Keeping the universe connected.

Integrating Communication and Navigation

WG-B – New Concepts for Integrating Communication and Navigation for Space Users

Jennifer Donaldson, NASA Goddard Space Flight Center

Xi'an, China, November 4–9, 2018

Objective

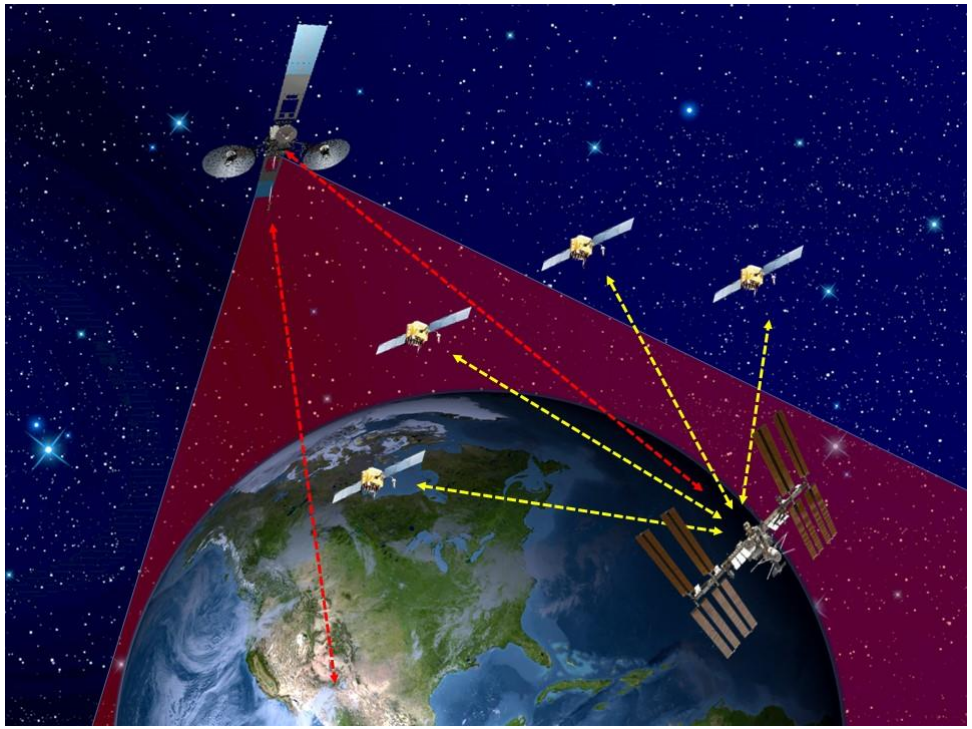
- Current space communications achieved through the NASA Near Earth Network (NEN) and Deep Space Network (DSN) ground terminals and the Space Network (SN)
  - Requires service scheduling by Mission Operations Centers (MOCs) days in advance
  - Few spacecraft perform autonomous, precise on-board navigation, two-way range and Doppler tracking is used for ground based orbit determination

- NASA's Vision for and Improved Future Network
  - Enables user-hailed services that are autonomously scheduled by the network
  - Provides spacecraft with radio-navigation signals and data to support precise orbit determination

- The Next Generation Broadcast Service (NGBS) is a concept for a beacon for providing:
  - a global a S-band navigation signal
  - GPS augmentation
  - unscheduled commanding

NGBS Service Description

- NGBS provides unique signals and data to *enhance user operations and enable autonomous onboard navigation*
- NGBS service consists of:
  - Global coverage via TDRSS S-band multiple access forward (MAF) service
  - Unscheduled, on-demand user commanding
  - Space environment/weather: ionosphere, Kp index for drag, alerts, effects of Solar Flares/CMEs
  - Earth orientation parameters
  - TDRS ephemerides and maneuver windows
  - **PN ranging code synchronized with GPS time for time transfer, one-way forward Doppler and ranging**
  - **Global differential GPS corrections**
  - **GPS integrity**

