Cognitive Networking Overview

Ohio Federal Research Network

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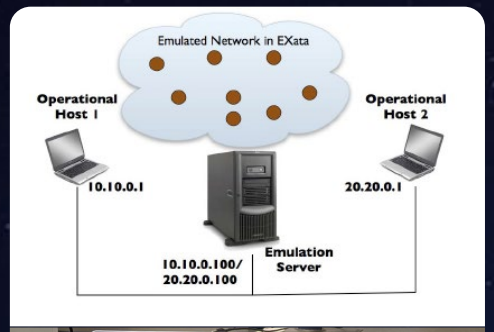
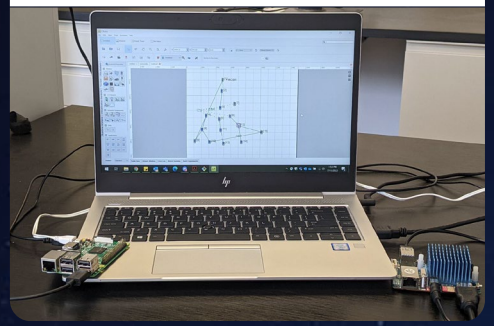
A view of NASA Glenn’s new Aerospace Communications Facility.
Credits: NASA/Sara Lowthian-Hanna

NASA GRC develops cutting edge communications technology for air and space

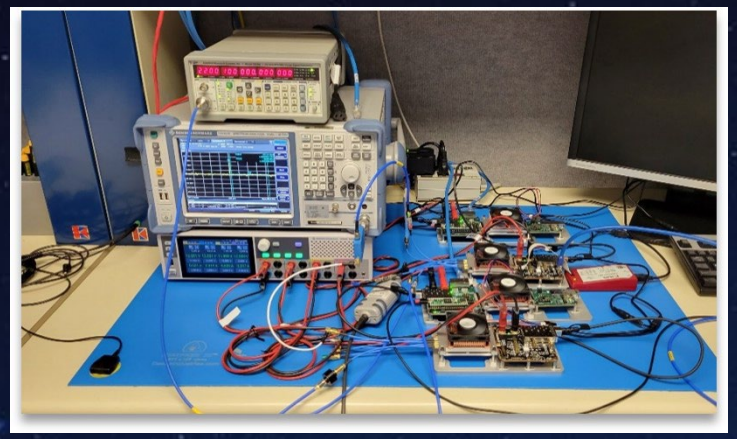
Our Labs at Glenn Research Center

Network Emulation



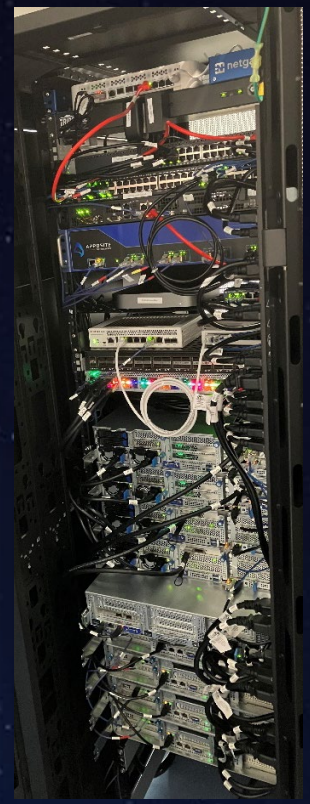


Software Defined Radio



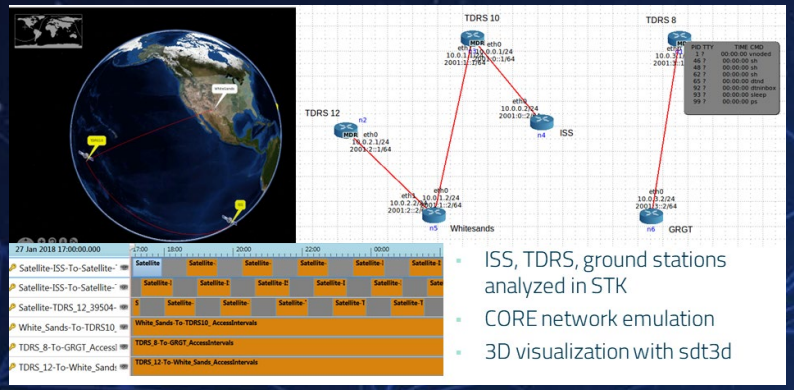
Software and Protocol Development

Virtualization and High-Performance Networking



Optical Communication

Modeling and Simulation



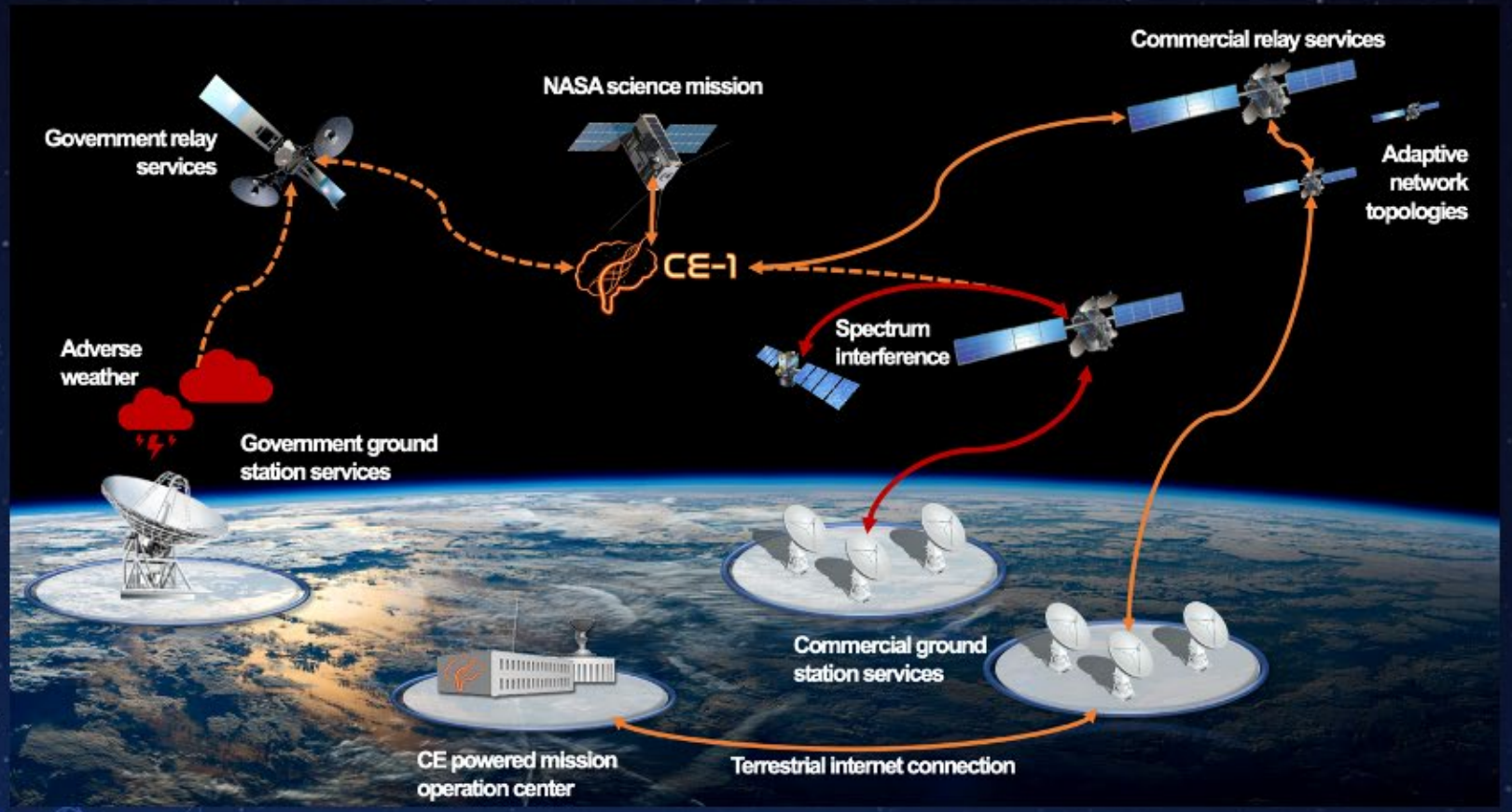
- ISS, TDRS, ground stations analyzed in STK
- CORE network emulation
- 3D visualization with sdt3d

Flight Preparation and Testing

Cognitive communications technology supports NASA operations in complex, crowded, and dynamic space-environments.

Managing spacecraft communications is increasingly challenging

