Monitoring The Changing Earth From Space

A Joint NASA-ISRO Radar Mission Concept for a Dynamic Planet

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California Institute of Technology

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Monitoring the Changing Earth from Space
Outline

- A bit of background on the speaker and on radar at JPL
- Video introducing the NASA-ISRO radar mission concept
- Science/Applications benefits to society
- Mission design and other cool stuff
- Conclusion

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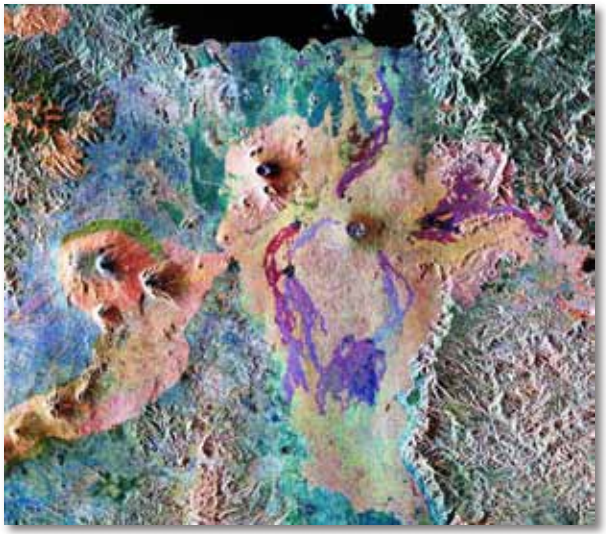
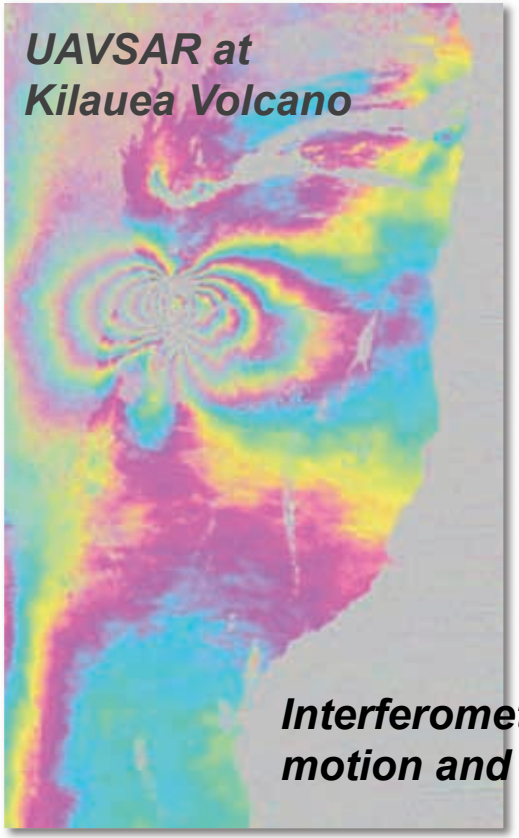
SAR Extends Imagery Beyond the Visible Spectrum

SAR observations allow us to experience the Earth in a fundamentally different light, day or night, independent of cloud cover

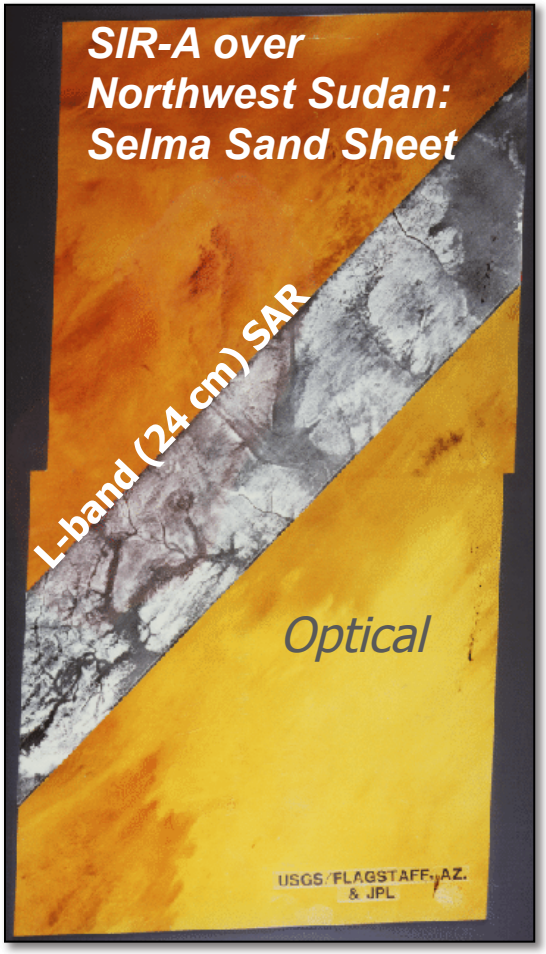
SIR-C over Africa



Polarization and frequency diversity to characterize surfaces and measure moisture



Interferometry to measure motion and surface change



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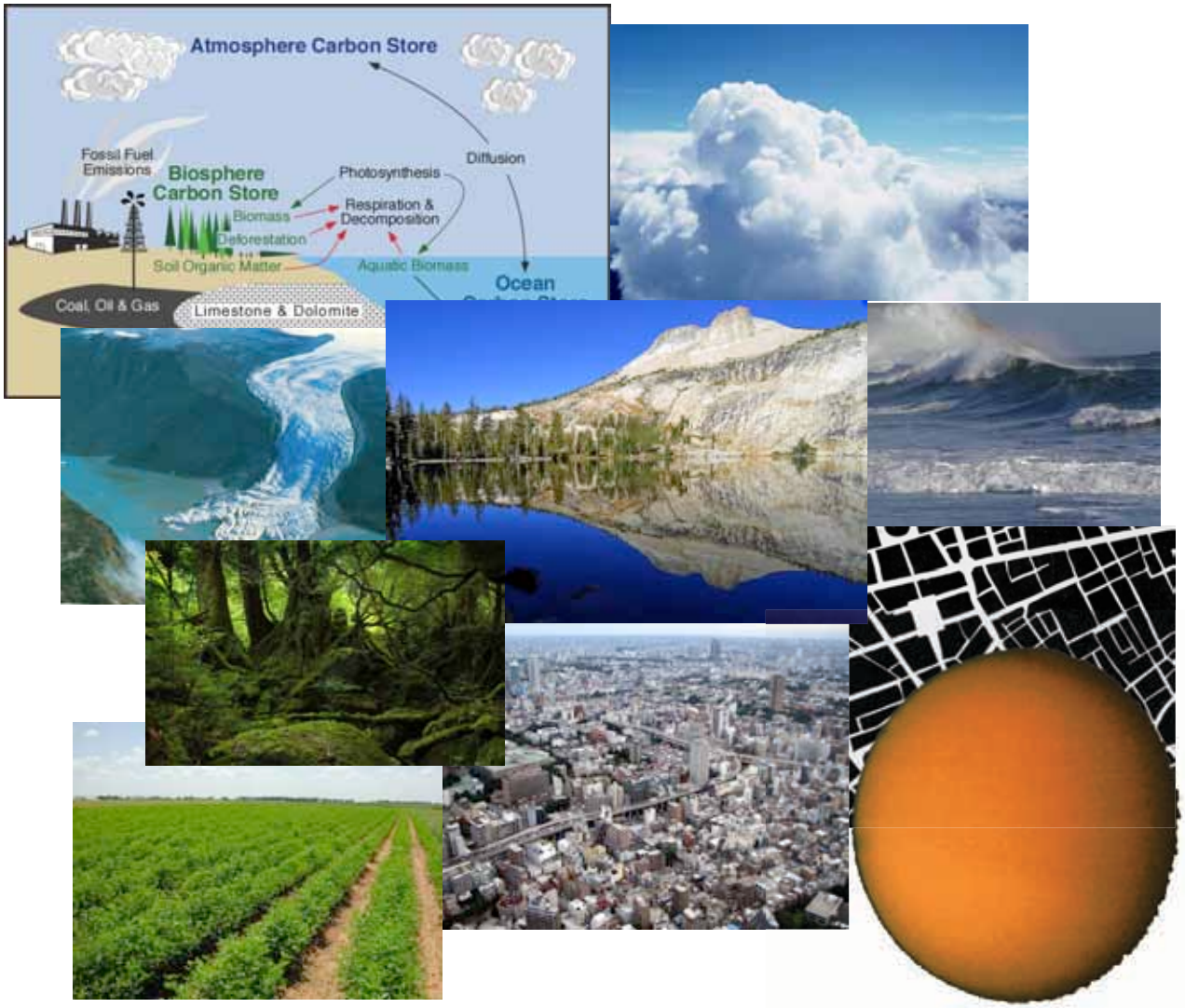
Radar Applies Across a Broad Set of Disciplines

- Topography
- Geography
- Chemistry
  - Composition
  - Phase
- Dynamics
  - Thermo-
  - Hydro-
  - Geo-
  - Bio-



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Gallery of JPL Missions

Also: Galex 2003 MMM 2008 Diviner 2009 Kepler 2009 Herschel 2009

Grail
Sep 2011
Moon Gravity

Juno
August 2011
Jupiter

NuSTAR
June 2012
High Energy X-ray

Mars Science Lab
August 2012
Curiosity Rover

Aquarius/SAC-D
June 2011
Sea Salinity

Explorer 1-5
1958
Van Allen Belts

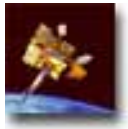
Ulysses
1990
Solar Polar Orbit

Microwave Instrument
2004
Rosetta Comet Orbiter

MARSIS
2003
Deep Sounder

Spitzer Telescope
2003
Infrared Telescope

Seawinds
2002
Ocean Winds



Pioneer 3-4
1958
Lunar Flybys

Wide Field Camera
1990
Fix Hubble

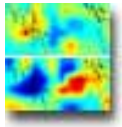
Mars Rovers
2003
Rovers

Genesis
2001
Solar Wind
Samples

Rangers
1961-1965
Lunar Surveys

Topex/Poseiden
1992
Ocean Altimeter

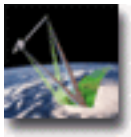
Emission Spectrometer
2004
Infrared Sensor



Microwave Sounder
2004
Ozone

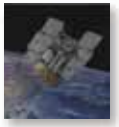
AIRS
2002
Infrared Sounder

SRTM
2000
Earth Radar



Surveyors
1966-1968
Lunar Landers

Global Surveyor
1996
Mars Orbiter



Grace
2002
Earth Gravity

Deep Space 1
1998
Ion Engine

Mariner 1-2
1962
Venus Flybys

Cassini
1997
Saturn & Moons

Deep Impact
2005
Smash Comet
EPOXI

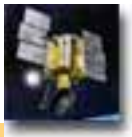
MRO
2005
SHARAD

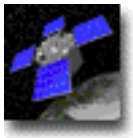
Cloudsat
2006
Precipitation

Jason 1
2001
Ocean Altimetry

VLBI
1997
Astronomy

Mariner 3-4
1964
Mars Flybys





Pathfinder
1996
Mars Rover

Mariner 5
1967
Venus Flyby

Stardust
1999
Comet Wild-2

Quickscat
1999
Sea Winds

Radiometer
1999
Earth Thermal

Multi-Angle Spect
1999
Earth Imaging

Active Cavity
1999
Solar Radiance

Keck
2001
Astronomy

Mars Odyssey
2001
Mars Imaging

NSCAT
1996
Earth Winds

Mariner 6-7
1969
Mars Flybys

Mariner 8-9
1971
Mars Orbiter

Mariner 10
1973
Venus / Merc

Viking
1975
Mars Landers

Voyager
1977
Grand Tour

Seasat
1978
Earth Radar

Solar Explore
1981
Earth Ozone

SIR A, B, C
1981, 84, 94
Earth Radar

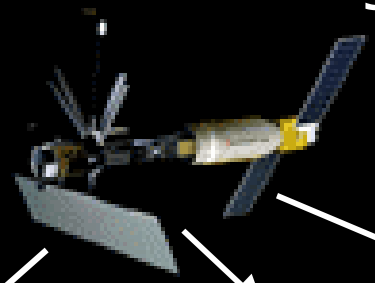
Infrared Sat
1983
Telescope

Magellan
1989
Venus Radar

Galileo
1989
Jupiter

Mars Observer
1992
Mars Orbiter

How it began in Space … The Legacy of SeaSat



ALTIMETER

TOPEX / Poseidon (1992)

Jason -1 (2001)

Ocean Surface Topography Mission: (2008)

SCATTEROMETER

NSCAT (1996)

QuikSCAT (1998)

SeaWinds (2002)

Ocean Vector Wind Measurement: (~2014)

RADIOMETER

Sea Surface Salinity: Aquarius (2009)

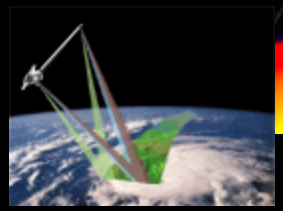
Soil Moisture & Freeze/Thaw: SMAP (~2015)

SYNTHETIC APERTURE RADAR

SIR -A (1981)
SIR -B (1984)
SIR -C (1994)

Magellan (1989)
Cassini (1997)

SRTM (2000)



L-Band InSAR (Proposed)

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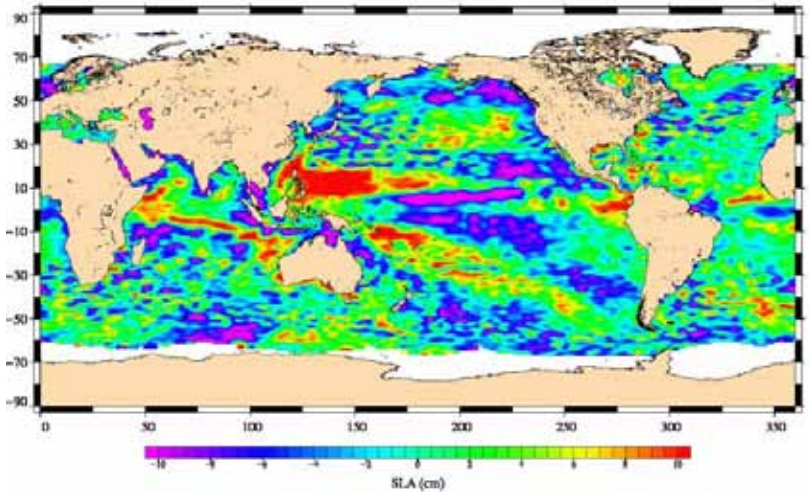
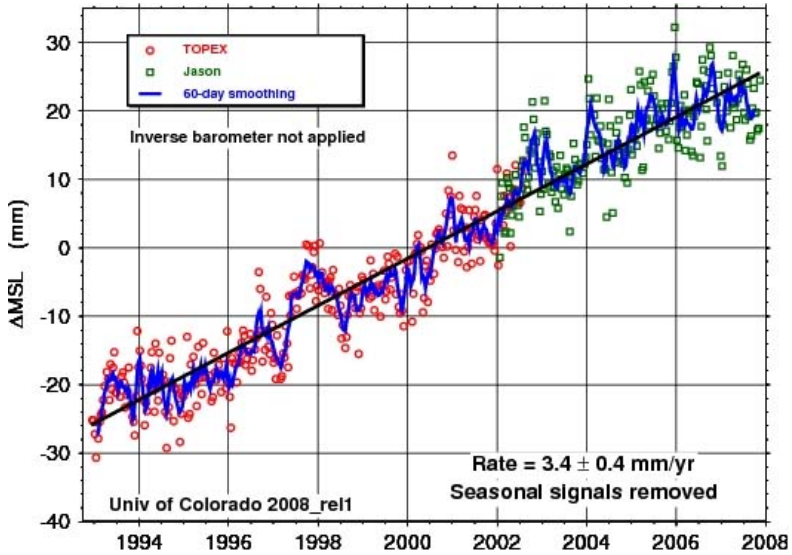
TOPEX-Jason 1-OSTM Altimetry



Less than a month after launch, the NASA-French space agency Ocean Surface Topography Mission (OSTM)/Jason 2 oceanography satellite produced its first complete maps of global ocean surface topography, surface wave height and wind speed



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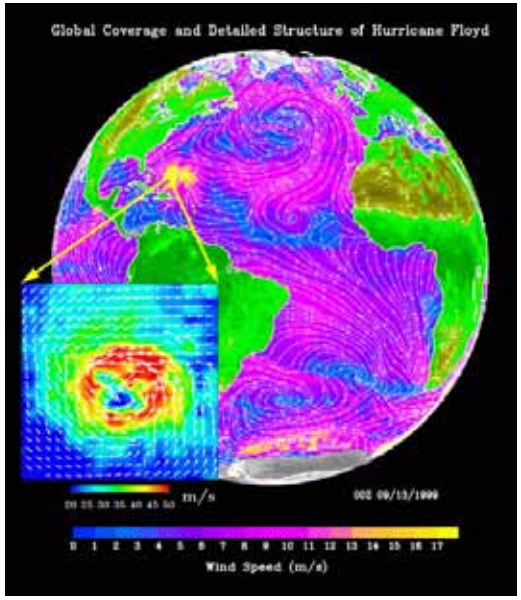
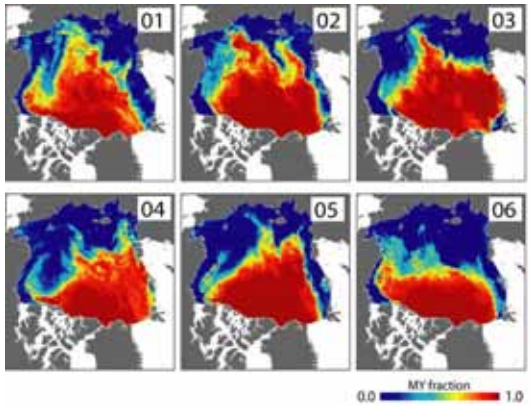
Scatterometers for Ocean Wind

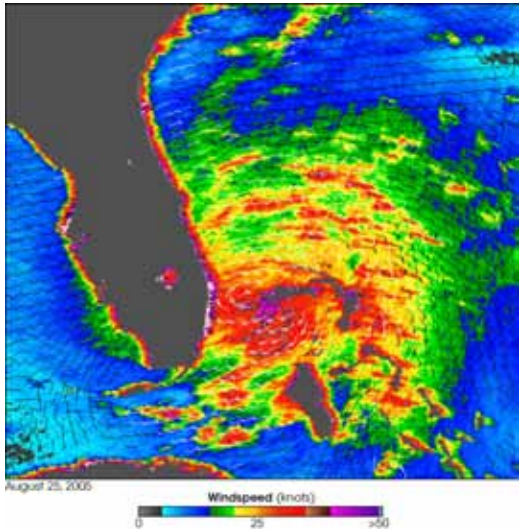
- *Scatterometers* are radar instruments that measure the reflective properties of the Earth's surface
- Winds roughen the sea, so radar reflectivity can be used to estimate wind speed
- Also useful for ice tracking, ice melting, salinity, soil moisture and other applications

Seawinds on QuikSCAT



Future Mission: Dual-frequency concept





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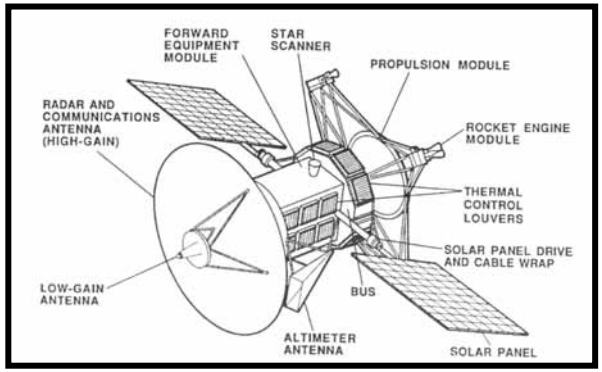
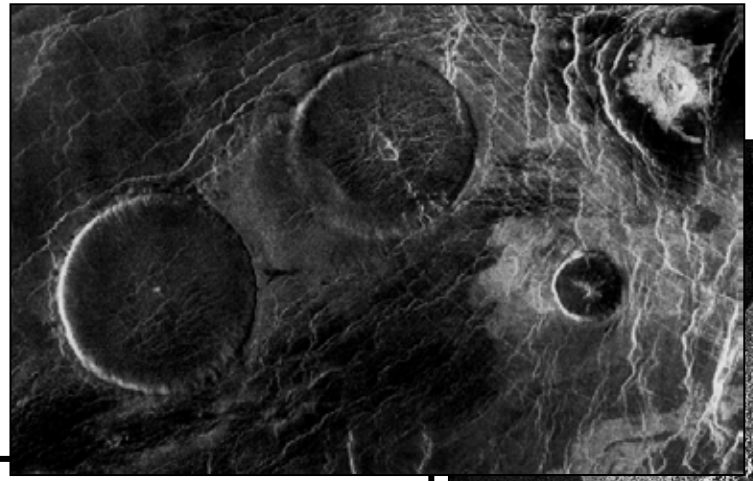
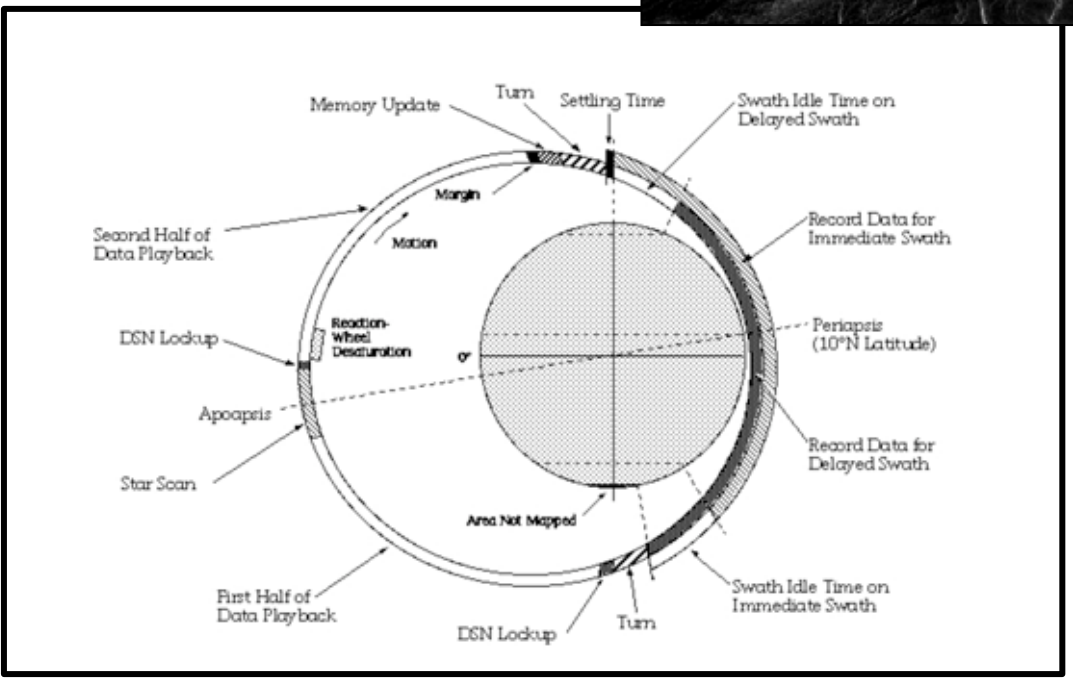
Magellan Radar Mission to Venus





