Antenna :

Needs and Technologies

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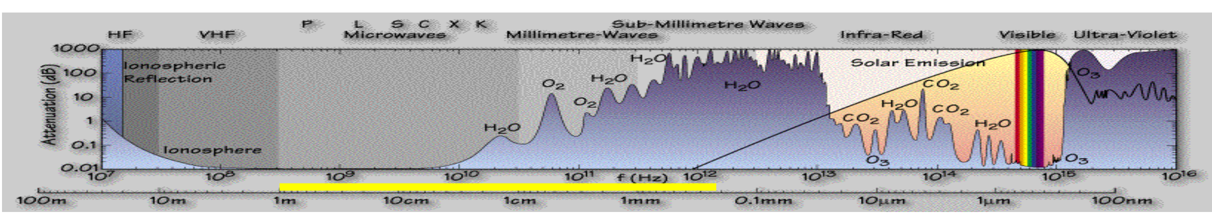
Introduction

Frequency Domain and technologies



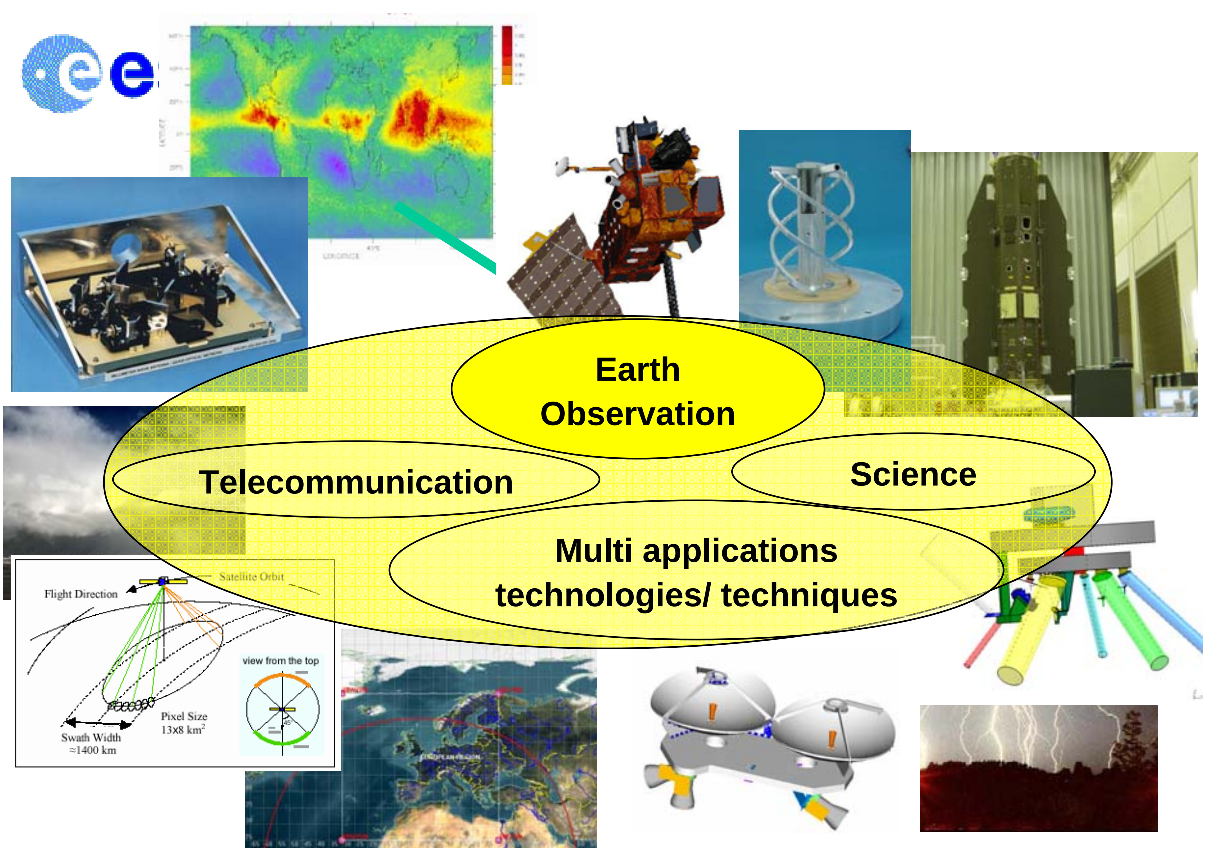
Earth Observation
Science and Radioastronomy
Human space flights
Launchers
Telecommunication
User terminals
Navigation
TT&C and Data transmission

Antennas required for all Space missions (Earth Observation, Telecommunication, Navigation, Science, TT&C, human spaceflights and user terminals)

- Optimization of antenna performances is requested for link budget and to increase overall system capacity
- Antenna sub-systems characterized by strong links with overall system design and spacecraft/mission optimization.

➔ *Mandatory to develop and maintain in parallel several antenna technologies, concepts and architectures for the different frequencies, bandwidths and radiating aperture diameters.*

➔ *Complex process involving several skills closely coordinated is required to ensure a competitive compromise between radio-electrical, mechanical and thermal performances.*



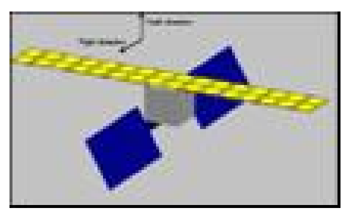
P-Band Synthetic Aperture Radar

- Recent frequency allocation for P band (432-438 MHz) for space-borne radar
- Interest from the scientific user community for applications including biomass monitoring and Antarctic ice sheet sounding
- Need to develop very large surface antennas (typically 50 m2)
- Require the development of lightweight and cost effective innovative concepts compliant with the use of low cost launchers (compact stowed volume)
- Ice-sounding mission : nadir-looking radar
- BIOMASS mission : side looking

P-Band SAR possible Antenna concepts

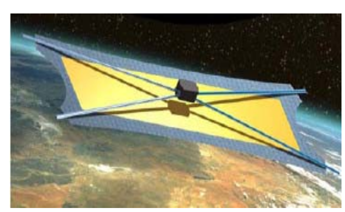
Direct Radiating Array based on deployable rigid panels

