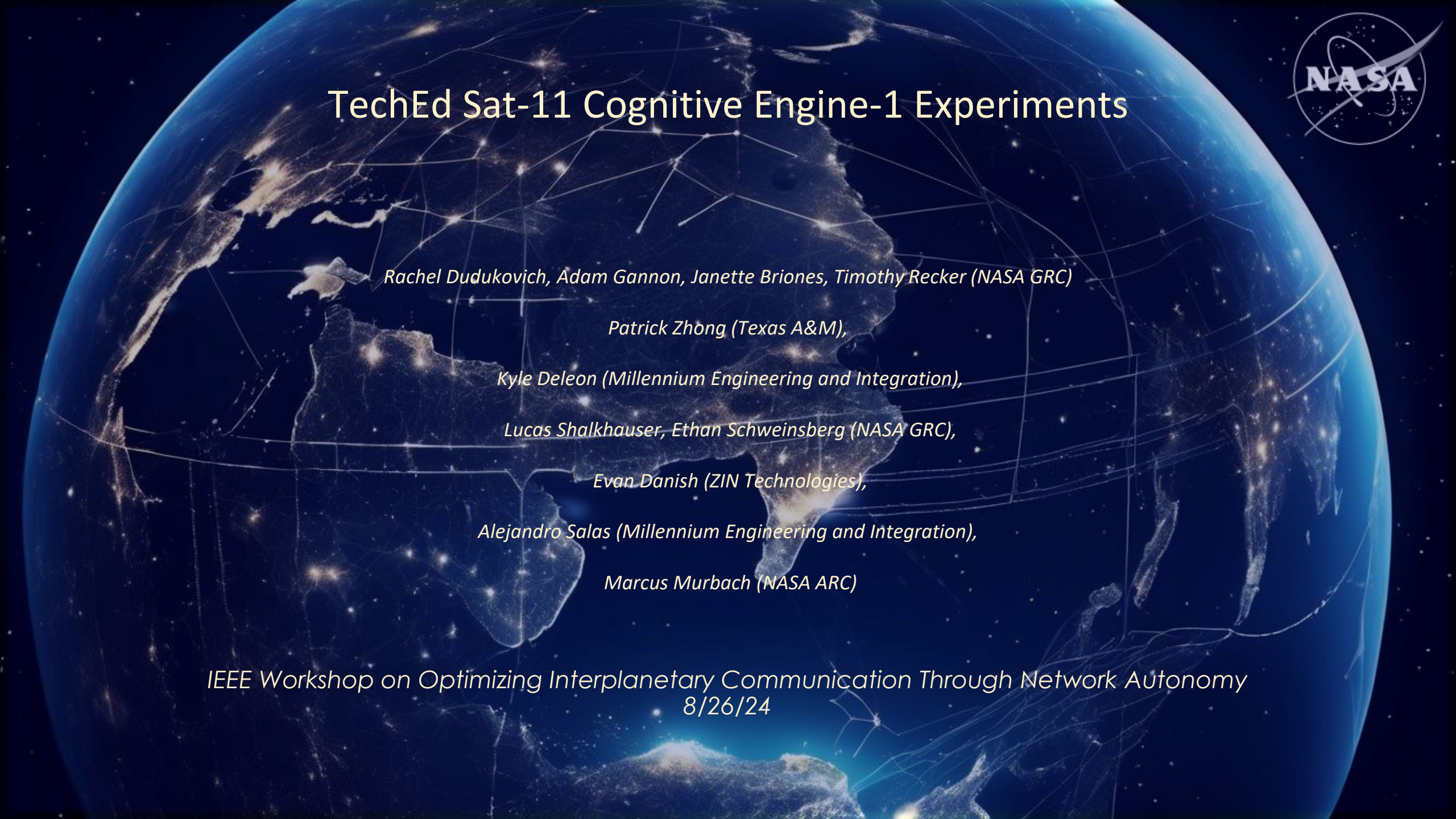


TechEd Sat-11 Cognitive Engine-1 Experiments

Rachel Dudukovich, Adam Gannon, Janette Briones, Timothy Recker (NASA GRC)

