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Cognitive Engines for Provisioning Commercial Gateways

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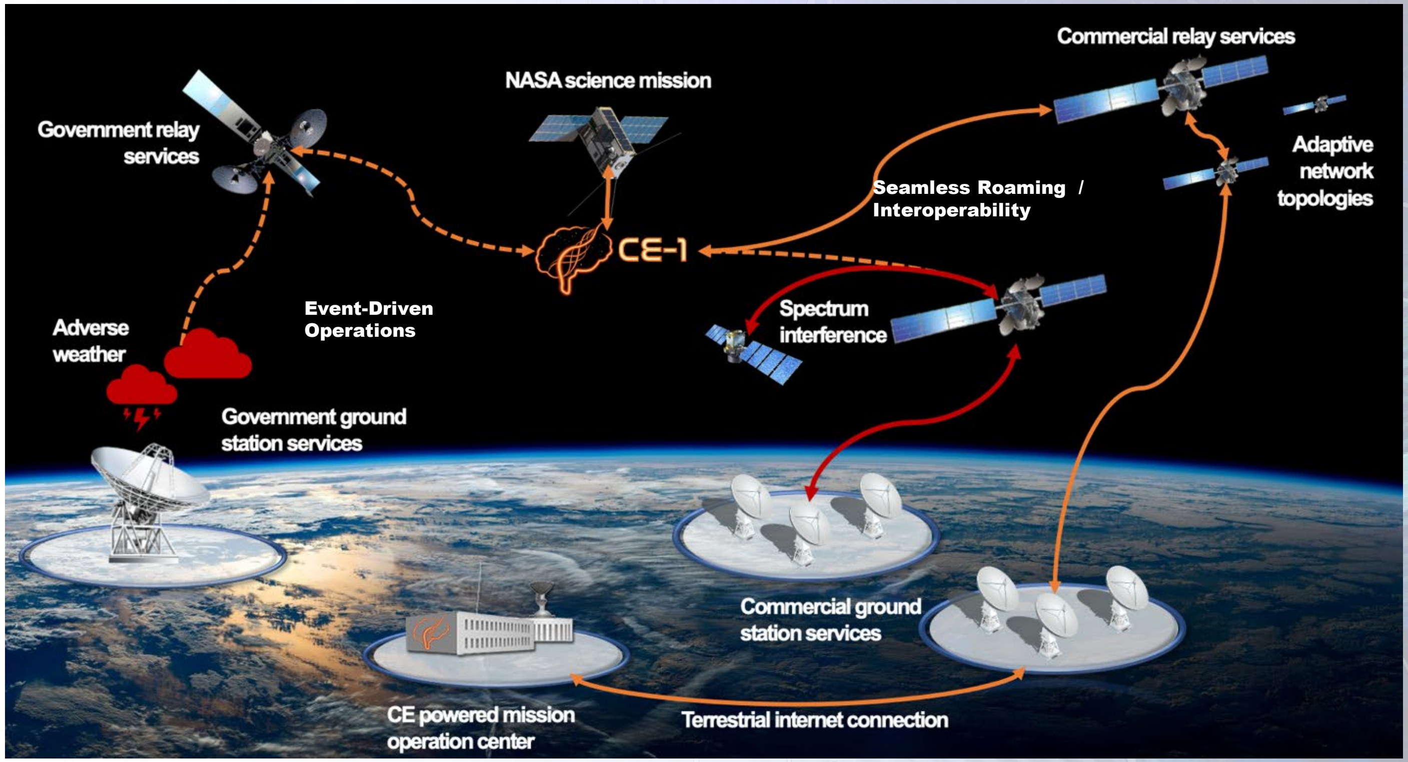
Space Applications for Cognitive Systems

Future space will require new capabilities, dynamic configurations, increased networking, and resilience against emerging threats

