

# EVOLUTION OF SAR TECHNOLOGY IN ISRO

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# IMAGING SENSOR DEVELOPMENT

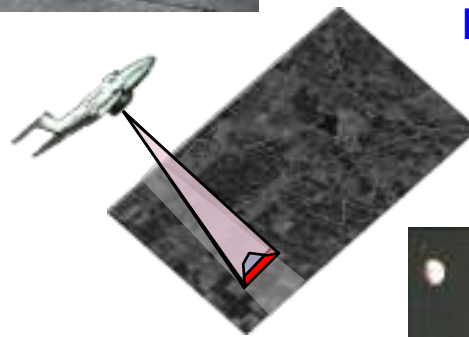
## Imaging Sensor



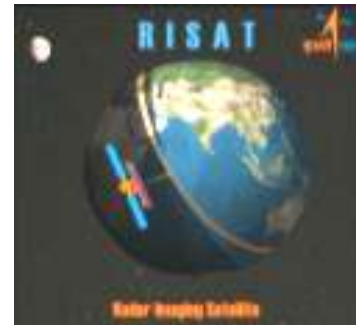
SLAR 1985-1989



ASAR 1989-2002



DMSAR 2005-2007

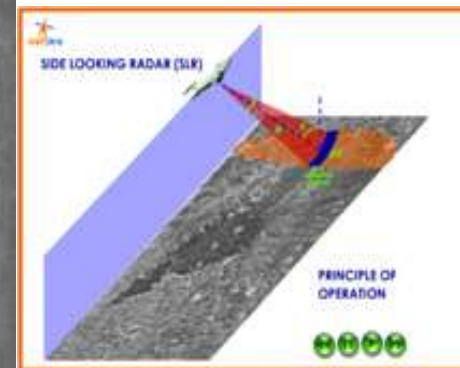
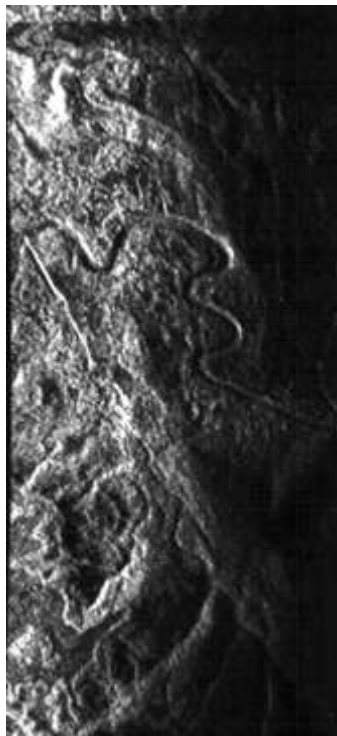


RISAT 2002-2012

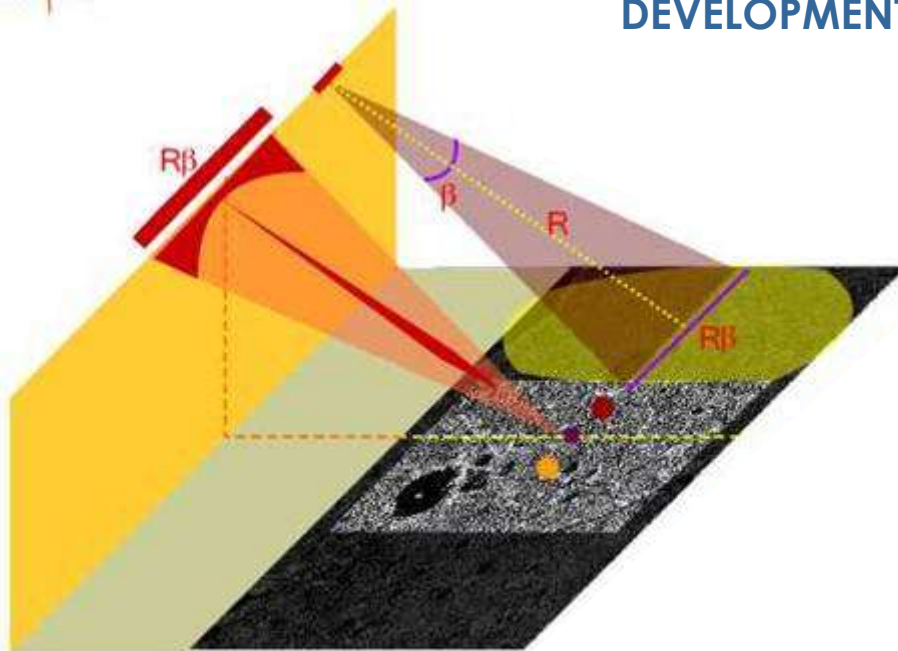


## X-BAND SLAR DEVELOPMENT (1985-1989)

- 9.6 GHZ, HH
- 25 KW PEAK POWER
- ALTITUDE 3 KM
- SWATH 5 KM
- PLATFORM DAKOTA DC-10



1. X-BAND SLAR DEVELOPMENT WAS AN IMPORTANT MILESTONE FOR DECIDING THE SUBSEQUENT COURSE OF SAR DEVELOPMENT
2. THIS DEVELOPMENT GAVE HANDLE TO MANY ASPECTS OF HARDWARE REALISATION, DATA EXTRACTION AND IMAGE INTERPRETATION
3. IT LED TO BUILDING OF A TEAM WHICH ACTS AS A PIVOT FOR SAR DEVELOPMENT



# IMAGING BY RADAR

## ADVANTAGES:

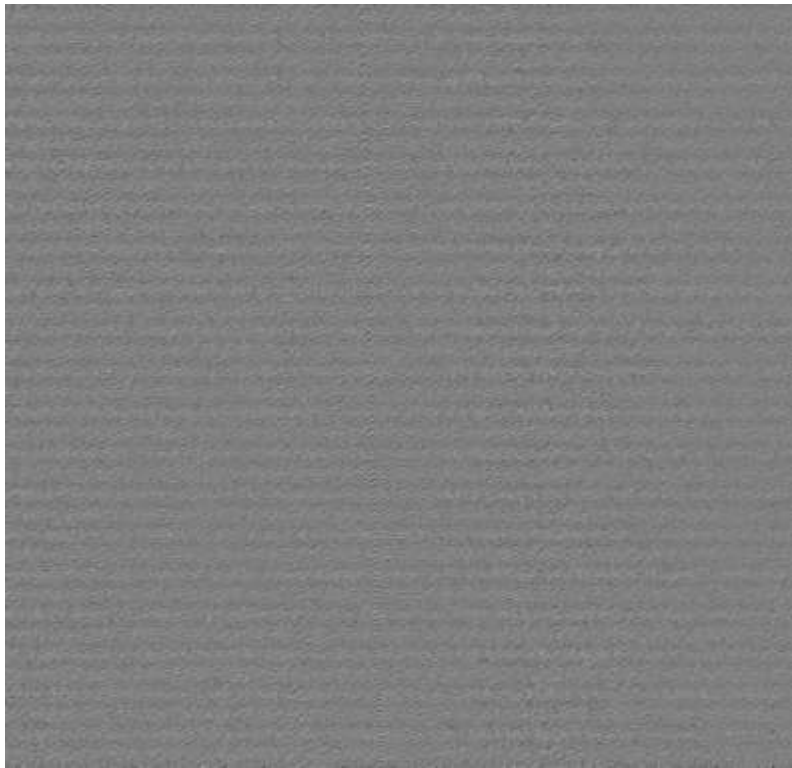
- 24X365 SENSOR, CAPABLE OF IMAGING IN NIGHT, THROUGH CLOUD, RAIN, FOG, HAZE, DUST
  - AMPLITUDE, PHASE AND POLARISATION DISCRIMINATION CAPABILITY
- VERY HIGH CONTRAST FOR MAN MADE OBJECTS. IN GENERAL THE CONTRAST IS VERY HIGH COMPARED TO OPTICAL SENSORS.
- RESPONSE IS PRIMARILY GOVERNED BY GEOMETRIC STRUCTURES AND HENCE COMPLEMENTARY TO OPTICAL IMAGING
  - SAR IS GEOMETRICALLY VERY ACCURATE

## DISADVANTAGES:

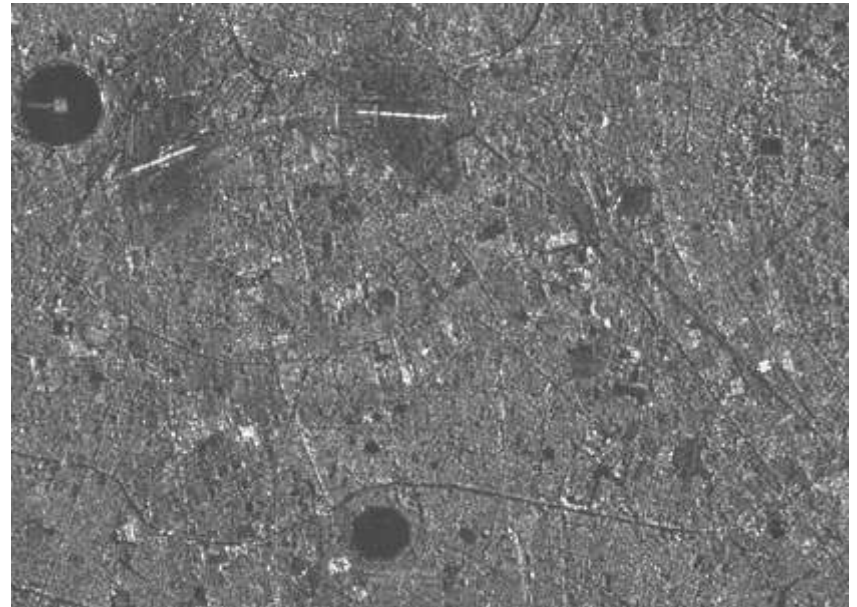
- TECHNOLOGY, ALGORITHM AND COST INTENSIVE
- RESPONSE DO NOT CONFORM TO WHAT HUMAN EYES ARE ACCUSTOMED TO. APPLICATIONS OF THESE TYPE OF SENSORS IS EVOLVING

# ASAR DEVELOPMENT(1989-2002)

**SYNTHETIC APERTURE RADAR(SAR) REMOVES THE LIMITATIONS ON AZIMUTH RESOLUTION, MAKES IT INDEPENDENT OF RANGE**



**SAR RAW  
DATA**



**SAR IMAGE**

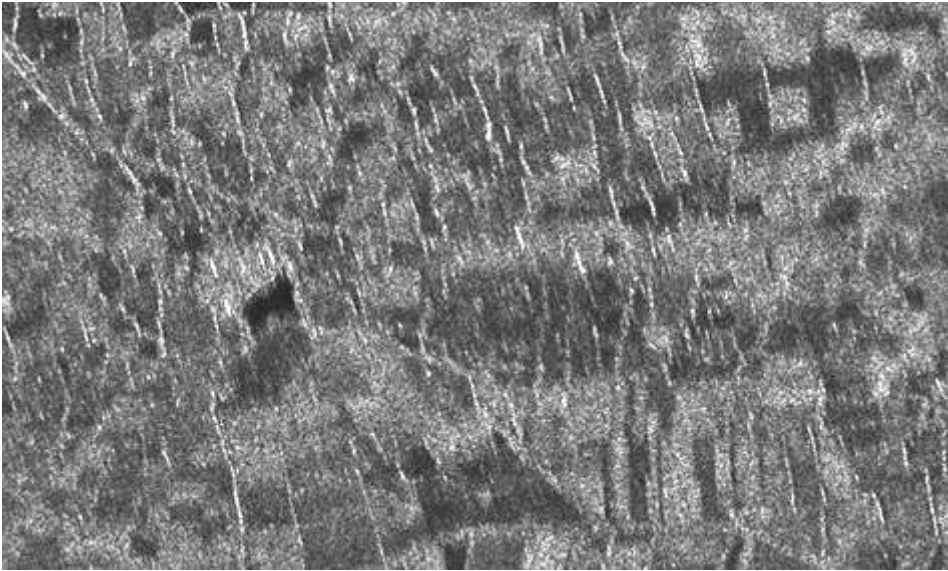


# C-Band ASAR

## FIRST FLOWN ON MAY 20 1992



<b>Operating frequency</b>	<b>5300 MHz</b>
<b>Polarisation</b>	<b>HH, VV</b>
<b>Antenna pattern</b>	<b>Cosec<sup>2</sup></b>
<b>Back scattering coefficient</b>	<b>-30 to +7 dB</b>
<b>Instantaneous dynamic range</b>	<b>~ 20 dB</b>
<b>Slant range resolution</b>	<b>6 m</b>
<b>Azimuth resolution</b>	<b>6 m</b>
<b>Radiometric resolution</b>	<b>≤ 2.5 dB</b>
<b>Swath coverage</b>	<b>25 Km</b>



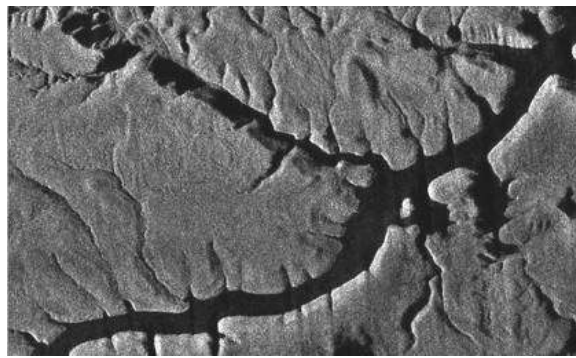
**ASAR IMAGE WITHOUT  
MOTION COMPENSATION**

**ASAR IMAGE WITH  
MOTION COMPENSATION**



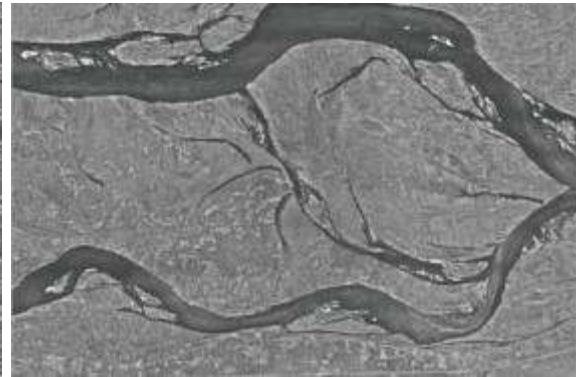
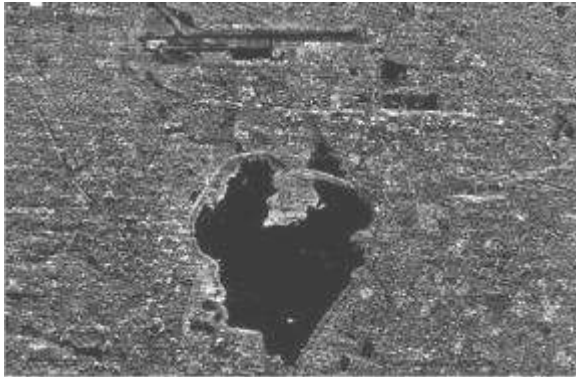


