ISSRDC

Stress Testing High Performance Networking in the International Space Station’s Software Development and Integration Laboratory

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Presenters: William Pohlchuck, Dr. Rachel Dudukovich

DTN on the International Space Station

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2023 Technical Sessions

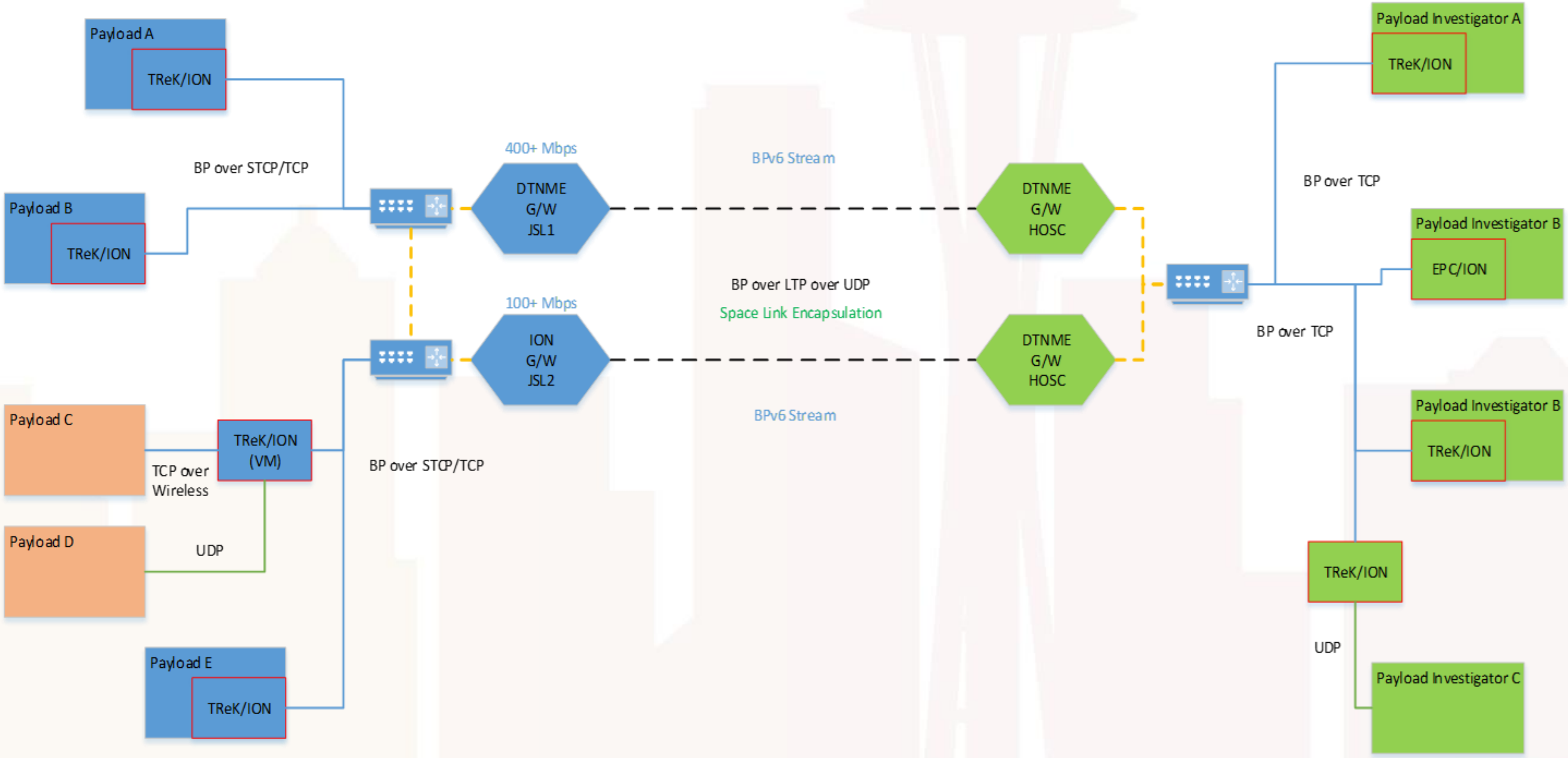
ISSRDC

DTN on ISS

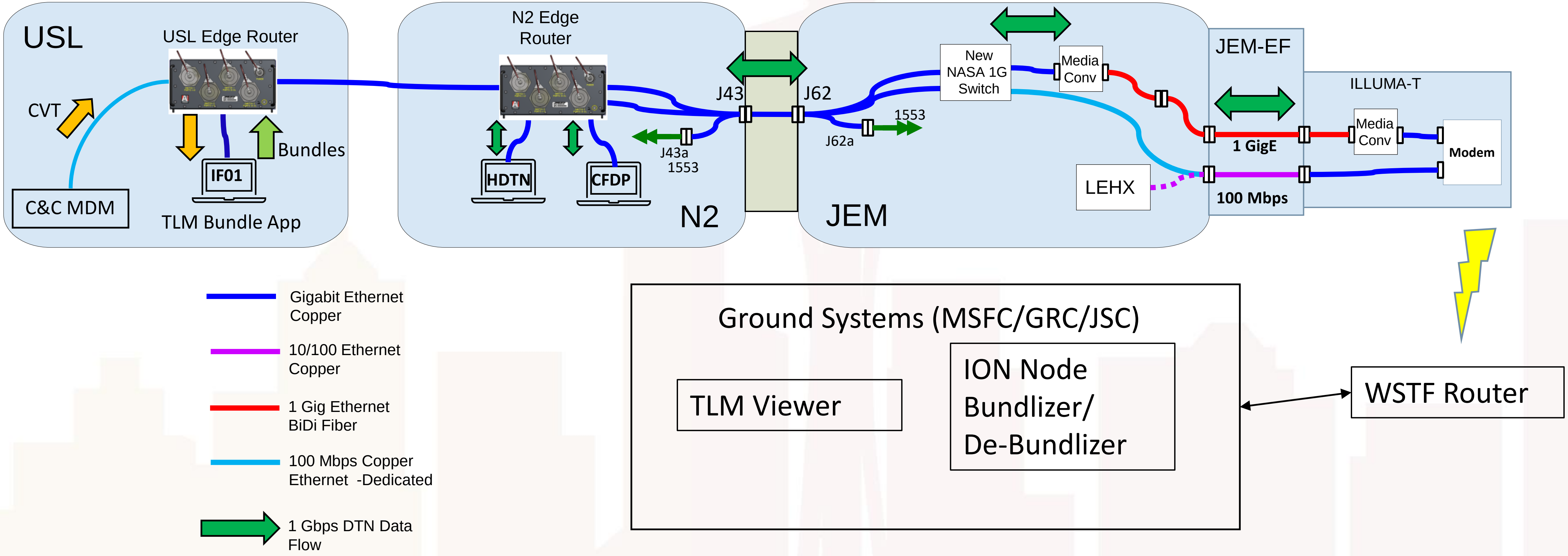
- ISS DTN Project provides the following:
  - ISS Disruption Tolerant Networking (DTN) Architecture for flight, ground, and test/simulation systems (includes MSFC-HOSC, MCC-H, and SCTF/SDIL)
  - Increased reliability of payload data transfers between ISS and remote payload control centers during communication outages
    - MSFC-HOSC, MCC-H, and ISS DTN nodes will store user file uplinks/downlinks and forward bundles as Ku-band becomes available
  - Increased automation of Payload Developer (PD) requests for data transfers
    - Reduce PD real-time support to access and downlink science data