- Ultra-light foldable panels such as solar array (existing H/W, limited height, product maturity around 2010)



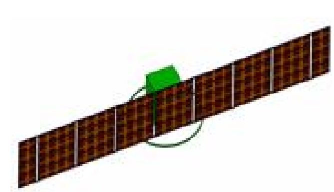
DRA based on deployable membrane

- Membrane deployed using extendable booms developed for the Solar Sail demonstrator by KAYSER-THREDE (Very compact stowed configuration, product maturity around 2015)



DRA based on membrane foldable panels

- Foldable panel made by a frame supporting a membrane (Very high surface achievable, low mass and stowed volume, product maturity to be assessed)

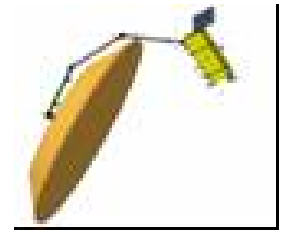


(courtesy of Thales Alenia Space)

P-Band SAR possible Antenna concepts

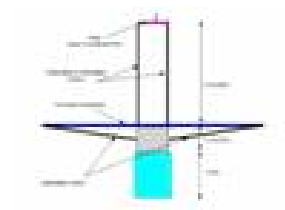
Mesh reflector antenna

- Can allow a combined mission biomass / Ice-sounding
- High antenna surface achievable
- Detailed mass to be assessed
- Reflector and Feed accommodation to be analysed



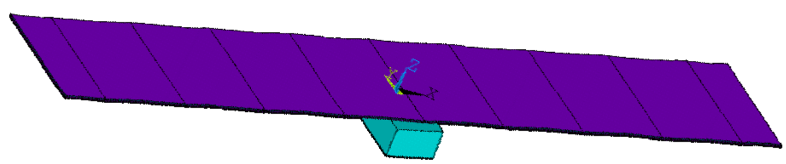
Reflectarray antenna

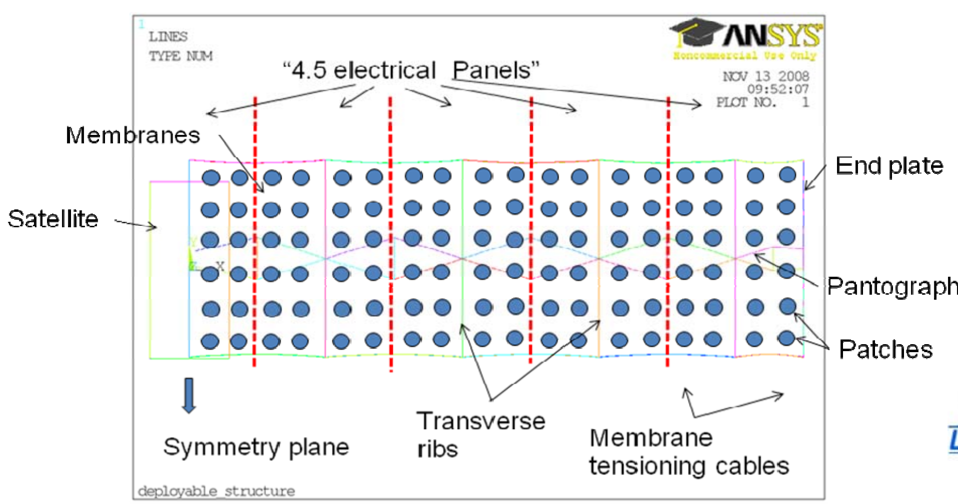
- Expected low mass
- Relatively compact source
- RF performances to be confirmed
- Feed accommodation to be assessed



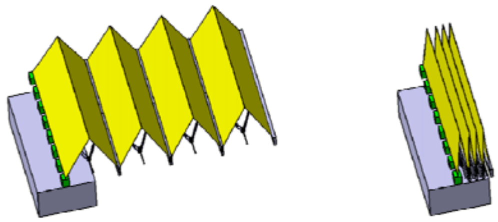
(courtesy of Thales Alenia Space)

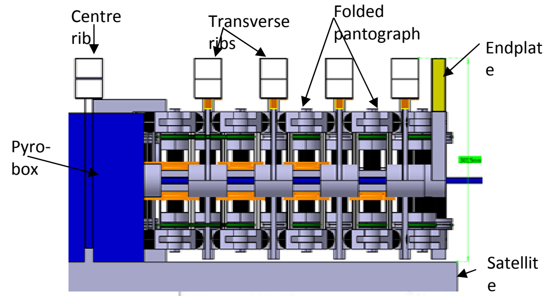
DRA size 67.7 m²
Length 20.16 m
Height 3.36 m
Number of "electrical panels" 9

