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Automated Spacecraft Communications Service Demonstration Using NASA's SCaN Testbed

National Aeronautics and Space Administration

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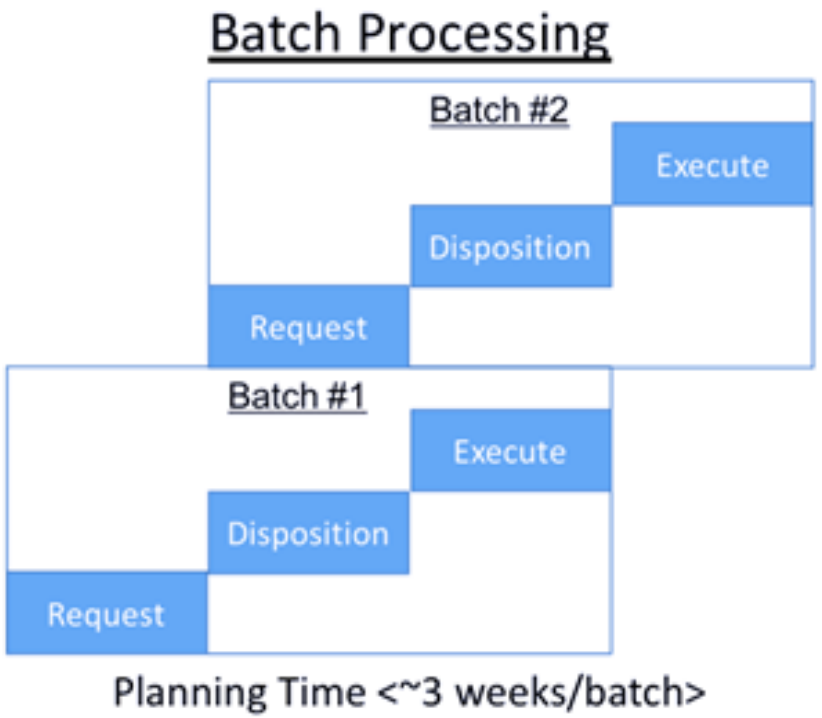
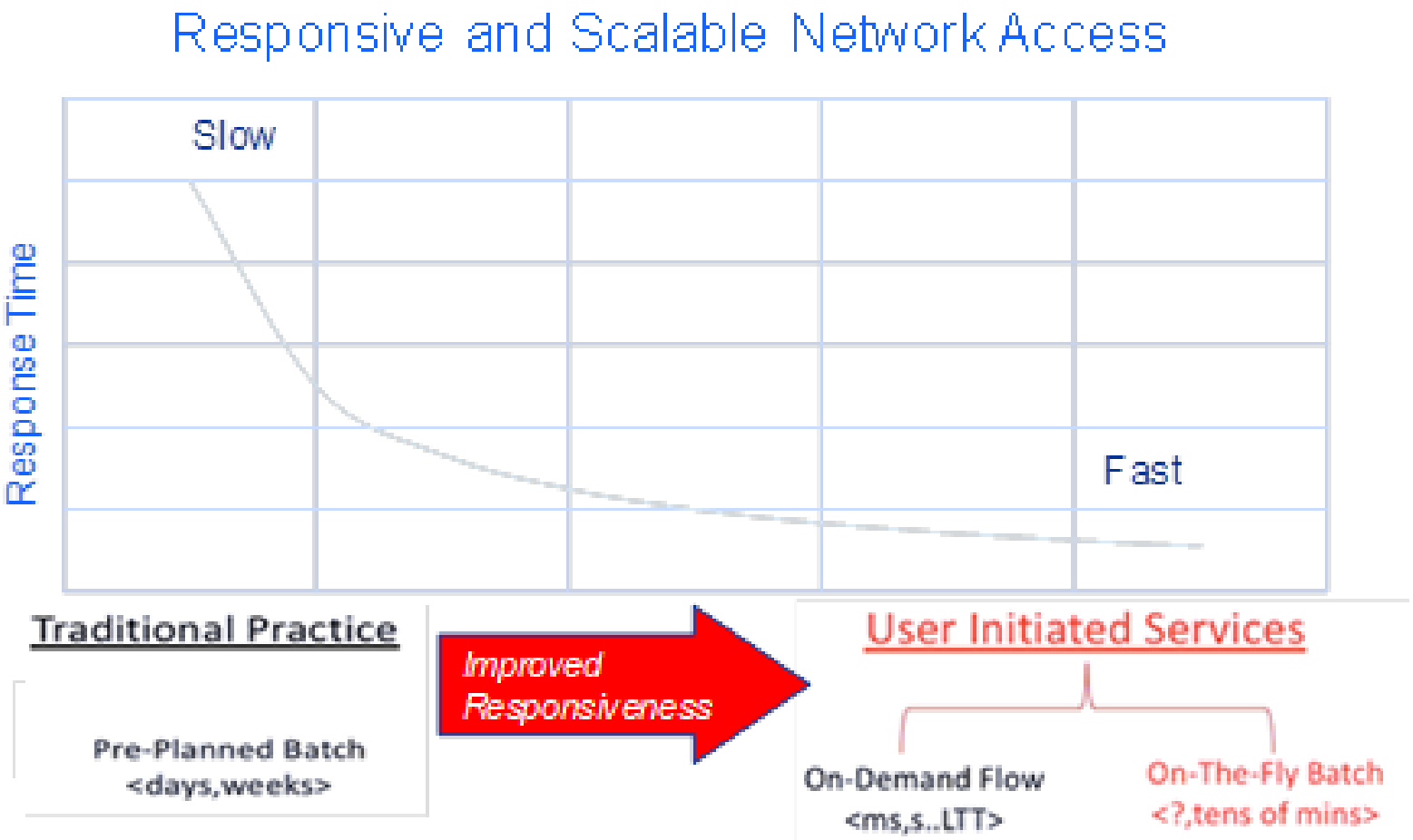
NASA Traditional Communication Services