    - Reduces need for duplicate storage and extra retrieval actions
  - Mechanism to alleviate extensive support to plan payload transfers around loss of communications.
  - Mechanism to use standard, publicly available protocols, avoiding the use of costly custom protocol implementations
  - Opportunity to gain valuable experience using DTN, which is the expected communication protocol of choice for future space exploration
  - Current ISS bandwidth Ku-Band space-to-ground capability is approximately 500 Mbps downlink/20 Mbps uplink for all ISS data (not just DTN)
  - HDTN will be utilized in the upcoming ILLUMA-T experiment and will provide increased space-to-ground bandwidth utilizing a 1 Gbps laser-based communication system.

Current DTN Architecture on ISS

- Initially deployed with single DTN gateway (ION) May 2016 with limit around 30 – 50 Mbps
- Updated with second DTN gateway (DTNME) Mar 2023 with expected capability around 200 Mbps

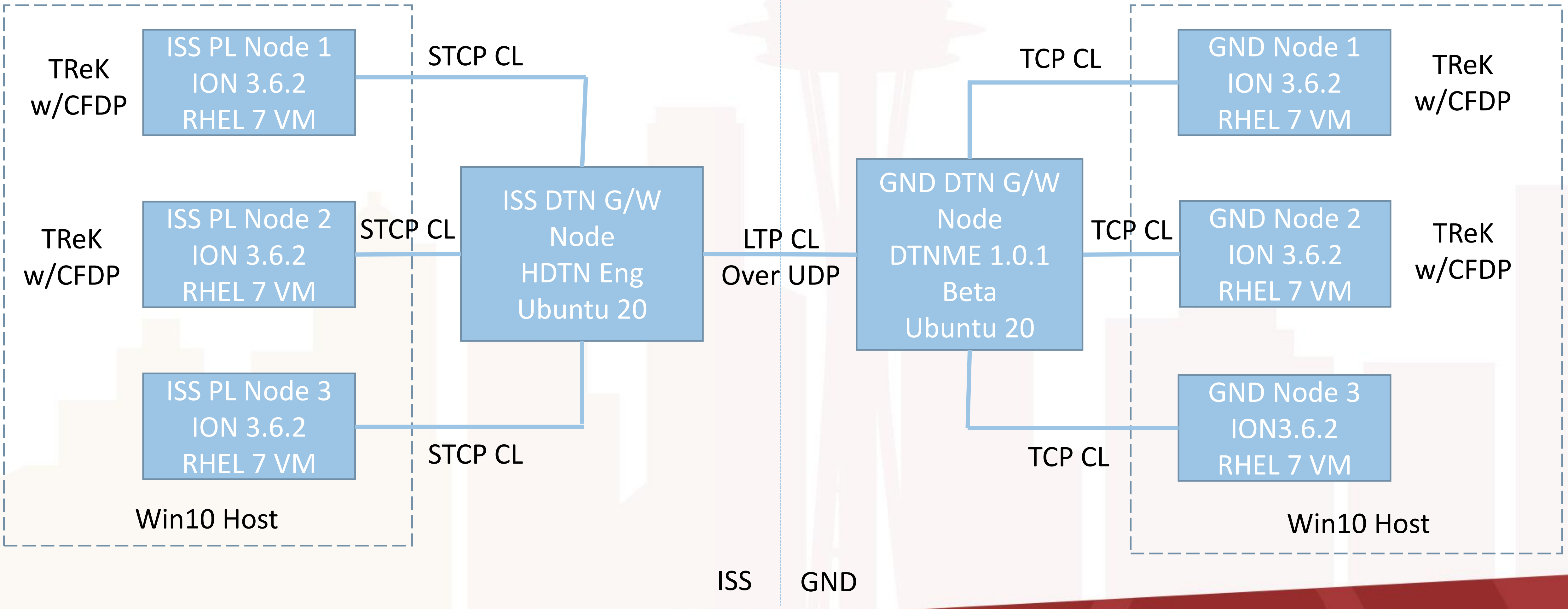


Planned ISS ILLUMA-T/HDTN Experiments (2024)



ILLUMA-T/JSL with HDTN Joint Test DTN Setup

- Goddard Space Flight Center, September 2022



HDTN Testing in JSC’s Software Development and Integration Laboratory

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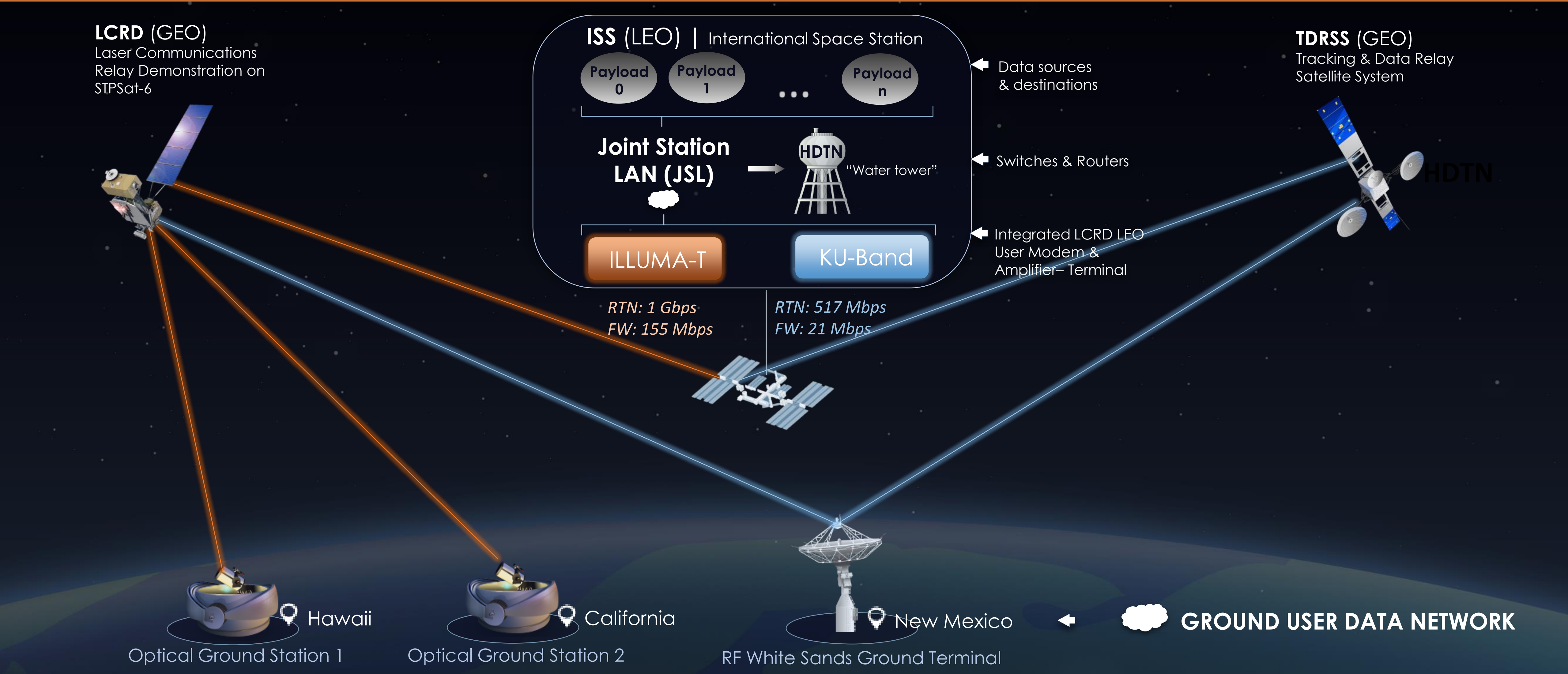
HDTN ISS CONCEPT OF OPERATIONS

Delivering a high rate (Gbps) networking system to the ISS to support an upcoming laser communications demo (collaborating with GSFC, MSFC & JSC)

