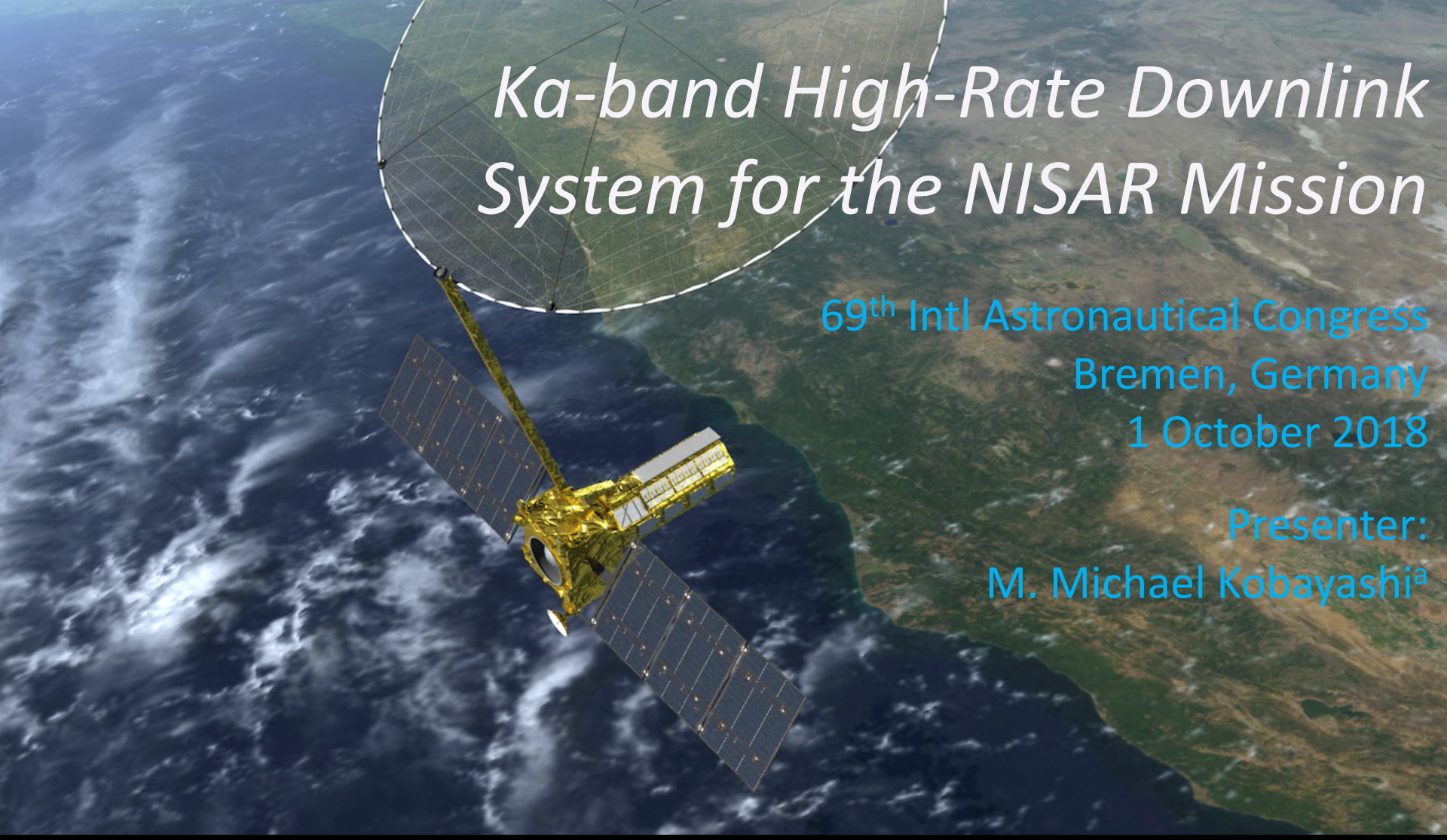

Ka-band High-Rate Downlink System for the NISAR Mission

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Presenter:
M. Michael Kobayashi[a]

Frank Stocklin[b], Michael Pugh[a], Igor Kuperman[a], David Bell[a], Salem El-Nimri[b], Brad Johnson[b], Nancy Huynh[b], Shane Kelly[b], James Nessel[b], Andy Svitak[b], Tim Williams[b], Nancy Linton[b], Meghan Arciaga[b], Asoka Dissanayake[b]

