

**International Space Station Mechanisms and Maintenance
Flight Control Documentation and Training Development**

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International Space Station (ISS) crew and flight controller training documentation is used to aid in training operations. The Generic Simulations References SharePoint (Gen Sim) site is a database used as an aid during flight simulations. The Gen Sim site is used to make individual mission segment timelines, data, and flight information easily accessible to instructors. The Waste and Hygiene Compartment (WHC) training schematic includes simple and complex fluid schematics, as well as overall hardware locations. It is used as a teaching aid during WHC lessons for both ISS crew and flight controllers. ISS flight control documentation is used to support all aspects of ISS mission operations. The Quick Look Database and Consolidated Tool Page are imagery-based references used in real-time to help the Operations Support Officer (OSO) find data faster and improve discussions with the Flight Director and Capsule Communicator (CAPCOM). A Quick Look page was created for the Permanent Multipurpose Module (PMM) by locating photos of the module interior, labeling specific hardware, and organizing them in schematic form to match the layout of the PMM interior. A Tool Page was created for the Maintenance Work Area (MWA) by gathering images, detailed drawings, safety information, procedures, certifications, demonstration videos, and general facts of each MWA component and displaying them in an easily accessible and consistent format. Participation in ISS mechanisms and maintenance lessons, mission simulation On-the-Job Training (OJT), and real-time flight OJT was used as an opportunity to train for day-to-day operations as an OSO, as well as learn how to effectively respond to failures and emergencies during mission simulations and real-time flight operations.

Nomenclature

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|----------------|---|
| <i>ACBM</i> | = Active Common Berthing Mechanism |
| <i>CAS</i> | = Common Attach System |
| <i>CBM</i> | = Common Berthing Mechanism |
| <i>CQ</i> | = Crew Quarters |
| <i>EVA</i> | = Extravehicular Activity |
| <i>FCPTT</i> | = Flight Controller Part Task Trainer |
| <i>FCT</i> | = Flight Control Team |
| <i>Gen Sim</i> | = Generic Simulations References SharePoint |
| <i>JSC</i> | = Johnson Space Center |
| <i>IFM</i> | = In-Flight Maintenance |
| <i>ISS</i> | = International Space Station |
| <i>IVA</i> | = Intravehicular Activity |
| <i>MCC</i> | = Mission Control Center |
| <i>MWA</i> | = Maintenance Work Area |
| <i>NASA</i> | = National Aeronautics and Space Administration |
| <i>OJT</i> | = On-the-Job Training |
| <i>OOM</i> | = On-Orbit Maintenance |
| <i>ORU</i> | = Orbital Replacement Unit |
| <i>OSO</i> | = Operations Support Officer |
| <i>PAS</i> | = Payload Attachment System |

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|--------------|---|---|
| <i>PCBM</i> | = | Passive Common Berthing Mechanism |
| <i>PMM</i> | = | Permanent Multipurpose Module |
| <i>PTT</i> | = | Part Task Trainer |
| <i>PWD</i> | = | Potable Water Dispenser |
| <i>RAM</i> | = | Repair and Maintenance |
| <i>SGMT</i> | = | Simulation Greenwich Mean Time |
| <i>SME</i> | = | Subject Matter Expert |
| <i>SSTF</i> | = | Space Station Training Facility |
| <i>SVMF</i> | = | Space Vehicle Mockup Facility |
| <i>UCC</i> | = | Unpressurized Cargo Carrier |
| <i>UCCAS</i> | = | Unpressurized Cargo Carrier Attachment System |
| <i>USOS</i> | = | United States On-Orbit Segment |
| <i>USRP</i> | = | Undergraduate Student Research Program |
| <i>WHC</i> | = | Waste and Hygiene Compartment |

