TDRSS Augmentation Service for Satellites (TASS)

National Aeronautics and Space Administration

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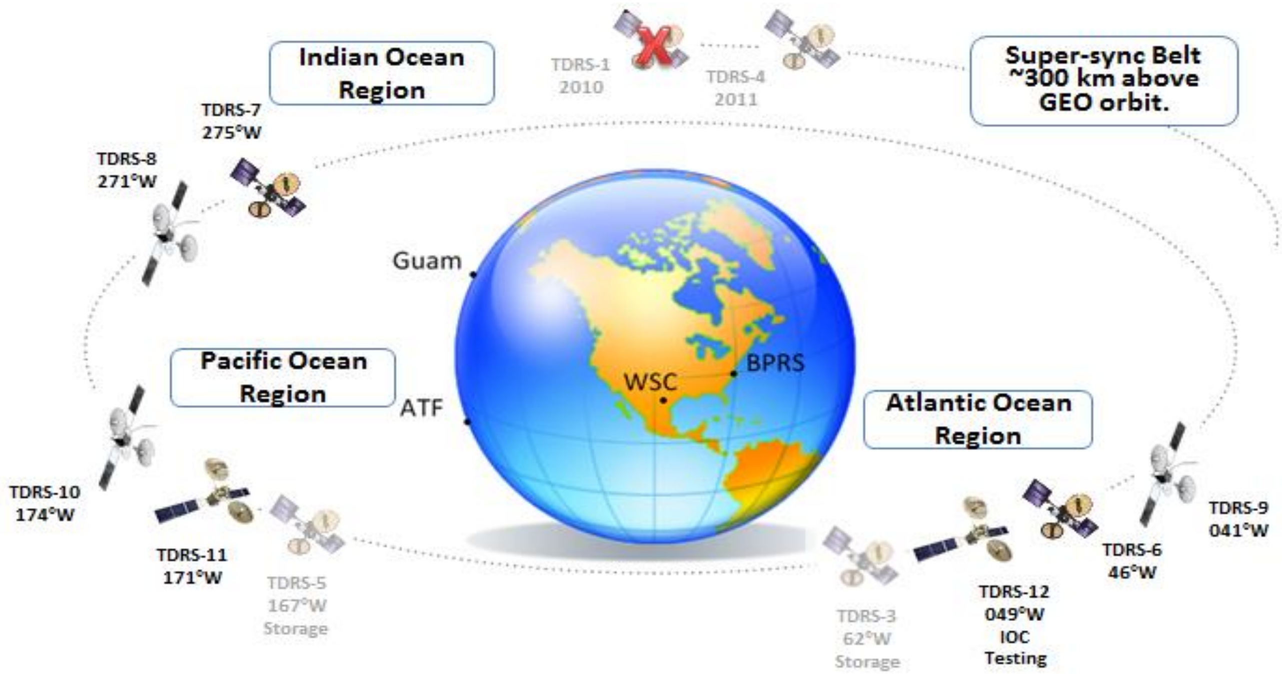
NEXT GENERATION BROADCAST SERVICE (NGBS)

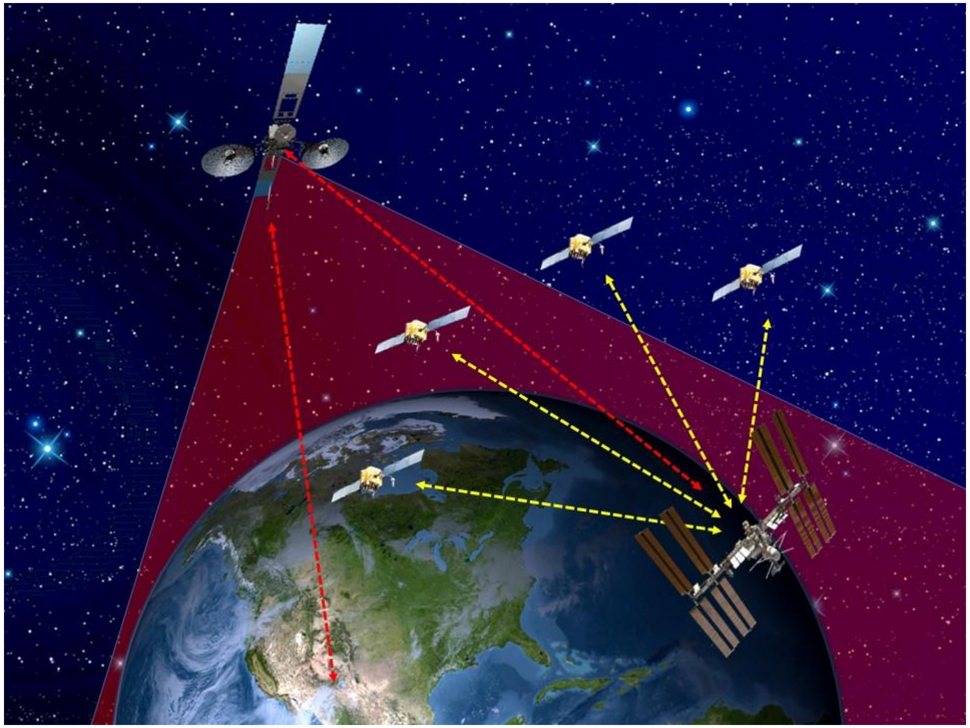
Objectives



- Current: space communications achieved through the Near Earth Network (NEN) ground terminals and the Space Network (SN)
  - The SN is composed of the Tracking and Data Relay Satellites (TDRS)
  - Requires service scheduling by Mission Operations Centers (MOCs) days in advance
  - Few spacecraft perform autonomous, on-board navigation
- Improved, future network
  - Enables user-hailed services that are autonomously scheduled by the network
  - Provides spacecraft with radiometrics and data to support autonomous, on-board navigation
  - Expands service volume

