Integrating Communication and Navigation: Next Generation Broadcast Service (NGBS)

National Aeronautics and Space Administration

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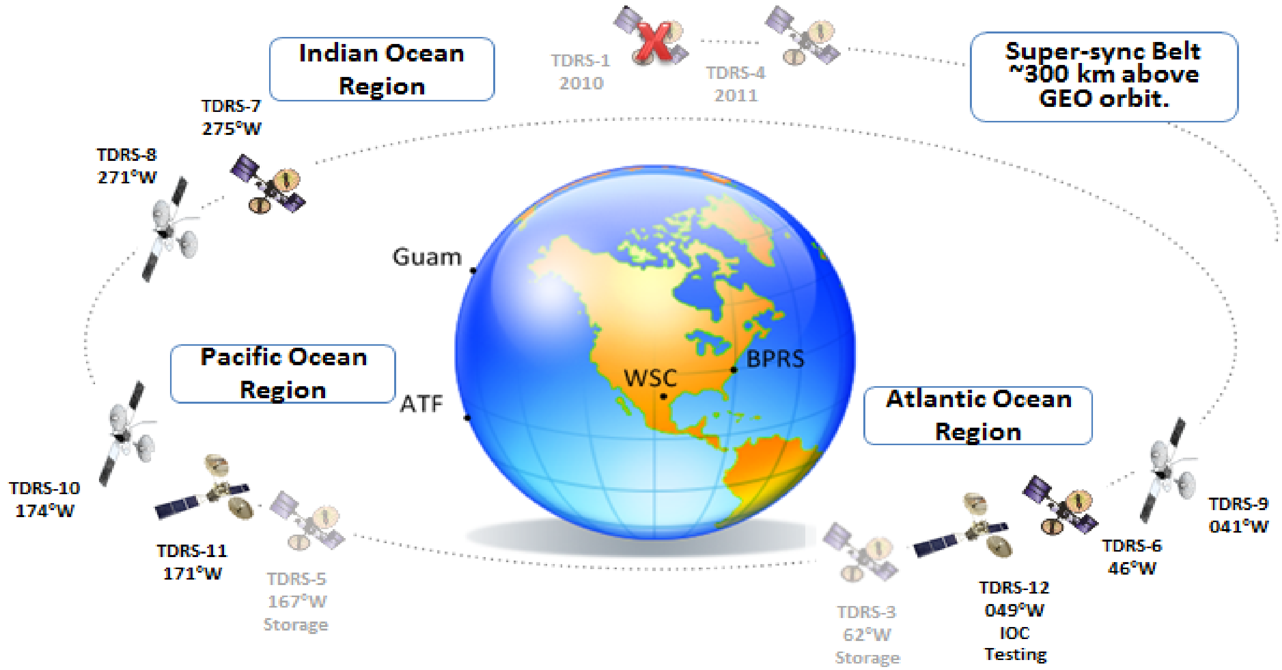
NEXT GENERATION BROADCAST SERVICE (NGBS)

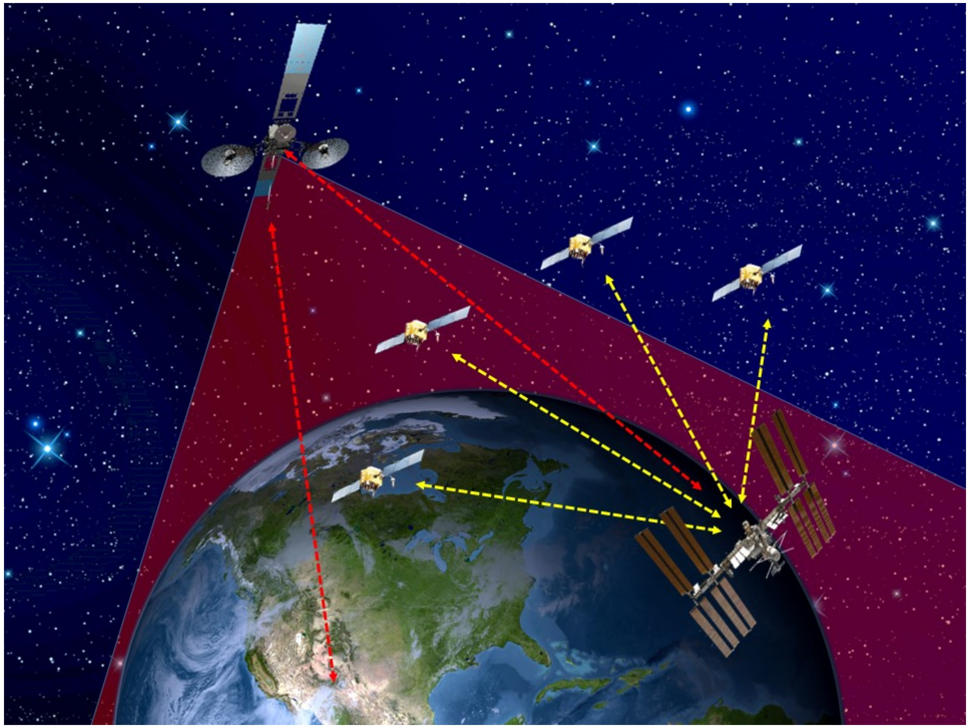
Objectives



- 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 Benefits to Current and Future Users