Patrick Zhong (Texas A&M),

Kyle Deleon (Millennium Engineering and Integration),

Lucas Shalkhauser, Ethan Schweinsberg (NASA GRC),

Evan Danish (ZIN Technologies),

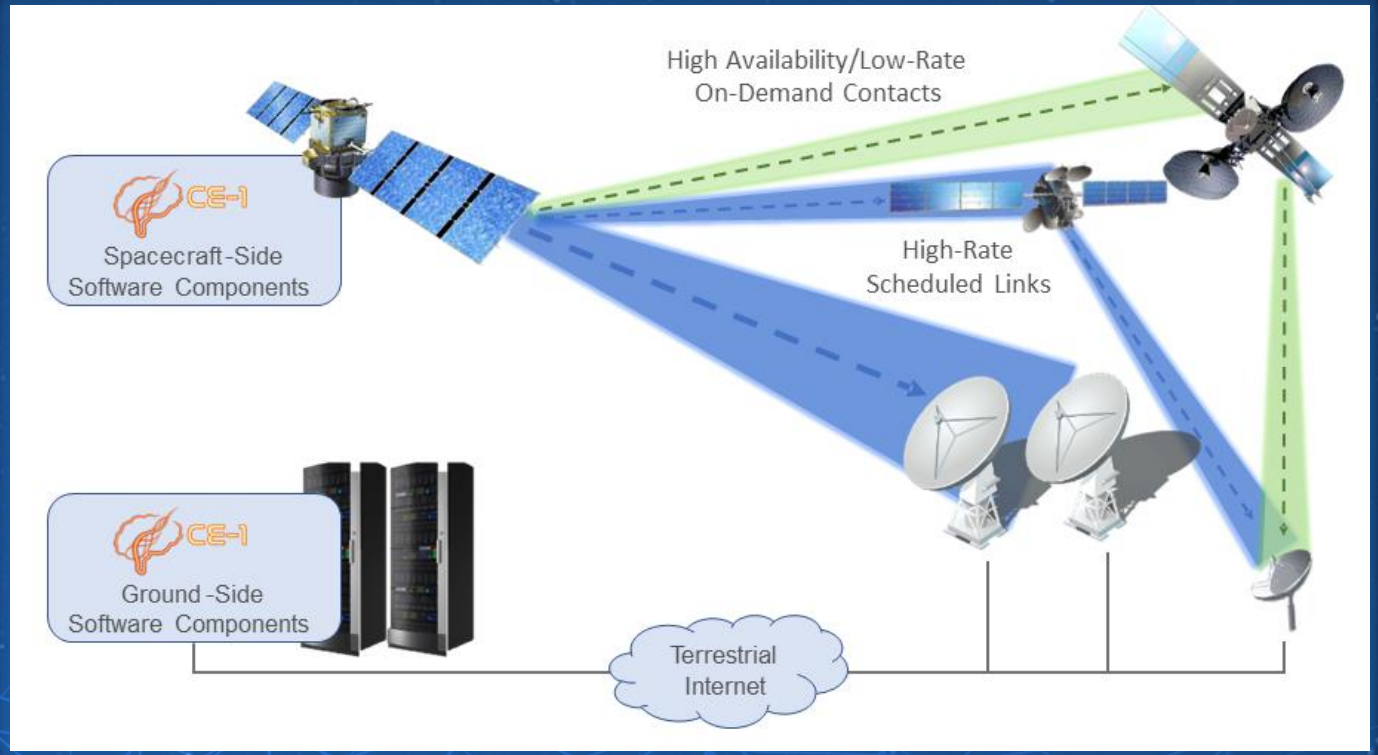
Alejandro Salas (Millennium Engineering and Integration),

Marcus Murbach (NASA ARC)

IEEE Workshop on Optimizing Interplanetary Communication Through Network Autonomy
8/26/24

Motivation

- Operate aspects of Cognitive Communications in a flight environment
- Dynamically schedule commercial ground station service
- Demonstrate interplanetary networking protocols
- Utilize commercial automation tools via AWS

