Large Deployable Antennas
Mechanical Concepts

1. Background
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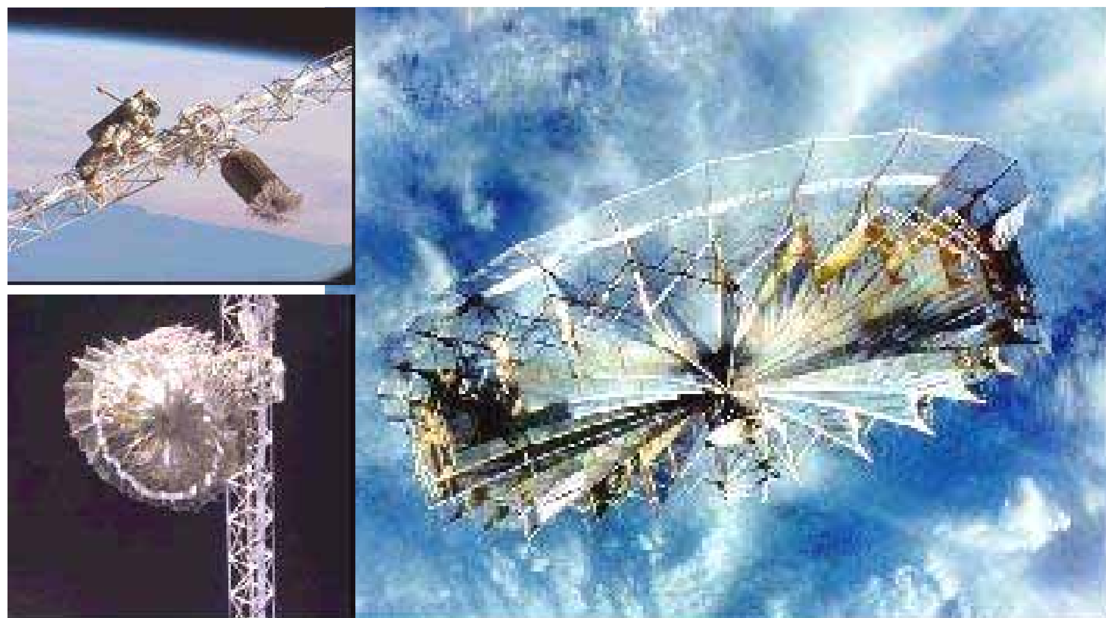
3. Other reflector concepts: CFRS shell-membrane, CRTS and Improved Spring-back
4. STEP phased array P-band SAR antenna

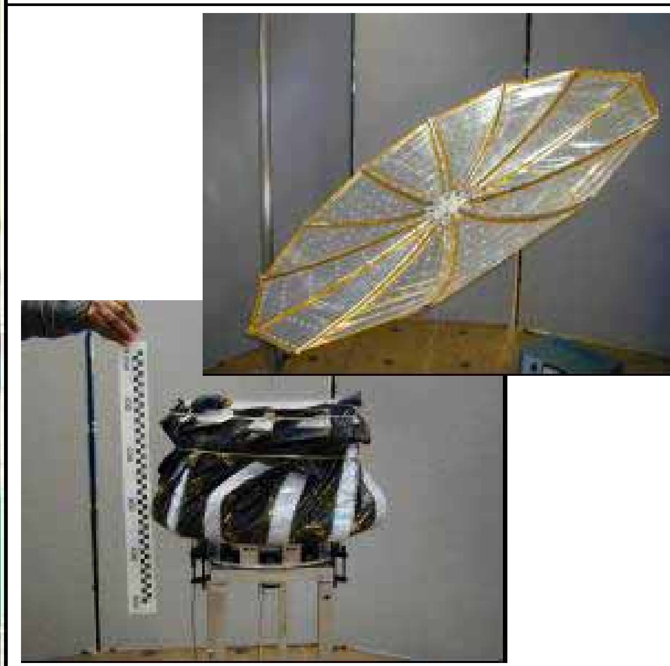
Dr. Julian Santiago-Prowald
Structures Section
ESA-ESTEC

Background

Unfurlable mesh reflector, 5 m, MBB 1986.	Deployable Mesh Reflector 5.5 m, EGS (Georgia/Russia, flight test model on the orbital station MIR)
	

Large Deployable Antennas Mechanical Concepts

Background

Contraves (Oerlikon) 12 m inflatable antenna	Collapsible Ribs Tensioned Surface (DSL Cambridge University, ESA patent)
	