Radar **to image through clouds**



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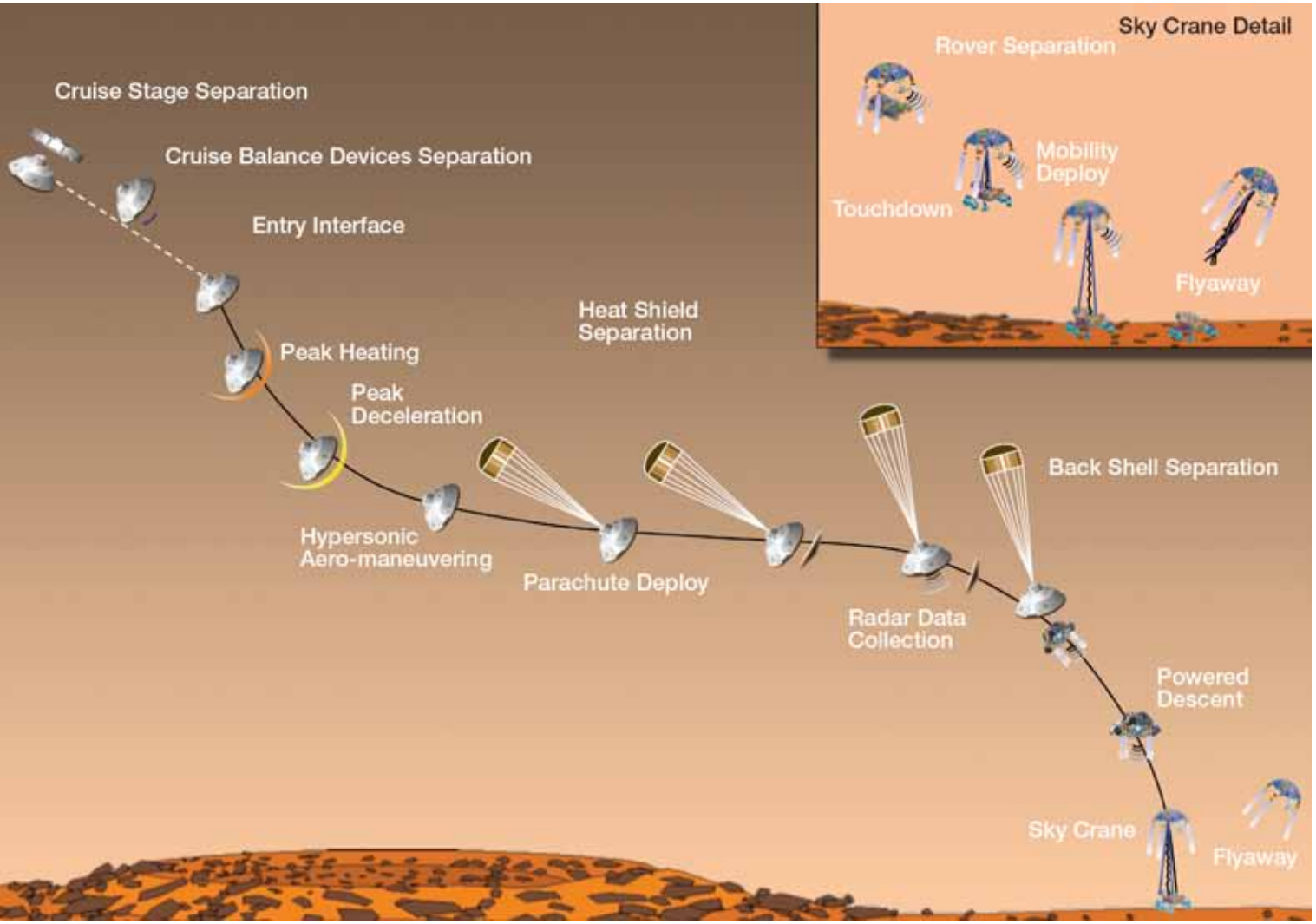
Timeline of Major Mission Events During Curiosity's August 5, 2012 Landing



Time Event Occurrence Received on Earth (PDT)

[10:24:33.8 PM] Atmospheric Entry

[10:28:53.0 PM] Parachute Deploy

[10:29:12.7 PM] Heat Shield Separation

[10:31:26.7 PM] Rover Separation (from Descent Stage)

[10:31:45.4 PM] Touchdown

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Introduction to Monitoring the Changing Earth

National Aeronautics and Space Administration
Indian Space Research Organisation (ISRO)

The NASA–ISRO SAR (NISAR) Mission Concept

Approved for unlimited release CL# 13-4886
Eric M. De Jong, Paul A. Rosen, Yunjin Kim, Michael Stetson, Koji Kuramura, Jason Craig,
Vince J. Realmuto,Peter Xaypraseuth, Russell H. Segawa, Louise A. Veilleux, Ryan J. Ollerenshaw, Shigeru Suzuki,
Solar System Visualization Project, Jet Propulsion Laboratory, California Institute of Technology.

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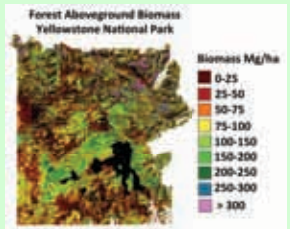
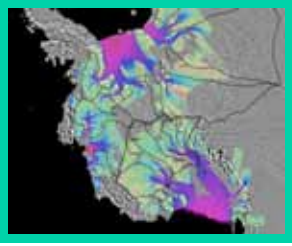
Science & Applications to Implementation

Ecosystems



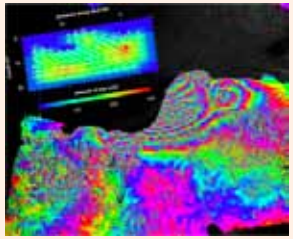
- Biomass, disturbance,
- Effects of changing climate on habitats and CO_2
- Agriculture

Ice Dynamics



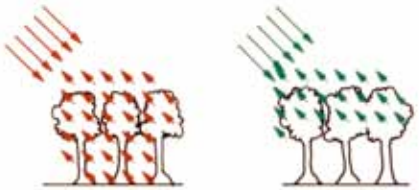
- Ice velocity, thickness
- Response of ice sheets to climate change & sea level rise

Solid Earth

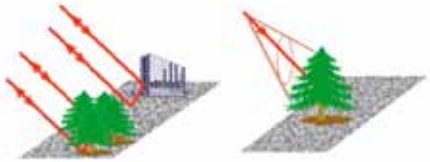


- Surface Deformation,
- Hazards Response,
- Water Resource Management

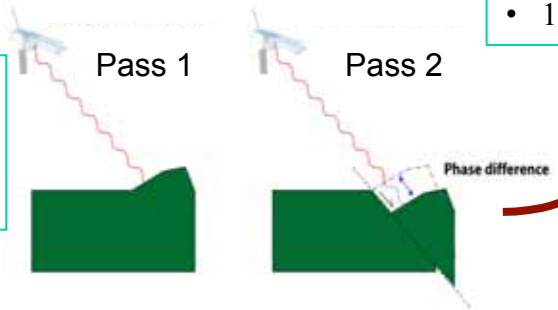
L- and S-band Wavelength

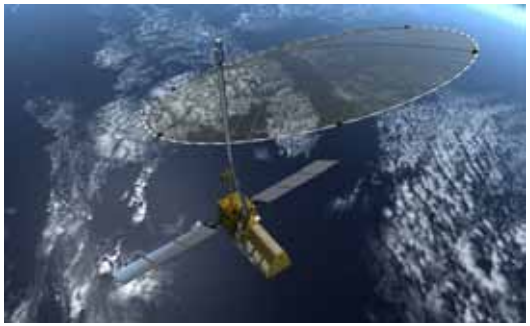


Polarimetry



Repeat Pass InSAR





Mission Concept:
- L- and S-band SweepSAR with a large reflector
- 747km altitude, circular, 98 degrees inclination, sun-synchronous, dawn-dusk (6 AM-6PM)
- 12-day repeat

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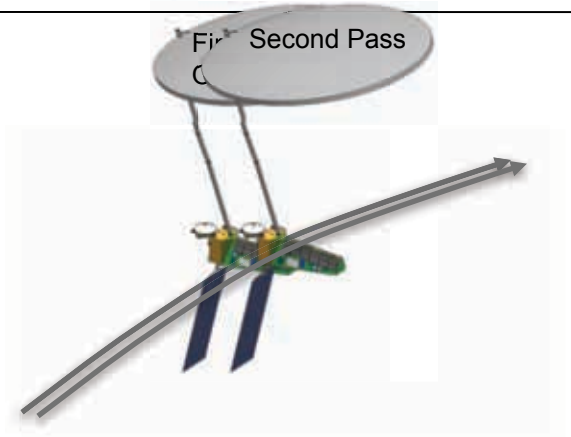
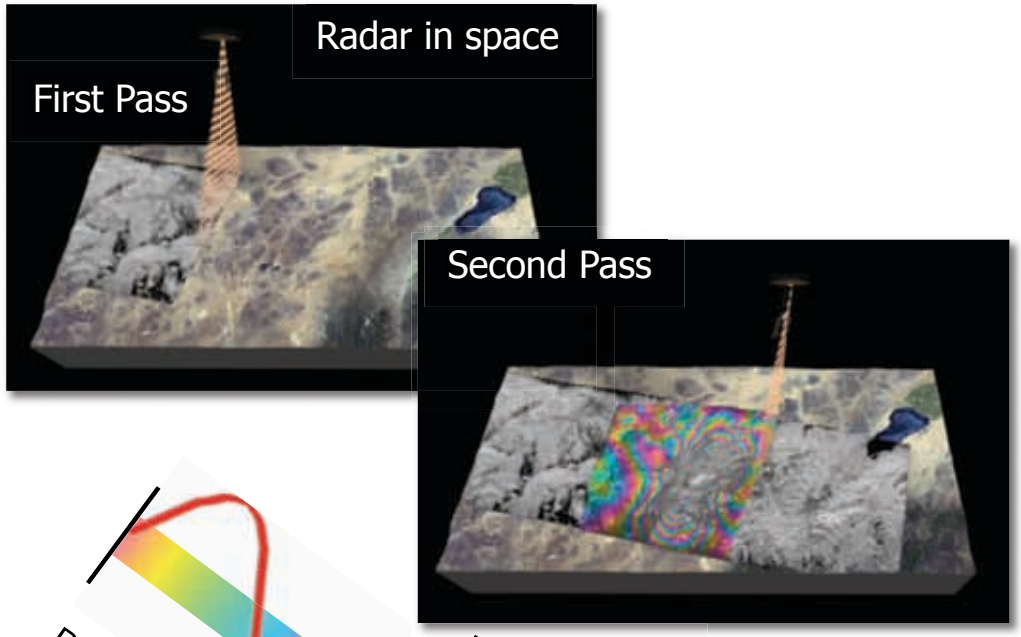
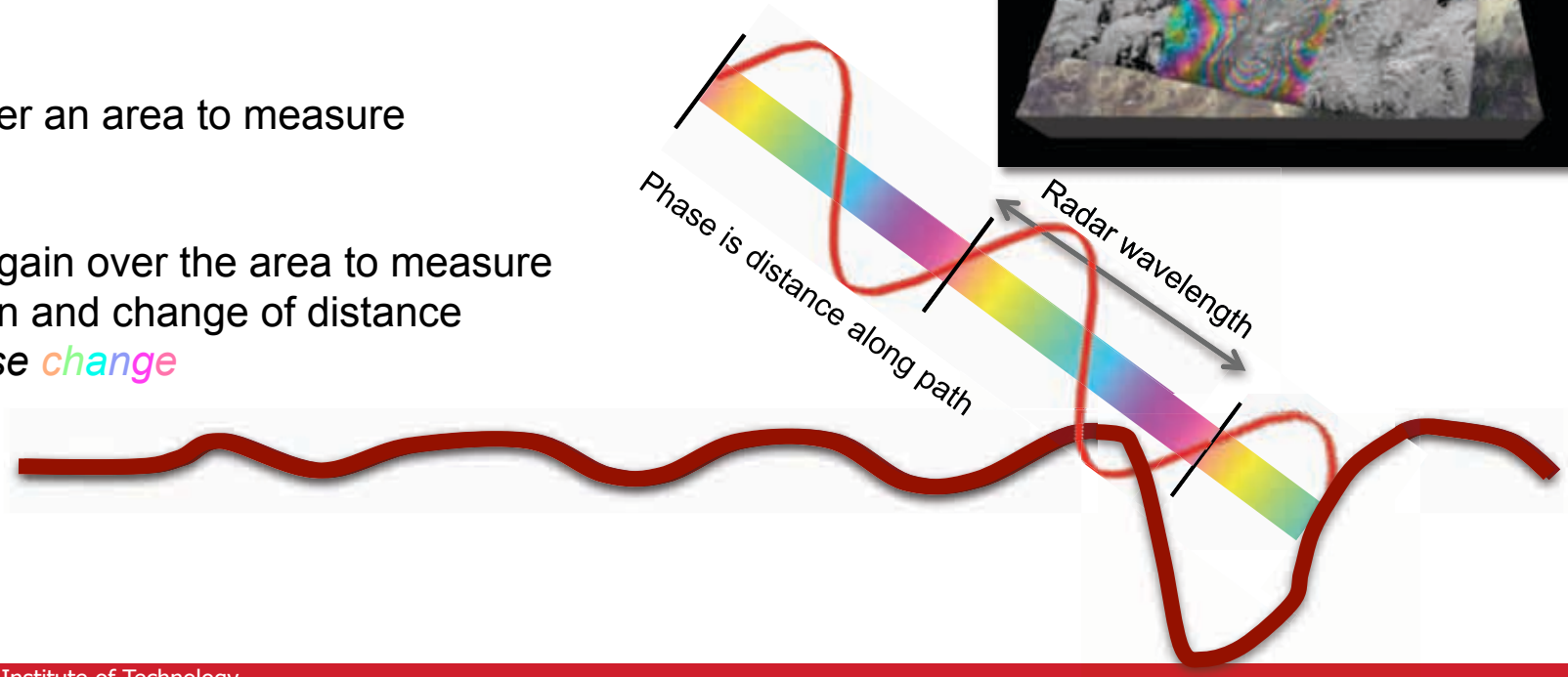
Interferometry for Measuring Surface Movement





Radar flies over an area to measure reflection

Radar flies again over the area to measure new reflection and change of distance through *phase change*



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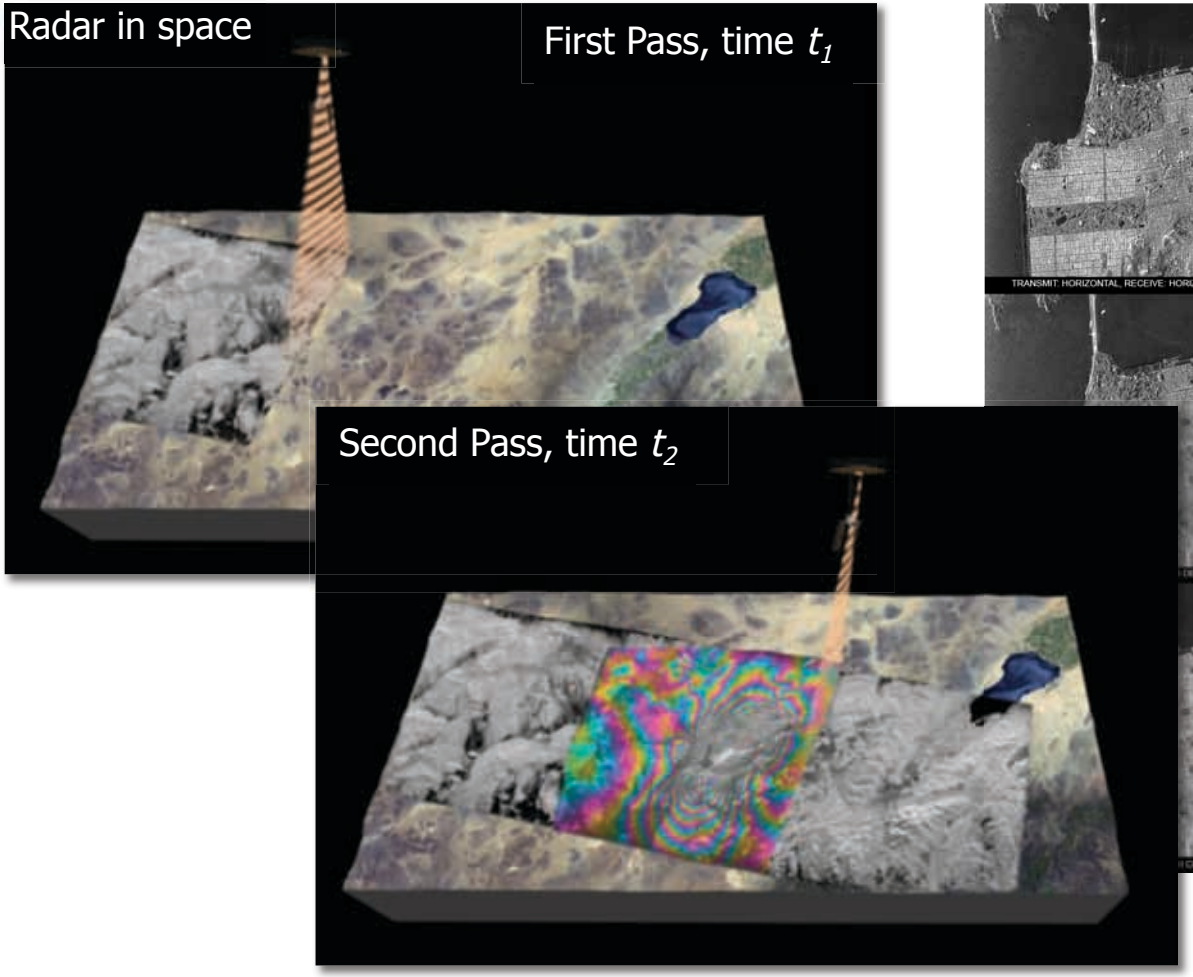
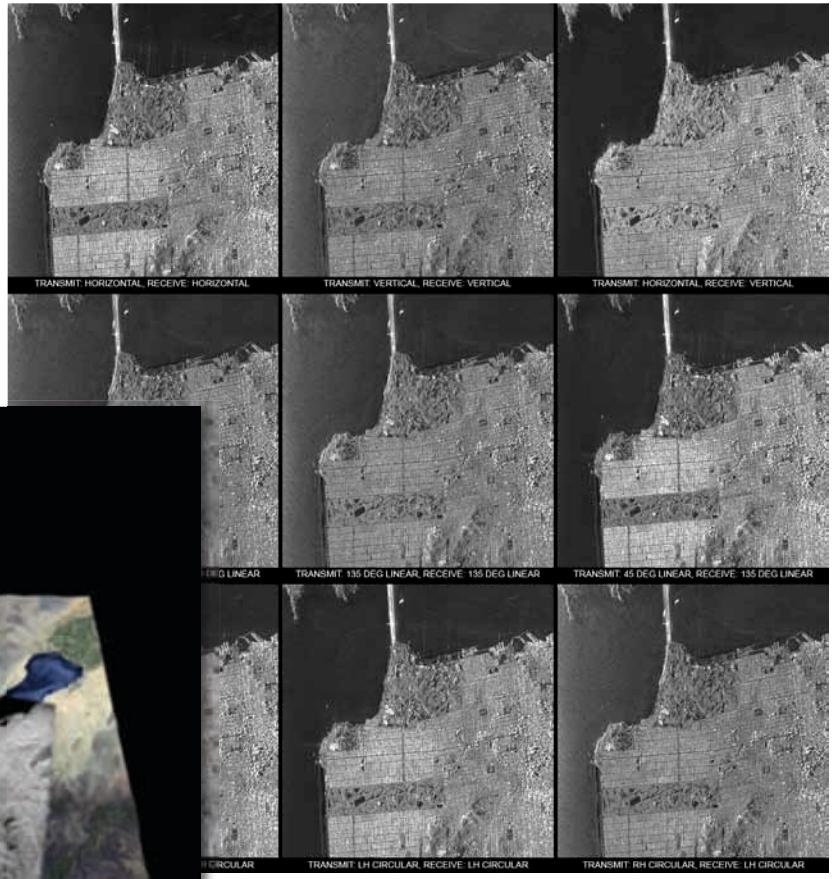
NI-SAR Measurements to Achieve Science Objectives

Repeat Pass Interferometry



Polarimetric Diversity



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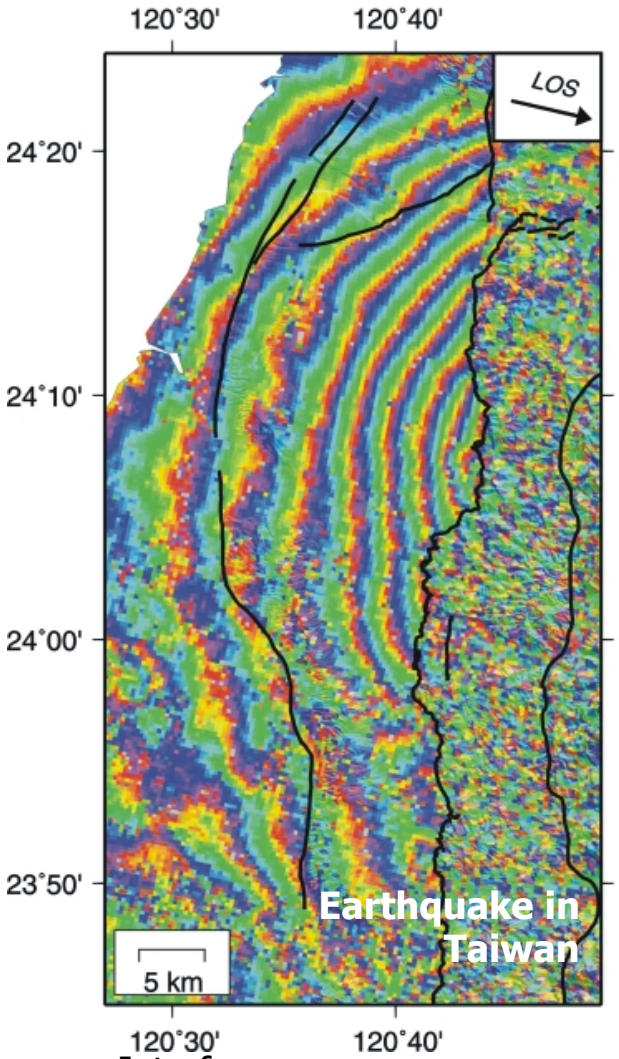
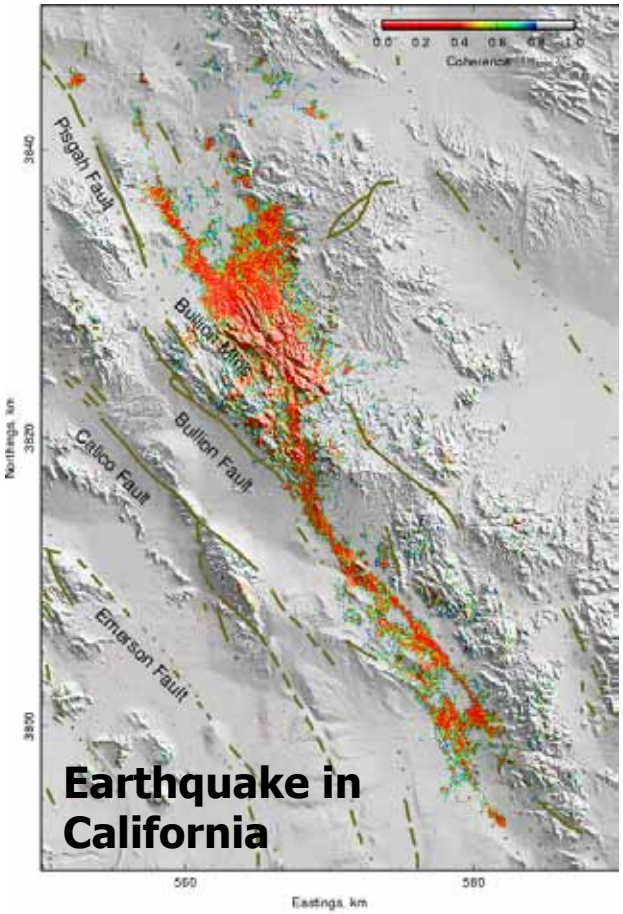
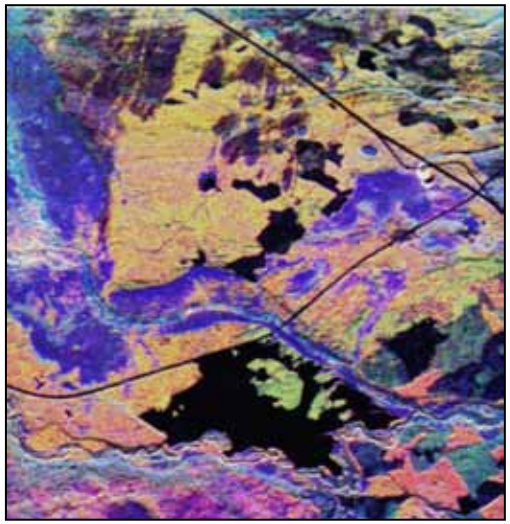
Basic Geodetic & Imaging Measurements



Interferogram –
How much motion?



