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Paper Session II-B - Combining Tools, Tasks, Flight Hardware & Astronauts in Pre-flight Ground Fit Checks for On-orbit Success

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Combining Tools, Tasks, Flight Hardware and Astronaut Pre-Flight Ground Fit Checks For On-Orbit Success

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Abstract:

This paper will discuss the process of performing "Fit checks" which refers to mating flight hardware together on the ground before they will be mated on-orbit. The concept seems simple but it can be difficult to perform operations like this on the ground when the flight hardware is being designed to be mated on-orbit in a zero-g and/or vacuum environment of s Also some of the items are manufactured years apart so how are fit checks performed on these components if one piece is on-orbit before its mating piece is planned to be b Both Internal Vehicular Activity (IVA) and Extra-Vehicular Activity (EVA) fit checks will be presented. Details include; how fit checks should mimic on-orbit operations. A series of photographs will be included that were taken during fit checks performed on International Space Station (ISS) flight elements and the paper will conclude with lessons learned as a result

Fit Check Definition:

Fit check refers to mating two (or more) flight items together on the ground. Fit checks can relate to an electrical cable being mated between first ISS element Unity and the Laboratory element, fluid line being mated between Unity and the Airlock, two pieces of structure being mated together like the Ku-band antenna and its boom, Orbital Replaceable Unit (ORU) mounted to its on-orbit location. ORU's, like batteries or electronic boxes, are items that can be installed on-orbit by the Astronauts/Cosmonauts, or on the ground before launch, with the capability to be removed/repositioned at a later time as part of normal on-orbit maintenance operations. Example; if battery replacement is necessary, everything possible needs to be done ahead of time to assure this item can be removed and replaced with a good battery. Fit checks help assure this change-out of hardware is successful. Some times flight-to-flight fit checks are not possible, so master units, which simulate the flight items should be used, but all efforts should be made to use flight hardware. Note: For purposes of this paper, Astronauts/Cosmonauts will be refereed to as the "Crew".

On-orbit Operational Scenarios:

The fit check acts like a dry run for the actual on-orbit operations that will be performed by the Crew. These operations could be IVA or EVA related which are part of the normal assembly sequence of Space Station, or part of a contingency plan regarding repairs for failures on-orbit or off-nominal sequence that is critical to allowing assembly operations to continue. Fit checks of the hardware will usually determine the proper order, or sequence of events that need to occur. Planning takes place on what the Crew should do to accomplish a task, and the fit check validates the planning.

Internal Vehicular Activity (IVA):

IVA relates to tasks performed by the Crew in a shirtsleeve environment internal to pressurized Space Station Elements, like Unity, the Laboratory Module and Airlock. An IVA task could be as simple as turning a valve, to connecting 20+ electrical and fluid lines between ISS elements, or total activation of the new ISS element that has just arrived on-orbit. IVA task can perform by 'Station Crews' that are permanently occupying the Space Station or Crews aboard vehicles just launched from Earth. Many IVA tasks can be performed at the same time because the large numbers of crew members present inside the pressurized ISS elements. What is critical to IVA operation is usually the sequence of steps that need to be performed and maintaining a certain order of tasks, one-after-another, to assure successful completion. Stand-alone IVA task are mostly straightforward, but the problem occurs when IVA tasks are integrated with other operations, like berthing an element on-orbit. IVA pre-flight fit checks allow the Crew to perform a dry run of what they actually will be performing in Space using the same flight tools, flight hardware and sequence of steps (flight procedures). IVA can be similar to normal tools used every day here on Earth. Access to the hardware is relatively easy and the flight hardware can be designed and operated very similar to normal everyday operations on the ground. This allows extra time and resources to solve any problems that may occur during the IVA operations. Even with these similarities to ground operations, fit checks are mandatory to assure successful operations, because if something does not work on-orbit, the only way to fix it may be to bring it back to the ground, which nobody wants to do. Photo #1 is an IVA task performed by the STS-88 flight crew during their mission in December 1998.

Photo#1 – Bob Cabana & Sergei Krikalev are about to open the Unity Forward hatch allowing access into the Unity ISS element. Note the flight procedure being checked to assure proper steps are followed.

