

International Space Station United States Operational Segment Crew Quarters On-orbit vs. Design Performance Comparison

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ABSTRACT

The International Space Station (ISS) United States Operational Segment (USOS) received the first two permanent ISS Crew Quarters (CQ) on Utility Logistics Flight Two (ULF2) in November 2008. As many as four CQs can be installed in the Node 2 element to increase the ISS crew member size to six. The CQs provide crew members with private space that has enhanced acoustic noise mitigation, integrated radiation-reduction material, communication equipment, redundant electrical systems, and redundant caution and warning systems. The rack-sized CQ system has multiple crew member restraints, adjustable lighting, controllable ventilation, and interfaces that allow each crew member to personalize his or her CQ workspace.

The deployment and initial operational checkout during integration of the ISS CQ to Node 2 is described in this paper. On-orbit to original design performance is also compared for the following key operational parameters: interior acoustic performance, airflow rate, temperature rise, and crew member feedback on provisioning and restraint layout.

INTRODUCTION

The International Space Station (ISS) Crew Quarters (CQ) provides an acoustically quiet and visually isolated area in which crew members can sleep, relax, and retreat to a private area on board the ISS. These simple functional requirements result in complex and competing sets of derived requirements for the hardware [1]. The first two CQs were launched in a Multi-Purpose Logistics Module (MPLM) on Space Shuttle Utility Logistics Flight 2 (ULF2) in November 2008. These two CQ were subsequently transferred from the shuttle MPLM to the ISS Node 2, *Harmony*, equipment bay 5 port and starboard locations.

Four CQs will eventually be located in Node 2 to form the "ring" configuration that is shown in Figure 1.

Current ISS Program plans are to launch a third CQ unit on ISS Assembly Flight 17A in August 2009 for installation in the Node 2 deck location. The fourth CQ is planned for launch on ISS Assembly Flight 19A in 2010 for installation in the Node 2 overhead location. Figure 1 shows the on-orbit configuration for each CQ, including the deployment of the pop-up (shown in magenta) and the

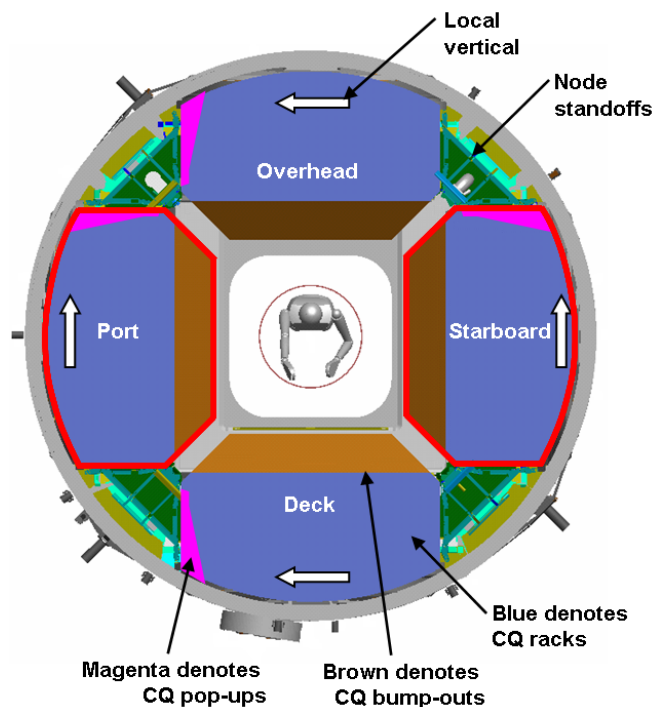


Figure 1. CQ location within Node 2 indicating the port and starboard units that were launched on ULF2.

bump-out (shown in brown) units that contain ventilation equipment. These two hardware deployments provide both a real and a perceived increase in habitable volume over the standard ISS rack volume (shown in blue).

The ISS CQ racks and additional regenerative life support racks set the framework for increasing the ISS crew member complement from three to six. This increase in crew member complement will help provide the capability for ISS to reach its full science research potential. This paper describes how the CQ flight hardware meets the original design intent, on-orbit deployment activities, and initial crew feedback concerning CQ habitability. The ISS CQ provides an improvement in acoustic mitigation, thermal control, and electronics integration over the U.S. Temporary Sleep Station in the laboratory module and the Russian Kayutas in the Service Module [1].

