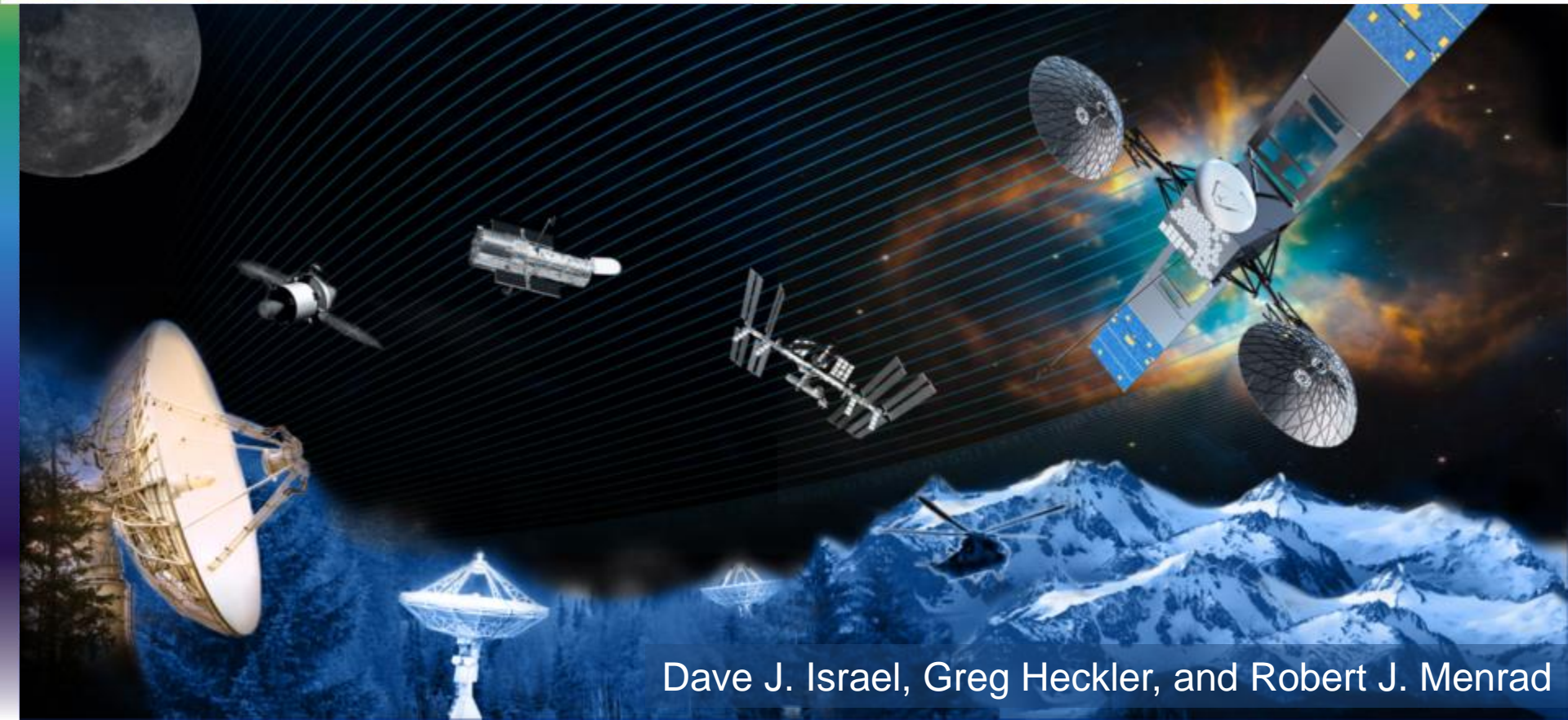


Space Mobile Network

A Near Earth Communications and Navigation Architecture

IEEE Aerospace Conference, March 2016



Dave J. Israel, Greg Heckler, and Robert J. Menrad

Introduction



- NASA's Space Communications and Navigations (SCaN) Program is responsible for all NASA space communication and navigation activities.
 - Deep Space Network (DSN)
 - Near Earth Network (NEN)
 - Space Network (SN)
- SCaN chartered the *Earth Regimes Network Evolution Study* (ERNESt), which was completed in May 2015.
 - NASA's Goddard Space Flight Center (GSFC) led study to create a next generation near-Earth space communications and navigation architecture for 2025 and beyond.
 - Goals:
 - Provide communication and navigation services to missions within 2M kilometers of the Earth (just beyond the Earth-Sun L2 point).
 - Customizable and scalable
 - Include industry and international partners
 - Advance new science and technologies
 - Reduce commoditized costs.

The resulting ERNESt architectural framework was named the "Space Mobile Network (SMN)," to accentuate the focus on the user experience with analogies to the terrestrial mobile wireless smartphone user experience.

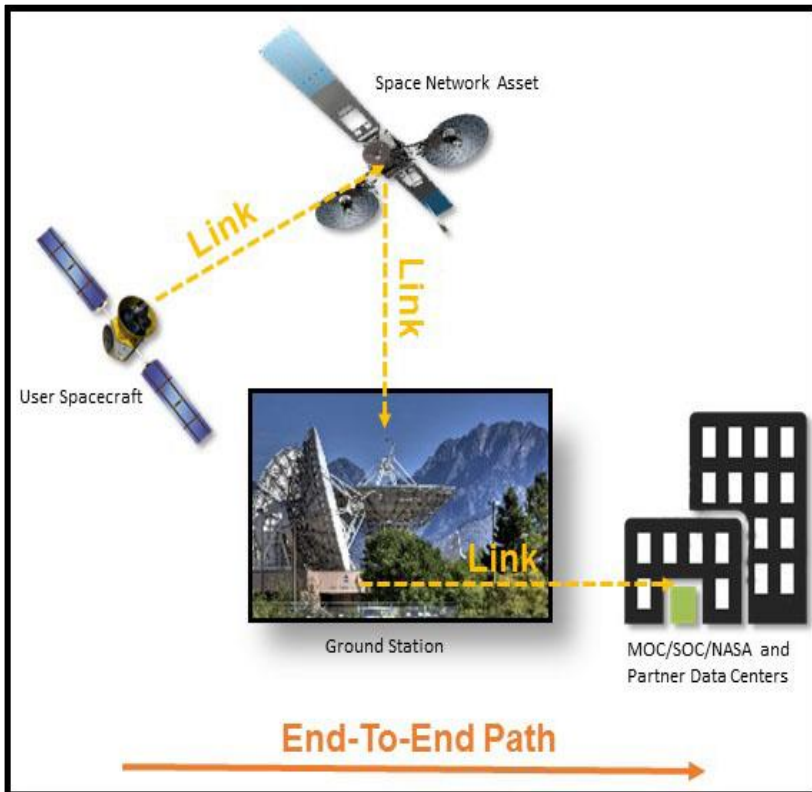


Comparing the Space Mobile Network to Terrestrial Wireless Communications Systems



<p style="text-align: center;">Terrestrial Wireless Communication Systems</p>	<p style="text-align: center;">Space Mobile Network (SMN)</p>
<p>Ability to connect to and access others connected to the same network at anytime</p>	<p>The user experience should be the same as today's Internet cloud experience where a user knows that once they connect themselves to "the cloud," services, sources, and destinations are available</p>
<p>Current position knowledge</p>	<p>Next Generation Broadcast Service (NGBS) to provide a continuously available global coverage and navigation beacon data signal.</p>
<p>Hand-held computing power</p>	<p>Will minimize user burden including the Size, Weight, and Power (SWaP) required for the flight systems.</p>
<p>Activities are not constrained by having to meet at a pre-determined time and location.</p>	<p>User Initiated Services (UIS) will allow customers to receive service without a priori scheduling ahead. (expanding ops concepts)</p>
<p>Expectation of full bandwidth end-to-end communications whenever they have a connection – live video on demand, for example.</p>	<p>Has more implementation flexibility while still meeting user requirements. Will ensure that the user's data volume is delivered to the desired destination in the science driver case or delivered off of the user platform in the onboard storage limitation case within a latency requirement.</p>

