2) as shown below.

Table 1: {XX Program} Goals and {Project Name} Objective Traceability *{Add more as necessary}*

{XX Program} Strategic Goal	Linked {Project Name} Objective(s)
{Define Goal 1} example: Enable and Innovate small spacecraft demonstration of new technologies and capabilities on orbit at Cislunar orbit.	{Define Obj L1-1} example: Enable execution of missions at much lower cost than previously possible. {Define Obj L1-2} example: Substantially reduce time required for development of spacecraft, from authority to proceed until initial launch capability. {Define Obj L1-3} example: Expand the capability of small spacecraft to execute missions at the Cislunar environment
{Define Goal 2}	{Define Obj L1-4} {Define Obj L1-5} {Define Obj L1-6}
{Define Goal 3}	{Define Obj L1-7} {Define Obj L1-8} {Define Obj L1-9}

Table 2: {Project Name} Success Criteria *{Add more as necessary}*

ID	Objectives	Success Criteria
L1-1	{Define}	{Define}
L1-2	{Define}	{Define}
L1-3	{Define}	{Define}

3.4 Customer or Beneficiary, Stakeholder, and External Partner Definition and Advocacy

{Per NPR 7120.8, and if applicable, briefly introduce customer, stakeholder, partners of the system, and partner engagement.} The {Project Name} customer is {XX}. The projects are all managed at {Company/organization Name}. The mission/flight operations, ground segments, launch/flight service

5.3 Project Reviews

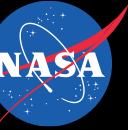
{Explain type of reviews that will be performed and justifications that are beyond as those captured in section 4.4.} Reviews shall be scaled as appropriate to the size / complexity / and risk posture of the project.

The required products and their associated maturity for the {Project Name} project at each of the review are shown below in Table 4.

{Note: It is recommended to have an SRR/SDR at the beginning of the project to understand the requirements of the mission.}

Table 4: {Project Name} Project Reviews

Review Name	Purpose	Technical Products (Required State)
System Requirements Review (SRR) Refer to NPR 7123.1 Table G-1 for information about technical products and purpose (Examples are given in this table) NPR 7123.1C – Appendix G (nasa.gov)	<ul style="list-style-type: none"> – Evaluation of the System Requirements for the Mission Concept – Review the preliminary Functional and performance requirements – Review the customer or stakeholders needs – Evaluate the scope of the project – Understand the risk posture, resources and constrains 	<ul style="list-style-type: none"> – System requirements document (Draft) – Project Plan (Draft) – Risk Assessment (Draft) – Safety Mission Assurance (Draft) – Concept of Operations (Draft) – Systems Engineering Management Plan (Draft)
Mission Concept Review (MCR) Refer to NPR 7123.1 Table G-3 for information about technical products and purpose (Examples are given in this table) NPR 7123.1C – Appendix G (nasa.gov)	<ul style="list-style-type: none"> – Mission Concept – Functional and performance requirements – Preliminary project plan – Stakeholder expectations 	
Flight Readiness Review (FRR)	Review of Project Documentation and Artifacts for:	<ul style="list-style-type: none"> – Launch Vehicle Requirement verification products



SST Program Documents - SEMP Template

Systems Engineering Management Plan

Contains detailed information regarding what certain SEMP areas need to have and examples to follow.

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5. COMMON TECHNICAL PROCESS IMPLEMENTATION

[LSE will address the technical implementation of the project with the 17 common technical processes described in this section, example as follows] Each of the 17 Common Technical Processes will have a separate subsection that contains the plan for performing the required process activities as appropriate. Implementation of the 17 Common Technical Processes includes: (1) generating outcomes needed to satisfy the entry and exit criteria of the applicable product life-cycle phase or phases; and (2) producing the necessary inputs for other technical processes. These sections contain a description of the approach, methods, and tools for:

- Identifying and obtaining adequate human and nonhuman resources for performing the process, developing the work products, and providing the services of the process.
- Assigning responsibility and authority for performing the planned process, developing the work products, and providing the services of the process.
- Training the technical staff performing or supporting the process, where training is identified as needed.
- Designating and placing designated work products of the process under appropriate levels of configuration management.
- Identifying and involving stakeholders of the process throughout each phase of the life cycle.
- Monitoring and controlling the process.
- Objectively evaluating adherence of the process and the work products and services of the process to the applicable requirements, objectives, and standards and addressing noncompliance.
- Reviewing activities, status, and results of the process with appropriate levels of management and resolving issues.