Decorrelation –
How severe the change?



Polarimetry –
How much carbon?

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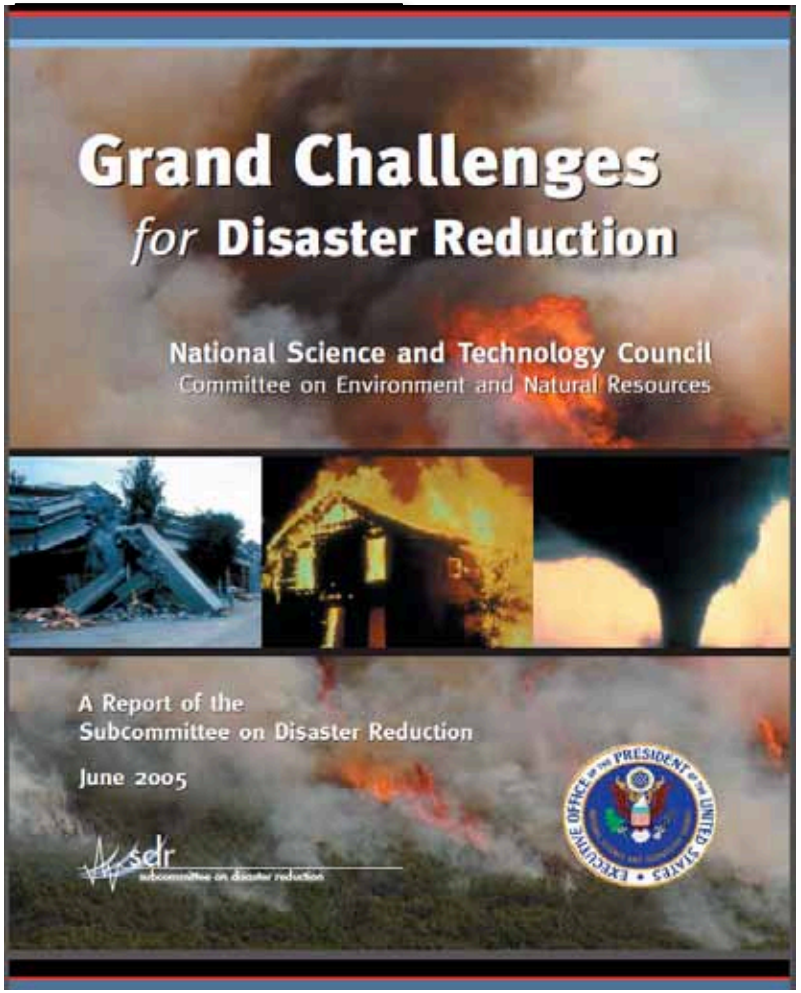
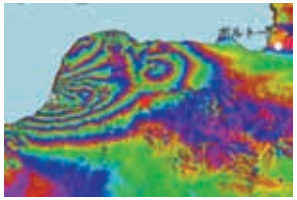
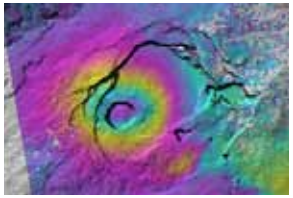
US and India Share Many Common Goals in Disaster Reduction and Mitigation

NI-SAR will support 9 of the 13 identified *Grand Challenge* hazards

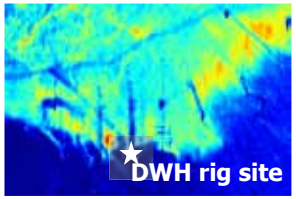




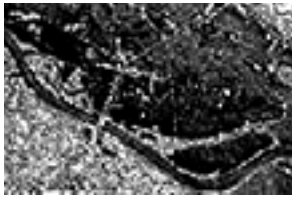
Earthquakes



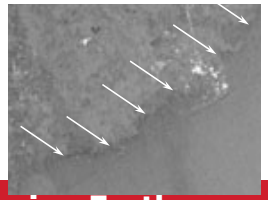
Volcanoes



Anthropogenic-Technological Disasters



Floods



Coastal Inundation

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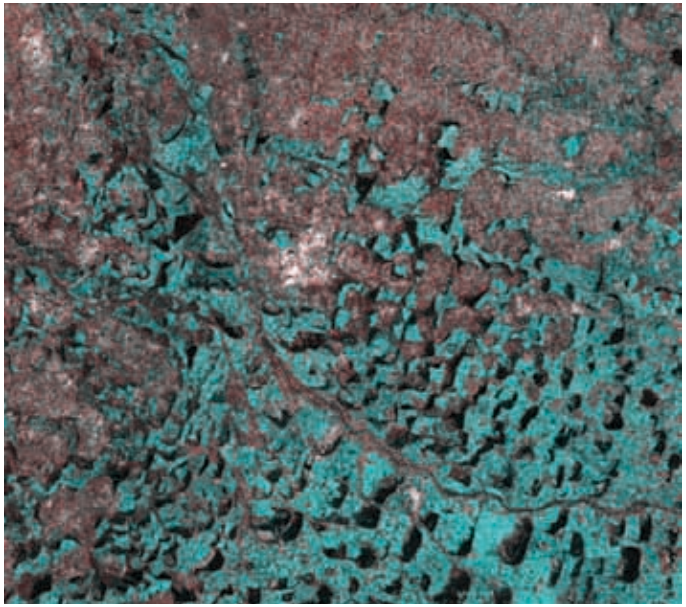
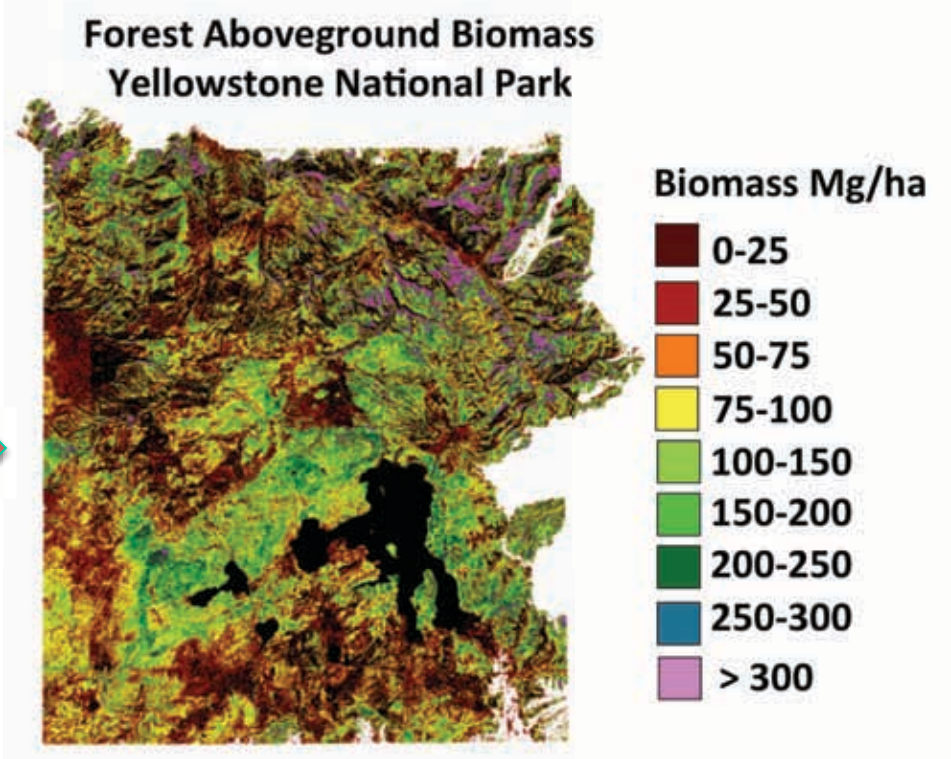
NASA-ISRO SAR Mission Extends India's Science and Applications Programs

- RISAT-1, India's first SAR Mission, is best suited to monitoring light (low biomass) crops.
- The NASA-ISRO SAR Mission extends these capabilities to heavier crops and regenerating forests



RISAT-1 C-band Two-date composite of Sivaganga Area of Tamil Nadu showing Samba rice area (cyan colour)



NASA-ISRO L/S-band SAR Mission would enable higher density biomass estimates

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Benefits of both US-contributed L-band SAR and India-contributed S-band SAR

- *Global* L-band data with unprecedented spatial and temporal sampling will drive new directions in science and applications
- *Globally distributed but targeted* S-band data for science applications would be a fundamentally new data set

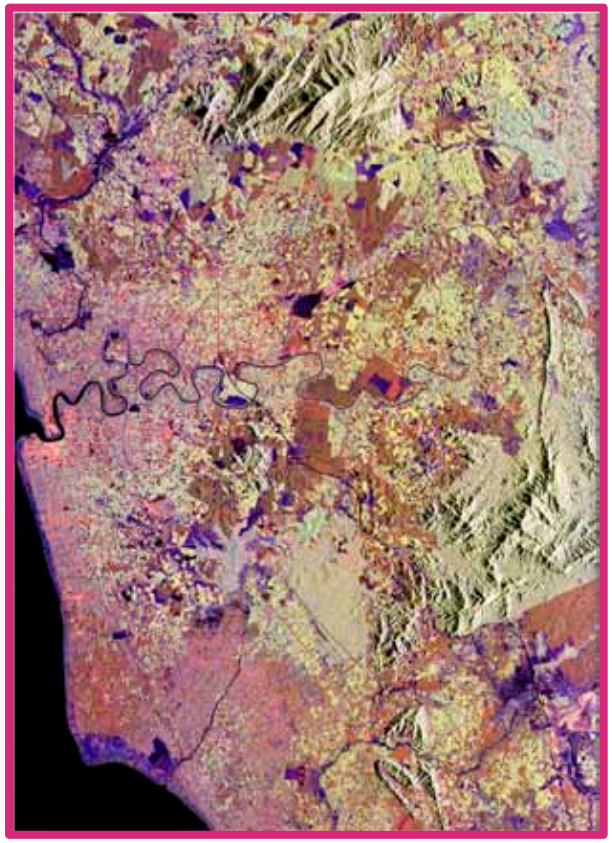
Wheat Fields,

Dnieper River, Ukraine

Red: LHH
Green: LHV
Blue: CHV

Rubber, banana, and oil palm trees,

Muar, Malaysia



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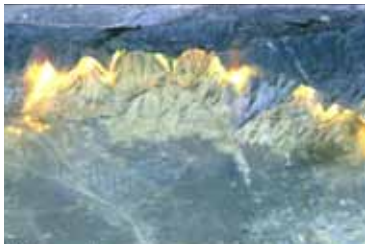
The NASA-ISRO SAR Mission Captures the Earth in Motion



- *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
    - Tracking evolving hazards
- C*omprehensive* 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

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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

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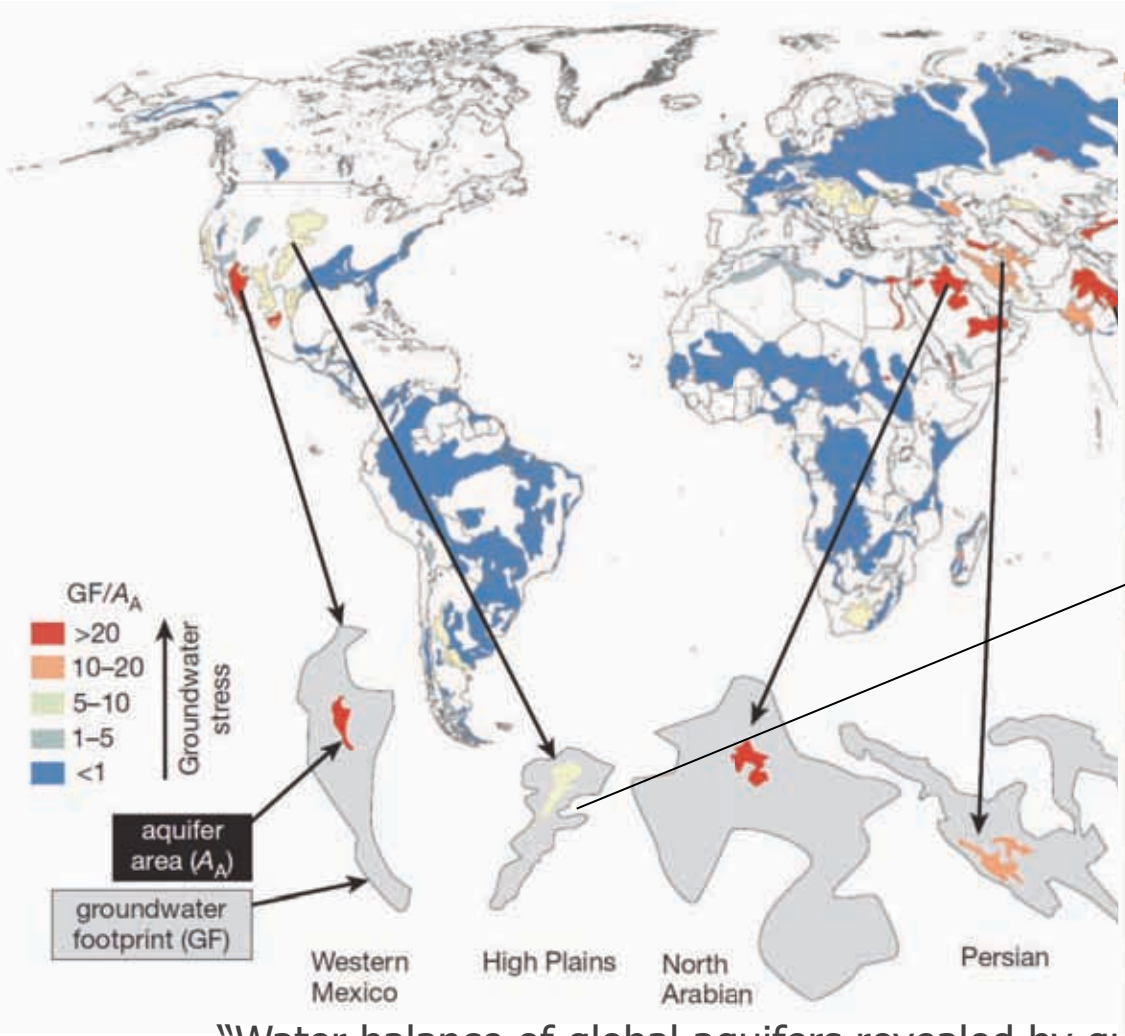
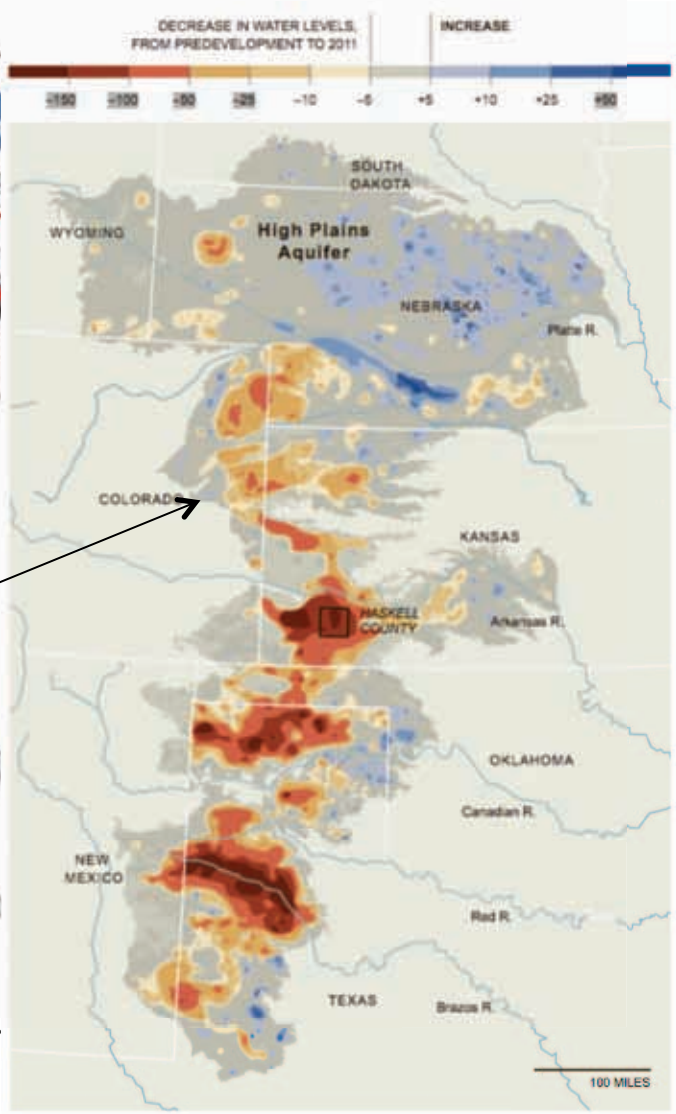
Locations of the World's Aquifers





"Water balance of global aquifers revealed by gr
Gleeson, T., et al. (2012) Nature 488, 197–200

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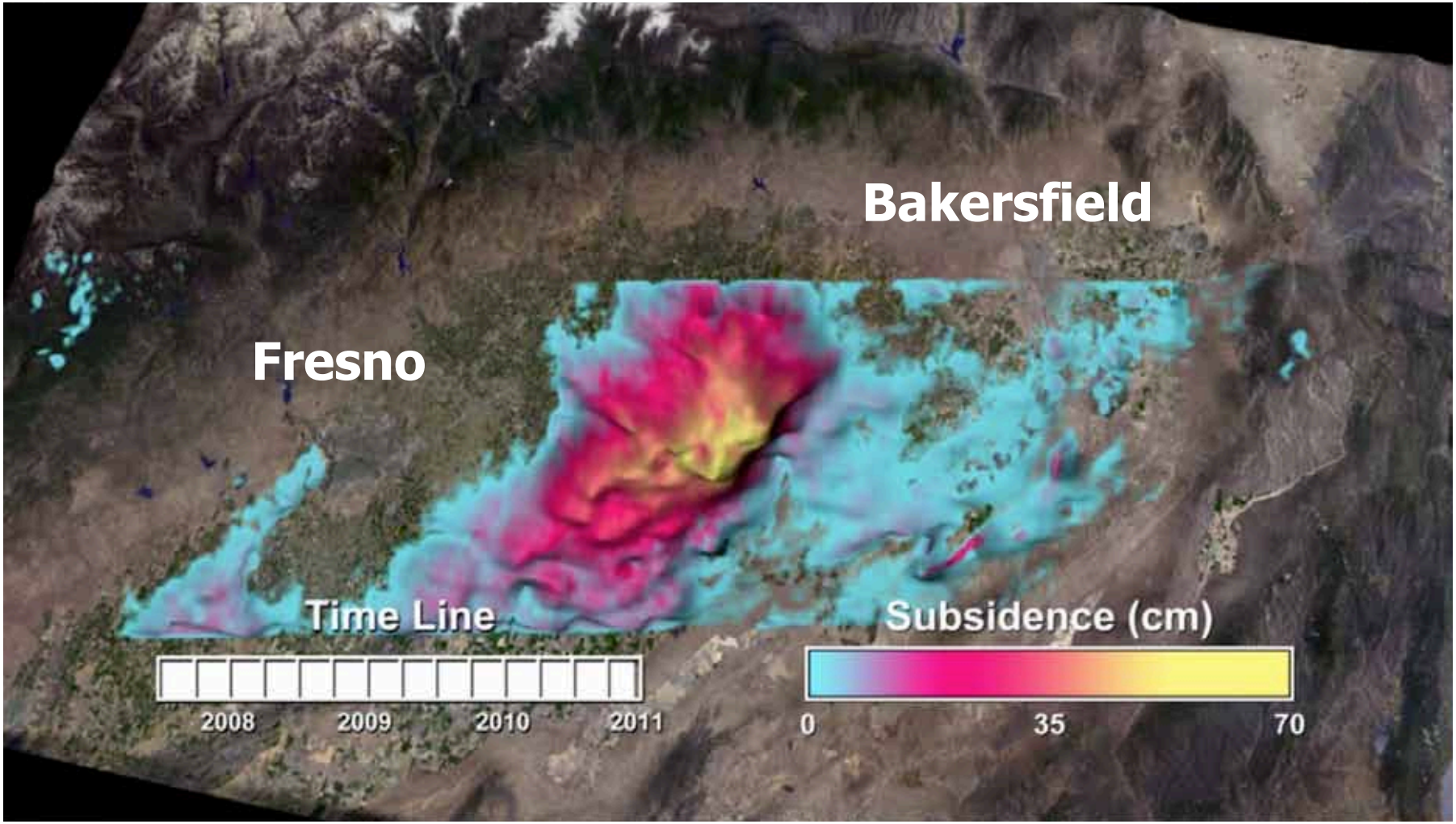
Measured Aquifer Depletion with Radar Time Series



Credits: InSAR analysis – Zhen Liu, Tom Farr (JPL); Visualization – Vince Realmuto (JPL)

http://photojournal.jpl.nasa.gov/catalog/PIA16293

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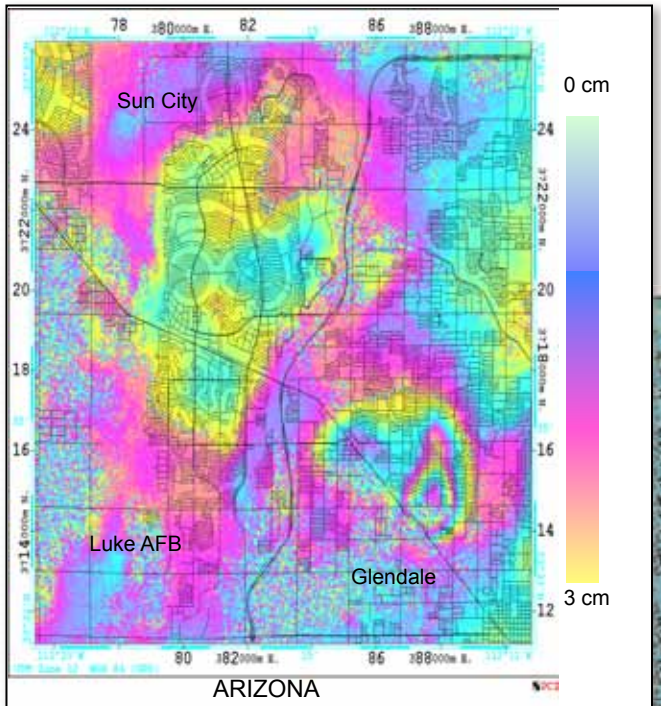
Subsurface Reservoirs & Subsidence

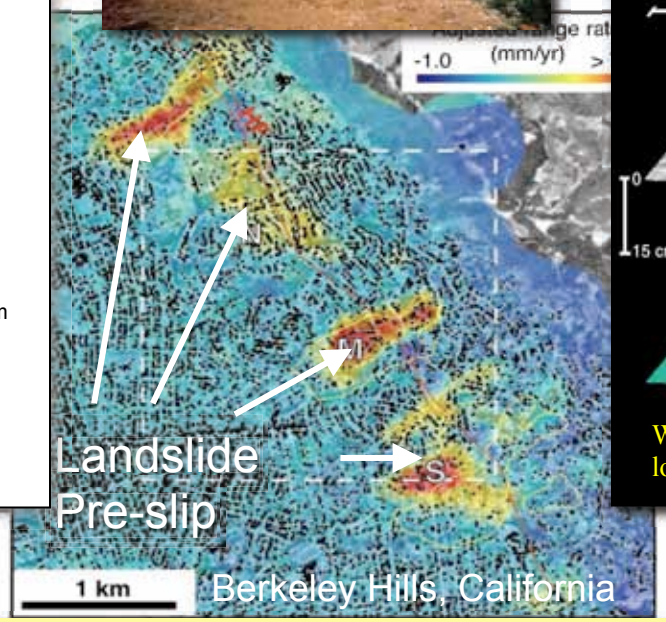
Water, Oil and Gas Resource Usage, Carbon Sequestration

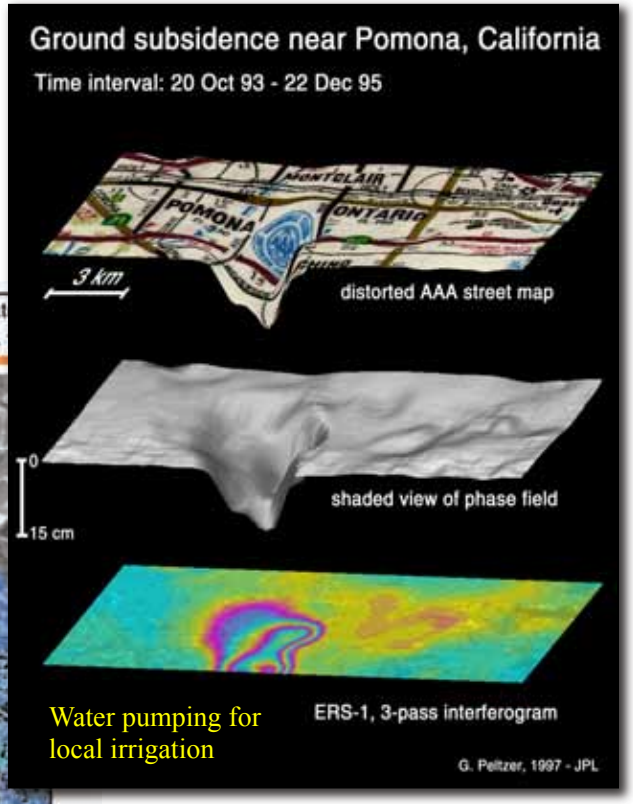


Produced by Vexcel Corporation under NASA's State & Local Partnership Program, John C. Stennis Space Center.