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

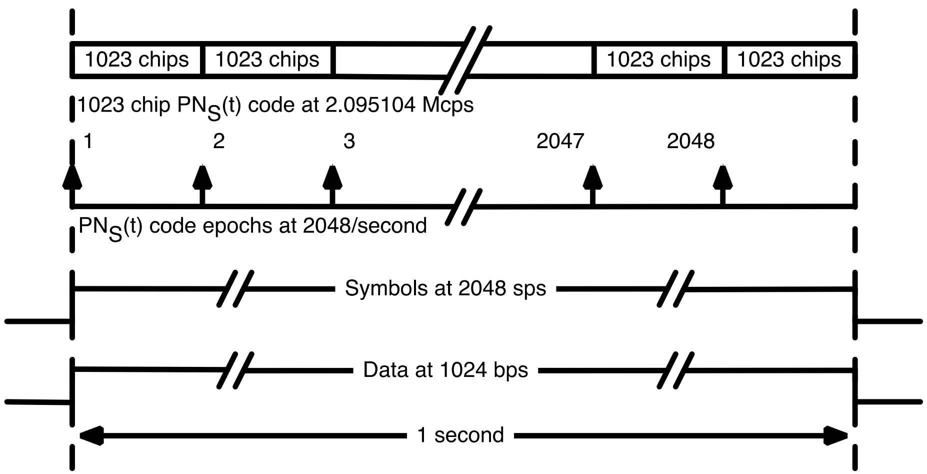
- Many of our current and future science missions study transient phenomena (gamma-ray burst, gravitational waves)
- Investigation of these events requires coordinated observations between ground and space-based assets. **Fast communication between observatories is essential.**

- Identified several missions that would benefit from this service:
  - Current missions: Fermi and Swift
  - MIDEX proposals: Survey and Time-domain Astronomical Research Explorer (STAR-X) and Transient Astronomy Observatory (TAO).

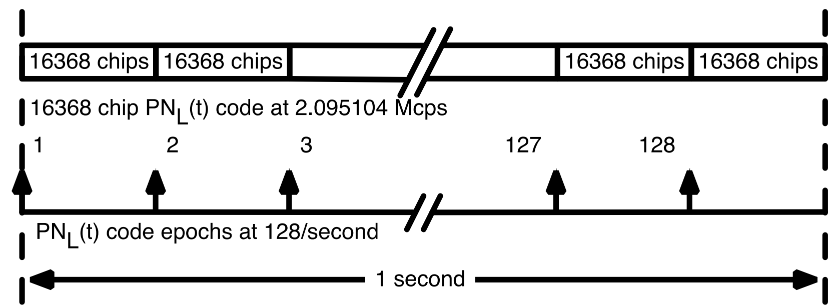
- Network benefits
  - Demand Access Service (DAS) & NGBS enable User Initiated Service (UIS)
  - Reduces burden on the network for radiometric tracking scheduled time
  - Enables precise, autonomous navigation for the relay

Signal Structure

Inphase Channel (Data)



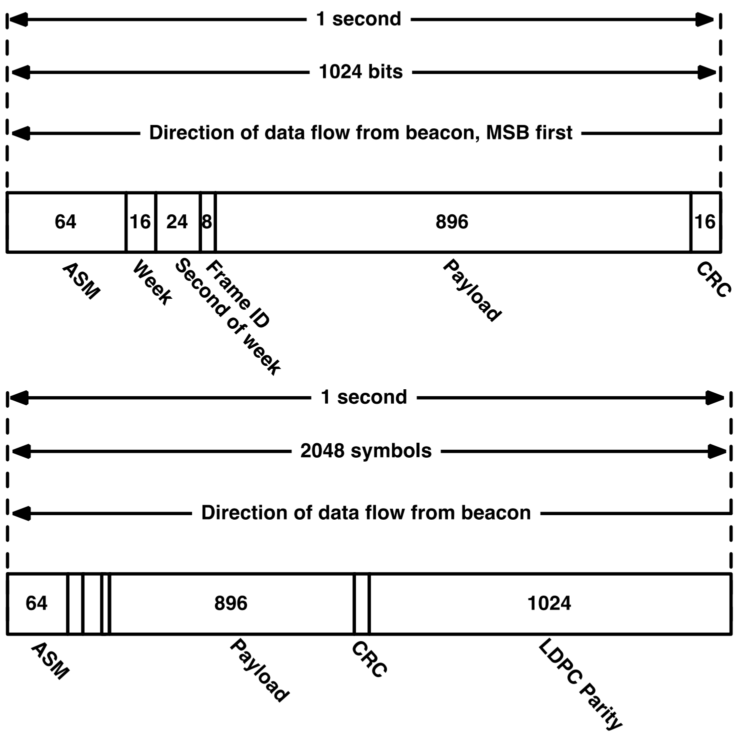
Quadrature Channel (Pilot)