The SE Common Technical Processes model, commonly referred to as the "SE engine" in NPR 7120.1, is used to drive the development of the (Project Name) project. The 17 Common Technical Processes will be incorporated into the development of the system as shown below in Table 2.

Table 2: The 17 Common Technical Processes Table

ID	Major Processes	Sub-Processes	Common Technical Processes
A	System Design Processes	Requirements Definition Processes	Stakeholders Expectations Definition Technical Requirements Definition
		Technical Solution Definition Processes	Logical Decomposition Design Solution Definition
B	Product Realization Processes	Design Realization Processes	Product Integration Product Implementation Product Verification Product Realization
			Product Transition Process
		Technical Planning Processes	Technical Planning
C	Technical Management Processes	Requirement Management	Requirement Management
		Technical Control Processes	Interface Management

5.4 Logical Decomposition

Logical decomposition is the process of creating the detailed functional requirements that enable the (Project Name) Project to meet the stakeholder expectations and improve the understanding of the defined technical requirements and the relationships among the requirements. For the (Project Name) Project, the process of decomposing the parent requirements into a set of logical decomposition and their associated sets of derived technical requirements is performed in the (Describe where the logical decomposition is defined).

5.5 Product Integration

The integration and test flow for the (Name of System) system will be defined in the (Name of System) burn-in, integration, test, and verification of the (Name of System) project I&T Plan.

5.6 Product Verification

Verification will be performed at the appropriate level of assessment, subsystem or system level. Physical interfaces will be verified. Furthermore, verification will be performed both before and after assembly into a higher level of assembly. For more information on verification, see Section 5.7.

5.6.1 Verification Methodology

The verification method for each requirement will be tracked in the (Name of System) database. Unless otherwise specified, when more than one verification method is used for a requirement, it will be assumed verification is to be done by the (Name of System) project technical team. There are, however, constraints where the payload system and the S/C system have attachment points, a flow from one system to another. These interfaces are elaborated in the (Name of System) Payload to S/C Bus ICD, or the (Project Name) Payload Element ICD, space demonstration. (Additional methods of verification may be added to the risk tolerance and resources of the project.)

5.6.1.1 Test (T)

Test is a method used to determine quantitative compliance with requirements. Test can involve the use of instrumentation and specially instrumented equipment under simulated or flight equivalent conditions to specified environments to measure and record

6.8 Boundary of Technical Effort

This subsection contains a description of the boundary of the general product technical effort, including technical and project constraints (governing hardware, predefined interfaces, cost, schedule, and technologies) that specifically, it identifies what can be controlled by the technical team (in what influences the technical effort and is influenced by the technical effort outside the boundary). Specific attention should be given to functional, and electronic interfaces across the boundary.

The high-level system block diagram for the (Project Name) project is shown in Figure 6.

(Insert a diagram describing the High-Level System architecture for the (Project Name) project.)

Figure 6. High-Level (Project Name) System Architecture

The boundary of the (Project Name) (System Name) system flight system is shown in Figure 6. The design of the system elements inside the boundary is, in general, the (Project Name) Project technical team. There are, however, constraints where the payload system and the S/C system have attachment points, a flow from one system to another. These interfaces are elaborated in the (Name of System) Payload to S/C Bus ICD, or the (Project Name) Payload Element ICD, space demonstration. (Additional methods of verification may be added to the risk tolerance and resources of the project.)

