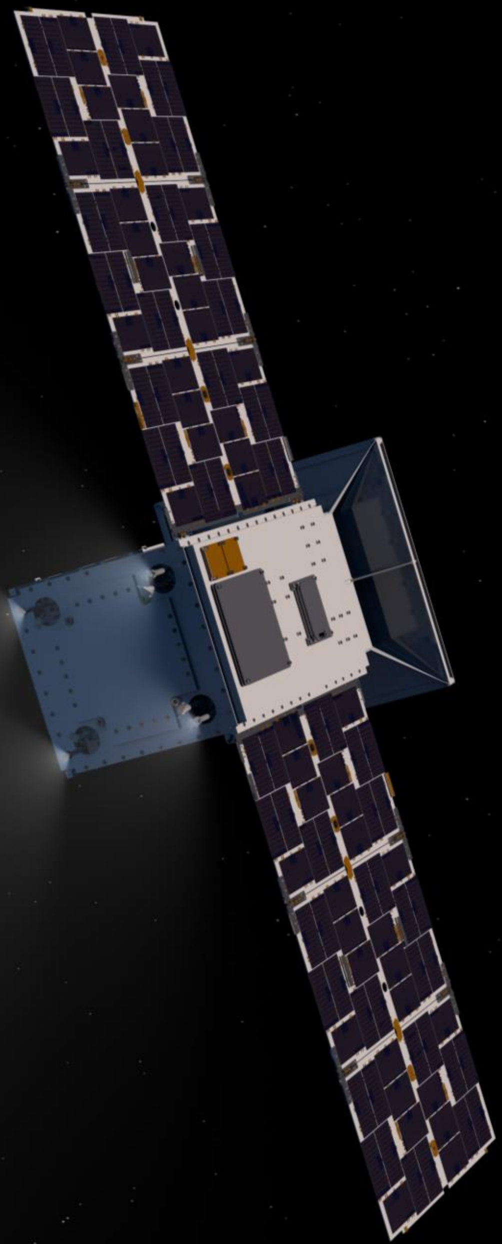
National Aeronautics and
Space Administration



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

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Agenda

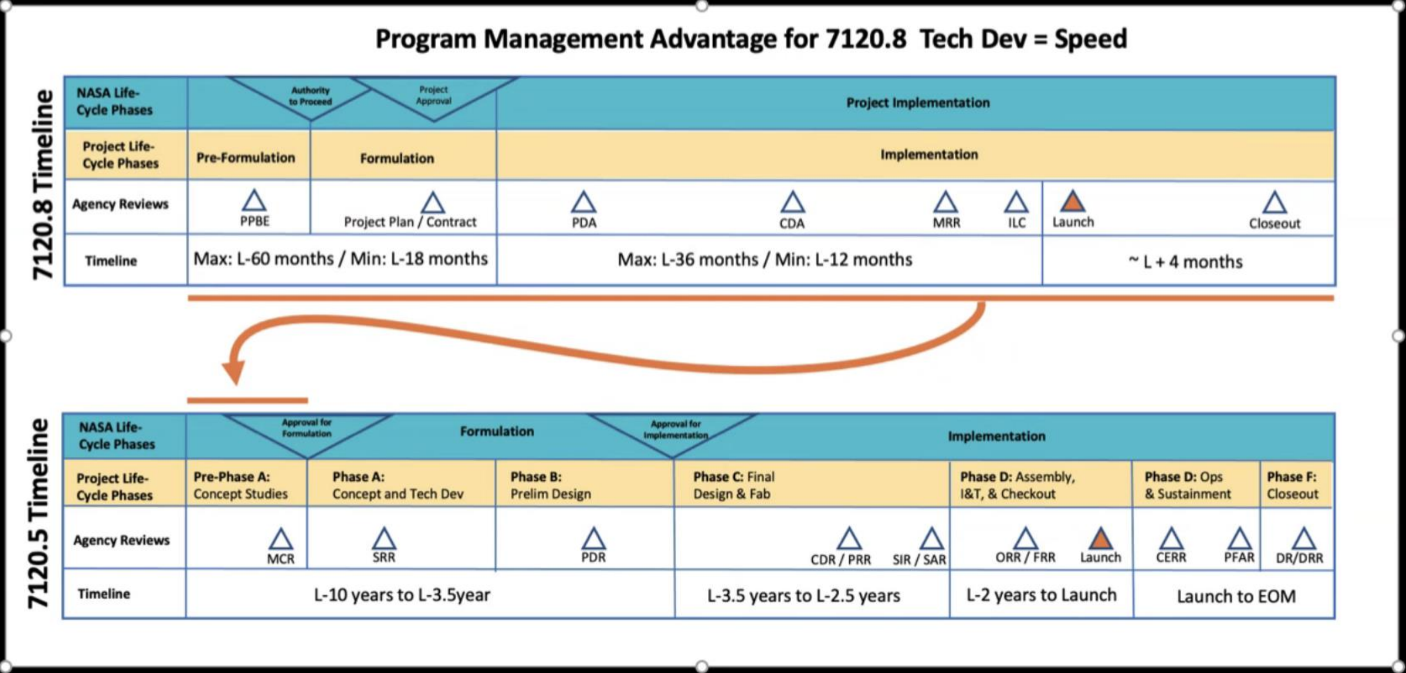
- The Small Spacecraft Technology Program Guidebook for NASA Procedural Requirement (NPR) 7120.8 is a top-level document to guide project management approaches to NPR 7120.8 NASA Research and Technology Program and Project Management Requirements

