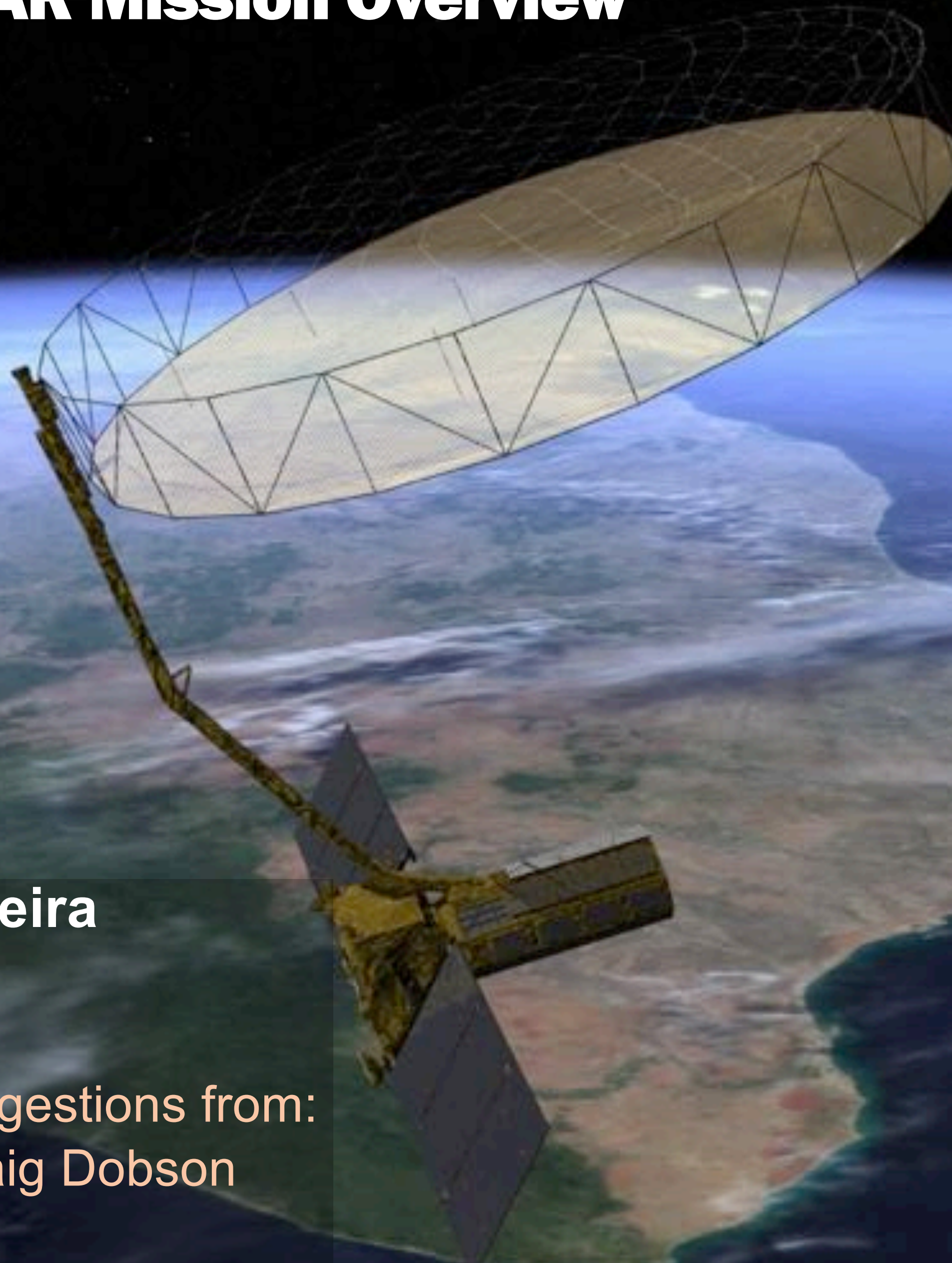
The NISAR Mission Overview



Josef Kellndorfer, Paul Siqueira

January 2017, KC23 Meeting

With considerable inputs and suggestions from:

- Paul Rosen, Sean Buckley, Craig Dobson
- JPL NISAR Project Team,
- NISAR Science Definition Team

NISAR Mission at a glance

- Four Level-1 Disciplines
  - *• Ecosystems, • Ice Sheets, • Solid Earth Dynamics, • Applications*
- L- & S-band 12-day orbital repeat
- 240 km swath using SweepSAR
- Launch in mid- to late-2021
- 3TB/day data downlink

Science Overview and Program Context

- NRC Decadal Survey recommended a DESDynI Mission for near-term launch to address important scientific questions of high societal impact.
- NASA's Climate Architecture identified the radar's important role in climate (cryosphere and carbon) and water cycle science.

- The NASA SDT has developed a set of integrated requirements to respond to the Climate Architecture and other important questions, with ISRO Science participation

Dynamics of Ice: Ice sheets, Glaciers, and Sea Level

- *Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur?*
- *What will be the resulting time patterns of sea-level rise?*
- *How are alpine glaciers changing in relation to climate?*

Ecosystems and Biomass Change

- *How do changing climate and land use in forests, wetlands, and agricultural regions affect the carbon cycle and species habitats?*
- *What are the effects of disturbance on ecosystem functions and services?*

Solid Earth Deformation: Hazard Response

- *Which major fault systems are nearing release of stress via strong earthquakes?*
- *Can we predict future eruptions of volcanoes?*
- *What are optimal remote sensing strategies to mitigate disasters and monitor/manage water and hydrocarbon extraction and use*

Coastal Processes: India

- *What is the state of important mangroves?*
- *How are Indian coastlines changing?*
- *What is the shallow bathymetry around India?*
- *What is the variation of winds in India's coastal waters?*

Proposed NASA-ISRO Synthetic Aperture Radar (NI-SAR) Mission Objectives

Key Scientific Objectives:

- Understand the response of ice sheets to climate change and the interaction of sea ice and climate
- Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems
- Determine the likelihood of earthquakes, volcanic eruptions, and landslides

