

SAFETY PANEL RESOURCES

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ABSTRACT

The goal of this paper is to explore what resources are potentially available to safety panels and to provide some guidance on how to utilize those resources. While the examples used in this paper will concentrate on the Flight Equipment and Reliability Review Panel (FESRRP) and Extravehicular Activity (EVA) hardware that have come through that panel, as well as resources at Johnson Space Center, the paper will address how this applies to safety panels in general, and where possible cite examples for other safety panels.

1. Introduction

Due to the need for the independent evaluation of the safety of hardware and operations on manned spaceflight programs, these programs have established safety panels. The panels consist of representation from the various organizations within the program: the engineering directorate, the mission operations directorate (MOD), the life sciences directorate, the crew office, and the safety directorate. The program also has membership on the safety panel. Additional members are called in when appropriate, such as the EVA office when the hardware will be used in the EVA environment. The safety panels ensure that the hardware and operations meet program requirements for safety. Frequently, the safety panel review identifies hazards and needed controls that the hardware project did not develop during the initial safety assessment, in many cases due to the safety panels ability to look at the hardware or operation from a fresh, unbiased, vantage point, but also due to the familiarity of the safety requirements that the panel has obtained.

Periodically, topics arise for which additional expertise is desired beyond that which the core panel members have. In the case of EVA hardware or EVA operations this is often the case. When additional insight is needed into the one hundred percent oxygen environment inside the suit, the safety panel can request additional insight from the White Sands Test Facility experts in high oxygen environments and/or the suit hardware experts. Another example would be requesting insight from the crew trainers for EVA operations for questions regarding the ability to avoid contacting a certain part of the hardware, such as when a sharp edge, shatterable material, or pinch point needs to be avoided. In either of these instances, the safety panel in question has resources to call upon to help answer these concerns.

Also, it's possible to ask for assistance with mechanisms concerns, structural failure questions, electronic failures, plasma, or thermal concerns, among others. If an integrated concern arises with hardware not addressed by the specific safety panel, it is possible to consult or have joint meetings with multiple safety panels to address the interfacing hardware. These resources are not always readily apparent to the safety community as a whole, but should be utilized to ensure the risks are well understood and documented prior to completion of the independent safety assessment by the program safety review panel.

In an effort to clarify the need for experts to be consulted, several examples will be discussed.

2. GFE

The FESRRP reviews all Government Furnished Equipment (GFE) for flight safety. The periodically consults various experts to determine the appropriate controls and what level of risk should be documented for the Shuttle and ISS program.

2.1. OBSS Lasers

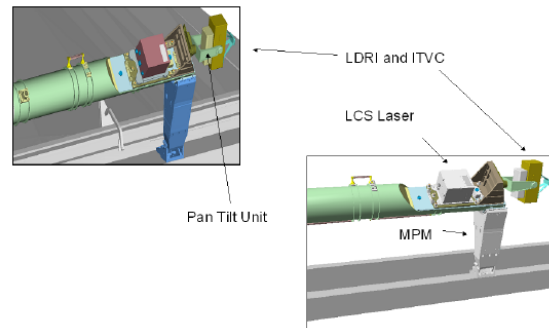


Figure 1. Inspection Sensors

The Laser Dynamic Range Imager is one of the sensors which is part of the Orbiter Boom Sensor System (OBSS) used to provide on-orbit inspection of the Orbiter thermal protections system. The FESRRP consulted the JSC expert in non-ionizing radiation, when the question arose whether the laser was powerful enough to cause eye damage to the crew, both during EVA operations, and IVA when the Boom was close to the Orbiter windows. The engineering expert for the Orbiter windows was also consulted during this discussion to establish the transmittance properties of

the window. The laser expert concurred with the hardware provider's analysis for the necessary keep-out zone for the EVA crew and with the recommendation for the IVA crew to wear specific sunglasses when the LDRI was within the distance where eye damage was possible even with the window transmittance.

The Laser Camera System (LCS) is the other sensor on the OBSS that uses a laser for imaging, and the FESRRP also consulted the JSC expert in non-ionizing radiation and received concurrence with the hardware providers recommended keep-out zone. However, during the detailed test objective the Shuttle program used to establish the stability of the Boom as an EVA worksite for repair, it was necessary for the EVA crew to enter the keep-out zone for both sensors. To establish the necessary levels of controls, the safety panel had a joint meeting with the ISS Safety Review Panel as well as the Orbiter safety review panel. The safety panels also utilized the MOD EVA experts to address the operational controls and when entering the keep-out zones was necessary. This discussion resulted in agreement that the laser hazard was considered catastrophic for both sensors, with the assistance of the JSC non-ionizing radiation expert clarifying the power and potential results of loss of eyesight. This case demonstrates the need for experts in several different fields, the laser expert, the window expert, and the EVA operations experts, as well as the potential to consult other safety panels when integrated issues arise.