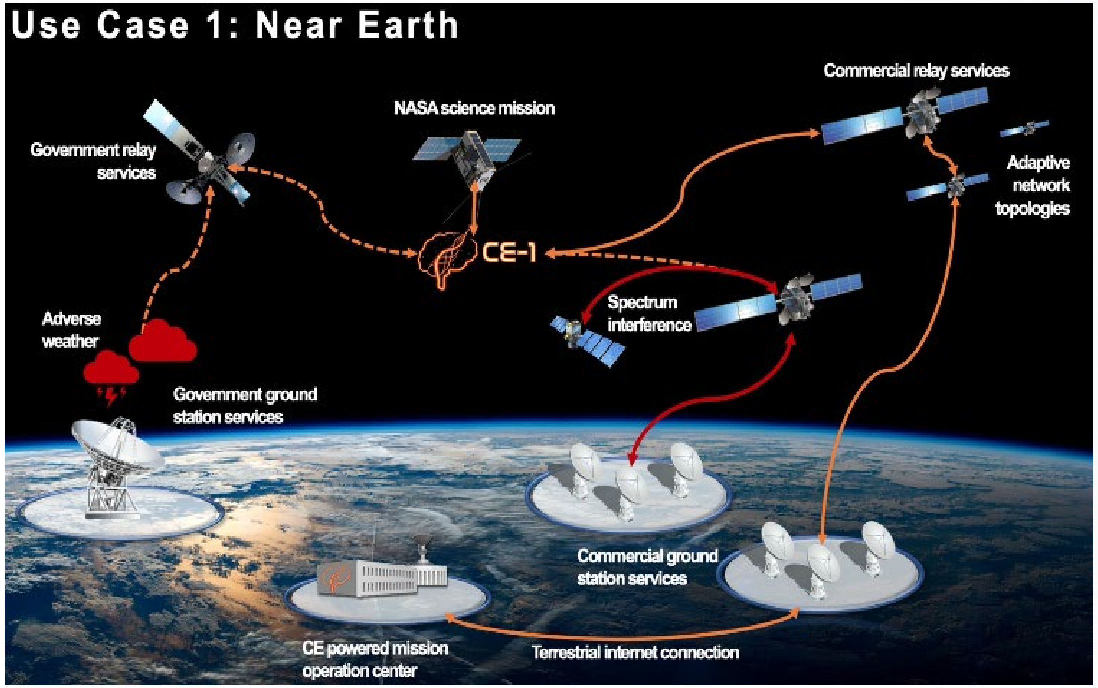
- Data Fusion & Edge Processing
- Increased Autonomy
- Situational Awareness
- Rendezvous & Proximity Ops
- Dynamic Data Transport
- Integration of Commercial/Gov't Constellations & Gateways



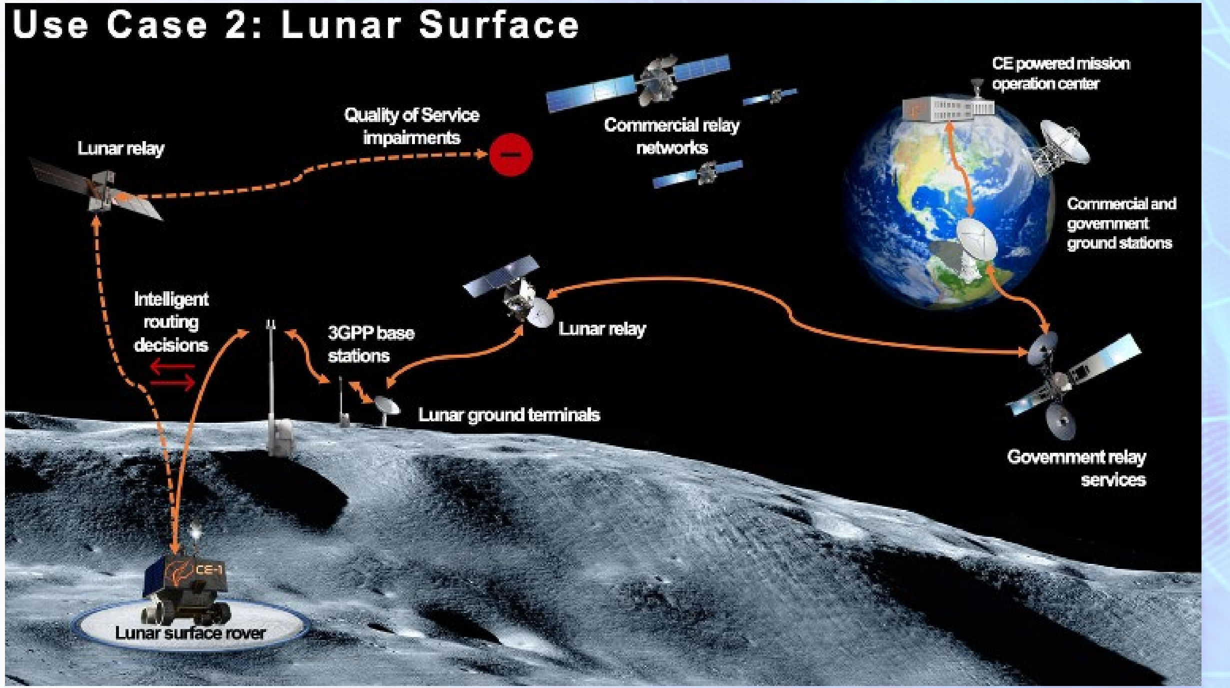
Future capabilities are dependent on cognitive engines tailored to space operations