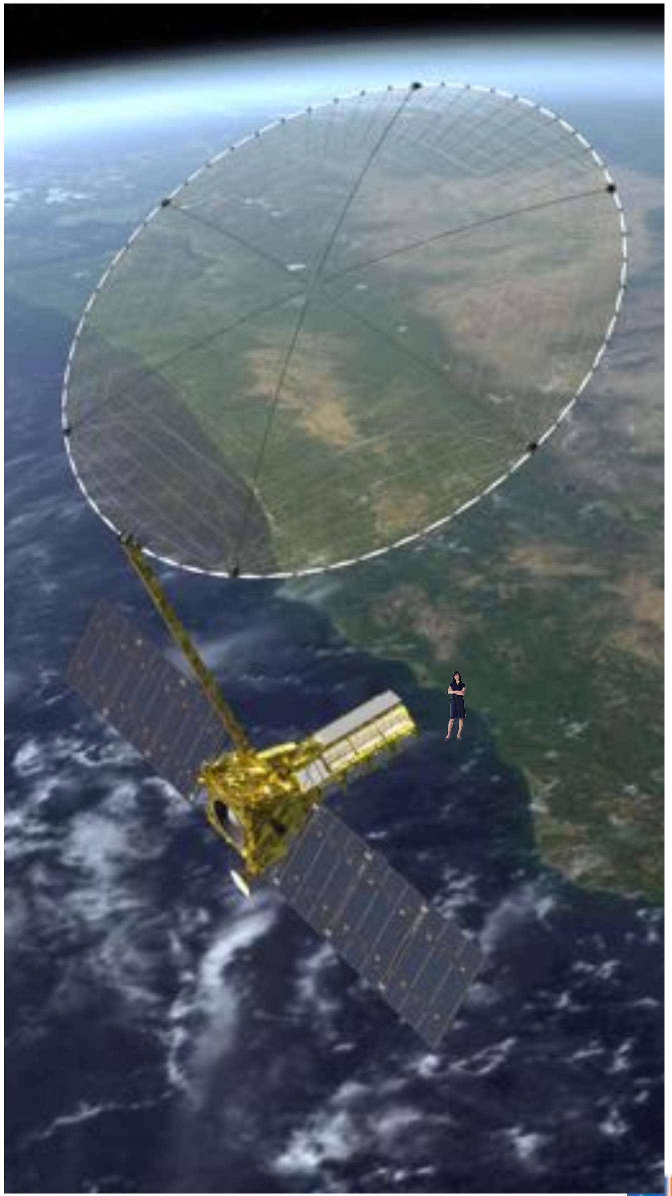
Key Applications Objectives:

- Understand societal impacts of dynamics of groundwater, hydrocarbon, and sequestered CO_2 reservoirs
- Provide agricultural monitoring capability in support of food security objectives
- Apply NI-SAR's unique data set to explore the potentials for urgent response and hazard mitigation

To be accomplished in partnership with the Indian Space Research Organisation (ISRO) through the joint development and operation of a space-borne, dual-frequency, polarimetric, synthetic aperture radar (SAR) satellite mission with repeat-pass interferometry capability

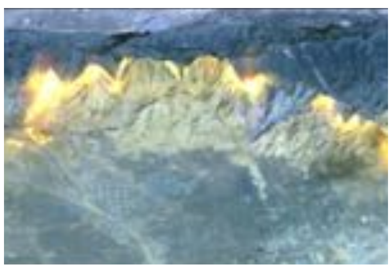
A NASA-ISRO SAR Mission Concept Inspired by the Decadal Survey

- The NASA-ISRO SAR mission concept addresses a broad range of US science and applications objectives assigned in the 2007 Decadal Survey to the Tier 1 DESDynI Mission, and identified in NASA's Climate Architecture
- The mission is now a partnership between NASA and ISRO, with many exciting "firsts":
  - Dual-Frequency (L- and S-band) free-flyer
  - Unprecedented coverage, resolution, and sampling in time
  - New SAR technology to realize wide swath
  - ISRO agreement to open data policy
  - Major mission-level, balanced, NASA-ISRO partnership



The Proposed NASA-ISRO SAR Mission Would Capture the Earth in Motion






- *Dense temporal and spatial sampling*
  - Reveals the mechanisms that drive poorly understood surface processes
    - Fast-transients on Ice sheets and glaciers
    - Disturbance and recovery in forests, wetlands and agricultural systems
    - Tracking evolving hazards
- *Comprehensive* global measurements
  - Of ice to improve climate projection accuracy
  - Of ecosystems to reduce land carbon flux uncertainties
  - Of solid earth to improve disaster forecasting and risk assessments
- *Targeted* regional measurements
  - New science
  - New applications
  - Hazard response

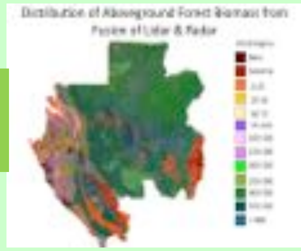
Societal Challenges and What a NASA-ISRO SAR Could Contribute

Challenge	SAR Benefit Through Regular Monitoring of:
Global Food Security	- Soil moisture and crop growth at agricultural scale - Desertification at regional scales
Freshwater Availability	- Aquifer use/extent regionally - Water-body extent changes - Glaciers serving as water sources
Human Health	- Moisture and vegetation as proxy for disease and infestation vectors
Disaster Prediction & Hazard Response	- Regional building damage and change assessment after earthquakes - Earthen dams and levees prone to weakening - Volcanoes, floods, fires, landslides
Climate Risks and Adaptation	- Ice sheet/sea-ice dynamics; response to climate change - Coastal erosion and shoreline migration
Urban Management and Planning	- Urban growth through coherent change detection - Building deformation and urban subsidence
Human-activity Based Climate Change	- Deforestation's influence on carbon flux - Oil and gas reservoirs

NISAR Mission Concept Overview

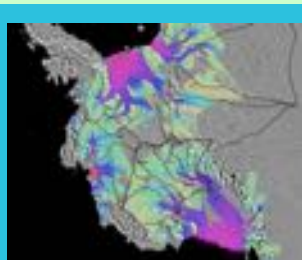
Mission Science

Ecosystem Structure



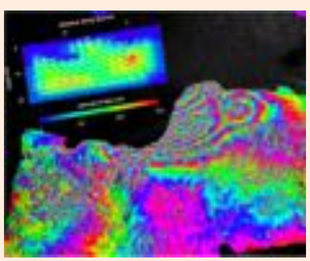
Biomass disturbance; effects of changing climate on habitats and CO_2