2.2. RCC Plug Repair

The Reinforced Carbon-Carbon (RCC) plug repair can be performed EVA to repair damage to the Orbiter RCC. The RCC plug repair assembly (PRA) consists of a flexible carbon silicon cover plate and an attachment mechanism used to attach and hold the cover plate to the Orbiter. During the safety panel assessment of the RCC plug assembly, several issues arose that required expertise beyond that of the nominal panel members. A materials expert was asked to help the panel understand the reaction of the PRA materials to re-entry heating and loads. Due to the fact that the Plug repair project used two separate arc-jet facilities during development testing and qualification testing, the panel also asked an expert in arc-jet testing to clarify how differences in the two facilities would effect the test results. Additionally, the MOD representative to the panel requested that the MOD EVA person responsible for training the crew and writing procedures for the RCC Plug repair attend and help discuss what training the crew nominally received, as well as confirming the feasibility of any operational controls suggested during the safety review. Without the assistance of all of these experts, the safety panel would not have been able to effectively determine what risk to document on the hazard reports for the ability to safely repair the Orbiter RCC.

2.3. T-RAD

The Tile Repair Ablator Dispenser (T-RAD) assembly is a tool that provides containment and a single use dispense of the Shuttle Tile Ablator (STA-54) material for use in a contingency tile repair. It is the second generation of tools for this task.

For the previous tool, the safety panel consulted the toxicologists for an accurate assessment of the toxicity of the STA-54 components. One component had a material that separated out over time. This material was known by the toxicologists to be toxic, but had little testing or empirical data, so the toxicologists had to perform some additional testing to clarify the properties of the material, and determine that the material was toxicity hazard level 2. This resulted in the need for additional levels of containment for the material during stowage in the Orbiter middeck, to prevent exposure to the cabin environment. Without consulting the toxicology experts in this case, the safety panel would not have been able to clarify the need for additional levels of containment, nor accurately document the level of risk. Outside expertise identified areas of increased risk, which required the programs to provide additional controls.

Once the program decided to perform an on-orbit verification that the T-RAD could perform a repair, the safety panel had to assess the removal of the T-RAD from the additional levels of containment. This necessitated consulting with the EVA crew and the MOD personnel training the crew to ascertain what operational controls were viable to mitigate and control the risk of exposure during the short period of time needed to prepare for the EVA. While the safety panel representative for the EVA office and the crew could have coordinated with both parties outside the panel meeting, it was much more time effective to have those people present. Being part of the discussion also allowed the MOD personnel to understand the rationale behind the controls, such as the need to examine the T-RAD for fluid leakage prior to removal from the outer bags. The on-orbit test was successfully performed without exposing the crew to the toxic material.

2.4. ERAD

The Enhanced Right Angle Drive (ERAD) is an EVA tool constructed with drive shafts and gearing to receive an input torque and apply an output torque perpendicular to the direction of the input. It was developed to overcome the shortcomings of the Right Angle Drive (RAD) currently used for ISS tasks because the RAD has inconsistent output, excessive drive train gear wear, restricted capabilities, and a limited cycle life.

The safety panel has had some initial meetings with the ERAD project, although it has not completed the safety process. During these initial meetings, the safety panel directed the project to consult with the Mechanical Systems Working Group (MSWG) to determine whether ERAD could be considered design for minimum risk (DFMR) for breaking torques. The MSWG is also providing direction to the ERAD project to help determine the appropriate cycle testing including side load testing.

Considering the nature of the ERAD hardware, it is important to involve the MSWG early in the discussions, and to make sure their input is considered during the safety panel discussions.

2.5. PTU Straps

Due to the large volume of the JEM module, the Pan Tilt Unit (PTU) located on the elbow of the RMS was at risk of contacting the JEM module or Orbiter radiator during the launch phase of STS-124. The PTU strap was designed and built to prevent the PTU from moving enough during the launch to on-orbit phase of the flight to contact either the JEM or radiator. The PTU strap consisted of elastic straps and hook and pile to aid in the ease of removal during EVA, so that the PTU could be used for situational awareness during RMS maneuvers later in the flight. Due to the fact that hook and pile is not generally used to withstand vibration launch loads, the safety panel consulted with a structures expert who had previously certified hook and pile for use restraining cables in the payload bay compartment to restrain cables. The recommendation to the panel was to have the hook and pile pull-tested in a sufficient amount to determine the strength of that particular lot of hook and pile and to determine the minimum amount of overlap. The structural expert also clarified to the panel what cleanliness and procedural verifications should be given by the project. Without the assistance of the structural expert the safety panel would not have been able to resolve what verifications were needed to assure an acceptable design.