Dynamic End-To-End Data Path



- Most spacecraft users operate with the knowledge that a link is not always available and thereby, store their data onboard, and transmit the data based on a latency requirement.
- A mission that needs to offload data in order to free up onboard storage or meet some other operational constraint is only really concerned with the speed of the space link from their spacecraft to the communications asset. (“Get this data off my platform”)
- A mission with science data delivery timeliness requirements, such as one that updates hurricane forecasts for example, will be concerned about the effective data rate between the user platform and data destination (i.e. an end-to-end path). (“Get this data to its destination”)

The significant difference between terrestrial communications networks and the Space Mobile Network is the specification of data volume delivery instead of the specification of data rates.



Link Types



Continuously Available Low Rate Links

- The current NASA Space Network is able to provide continuous low rate return links via the TDRSS Multiple Access (MA) system.
- The SMN will provide links that are continuously available and minimize required user transmit power and related user burden
 - The availability requirement likely drives the solution to space-based relays, which in turn leads to a requirement for low relay payload SWaP.
 - The ERNESt team identified candidate technology solutions including Optical MA, Ka-Band MA, and enhanced S-Band MA.

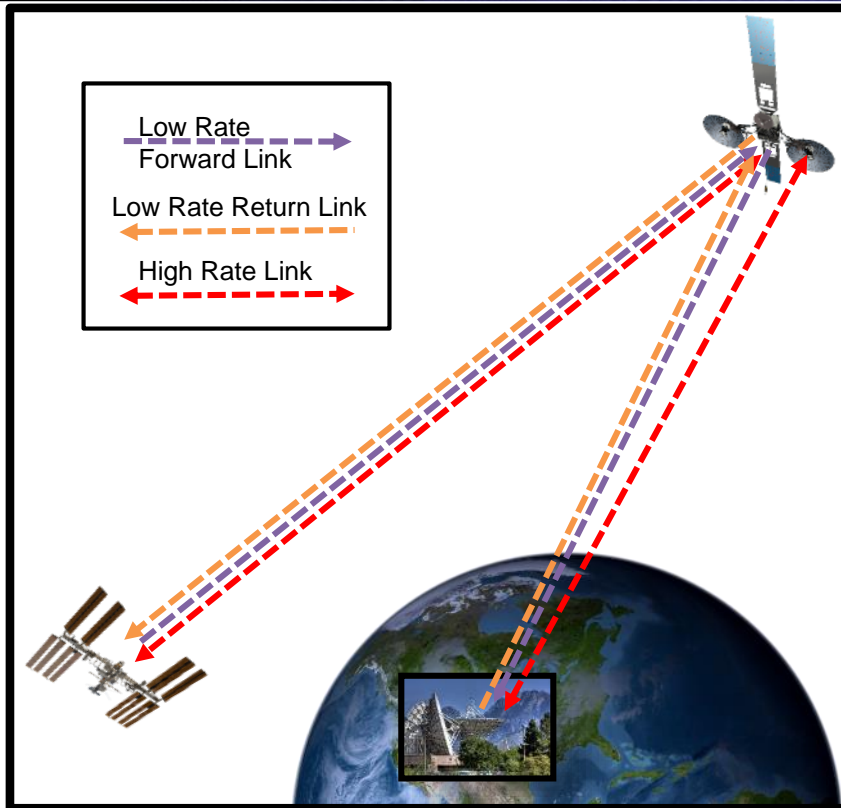
High Rate Forward and Return Links

- Unlike Low Data Rate links, High Data Rate links will likely have reduced availability
- LEO mission direct to Earth downlinks may be achieved at much higher data rates, but the total view periods to ground stations would be less than the view periods to a GEO relay constellation.
- These links may be either RF or optical links, space based relay or direct to Earth