[a]Jet Propulsion Laboratory, California Institute of Technology

[b]Near Earth Network, Goddard Space Flight Center

Presentation Outline

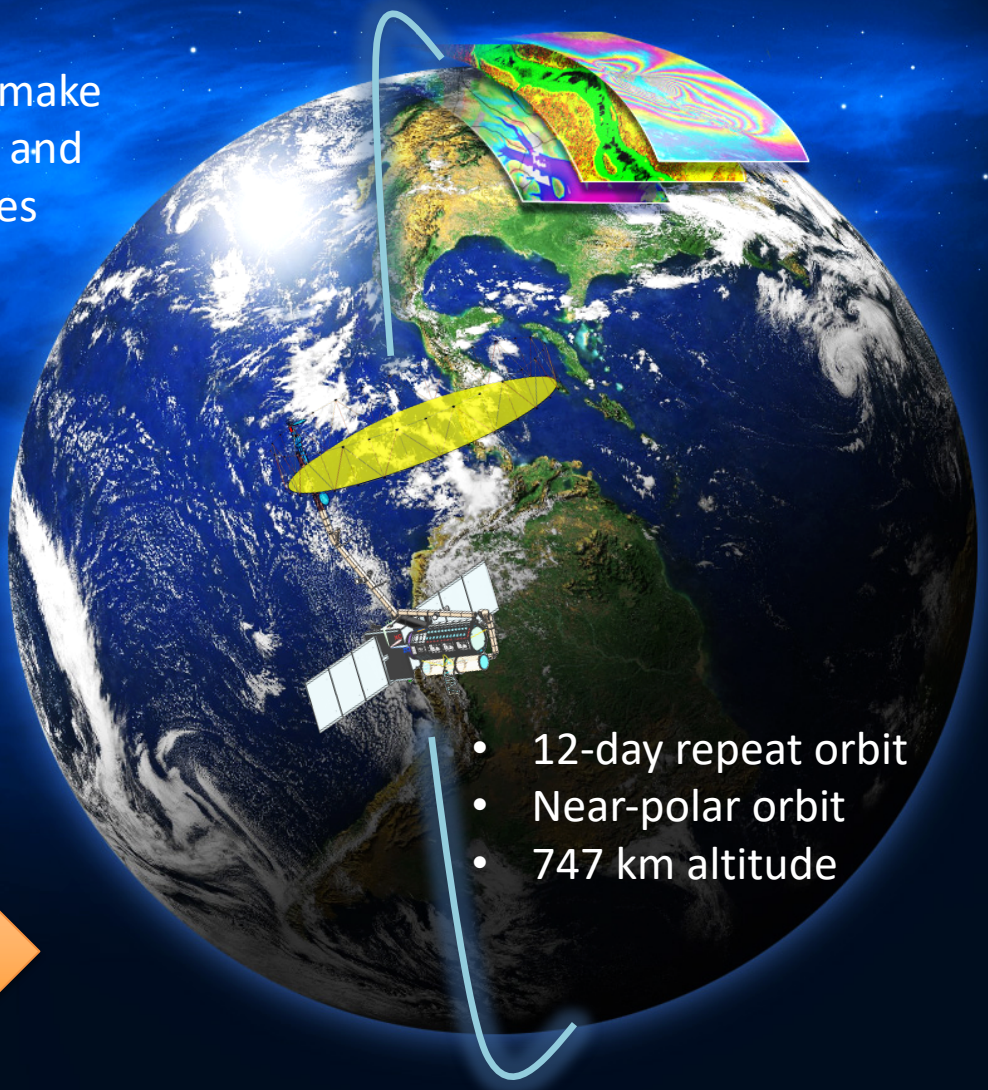
- NISAR Mission Overview
- Gbps Science-Data Generation
- Two Independent Ka-band Downlink Systems
- Advanced Reconfigurable Software-Defined Radio
- Transmit Spectrum Compliance
- Proposed NEN Ground Stations
- Data Acquisition Processing and Handling Network Environment (DAPHNE)
- NASA/JPL System to NEN Link Analyses
- Conclusions and Future Work

NISAR Mission Overview

Collaboration Mission:
National Aeronautics and Space Administration + Indian Space Research Organisation

NISAR is an all-weather radar mission to make integrated measurements of the causes and consequences of Earth surface changes