Cryosphere



Ice velocity, thickness; response of ice sheets to climate change and sea level rise

Solid Earth

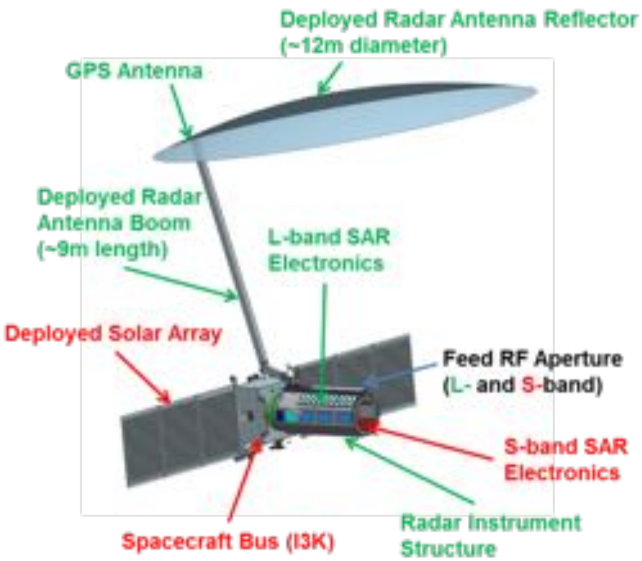


Surface deformation; geo-hazards; water resource management

- Directed mission within the Earth Systematic Missions Program under NASA Earth Science Division
- Category 2 project (NPR 7120.5E) and Payload risk class C (NPR 8705.4)
- Major international partner: Indian Space Research Organisation (ISRO)
- Baseline launch date: No earlier than December 2020
- Dual frequency L- and S-band Synthetic Aperture Radar (SAR)
  - L-band SAR from NASA and S-band SAR from ISRO
- Sweep SAR technique (large swath) for global data collection
- Baseline orbit: 747 km altitude circular, 98 degrees inclination, sun-synchronous, dawn-dusk (6 AM–6 PM), 12-day repeat
- Repeat orbit within ± 250 m
- Spacecraft: ISRO I3K (flown at least 9 times)
- Launch vehicle: ISRO Geosynchronous Satellite Launch Vehicle (GSLV) Mark-II (4-m fairing)
- 3 years science operations (5 years consumables)
- All science data (L- and S-band) will be made available free and open, consistent with the long-standing NASA Earth Science **open data policy**

NISAR Concept Observatory & Work Share

On-Orbit Configuration



GSLV Mark-II

ISRO

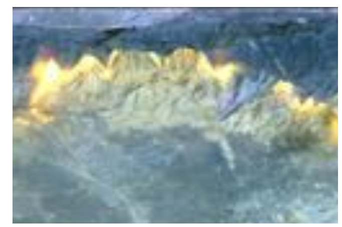
NASA

NISAR Concept Science Observation Overview

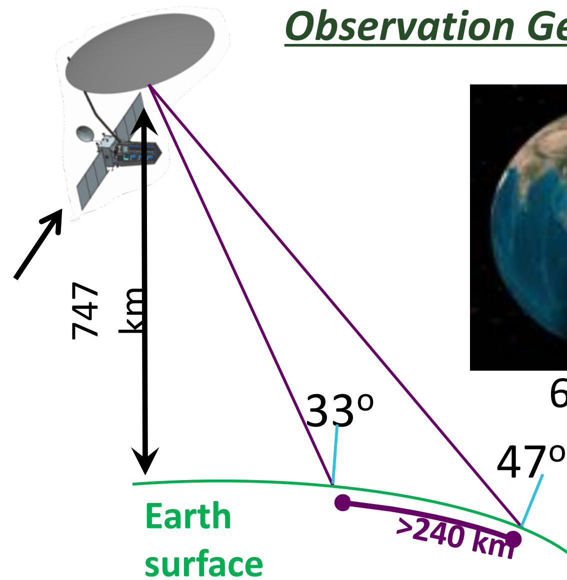
NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, north and south

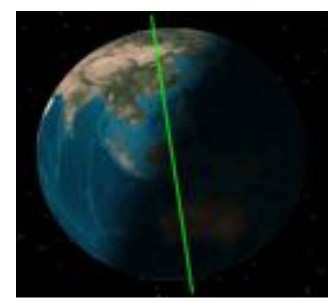
NISAR Would Uniquely Capture the Earth in Motion