Use Cases – autonomous communication system operations in Near-Earth and Lunar domains

CE-1 is a prototype unit comprised of multiple software sub-systems and will be demonstrated in an emulated environment focused on two Agency relevant use-cases: a LEO science mission and a lunar surface exploration mission.



Use Case 1 highlights the near-term value proposition for cognitive engine technology and will stress CE-1 in a complex, crowded, and dynamic ecosystem



Use Case 2 stresses CE-1's networking and routing capabilities, which are critical for cognitive engine functionality in the lunar domain

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

Cognitive Engine-1

NASA's first step towards adopting a cognitive future.

Cognitive Engine-1 (CE-1): Automation software and AI/ML-enabled algorithms enable CE-1 to conduct routine operations and respond to adverse events without requiring human operator input.

Autonomous scheduling

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.

Seamlessly adapt to a changing environment

Cognitive algorithms allow CE-1 dynamically reconfigure based on observed performance, discover new network assets, and adapt to bad weather.

Maximize performance

Adaptive coding and modulation allow CE-1 to optimize data throughput during a pass, while intelligent fragmentation optimizes throughput over a set of passes.

Build for the future

CE-1 is a platform for development of future low-SWaP cognitive engines intended for use in satellites and robotic exploration systems.

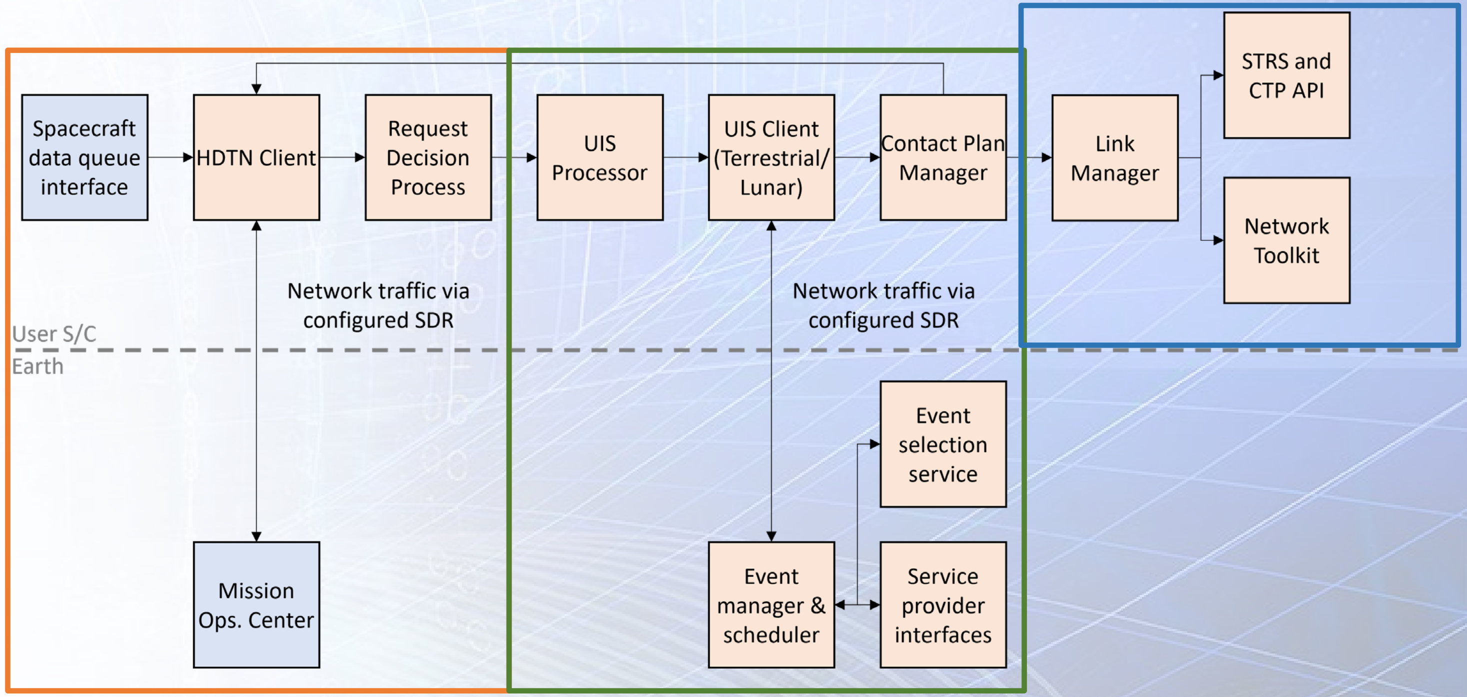
CE-1 Automated System Capabilities

Automatic Data Handling:

- High priority earth observation data enters CE-1 message queue. CE-1 autonomously handles all remaining steps in communications process.
- Data from an underperforming contact will remain in storage, which will trigger an additional request for service.

Fulfill Requests for Service:

- Automatically schedules and coordinates space communication service with the appropriate network service provider. Spacecraft increases network efficiency by only scheduling time required to meet data needs.
- Seamlessly interacts with government and commercial relay service providers and multiple DTE providers while complying with lower-layer protocols required to operate on a provider network.
- Automatically rescheduling in case of a failed pass makes best effort to meet latency constraints.



CE-1 Automated System optimizes communications link throughput, data routing, and systems-wide communication orchestration

Establish Radio Links:

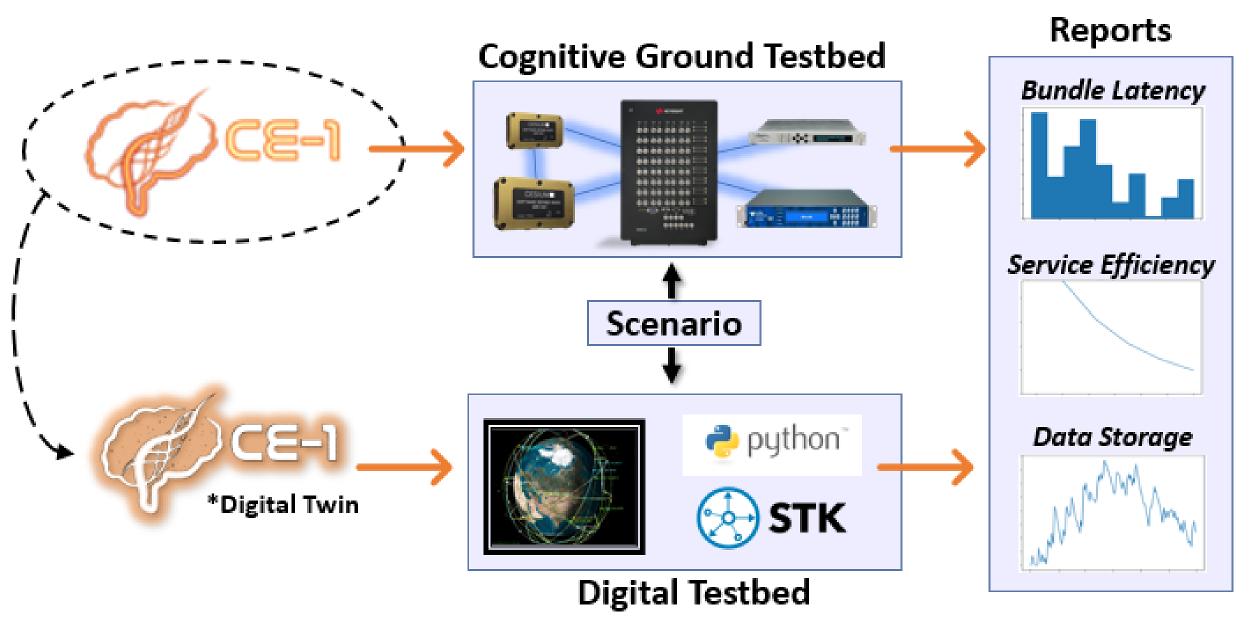
- Providers may require certain parameters at physical, link, and network layer for compatibility.
- SDR with provider-specific waveform will configure itself to flow network traffic to the MOC without human operator input.