- Major Drivers
  - data volume
  - data delivery latency tolerance
  - predictability of service demand
- Demand Increasing
  - service frequency
  - number of users
    - CubeSat launches increased 10x in past 5 years*
- Constraints
  - spectrum policy
  - link channel access
  - availability
  - other orbital or signal phenomena



* Science Magazine 29Sep2017 – Vol 357, Issue 6358

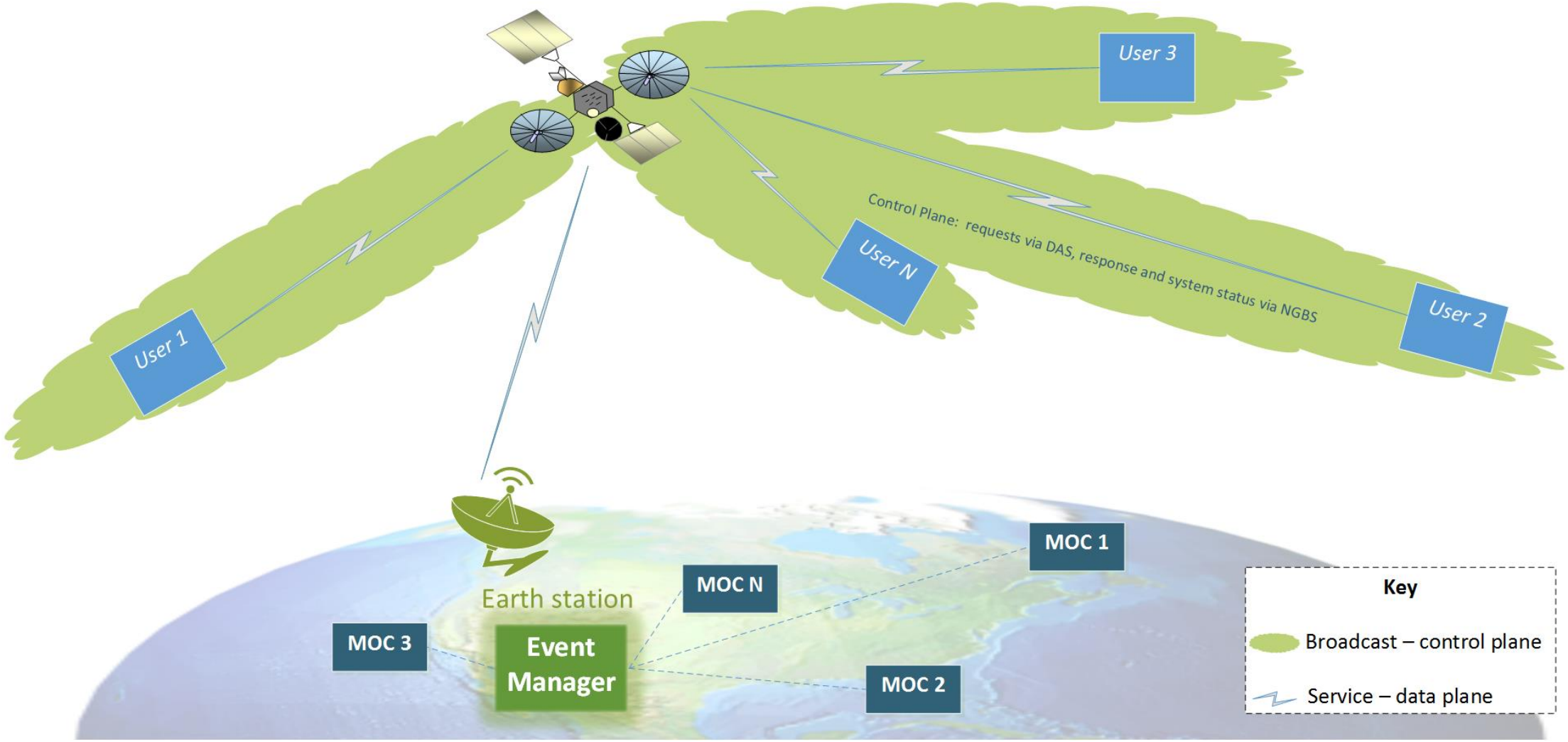
Improving Services with On-the-fly Scheduling