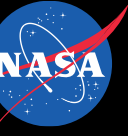
The (Project Name) Project Team has varying degrees of involvement with different elements. Table 8 captures Lead/Not Controlled roles of technical elements and factors. For areas marked as "Influence," the project does not control, either by choice or by programmatic constraint. Reduced design risk in many areas in order to reduce cost and schedule risk.

Table 8: Control of Technical Elements (Add more as appropriate)

Type of Control	Element	Constraints
{Identify the control of the element. Either "Lead" or "Not Controlled"}	• {Subsystem Name}	{Name the lead responsible for the development of the element.}
{Lead}	• {Spacecraft Bus}	{Bus design with ABC Co that will be developed under a contract}
{Lead}	• {Payload Subsystem}	{ABC Co leads development of the Payload Element...}
{Lead}	• {Mission Operations}	{Ground station and support will be implemented through a contract}

9.2 Compliance Matrix (Complete columns "Comply?" and "Justification"; *if additional/supporting information is necessary, capture as appropriate under the "Justification" column)

Req ID	NPR Section	Requirement Statement	Rationale	Comply?* (Fully Compliant, Tailored, Not Compliant)	Justification
SE-01 to 05		Deleted	See rationale in the Deleted Requirements Table J-1.		
SE-06	6.1.8	The Engineering Technical Authority (ETA) shall approve the SEMP, waiver or deviation authorizations, and other key technical documents to ensure independent assessment of technical content.	This requirement ensures that the ETA has reviewed and approved of key Systems engineering documents.		
SE-07	3.2.2.1	Program/Project Managers shall identify and implement an ETA-approved Stakeholder Expectations Definition process to include activities, requirements, guidelines, and documentation, as tailored and customized for the definition of stakeholder expectations for the applicable product layer.	This requirement ensures that the program/project and the ETA identifies how they will gather and address stakeholder expectations. This ensures that the program/project will gain a thorough understanding of what the customer and other stakeholders expect.		
SE-08	3.2.3.1	Program/Project Managers shall identify and implement an ETA-approved Technical Requirements Definition process to include	This requirement ensures that the program/project and the ETA identifies how they will select and gain		



SST Program Documents - SMAP Template

Safety & Mission Assurance Management Plan

Easy to digest guidelines on how to create a SMAP with examples and recommendations

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10.13 Verification and Validation (V&V)
10.14 Final Acceptance
10.15 Acquisition Risk Management
11 Software Assurance
12 EEF Parts

3.4 Project Category and Risk Classification

*[Define where the project falls into risk categories and define the categories] [Project Name] as a DNH project. Allows very high technical risk, but complies with safety requirements to last any amount of time, only a requirement not to harm the vehicle) and human personnel. No mishap will be declared if the payload does not on flight. The project will be managed by [Organization Name]. The [Project Name] project classification and acceptable risk posture. *[Further define DNH approach, Appendix E for guidance.]**

3.5 Complex / Critical

*[Further define project classification, utilize organization internal documents, NASA NPR 8730.5 or insert organization internal document], [Project Name] is a Complex project but has **Safety Critical Items**. A Project Critical Items List (PCIL) is attached as an appendix in this document. Because [Project Name] is a "DNH" Project, **classify these as "DNH," unless another requirements document, specified in the characteristics as listed below:***

- Allowable technical risk is very high.
- There are no requirements to last any amount of time, only a requirement to last any amount of time, only a requirement not to harm the platform (ISS, host spacecraft, etc.).
- No mishap would be declared if the payload does not function.

Furthermore, (NPR 7120.8 or insert organization internal document) requires 7120.8, section 5.2.2.11: *"The project Safety & Mission Assurance (S&MA) Lead implementation of safety, reliability, maintainability, and quality assurance policies serves as advisor to the project manager and implements the S&MA technical authority."* [Project Name] has several elements that can create a safety issue, which deem it Critical. [Project Name] shall identify safety hazards that can affect personnel, impact the launch provider. This process requires Preliminary Hazard Analysis to request by the Launch Provider, a Safety Data Package (if required) is generated and controls that will be submitted to the launch provider for approval.