Evaluating CE-1 Performance

- CE-1 Automated system will be evaluated using two approaches
  - Software Simulation – Digital Testbed
  - Hardware Emulation – Cognitive Ground Testbed

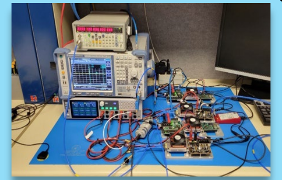
- Digital Testbed provides Python-based emulation of the distributed CE-1 system, using identical scenario definition files, and same STK backend for link analysis. Provides early exploration of alternative algorithms, and long-duration statistics

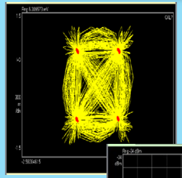
- Cognitive Testbed provides hardware-based environment with high-fidelity emulation of user-spacecraft, government and commercial service providers, communications channels and impairments. Hosts CE-1 prototype implementation and provides real-time results

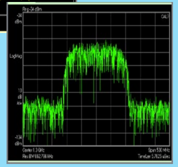


Cognitive Ground Testbed (CGT) Core Components

Multi- User Spacecraft Emulation





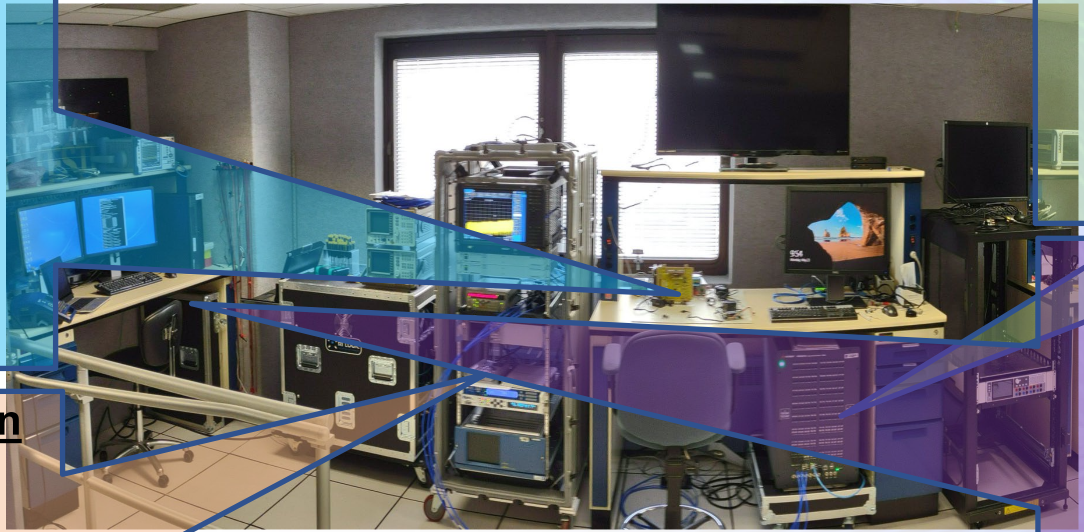


- SDR hosts library of waveforms for each service provider, CSP and Gov
- Flight computer simulates behavior of node types
- SDR+CPU hosts CE-1 algorithms

Multi-Channel RF Emulator

- 24 port RF Channel Simulator – delay, Doppler, attenuation, fading
- Spacecraft Orbital Dynamics and Mission Scenarios Simulation
- Interference insertion, weather impairments

SOAP GCAS STK



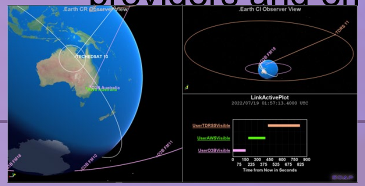
Multi-Service Provider Emulation

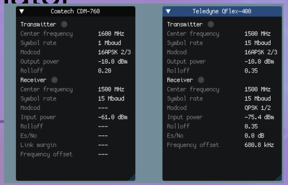
- Service-provider unique waveforms + modems
- (Gov & Commercial)
- Emulated service management interfaces (scheduling, etc)

The CGT has been built and is operational, which allows the Cognitive team to demonstrate increasingly mature cognitive space communication systems. As a result, trust in cognitive technologies grows.