Commercialization trends are making space a more complex, crowded, and dynamic environment. Operators must handle routine tasks such as scheduling service and selecting optimal service providers for a larger number of assets and adverse events such as spectral interference are becoming more common.



CE-1 Near-Earth Challenges

Proposed solution is an autonomous communication system, Cognitive Engine 1 (CE-1)

NASA CE-1 will deliver high-speed, robust, and cost-effective communications while providing seamless roaming between networks.

No more schedule forecasting

CE-1 works with emulated NASA and commercial networks to schedule services without requiring input from mission or network operators.

Block out noisy neighbors

CE-1 detects, mitigates, and learns to avoid or mitigate interference from other spacecraft and ground assets.

Increases network efficiency

Spacecraft increases network efficiency by only scheduling time required to meet data needs. Reschedule in case of failed pass makes best effort to meet latency constraints.

Autonomously fulfill communication needs

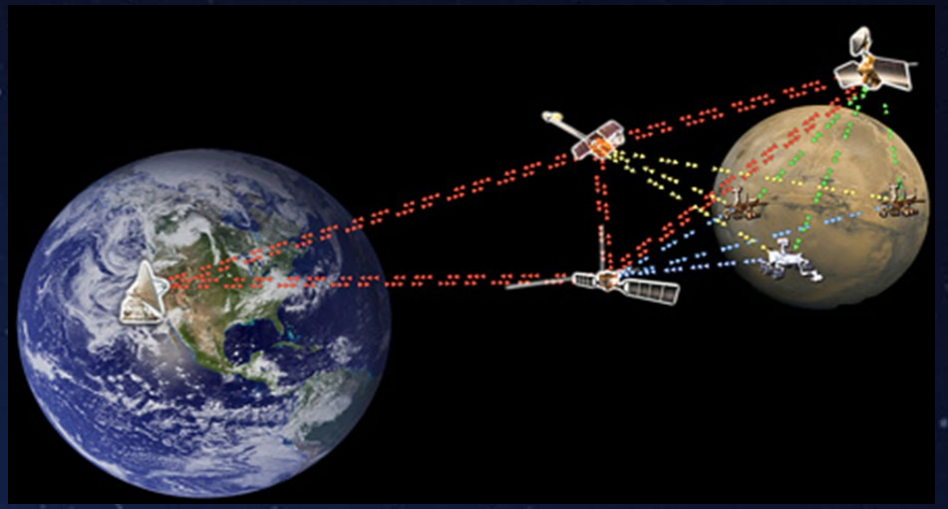
CE-1 components on spacecraft and ground autonomous fulfills communication needs – no human in the loop.