LITTLE RUNN OF KUTCH

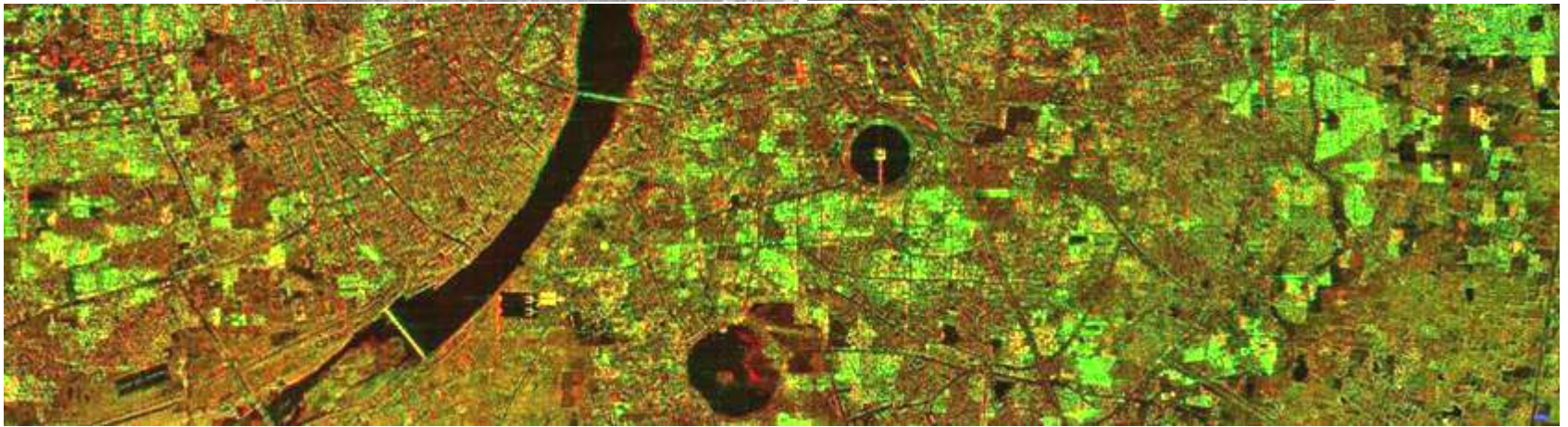


NANDYAL FOREST

HYDERABAD



ASAR IMAGE OF GANGES NEAR PATNA



Area: Ahmedabad, Gujarat  
Green : VV, Red: HH

**Table-3**  
**Summary Specifications of Airborne Imaging Radar**

	<b>SLAR</b>	<b>ASAR</b>	<b>DMSAR</b>
<b>Frequency</b>	<b>9.6 GHz (X-Band)</b>	<b>5.3 GHz (C-Band)</b>	<b>5.35 GHz (C- Band)</b>
<b>Polarisation</b>	<b>HH</b>	<b>VV/HH</b>	<b>VV/HH</b>
<b>Platform/Altitude</b>	<b>Dakota (2-3 km)</b>	<b>Beechcraft (8 km)</b>	<b>Beechcraft (8 km)</b>
<b>Pulsewidth/ Chirp Bandwidth</b>	<b>80/300 ns</b>	<b>20 µsec 25 MHz</b>	<b>20 µsec 225,75,37.5,18.7 5 MHz</b>
<b>Resolution/Swath</b>	<b>50-100 m/ 5 km</b>	<b>6-8 m/ 25 km</b>	<b>1 m/6 km 3 m/ 25 km 5 m/50 km 10 m/70 km</b>
<b>PRF</b>	<b>850 Hz</b>	<b>425-525 Hz</b>	<b>452 hz</b>
<b>Peak Power</b>	<b>25 kW</b>	<b>2 kW</b>	<b>8 kW</b>
<b>Antenna Length/ Pattern</b>	<b>2 m/ Cosine Weighted</b>	<b>1.3 m/ Cosec<sup>2</sup></b>	<b>1.3 m/ Cosec<sup>2</sup></b>

## C-Band DMSAR FIRST FLOWN ON NOV 26 2005



<b>Operating frequency</b>	<b>5350 MHz</b>
<b>Polarisation</b>	<b>HH, VV</b>
<b>Slant range resolution</b>	<b>1 m (Exp), 3 m, 5 m, 10m</b>
<b>Azimuth resolution</b>	<b>1 m (Exp), 3 m, 5 m, 10m</b>
<b>Swath coverage</b>	<b>6 Km (Exp), 25 km, 50 km, 75 km</b>



FLIGHT DIRECTION ←

ILLUMINATION  
DIRECTION  
↓

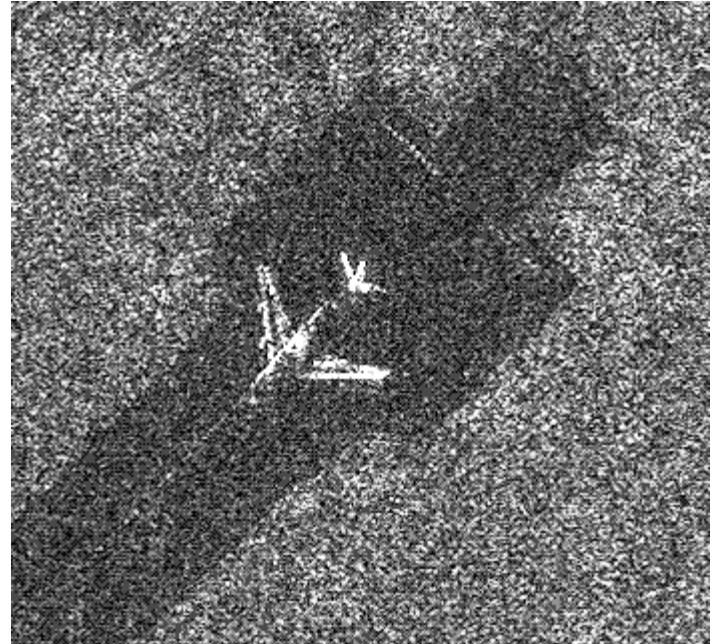


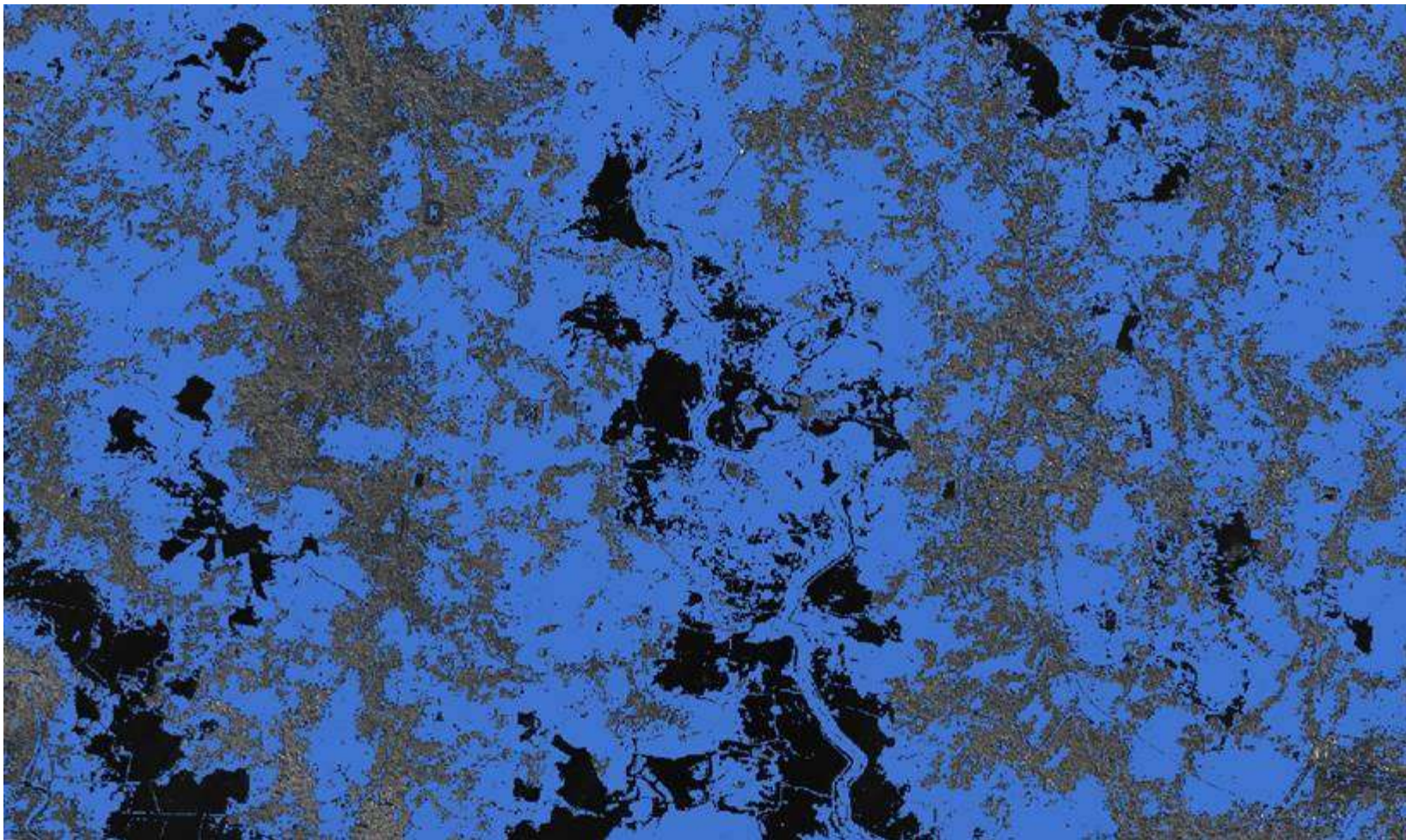
**Different Crop Height is  
Discernible due to  
Shadow Effect**

**1 m Resolution**

ILLUMINATION  
DIRECTION  
→

FLIGHT DIRECTION  
↓





**EXTENT OF FLOOD FROM PREFLOOD IMAGE OBTAINED ON 23/06/07 AND FLOOD IMAGE OBTAINED ON 03/08/07**

**BLUE COLOUR: FLOODED REGIONS**



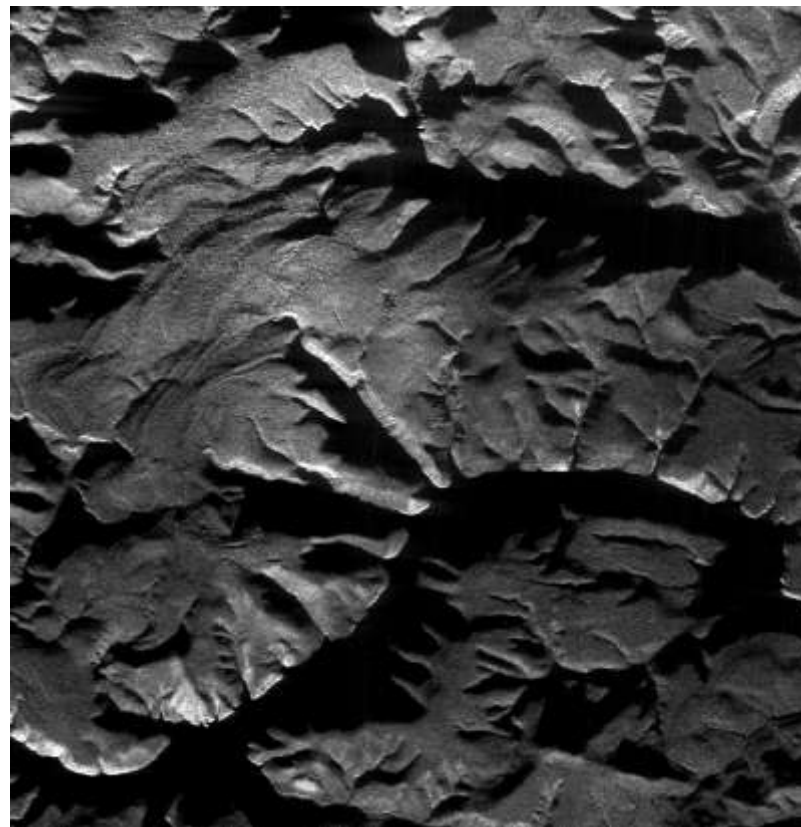
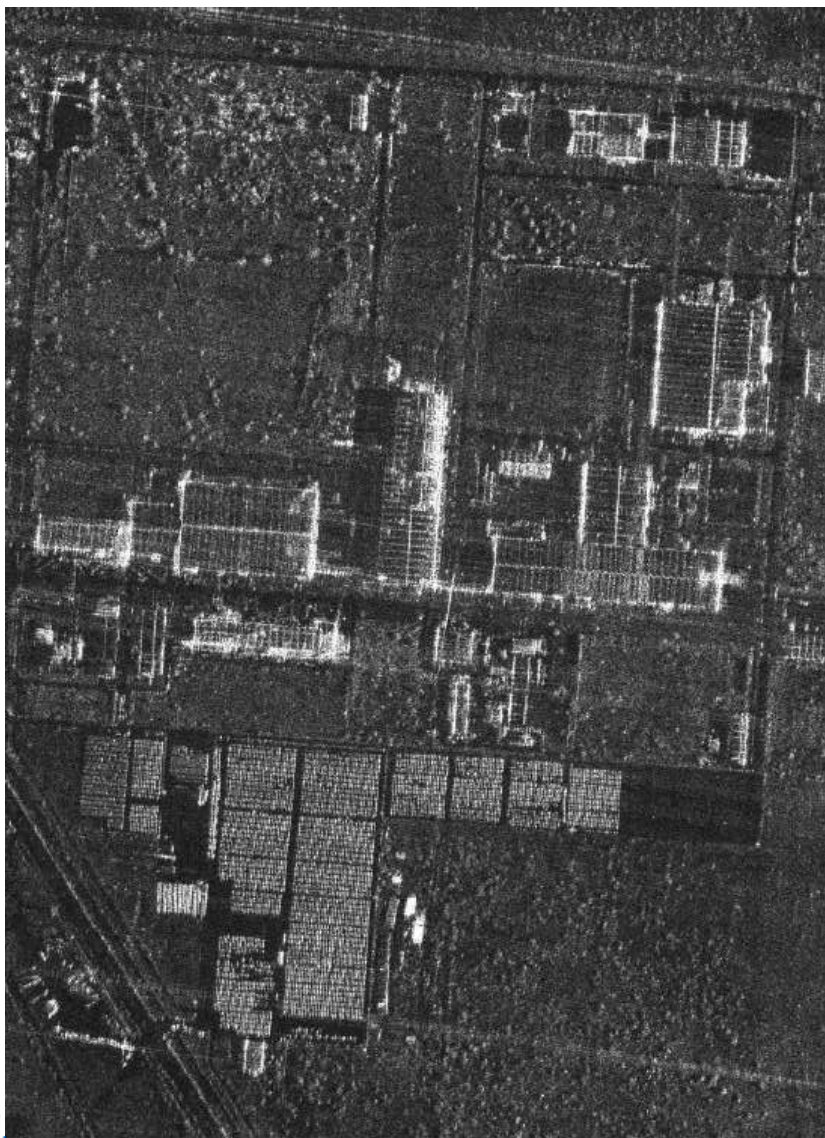


**KOSI BREACH  
LOCATION**

**DATE:  
02-10-2008**

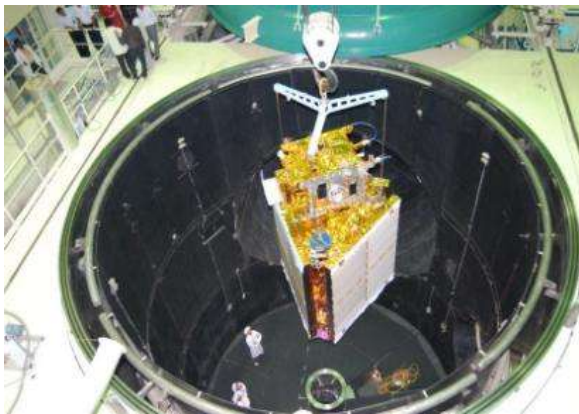
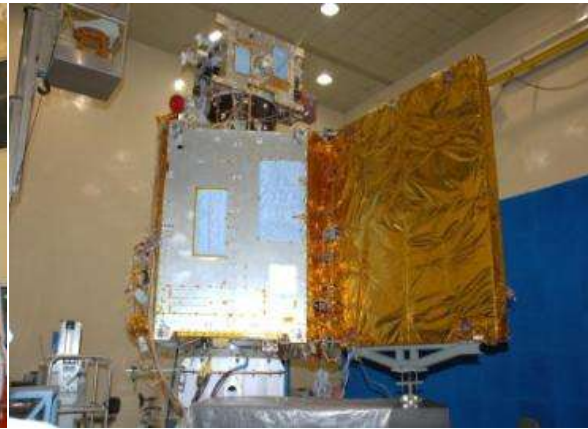
**1m , VV**

