SpaceOps 2018:
Space Mobile Network Concepts
for Missions Beyond Low Earth Orbit

NASA/Goddard Space Flight Center

David J. Israel
Christopher J. Roberts
Robert M. Morgenstern

Caltech/Jet Propulsion Laboratory
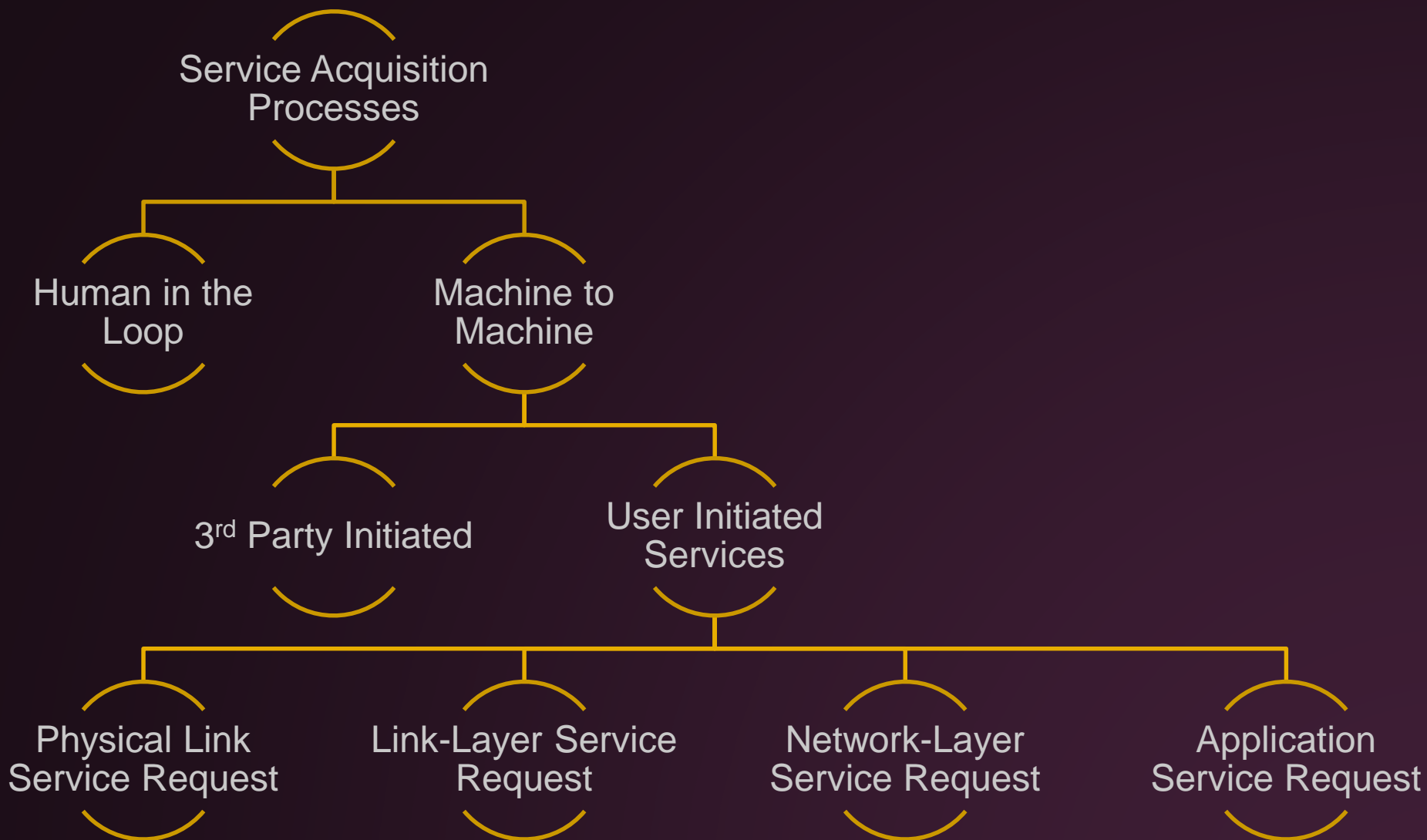
Jay L. Gao
Wallace S. Tai

