National Aeronautics and
Space Administration

Quick Start Guide to Payload Design

Sep 27, 2024

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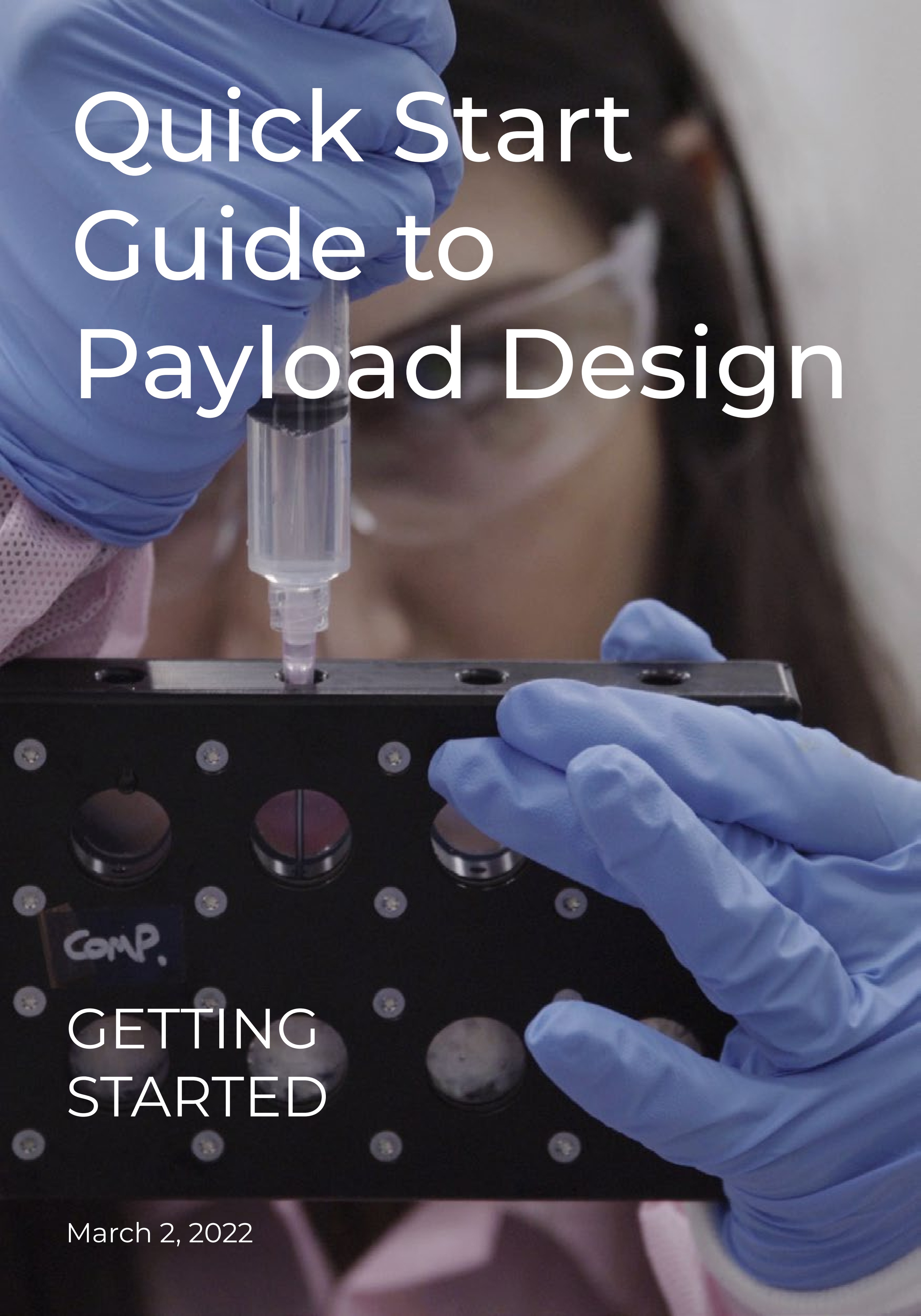

GETTING STARTED

March 2, 2022

Getting Started

From Here → To There

It can be a long journey from having a great idea for a science investigation in space to seeing it operated on the International Space Station and receiving the results. This Quick Start Guide provides a high-level road map to help you, the Payload Developer, know who you'll encounter, understand what milestones are ahead, and give you an idea of the path you'll travel on that journey. In addition, this Guide provides a foundation to assist you in designing your payload within NASA's constraints using best practices and lessons learned from more than 20 years of payload development experience.

Are you just getting started and need inside information for your discipline on conducting experiments on the station? The ISS Researcher's Guide series provides links to 17 free downloadable booklets that serve as introductions for potential users of the station platform. Each guide provides discipline-specific context for conducting station research, including available hardware and laboratory environments, to assist researchers in their efforts to connect to research opportunities. Since each payload requires both a sponsor and funding, these Guides provide an overview of the most applicable pathways to connect to these resources.

Once you've determined how to plug into one of the available methods to connect your payload to the International Space Station activities, you'll work with your Sponsor to create the contracts required to secure funding and begin integration of your payload into the station program.

As projects are selected and approved, the

The ISS Researcher's Guides are available at the following web address:

https://www.nasa.gov/station-researchers-guides/

integration process begins and you will be assigned a Payload Integration Manager or PIM. The PIM is considered your primary point of contact or interface with the ISS Program, and will be your guide on your payload's journey to and from the Space Station. In a nutshell, the PIM's job is to help ensure the safe launch, integration, operation, and data return for your payload. The PIM will build an integration schedule to keep you on track as you approach key milestones and reviews together. The PIM will also facilitate PIM Tag-Ups that will include you and the integration team to keep everyone in sync along the way. In addition, PIM-led orientation meetings provide more in-depth explanations of the topics provided in this Guide.

Speaking of the PIM, during your payload development journey, you will encounter acronyms - lots of acronyms (after all, who wants to say Payload Integration Manager when PIM is more efficient?). NASA is full of acronyms because each piece of equipment, each formal meeting, each process and organization and role has its own long name that can contribute to cumbersome conversations without the use of their short names. Don't worry – we have links for that! (See our FAQs.) If an acronym (or conversation full of them) is not clear to you, be sure and ask for clarification.

Entering the integration phase brings with it a decision of consequential importance: what to name your payload/investigation. Typically, a working name will be used during the initial phases of development, but once your payload is added to the Integrated Payload List (IPL) and a Payload Integration Agreement (PIA) is developed and signed, it can be very difficult to change the name. So think carefully about your payload name, including any resulting acronym. Note that many payloads have a long, descriptive name and a short name by which it is known in conversation for meetings and during on-orbit operations. Discuss your ideas with your assigned PIM, who can make sure your chosen name is not a duplicate or too similar to another payload or investigation.

Other topics covered in this Guide include information on Payload Engineering and Payload Safety. These sections, along with the FAQs, provide an introduction designed to get you started. Additional detailed information will be provided as you need it by your PIM and the appropriate team member.

In these sections, you'll see guideposts labeled as Tips ( ) or SOS (!). A Tip provides helpful information that can make your planning and design progress more smoothly. An SOS indicates what to do if you run into problems or concerns and need help.

Also be sure to check out the FAQs for additional information on how to interact with NASA's payload integration processes successfully.