I. Introduction

The OSO/RAM groups, DX42 and DX43, support all aspects of International Space Station (ISS) mechanisms and maintenance training and flight control operations. Areas of expertise include the Common Berthing Mechanism (CBM), Common Attach System (CAS), and USOS Intravehicular Activity (IVA) maintenance. The CMB is the attachment system used to mate and demate the ISS pressurized nodes, or modules. The CBM provides the structural load carrying capability and sealing interface that allows for transfer of people and material between modules. The CBM consists of two major assemblies: an Active CBM (ACBM) and a Passive CBM (PCBM). The ACBM is on the orbiting segment, while the PCBM is on the new element to be mated. The CAS is used on the ISS to support payload and Unpressurized Cargo Carrier (UCC) logistics functions by providing a remotely operated mating and structural attachment point with connections for power and data. There are two types of CAS on board the ISS: the Unpressurized Cargo Carrier Attachment System (UCCAS) and the Payload Attachment System (PAS). A total of six CAS sites are available, with two UCCAS sites on the Port 3 truss segment and four PAS sites on the Starboard 3 truss segment. The UCCAS and PAS sites are identical except that the UCCAS contain a redundant Integrated Motor Controller Assembly for both the Capture Latch Assembly and Umbilical Mechanism Assembly.

OSO/RAM also works closely with Crew Systems hardware, including Crew Quarters (CQ), Waste and Hygiene Compartment (WHC), and Potable Water Dispenser (PWD), as well as Photo/TV. “OSO” (Operations Support Officer) is a certified Flight Control Team (FCT) position, and “RAM” (Repair and Maintenance) is a certified Space Station Training Facility (SSTF) position. Responsibilities fall under two divisions: training, carried out by the RAM group, and flight control, carried out by the OSO group. The RAM group is responsible for training astronauts, flight controllers, and instructors while utilizing the Space Vehicle Mockup Facility (SVMF), Part Task Trainer (PTT), Flight Controller Part Task Trainer (FCPTT) and the SSTF. The OSO group is responsible for flight control operations including OSO console support, In-Flight Maintenance (IFM) procedure creation and support, new system hardware design, installation and support, and existing systems hardware troubleshooting and maintenance. The focus of this project was to develop ISS crew and flight controller training documentation, develop flight control documentation, and participate in ISS mechanism and maintenance lessons, as well as on-the-job training (OJT).

II. ISS Crew and Flight Controller Training Documentation

Responsibilities of the RAM group include training astronauts, flight controllers, and instructors, as well as creating and maintaining ISS crew, flight controller, and instructor training documentation. These documents include lesson plans, facility requirements, training aids, handouts, and electronic databases. They are then used to aid in training operations ranging from classroom and SVMF instruction to flight simulations. There are also many different types of flight simulations that range from generic increment operations to flight specific tasks. Flight simulations require a specific type of training documentation. In order to prepare and execute a successful simulation, the instructors need information about the simulation in a well organized, consistent, and easily accessible database. This portion of the project included creating a training schematic to be used as a teaching aid during crew and flight controller training for the WHC. A SharePoint site was also created to be used as a database to aid RAM instructors and OSO flight controllers during preparation, setup, and execution of generic flight simulations.

A. Waste and Hygiene Compartment Training Schematic

The WHC training schematic was created to be used as a teaching aid during crew and flight controller lessons along with the WHC training mockup located in the SVMF. The schematic itself includes three main sections: a simplified fluid schematic, a complex, detailed fluid schematic, and overall Orbital Replacement Unit (ORU) locations within the WHC. The first step in creating such a schematic was to gather and become familiar with existing flight controller documentation for the WHC, such as summary sheets, OSO console handbooks, and lesson handouts. The next step was to attend the WHC lessons in the SVMF and become familiar with the WHC itself through hands-on instruction. These lessons included WHC Systems Overview, WHC Nominal Operations, and WHC Maintenance Skills. During these lessons, it became apparent what information would be helpful for the instructor to have readily available. The last steps were to update existing references, meet with the WHC Subject Matter Expert (SME) to determine the final information to be included on the schematic, and finally produce the schematic itself. The training schematic now resides in the SVMF with the WHC training mockup for use during crew and flight controller lessons.