FLIGHT HARDWARE COMPLETION

Schedule challenges during hardware fabrication and unanticipated test issues resulted in some modifications to the flight hardware configuration. It is beneficial to highlight a few of these schedule issues because they contributed to some of the ground and installation issues.

Since the start of the ISS CQ project, it was known that an integration test, or a rack-level fit check, between the CQ and Node 2 was not feasible because of the late initiation of the CQ project. No CQ hardware existed at the time of the Node 2 launch. This risk was mitigated, however, by interaction with subsystem managers of

mating hardware during requirements development. Additionally, several CQ project and design engineers traveled to Kennedy Space Center (KSC) to view and document the flight Node 2 bay 5 hardware interfaces prior to launch of that ISS element in May 2006. Finally, CQ used mating electrical connectors from the Node 2 residual inventory to ensure compatibility. Yet despite this risk mitigation, the inability to perform an integrated functional test with Node 2 has resulted in some minor on-orbit issues.

The completed port and starboard CQs were scheduled to be shipped to KSC by the end of July 2008. However, due to electrical assembly and test issues, only the structural elements of the CQ racks were completed in time to meet the required shipment date. Although this was not desirable from an integration standpoint, the rack structures were shipped, without electronics, to ensure that the approximately 360 kilograms of structural mass would make the launch schedule. Consequently, the CQ structure and electronics were not integrated and tested with their intended flight structure at the Johnson Space Center (JSC). Electronic assemblies were completed just prior to installation of the CQ racks into the MPLM. Full electrical functional tests were performed using the deck and overhead CQ racks at JSC prior to shipping the port and starboard electronics to KSC, thus reducing the risk of complications at KSC. Integrated testing revealed an unanticipated flow condition, which is discussed in the on-orbit activation section that required modification of on-orbit procedures but was not critical to hardware shipment. The electronics were delivered and successfully integrated without significant issues at the KSC Space Station Processing Facility.

The hardware development schedule made flight hardware unavailable for crew training in an on-orbit configuration. Several opportunities were provided to the crew to view flight hardware components at various manufacturing stages. Additionally, the previously developed mid-fidelity mockup was available for comparison of basic assembly features. As this mockup did not contain electronics, checkout training could not be performed. The flight hardware was therefore checked for tool access and sharp edges; it was then extensively coordinated to ensure that labeling and accurate crew procedures were in place during development. Despite this, the inability to provide a fully functional, flight-like trainer contributed to some on-orbit installation issues.

FLIGHT HARDWARE DESCRIPTION

The flight hardware met the initial design intention. Figure 2 illustrates the CQ configuration for launch. Note that this configuration differs from the on-orbit configuration in that it reverses the bump-out and retracts the pop-up to meet MPLM rack envelope requirements. The reversed bump-out is evident by comparing Figure 2 and Figure 3. The retracted pop-up is evident by comparing Figure 2 (no white material) and Figure 4 (horizontal white material) or Ulf2 bay 5 Figure 1 but without the magenta area.