Extra-Vehicular Activity (EVA):

EVA, unlike IVA, is performed out in the vacuum of space. The EVA Crew wears
suit containing breathing, pressured & temperature controlled environment. Th
the crew can spend EVA do to limited consumables in the suit. Also, special t
need to be designed, plus most EVA operations will take place with only two cr
thus limiting the number of tasks performed during each EVA operation. The cr
some many tools and pieces of hardware. Even though there are toolboxes and lo
outside of ISS to mount more tools and hardware the crew only has two hands wi
storage locations on the suit. Plus having limited time in the suit, the crew
back n forth to all the different locations on the ISS to retrieve more items.
operations, crews launched from the ground will be performing most of the EVA
which limits the number of EVA operations per mission. EVA Fit checks are then
there is very little extra time or extra resources to fix problems. Tools ha
hardware have to fit, mechanical devices have to function everytime during an
EVA fit checks, performed by the crew during pre-flight activities, will comb
special flight/flight-like tools with the flight hardware and the planned pro
fit the hardware, no interference's exist between the tools & other hardware,
together as planned and that the procedures are accurate and have all the det
perform the task. As with IVA, EVA tasks and the order they are performed cou
difference between success and failure.

Photo#2 - STS-88 EVA crew, Jim Newman and Jerry Ross during EVA activities in the First U.S. ISS mission (ISS-2A) that berthed the Unity Element with the Zarya Element in December of 1998.

Lessons Learned:

Lessons learned on each mission are applied to future missions. This will avoid the same mistakes over-and-over again, help improve the design process to get a better database on which to draw from when designing new fight hardware, assist problem solving if similar instances occur due to error or unexpected hardware failure and allow the ISS program to grow and gain more experience on how to live and work in space.

The following is a series of lessons learned while performing pre-fight fit checks during assembly, integration and testing for the first two planned U.S. ISS missions. Reference to on-orbit operations will be discussed and how the fit checks contributed to the successful U.S. ISS flight. These are just a subset of a larger database of lessons learned while working these missions. As of this writing, the first U.S. ISS element, Unity, is berthed to the Russian Zarya element on-orbit, and the Z1 truss, P6 segment, Laboratory Module and Multiple Pressurized Logistic Module are located in the Space Station Processing Facility (SSPF) at Kennedy Space Center. All ground photo’s shown were taken in the SSPF.

Static Fit Checks:

As the name implies, these are fit checks that are static in nature. Examples include an EVA fit check of thermal blankets over electronic boxes and an IVA electrical & fluid connector mate to the Unity. Because Unity is the core element to ISS, 5 future flights and contain will be many Electrical and Fluid cables/connections between Unity and the new ISS elements. A process was put in place to fit check all future fluid and electrical jumpers that will make these connections. This meant accelerating many future EVA jumpers to allow the fit checks to occur before Unity was launched. Some of the jumpers required tools that will be described later in this paper, but most were a simple static mate to assure the two items would mate on-orbit. <u>Lesson learned, perform fit checks even fo</u>r static cases.

Photo#3 – Astronaut Jerry Ross fit checks thermal cover that will be placed the Unity Multiplexer/Demultiplexer (MDM) during STS-88 EVA operations. Note additional Velcro location needed to secure strap.

Photo #4 – IVA Fluid jumper mates proper to fitting but interferes with near-by structure. Solution, modify end of jumpe with “S” fitting.

Photo#5 - EVA glove gets caught between handrail and shield. Solution, place 1" spacer under handrail to allow more volume between handrail from shield.

Photo #6 - Successful glove use during STS-88 EVA operations, in December 1998.

Dynamic Fit Checks:

Dynamic fit checks deal with items that once placed in a desire location, have dynamic components that if not exercised during fit check could cause on-orbit problem. Photo#7 is the S-Band Antenna Subassembly (SASA) boom, SASA not. On-orbit the high gain antenna of the SASA can pivot and rotate so this same operation was performed during the dynamic fit check and it was discovered more space was required between the high gain antenna and boom. This never would have been caught if the team had performed only a "static" fit check of the SASA to its boom. Lesson learned, perform dynamic fit check not just static fit check if applicable.

Photo#7 – Dynamic fit check of The S-Band Antenna Subassembly (SASA), not shown noted more space was needed between the high gain antenna and boom. Solution, modify

Flight Configuration:

Photo’s #8 & #9 are of the Crew Equipment Translation Aid (CETA) light boom fit to Unity at launch Pad 39A. Photo #8 is just the interface bracket to Unity which fits just fine, but when the boom is added, Photo #9, i.e. now the boom assembly is in its flight configuration, the boom interferes with surrounding blanket material. Lesson learned, perform hardware fit ch its flight configuration. Even a temporary installation of flight hardware in surrounding areas better than not having any hardware. Note: This fit check was very late in the processing flow, so if the problem could not be solved quickly, delaying the launch may have resulted. Lesson learned, perform fit check as early as possible with flight hardware in flight configuration.