- User Initiated Services provide improved responsiveness through the use of narrowband on-demand link channels to create on-the-fly batches for access to wideband resources.

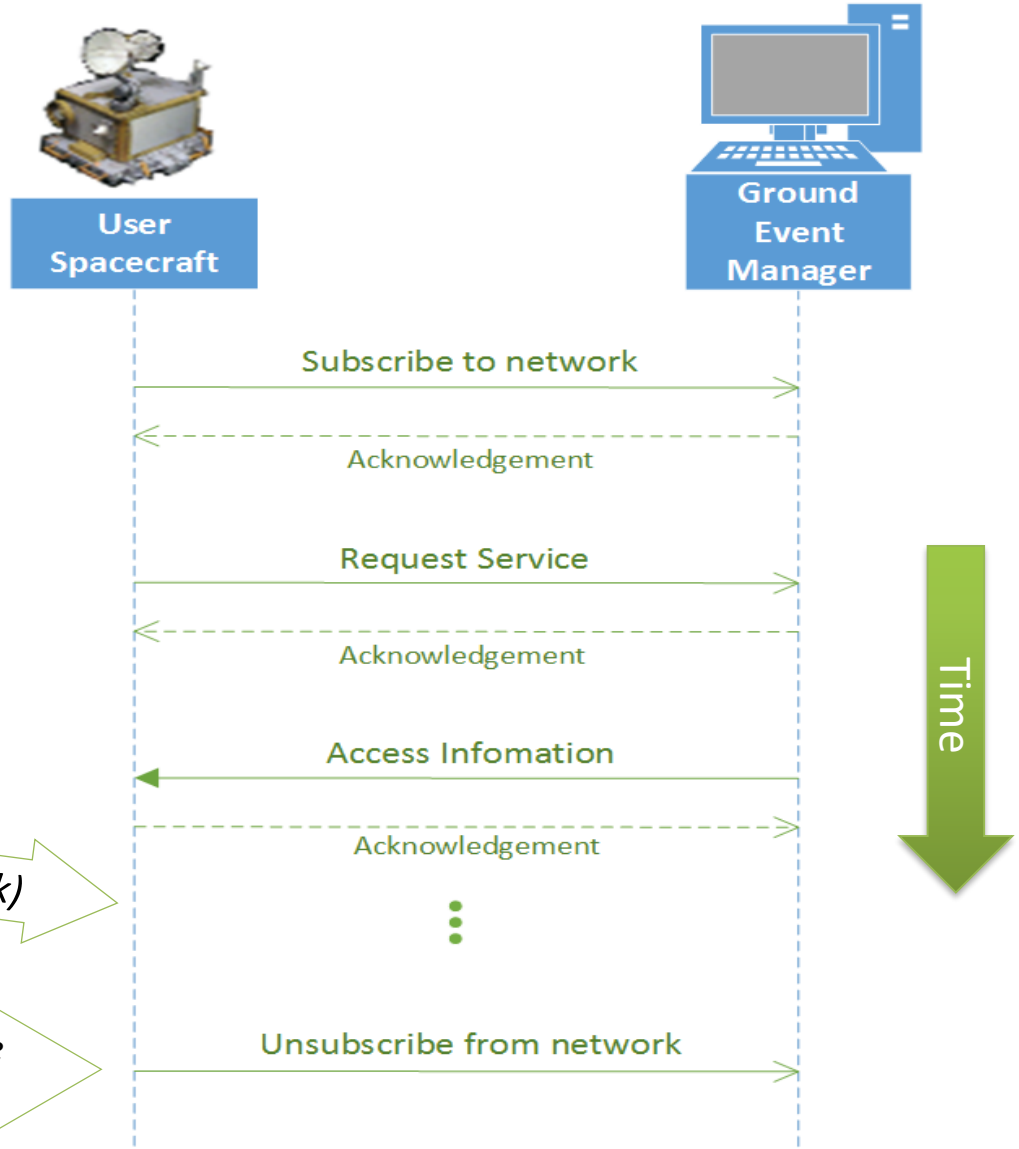
- In the limit, with instantaneous setup and teardown configuration times, the wideband resource effectively becomes a flow resource.