[Project Name] is Complex as well due to key attribute that will require inspection to design requirements and safety controls that will be verified by an SMA independent. [Project Name] is considered a Safety Critical Project. This determination shall comply with SAE AS9100 or ISO 9001 clauses that are aligned with [Company Name] Requirements. This mapping is defined in (APD 1280.1 or insert organization internal document) will ensure the [Project Name] project complies with the appropriate (APD/APR/ internal documents) to fulfill the Safety Critical requirement(s).

4 Roles and Responsibilities

[Explicitly explain roles and responsibilities, as applicable to your project, of specific]

4.1 Project Manager (PM)

- Has overall responsibility for SMA for the [Project Name] project, will implementation of SMA to the [Project Name] Chief Safety and Mission Assurance the [Project Name] project complies with NASA SMA Requirements.
- Provides the resources to implement the SMA requirements of the project.
- Ensures that all hazards are identified, and controls have been implemented.
- Responsible for all risks impacting SMA requirements and are reduced to a level that is acceptable.
- Leads and approves all safety deliverables prior to submittal (i.e., Safety Critical Hazard Reports). *[SMA and PM may collaborate on these efforts]*
- Ensure that all employees working on this project are certified and trained to workmanship requirements.
- Accept any residual risks that result from balancing project's schedule, cost, and performance requirements.
- Inform [Management Organization] of accepted residual high risks from nonconformances.

5 Risk Management

[Define the risk management plan] The Project Manager will document the project's approach for Continuous Risk Management (CRM).

The CSO is a member of the Project Risk Management Team. The Project Manager has final authority when a risk is identified and shall ensure the risk process is followed and each risk is addressed during the risk management meeting.

5.1 Risk-based handling of nonconforming items

The project shall document safety critical nonconformances in the reporting system [insert organization reporting system]. The form shall be used with the mission risk classification identified by the project. The reporting system shall include but are not limited to:

1. Noncompliance (Critical) - A nonconformance that could result in a likely to prevent performance of a vital or essential function.
2. Noncompliance (Major) - A nonconformance that could result in a major nonconformance affect form, fit, or function.
3. Noncompliance (Minor) - A deficiency that could result in the quality of a product or service or on the project. Minor noncompliance may include, for example, a quality system requirement or failures to meet requirements.

documented on the project procedures.

10.3 Workmanship Standards (WS)

[Refer to Appendix F: Guide for Workmanship, which provides workmanship standards based on the project risk and resource]

CSO shall verify that all personnel supporting activities with workmanship certified and defined by the project.

This includes but is not limited to Institute of Printed Circuits (IPC) standards, Polymeric, and Crimping.

An example for this section is provided:

The design and workmanship standards for work or assembly shall be used unless noted otherwise.

COTS parts are exempted from this requirement. However, shall meet the workmanship requirements identified by the project.

- All Electrostatic Discharge Sensitive (ESDS) Electronic parts shall be handled in accordance with the Project Electrostatic Discharge Control Program for Protection of Assemblies and Equipment (Excluding Electrically Insulated Assemblies, IPC J-STD-001E-2010).
- Conformal Coating and Staking: NASA-STD-8739.1, Conformal Coating of Printed Wiring Boards and Equipment.
- Soldering -Joint Industry Standard Requirements for Assemblies, IPC J-STD-001E-2010.
- Crimping, Wiring, and Harnessing: NASA-STD-8739.1, Harnesses, and Wiring".
- EEE Parts: (document number XXX).

10.4 Workmanship for COTS

Commercial Off The Shelf (COTS) parts will be adhering to the project workmanship standards.