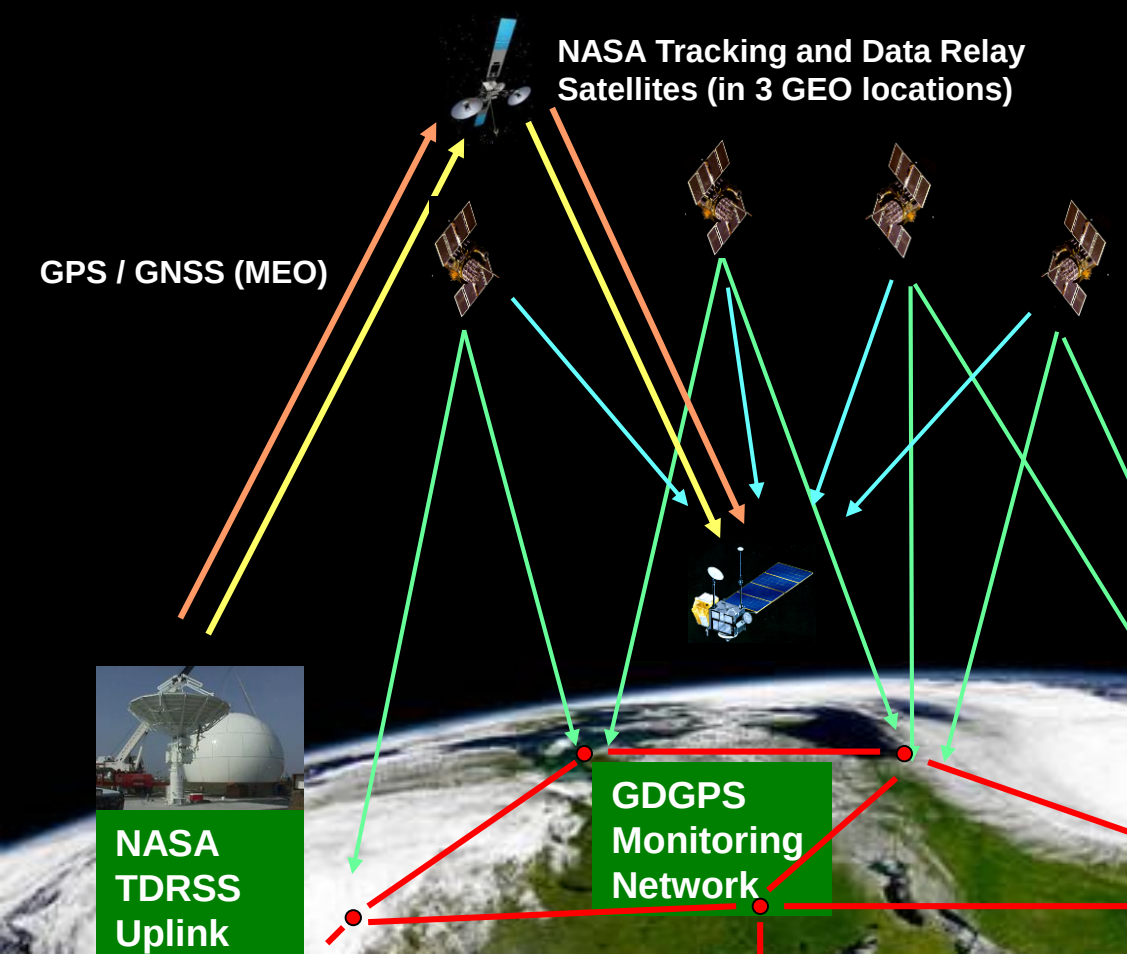


NGBS has direct benefits in the following areas:

- Science/payload missions
- SCaN/Network operations
- TDRSS performance
- GPS and TDRSS onboard navigation users
- Conjunction Assessment Risk Analysis
- Capabilities consistent with the modern GNSS architecture