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:

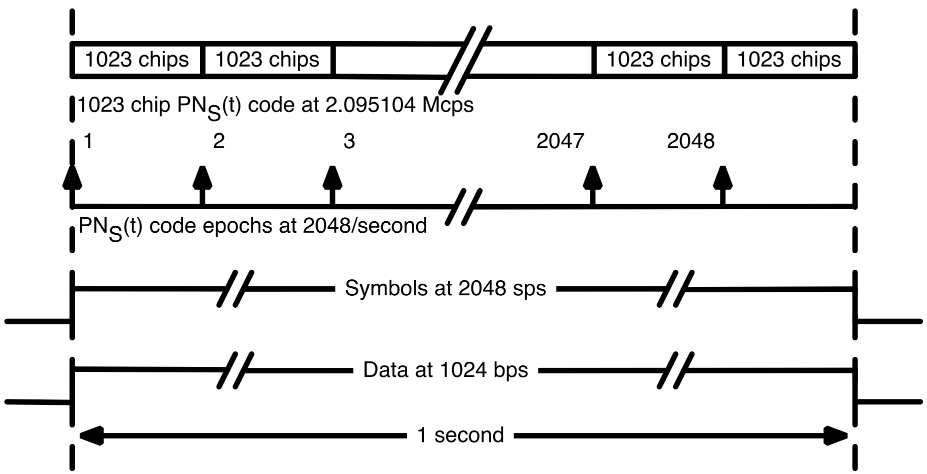
- Science/payload missions
- SCaN/Network operations
- TDRSS performance
- GPS and TDRSS onboard navigation users
- Conjunction Assessment Risk Analysis
- Capabilities consistent with the modern GNSS architecture

NGBS and the Space Mobile Network

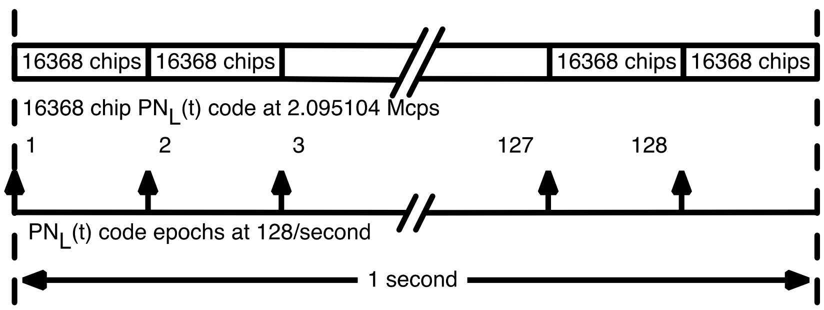
- Proposed Space Mobile Network (SMN)
  - Similar to the architectural concepts that enable today's terrestrial wireless networks
  - Provides automated delivery of communication services and always available positioning and navigation capability
  - User-hailing paradigm:
    - Spacecraft ("users") autonomously request a communications link from the network
    - Network autonomously schedules comm. link, considering relative locations of user and network nodes
- NGBS support of user-hailing
  - Beacon concept allows access to any spacecraft within the service volume
  - Signal structure allows radiometrics (range and Doppler measurements)
  - TDRS Ephemerides and Maneuver Windows provide relay location and integrity
- Additional benefits of NGBS
  - Data to supplement and improve on-board navigation (e.g., EOPs, TEC, Kp index, DGPS)
  - Forward commanding
  - Space weather

Signal Structure

Inphase Channel (Data)



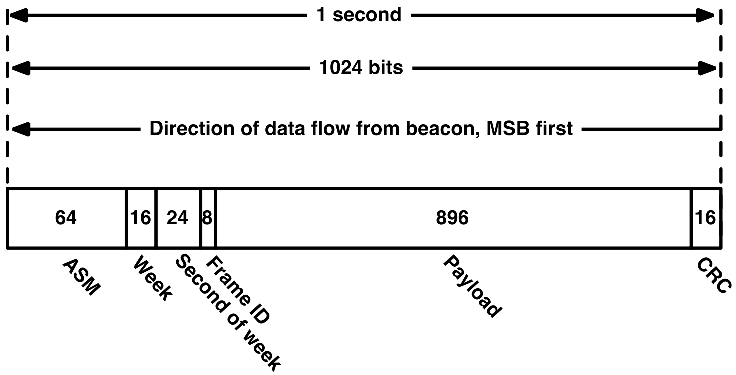
Quadrature Channel (Pilot)