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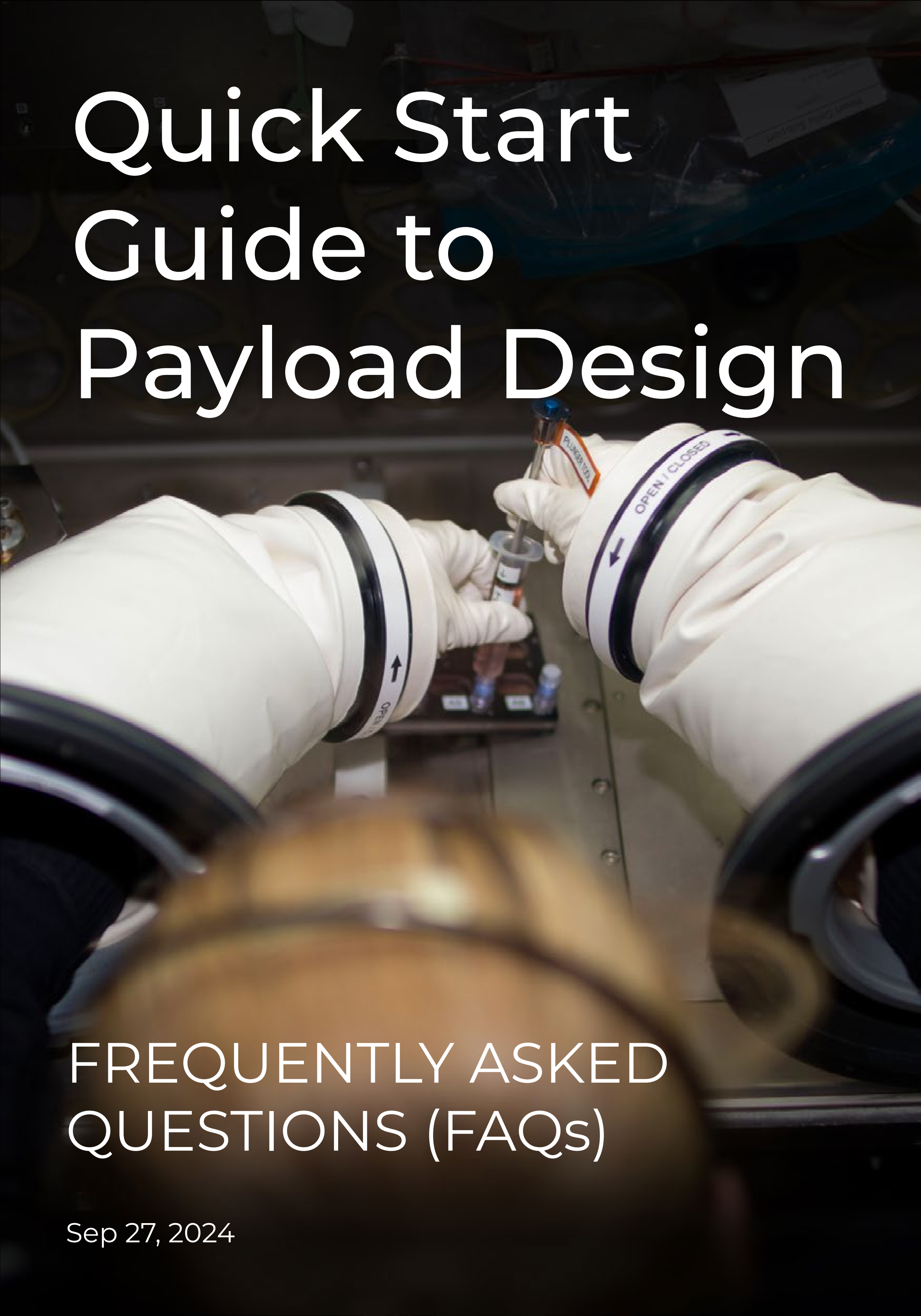


FREQUENTLY ASKED QUESTIONS (FAQs)

Sep 27, 2024

Frequently Asked Questions (FAQs)

PEOPLE — WHO WILL HELP?

Q: Who will I encounter during the payload development process (names, affiliations, roles, responsibilities, contact info)?

A: An integration team of individuals from relevant offices and departments is assigned to support your project for its duration, based on the specific needs of your payload. You will meet some of these team members at your project's Kickoff meeting. Contact lists with names, titles, affiliations, roles, phone numbers, and email addresses are typically provided. Note: Your primary contact will be your assigned Payload Integration Manager (PIM), who will be able to connect you with the rest of the team (more about the PIM below).

Q: When will I interact with these individuals and/or teams?

A: Taking a payload or experiment from concept to flight will take time, and you will go through a methodical process that evolves as payload development matures. At different junctures of this integration flow, you will work with different individuals with various areas of expertise.

Q: Where can I find a directory of everyone?

A: There are a number of locations for finding contact information:

- Your PIM
- Roster files made available at your Kickoff meeting
- PIM Roadshow materials
- ORBIT database, (see 'List of Contacts' file for your payload)
- NASA Global Address Directory

Your PIM can show you how to access each of these resources.

Q: Who are the key personnel?

A: Your most important and frequent contact is the Payload Integration Manager (PIM), who will guide you through the integration process, answer questions, make referrals, and enlist additional support, if needed. You are encouraged to go to your PIM for assistance first. He or she is your central liaison to NASA. PIMs typically work for Boeing or GC Controls.

The PIM's role is:

- To act as your point of contact and guide on this journey.
- To assist you to ensure the safe launch, integration, operation, and data return for your payload.
- To build an integration schedule to help keep your project on track as your project approaches key milestones and reviews.
- To facilitate regular PIM Tag-Ups that include you and the integration team to routinely keep all project components, personnel, milestones, and issues in sync.

You may also occasionally interact with a Research Portfolio Manager (RPM), a civil servant from the ISS Research Integration Office (Code OZ at NASA/Johnson Space Center) who supports the sponsor and NASA's ISS Research Integration Office in collaboration with the PIM.

Q: What if my PIM is not available when needed?

A: Often a backup PIM is assigned to whom you can reach out. Also, the manager or lead of the PIM team can be contacted for assistance.

Q: What will I need help doing during the process vs what ought I expect to accomplish independently?

A: Some payload developers or implementation partners might feel well-equipped to facilitate certain aspects of their project development on their own; however, there are specific areas within the integration and operations process that require NASA support. You will be advised when these items come up, and subsequent NASA guidance will help to ensure the safe launch, integration, operation, and data return for your payload.

Q: What if things aren't working out with someone?

A: If an issue arises that is inhibiting your progress and does not involve your PIM, have a conversation with the PIM about your concerns.

PROCESS — WHAT SHOULD I EXPECT?

Q: How does the integration process work?

A: The ISS Program uses an orderly process for executing the end-to-end activities required to integrate station payloads. This structure provides a process flow tailorable to the specific needs and maturity of each payload. The process covers the entire life-cycle, from the point of receiving funding to the return of data results from experiment operation in orbit. Integration activities ensure that the information exchange between you as the Payload Developer (PD) and the Program are timely and that they support integration and flight readiness milestones. Throughout, the process focuses on early identification of risk and risk mitigation. Consider integration to be an orderly process of specific phases of activity all aimed toward launching your payload to ISS, have it operate on the station, and return results back to you.

Q: What kind and amount of paperwork should I anticipate?

A: Your PIM will explain what the paperwork expectations are for data submittals, other deliverables, meeting attendance, and more. You will be guided along the way, and there are resources and people to support you in providing required documentation, data input, etc.

As an example, the payload development process will typically include providing the following types of information:

- Payload hardware/science overviews, including science timelines, data requirements, and success criteria.
- Payload planning overview data.
- Hardware mass/dimension properties for manifesting.
- Safety/hazard information applicable to the payload.
- Hardware testing data/ISS interface verification data.
- Launch and return constraints data pertaining to turnover, scrubs, launch to activation timelines.
- Research planning data.
- Crew procedure information/training products, if needed.

Q: When will we be done and ready to fly?

A: Each experiment's development and integration is unique, but on average, getting onboard takes 6 months to 2 years.

Q: Where will I have to go?

A: While much of the development and integration work is handled online using NASA database tools, teleconferences, emails, etc., during the activity at any given time throughout the process, you may be required to attend meetings in person. Your PIM will inform you about when or where you might be required to be present to support.

Q: How much am I responsible for?

A: Your PIM will explain what the expectations are concerning any data inputs, deliverables, meeting attendance, and other information. You will be guided along the way and resources and people are available to support you.

Q: Throughout the schedule outlined for development of my payload, will there be any flexibility in deadlines, if needed?

A: The schedule can be flexible to a degree. Please address any issues or concerns about the schedule with your PIM, and he/she will work with you to set the most realistic schedule, including working to revise it as necessary as your experiment/hardware develops.

Q: Where can I obtain any ISS Program documents listing out requirements for development of new payloads; e.g. SSP 57000 - Pressurized Payloads Interface Requirements Document?

A: Most of the ISS Program's technical documents and publications are contained within the Electronic Document Management System (EDMS), an online repository housed within the NASA network. Once your payload development project is under way, you can capply for a NASA Domain Credential (NDC) account with NASA IT Personnel, and upon approval, you will be able to access the EDMS library and search and obtain technical documents. Your PIM can initiate the facilitation of this NDC access with you, as well as indicate which documents are pertinent to the data you will need.

Q: What kinds of meetings will I be expected to attend and how many are there?

A: The Development and Integration process is tailored to the particular investigation and the team developing and integrating the payload. Every payload/investigation must meet certain safety requirements and feasibility criteria. The integration team determines the number of meetings required for your particular payload, along with the schedule and meeting cadence, at the beginning of the integration process. As time progresses, the team may collectively determine what level of engagement is required until the payload is launched, executed, and returned (if applicable) to the Principal Investigator. However, the work will vary depending on payload complexity in order to help you gauge the amount or type of work will be involved.

