Jet Propulsion Laboratory
California Institute of Technology

The NASA-ISRO Synthetic Aperture Radar (NISAR) Mission
The Final Stretch Toward a New Capability for Earth Science and Applications

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Slides from Paul A. Rosen and NISAR Team

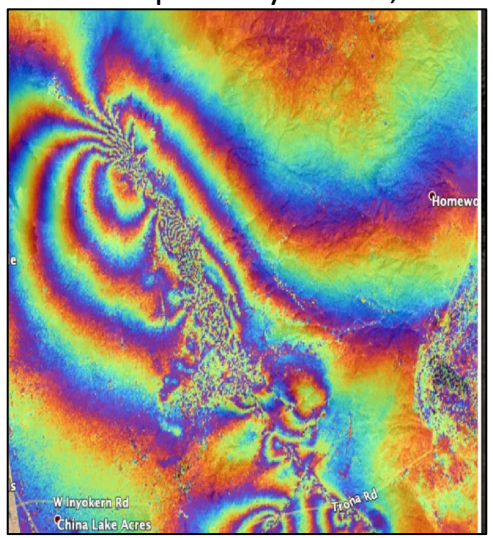
Jet Propulsion Laboratory

California Institute of Technology

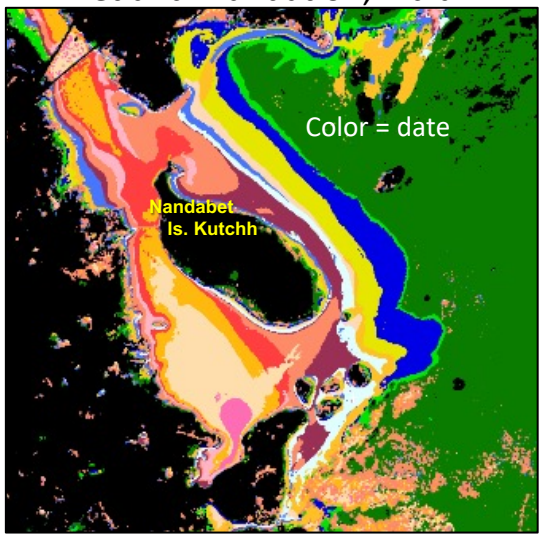
2023 ESA Biomass and PolInSAR Workshop

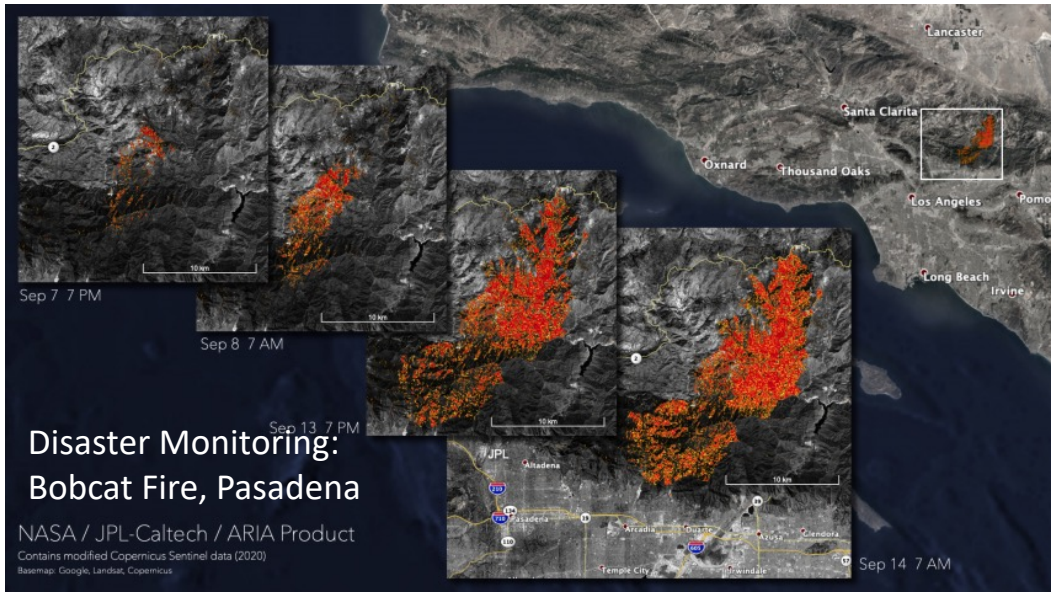
NISAR Science Capturing a Dynamic Earth

Earthquake Dynamics, CA



Wetland Inundation, India

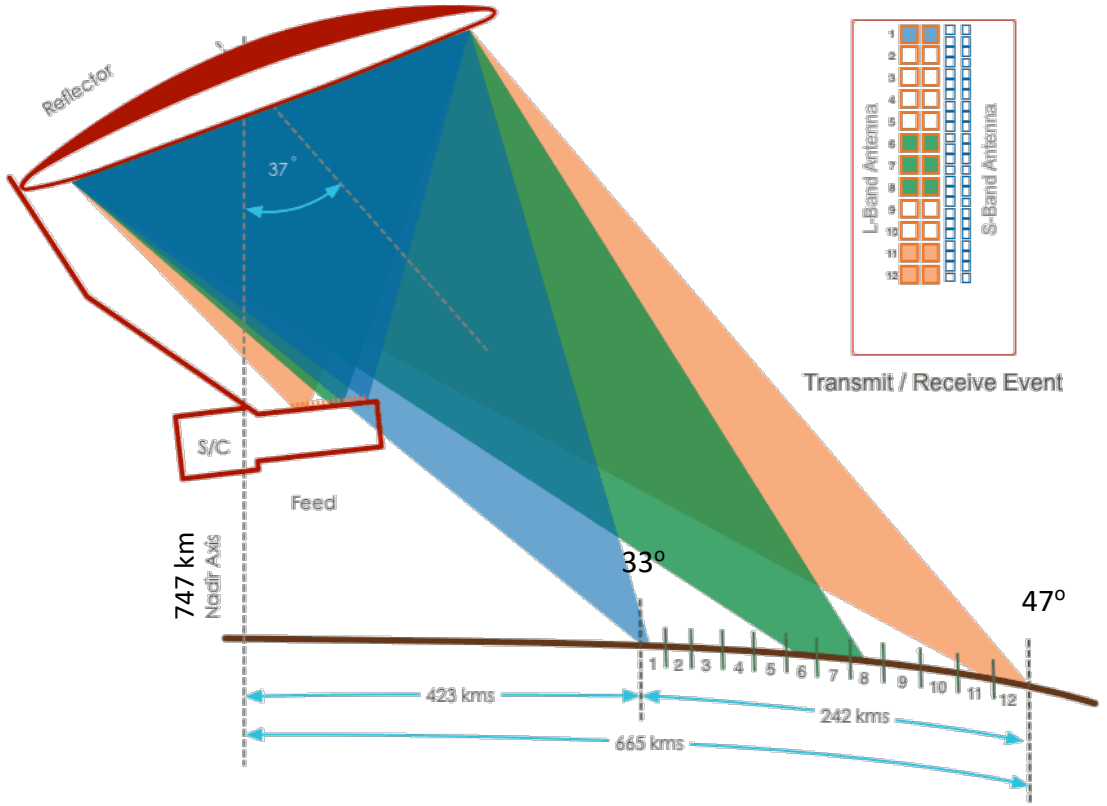




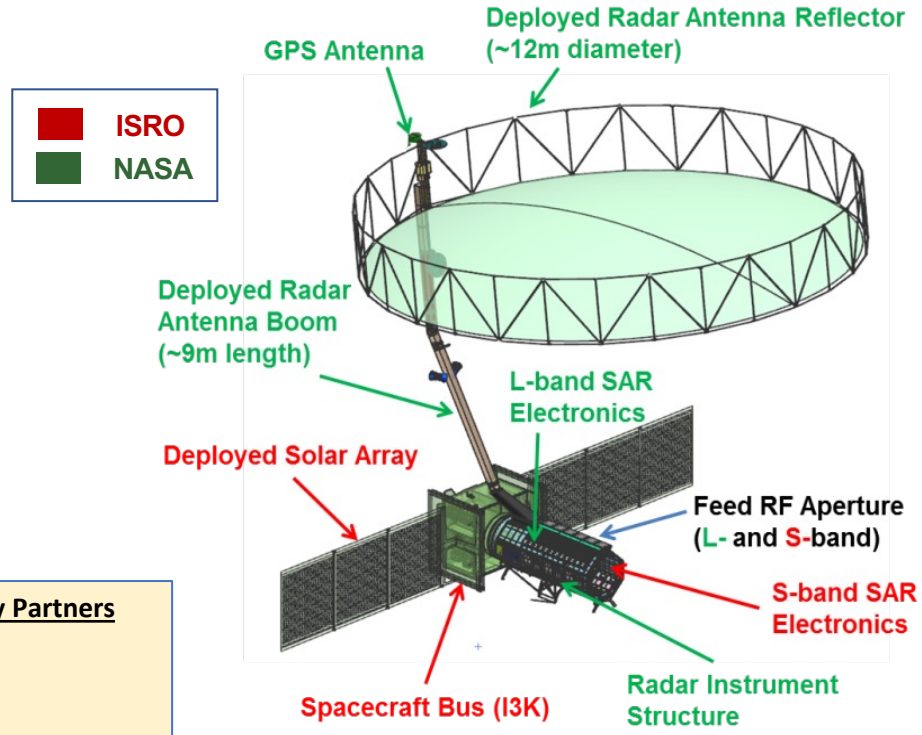
- **Dynamics of Ice: Ice sheets, Glaciers, and Sea Level**
  - *Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur?*
  - *What will be the resulting time patterns of sea-level rise?*
  - *How are alpine glaciers 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?*

NISAR Science Observation Summary

NISAR Characteristic	Would Enable
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9.4 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 on 6am/6pm orbit	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 yrs (NASA) / 5 yrs (ISRO) science operations	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 10% (S) / 50% (L) duty cycle	Complete land/ice coverage
Left-only pointing (Left/Right capability)	Uninterrupted time-series Rely on Sentinel-1 for Arctic