Observation Geometry



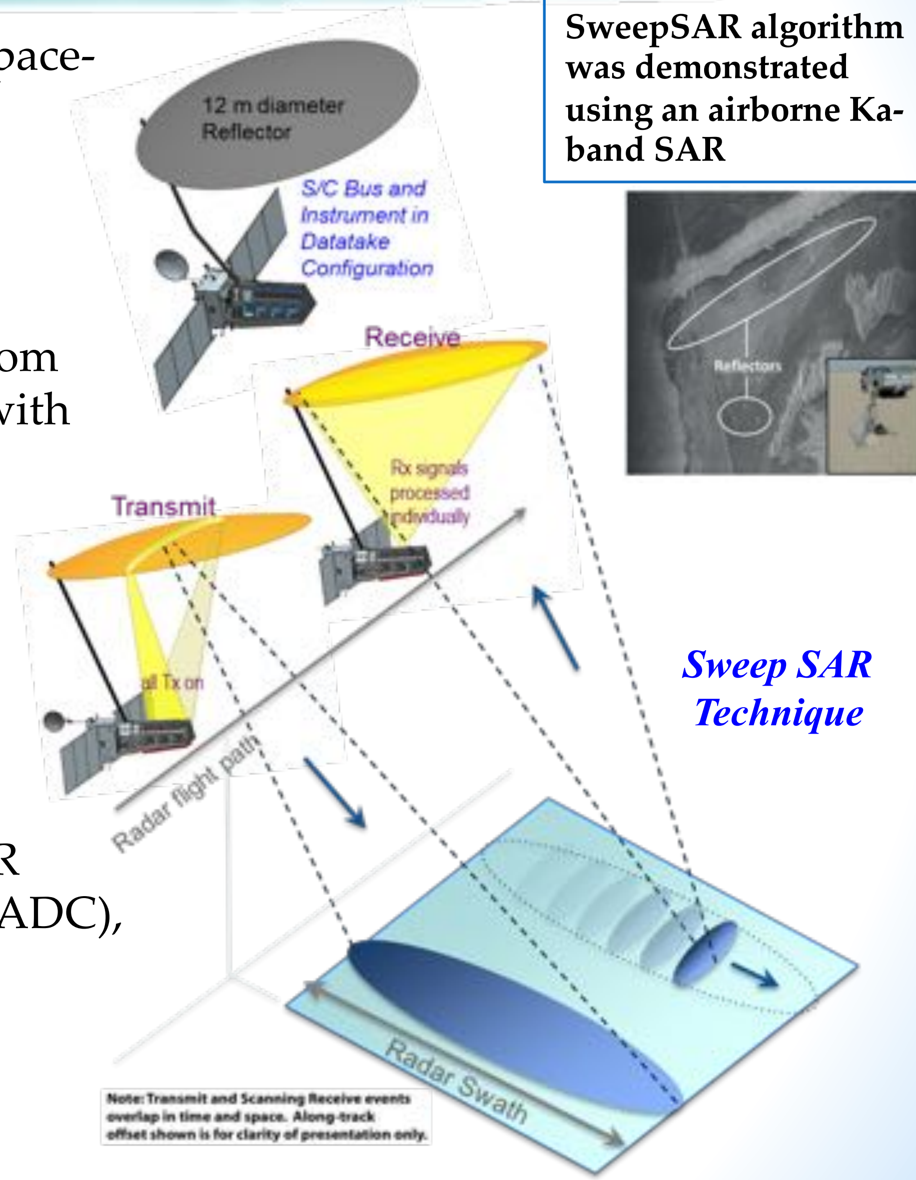


6 AM / 6 PM

Radar Payload Concept

- World's first dual frequency (L- and S- band) space-borne SweepSAR
- Repeat pass interferometry
- Fully polarimetric SAR capability
- Array-fed reflector (boresight at ~37 degrees from nadir, transmitting a fan beam, and receiving with multiple pencil beams)
  - Shared reflector for both L- and S-bands
  - Separate L- and S-band feeds
  - F/D = 0.75
  - Incidence angles: 30 – 42 degrees
- Observatory pointing control +/- 273 arcsec
- Active front-end electronics, high efficiency T/R module, high rate analog-to-digital converter (ADC), and on-board processing

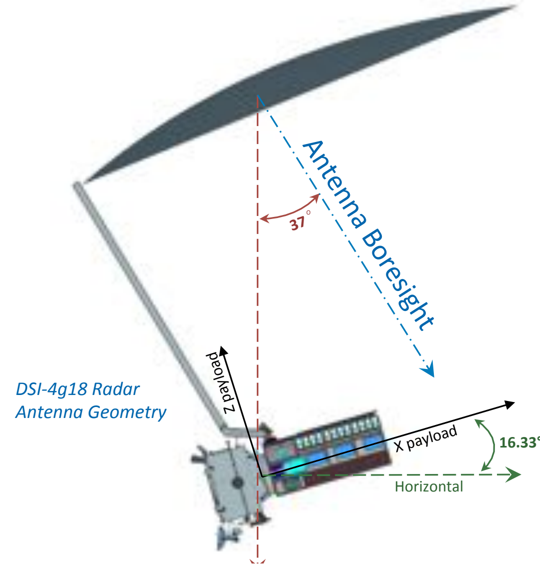
SweepSAR algorithm was demonstrated using an airborne Ka-band SAR

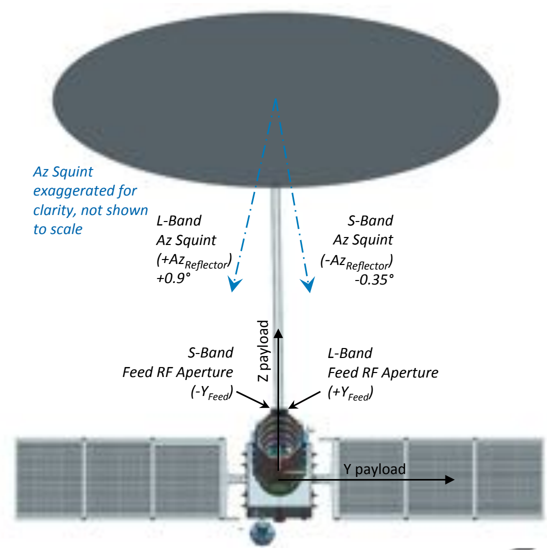


Sweep SAR Technique

L-SAR Instrument Features

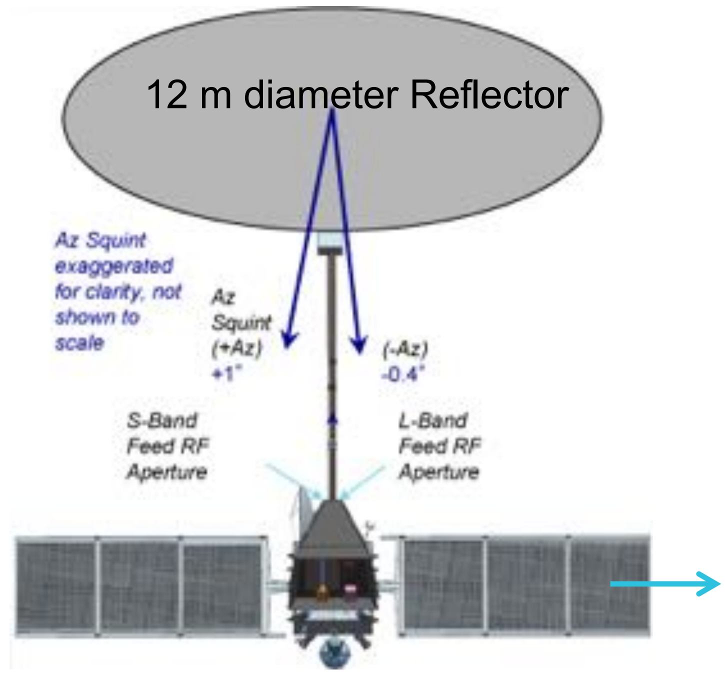
- Side looking L-band Synthetic Aperture Radar
- Polarimetry for classification and Biomass
- Repeat pass interferometer for deformation
  - Tight Orbit and Pointing Control
  - Tight phase stability over imaging time
- Split Spectrum for ionosphere mitigation
- Multi-beam Array fed Reflector to achieve a 240 km swath
  - SweepSAR timing and Digital Beam Forming to reduce ambiguities and preserve resolution / looks
- PRF Dithering to fill transmit interference gaps
- Seamless mode transitions to minimize data loss
- On-board filtering and compression to reduce downlink