Water pumping for local irrigation

Oil subsidence management





Water pumping for local irrigation

- ***Radar can measure surface deformation over wide areas to characterize what is happening at depth and on the surface – withdrawal or replenishment of fluids and landslides – to provide new information to resource planners where little data exists at the regional scale.***

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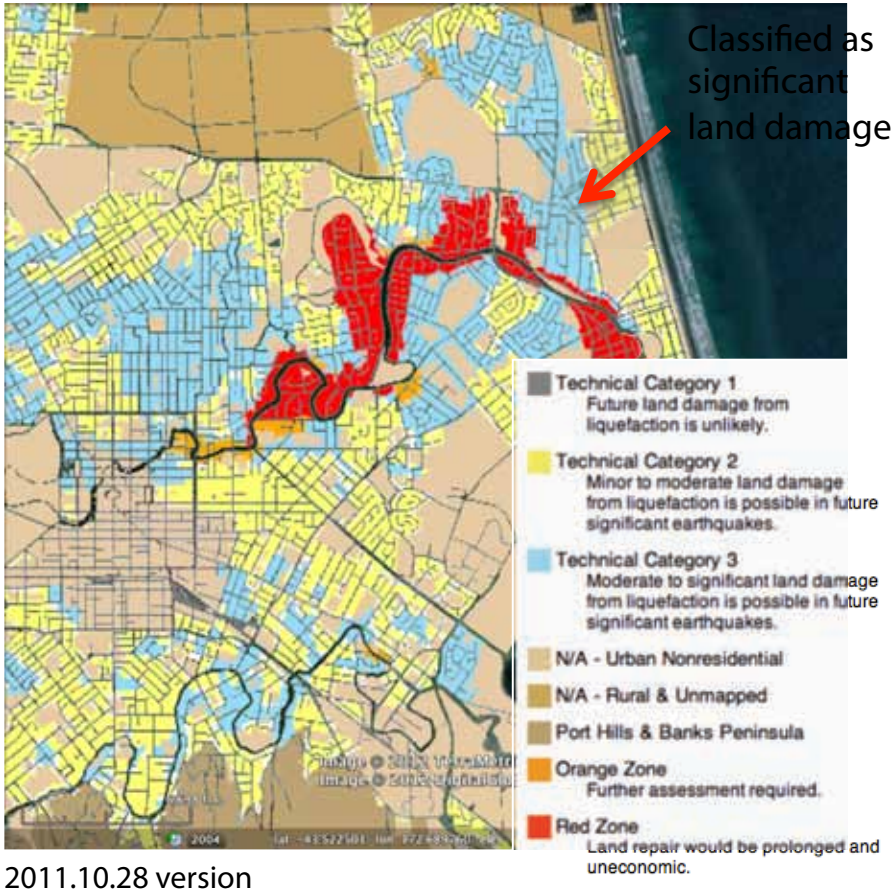
Radar Derived Damage Proxy Map vs Ground Truth

From radar data acquired **3 days** after EQ

Damage Proxy Map (ALOS PALSAR A335):
2010.10.10 – 2011.01.10 – 2011.02.25
Google Earth (GeoEye) Image: 2011.02.26

Technical Classification Map first released **8 months** after EQ



2011.10.28 version
Data provided by the New Zealand Government
http://data.govt.nz

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Cliff Collapse

Photo Courtesy David Petley

Luxury homes teeter on the edge after huge landslides in Redcliffs, near Christchurch (Photo by Torsten Blackwood from AFP).

Damage Proxy Map

2010.09.03

EQ M6.3

2011.02.23

2011.02.26

Liquefaction in Bexley

Cars stuck in the mud, Bexley
(Brett Phibbs/AFP/Getty Images)

Water Inundated Bexley (Mark Mitchell/New Zealand Herald/Associated Press)

Damage Proxy Map

2009.03.04

2011.02.23

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NASA-ISRO SAR Mission Concept

- Launch date: September 2020
- New Two-frequency L- and S-band Synthetic Aperture Radar (SAR)
- New Sweep SAR technique for rapid global data collection
- Orbit:
  - 747km altitude circular
  - 98 degrees inclination
  - sun-synchronous, dawn-dusk (6 AM – 6 PM)
  - Exact 12-day repeat within +/- 250 m
- 3 years science operations, but could last many more years
- Data are 10 m resolution or coarser, suitable for science and civilian applications
- Science data from both L- and S-band SAR will be available without any restrictions

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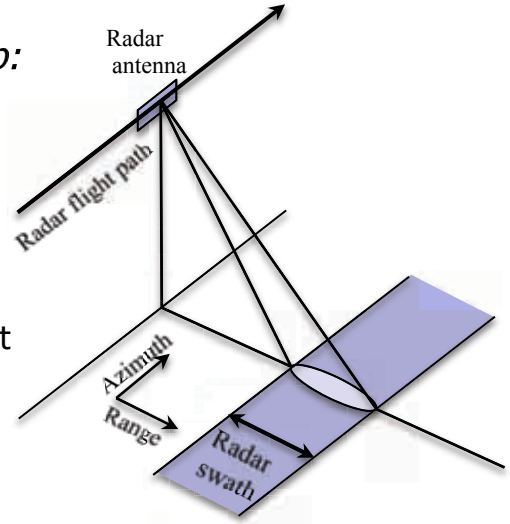
Radar Design to Achieve Multidisciplinary Objectives

- Short Repeat Period for Deformation science drives the Radar Swath
  - E.g. 12-day Repeat Period => 240 km Swath Width
- Sensitivity needed for Biomass (cross-pol) measurement drives Antenna Size and Radar Power

- A new SweepSAR technique was adopted as a means to achieve much wider swath than conventional SAR strip-mapping, without the performance sacrifices associated with the traditional ScanSAR technique

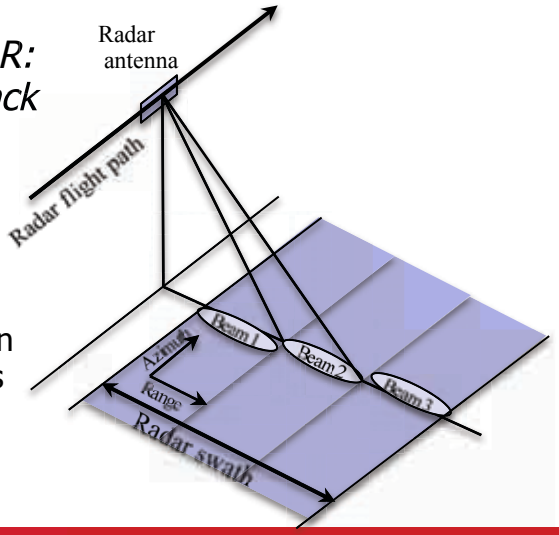
Conventional StripMap: <~70km Swath

Resulting ~40 day repeat would *NOT* meet Deformation and Ice Science Requirements



Conventional ScanSAR: non-uniform along-track sampling

Resulting degradation in effective azimuth looks would *NOT* meet Ecosystem Science Requirements



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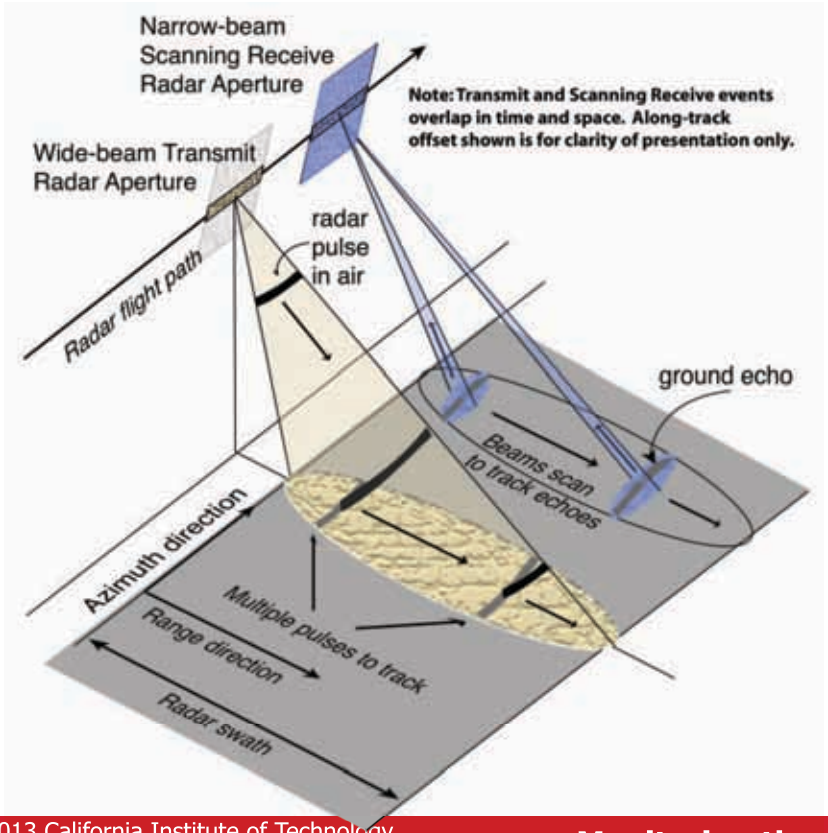
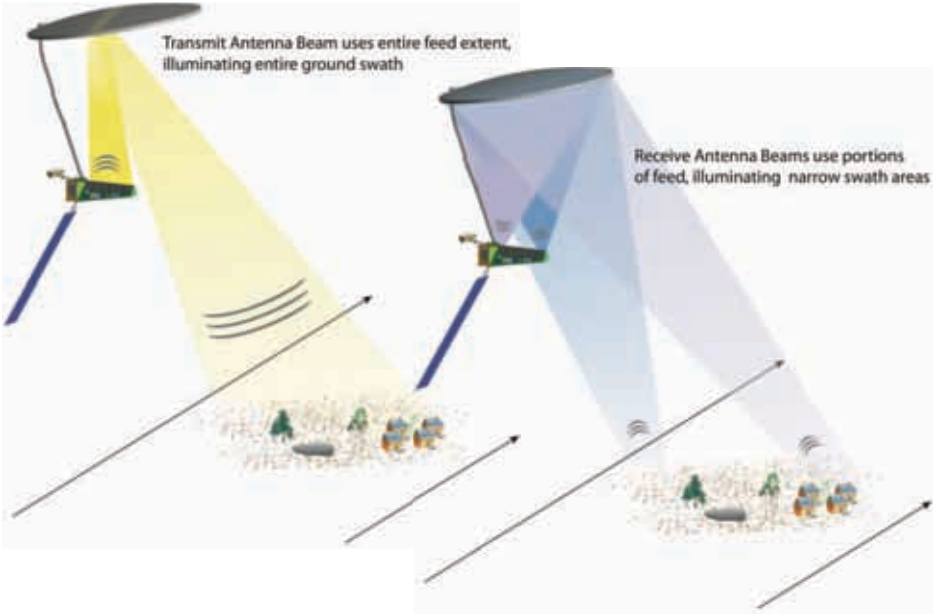
SweepSAR – First-of-a-kind Scan-on-receive Radar using Array-Fed Reflector

SweepSAR – Scan-on-Receive Radar

- Transmit pulse over wide beam in elevation
- Receive echo over narrow beam tracking echo with scanning receive beam
- Can require multiple simultaneous receive beams to track multiple echoes

- Removes standard SAR performance limits using Digital Beamforming techniques on receive using reflector
- Achieves high area coverage at fine resolution and full polarization





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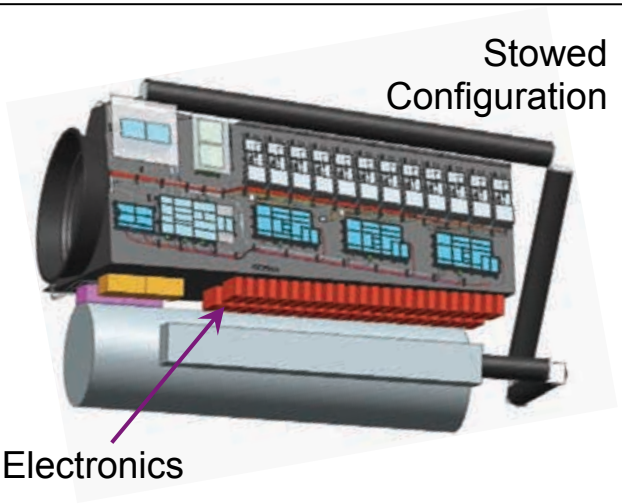
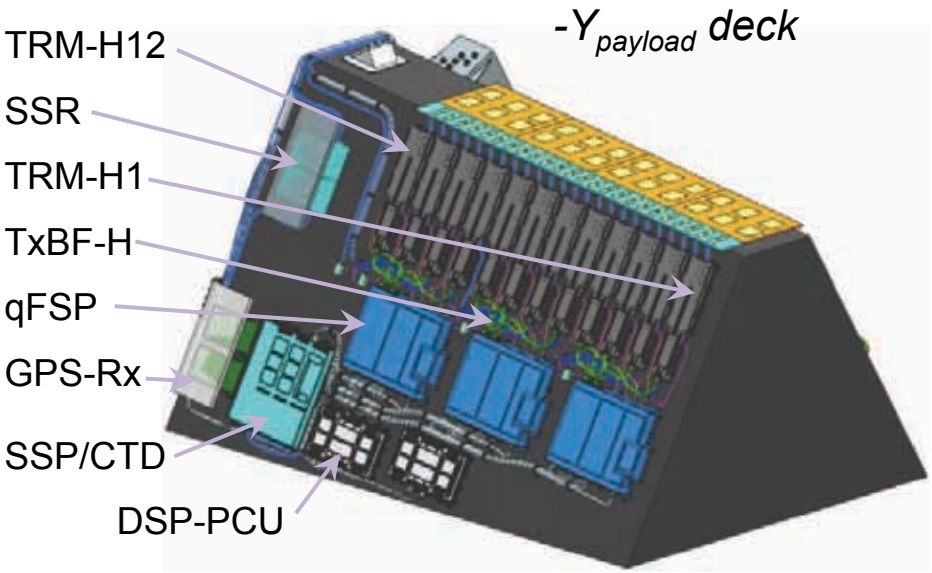
Radar Instrument Configuration

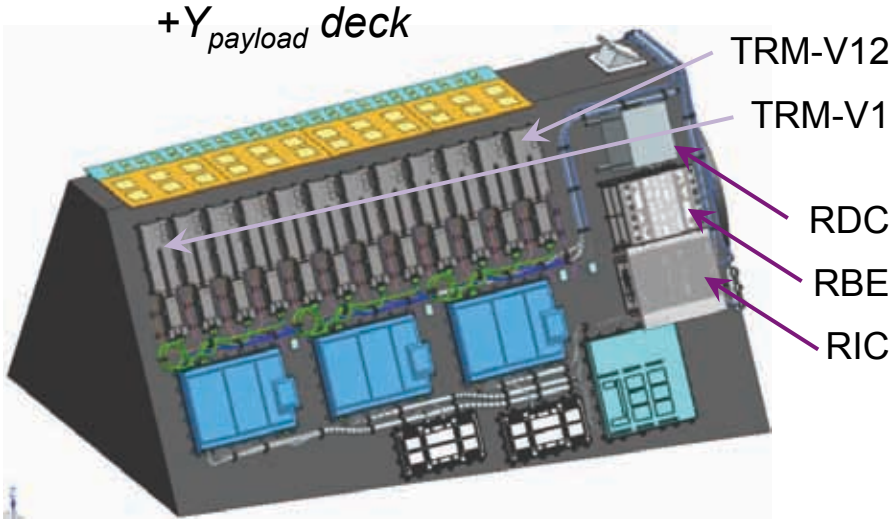
Integrated Radar Instrument Structure Layout

- All Radar Instrument components are mounted on the Radar Instrument Structure (RIS) to keep S/C interfaces simple, and to facilitate instrument integration, test, and calibration prior to delivery to ATLO with S/C
  - +Z (zenith-facing) deck accommodates the L-Band and S-Band Feed RF Aperture (FRAp) panels
  - +Z deck also provides mounting for Reflector Boom
  - -Z deck accommodates ISRO S-Band Electronics



- +Y and -Y decks accommodate the L-band Electronics, GPS Electronics, and Data Recorder





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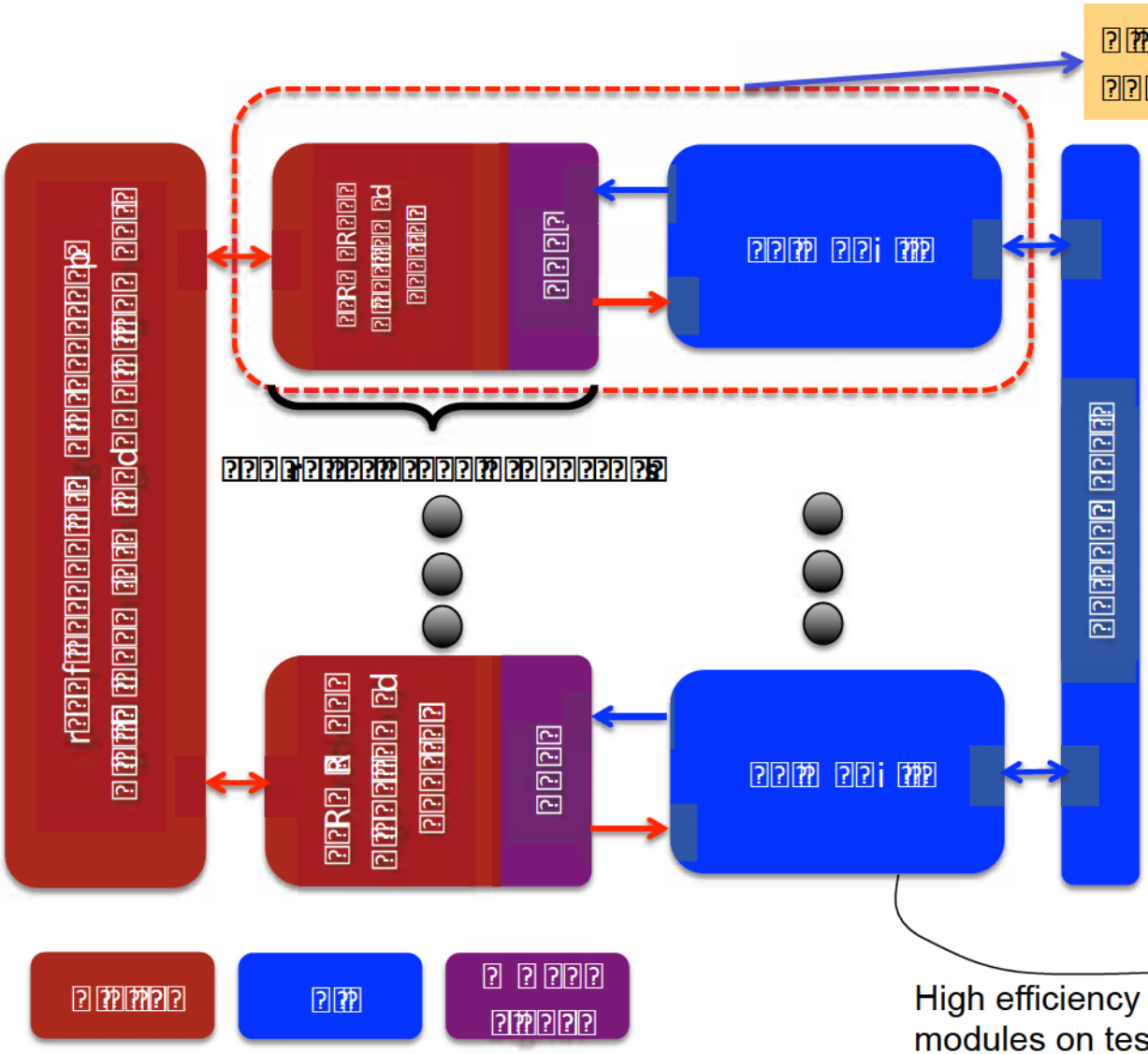
High-level Block Diagram of Beamformer/ Calibration and TR Front End Technologies