B. Generic Simulations References SharePoint Site

The Generic Simulations References SharePoint (Gen Sim) site is a reference database used as an aid to prepare and carry out flight simulations. The Gen Sim site consists of a homepage including a summary table containing flight times and increments for each individual simulation. The homepage also includes a discussion board for instructors, as well as templates and instructions for scripting new simulations. Each simulation also has its own page which is accessible from the homepage. Each simulation page is constructed with a consistent layout that includes relevant simulation information. This information includes Simulation Greenwich Mean Time (SGMT) start and end times, datastore sheets, rack topology, upcoming flight information, daily summary, handover logs, and simulation specific products. The SGMT times give the exact times that the simulation will start and end. The datastore sheets contain the simulated telemetry to be used during the simulation. Rack topology documents summarize the layout of the racks in each module of the ISS. The upcoming flight information, daily summary, and handover logs give further details of the segment of a mission being simulated, the state of the ISS, and a summary of activities leading up to the simulation. The process used to create the Gen Sim database first required participating in a mission simulation from the RAM instructor standpoint. The next step was to note the vital information needed to prepare and execute a successful simulation. After determining the necessary information with the RAM instructors, the template for the homepage and each simulation page was created. Finally, the pages were populated with existing simulation documents gathered from various locations.

III. ISS Flight Control Documentation

Responsibilities of the OSO group involve all aspects of flight control operations including OSO console support, In-Flight Maintenance (IFM) procedure creation and support, new system hardware design, installation and support, existing systems hardware troubleshooting and maintenance, and flight control documentation creation. These documents are used to support ISS mission operations and include console handbooks, summary sheets, procedures, and electronic databases. The purpose of the documentation is to quickly provide information to the OSO flight controllers in real-time in order to improve discussions with the Flight Director and CAPCOM. This portion of the project included creating imagery-based reference Quick Look page for the Permanent Multipurpose Module (PMM). A Consolidated Tool page was also created as a reference for the Maintenance Work Area (MWA).

A. Permanent Multipurpose Module Quick Look

The PMM Quick Look page was created to be used as a reference database for OSO flight controllers during real-time ISS mission operations. The page is organized in schematic form to match the layout of the interior of the PMM. The overview of the module is organized into zenith and nadir endcones, as well as standoffs and rack bays sorted by port, aft, starboard, and forward directions. Each endcone is then sorted into port, aft, starboard, and forward panels. The ORUs on each panel are then listed along with multiple images. The images show the ORUs from different angles in order to give the OSO flight controller good views of the fasteners and power/data ports used. The first step in creating this database was to meet with the PMM SME and determine what layout would be best and which ORUs to include. The next step was to gather and organize images including multiple views of the interior of the PMM, as well as multiple views of each ORU. Finally, the pages were created and approved by the SME and are now accessible to OSO flight controllers on console. Forward work for the PMM Quick Look page includes developing and populating appropriate templates for the individual rack and hardware locations once the PMM is on-orbit and installed on the ISS.

B. Maintenance Work Area Consolidated Tool Page

The MWA Consolidated Tool page is a database used to aid OSO flight controllers during real-time flight and maintenance activities involving a frequently utilized work platform aboard the ISS. The MWA consists of four main components: the Work Surface Area, Containment System, Utility Kit, and Utility Strip. The database consists of a homepage including descriptions of each of the four components that make up the MWA, including pictures showing the MWA installed and in various configurations, utilizing all the major components. Also included on the home page is MWA safety information, procedures, and technical data. The safety information includes the minimum margins of safety allowed for use with the MWA. Also included is a link to the procedures detailing MWA installation on-orbit. The technical data provided includes, weight, volume, power, lifetime, and strength and fracture calculations of the MWA. The final details on the homepage include certifications for use of the MWA, as well as videos demonstrating use of the MWA.