The data rates and physical characteristics of these links will evolve based on trades to optimize the availability and or link performance



User Initiated Services

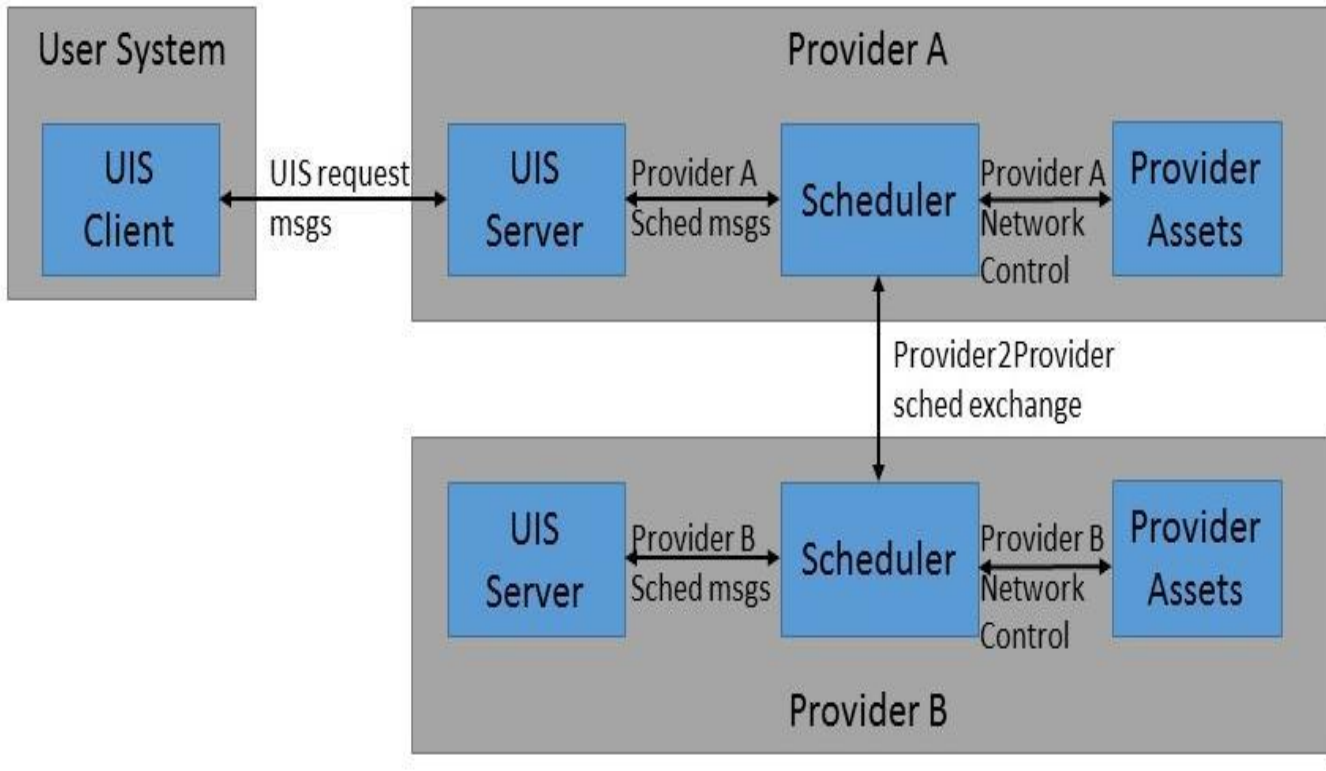


SMN Provides Continuously Available Forward and Return Links and Enables Users to Schedule High Data Rate Forward and Return Links through User Initiated Services (UIS), a revolution in mission execution.

- When the spacecraft requires services, such as a high data rate link, it transmits a request to the network over the low rate link.
- The network determines the next available opportunity to support the mission and responds to the request with the time and information required for the mission to access the service.
- When the service time arrives, the mission receives the requested service.
- The requested service could be provided by a space relay or ground station from any compatible and participating provider (NASA, commercial, international, etc.).
- The system would still support scheduled services as today, but it would support the larger percentage of users on the continuously available and UIS scheduled services, allowing the network to be more responsive and efficient.
- The implementation of UIS requires a protocol for a user to negotiate a service request, either over a space link or terrestrially.
- The likelihood of receiving the desired service and guaranteed maximum wait time would have to be within user expectations



Dynamic Link Allocation and Scheduling



- The UIS will also require a scheduling system capable of dynamically fielding the requests: comparing them against available resources, schedules, and priorities.
- The system must also provide a way to dispatch the now scheduled service details to the user systems and provider elements
- Services can be provided by a combination of providers and scheduling systems

In the case of today's terrestrial mobile network user, there are no apparent scheduling activities required for the user to get the desired service. The user pulls out their device and dials, enters a website address, or, as is becoming more prevalent, the mobile device is continuously requesting, receiving, and transmitting data without any required user action. Though there is no apparent scheduling, the network is still constantly allocating bandwidth and other resources to meet all of the performance requirements.

Disruption/Delay Tolerant Network



- It is typical that the user is not requesting service to deliver data immediately to the final destination but rather requesting service to offload the onboard storage.
- A Disruption/Delay Tolerant Network (DTN) allows additional flexibility in the implementation, allocation, and scheduling of the end-to-end path.
- DTN protocols have been demonstrated to provide the store-and-forward network capabilities to support the automated data buffering, routing, and quality of service required to provide this dynamic end-to-end path data distribution
- DTN-enabled provider node will permit a user to offload their data at whatever rate their space link allows, while still allowing the provider flexibility to optimally implement, allocate, and schedule all the nodes and links along the rest of the end-to-end path.
- In the near-earth environment, it is also expected that some scenarios can be supported using IP for the network layer services. Support of DTN and IP within the architecture are not mutually exclusive.

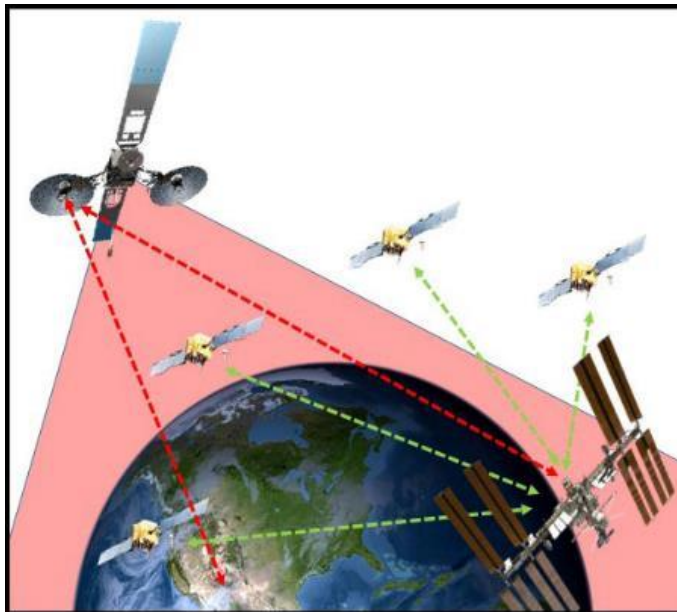
Trades need to be done to determine the amount of processing, storage, and network functionality to include on a space relay node, as opposed to performing these functions in ground-based systems.



Next Generation Broadcast Service (NGBS)



- The Next Generation Broadcast Service (NGBS) is currently under development to demonstrate a Multiple Access Forward link beacon signal design that can be implemented to provide radiometrics or optometrics for onboard navigation, a path for UIS data, and individual mission data.
- In many cases, knowledge of the relay location will be necessary for the user to radiate a UIS request.
- This link will provide orbital data; which, in combination with the user's autonav capability will the request to be radiated in the proper direction.