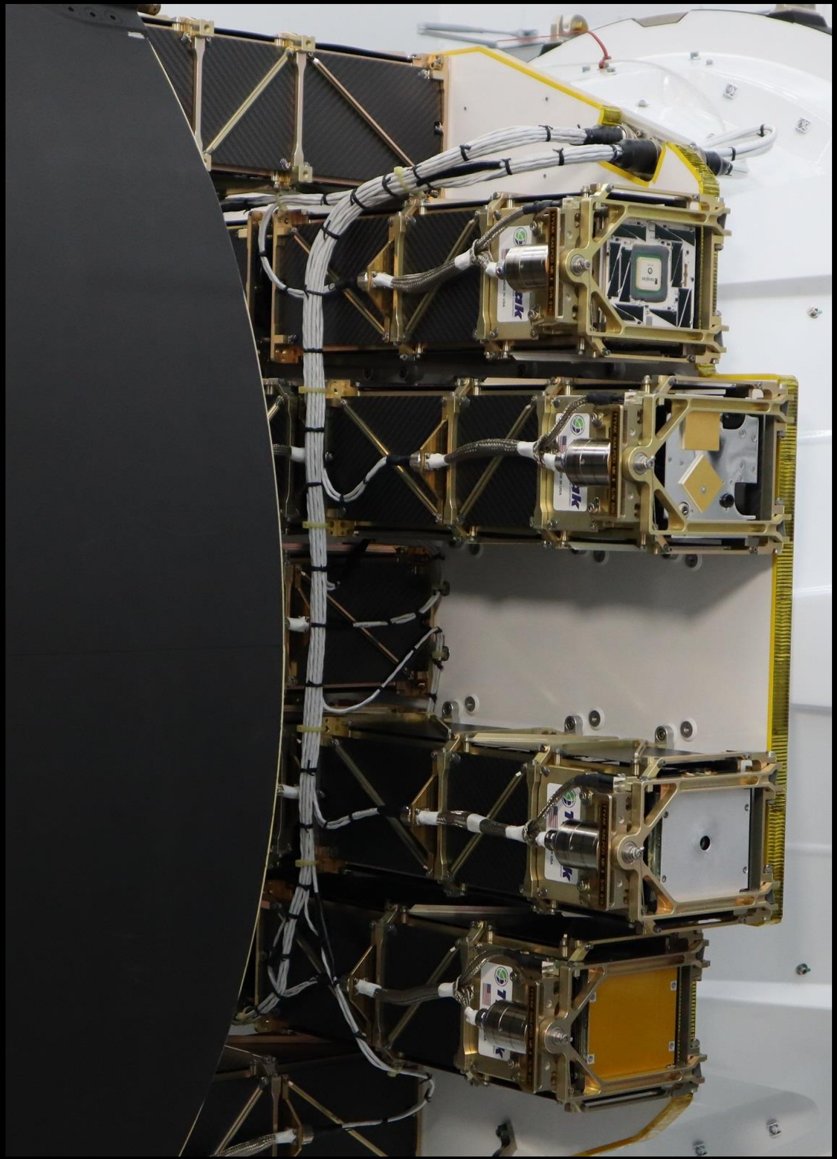
- SST Program Documents contain both technical manuals and document templates

