Paper Session II-B - Combining Tools, Tasks, Flight Hardware & Astronauts in 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 refer 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. Additionally, 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? Both the Internal Vehicular Activity (IVA) and Extra-Vehicular Activity (EVA) fit checks will be presented. Details include: how fit checks should mimic on-orbit operational scenarios. Photographs 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. This can involve mating electrical cables between first ISS element Unity and the Laboratory element, fluid lines being mated between Unity and the Airlock, two pieces of structure being mated together like the Ku-band antenna and its on-orbit location or electronics, items that can be installed, or Orbital Replaceable Units (ORU) mounted to its on-orbit location like batteries or electronic boxes, items that can be installed. If battery replacement is necessary, everything needs to be done ahead of time to assure this can be removed and replaced with a good battery. Fit checks help assure this change-out of hardware is successful. Sometimes flight-to-flight fit checks, which consider the fact that the flight items should be made to use flight hardware. Note: For purposes of this paper, Astronauts/Cosmonauts will be referred to as the “Crew”.

On-orbit Operational Scenarios:
The fit checks like dry runs for the actual 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. These could be part of a contingency plan regarding repairs for failures or off-nominal sequences that are critical to allowing assembly operations to continue. Fit checks of the hardware will usually determine the proper order of events. The correct sequence of operations is critical to the successful completion of the assembly. Planning at the design stage will take place on what the Crew should do to accomplish a task, and the fit check validation will ensure the planning is correct.

Internal Vehicular Activity (IVA):
IVA relates to tasks performed in a shirtsleeve environment in pressurized Space Station Elements, like Unity, the Laboratory Module, and the Airlock Module. An IVA task could be as simple as turning a valve, connecting 20+ electrical and fluid lines between ISS elements or total activation of a new ISS element. An IVA task can be performed by the Station Crews that are permanently occupying the Space Station. These Crews aboard the Space Station can perform IVA tasks just as when they are performing IVA tasks on Earth. Many IVA tasks can be performed at the same time because of the large numbers of crew members present inside pressurized ISS elements. What is critical to IVA operations usually the sequence of steps that need to be performed, maintaining a certain order of tasks. IVA tasks are integrated with other operations, like berthing an element on-orbit, allowing the Crew to perform a dry run of what they will actually be performing in Space using the same flight tools, flight hardware and sequence of steps. IVA tasks can also be performed at the same time as normal IVA tasks. IVA tasks can be 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 a suit containing breathing, pressurized & temperature controlled environment. Thus limiting the number of tasks performed during each EVA operation. The crew can spend EVA do to limited consumables in the suit. Also, special tools need to be designed, plus most EVA operations will take place with only two crew members, thus limiting the number of EVA operations per mission. EVA Fit checks are then performed by the crew during pre-flight activities, will comb special flight/flight-like tools with the flight hardware and the planned procedure to 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 details of the task. As with IVA, EVA tasks and the order they are performed can make a difference between success and failure.

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

Lessons learned on each mission are applied to future missions. This will avoid mistakes over-and-over again, help improve the design process, get a better database on which to draw from when designing new flight hardware, and gain more experience on how to live and work in space.

The following is a series of lessons learned while performing pre-flight checks during assembly, integration, and testing for the first two planned U.S. ISS missions. These are part of a larger database of lessons learned while working these missions. The first S.ISS element, Unity, is berthed to the Russian Zarya element, and the Z1 truss, P6 segment, Laboratory Module, and Multiple Pressurized Cargo Module are located in the Space Station Processing Facility (SSPF) at Kennedy Space Center. All ground photos shown were taken in the SSPF.

Static Fit Checks:

As the name implies, these are fit checks that are stationary. Examples include EVA fit checks of thermal blankets over electronic boxes and an IVA electrical connector mate to the Unity. Because Unity is the core element to ISS, 5 future missions will contain 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 IVA jumpers to allow the fit checks to occur before Unity was launched. Some of the jumpers required bolts that will be described later in this paper, but most were simple static mates that need to be assured to mate on-orbit.

Lesson learned, perform fit checks even for static cases.

Photo #3 – Astronaut Jerry Ross fits EVA thermal blanket to the Unity Multiplexer/Demultiplexer during STS-88 EVA operations. Note additional Velcro location needed to secure strap.

Photo #4 – IVA Fluid jumper mates properly to fitting but interferes with nearby structure. Solution, modify end of jumper 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 problems. For example, the S-Band Antenna Subassembly (SASA) boom, SASA not shown. On-orbit, the high gain antenna of the SASA can pivot and rotate, simulating the same operation as performed during a dynamic fit check. It was discovered during a dynamic fit check of the SASA that more space was needed 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 check to Unity at launch Pad 39A. Photo #8 of the interface bracket to Unity which fits just fine, but when the boom is added, the boom assembly is in its flight configuration. The boom interferes with surrounding blanket material. Lesson learned: perform fit check of flight hardware in its flight configuration. Even a temporary installation of flight hardware is 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 material, 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 a complete fit check. Photo #10 is a picture of Unity in its Element Rotation Stand (ERS), which is 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, which forced the fit check at the launch pad. Photo #11 shows a lifting sling interfering with opening the EVA Tool Storage Device (ETSD) door during a dynamic fit check. The sling needed to continually support the box during the fit check 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 tools will work as planned, but until the tool is placed in with the flight 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 manner desired. Lessons learned, we check, use tools (or flight-like) that will be used during the on-orbit operation.

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 fit personnel need to assure surrounding 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 satellite 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 attempts, but the Trunnion Pin Attachment Device (TPAD) would not grasp the trunnion 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 satellite extended beyond the radial distance and interfered with the Angle Brace on the Structure (ABS) Common Bracket Clamp (CBC). Because of this interference, the berthing adapter.

Conclusion:
Fit checks are mandatory to help assure mission success. Planning the fit check 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 configuration. 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 operation comes time to perform the real operation, in orbit above the Earth, moving at 1 operation will be a success.