2.6. SARJ repair tools

The Solar Array Rotary Joint (SARJ) repair discussions resulted in several repair tools being developed. These tools included a large area cleaning wipe (LACW), a SARJ Trundle Bearing Assembly (TBA) and Drive Lock Assembly (DLA) Bag, an EVA grease gun, and a SARJ Debris Container, among other tools. During the safety panel review for these tools, some integrated concerns were brought up by the panel members that required actions be assigned for the project to coordinate with the ISS safety review panel and materials experts. This is an example of how to receive expert opinions to resolve panel concerns when the experts have not been coordinated with previous to the safety review. This is

a valid approach if the safety panel is reviewing the hardware in a phased approach, but may impact the schedule of the project, particularly if it is a short-turnaround project.

In the case of the SARJ repair tools, the panel requested that the project coordinate with the integrator for the assessment for the actual SARJ repair. The question arose at the panel whether it was possible to have a sharp edge on the SARJ ring cut through the EVA wipe. Additionally, the panel asked if the grease in the EVA grease gun was a contamination problem for the EMU or the ISS hardware. The EMU engineers and materials experts confirmed there were no compatibility issues. This led to a follow-up action from the panel regarding SARJ contaminants entrained in the grease being returned in the SARJ TBA and DLA bag. The materials experts confirmed that the contaminants did not result in either an off-gassing or flammability hazard once in the cabin environment. Although the actions resulted in answers prior to the final safety reviews, and resolved the issues to the satisfaction of the safety panel, if the materials expert had been able to be present at the review time would have been saved for the overall project schedule.

2.7. HHM

The Hand-held Microphone (HHM) provides communication ability in 2 forms, Intercom (Crew to crew) and Transmit (Crew to Ground). The HHM is used for various activities; including Public Affairs. The HHM was recently revised to increased EMI resistance, as well as with a detachable cable to fix a stress issue which had led to failures. During the re-design and build of the HHM, several failures were seen during acceptance testing. The safety panel asked the HHM project to clarify the cause of the failures, and what controls had been added to prevent these failures in the future. The failures were caused by the incorrect installation of capacitors. The safety panel asked the JSC Receiving and Test Facility (RITF) to clarify what results they had obtained from examining the failed hardware. The RITF representative brought X-rays and pointed out where the capacitor had been incorrectly installed. This gave the safety panel a better understanding of the adequacy of the changes the project made to the design drawings and verifications to ensure the failure did not re-occur. Additionally, the RITF is an independent testing facility which gives the safety panel notification of concerns. The HHM review was an example of using the resources the RITF has available to clarify the verifications available to a project and what those verifications entail.

3. EVA PAYLOADS

3.1. AMS

The Alpha Magnetic Spectrometer (AMS) is a state-of-the-art particle physics detector. The primary component is a cryomagnet which generates a strong electromagnetic field. The magnetic field can be dissipated, quenched, then recharged if needed. The magnetic field has an internal field strength of 8600 gauss and an external field strength of 2000 gauss.

When the AMS originally started discussion with the Payload Safety Review Panel (PSRP), the EVA representative to the PSRP pointed out that the Extravehicular Mobility Unit (EMU) could potentially be damaged due to a strong magnetic field, losing the function of the fan. This results in a lack of flowing oxygen, which can overheat the crew and result in carbon dioxide build-up. This concern required the expertise of the EMU engineers to determine what magnetic field strength the EMU was capable of withstanding without causing a hazard. Subsequent testing resulted in the certification of the EMU to 300Gauss. Additionally, the EVA Office working with the MOD established the nominal EVA translations paths near the AMS, and the capacity for remaining far enough away from AMS to not expose the EMU to greater than 300 gauss. This includes performing necessary tasks for ISS hardware maintenance nearby, as well as any potential payload operations.

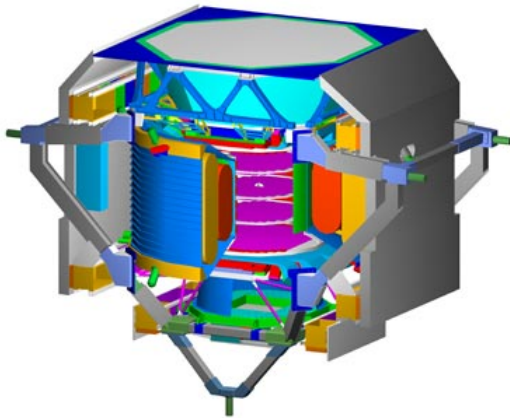


Figure 2. AMS

Although the EVA Office representative to the panel could identify that a potential issue was present, without the input of the EMU engineers and the EVA Office and MOD EVA this issue could not have been resolved. Ideally, the hardware provider will identify an issue like this, and the appropriate panel member will identify the necessary people to consult as in this example.