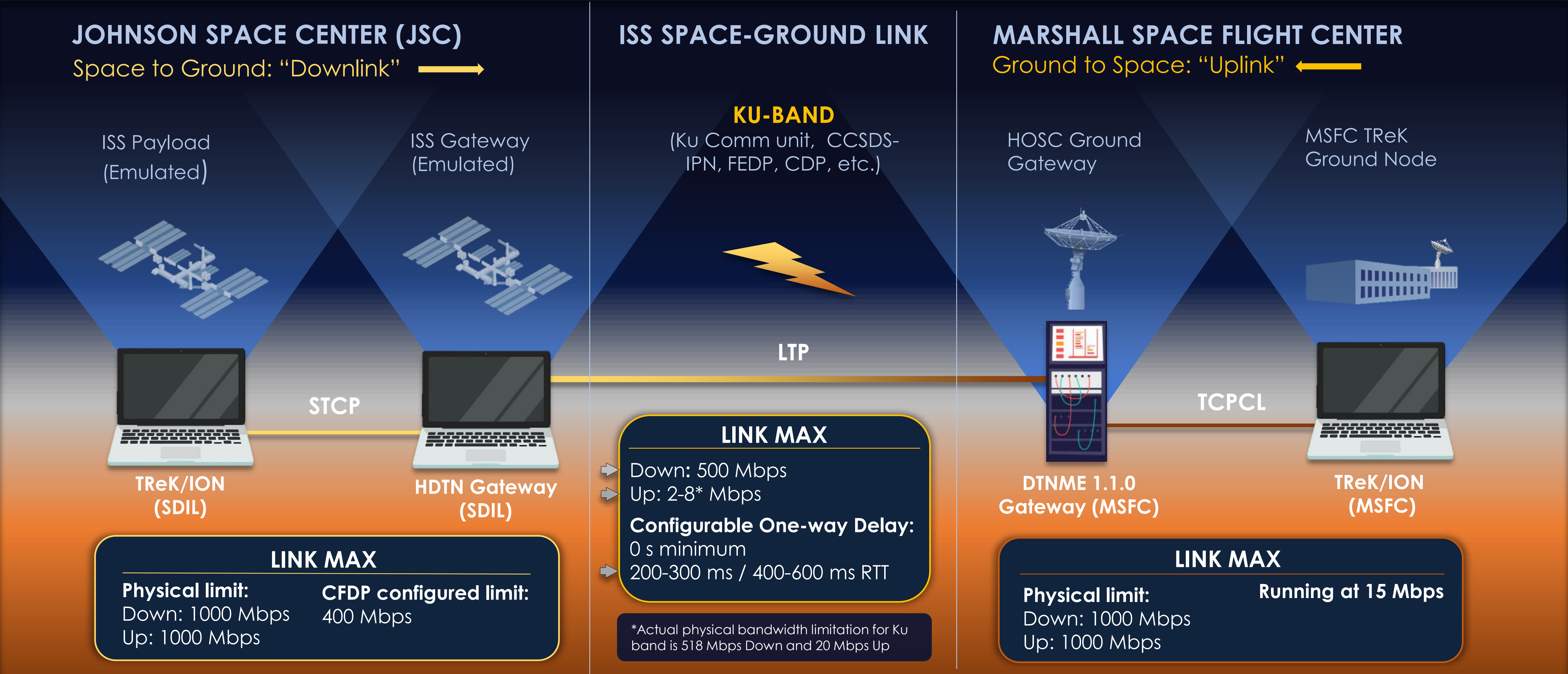


SDIL End-to-End Testing

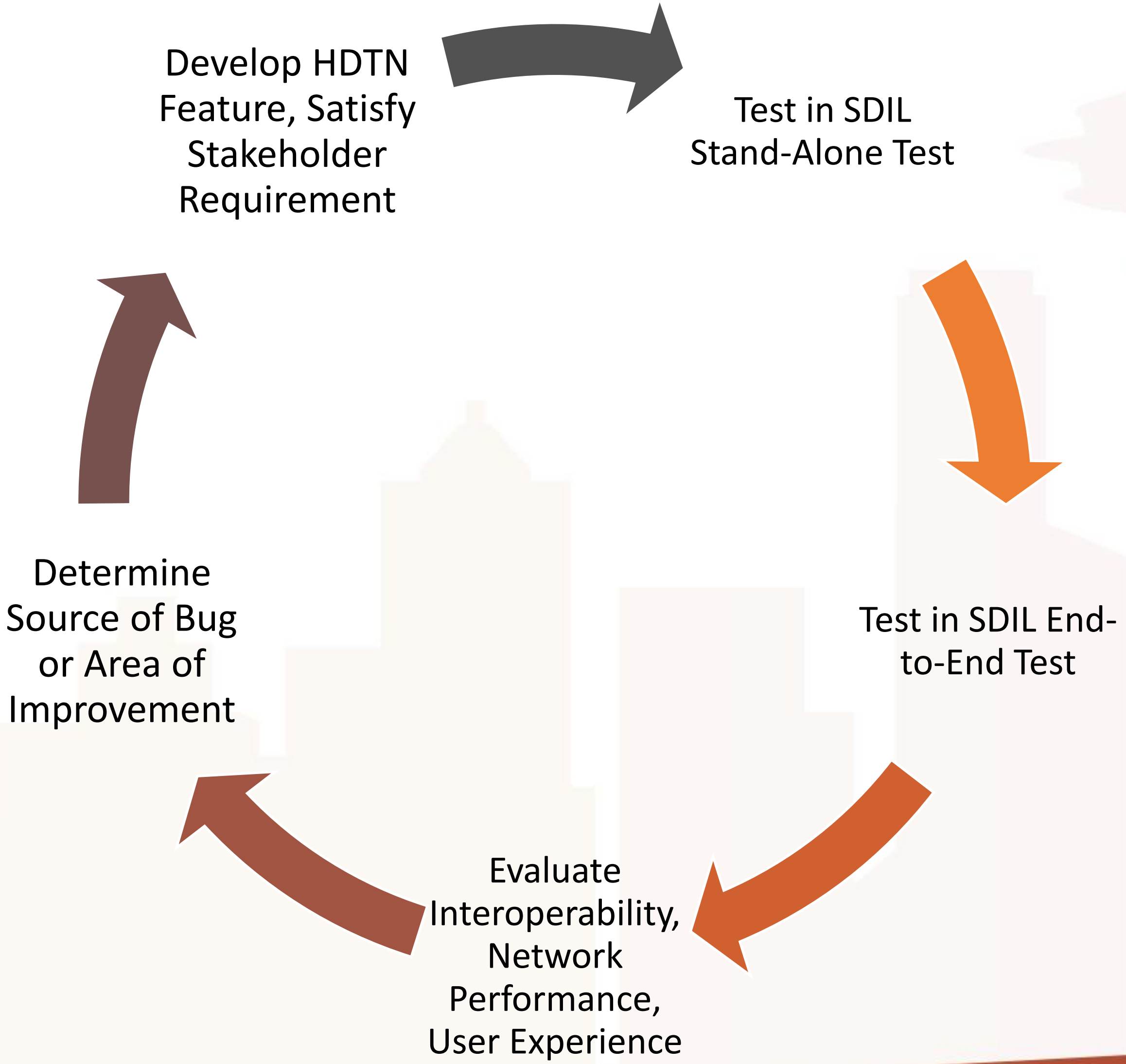
OBJECTIVES

8/2022-5/2023

- Saturate RF Link
- Demonstrate store-and-forward w/ reliable transport
- End-to-end interoperability



Testing Process



- Test team from JSC, GRC, and MSFC completed 15 stand-alone tests and 7 end-to-end tests between 6/2021 and 5/2023
- Final result is HDTN Stable Release V1.0.0