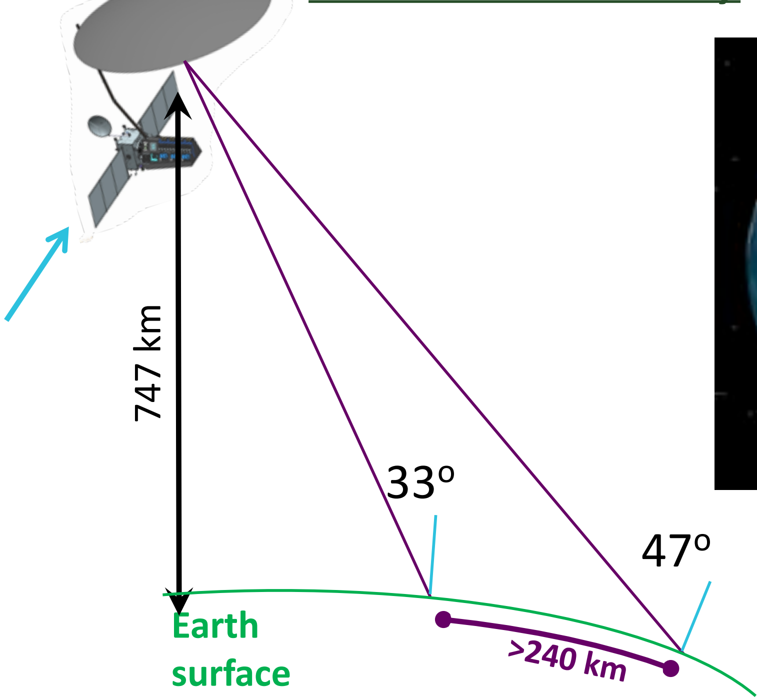


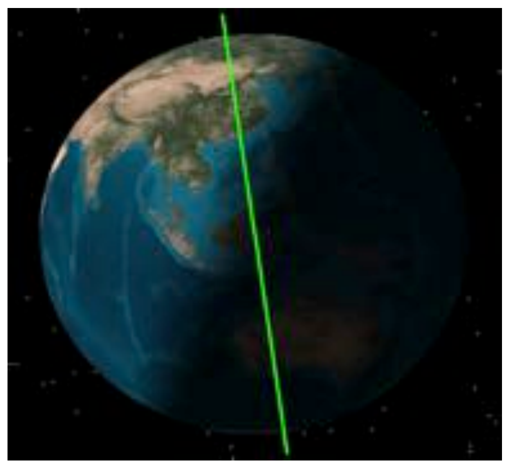
NISAR Imaging and Orbit Geometry

- Wide swath in all modes for global coverage at 12 day repeat (2-5 passes over a site depending upon latitude)
- Data acquired ascending and descending
- Left/Right Pointing Capability (Right nominal)