Outline

- Space Mobile Network Overview

- Space Mobile Network LEO User Example

- Generalized UIS Framework

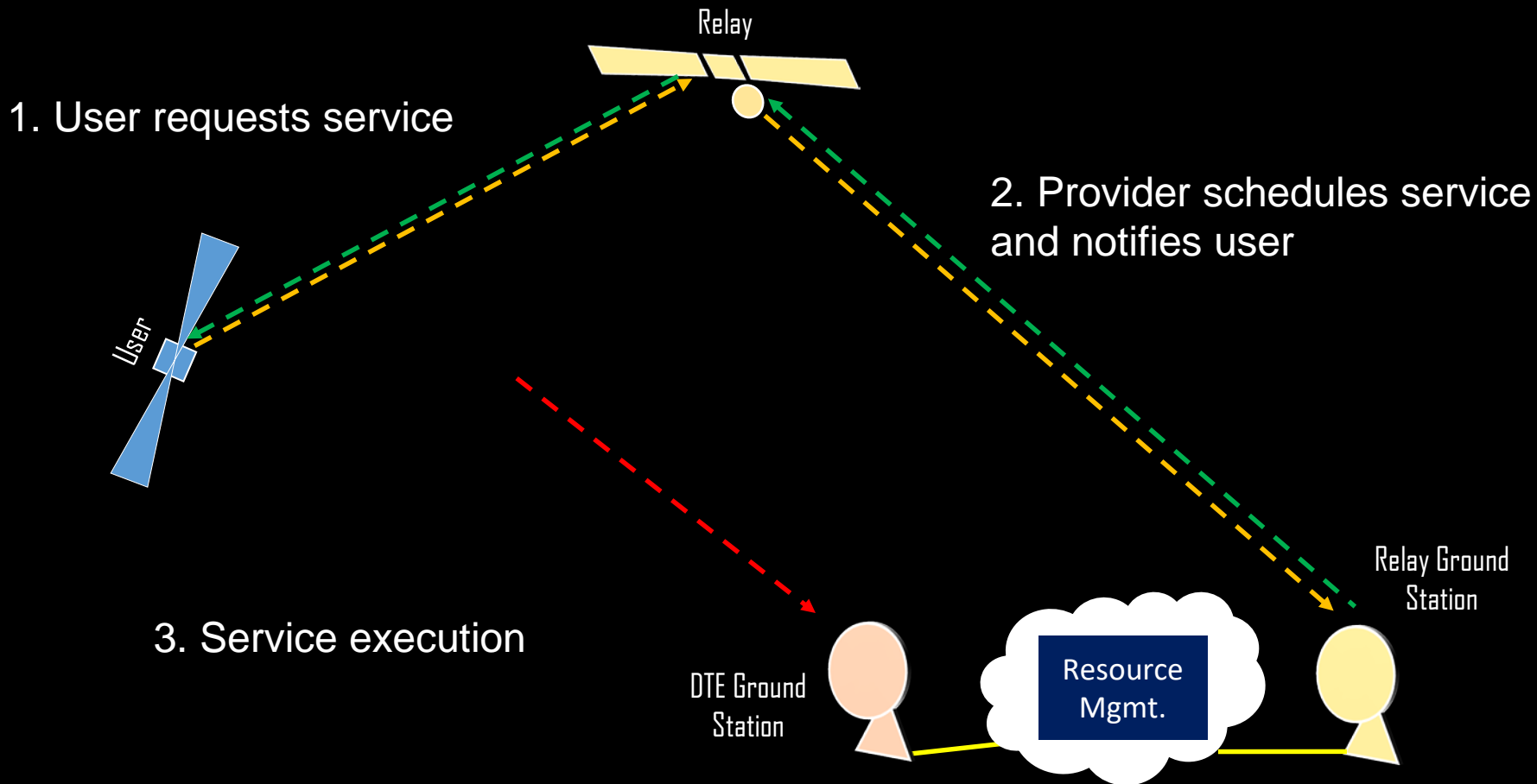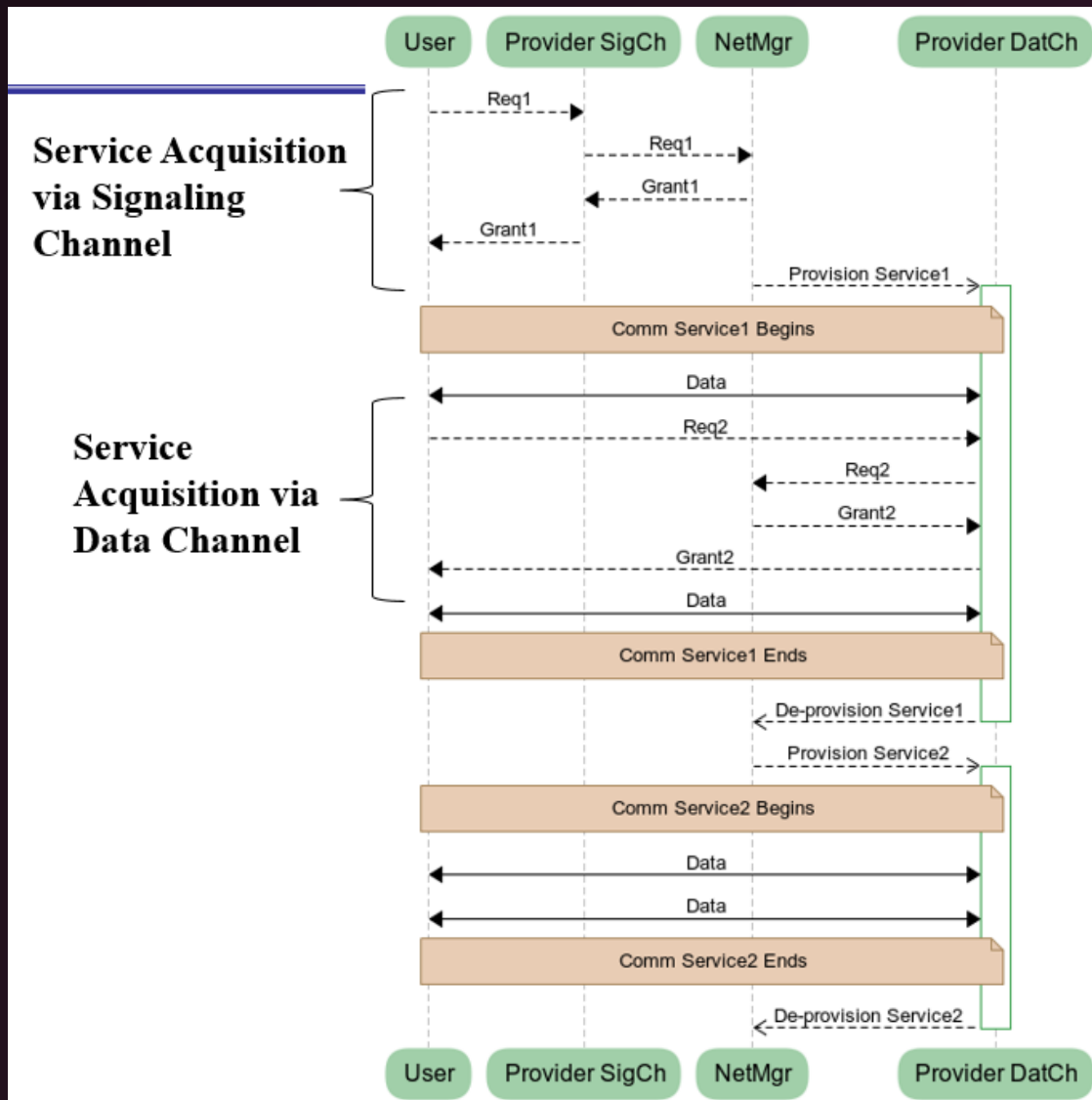- Space Mobile Network Beyond LEO Examples