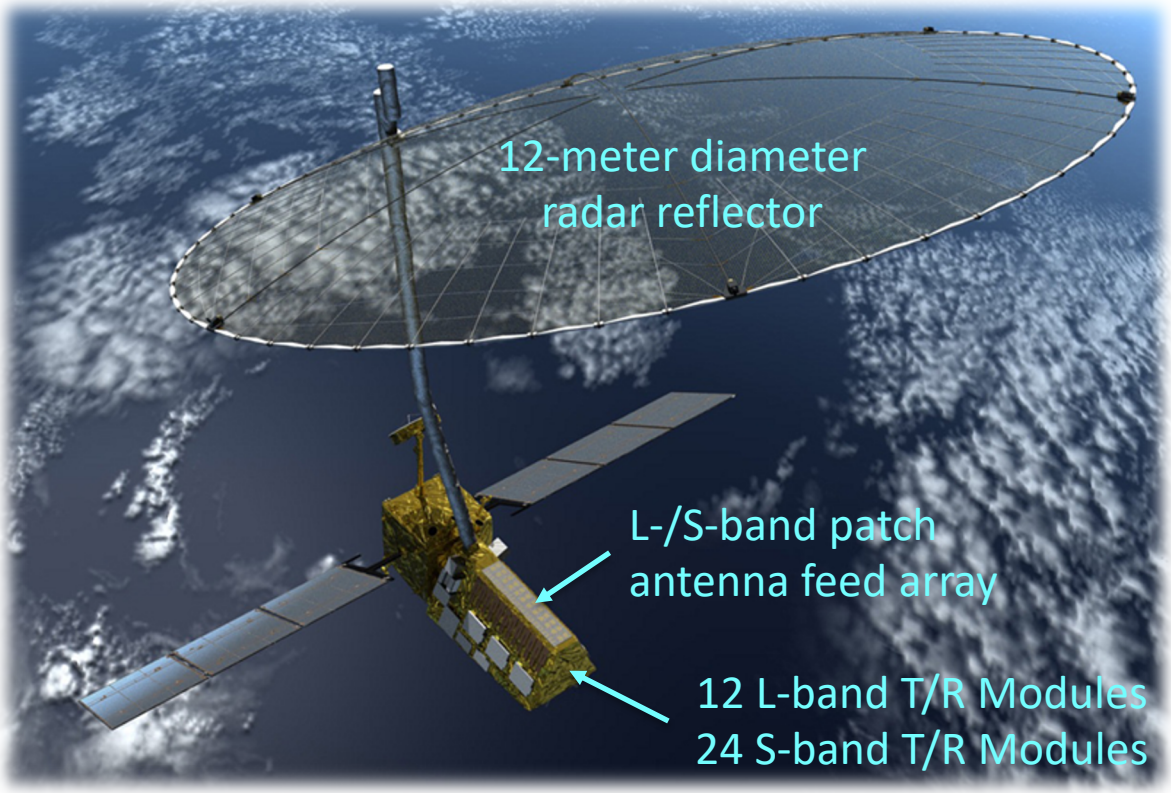
- Response of ice sheets to climate change and the interaction of sea ice and climate
- Carbon storage and uptake in wooded, agricultural, wetland, permafrost
- Likelihood of earthquakes, volcanic eruptions, and landslides, with potential for urgent response and hazard mitigation
- Societal impacts of dynamics of water, hydrocarbon, and sequestered CO_2 reservoirs



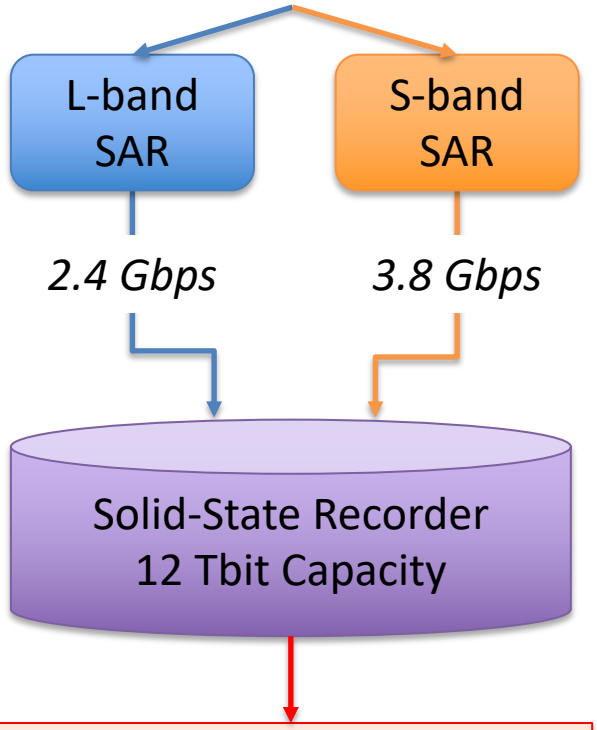
- 12-day repeat orbit
- Near-polar orbit
- 747 km altitude

Gbps Science-Data Generation

Advanced capability Sweep Synthetic Aperture Radar technology for 240 km radar swath [1]