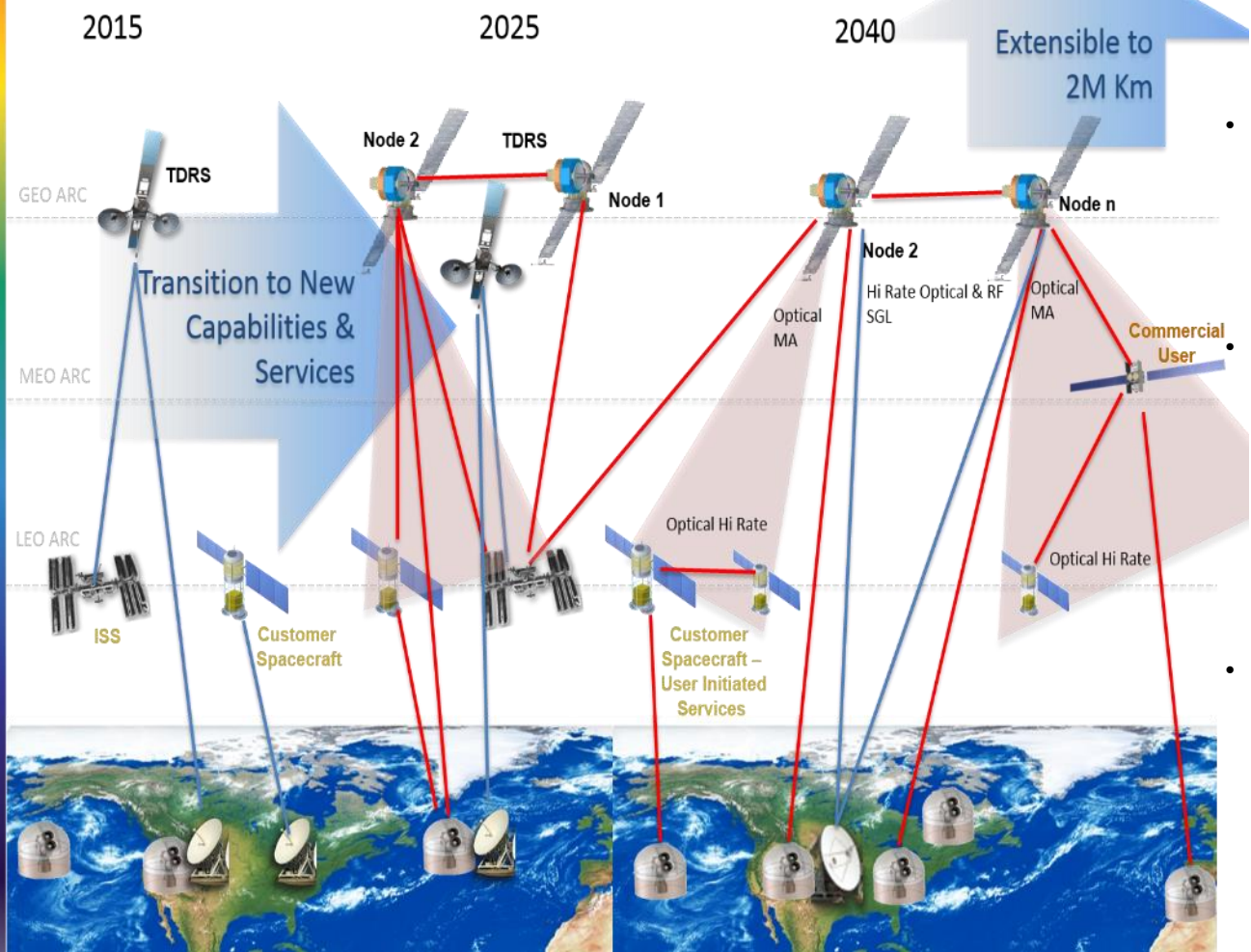
The Next Generation Broadcast Service (NGBS), formally known as the TDRSS Augmentation Service for Satellites (TASS), will demonstrate a forward beacon that can be utilized for the sending and receiving of critical UIS communications, individual mission data, and radiometrics or optometrics for onboard navigation.