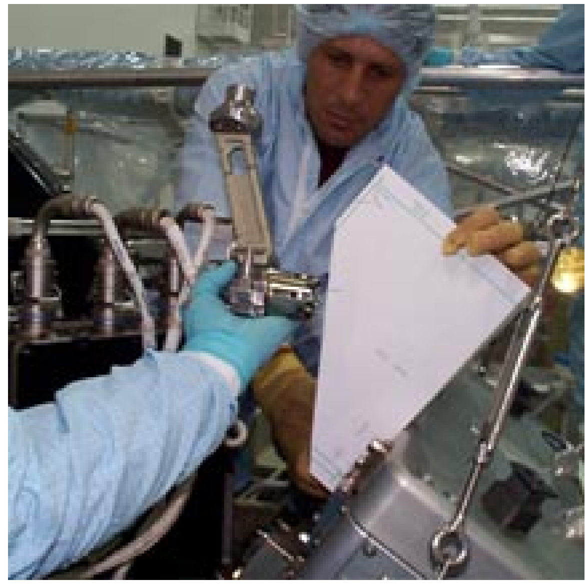
Photo #8 - CETA light boom interface bracket fit check to Unity, minus boom. Fit check good.

Photo #9 - CETA light boom interface bracket fit check to Unity, including boom. Boom interferes with blanket not allowing boom to fully seat. Solution, reposition blanket material.

Assure Ground Support Equipment (GSE) is Compatible with Fit Check:

In an attempt to perform static and/or dynamic fit checks, the GSE can interfere with accomplishing the complete fit check. Photo# 10 is a picture of Unity in its Element Rotation Stand (ERS), white structure with markings, located in the SSPF. The CETA light boom, stated above, is approximately 4 feet long and is to be fit checked at the white blanket area located in the middle of the photo. The problem is the ERS ring is closer than 4 feet, th static fit check of the CETA light boom (which forced the fit check at the launch pad). Photo #11 shows a lifting sling interfering with the EVA Tool Storage Device (ETSD) door opening during a dynamic fit check. The sling needed to continually support the box during fit check, thus the sling could not be removed to allow door opening. Lessons learned, assure GSE is compatible with static and dynamic fit checks.

Photo #10 - ERS prevents fit check of 4-foot long CETA light boom. Solution fit check at the launch pad.



Photo#11 - Sling leg prevents ETSD doors from being opened during dynamic fit check. Solution, create template of door.

Tools:

Fit checks of flight/flight-like tools to flight hardware is mandatory. Many the tools will work as planned, but until the tool is placed in with the fligh there is no way to know for sure. The tool may fit the item perfectly, but the tool may prevent using the tool in the <u>manner desired. Lessons lea</u>rned, w <u>check, use tools (or flight-like) that will be used durin</u>g the on-orbit operat

Photo # 12 – Tether fit check used to release CBM deployable cover launch locks during STS-88 EVA operations. The tether worked great on-orbit.

Photo #13 – Fluid fitting torque device check to Unity fluid fitting. Device f but personnel need to assure surroundin hardware will not interfere with operat

Lessons learned from previous Shuttle missions:

The following is a summation of information contained in NASA Document, NSTS 0
VOLUME XIV, Appendix 7 (Formerly JSC 10615) System Description and Design Data-
Extravehicular Activities

Shuttle mission 41C - Solar Max capture

The objective of the first EVA, EVA-1, was to fly about 200 feet to the satell
dock to the satellite, arrest its spin rate with the MMU thrusters, orient it
grapple with the RMS, secure it in the payload bay, and start repair. EVA-1 b
morning of April 8, 1984. The docking attempts using the MMU were. Three att
made, but the Trunnion Pin Attachment Device (TPAD) would not grasp the trunnic
satellite. It was later found that this was due to a poorly documented therma
pin, which kept the TPAD jaws from clamping on the trunnion.

51A - PALAPA & WESTAR satellite retrieval

On Mission 51-A, the first EVA took place on flight day 5, November 12, 1984.
One major problem was encountered when one of the waveguides on the PALAPA sat
extended beyond the radial distance and interfered with the Angle Brace on the
Structure (ABS) Common Bracket Clamp (CBC). Because of this interference, the
be installed and used for handling the Satellite with the RMS during installati
berthing adapter.

Conclusion:

Fit checks are mandatory to help assure mission success. Planning the fit che
process will help avoid problems during the fit check. Coordinate the use of
and to make sure the flight hardware is configured in flight/flight-like confi
will be a static and/or dynamic fit check, does the GSE support the planned fi
whole operation compatible with the Crew and the work they have to perform to
actual operation on-orbit. Building on lessons learned from previous missions
of these elements are needed to assure the fit check mimics the on-orbit opera
comes time to perform the real operation, in orbit above the Earth, moving at 1
operation will be a success.