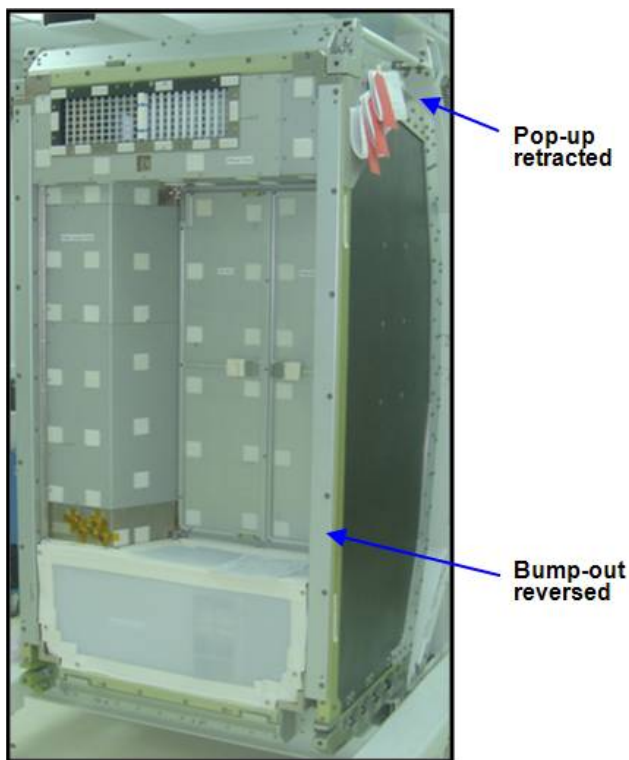


Figure 2. Launch configuration of CQ showing interior of bump-out without acoustic blankets.

The white squares of hook-and-loop fastener that are shown on the structure allow attachment of the acoustic blankets. The “raised” areas at the left side and the top are the intake ventilation duct system. The white mesh at the bottom is the blockage prevention net over the exhaust duct system. The intake and exhaust ducts each contain one fan with a tachometer and air flow sensor. The intake and exhaust fans are in series to provide redundancy and optimize thermal performance [1]. Electrical connectors, which are covered in protective tape, are the power and signal interfaces for fan status, power conversion, and egress lighting.

Figure 3 shows the exterior on-orbit configuration of the CQ with the acoustic blankets in place. The on orbit configuration provides 2.1 m³ of interior volume for the crew member. The black carbon fiber composite side panel, which is shown on the left, is not exposed to the aisle on orbit. The intake screen for the ventilation duct is located to the left of the door. The standard ISS rack power switch (RPS) is located below the intake screen.

The on-orbit configuration of the pop-up, which is shown in Figure 4, provides additional interior volume and head room for taller crew members. The white plastic material is part of the ultra-high molecular weight polyethylene (UHMWPE) radiation shielding material that is present in the pop-up and back wall of each CQ.

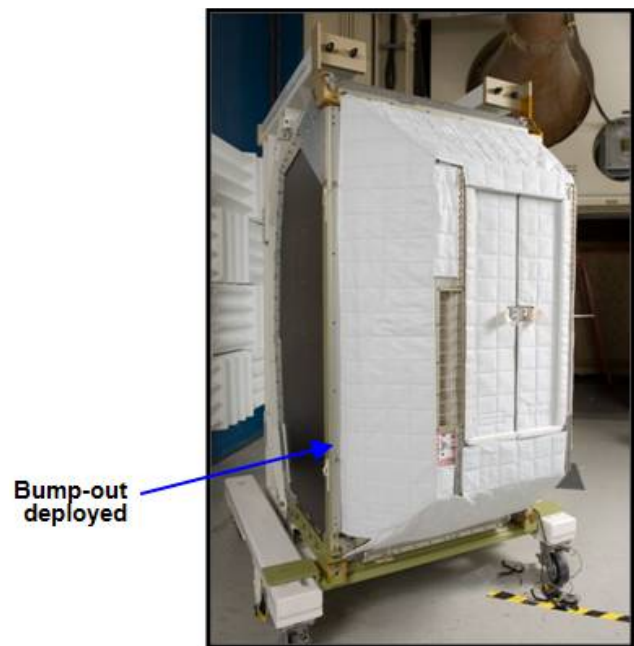


Figure 3. CQ on-orbit configuration in a rack handling adapter (white tubular structure) during acoustic certification tests.



Figure 4. Side view of CQ top showing the pop-up deployed configuration.

Electronics within the CQ are centrally located on the utility wall, thereby freeing up the back wall and opposite side wall for crew items. Note that the silver-colored back wall is additional UHMWPE material. The General Luminaire Assembly (GLA) on the side wall is mounted on tracks to allow crew adjustment in Figure 5. The computer work table (not present in Figure 5) location is also adjustable along the tracks. The white fabric tab at the top is the handle for pulling down the pop-up.

The interior of the CQ, with the white acoustic blankets installed, is much brighter over an interior in which just electronics are installed over bare walls. Figure 6 shows a fully outfitted utility wall (except for the computer table). Note that Figures 5 and 6 illustrate mirror image configurations of the CQ. These mirror configurations maintain the local vertical orientation in Node 2 between opposing CQs [1] across the aisle way.