Each of the four main components has its own page that can be accessed from the homepage. Similar to the homepage, each individual component page consists of the following sections: components, pictures, safety, usage, procedures, technical data, certification tests, usage videos, and additional relevant data. The pages were created with a consistent layout in order to aid the OSO flight controllers in knowing where to quickly find the information they need. The process used to create the MWA Tool page first required gathering and becoming familiar with existing flight controller documentation for the MWA, such as summary sheets, OSO console handbooks, and lesson handouts. The next step was to participate in MWA crew and flight controller lessons and to note the vital information presented during the lessons. After determining the necessary information with the MWA SMEs and instructors, the template for the homepage and each of the components were created. Finally, the pages were populated with existing photos, procedures, engineering drawings, certifications, usage videos, and general information.

IV. ISS Mechanisms and Maintenance Lessons

Part of the training process for the OSO/RAM groups includes participating in various classroom, as well as SVMF, crew and flight controller training lessons. These lessons are divided into On-Orbit Maintenance (OOM), Crew Systems, Mechanisms, and Photo/TV categories. The purpose of these lessons is to provide an overview of crew and flight controller training of ISS mechanisms, maintenance, crew systems, and photography/TV. A beneficial result of these lessons are providing students with hands on experience utilizing and maintaining the various systems the OSO/RAM groups are responsible for. Another valuable product of participating in these lessons is gaining insight into RAM instructor's roles as crew and flight controller trainers. The OOM, Crew Systems, and Photo/TV lessons utilize a more hands-on method of teaching, most commonly used for ISS crew training, while the Mechanisms lessons provide more ground operator based training. The Mechanisms lessons provide experience as an OSO flight controller and mechanism operator. This experience includes OSO console display monitoring, navigation, and commanding. Finally, the most relevant benefit of these lessons is to provide better understanding of ISS mechanisms and systems in order to develop ISS training and flight control documentation.

V. Mission Simulation and Real-Time OJT

On-the Job Training (OJT) at the SSTF and Mission Control Center (MCC) is an integral part of operations within the RAM and OSO groups. It is designed to provide initial experience during simulation and real-time flight operations, as well as to provide continued exposure in order to enhance skills as a RAM instructor and OSO flight controller. Mission simulations and real-time operations have a wide variety of content that range from daily maintenance activities aboard the ISS, to major mechanism commanding, such as operation of the CBM during installation of a new module to the ISS, or securing an external payload with the CAS system. During mission simulations and real-time operations, RAM instructors are looking for the flight controllers to utilize a basic process while supporting ISS activities. The basic process OSO flight controllers use to approach any issues that may arise during maintenance or mechanism operation is the failure, impact, and workaround approach. The first step is to identify the initial failure during operations. From that point, the impacts of that failure are assessed. Flight controllers determine how crew safety, hardware, and mission objectives are affected. Finally, workarounds are proposed, further discussed, and finalized. Along with the knowledge and experience gained during simulation and real-time OJT, confidence building is part of the main goal of participating in OJT.

VI. Conclusion and Forward Work

ISS mechanisms and maintenance training and flight control are the main responsibilities for the RAM/OSO groups. Crew, instructor, and flight controller training is led by the RAM group, while flight control operations and support are led by the OSO group. Tasks within these groups include flight controller and training reference documentation development, as well as participation and instruction of ISS mechanisms and maintenance lessons and simulation and real-time OJT. As part of this project, training documents were created for the WHC and Gen Sim references. Flight control reference documentation was also created for the PMM and MWA.

Forward work and requirements of this project include maintaining and updating the training reference documentation created for the WHC and Gen Sim site. Upon creation of new generic simulations, existing Gen Sim site templates can be followed to compile documents for inclusion of the new sim into the existing site. Additionally, the flight control reference documentation for the PMM and MWA will require maintenance and updating. After the PMM is on-orbit, installed on the ISS, and final rack locations determined, the Quick Look site will be modified to include up-to-date rack configurations and will require appropriate photos reflecting those configurations. The MWA tool page may also be updated with any additionally acquired technical, safety, and usage information, as well as including any new procedures developed that utilize the MWA.

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