3.2. PLEGPAY

The Plasma Contactor Electrical Grounding Payload (PLEGPAY) is a scientific experiment that is part of the

European Technology Exposure Facility, a set of scientific payloads located on one of Columbus's external platforms. PLEGPAY is designed to get in-flight validation of the plasma contactor as an active control for electrostatic discharge. EuTEF was deployed on flight 1E. Boeing Space environments identified three periods after deployment where unusual floating potential was witnessed. Floating potential (FP) is the difference in electrical potential between the International Space Station (ISS) conducting structure and the surrounding ionospheric plasma.

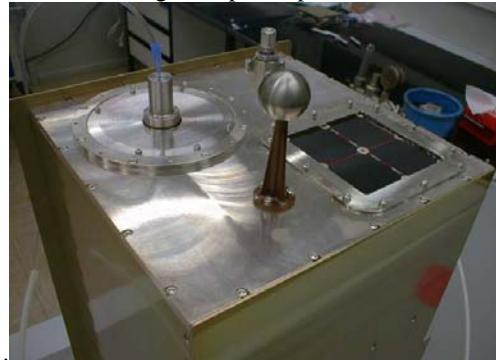


Figure 3. PLEGPAY

The NASA environments expert was not originally consulted by the safety review panel during the pre-launch flight safety reviews. Subsequent to the identification of the potential for PLEGPAY to affect the FP, the environments expert came to the safety panel to discuss the hazard potential and recommended operational controls.

FP variations could affect the control for electrical shock of the EVA crewmembers. If the plasma environment potential voltage is more than 40V higher than ISS structure, then when the EVA crewmember contacts ISS structure with a metallic part of the EMU, the electrical potential may arc through the crewmember, resulting in loss of the EVA crew. Additionally, the EMI/EMC effects on ISS hardware and the impact to visiting vehicles may result in a hazard. The PLEGPAY owners have agreed to remove power during EVA operations to ensure no additional risk to the EVA crew.

PLEGPAY demonstrates the need to consult experts, even when an issue is not brought up by the hardware provider during the safety review. It behoves a safety panel to ask the expert if they have a concern with hardware that may impact their area before on-orbit operations identify a problem. Any time the ISS environment may be impacted, the question should be asked even if the hardware provider believes that the impact is benign. However, this is an excellent example of the experts necessary being consulted to resolve a real-time issue with the assistance of the safety panel to

update the hazard reports so that on-orbit operational controls can be accurately documented.

4. ISS HARDWARE

4.1. Solar Array Repair

During the STS-116/12A.1 Shuttle/ISS flight, the P6 solar array being retracted jammed, necessitating an EVA to assist in unbinding and retracting the solar array. Prior to the STS-117/13A flight, which retracted the other P6 solar array, the ISS safety panel discussed what controls would be in place to prevent the EVA crew from exposure to electrical arcing and sparking, with the potential loss of crew due to electrical shock or exposure to molten metal. The safety panel asked for clarification from the EMU engineers on what testing had been performed to verify the isolation the EMU glove provides for electrical shock, and asked the electrical expert in ISS maintenance whether shunting the solar array would provide an additional level of protection. . The safety panel concurred with the ISS integrator's recommendation to tape the tools used in the solar array operations, with the concurrence of the electrical experts. The use of the tape allowed the necessary insulation to prevent the electrical charge from travelling along the tool to the EVA crewmember. The safety panel also asked the electrical environments expert to clarify the scenario for what contact could result in EVA crew electrical shock. The additional recommendation was made to tape the wrist rings of the EMU, to remove one potential path for electrical shock. This resulted in a discussion of whether additional metallic components needed to be taped to reduce the risk of electrical shock to the crew. With the assistance of the electrical experts, the EMU engineers, and the crew who would be performing the task on 13A, it was determined no additional taping was required. Without the input of these experts, the safety panel would have had a difficult time resolving the issues and coming to a conclusion for controls with concurrence from all the involved organizations.

5. CONCLUSION

There are many other examples of when safety panels have found it necessary to consult outside experts. The important thing to keep in mind when a safety panel addresses an issue that requires additional expertise is that outside resources are available. Ideally the panel representative from the applicable organization will be able to reach into that organization and have the expert come to the panel meeting to help discuss the issue. Alternatively, the safety panel executive officer can ask an expert to attend or teleconference in, such as asking an oxygen expert from White Sands Test facility to participate in a discussion on new hardware being located internal to the EMU, a one-hundred percent oxygen environment. If the expertise needed is not

locally available, an expert from another center or from outside the space agency should be consulted. Even if the panel does not believe there is an issue with the hardware, if the hardware involves operations or material outside the common use, then the safety panel needs to consult the appropriate expert to ensure that off-nominal scenario is appropriately analyzed.