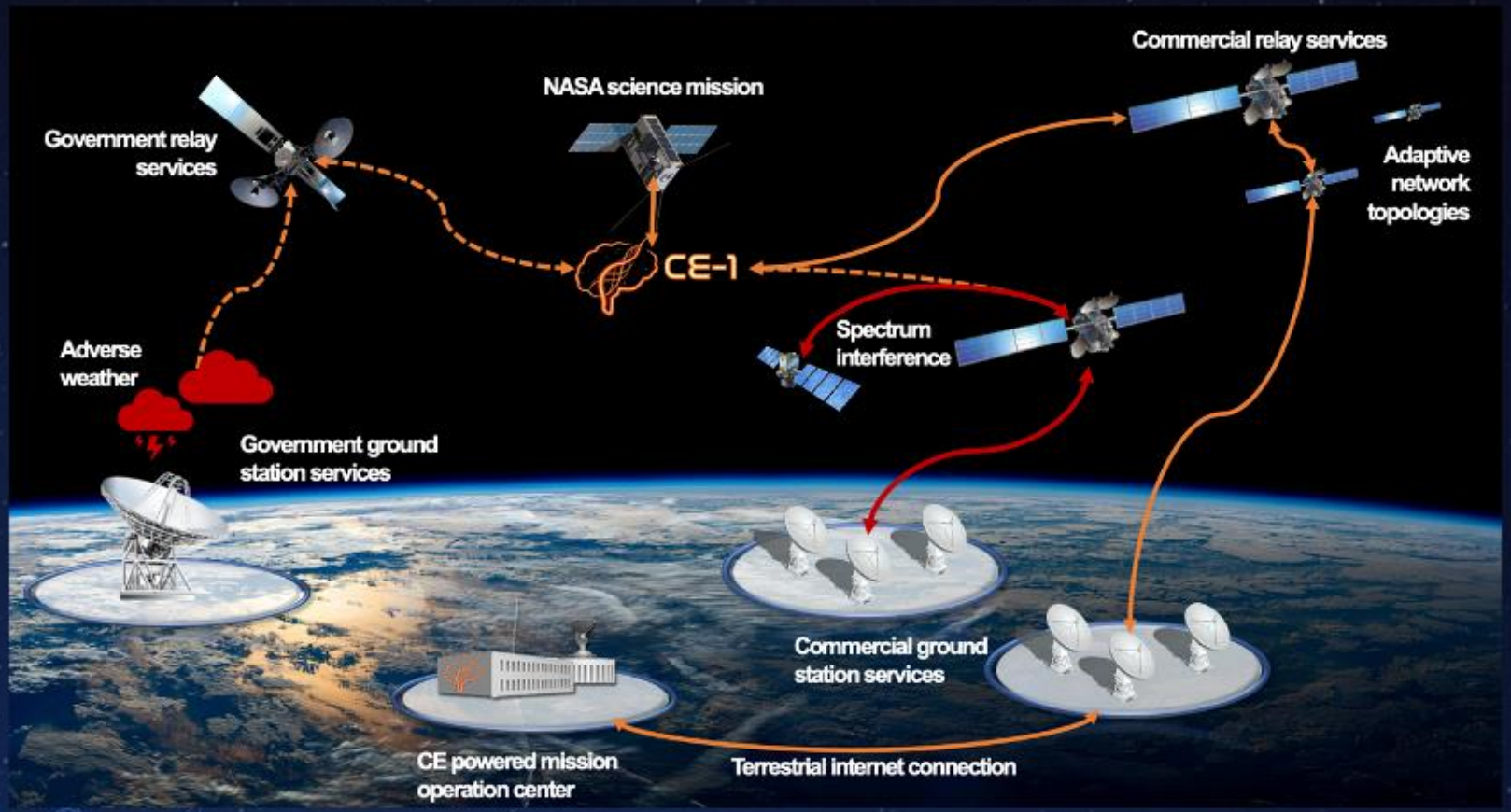



Cognitive Engine 1

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.

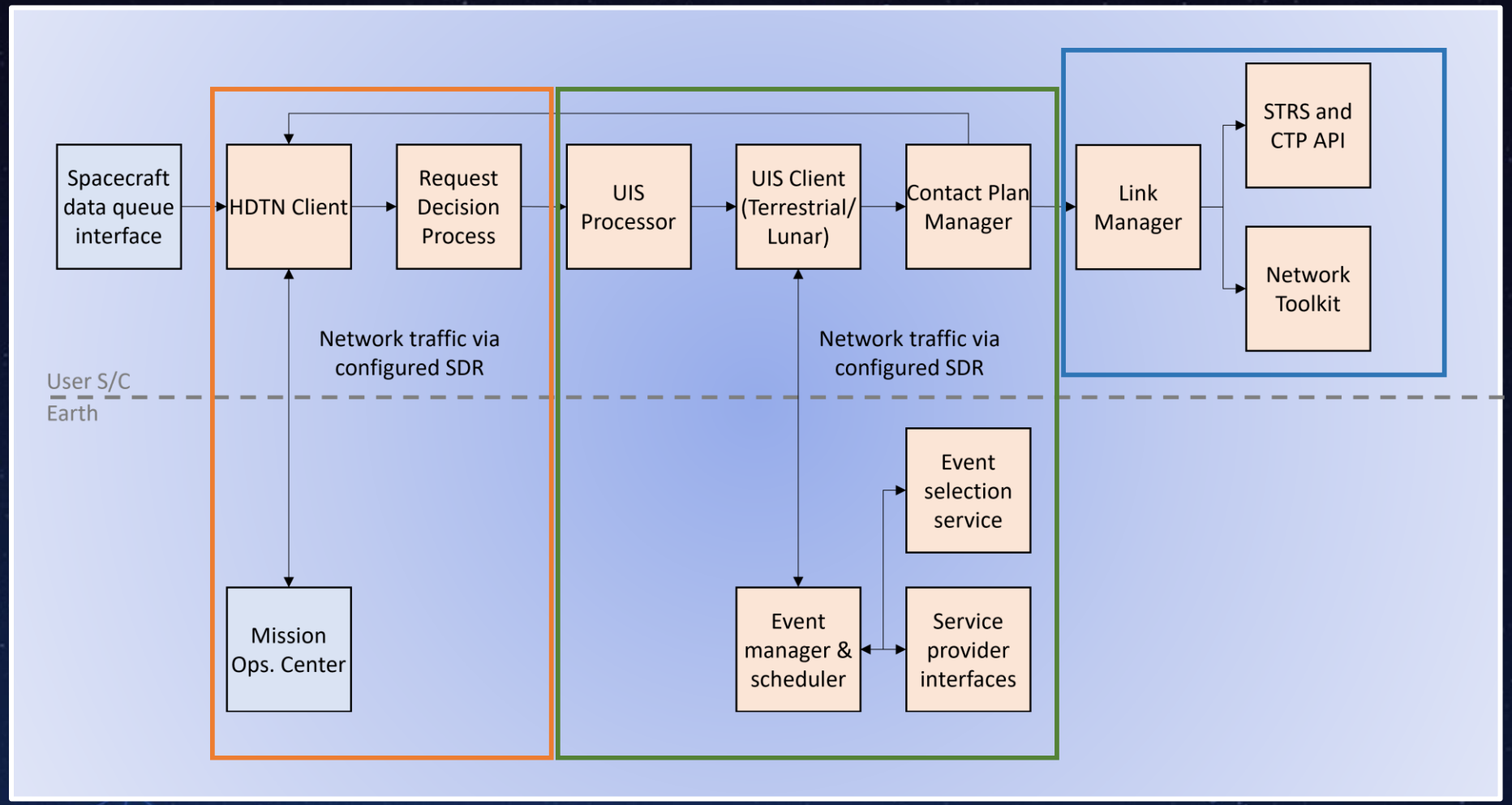
Cognitive Engine-1 Main Components

HDTN:

- High-rate Delay Tolerant Networking
- DTN makes store-or-forward and next-hop destination decisions.
- Mitigates disruptions and delays, and provides secure and reliable data transport
- Packages data as “bundles”