Testbed Controller

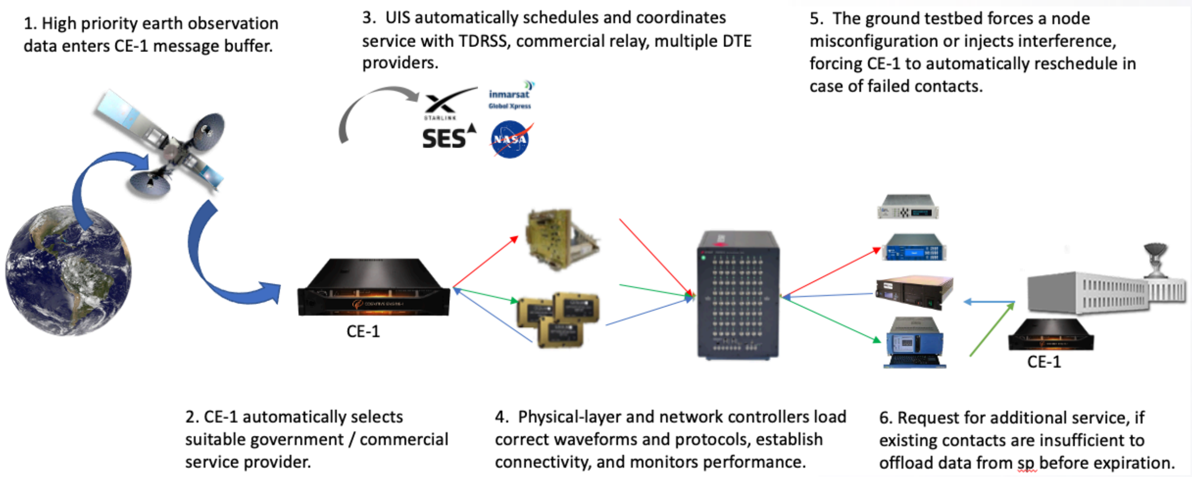
- Automate testbed emulations
- Interface with User-Initiated Service (UIS)
- Synchronize configurations with channel emulator, service providers, and radios
- Visually display status of service providers and emulator