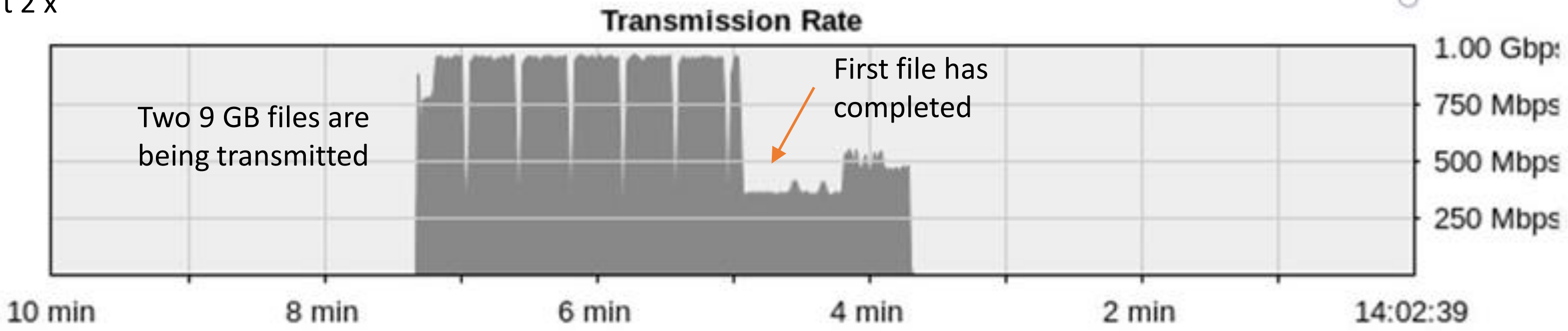
Testing Process

LAN A → LAN B

Rate: 1.000 Gbps Delay: 2000 ms Loss: 0% BER: 0 Traffic: 0% Queue: 300 ms Duplication: 0% Reordering: 0%

	Transmission Count		Drops					Duplication		Reordering	
	Bytes	Frames	Loss	BER	Queue	Total	Percent	Frames	Percent	Frames	Percent
Forwarded	823,697,845,009	605,658,514	0	0	0	0	0.00%	0	0.00%	0	0.00%
Background	0	0	0	0	0	0	0.00%	0	0.00%	0	0.00%

Optical link emulation: transmit 2 x 9 GB files over 1 Gbps link



- SDIL stand-alone test can emulate both Ku-band (RTN: 517 Mbps, FW: 21 Mbps, 600ms RTT) and optical (RTN: 1 Gbps, FW: 155 Mbps, 4 s RTT)
- SDIL uses Linktropy network emulator for rate limits and delay
- HDTN lab has recently acquired Netropy link emulator to develop similar capabilities
- End-to-end test emulates Ku-band and incorporates both SDIL and MSFC HOSC
- End-to-end test uses real Ku-IP services on the ground

Test Results Summary

Test Criteria	Outcome	Comment
Bundle Ping	Success	HDTN GUI includes Bping capability
ION STCP Interoperability	Success	Minimal configuration required
TReK CFDP Compatibility	Success	HDTN serves as pass-through gateway
DTNME LTP Interoperability	Success	Minor configuration settings required
Control LTP rate limit	Success	Rate limit tested from 100-425 Mbps for Ku-band
Small file transfer (25 MB)	Success	File sizes tested: 25 MB, 1 GB, 2GB, 4 GB, 9 GB
Large file transfer (9 GB)	Success	HDTN is able to saturate link up to 425 Mbps for Ku-band, 1 Gbps for optical
Recover from loss of signal (LOS)	Success	HDTN detects LOS, stores data, and resumes on AOS using LTP ping
Transfer 2 files simultaneously (2x 2 GB)	Success	HDTN supports multiple inducts and outducts
File Uplink (2 Mbps rate limit)	Success	Bidirectional end-to-end test completed

HDTN Software Process and Technology Readiness

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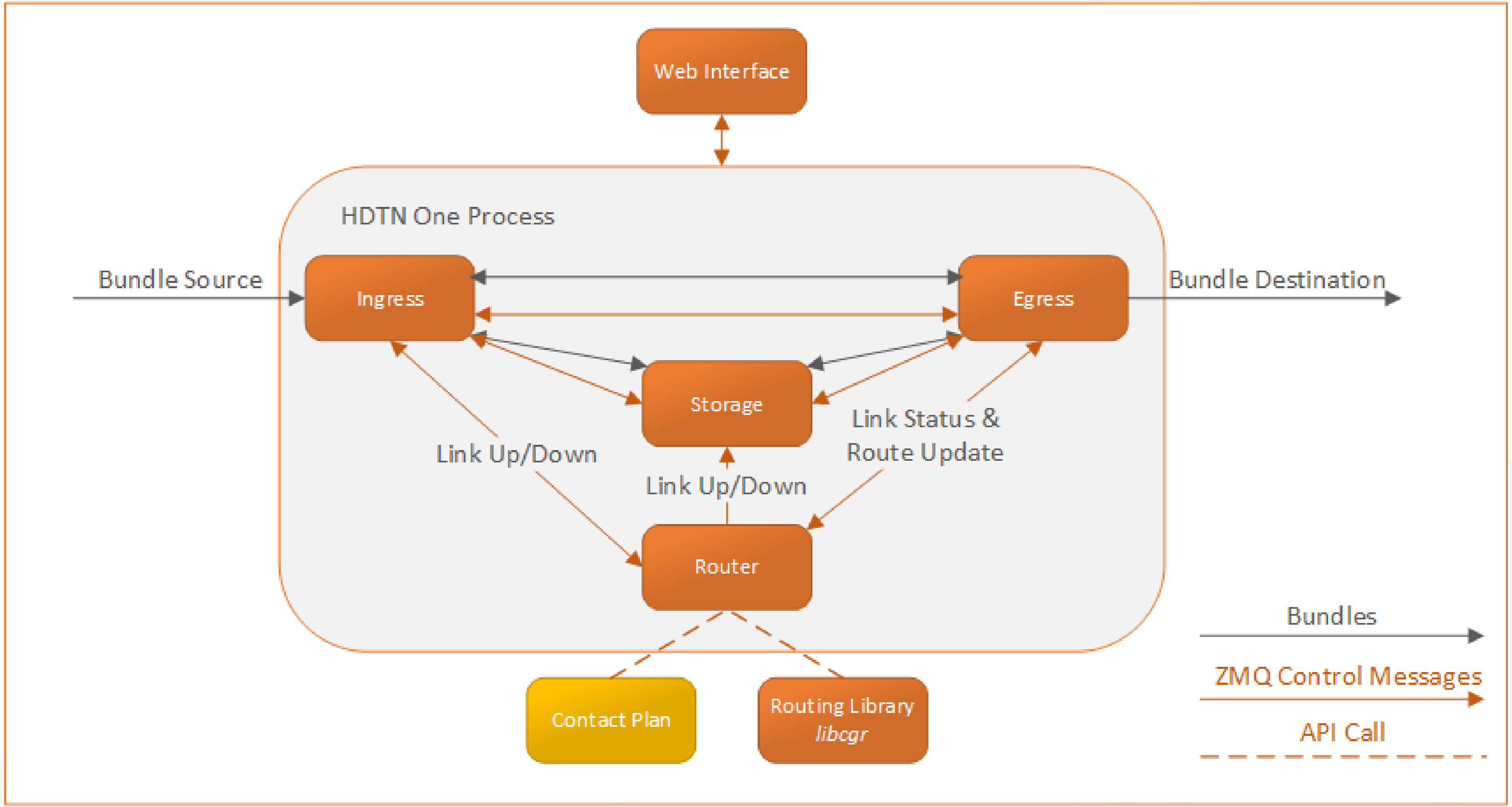
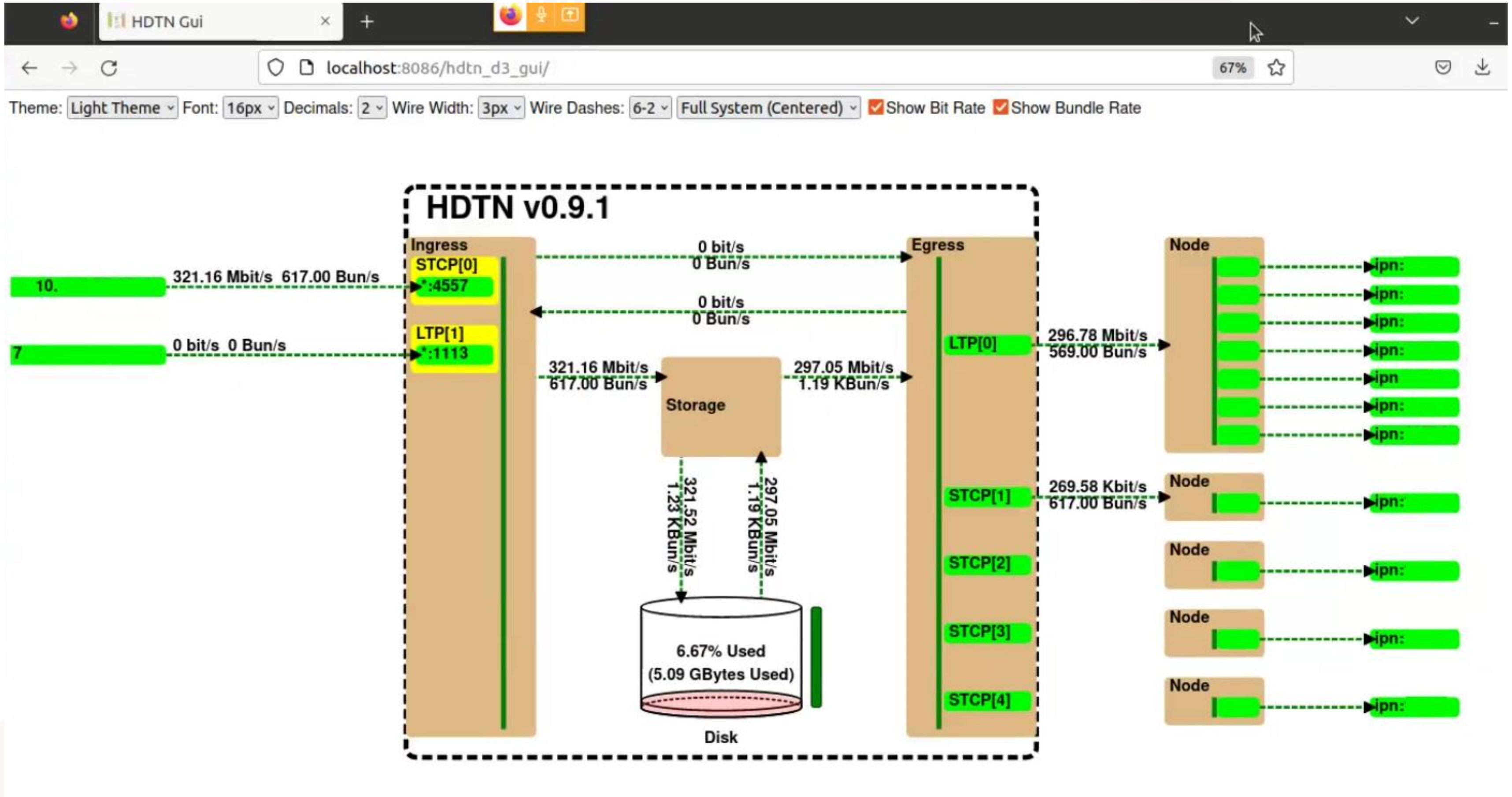
HDTN Architecture



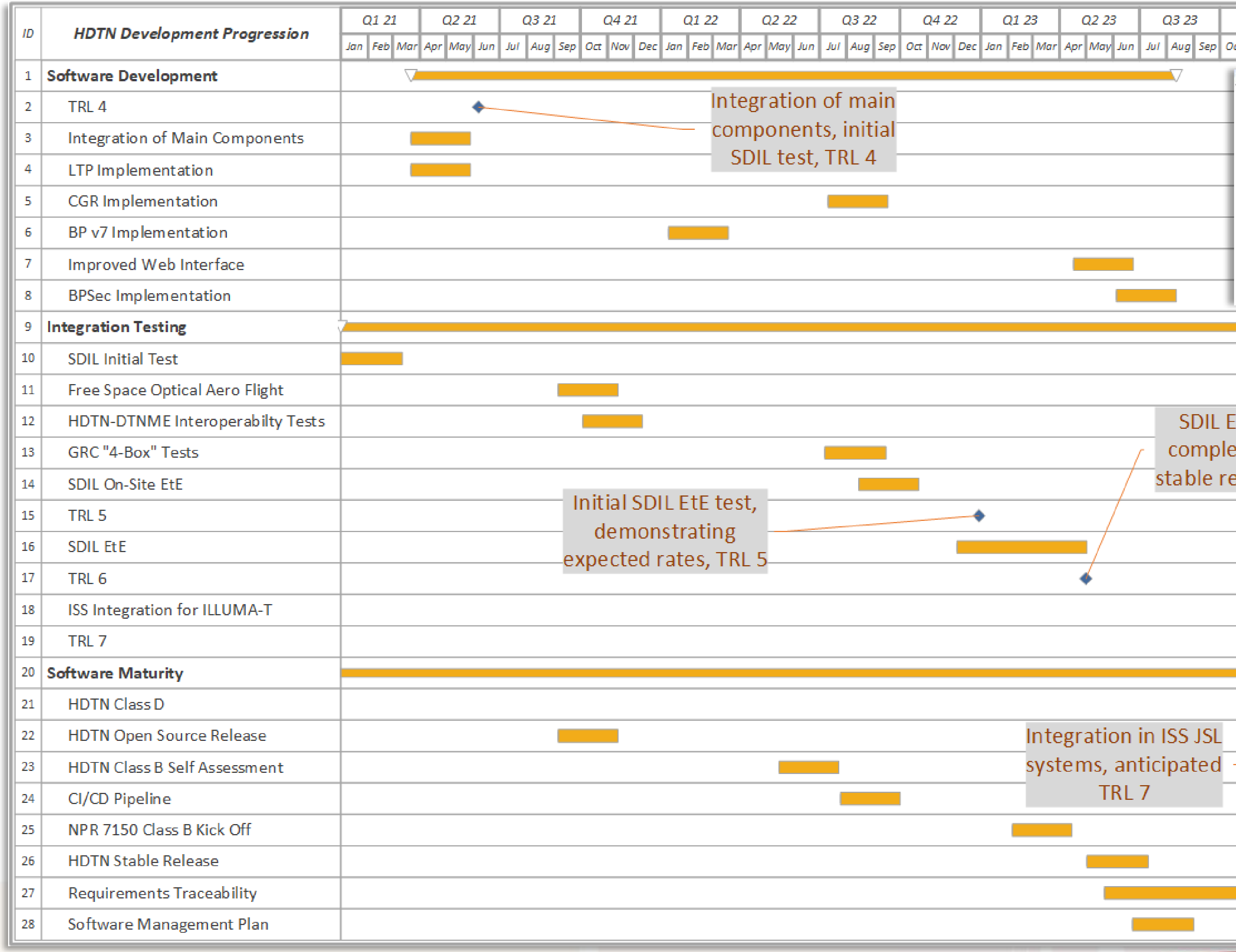
Project Website:
https://www1.grc.nasa.gov/space/scan/acs/tech-studies/dtn/

GitHub:
https://github.com/nasa/HDTN

HDTN Features



- Web interface system view and metrics logging
- BP v6 and v7
- LTP, STCP, TCPCL v3, and TCPCL v4
- BPSecurity
- Contact Graph Routing and support for external routing algorithms
- BpSendFile, BpReceiveFile, Bping, BPGen, BPSink
- Administrative logs and statistics


ID
HDTN Development Progression
Q1 21
Q2 21
Q3 21
Q4 21
Q1 22
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Q4 22
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Q4 23
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Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
1 Software Development
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3 Integration of Main Components
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5 CGR Implementation
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8 BPSec Implementation
9 Integration Testing
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Initial SDIL EtE test, demonstrating expected rates, TRL 5
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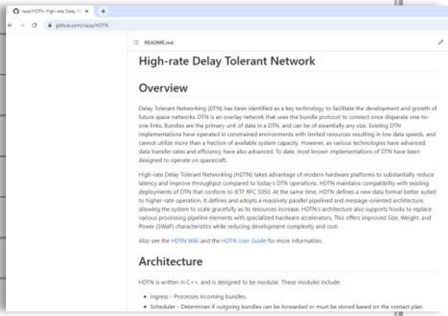
Integration in ISS JSL systems, anticipated TRL 7


High-rate Delay Tolerant Network
Overview
Architecture


NASA/TM-20220011407
Developing High Performance Space Networking Capabilities for the International Space Station and Beyond


| NODIS Library | Program Formulation(7000s) | Search |
NASA Procedural Requirements
NPR 7150.2D
Effective Date: March 08, 2022
Expiration Date: March 08, 2027
COMPLIANCE IS MANDATORY FOR NASA EMPLOYEES
Subject: NASA Software Engineering Requirements
Responsible Office: Office of the Chief Engineer
View all pages in PDF
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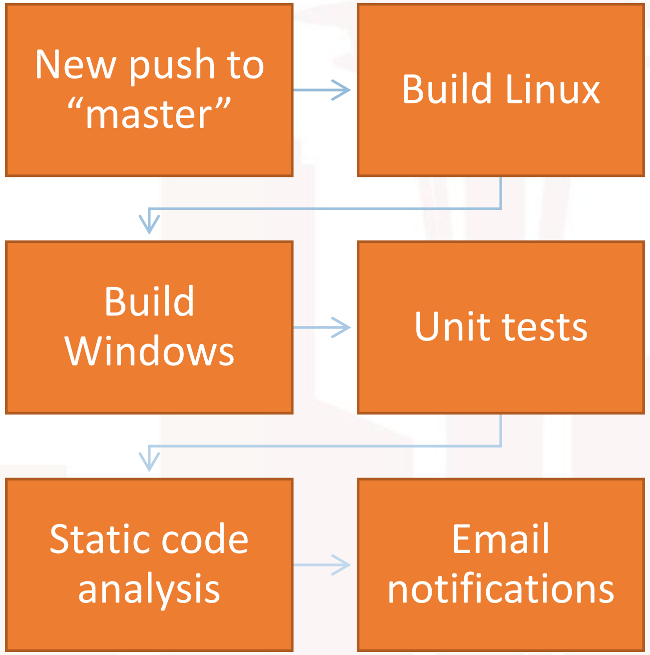
Chapter 2. Roles, Responsibilities, and Principles Related to Tailoring of the Requirements
Chapter 3. Software Management Requirements