ESA's Unfurlable 12 m LDA Programme

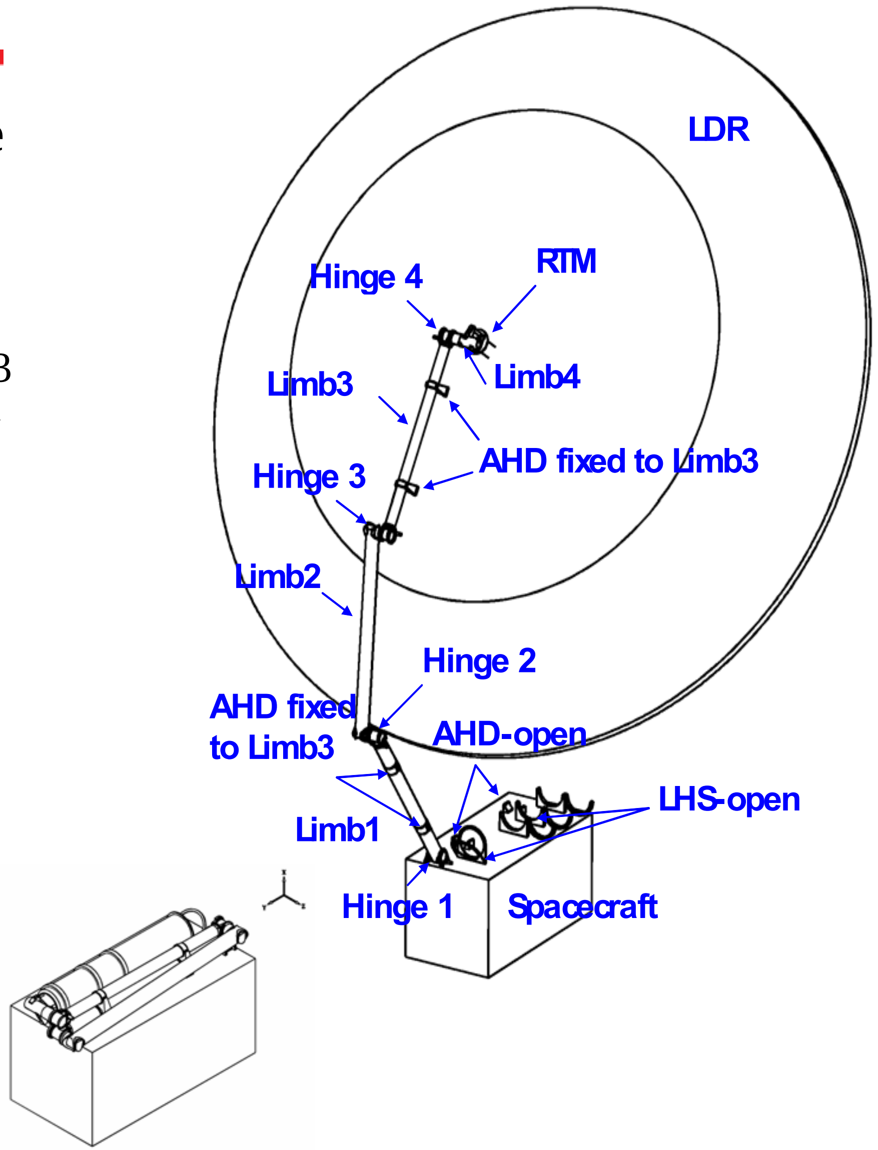
- The ESA Large Deployable Antenna (LDA) project is devoted to the qualification of technologies of a 12 m aperture system within the ARTES 5 programme.
- System parameters are selected for S-UMTS telecommunications such that global coverage is implemented. Furthermore sufficient flexibility for other scenarios, including Earth Observation and Science applications, is taken into account.
- The 12 m reflector design, manufacturing and experimental verification of requirements are finalized.
- The magnitude of some testing activities has been of an unprecedented scale in the development of European technologies, requiring dedicated efforts from NPO EGS, RSC ENERGIA, THALES ALENIA SPACE ITALIA and ESA.

ESA's Unfurlable 12 m LDA Programme

- The LDA consists of:
  - –Reflector
    - Paraboloid, 12 m circular projected aperture, 6.3 m of focal length and an offset clearance of 3 m
    - unfurlable supporting structure
    - hold-down system for the interface toward the spacecraft
  - –Arm
    - four hinges
    - four limbs
    - two hold-downs
  - –Reflector trimming mechanism
    - joining the reflector dish and the arm

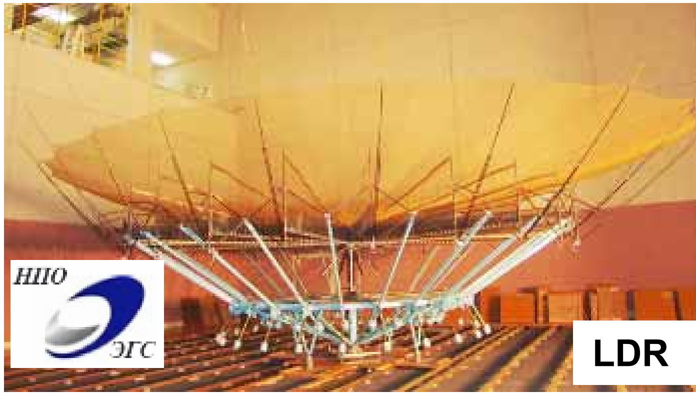
The configuration has been designed to comply with PROTON and ARIANE allowable fairing volume

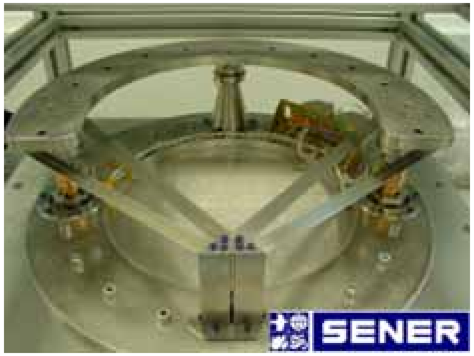
- Maximum length envelope is 4300 mm.