Here are some examples of activity you can anticipate in conjunction with NASA:

- Kickoff
- PIM tag-ups throughout the integration phase
- Safety reviews
- Verification requirements/testing coordination
- Shipping/final packaging/mass verification of hardware prior to turnover

Q: Where can I find a list of NASA acronyms?

A: NASA maintains a database called Acronym Central at this link:
https://www9.jsc.nasa.gov/acronymcentral/scripts/index.cfm
(note: this web page is viewable once you are granted access to NASA's internal network)

In addition, the documentation or database tools you are provided usually will have acronyms spelled out or listed for reference. Your PIM also can answer acronym questions.

Q: Am I required to provide backup payload hardware as replacement for my original in case an accident occurs at launch or before?

A: Not in every case; there are plenty of payloads where the hardware flying is the only hardware that exists. Having a full replacement for your experiment could be very expensive. It is recommended, however, that if affordable, you should have some replacements for pieces that are most likely to fail so the hardware can be repaired if it goes down in the lab on the ground. Alternately, if the experiment has perishable components/samples, it is advisable to have back-ups of these elements in case the launch slips.

Q: What if I need resolution to an issue with the process?

A: Consult with your PIM, who is always your first line of communication.

TOOLS — WHAT TOOLS ARE AVAILABLE?

Q: What kinds of software and databases will I encounter?

A: Depending on the needs and requirements for info/data submittal, a range of online tools have been developed to help facilitate and share your info/data with NASA. For example, one of the most frequently used tools that captures much of your data inputs during the integration process is the ISS OZ Requirements Baselining and Integration Tool (ORBIT). ORBIT is a web-based software system intended to provide users, specifically International Space Station (ISS) payload developers, with a single-source location for input and communication of information required during the payload integration process for the purpose of launching, operating, and/or returning payloads on the ISS.

Additional online tools you might encounter address research planning, payload interface requirements, general planning, flights, as examples. Your PIM and other support personnel will guide you on which databases will serve your particular set of needs. Orientation and training are included.

Q: Do I have to use these databases? Even though the ORBIT online database is a comprehensive tool used for much of the integration process, it looks daunting. Will there be anyone to assist me in learning it, using it, etc.?

A: These tools are the go-to location for all the support organizations you rely on to fly your payload, so yes, their use is required. The tools were developed based on years of clients walking through the payload integration and operations processes with NASA support personnel and have been customized using essential client input to efficiently collect the most appropriate and accurate data applicable to your project. As always, crew and payload safety and experiment success remain prime objectives. If desired, you can request that the PIM assign a Payload Data Integrator (PDI), who will interact with the databases on your behalf. As the PD, you will still have to provide any data required/requested, but the PDI interacts directly with the tools to populate databases, etc.

Q: How do I learn enough to get up to speed?

A: Depending on which online application you are offered, you can access training classes, documentation, support personnel, user forums, payload data input personnel, helplines, and your PIM to help orient you. As an example, for ORBIT, there is a users' forum held monthly for explaining any software updates and answering questions. Ask your PIM how to receive notice of this particular forum and any other user support for online tools.

Q: Who will provide support, technical and otherwise?

A: Your assigned PIM will be the primary point of contact who provides you with support services and guidance throughout the duration of your project. A variety of additional personnel and subject matter experts are available along the way for assistance with specific areas of activity.

Q: Will I be able to use NASA's online database tools for integration in either a Windows or Mac environment? What about a mobile platform; are there apps available?

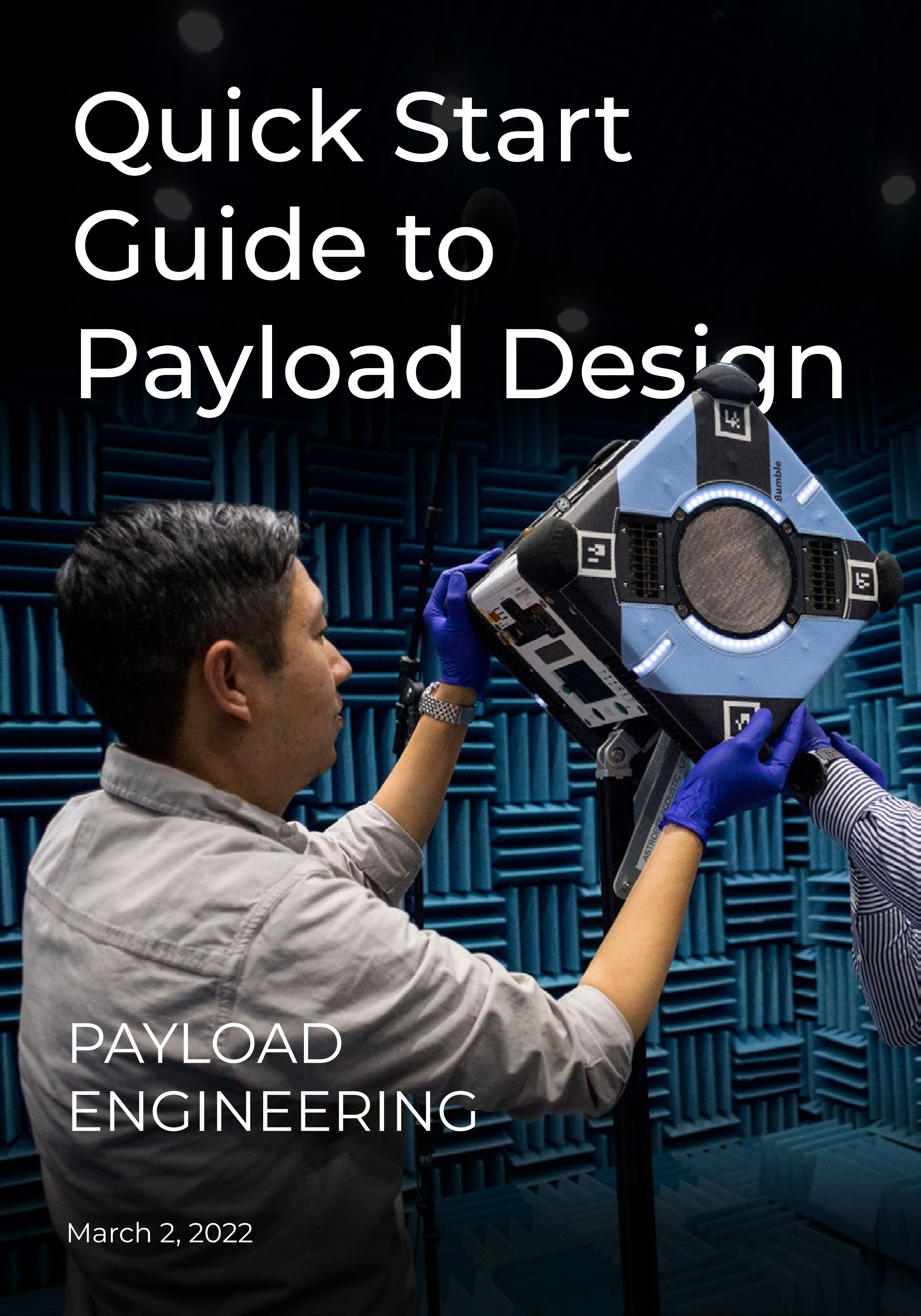
A: NASA's online database tools functions in either Windows or Macintosh operating systems. Regarding use of mobile platforms and corresponding apps, mobile devices are not fully approved for use at this time, so computer workstations are the primary systems for interacting with integration online database tools. For further information, please consult with the IT technical support personnel made available to your team.

Q: Will I need to apply for and receive access to a NASA IT account so I can use NASA's online database tools for integration?

A: Yes. NASA's online database tools are accessible via a NASA IT account. Typically, an RSA SecurID token is issued to you for purpose of logon. Your PIM will help guide you through the steps to apply for the account and token.

Q: Where can I suggest improvements?

A: You can always provide suggestions for process or tool improvements to your PIM, who will determine how to approach or share with a subject matter expert to consider.



Quick Start Guide to Payload Design

PAYLOAD ENGINEERING

March 2, 2022

Payload Engineering

Building a better mousetrap

While engineering designs vary as widely as payload purposes, they are all subject to the physical, chemical, and mathematical principles understood by NASA discipline experts who support the ISS Program. ISS hardware, software, and operations are organized functionally into systems and sub-systems with leading experts that provide support in each of these areas.