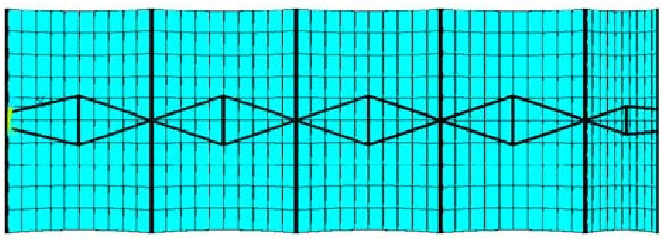


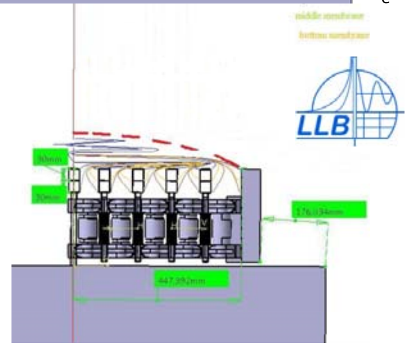


Folding of membranes using a pantograph

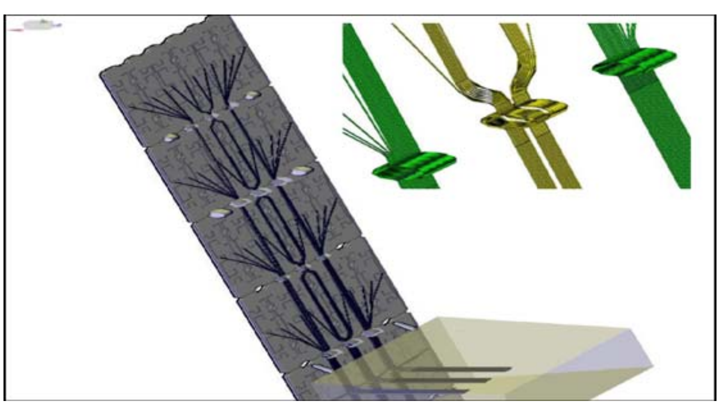




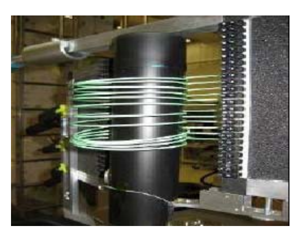




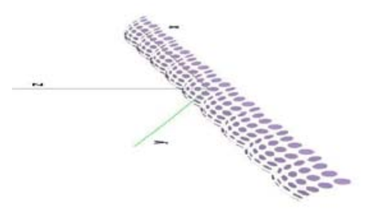
RF Harness routing

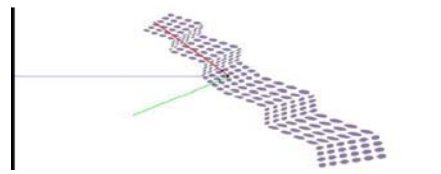


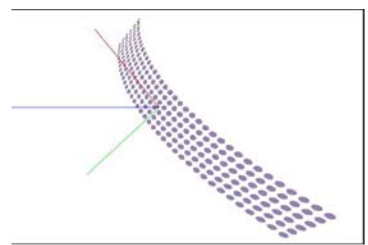
Resistive torque too high : 0,58 Nm



Resistive torque much better : 0,27 Nm







Impact of deformations on RF performances

Systematic deformations

- •At panel level (manufacturing)
- •Tilt angle between panels
- •Deformation at antenna edge

Non systematic deformations (thermal aspects)

•Coupled with thermal analysis task

•Temperature gradient limitation over antenna surface

•Antenna RF performances robust to deformations

Earth Observation

Interferometer concepts

- Interferometer receiver concept allows producing high-resolution instruments with limited overall volume and mass.
- Siral SAR/Interferometric Radar Altimeter Flight model (Courtesy of SES) to fly on CryoSat (mission under development by Astrium-GmbH) designed to measure the thickness variation of floating sea ice

November 2008 Antenna technologies

Earth Observation

(sub)-mmw interferometer concepts

GEO-SOUNDER is a potential candidate for the Earth Watch program.

- Observation of rapidly evolving meteorological phenomena such as convective systems, precipitation and cloud patterns.
- Geostationary observations provide continuous coverage of the same region, which is essential for nowcasting.
- Nevertheless this imposes:
  - Tight constraints on the antenna aperture for achieving the required spatial resolution
  - The necessity for imaging with two-dimensional scanning
- The proposed frequencies range from 54 to 875 GHz
- Instrument preliminary selected between
  - Real antenna aperture with mechanical scan
  - Synthesised (sparse) array associated with interferometry.

Earth Observation

GEO-Sounder Interferometric synthetic aperture radiometer

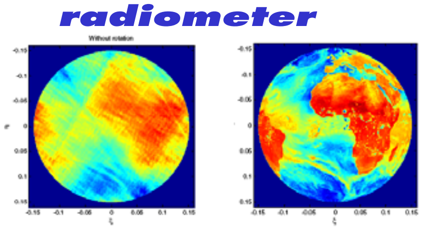
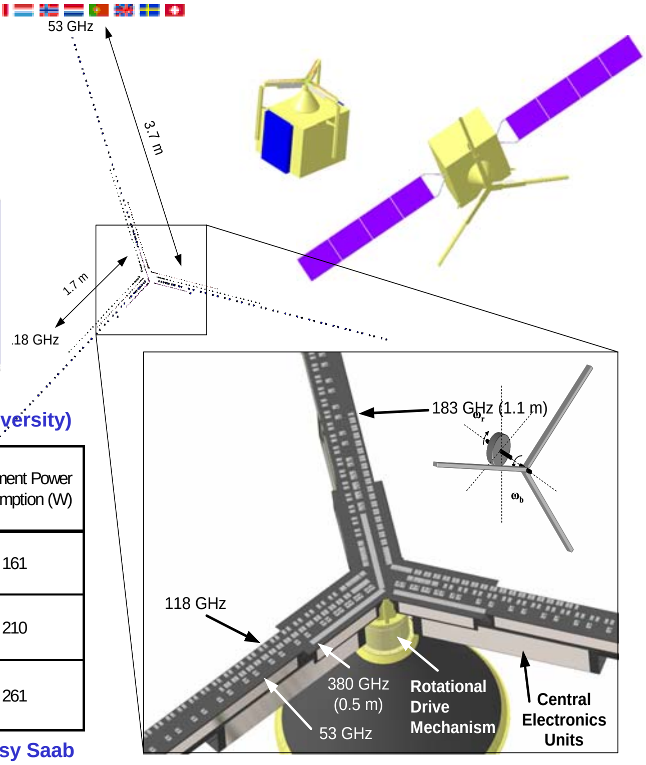
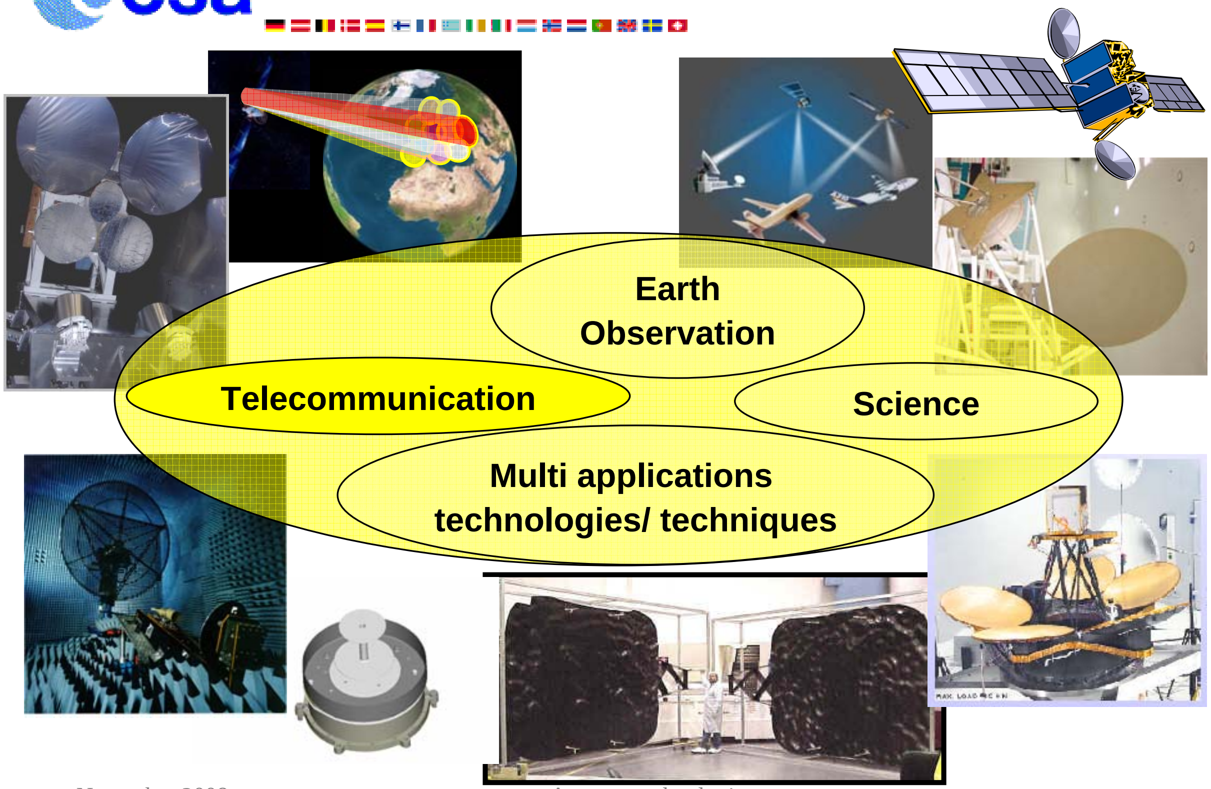


