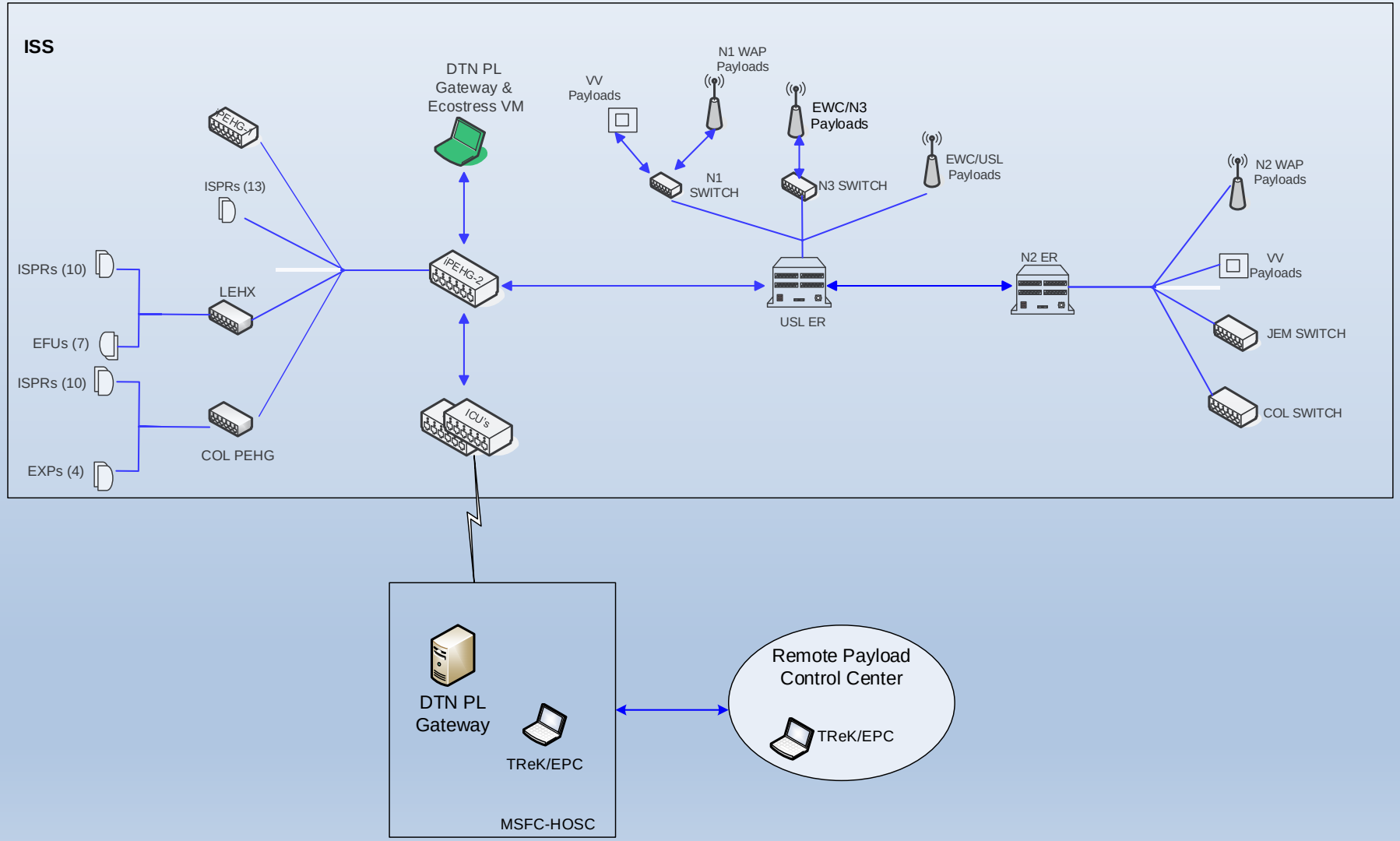
Application of Delay Tolerant Networking on the International Space Station