  - 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





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.

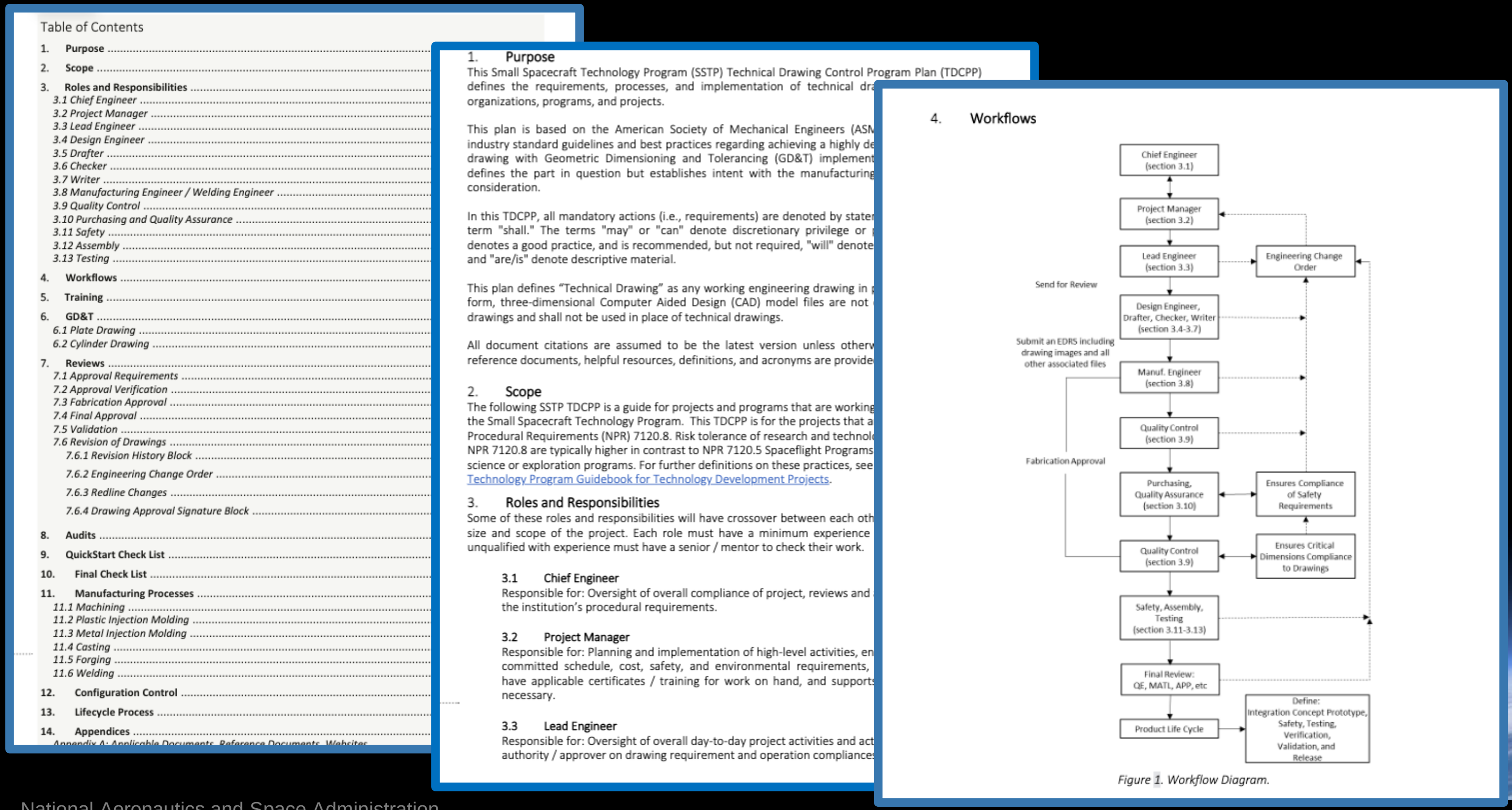
Phase	Activity	Output(s)
Pre-formulation	Preliminary planning (NPR 7120.8 Sect 4.2.5). Often omitted from SST projects which proceed from ATP	Scope, from SST Program
ATP (KDP)	SST approval of proposed project to enter Formulation Phase (NPR 7120.8 Sect 4.2.6)	Approval, Preliminary Project Plan
Formulation	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 learns.