- 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



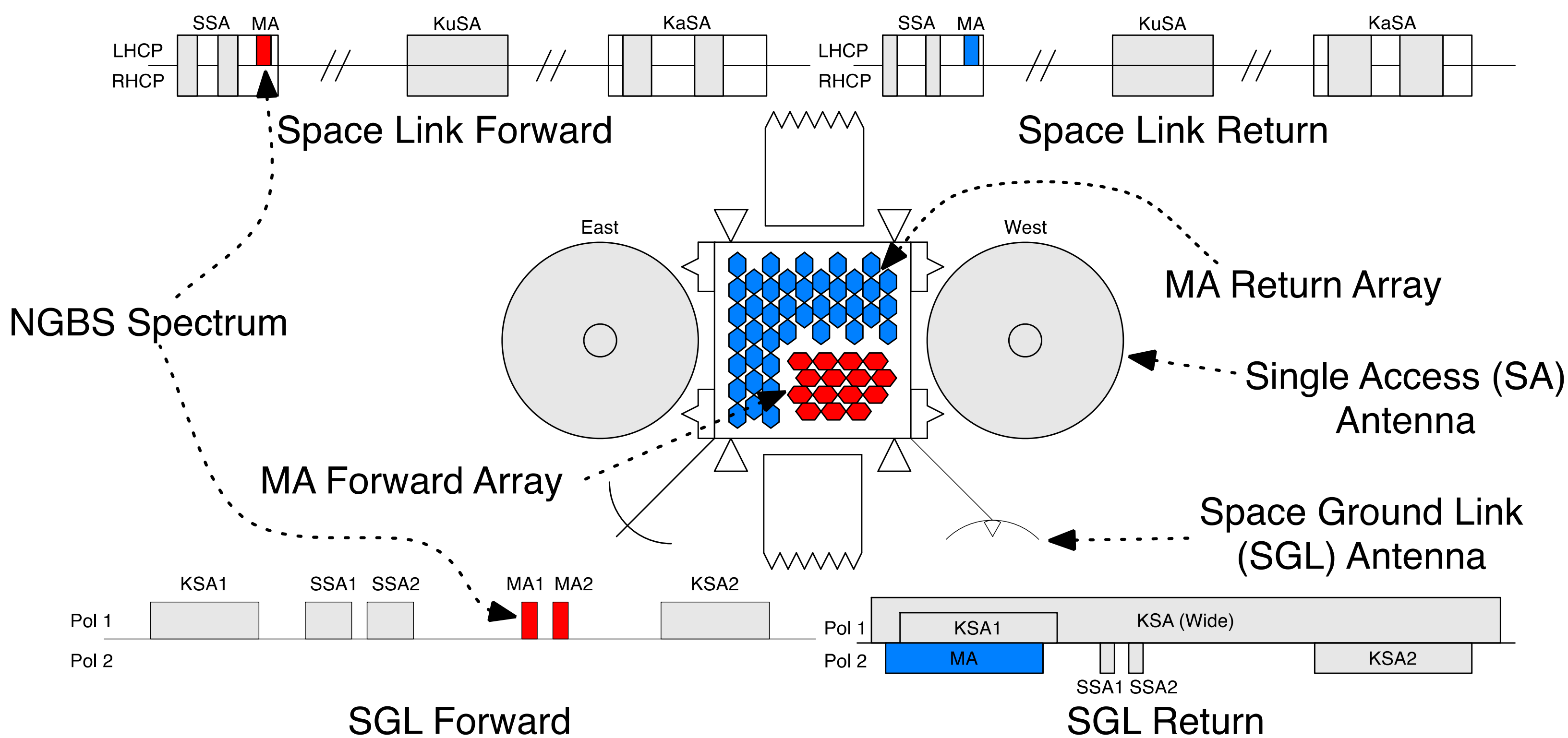
Data Message Allocations

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.