Image without and with rotation
(Raw data courtesy of P. Eriksson, Chalmers University)



	Instrument Mass (kg)	Instrument Power Consumption (W)
Basic nowcasting system 53, 183	214	161
Extended nowcasting system 53 , 118, 183	235	210
Advanced nowcasting system 53, 118, 183, 380	253	261

Geostationary Atmospheric Sounder (Courtesy Saab Space, Omnisys & ESA)



Telecom Technology Goals

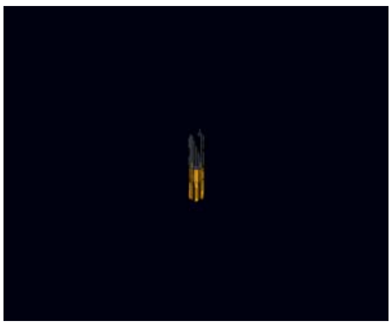
- Support the dynamic MSS market (both interactive and broadcast)
  - *Make available flight proven European Large Reflectors at L,S, (C) Band*
  - *Make available low profile low cost mobile user terminals*

- Support the evolving FSS/DBS Ku-band market
  - *Improve competitiveness of conventional antennas*
  - *Develop next generation C-Ku Band shaped beam(s) antennas*
    - Increase capacity ,power, implement linguistic beams
  - *Make available cost efficient, high power and flight proven flexible antennas to comply with operator's needs in terms of power/beam/coverage reconfigurability to allow shorter time to market and ability to cope with users demand changes along satellite lifetime*
    - **Single beam reconfigurable Ku-band antennas**
    - **In-flight reconfigurable multiple beams Ku-band antennas**

- Make available solution for BSS
  - *Make available very stable and large Ku-Ka Band Reflectors*
  - ***Propose solutions for multiple beams antennas from a single aperture***
  - ***Make available next generation multiple beams Ka-band antennas***

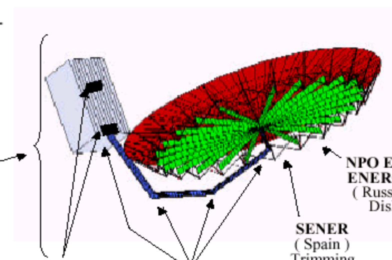
Large Deployable Antenna EQM

(Courtesy of Thales Alenia Space and EGS)



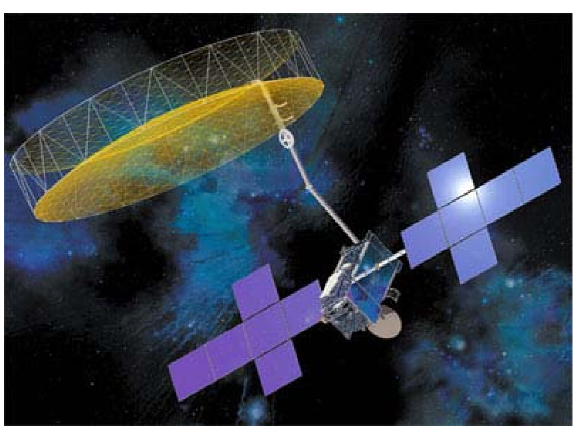
Development in frame of ESA Program on Advanced Systems and Telecommunications Equipments (ASTE),