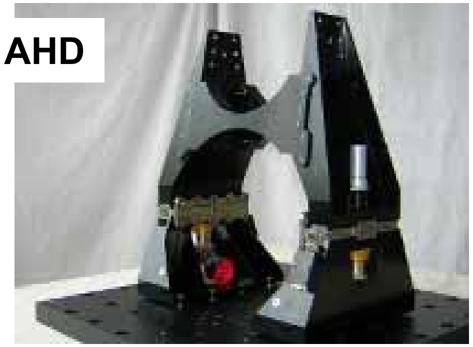
ESA's Unfurlable 12 m LDA Programme

- **THALES ALENIA SPACE ITALIA: Prime Contractor**, System & RF designer of the overall system,
- **NPO EGS (Russia): reflector dish (LDR) development**
- **RSC ENERGIA (Russia): LDR manufacturing & testing**
- **SENER (Spain): reflector trimming mechanism** (RTM) development and qualification
- **RUAG** [former HTS] **(Switzerland): reflector arm** hinges (ADB), inclusive of the tubes of the arm limbs, development and qualification
- **MAGNA STEYR (Austria) Antenna limbs hold-down** (AHD) development and qualification.





RTM



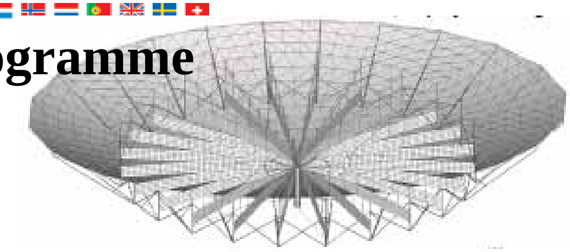
ESA's Unfurlable 12 m LDA Programme

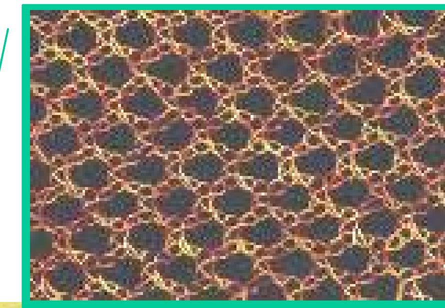
Optics geometry:	
• Configuration:	offset, parabolic
• Projected aperture:	12 m, circular
• Dish dimensions:	12 x 14.7 m
• Focal length:	6.3 m
• Offset clearance:	3.0 m
Dimensions of the Reflector Dish in launch configuration:	
• Diameter/Length:	≤ 0.7/3.5 m
Weight of dish, inclusive of hold-downs system:	≤ 70 Kg
Stiffness of deployed dish:	>1.7 Hz,
Surface accuracy (RMS of deviations):	≤ 2.5 mm
Pointing Stability, half cone angle	<0.05°
Weight of reflector System (incl. Arm and mechanisms):	< 220 kg
Stiffness of LDA assembly including arm:	>0.6 Hz
PIM performances (5th order, with two carriers of 23 dBW):	≤ -140 dBm

The RTM shall be able to:

- **Position the fully deployed LDR between a range of ±1.5°**
- **The positioning accuracy of the fully deployed LDR shall be within 0.017 degrees.**
- **The positioning resolution of the fully deployed LDR shall be lower than 0.0025 degrees**

ESA's Unfurlable 12 m LDA Programme



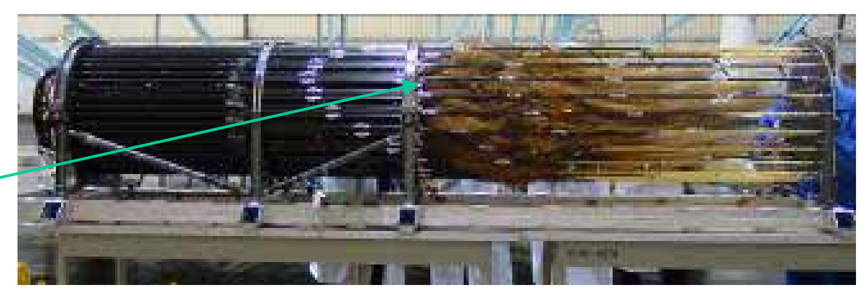


The reflector (LDR) consists of:

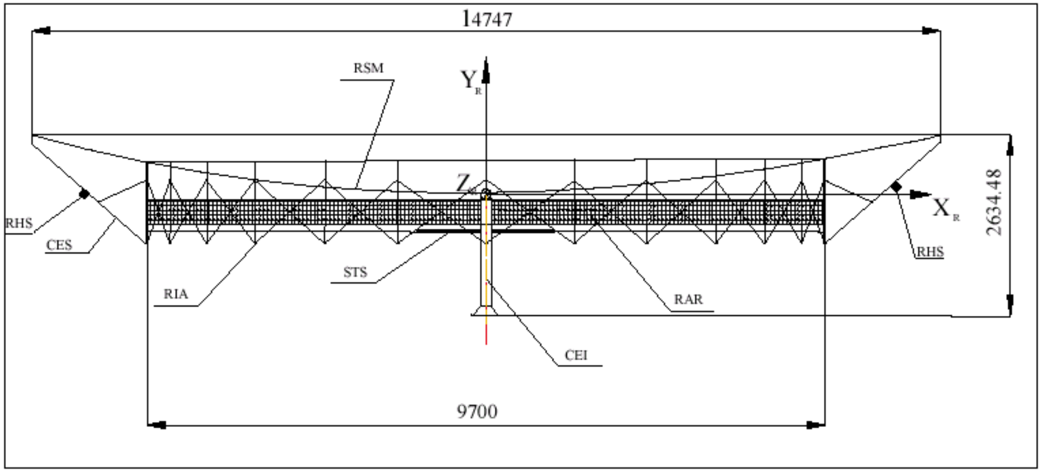
- a RF reflective mesh
- an unfurlable supporting structure:
  - Force Ring with actuators, generates the deployment
  - Consoles make the elliptical contour
  - Central Interface provides the interface with the support arm

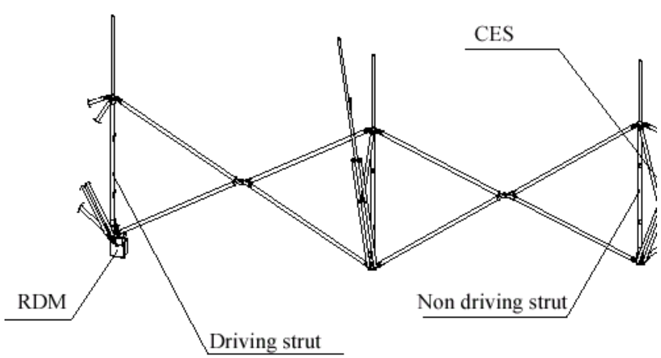
- Radial Ribs connect the central interface to the force ring and provide a solid reference to the mesh profile

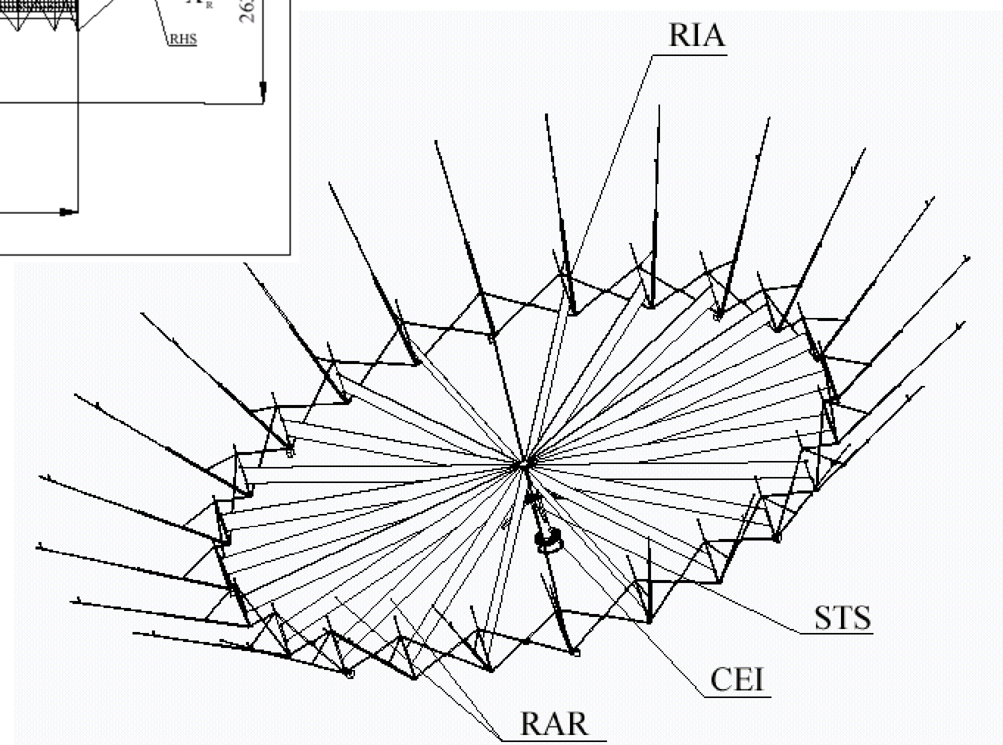
The development includes the LHS for holding the dish against the spacecraft.