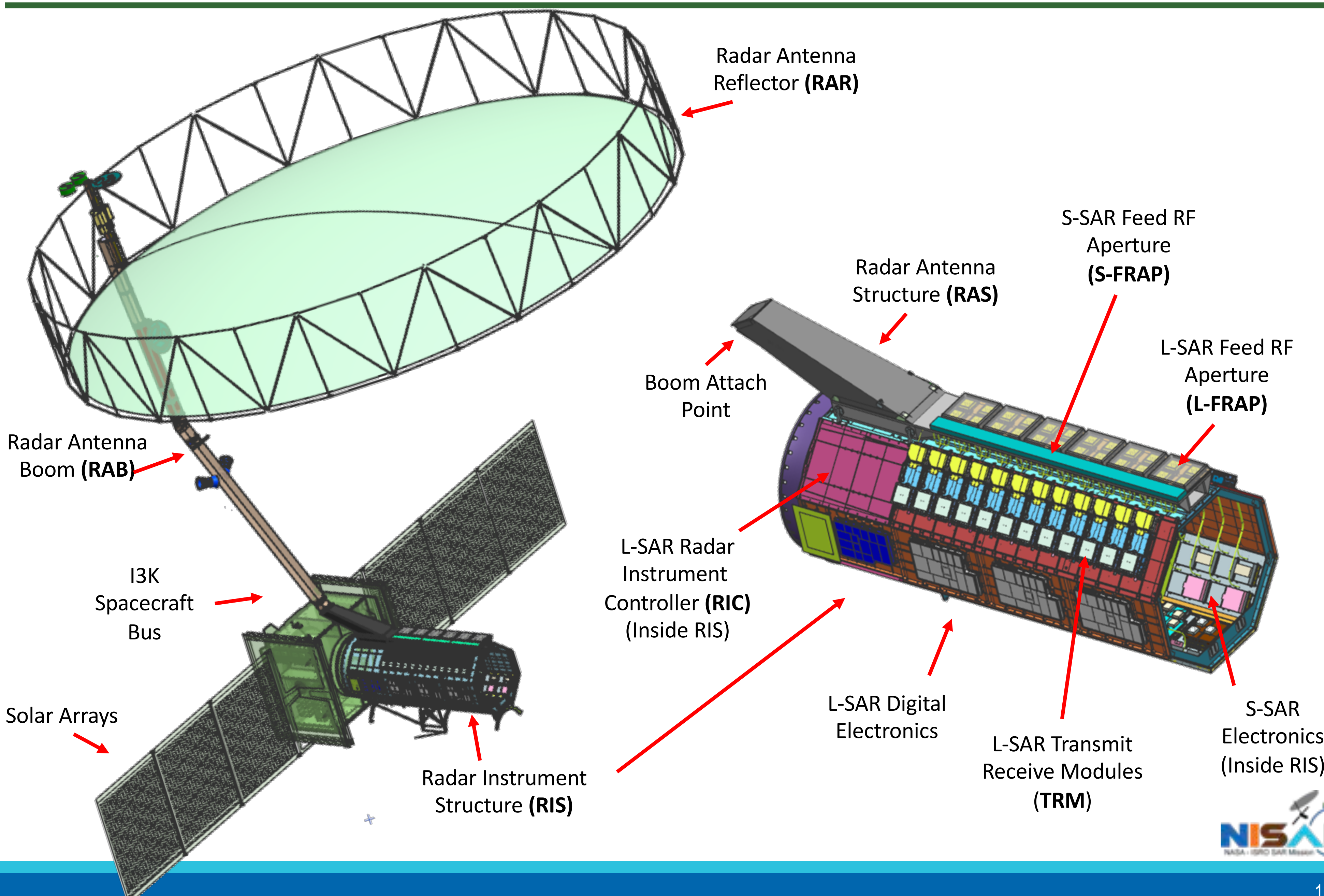
Observation Geometry





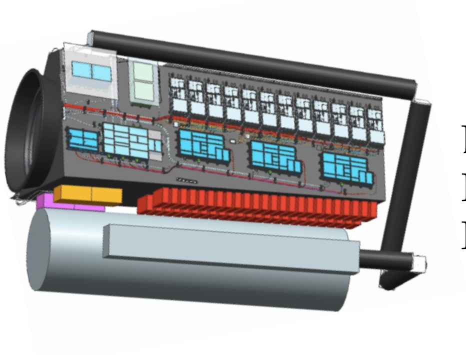
6 AM / 6 PM Orbit
98.5° inclination
Arctic Polar Hole: 87.5R/77.5L
Antarctic Polar Hole: 77.5R/87.5L

Instrument Physical Layout

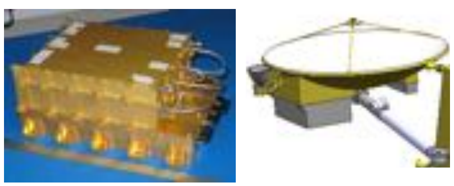


NISAR Instrument Housing

ISRO NASA Work Share



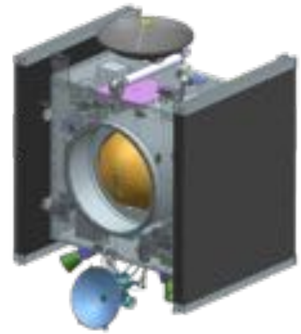
L-band SAR electronics
Instrument structure
Reflector boom assembly



High data rate telecom

GPS

High capacity
solid state recorder

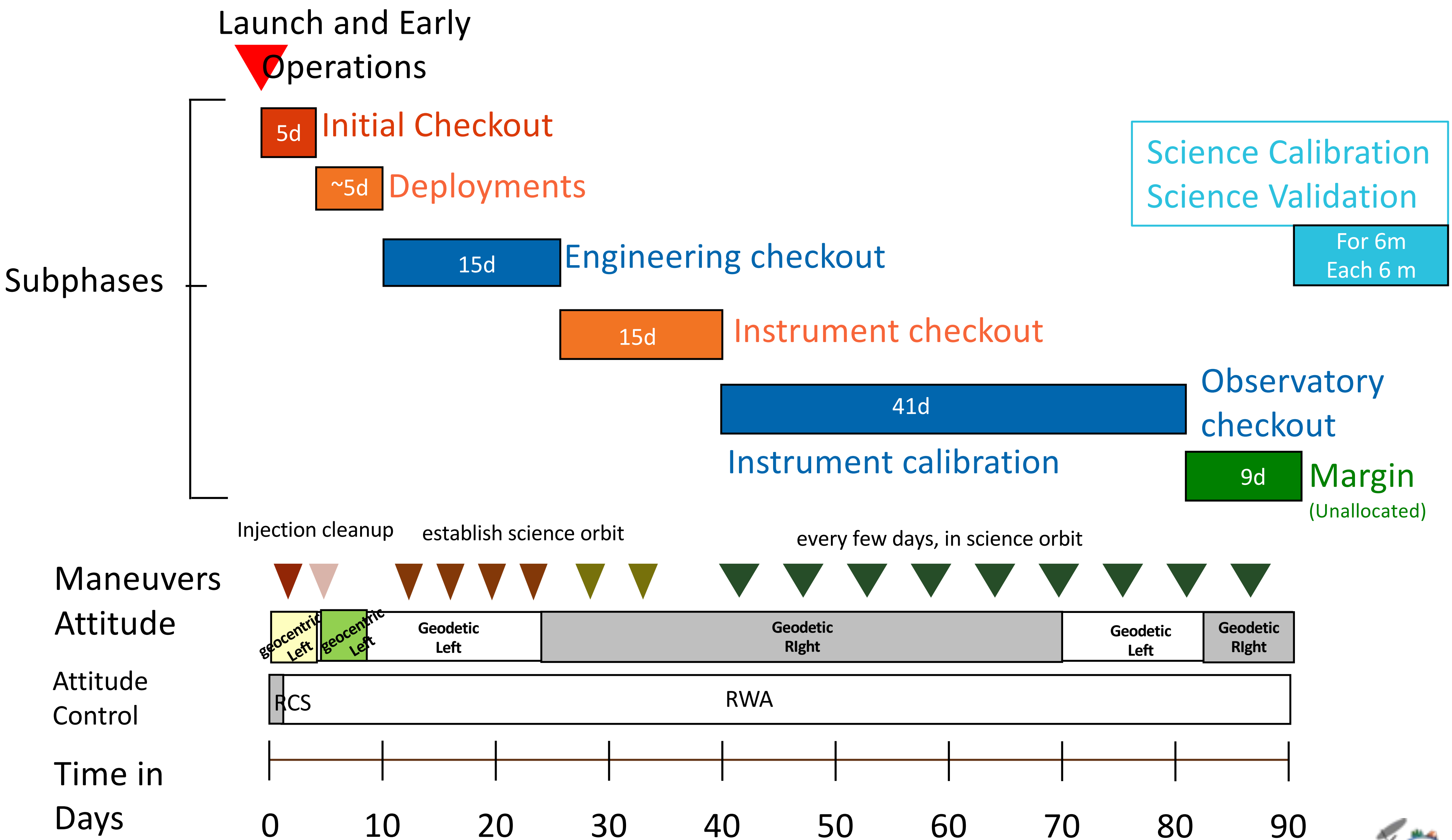


Spacecraft (I3K)