NASA's Pressurized Payloads Interface Requirements Document (SSP 57000) is the principle source for interface design requirements for all NASA-developed payloads operating in the pressurized volume of the ISS. Payload developers must verify the applicable requirements in this document to ensure the safety of the ISS crew, transport vehicles, on-orbit ISS systems hardware, and neighboring payloads. This document also provides design guidance that ensures the basic operation of the payload and affects the payload's mission success. It is your responsibility as payload developer (PD) to design in accordance with the design guidance.

NASA is equipped with laboratories and other facilities designed to support payload projects throughout their lifecycles. Although each of these experts fulfills an important role within the ISS Program — such as ensuring safety or providing necessities for the crew — all of them have something to offer you as a (PD) to help you achieve payload mission success.

The following content draws from the expertise and experience of individuals across the organizations mentioned above. The sections within this chapter highlight specific considerations that should concern you while completing the engineering design, development, and verification activities associated with your payloads.

> You are encouraged to coordinate closely with your Payload Integration Manager (PIM) and reach out to experts in areas relevant to your payload.

CONSIDERATIONS FOR PAYLOAD DESIGN

This section describes several aspects of space flight that you will need to take into account during the payload development process.

Keep in mind that payloads that use less of the station's limited resources are more easily accommodated. Keeping resource usage to only what is absolutely required and finding ways of reducing the use of resources improves a payload's opportunities for mission success.

Crew

Pressurized payloads share the ISS environment with the crew, whether they are passive/autonomous (not requiring crew time) or active (requiring crew time). ISS engineering experts are available to assist with the design approach and verification process to prepare the payload for crew interaction. Your PIM will conduct a payload Kickoff meeting where these requirements are introduced. The PIM is the liaison between you and various ISS experts.

Consider the number of crew absolutely required to complete your payload operations.

Thermal

The ISS offers payloads different types of thermal control: active, passive, and conditioned stowage.

The **Active Thermal Control System (ATCS)** is an internal system (inside the ISS) that uses a closed-loop (series of tubes) that circulates chilled water and pulls excess heat from racks and payloads. In this system, there are two temperatures available: a 4°C Low Temperature Loop (LTL) and a 17°C Moderate Temperature Loop (MTL).

The **Passive Thermal Control System (PTCS)** is also an internal system that removes heat using forced cabin airflow across the payload.

When designing your payload, consider the thermal requirements and what would be ideal: ATCS or the PTCS.

Conditioned Stowage provides for the specific temperature needs for scientific samples and other temperature-sensitive payload items. This resource consists of several active devices, such as freezers, refrigerators, and incubators as well as passive assets like Coldbags and Ice Bricks. These options are available on ISS, plus during launch and return. Standard conditioned stowage temperatures are -32°C and +4°C. All other temperatures are considered a unique re- quest.

Conditioned stowage is one of the most limited resources on ISS. To ensure that your payload is accommodated for conditioned stowage, keep sample dimensions as small as possible.

Electrical

The ISS Electrical Power Distribution and Control (EPDC) system provides power to the ISS and payloads. Your PIM will discuss its intricacies during your Kickoff meeting and throughout the development process and will facilitate interactions with the Electromagnetic Effects (EME) and the Electrical Power System (EPS) Teams. The EME Team provides Power Supply and EMI Filter design guidance for compatibility with the ISS system and other payloads. The Electrical Power System (EPS) Team provides guidance on power interface requirements.

Engaging the help of the EME team early and often is an important practice to ensure success in electrical design. The EME team can help you understand the EPDC requirements and offer proven methods to meet them in addition to providing test facilities equipped to support electrical and EMI testing.

When designing your payload, take into consideration the following design factors:

Power Interface Design

Two-fault tolerant controls and verifications are required to ensure crew safety through the following approaches:

Redundant or Designed for Minimum Risk (DFMR) Bonding of all crew accessible surfaces (including cables) that can be energized after a failure or electrical fault (i.e., test for a minimum of class H bond <0.1 Ohm or use of double insulation).

Electrical isolation between primary power and chassis and secondary power.

EME Team can provide support and guidance on design and verification of all classes of bonding required for your payload.

Power Quality Testing

The EPS combines critical (ISS core systems) and non-critical loads (payloads) in the same power feed; therefore, additional systems-level requirements are in place to protect the system. It is important to involve the EME and EPS Teams early in the design of the payload.

Electromagnetic Compatibility (EMC) Design

When designing your payload, keep in mind that there are electromagnetic standards that must be met. Early communication with you PIM and the EME team will help lead to a successful design.

Designing for electromagnetic compatibility up front will reap dividends later in the process by reducing costs and schedule impacts from later design changes due to EMI issues.

> Review this paper, Electromagnetic Compatibility Considerations for International Space Station Payload Developers, for specific guidance.

Some PDs prefer to buy Commercial-Off-The Shelf (COTS) products for their payloads. If a COTS product is being considered, EME experts can help based on experience with previous payloads.

Electromagnetic Interference (EMI) Testing

EMI testing occurs near the end of the payload development lifecycle. This testing is a requirement for flight.

> Be sure to account for EMI early in your payload design to ensure it will pass testing and move forward to flight.

If stated in the Payload Integration Agreement (PIA), NASA can provide testing services. Otherwise, testing can be performed at a commercial facility. Talk to your PIM about testing options.

Electrical Power Distribution and Control (EPDC) Design

In coordination with your PIM, the EME, Safety, and EPS Teams will provide assistance with initial requirements for payload development and design. It is important to engage with these teams early in the design phase.

In a microgravity environment, there is no convective cooling: objects and structures using electricity that heat up on the ground likely will get much hotter on orbit.

Example: Laptop chargers are familiar COTS products that tend to heat up while charging during ground operations. While on-orbit, they can heat up to temperatures that exceed touch temperatures, potentially endangering the crew. Additional fans provide a solution.

The ISS electrical system has a 32-volt shock limit, which is lower than what most payload developers expect.

> By engaging with the EME Team early and not waiting until the Phase I safety review, cost and schedule impacts can be reduced or eliminated.

Example: If a PD up-converts from the 28 *volts provided by the ISS, the PD could unwittingly introduce a situation requiring a two-fault tolerance. If this requirement is not taken into account early on, the payload's electrical system will have to be modified.*

Also consider the materials used in the electrical system. Polyvinyl Chloride (PVC) insulation is not permitted for use on the ISS based on its flammability risk.

> Teflon-coated wiring is optimal.

Battery Design and Testing

Your PIM will assist in connecting you with the Safety Team for assistance with the battery selection process. It is important to understand the full implications of what is required to implement a design using battery power and the time required to do so.

> ! NASA can build batteries, or COTS batteries can be used after testing.

All batteries, regardless of type, have potential risks:

- Lithium ion (Li-ion) produce a lot energy by operating a higher capacity, but unique circuitry that leads to the potential of thermal runaway. Thermal runaway propagation-resistant batteries are required if the capacity is over 80 watt-hours. With Li- ion batteries, rigorous safety hazard mitigation and safety plan documentation are requirements.
- Alkaline and electrolyte batteries can leak and have venting issues.
- Nickel cadmium batteries are easier to work with and do not have thermal runaway issues. The drawback is that they may not be powerful enough for some applications.

Capacitor Component Testing/Screening

When using capacitors, it is important to understand the hazards associated with wet electrolytic capacitors — particularly aluminum electrolytic and wet tantalum types — since they present the possibility for toxic material to reach the crew. Engage the Safety team early in the design phase.

> Avoid aluminum electrolytic capacitors. Electrolytes tend to react with the dielectric material, creating a short. When activated after being off for some time, the capacitor may fail quickly. Similarly, tantalum capacitors can have unexpected failure modes. Treating them for moisture problems via sealing them or baking them out tends to help avoid shorts. Ask your PIM for recommendations on appropriate capacitors for your payload.

EEE Parts and Ionizing Radiation

The EEE part selection and the effects of ionizing radiation are closely monitored for ISS hardware.

> Select parts from known manufacturers with an emphasis on quality and reliability.

> ! Your PIM can help you navigate interactions with the experts on what EEE parts may work for your payload.

For COTS parts, it is good practice to ask about qualification testing and their current Failure-in-Time (FIT) rate when considering manufactures.

> A FIT rate of approximately 20 is a good rule of thumb when selecting parts.

Ionizing radiation for internal payloads is a recognized but minor concern. If your payload is sensitive to radiation, the options for parts should include redundancy and proton testing.

Consider performing a "burn- in" on the payload or a particular electronics assembly by simply letting it run, perhaps for a few weeks. This is a cost-effective method to identify longevity problems in the design.