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

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

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

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

This plan defines "Technical Drawing" as any working engineering drawing in 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 otherw reference documents, helpful resources, definitions, and acronyms are provide

2. Scope

The following SSTP TDCPP is a guide for projects and programs that are working the Small Spacecraft Technology Program. This TDCPP is for the projects that a Procedural Requirements (NPR) 7120.8. Risk tolerance of research and technol NPR 7120.8 are typically higher in contrast to NPR 7120.5 Spaceflight Programs science or exploration programs. For further definitions on these practices, see Technology Program Guidebook for Technology Development Projects.

3. Roles and Responsibilities

Some of these roles and responsibilities will have crossover between each oth size and scope of the project. Each role must have a minimum experience unqualified 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 the institution's procedural requirements.

3.2 Project Manager

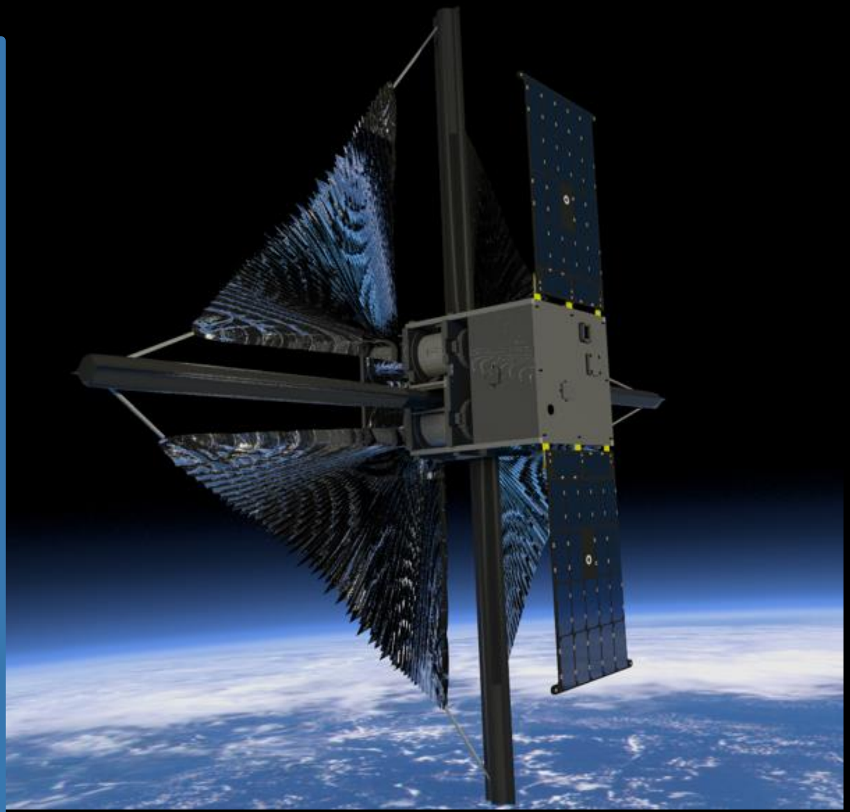
Responsible for: Planning and implementation of high-level activities, en committed schedule, cost, safety, and environmental requirements, have applicable certificates / training for work on hand, and supports necessary.