- Conclusions

Space Mobile Network

High-Availability Links
- Maximize coverage and availability
- Maximize link performance, while maintaining availability

High-Availability Return Link

High-Availability Forward Link

High-Performance Links

High-Performance Links
- Maximize link performance
- Minimize complexity of required scheduling

Network Service Provider
- Relays and ground stations provide access points to larger network
- Maximize service capabilities
- Minimize operations costs
- Automated real-time and store-and-forward data delivery
- Standardized services and interfaces
- Maximize interoperability between NASA, domestic and international partners, and commercial providers

High-Performance Links

User Data

User Spacecraft
- Maximize comm & nav performance
- Minimize size, weight and power
- Maximize autonomy

High-Performance Links
- Maximize link performance
- Minimize complexity of required scheduling

User Mission and Science Ops Center
- Maximize mission return
- Minimize complexity
- Minimize operations costs

Service Acquisition Processes

Relay

1. User requests service

2. Provider schedules service and notifies user

User

3. Service execution

Relay Ground Station

DTE Ground Station

Resource Mgmt.

Key: — — ➤ User Service Request   ◀ — — — Provider Response   — — ➤ High-Performance Link

UIS Service Acquisition Protocol Framework

- Basic Framework
  - Service provider pre-provisions a signaling channel for service acquisition; signaling channel carries UIS SAP messages.
  - Users can utilize the signaling channel to request service on data channel.
  - Users with existing service on data channel can use it to send both user data and UIS SAP messages to acquire additional service.