Seamlessly roam and adapts to a changing environment

Provides seamless roaming between government and commercial providers of both relay and DTE links. Cognitive algorithms allow CE-1 dynamically reconfigure based on observed performance, discover new network assets, and adapt to bad weather.

Delay/Disruption Tolerant Networking (DTN)

- DTN is NASA's solution for automated and reliable communication in high latency space networks without end-to-end connectivity
- Suite of communication protocols to support an interoperable space network
- Buffers data until a transmit opportunity arises
- Uses the bundle protocol, an approach for space network transport that forms a store-and-forward overlay network
- High-rate Delay Tolerant Networking (HDTN) is GRC's performance optimized DTN implementation



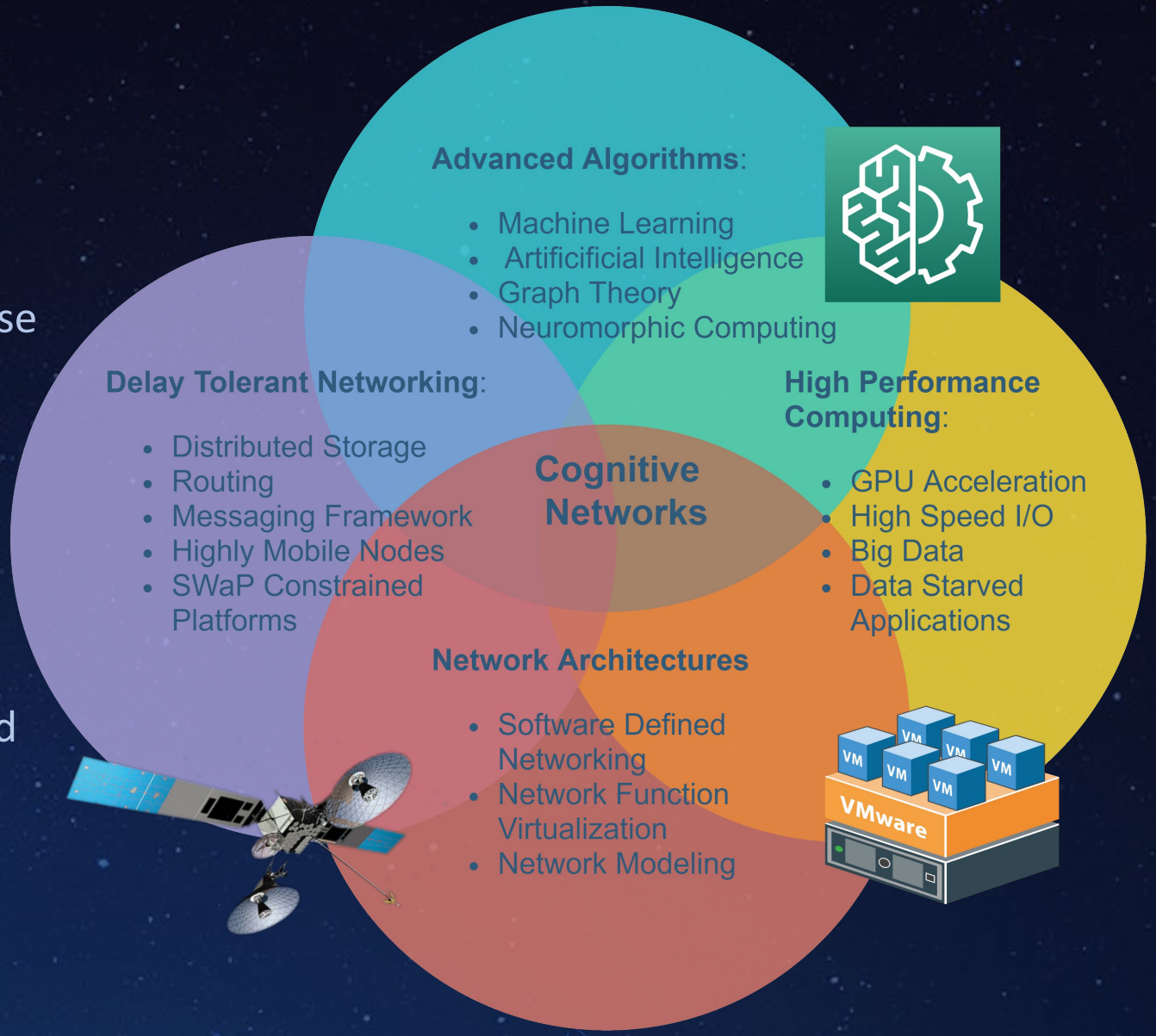
Store
Carry
Forward…

Cognitive networking encompasses several technology areas to develop:

- Autonomous network implementations that sense and adapt to optimize network and system level performance

Meet the challenges of:

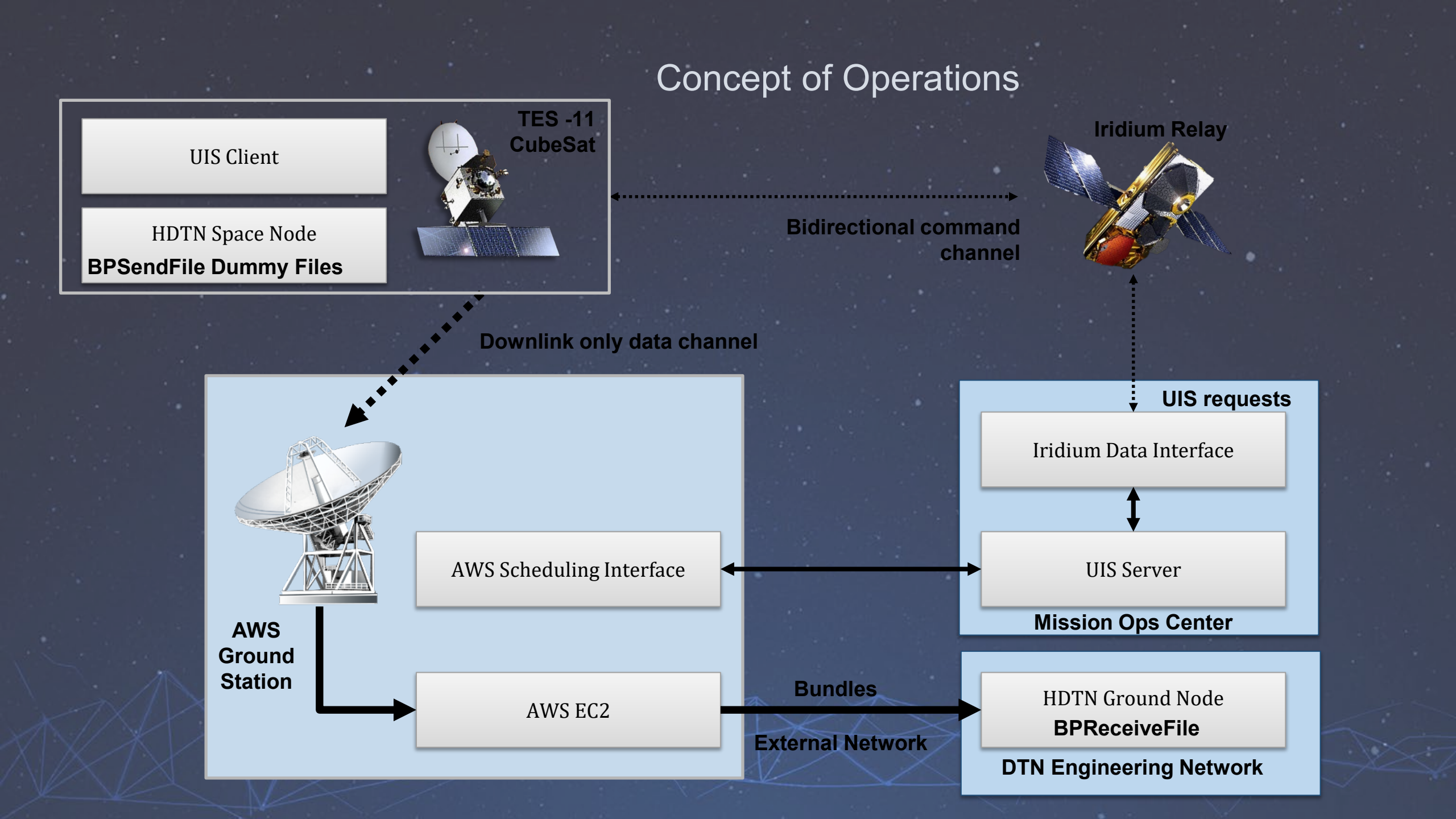
- Scalability of the network
- Low Size, Weight, and Power (SWaP) platforms
- Manage data storage, prioritization, custody, and security
- Interoperability across heterogenous protocols
- Increased data return
- Mobile, intermittently connected network



Flight Demonstrations:

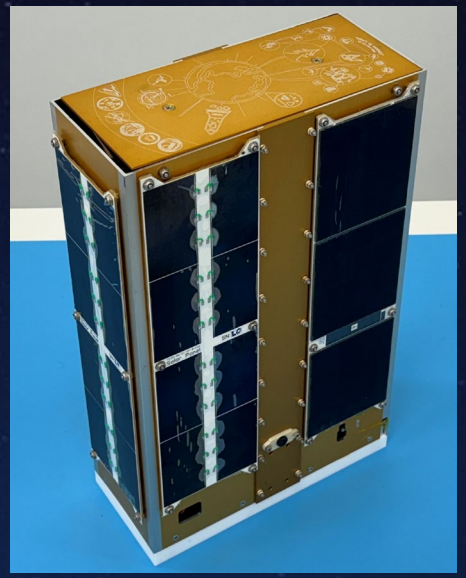
TechEdSat-11

Concept of Operations

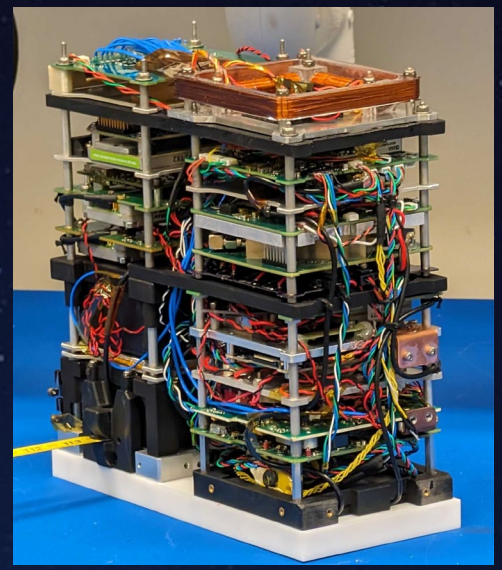


TechEdSat-11

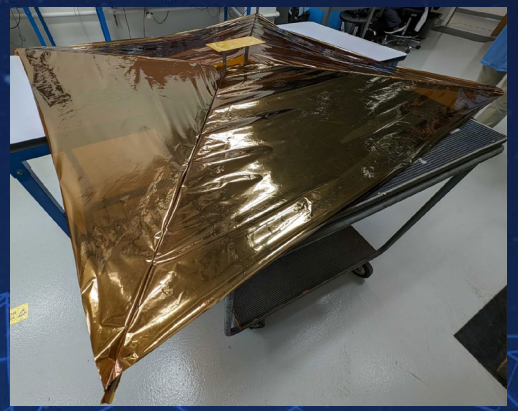
- 6U CubeSat developed at NASA ARC
- 12th spacecraft developed by the TechEdSat-N/Nano Orbital workshop team
- Primary Experiments
  - >Custom S-Band Radio with software developed by GRC, ARC
  - >Custom UHF radio developed by NOAA/MicroCom
  - >New high-capacity power system
  - >Upgraded core avionics system with new payload computer and sensor board
  - >Next revision of the ExoBrake reentry device