- CSO shall perform visual inspection of all Flight COTS parts.
- CSO shall document any non-conformance of COTS parts.
- CSO shall inspect all COTS that had been modified to a level that is acceptable.
- The project shall determine screen plan for COTS parts on the project procedures.
 - o Screening Plan may include the following:
 - Additional WS to meet section 10. Note: Any COTS part that is modified to meet WS must be documented in the Subject Matter Expert(s) must determine the environmental screen testing.
- Any non-conformance COTS part will be downgraded and documented in the Traveler.
- If flight COTS part fail during the higher assembly environment, the failure in (PRACA, Jira, or equivalent system) and previously screened COTS part, or correct the COTS part and document in the Traveler.

10.11 MRB

[review board consisting of technical and administrative personnel; refer to Appendix D which provides recommendations about the MRB process and elements]

The MRB shall consist of technical and administrative personnel who meet on an as-required basis to define NCRs:

- Review and disposition on NCRs.
- Establish criteria for what shall the Categories of Nonconformances should be.
- The MRB will participate in the review and disposition of NCRs.
- The MCR includes but is not limited to:
 - o Chief of Safety Mission Assurance (e.g., Chairperson)
 - o Program/Project Manager
 - o Project Engineer
 - o Group leads and technical consultants as required
 - o Others as designated by the Chairperson
- The Program/Project Manager will have final disposition authority on all MRB issues.

Other Support *[as defined by the Project Office]* The Project Office may request specific reviews by the Engineering office, Quality Assurance and/or Safety, in support relative to a specific change request and/or other support action.

10.12 Integration and Testing (I&T)

CSO, through assessments, shall determine the level of QE oversight and MIPs for procedures and test plans. All critical safety hazardous procedures shall be supported by the CSO. CSO shall ensure conformance to requirements during integration and test processes. All flight products and associated GSE shall be assembled or disassembled using approved drawings and/or procedures. All tools and instruments used in assembly or testing of flight or ground test safety critical hardware (e.g., torque wrenches, voltmeters, etc.) shall be calibrated and documented on As-run procedures and verified by QE.

10.13 Verification and Validation (V&V)

As appropriate, the project will use analysis, inspections, and tests to verify that the flight unit passes flight verification activities. Throughout the project lifecycle, the SMA will review the I&T Plan and the requirements to ensure that components, sub-assemblies, assemblies, and final assembly meet required performance standards. The project I&T Plan details planned tests during the development cycle. The Mission Systems Engineer will collaborate with the SMA to identify key inspections points within the various test standard operating procedures and to determine SMA's support responsibilities at Test Readiness Reviews.

10.14 Final Acceptance

CSO shall ensure all Statement of Work (SOW), PO, contracts, and Service Request (SR) have the appropriate level of deliverables defined to support objective evidence that the supplier has met the requirements of the product specifications. This defined list of deliverables will be submitted with the EIDP. The EIDP shall be reviewed and approved (stamp or signature) by a QE representative from the delivering party prior to final delivery of the completed hardware. QE personnel will review and accept an EIDP which will include the following, as applicable:



SST Program Documents - CMP Template

Configuration Management Plan

Explains what a CMP includes, how to implement the Change Control Boards and Configuration Structures.

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2.1.3 Configuration Management Representative(s) (CMR) *(group responsible for managing the CM activities)*

The CMR reports directly to the Program/Project Manager *(define; dependent on the organization or project)*. The CMR is responsible for managing the Program/Project CM activities in accordance with the CMP and shall (as agreed between the Program/Project Manager and Lead System Engineer (LSE):

- Provide CM guidance, direction and support.
- Facilitate and endorse the documentation, implementation, and maintenance of the CM processes.
- Coordinate with Program/Project team members, change control boards, and other individuals involved in managing, operating, and maintaining the CM process.
- Ensure that updates to the configuration information, CM library information and change requests are maintained in a CM Status Accounting System.
- Updates and posts all documents into the database as well as archives all documents at the end of the project.
- Verifies that no outdated items or drawings are in use following acceptance of changes (i.e., works with test and manufacturing leads).