ESA’s Unfurlable 12 m LDA Programme







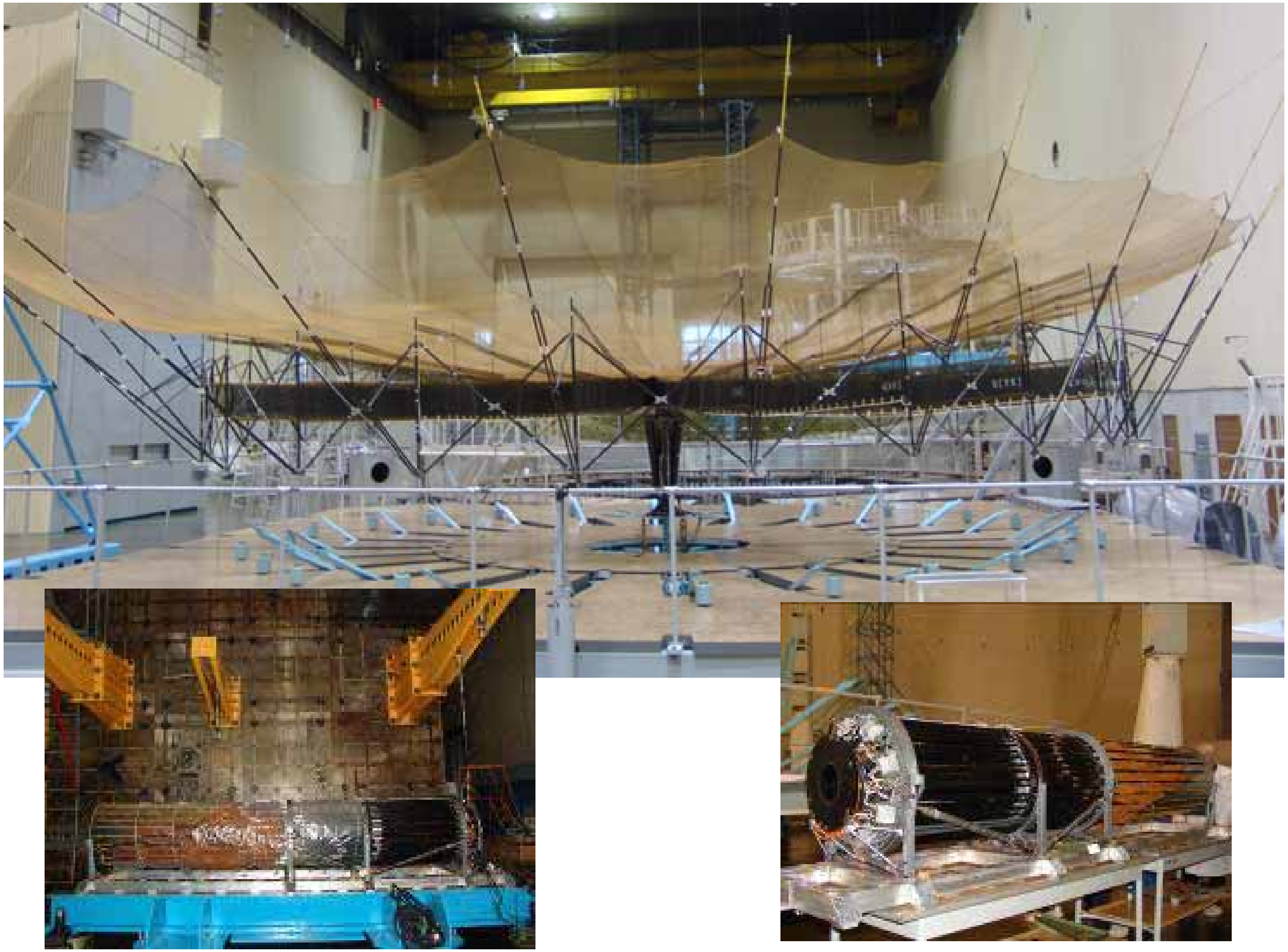
Large Deployable Antennas Mechanical Concepts

LDR stowed	LDR semideployed	LDR fully deployed
		

ESA’s Unfurlable 12 m LDA Programme

Test	Configuration
PIM Products	Deployed
Deployment 1	Stowed to deployed under 0-g suspension
Deployment 2	Stowed to deployed under 0-g suspension
Surface check	Deployed. 400 control points
Stiffness	Deployed
Deployment 3	Stowed to deployed under 0-g suspension
Detailed surface measurement	Deployed. 3000 measurement points
Sine Vibration	Stowed
Acoustic Vibration	Stowed
Shock (pyro release)	Stowed
Deployment 4	Stowed to deployed under 0-g suspension
Depressurisation	Stowed
Thermal vacuum	Stowed
Thermal vacuum with release	Stowed and initial release
Deployment 5	Stowed to deployed under 0-g suspension

Large Deployable Antennas Mechanical Concepts

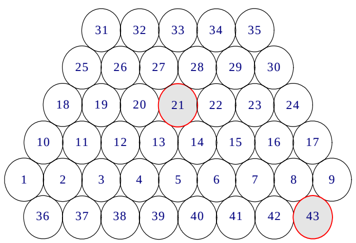


ESA's Unfurlable 12 m LDA Programme

LDR Qualification

- The PIM test has evidenced that the reflector, at L-band, when illuminated by two carriers of 166 Watt each, generates **PIM level below -140 dBm and -145 dBm at 5th and 7th** order respectively.
- **LDR** weighed **mass is 74 kg** including the LHS systems
- LDR mass without LHS is 59 kg.
- **Deployed stiffness** has been verified when the reflector was supported by a gravity compensation system. The measured resonance frequency is ≅ **1 Hz**, after removing by analysis the effect of the suspended masses of the gravity compensation system.
- **Sine, Acoustics and Release with pyroshock of the release systems**
- **Thermal and Vacuum**

ESA's Unfurlable 12 m LDA Programme



The mesh shape accuracy has been measured with a **laser radar instrument**.