## Very Recent DMSAR Images (March-2014)









**26<sup>th</sup> April, 2012 : RISAT-1 Launch**

**27-28<sup>th</sup> April 2012 : Orbit raising from 486 to 536 km**

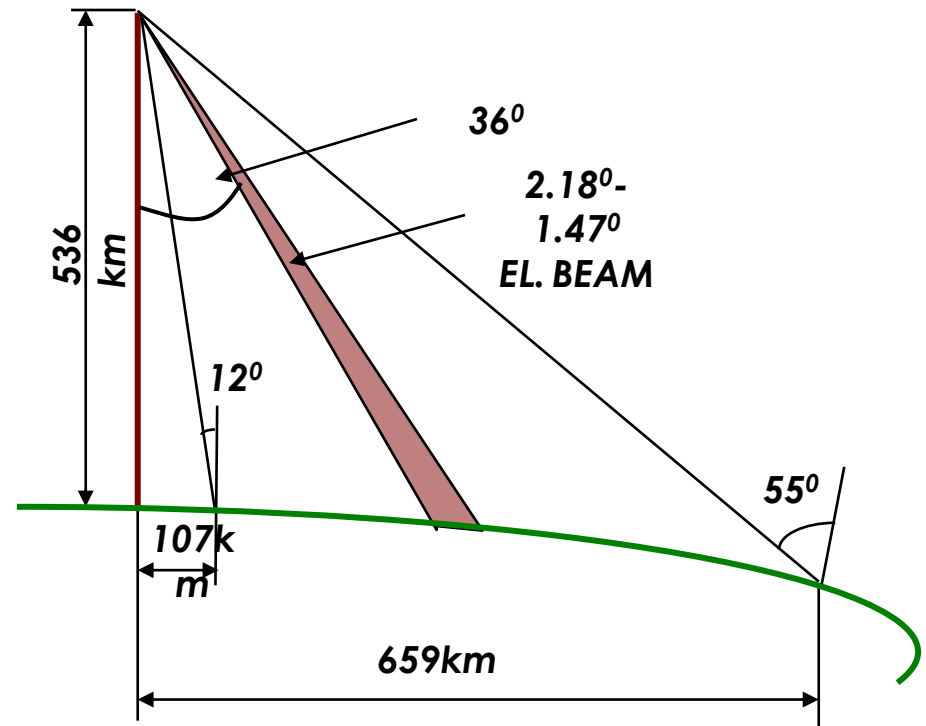
**29-30<sup>th</sup> April 2012 : Switching on of spacecraft subsystems and compatibility check with ground systems**

**1<sup>st</sup> May, 2012 : RISAT-1 Imaging Operation**

## FEATURES OF RISAT SAR

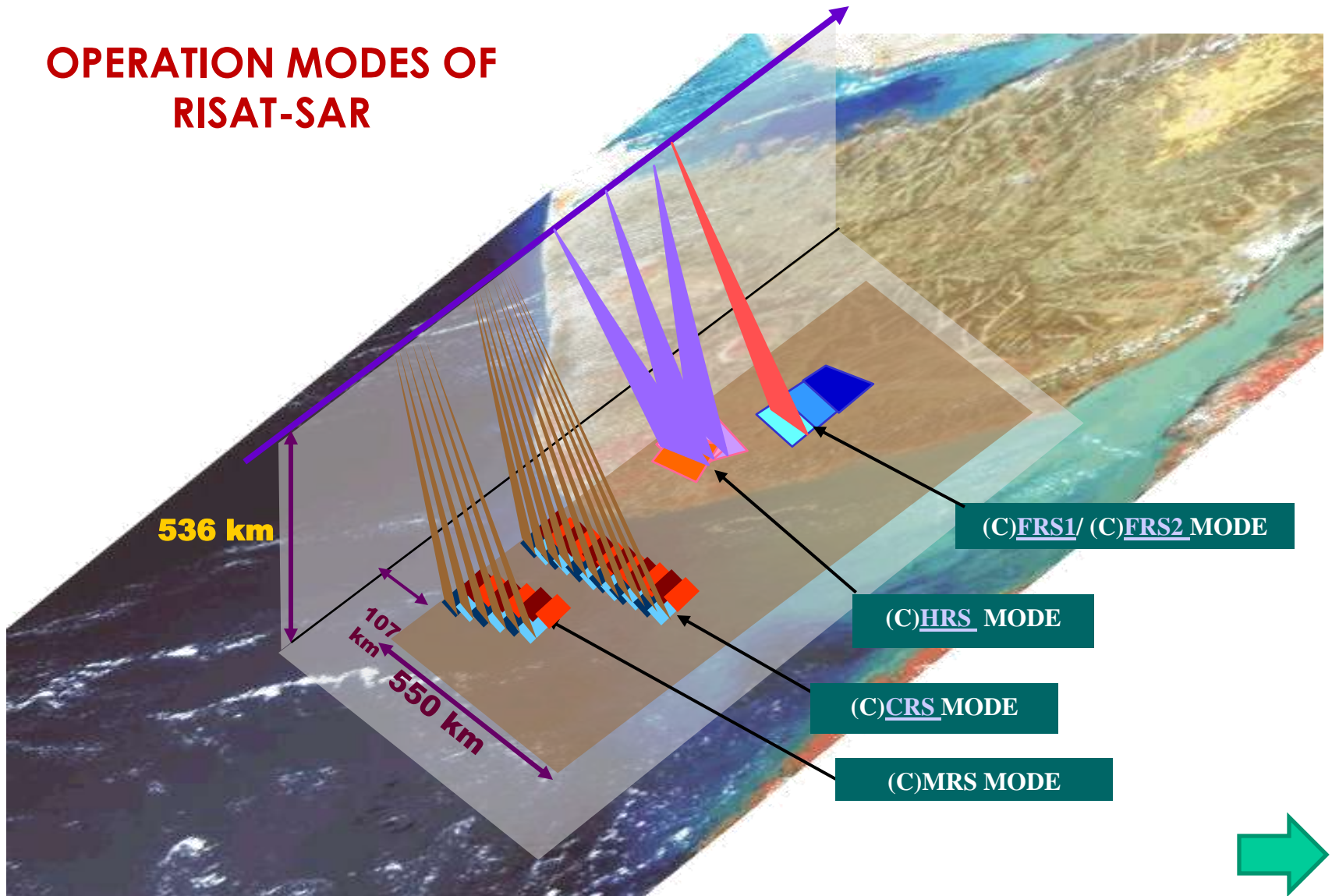
- ACTIVE PHASED ARRAY ANTENNA
- STATE OF THE ART ELECTRONICS
- SUPPORTS VARIOUS IMAGING MODES FROM SPOTLIGHT TO SCANSAR WITH RESOLUTION FROM 1-50 M AND SWATH FROM 10-230 KM
- TRANSMISSION IN H/V/CIRCULAR POLARISATION AND RECEPTION IN H AND V POLARISATION
- UNIQUE FEATURE OF CIRCULAR POLARIMETRY AND LARGE SPOT IMAGING

## IMAGING GEOMETRY

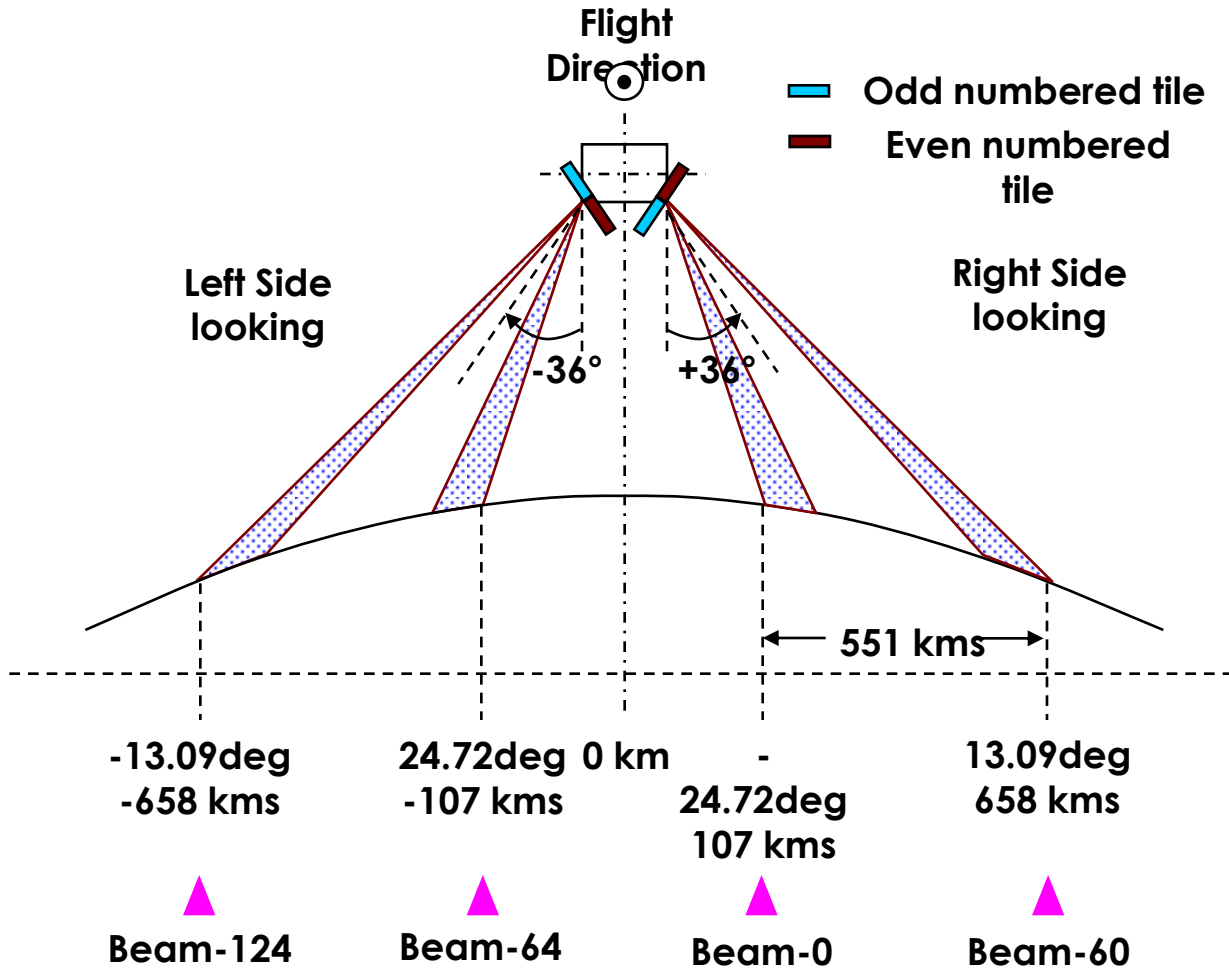


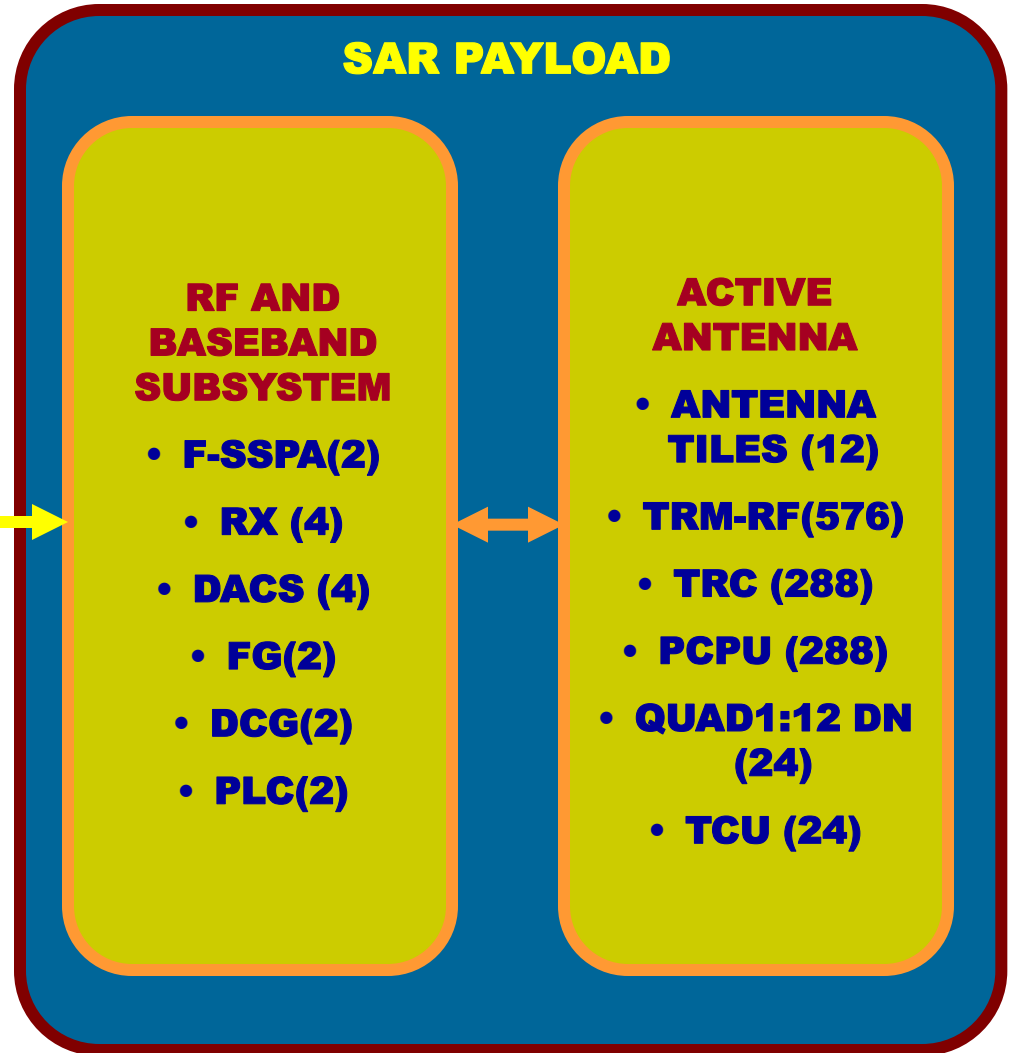
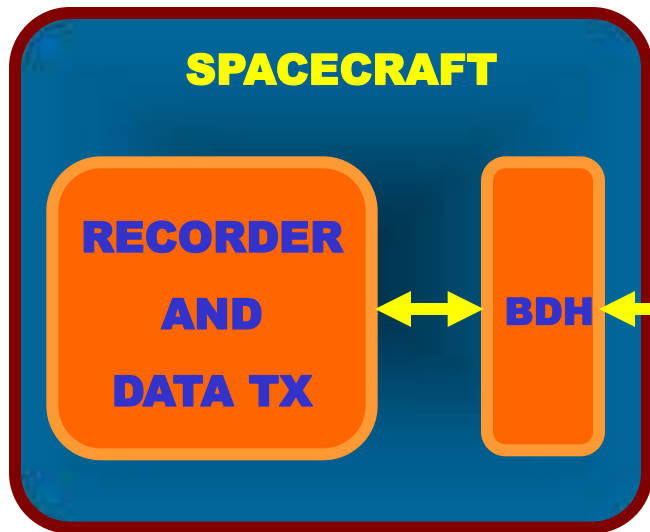


# OPERATION MODES OF RISAT-SAR



# ANTENNA PATTERN CHARACTERIZATION – BEAM CONFIGURATION



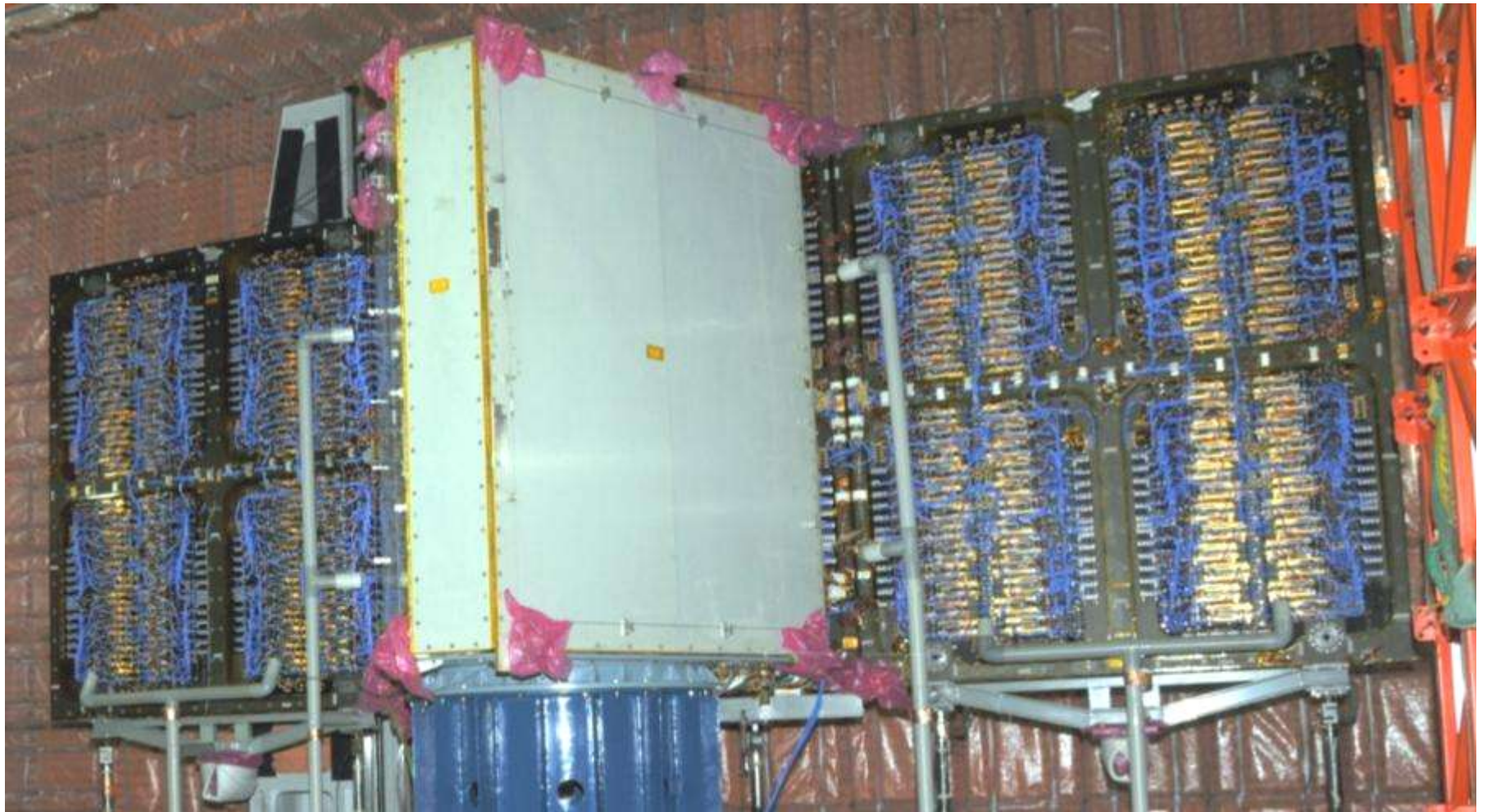








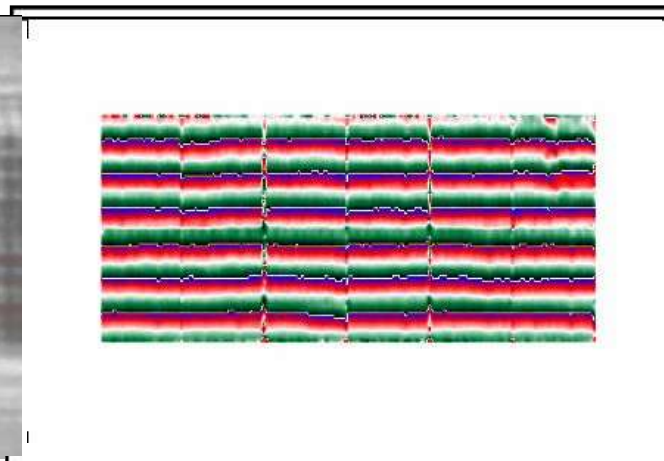
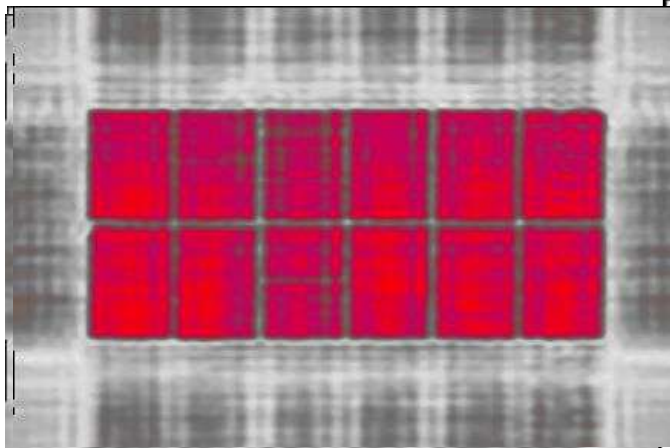
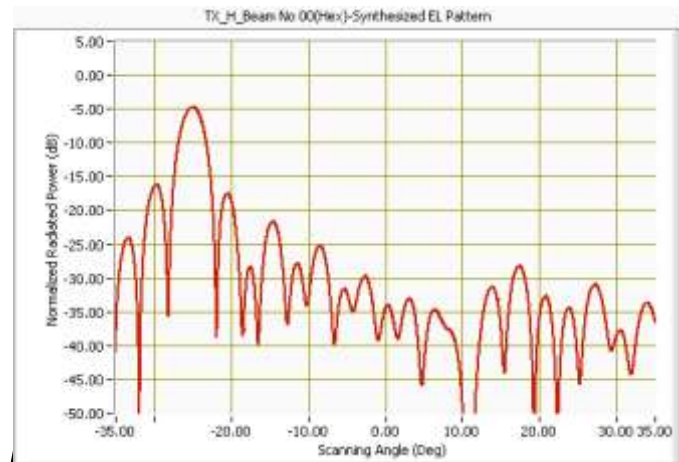
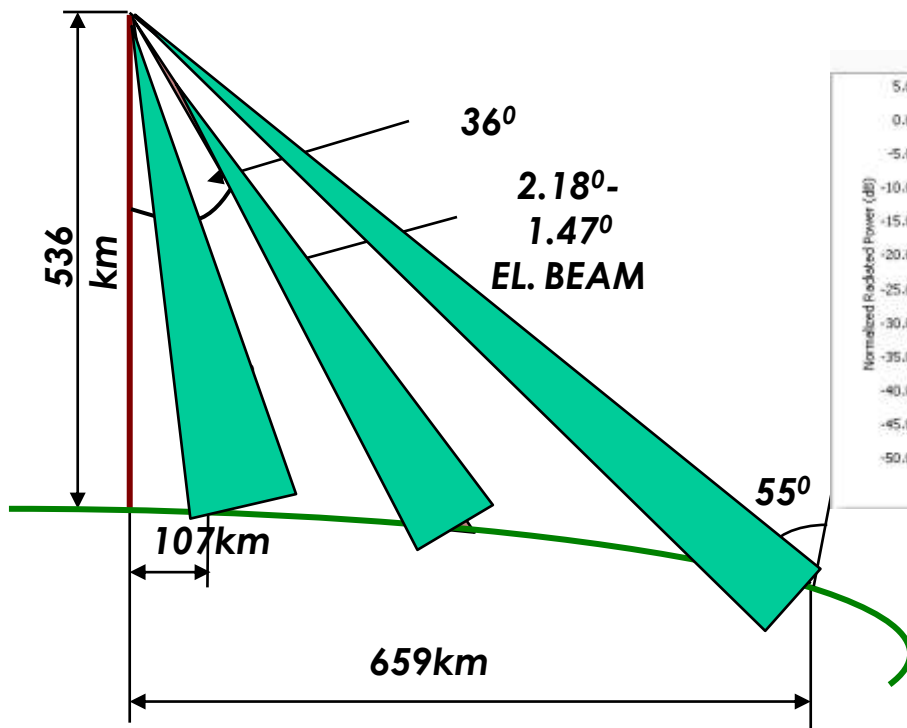




**RISAT-SAR UNDERGOING CHARACTERIZATION IN NEAR-FIELD MEASUREMENT CHAMBER**







## TOTAL POWER DISSIPATION FOR RISAT-SAR

1. Total Deck Dissipation 113.4 watts

2. Active Antenna 822 watts

Without RF Pulsing (DC Power)

With RF Pulsing (Imaging) 1854 Watts-3884 Watts

## TOTAL MASS FOR RISAT-SAR

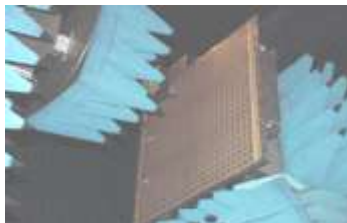
1. Panel-1 289.31 kg

2. Panel-2 289.89 kg

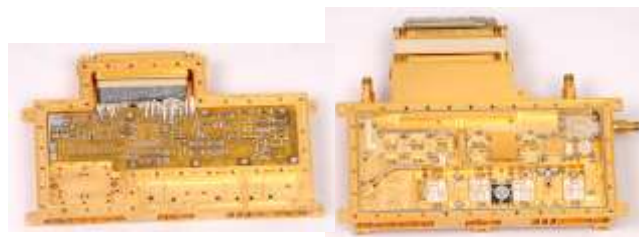
3. Panel-3 291.28 kg

4. Deck Elements 54.84 kg+~5kg Harness

**Total 925.32 kg+~5kg Harness**



**PRINTED  
ANTENNA –  
ASTRA, SLT**



**TR MODULE-ASTRA**

**MINIATURISED  
EPC FOR TR  
MODULE -  
CENTUM**



**GLIMPSE OF SOME OF  
NEW TECHNOLOGIES  
DEVELOPED DURING  
RISAT PROGRAMME**

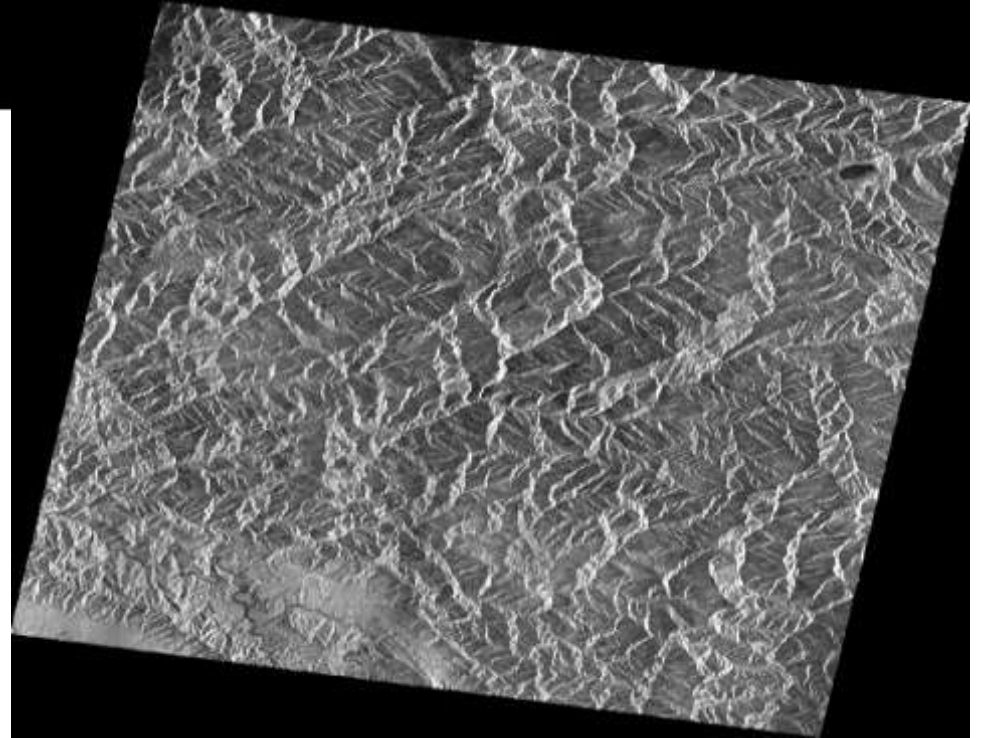
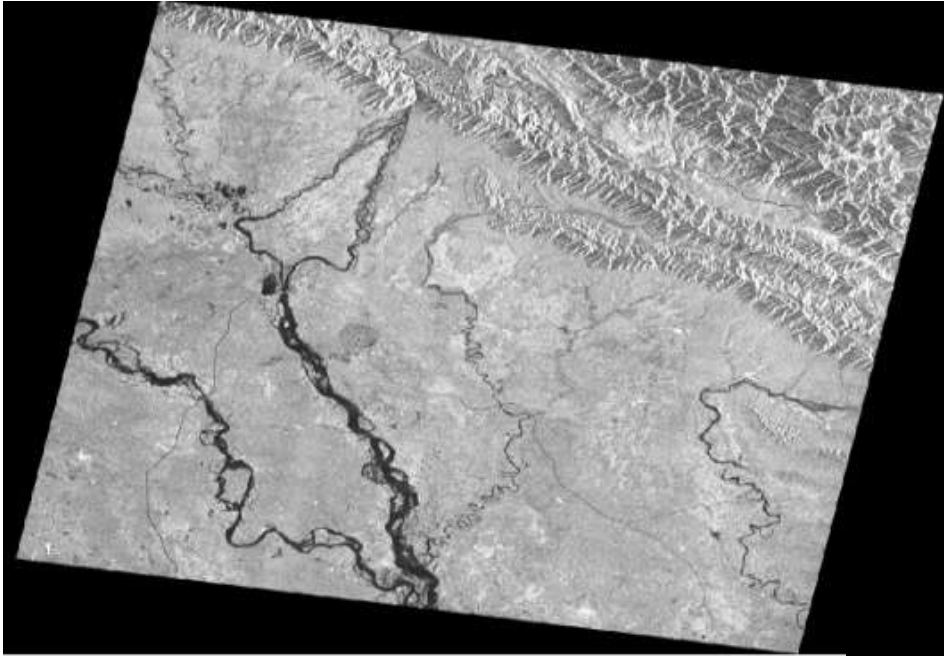


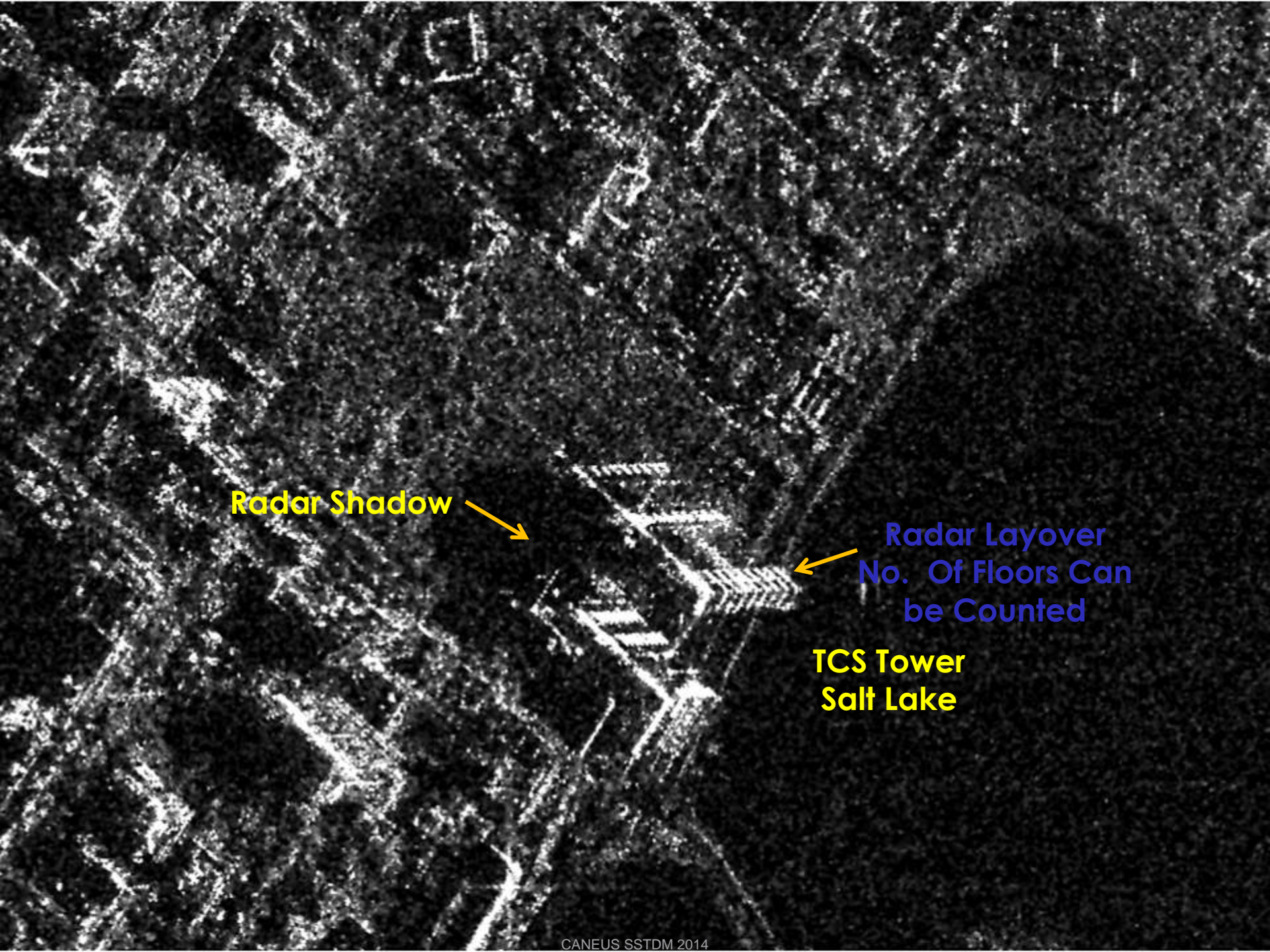
**3 AXIS SCANNER FOR NF  
ANTENNA TEST FACILITY-  
BOMBAY MACHINES**



**TR CONTROL  
COMPUTER-  
CENTUM, ASTRA**







**Radar Shadow** →

← **Radar Layover**  
**No. Of Floors Can**  
**be Counted**

**TCS Tower**  
**Salt Lake**



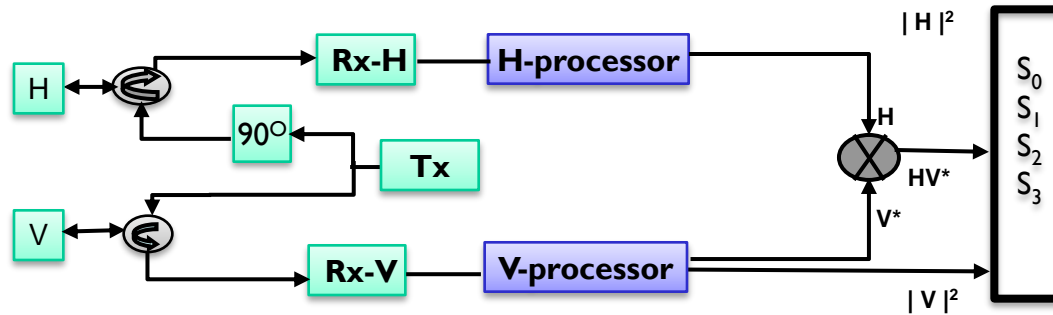
# Mt. Kelud , Indonesia



Imaged by RISAT-1 on 9<sup>th</sup> March,  
2014



# Hybrid Polarimetry



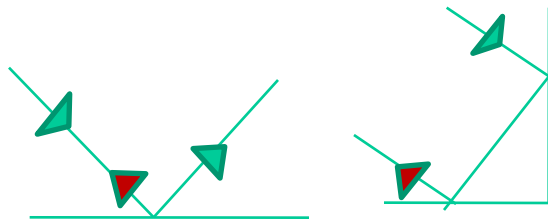
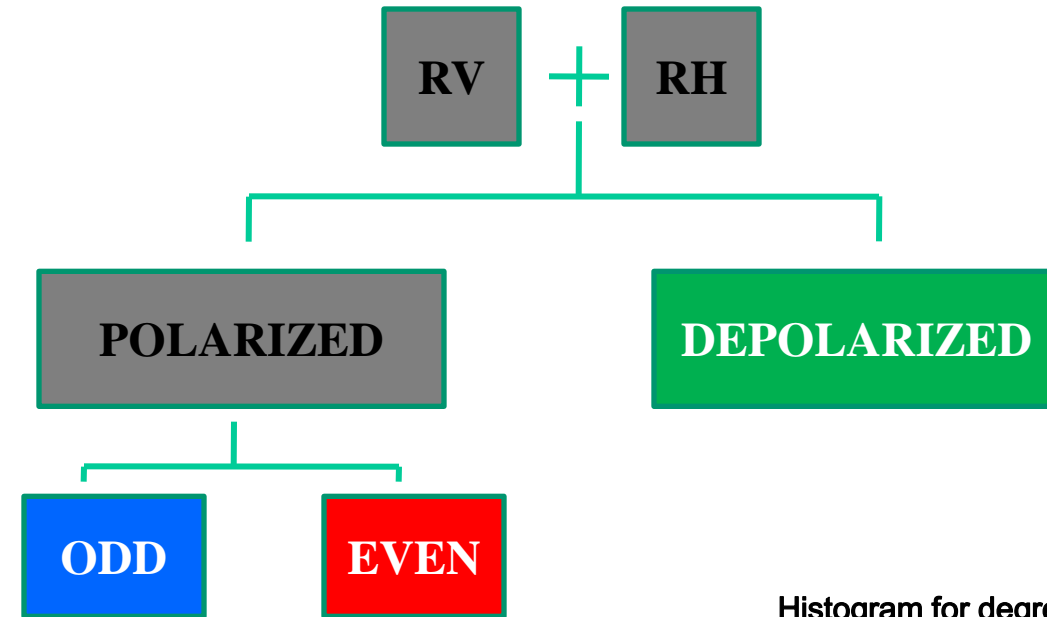
Hardware Realization of Circular Polarimetry

$$S_0 = \langle |E_{RH}|^2 + |E_{RV}|^2 \rangle$$

$$S_1 = \langle |E_{RH}|^2 - |E_{RV}|^2 \rangle$$

$$S_2 = 2 \Re \langle E_{RH} E_{RV}^* \rangle$$

$$S_3 = 2 \Im \langle E_{RH} E_{RV}^* \rangle$$



**Relative Phase**  
 $\delta = \text{atan}(S_4 / S_3)$

**Degree of Polarisation**  
 $m = \frac{(S_2^2 + S_3^2 + S_4^2)^{1/2}}{S_1}$

**m-delta  
 Decomposition  
 (Patent applied)**

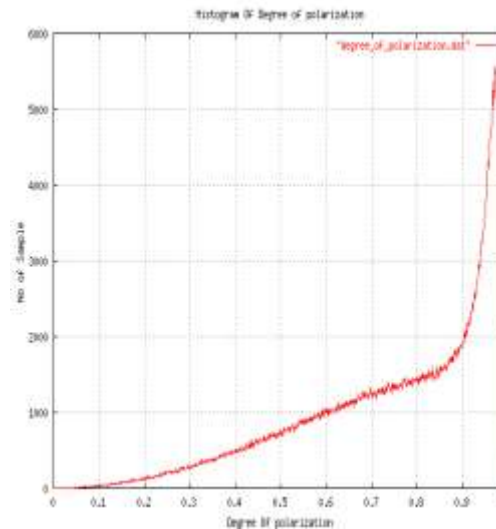
$$S_0 = \langle |E_{RH}|^2 + |E_{RV}|^2 \rangle$$

$$S_1 = \langle |E_{RH}|^2 - |E_{RV}|^2 \rangle$$

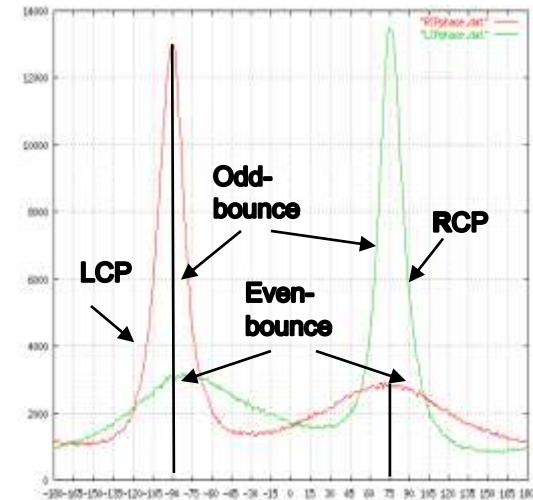
$$S_2 = 2 \Re \langle E_{RH} E_{RV}^* \rangle$$

$$S_3 = 2 \Im \langle E_{RH} E_{RV}^* \rangle$$

Histogram for degree of polarization



Histogram for Relative phase between v-channel and h-channel



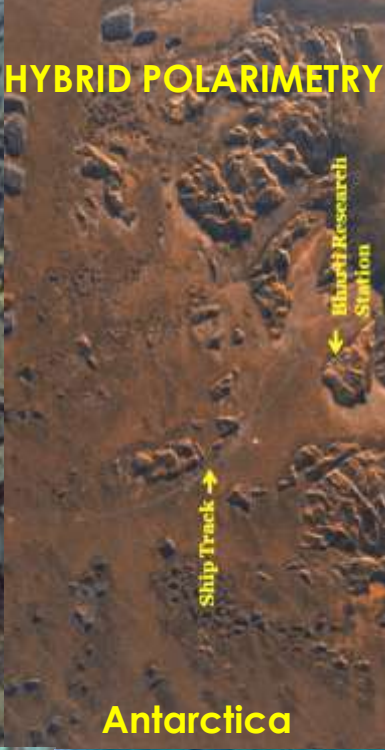
**RISAT-1 HYBRID POLARIMETRY RESULTS**



**Andaman Sea**



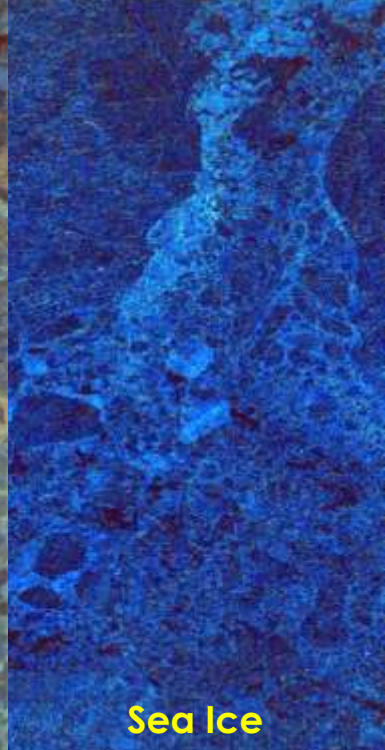
**Pali, Rajasthan**



**Antarctica**



**Tunisia**



**Sea Ice**



**Andaman Sea**



**SABARMATI**



**OIL SPILL,  
NORWAY**



**AHMEDABAD**



**RISAT-1 HYBRID POLARIMETRY ONLY CAN PROVIDE POLARIMETRY IN SCANSAR MODE**



# DUM DUM AIRPORT

Belghareia  
Expressway

Jessore  
Road

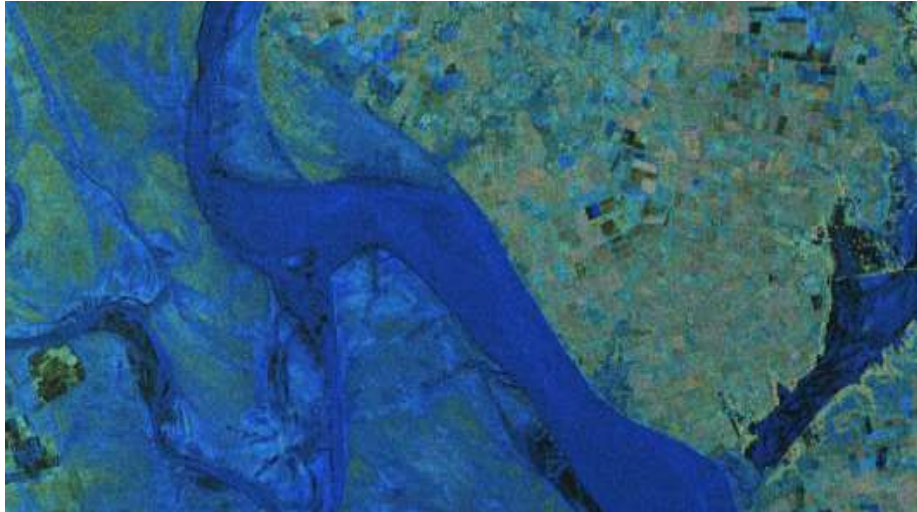
New  
Integrated  
Airport  
Terminal

Central  
Jail

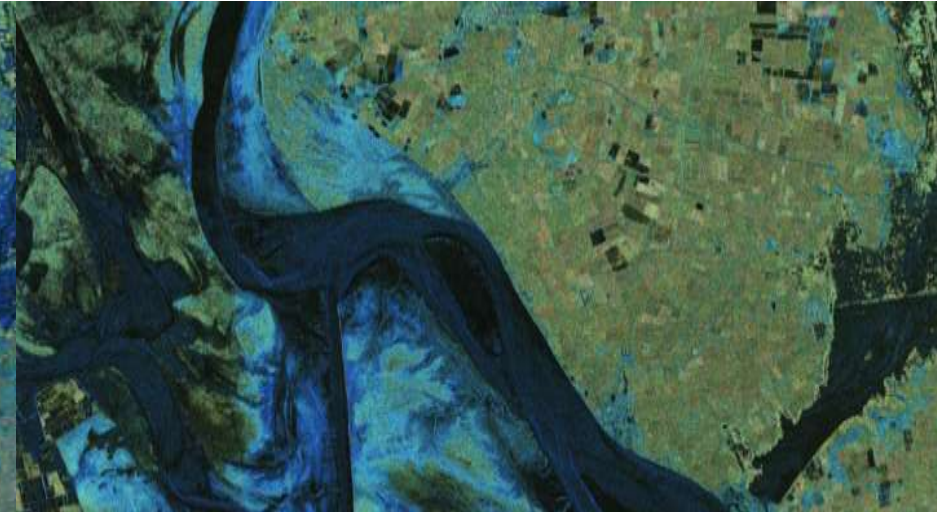
VIP Road



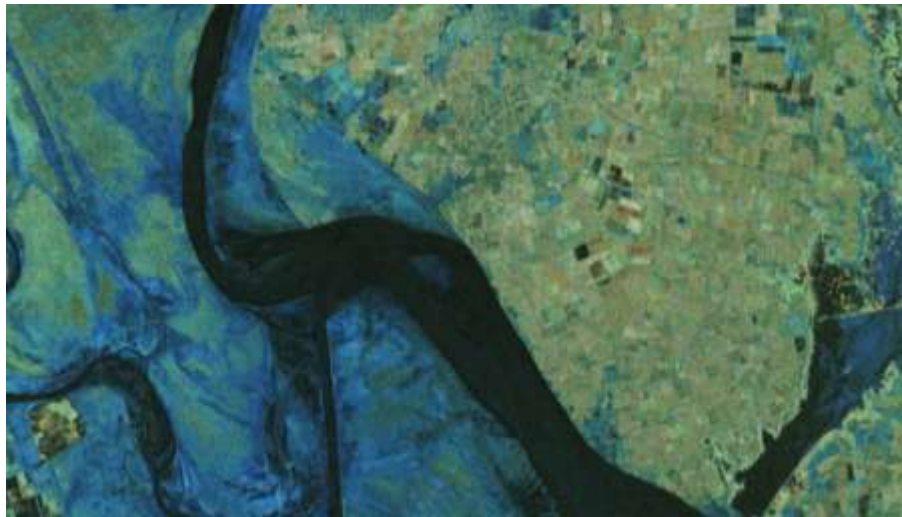
# Polarimetry Signatures of crop area at various Incidence Angles



Incidence Angle - 22°



Incidence Angle - 30°



Incidence Angle - 38°



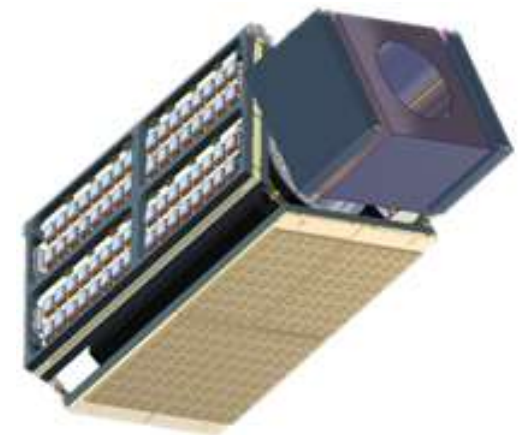
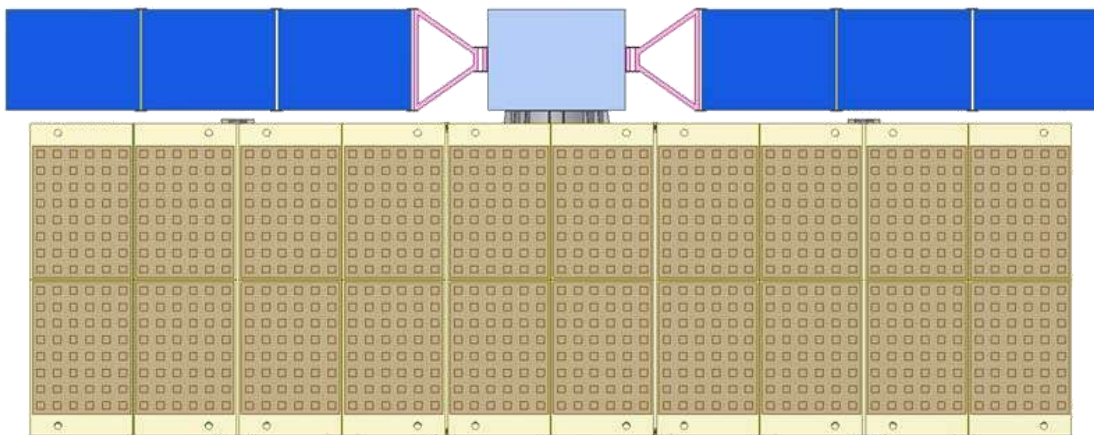
Incidence Angle - 44°



# L-BAND SPACEBORNE SAR

## L-Band Active SAR Basic Configuration:

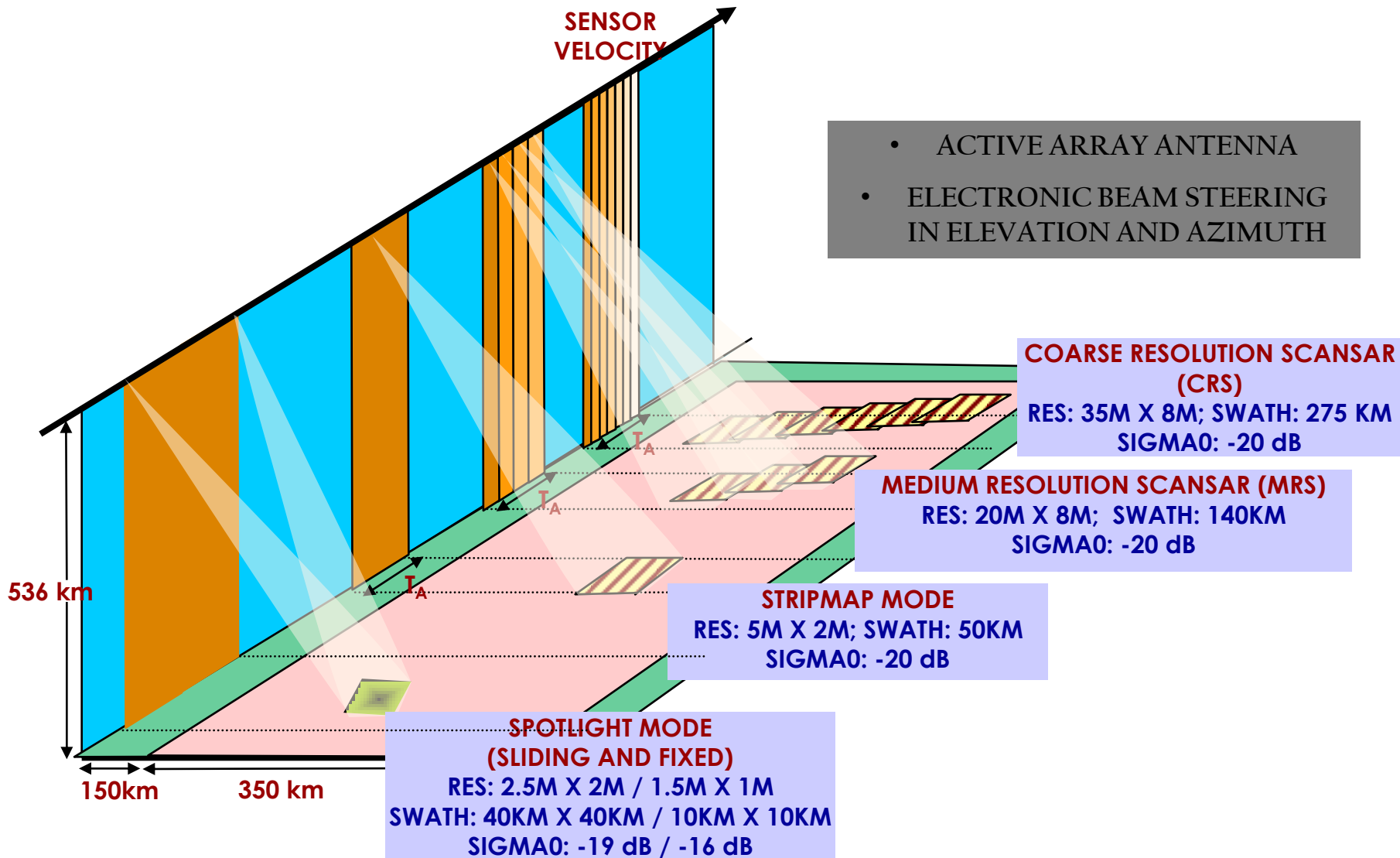
- L-band Active SAR at 1.25 GHz frequency
- Active Phased Array Antenna of size 11m x 3m
- 320 TR Module pairs
- Single/ Dual/Circular/Full polarization capability
- Supports various Imaging Modes from Spotlight to ScanSAR
- High Resolution mode with spatial resolution better than 1 m



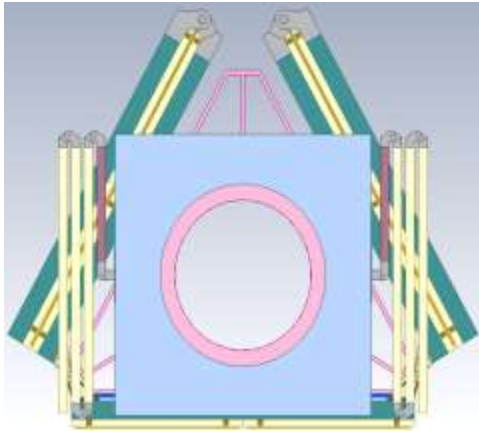
# Brief System Specifications

Platform Specifications	
Frequency	1.25 GHz
Altitude	536 km
Platform Velocity	7.5 km/s
Imaging Geometry	
Look Angle	15.58° to 41.96°(Single/Dual/Circular-Pol operation) 15.58° to 31.94° (Full Pol operation)
Swath	50 km – 200 km
Off-Nadir	150 km – 500 km
System Parameters	
Frequency	1.25 GHz
Chirp Bandwidth	18.75 MHz, 75 MHz, 225 MHz
Peak Power/TRM at TRM output	46 dBm
Number of TR Modules	320
Antenna Size (Nominal)	11 m x 3 m
Antenna Gain	35 dBi
Antenna Beamwidth	1.27° (az) x 4.6°(elev)
PRF (Single,Dual, Circ/Full-Pol,ARI)	1800 Hz – 2050 Hz / 3600 Hz – 3850 Hz
Pulse Width	10uS, 20uS

# Imaging Configuration



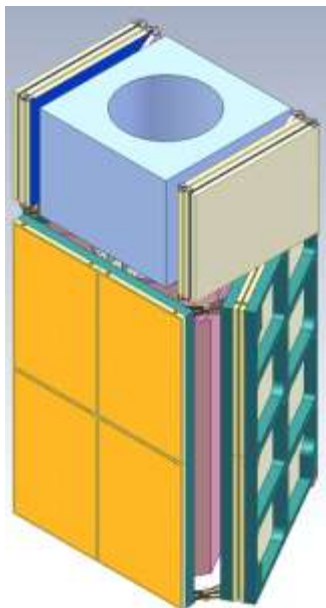




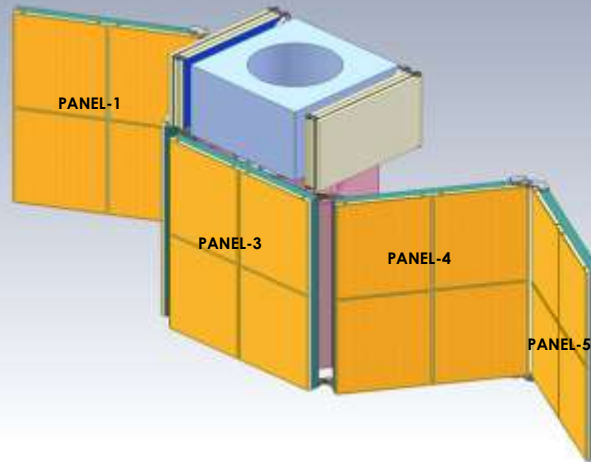
STOWED ANTENNA (TOP VIEW)

## ACTIVE ANTENNA CONFIGURATION

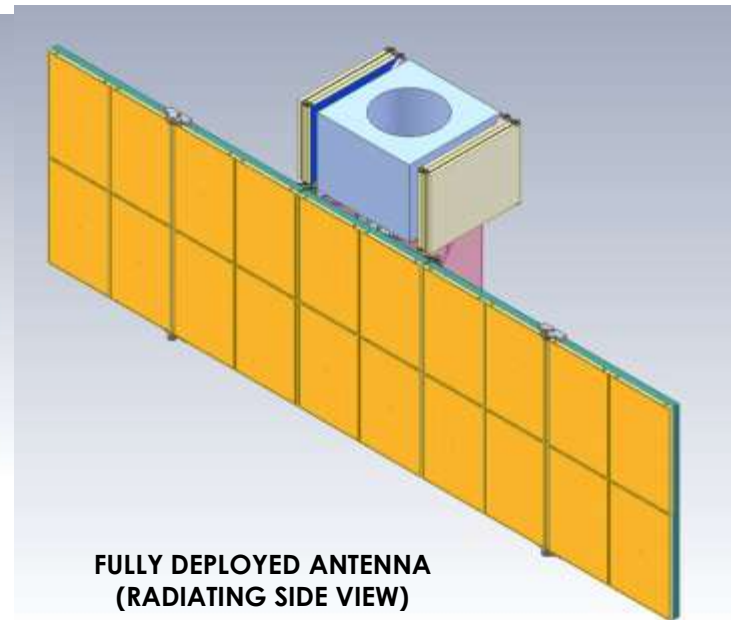
- APPROX WEIGHT OF ANTENNA: 735 KG
- ROLL TILTING REQD FOR LEFT/RIGHT LOOKING
  - WITHOUT CIRCULAR OR LINEAR POL,
    - AVG RF POWER: 230 – 265W => TOTAL DC POWER: 1400 – 1500W
    - WITH CIRCULAR OR LINEAR POL,
      - AVG RF POWER: 460 – 530W => TOTAL DC POWER: 2700 – 3100W



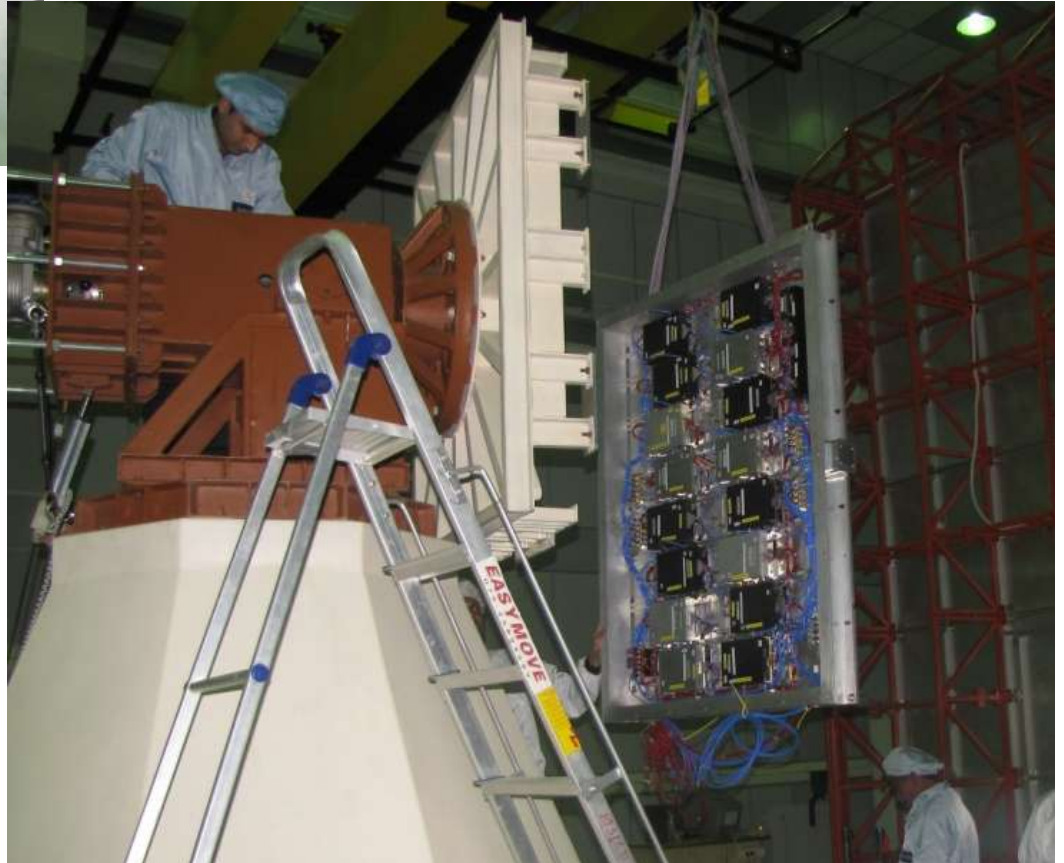
STOWED ANTENNA (SIDE VIEW)



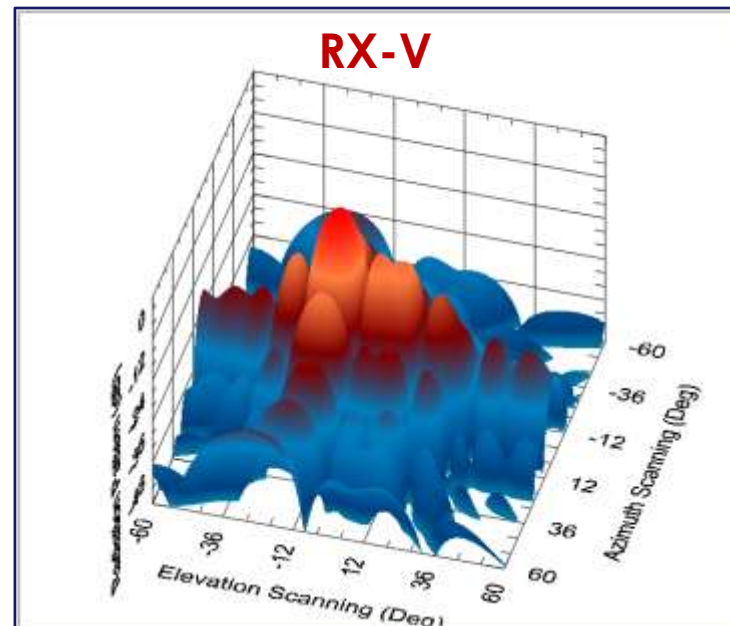
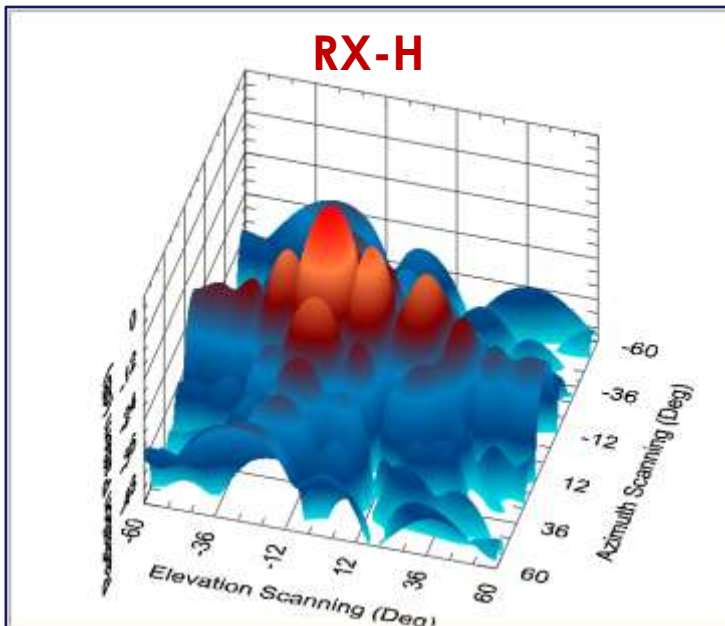
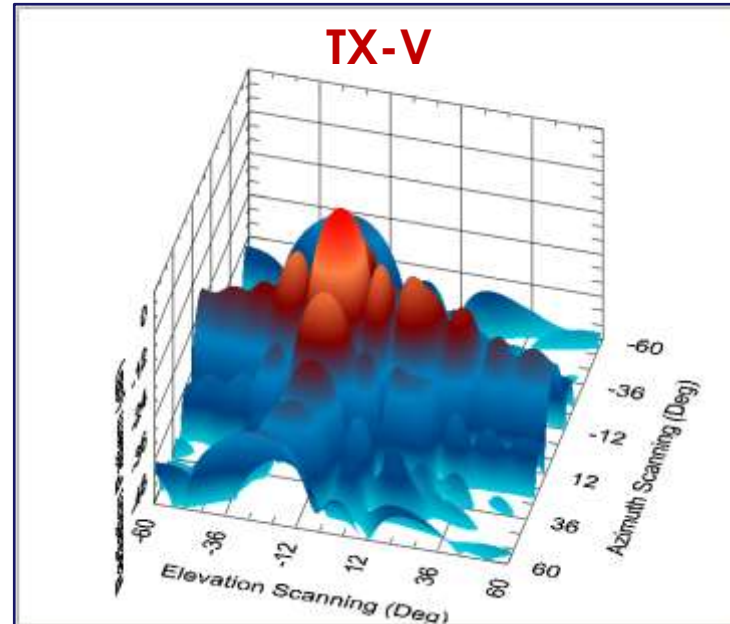
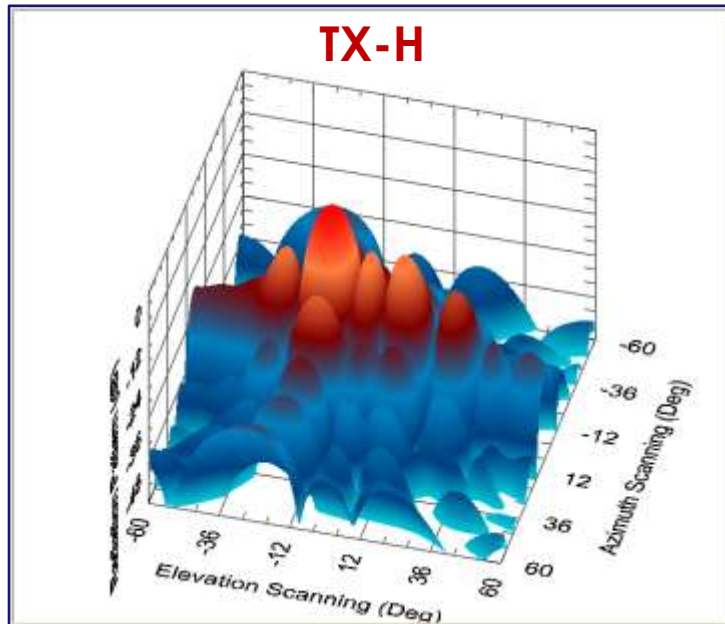
PARTIALLY DEPLOYED ANTENNA  
(RADIATING SIDE VIEW)



FULLY DEPLOYED ANTENNA  
(RADIATING SIDE VIEW)

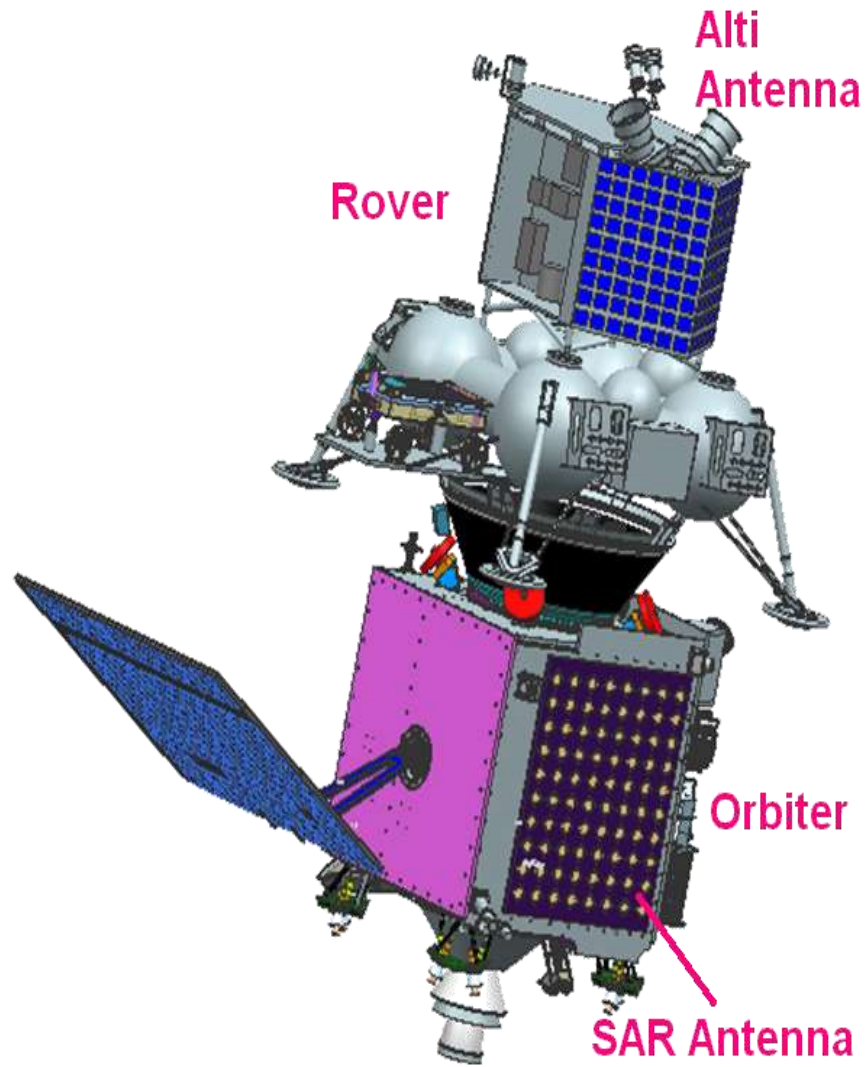


# L-Band Antenna Patterns – Side View

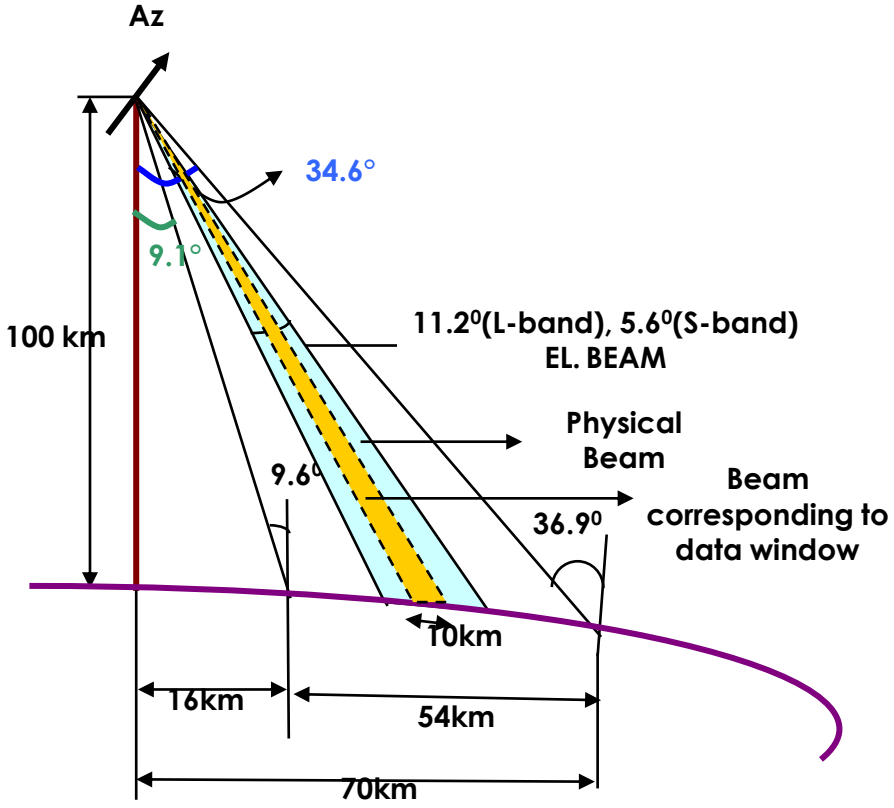




# L&S Band SAR for Chandrayan-2





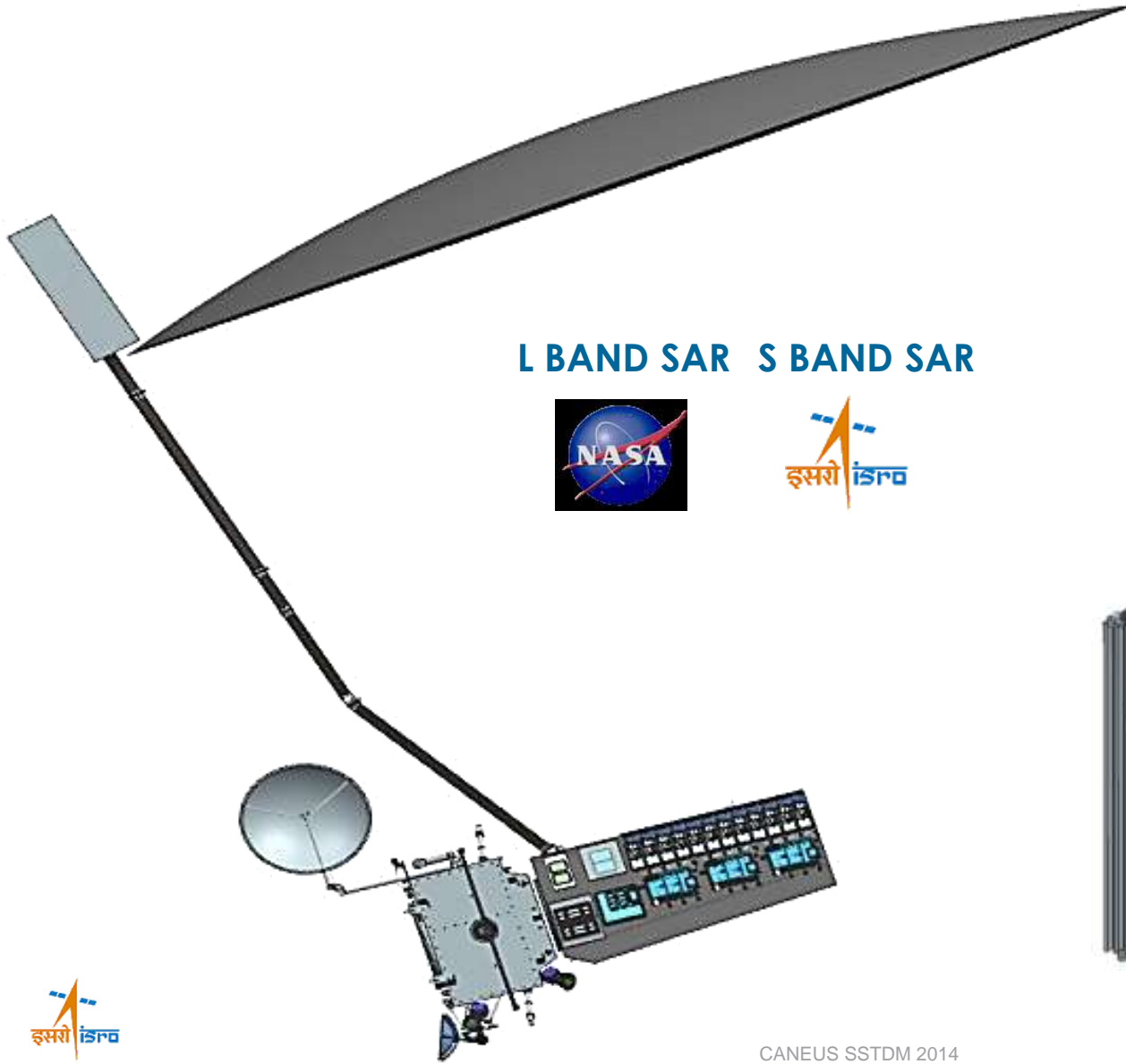


Specifications				
Coverage	16-70 (Km)			
Incidence angle	9.6-36.9 (Deg)			
Look Angle	9.1-34.6 (Deg)			
Resolution	2-75 (Meter)			
Swath	10 (Km)			
	L-band SAR		S-band SAR	
Slant Range Resolution	2m	75m	2m	75m
Azimuth Resolution	2m			
Radiometric Performance	<-10 dB	-35 to -28 dB	<-10 dB	-25 to -21 dB
Mass	15.62 Kgs			
Raw Bus Power	101 W		103 W	
Operating Modes	Stand alone – L , Stand alone – S , Simultaneous L&S (L- Master)			
Data Rate	160 Mbps (Max)			
Features	Programmability to meet Power and Data rate constraints.			