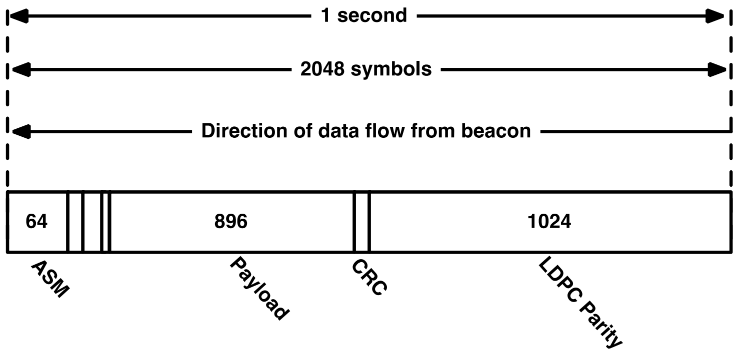


- PN_S 1023 chips; PN_L 16368 chips
- 2048 PN_S sequences/second, 128 PN_L sequences/second
- 2.095104 Mcps (1023x2048) spreading rate
- Rational timebase, 2105.579520 MHz (1023x2048x1005) carrier frequency
- 10:1 power ratio on I and Q channels (Q is a dataless pilot)
- 1024 bps, CCSDS LDPC (2048, 1024) rate ½ encoded
- Designed for acquisition with zero a-priori information (lost in space)
- Designed for weak signal tracking

Data Message

Frame Structure





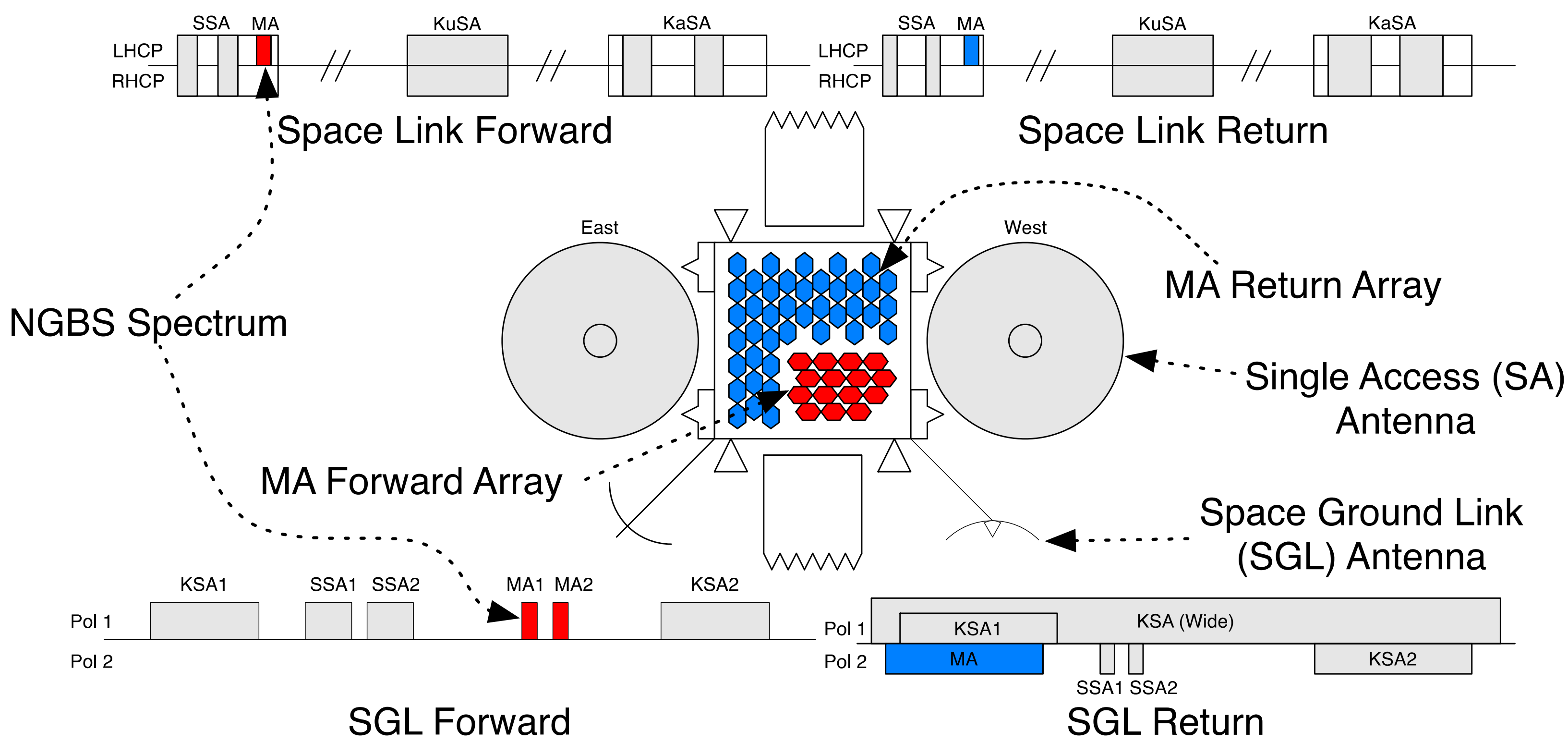
Data Message Allocations

Message	Label	Size (bits)	Quantity	Refresh Interval (s)	Data Volume
ASM	ASM	64	1	1	640
Week	WK	16	1	1	160
Second of Week	SOW	24	1	1	240
Frame ID	FID	8	1	1	80
GPS Integrity	A	184	10	10	1840
GPS Differential Corrections	B	72	32	10	2304
TDRS Ephemerides	C	200	10	10	2000
User Commands	D	200	4	10	800
Spares	E	200	4	10	800
Space Environment	F	152	3	10	456
Ionsphere	G	200	1	10	200
Solar flux	H	128	1	10	128
Earth Orientation	I	48	1	10	48
TDRS Health & Safety	J	200	1	10	184
Unused	U	200	1	10	200
CRC	CRC	16	1	1	160
				Totals	10240

- Data message in a framed structure, 10 seconds to broadcast entire message.
- ~80 bps on average allocated to user command. With spares & unused, 180 bps.
- Goal to achieve 2048 bps data rate. If achieved, 1024 bps will be allocated for user commands.

