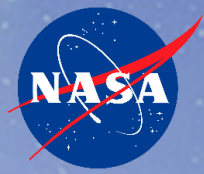
National Aeronautics and Space Administration



Cognitive Communications for NASA Space Systems

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Cleveland, Ohio, United States of America

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37th International Communications Satellite Systems Conference (ICSSC)

Overview

1. **Defining the Problem Space**
2. **Defining Cognition**
3. **Applied Research Focus Areas**
4. **Conclusions**

NASA's Space Communication Networks

Near Earth Network

- Primary Customer: Earth Science / Polar Orbit

Deep Space Network

- Primary Customer: Deep Space / Planetary

Space Network

- Primary Customer: Low Latency

New Opportunity Areas

- Integrate commercial services
- Lunar communications

Defining the Problem Space

Changing Mission and Communication Paradigms

Ground Stations as a Service

- On-demand scalability: coverage, bandwidth
- Minimal up-front cost
- Can be paired with a data center

Mega-constellations in Low Earth Orbit

- High-rate, low-latency communication

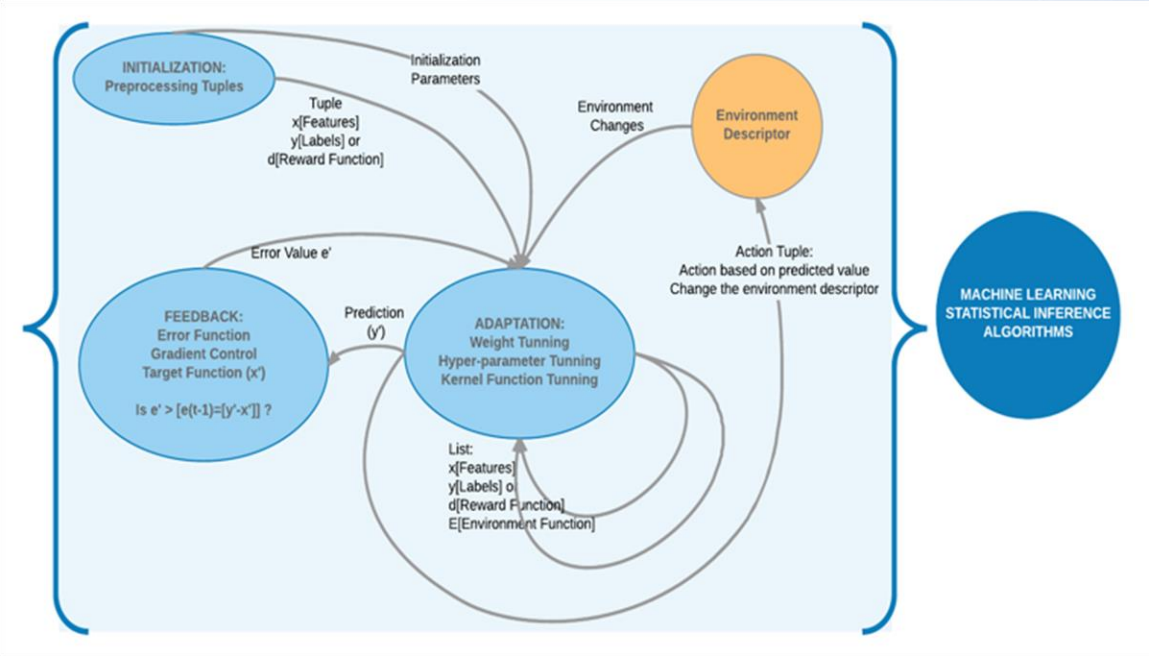
Small Satellite Deployments

- Fast, cheap access to space
- Rapid growth in number of space vehicles
- Distributed, multi-point science missions

Cognition and Cognitive Radio

Key Principles:

- System, or part of a system
- Able to mitigate obstacles
- Responds to and learns from environment
- Achieves beneficial goals toward mission completion



Cognitive Engine: A decision-making algorithm that enables part of a cognitive system