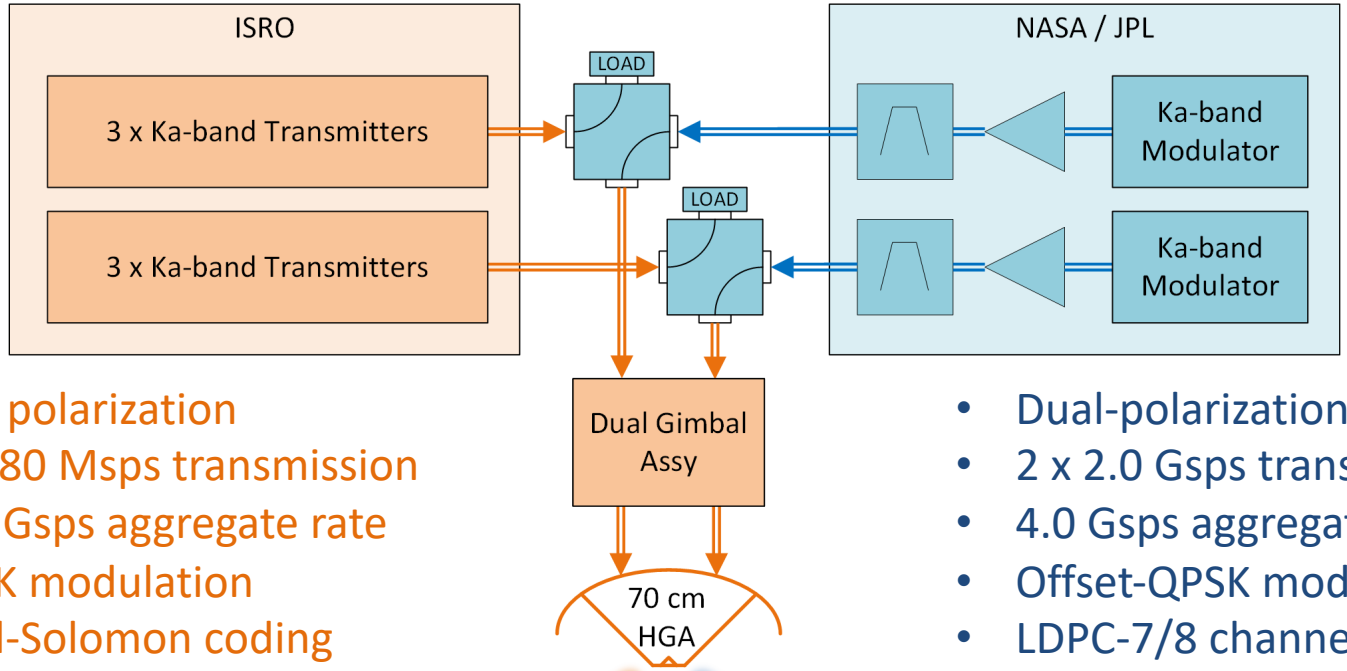
Simultaneous dual-frequency science observations



Driving telecom requirement: ***downlink 26 Tbit/day of science/engineering data***

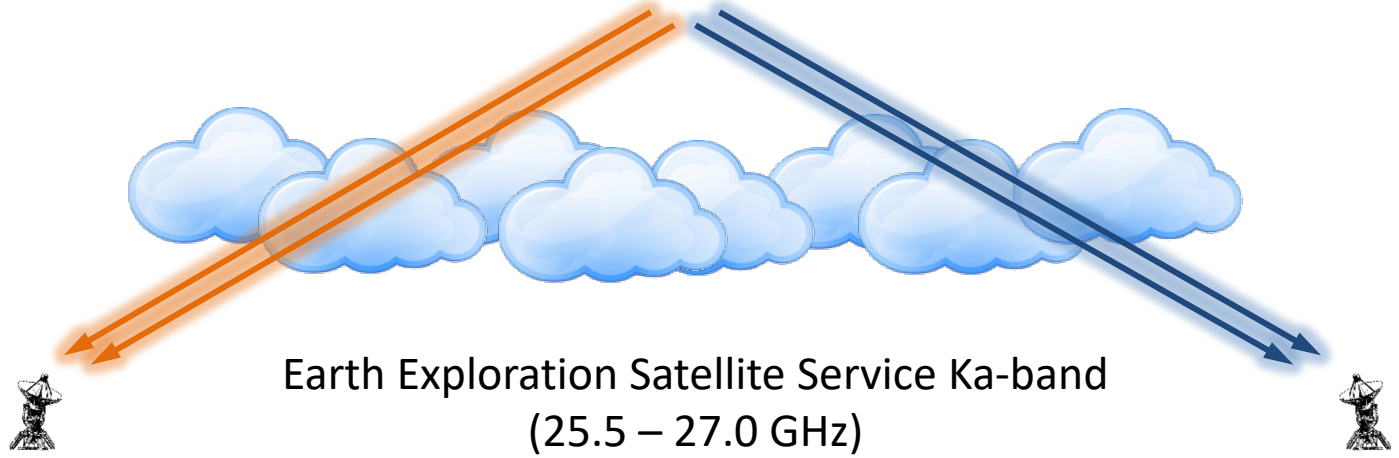
[1] P.A. Rosen, Y. Kim, R. Kumar, T. Misra, R. Bhan, V.R. Sagi, "Global Persistent SAR Sampling with the NASA-ISRO SAR (NISAR) Mission," IEEE Radar Conference, Seattle, WA, USA, 2017, 8-12 May, doi: 10.1109/RADAR.2017.7944237