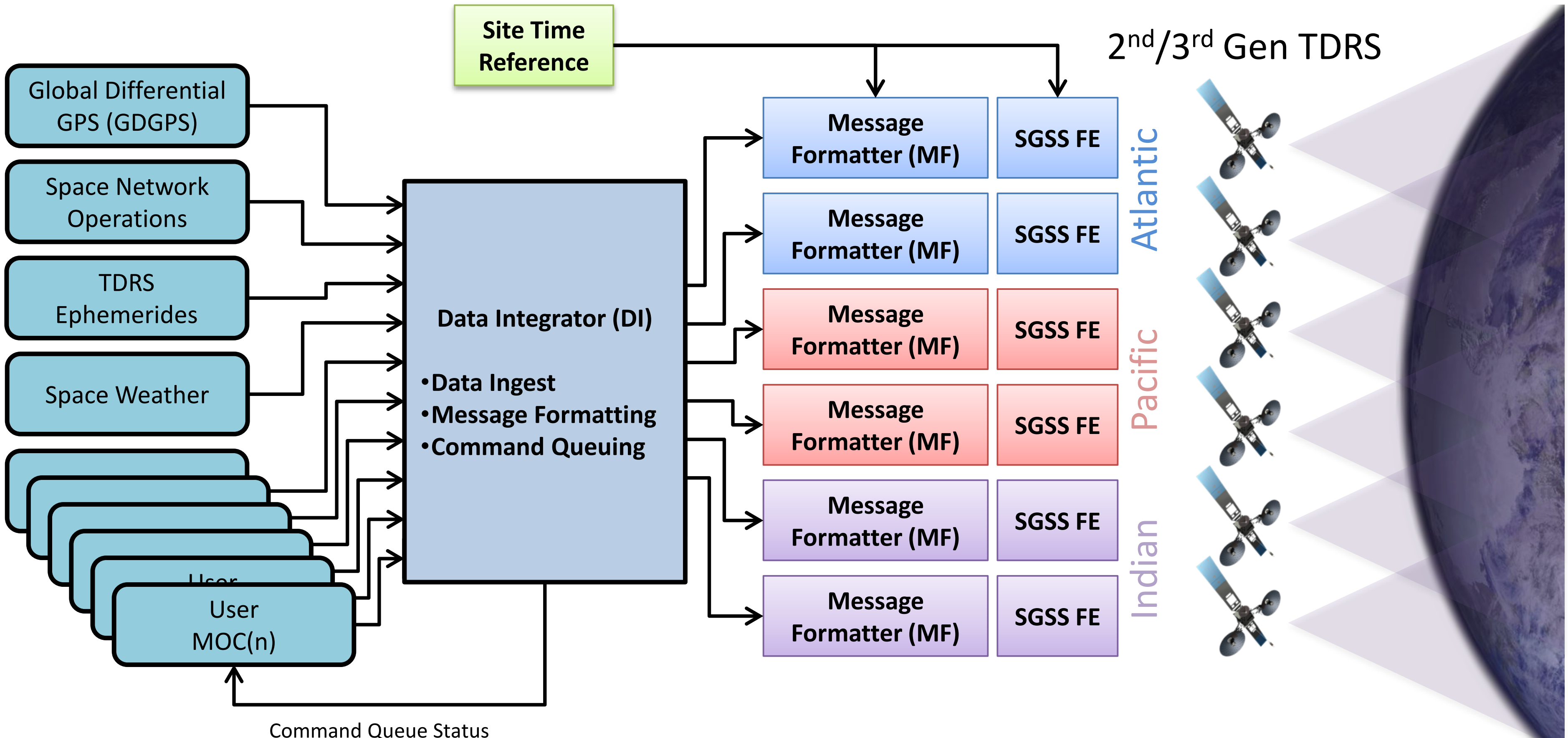
SYSTEM ARCHITECTURE

Space Element



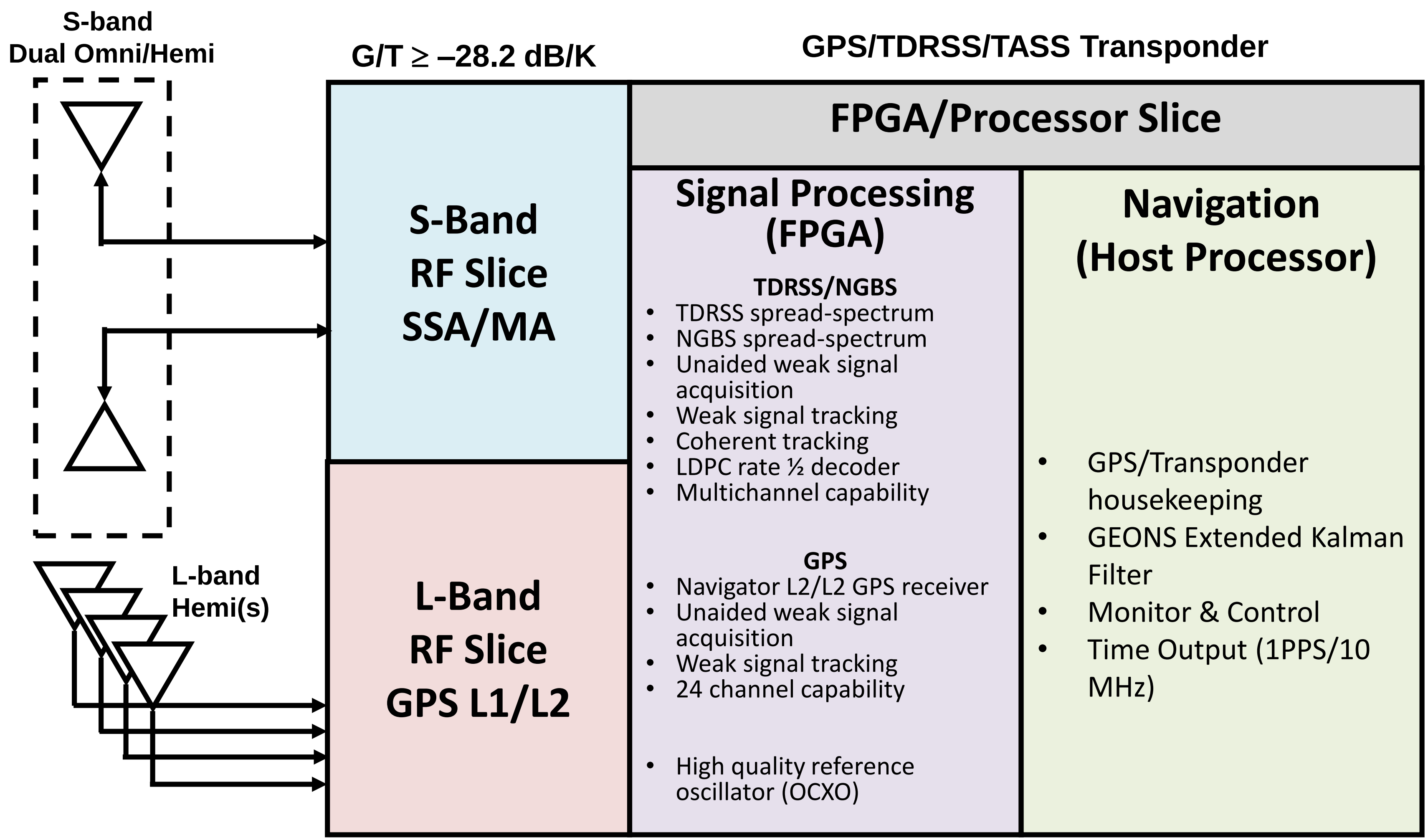
- 2nd/3rd gen TDRS used to broadcast NGBS beacon
- MA forward (MAF) array can be split to provide two simultaneous MAF services
  - Current Space Network ground system does not support this capability
- MA return (MAR) array supports Demand Access Service (DAS)
- In concert with DAS, NGBS will provide a unique anytime/anywhere two-way communications channel

Ground Element



- Data Integrator (DI) located at WSC
- Message Formatters (MF) located in each NGBS enabled ground system