3.2.1 Configuration Structure

To identify the project documents, the following convention is defined for all documents:

TZPZ-XX-Y_	(Example: TZPZ-05-E001)
ZPZ	The number of satellite and payload
XX	The Work Breakdown Structure (WBS) specific to the document. See Appendices B and C for convention
Y	Configuration Structure. See Appendix D for convention
The following numbering protocol shall be used for identifying the project documents for {Project Name}: <i>(Projects may change as necessary)</i>	
TZPZ-XX-E_	Electrical (Schematics and Wiring Diagrams)
TZPZ-XX-M_	Mechanical (Assembly, Fabrication Drawings and Part Numbers)
TZPZ-XX-PD_	PCB Draft Dimension Drawings
TZPZ-XX-PC_	PCB Layout (Gerber File)
TZPZ-XX-PL_	Parts List
TZPZ-XX-XA_	Agreements, Architectural and Engineering studies, Reviews such as CDR and Operational Readiness Review. (i.e. PRR, PDR, CDR, etc.)
TZPZ-XX-XB_	Management / Financial Plans, Reports and Studies. (Project Management Plans, Schedules, cost estimates)
TZPZ-XX-XC_	Computer Software Listings and Codes
TZPZ-XX-MA_	Manuals and Instructions, Work Instructions – Procedures

Example Table 1

Bread Board	Proto Flight	Flight	Delivery
Design, Production, Test	Design, Production, Test	Design, Production, Test	
Use the Engineering Document Numbering System (obtain #s from EDC)	Use the Engineering Document Numbering System (obtain #s from EDC)	Use the Engineering Document Numbering System (obtain #s from EDC)	Submit "as-built" drawings / documents to EDC (or other)
Release only <u>draft</u> check prints / documents for review	Release only <u>draft</u> check prints / documents for review	Release <u>non-draft</u> check prints / documents for review	Follow signature Approval Matrix for drawings / documents submission

Appendix C: Project Standard WBS Elements Definitions (from NPR 7120.8, Appendix I)

Element 1 – The business and administrative planning, organizing, directing, coordinating, controlling, Project and approval processes used to accomplish overall Project objectives, which are not Management: associated with specific hardware or software elements. This element includes project reviews and documentation (including NEPA), non-project owned facilities, and project reserves. It excludes costs associated with technical planning and management, and costs associated with delivering specific engineering, hardware and software products.

Element 2 – The technical and management efforts of directing and controlling an integrated Systems engineering effort for the project. This element includes the efforts to define the project Engineering: vehicle - ground system, conducting trade studies; the integrated planning and control of the technical program efforts of design engineering, software engineering, specialty engineering, human rating, system architecture development, and integrated test planning, system requirements writing, configuration control, technical oversight, control and monitoring of the technical program, and risk management activities. Documentation Products include mission/system requirements document (MSRD); interface control documents (ICDs); Risk Management Plan and Verification and Validation (V&V) Plan. Excludes any design engineering costs.



SST Program Documents - ODAR Template

Orbital Debris Assessment Report & End of Mission Plan

Provides examples on how to filled information and examples of failures modes

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Page Break

1.0 Purpose
The Small Spacecraft Technology Program (SSTP) for Orbital Debris Assessment Report (ODAR) instructional guide and template is for the spacecraft developer outside of NASA and is intended to provide guidance and thought process when designing hardware for space. This ODAR guide establishes and describes the process in meeting the requirements for the spacecraft as defined in NASA-STD-8719.14.

1.1 Scope
This ODAR follows the format in NASA-STD-8719.14, Appendix A.1 and includes the orbital debris mitigation requirements for the spacecraft captured in sections 1 through 8 below for the (Project Name). Sections 9 through 14 apply to the launch vehicle ODAR and are not covered in this document. Text in curly brackets "[text]" represent information to be captured (e.g., (Project Name)) when preparing the project-specific ODAR, and italic text in curly brackets "(text)" represents guidance/information for a section being prepared and should be deleted from the document prior to release.