NASA-ISRO SAR Mission
Close integration with international partner

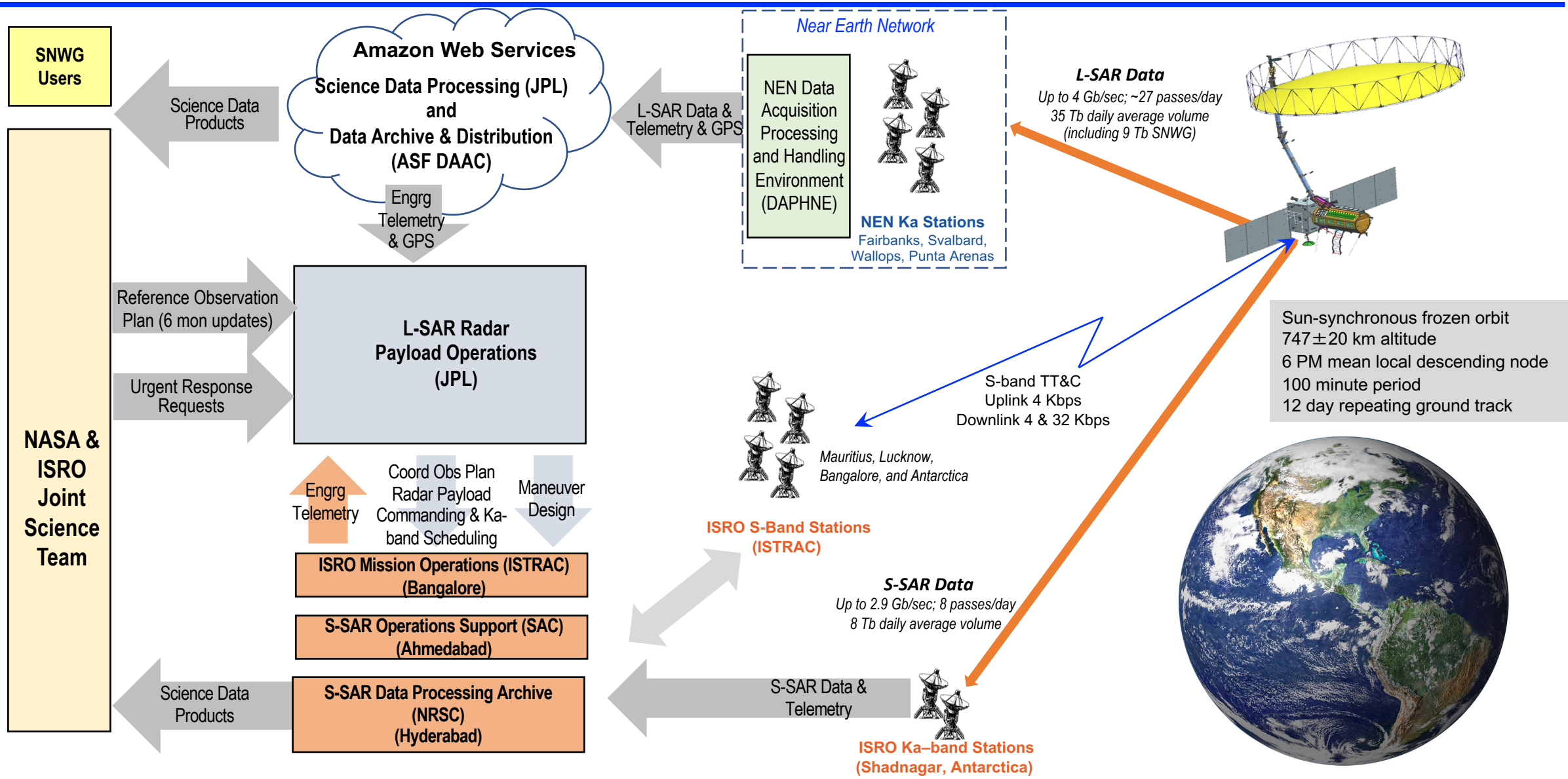


Industry Partners
Airbus
Amazon
BAE
Boeing
Gore
Maxar
Northrop Grumman
Raytheon
Seakr
Sierra Lobo
Sierra Microwave
The Aerospace Corp.
Xilinx

	Mass (kg)	Power (W)
Spacecraft Mainframe	920	1312
Engineering Payload	134	640
L-SAR	283	1515
S-SAR	314	2757
Common Instrument Structure	466	
Reflector and Boom	292	
Propellant	269	
Total	**2678**	**6224**

NASA Provides	ISRO Provides
• L-band SAR • Shared P/L structure & 12m reflector and boom	• S-band SAR • S-SAR baseband data handling (BDH)
• Engineering payload - GPS, Power & Pyro - Payload Data System with 12 Tb recorder - NEN-compatible high rate Ka-band system	• Spacecraft Bus (I3K) • ISRO-compatible high rate Ka-band system • Observatory I&T • GSLV Launch Vehicle
Integrated radar observation planning and operations	Spacecraft operations (command uplink, telemetry and tracking)
L-SAR data downlink to NEN Ka-band stations	S-SAR, select L-SAR data downlink to ISRO stations
L-band science data processing and distribution	S-band science data processing and distribution
NASA Science Team	ISRO Science Team

NISAR Operations Overview



NISAR Development Status

L-SAR I&T (JPL)
April 2019-Jan 2021

Engineering Payload Buildup (JPL)
June 2020 – June 2021

Surrogate S/C with Engineering Payload Elements Integrated

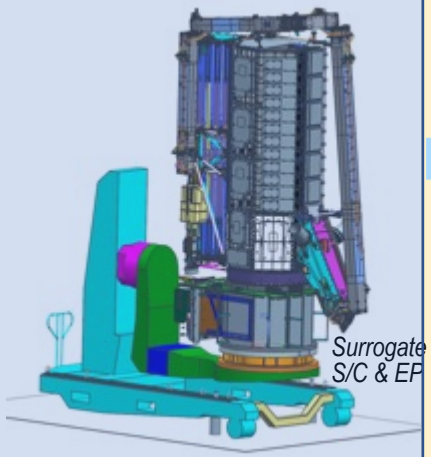
RIS "Clamshell" Delivered to SAC for S-SAR Integration (June 2019)

DTM I&T (JPL) Dec '20

Completed!