Two Independent Ka-band Downlink Systems



- Dual polarization
- 6 x 480 Msps transmission
- 2.88 Gsps aggregate rate
- 8-PSK modulation
- Reed-Solomon coding

- Dual-polarization
- 2 x 2.0 Gsps transmission
- 4.0 Gsps aggregate rate
- Offset-QPSK modulation
- LDPC-7/8 channel coding



Earth Exploration Satellite Service Ka-band
(25.5 – 27.0 GHz)

ISRO Ka–band Station
(NRSC)

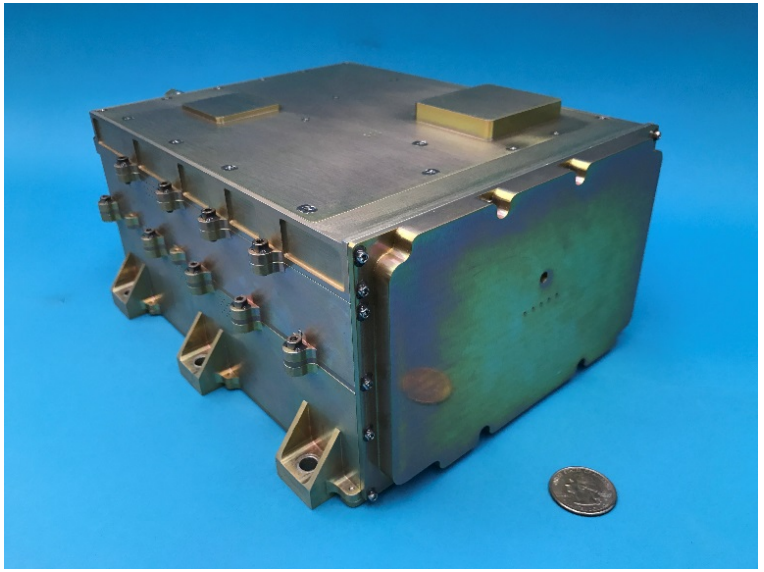
NASA Ka-band Stations
(Goddard NEN)

Advanced Reconfigurable Software-Defined Radio

TX Specs	
Frequencies	Ka-band (25.5 – 27.0 GHz)
Bandwidth	< 1.5 GHz
Coded Data Rates	500, 1000, 2000 Msps
Modulations	QPSK/OQPSK, and others supported
Digital Pulse Shaping	Root Raised Cosine (optional)
Channel Coding	LDPC with Rate 223/255 (~7/8)
RF Output Power	+12 dBm

Environmental Specs	
Flight Allow. Temp	-20°C to +50°C
Dynamics	15 Grms random vibe; 2000 g shock
Radiation Tolerance	50 krad (Si) min at component level