User Initiated Services System Architecture



User Initiated Services Protocol - messaging

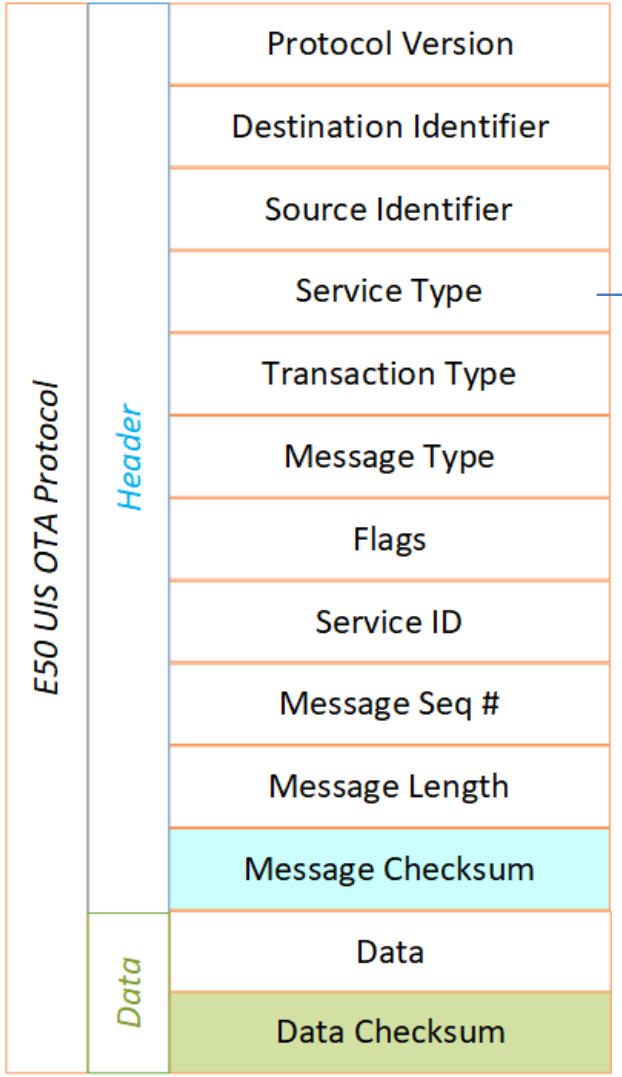
- A typical message exchange of the draft protocol used for this demonstration is shown.
- The protocol has not been finalized, but will evolve as need for UIS development.



Service executed (e.g. downlink)

Upon service completion, the user unsubscribes to free Event Manager processing.

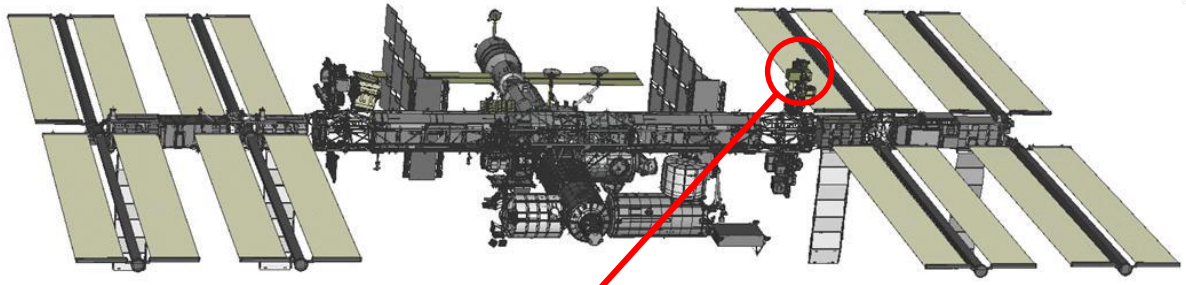
User Initiated Services Protocol - format