SIT-2 & 3 (JPL)
Radar Payload I&T
Feb '21- Feb '23

Radar Payload (with BDH, GPS & SSR



Surrogate S/C & EP

SIT-4 (URSC)
Observatory I&T
Mar '23-Jan '24

Satellite Integration & Test Establishment (ISITE) Bangalore

Launch Operations (SHAR) & Launch
Jan 2024

Geosynchronous Launch Vehicle (GSLV) Mark II

Satish Dhawan Space Centre

Sriharikota

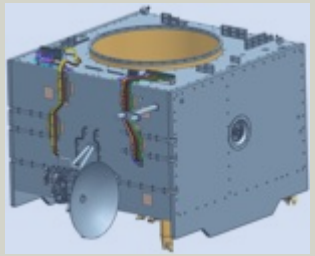
March '21

August '21

S-SAR I&T (SAC)

Baseband Data Handler (BDH) (URSC)

Satellite Mainframe I&T
Mar '21-Feb '23



ISITE, Bangalore

Boom/Reflector Integration

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

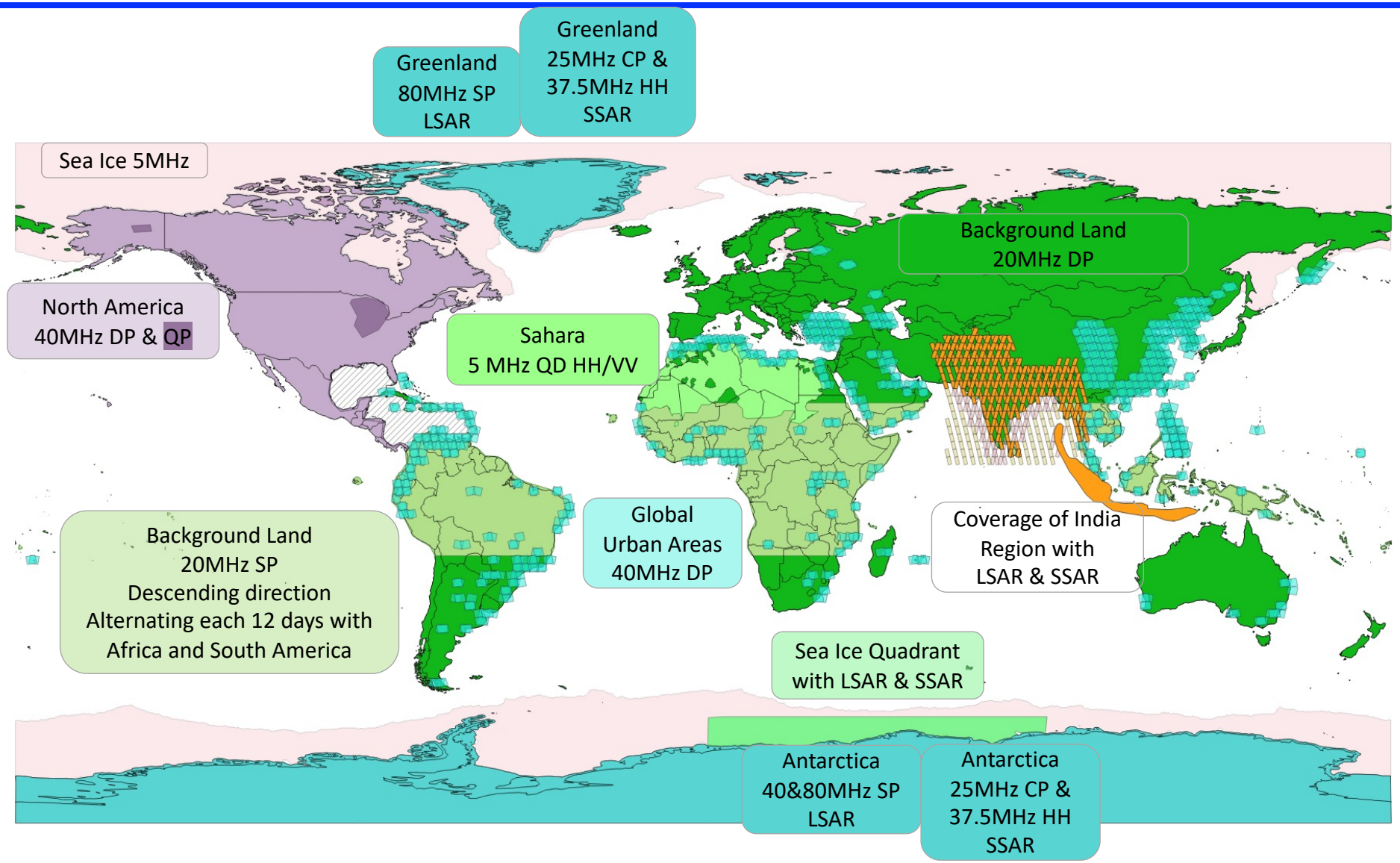
- Observation strategy employs a small subset of possible modes*

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 Hi-Res					s = 1 p	
Himalayas			CP RH/RV		s = 1 p	
India Agriculture	QP				s = 1 p	
India Coastal Ocean			DP HH/HV or VV/VH		s = 1 p	
Sea Ice Types	DP VV/VH				s = 3 p	

*Example – actual modes in current plan vary geographically and seasonally

Current Observation Plan
Revised every 6 months

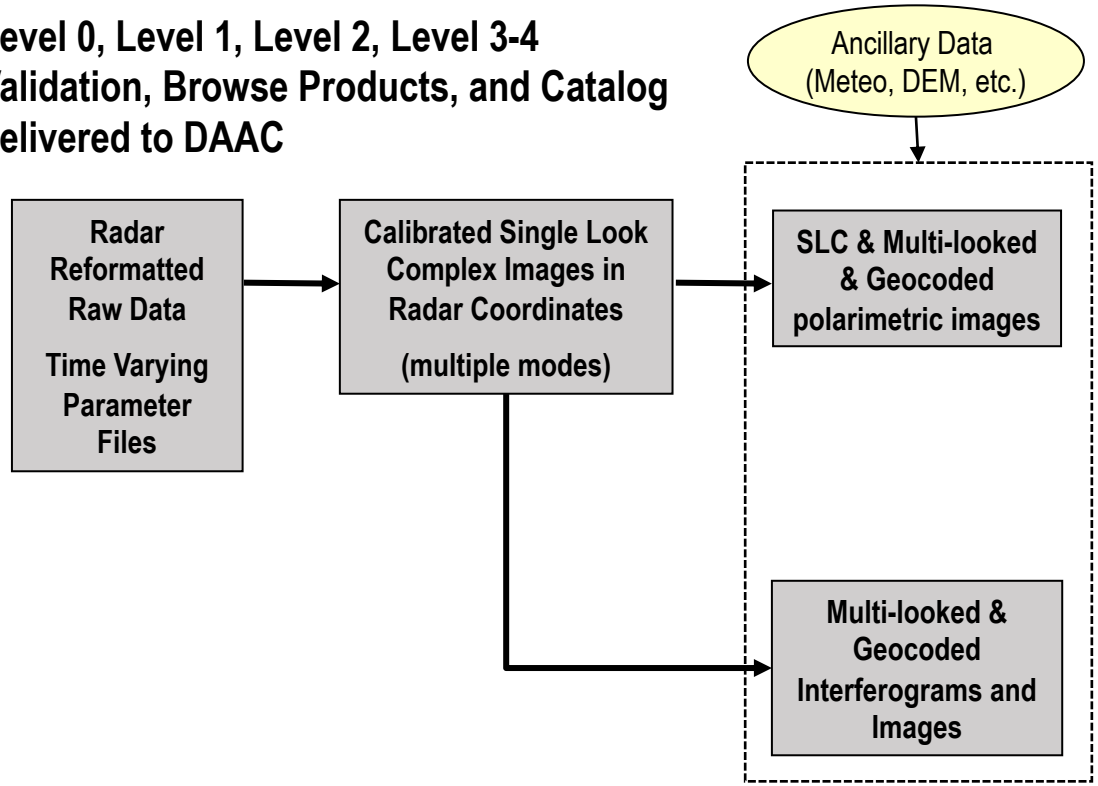
SP – Single Pol
DP – Dual Pol
QP – Quad Pol
CP – Compact Pol



NISAR Level 0, 1, & 2 Product Overview

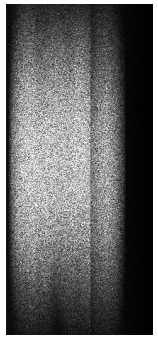
Level 0	Level 1	Level 2

Level 0, Level 1, Level 2, Level 3-4 Validation, Browse Products, and Catalog delivered to DAAC

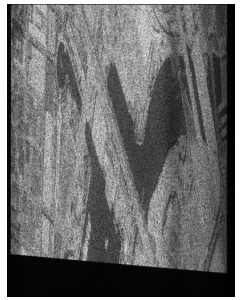


NISAR's DAAC:
Alaska Satellite Facility

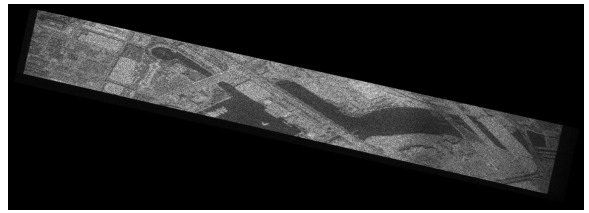
L0 - Raw



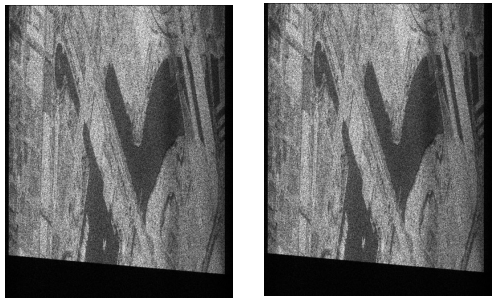
L1 - RSLC



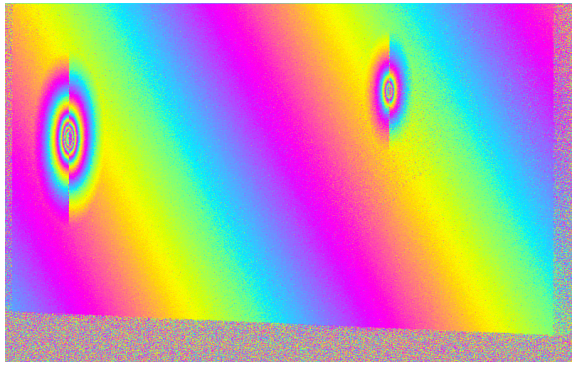
L2 - GSLC



L1 – RSLC (time 1, 2)



L1 – RIFG



Resolution/Posting/Bands Specification

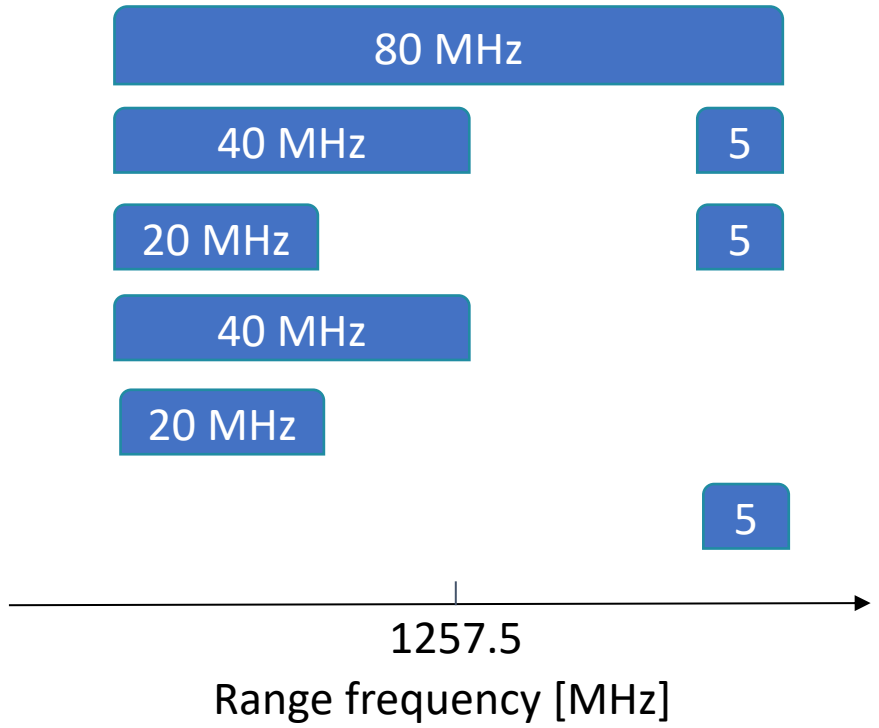
- The L-band radar with a total bandwidth of 77 MHz is capable of acquiring data in many different science modes
- The radar can transmit waveforms with parts of the spectrum in lower and upper parts of the total spectrum
- Depending on the range bandwidth, pulse width, PRF and the transmit/receive polarizations, NISAR has over 100 modes
  - A limited number will be used in science operations

RSLC resolution and posting

Range bandwidth	Azimuth resolution	Slant range resolution	Azimuth posting	Slant range posting
5 MHz	~6 m	30 m	~5 m	25 m
20 MHz	~6 m	7.5 m	~5 m	6.25 m
40 MHz	~6 m	3.75 m	~5 m	3.12 m
80 MHz	~6 m	1.95	~5 m	1.56 m

- Range weighting: Kaiser(1.6) spectral window
- Azimuth weighting: Azimuth antenna pattern

Range spectrum of different radar modes



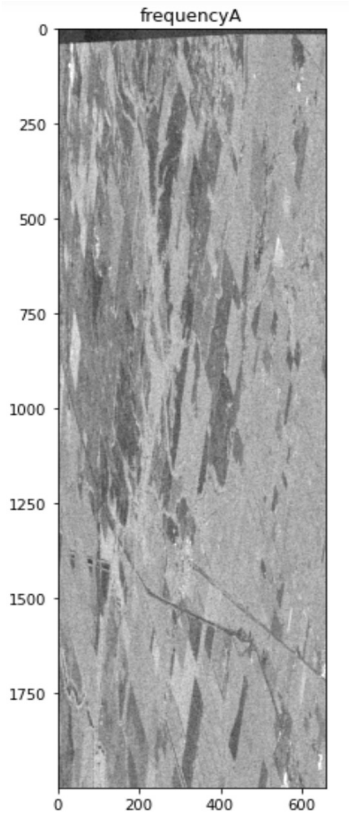
The separation between frequency A (20 MHz) and B (5 MHz) enables a less noisy ionospheric phase estimate.

RSLC Data layers

Example of **NISAR-like** RSLC data simulated from **UAVSAR** L-band acquisition
HDF5 NISAR-like products available at https://uavsar.jpl.nasa.gov/science/documents/nisar-sample-products.html

Frequency A / 20 MHz

Frequency B / 5 MHz



Azimuth Pixels (Length): Same for 5 MHz and 20 MHz SLC

20 MHz Posting:
Azimuth: 5 m
Range: 6.25 m

5 MHz Posting:
Azimuth: 5 m
Range: 25 m

Range Pixels (Width) of 20 MHz SLC is 4X the 5 MHz SLC

NISAR L2 SAR Products

Level 0	Level 1	Level 2

Level 0, Level 1, Level 2, Level 3-4 Validation, Browse Products, and Catalog delivered to DAAC

Ancillary Data (Meteo, DEM, etc.)

Radar Reformatted Raw Data

Time Varying Parameter Files

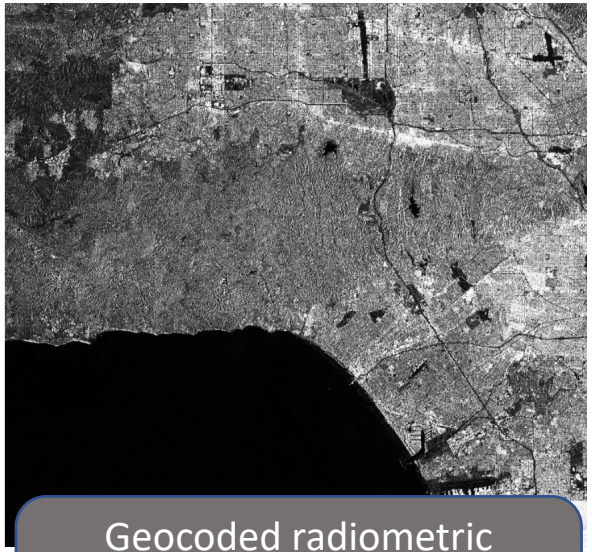
→ **Calibrated Single Look Complex Images in Radar Coordinates**

(multiple modes)

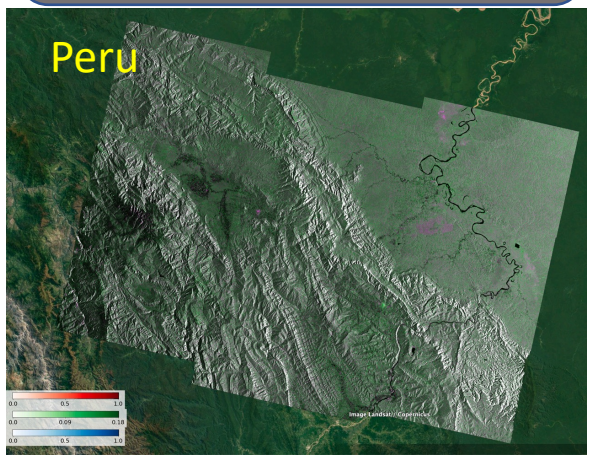
→ **SLC & Multi-looked & Geocoded polarimetric images**

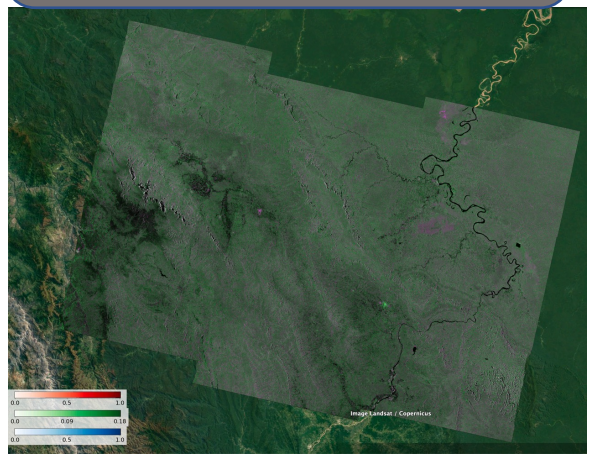
→

Geocoded Covariance (GCOV) Simulated NISAR from Sentinel-1 data



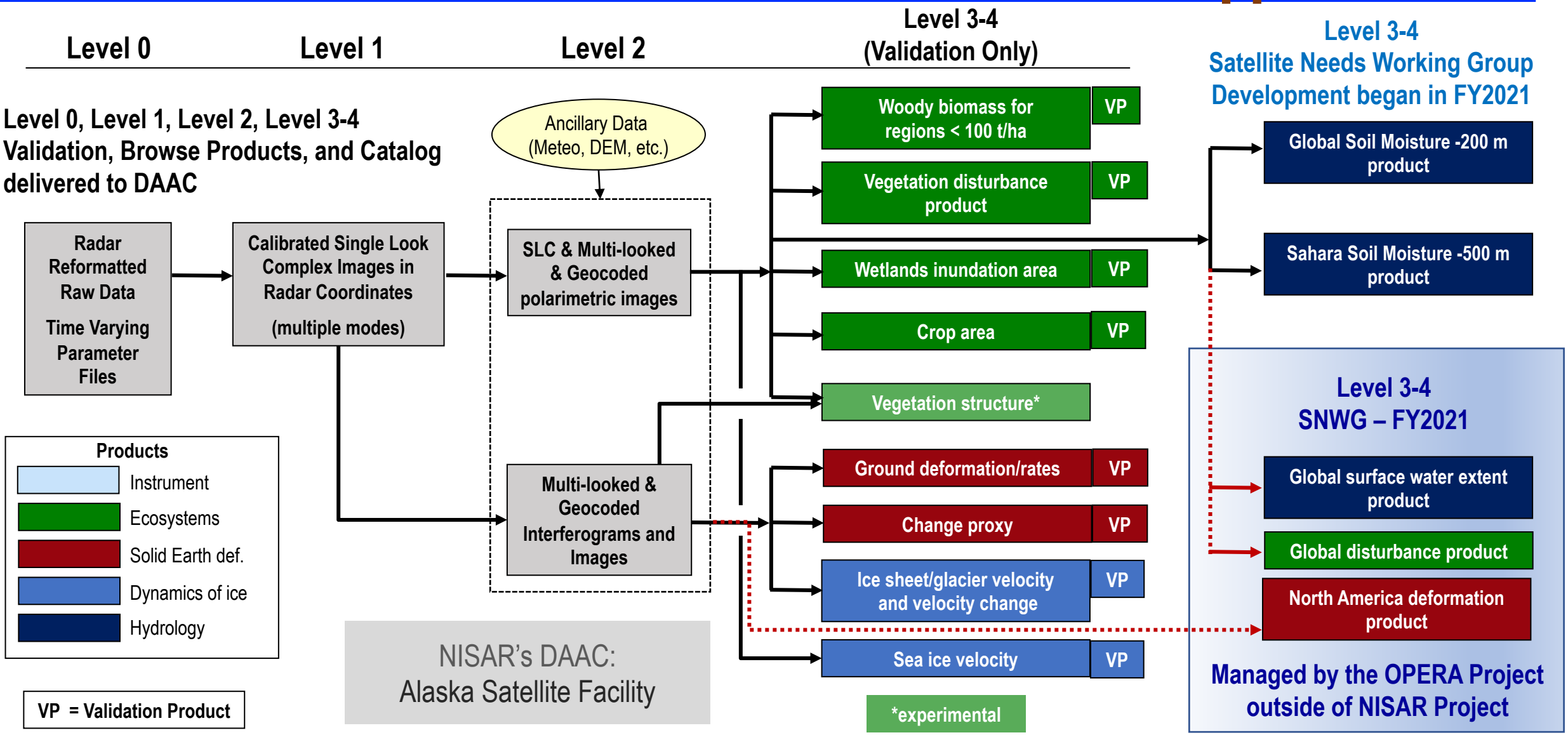
Geocoded radiometric terrain correction (RTC: GSLC) collected Sentinel-1 data





NISAR's DAAC:
Alaska Satellite Facility

NISAR Science Data Analysis and Archive Approach



Science Data System Summary

- Ingest 35 Tbits (4.4 TB) of raw data per day on average
- Automatically generate L-SAR L0a, L0b, L1, and L2 science products (> 70TB/day)
  - Generate S-SAR L0 science product for data downlinked through NASA Ka-band
- Perform bulk reprocessing twice during mission
  - 8 months of data after L2 product validation at 4x rate
  - 12 months of data at end of mission at 3x rate
  - Anticipate assessing additional processing / reprocessing options before launch
- SDS is sized to produce L1 data within 1 day latency (4 hours in Urgent Response)

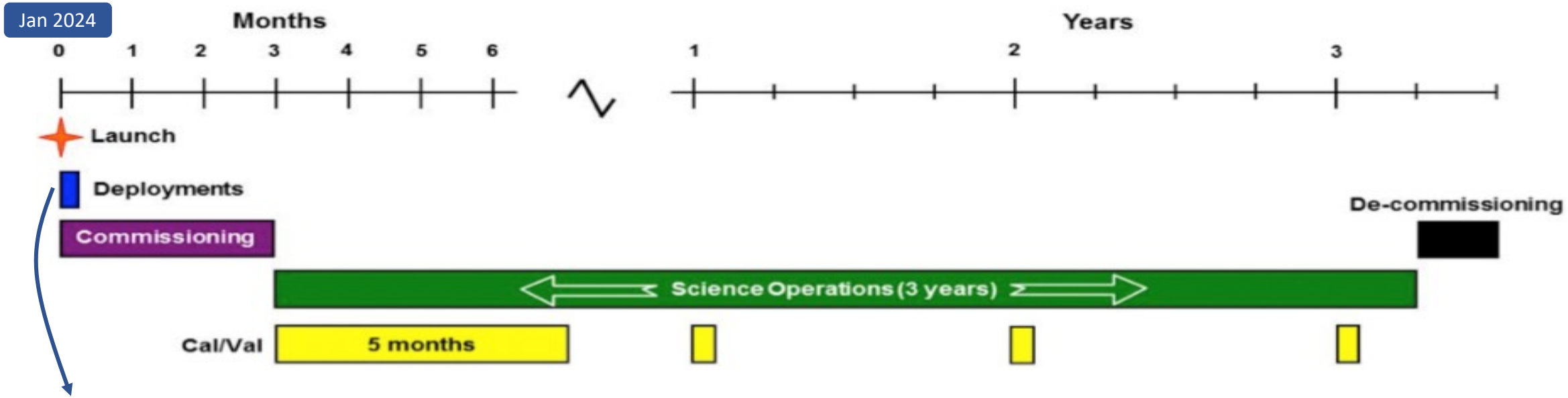
Products	Requirement	Current Best Estimate	Urgent Response
L0	24 Hours	12 Hours	2 Hours
L1	9 Days	1 Day	4 Hours
L2	9 Days	2 Days	6 Hours

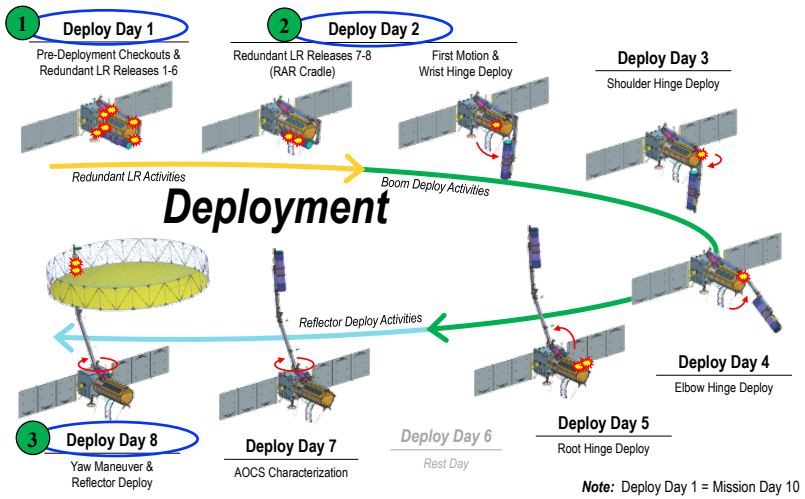
Open-Source Science for NISAR

- Open data – per NASA data policy – at the Alaska Satellite Facility DAAC
  - Pre-launch Sample products: https://uavsar.jpl.nasa.gov/science/documents/nisar-sample-products.html
  - Post-launch Science products
  - *NISAR will be two times larger than the current EODIS Archive.*
- Open Source Software – SDS and data processing code available for download
  - InSAR Scientific Computing Environment, Enhanced Edition (ISCE3): https://github.com/isce-framework/isce3
- Open Source Science algorithms for science products
  - Jupyter notebooks available for download: https://gitlab.com/nisar-science-algorithms
- Open Source Training Opportunities
  - Jupyter notebooks in cloud training environments at Alaska Satellite Facility OpenScienceLab
  - ARSET and other courses: https://nisar.jpl.nasa.gov/resources/sar-education-resources/
- Free cloud computing resources for NASA subscribers

The next hurdle for scientists: bringing them to cloud by developing straightforward and user-friendly cloud-based workflows

What happens after launch?





- Three-month Commissioning Phase
- Three Year Baseline Science Operations
  - Five years for ISRO
- Five-month Cal/Val Phase overlaps with Science Ops
- Periodic Cal/Val throughout
- Science Operations extended pending NASA Senior Review

Summary

- NISAR is in its final phase of integration for launch in early 2024
- Global products to Level 2 will be fully and openly available to the global community
- Cloud-based data, tools and services will facilitate access and use
- Broad scientific and applied uses
  - engaged and excited community ready for the data

For more information: ***https://nisar.jpl.nasa.gov***