

Development Status of Compact X-band Synthetic Aperture Radar Compatible with a100kg-class SAR Satellite and Its Future Plan

Hirobumi Saito

*Japan Aerospace Exploration Agency (JAXA),
Institute of Space and Astronautical Science (ISAS)*

Outline

1. Mission of Small SAR for Small Satellite
(2015-2018, Japanese Cabinet Office Program “ImPACT”)
2. Strategy of Small SAR Satellite
3. Engineering Model of Small SAR
 - 3.1 SAR Antenna RF Test
 - 3.2 SAR Antenna Mechanical/Thermal Test
 - 3.3 1kW GaN X-band Power Amplifier
 - 3.4 High Speed Down Link (1.5-3Gbps)
4. Future Plan

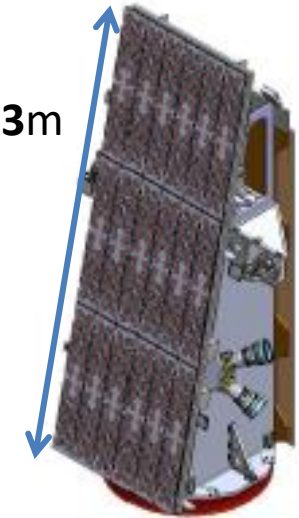
1 Mission of Small SAR Satellite

Proposed 100kg class SAR Satellite

NovaSAR-S

400kg

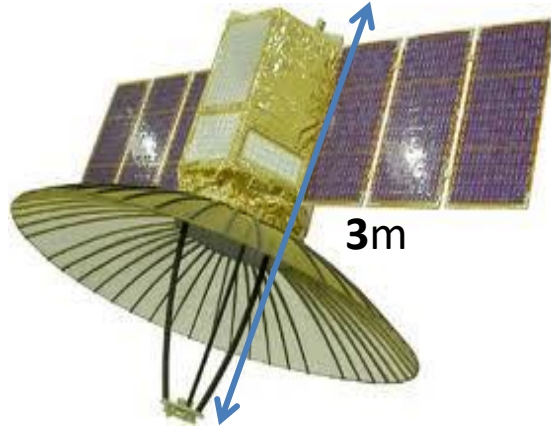
Resolution 6m



TecSAR

300kg

Resolution 1m



Proposed MicroXSAR

satellite mass < 130kg

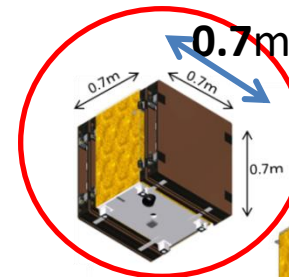
stowed 0.7³m

Resolution

10-3 m (constellation for commercial)

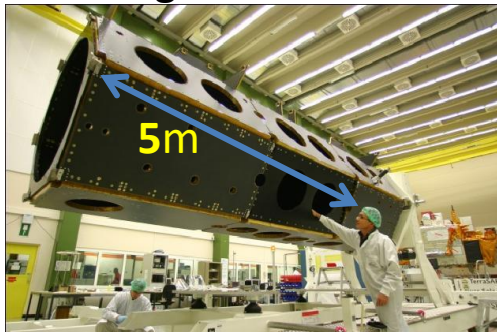
1m @300km (responsive mission)

Target cost < \$6M ← ~~\$20M~~



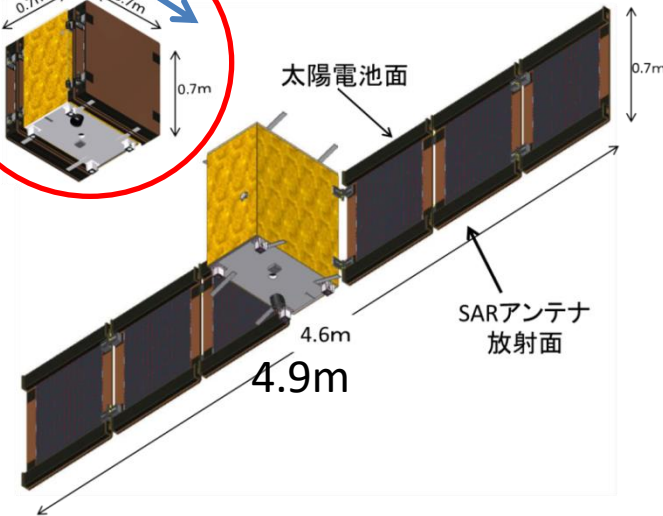
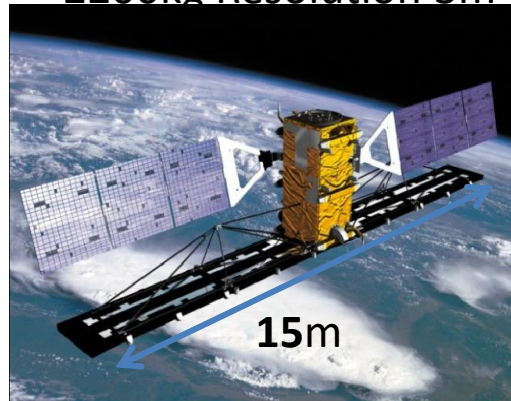
TerraSAR-X

1230kg Resolution 1m



RadarSat-2

2200kg Resolution 3m



1 Mission of Small SAR Satellite

SAR System Specification for 130kg Satellite

Ground Resolution = 3 –10m @600km

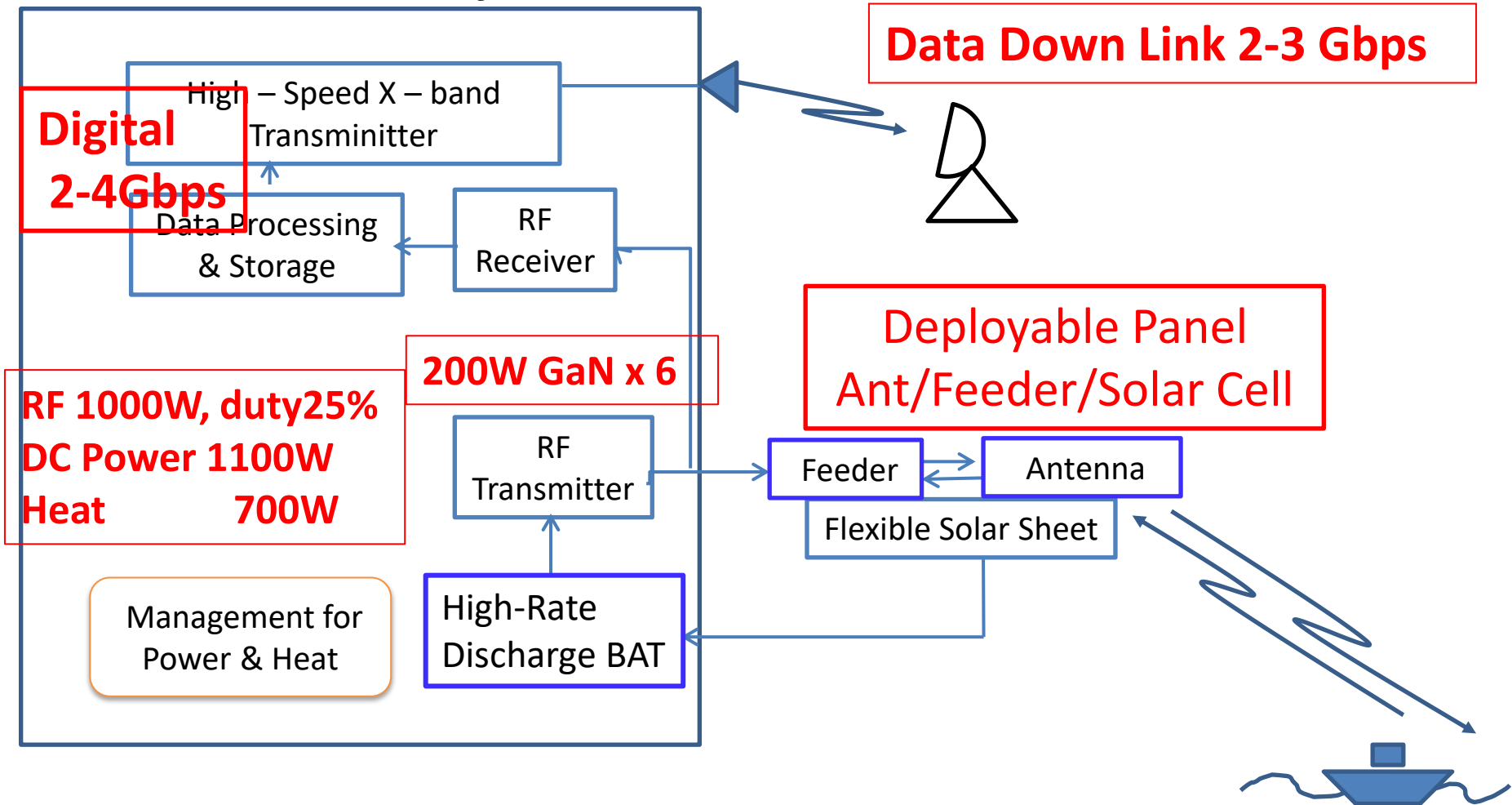
1m @300km(short life)

Item	SAR Mode	
	Strip Map	Sliding Spot Light
Altitude	600km	300km
Resolution	3m	1m
Center Frequency	9.65GHz	
Swath	25 km	10 km
Chirp Band Width	75MHz	300MHz
Polarization	V/V	
Antenna Size	4.9 m×0.7 m	
Ant Panel Efficiency	50%	
TX Peak Power	1000 ~ 1100 W	
TX Duty	25%	
System Loss	3.5 dB	
System Noise Figure	4.3 dB	
Off Nadir Angle	15 ~ 45 deg	
Pulse Repitition Frequency	3000 ~ 8000 (TBD) Hz	
NESZ (beam center)	-15dB	-22dB
Ambiguity (beam center)	>15dB	

2 Strategy of Small SAR Satellite

SAR System Block & Technology Strategy

Satellite Body



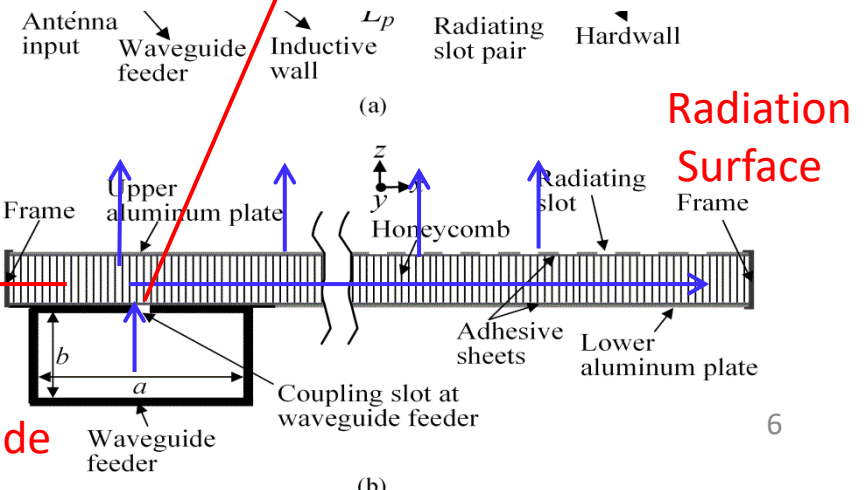
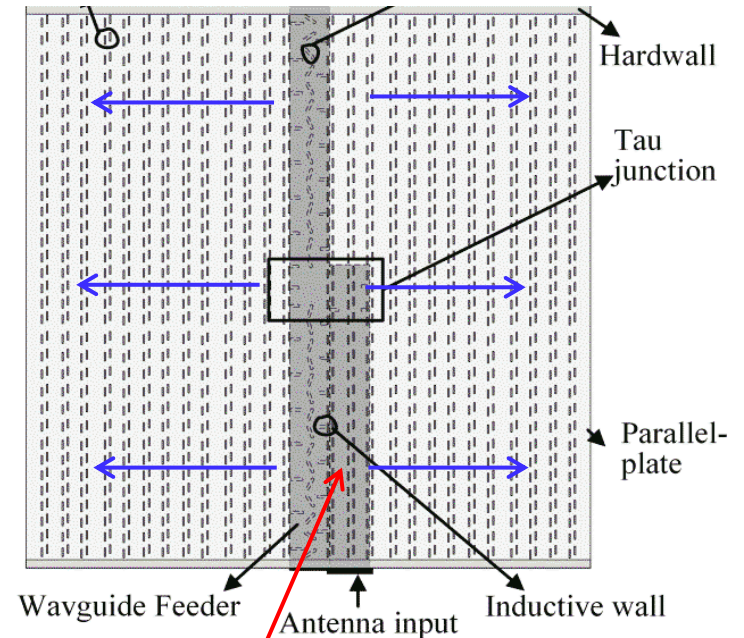
3.1 SAR Antenna RF Test

Rectangular Honeycomb Panel, Slot Array Antenna with Waveguide Feeder



Ant Efficiency 55%
Gain 36.6dBic

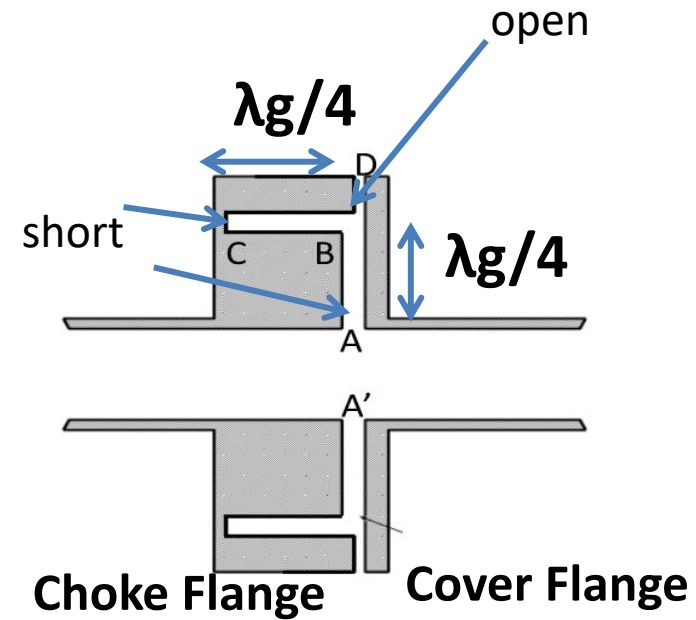
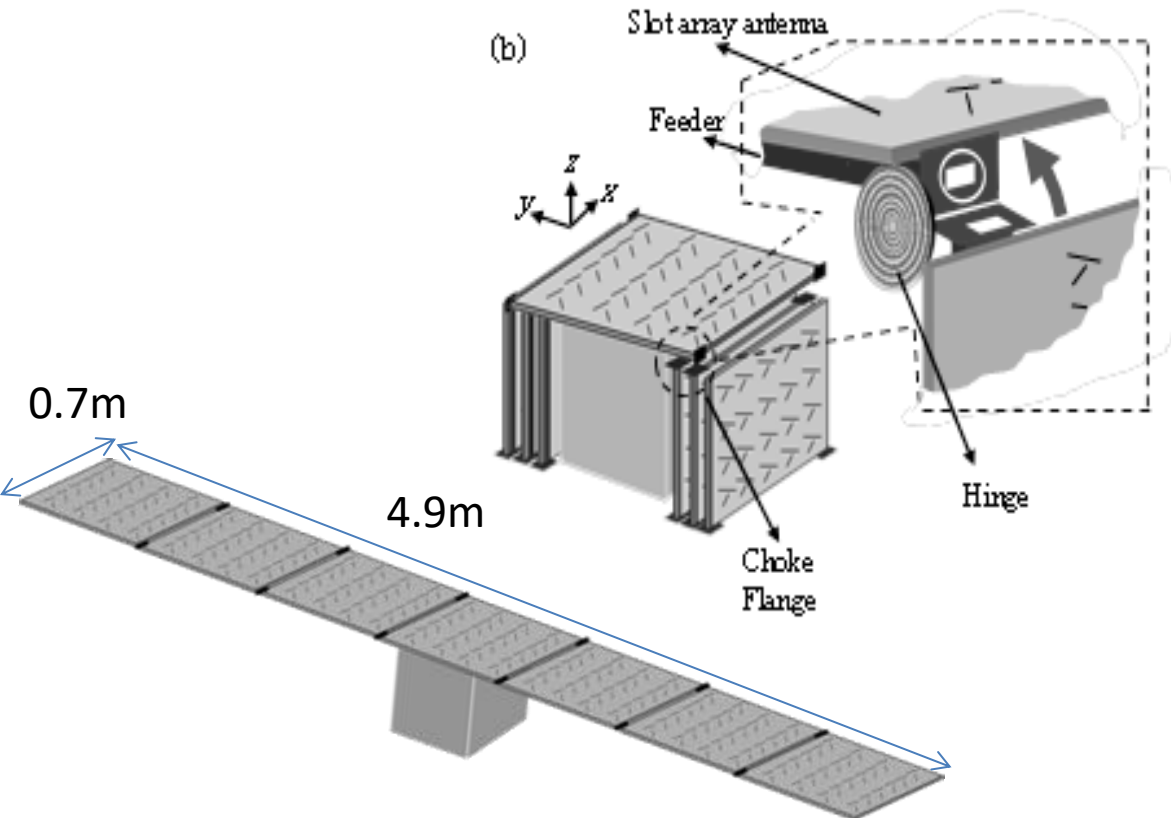
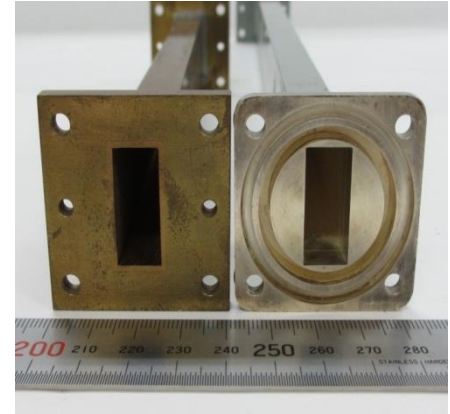
Aramid
Honeycomb



3.1 SAR Antenna RF Test

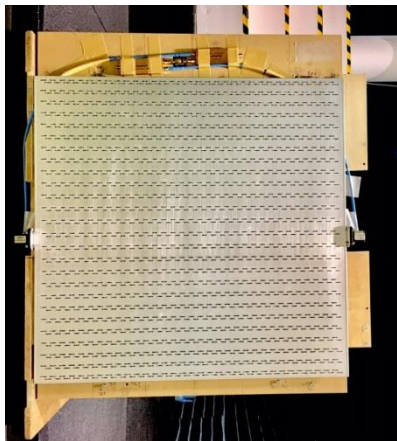
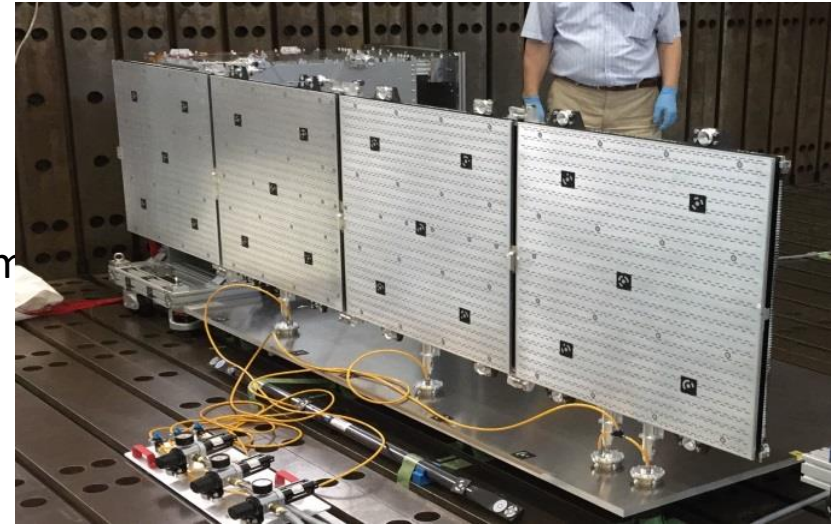
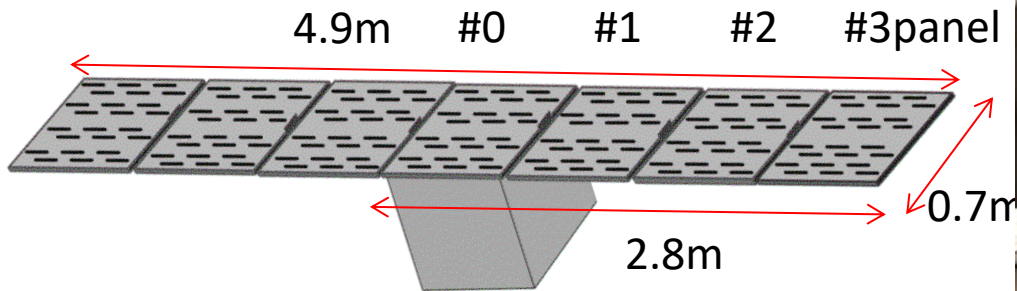
Noncontact RF Feed with Choke Flange at Hinge Position at Hinge Position

- Waveguide Feeds RF to Deployable Antenna Panel
- Choke & Cover Flange at Hinge Position
- Low RF Loss (<0.1dB) with Gap 1-2mm

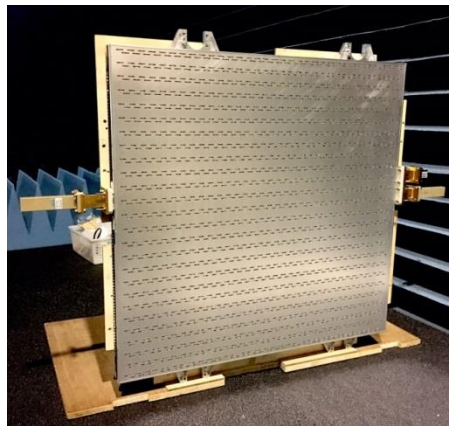


3.1 SAR Antenna RF Test

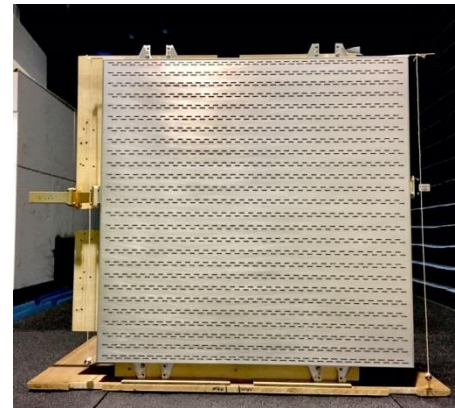
Engineering Model of One Wing-Antenna (4 Panels 2.8m x 0.7m)



Panel #0



Panel #1



Panel #2

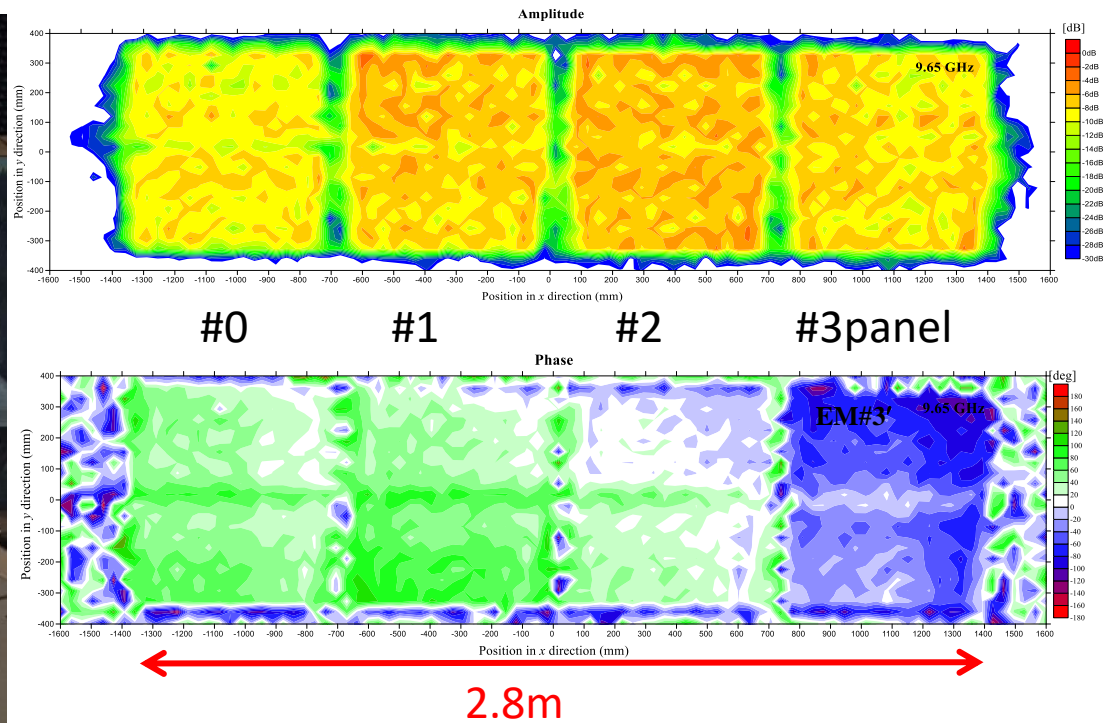
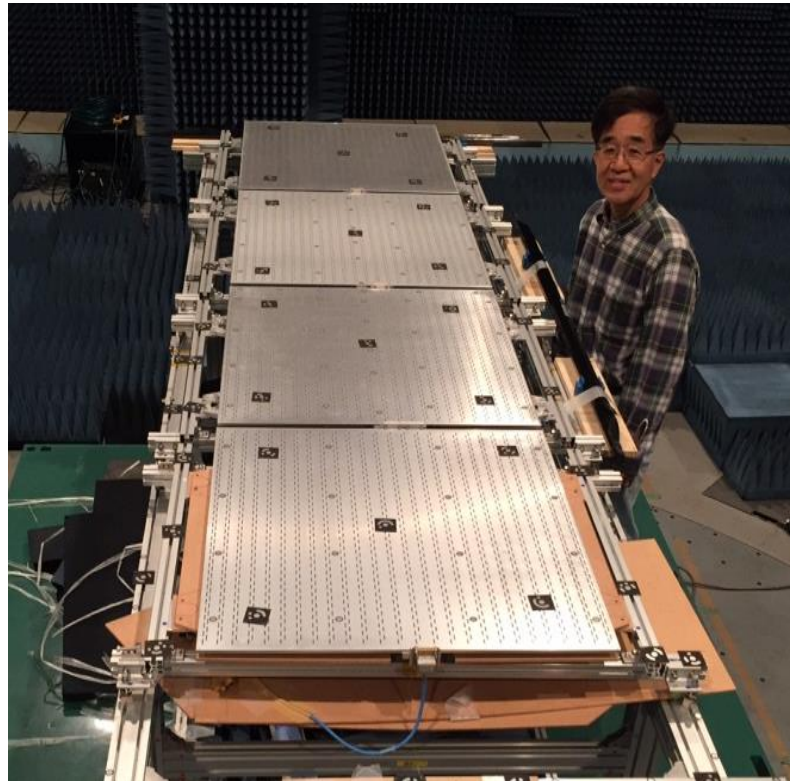


Panel #3 8

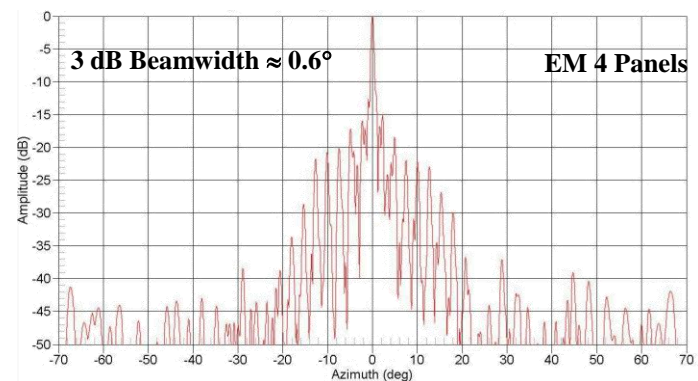
3.1 SAR Antenna RF Test One Wing (4 Panels) Near Field Measurement

at A-Metlab/Kyoto Univ

Aperture Distribution (Amp/Phase)



Far Field Pattern (Cross Range Direction)

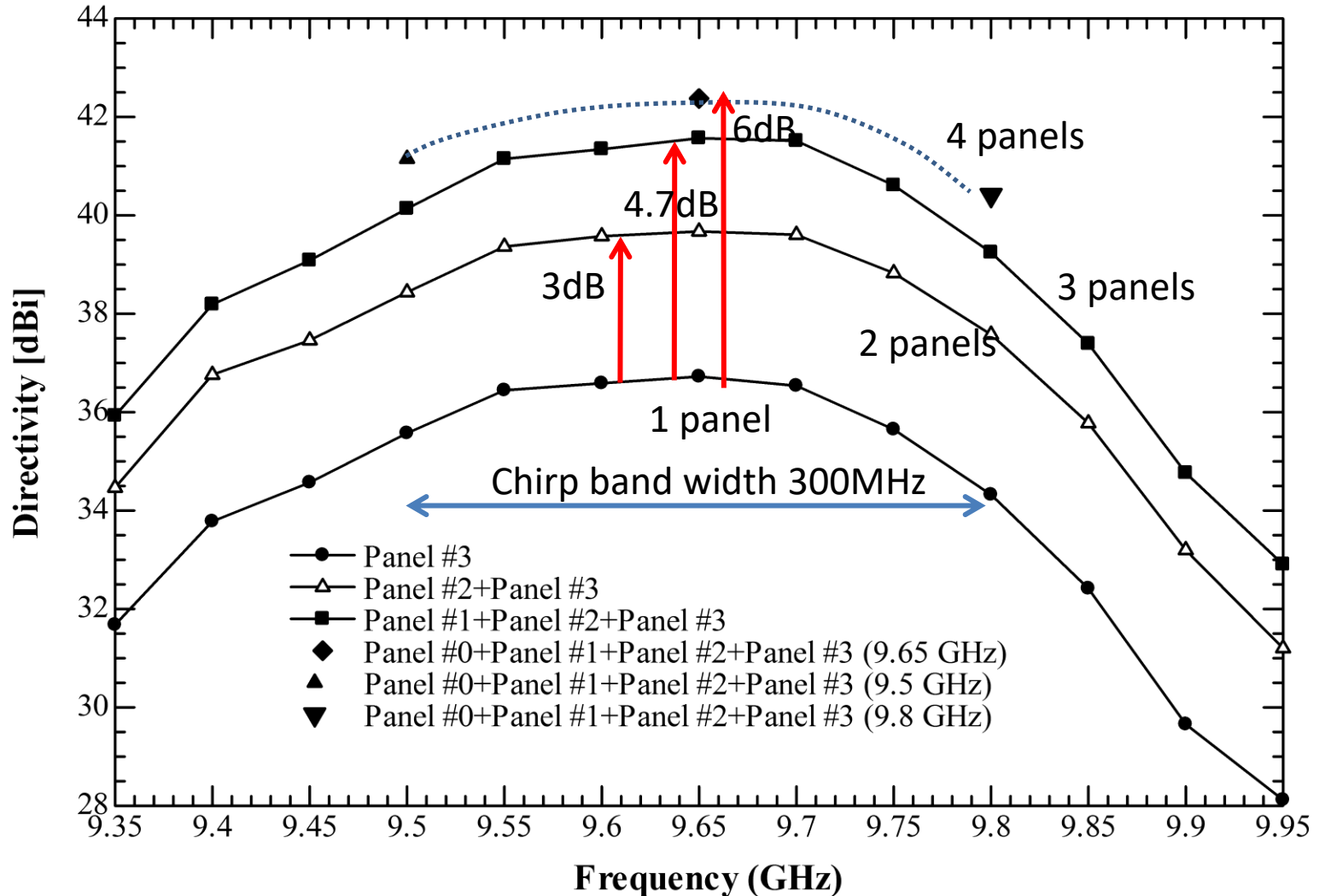


- Nearly uniform amplitude/phase Distribution
- Far field pattern of cross range is as expected

3.1 SAR Antenna RF Test

Measured Directivity Gains of Antenna Wing

Directivities of 2 panels, 3 panels and 4 panel increase by 3dB(x2) , 4.7dB(x3), 6dB(x4)



3.2 SAR Antenna Mechanical/Thermal Test

Antenna Mechanical Tests

Vibration test



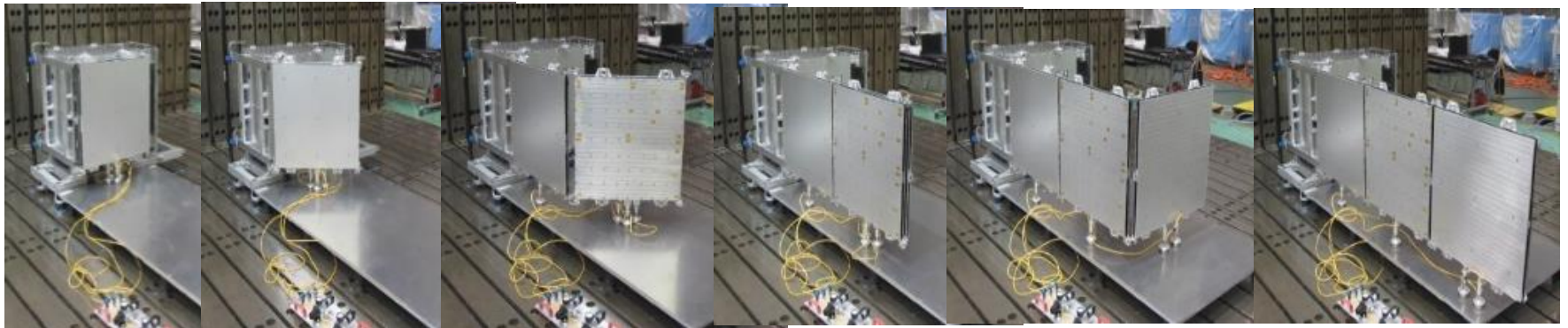
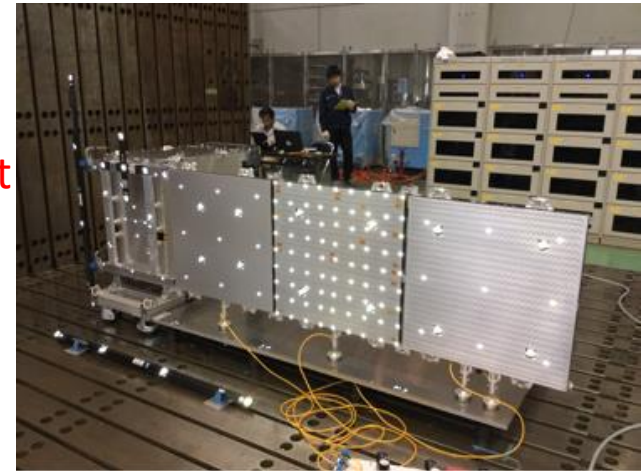
Acoustic test



surface
repeatability
< 0.4mm rms
before/after
vibration test

satellite
in acoustic
chamber

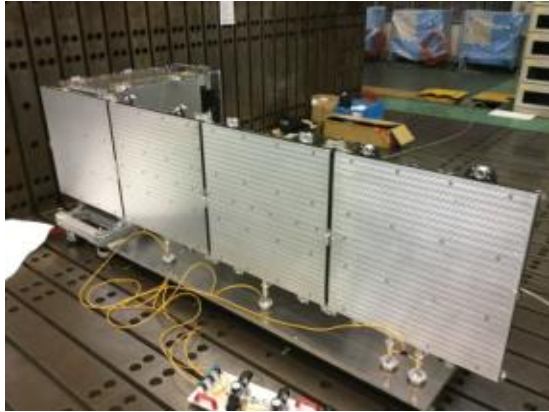
Antenna surface measurement
by photogrammetry.



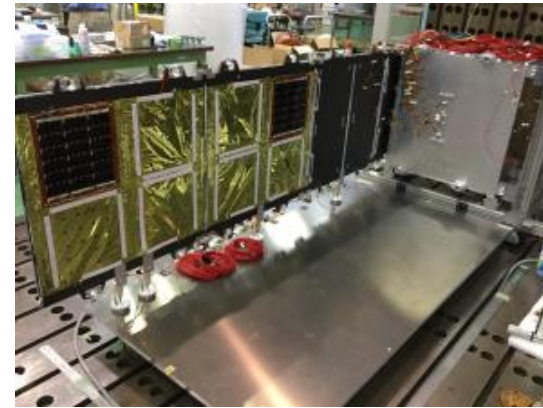
Deployment test of one-wing antenna with air bearing

3.2 SAR Antenna Mechanical/Thermal Test Antenna/Solar-Cell on Same Panels

Front: Antenna Surface
Thermal deformation
< 0.7mm rms $\lambda/40$



Rear: Solar-Cell Panel
Solar-Cell 120°C on MLI



MLI

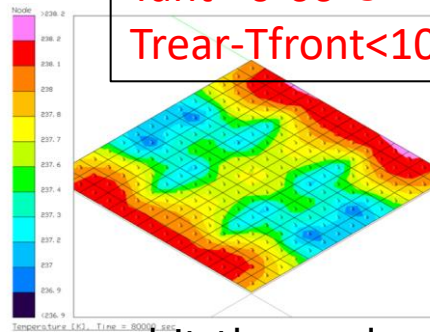
Flexible
Solar Sheet



Thermal Design

Thermo-Deformation Design

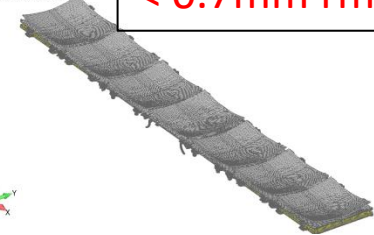
Tant = 0-60°C
Trear-Tfront < 10°C



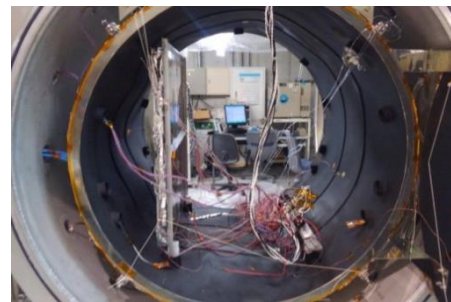
on-orbit thermal analysis

< 0.7mm rms

アウトライン: NX NASTRAN Case 1
 変形(2.266): Total Translation



on-orbit deformation analysis



thermal vacuum test

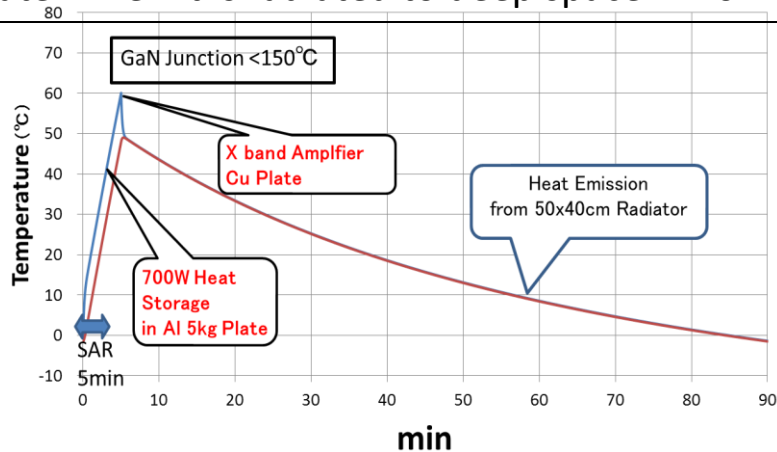


deformation measurement in air

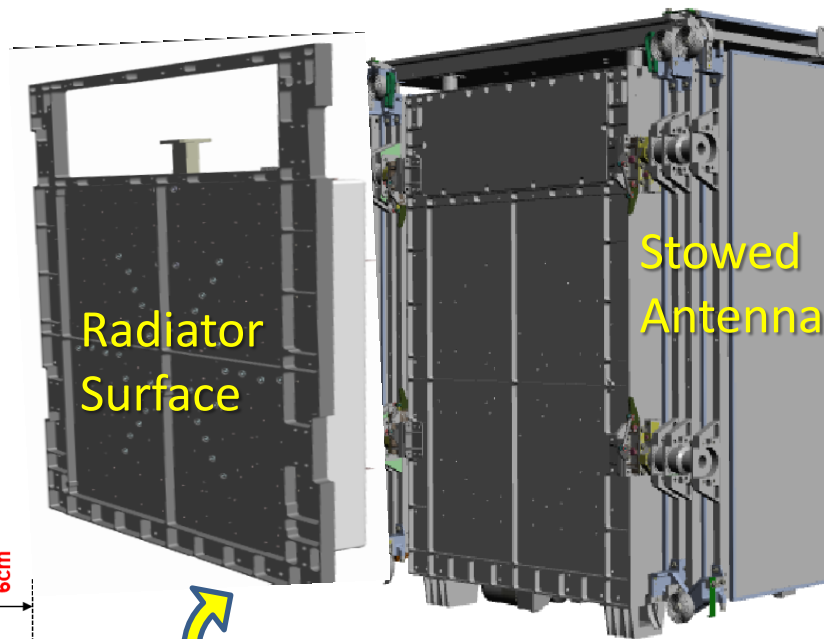
3.3 1kW GaN X-band Power Amplifier

1kW X-band Amplifier

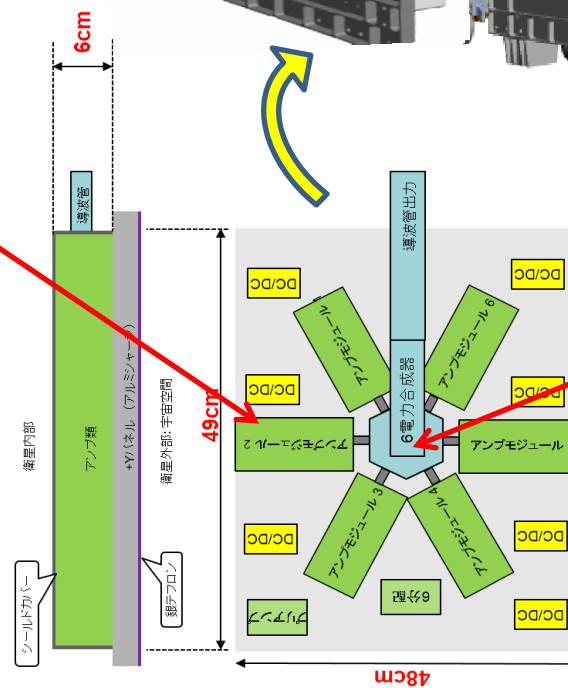
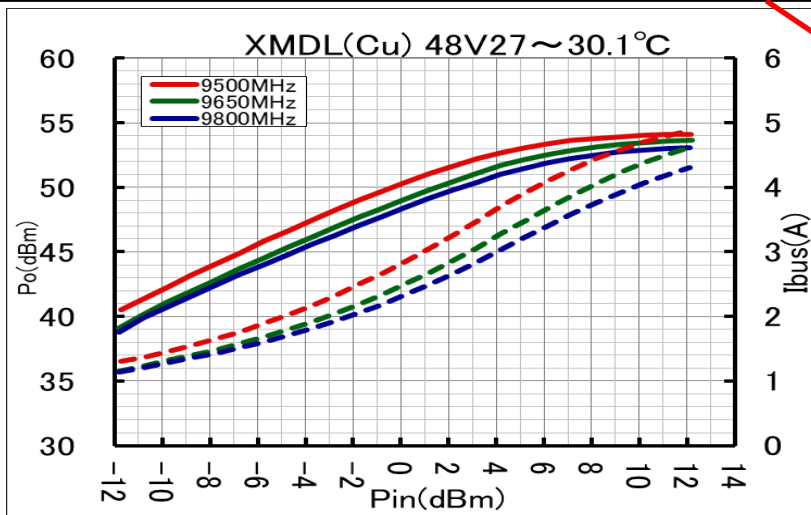
700W heat in 5 min SAR operation is stored in Al 4kg plate. Then it is radiated to deep space in 40 min.



+Y Panel
Al plate
(4kg)



Measured Data of 200W(53dBm) GaN Module



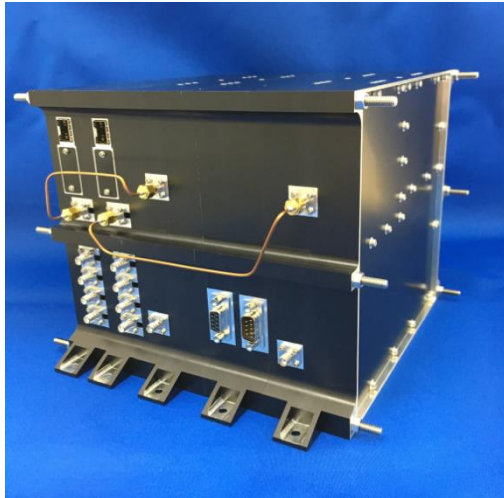
6 power
combiner

3.4 High Speed Down Link

Test Model under development

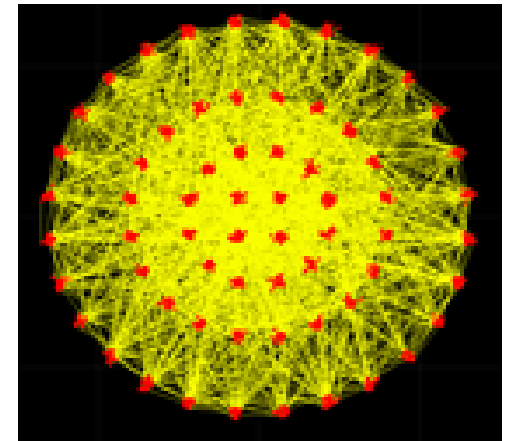
3.5Gbps X-band Down link

Test Model of Transmitter, 64/256APSK , 2 Channel



Modulation	QPSK~256APSK
Polarization	RHCP/LHCP 2ch
Bit rate	max 3.5Gbps/2ch
Protocol	DVB-S2X
Error Correction	LDPC
RF Output	1W/ch
DC Power	60W(TBD)
Size	200x200x200
Weight	7kg(TBD)
Others	Deep Space Band Filter

Received Constellation w/o RF
DVB-S2X, 64APSK(5/6), 1.75Gbps

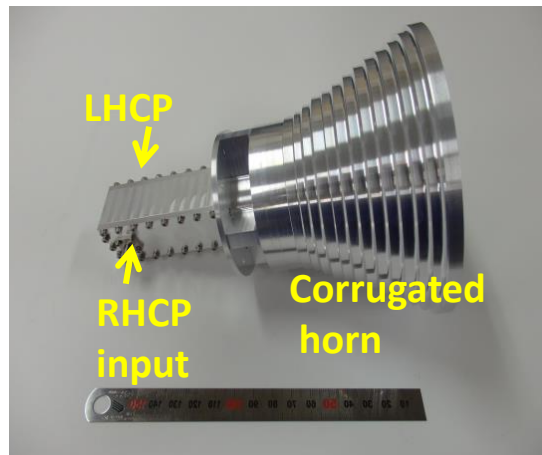


1symbol represents 6 bits.

Dual Polarization Antenna

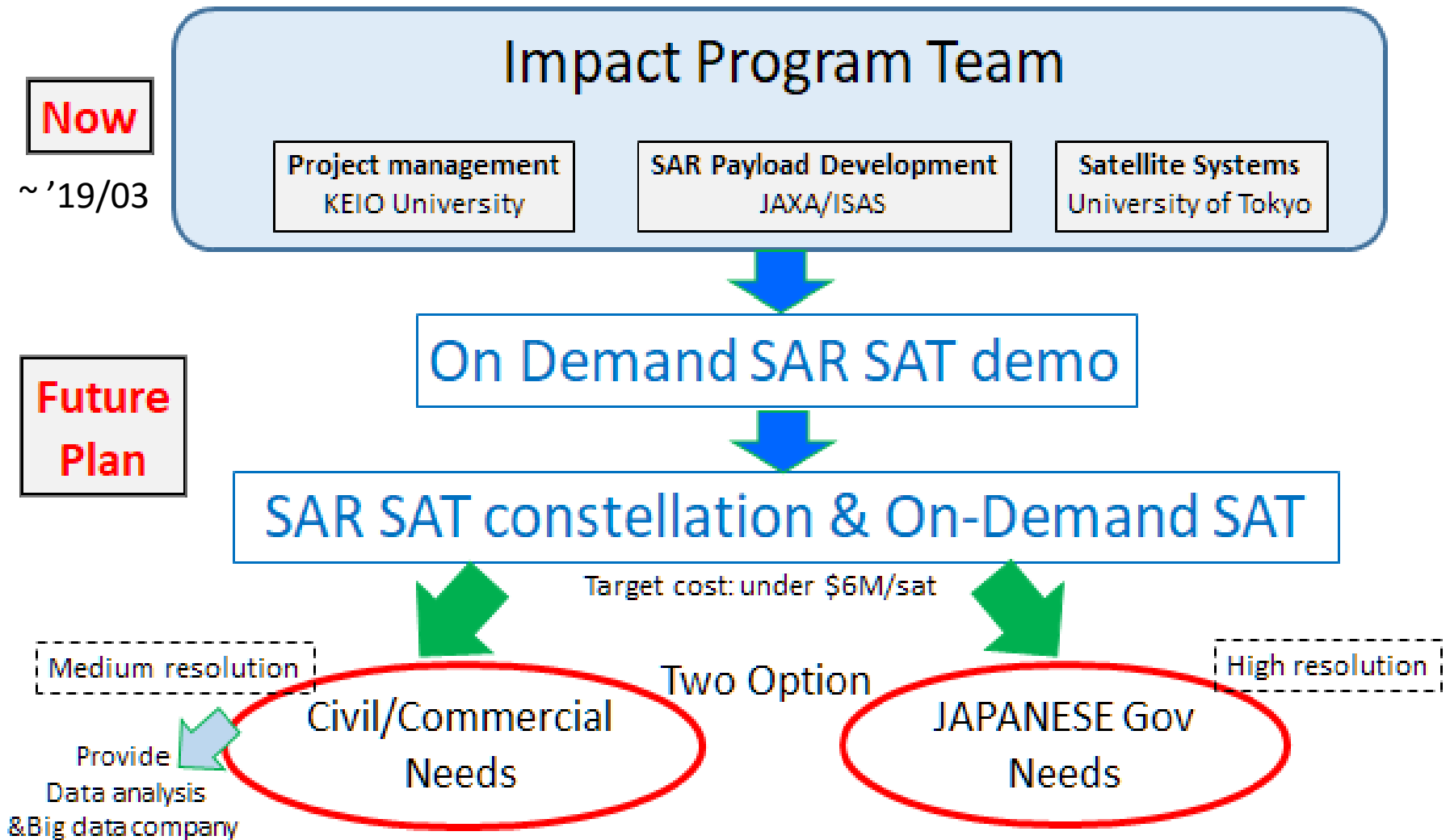
Gain 17dBi

XPD >33dB



4 Future Plan

Post “ImPACT”



Conclusions

1. Now in EM phase of small SAR for 130kg satellite.
(Japanese Cabinet Office Program “ImPACT”, 2015-2018)
2. EM development/test results (preliminary)
deployable panel slot array antenna
+ non-contact waveguide feeding,
1kW X-band power amplifier
1.5-3Gbps X-band transmitter
3. Future plan (Post “ImPACT”)
Demonstration Flight
Constellation for Civil/Commercial
& On-demand SAR SAT for Japanese Gov.

Acknowledgement

- This work is funded by ImPACT Program of Council for Science, technology and Innovation (Cabinet Office, Government of Japan)