TES-11 Spacecraft



TES-11 Avionics Stack

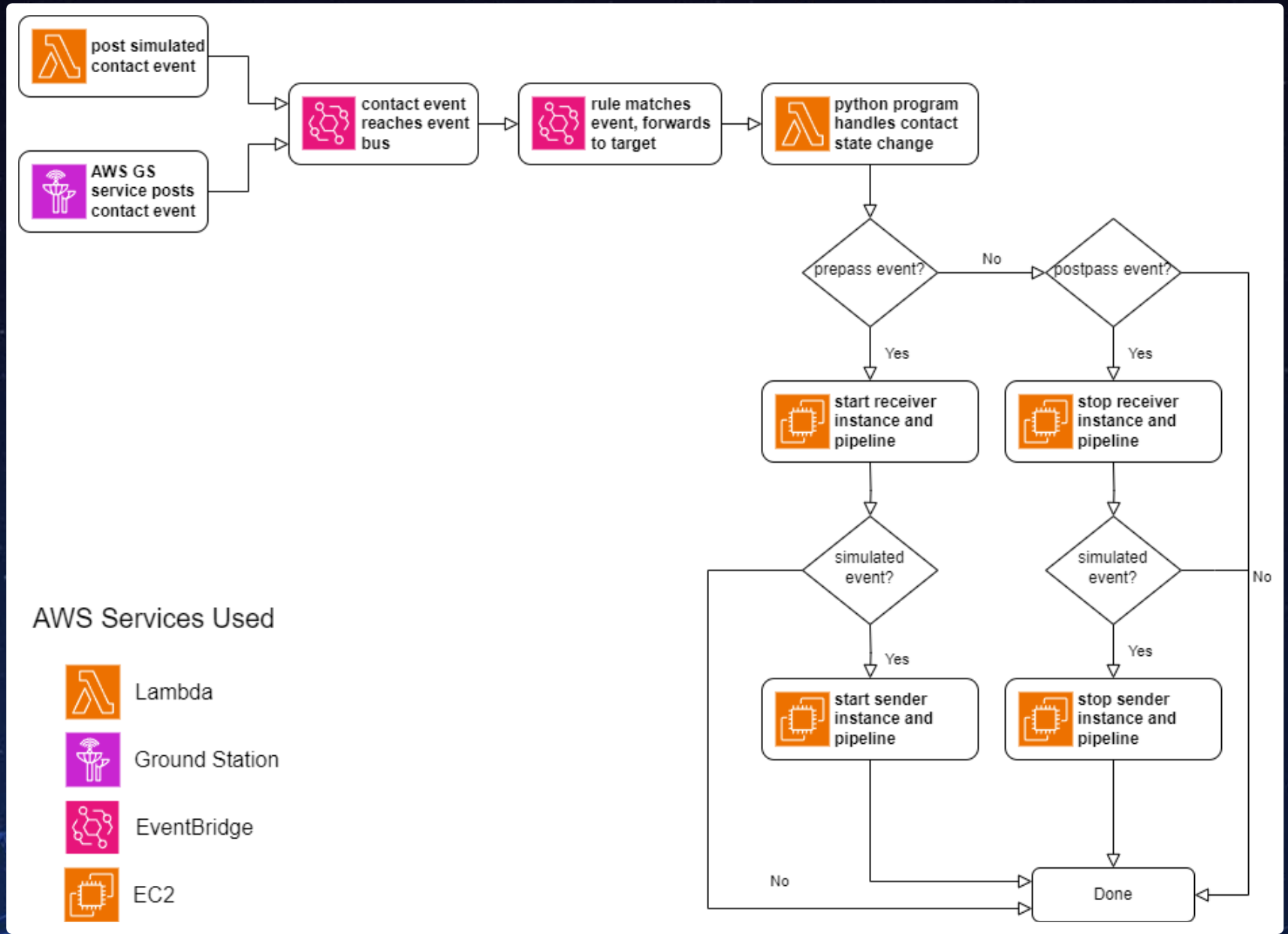


TES-11 Deployed ExoBrake

Artwork developed by local schools

Automation

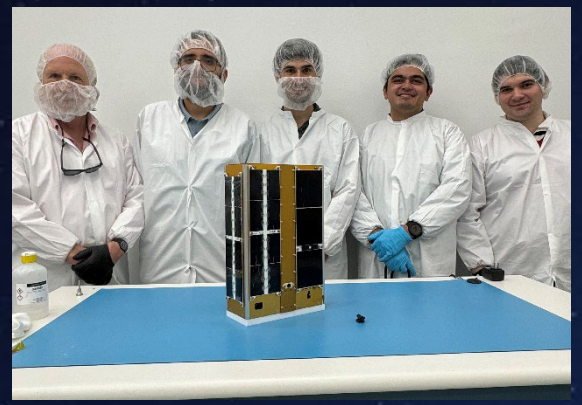
- Spacecraft experiment performs autonomous ground station scheduling
- Commercial ground station signal processing pipeline
- Cloud services are configured for automated data processing and delivery