3.3 Lead Engineer

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

4. Workflows

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.

Contents

High-Risk Novice Approach

Setting: This is your first-ever space-application PCB and one of your first PCB desig
start somewhere, and this is honestly not a bad place to start. You are allowed a ha
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 PC
    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 siz
    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 swit
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_Nederlander-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/raddatabase/raddatabase.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

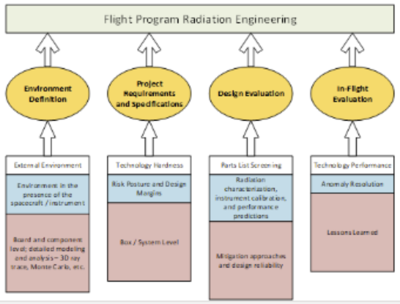
Industry standards on radiation testing, guidelines on assurance methodologies, and bodies of knowledge for technology failure modes exist to aid in the engineering discipline of radiation effects on Electrical, Electronic and Electromechanical (EEE) components [1-5]. NASA does not currently have an 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 spaceflight 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.

Figure 1. RHA activities [19]



Parts criteria standards (radiation):

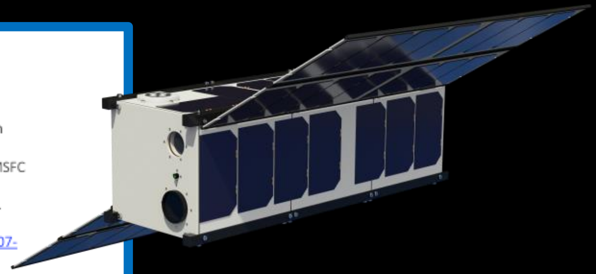
1. NASA Office of Safety and Mission Assurance: Discipline-EEE Parts. https://sma.nasa.gov/sma-disciplines/eee-parts
2. NASA Electronic Parts and Packaging Program. Electronic Radiation Characterization Project (ERC). https://nepp.nasa.gov/pages/Radiation.cfm
3. MSFC Tech Standard -3012; EEE parts management and control requirements for MSFC space flight hardware. https://nepp.nasa.gov/files/26094/MSFC-STD-3012A.pdf
4. 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
5. Standards for radiation effects testing: Jean-Marie Lauenstien (GSFC). https://ntrs.nasa.gov/api/citations/20150011462/downloads/20150011462.pdf

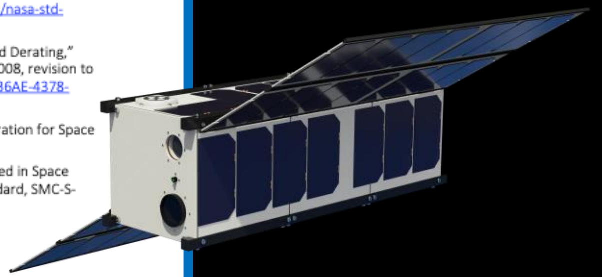
Parts criteria standards (not radiation):

6. "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
7. 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/docuploads/FFB52B88-36AE-4378-A05B2C084B5EE2CC/EEE-INST-002_add1.pdf
8. "Space Product Assurance Derating - EEE Components," European Cooperation for Space Standardization, ECSS-Q-ST-30-11C Rev 2, June 23, 2021.
9. "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://apps.dtic.mil/sti/pdfs/AD1112325.pdf

COTS focused documents:

10. "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
11. 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
12. "Guideline for the Selection of COTS Electronic Parts in Radiation Environments" JPL Publication 19-9. https://hdl.handle.net/2014/51837
13. 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)	– 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	– 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)	– Mission Concept – Functional and performance requirements – Preliminary project plan – Stakeholder expectations	
Flight Readiness Review (FRR)	Review of Project Documentation and Artifacts for:	– 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 pro described in this section, example as follows} Each of the 17 Common Technical Processes will ha separate subsection that contains the plan for performing the required process activities as appr tailored. Implementation of the 17 Common Technical Processes includes: (1) generating outco needed to satisfy the entry and exit criteria of the applicable product life-cycle phase or phases; a producing the necessary inputs for other technical processes. These sections contain a descriptio approach, methods, and tools for:

1) Identifying and obtaining adequate human and nonhuman resources for performing the process, developing the work products, and providing the services of the process.
2) Assigning responsibility and authority for performing the planned process, developing th products, and providing the services of the process.
3) Training the technical staff performing or supporting the process, where training is identi needed.
4) Designating and placing designated work products of the process under appropriate leve configuration management.
5) Identifying and involving stakeholders of the process throughout each phase of the life c
6) Monitoring and controlling the process.
7) Objectively evaluating adherence of the process and the work products and services of th process to the applicable requirements, objectives, and standards and addressing noncompliance.
8) Reviewing activities, status, and results of the process with appropriate levels of manage and resolving issues.

The SE Common Technical Processes model, commonly referred to as the "SE engine" in NPR 712 be used to drive the development of the {Project Name} project. The 17 Common Technical Proc that will be incorporated into the development of the system are shown below in Table 2.

Table 2: The 17 Common Technical Processes Table

ID	Major Processes	Sub-Processes	Common Technica
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	Product Transition
C	Technical Management Processes	Technical Planning Processes	Technical Planning
		Technical Control Processes	Requirement Management
			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} syster burn-in, integration, test, and verification of the {Name of Syst the project I&T Plan.

5.6 Product Verification

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

5.6.1 Verification Methodology

The verification method for each requirement will be tracked i database. Unless otherwise specified, when more than one v requirement, it will be assumed verification is to be done by c methods must be used in order to show compliance with the v option of using one verification method versus another verifi will be specified in the database.

There are four verification methods that will be used by the p Demonstration. *{Additional methods of verification may be ad the risk tolerance and resources of the project.}*

5.6.1.1 Test (T)

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

6.8 Boundary of Technical Effort

This subsection contains a description of the boundary of the technical effort of the general pro technical effort, including technical and project constraints (governing N 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 eff the technical team (outside the boundary). Specific attention should be functional, and electronic interfaces across the boundary.

The high-level system block diagram for the {Project Name} project is sh

{Insert a diagram describing the High-Level System architecture for

Figure 6. High-Level {Project Name} System Architec

The boundary of the {Project Name} {System Name} system flight syster Figure 6. The design of the system elements inside the boundary is, in ge {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 e Payload to S/C Bus ICD, or the {Project Name} Payload Element ICD, spa

The {Project Name} Project Team has varying degrees of involvement wi different elements. Table 8 captures Lead/Not Controlled roles of techni constraints and factors. For areas marked as "Influence," the project do Control, either by choice or by programmatic constraint. Reduced desig many areas in order to reduce cost and schedule risk.

