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## Payload Operations

### Introduction

The objective of this paper is to provide the future ISS scientist and/or engineer a sense of what ISS payload operations are expected to be. This paper uses a real-time operations scenario to convey this message. The real-time operations scenario begins at the initiation of payload operations and runs through post run experiment analysis. In developing this scenario, it is assumed that the ISS payload operations flight and ground capabilities are fully available for use by the payload user community. Emphasis is placed on telescience operations whose main objective is to enable researchers to utilize experiment hardware onboard the International Space Station as if it were located in their terrestrial laboratory. An overview of the Payload Operations Integration Center (POIC) systems and user ground system options is included to provide an understanding of the systems and interfaces users will utilize to perform payload operations. Detailed information regarding POIC capabilities can be found in the POIC Capabilities Document, SSP 50304.

### POIC Systems and User Interface Options

The Payload Operations and Integration Center (POIC) is an International Space Station (ISS) facility that manages the execution of on-orbit ISS payloads and payload support systems in coordination with the Mission Control Center in Houston (MCC-H), the distributed International Partner (IP) Payload Control Centers (PCCs), Telescience Support Centers (TSCs), and payload-unique facilities. The POIC is comprised of the Payload Data Services System (PDSS), the Enhanced Huntsville Operation Support Center (HOSC) System (EHS), the Payload Planning System (PPS), and the Enhanced Mission Communications System (EMCS). PDSS acquires, stores, and distributes ISS data to the EHS, IPs, TSCs, and other payload-unique facilities. The EHS performs command processing and real-time and near-real-time telemetry processing for pre-launch integration and checkout, simulation training, and flight operations. The EHS also provides a Payload Information Management System (PIMS). The PPS provides a set of software tools to automate planning and schedule payload activities. The EMCS receives voice, video, and data from external interfaces and distributes voice and data to the POIC user community. Downlink video is distributed to the payload user community by JSC. Figure 1-1 illustrates the relationship of the POIC and its systems with the ISS, MCC-H, and the POIC user community.

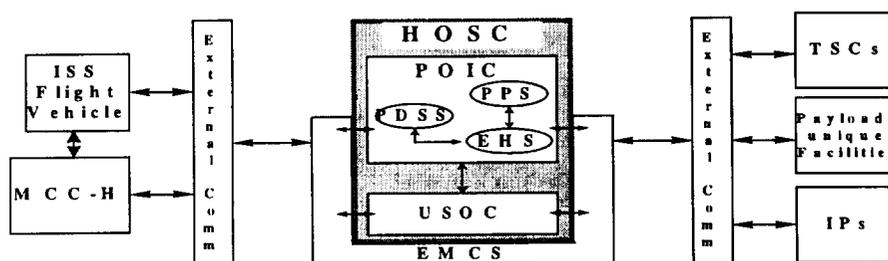


Figure 1-1. POIC Context Diagram

The POIC and its supporting systems (PDSS, EHS, PPS, and EMCS) reside primarily within the Marshall Space Flight Center (MSFC) HOSC. The United States Operations Center (USOC) also resides within the HOSC and provides an ISS host facility where payload users can choose to control and monitor the operations of the onboard payloads instead of being located remotely.

Users choosing remote access to POIC capabilities and interfaces are provided several options. Some of the options available are:

- obtain a copy of the EHS software to be run at the user's site
- access POIC capabilities through X-Windows and Web interfaces
- develop Ground Support Equipment (GSE) software to interface with the POIC systems
- use the Telescience Resource Kit (TReK)
- or use a combination of any of the above.

For the purposes of this paper, the option that will be discussed in the scenario will be the TReK option. The POIC Capabilities Document should be referenced for further information regarding other options. The TReK option is suitable for small payload and/or experiment teams or individuals that require minimal ground support tools in order to monitor and control low data rate payloads. It is intended to support a single individual. In a team setting, each individual on the team would need a TReK platform. Each TReK platform operates independently from other TReK platforms. A TReK system is a personal computer (PC) configured with Commercial Off The Shelf (COTS) software, shareware, freeware, and Marshall Space Flight Center (MSFC) Mission Operations Laboratory (MOL)-developed software to provide the same basic functions as a workstation located within the POIC. Hence a remote user has the same set of capabilities that are provided to a user that resides in the POIC. TReK users have local control over their systems, and as such also have responsibility for system configuration, system management, and security. TReK provides users telemetry acquisition, processing, storage, monitoring and manipulation capabilities. TReK also provides users command and database capabilities, along with several standard utilities (such as a web browser, electronic mail, word processing, etc). Since TReK is a commercial PC and TReK users have control over their system, they are free to add other software products (user developed or COTS) to their TReK system that they find useful in their operations activities. To provide POIC-like capabilities, TReK utilizes POIC interfaces to access real-time telemetry, to send and receive commands, and transfer files between TReK and the POIC. TReK also provides access to POIC capabilities to request real-time and stored telemetry, access to the Payload Information Management System, access to the POIC telemetry and command databases, and voice communications.