High efficiency GaN TR modules on test fixture

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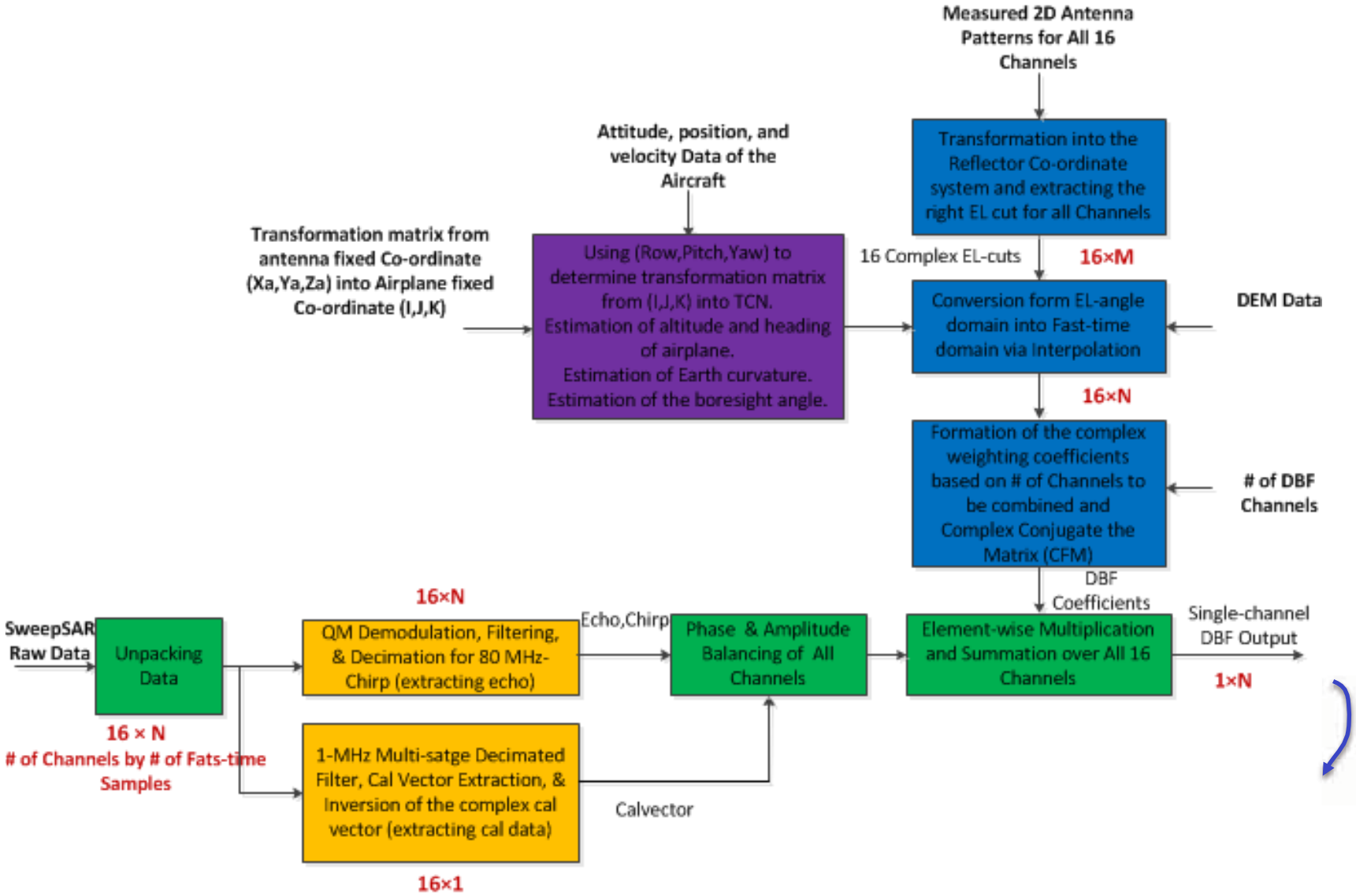
SweepSAR Digital Combining Algorithm



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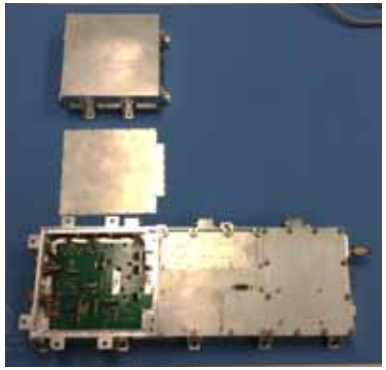
Technology Development for Mission



Prototype L-band T/R module

Prototype control & timing board

Prototype first stage processor

Integrated test environment

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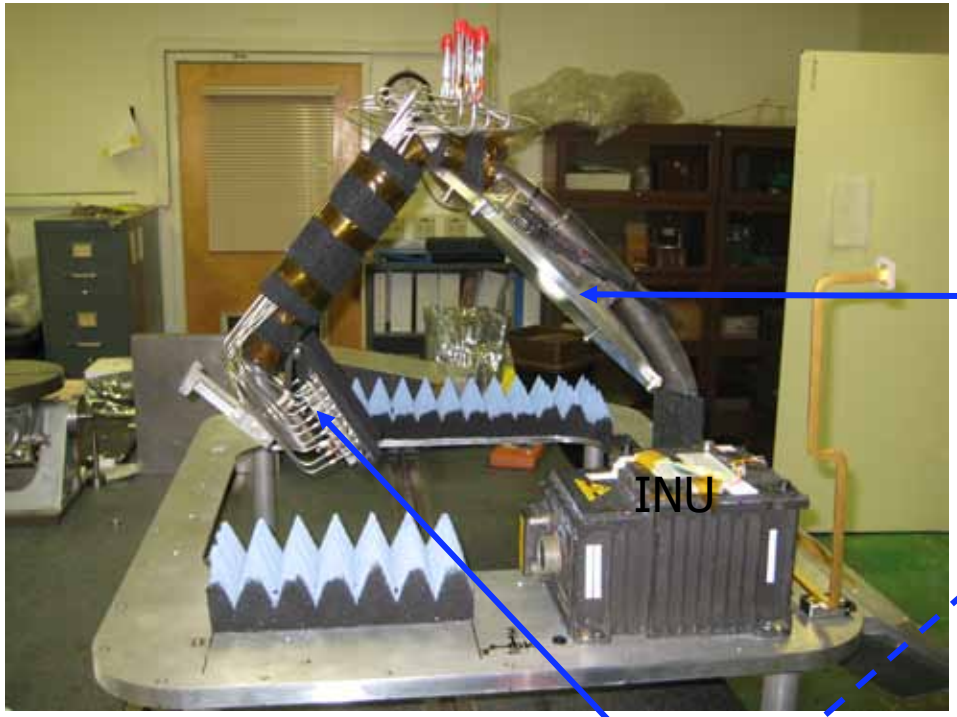
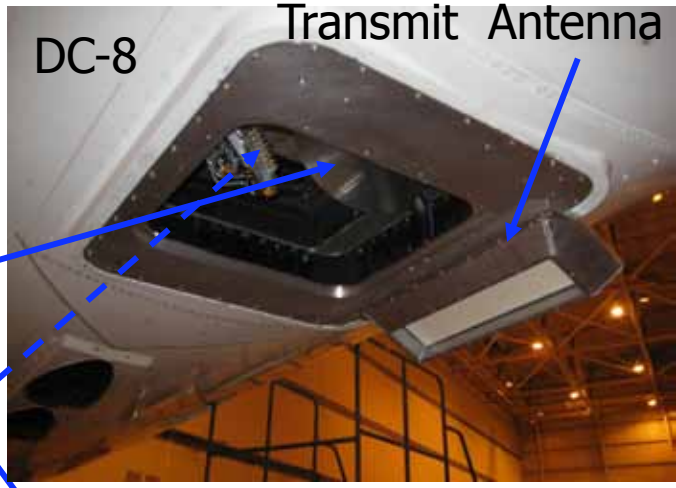
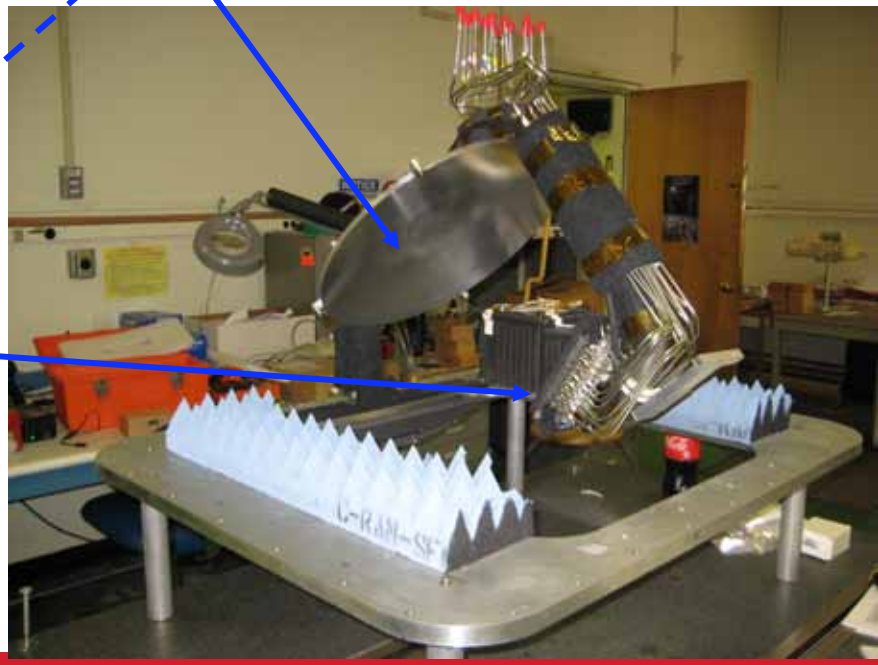
Ka-band Scaled SweepSAR Demonstrator





Reflector



Feed Array

From: S. Hensley, *et al*, "First Results from an Airborne SweepSAR Demonstration at Ka-band" IGARSS 2011

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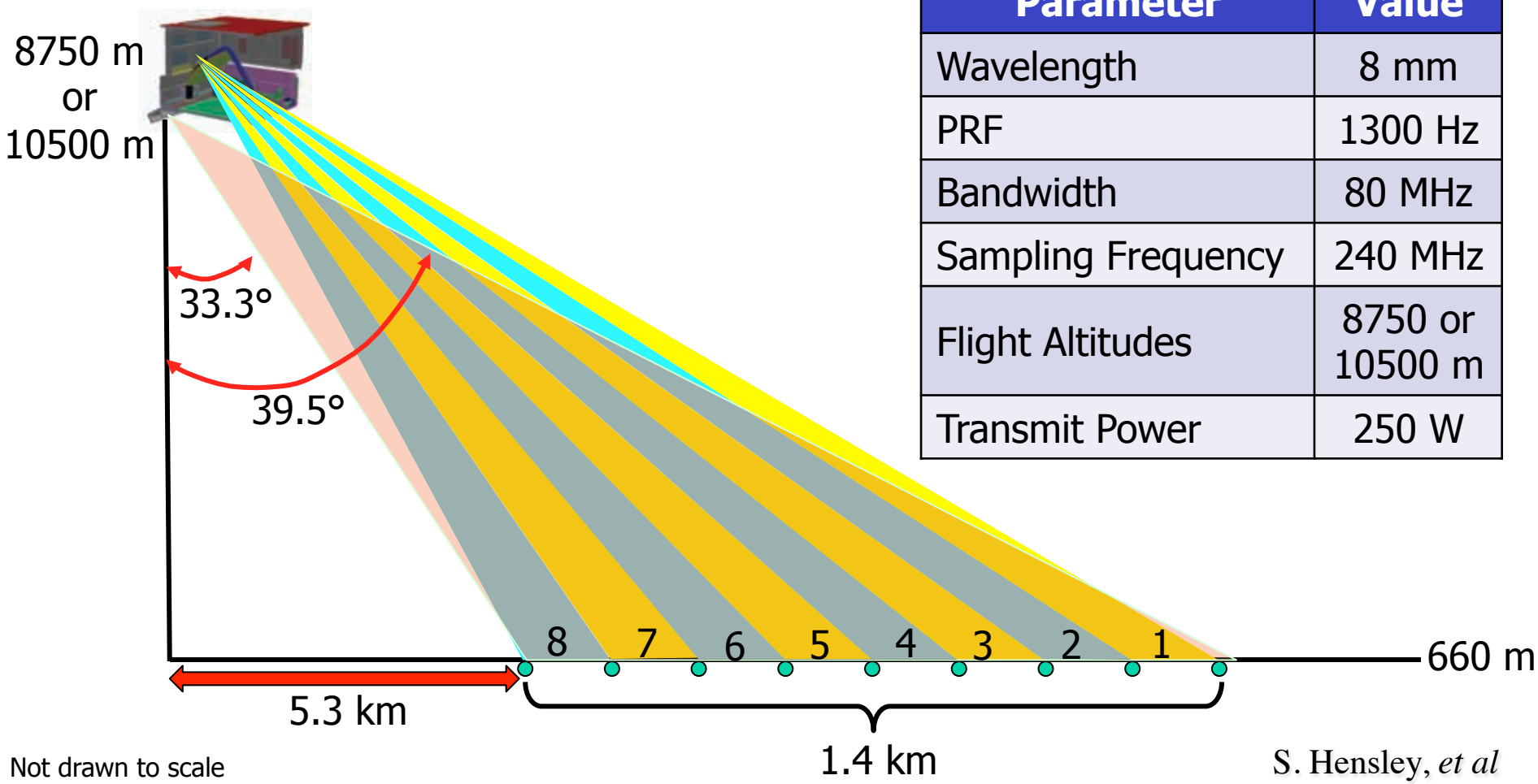
Ka-band Demonstrator Radar Parameters and Mapping Geometry

- The eight beams map a swath extending from 33.3°-39.5° that gives a swath width of 1.4 km



Radar Parameters

Parameter	Value
Wavelength	8 mm
PRF	1300 Hz
Bandwidth	80 MHz
Sampling Frequency	240 MHz
Flight Altitudes	8750 or 10500 m
Transmit Power	250 W

S. Hensley, *et al*

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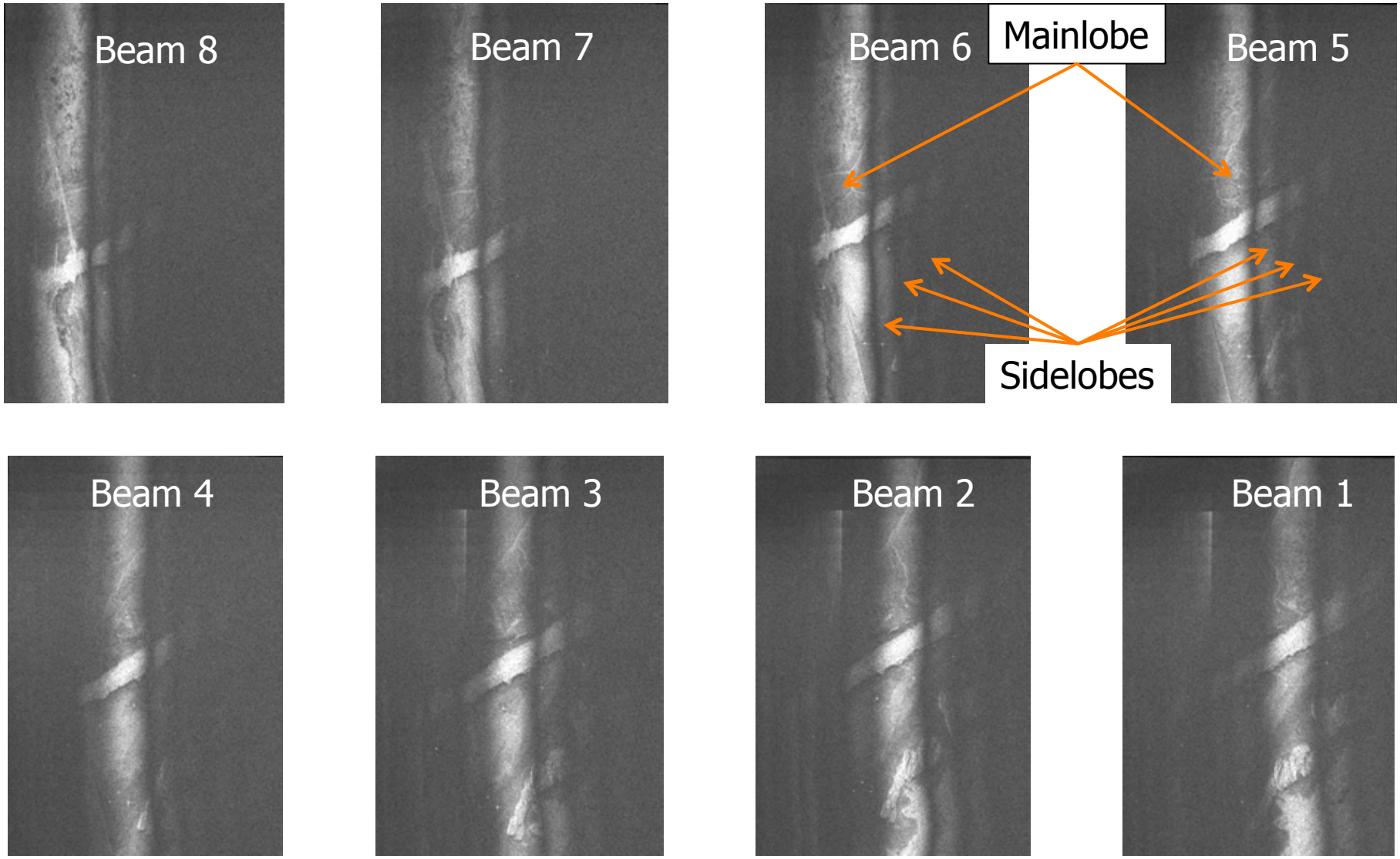
Ka-band Individual Beam Imagery



S. Hensley, *et al*

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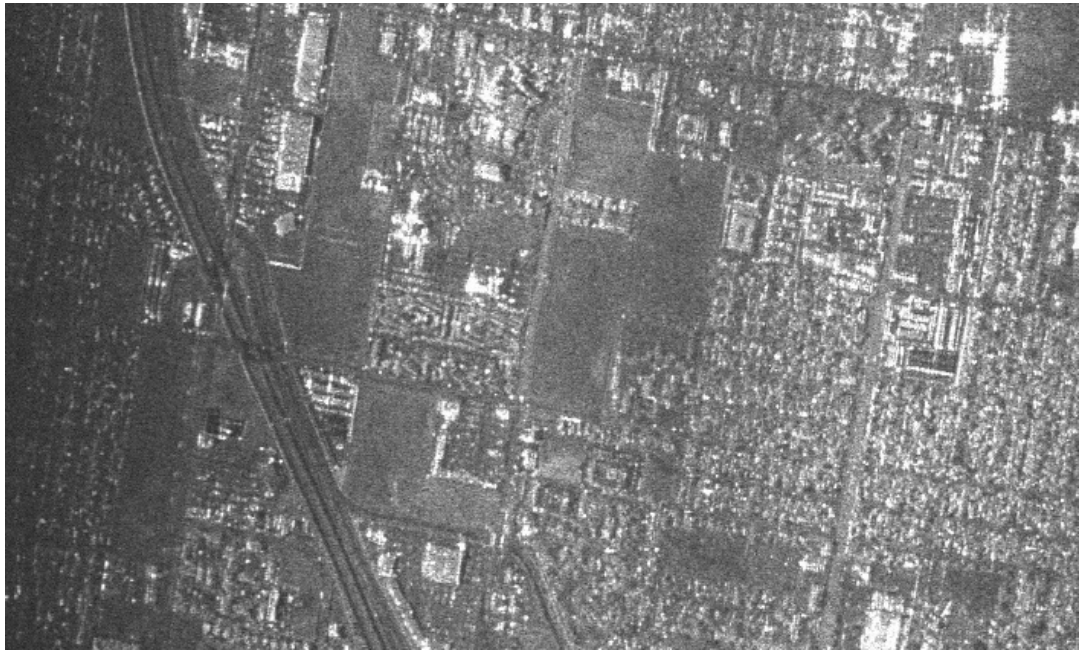
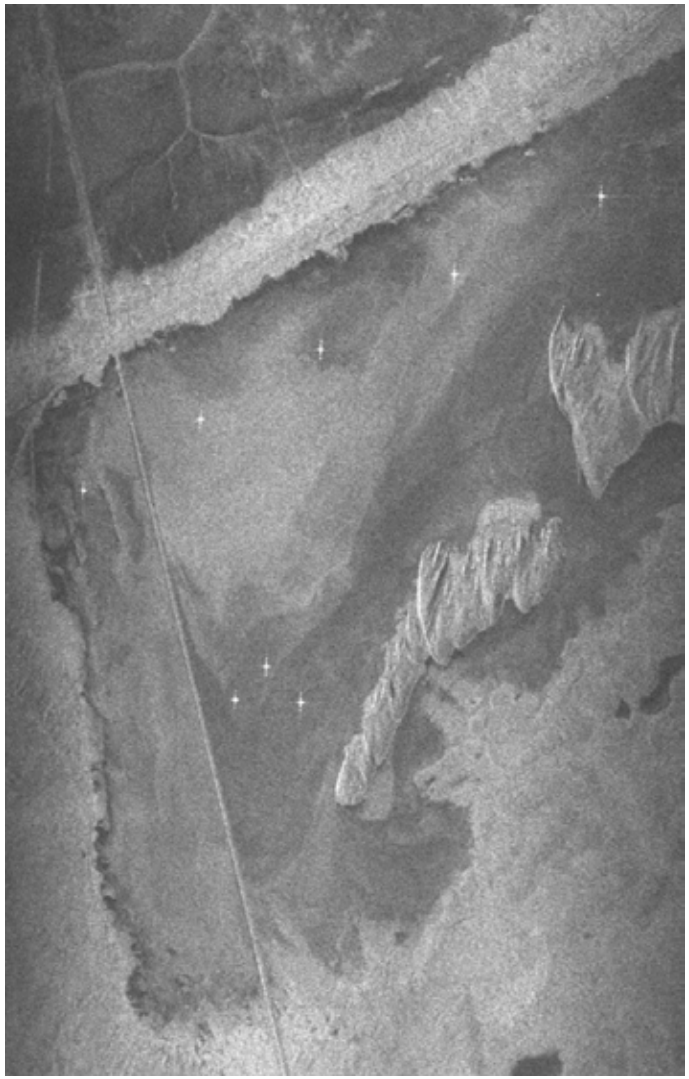
SweepSAR Airborne Demo Data Processing

- Processed data from 6 flight lines to show results are consistent and repeatable from pass to pass
- Analyzing impulse response from corner reflector data to quantify beam combining effects on image performance
- Now running airborne data through prototype flight hardware to combine beams in real time



Reprocessed DBF Image from Flight Line 3



Reprocessed Image from Flight Line 7

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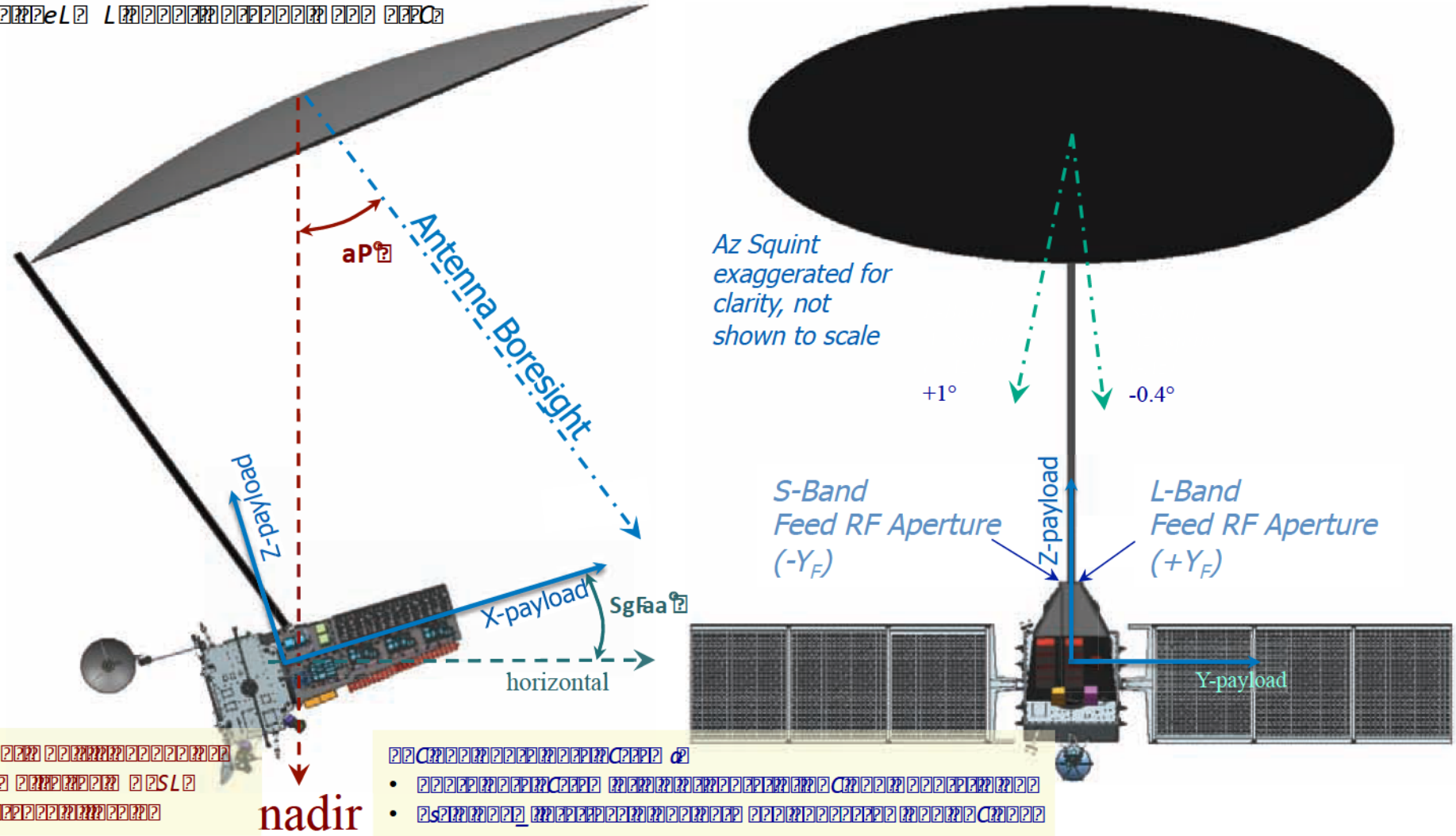
Radar Instrument Configuration
On-Orbit Datataking Orientation