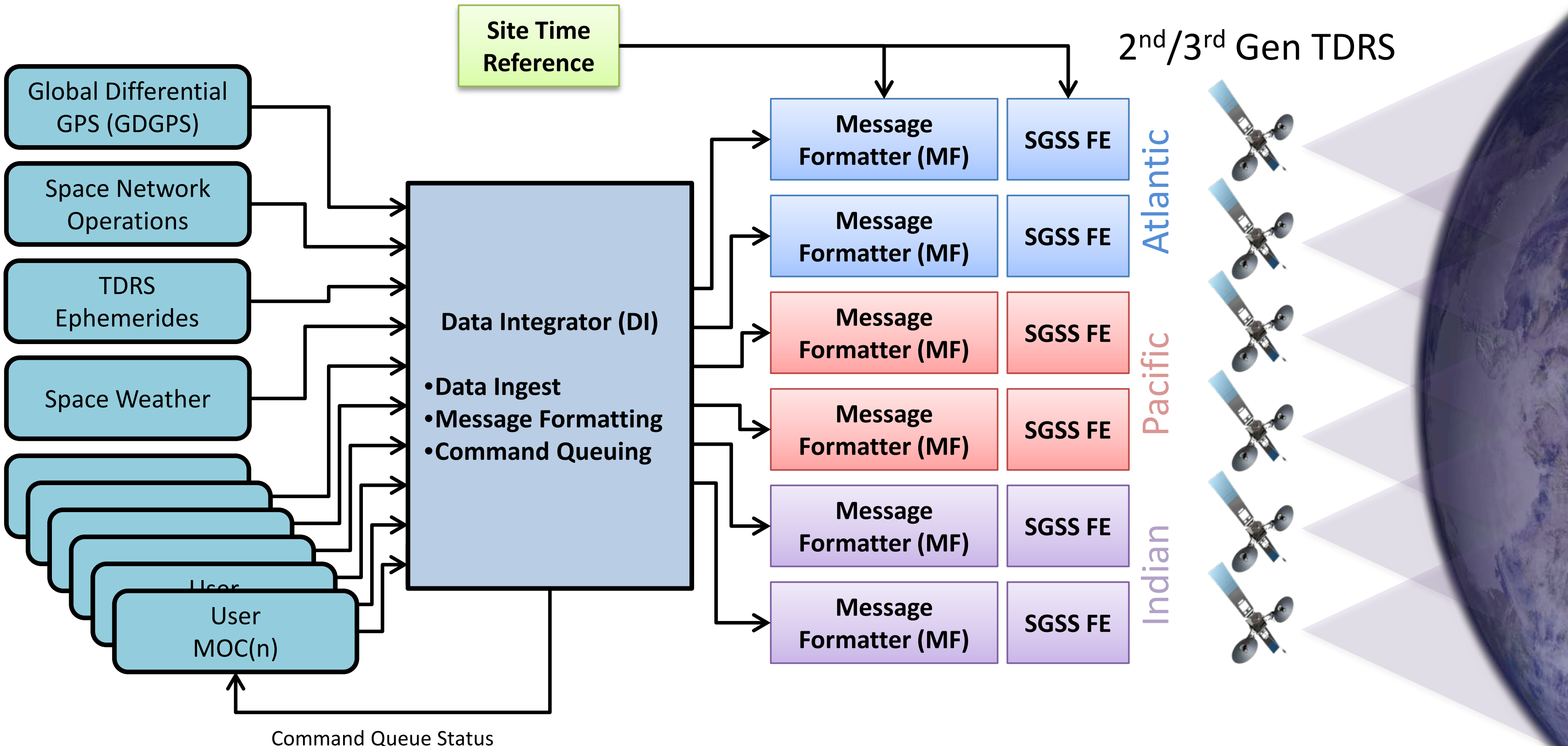
SYSTEM ARCHITECTURE

Space Element



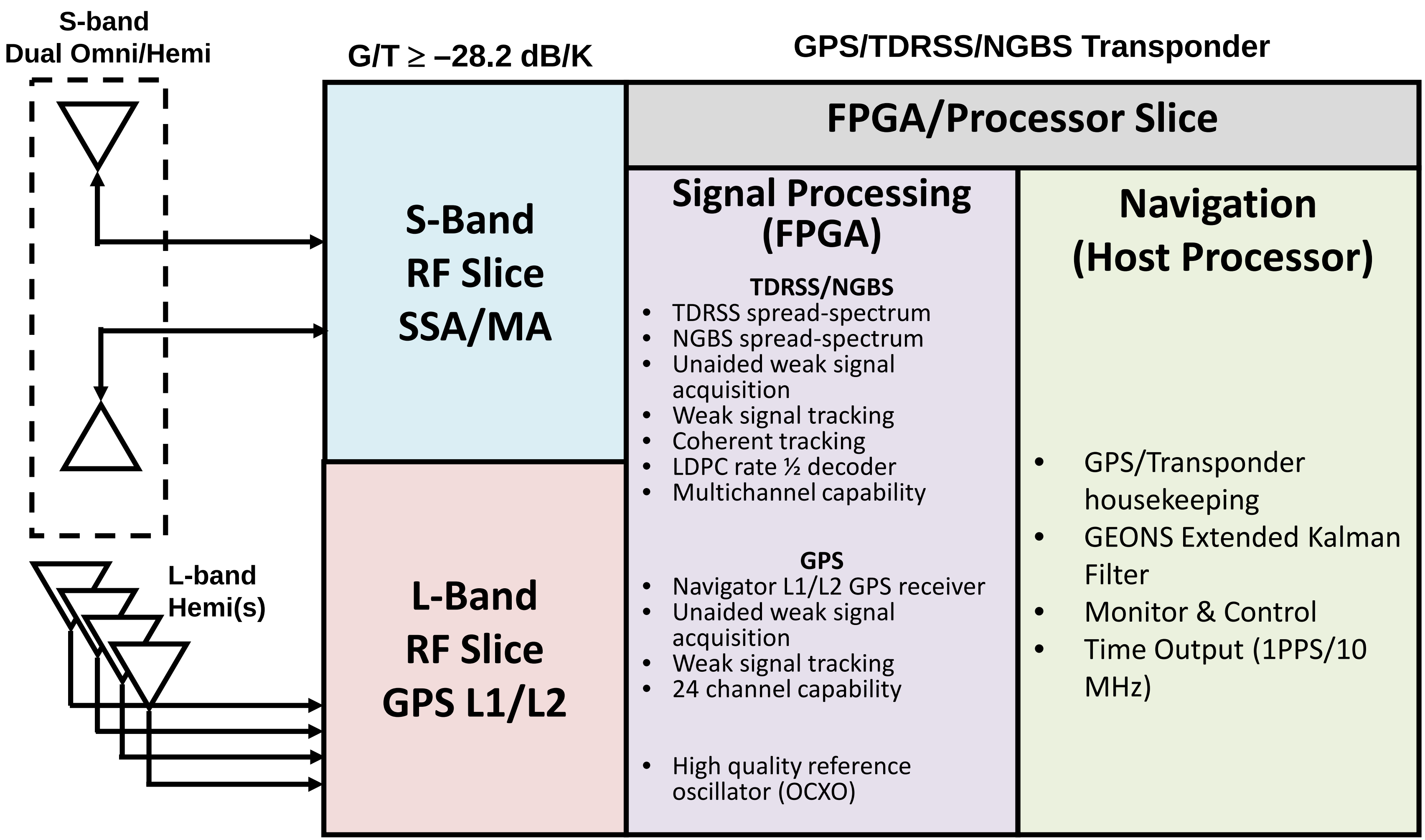
- 2nd/3rd gen TDRS used to broadcast NGBS beacon
- MA forward (MAF) array can be split to provide two simultaneous MAF services
  - Current Space Network ground system does not support this capability
- MA return (MAR) array supports DAS
- In concert with DAS, NGBS will provide a unique anytime/anywhere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