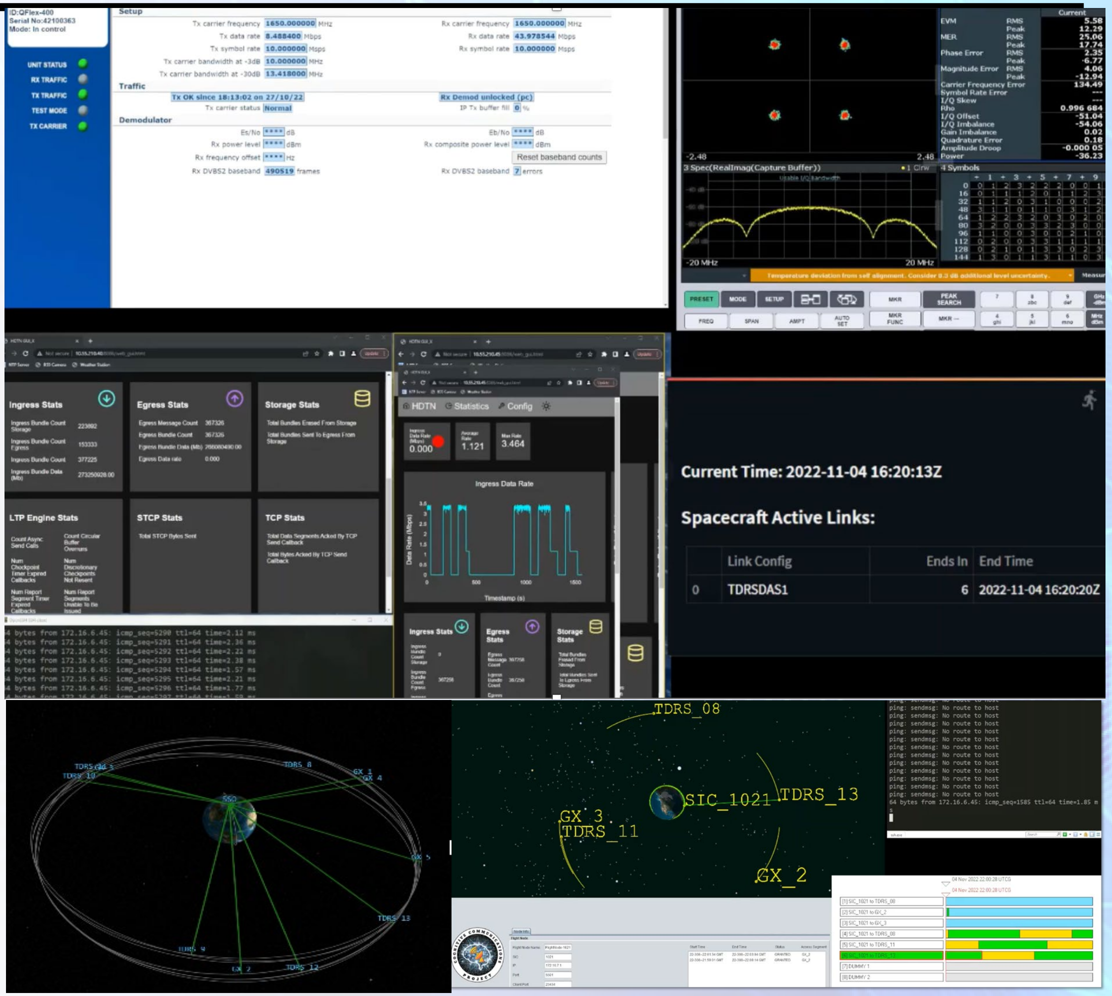


CE-1 Automated System Prototype Demonstration

- Testing and evaluation underway of CE-1 prototype on emulation testbed
- Demonstrated seamless roaming and autonomous switching between several emulated government and commercial providers of both relay and DTE links
- CE-1 components on spacecraft and ground automatically fulfills communication needs – no human in the loop
- API compatibility with NASA TDRSS and AWS scheduling interfaces



CE-1 CONOPS for emulated environment



CE-1 real-time performance data

Cognitive System Vision

Operate autonomously

- CE-1 will operate without human interaction or intervention. CE-1 is expected to schedule its own communication services; react to interference, dynamic spectrum environments, and changes to network performance; and learn to make optimal decisions based on pervious and anticipated system performance.

Enhance interoperability benefits

- CE-1 decision making will enable NASA missions to dynamically interact with an array of commercial and government networks based on learnt Quality of Service (QoS) and channel performance.

Maximize performance

- CE-1 will improve data throughput, minimizing error rates and reduce occurrences of lost or expired data bundles relative to baselined systems not utilizing cognitive engine technology.

Many potential use cases

- Provides a flexible platform for development/demonstration of a range cognitive capabilities
- Explore commonality and use cases between NASA, USSF and Aerospace Corporation
- Seeking opportunities for on-orbit demonstrations

CE-1

Cognitive Engine-1

NASA's first step towards adopting a cognitive future.

Questions & Collaboration

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Abstract

Resilient future space systems will require the integration of many different space and ground networks, including government and commercial. Commercial gateways and ground networks are becoming increasingly available. However, commercial services cannot be leveraged to augment capacity and/or support resiliency without capabilities to dynamically orchestrate the transition from one space network asset to another. The integration of disparate space capabilities (e.g. commercial receive/transmit networks and gateways) requires a complex process of threats identification, environmental assessment (e.g. weather), communications path management, orbital analysis, services provisioning, operational cutover, and cross-domain cyber defense. Distributed and automated capabilities needed to perform these functions do not currently exist. NASA Glenn Research Center and The Aerospace Corporation have been collaborating on architectures, frameworks, reference designs, and prototypes for cognitive systems for space communications. This research aims to develop decentralized space and ground networks with artificial intelligence (AI) agents optimizing communications link throughput, data routing, and systems-wide communication orchestration. An advanced cognitive testbed and prototype has been built to demonstrate the ability to autonomously switch between government and commercial gateways for space-to-ground links based on dynamic environmental and network state. This prototype leverages AI/ML (artificial intelligence/machine learning) to continuously improve the systems ability to correctly assess the impacts of environmental conditions (e.g. weather) and other factors impacting space-to-ground links. The prototype also has the ability to autonomously provision new space-to-ground links (via commercial gateways) in response to changing conditions. This presentation will provide a summary of space cognitive communications research, demonstrate capabilities of the prototype, and describe opportunities for cognitive systems in future space architectures.