- Antenna Boresight pointed 37° from Nadir; Payload X-axis rolled 16.33° relative to horizontal

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Radar System Parameters

Target-dependent Commandable Instrument Parameters for Primary Science Modes:

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	meHc	fsce	mc	myP	Lyy	[illegible]	nnn	a
[illegible]	[illegible]	[illegible]	[illegible]	Le	fsce	ye	myP	Pym	[illegible]	fecm	a
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[illegible]	[illegible]	[illegible]	[illegible]	ye	fsce	ye	myP	fees		fecm	a
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[illegible]	[illegible]	[illegible]	[illegible]	mc	meeet	mc	mcc	sen	fPLs	a	lfl
[illegible]	[illegible]	[illegible]	[illegible]	mc	fLcet	mc	mnL	sen	fLPe	a	sPy
[illegible]	[illegible]	[illegible]	[illegible]	nl c	fLcet	ye	mny	sen	mcPl	a	fenl
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[illegible]	[illegible]	[illegible]	[illegible]	nl c		ye	mny				
[illegible]	[illegible]	[illegible]	[illegible]	mc	fLcerh	mch	myP	Lsc	fLPe	nny	sPy
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[illegible]	[illegible]	[illegible]	[illegible]	nl c			mse				
[illegible]	[illegible]	[illegible]	[illegible]	ye	fceerh	yeh	mnc	fmnf	nlsP	fcyf	nmcf
[illegible]	[illegible]	[illegible]	[illegible]	nl c		ye	msf				

[illegible]

- Swath is defined by:
  - NE$\square_0$ Threshold at -25dB for all modes
  - Ambiguity Threshold at -20 dB for all modes except L-Band QP (L4)
  - S-SAR requirements assumed to be the same as L-SAR

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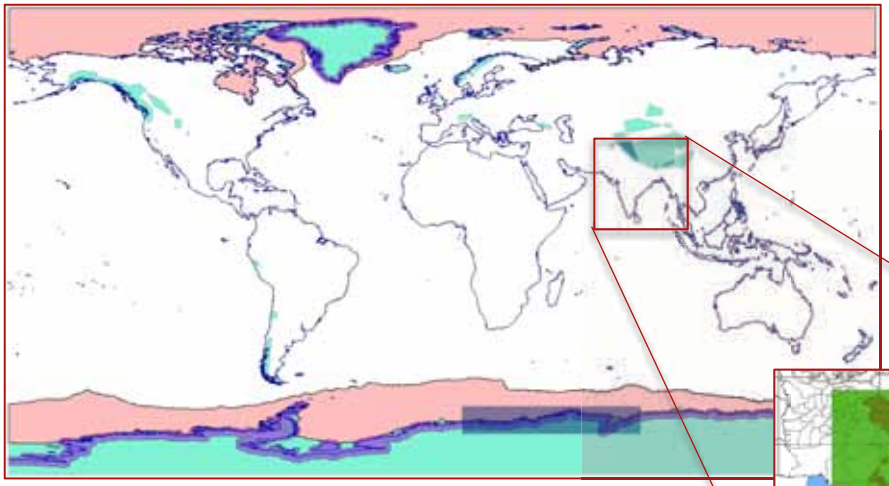
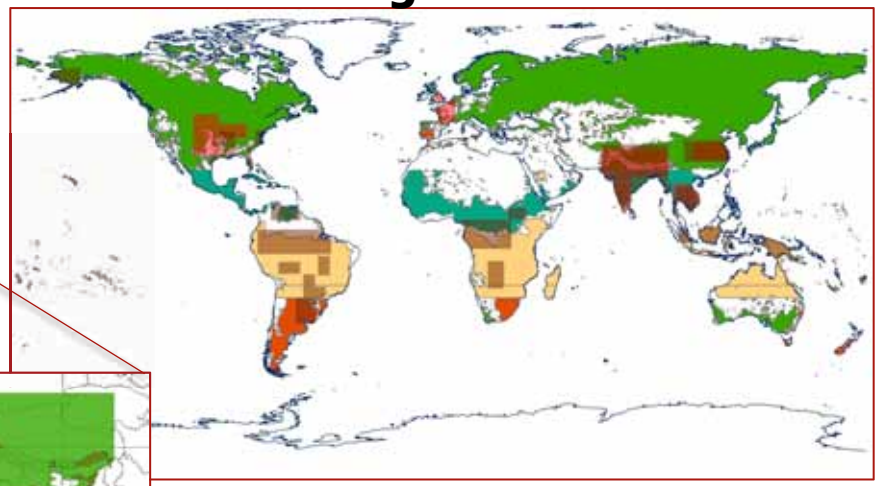
NASA-ISRO Comprehensive Observations Plan Exploiting L- and S-Band Radars

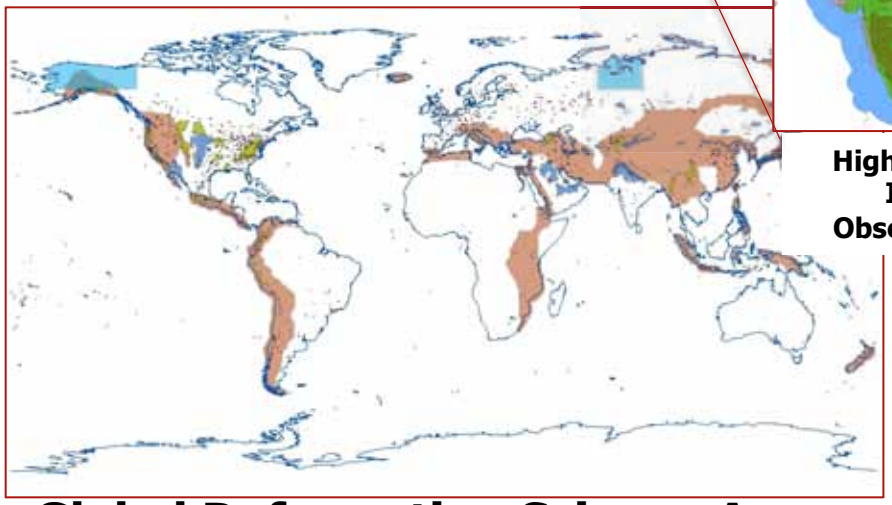
Global Ice Sheet and Glacier



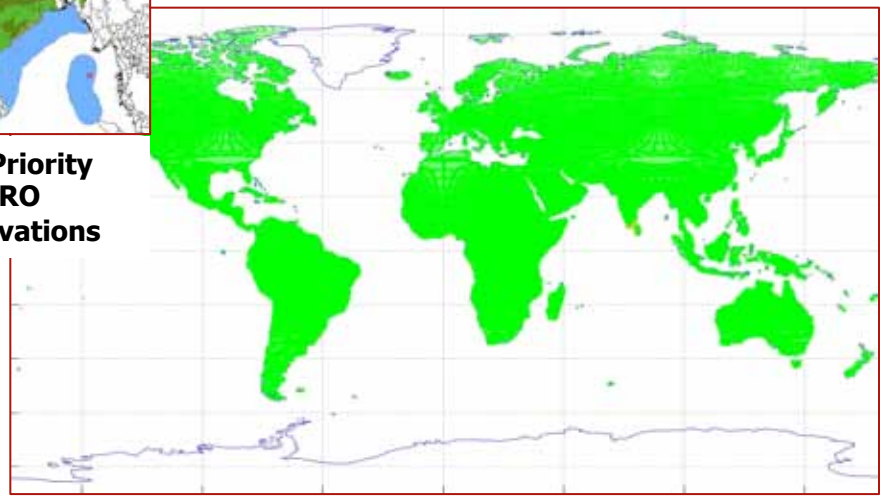
Global Vegetation Cover



High Priority ISRO Observations



Global Deformation Science Areas



Global Background Mission

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ISRO Observation Requirements beyond Global L-band Observation Plan

Objective	Wavelength	Region of Interest	Repeat Frequency	Modes
Coastal Erosion	L or S	Regions of India	Half-yearly	HH/HV
Mangroves	L or S	Coasts of India	Half-monthly for 4 mos.	DP - QP
Tide Lines	L or S	Regions of India	Selective Monthly	HH/HV
Bathymetry	L or S	Off-shore of India	Half-yearly	VV
Wave Spectra	L or S	Global distribution	Weekly	VV
Coastal Winds	L or S	Regions of India	Weekly	VV/HH
Sea-ice Thickness	L and S exp*	Defined polar targets	Half-monthly	DP – QP
Mountain Glaciers	L and S exp*	Himalayas	Half-monthly	DP – QP
Alpine Vegetation	L and S exp*	Himalayas	Half-yearly	DP – QP
Soil Moisture	L exp*/ S exp*	Regions of India	Weekly	DP – QP
Land Subsidence	L and S exp*	Regions of India	Monthly	HH
Landslides	L and S exp*	Regions of India	Weekly in rainy season	HH

*exp – experimental

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Government sponsorship acknowledged.

Jet Propulsion Laboratory
California Institute of Technology

The NASA-ISRO SAR Mission Concept is Uniquely Designed to Address Societal Challenges

- A NASA-ISRO SAR Mission would realize the promise of the capabilities demonstrated in this presentation:
  - L-band SAR data
  - Additional S-band data to extend the range of sensitivity in critical areas
  - Reliable, regular, and frequent observations of areas of interest
  - Free, open access to data
  - Dense temporal and spatial sampling over the globe
- The NASA-ISRO SAR mission is the only mission concept designed to provide the needed measurements to realize this potential in the foreseeable future
- The mission would be a major source of data for many other agencies in the United States and India

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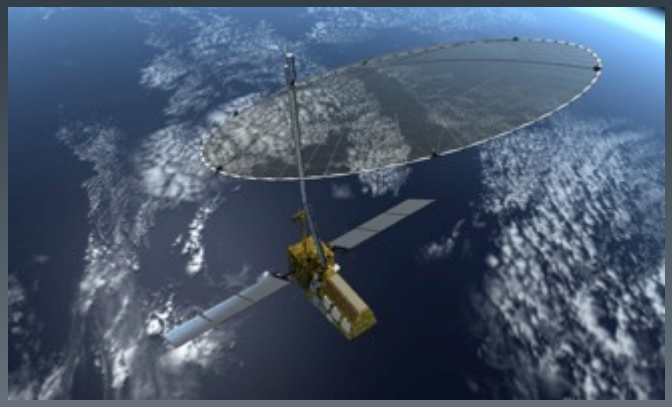
Government sponsorship acknowledged.

NASA-ISRO SAR Collaboration

Monitoring the dynamic Earth from Space - a NASA-ISRO Radar Mission

IIT Kharagpur Lecture
25 November 2013

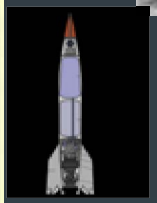


Dr Paul Rosen, Project Scientist
Mr Alok Chatterjee, Mission Interface Manager
JPL/Caltech

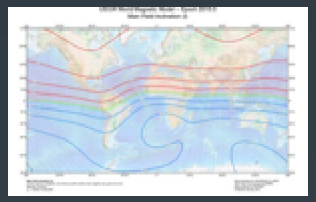
Dynamic Earth

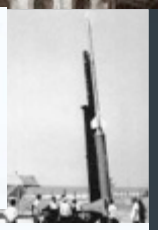
The Births

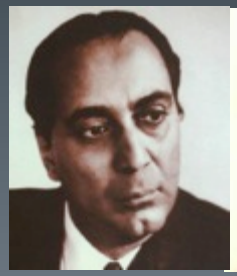
NACA 1915 → NASA 1958



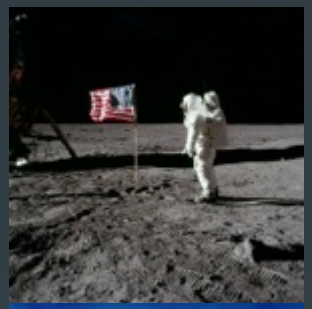
INCOSPAR 1962 → ISRO 1969

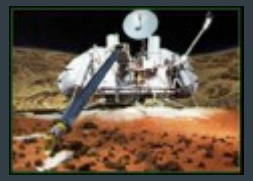
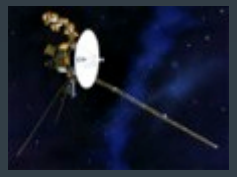


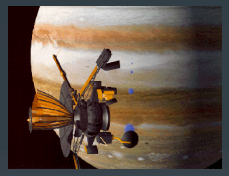


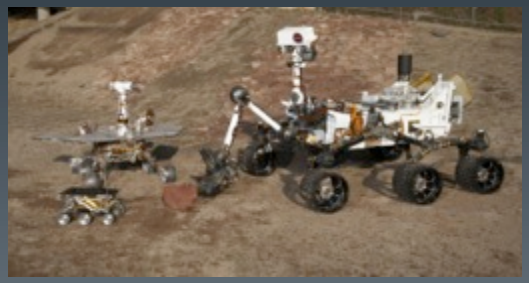


NASA Growth







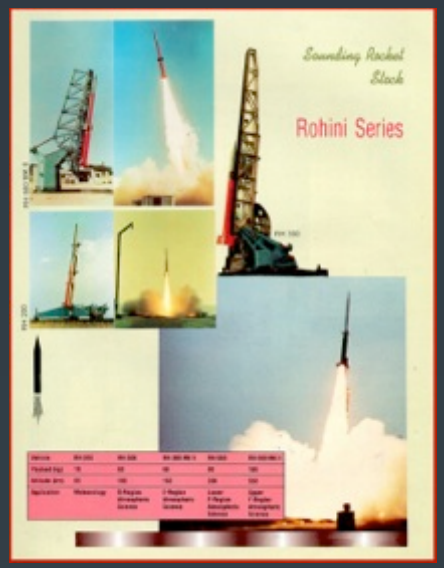
Apollo

Shuttle

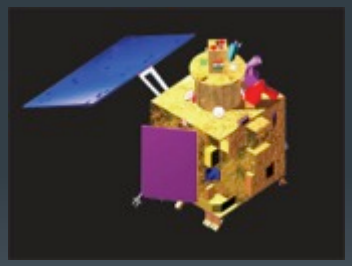
Station

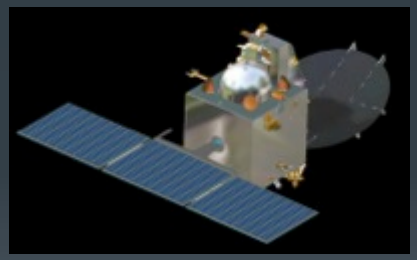
Planetary

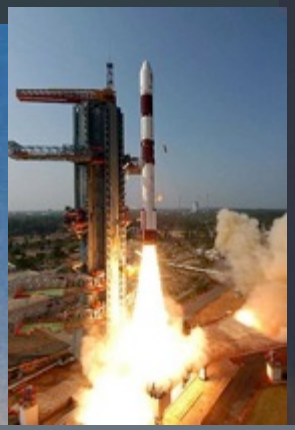
ISRO GROWTH

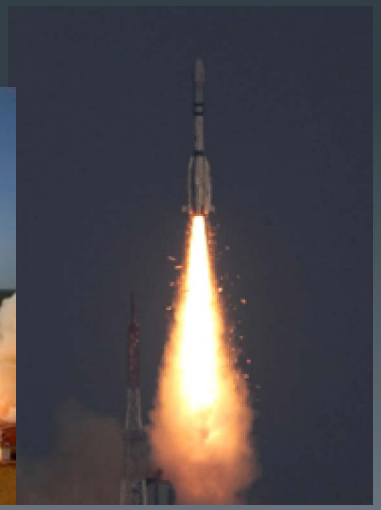

Sounding Rocket
Block
Rohini Series

Chandigarh
Dehradun
New Delhi
Lucknow
Jodhpur
Shillong
Bhopal
Ahmedabad
Kharagpur
Nagpur
Mumbai
Hyderabad
Tirupati
Sriharikota
Hassan
Bangalore
Thiruvananthapuram
Mahendragiri



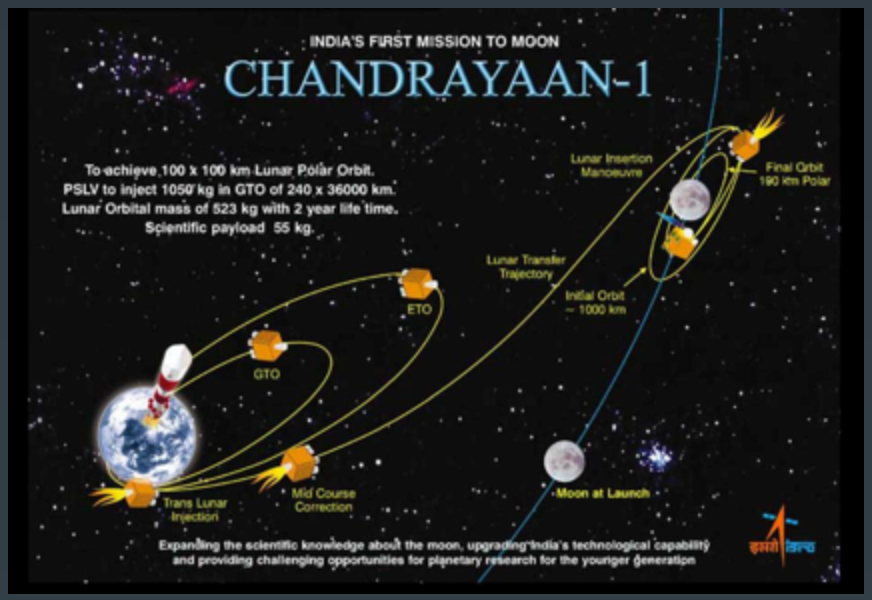


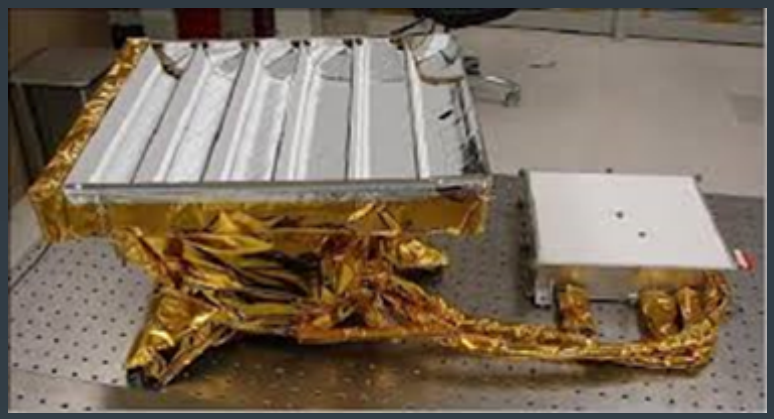




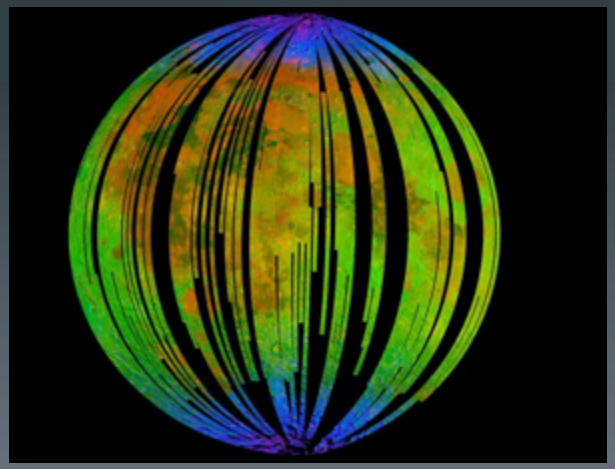
Pioneers & Builders

Chandrayaan-1 NASA-ISRO Collaboration



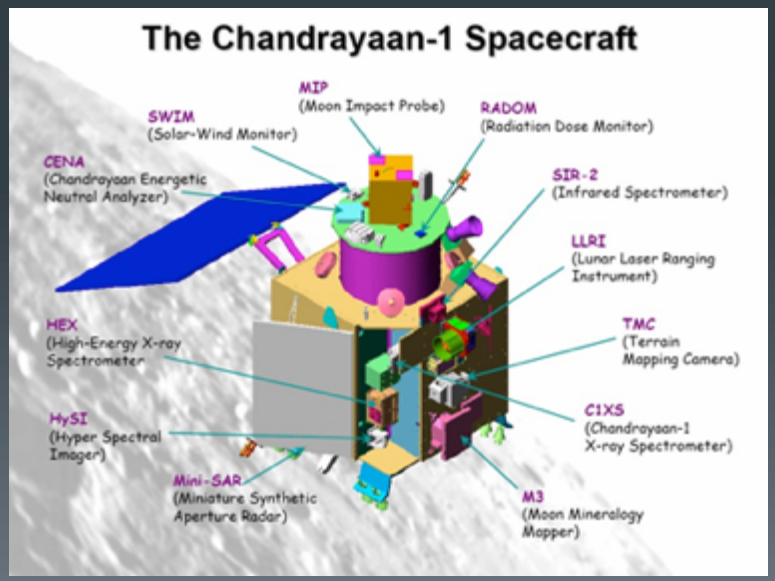


JPL Moon Mineralogy Mapper (M^3) Instrument



M^3 Results

ISRO Launch

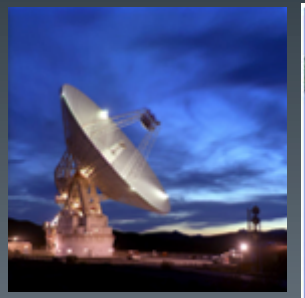


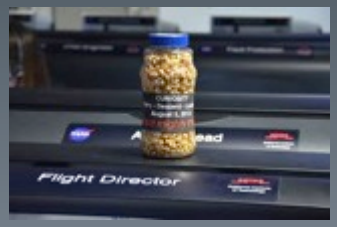
ISRO Spacecraft

JPL Support for Chandrayaan-1 Mission

NASA/ JPL Navigation Support for ISRO Mangalyaan Mission

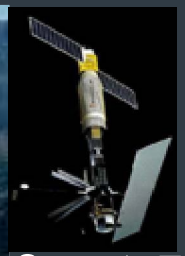
- **JPL Navigation Support:**
  - First time ISRO mission going beyond Earth-Moon system into deep space
  - JPL navigation expertise in deep space trajectory and maneuver design provides validation and critical backup to the ISRO Flight Dynamics Team
- **JPL Tracking Support:**
  - Provides continous coverage to track and control the spacecraft's safe journey to Mars
  - DSN's global coverage (Goldstone, Madrid, Canberra) will provide backup tracking support when the spacecraft is not visible to the ISRO Deep Space Network (IDSN) at Bangalore (32m)
  - DSN's very large 70m stations will provide coverage of the critical activities during the Mars Orbit Insertion (MOI) on Sep 24 2014
  - JPL/DSN Validation of IDSN deep space tracking capabilities
- **"Good luck" peanuts**