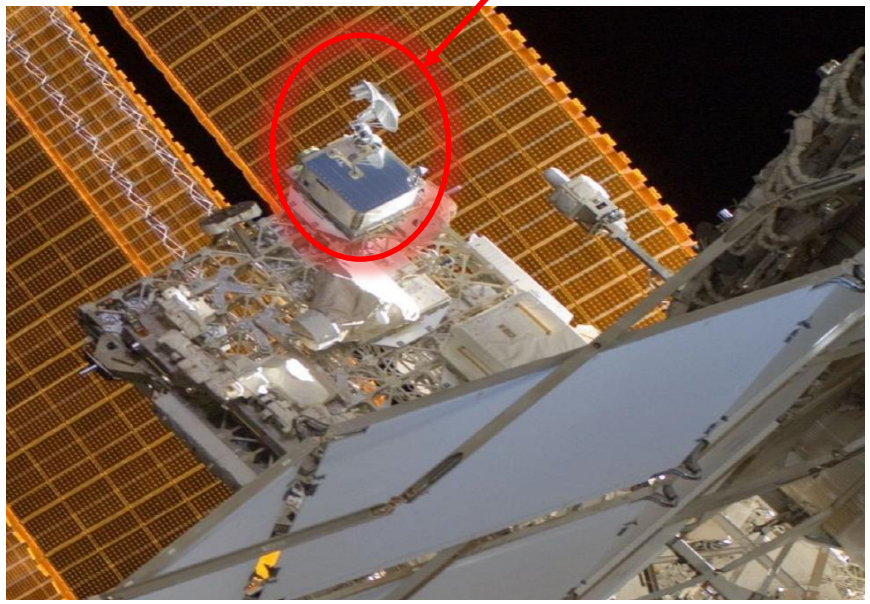


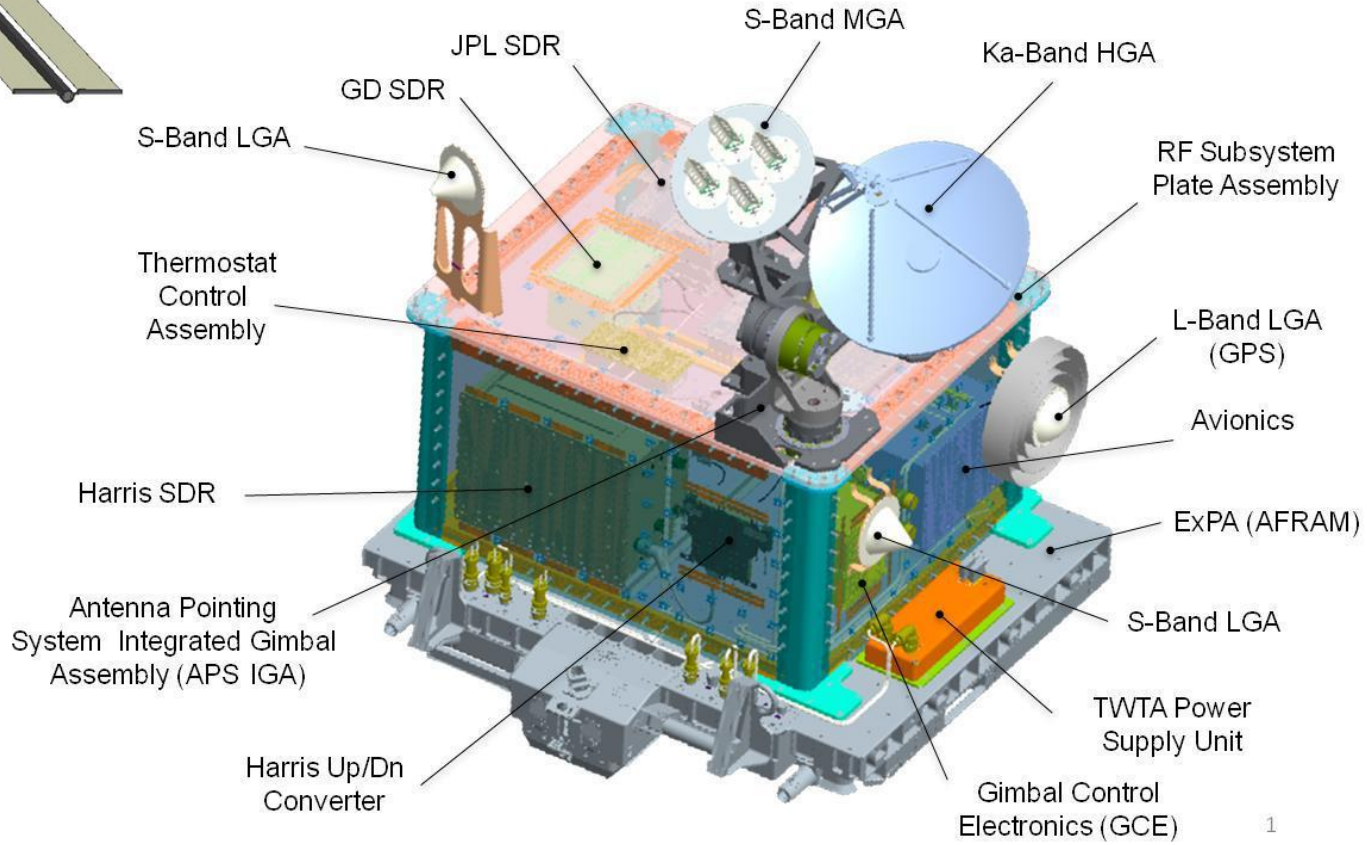
Service Type	Name	Application
0	Subscription/ Registration	Registration and Time Synchronization
1	Data Volume	Science Data Downlink
2	Open Downlink Channel	Telemetry
3	Open Uplink Channel	Command
4	Radiometric Tracking Service	Navigation
5	Optometric Tracking Service	Navigation
6	Emergency	Mission specific e.g. high temp, low battery