Table 8: Control of Technical Elements *{Add more as appr*

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}

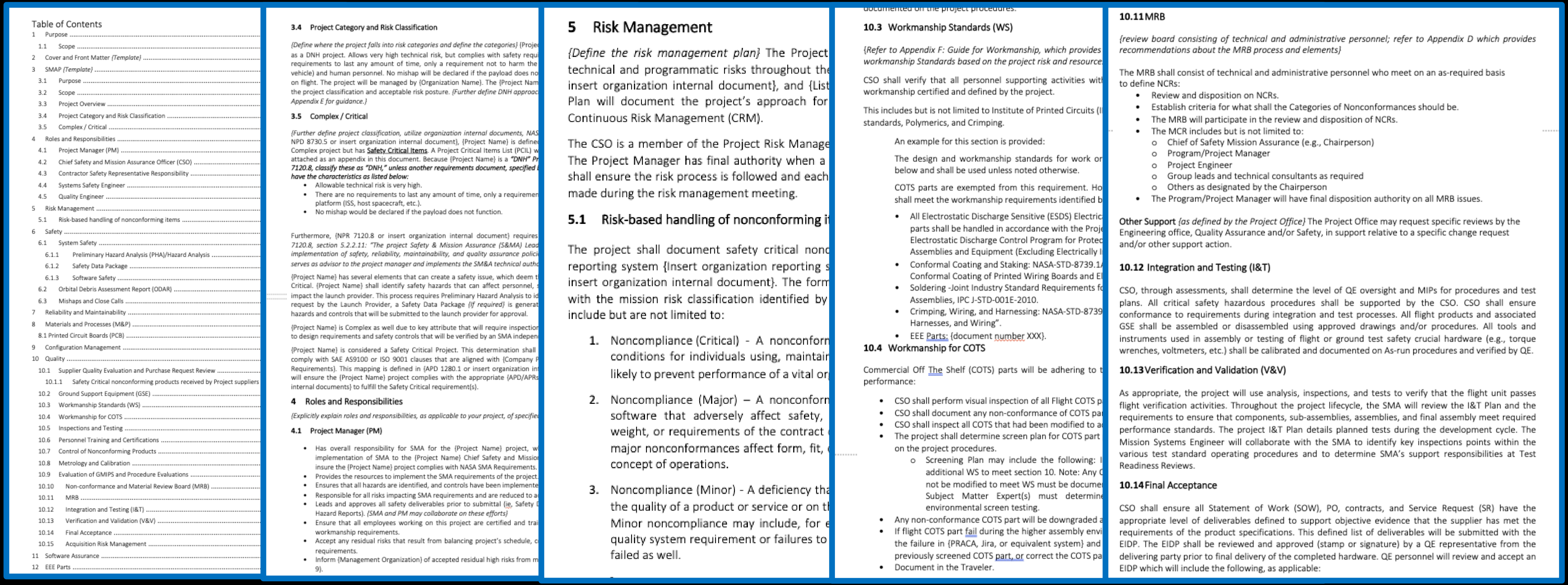
9.2 Compliance Matrix {Complete columns "Comply?" and "Justification";*if additional/supporting information is necessary, capture as appropriate under the "Justification" column}

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



SST Program Documents - CMP Template

Configuration Management Plan

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

Table of Contents

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).

Example Table 1

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

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}: *{Projects may change as necessary}*

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

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

Element 1 – Project Management: The business and administrative planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish overall Project objectives, which are not 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 – Systems Engineering: The technical and management efforts of directing and controlling an integrated engineering effort for the project. This element includes the efforts to define the project 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 establi 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 d 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 covere this document. Text in curly brackets "{text}" represent information to be captured (e.g., {P 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 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 matte sections (e.g., title page, signature page, revision log, table of contents, etc). The title page should i at a minimum, the title of the document, the document release date, and the document version. Th

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 0/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 ...nd launch vehicle is less than 0.001 (excluding small particle impacts) ...49).

...**ent:**

...**ty:** 0.001.
...**ty:** 0.000.

...**ale and FMEA details:**
...*essel Failure:*
...ented per {name of Launch Vehicle} safety standards.