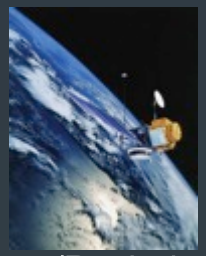


Space Radar Development

NASA/ JPL



Seasat
1978



Topex/Posiedon
1992

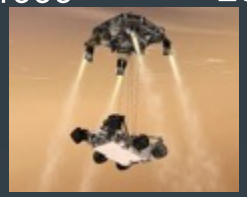
QickScatt
1999

SRTM
2000

Cloudsat
2006

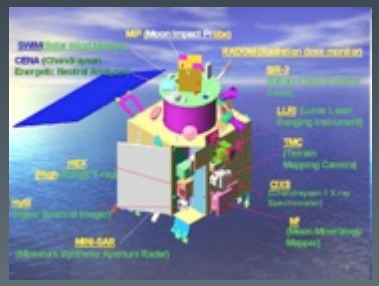
Magellan
1989

Cassini
1997



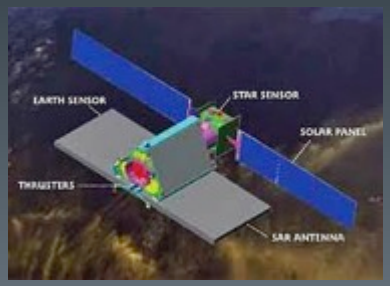
MSL/Curiosity
2011

ISRO/SAC

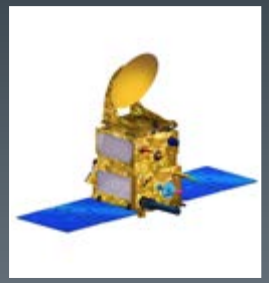


Chandryaan-1
2008

Oceansat-2
2009



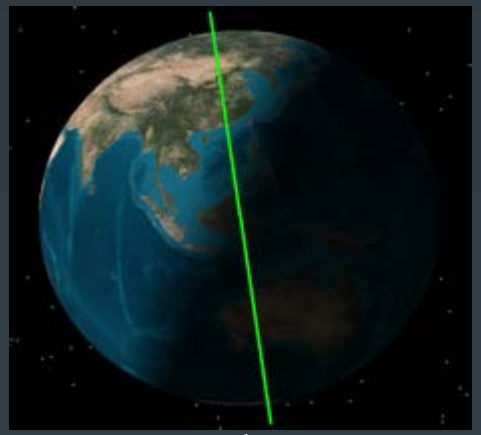
RISAT-1
2012



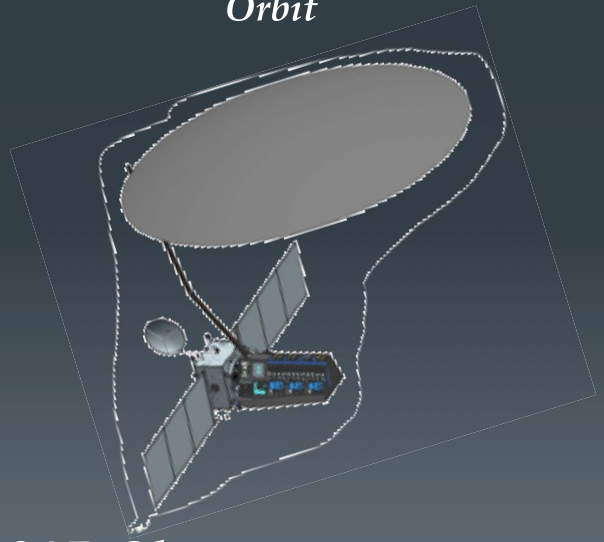
SARAL
2013

NASA-ISRO SAR Mission Concept

- Launch date: September 2020
- New Two-frequency L- and S-band Synthetic Aperture Radar (SAR)
- New Sweep SAR technique for rapid global data collection
- Orbit:
  - 747km altitude circular
  - 98 degrees inclination
  - sun-synchronous, dawn-dusk (6 AM – 6 PM)
  - Exact 12-day repeat within +/- 250 m
- 3 years science operations, but could last many more years
- Data are 10 m resolution or coarser, suitable for science and civilian applications
- Science data from both L- and S-band SAR will be available without any restrictions



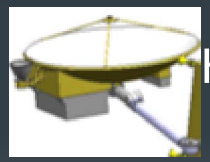
Orbit



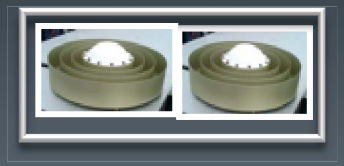
SAR Observatory

ISRO-NASA Work Share

L-band SAR electronics
Instrument structure
Reflector boom assembly

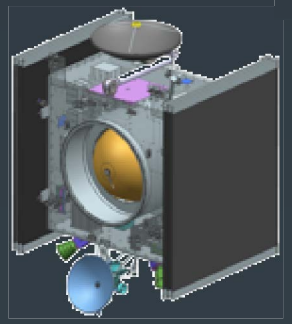


High data rate telecom



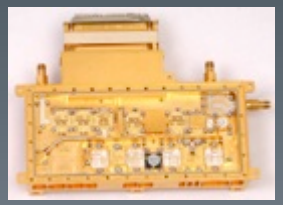
GPS

High capacity
solid state recorder



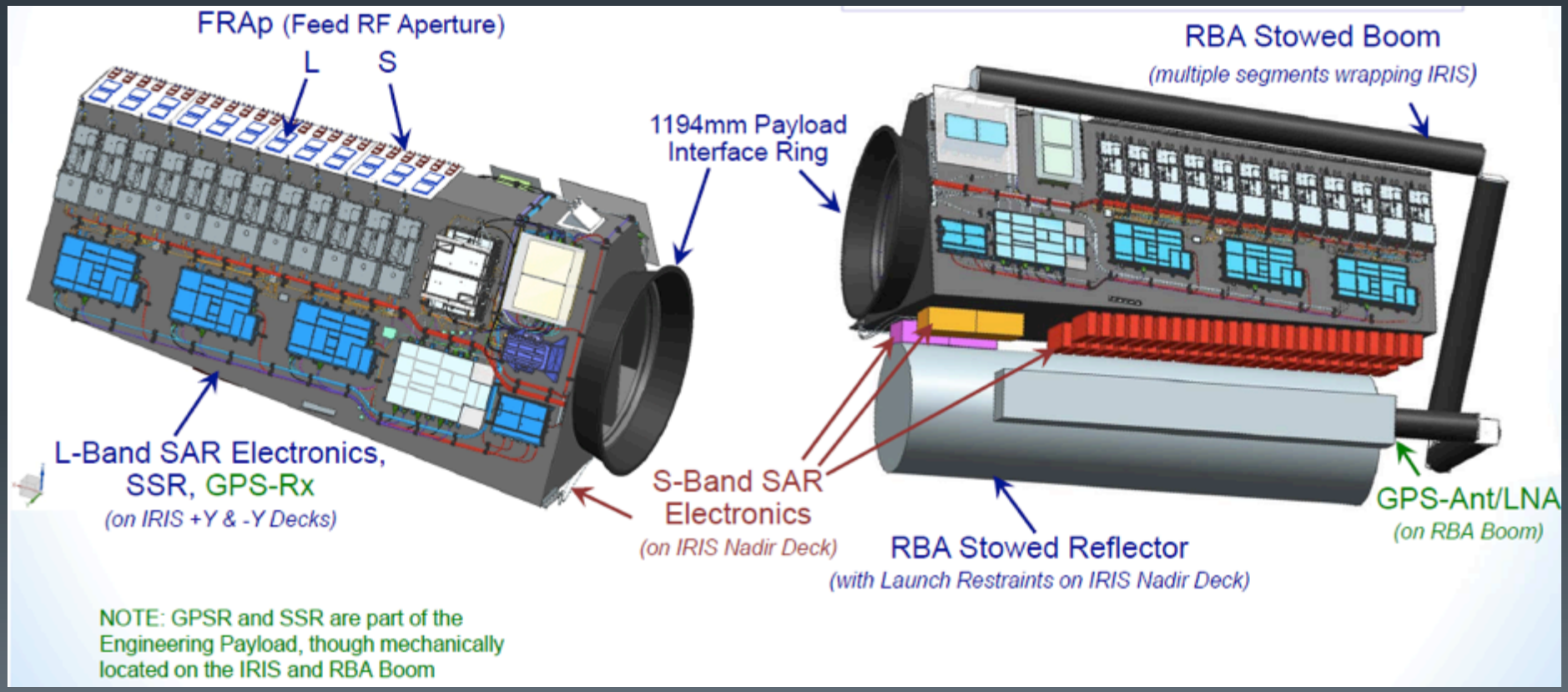
Spacecraft (I3K)

Launch vehicle (GSLV)

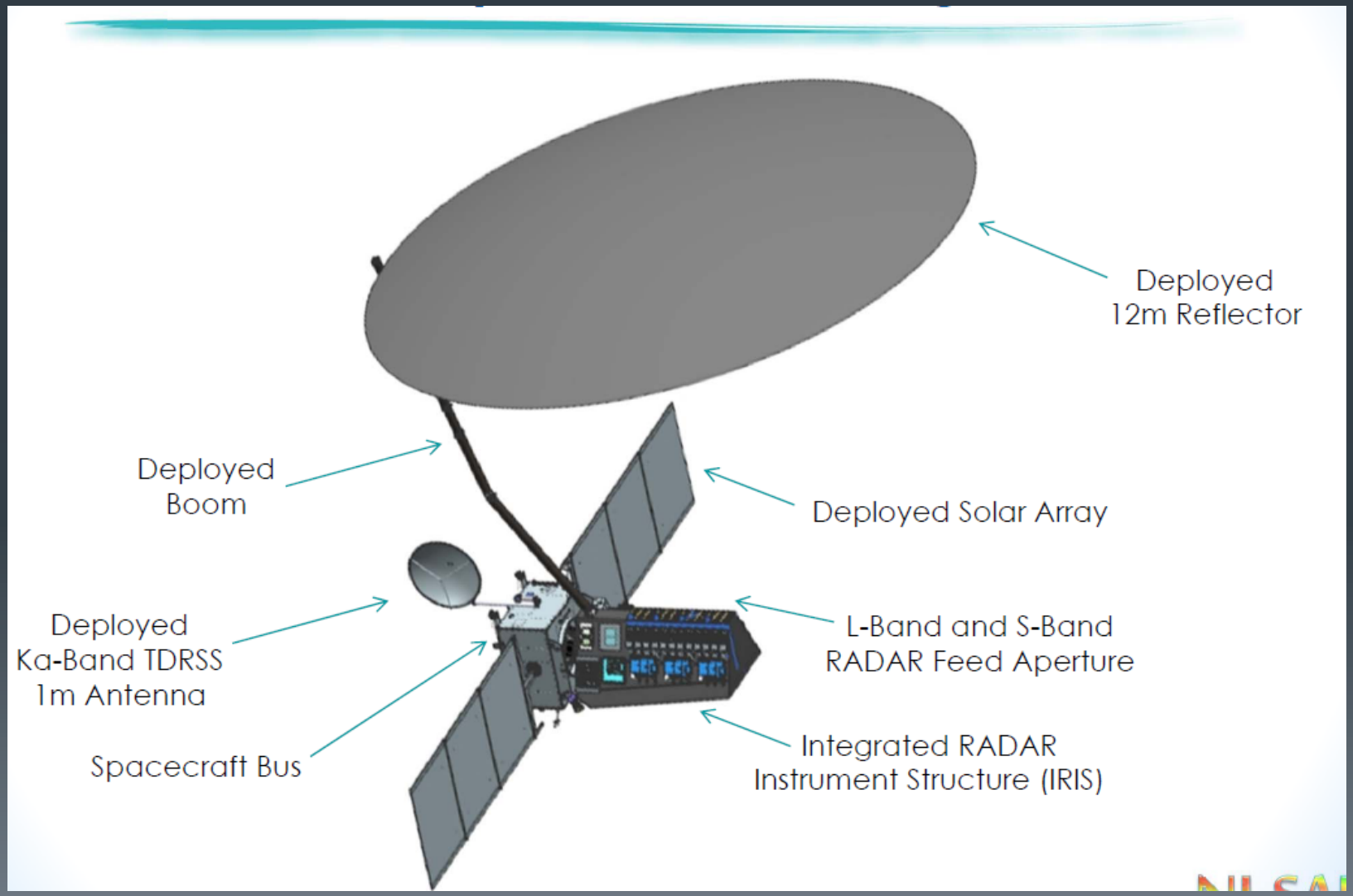


S-band SAR electronics

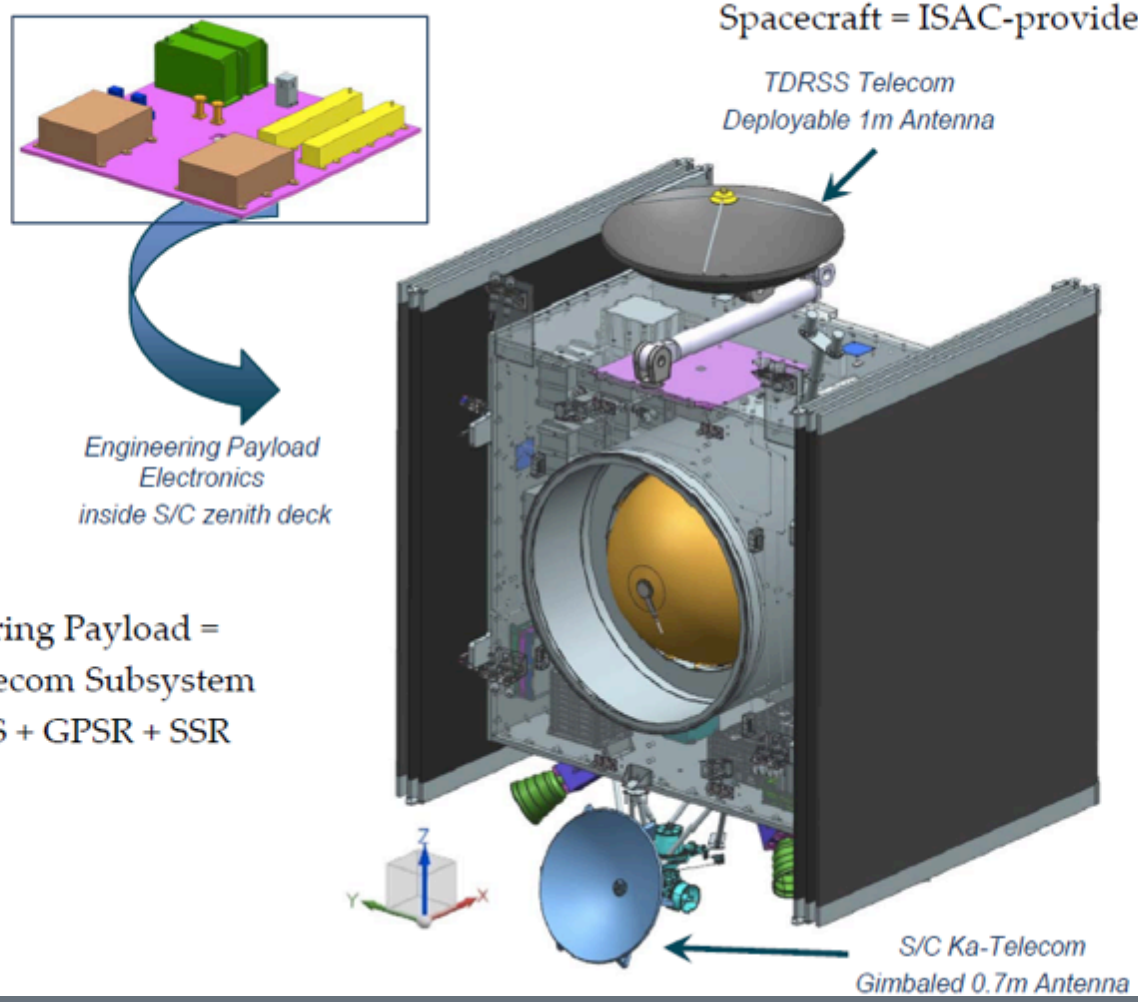
Proposed L-S Band Radar Configuration



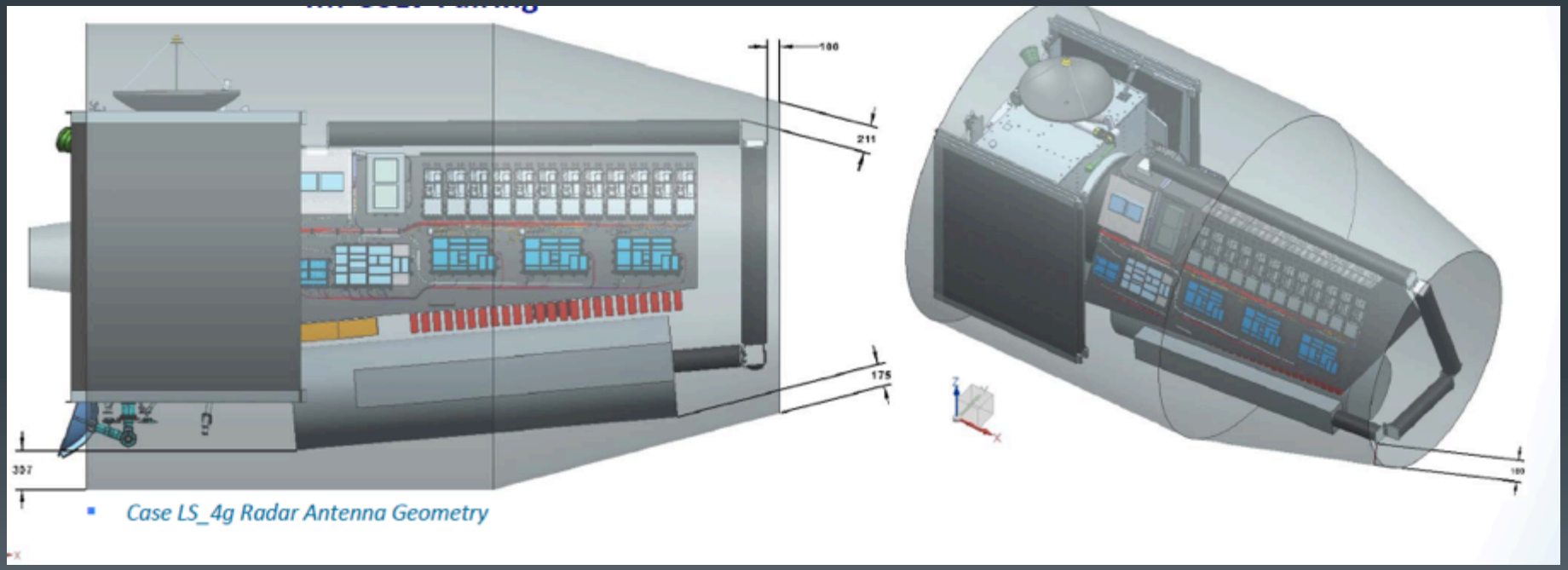
On-Orbit Proposed Payload Deployment Configuration



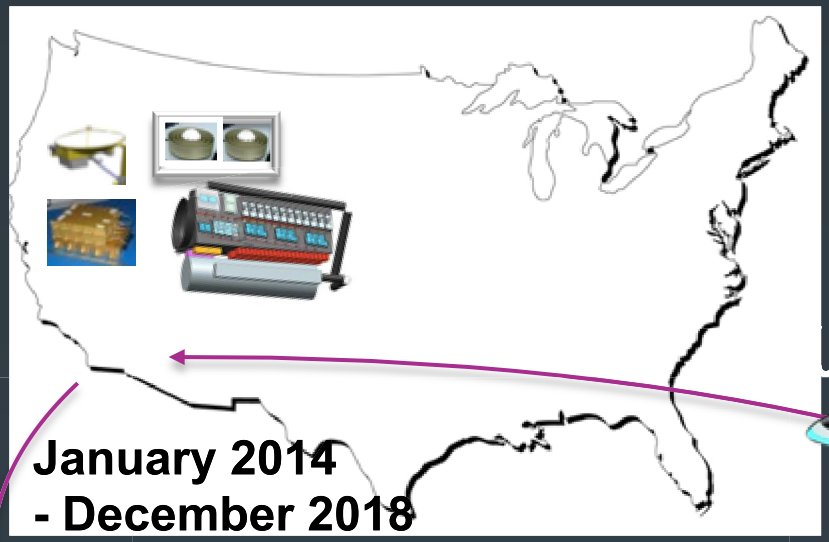
ISRO Spacecraft Configuration



Payload Inside ISRO GSLV Launch Vehicle

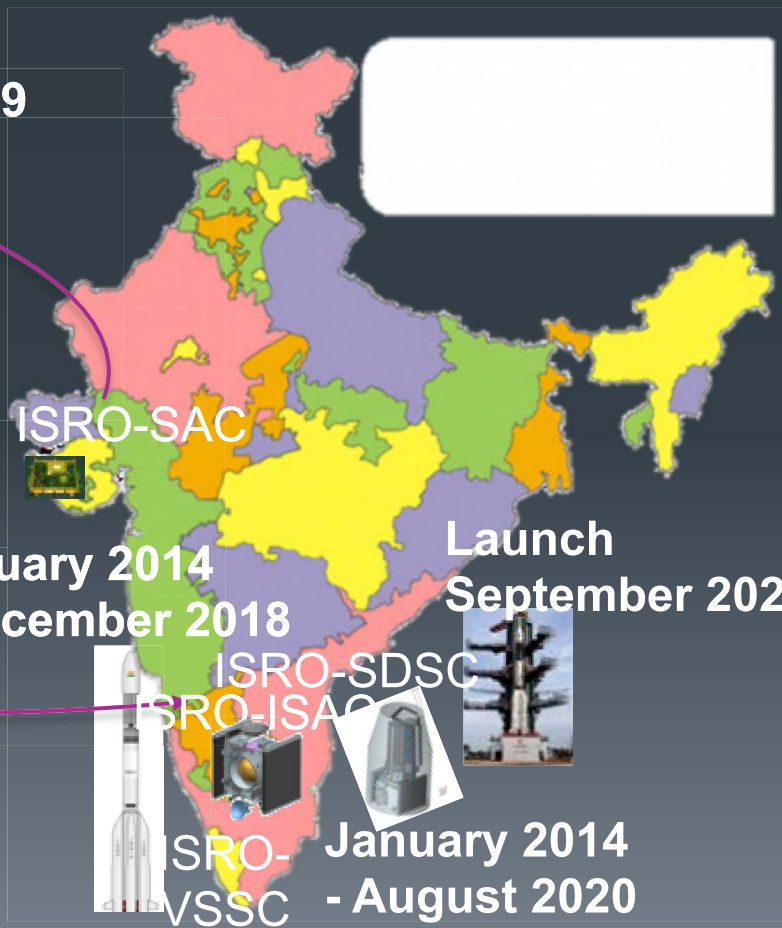


Observatory Development Flow



January 2014
- December 2018

January 2019



System Integration & Test at JPL
(L-SAR and S-SAR Integration & Payload Test)