STRUCTURES AND MECHANISMS

When developing your payload, it is important to engage NASA's Structures and Mechanisms (S&M) experts early in the design phase. These experts will help you deter- mine how your payload and structural loads will play a factor in moving forward with the ISS Safety and Review Panel (ISRP). When designing your payload, fault tolerance requirements and options should be understood to ensure the hardware is created with enough flexibility to operate on the ISS.

Work with the S&M experts prior to entering the safety review process to determine whether your payload would be designated as 'Safety Critical.'

Structural Loads

Structural loads may arise from mechanical, pressure-related, vibration-related, inertial, and thermal forces applied to structural elements. All payloads must limit their disrupting effects on the microgravity environment. Keep the following information in mind during the design phase of your payload:

The three categories of disruption are Quasi-Steady, Vibratory, and Transient.

Quasi-Steady Launch and Landing Loads

Quasi-Steady refers the state that the vehicle experiences when traveling through the atmosphere. In this state, the turbulence experienced occurs slowly and quickly reaches equilibrium therefore creating a seemingly steady state. Acceleration loads need to be considered for your payload.

Payloads in their launch, on-orbit, or landing configurations must provide positive margins of safety when exposed to accelerations.

Vibratory Loads

Your payload should be designed to withstand vibrational loads. If your payload is vibration-sensitive, the ISRP will recommend Protoflight Random Vibration Hardmount Testing.

Vibration testing and analysis are recommended to verify the function of any payload that includes electronics, close tolerance moving devices, or optical equipment.

Whenever possible, leave tolerances loose to enable on-orbit operations, such as payload installation.

Structures can change shape compared to their ground measurements when in microgravity.

Fracture Vulnerability

All payload equipment is evaluated for potential breakage that could cause harm to the crew, ISS, or visiting vehicles.

Fracture control analysis should be performed concurrently with the stress analysis early in the development of the payload.

Primary structural elements may be classified as low-risk, non-Fracture Critical as long as the working stresses are low, use of proper materials, and satisfactory fatigue life are demonstrated.

To decrease the potential of payload fracture, consider the parts and materials used in the design. There should be no welds, castings, forgings, or additive manufacturing. Materials prone to shattering, such as glass, ceramics, etc., must be contained.

The containment of hazardous materials/fluids must be 2-fault tolerant (yielding three levels of containment). Otherwise, the primary container will become Fracture Critical.

Mechanisms

If your payload has mechanisms, addressing considerations early in the design process is crucial. Your PIM and S&M experts will help you through this process with the first step of developing a mechanical fault tolerance strategy.

Focus your efforts on incorporating mechanical redundancy wherever possible and determining whether to implement a Design for Minimum Risk (DFMR) strategy. (DFMR is a process that allows Safety Critical mechanisms to achieve fault tolerance through rigorous design, analysis, testing, and inspection practices rather than through true physical redundancy.)

Mechanical fault tolerance is always preferred, either in the form of like or unlike redundancy. Some examples of incorporating like mechanical fault tolerance include dual rotating surfaces for hinges and secondary sliding surfaces.

MATERIALS

The JSC Materials and Processes team consists of experts to assist you in the selection of materials for your payload. This team differentiates payloads into the Simple or Complex categories described below.

Payloads will need to meet the verification requirements set by the JSC Materials and Processes team. Contact your PIM for guidance.

Simple Payloads

Simple Payloads are those that have minimal ISS vehicle interfaces and little to no structural hardware (i.e. welded seams). Examples of a simple payload include container kits, syringe kits, consumable re-supply kits, and Commercial-Off-The-Shelf (COTS) hardware such as cameras, syringes, filters, sample container bags to name a few. The primary concerns for simple payloads are flammability and toxic off gassing.

COTS hardware can be accepted through the COTS certification process. Contact your PIM for assistance with this process.

Complex Payloads

Complex Payloads are those that do not meet the criteria of a Simple Payload. These primarily include structures and will need to comply with the Structures and Mechanisms requirements.

All materials used for Safety Critical structural components require certification as to their composition and properties.

Structural payloads should avoid using complex materials processes such as additive manufacturing, welding, brazing, structural adhesive bonding, forging, casting, and structural soldering in Safety Critical structural components.

Payload Guidance

For Complex Payloads, the Materials and Processes Technical Information System (MAPTIS) contains a collection of verified test data on standard design materials that will be crucial when designing your payload. MAPTIS provides letter rating on flammability, fluid compatibility, stress corrosion, toxic off gassing, and vacuum outgassing.

> MAPTIS experts are available when you request assistance through your PIM.

Materials Flammability

The flammability of materials is an important consideration when designing your payload. The basic requirement for flammability is that the materials be nonflammable. The materials that you are envisioning for your payload may be tested for acceptability.

> Something to keep in mind that some flammable materials can be accepted by configuration analysis, such as containment or low quantity.

> Standard flammability test data typically used for ground applications in air environments are not conservative enough for the oxygen-enriched ISS pressurized environment. Consult your PIM to determine the appropriate expert to assist in choosing your material.

Common nonflammable materials are listed below. Talk to your PIM about any specific material you want to use.

- Teflon (Tetrafluoroethylene (TFE), Fluorinated ethylene propylene (FEP), and Perfluoroalkoxy (PFA))
- Nomex (HT 9040 and some additional grades, but not all)
- Polycarbonates (Lexan, Macrolon), 1/8 inch or thicker
- Kapton and other polyimides
- Ultem
- Painted metal

Common flammable materials are listed below. These materials are not expressly prohibited and may be acceptable within the total payload configuration. Be sure to discuss any materials you want to use with you PIM and materials experts.

- Paper
- Polyethylene
- Polypropylene
- Acrylonitrile butadiene styrene (ABS)
- Nylon
- Hook-and-loop fasteners (such as VELCRO® or similar products)
- Polyvinyl Chloride (PVC)
- Polyethylene terephthalate (PET)
- Cotton
- Polyester
- Wool

> Complete lists of nonflammable and flammable materials are avail- able. Please contact your PIM to discuss with the material experts.

Off Gassing and Outgassing

When materials release gases into the environment, this is referred to as off gassing. Should toxic off gassing occur on the ISS, it may create a toxic environment for the crew.

> Toxic off gassing is frequently confused with toxic hazard ratings. The toxic hazard rating pertains to fluids only and the hazard that would occur if the entire amount of fluid were released into the ISS cabin atmosphere.

There are times that “off gassing” and “outgassing” terms are frequently confused. Off gassing typically occurs inside the pressurized vehicle whereas outgassing occurs outside the vehicle in a vacuum.

> When navigating off gassing requirements, keep in mind that unmodified COTS hardware that contains less than 20 pounds (total mass) of polymeric materials need not be tested for off gassing, with some exclusions.

> Outgassing may result in contamination of the vehicle transporting your payload or the ISS. There is potential that your payload’s surface or near-by payloads could be contaminated. You can find an extensive list of outgassing data in MAPTIS.

Fluid Compatibility and Stress Corrosion

Your payload materials must be compatible with any fluids with which they come into contact.

> A few of the materials that are permitted to come into contact with the Internal Thermal Control System (ITCS) coolant loops include internal metallic materials made of stainless steel, materials with a nickel base, or titanium alloys. Aluminum alloys containing greater than 5 percent copper are not permitted.

Additional requirements to keep in mind with respect to materials and the ISS:
Payload materials that provide structural support need to meet stress and corrosion requirements.

Water-soluble volatile organic compounds are strictly controlled within the environment of the ISS. The release of methanol, ethanol, isopropyl alcohol, n-propyl alcohol, n-butyl alcohol, acetone, ethylene glycol, and propylene glycol are restricted in the ISS pressurized elements because the water recycling system can remove only limited quantities of these com- pounds from water condensate.

RADIO FREQUENCY AND SPECTRUM MANAGEMENT

If you are planning using radio frequencies in your payload design, it is important to engage the spectrum management team early. Your PIM will assist in helping you reach the experts.

> ! Your PIM will guide you through the licensing processes (should your payload require it). They may seem a bit complex but they are necessary to minimize potential technical anomalies, interventions, and risks to mission success.

INFORMATION TECHNOLOGY FOR YOUR PAYLOAD

There are several options for telemetry, Health & Status monitoring, and commanding for your payload from the ground. Your PIM will connect you to the experts that will help determine which options will work best for your payload.