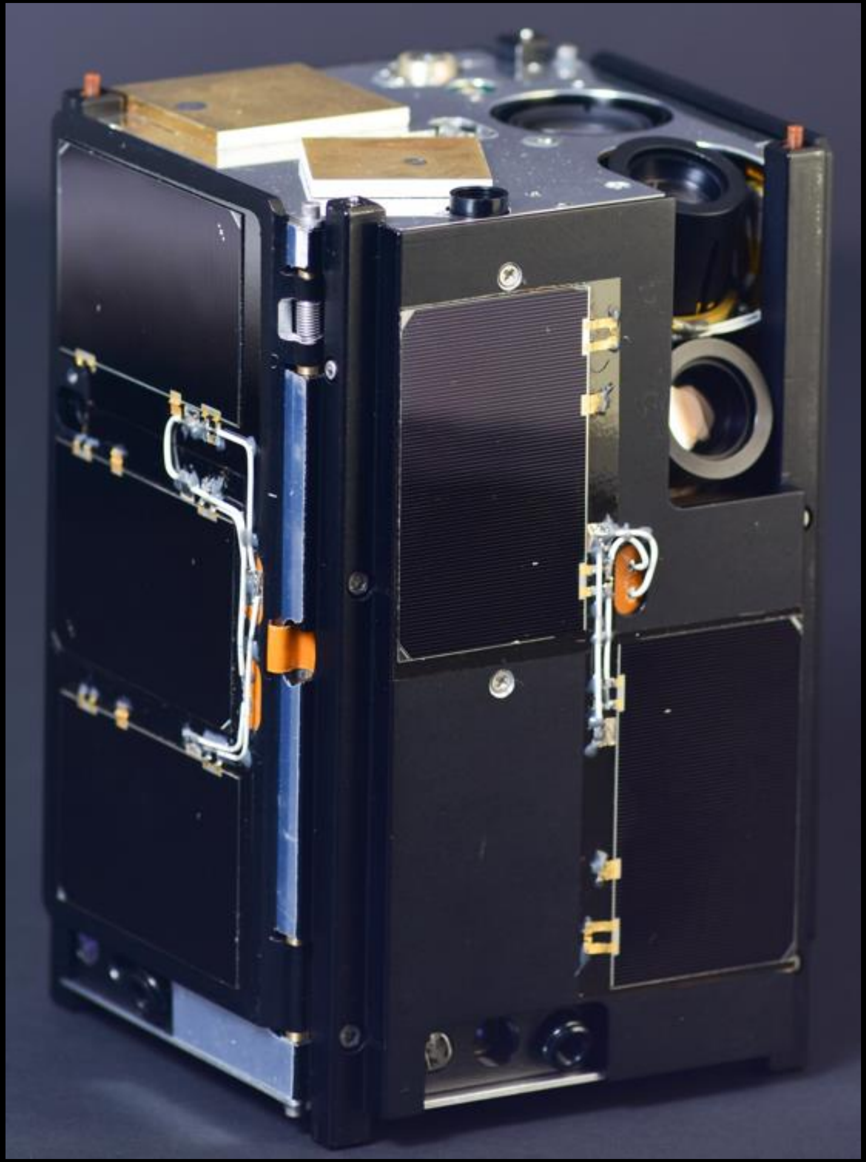
...*Depends on design, follow the example}:*
...re modes below might result in battery explosion with the possibility of ...generation. However, in the unlikely event that a battery cell does ...pture, the small size, mass, and potential energy, of these small ...h that while the spacecraft could be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

...mitigations are specific to the Launch Vehicle / ISS / other form of ...must change accordingly:

...*igations described for each failure mode, each project will be different}*

...ttery Internal short circuit.
...Example} Complete proto-qualification and environmental acceptance ...ry name}. The acceptance tests are shock, vibration, thermal cycling, ...ests followed by maximum system rate-limited charge and discharge to ...internal short circuit sensitivity exists.
...*ts required for realized failure:* Environmental testing **AND** functional ...rge 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

Technical Manual

- Radiation
- Space Printed Circuit Board
- Drawing
- Electrostatic Discharge
- Workmanship

Document Templates

1.0 Project Management Plan
2.0 Systems Eng. Plan
3.0 Safety & Mission Assurance Plan
4.0 Science & Tech
5.0 Payload Sys
6.0 Spacecraft
7.0 Concept of Ops
8.0 Systems I&T
9.0 Ground Sys

Cycle Review Guides

- Internal Review
  - Drawings
  - Analysis
  - Traceability
  - Risks
- Panel Review
  - SRR
  - MCR
  - PDR
  - CDR
  - FRR

Integration Document Templates

- ICD Verification
- V&V
- Standard/Reference Safety
- For ISS PSRP Doc

Certificate of Compliance

Certificate of Flight Readiness

Delivery & Launch!

Published Document
In Progress Document

nasa.gov/smallspacecraft