Ground Element



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

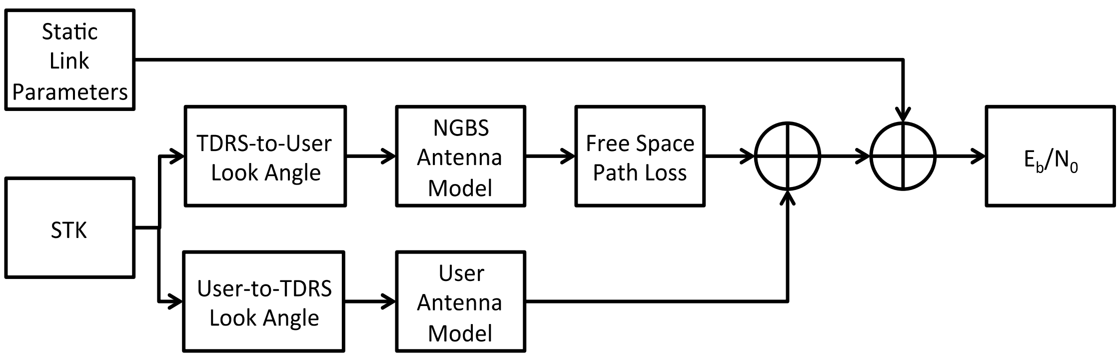
User Element

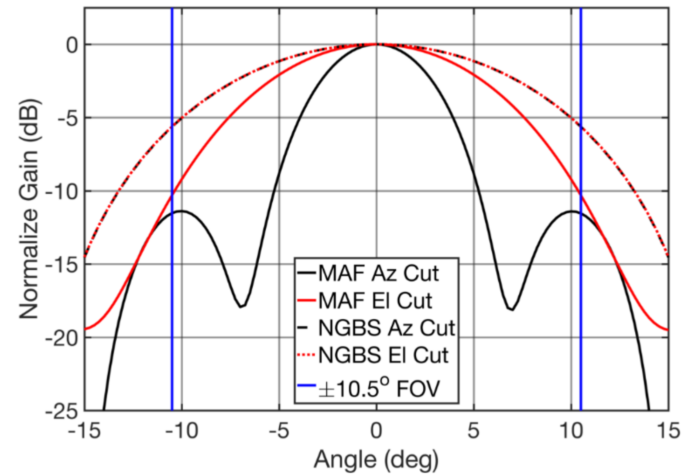


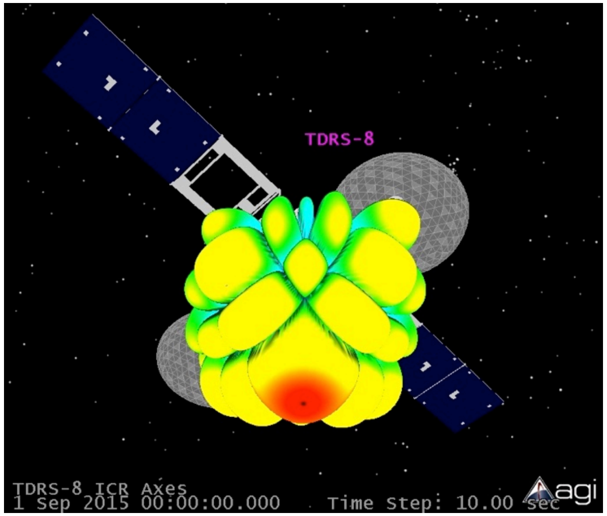
CURRENT STATUS

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

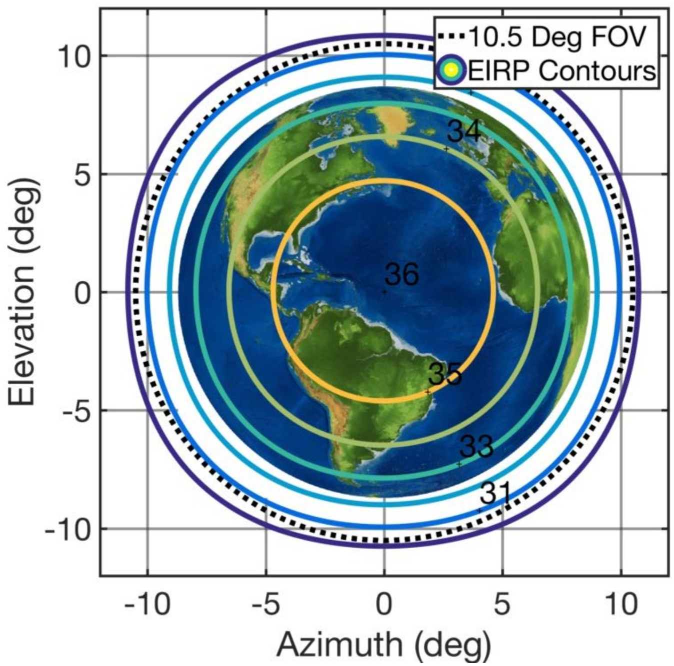






- Static link parameters combined with dynamic STK/MATLAB analysis
  - NGBS & user antenna models
  - Slant range
- Analyzed all combinations of NGBS constellation, user orbit, and user antenna models