July 2019

ISS DTN Service Overview

- The ISS Payload DTN Service was deployed in May 2016
- ISS has implemented a 4 node DTN architecture for payloads that consist of
  - Ground Payload Node
  - Huntsville Operations Support Center (HOSC) Gateway Node
  - Onboard Gateway Node
  - Onboard Payload Node
- The DTN service is currently configured to support 30 Mbps downlink rate from ISS
- Most DTN users utilize the Telescience Resource Kit (TReK) software package for DTN
- Tough sell initially, but with services such as TReK, were able to add payloads
- Every ISS DTN Payload is assigned a unique Space Node ID and a Ground Node ID for DTN data transfer

JSL PL DTN Architecture



Arcturus Operations Purpose and Objective

Several Tech Demos have arisen which require real time command and telemetry as well as flexibility, low cost and the ability to add Customers quickly. The existing command and telemetry system is Criticality 1 and therefore specifically designed to be none of these things.

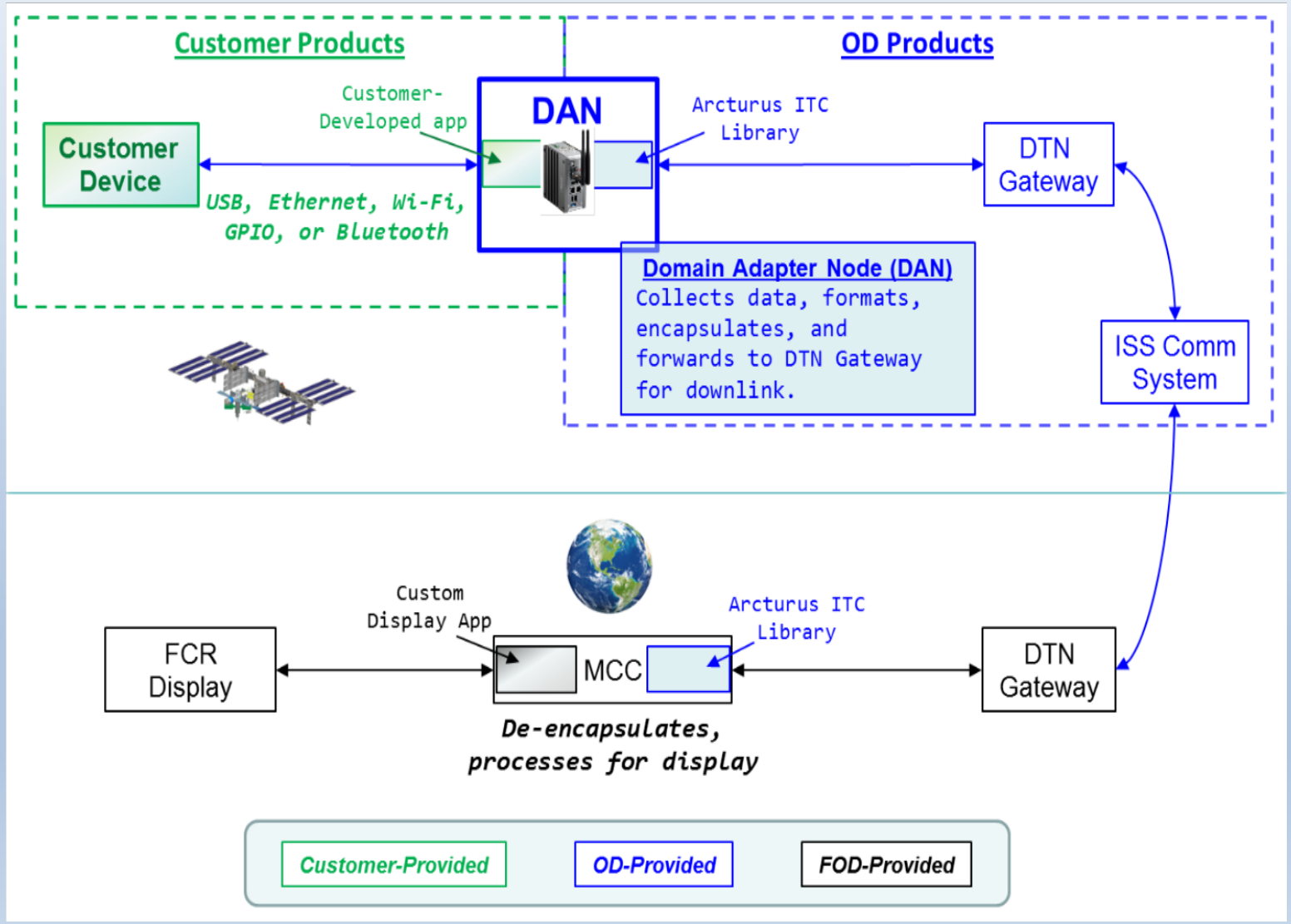
Existing flexible systems, like SSC, provide strong file transfer capabilities, but not real time telemetry and not commanding, apart from remote desktop connections. Therefore, development of a new command and telemetry system was warranted.

