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

Michael E. Haddad  
NASA Kennedy Space Center

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

by

Michael E. Haddad  
NASA  
Kennedy Space Center

**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 in space. 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. 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 internal and external EVA and IVA (Extra-Vehicular Activity) fit checks will be presented. Details include; how fit checks should mimic on-orbit operations. Space 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. It checks such things as 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 Orbital Replacable Unit (ORU) mounted to its on-orbit location like Batteries. Batteries, electronic boxes are items that can be installed on-orbit by the Astronauts/Cosmonauts on the ground before launch with the capability to be removed/repositioned at a later time as part of normal operations. Experience if battery replacement is necessary, everything possible 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. Some times flight attendants flight checks master units, which simulate the flight items should be used, but a dummy pass 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 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. A part of a contingency plan regarding repairs or failures on-orbit off-nominal sequence that is critical to allowing assembly operations to continue. Fit checks of the hardware will usually determine the proper order 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 a shirt-sleeve environment internal pressurized Space Station Elements, like Unity, the Laboratory Module. 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 be performed by 'Station Crew' or by a temporarily occupying the Space Station or Crews aboard vehicles just launched from Earth. Many IVA performed at the same time because the large numbers of crew members present inside the pressurized ISS elements. What is critical to IVA operations is usually the sequence of steps that need to be performed and maintaining a certain order of tasks, one-after-another, successful assurance. Stand-alone IVA tasks are mostly straightforward, but the problem occurs when IVA tasks are integrated with other operations, like berthing an element. Flight checks allow the Crew to perform a dry run of what they are performing in Space using the same flight tools, flight hardware and sequence of steps (flight procedures) as IVA normal tools used every day here on Earth. Access to batteries 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 operation. Even with these similarities, ground operations fit checks are mandatory to assure successful operations, because if something goes wrong, it may be too late to fix it may be to bring it back to the ground, which nobody wants to do. IVA task #1 performed by the STS-88 flight crew during their mission in December 1998.



Photo#1 - Bob Caban and 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, pressured & temperature controlled environment. The crew can spend EVA doing 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 tasks performed during each EVA operation. The crew carries some many tools and pieces of hardware. Even though there are toolboxes and lockers outside of ISS to mount more tools and hardware the crew only has two hands with limited storage locations on the suit. Plus having limited time in the suit, the crew must go back and forth to all the different locations on the ISS to retrieve more items. For unassisted 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 performed, there is very little extra time or extra resources to fix problems. Tools and hardware have to fit, mechanical devices have to function every time during an EVA fit check, performed by the crew during pre-flight activities, will combine special flight/flight-like tools with the flight hardware and the planned procedure to profit the hardware, no interference exists between the tools & other hardware together as planned and that the procedures are accurate and have all the details to perform the task. As with IVA, EVA tasks and the order they are performed could make the 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 with 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 database on which to draw from when designing new flight hardware, assist in identifying errors due to error or unexpected hardware failure 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. Reference to on-orbit operations will be discussed and how the fit checks were fulfilled to ISS flight. These are a subset of a large 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 Logistics Module are relocated 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 checks are static in nature. Examples include an EVA fit check of thermal blankets, electronic boxes and an IVA electrical fluid connector to the Unity. Because Unity is the core element to ISS, 5 future flights will be many Electrical and Fluid cables/connections between Unity and the new ISS elements. A process was put in place to 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 require 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. Lesson learned, perform fit checks even for static cases.



Photo #3 - Astronaut Terry Ross fit checks thermal cover that will be placed on the Unity Multiplexer/Demultiplexer during STS-88 EVA operations. Note additional micro location needed to secure strap.



Photo #4 - IVA Fluid jumper mates proper to fitting but interferes with near-by 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 desired location have dynamic components that if not exercised during fit check could cause a problem. This problem with the S-Band Antenna Subassembly (SASA) boom, SASA not. On-orbit the high gain antenna of the SASA can pivot and 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 performed 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) lightboom fit launch Pad 39A. Photo #8 shows the CETA lightboom fit to Unity which fits just fine but when the boom is added to #9, i.e. now the boom assembly is in its flight configuration, the boom interferes with surrounding blanket material. Lesson learned, perform fit check in its flight configuration. Even a temporary installation of flight hardware is better than not having any hardware. Note: This fit check was very close to the 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 lightboom fit check to Unity minus boom. Fit check good.



Photo #9 - CETA lightboom 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 lightboom, 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, the fit check of the CETA lightboom (which forced the fit check at the launch pad). Photo #11 shows a lifting sling interfering with the EVA Open Storage Device (ETSD) door during a dynamic fit check. The sling needed to continually support the legs fit could not be removed to allow door opening. Lessons learned, assure GSE is compatible with static and dynamic fit checks.



Photo #10 - ERS prevented check of 4-foot long CETA lightboom. Solution: fit check at the launch pad.

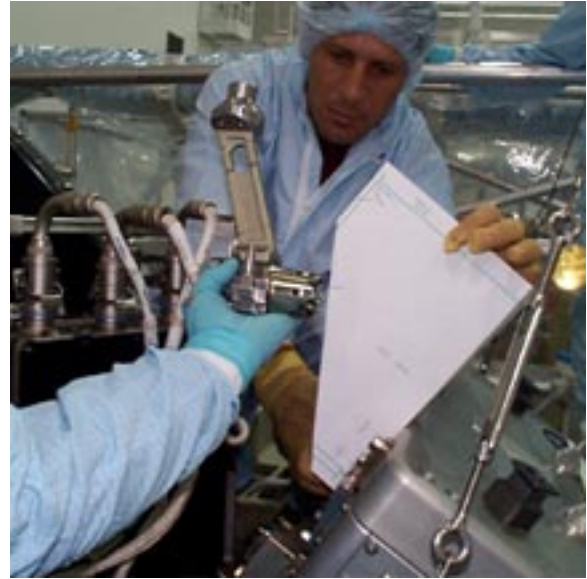


Photo #11 - Slings prevented STSD doors from being opened during dynamic fit check. Solution, create template of door.

**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 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, w check, use tools (or flight-like) that will be used during 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 had 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 began on the morning of April 8, 1984. The docking attempts using the MMU were. Three attempts were made, but the Trunnion Pin Attachment Device (TPAD) would not grasp the trunnion of the satellite. It was later found that this was due to a poorly documented thermal 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 CBC could not be installed and used for handling the Satellite with the RMS during installation and 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 ground support equipment and to make sure the flight hardware is configured in flight/flight-like configuration. Whether the fit check will be a static and/or dynamic fit check, does the GSE support the planned fit check, and is the whole operation compatible with the Crew and the work they have to perform to accomplish the actual operation on-orbit. Building on lessons learned from previous missions, more ground support equipment of these elements are needed to assure the fit check mimics the on-orbit operation. When it comes time to perform the real operation, in orbit above the Earth, moving at 17,000 mph, the operation will be a success.