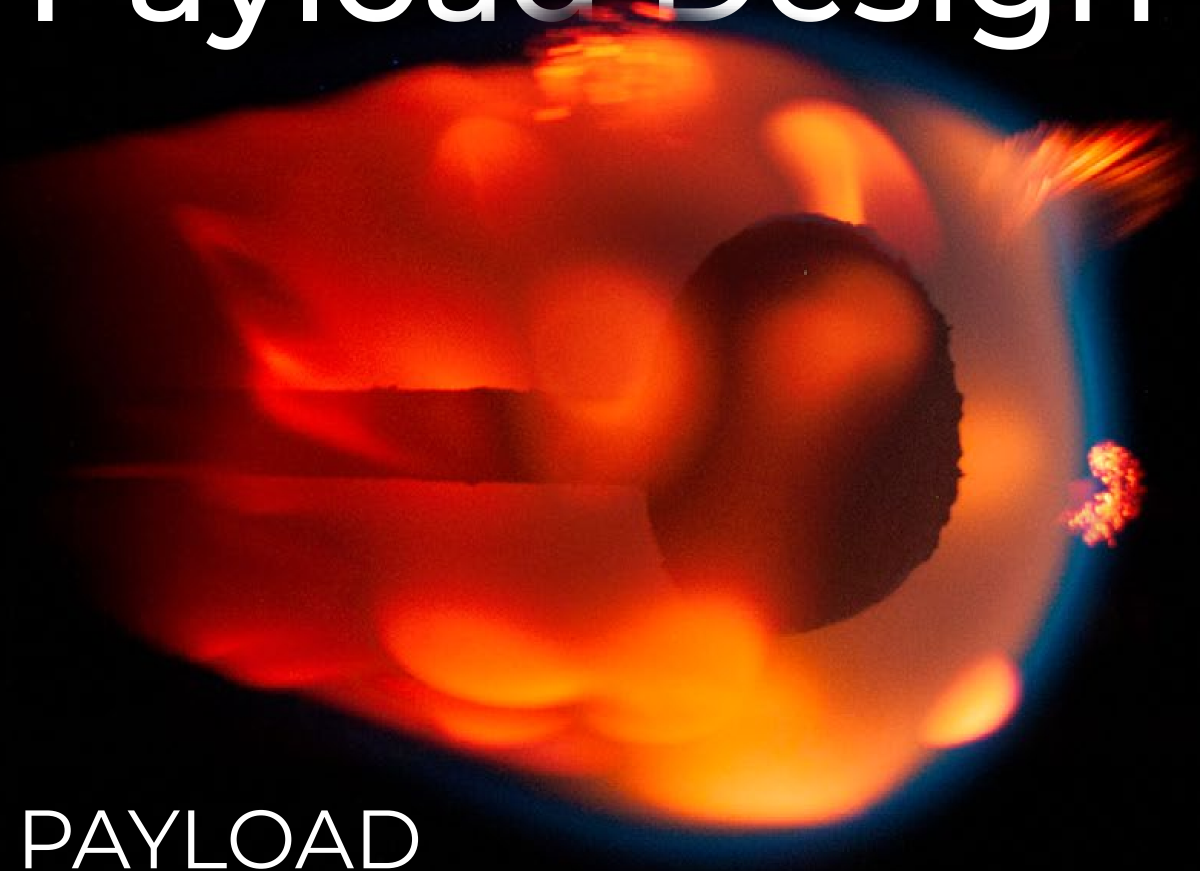
> Separate your ISS interfaces from your science software as much as possible to facilitate pre-approvals with your software integration.

REQUIREMENTS VERIFICATION

Success with requirements verification can be achieved by following the best practices throughout your payload's lifecycle:
Stay in close contact with the PIM
Openly communicate preliminary pay- load design data
Engage NASA experts early and often
Keep stakeholders apprised of payload design changes

> ! You have access to support throughout the entire process of building your payload. Working together with experts will facilitate your success in meeting your scientific objectives while verifying that the crew and the ISS remain safe.

Quick Start Guide to Payload Design



PAYLOAD SAFETY OVERVIEW

March 2, 2022

Payload Safety Overview

Don't try this at home

Safety Reviews are required for all spaceflight hardware going to the ISS, including payload, science, equipment and commercial. These reviews span all aspects of the payload's development and performance. Reviews consider the design, operations, functional capabilities of the payload's flight hardware and the associated ground support equipment a payload needs throughout its entire lifecycle.

There are four levels, or phases, of Safety Reviews aligned to the design maturity of the payload.

The payload will need to meet safety requirements associated with each stage.

- Phase 0: Safety Technical Interchange Meeting (TIM)
- Phase I: Safety Review for payload's Preliminary Design
- Phase II: Safety Review for payload's Critical Design
- Phase III: Safety Review for payload's Final Acceptance

Documentation of a payload's potential hazards and controls matures over the course of these reviews, ending with verifications for all controls. The Safety Review phases act as milestones and gates for payloads along the path to ISS.

The ISS Safety Team provides safety oversight, guidance and review during the phased Safety Review process. Much of the team's time is dedicated to ensuring successful and active safety engagement as part of the payload integration process. They work with all payload teams, from first time Payload Developers (PDs) to repeat PDs.

> Your Payload Integration Manager (PIM) will connect you with personnel to help shepherd you through the multi-staged safety process.

At the payload Kickoff meeting, you are introduced to the Safety Review Process and are provided preliminary information on important safety concepts such as the meaning of a payload being designated "Safety Critical." The Kickoff's safety presentation provides insight into how safety requirements, issues and concerns are managed throughout the payload development and integration process.

You will receive a large amount of information at the Kickoff, including an explanation of the Safety Process. However, it is not necessary to understand fully the entire process and elements at this early stage. PIMs and safety personnel will guide you on how best to prepare for each Safety Review Phase and associated milestone review meeting.

> Your PIM can provide clarification regarding safety requirements and receive recommendations for avenues to get help. If anything seems unclear, ask! In addition, specific requirements vary for individual payloads. Understanding fundamental safety requirements up front will help you lay a solid foundation for upcoming ISS Safety Review Panel (ISRP) Reviews.

During the Kickoff meeting, be sure to take time to discuss safety with your team as well as with NASA experts who can provide valuable guidance up front, saving disappointing setbacks. This interaction is especially important if you are new to ISS or if you were PD for a different payload.

Note that the Safety Review Process can be taxing, and you may require extra or more personalized and intensive guidance/assistance. Receiving assistance is especially important when approaching a formal Safety Phase Review to mitigate schedule risks and stay on track for mission success.

Payloads can have many safety requirements, and information overload can result in inefficient and incomplete data for a phase review.

To keep safety in perspective, two Space Station Program (SSP) documents are key:

SSP 30599 Safety Review Process: Contains process description and data requirements

SSP 51721 ISS Safety Requirements: Contains top-level NASA technical requirements for experiment and non-experiment hardware.

> Your PIM can provide clarification on important aspects of safety requirements documents as they relate to your payload.

THE SAFETY REVIEW PROCESS

The Safety Review Process is a joint responsibility of the PD, NASA ISRP, and visiting vehicle (VV) owners. ISS Program and VV owners manage requirements. The ISRP and technical support evaluate payload compliance throughout the phased process. You likely will interact mostly with the ISRP.

> To succeed at Safety Reviews, begin early to establish safety as an integral part of hardware design/development process. A best practice is to assess payload hardware for all potential hazards throughout all mission phases and maintain good documentation on configurations, materials and parts. These documents may be key evidence for meeting a safety requirement.

> ***Make sure safety is part of your design.***

Expectations grow at each phased Safety Review:

- Phase 0 TIM: seeks images, diagrams and other informal documentation to inform the ISRP of payload objectives and concepts for design and operations and to enable provide recommendations.

- Phase I: This phase corresponds to the Preliminary Design Review and delves deeper into evolving payload needs and hazards. Initial Hazard Reports, which define causes and controls, are due. Preliminary verification methods may be presented, but full development is not yet required.

- Phase II: This phase corresponds to the Critical Design Review. Design iterates to ~60 percent completion, and final planned verification methods are identified.

  Note: Payloads that undergo major change or have incomplete products entering advanced safety reviews may need to return to earlier phases.

- Phase III: With the design finalized, the status of verifications that were successfully performed/completed are reported. All analysis is completed with only nominal open work remaining; e.g., late inspections, late filling operations, etc. Special TIMs can be held to address any problems or necessary changes to previously agreed-upon designs or hazard control/verification approaches.

> The types of reviews and the relative depth of detail required depend on payload hardware complexity, technical maturity, and hazard potential and may be modified by the ISRP chairperson in conjunction with you as PD. Additionally, the Safety Review Process may be tailored as appropriate and agreed to between the PD and ISRP. By the end of the process, there may be some residual safety risk the ISS Program could consider to help you achieve the requested science objectives.