## ***Prologue***

Dr. Reilley Smart, a professor at the University of Greater Knowledge, is the Principal Investigator on a station experiment studying fluid physics. There are three people on Dr. Smart's team. His primary assistant Lois is a graduate student at the University of Greater Knowledge. Dr. Smart's experiment uses a special test cell that is placed in the Fluid Physics Facility Processing Apparatus which is located in an EXPRESS Rack in the US Element. This Facility provides the electrical interfaces, computer control, temperature control, and video support services required to conduct his experiment operations. A typical operations scenario involves the Facility Engineer activating the Facility, then the crew installing the test cell in the chamber. The experiment team then activates the experiment by ground command and initiates a computer program which sends commands to the facility and test cell to execute a series of test profiles. During the course of these profiles, telemetry data and downlink video are transmitted to the ground for real-time monitoring of experiment performance by Dr. Smart and his science team at the University. Adjustments to the profile can be made in real-time via ground commands from the science team. If communications coverage is not available, telemetry and video from the test can be recorded onboard and later downlinked to the science team for subsequent analysis. After completion of the experiment run, the science team sends commands to deactivate the test cell. The crew then removes the test cell and stows it for future experiment performances and the Facility Engineer deactivates the facility. Based on their analysis of test results, Dr. Smart can modify the computer file containing the test profile to adjust profile parameters for future experiment runs.