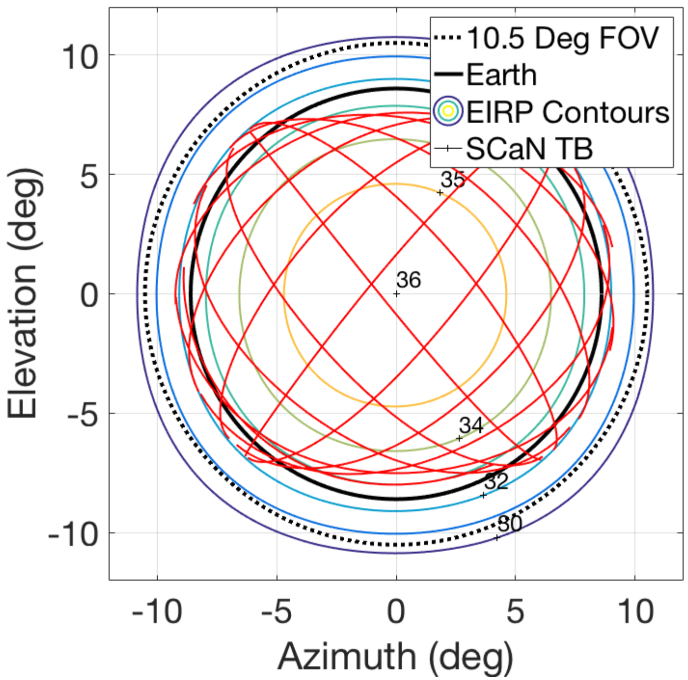
Coverage Analysis

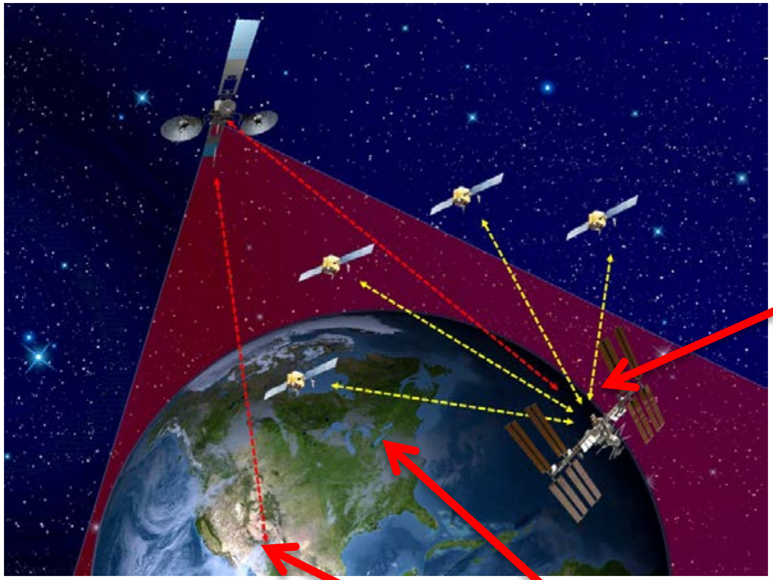


	NGBS Configuration	3 Beacon	5 Beacon	3 Beacon	5 Beacon
Orbit	User Antenna Model	% Availability		Outage Duration (Minutes) 90% Bound	
ISS	GPM	98.46	99.80	0.45	0.45
ISS	-3 dB ISO	100.00	100.00	0.00	0.00
ISS	MMS	99.97	99.97	0.00	0.00
ISS	LADEE	100.00	100.00	0.00	0.00
SSO LEO	GPM	92.16	97.94	0.67	0.45
SSO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

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

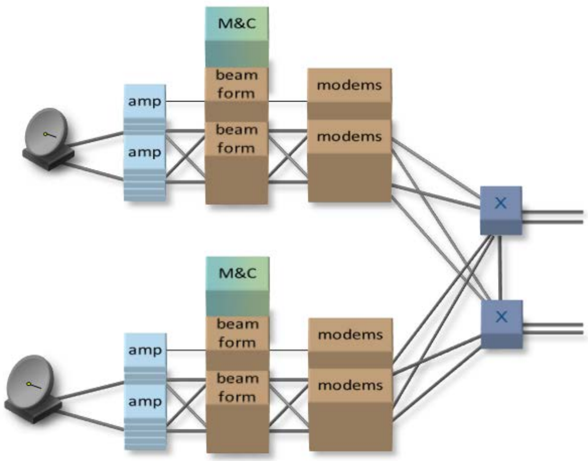
Ground measurements taken at White Sands Complex (WSC) & Glenn Research Center (GRC)