Objective:

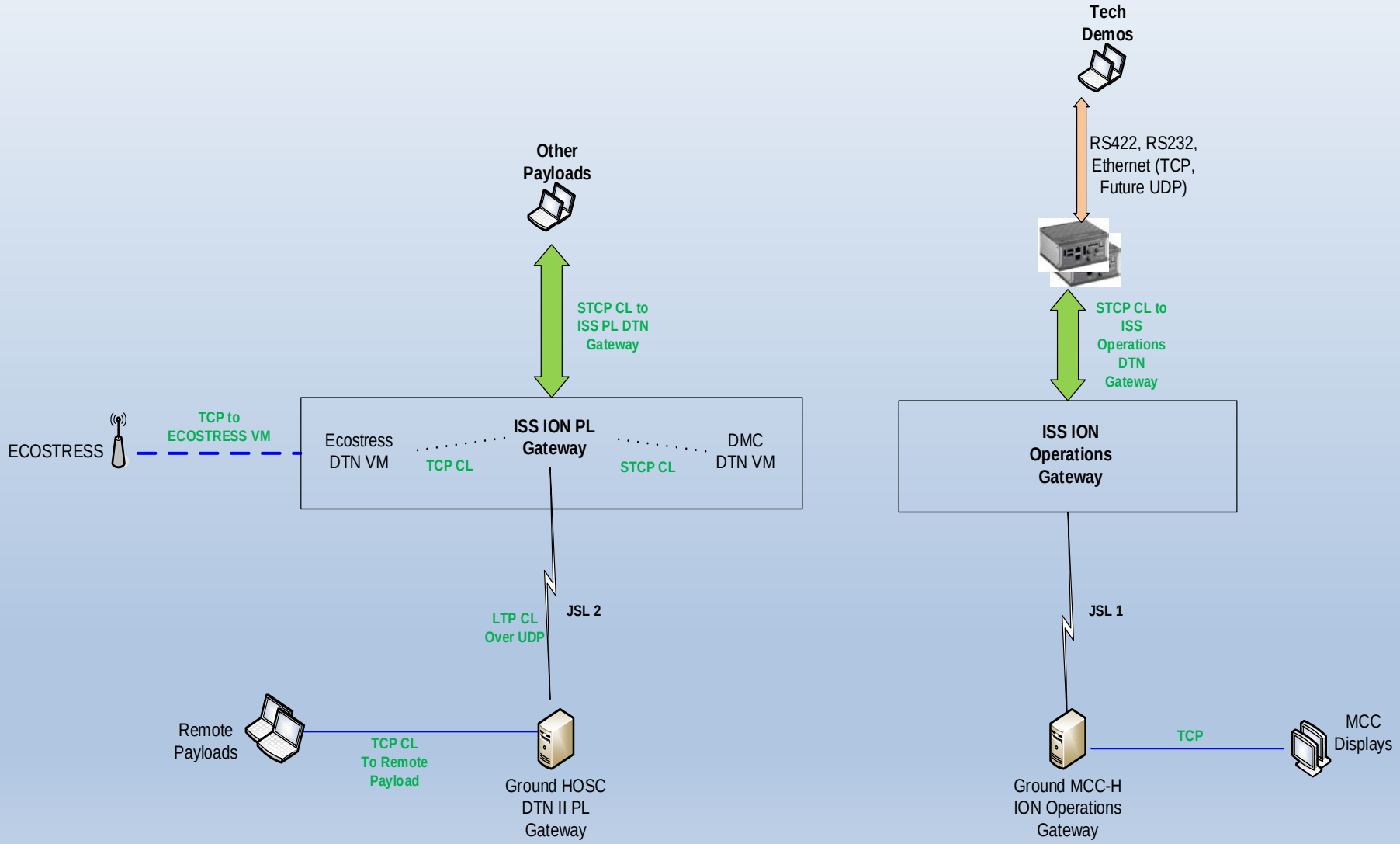
Create a Ethernet/Ku-based non-critical command and telemetry system where:

1) The System is used with the existing SSC and JSL systems.
2) Displays are integrated into current MCC consoles.
3) The Components / standards are COTS based where possible.
4) Components and System as a whole are developed for upgradability.
5) The System is managed by SSC processes, providing maximum flexibility and upgradeability.

ISS Arcturus DTN Architecture



JSL ISS DTN Protocols



ISS Payloads/Arcturus Using DTN

Payload	Planned Date	Platform
ASTROBEE1 (NASA)	Active	Linux
ASTROBEE2	Active	Linux
Bio Fabrication Facility	Active	Linux
Cold Atom Lab	Active	Win
DMC VM	Active	Win
ECOSTRESS	Active	Linux
Hermes	Active	Linux
Human Research Facility (HRF) Laptop 1	Active	Win
HRF Laptop 2	Active	Win
HRF Laptop 3	Active	Win
LSG/MSG	Verified	
NanoRacks (Platform 1, Platform 2, Spare)	Active	Win
PAUL (Kentucky Space LLC)		
Plant Habitat	Active	Linux
Refabricator	Active	Win
Spaceborne Computer	Active	
TangoLab-1 (Kentucky Space LLC)	Active	Linux
TangoLab-2 (Kentucky Space LLC)	Active	Linux
TReK Demostration Payload	Active	Win
BEC Atom Lab	2020	TBD
Biochip (Hnu)	TBD	TBD
Dexter Deployable Vision System (DDVS)	IN65/66	TBD
Microscopy Lab (Hnu)	TBD	TBD
Mobile Space Lab (Hnu)	IN62	TBD
Multi-Purpose Variable-g Platform (MVP)	IN60	Linux
Rodent Research	2021	TBD
Spacecraft Atmospheric Monitor	TBD	Win
Spectrum	IN61	TBD

Arcturus Tech Demo	Planned Date
Brine Processor Assembly	TBD
EMU Data Recorder	TBD
Four-Bed Carbon Dioxide Scrubber	TBD
MiniCO2	TBD
Thermal Amine Scrubber	Active
Toilet Data Recorder	TBD
Urine Transfer System	TBD
High-def EVA Camera Assembly	TBD

- TReK is one of the Huntsville Operations Support Center (HOSC) remote operations solutions
  - Used to monitor and control International Space Station payloads from anywhere in the world.
  - Don't have to be DTN expert to get your data
- The ISS program is providing the TReK Toolkit software as a generic flight software capability offered as a standard service to payloads
- The TReK Demonstration Payload started operating on an ISS provided T61p Laptop on May 27, 2016. It transitioned to an ISS provided ZBook on April 16, 2019.

- ISS DTN Capabilities:
  - Transfer files (send and receive) using CFDP.
  - Configure and Manage (start, stop, monitor) ION DTN node.
  - Use Dropbox Capabilities with DTN: CFDP, File Fragmentation, File Encryption/Decryption
- Ground DTN Capabilities:
  - Transfer files (send and receive) using CCSDS File Delivery Protocol (CFDP)
  - Configure and Manage (start, stop, monitor) ION DTN node.
  - Use Dropbox Capabilities with DTN: CFDP, File Fragmentation, File Encryption/Decryption

- Software:
  - IONconfig Application - Provides the capability to generate ION configuration files and scripts. The scripts (Windows batch files and Linux shell scripts) can be used to start and stop ION. This application has a graphical user interface.
  - IONizer Application - Provides capabilities to start, stop, and monitor ION. This application has a graphical user interface.
  - IONizer Library - Provides an application programming interface to start, stop, and monitor ION.