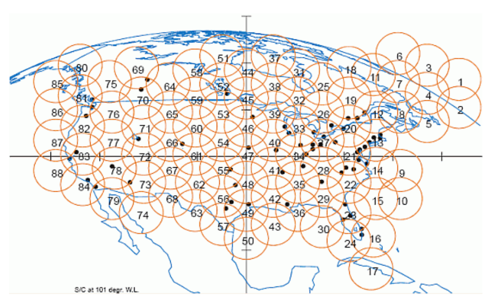
Element of the Agency's "ARTES" Program



12*15 m

Very large apertures for Telecommunications

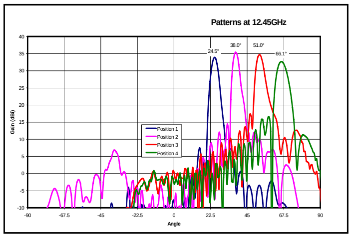


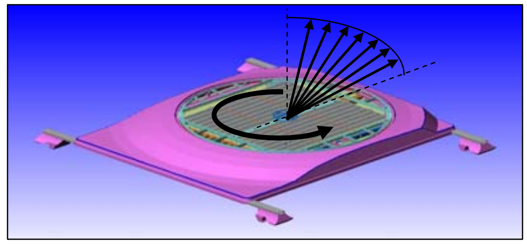


Spot Beam Coverage of North America

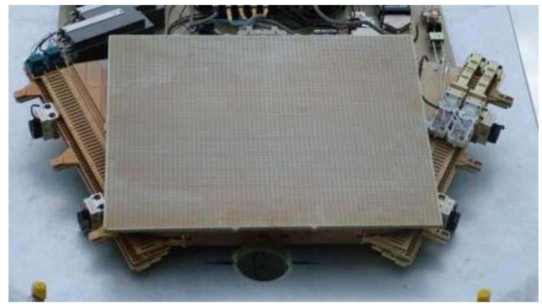
Terrestar is to operate at S-Band with an 18m reflector
Source: Space Systems Loral
MSV satellites, successors of M-SAT, should carry 22m reflectors from 2010 onwards

Products under development for aircraft in flight entertainment





Space Engineering
baseline concept



ERA G3 Tx/Rx antenna for trains/airplanes
Electromechanical elevation scan 20o to 70o scan
Low cost injection moulded and metallised plastic

Make available single beam reconfigurable Ku-band antennas

Needs

- Change of orbit position and coverage just before or during operations
- Change in traffic intensity
- In-orbit adaptability to varying weather conditions
- Compensation for in-orbit anomalies such as thermal distortions, creep etc.

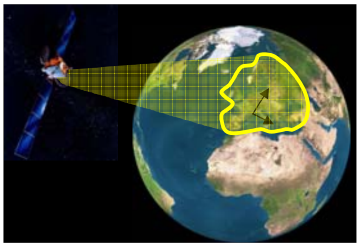
Improvement requested w.r.t. existing solutions based on steerable beam antennas.

- 4-axis steerable antenna
- Reflectarray active or passive
- Reconfigurability at focal array (using VPD)
- Reconfigurable sub-reflector shape
- Parasitic structure between focal array and sub-reflector

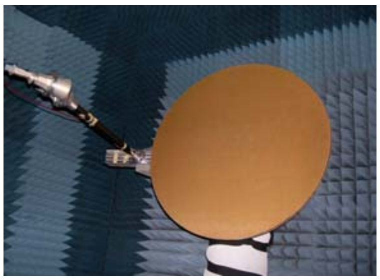
Mandatory to develop the associated technologies for buiding blocks

- Efficient, flexible, high linearity and compact TWTA (for Ku/Ka Array Fed Reflectors)
- RF MEMS based reconfigurable telecommunication reflectarrays
- Mini tubes (up to 40 W) for efficient semi-active solutions
- Ferrite components such as Variable Power Dividers (European secured source)
- ONET output losses and isolation improvements
- Power, multipaction and PIM issues associated to the centralization of power generation

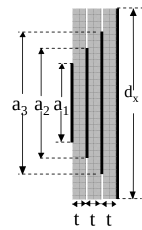
Regional Contoured Beam: Reflectarray

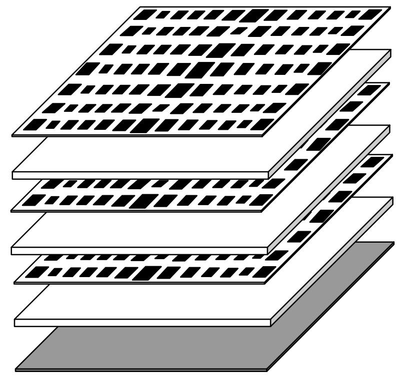


Regional Contoured Beam
G ≈ 28 dBi



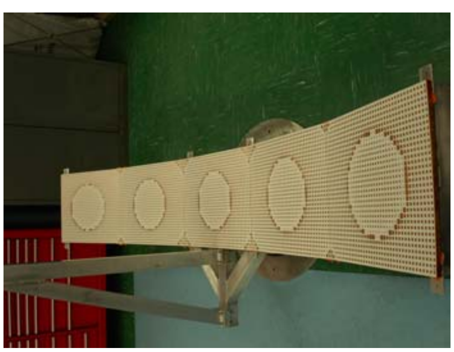
Multi-layer reflectarray
with patches of variable size

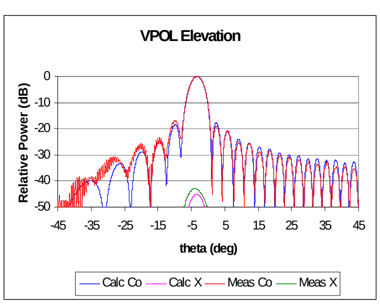




Reflectarray for Contoured Beam

Courtesy Prof. Encinar U. Madrid & Thales Alenia (2007)

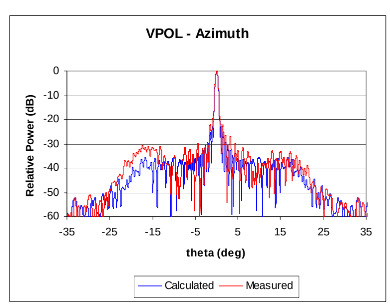




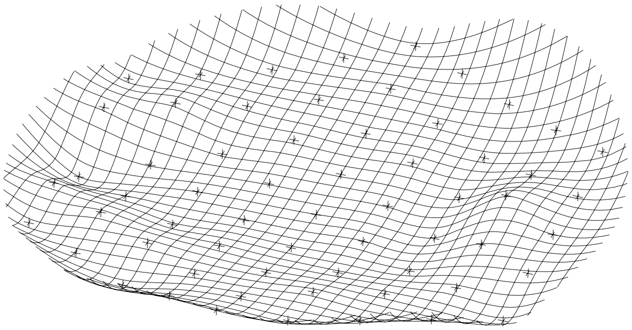
Courtesy J. Huang
NASA-JPL

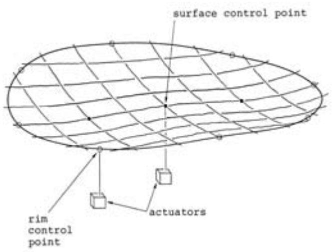
Measured antenna efficiencies:
V-pol 48%
H-pol 51%

Uses ESA Patent !