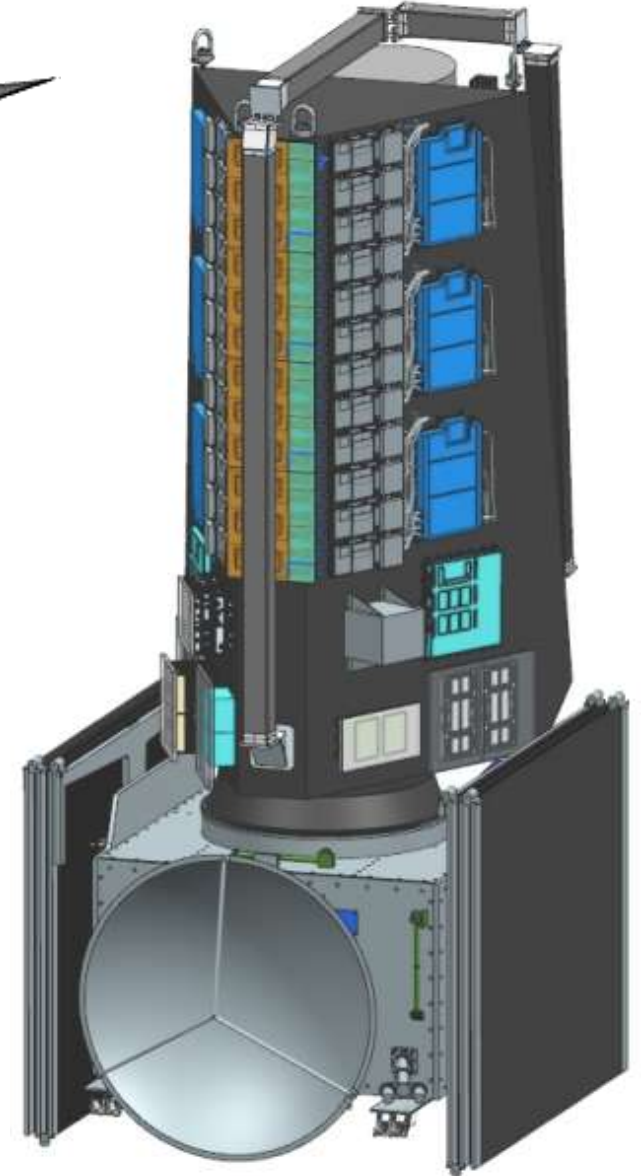


# NI-SAR (NASA-ISRO SAR)

## To Measure and assess Deformation, Eco System and Dynamics of Ice

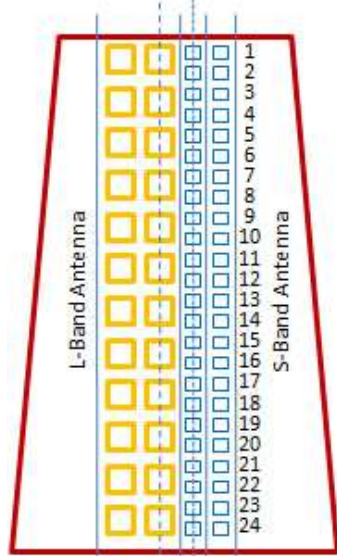


L BAND SAR S BAND SAR

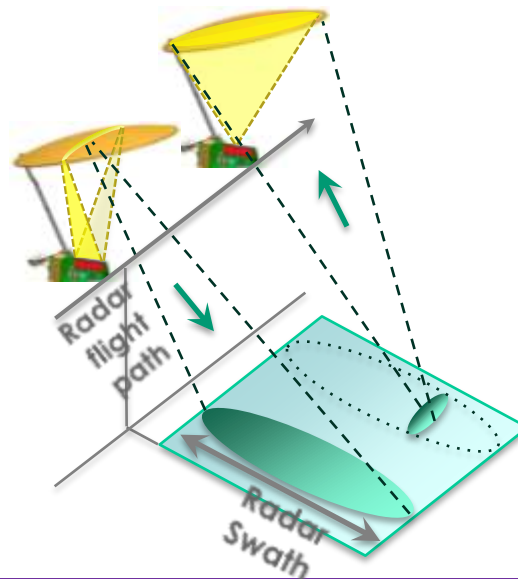


# NISAR S-band Tx/Rx Operation

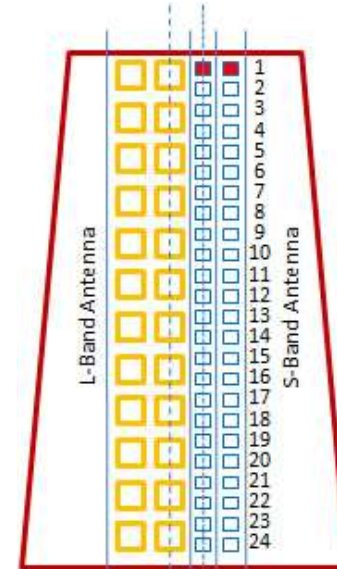
## TRANSMIT ILLUMINATION



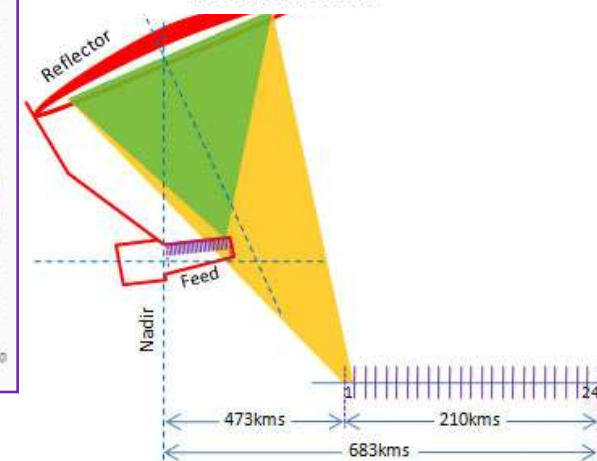
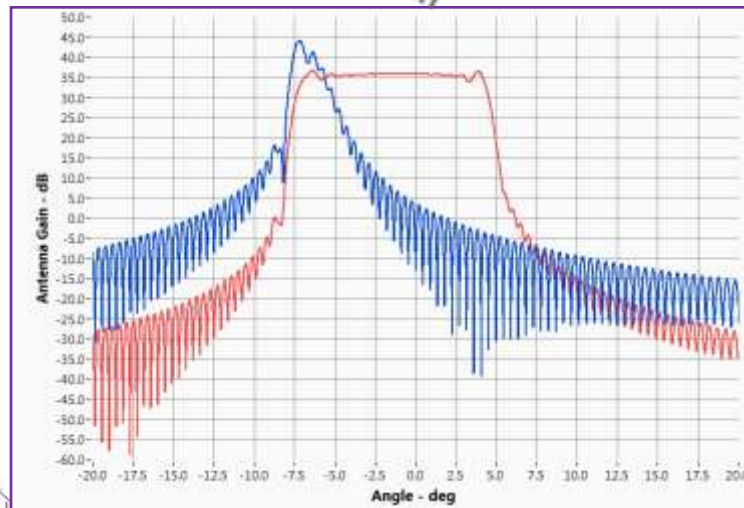
Spacecraft Bus side



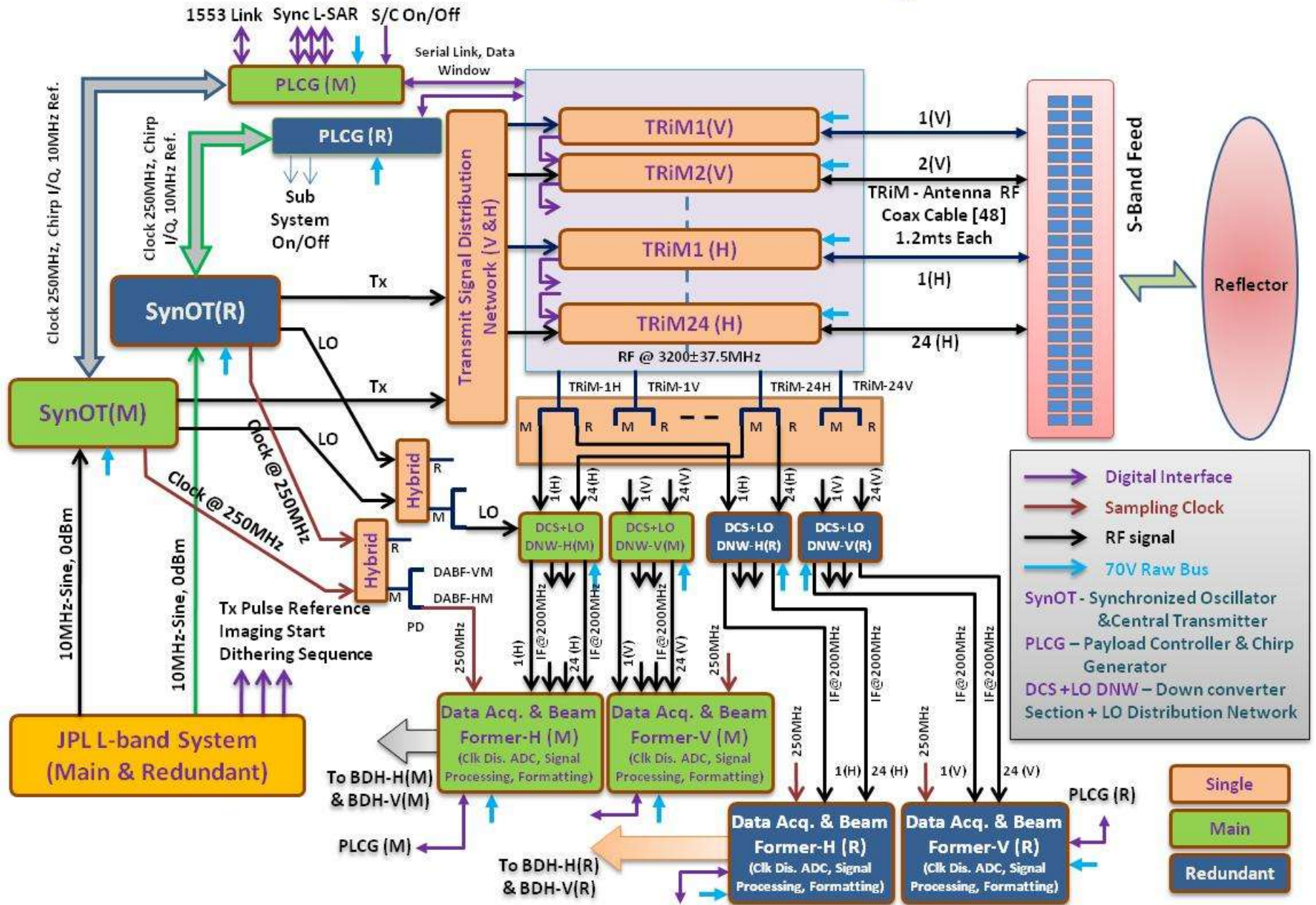
## RECEIVE ILLUMINATION



Spacecraft Bus side

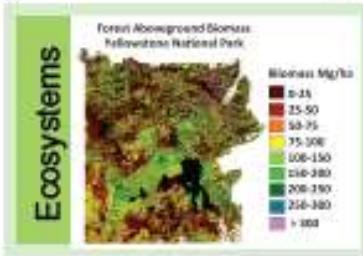


# Option-2: S-Band SAR – Block Diagram

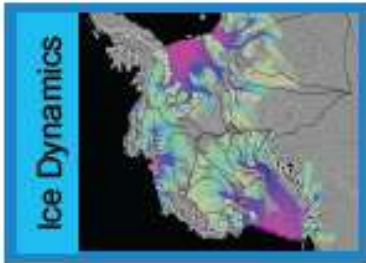




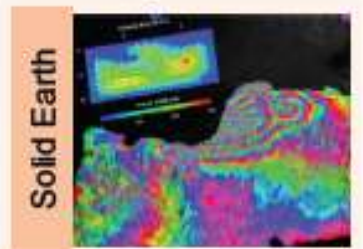
- Biomass, disturbance, agriculture
- Response to climate change & CO<sub>2</sub>



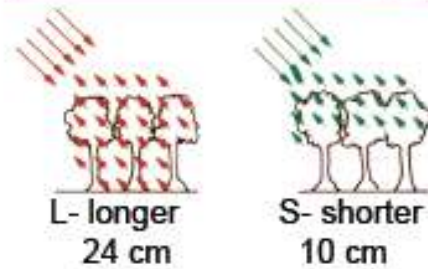
- Ice velocity
- Response to climate change & sea level rise



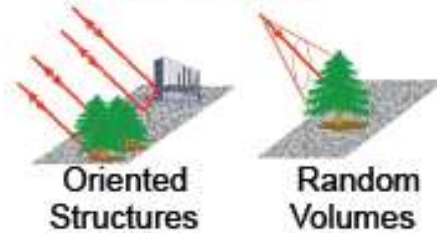
- Surface deformation, disruption
- Hazards response, water resources



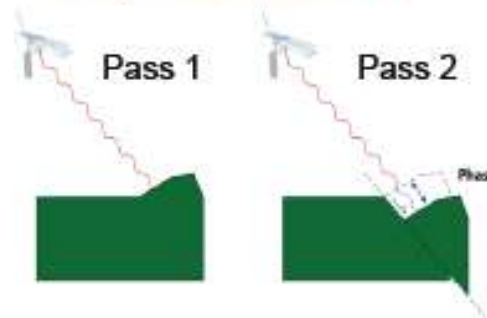
### L- and S-band Wavelength



### Polarimetry



### Repeat Pass InSAR



- Measurement accuracy
- Time-series-enabled science

- 12-day exact repeat orbit
- 5-10 m resolution
- Global coverage
- 3 years of observations

- Swath > 240 km
- 747 km altitude, circular, 98 deg. inclination, sun-sync (6AM-6PM)
- Pointing control < 273 arcsec
- Orbit control < 500 m
- > 30% observation duty cycle
- Left/Right pointing capability



*THANKS*

**Review By Chairman, ISRO 19<sup>th</sup> March**