Checksums added to original draft protocol for messaging integrity

SCaN Testbed on-board ISS







UIS Flight System Test Configurations

TEST 1 - Autonomous Relay Link:

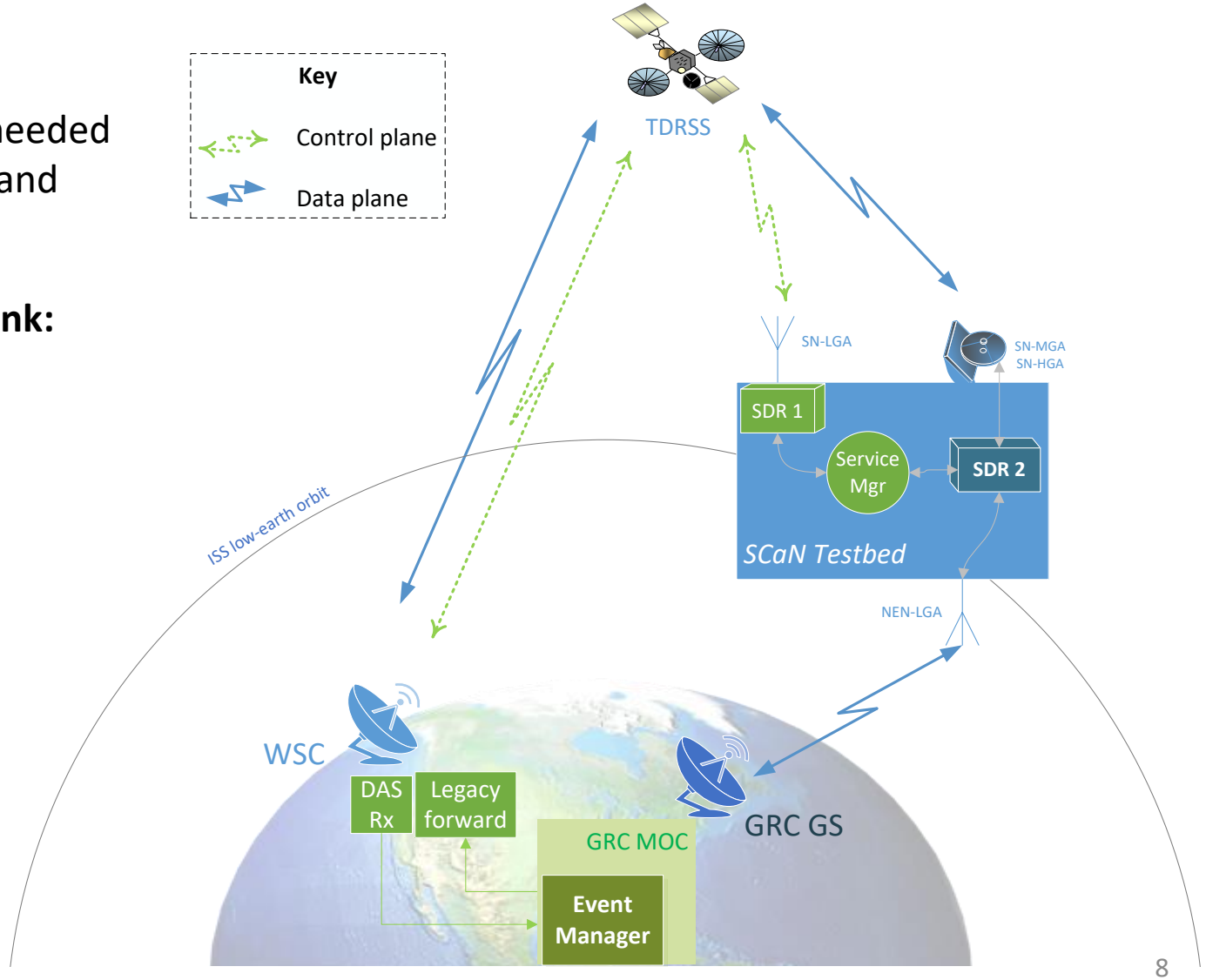
- Requests downlink service for science data as needed
- Dedicated control plane SDR: making requests and listening to “broadcasts”

TEST 2 - Autonomous Relay or Direct-to-Ground Link:

- Adds use of the GRC S-band ground station
- Event Manager selects best link type

TEST 3 - Autonomous Relay Link with Single SDR:

- Uses a single SDR for the control and data plane
- switches to downlink data waveform for granted service events
- Otherwise runs control plane waveform to send requests and listen for “broadcasts”



UIS Flight demonstration
Autonomy in Flight & Ground

SCaN Testbed Autonomously:

1. Requests downlink service for science data as needed
2. Configures SDRs and RF Subsystem for scheduled service
3. Computes and propagates antenna pointing
4. Collects Ka-band spectrum data
5. Shuts down subsystems when not needed

Ground Event Manager Autonomously:

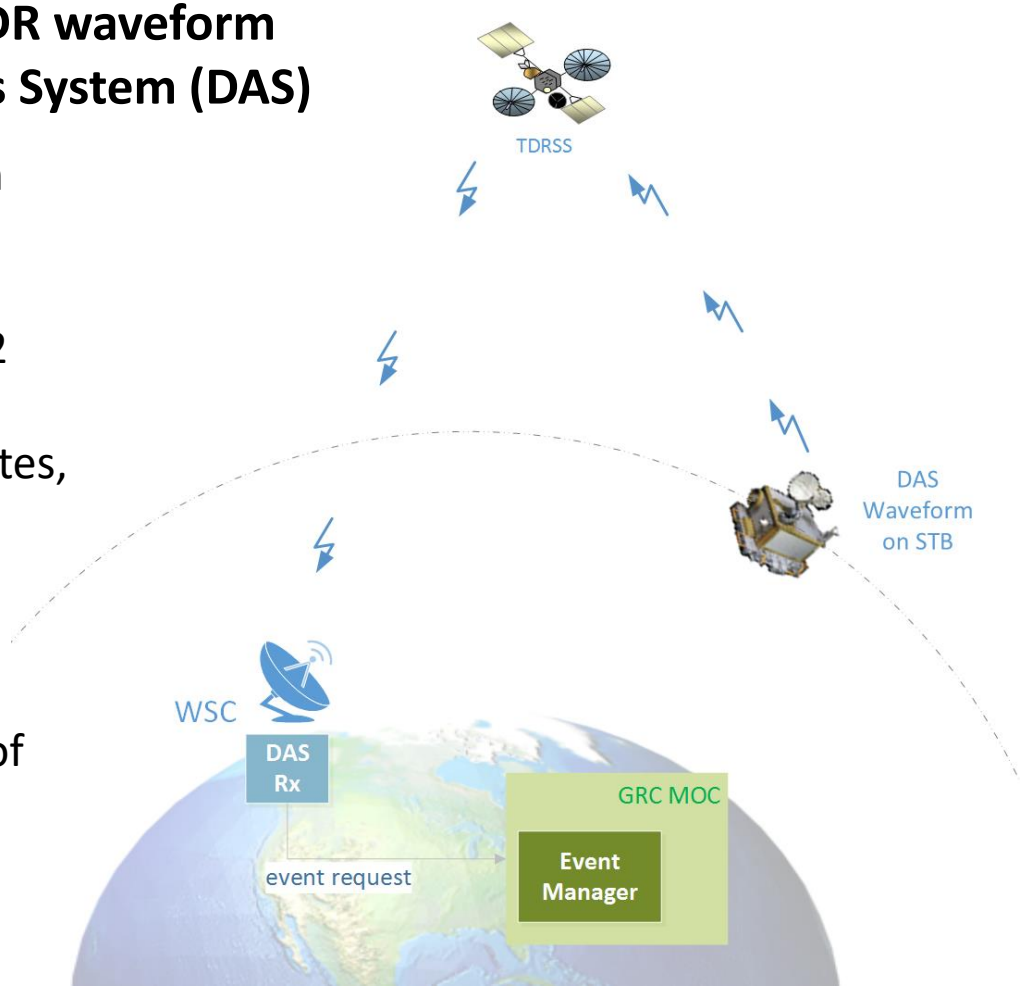
1. Listens for requests from users (flight)
2. Submits requests to Space Network Access System (SNAS)
3. Sends scheduled event(s) parameters to flight nodes
4. Resolves schedule conflicts between users

Exploring potential benefit of applying ML to improve scheduling/utilization, network performance, anomaly identification, etc.