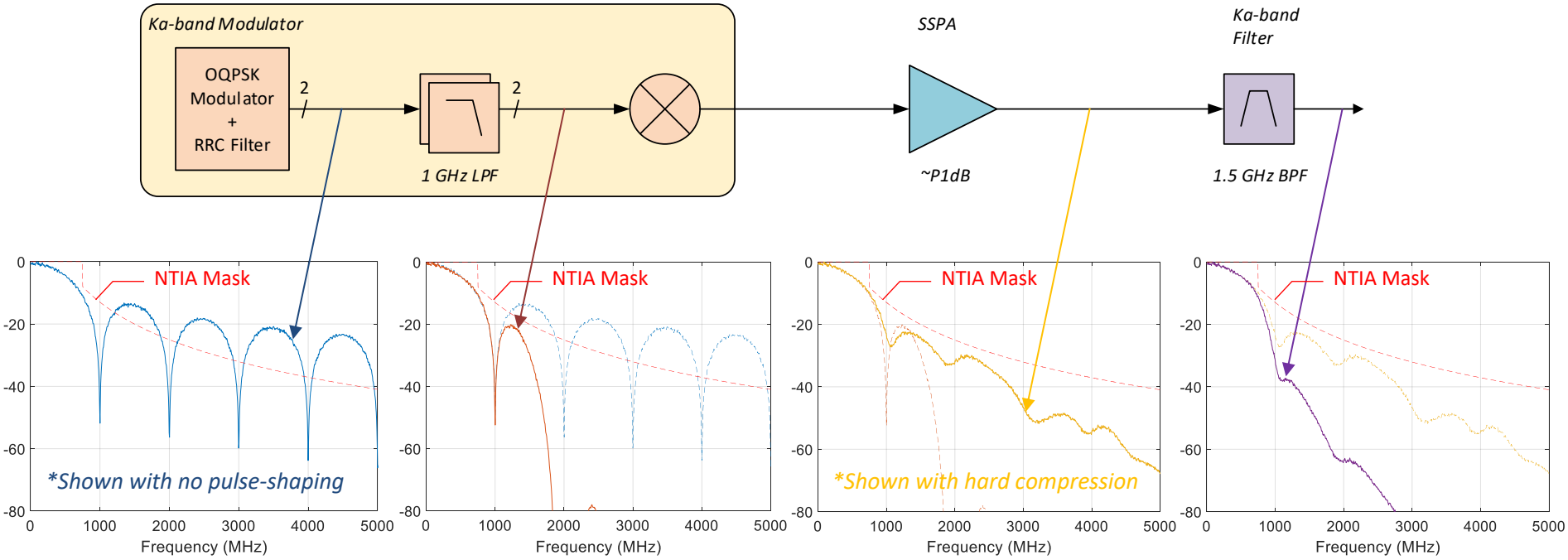
Interface Specs	
Power Consumption	40 W Transmit Mode; 20 W Standby Mode
Cmd/Tlm Interface	1553, RS-422, or SpaceWire (option)
High-speed Data	TLK WizardLink SERDES (up to 2 Gbps)
Power Interface	22-36 V Unregulated Bus
Mass/Dimensions	4.5 kg / 25 x 20 x 11 cm (L x W x H)



[5] M. Pugh, I. Kuperman, M. Kobayashi, F. Aguirre, M. Kilzer, C. Spurgers, "High-Rate Ka-Band Modulator for the NISAR Mission," IEEE Aerospace Conf., Big Sky, MT, USA, 2018, 3-10 March, doi: 10.1109/AERO.2018.8396451.

Transmit Spectrum Compliance

NTIA compliance requires NASA/JPL signal to be band-limited to 1.5 GHz bandwidth



KaM employs further pulse-shaping RRC filter to reduce inter-symbol interference losses

Baseband low-pass filter with 3-dB cutoff at 1.0 GHz for sidelobe level reduction

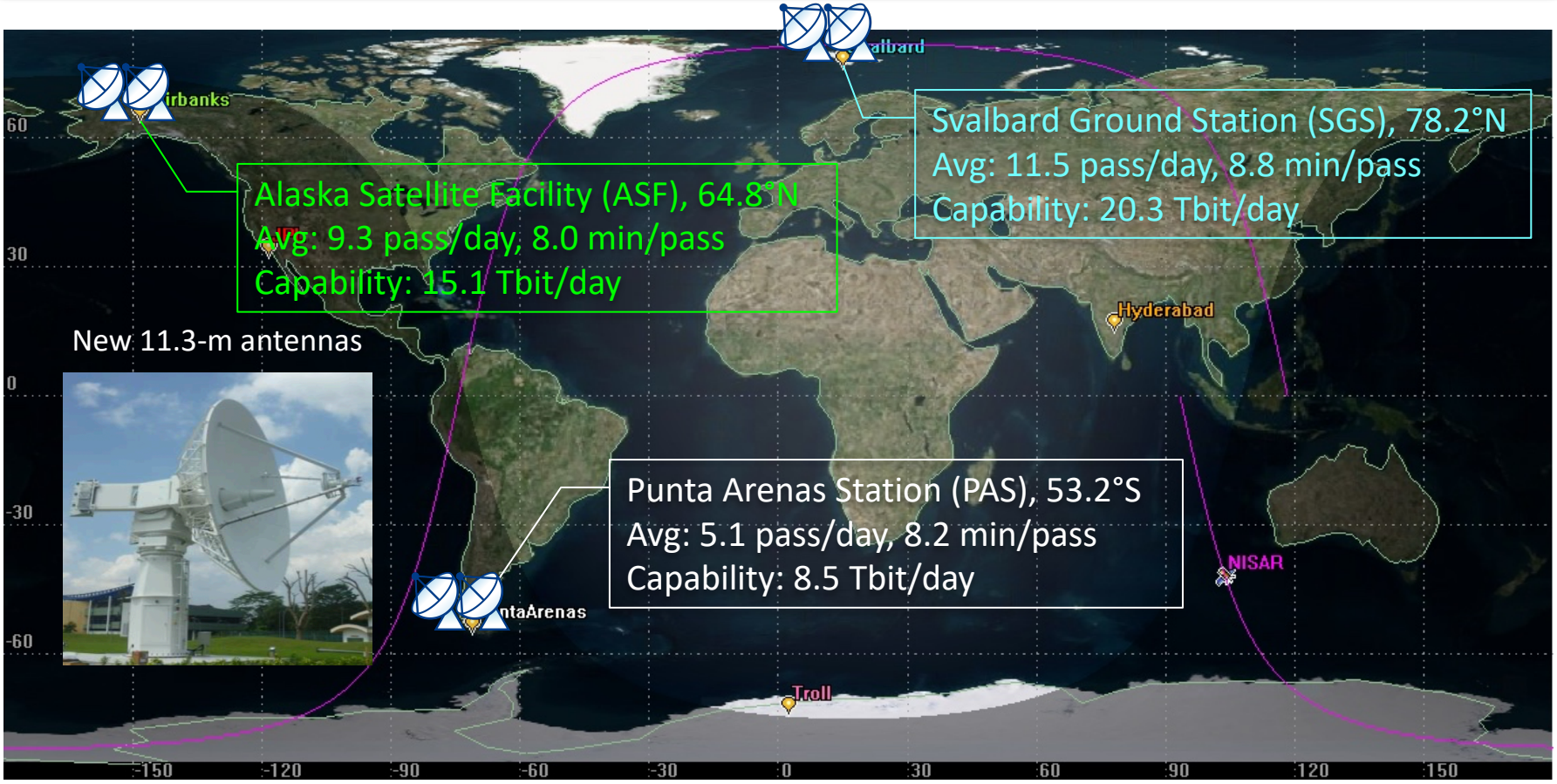
Spectral regrowth from amplifier at 1-dB compression point (lower AM-PM effects)