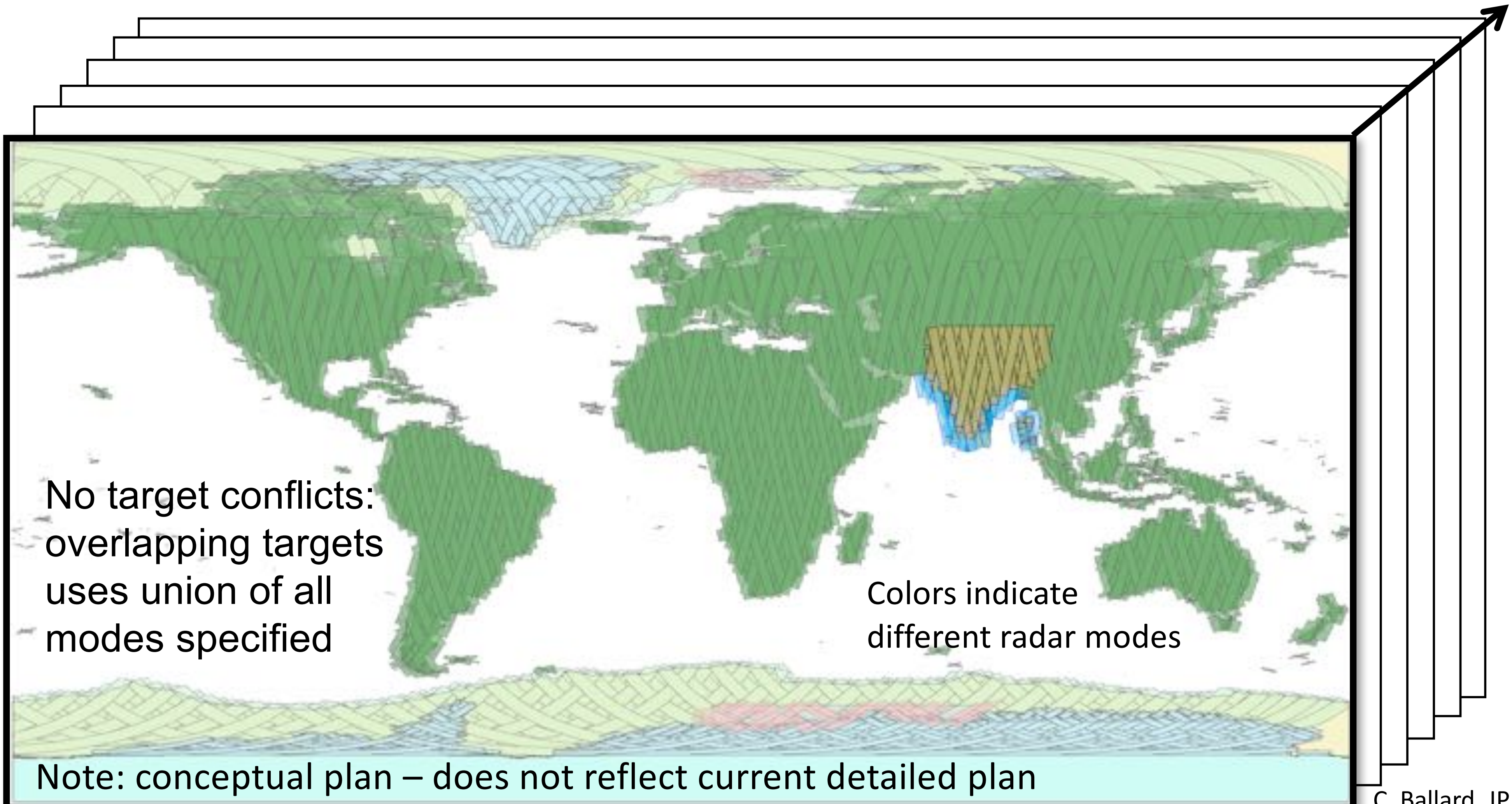
Launch vehicle (GSLV)