## ***Real-time Operations Scenario***

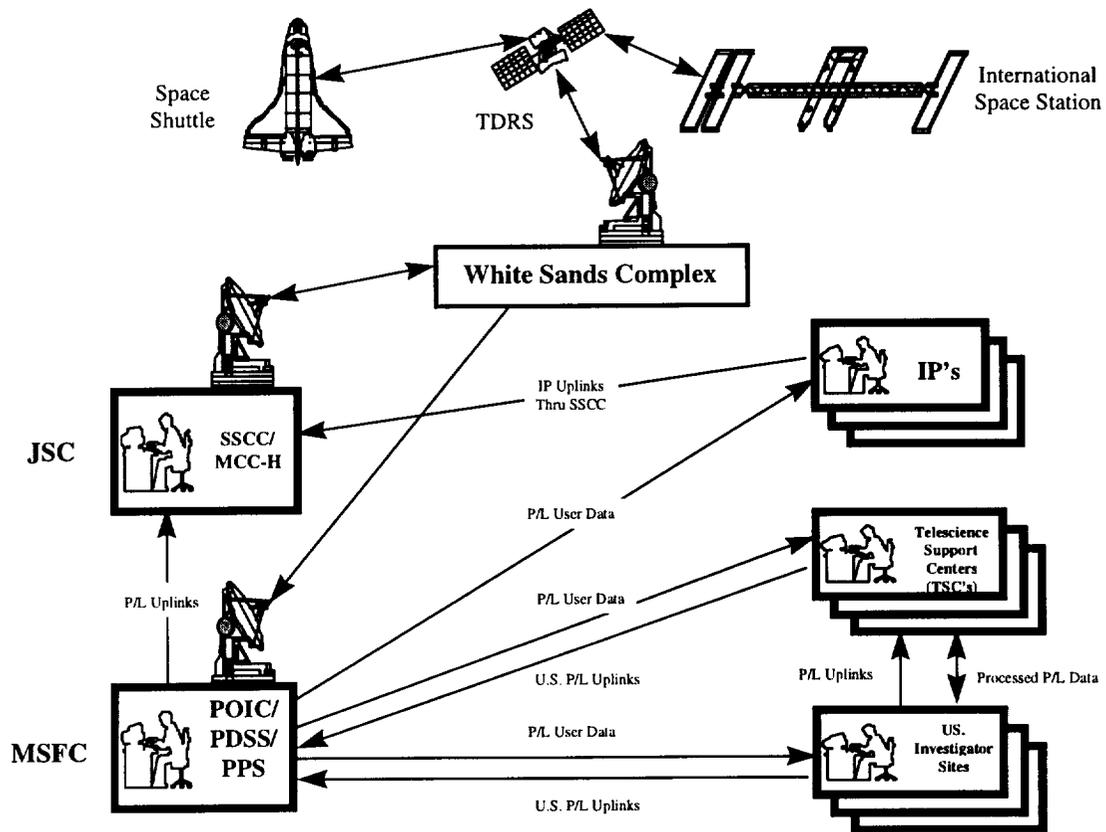
### **Execution Preparation**

The first time we dropped in to see Dr. Smart, he and his science team were preparing for an upcoming performance of their experiment. During their run the previous week, Dr. Smart's graduate student Lois used their TReK system to record the telemetry that was downlinked during the run. During the week the team analyzed the data using their favorite COTS software and decided to make some modifications to enhance science results during their next run. They identified the changes in an Operations Change Request which is part of the POIC Payload Information Management System (PIMS). PIMS is an electronic information management system used by payload users, POIC cadre, and others for increment preparation and execution. The primary purpose of PIMS is to provide centralized payload operations information management for controlling changes to payload operations and managing the products required to support operations execution. To submit the Operations Change Request, Lois used their TReK web browser to connect to PIMS and submit the Operations Change Request. The change request was reviewed and approved for implementation by the POIC cadre. The team was moving out to implement all of the changes required to prepare for the next run. The computer profile was modified to make some of the required adjustments. Lois accessed PIMS to transmit the revised profile to the POIC for uplink to the Space Station. She also updated the crew procedures in PIMS to reflect some changes required to support the revised operations scenario and used PIMS to send the procedures update to the POIC.

Prior to the run, refresher training was scheduled for the crew to review the installation and removal procedures for the test cell since it had been a long time since they had received training on this hardware and experiment. Additionally, Dr. Smart had requested that the crew monitor the experiment run and provide some real-time feedback to the science team regarding details of the fluid phenomena they were trying to see. The science team had prepared a short instructional video discussing and illustrating the science they were looking for, what specific details they wanted the crew to look for and how they wanted the crew to respond. This video had been transmitted to the POIC and was uplinked to the station to support the refresher training session. Lois used the TReK web browser to access the Payload Planning System to retrieve the Short Term Plan for the upcoming week. By looking at the Short Term Plan the team knew they would be running on Wednesday, and would find out Monday afternoon the specific scheduled time. Until then, it was back to the classroom.

### **Experiment Execution**

Our next visit to Dr. Smart wasn't scheduled till 2:00 Wednesday afternoon, but we got there a little early. Dr. Smart and his science team were gathered in the lab making final preparations for their next run. We asked the team several questions regarding how their telemetry was sent to them and how they commanded their payload. Dr. Smart drew figure 2 on the board.



Dr. Smart indicated that their Space Station telemetry is downlinked from the Space Station via the Tracking and Data Relay Satellite to the White Sands Facility where it is then sent to MSFC's PDSS. The PDSS then transmits the telemetry directly to their university where it is routed to their TReK workstation. On the other hand, their commands are sent to the POIC's EHS where it checked to ensure that there are no hazardous commands and that the source and destination of the commands are valid. The EHS then forwards the commands to JSC's MCC-H where it is sent to White Sands, uplinked to TDRS, and then to the Space Station. Dr. Smart also mentioned that he received command responses that let him know that his command was successfully received by JSC and then the onboard flight system. Dr. Smart also indicated to us that he is required to identify his telemetry and command requirements preflight, to ensure that communication links are properly established between his university and the MSFC. As part of this input, his team arranged to receive multiple telemetry streams from PDSS.

Dr. Smart then focused our attention on Lois who was setting up their TReK system to capture the telemetry they were interested in for this run. Although PDSS would be sending them several telemetry streams, they were only interested in one of the streams for this run. Lois started the TReK telemetry processing software and identified the stream they were interested in. She knew that they wanted to record the stream, but decided she would wait and turn the recording on once they got to the important part of the run. Since they weren't interested in analyzing the data from the first part of the run there was no need to record it. She knew that if they decided they wanted the data at a later date, they could always use their TReK web browser to access POIC services to submit a request to have PDSS redistribute the data.

While Lois was finishing her preparations for the upcoming run, we got a briefing about the latest operations activities. The refresher training that morning went great. The crew watched the video and then stepped through the procedure updates. Since they had a few questions, the POIC enabled Dr. Smart on the Air-to-Ground voice loop. Since the team's TReK system is equipped with voice communications

software and a microphone, Dr. Smart used it to communicate with the Crew to discuss the changes and answer their questions. After the voice conference with the Crew, everyone felt more prepared and ready for the next run. She then accessed PIMS to store the command file she had created earlier that contained the revised profile information and the commands that would start the automated experiment run. A few minutes later she accessed the TReK command software to verify that the file had been uplinked.