UIS Flight demonstration
Efficient Requests via DAS

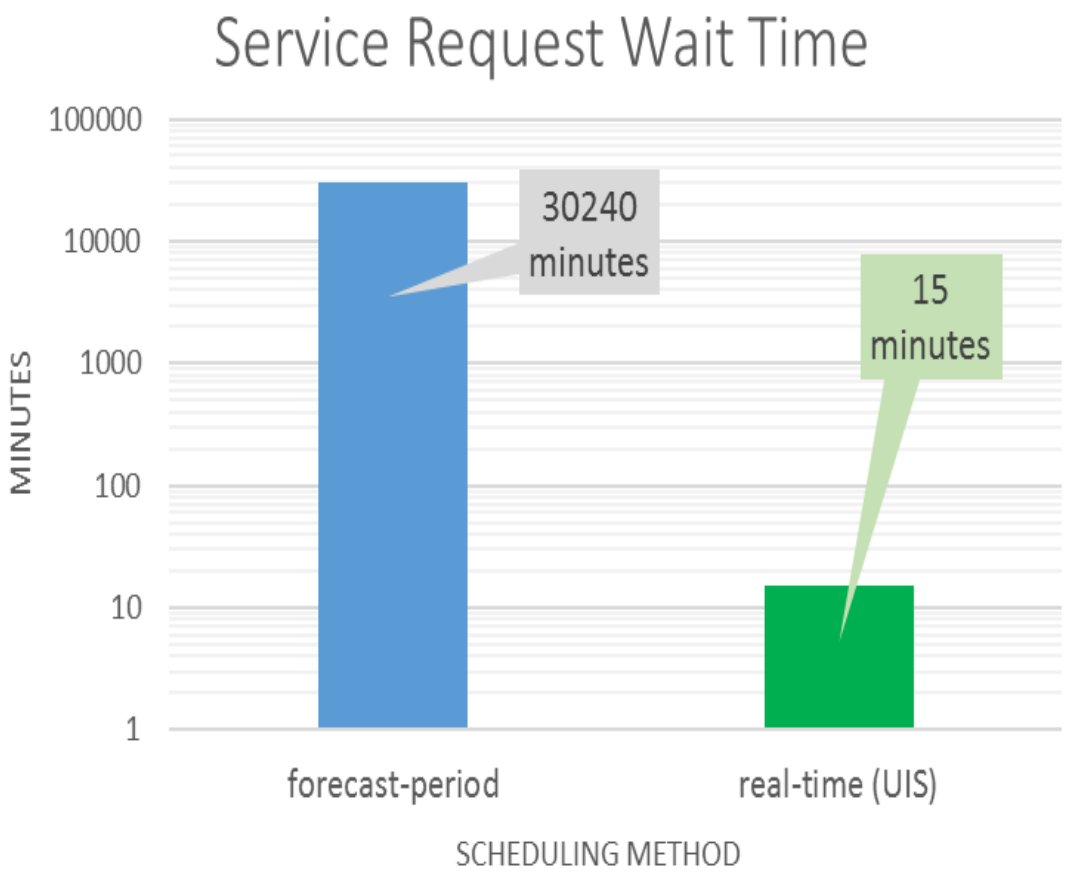
UIS Requests made with new SDR waveform and the existing Demand Access System (DAS)

- Automated requests only turn on transmitter (power amp) for a minimal time.
- ~15 seconds of transmit time at 2 kbps
- Actual information is only 260 bytes, one AOS frame, with Idle frames sent before and after to facilitate DAS receiver sync and ensure reception of data.
- Demonstrates very efficient use of existing DAS
- Low power and narrow BW user spacecraft burden for future UIS implementation



Flight demonstration Testing Summary

- Six days of testing in August and September
  - 17 service requests granted and executed
  - Over 200 minutes of service minutes autonomously executed
  - Scheduled with as little as 15 minutes lead time instead of 3 weeks.
  - Autonomously tracked Sun, collected raw spectrum data.
- Simulated users integrated with actual flight user (i.e. STB)



UIS Flight demonstration
Aug. 21, 2017 Solar Eclipse Tracking

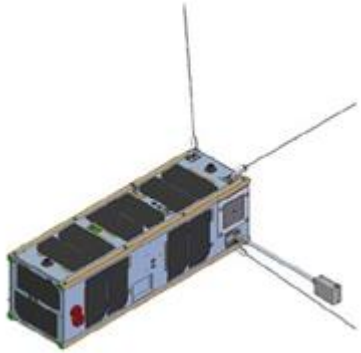
- Autonomously sun tracked and captured ADC samples with Ka-band SDR during three ISS orbits through eclipse.

- UIS software was used with modified scripting.
- Captured 2.3 GB of ADC data.

- Autonomous operations also allowed simultaneous staff participation in an Eclipse Outreach Event in a public park...

Future Work

- Additional testing with SCaN Testbed:
  - Integrate adaptive/cognitive links for data transfer
  - Integrate secure and disruptive tolerant networking
  - Implement cross-layer optimization
  - Direct-to-ground control plane
- Mission infusion of UIS flight software components
  - Refactoring into NASA's Core Flight Software
  - Demonstration on different & smaller platforms, e.g. cubesats
- Space Architecture Infusion
  - Simplify scheduling
  - Facilitate NASA and Commercial service disaggregation



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