Demo #1 Results

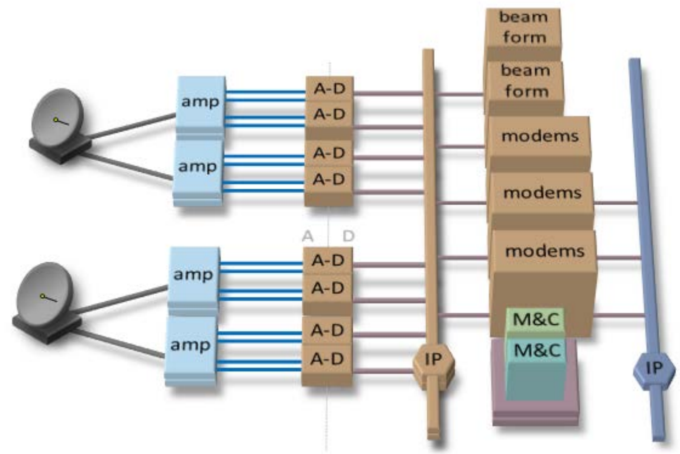
- Used TDRS-12 to perform live sky demonstration of 4-element MAF beacon configuration
  - Ground observations at WSC and GRC confirmed MAF phased-array model and EIRP predicts
  - TDRS-12 payload was stable during 48 hr 4-element MAF test
  - **Testing validated peak EIRP (>36.0 dBW) and beacon pattern for 2nd and 3rd generation TDRS**
- Ready to move onto further demos with modulated signals

Ground Element

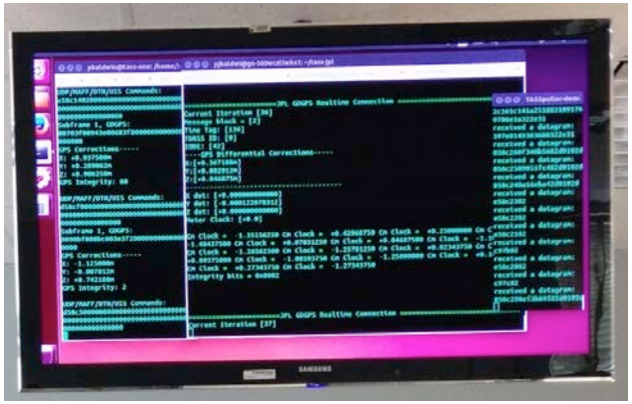
Legacy SN Ground System



SGSS Architecture

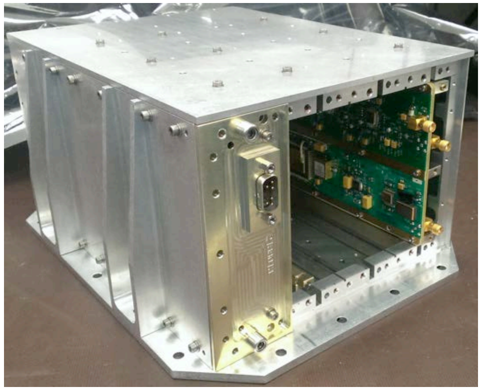


- SN Ground Sustainment System (SGSS) architecture will:
  - Enable dual MAF capability built into 2nd and 3rd generation TDRS
  - Allow for low cost insertion of NGBS ground system hardware
  - Reduce one-way forward ranging errors
- Data Integrator (DI) and Message Formatter (MF) software under development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