Since Dr. Smart had concluded the briefing, we turned our attention back to the team. They were now completing their standard pre-support communications checks. During our briefing with Dr. Smart, they ran into a few problems with the communications lines. They contacted the POIC Communications team over a voice loop to work the problem. After a few minutes, the problem was resolved and now they were ready to go.

Right on schedule, telemetry started to appear on the telemetry displays. Everything looked nominal - the EXPRESS Rack and Fluid Physics Facility Processing Apparatus were powered up and telemetry indicated they were ready for the experiment run. The voice loop on their TReK system came alive with a call from the Facility Engineer reporting the facility had been activated by the crew and they were starting to install the test cell per the revised crew procedures. A few minutes later, Lois heard over another voice loop that she had been enabled for ground commanding, so she was ready to complete the ground portion of the experiment activation as soon as the crew finished installing the test cell. Per the procedures, the crew called down on the Air-to-Ground voice loop and reported that the test cell was installed and ready to go.

At this point, Lois called up several displays on the TReK system to verify the experiment configuration. She then proceeded to send the commands to the experiment to complete the experiment activation. As she sent the commands, she verified their receipt and execution by monitoring the downlink telemetry on one of the displays.

As scheduled, the video appeared on her monitor and Lois turned on the VCR. Using the voice loop she made one last call to the POIC to have the cadre relay to the crew that they needed to be available in 10 minutes to monitor the experiment run and voice down their observations. Dr. Smart and his science team intently watched the TReK displays as the data came in. A few days ago they had built some new displays that used both tabular layouts and graphs to display the data. They could see that their new displays were an improvement over their earlier ones. Since they were now coming up on the important part of the run, Lois turned data recording on so their TReK system would record the telemetry stream for later analysis.

Twenty minutes later...

Since their TReK system was equipped with an Acquisition of Signal/Loss of Signal (AOS/LOS) prediction utility, Lois could see that they were coming up on a Loss of Signal. According to the schedule the Loss of Signal was expected to last about 10 minutes. Lois knew that they would not lose any data. The data would be captured on board the station and then dumped to the ground. When the data was dumped to the ground PDSS would distribute the data and tag it as dump data. The time period of the downlink of the dump data is in the data flow timeline. The team would then be able to receive the real-time data stream simultaneously with the Dump (recorded) data stream and have their TReK system record both streams at the same time.

During the LOS, Dr. Smart and his team did a quick analysis of the experiment progress and discussed any changes to the experiment settings that needed to be made when they regained communication with the experiment.

Just prior to the AOS period, Lois verified that the dump is scheduled to start just after AOS. She configured the TReK system to receive the Dump telemetry stream in parallel with the real-time stream. A few minutes later, when they entered the AOS period, they were receiving and recording both the real-time stream and the dump stream simultaneously. A short time later, the Facility computer finally

reached the end of the automated profile and sent a message in the telemetry stream to announce that the run was complete. Lois turned off the VCR and then started the deactivation procedure. Upon completion of the ground commanded portion of the procedure, she used the voice loop to notify the POIC cadre and Facility Engineer that she was ready for the crew to remove the Test Cell and was handing the rest of the operations over to the Facility Engineer. The POIC cadre notified the crew who then completed their part of the operation, including removal and stowage of the test cell. After the crew told the cadre they were done, the Facility Engineer then completed the deactivation of the Facility. Meanwhile, Lois wrapped things up in the lab and headed out to study for midterm exams.

## Post Run Experiment Analysis

We just happened to walking by the lab a few days later and noticed the door was open. Dr. Smart and Lois were staring intently at a graph on their TReK system. They told me that they had just received some data from PDSS that filled in some gaps. Dr. Smart had analyzed the data and video from the experiment run and thought they were getting really close. The crew had given them some really valuable insight into what was really happening, things they just couldn't get from the video and data. For their next run, he wanted to make some slight adjustments to the profile and leave everything else the same. He needed to get in the Operations Change Request for a file uplink of the revised profile and he needed to include a few changes in the Short Term Plan. No big deal... business as usual.

## **Conclusion**

This fictional scenario used a simplistic approach to convey the payload operations capabilities available to remote users and to convey the relationship between the remote user and the cadre. Detailed information regarding TReK and other POIC capabilities is available in the POIC Capabilities Document. This document is available on the Web at <https://red-dwarf.msfc.nasa.gov>. Information regarding TReK hardware and software configurations, schedules, software, and documentation is available from the TReK Web site at <http://snail.msfc.nasa.gov/trek/trekfrme.htm>.