- Service Acquisition Protocol (SAP) facilitates user requests and provisioning of resources by network management. This operates as an application over the links.
  - This process is common to all service domain.

- Multiple Access Protocol (MAP) executes the assignment of provisioned multiple access resources to specific service instance. This is a link-layer function.
  - This mechanism differs for various physical domain.

- SAP message exchange is supported at the lower layer via various MAP depending on how signaling occurs, either in-band or out-of-band.
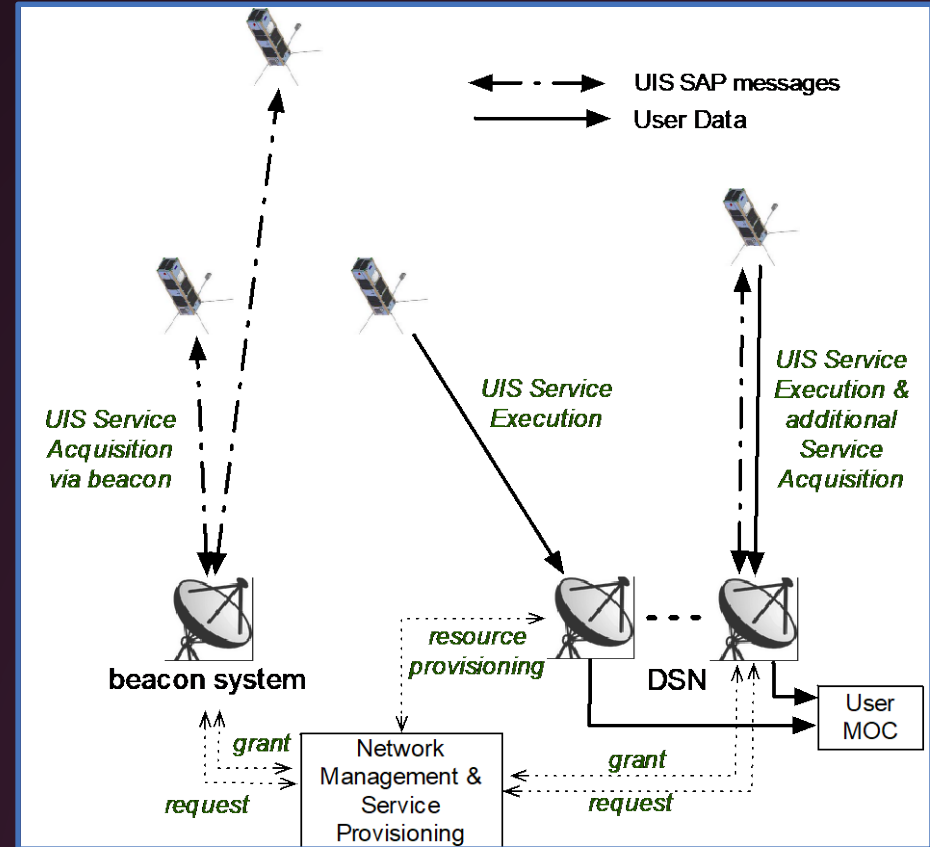
User Initiated Service SAP

- Request initiation by user
  - Request can be specified as exactly desired.
  - Request can be specified with open-range parameter of time, duration, data rates, code, etc. If so, provider granting service must fill in open parameters.

- Provider responds to request by either (a) granting request as is, (b) granting request with additional input, (c) denying request allowing user time-out, (d) cancelling grant by NAK

- SAP is nominally a two-way handshake (ACK) process with user time-out:
  - Users must receive request confirmation from provider within time-out period.
  - Provider explicitly cancel (NAK) priori grant to de-conflict with high-priority user.
  - Provider may release/cancel provisioned resource upon determination that service was not utilized.
  - OPTIONAL: A one-way handshake process might be considered for high-priority off-nominal events, e.g., spacecraft emergency. In such case, a high-detection probability, low-false-alarm signal mechanism is used and the user assumes the provider will correctly receive request and grant service without further confirmation.

- High-availability links provided by a single aperture (MSPA/MUPA)

- User Initiated Service SAP performed via beacon system
  - May be one way for long delay links
  - Two-way handshake for shorter delay links

- High-performance links provided by any available apertures capable of closing the links.

- Network-layer service (DTN bundles) routes data from any access point to destination.

- High-availability links provided by a multiple access system, such as Prox-1 Hailing Channel

- User Initiated Service SAP performed between user and relay
  - Relay manages resources locally to avoid long delays in communication with Earth.