Transition Strategy



Evolution of NASA's Near-Earth C&N Architecture to Space Mobile Network (as proposed in the ERNESt study)



- SMN architectural framework and operations concepts can begin to be implemented before any new space relay nodes or ground station antennas are deployed
- The RF bent-pipe design of the TDRSS satellites allows new services to be implemented at ground station locations to provide full orbital coverage.
- Though the performance of initial demonstrations may be limited to lower data rates or longer latency than desired, the implementation will allow for the demonstration of the benefits, the requirements and the challenges of the future systems.
- TASS and the already existing Demand Access System (DAS) can be used for the space link communications channels for the first instantiations of UIS clients and servers tied into the TDRSS scheduling system. The demonstration can be expanded to tie into the Near Earth Network scheduling system to demonstrate the provider peering ops concept.

Conclusions



- The Space Mobile Network architecture produced by the ERNESt team has identified architectural features and a transition strategy.
- SMN focuses on moving the space communications and navigation user experience closer to the terrestrial mobile network user experience
- NASA SCaN continues to validate and refine the next generation architecture, to develop the associated technology, and to implement the first demonstrations and early operational capabilities.



References



- “Earth Regimes Network Evolution Study,” NASA. 1 May 2015.
- Israel, David J., Bernard L. Edwards, Keith E. Wilson, and John D. Moores. "An Optical Communications Pathfinder for the Next Generation Tracking and Data Relay Satellite." SpaceOps 2014, Pasadena, CA. 2014.
- Israel, David J., Donald M. Cornwell, Gregory D. Menke, W. John Guineau, "Demonstration of Disruption Tolerant Networking across Lunar Optical Communications Links." AIAA Space 2014, San Diego, CA. 2014.
- “NGMN 5G White Paper,” NGMN Alliance. 17 February 2015.
- “Operations Concept for a Solar System Internetwork (SSI)”, Interagency Operations Advisory Group Report, October 2010.
- “Optical Link Study Group Final Report,” IOAG.T.OLSG.2012. 5 June 2012.



Acronyms



C&N - Communication and Navigation
DSN - Deep Space Network
DTN - Disruption/Delay Tolerant Network
ERNESt - Earth Regimes Network Evolution Study
ESC - Exploration and Space Communications
GEO - Geosynchronous Orbit
GSFC - Goddard Space Flight Center
LEO - Low Earth Orbit
MA - Multiple Access
NASA - National Aeronautics and Space Administration
NEN - Near Earth Network
NGBS - Next Generation Broadcast Service
RF - Radio Frequency
SCaN - Space Communications and Navigations
SMN - Space Mobile Network
SN - Space Network
SWaP - Size, Weight, and Power
TASS - TDRSS Augmentation Service for Satellites Service
TDRSS - Tracking and Data Relay Satellite System
UIS - User Initiated Services





MISSION

As a national resource, the Exploration and Space Communications (ESC) Projects Division enables scientific discovery and space exploration by providing innovative and mission-effective space communications and navigation solutions to the largest community of diverse users.

GSFC/ESC EXECUTIVE LEADERSHIP TEAM

Bob Menrad, Associate Director
Cathy Barclay, Deputy Program Manager/Execution
Mark Brumfield, Deputy Program Manager/Implementation
Dave Israel, ESC Architect
Tracy Felton, Program Business Manager
Mike Weiss, Associate Program Manager

ACKNOWLEDGEMENTS

The authors thank SCan, the ERNESt team and Carolyn Crichton, for helping to make this presentation possible.

PRESENTER:

David Israel
david.j.israel@nasa.gov
301-286-5294

STAY

CONNECTED: <http://esc.gsfc.nasa.gov/> Facebook: @NASA.ESC, @NASA.TDRS, @NASASCaN, Twitter: @NASA_TDRS, @NASALaserComm