UIS:

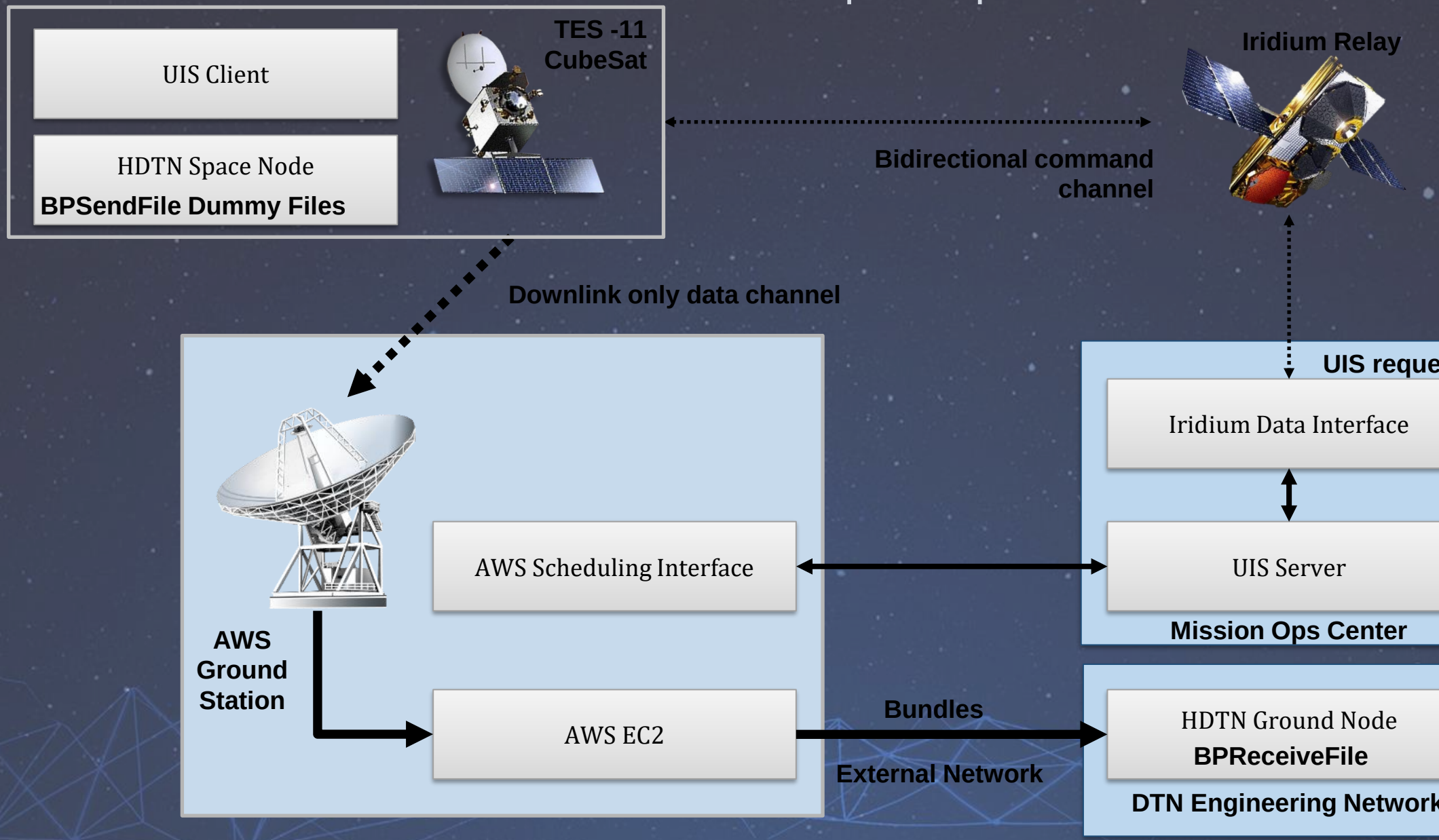
- User Initiated Services
- Allows spacecraft to request high-rate data service
- Uses low-rate command channel to contact ground server
- Ground server performs scheduling of commercial and government relay service
- Selects optimum service based on requested data volume, deadline and availability



Cognitive Engine-1 Automated System

Experiment Overview

Concept of Operations



Experiment Phases

Check Out

- Check out radios, avionics, and battery
- Identify TES-11 and receive TLE

Phase 1

- Send UIS request from TES-11 and receive at NASA GRC
- TES-11 should receive response from UIS

Phase 2

- UIS will schedule antenna time with AWS Ground Station
- TES-11 will then start the S-band transmission of data at the proper time
- Signal will be received by AWS Ground Station
- Separately, HDTN will transmit bundles via the TES-11 S-band radio

Phase 3

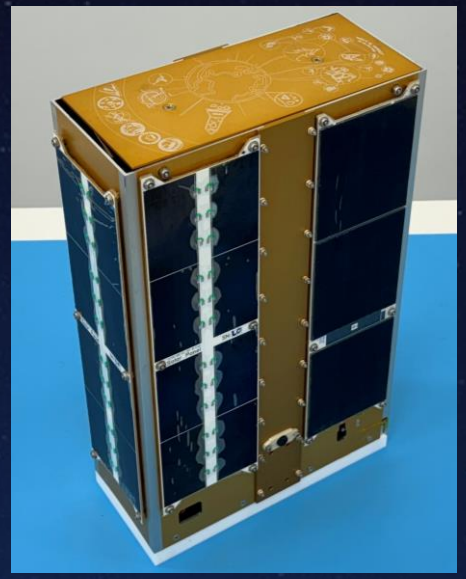
- TES-11 will simulate data generation, multiple UIS messages will be sent, received, and scheduled with AWS
- HDTN will send a series of bundles which should be correctly received at the AWS cloud.