Research Focus Areas

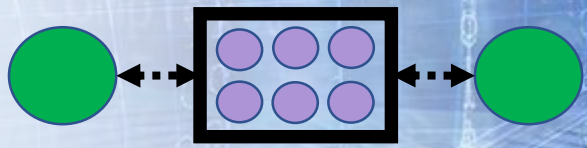
Cognitive Engines

(Implement at all layers)

Cognitive Links

Cognitive Networks

Cognitive Systems



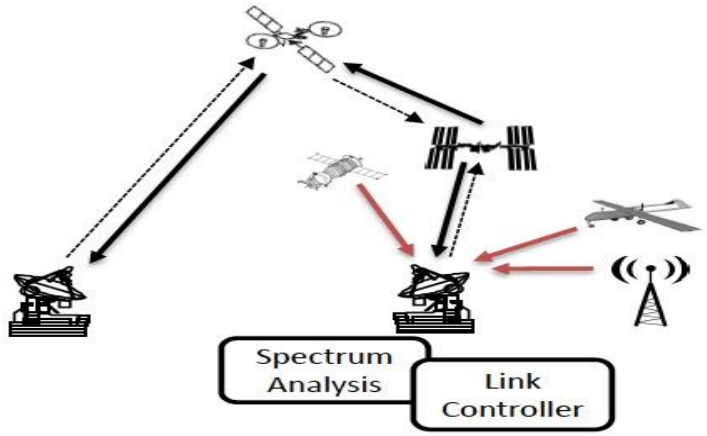
Cognitive Enabling Technology

Applied Research Focus Areas

Cognitive Links

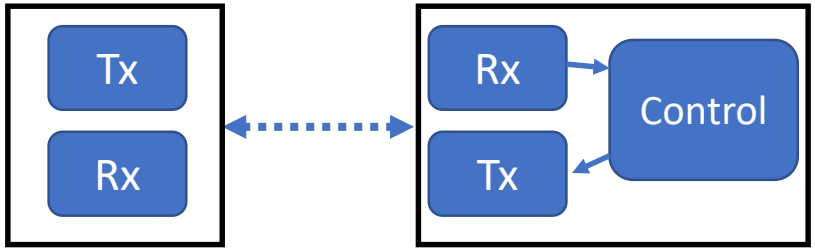
"Point-to-point connections between two devices"