Transmit band-pass filter with 3-dB cutoff at 25.5 to 27.0 GHz for spectral regrowth level reduction

Proposed NEN Ground Stations

Each NEN site will be upgraded with:

- Prime and backup 11.3-meter tri-band S/X/Ka subreflectors (67.7 dBi Ka-band gain)
- New high-data rate receivers and baseband data processing units

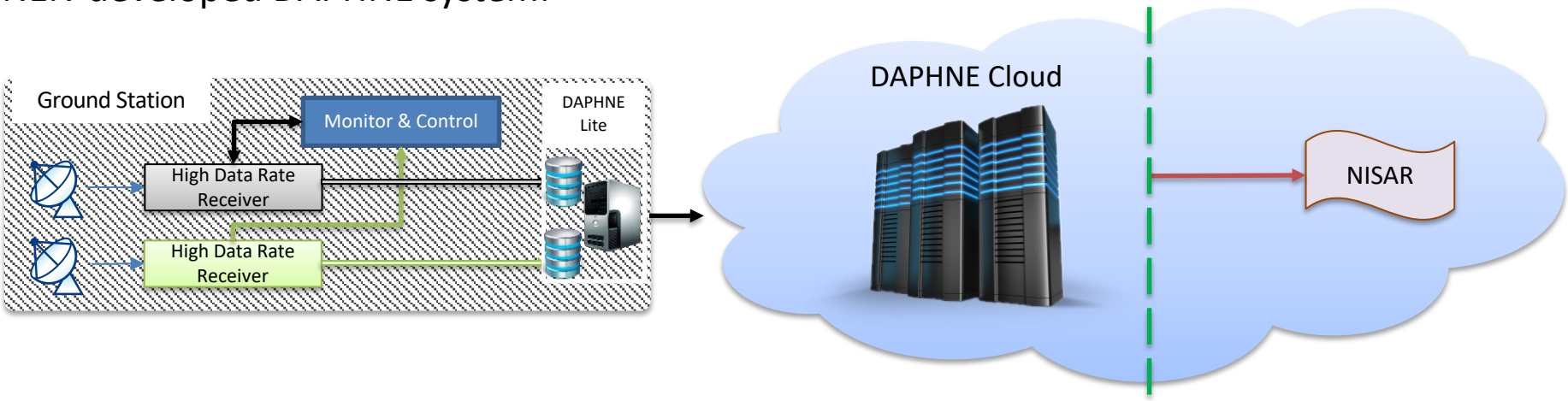


*Exercising all downlink opportunities can transfer **up to 43.9 Tbit/day** of data.*

Data Acquisition Processing and Handling Network Environment

NISAR will generate **over 3.5 Petabytes of data** over the course of the mission
Delivery of large quantities of data over traditional networks is **costly and impractical**

NEN-developed DAPHNE system:



DAPHNE Lite (local at each ground station):

- Capture data from high-rate receiver
- Handles VC prioritization
- Deliver data to the cloud