Phase 4

- UIS will schedule a link as in Phase 3 but HDTN will flow bundles over the link instead of simulated data.
- Attempt to transfer bundles from AWS cloud to DTN Engineering Network

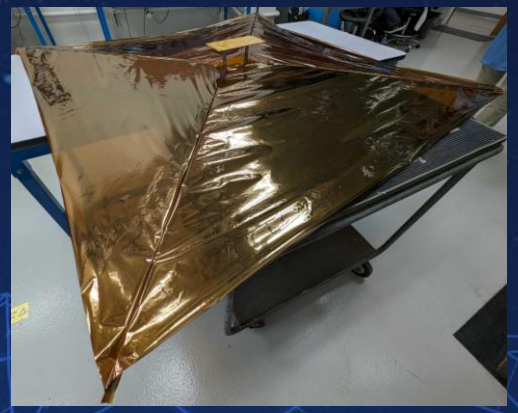
TechEdSat-11

- 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

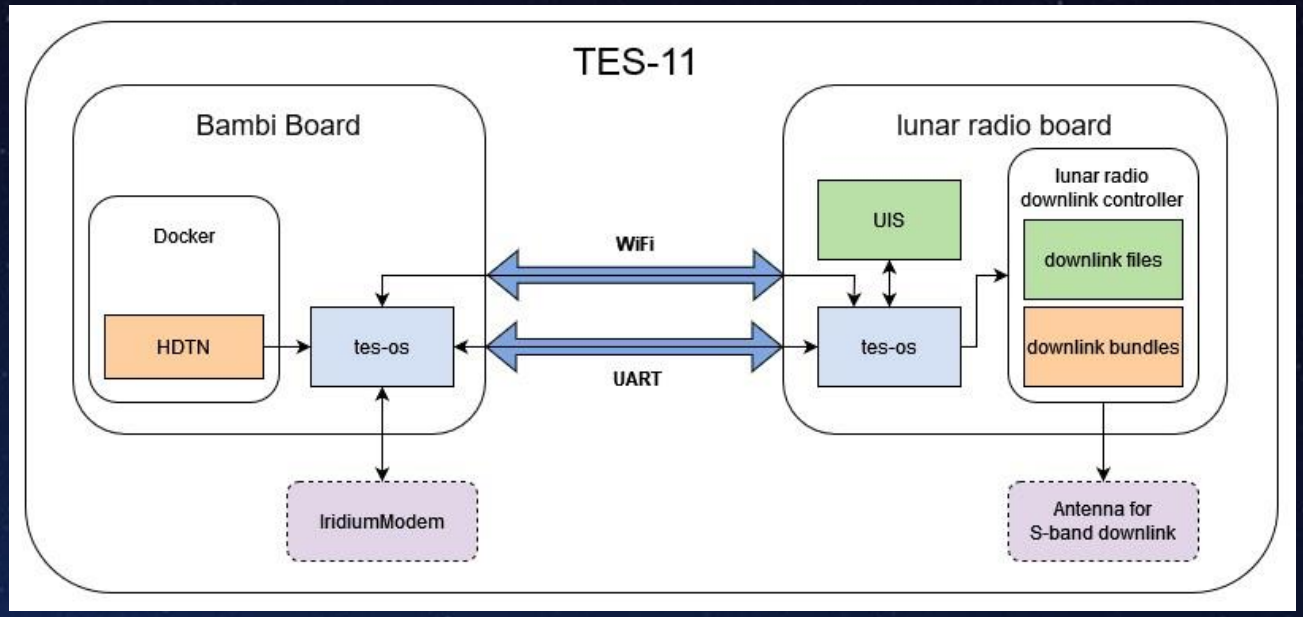


TES-11 Deployed ExoBrake

Artwork developed by local schools

Flight Software and Avionics

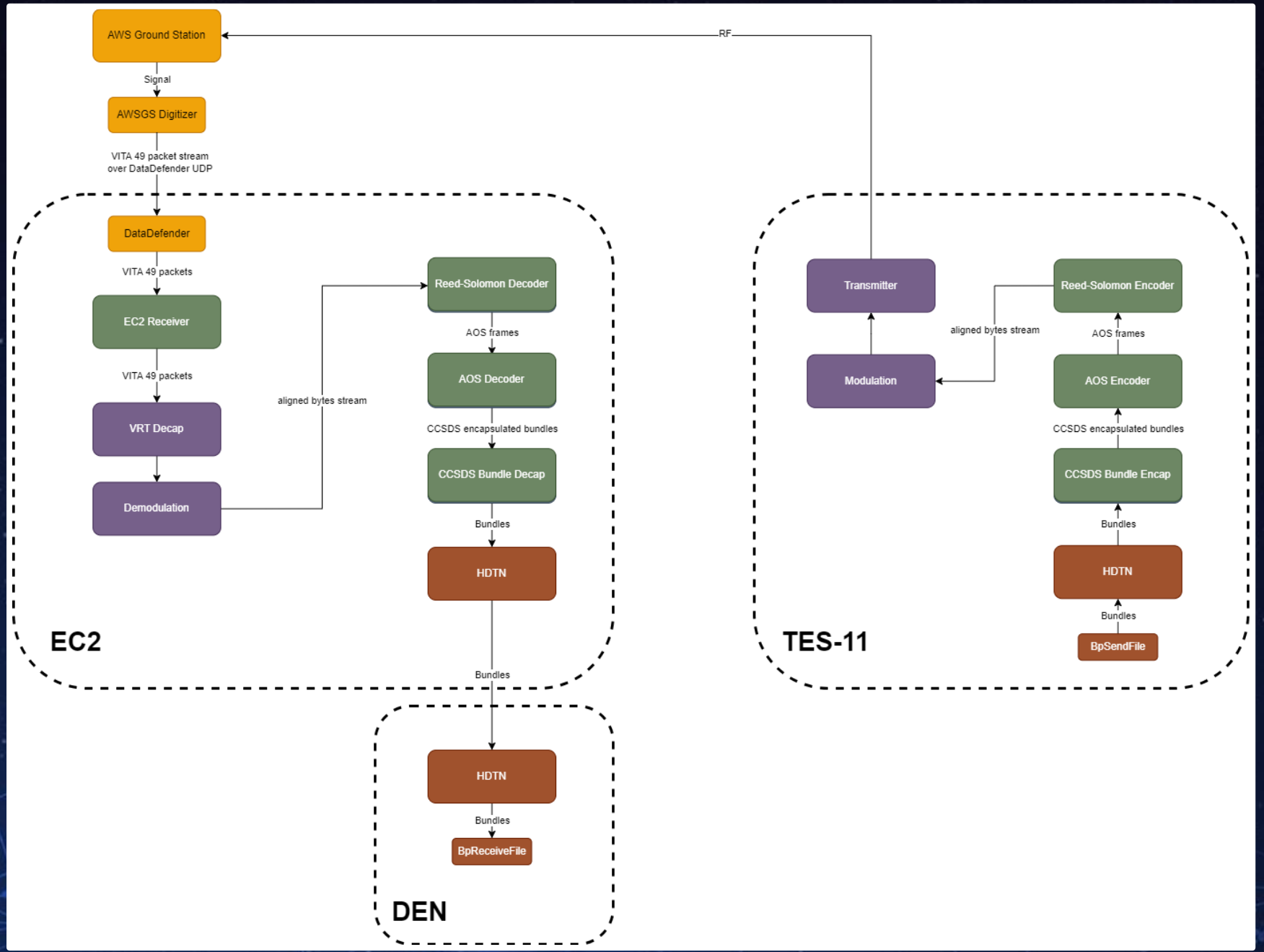
- TES-11 platform consists of multiple interconnected boards
- Lunar Radio board runs UIS software and handles downlink to the ground
- Beacon And Memory Board Interface (BAMBI) board hosts HDTN and handles command and control
- Iridium modem uses short burst data service for bi-directional low-rate command and control
- TES-OS is a custom-built application for TechEdSat developed by NASA Ames used for command and control and experiment orchestration
- UIS and HDTN are the GRC experiments
- Interface software between the components



- BAMBI board consists of a Portenta X8 processor
- Lunar Radio board consists of an Ettus B205mini SDR and a Digi ConnectCore 6UL system-on-module