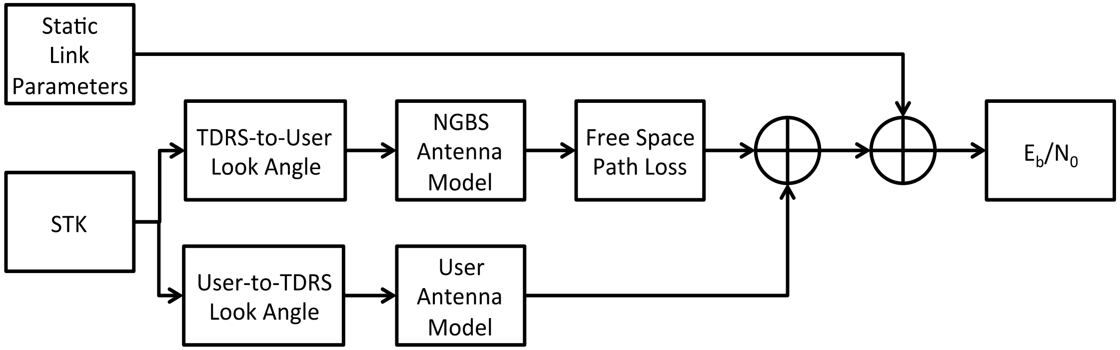
User Element

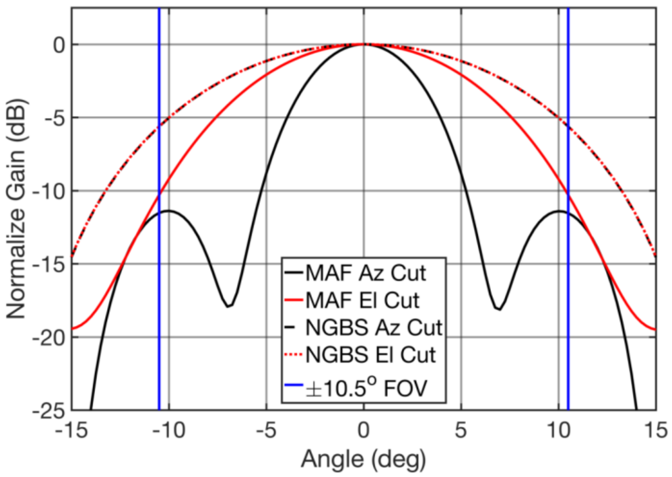


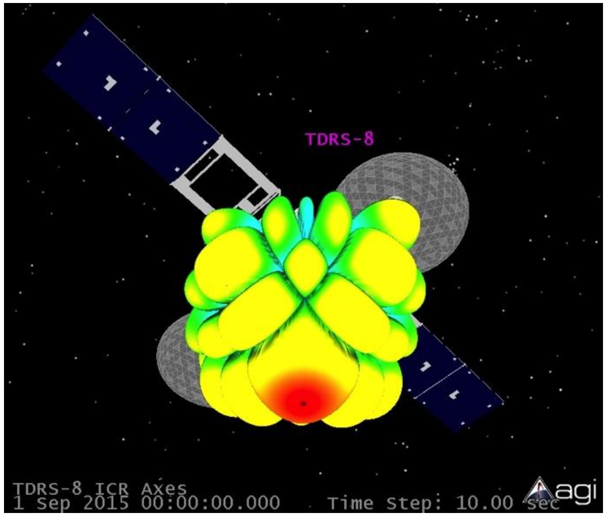
CURRENT STATUS

Coverage Analysis

Simulation Parameter	Options
User Orbit	Low inc LEO, SSO LEO
User Antenna	-3 dB ISO, GPS, MMS, LADEE
MAF Configuration	4 Element
NGBS Constellation	3 nodes, 5 nodes

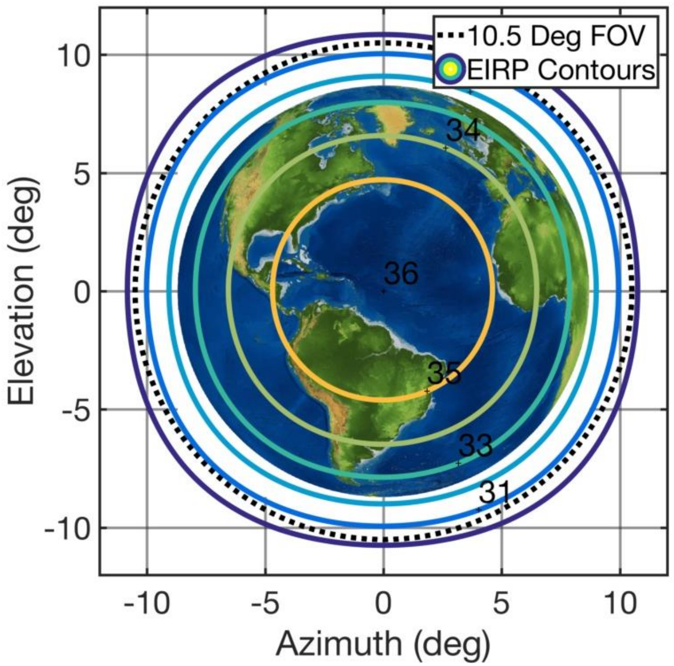






- Static link parameters combined with dynamic STK/MATLAB analysis
  - NGBS & user antenna models
  - Slant range
- Analyzed all combinations of NGBS constellation, user orbit, and user antenna models