2.0 Cover and Front Matter (Template)
The following information details the content that should be captured on the cover and front matter sections (e.g., title page, signature page, revision log, table of contents, etc). The title page should include, at a minimum, the title of the document, the document release date, and the document version. The

3.0 Assessment Report Format
ODAR Technical Sections 1 through 8 (spacecraft) Format Requirements are as follows:

3.1 ODAR Section 1: Program Management and Mission Overview
(Define management and mission overview, *more or less as necessary, example as follows*):

Mission Directorate: {Insert responsible entity}
Engineer Director: {Insert name and affiliation}
Mission Design Division, Division Chief: {Insert name and affiliation}
Project Manager/Senior Scientist: {Insert name and affiliation}
Schedule of mission design and development milestones (if applicable) from NASA mission selection through proposed launch date, including spacecraft PDR and CDR (or equivalent) dates:

Mission Selection:	{Insert Date}
Mission Chief of Engineering Review:	{Insert Date}
PDR	{Insert Date}
CDR	{Insert Date}
PSRP O/I/II:	{Insert Date}
PSRP III:	{Insert Date}
Integration to X:	{Insert Date}
Launch to X:	{Insert Date}
Launch from X:	{Insert Date}

Mission Overview:
(High level overview of the project mission, example as follows): The {Project name} satellite will be hard-stowed onto the {Launch vehicle}. {Project Name} will test and validate three different technologies in Low Earth Orbit (LEO)...

Launch vehicle and launch site: X
Proposed launch date: {Insert date}
Mission duration: X
Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination:

This system will allow {Project name} to be launched at a velocity of X cm/sec and at an angle of X degrees relative to the X into a circular orbit initially approximately X km relative to Earth's surface.

The {Project name} orbit is defined as follows:
Apogee: X km
Perigee: X km

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4:
Requirement 4.4-1: Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon:

For each spacecraft and launch vehicle orbital stage employed for a mission, the program or project shall demonstrate, via failure mode and effects analyses or equivalent analyses, that the integrated probability of explosion for all credible failure modes of each spacecraft and launch vehicle is less than 0.001 (excluding small particle impacts) (49).

Probability:
 Probability: 0.001.
 Probability: 0.000.

Failure Mode and FMEA details:
Vessel Failure:
 Governed per {name of Launch Vehicle} safety standards.

(Depends on design, follow the example):
 Failure modes below might result in battery explosion with the possibility of energy generation. However, in the unlikely event that a battery cell does rupture, the small size, mass, and potential energy, of these small cells such that while the spacecraft could be expected to vent gases, most likely the battery rupture should be contained within the vessel due to the lack of energy.
 Probability Low. It is believed to be much less than the 0.0001% requirements. Failure modes are multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).

Mitigations are specific to the Launch Vehicle / ISS / other form of orbital platform and must change accordingly:
 Mitigations described for each failure mode, each project will be different)

Battery Internal short circuit.
 Example) Complete proto-qualification and environmental acceptance testing (by name). The acceptance tests are shock, vibration, thermal cycling, and electrical tests followed by maximum system rate-limited charge and discharge to ensure that internal short circuit sensitivity exists.
 Tests required for realized failure: Environmental testing AND functional performance tests must both be ineffective in discovery of the failure mode.