NGBS System Architecture

- **NGBS supports space users:**
  - **Rapid Forward Commanding**
  - **Precise GNSS-based on-board autonomous navigation**



1) User spacecraft acquires GNSS signals

2) A ground network monitors GNSS satellites

3) TDRSS satellites relay GDGPS differential corrections to space users

4) Signal incorporates GNSS-independent Doppler & Pseudorandom Noise (PRN) ranging code for independent measurement

- **Data Channel (In-phase) and Pilot Channel (Quadrature)**
- **Short and Long PN Codes**
- **Center frequency is an integer multiple of spreading rate, providing a coherent rational time base tied to a ground reference**

NGBS Benefits to Users

- A broadcast beacon service has the ability to improve the level of autonomous operations for users
  - Facilitates autonomous or MOC-in-the-loop re-pointing for science observations, **increases mission science return**
  - Provides common information for situational awareness
  - Provides unscheduled, continuously-available alternative to GPS navigation, or supplements and provides resiliency to GPS solution

- Many of our current and future science missions study transient phenomena (gamma-ray burst, gravitational waves)
  - Investigation of these events requires coordinated observations between ground and space-based assets. **Fast communication between observatories is essential.**

- Integrating navigation signals into communication services increases spacecraft autonomy
  - Users can take advantage of software defined radios to reduce size, weight, and power for overlapping radio navigation and radio communication hardware

Conclusions

- Space users have distinct needs that aren't being provided by the existing communication networks

- A future network infrastructure can offer many benefits, including the ability to integrate communication and navigation into one system, provide information for increased navigation accuracy and more

- NGBS is an example of what such a future network component could offer, as provided by NASA via the SN
  - Concept could be extended to communication relay satellites in the lunar vicinity

NASA is interested in hearing about other future service architectures

Backup

NGBS Development and Status

- **NGBS is an evolution of the TDRSS Augmentation Service for Satellites (TASS)**
- **Timeline**
  - 2000: GDGPS operational
  - 2006-2007: TASS demo service on a TDRSS satellite (TDRS-1). Protoflight TASS signal tracked using a ground-based receiver.
  - 2016: Renamed NGBS; Demo 1 on TDRS-12 to validate beacon pattern
- **TASS Signal-in-Space Tests***
  - Validated all major system capabilities
  - Received and tracked carrier phase and PRN code
  - Real-time data streaming from the JPL
  - End-to-end GDGPS data authentication
  - Viterbi encoding/decoding
  - Validated both IF and baseband interface options for the TASS transmitter at White Sands Complex
  - Validated link budget and end-to-end latency (7 sec)

NGBS Capabilities*

	State of the Art (unaugmented GPS)	GDGPS
Real-time orbit determination	1-5 meters	0.1 - 0.3 m
Real-time time-transfer	~10 nsec	~1 nsec
Integrity **(GPS malfunction flags)**	Not available	Included

- **NGBS Demonstrations**
  - Data Integrator (DI) and Message Formatter (MF) ground demonstration
    - User commands transmitted through the system
    - TDRS ephemeris and space weather data sources were streamed from recorded data
    - Data ingest of real time GDGPS data from JPL
    - Data was modulated on a S-band carrier, demodulated, and decoded
  - Used TDRS-12 to perform live sky demonstration of 4-element MAF beacon configuration (July 2016)
    - Testing validated peak EIRP (>36.0 dBW) and beacon pattern for 2nd and 3rd generation TDRS

(*) Y. Bar-Sever, L. Young, J. Rush, F. Stockling, The NASA Global Differential GPS System (GDGPS) and The TDRSS Augmentation Service for Satellites (TASS), *Proceedings of the 2nd ESA Workshop on Satellite Navigation User Equipment Technologies*, 2004. http://www.gdgps.net/system-desc/papers/Bar-Sever.pdf