As part of the ISS Safety Review Process, payloads are required to demonstrate compliance with applicable ISS requirements. Assigned ISRP members and technical support staff perform independent reviews of each payload's safety assessments and provide input to the ISRP.

> Many PDs think they can complete all the safety documentation to the satisfaction of the ISRP singlehandedly. However, experienced safety engineers are able to more easily and thoroughly identify potential hazards and develop controls that instill confidence among safety representatives. Best practice suggests that including a safety expert on your team to help you through these phases is optimal. This additional support allows you to focus your attention on managing the process, consulting with the Safety Payload Engineer (SPE) and Client Safety Engineer (CSE) (described in the next section) and engaging other members of your team as needed.

> Even if you do not have a dedicated safety engineer on your team, it is recommended that you designate an individual as an ISS representative (such as a systems engineer or safety expert) as a liaison who attends the formal Safety Reviews for each phase in person. Other experts should be on call during these meetings to answer questions in real-time.

Ultimately, the purpose of the Safety Review Process is to ensure that payloads do not compromise the safety and health of the crew nor the capabilities of the ISS.

RESOURCES FOR SAFETY ADVICE

The Safety Payload Engineer (SPE)

assigned to each payload executes the Safety Review process and helps assure payload safety on behalf of the ISRP. While their primary duty is independent safety review and evaluation of the PD-provided safety analysis, they are committed to helping the payload succeed.

! The SPE is your primary safety resource and helps communicate safety expectations and their intent so you can design hardware/software to an acceptable level of risk to the crew and vehicle. More generally, the SPE will advise you on reaching and passing each of the Safety Review gates. Like the PIM, the SPE can leverage the help of various discipline experts who can take on issues and be instrumental in helping you succeed while preserving safety.

While these experts are available to assist you through the process, you are responsible for completing the safety documentation. You have the most knowledge about and are ultimately responsible for the payload and related documents.

! For some PDs, an additional level of support may also be available. The Client Safety Engineer (CSE) is a senior SPE authorized to provide additional tailored services to PDs in safety analysis and safety product development. The CSE serves independently from the SPE during ISRP reviews. CSEs are assigned in response to authorization/agreement from the ISS Program.

For integrated help with a multi-discipline challenge, you can work with the assigned SPE and request informal working group meetings prior to phased Safety Reviews to receive support resolving an issue. Making use of these groups is an excellent way to engage expertise within NASA. Experts can assist you by providing their understanding of any technical safety constraints that could affect a project.

! Working group experts can suggest potential means to control hazards based on previously successful implementation approaches. They can help guide you through the safety process and steer your team to develop practical hardware designs and proven methods of operation, avoiding payload characteristics and thresholds that necessitate additional tests, controls, redundancy, and complication.

Bottom line: Safety experts are here to help get your payload through the integration process while assuring your payload meets all safety requirements. Be sure to ask for safety contacts by discipline and reach out to them early in the project lifecycle.

HAZARD ANALYSES AND HAZARD REPORTS

Performing Hazard Analyses and preparing Hazard Reports (HRs) are two crucial tasks for any PD. Hazard Analyses involve systematically identifying hazards, causes, controls, and associated verification methods. Hazard Reports summarize how payload design and operations demonstrate compliance with requirements and prevent hazards.

Payload hardware and software are assessed for all potential hazards throughout all mission phases. If a hazard cannot be eliminated in design, the hazard will be controlled to mitigate the likelihood and the consequences of the risk to an acceptable level.

HRs can be time- consuming to complete, and the standard templates are written to address many different types of hardware and cases in one document. Your Hazard Report will never use all the possible cases, so you will need to delete all the irrelevant cases from your payload-specific HRs.

Since the HR template is a guideline intended to be tailored or customized to the needs of the specific payload, using HR templates without customizing them may raise concerns with the Safety Panel. Since each payload is unique, you will demonstrate to the panel you and your team understand the logic and approaches defined within the generic HR templates by modifying them as appropriate for your specific design and operations.

Controlling hazards by design

In the event it is impossible to remove a hazard completely, there are two options for controlling hazards during payload hardware development/ design. Each of these terms carries specific meanings and ramifications.

Design to Tolerate Failures indicates hazard controls are required.

Design for Minimum Risk requires only minimum supporting data and relies on design robustness.

Hazard severity classifications are defined as follows:

- Marginal - Any condition that may *(a)* cause damage to an ISS end item, the loss of which itself does not constitute a critical or catastrophic hazard, and/ or *(b)* an injury that does not require medical intervention from another crewmember nor consultation with a Flight Surgeon.

- Critical - Any condition that may cause *(a)* a non-disabling personnel injury or illness, *(b)* loss of a major ISS end item, *(c)* loss of redundancy (i.e., with only a single hazard control left) for on-orbit life sustaining function, or *(d)* loss of use of systems needed for essential logistics.

- Catastrophic - Any condition that may *(a)* cause a disabling or fatal personnel injury or illness, *(b)* loss of ISS, *(c)* loss of a crew-carrying vehicle, or *(d)* loss of a major ground facility.

For additional rationale, explanation and examples for each of these severity definitions, see *SSP 51721, ISS Safety Requirements*.

!

During a safety review, the ISRP may deem an item to be "Safety Critical." This designation indicates the item has a feature/aspect whose failure may result in a critical or catastrophic hazard. Safety experts are familiar with this designation and can provide guidance on typical hazard controls and verification methods to consider should the hardware contain Safety Critical elements.

THE SAFETY DATA PACKAGE

To meet ISS Program safety and interface requirements and guidelines, you must provide evidence that the payload meets the requirements described in program documents. You will demonstrate this evidence by providing information through the Safety Data Package (SDP), which ISRP technical reviewers evaluate. Updated and refined by the PD team throughout Safety Review Process, the SDP typically includes details for the payload, including hardware design information and the Concept of Operations. The ISRP expects you to provide an assessment of potential hazards, detailing your approach towards hazard control and associated verification activities.

The SDP defines hazards, hazard controls, and verification of hazard controls. The PD identifies all hazards and ensures that proper hazard controls have been developed and implemented for each hazard.

The SDP encompasses all safety-related information pertaining to a payload, including hazard identification, classification, issue(s) resolution, if applicable, and a record of all failures/anomalies with special emphasis on those pertaining to safety. Note: The ISRP has available supplemental information on assessing hardware for safety, performing a Hazard Analyses, and constructing an SDP. These resources can be provided by the assigned SPE/CSE.

> A good SDP follows a logical, structured format, using a common application with a reader-friendly platform; e.g., Word, PowerPoint, PDF, but not Excel. Charts, diagrams and other helpful elements are recommended for conveying information as clearly as possible to the ISRP.

Through developing the SDP and HRs, you communicate with NASA that your team has addressed safety throughout the development of the payload.

Upon completion of each phased Safety Review, the Safety Data Package with approved Hazard Reports serves as formal documentation that a payload has been evaluated for any potential safety risks and that the mitigation of these risks has been thoroughly considered and adequately controlled.

> The SDP should evolve with additional details added to it throughout the phased Safety Review process. See Figure 1, Schematic process flow for SDP.

By working together, you and the NASA safety representatives can find ways to mutually succeed in fulfilling the obligation to fly safely.

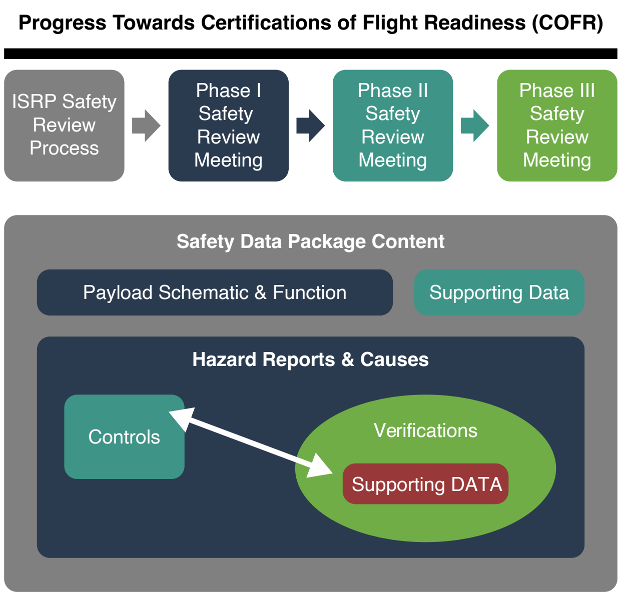
SAFETY REVIEW OVERVIEW – PHASE 0 EXAMPLE

The ISRP Chair is responsible for determining whether a payload is safe for flight based on the recommendations of panel members. The Chair's focus is on HRs and safety Non-Compliance Reports generated throughout the Safety Review. The Chair aims to approve the payload; however, it is your responsibility to provide enough rationale to enable them to do so.