Automatic handling of (simulated) contact events

Launch

- TES-11 is a part of NASA's ELaNa 43 mission with Firefly Aerospace
  - Successfully integrated the spacecraft on April 2024 at Firefly's payload integration facility
  - Successfully launched on the Firefly Alpha Noise of Summer mission July 3, 2024
- TES-11 made first contact 23 minutes after deployment through its primary Iridium radio



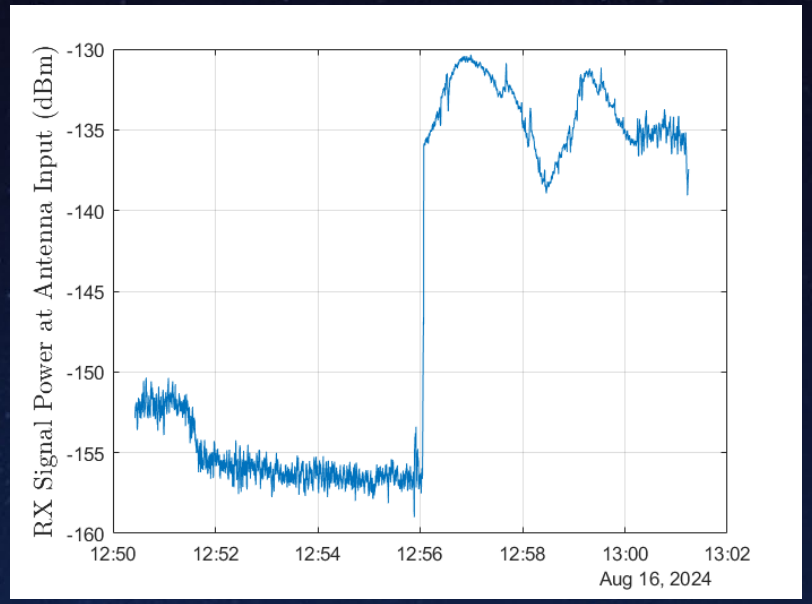
TES-11 team during dispenser integration

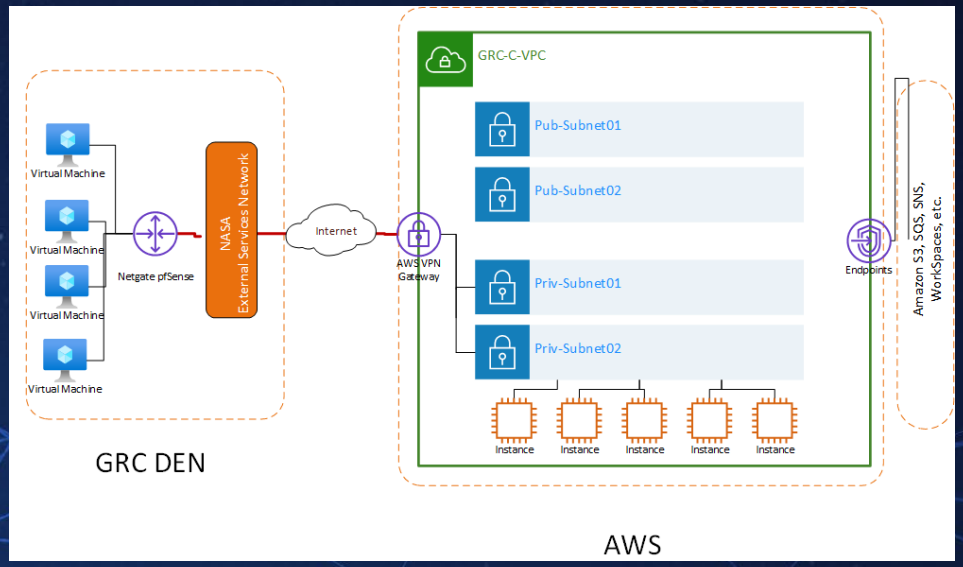
Firefly Alpha seen from LA area

Firefly Alpha dispensing satellites

TechEdSat-11 Current Status

- Using UIS software, the satellite can schedule an AWS contact itself and transmit data at scheduled time
- HDTN can transmit bundles via S-band radio that are decoded in real time
- Stream is delivered to a particular EC2 host on the network, where IF samples are processed by gnuradio programs and bundles by HDTN
- UIS and HDTN have also been used together to schedule a contact and transmit bundles
- Setting up GovCloud connections to the DEN and to Commercial Cloud





Flight Demonstrations:

International Space Station

2024 Demos: Internetworked ISS Experiments

Enhancing High-Rate RF & Optical Networks

LCRD (GEO)
Laser Communications Relay Demonstration on STPSat-6

Cerf talks to Hooke

RTN: 1 Gbps
FW: 155 Mbps

ISS (LEO)
Hooke's Node
(HDTN)

RTN: 517 Mbps
FW: 21 Mbps

PC-12 (aero)
Cerf's Node
(CDTN)

Experiment Objectives:

- Stream scientific data across multiple independent networks
- Interoperate multiple DTN implementations
- Emulate several mission con-ops w/induced latencies
- Baseline performance across different network configurations
  - TCP, STCP, LTP with/without custody
  - Adaptive 4k HD video resolutions & rates
  - Security (encryption and authentication)
  - Link handoffs and outages

laser

Ka-band

Hawaii
Optical Ground Station 1

California
Optical Ground Station 2

New Mexico
RF White Sands Ground Terminal

Ohio

GROUND USER DATA NETWORK

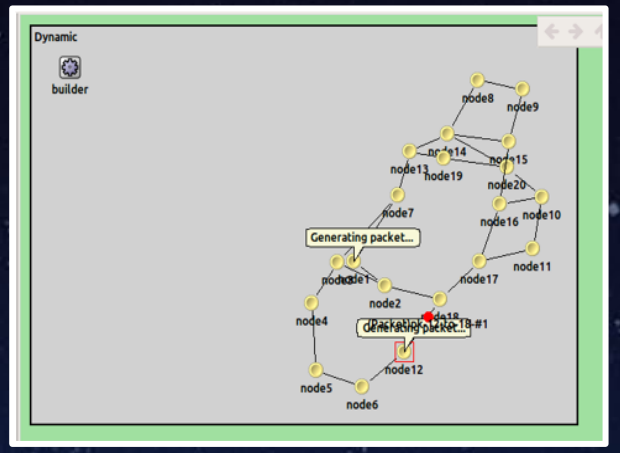
Highlights

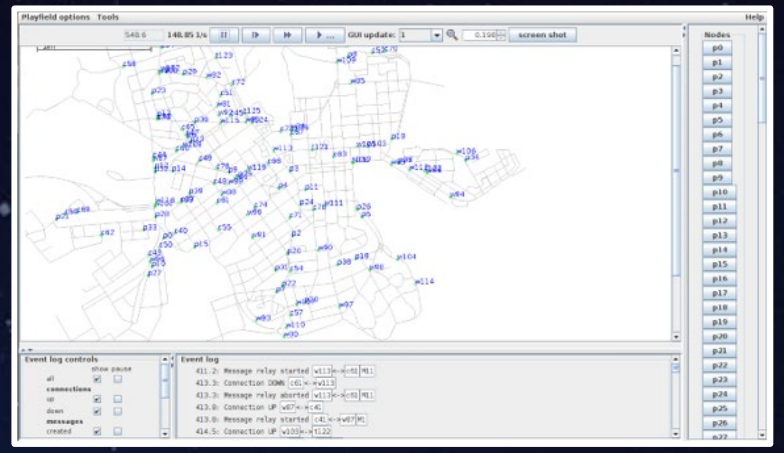
- Demonstrated DTN over laser communication from the ISS to earth and from earth to PC-12 aircraft
- HDTN achieved data rates of 900 Mbps
- First demonstration of high-rate DTN in space
- First use of Bundle Protocol version 7 on the ISS
- First demonstration of Bundle Protocol Security in space

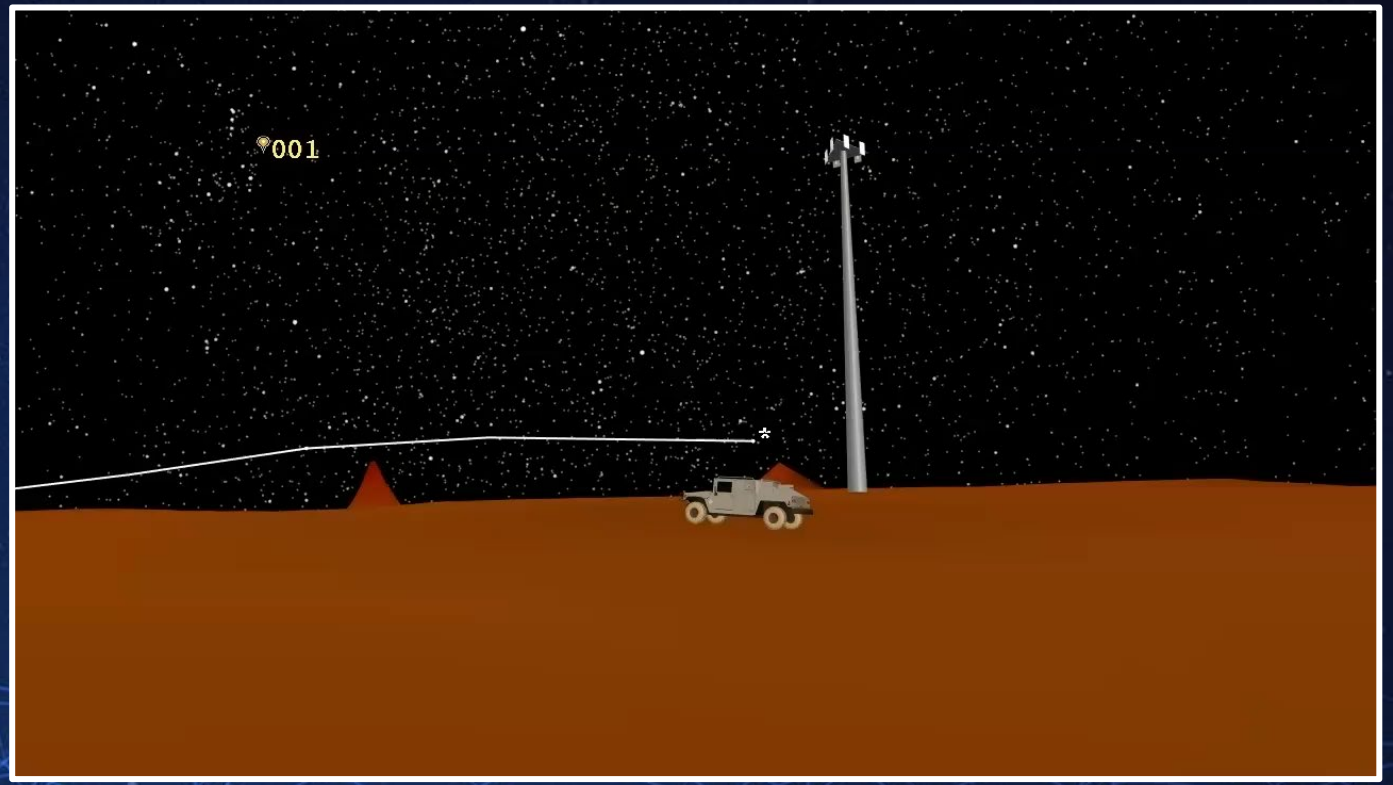
Technology Development

Simulation Platforms

- **Open source discrete event simulators**: ONE, DTNSim and ESTNeT based on OMNeT++ provide framework for low TRL algorithm and protocol proof-of-concept
- **Commercial simulators**: System Tool Kit provides extensive physical layer modeling, integration with other packages
- **Custom developed digital twin**: Modeling of complete spacecraft communication system spanning multiple layers including orbital assets, links, network protocols, and onboard storage.