December 2018
- October 2019

October 2019

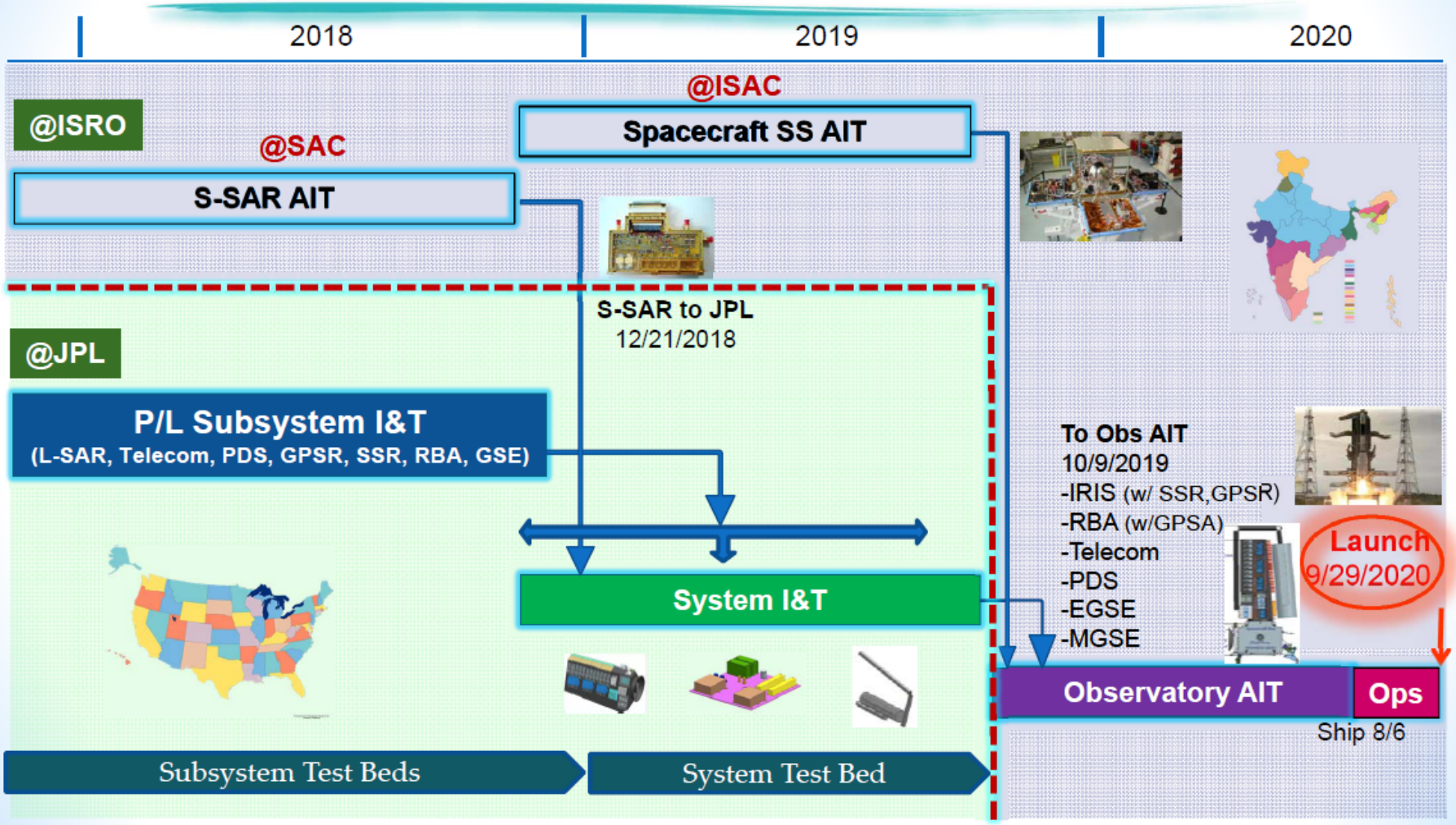
January 2014
- December 2018

Launch
September 202

January 2014
- August 2020

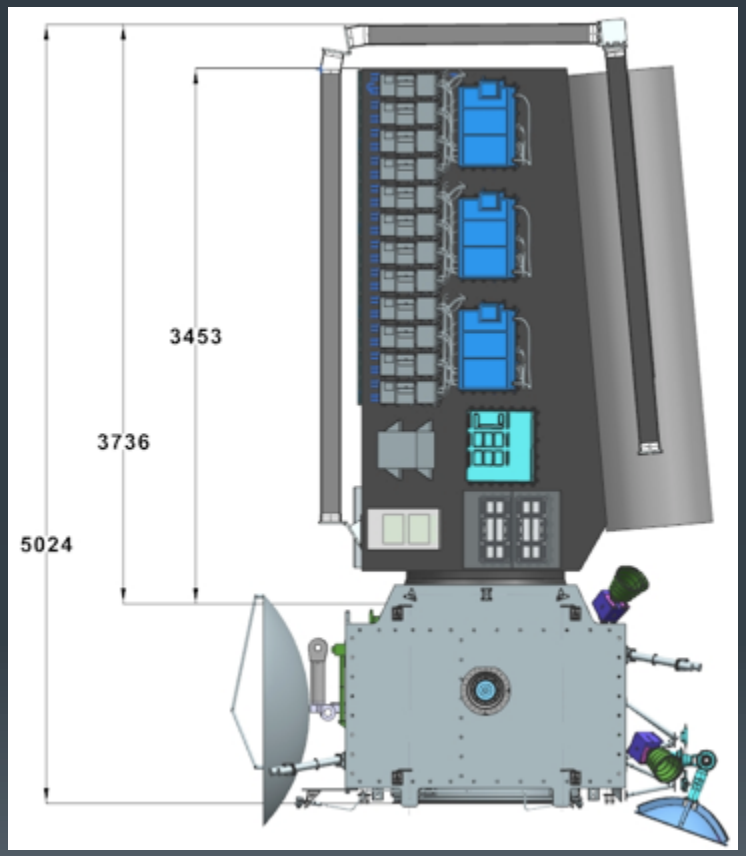
Jet Propulsion Laboratory
California Institute of Technology

NI-SAR I&T Concept



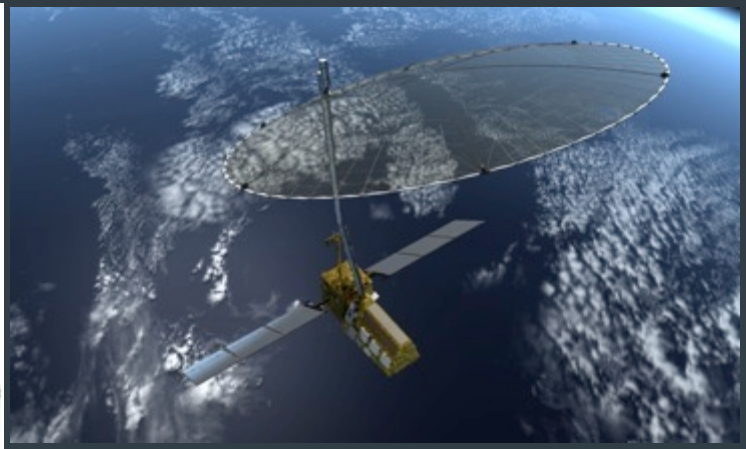
NI-SAR

Proposed Payload Configuration



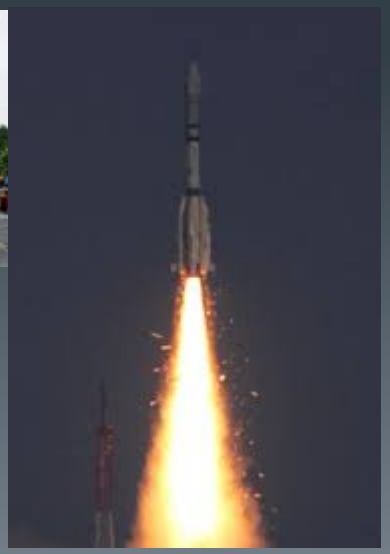
Integrated Observatory
(Spacecraft + Radar Payload)
Launch Configuration

Flight System in Launch Configuration (Inside India's GSLV)



Flight System in In-Orbit Deployed Configuration

At launch site for GSLV launch



GSLV Flight History

Source: ISRO Hq

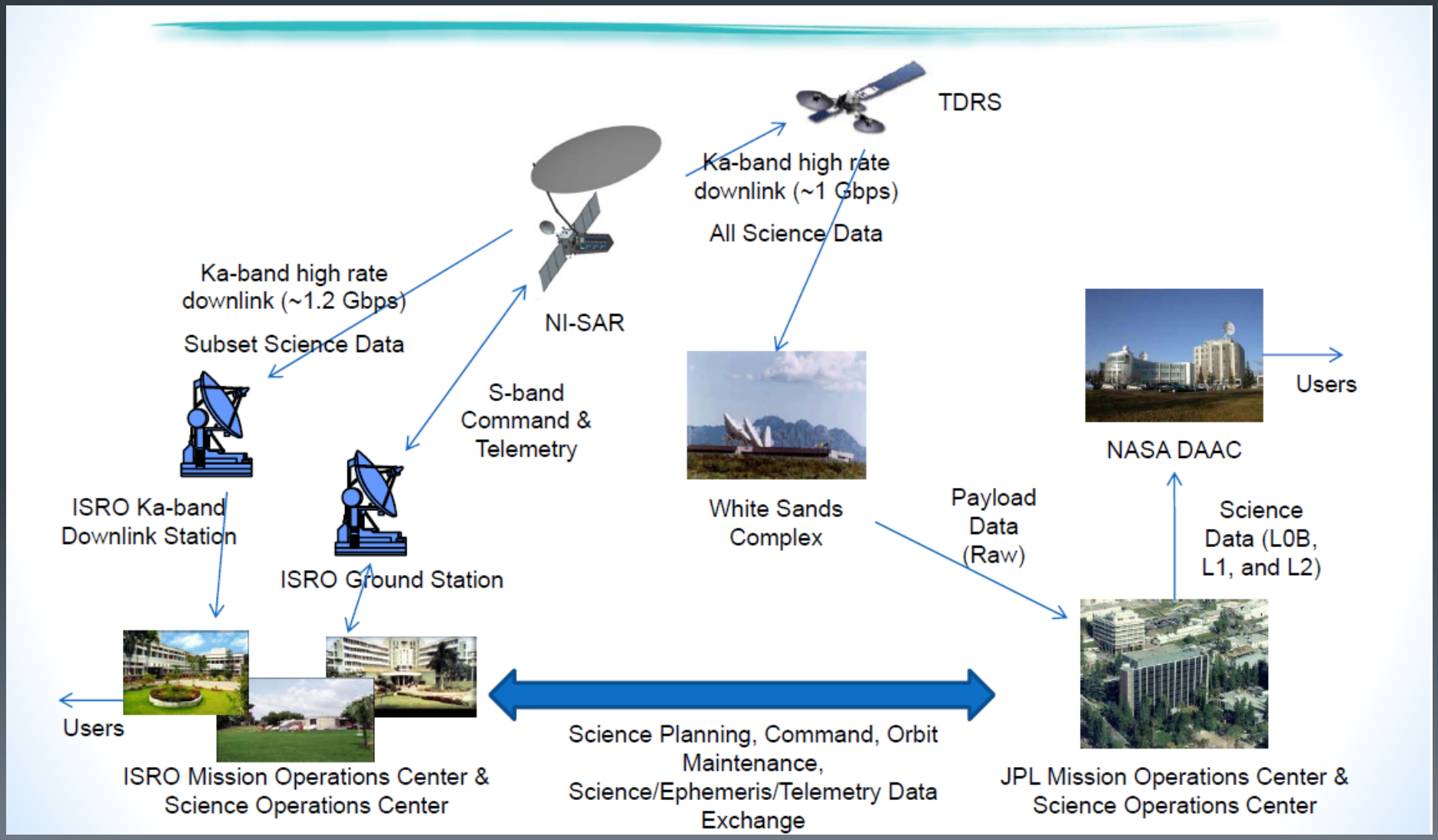
Launch Date	Flight	Payload	Config	Result	Comments
18 Apr 2001	D-1 (Mk I a)	GSAT-1 (1,540 kg)	-Russian Cryo Stage -3.4-m Al Fairing	Success	• Developmental flight • Cryo stage underperformed; S/c injected into lower orbit • Orbit raised using S/c propulsion resulting in reduced life
8 May 2003	D-2 (Mk I a)	GSAT-2 (1,825 kg)	-Russian Cryo Stage -3.4-m Al Fairing	Success	• Developmental flight
20 Sep 2004	F-1 (Mk I b)	GSAT-3/ EDUSAT (1,950 kg)	-Russian Cryo Stage -3.4-m Al Fairing	Success	• Operational flight
10 Jul 2006	F-2 (Mk I b)	INSAT 4C (2,168 kg)	-Russian Cryo Stage -3.4-m Al Fairing	Failure	• Sudden loss of thrust in one of four liquid strap-on stages soon after lift-off leading to vehicle break-up at 62 secs
2 Sep 2007	F-4 (Mk I b)	INSAT-4 CR (2,130 kg)	-Russian Cryo Stage -3.4-m Al Fairing	Success	• S/c placed in different orbit due to anomaly in lower stage control power plant • Orbit raised to GSO using S/c propulsion • S/c operationalized with mission life of 12 years
15 Apr 2010	D-3 (Mk II)	GSAT-4 (2,220 kg)	-Indian Cryo Stage -4-m Comp Fairing	Failure	• First flight test of the ISRO designed and built Cryogenic Upper Stage (CUS) • Cryogenic Upper Stage failure to ignite~ 300 s into flight • First flight of 4-m composite fairing -deployed
25 Dec 2010	F-6 (Mk I c)	GSAT-5P (2,310 kg)	-Russian Cryo Stage with increased prop load -4-m Comp Fairing	Failure	• Vehicle lower stage electronics dis-connected from Equipment bay (EB) due to inadvertent breakage of cryo stage lower shroud, leading to loss of control and vehicle break-up at 53 seconds

GSLV Flight Manifest

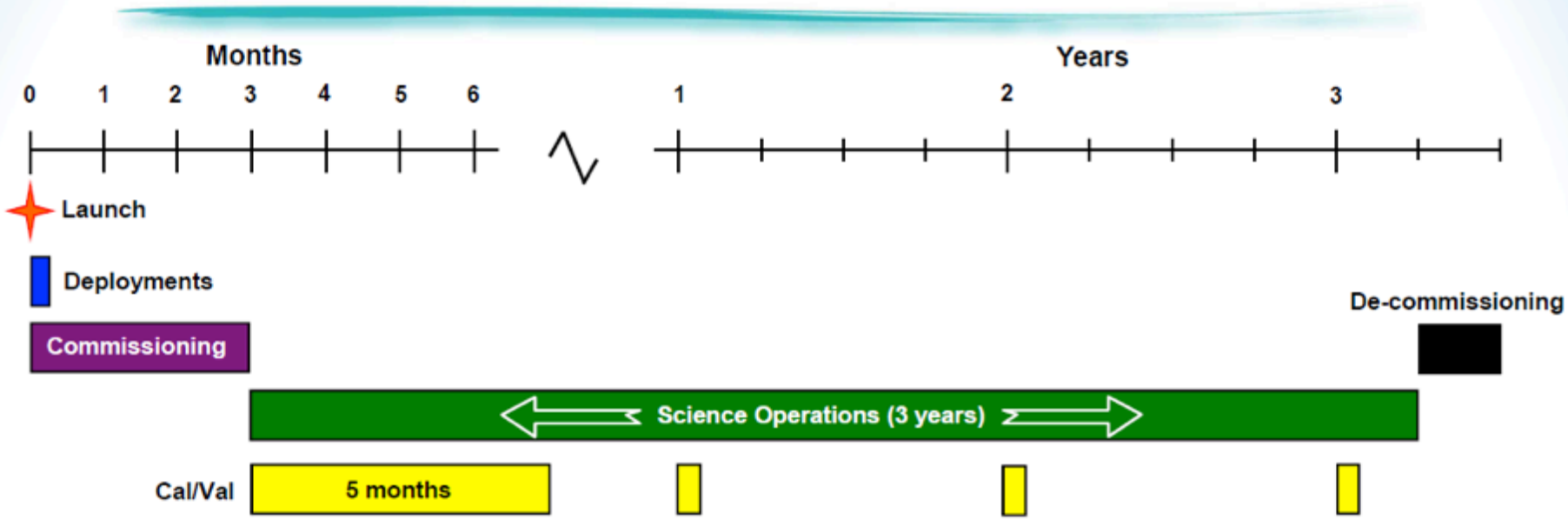
Launch Date	Flight	Payload	Config	Result	Comments
Dec 15, 2013	D-5 (Mk II)	GSAT-14 GTO/ GSO	Indian Cryo Stage 3.4-m Al Fairing		• Aug 19, 2013 launch attempt scrubbed due to 2nd stage fuel leak • 2nd flight of Indian Cryo stage
2014	D-6 (Mk II)	GSAT-6 GTO/ GSO	• 4-m fairing		
2015	F-08 (Mk II)	Chandrayaan-2 GTO/ Moon	• 3.4m/4-m fairing		• Being assessed and to be decided
2016	F-09 (Mk II)	GSAT-9 GTO/ GSO	3.4-m Al Fairing		
2016-2017	F-10 (Mk II) F-11 (Mk II)	GSAT-6A GTO/ GSO GISAT GTO/ GSO	4-m Fairing 3.4 m Al Fairing		
2017-2018	F-12 (Mk II) **F-14** (Mk II)	GSAT-7A GTO/ GSO INSAT-3DR GTO/ GSO	3.4 m Al Fairing 3.4 m Al Fairing		
Sep 2020	**F-16 Mk II**	**NI-SAR 747 km SSO**	**4-m Comp Fairing**		• **4rd / 5th Flight of 4-m composite fairing**

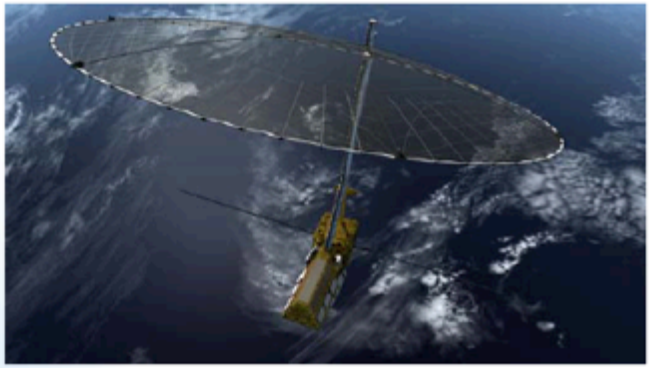
Source: ISRO Hq

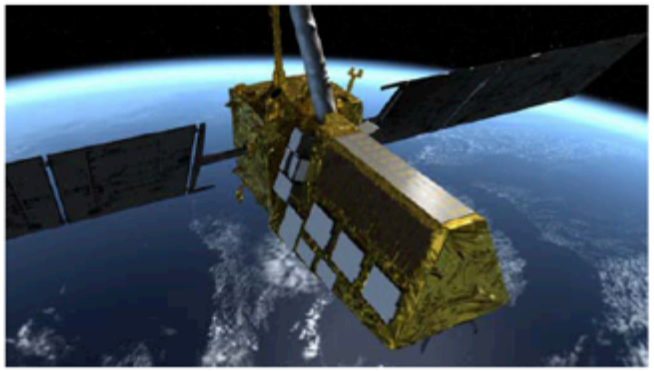
Proposed Mission Architecture

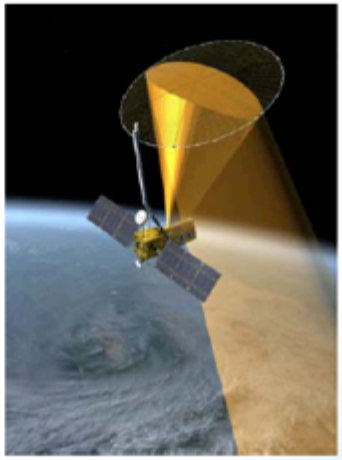


Proposed Mission Timeline



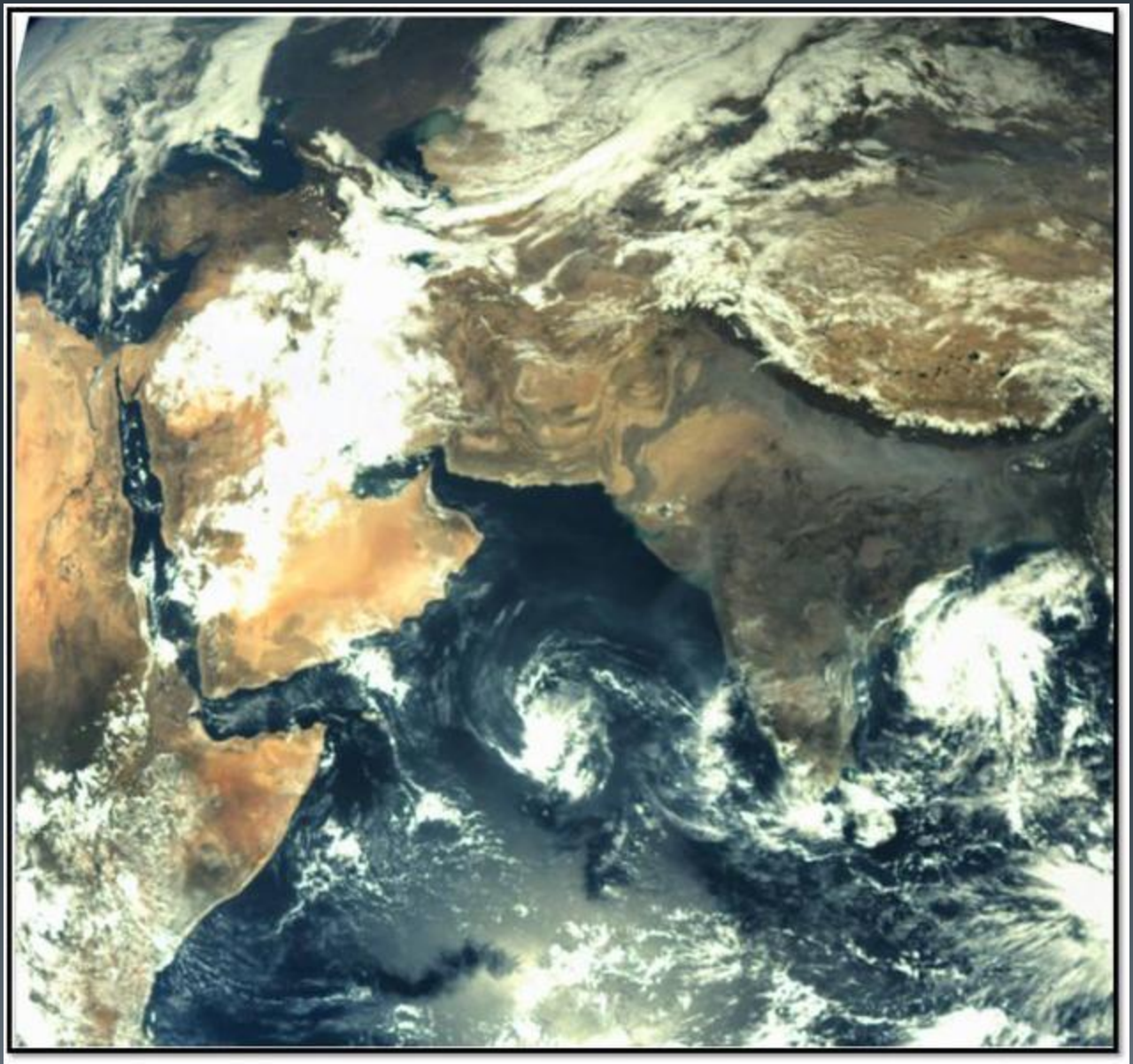






Interface Challenges

- Technical Challenges
  - Project size and Scope
  - GSLV reliability improvement
  - Payload pointing accuracy
  - Mission operational complexity
  - Large Data volume and downlink
- Process Challenges
  - Joint processes needed in system and interface engineering
  - Maintain own internal processes for each organization
  - Documentation, Reviews, Schedule
- Logistic and Cultural Challenges
  - Time Differences of 12.5 to 13.5 hours
  - Cultural norms
  - Language
  - Travel constraints
  - Use non-travel communication means like videocon, webex etc

Summary

- NI-SAR mission is a major Earth science/ application mission with substantial societal benefits
  - The NI-SAR mission will be the world's first dual frequency (L- and S-band) SweepSAR mission.
  - Innovative collaboration with ISRO has enabled this exciting mission concept.
  - Both parties are keen on the win-win mission collaboration
- ISRO & NASA are in a strong position to take the collaboration to the next level of formulation and implementation.
- Recent collaborations have helped form the basic relationship between the two organizations for future
- Both agencies should get the public involved through outreach activities and public education
  - Will inspire the young generation to take up science & technology as a viable career