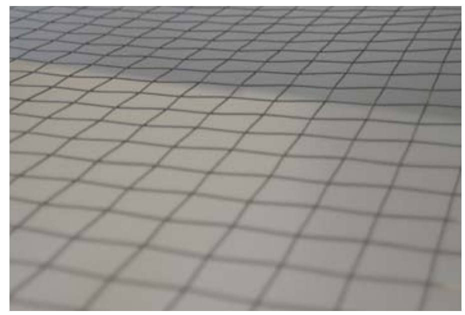


Reconformable reflector with interwoven flexible wires

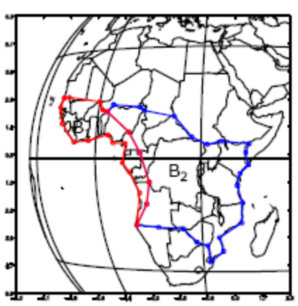


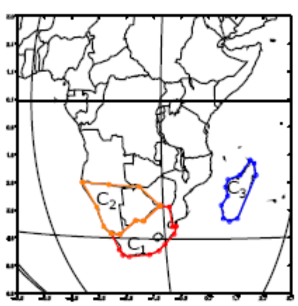


- Diameter of model: 0.3 m
- Piano wires, diameter: 0.3 mm (steel)
- Distance between wires: 10 mm
- Specific weight of wire grid: 92 g/m^2



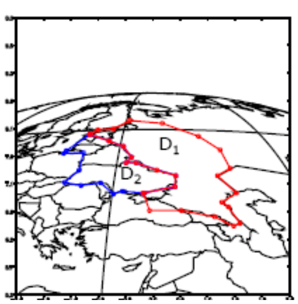
Intercontinental Mission, lateral face antenna





Suggested by TAS:

- geostationary satellite between 10E and 70E (36E).
- 3 coverages: B_1+B_2 C_1+C_2+C_3 D_1+D_2
- minimum XPD of 30 dB
- beam pointing error of 0.12°
- Tx/Rx case
- Tx=10.95-12.5 GHz and Rx=13.75-14.5 GHz. 10.95GHz, 11.7GHz, 12.5GHz, 13.75GHz, 14.5GHz
- dual linear polarization: single only
- lateral antenna and Earth deck antenna



Polygon and antenna gain		Polygon and antenna gain		Polygon and antenna gain	
B_1	Ref	C_1	Ref	D_1	Ref
B_2	Ref - 4 dB	C_2	Ref - 1 dB	D_2	Ref - 4 dB
		C_3	Ref - 7 dB		

Reconfigurability studied in switching from one coverage to the other for a fixed orbital location.

Non-periodic Direct Radiating Arrays for Multiple Beam Space Telecommunication Missions

Studied in the frame of a Phd partnering with Delft Technical University (C. Vigano and I.Lager), Thales Alenia Space (G.Caille) and ESA (G.Toso and C.Mangenot)

Interesting properties of non-periodic arrays w.r.t. periodic arrays and thinned arrays

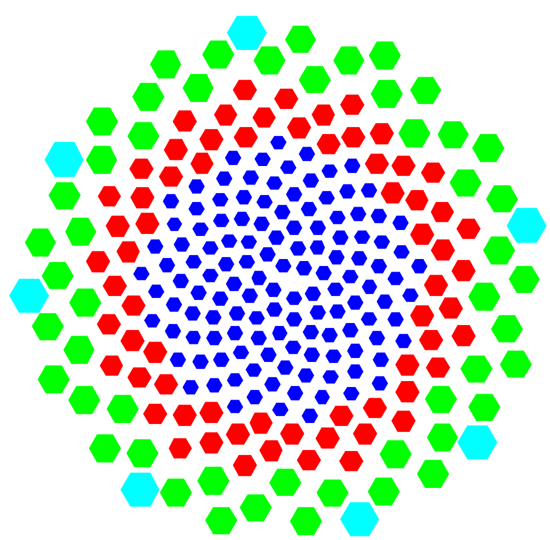
Expected way to reduce active control number with phase control only

Target for satellite multibeam telecommunication transmit antennas

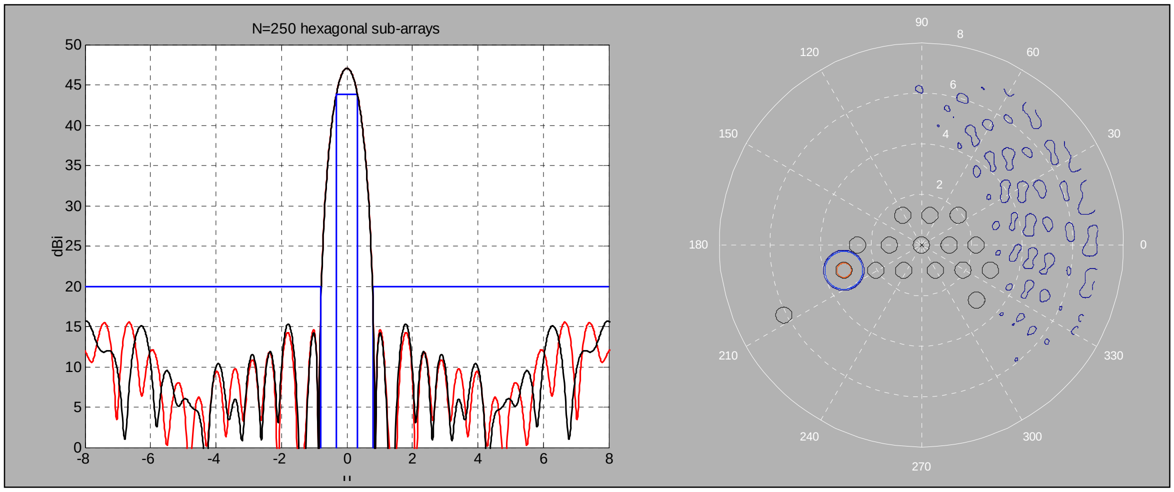
4 different sub-arrays

The array is composed by 4 kinds of sub-array all of them hexagonal with the number of rings from 2 to 5.