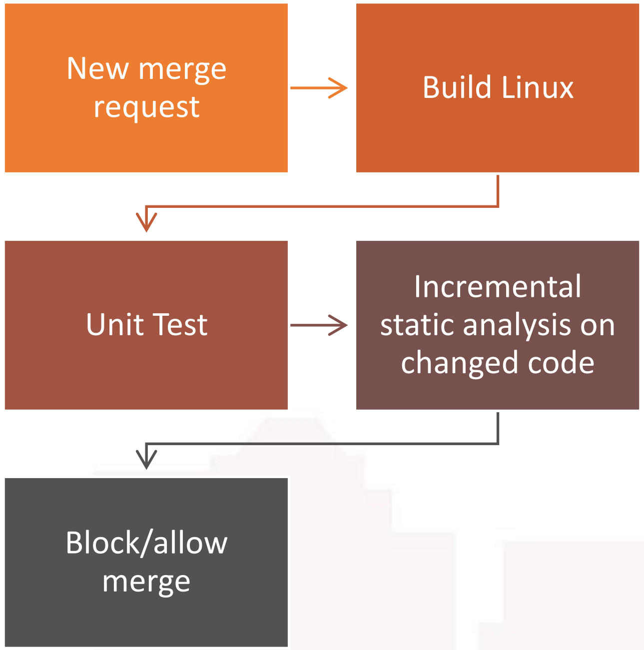
CI/CD Pipeline

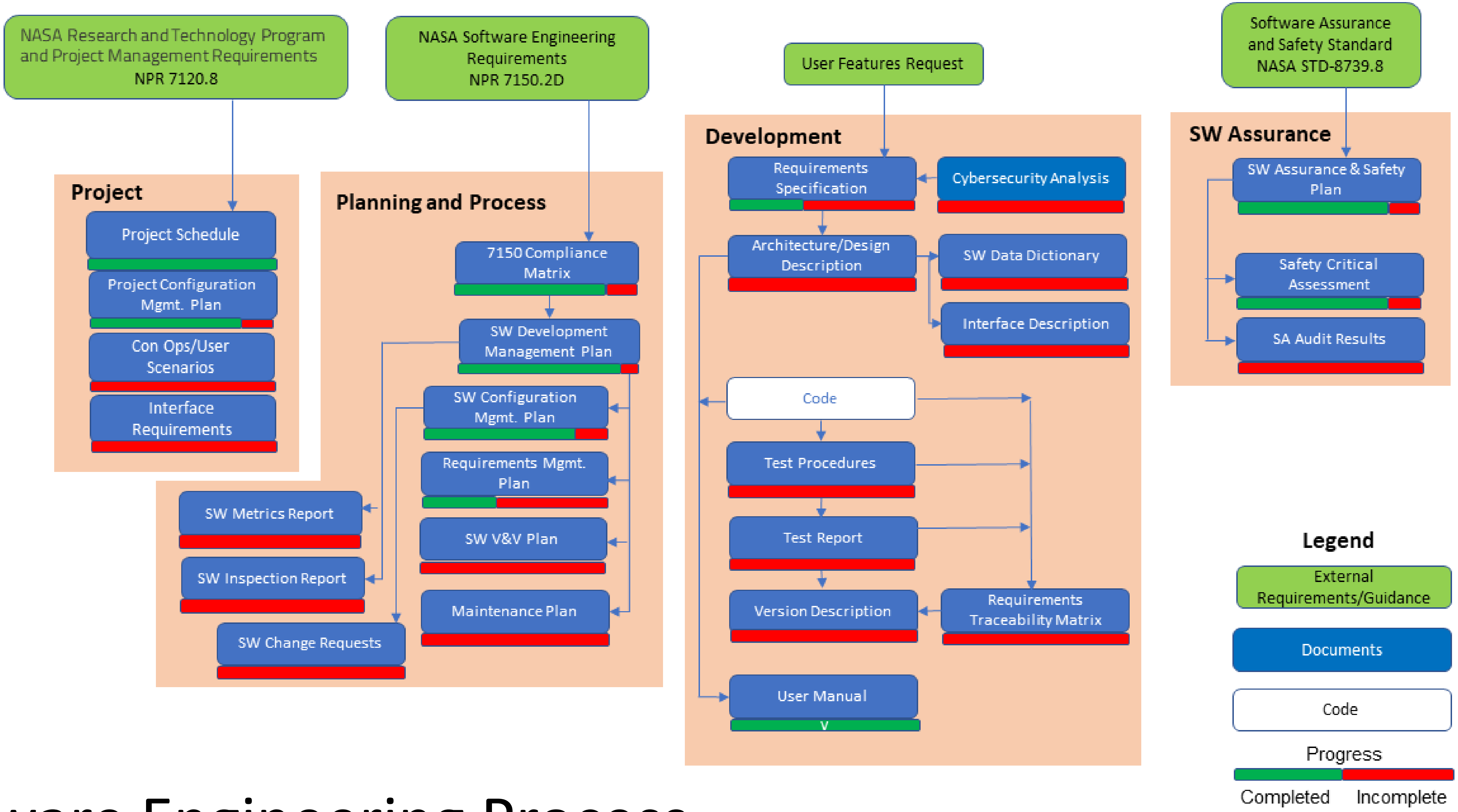
- Set up CI/CD pipelines in GitHub and GitLab
- Prevent defects from entering the code base
- Catch breaking changes quickly

GitHub (public) CI pipeline:



GitLab (internal) CI pipeline:





Software Engineering Process

Acknowledgements

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