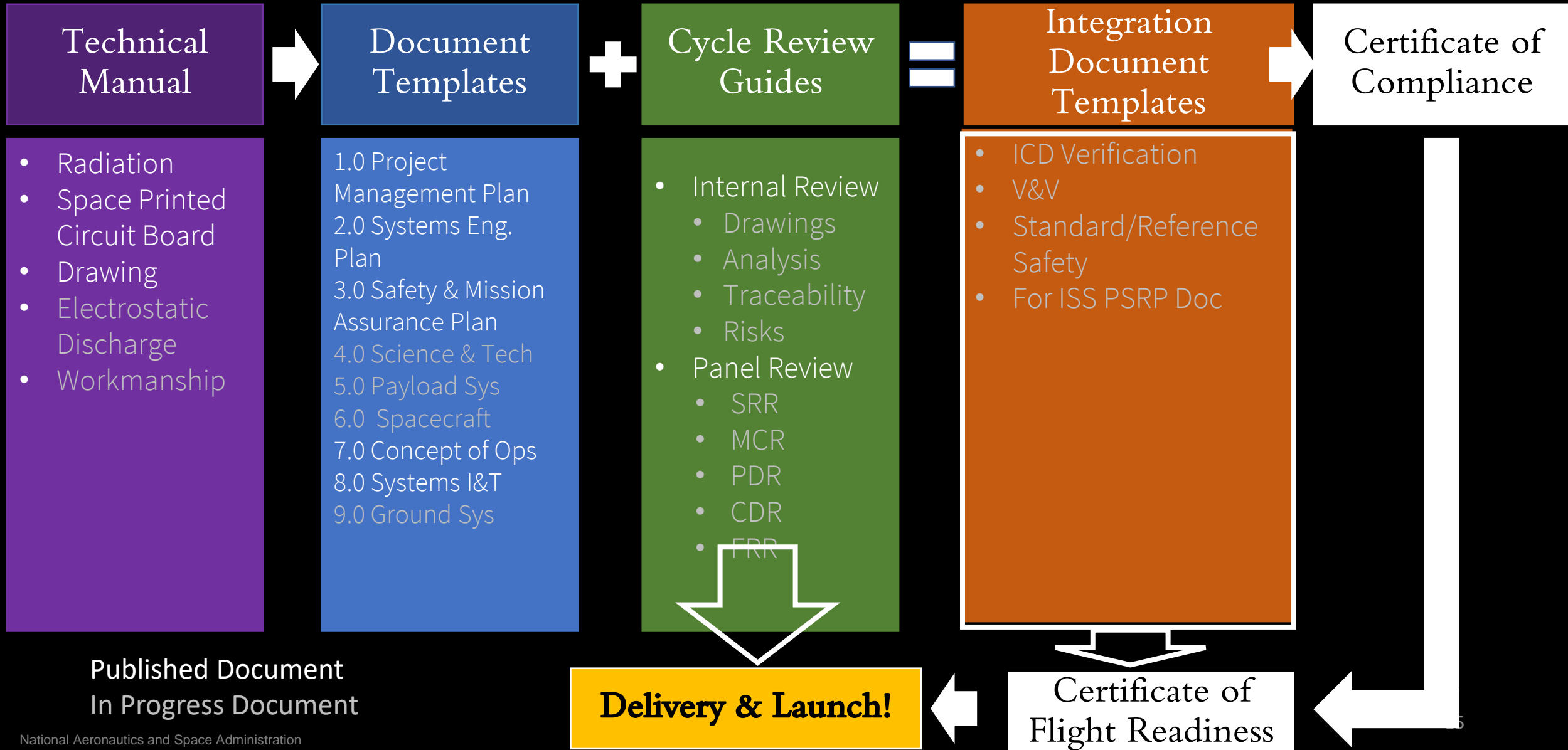


Additional Documents



Document	Descriptor	Document Type
PDR & CDR Presentation Development Guide	Checklist development guide for PDR/CDR design review presentations	Guide
Concept of Operations	Concept of Operations document development template	Template
Flight Readiness Review Presentation Development Guide	Checklist development guide for FRR presentation	Guide
Mission Concepts Review Presentation Development Guide	Checklist development guide for MCR presentation	Guide
Operational Readiness Review Presentation Development Guide	Checklist development guide for ORR presentation	Guide
Test Development Plan	Test Development Plan document development template	Template
Master Environmental Test Report	[ISS LAUNCH ONLY] ISS-required test report document development template	Template
Fracture and Fastener Control Summary	Fracture and Fastener Control Summary document development template	Template
Parts and Materials List	Parts and Materials List document development template	Template
Safety Data Package	Safety Data Package document development template	Template

Document Implementation





nasa.gov/smallspacecraft