The 57.92% of the total area is covered.



4 different sub-arrays



SLL perfect even during scan but EOC level not enough (EOC min=42.85dBi)

Make available very stable and large Ku-Ka Band Reflectors

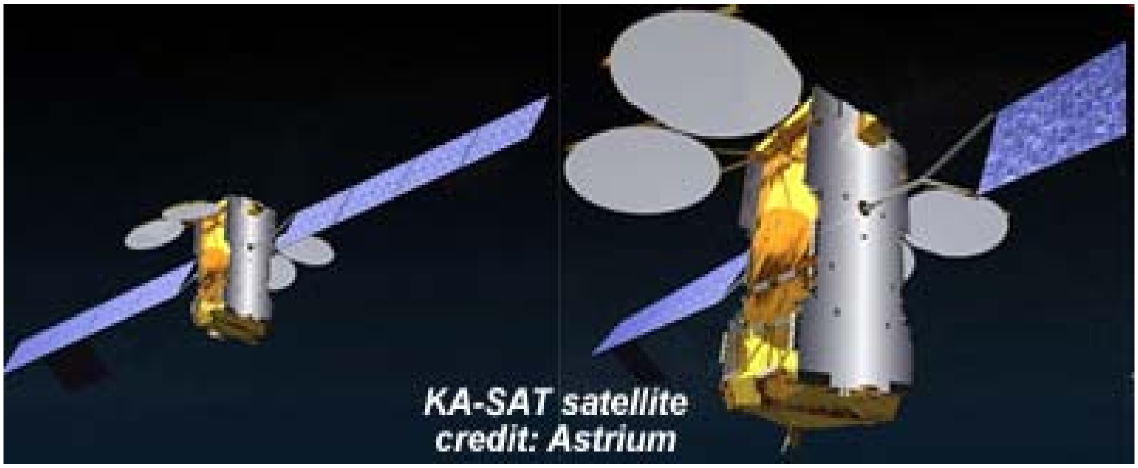
Broadband Antenna sub-system can be split in two main concepts with different technological maturity and coverage flexibility:

- Antenna using « 1 feed per beam » concept leading to use at least 3 radiating apertures to generate all the beams
- Antenna using « multiple feeds per beam » concept leading to much complex architecture but compatible with the use of only one radiating aperture to generate all the beams

Large number of activities funded in the recent past for the One Feed per Beam antenna concept have resulted in qualified hardware. Remaining antenna targets:

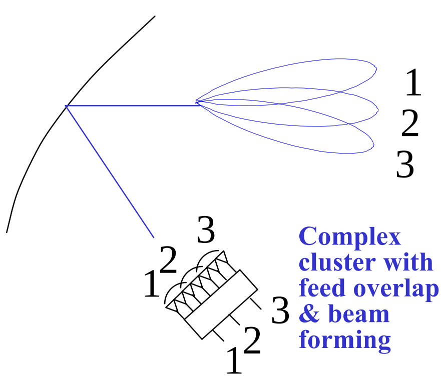
- Make available feed technologies and innovative concepts
- Allow the accommodation of a large number of missions by sharing antenna aperture (frequencies Tx/Rx , polarizations)
- Improve thermo-elastic stability for large Ku and Ka band reflectors (diameter range from 2 to 4 meters)

“Single Feed Per Beam ” Satellite implementation

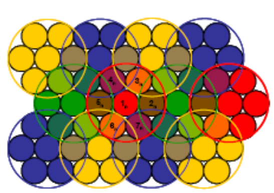


“Multiple Feed Per Beam ” Satellite implementation

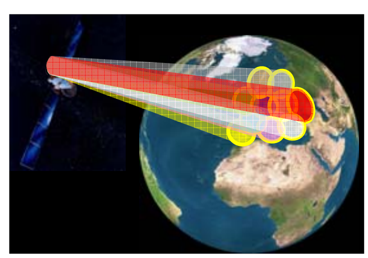
- Typically 7 to 19 feed horns per beam
- All beams originate from a single reflector antenna aperture
- To meet beam footprint and sidelobe requirements, adjacent beams must share feed horns



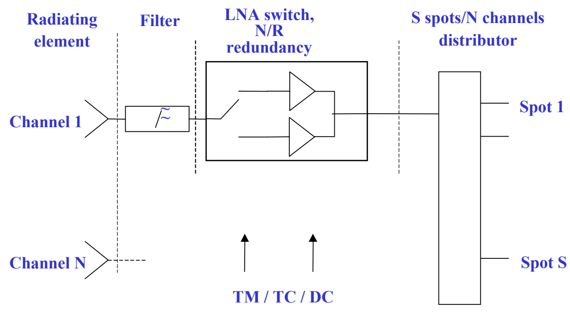
Complex cluster with feed overlap & beam forming

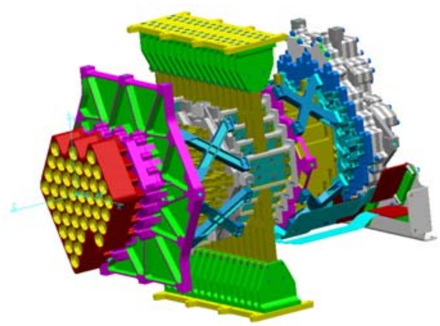


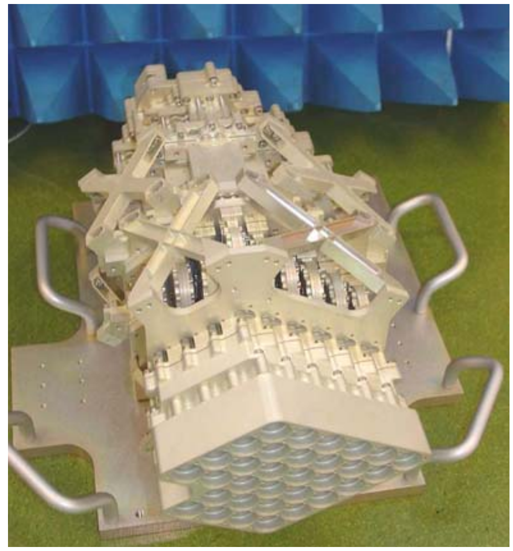
Adjacent beams share feeds



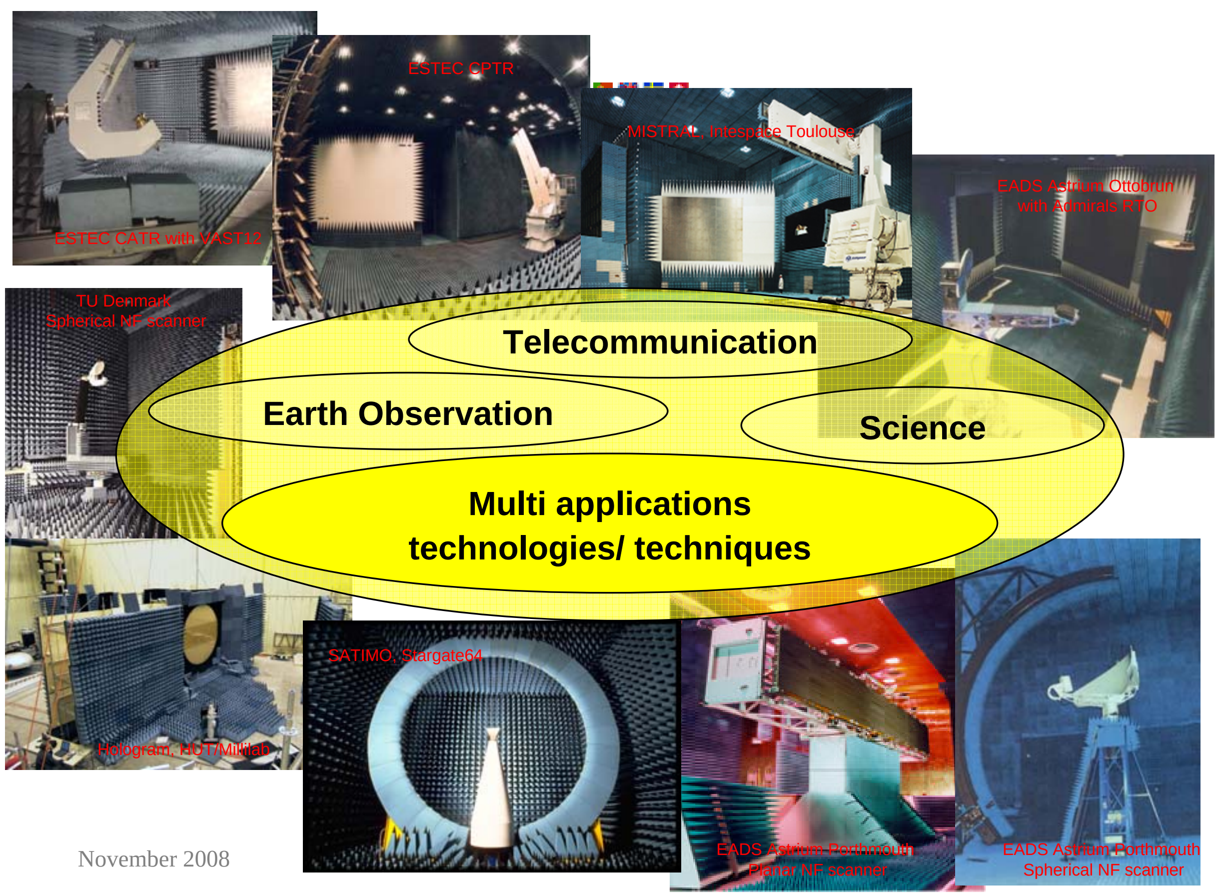
Multiple Spot Beams







–Feed Array CAD view and hardware (Courtesy of Thales Alenia Space)



Multi applications Technologies/Techniques

Improve RF test techniques

- Develop new tests techniques for multibeam antennas to perform direct measurement of payload performances
- Improve accuracy of antenna radiated phase measurement to cope with interferometric instruments, navigation antennas and calibration needs.
- Develop new test techniques for sub-mm wave antenna measurements, such as the Hologram Compact Range, Electro-Optical probing, Phaseless Near Field and new sub-mm components
- Improve measurement / error correction techniques for very low sidelobe antennas
- Investigate combined measurement-simulation approaches to reduce testing time
- Novel Techniques For General Antenna Characterisation In The Time Domain
- Diagnostic Tests Techniques for Trouble Shooting of Antennas during Satellite AIV
- Near-Field Antenna Passive Intermodulation Products Testing with processing of near-field/far-field to localize the PIM source

Conclusions

- This paper has provided a short review on space antenna needs and associated architectures/technologies.
- For the selected missions, conventional Direct Radiating Arrays and Array Fed Reflector require a too large number of controls which impose finding alternative concepts:
  - Synthetic Aperture and Interferometric concept
  - Reflector based semi-active antennas
  - Array Fed Shaped Reflector
  - Reconformable sub-reflectors
  - Reflectarrays
  - Sparse and Overlapped arrays
  - Higher accuracy Antenna Pointing System
- Some of these concepts can only be used in receive mode, or for Earth Observation
- Some allow only reconfigurability of a single beam per polarisation
- In most cases large R&D efforts are still needed to reach the expected maturity level at affordable cost.