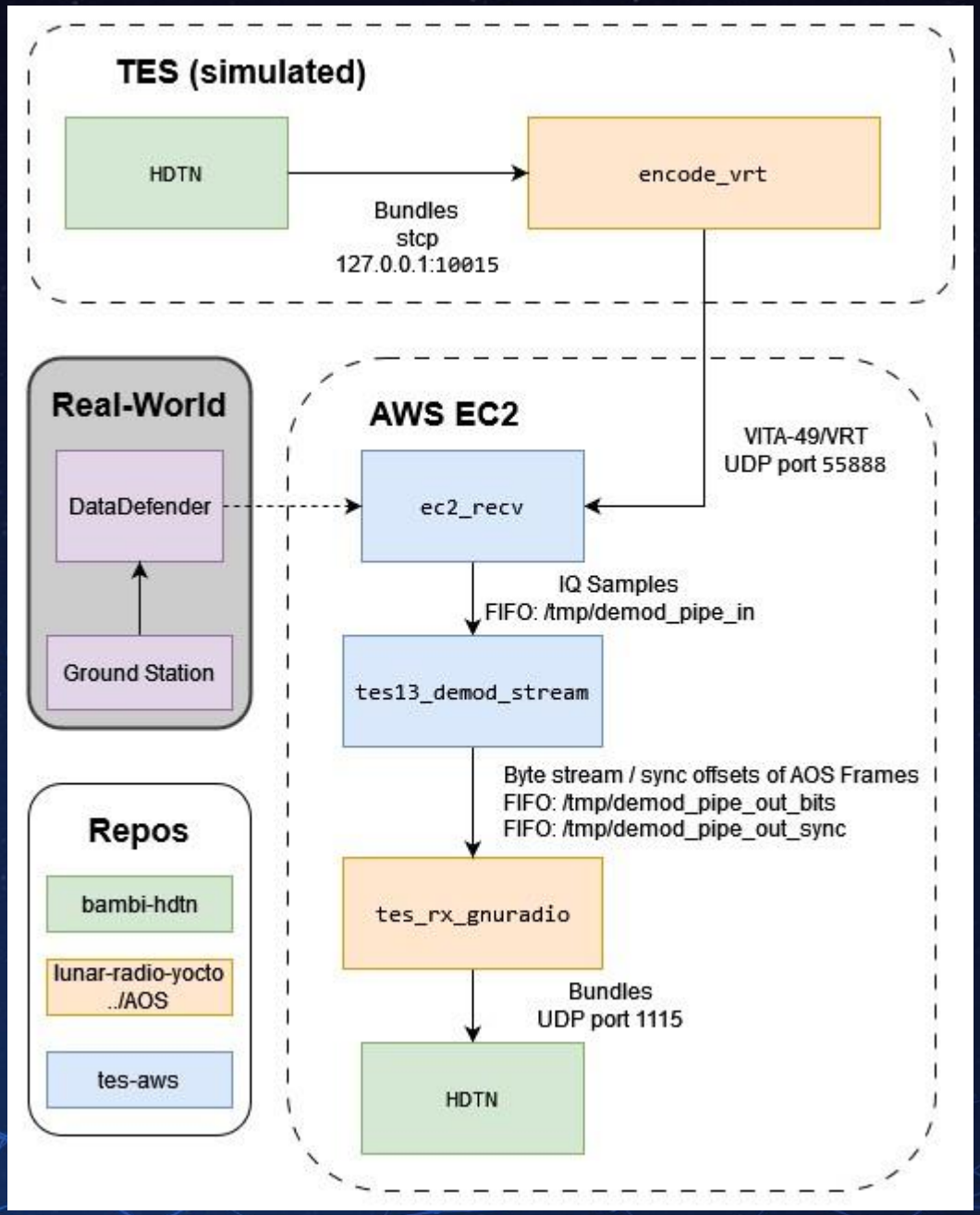

Ground Network

- An AWS EC2 instance on the ground performs de-encapsulation, demodulation, and decoding.
- Kratos DataDefender is required on AWS for streaming data from Ground Station to EC2
- Instance creation and software build and install automated using CloudFormation template and S3 buckets
- Instance and data pipeline started and stopped automatically in reaction to prepass and postpass events using AWS EventBridge and Lambda
- Recovered bundles can be forwarded to the DTN Engineering Network (DEN), our lab network which also contains additional VPN connections to the networks of other NASA centers and industry partners
- Basic two-hop network configuration intended to emulate a spacecraft delivering data to an operations center via the commercial services of some gateway



Ground Network Testing

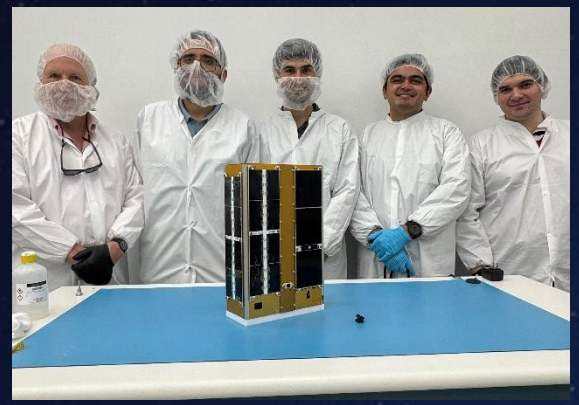
- Data pipeline can be tested using simulated TES on another EC2 instance
- Simulated contact events can be generated to trigger EventBridge rules, causing automatic startup and shutdown of instances and data pipelines
- Containerization via Docker makes it easy to run same Bundle Agent configuration and traffic flow on the satellite and the ground



Current Status

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



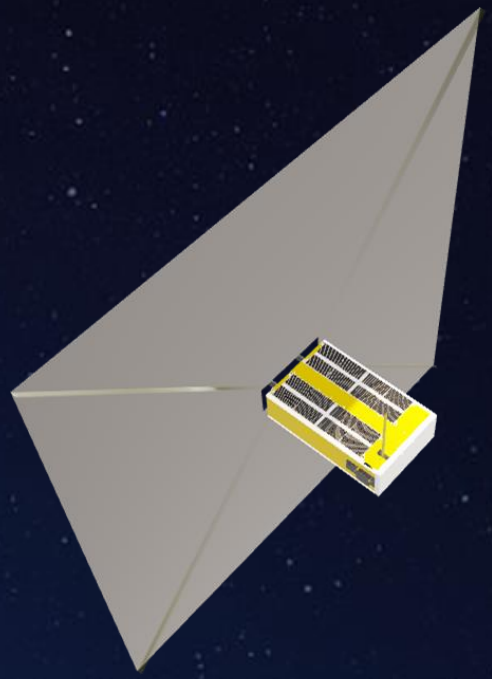
TES-11 team during dispenser integration

