

# Enhanced International Space Station Ku-Band Telemetry Service

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**The International Space Station (ISS) is in an operational configuration. To fully utilize the ISS and take advantage of the modern protocols and updated Ku-band access, the Huntsville Operations Support Center (HOSC) has designed an approach to extend the Ku-band forward link access for payload investigators to their on-orbit payloads. This dramatically increases the ground to ISS communications for those users. This access also enables the ISS flight controllers operating in the Payload Operations and Integration Center to have more direct control over the systems they are responsible for managing and operating. To extend the Ku-band forward link to the payload user community the development of a new command server is necessary. The HOSC subsystems were updated to process the Internet Protocol Encapsulated packets, enable users to use the service based on their approved services, and perform network address translation to insure that the packets are forwarded from the user to the correct payload repeating that process in reverse from ISS to the payload user. This paper presents the architecture, implementation, and lessons learned. This will include the integration of COTS hardware and software as well as how the device is incorporated into the operational mission of the ISS. Thus, this paper also discusses how this technology can be applicable to payload users of the ISS.**

## I. Introduction

THE International Space Station (ISS) program is diligently working to increase utilization of the resources this unique laboratory provides. Increasing the operation of experiments means making the Payload Developer's (PDs) onboard equipment more accessible to the PD team. The recent onboard upgrades provided a 25Mbps forward link and a 300Mbps return link across the Ku-band communications equipment. Included in the same upgrade was the ability to use the Internet Protocol (IP) Encapsulation (CCSDS 133.1-B-2) standard. Personnel within the Huntsville Operations Support Center (HOSC), location of the ISS Payload Operations and Integration Center (POIC), at the Marshall Space Flight Center (MSFC), are taking advantage of the increased bandwidth available to extend the onboard ISS Payload Local Area Network (LAN) to the Payload teams.

In defining the capability to extend the onboard LAN to the ground, it was important that the onboard payload system look and feel, to the PD team, as if they were onboard performing the experiment with a Payload LAN workstation. To make this possible the HOSC team developed the HOSC Payload Ethernet Gateway (HPEG).

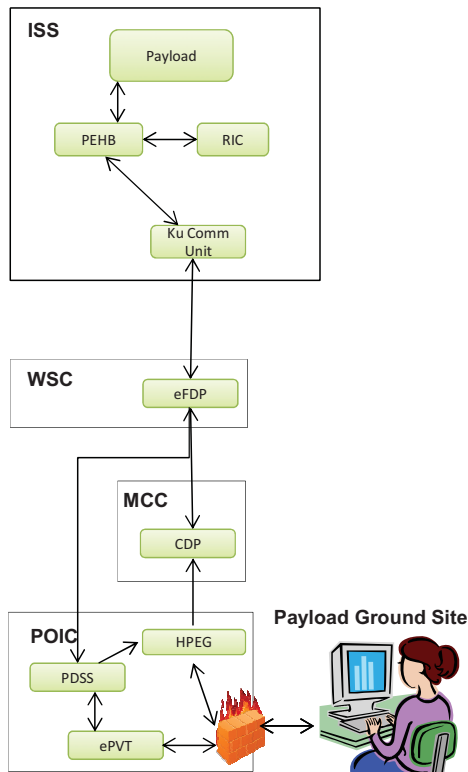
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**Figure 1. Systems used to enable payload users to take advantage of the Ku-forward link service.**

HPEG bridges the ground users with their onboard payload using standard IP traffic. This paper presents the architecture, implementation, and lessons learned for the HPEG and the extension of the onboard LAN to ground users.

## II. Background

The Obsolescence Driven Architecture Redesign (ODAR) project completed spring of 2013, enables use of the Consultative Committee for Space Data Systems (CCSDS) IP Encapsulation standard for communications. ODAR enhancements also included increased forward (25Mbps) and return link (300Mbps) data rates. More bandwidth for communications enabled the POIC to extend the use of the Ku-forward link as a path to onboard payloads.

Figure 1 outlines the end-to-end data flow for the Ku-forward link service. Starting with the payload the data flows forward in this manner:

1. The Payload User initiates connection using standard applications through IP packets.
2. HPEG service checks that the user is trying to send to an authorized destination and port. After verifying the user traffic, the HPEG will translate the address and forward for IP encapsulation and inclusion in the POIC forward link connection.
3. The Mission Control Center in Houston (MCC-H) manages the aggregated forward link. The Communications Data Processor (CDP) takes the POIC and MCC-H forward link traffic, insuring it does not exceed 25Mbps, and sends the data onward to the ISS.
4. A POIC managed device, the enhanced Functionally Distributed Processor (eFDP),

completes the formatting required to place the data on the Radio Frequency (RF) link.

5. Once onboard the Ku Communications Unit pulls the IP packet back out and places it on the Payload LAN to be received by the payload.

Communications on the Ku-return link follow the same path onboard just in reverse. It is on the ground where it changes little. Payload return data is sent directly to the POIC.

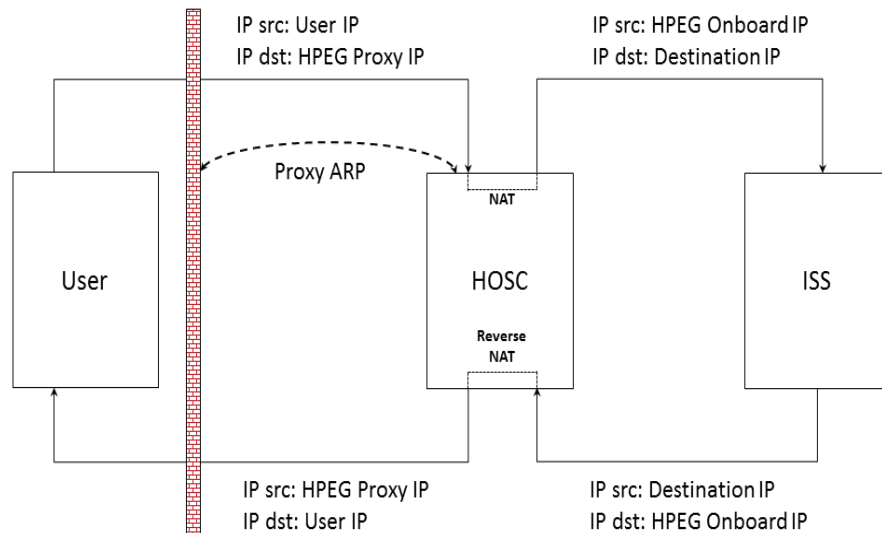
1. The Payload sends the IP packets to the Ku Communications Unit.
2. Once on the ground, the eFDP pulls out the payload traffic and forwards it to the POIC for processing.
3. The Payload Data Services System (PDSS) server forwards the traffic related to the Ku-forward service to the HPEG.
4. The HPEG then reverse translates the packets putting the payload user addresses back into the IP header and sends the packet to the user.

## III. Phase One System Modifications

Changes to the onboard and ground systems are being implemented in a phased approach. Phase I allows the POIC flight team, also know as the Cadre, access to the use of IP protocols on the forward link. The Cadre are helping to verify the changes made to the system. This also provides them an opportunity to tweak operations procedures regarding the management of the service for users. Phase II enables remote payload users access to begin using the IP protocols. Phase II also introduces the use of the CCSDS File Delivery Protocol (CFDP) [CCSDS 727.0-B-4] for initial use by the Cadre. In Phase III all capabilities are available for all users. The majority of systems changes were made and installed within the systems in the POIC.

### A. Packet Routing Example

Before exploring the changes to the rest of the system, it is important to introduce how the packets are managed to be correctly translated between the ground and onboard systems. Performing a Network Address Translation (NAT) is required to prepare the packets for routing on the destination LAN. The HOSC systems will provide the NAT for packets being placed on the Ku-forward link. For Ku-return link traffic a reverse NAT is performed to send the packets back to the user. NAT is not a new concept, but understanding how it is used will provide insight to later system change discussions. The NAT modifies the IP address fields in a IP packet so that the packet is now routable in the address space the packet is entering. If this translation did not occur, the onboard system would reject the packet when it was unpackaged from the IP Encapsulation frame in which it was transported. Figure 2 illustrates this process. Traffic accepted from the user has the HOSC provided Proxy IP address as the destination and the user IP address as the source. Within the HOSC system the source IP is translated to a recognized, routable onboard address, and the destination IP is set to the Payload destination actual address. The HOSC system will then work in reverse by taking the onboard addresses from the return packet and translating them back to the appropriate ground addresses and ship the packet to the payload user.



**Figure 2. Shows the IP address translation required for Payload users IP traffic to be routed correctly between onboard and ground systems.**

## B. POIC System Enhancements

The Ku-forward system is composed of four different components. Two are, the Ku Session Service and Ku Proxy Service, running on the External Private (ePVT) servers and one is, the HPEG Service, running on an internal operational server. The fourth component is the different user session status interfaces provided. Figure 3 diagrams the components and the data flows between them.

Each client session will have its own instance of a Ku Session Service and a Ku Proxy Service. (Note: The description of the Ku-forward system services in this section reflect the Phase I design. A later section describes the considerations and changes for Phase II of the installation.)

### 1. Ku Session Service

After the user authenticates with the HOSC systems, the user will begin the process of establishing a Ku-forward session by connecting to the Ku Session service. This service, through a defined interface outlined in the Payload to Generic User Interface Definition Document (PGUIDD), shows the user which destinations and protocols are available to that user. Once the destination for that session has been selected, the user will start the session and receive a Proxy IP address. This is the address to which the user will forward their IP traffic. In effect, this becomes the address of the server for that user. The proxy address is an address assigned from a pool of addresses that the HOSC systems will recognize and accept. Also assigned at this time is the HPEG onboard IP address. This IP address is used to translate the HOSC system to an address recognized by the ISS onboard systems. It is also assigned dynamically from a preassigned pool of IP addresses made available to payloads. Figure 2 above shows the use of the proxy addresses. The session service also provides Ku-forward system information to the user. The information provided is Ku-band forward and return acquisition status, if the user is enabled to use Ku-forward service, and if the HPEG service is currently available. Users will take advantage of this status making sure the system is ready for operations with their payload. The ePVT box in Figure 3 shows where the service is running.

## 2. Ku Proxy Service

The Ku Proxy service is paired with a session service. When the user starts a session, a proxy service is started to “listen” for the IP traffic. A raw socket will grab the packets sent from the user, perform the NAT, and send the traffic forward, multiplexing into the Ku-forward link. Before a packet is forwarded it is first checked to insure that the Ku-forward link is in Acquisition of Signal (AOS), the packet has a valid port (an exception is Internet Control Message Protocol (ICMP) Ping that has no port), and the user is enabled for Ku-forward communications. If any of these conditions is not met, the traffic will be dropped. For a port to be valid, it must be negotiated between the ISS Program and the payload user. As part of the discussion, the ports and protocols are reviewed by the ISS Program Information Technology (IT) Security Team for the onboard systems. Secure protocols are preferred for use and a list of recognized, acceptable secure protocols has been drafted. A subset of those have been listed as part of the standard service. An example of an included protocol is Secure Shell. The Ku Proxy service also logs all traffic, for a short amount of time, to be used for analysis if the system appears to be forwarding traffic incorrectly.

## 3. HPEG Subsystem

As a subsystem, the HPEG provides forward & return services and monitor & control capabilities. The monitor & control piece configures the HPEG system and reports status to the EHS System Monitor and Control (SMAC) software. It also receives commands from SMAC to insure that the HPEG subsystem is managed as part of the larger system. The forward service receives packets from the Ku Proxy service and properly formats them for the Johnson Space Center (JSC) CDP. HPEG forward service also throttles the maximum output rate to the POIC pre-negotiated portion of the Ku-forward maximum. This is done to ensure the POIC is a good steward of the resources allocated to payloads and payload systems. HPEG Subsystem Return Service receives traffic sent from ISS and then translates and ships the traffic to the Ku Proxy service. The HPEG Subsystem is seen in Figure 3 in the OPS labeled box.

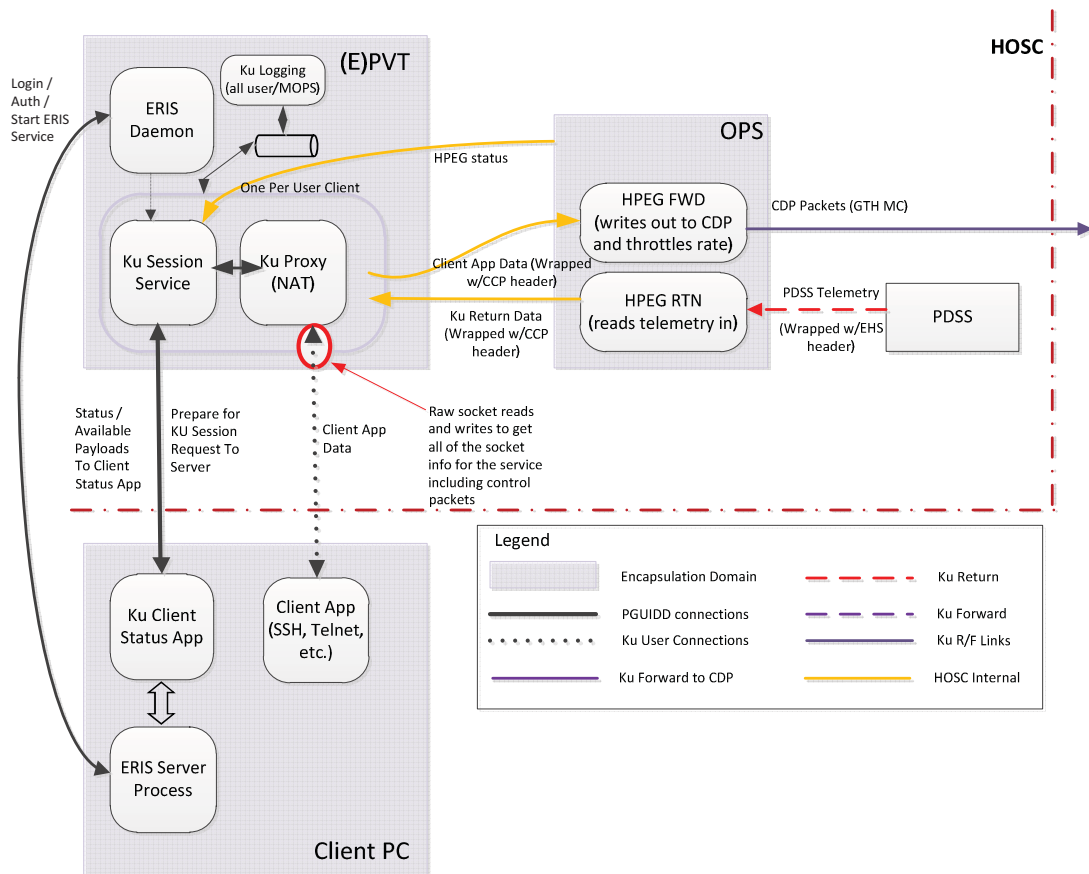
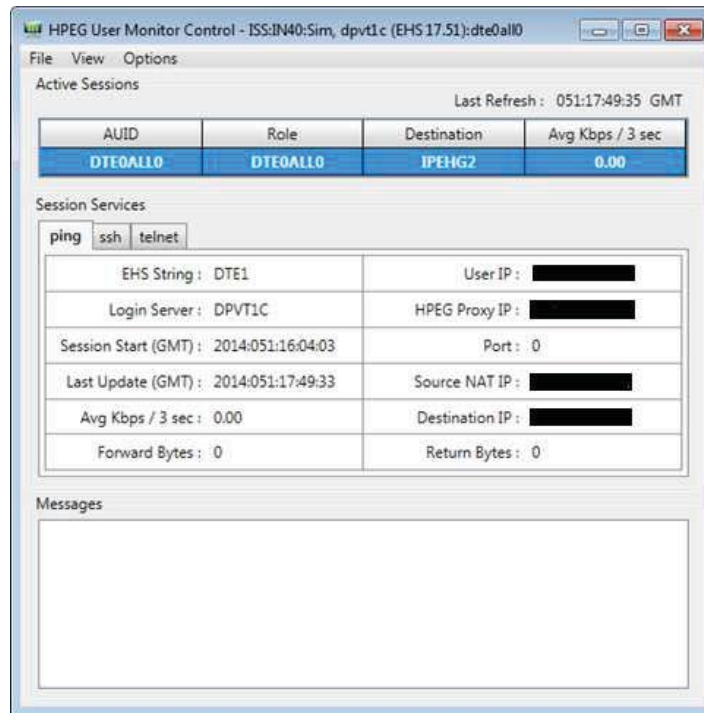


Figure 3. Ku-forward Service Data Flow

#### 4. Session Status User Interface

The user interface (Figure 4), used to assist the Cadre as well as POIC ground system controllers, monitors consumer usage of the HPEG system. This information is provided per user.

- AUID is the unique identifier for each user
- Role is typically the payload ID and will define the privileges for payload users.
- Destination indicates which location onboard the user is using.
- EHS String is which collection of equipment that user is operating from and indicates to the controllers in which activity the user is participating.
- The different IP fields help operators know which IP address to monitor if troubleshooting becomes necessary.



**Figure 4. HPEG User Monitor and Control User Interface provides operators insight into how the system is being used by each payload user.**

- Port will show which ports the user is using.
- Session Start time reflects when the user activity started.
- Last Update is changed each time the user performs a transaction.
- Data rate, shown as Avg Kbps/ 3sec) will be a very important field. This field will help the Payload Rack Officer (PRO) and Data Management Coordinator (DMC), two of the Cadre, insure that users are not exceeding their allocated data rate. In the event that a user is over running their allocation and impacting the traffic of other users, the PRO and DMC can coordinate to work with the user to insure the user can get back within their allocation. This screen will assist them finding which user to work with. The data rate calculation is averaged over three second intervals.
- Forward and Return bytes reflects the bytes sent and received.

#### IV. Phase II System Modifications

Phase II of the Ku-forward project adds an implementation of the CFDP application for payload users. This establishes when all users will have access to use Ku-forward for IP access to payloads. As with the Phase I changes, the first use of the CFDP will be by the Cadre. Having the Cadre use the service first provides time to use the service across the operational link verifying configurations and tuning is correct.

Making the CFDP application usable for all the users required careful consideration. Configuring the CFDP engine requires knowing, in advance, all the possible end points with which it could be communicating. The dynamic allocation of IP addresses used in Phase I required the users to update the CFDP configuration file every time they started the service. Changes are due to the configuration file mapping each End Point ID (EID) with its associated IP address. This means having to use another service, such as Secure Shell or Remote Desktop, to modify the onboard CFDP configuration before starting the CFDP application. The same configuration change is also needed on the ground system.

To simplify the use of the CFDP service it was decided to use a portion of the address space as reserved for CFDP users. Once a payload user is using CFDP, the POIC Customer Support Team (CST) will assign the user an onboard NAT address and a ground node ID. The user will use that IP address and node ID for the duration of his operations on ISS. It will also allow him to preconfigure the CFDP configuration file onboard. The only configuration remaining before starting the CFDP node is the enter the assigned proxy IP address. This is because the ground proxy IP address is still assigned dynamically for each session. The Ku Session service will also require the user to submit his assigned ground node at session start so that EHS can look up the reserved onboard IP address for that user. Other users not using the CFDP application will continue to work as they do in Phase I getting dynamic IPs for use onboard.

#### V. Conclusion

As the ISS continues to increase science utilization, it is important to take advantage of every resource available. Using the Ku-forward link enables payload teams the ability to more rapidly reconfigure experiments due to the increased bandwidth available. This empowers payload teams the ability to upload new configurations or provide new software loads more often. Direct access to the payload computers allows users better insight into the system operations allow better opportunities to troubleshoot their experiments when not performing as expected. Most importantly, the design of the system takes advantage of tools that utilize standard IP communications. Payload teams will be able to use off-the-shelf applications or standard socket libraries when developing software to take advantage of the Ku-forward link. The POIC continues to provide world class, novel solutions to our customers pushing the boundaries of system utilization to the edge of excellence.

#### Appendix

##### Acronym List

<b>AOS</b>	Acquisition of Signal
<b>AUID</b>	Application User Identifier
<b>CCP</b>	Central Command Processor
<b>CCSDS</b>	Consultative Committee for Space Data Systems
<b>CDP</b>	Communications Data Processor
<b>CFDP</b>	CCSDS File Delivery Protocol
<b>COTS</b>	Commercial Off The Shelf
<b>CPU</b>	Central Processing Unit
<b>CST</b>	Customer Support Team
<b>eFDP</b>	enhanced Functionally Distributed Processor
<b>EHS</b>	Enhanced HOSC System
<b>EID</b>	Endpoint Identifier
<b>ePVT</b>	external Private (LAN)
<b>ERIS</b>	EHS Remote Interface Server
<b>FWD</b>	Forward

<b>GMT</b>	Greenwich Mean Time
<b>GTH</b>	Ground Transfer Header
<b>HOSC</b>	Huntsville Operations Support Center
<b>HPEG</b>	HOSC Payload Ethernet Gateway
<b>ICMP</b>	Internet Control Message Protocol
<b>ID</b>	Identifier
<b>IP</b>	Internet Protocol
<b>ISS</b>	International Space Station
<b>IT</b>	Information Technology
<b>JSC</b>	Johnson Space Center
<b>Ku Comm Unit</b>	Ku Communications Unit
<b>Ku-Band</b>	12-18 gigahertz range in the electromagnetic spectrum
<b>LAN</b>	Local Area Network
<b>LOS</b>	Loss of Signal
<b>Mbps</b>	Megabits per second
<b>MCC-H</b>	Mission Control Center – Houston
<b>MOP</b>	Mission, Operational Support Mode, and Project
<b>MSFC</b>	Marshall Space Flight Center
<b>NAT</b>	Network Address Translation
<b>ODAR</b>	Obsolescence Driven Avionics Redesign
<b>PD</b>	Payload Developer
<b>PDSS</b>	Payload Data Services System
<b>PEHB</b>	Payload Ethernet Hub Bridge
<b>PGUIDD</b>	Payload to Generic User Interface Definition Document
<b>POIC</b>	Payload Operations and Integration Center
<b>PVT</b>	Private (LAN)
<b>RIC</b>	Rack Interface Controller
<b>RF</b>	Radio Frequency
<b>RTN</b>	Return
<b>TCP</b>	Transmission Control Protocol
<b>UDP</b>	User Datagram Protocol
<b>WSC</b>	White Sands Complex

### References

<sup>1</sup>CCSDS Encapsulation Service, CCSDS 133.1-B-2, Blue Book., Issue 2., July 2006 URL: <http://public.ccsds.org/publications/archive/133x1b2.pdf> [cited 17 April 2012].

<sup>2</sup>CCSDS File Delivery Protocol, CCSDS 727.0-B-4, Blue Book., Issue 4., January 2007 URL: <http://public.ccsds.org/publications/archive/727x0b4.pdf> [cited 17 March 2014].