Interference mitigation

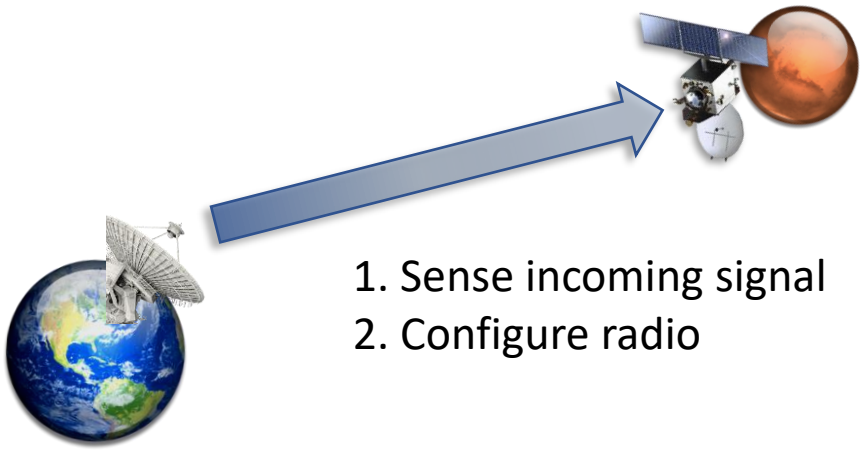


Link Optimization

Goal-based, multi-objective optimization

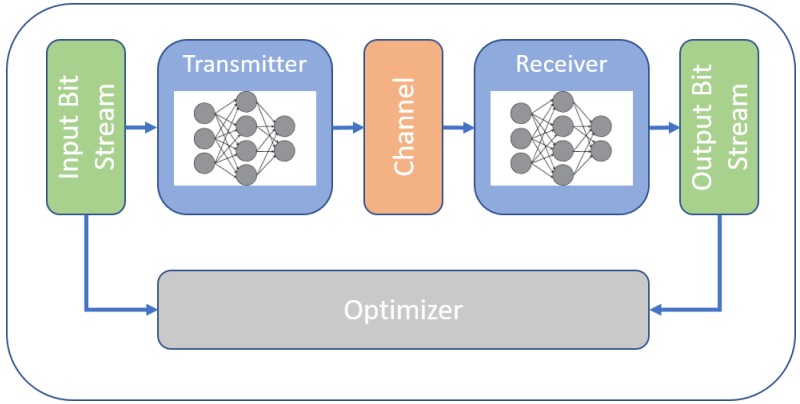


Automatic Receiver Configuration



1. Sense incoming signal
2. Configure radio

Deep Learning Communication Links



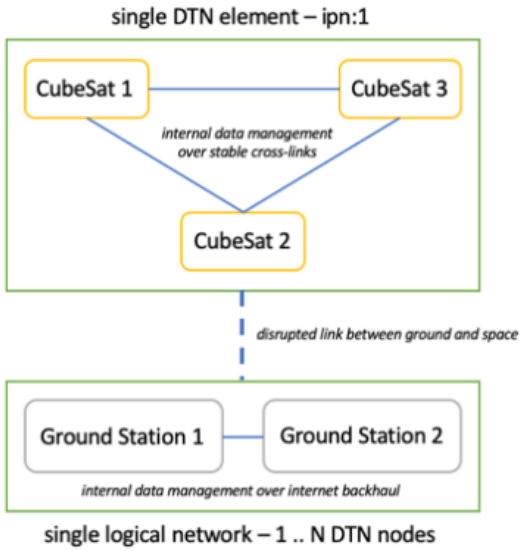
Applied Research Focus Areas

Cognitive Networks

"Multiple devices routing information among multiple links"

Delay-Tolerant Networking (DTN)

1. Minimum Reception Group (MRG) Assignment



2. Intelligent fragment movement within the MRG, and reassembly of fragments on the ground

"Drop Data Anywhere"

Cognition within DTN Protocols

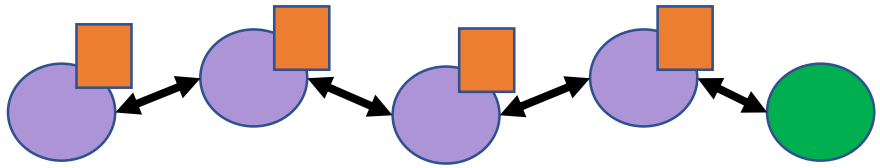
1. On-the-fly estimation of link parameters (RTT, rate) and protocol tuning.