DAPHNE Cloud:

- Provide long-term storage
- Processing of data
- Data sorting and delivery to mission

Science data is primarily processed in the cloud to reduce overall mission cost

NASA/JPL System to NEN Link Analyses

10° elevation with 99% weather availability

Parameter	Units	ASF	SGS	PAS
Transmit Power	dBW		0.0	
Circuit Loss	dB		-2.5	
Tx Antenna Gain	dBi		41.0	
Pointing Loss	dB		-0.5	
EIRP	dBWi		38.0	
Polarization Loss	dB		-0.1	
Path Loss	dB		-187.9	
Atmospheric Loss	dB	-6.8	-4.7	-7.0
G/T + Loss	dB/K	39.6	40.3	40.1
XPOL degradation	dB	-3.6	-5.0	-3.6
CNR Density	dB-Hz	107.8	109.2	108.1
Info Rate	dB-bps		92.4	
Received Eb/No	dB	15.3	16.8	15.7
Radio Loss	dB		-4.5	
Required Eb/No	dB		4.1	
Link Margin	**dB**	**6.7**	**8.2**	**7.1**

Attenuation estimates from ITU Model

Attenuation Effect	ASF	SGS	PAS
Gaseous absorption	1.17	0.94	1.59
Rain	3.07	1.19	1.99
Scintillation/Multipath	0.53	0.51	0.68
Cloud	2.57	2.54	3.37
Total Effects	6.83	4.70	6.99

$$A_{tot} = A_{gas} + \sqrt{(A_{rain} + A_{cloud})^2 + A_{scint}^2}$$

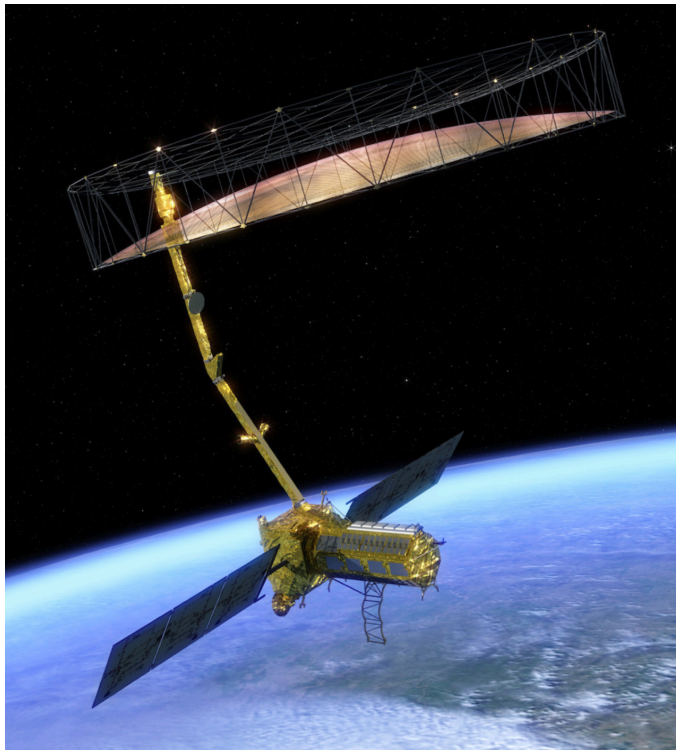
Cross-polarization (XPOL) degradation

- Rain-depolarization effects with higher atmospheric moisture content
- For NISAR, dominated by antenna cross-polarization discrimination

Radio Implementation Loss

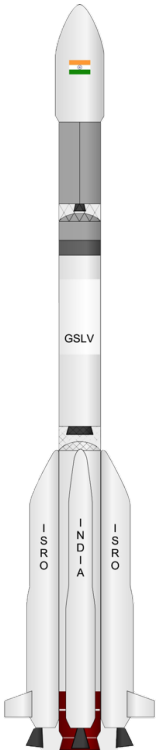
- Transmit filtering losses
- Amplifier distortion effects
- Receiver symbol timing errors
- Inter-symbol interference (ISI)

Conclusions and Future Work



- 4.0 Gsps dual-polarization downlink system
- NEN Ka-band ground station upgrades
- Data processing in the cloud w/ DAPHNE
- Large link margin (> 6 dB) to all stations
- Capability to meet and exceed 26 Tbit/day

- NISAR mission is currently in the flight hardware build and test phase
- Current launch scheduled no earlier than December 2021 on the ISRO-provided Geosynchronous Satellite Launch Vehicle (GSLV) Mark-II



Additional development is planned for higher transmit-rate Ka-band Modulator

- Provide 4 Gsps from a single transmitter using dual high-speed inputs
- Incorporate higher-order modulation such as 16-APSK

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov