A Dual-Frequency Spaceborne SAR Mission Concept

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A NASA-ISRO SAR Mission Concept

- The National Aeronautics and Space Administration (NASA) and the Indian Space Research Organization (ISRO) have been engaged in technical and programmatic exchanges on a possible joint SAR mission since December 2011
- A new SAR mission concept has emerged that addresses a broad range of science and applications objectives assigned in the 2006 US Decadal Survey to the proposed Tier 1 DESDynI Mission, as well as ISRO's long term observing plans
- The mission is now conceived as a partnership 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
  - Bilateral agreement on open data policy
  - Major mission-level, balanced, NASA-ISRO partnership

Mission Science Definition Team

- NASA selected a Science Definition Team (SDT) in Spring 2012 to help craft a scientifically compelling, *affordable* SAR mission

Project Scientist – Paul Rosen, JPL

NASA SDT Leads

Ian Joughin, Applied Physics Lab, U Washington (Dynamics of Ice)
Ralph Dubayah, U Maryland (Ecosystems)
Bradford H. Hager, MIT (Deformation/Solid Earth)

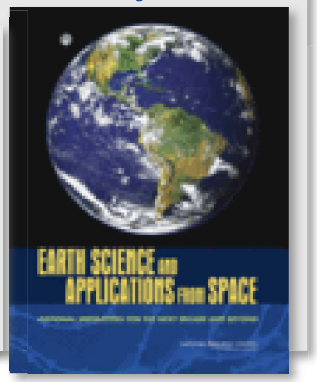
ISRO Science Contact – Manab Chakraborty, ISRO Space Applications Center

NASA SDT Members

Gerald Bawden, USGS
Kurt Feigl, U Wisconsin
Ben Holt, JPL
Josef Kellndorfer, Woods Hole Research Center
Ronald Kwok, JPL
Zhong Lu, USGS
Franz Meyer, U Alaska, Fairbanks
Matt Pritchard, Cornell University
Eric Rignot, UC Irvine
Sassan Saatchi, JPL
Mark Simons, Caltech
Paul Siqueira, U Massachusetts
Howard Zebker, Stanford University

Science Inspired by the "Decadal Survey"

- The 2006 US NRC Decadal Survey recommended the DESDynI Mission to address important scientific questions of high societal impact:
  - *What drives the changes in ice masses and how does it relate to the climate?*
  - *How are Earth's carbon cycle and ecosystems changing, and what are the consequences?*
  - *Understand the physics of earthquakes and volcanoes sufficiently to apply to mitigation of natural hazards*
- The Mission Science Definition Team (SDT), in partnership with ISRO scientists, has validated the continuing importance of these science objectives
- The NASA/ISRO SDT has developed a set of integrated requirements to address these and other important questions



- **Cryosphere, Ice sheets 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, e.g. Himalayan, glaciers, changing in relation to climate?*
- **Changes in ecosystems and biomass**
  - *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 - Extreme events**
  - *Are major fault systems nearing release of stress via strong earthquakes?*
  - *Can we predict the future eruptions of volcanoes?*
  - *What are optimal remote sensing strategies to respond to earthquakes, volcanoes, floods, fires, and other such disasters?*
- **Coastal Processes**
  - *What is the state of important mangroves of India?*
  - *How are Indian coastlines changing?*
  - *What is the shallow bathymetry around India?*
  - *What is the variation of winds in India's coastal waters?*

Draft NASA Level 1 Science Requirements

- For a minimum of 3 years:
  - *Measure displacements over Earth's land and ice covered surfaces with an accuracy of 20 mm with an average sampling capability of 6 days at hectare scale.*
  - *Measure sea ice displacements at 100 m/day accuracy on a 5 km grid every 3-days*
  - *Measure global woody aboveground biomass below 80 Mg/ha at 20 Mg/ha accuracy, and disturbance/recovery, at hectare scale, annually.*
  - *Acquire targeted data sets to characterize wetlands inundation, agricultural systems, aquifers, hydrocarbon reservoirs, permafrost, and coastal winds*
  - *In the event of a major natural or anthropogenic disaster anywhere in the world, data shall be made available for rapid response*

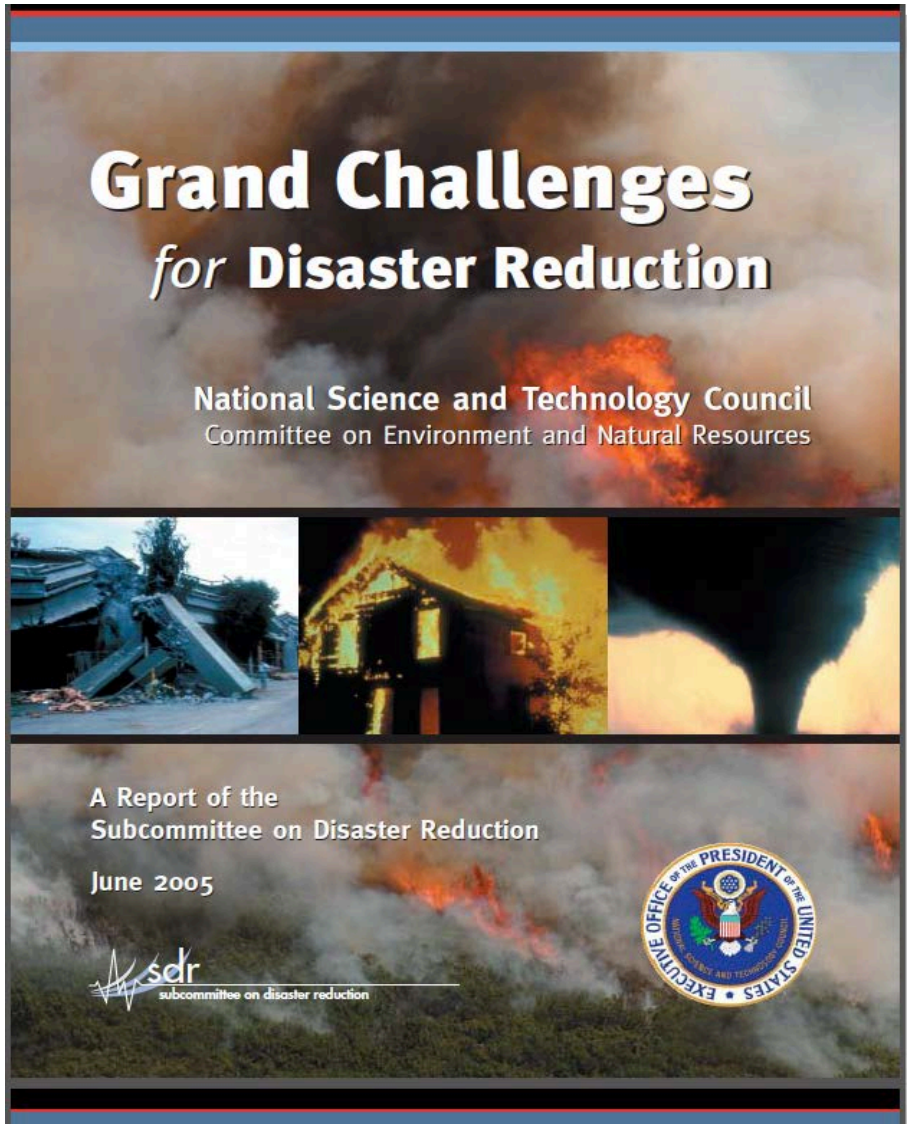
NASA-ISRO Joint Requirements Summary

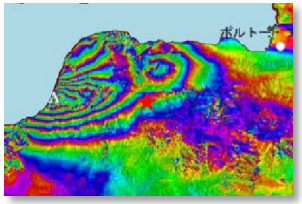
Science or Application Element	Requirements
Ecosystems [3,4]	
• Biomass Disturbance	• Global, seasonal estimates of disturbance and regrowth
• Agriculture	• Regional crop yield estimates surrounding growing seasons
• Wetlands and Coasts	• Regional seasonal estimates of inundation and mangroves
• Alpine Vegetation	• Focus on seasonal characteristics of Himalayan ecosystems
• Soil Moisture	• Regional soil moisture surrounding growing seasons
Deformation	
• Earthquake/Volcanic Cycle Deformation	• Weekly vector sampling of deformation processes on land in plate boundary zones globally
	• Biannual mapping of global land masses for intraplate events
• Land Subsidence, Landslides	• Regional weekly sampling of high-priority aquifers, subsurface reservoirs, and incipient or anticipated landslides
Cryosphere	
• Ice Sheet and Shelf Dynamics	• Weekly vector sampling of deformation processes of ice sheets in winter to capture inter-annual variability
• Sea Ice Dynamics	• Semi-weekly sampling of deformation of Arctic and Antarctic sea ice
• Sea Ice Thickness	• Explore potential for sea ice thickness estimation
• Mountain Snow/Glacier Dynamics	• Weekly vector sampling of deformation processes of mountain glaciers to capture inter-annual variability
• Permafrost and Freeze/Thaw	• Explore the potential of quantifying permafrost variability and freeze/thaw transition
Ocean Processes	
• Bathymetry	• Determine shallow bathymetry in India's coastal waters
• Wave Spectra	• Determine ocean wave spectra in India's coastal waters
• Coastal Winds	• Measure high-resolution coastal winds in India's waters
Other Disasters	
• E.g. Floods, Oil Slicks, Fires	• As natural disasters unfold, direct observation resources and accelerate dissemination of data to users

Societal Challenges and What a Dual Frequency SAR Could Contribute

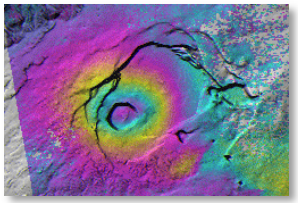
Challenge	SAR Benefit Through Regular Monitoring of:
Global Food Security	- Soil moisture and crop growth at agricultural scale - Desertification at regional scales
Freshwater Availability	- Aquifer use/extent regionally - Water-body extent changes - Glaciers serving as water sources
Human Health	- Moisture and vegetation as proxy for disease and infestation vectors
Disaster Prediction & 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 dynamics and changes in sea-ice cover - 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

A NASA-ISRO SAR Mission Could Provide Needed Data for 9 of 13 *Grand Challenge* Hazards

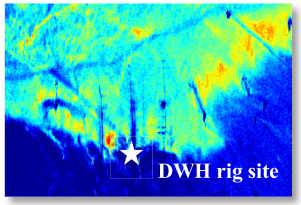




Earthquakes

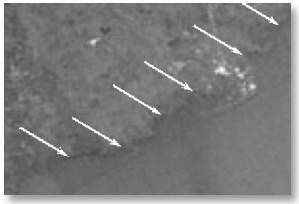


Volcanoes



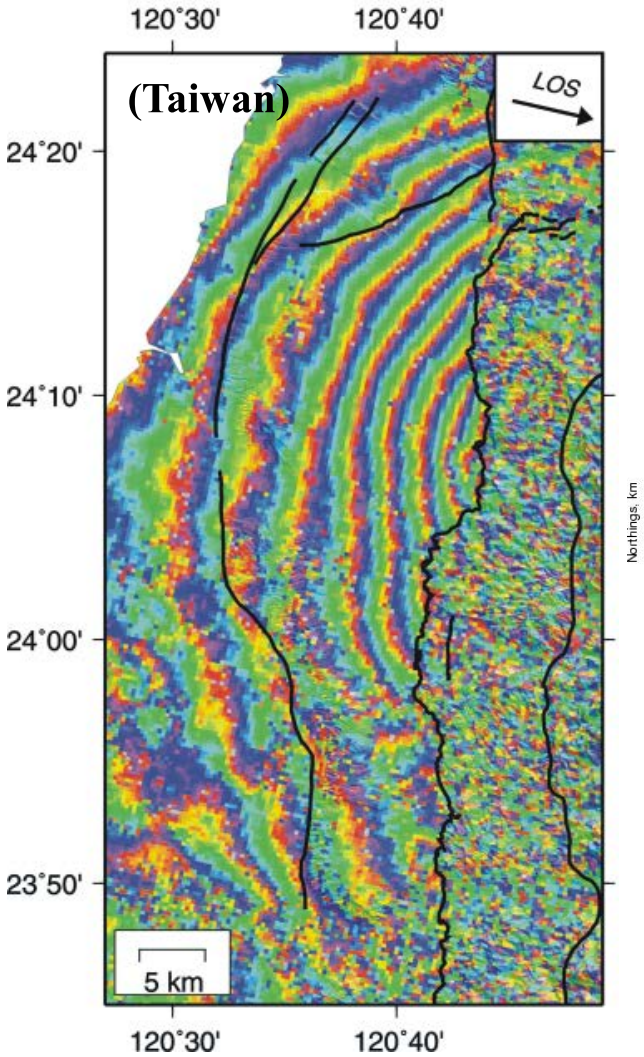
Anthropogenic-Technological Disasters

Floods

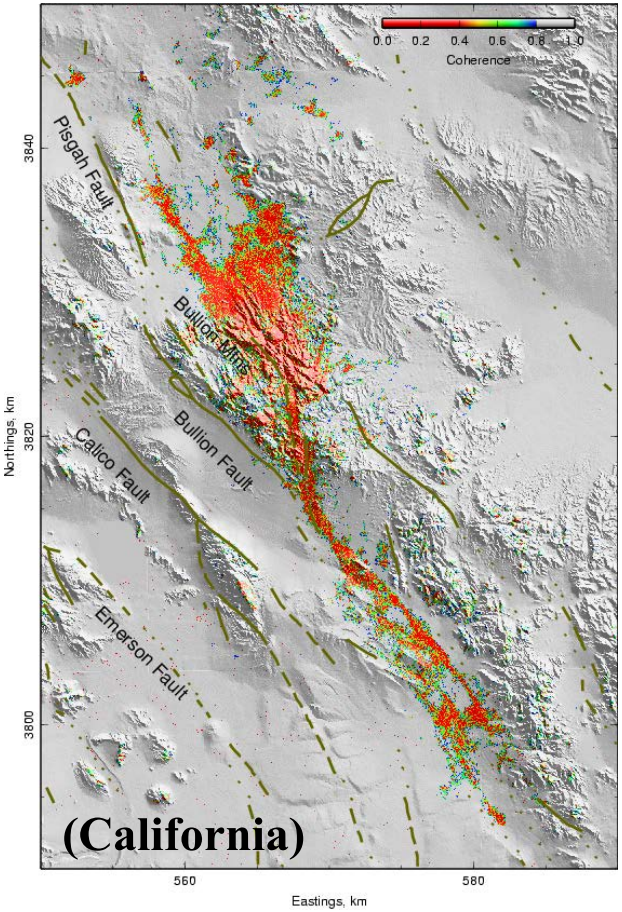


Coastal Inundation

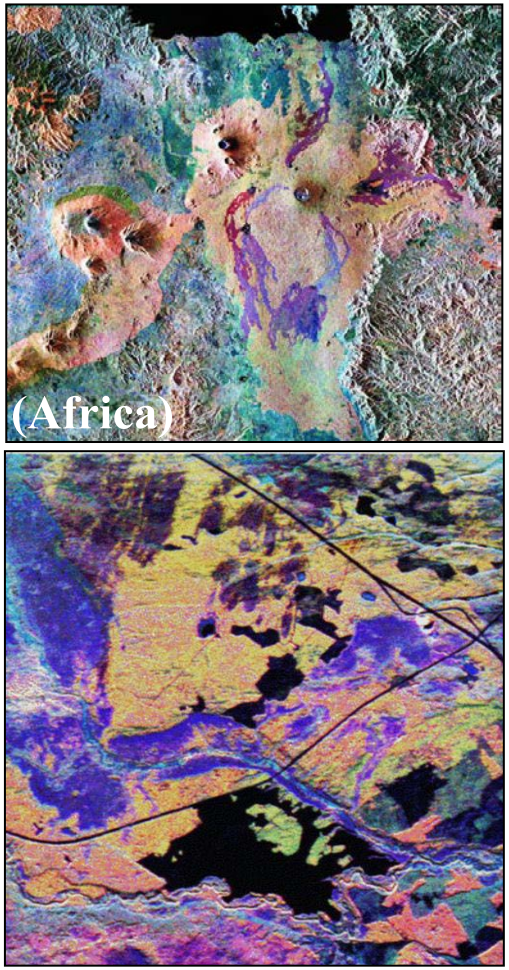
Basic Geodetic & Imaging Measurements



Interferogram

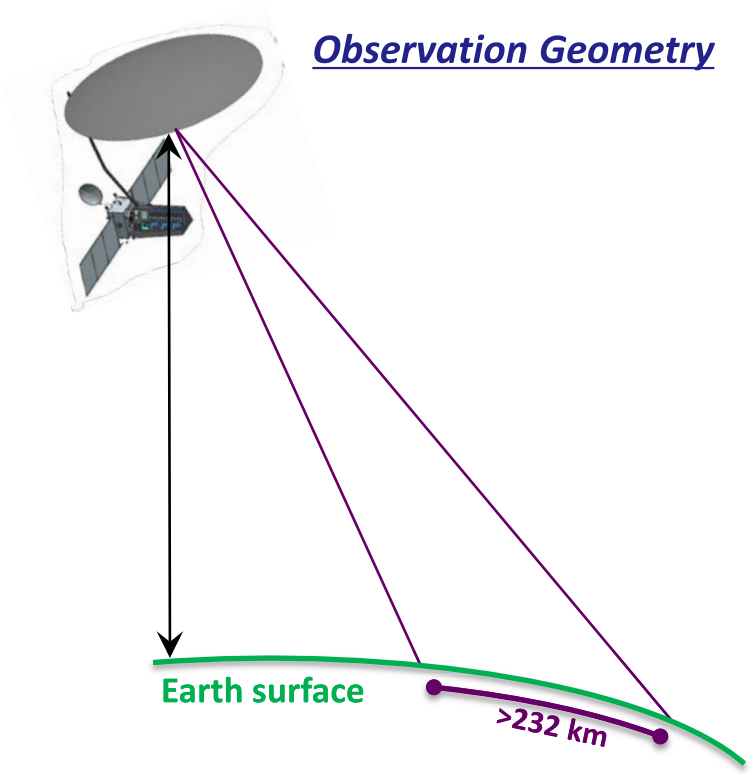


Decorrelation



Polarimetry

DESDynI Synthetic Aperture Radar Concept

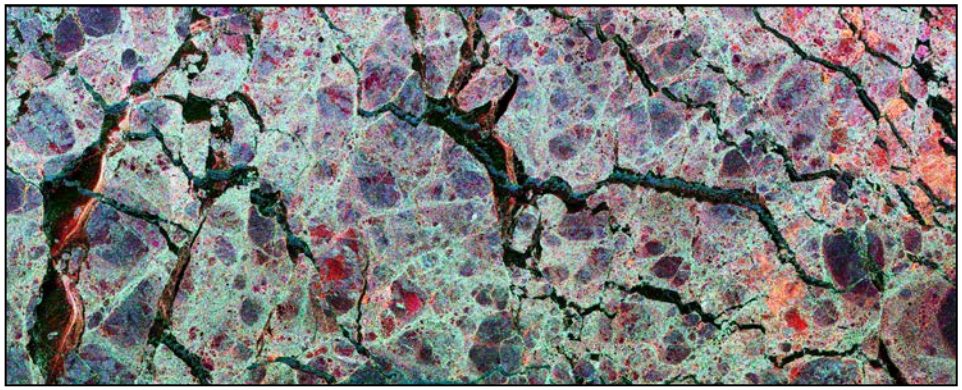


- Dual Frequency: L- and S-Band
- Primary Modes:
  - Solid earth deformation, ice sheets and glaciers: Single-Pol (HH or VV)
  - Ecosystems: Dual, Quad, Quasi-Quad Pol
  - Sea-ice: Low-BW Single-Pol (VV)
- Data acquired Left or Right of spacecraft track, ascending and descending
  - Wide swath in all modes would allow for 12 day repeat with overlap at equator (2-5 passes over a site depending upon latitude)
  - Mode used over any given area selected based on science need
  - Mode conflicts resolved through plan optimization

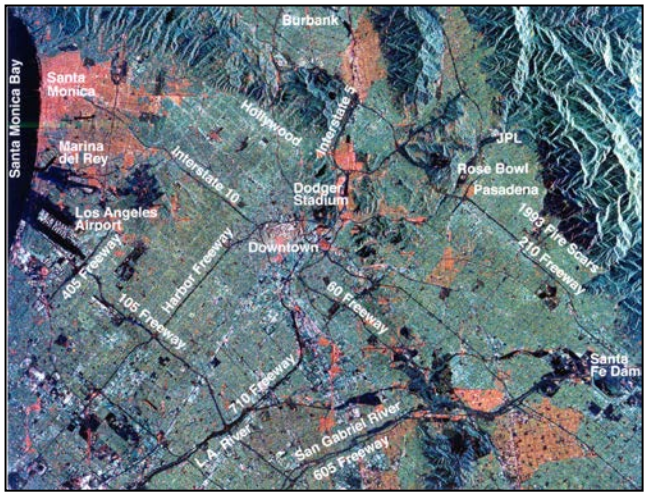
Benefits of both L-band and S-band

- Global L-band data with unprecedented spatial and temporal sampling would drive new directions in science and applications, responsive to the Decadal Survey
- Globally distributed but targeted measurements at S-band for science applications would be a fundamentally new data set
- Combination of simultaneous S-band and L-band data would be extremely powerful for discriminating differential scales in many disciplines
- Greater available bandwidth at S-band than L-band could enable focus on some areas at finer resolution

Red: CHH Green: LHV Blue: LHH



SIR-C/X-SAR observes Weddell Sea ice, Antarctica

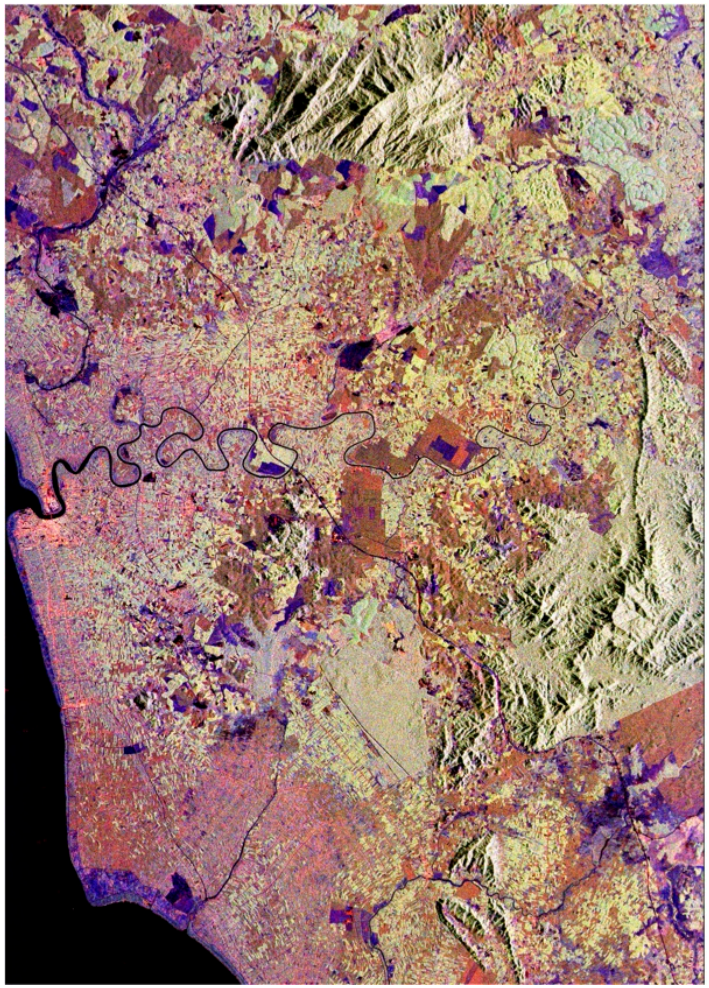


SIR-C/X-SAR over Los Angeles

Multi-frequency Data over Agricultural Regions

Wheat Fields
Dnieper River, Ukraine

Red: LHH
Green: LHV
Blue: CHV

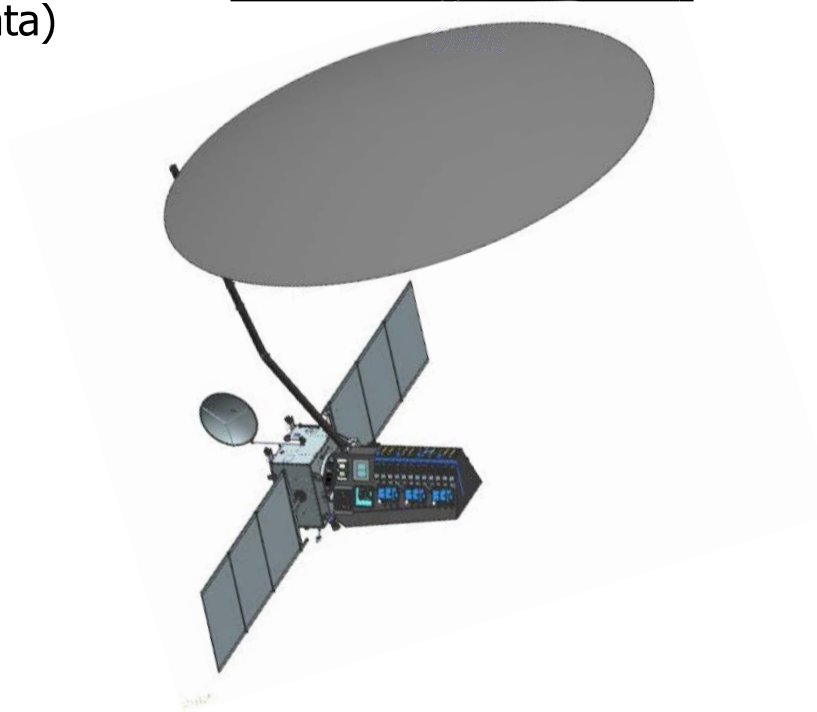


Rubber, banana and oil palm trees
Muar, Malaysia

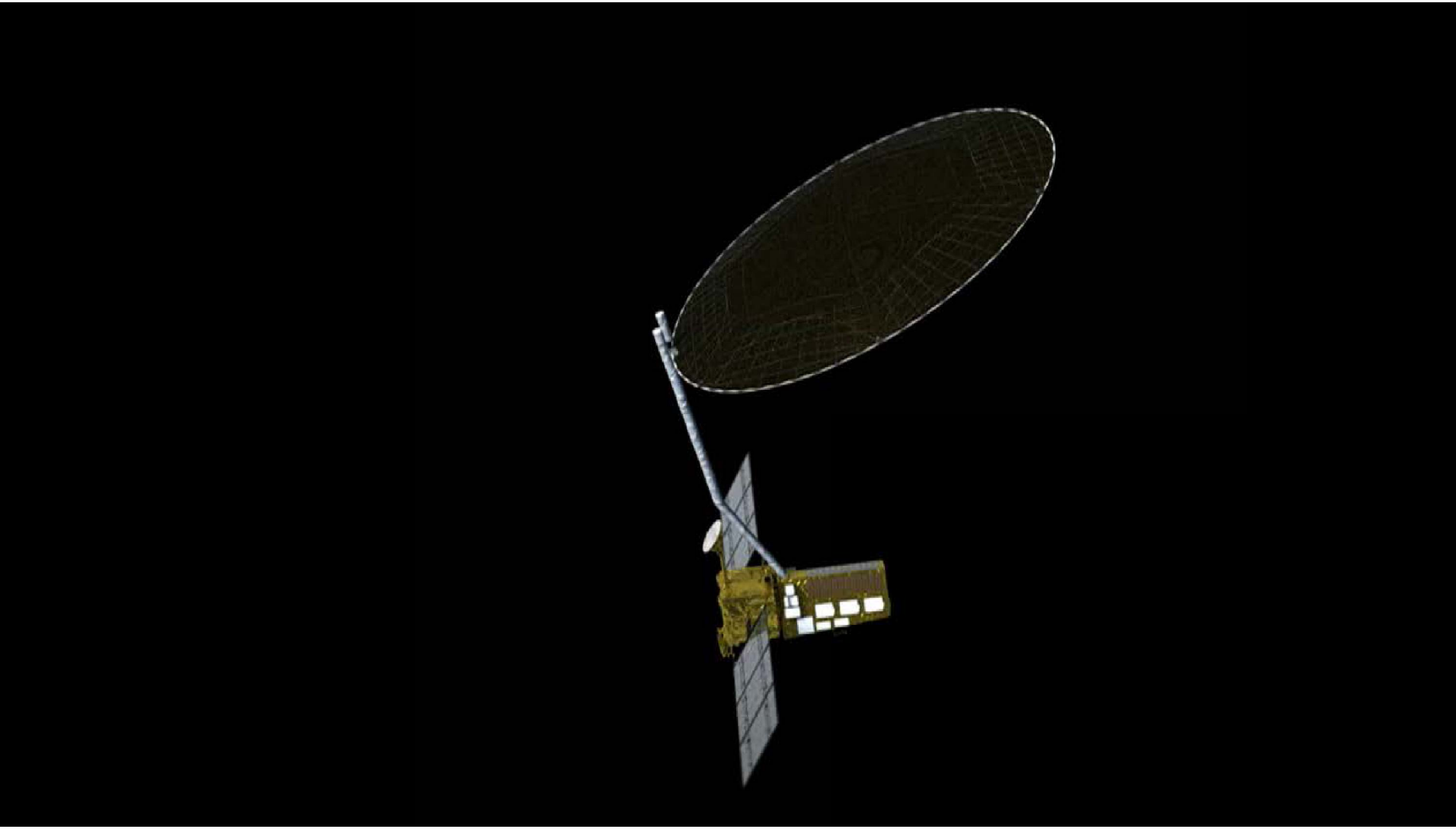
NASA-ISRO SAR Mission Concept

- Mission concept
  - L- and S-band Synthetic Aperture Radar (SAR)
  - Sweep SAR technique (large swath) for global data collection
  - 12-day repeat, 98-deg inclination, sun-synch orbit
  - 3 years science operations (5 years consumables)
  - Science downlink: NASA Ka-band TDRSS (all data) and ISRO Ka-band ground station (subset)

  - Primary instrument: NASA/JPL L-band SAR
  - Secondary instrument: ISRO S-band SAR
  - Spacecraft: ISRO I3K
  - Launch vehicle: ISRO GSLV



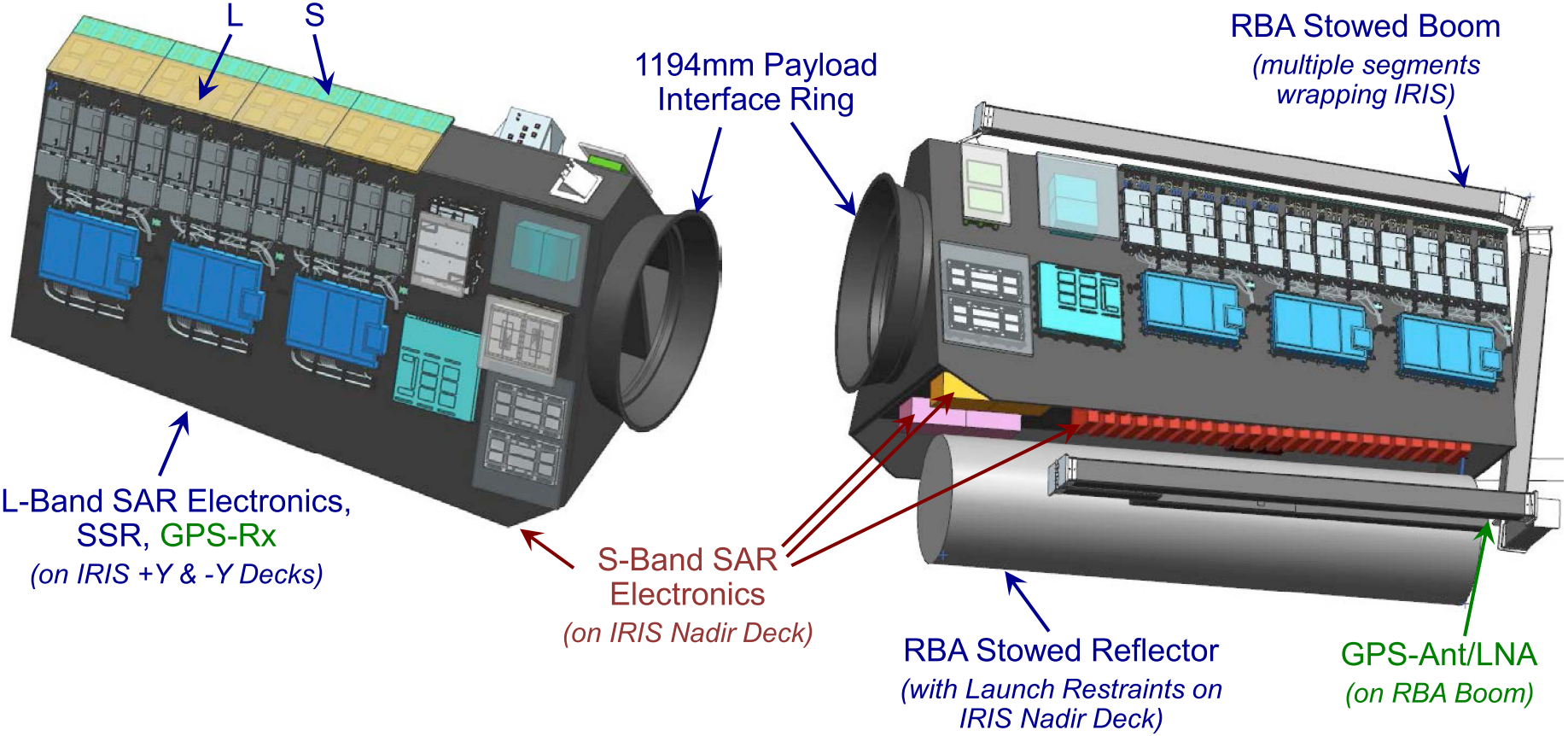
Spacecraft Concept - Animated



Proposed Radar Payload & Flight System Configuration

IRIS
(Integrated Radar Instrument Structure)

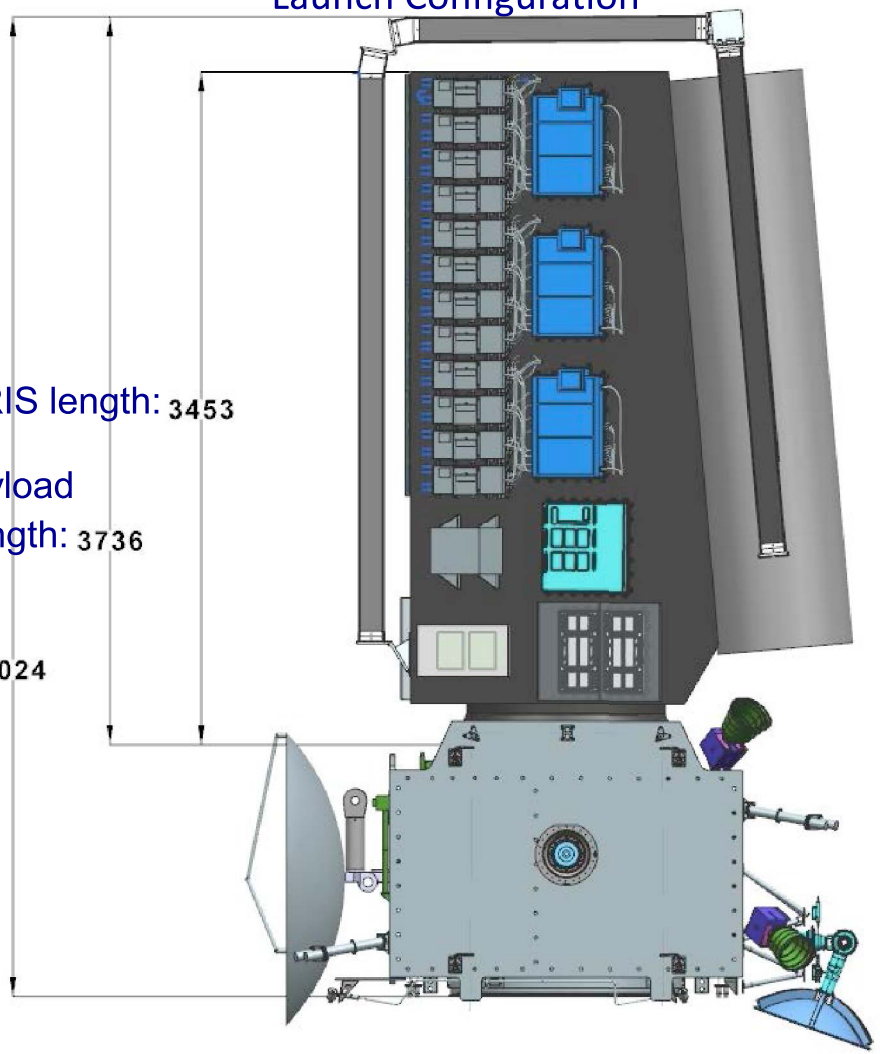
Radar Payload
= IRIS + RBA *(Reflector/Boom Assembly with integrated GPS-Ant/LNA)*



Proposed Radar Payload & Flight System Configuration

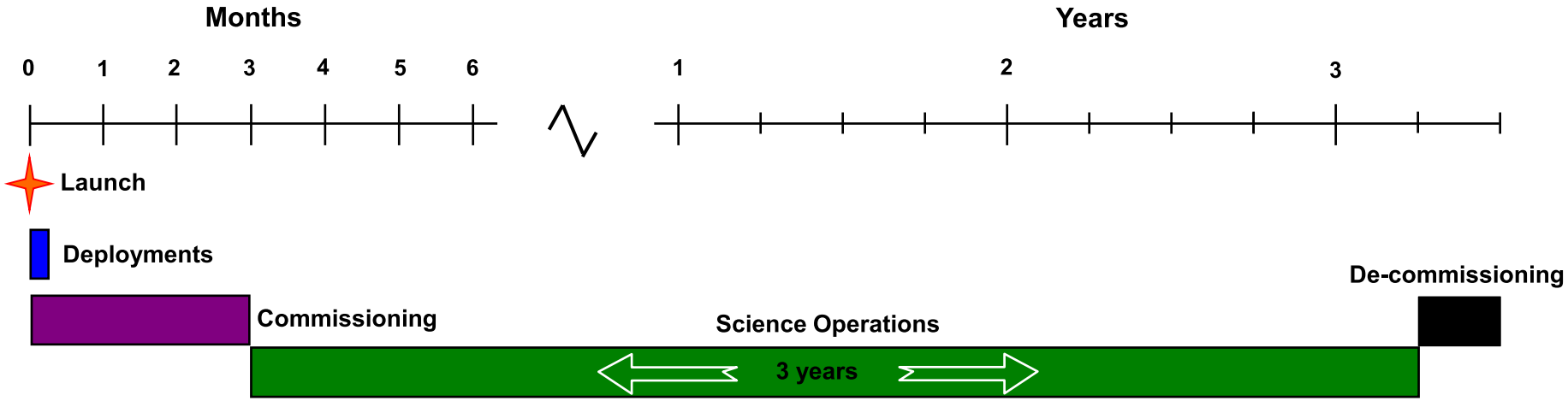
Integrated Observatory *(Spacecraft + Radar Payload)*

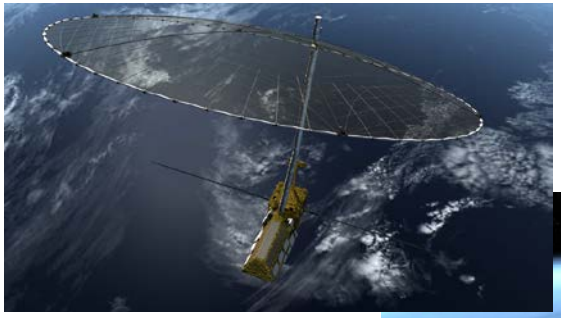
Launch Configuration

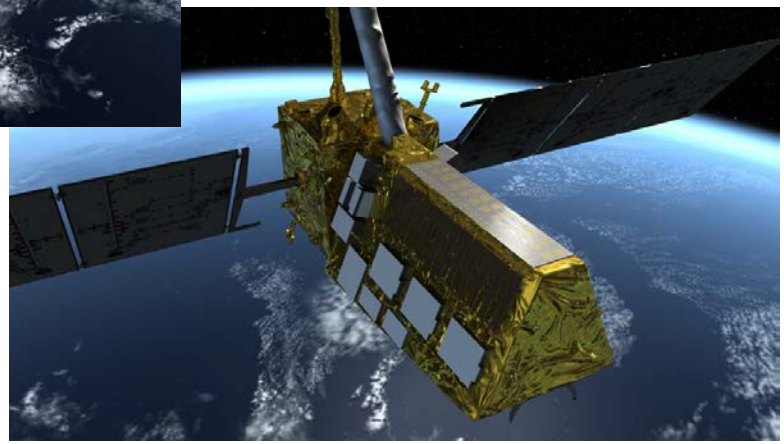


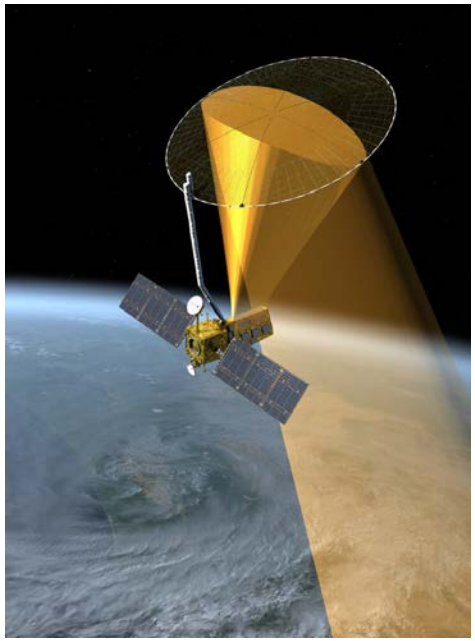
Flight System in Launch Configuration (GSLV)

Proposed Mission Timeline



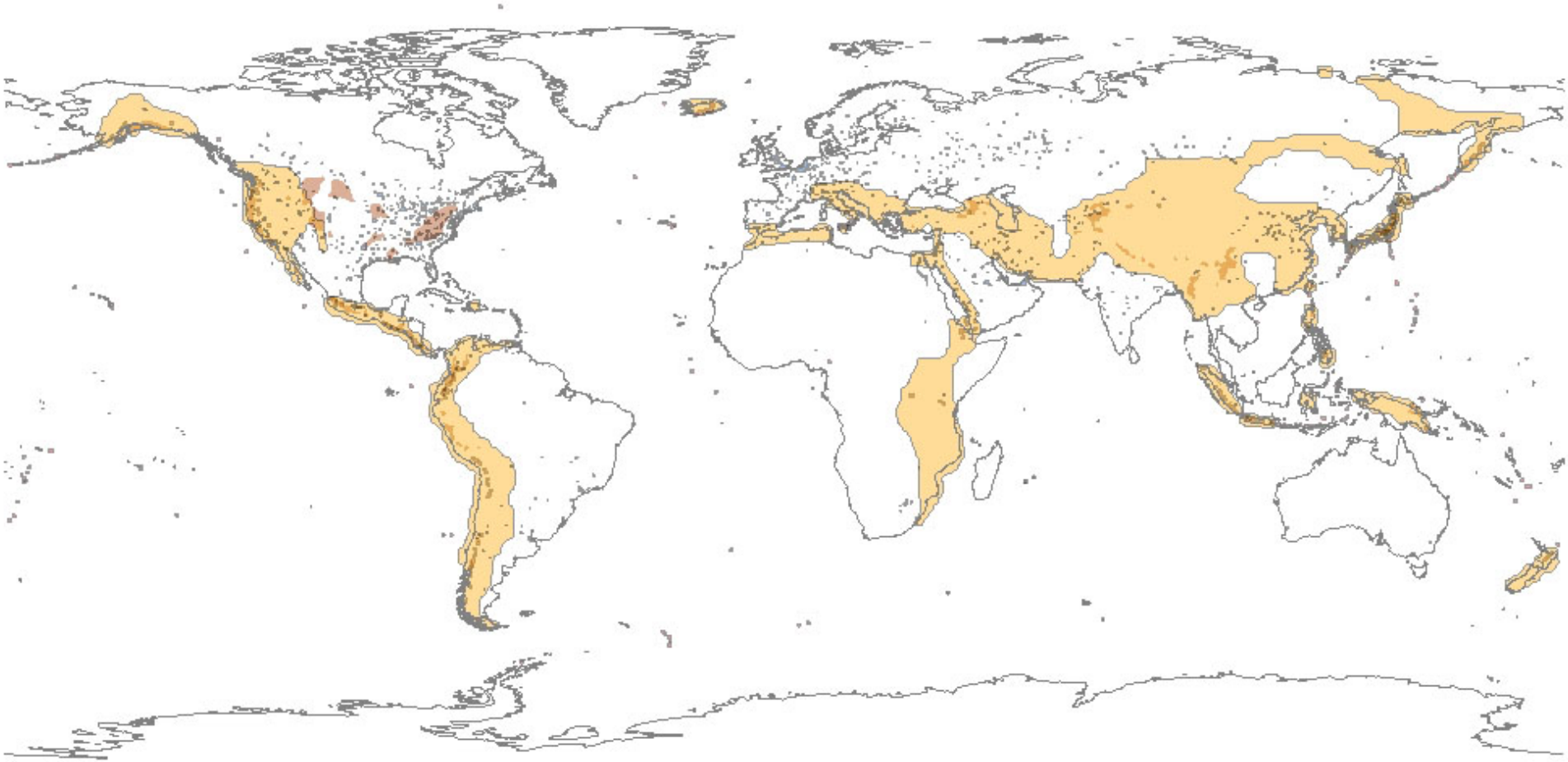




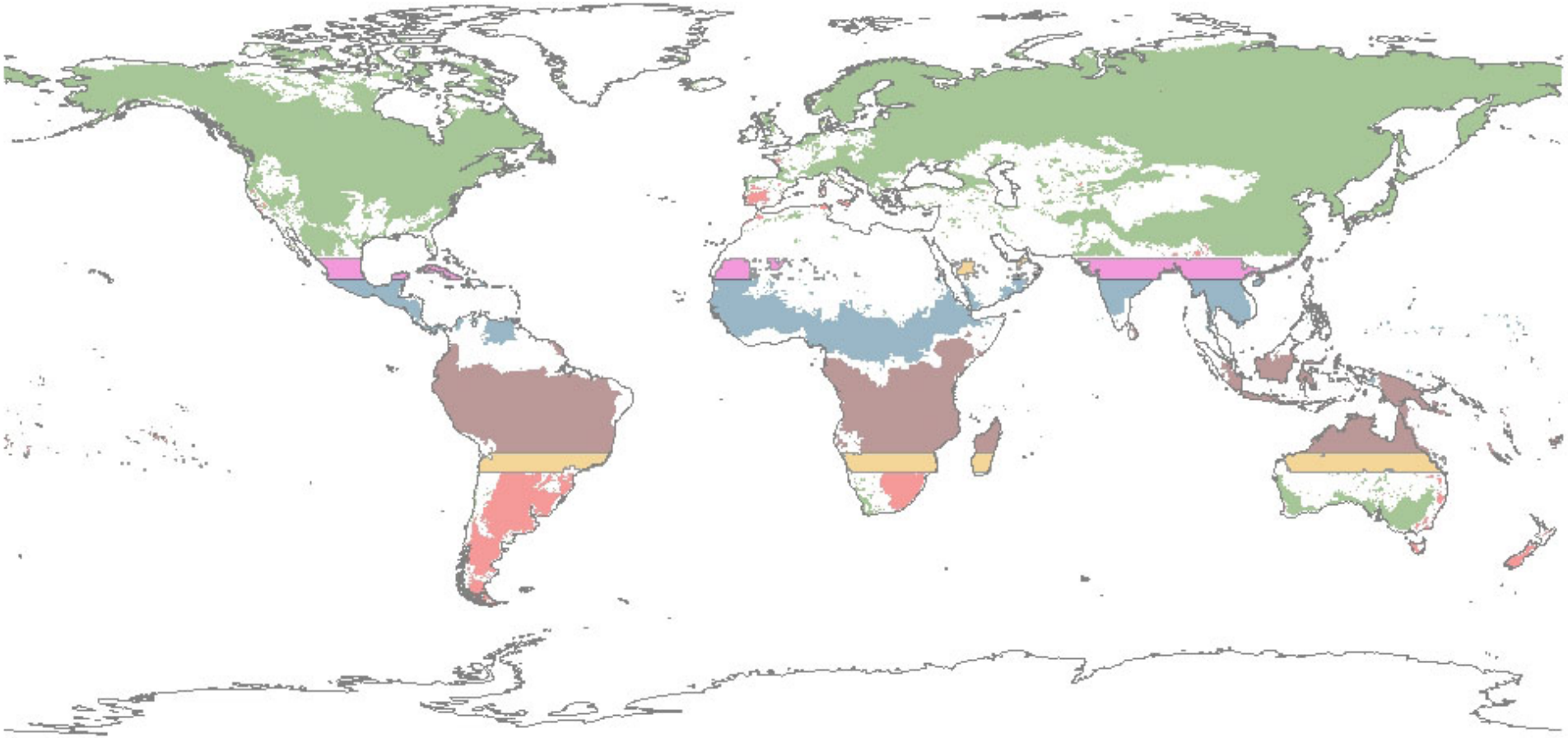


Artist's Concepts

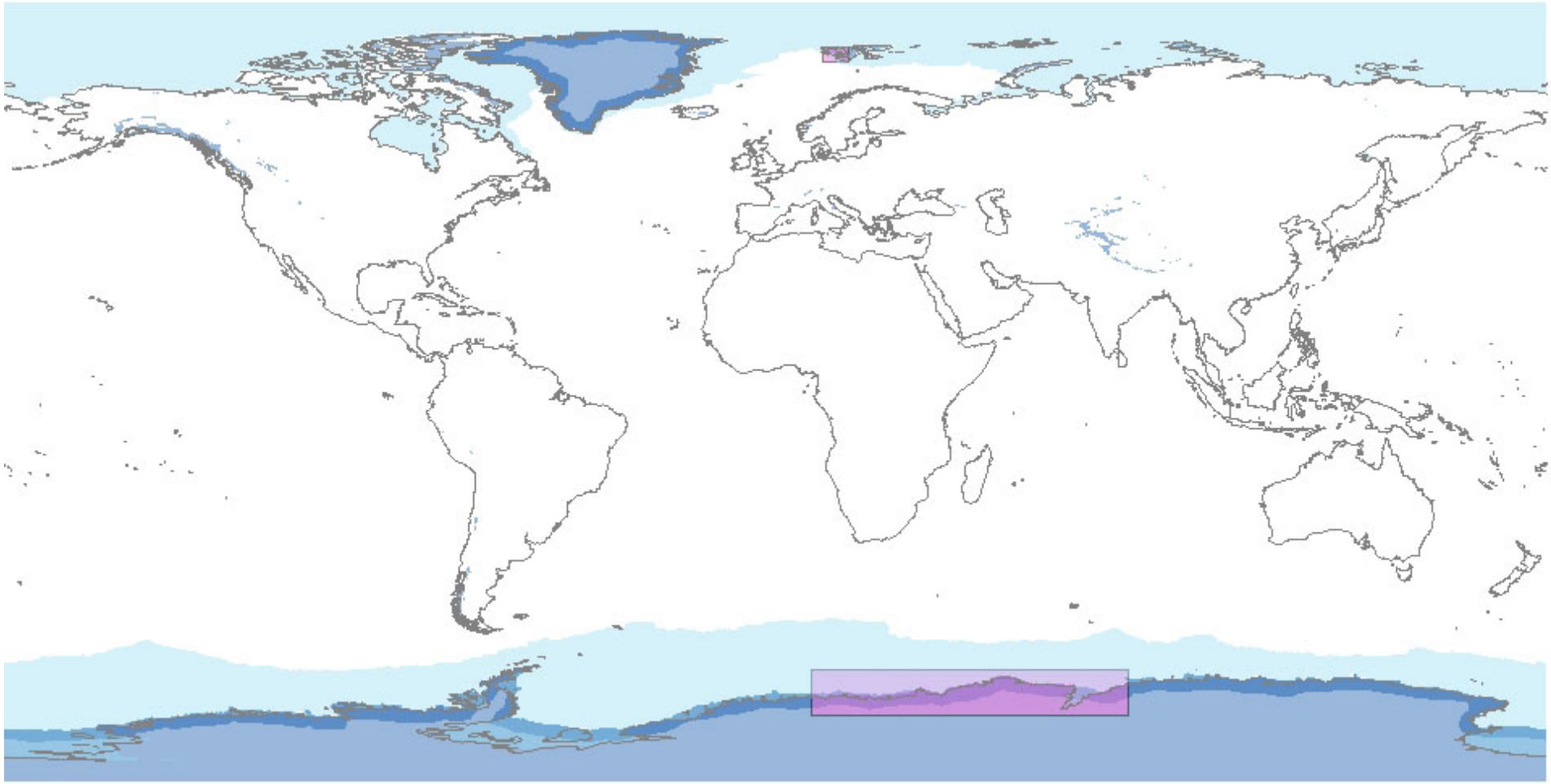
L-Band Deformation (Every Cycle) Science Targets



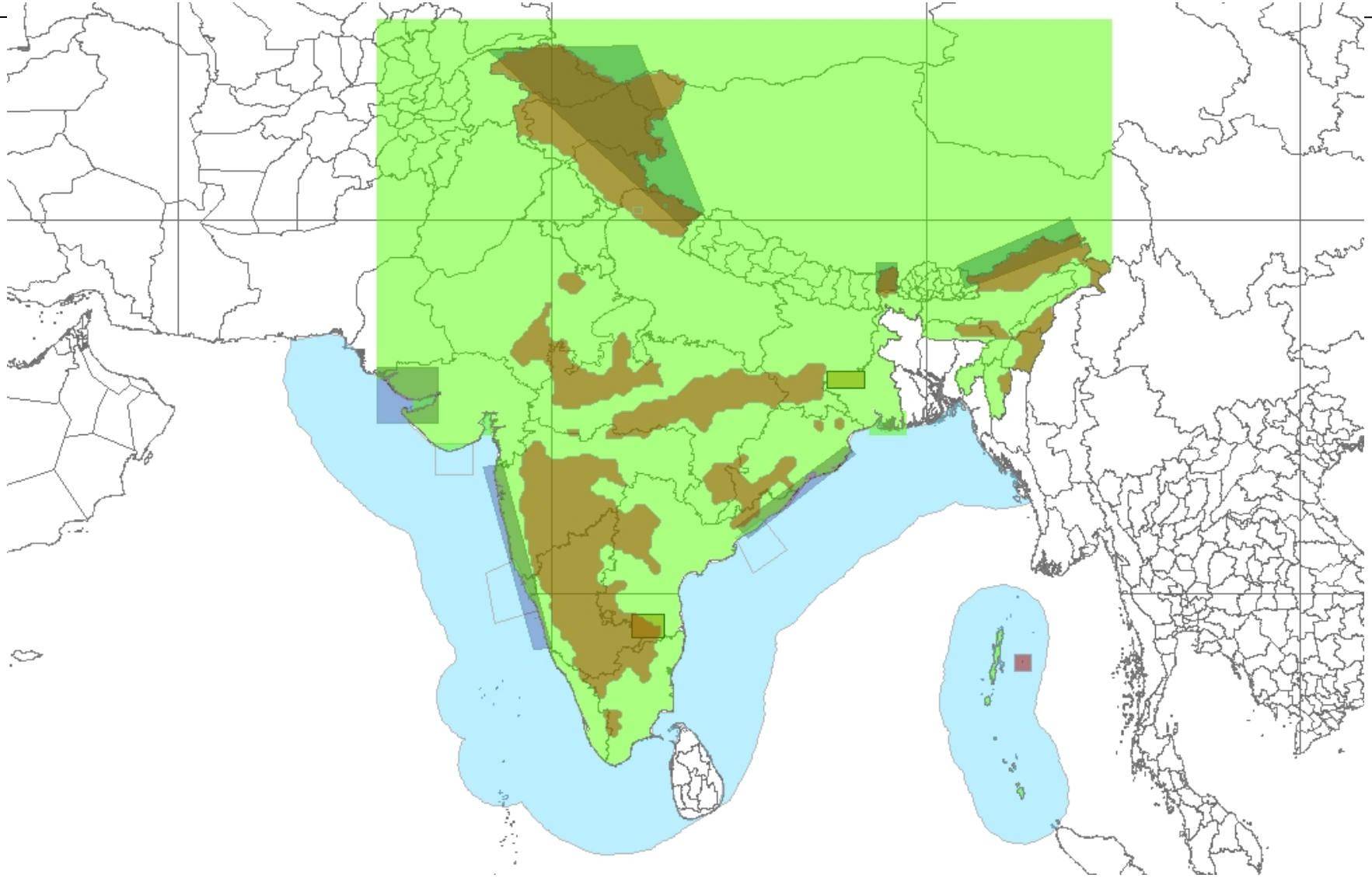
L-Band Ecosystems Science Targets



L-Band (blue) and S-Band (purple) Ice Science Targets



S-Band Non-Ice Targets



Primary SAR Instrument Modes

- DSI-I12S-4g14-018 / 13 June 2013

	Science					Performance		Resources		
Mode #	Primary Science Target (backscatter)	Freq Band	Polarization	BW [MHz]		PRF [Hz]	PW [µs]	DC Power [W]	S-SAR DC [W]	Data Rate [Mbps]
1	Solid Earth - Deformation *(soil)*	L	SP HH	20+5		1650	25	833	timeline-dependent heater only	333
1	Dynamics of Ice - Land Ice	L	SP HH	20+5		1650	25	833		330
4	Dynamics of Ice - Priority Ice	L	SP HH	80		1650	40	931		1052
5	Dynamics of Ice - Sea Ice	L	SP VV	5		1650	20	801		72
7	Ecosystem Structure *(shrubs)*	L	QP HH/HV/VH/VV	40		1550*	40	1237		1835
8	Ecosystem Structure *(shrubs)*	L	Quasi-Quad	40+40		1650	40	1270		2092
10	Ecosystem Structure *(shrubs)*	L	DP HH/HV	40		1650	40	995		1052
11	Ecosystem Structure *(shrubs)*	L	CP RH/RV	40		1650	40	1270		1108
12	S-Band SE, ES, DI *(shrubs)*	S	Quasi-Quad	37.5		1800†	40	3144	2551	1939
13	S-Band Coastal Winds *(ocean)*	S	DPTx HH/VV	25		1850†	25	2488	1895	694
14	S-Band SE, ES, DI *(shrubs)*	S	CP RH/RV	25		1850†	25	2488	1895	694
15	Solid Earth - Deformation *(soil)*	L+S	L: DP HH/HV	40		1650^	40^	2763	1768	1524
			S: CP RH/RV	25			25			
16	Ecosystem Structure *(shrubs)*	L+S	L: QP	20		1500*^	25^	3670	2627	1984
			S: CP RH/RV	25						
? 17	Ecosystem Structure *(shrubs)*	L+S	L: QP	40		1500*^	40^	4994**	3774	4919
			S: Quasi-Quad	37.5			40			

Max Power primary mode

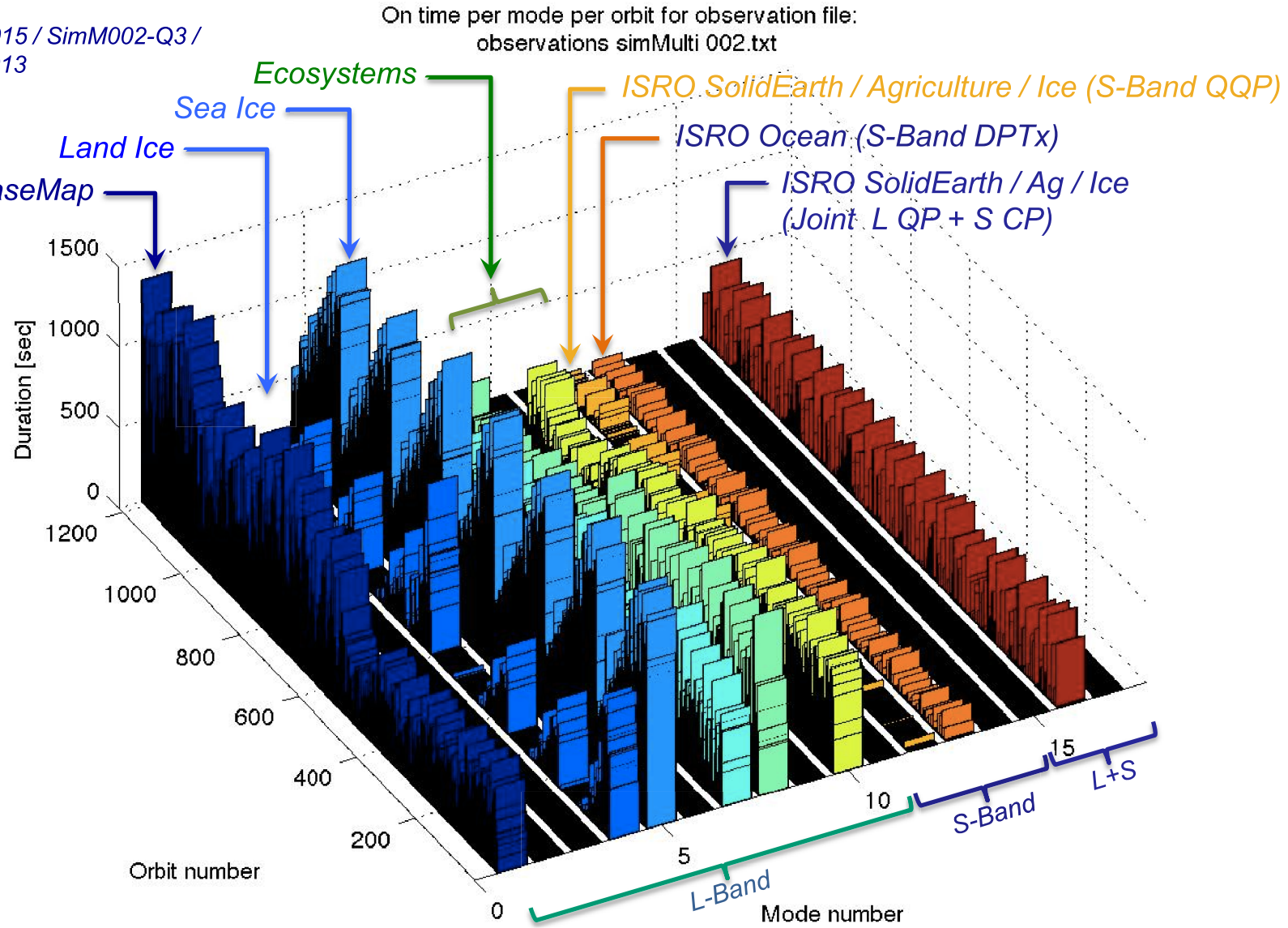
notes:
* PRF is per each Tx polarization; for Quad-Pol or Dual Co-Pol with interleaved Tx, effective timing is 2 x PRF
^ for joint dual-frequency modes, L-Band and S-Band must use a common PRF and blanking PW
† PRF selected by JPL performance tool to maximize swath; SAC may change to different value based on their performance criteria
** to be assessed relative to available peak power from S/C Power Subsystem

nominal modes for Multi-Mode mission simulation scenario; *changes for sim003 (pseudo-sim002.5) in red*

nominal modes for Radar Always-On reduced-mode mission simulation scenario

Mode Profile for Nominal Science Operations

- *DSI-I12S-4g8-015 / SimM002-Q3 / SDT 17 May 2013*

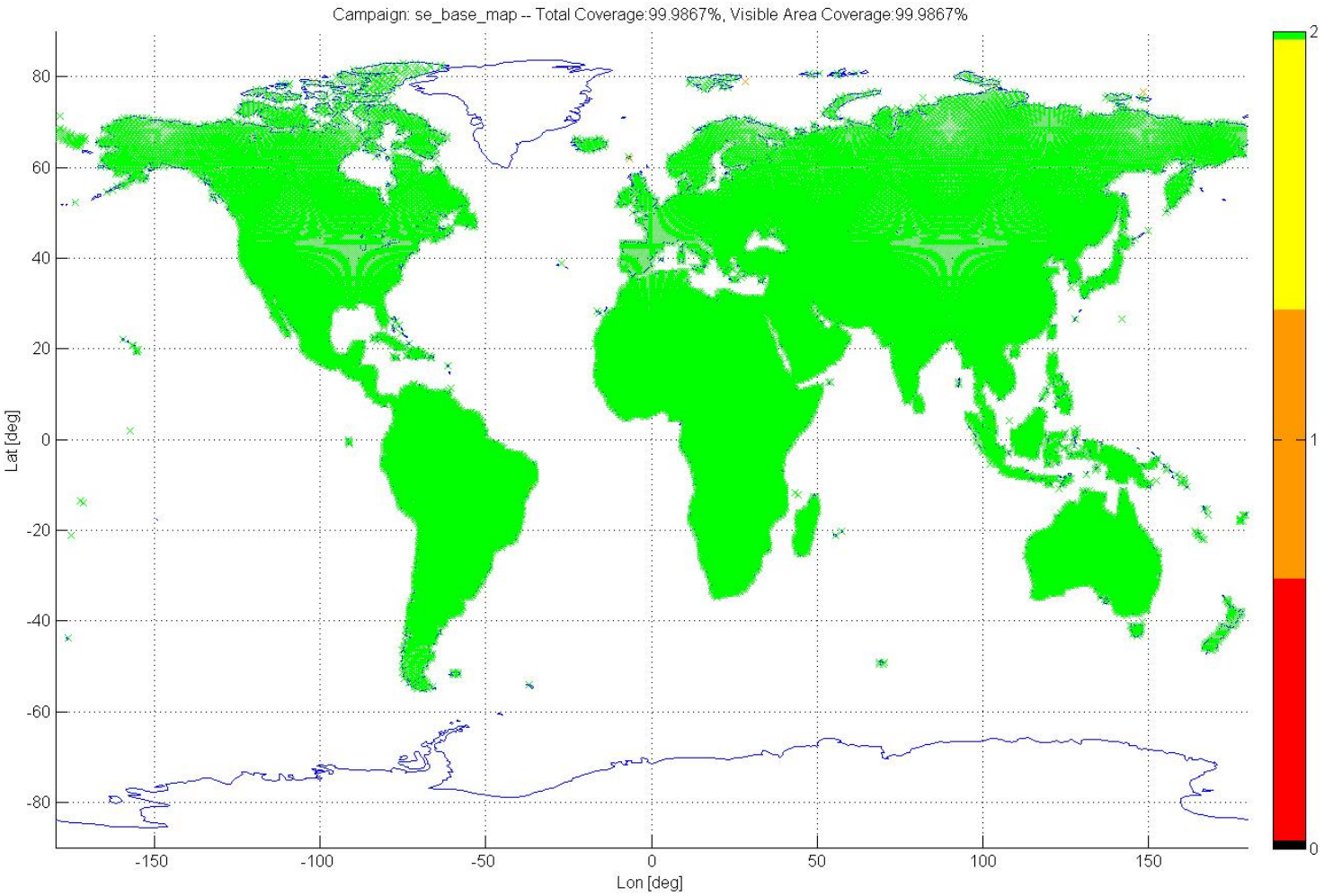


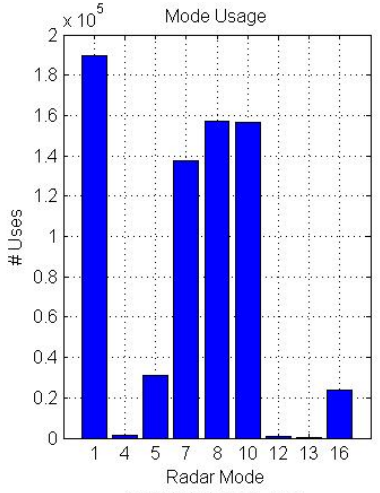
Summary and Next Steps

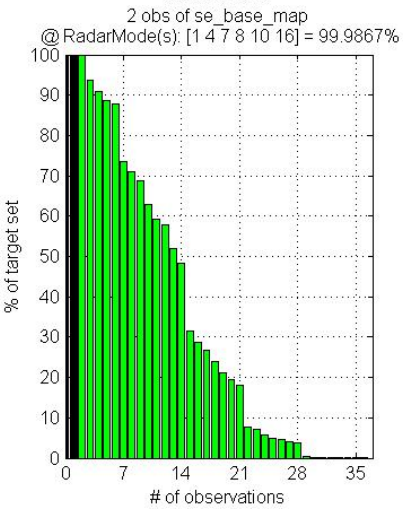
- The NASA-ISRO mission concept could be an exciting addition to the international constellation of SAR missions
  - Reliable, regular, and frequent L-band observations
  - Free, open access to data
  - Dense temporal and spatial sampling over the globe
  - Additional S-band data to extend the range of sensitivity in critical areas
- Project preparing for a Mission Concept Review in Fall 2013
- If successful, partnership approach would be developed in Phase A