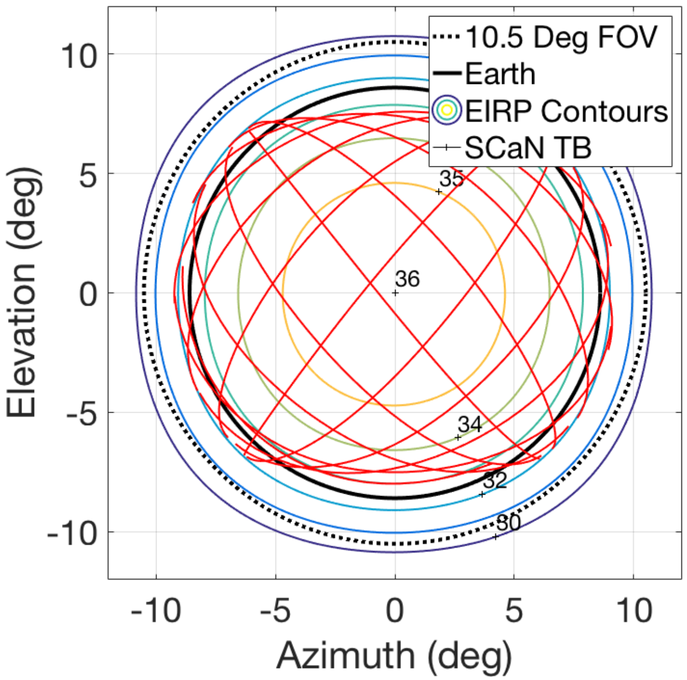
Coverage Analysis

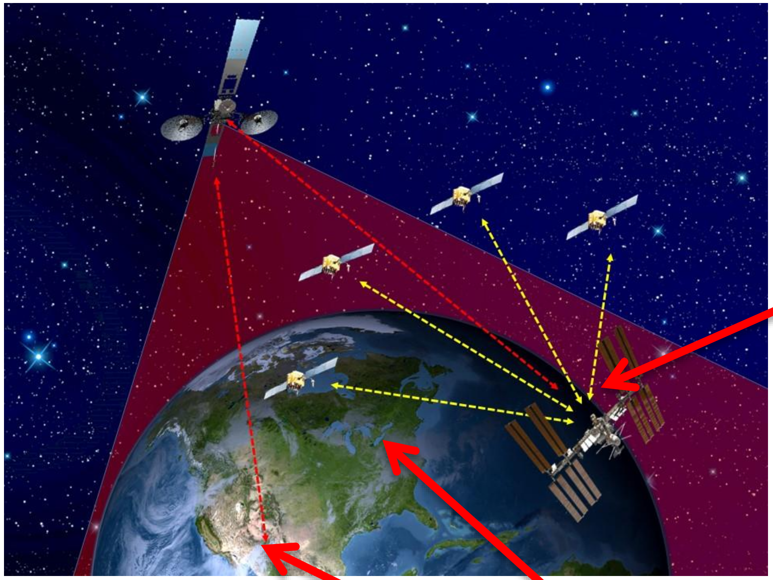


	NGBS Configuration	3 Beacon	5 Beacon	3 Beacon	5 Beacon
Orbit	User Antenna Model	% Availability		Outage Duration (Minutes) 90% Bound	
ISS	GPM	98.46	99.80	0.45	0.45
ISS	-3 dB ISO	100.00	100.00	0.00	0.00
ISS	MMS	99.97	99.97	0.00	0.00
ISS	LADEE	100.00	100.00	0.00	0.00
SSO LEO	GPM	92.16	97.94	0.67	0.45
SSO LEO	-3 dB ISO	100.00	100.00	0.00	0.00
SSO LEO	MMS	100.00	100.00	0.00	0.00
SSO LEO	LADEE	100.00	100.00	0.00	0.00

- Analysis incorporates 36 dBW peak EIRP, conservative user terminal G/T
- 3 TDRS constellation can provide global coverage with a 1024 bps data rate
- 1024 bps link is robust, 2048 has positive (slight) margin

NGBS Demo #1 – Global Beam





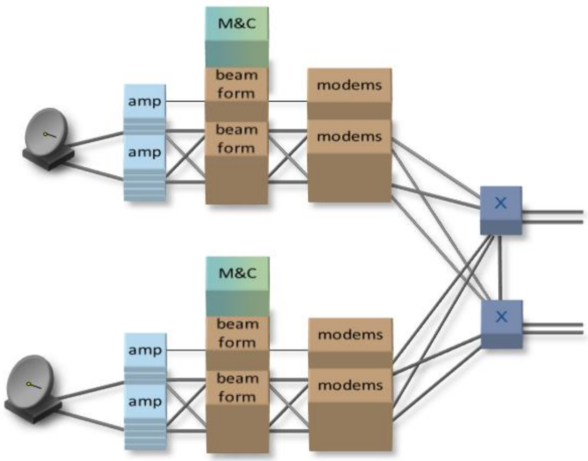
SCaN TestBed used to validate EIRP contours

Ground measurements taken at WSC & GRC

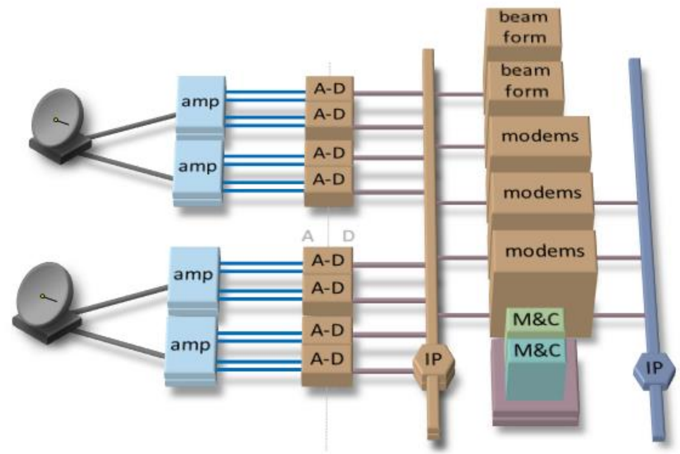
- Objective 1: validate 4 element array beam pattern and peak EIRP
- Objective 2: quantify 2nd gen TDRS MAF EIRP margin