2. Routing between multiple delay-tolerant networks

3. Use of multiple short contacts as a single long contact

Virtualization

Simultaneous processing and routing



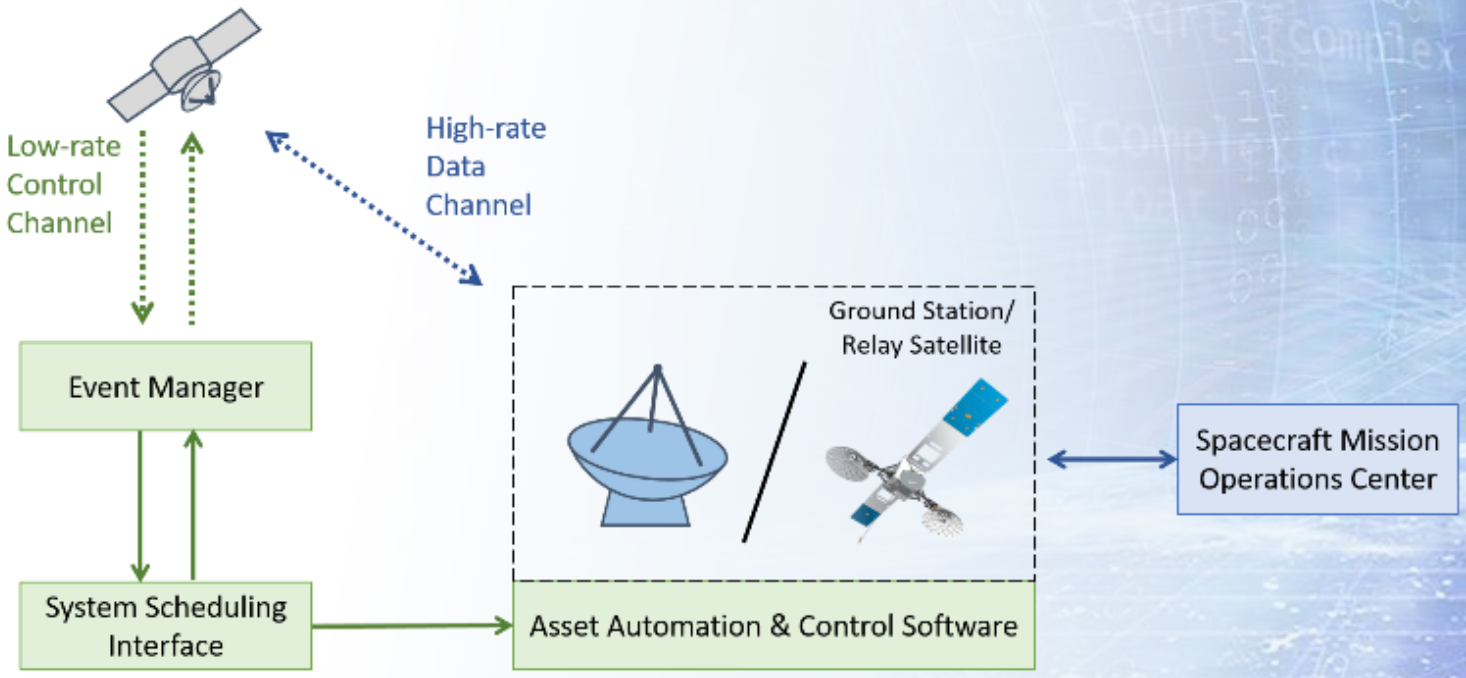
Applied Research Focus Areas

Cognitive Systems

"Interaction among devices and supporting infrastructure"

User Initiated Service:

- On-demand scheduling of data services
- Any available/compatible provider
- Machine-to-machine interface
- Load balancing, optimization for system-level goals
  - Availability, cost, latency, data volume, contact time



Applied Research Focus Areas

Cognitive Enabling Technology

"On-board processing, sensing, and adaptation capability"

On-board processing needs of cognitive engines:

Classical Algorithm	Offline Neural Network	Evolutionary Algorithm	Online Learning

Minimal……Significant

Candidate on-board processors:

- Multi-core processor (CPU)
- General Purpose Graphics Processing Unit (GP-GPU)
- Field-Programmable Gate Array (FPGA)
- Application-Specific Integrated Circuit (ASIC)
- Neuromorphic Processor

Main challenges:

- Power consumption, thermal dissipation
- Radiation tolerance

Conclusions

Modern Drivers for Cognitive

- Joint use of government and commercial network service providers
- Proliferation of small satellites (congestion)

Implementation of Cognition

- A system-level problem involving both users and networks
- Cognitive engines across the network stack (cross-layer)
- Likely requires enhanced on-board processing hardware

Goals and Outcomes

- Enhanced autonomy, reducing manual operator burden
- Improved reliability in remote or unpredictable environments
- Increased responsiveness to critical mission events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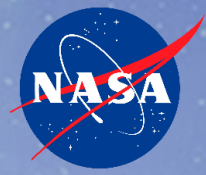

Thank You!

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