- High-performance links provided by other systems onboard relay

- Network-layer service (DTN bundles) routes data from any access point to destination
  - Store-and-forward DTN capability allows resources to be scheduled on a per-hop basis.
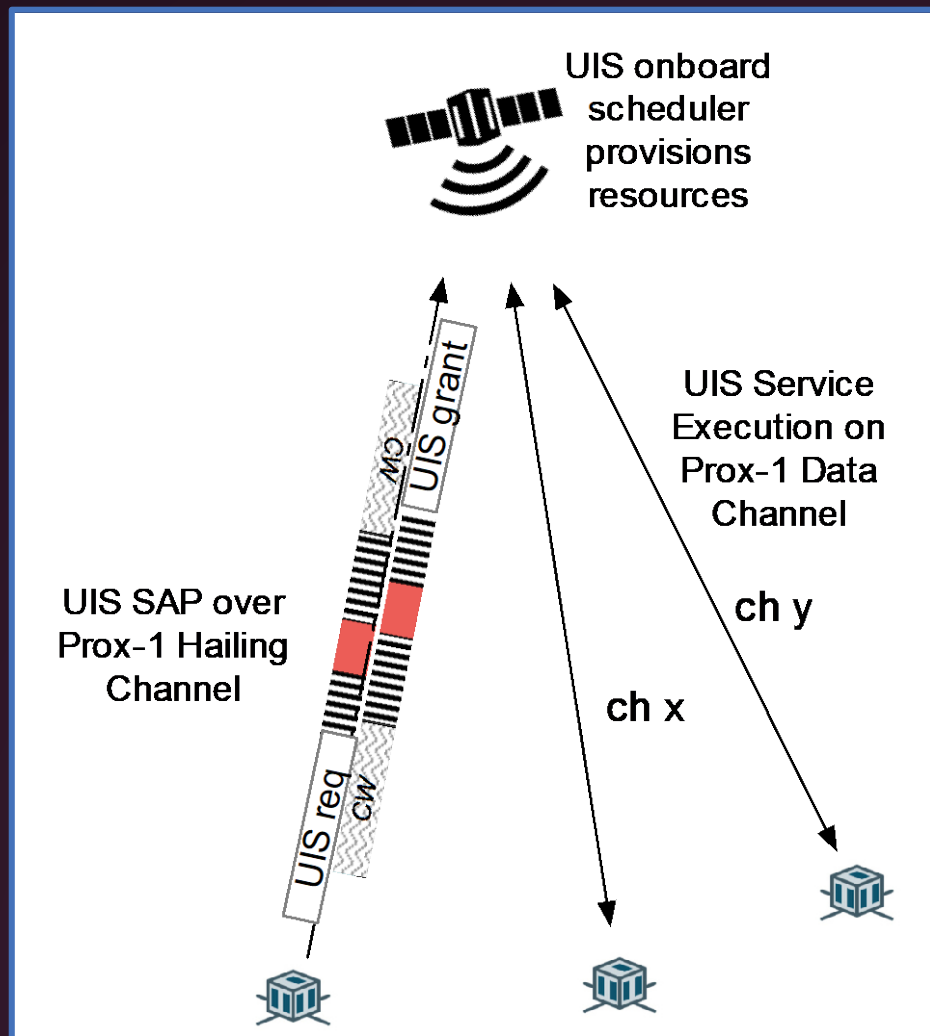
Conclusions

- The Space Mobile Network concept consists of four key components:
    - Networked Communications
    - High-Availability Llinks
    - High-Performance Links
    - User Initiated Service Service Acquisition Processes
- Mission operations concepts can remain consistent even as the missions move between the environments near Earth out to deep space.
- The specifics for how those links and service requests are performed will differ between environments, but that can be treated as the equivalent of "lower-layer" differences.
- Key next steps are to:
    - Refine the concepts and terminology
    - Define functional and performance requirements for target environments and operational concepts
    - Develop, model, and demonstrate protocols and implementations.
- The components can be implemented separately and build upon each other, allowing for a phased deployment of the Space Mobile Network.

Acknowledgments

- This work is in support of the NASA's Space Communications and Navigation Program Office

- The work carried out at the Jet Propulsion Laboratory, California Institute of Technology, was under a contract with NASA.

- C. J. Roberts would like to thank professors Tom Bradley and John Borky for their contributions in shaping the User-Initiated Services concept.

- D. J. Israel and C. J. Roberts acknowledge the contributions of Jacob Burke, Mark Sinkiat and Jacob Barnes in defining the UIS relay and DTE scenarios.

- We also acknowledge Seema Vithlani for her contributions in technical writing, technical editing and graphics development.