RMS (in the Reflector Ref. System):

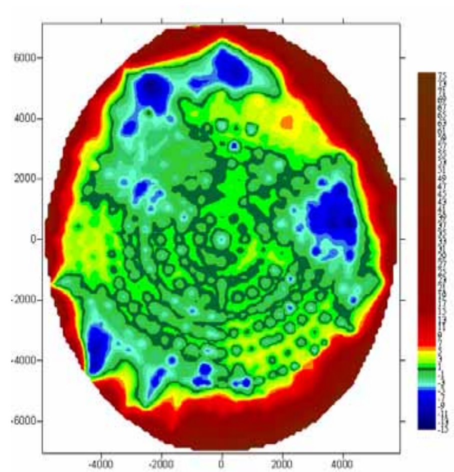
•**RMS = 2.44 mm within Φ 10 m**

•**RMS = 5.49 mm** on overall surface

(Best fit parabola with fixed focal length, data208)

An RF analysis has been performed on the S-UMTS scenario used for the Antenna RF Design, with a coverage implemented by 43 spot beams.

In order to minimize the RF performance degradations (EOC gain and Isolation), the measured surface, needs to be improved, in the area between Φ 9m and Φ 12m, mainly by improving the 0-g offloading GSE.



LDR Qualification

A dedicated gravity compensation system has been used:

- levers of the technological bench for supporting the reflector structure;
- masses (accurately calculated) applied on the LDR structure for compensating the mesh weight.

The correctness of the gravity compensation has been verified with:

- geometrical check with teodolite measurement of the supported LDR points (no distortion induced)
- equilibrium check with measurement of the forces applied by the levers (homogeneous forces distribution)

ESA's Unfurlable 12 m LDA Programme

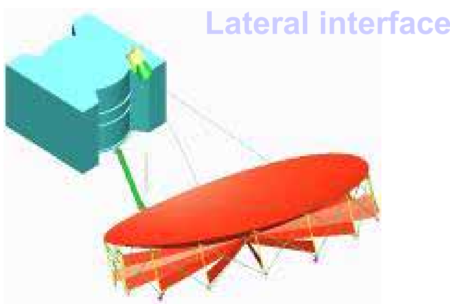
LDR Qualification

- The reflector deployment tests have been successfully performed.
- A dedicated MGSE for the gravity compensation has been designed for these tests, in order to simulate the 0-g condition in orbit.
- Five deployments have been performed
- Deployment repeatability has been verified with surface measurement on control points

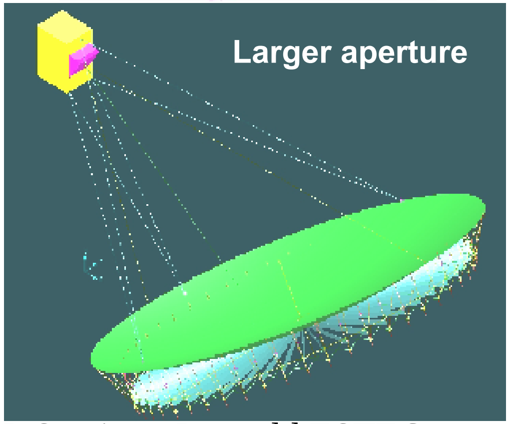
ESA's Unfurlable 12 m LDA Programme

- The LDA study has been performed to provide confidence on the possibility to design, develop, manufacture and qualify the Large Deployable Antenna integrated system.

- The contract covered the system design and analysis activities and the development and qualification of key components.



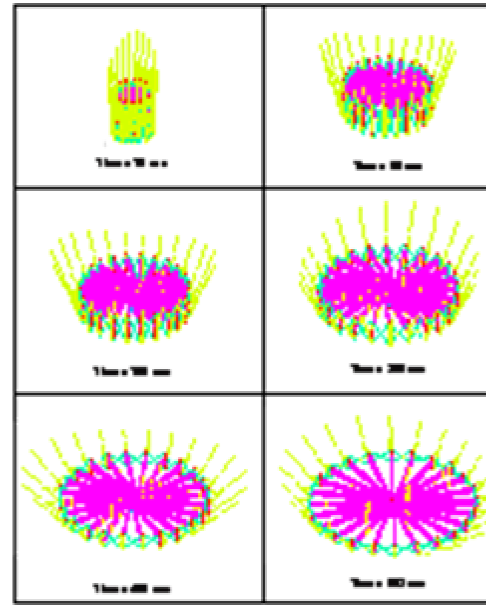
- Achievements:
  - RTM, ADB and AHD manufactured, tested & qualified
  - LDR manufactured, tested & qualified

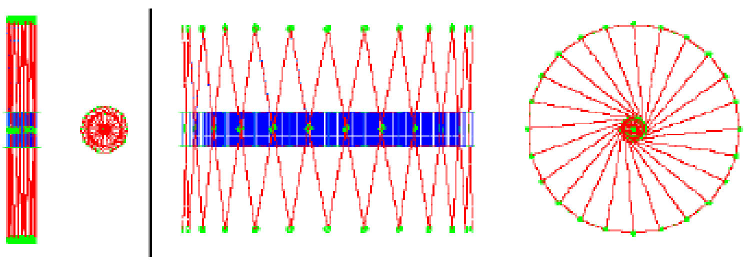


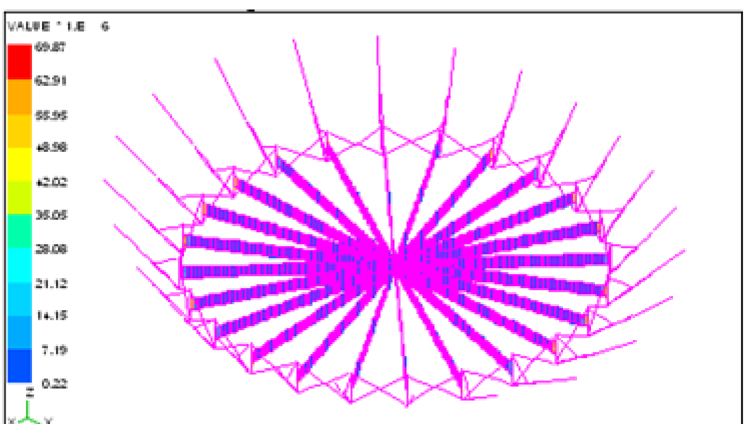
- Future Possible Activities:
  - Flight Experiment for in orbit LDA performance verification (launch with either Progress or Vega).
  - Higher RF bands utilization.
  - Expandability to larger diameters (> 18 m).
  - Lateral attachment.

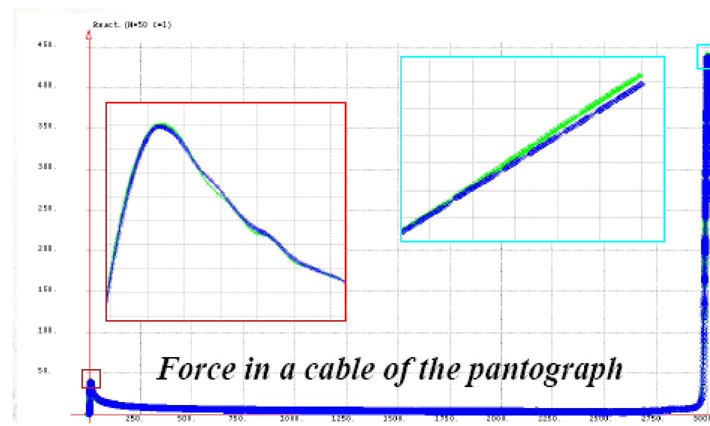
ESA’s Unfurlable 12 m LDA Programme

Specific simulation tools: Samcef-Mecano for non-linear, transient, FEM multibody simulation. Numerical algorithms considering energy-momentum conservation during long integration time and shocks (SAMTECH / Alenia)









ESA's Unfurlable 12 m LDA Programme

- A Flight Experiment has been preliminary studied
  - to verify the Large Deployable Antenna (LDA) Reflector Assembly performance in the orbit environment

- Specific mission objectives
  - In-orbit deployment of the LDA
  - Verification of the LDA reflector (LDR) in-orbit shape and stability
  - Verification of the Passive Inter-modulation Products (PIM) characteristics of the LDR in the orbital environment
  - RF characterisation by means of a TLC experiment based on LDA
    - Data relay
    - Satellite Digital Multimedia Broadcasting (S-DMB)

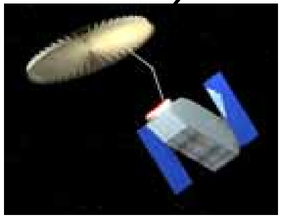
esa

LDA Applications

- Driving elements for LDA's applications:
  - high gain
  - multi-beam coverage
- Telecommunications in L / S band (MSS, DAB/DARS)
- Earth observation from P-band to C-band (SAR and Radiometer)
- Deep Space observation (radio-telescope and large base interferometers, VLBI)
- Military applications and intelligence (interception of earth radio signals for telecomm. and radar, P-band and X-band)

L/S Band (1.6-2.5 GHz)

Thuraya



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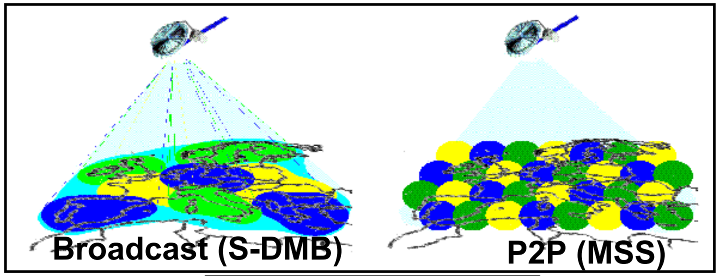
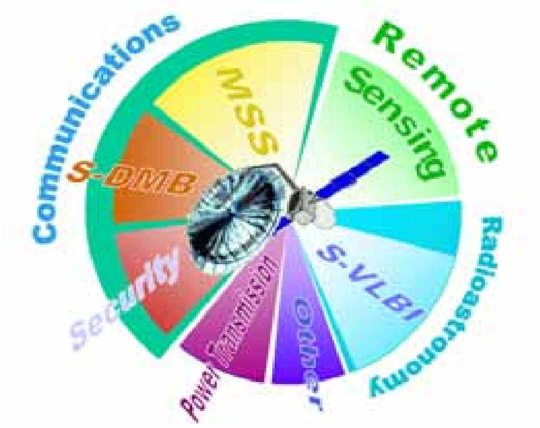
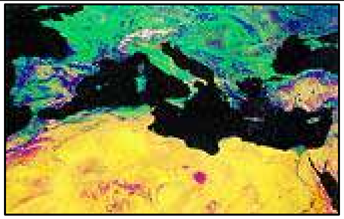
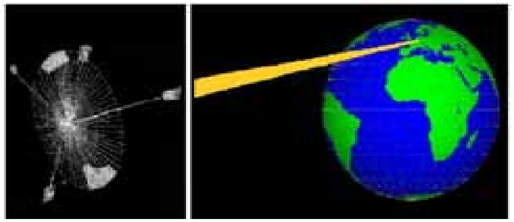