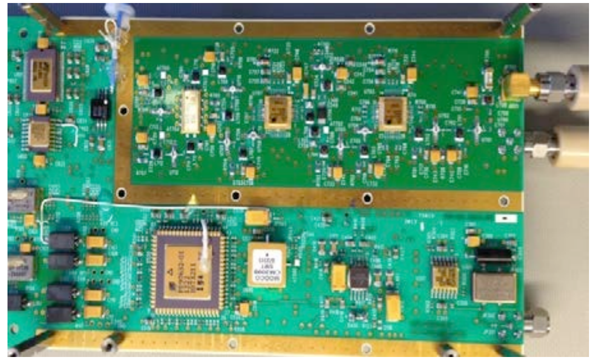


Real time data connection from JPL

Integrated Comm & Nav User Terminal



NavCube Engineering Test Unit with GPS + SpaceCube flight components

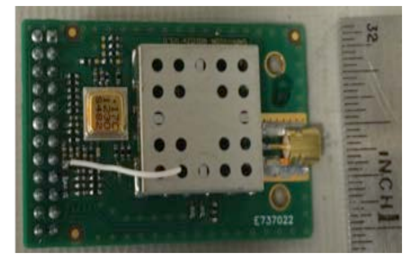


Dual-channel discrete component RF front-end electronics L1/L2C

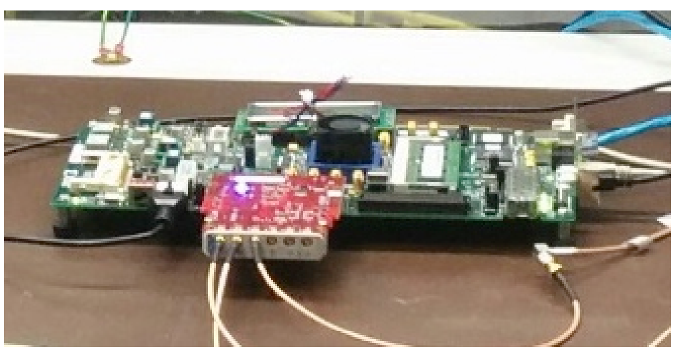
NavCube

Small SWaP FY16 IRAD

GPS RF ASIC demo board

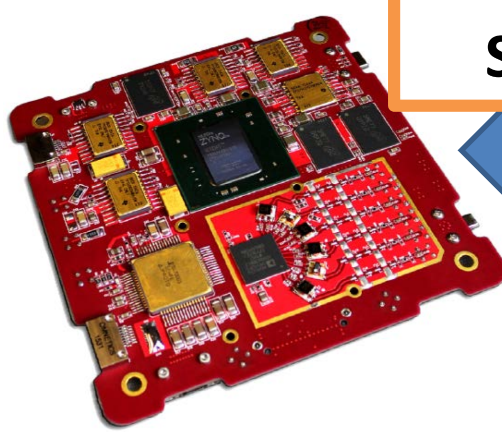


Breadboard

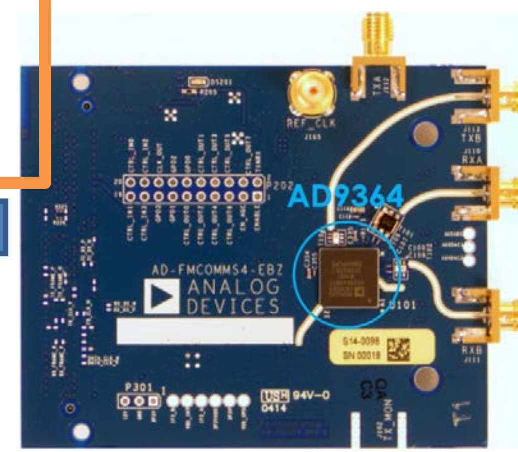


NavCube Development Platform
L1/L2 GPS receiver + TDRSS Transponder

Flight Ready SDR

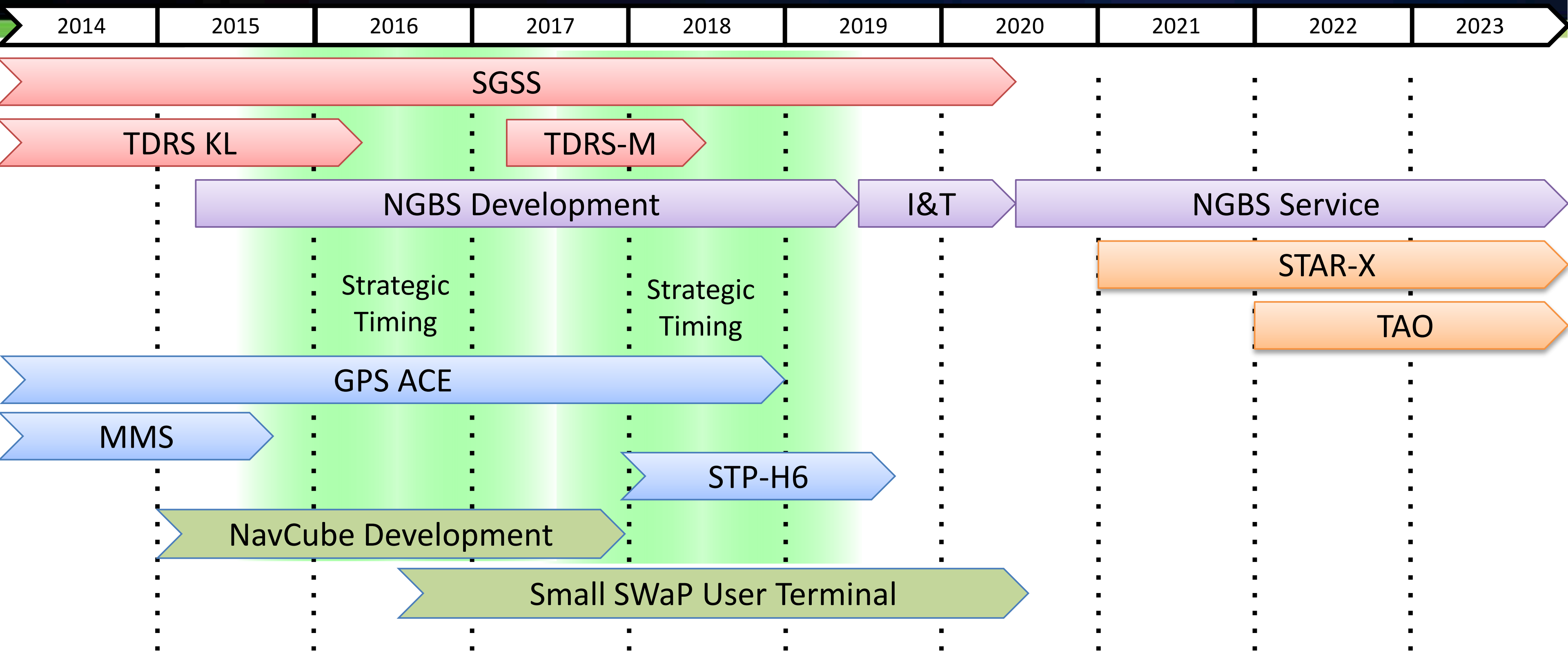


Rincon AstroSDR
Flight Receiver w/ AD9364



Analog Devices AD9364 RF Transceiver

Roadmap



- Strategic opportunity exists:
  - Launch of TDRS-M in Aug 2017 will provide 6 NGBS capable spacecraft
  - SGSS necessary for NGBS ground implementation
  - STP-H6 provides a low-cost opportunity to fly GPS portion of the NGBS user terminal, missed an opportunity to demonstrate NGBS on orbit
  - NGBS user element is built on mature Navigator GPS receiver technology
  - 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