Backup

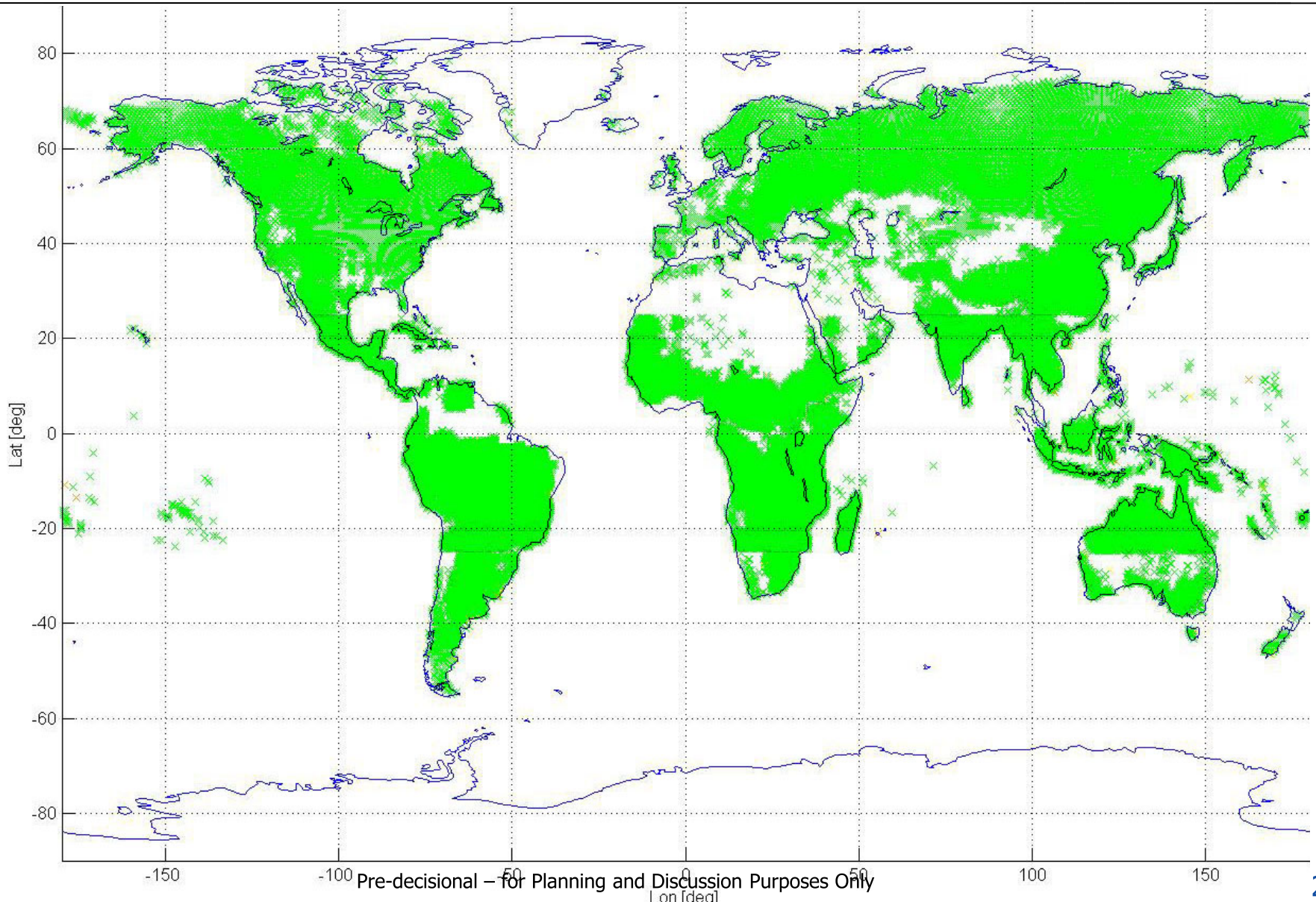
L-Band: Base Map Coverage Summary– 100%



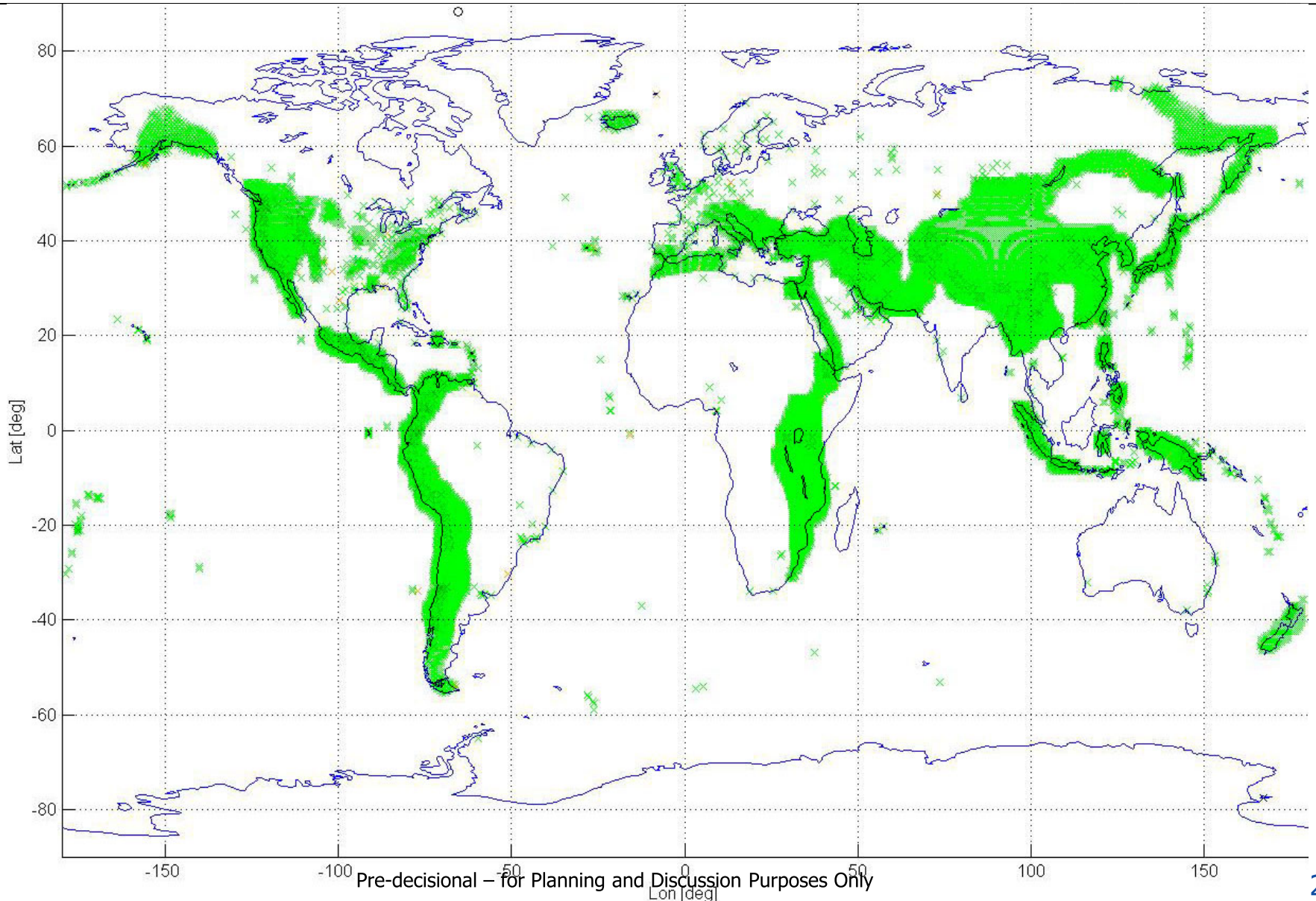




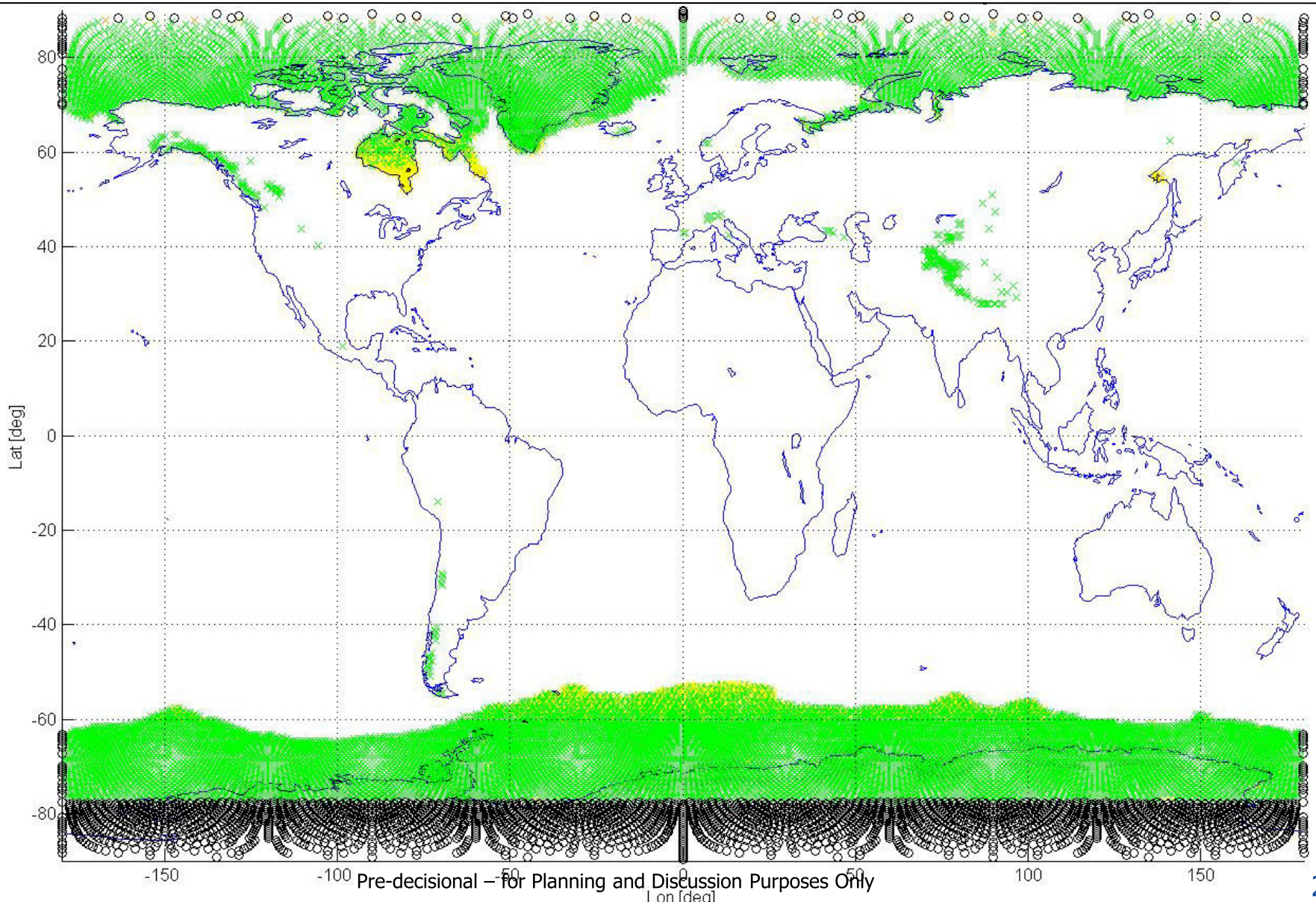
L-Band: Ecosystems Coverage Summary – 100%



L-Band: Deformation Coverage Summary – 100%



L-Band: Ice Coverage Summary – 88-100%



S-Band: Coverage Summary – 100%