Ground Element

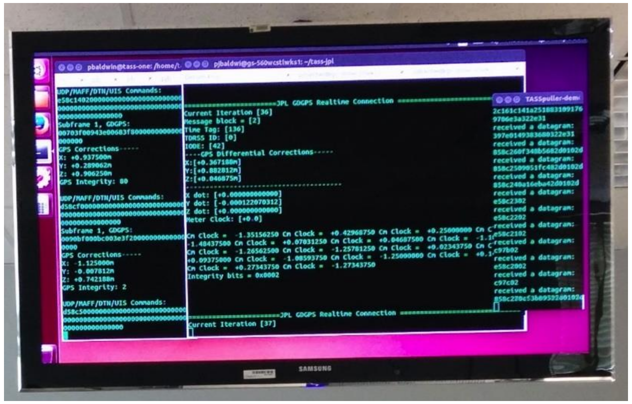
Legacy SN Ground System



SGSS Architecture



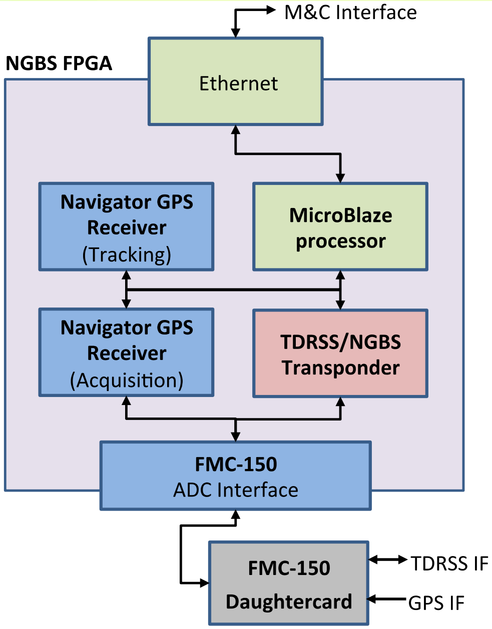
- SN Ground Sustainment System (SGSS) architecture will:
  - Enable dual MAF capability built into 2nd and 3rd generation TDRS
  - Allow for low cost insertion of NGBS ground system hardware
  - Reduce one-way forward ranging errors
- Data Integrator (DI) and Message Formatter (MF) software under development
  - 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

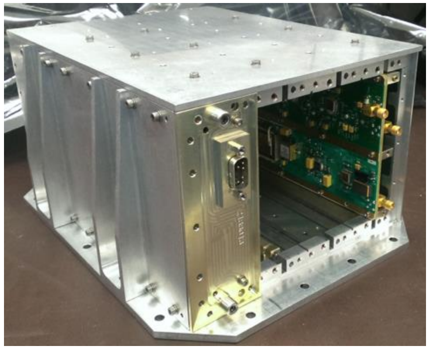


Real time data connection from JPL

User Element

ML605 breadboard development platform

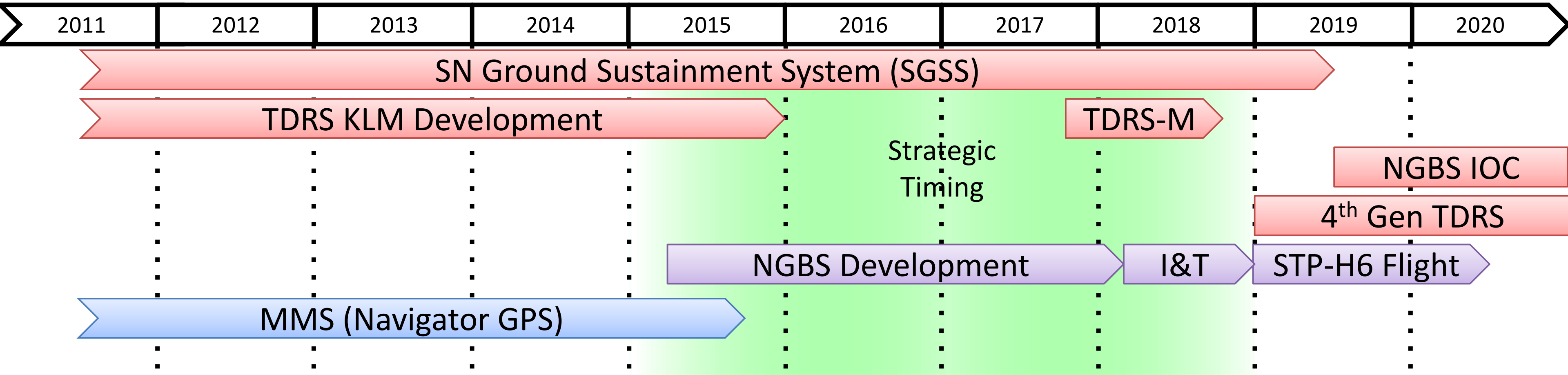




NavCube Engineering Test Unit with GPS + SpaceCube flight components

- NGBS terminal combines following mature technologies:
  - Navigator GPS
  - TDRSS transponder waveform
  - NGBS receiver waveform
  - Goddard Enhanced Onboard Navigation System (GEONS) flight software
  - SpaceCube 2.0 hardware
- STP-H6 provides a low-cost opportunity to flight qualify NGBS terminal
  - Launches in Dec 2018
- NBGS terminal intellectual property:
  - Deployable on lower SWAP hardware platform
  - Opportunity for smallsat/cubesat community

Potential for Initial Operational Capability



- Strategic opportunity exists:
  - Launch of TDRS-M in Oct 2017 will provide 6 NGBS capable spacecraft
  - SGSS necessary for NGBS ground implementation
  - STP-H6 provides a low cost opportunity to fly NGBS user element and demonstrate NGBS on orbit
  - NGBS user element is built on mature Navigator GPS receiver technology
- NGBS is a first step in advancing the next generation network paradigm as laid out in Space Mobile Network
  - Lessons learned from NGBS will inform beacon service on 4th gen TDRS

Closing Thoughts…

- NGBS:
  - With DAS, enables user-hailed services that are autonomously scheduled by the network
  - Provides spacecraft with radiometrics and data to support autonomous, on-board navigation and operations
  - Provides capabilities fundamental to the Space Mobile Network concept
- A fully operational beacon service will go beyond current implementation of NGBS:
  - Specifically designed service on "4^{th} gen" TDRS could provide increased data rate and also a greater service volume
  - Earth based beacons could offer much higher EIRP for users in HEO or cis-Lunar space
- Engagement from the user community is key