Firefly Alpha seen from LA area

Firefly Alpha dispensing satellites

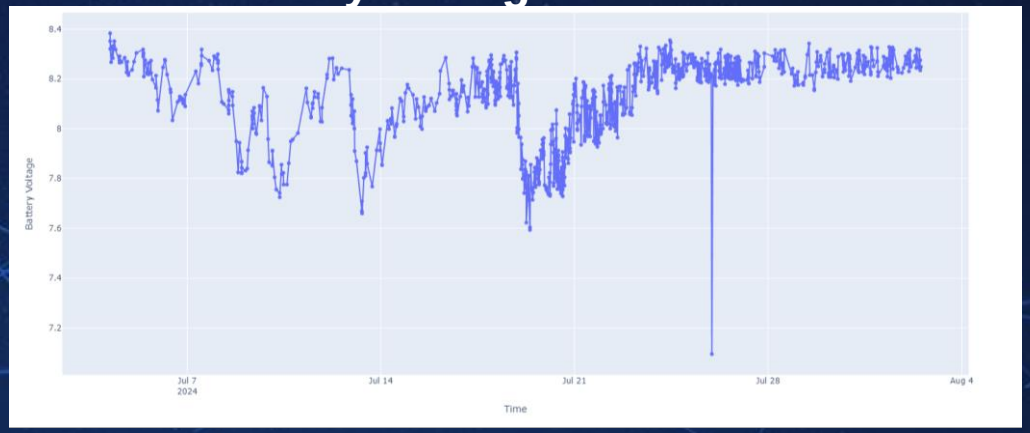
System Checkout

- Initial functional checkout phase is complete
  - All primary Iridium radios are operational
  - Core spacecraft avionics are operational and working as expected
  - New power system is operational, and batteries are charging as expected
- Started mission operations for the primary payloads
- Will begin tests with the S-Band radio this week
  - Test 1: Basic transmission over AWS ground station without cognitive software (completed)
  - Test 2: Initial UIS only test to ground station
  - Test 3: HDTN only test to ground station
  - Test 4: UIS and HDTN test over ground station



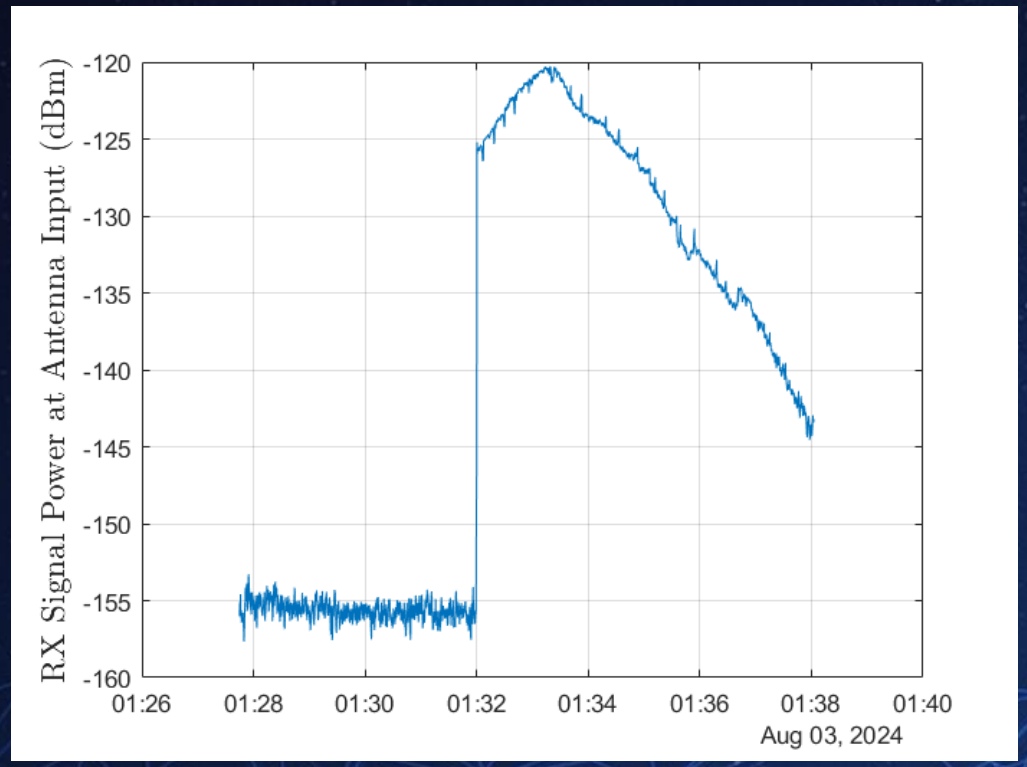
TES-11 Deployed Exobrake

TES-11 Battery Voltage over Time



Initial Pass with S-band Radio

- Scheduled 9-minute pass 01:29:01 to 01:38:01 on 8/3/2024
- High elevation (69°) with the satellite moving from north to south
- Decoder statistics show 39956 decoded AOS frames and a total of 42.1MB recovered



Acquisition of Signal at 01:31:59Z

TES-11 Line of Site to AWS OH

Conclusion

- TES-11 will demonstrate:
  - Automated scheduling
  - AWS commercial ground station demodulation pipeline
  - Space internetworking with HDTN
- TES-11 is currently operational and beginning experiments
- Future work includes AWS ground station integration with the DTN Engineering Network
- Plan future collaborations between NASA Ames Research Center and Glenn Research Center

Contacts and Resources

- GRC DTN: https://www1.grc.nasa.gov/space/scan/acs/tech-studies/dtn/
- HDTN: https://github.com/nasa/HDTN
- HDTN PI – Daniel Raible
- HDTN PLE – Rachel Dudukovich, rachel.m.dudukovich@nasa.gov

GRC DTN Team

- IEEE Cognitive Communications for Aerospace Applications Workshop: https://ccaaw.ieeecleveland.org/
- Cog Com PI- Janette Briones
- Cog Com PLE- Joe Downey

GRC Cognitive Com Team

- https://www.nasa.gov/centers-and-facilities/ames/what-are-nasas-technology-educational-satellites/
- TES PI – Marcus Murbach

ARC TechEd Sat Team