S-band SAR electronics

Commissioning Timeline



NISAR Systematic Observations Designed to Capture Earth's Dynamics



C. Ballard, JPL

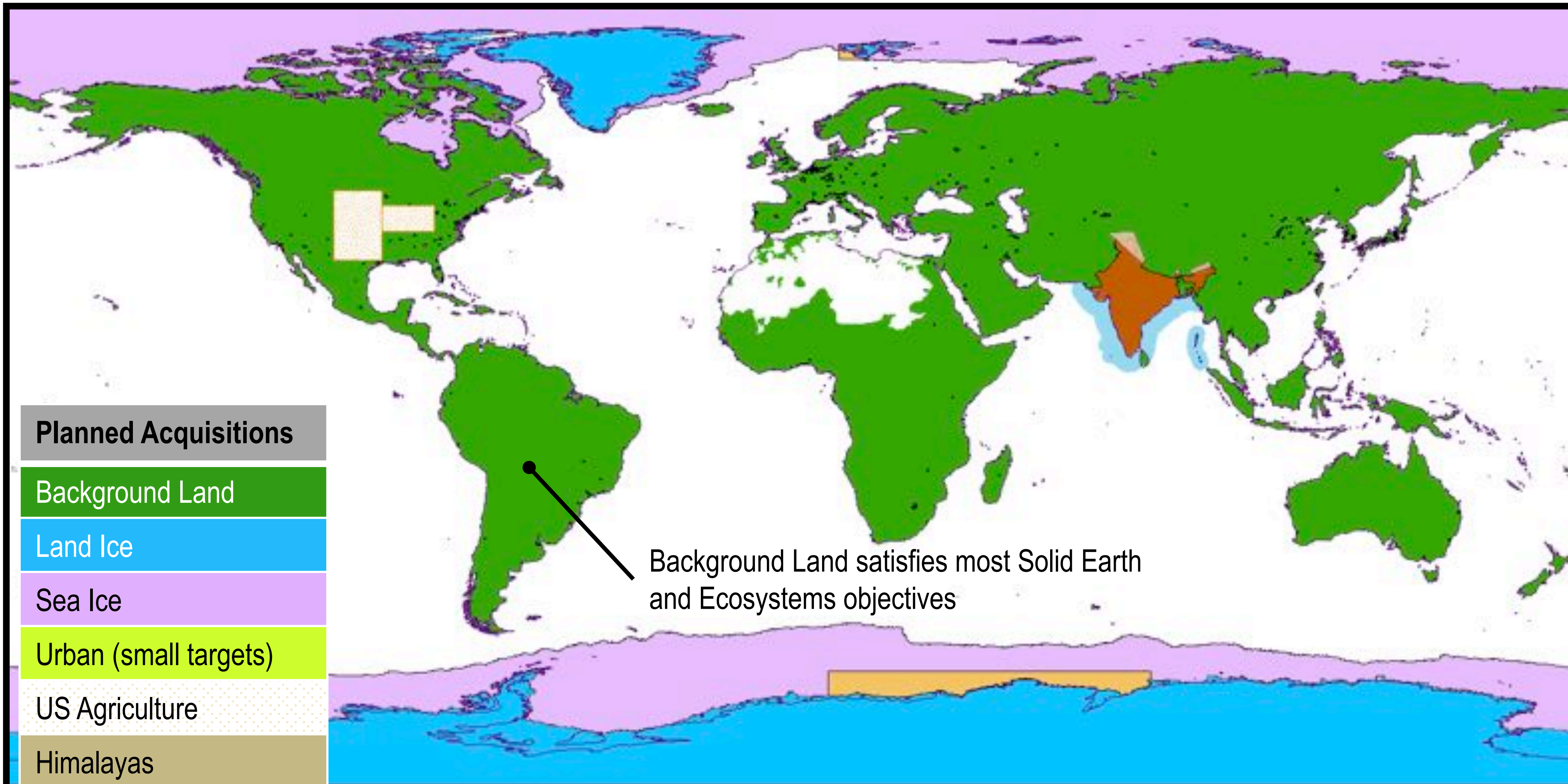
12-day regular sampling on ascending and descending to the extent possible

Proposed NISAR Science Observing/Operations Modes
Blanket Land and Ice Coverage Every 12 Days

- Observation strategy employs a small subset of possible modes

Observation Strategy	L-band		S-band		Culling Approach	
Science Target	**Mode+**	**Resolution**	**Mode**	**Resol.**	Sampling	Desc Asc
Background Land	DP HH/HV	12 m x 8 m			cull by lat	↙ ↖
Land Ice	SP HH	3 m x 8 m			cull by lat	↙ ↖
Sea Ice Dynamics	SP VV	48 m x 8 m			s = 1 p	↙ ↖
Urban Areas		6 m x 8 m			s = 1 p	↙ ↖
US Agriculture	QP HH/HV VV/VH				s = 1 p	↙ ↖
Himalayas			CP RH/RV		s = 1 p	↙ ↖
India Agriculture					s = 1 p	↙
India Coastal Ocean			DP HH/HV or VV/VH		s = 1 p	↖
Sea Ice Types	DP VV/VH				s = 3 p	↙

Proposed NISAR Mode-Specific Science Targets in Observation Plan



- Each colored region represents a single radar mode chosen to satisfy multiple science objectives over that area
- Avoids mode contention that would interrupt time series

NISAR Science Definition Team Pre and Post April 2016

SDT Member	Affiliation in 2016	Area*	2012-2016	2016-2019
Falk Amelung	University of Miami	SE/AT		Member
Gerald Bawden**	NASA	SE/HY	Member	
Adrian Borsa	Scripps Institution of Oceanography	SE/HY		Member
Bruce Chapman	Jet Propulsion Laboratory	EC		Member
Ralph Dubayah	University of Maryland	EC	Lead	
Kurt Feigl	University of Wisconsin	SE	Member	
Eric Fielding	Jet Propulsion Laboratory	SE		Member
Richard Forster	University of Utah	CR		Member
Bradford H. Hager	Massachusetts Institute of Technology	SE	Lead	Member
Benjamin Holt	Jet Propulsion Laboratory	CR	Member	Member
Cathleen Jones	Jet Propulsion Laboratory	AP		Lead
Ian Joughin	University of Washington, Applied Physics Laboratory	CR	Lead	Lead
Josef Kellndorfer	Earth Big Data LLC from 2016	EC/AP	Member	Member
Rowena Lohman	Cornell University	SE		Member
Zhong Lu	Southern Methodist University	SE	Member	Member
Francis Monaldo	National Oceanic and Atmospheric Administration	CR/OC		Member
Franz Meyer	University of Alaska, Fairbanks	CR/AP	Member	Member
Matthew Pritchard	Cornell University	SE	Member	
Eric Rignot	University of California, Irvine	CR	Member	Member
Sassan Saatchi	Jet Propulsion Laboratory	EC	Member	Member
Marc Simard	Jet Propulsion Laboratory	EC		Member
Mark Simons	California Institute of Technology	SE/AP	Member	Lead
Paul Siqueira	University of Massachusetts, Amherst	EC	Member	Lead
Howard Zebker	Stanford University	SE/AP	Member	Member

* SE = Solid Earth; AT = Atmospherics; CR = Cryosphere; OC = Oceans; HY = Hydrology = AP = Applications
** Moved to NASA HQ as IPA from USGS and stepped down from SDT.

Outlook as of November 2016

- NISAR passed its Program Design Review (PDR) in June 2016
- NISAR is currently in Phase C: Subsystem developments and instrument prototyping
- NISAR would provide a rich time-series of data globally for science and applications research on land and ice
- The project is engaging other agencies and science constituencies to explore other possible observations and benefits (e.g. coastal oceans)
- Scope of high-level science products from project itself is limited – NASA relying on research community to develop products as driven by science needs