- Documentation available on TReK Web Site (https://trek.msfc.nasa.gov)
  - TReK DTN Tutorial - (https://trek.msfc.nasa.gov/Documents/trek_5_1_1/trek_dtn_tutorial.pdf)
  - IONconfig User Guide - https://trek.msfc.nasa.gov/Documents/trek_5_1_1/trek_ionconfig_user_guide.pdf
  - IONizer User Guide - https://trek.msfc.nasa.gov/Documents/trek_5_1_1/trek_ionizer_user_guide.pdf

Benefits for Payloads/Operations

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- Offload scheduling
- Avoid manually scheduling retransmissions due to LOS
- With use of TReK, DTN communication is abstracted from the payload developer
- Increased reliability and efficiency of file transfers
- Cost savings to operations where data is queued and comes down so operator footprint is reduced

Changes Since Initial Deployment

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- Addition of payloads
  - 12 currently active
  - 13 confirmed for future activation
- Upgrade of laptop running On Orbit DTN Gateway
- Option for both wired and wireless payloads to transfer straight TCP packets, with DTN bundling provided by ISS utilities
- Implementation of Arcturus
- Increased Data Rates

Testing Capabilities

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- Remote testing with MSFC/JSC
- Payload developer can connect to MSFC/HOSC from payload developer site
- VPN connection available to connect payload device to on board test environment located at JSC

ION Development Feedback

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- ISS helping to refine DTN so DTN is both an operational and experimental capability.
  - Discovery of software issues affecting throughput and performance.
  - Discovery of software issues affecting troubleshooting tools.
  - Performance evaluation of a large DTN network (around 100 nodes)
  - Application of multiple convergence layer protocols (LTP, STCP, TCP)

On Orbit Observations with DTN

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- Ground server full at HOSC
  - Some payloads only access their data from the ground server at times that can extend up to a week
- Timeout values too low
  - Caused bundles to expire while in transit
- Use of older versions of ION software
- Improper shutdown of ION caused data loss

Future Plans for ISS DTN

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- Increase data rates (i.e., higher bandwidth)
- Redundancy (two on board DTN gateways for payload use)
- Use of higher bandwidth link
- Upgrades for Aggregate Custody Signaling and Delay Tolerant Payload Conditioning
  - Better uplink bandwidth efficiency and in-order data delivery as necessary
- Potential DTN Security upgrades which would include Bundle Protocol Security (BPSec) and Secure Key Distribution and Management
- Integration of the Asynchronous Management Protocol (AMP), CGR, SABR
- Addition of cryptography for DTN in TReK
- Support encrypting/decrypting files for DTN in TReK

Coordination and Appreciation

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- Tom Basciano – ISS DTN Project Manager
- Suzanne Davidson – Boeing JSL DTN Technical Lead
- Adam Schlesinger – AES DTN Project Technical Lead
- Lee Pitts – MSFC Lead DTN Architect
- Bill Pohlchuck – ISS DTN Lead Developer
- Gary Knickerbocker – MSFC Lead DTN Integrator
- Jeff Lippincott – TReK DTN Integrator
- David Zoller/Joshua Deaton – HOSC ISS DTN2 Gateway Developers
- Jarvis Hogan – ISS Network Specialist DMC
- Joanne Towne – HOSC ISS DTN Test Lead
- Dennis Botts – HOSC Customer Support Lead
- Dan Duncavage – Arcturus Project Manager
- Tyler Doubrava – Arcturus Project Lead
- Jim Wiehoff – ISS DTN Project Lead

Delay/Disruption Tolerant Networking for the International Space Station (ISS)

Tom Basciano – NASA ISS DTN Manager
Bill Pohlchuck – Boeing ISS DTN Lead Developer

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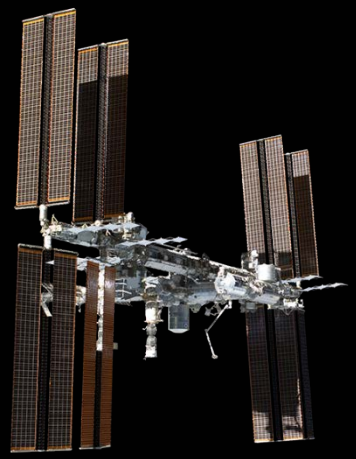

BACKUP

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