> Although the Phase 0 TIM is not required for PD teams, having this standalone TIM early in the process is an excellent way for you and the ISRP to begin to reach a common understanding regarding the payload. For PD teams that opt for a Phase 0 TIM, this is the first opportunity for the ISRP Chair and PD team to meet.

Phase 0 is an opportunity to convey your research objectives as well as the design and operations concepts to the ISRP. Sketches

figure 1
A schematic process flow for the Safety Data Package.



and preliminary payload design information are acceptable at this phase; plan to include as much detail as possible.

> Since your field of expertise is likely very different from those of the panel members, articulate information thoroughly but in layperson-level terms. Since the ISRP is more familiar with the ISS and its capabilities, the ISRP may be able to advise you on design or operational concepts that will facilitate easier flight certification, and the panel is expected to convey their information in understandable language to you.

Approximately two weeks prior to the Phase 0 review, provide presentation material to the ISRP that covers:

- What you want to achieve with your experiment/ demonstration.
- What you think the hardware will do.
- How the payload could potentially cause harm to the crew, the ISS or VV if it did not operate correctly.
- What the sources of the hazards are in the payload.
- What data are available to support the details?
- What major components your payload will include, such as lasers, sources of high temperature, toxic chemicals, biological samples, etc.

This information helps the panel envision the payload in context.

> **!** When needed, you may be referred to specific technical experts to receive the best assistance/resources to resolve any anticipated safety challenges as you progress through the phases of the Safety Review Process.

> Unless the payload has flown routinely and no design or operational changes or anomalies that would require more extensive in-panel discussions have been identified since the previous flight, it is recommended that you attend all formal Safety Phase Reviews, either in person or remotely. Alternately, a safety representative on your PD Team can fulfill this function.

> **!** There are phase-level checklists (available from the SPE/CSE) to assist the PD to help clarify expectations of the SDP, accompanying Hazard Reports and other supporting data and to ensure all necessary technical data are included. It is your responsibility to ensure quality control of the data and to know how and when this information needs to be provided.

> When preparing presentation materials for Safety Reviews, your objective is to explain how the payload works and why the payload is safe to fly. You will provide evidence that you have consistently prioritized safety throughout the design process, providing grounds to establish the desired rapport of trust. Aim to make your presentation comprehensible and succinct and include an orientation overview and illustrations.

The SPE/CSE will clarify what to expect at these reviews. Have experts on call during the review to help answer technical questions during the meeting. Unanswered questions are tracked, and you will be asked to respond to them at the next review if an answer is unavailable when asked during the review meeting.

> The job of the ISRP is to ensure the safety of the crew and vehicles, so the ISRP Chair will ask questions and provide feedback in order to gather ample evidence to approve the payload to fly. A PD who listens carefully at reviews and takes the advice of the panel — particularly regarding appropriate hazard definitions and controls — will be able to successfully navigate the safety review process.

A successful review demonstrates that the PD is thorough, has thought things through, knows the payload design well, understands the requirements, and has anticipated questions and prepared answers.

PAYLOAD SAFETY SUMMARY

Over the years of ISS research utilization, safety representatives have learned many lessons to apply to future development activities. PDs who approach the review process with a willingness to invest time early, demonstrate a thorough understanding of potential safety hazards and who display a willingness to have candid discussions will reap rewards in the later Safety Review phases. As is the case with each phase of the payload project lifecycle, communication and collaboration are key.

> If a requirement is unclear, ask for clarification. When possible, ask to connect with experts or specialists and get their feedback before design decisions are made. If only preliminary information is available, identify it as such and share it. Test prototypes and always keep complete records on materials, parts, and configuration.

Since it is the responsibility of ISS safety personnel to ensure the safety of the crew and the vehicle, be prepared when safety personnel ask questions to highlight missing information. Incomplete data can lead to rework and reconvening of phase meetings.

> The Safety Review Process can be facilitated by having a dedicated safety expert on the PD team, by designating an ISS representative (such as the team's project systems engineer) to attend each phase review. These highly recommended best practices are worthwhile investments for every PD to consider as part of their budget/resource planning.

> ! Seasoned ISS safety personnel may be able to assist with simpler or more reliable design/operational considerations. At a minimum, they will be able to help identify areas to improve efficiency, including solutions for reducing paperwork while continuing to meet ISS safety requirements.

While it is always the goal to eliminate or fully control hazards whenever possible, safety personnel understand that in some cases, an easy design solution is neither practical nor possible. In such cases, understand that the ISRP will continue to work jointly with you on the problem and explore options to determine the best solution — together.

A payload may be able to receive an Exception/Waiver for a particular requirement if the safety community understands the hazard, the environment, and the controls to the point that the ISS Program is willing to accept the residual risk.

The goal of everyone involved is to fly the payload safely in space. The PIM is your main source of support through the integration process, and there are multiple people available — Research Portfolio Managers (RPMs), SPEs/CSEs, and ISRP representatives with a variety of discipline experts — to support achieving this goal and the desired mission success.

Quick Start Guide to Payload Design

ACRONYMS

Sep 27, 2022

Acronyms

What does that mean again?

ACRONYM	MEANING	REFERENCED IN GUIDE SECTION(S)
ABS	Acrylonitrile butadiene styrene	Payload Engineering
ATCS	Active Thermal Control System	Payload Engineering
C	Centigrade	Payload Engineering
CoFR	Certification of Flight Readiness	Payload Safety
COTS	Commercial-Off-The-Shelf	Payload Engineering
CSE	Client Payload Engineer	Payload Safety
DFMR	Redundant or Designed for Minimum Risk	Payload Engineering
EDMS	Electronic Document Management System	FAQs
EEE	Electrical, Electronic, and Electromechanical	Payload Engineering
EMC	Electromagnetic Compatibility	Payload Engineering
EMI	Electromagnetic Interference	Payload Engineering
EPDC	Electrical Power Distribution and Control	Payload Engineering
EPS	Electrical Power System	Payload Engineering
FAQs	Frequently Asked Questions	Getting Started / FAQs
FEP	Fluorinated ethylene propylene	Payload Engineering
FIT	Failure-in-Time	Payload Engineering
IPL	Integrated Payload List	Getting Started
ISRP	ISS Safety and Review Panel	Payload Engineering / Payload Safety
ISS	International Space Station	Getting Started / FAQs / Payload Engineering / Payload Safety
IT	Information Technology	FAQs

ITCS	Internal Thermal Control System	Payload Engineering
JSC	Johnson Space Center	Payload Engineering
Li-ion	Lithium ion	Payload Engineering
LTL	Low Temperature Loop	Payload Engineering
MAPTIS	Materials and Processes Technical Information System	Payload Engineering
MTL	Moderate Temperature Loop	Payload Engineering
NASA	National Aeronautics and Space Administration	Getting Started / FAQs / Payload Engineering / Payload Safety
NDC	NASA Domain Credential	FAQs
ORBIT	OZ Requirements Baselining and Integration Tool	FAQs
OZ	ISS Research Integration Office's Mail Code OZ at NASA/Johnson Space Center	FAQs
PD	Payload Developer	FAQs / Payload Engineering / Payload Safety
PDI	Payload Data Integrator	FAQs
PET	Polyethylene terephthalate	Payload Engineering
PFA	Perfluoroalkoxy	Payload Engineering
PIA	Payload Integration Agreement	Getting Started / Payload Engineering
PIM	Payload Integration Manager	Getting Started / FAQs / Payload Engineering / Payload Safety
PSE	Safety Payload Engineer	Payload Safety
PTCS	Passive Thermal Control System	Payload Engineering
PVC	Polyvinyl Chloride	Payload Engineering
RPM	Research Portfolio Manager	FAQs / Payload Safety
RSA SecurID	A two-factor authentication technology used to protect network resources	FAQs
S&M	Structures and Mechanisms	Payload Engineering
SDP	Safety Data Package	Payload Safety
SSP	Space Station Program	Payload Safety
TFE	Tetrafluoroethylene	Payload Engineering
TIM	Technical Interchange Meeting	Payload Safety
VV	Visiting vehicle	Payload Safety