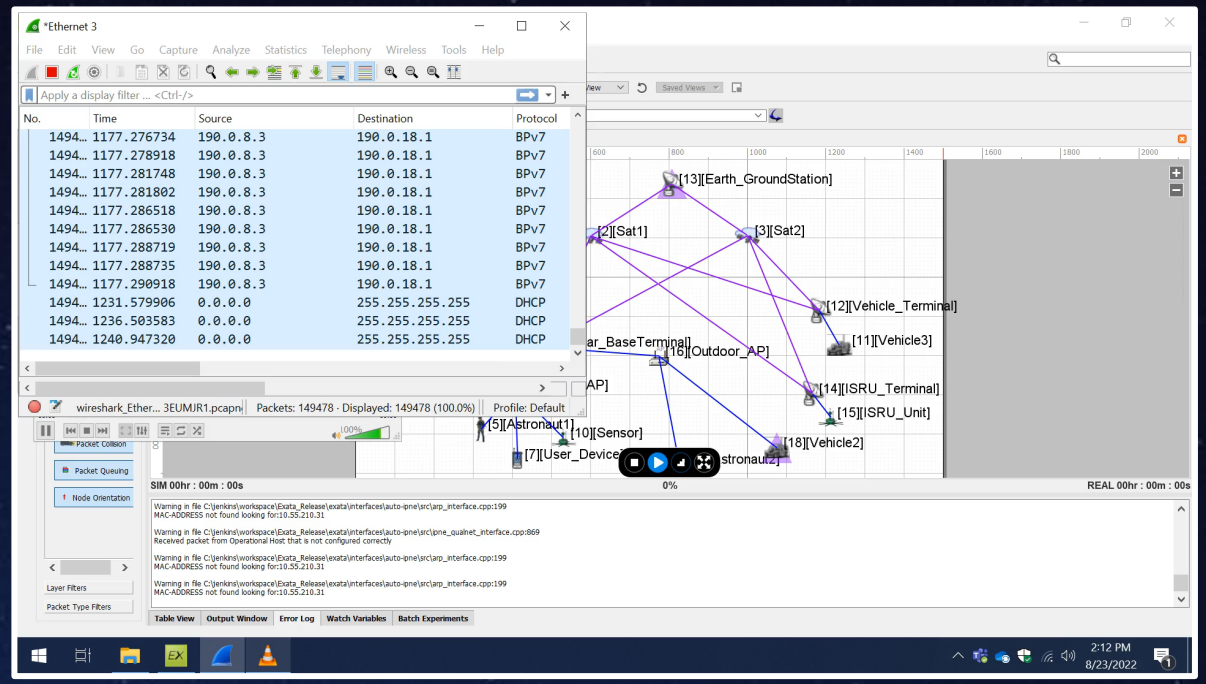


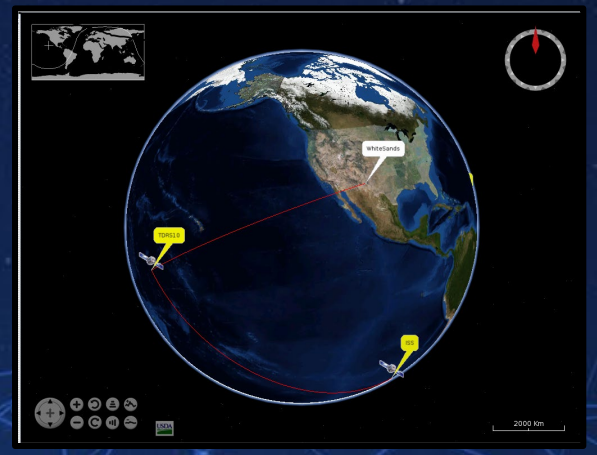


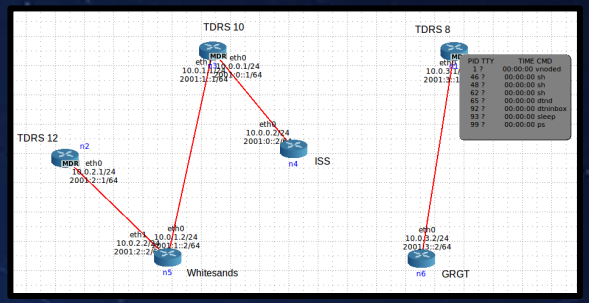


Emulation Platforms

- **Open source network emulators:** CORE/ EMANE uses OS network stack and containers for network level emulation with configurable radio models.
- **Commercial emulators**: EXata is integrated with STK and Wireshark, provides built-in visualization and metrics. Netropy emulator easily connects to LAN devices.
- **Custom testbeds and emulators**: Full system combining commercial components, custom scripts and software, and flight-like hardware.







Operations

- Improve user experience
- Scheduling
- System configuration
- Tuning parameters
- Develop trust in AI/ML solutions