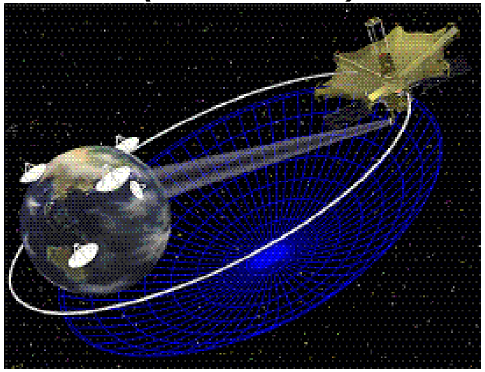




Altimeters / Radiometers / Sar (P to X band)



SIGINT (Signal intelligence)



S-VLBI (space very large based interferometers: 8 GHz, 22 GHz, 43 GHz & 86 GHz.

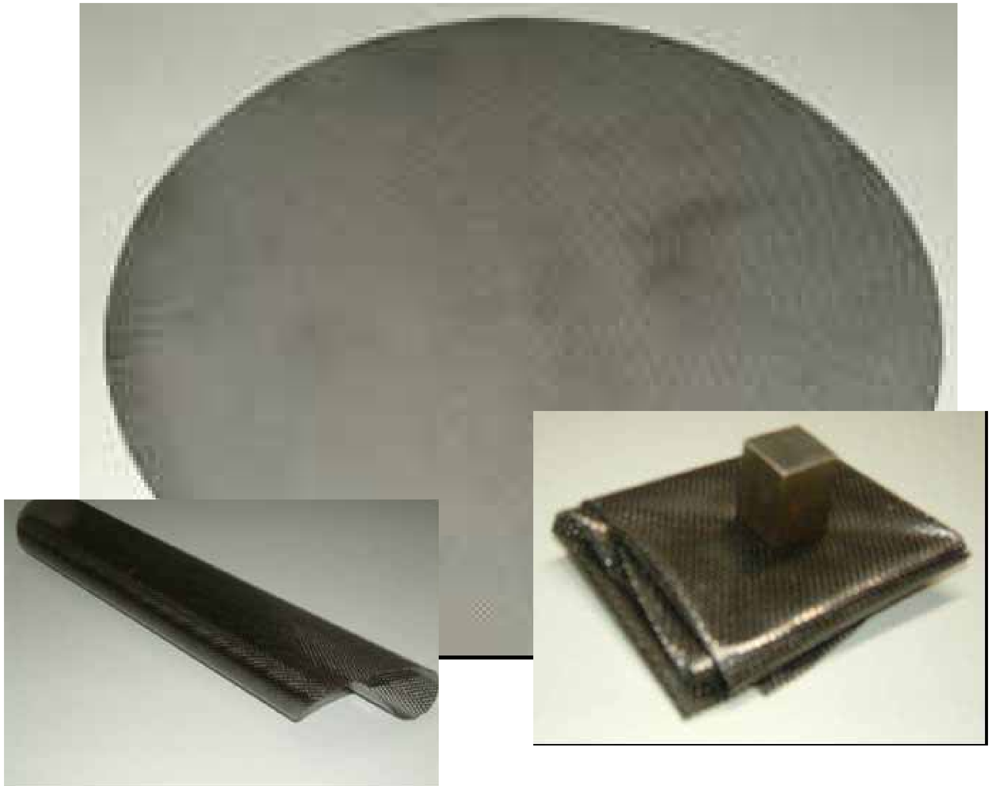
Other reflector concepts

CFRS material-based foldable reflectors: SMART and SAFIRS (LLB-TU Munich)

See presentation by Dr. L. Datashvili.

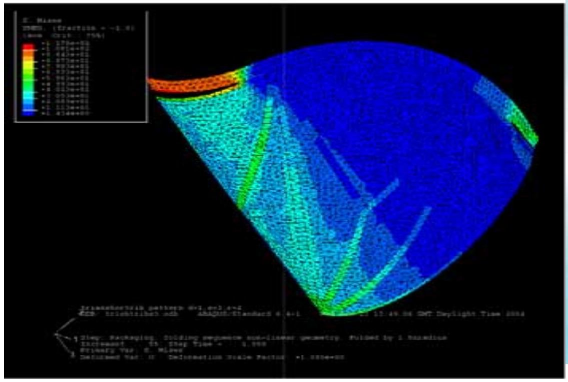
Carbon Fibre Reinforced *Silicone* flexible shell-Membrane made out of Triax carbon fibre fabric reinforced silicone

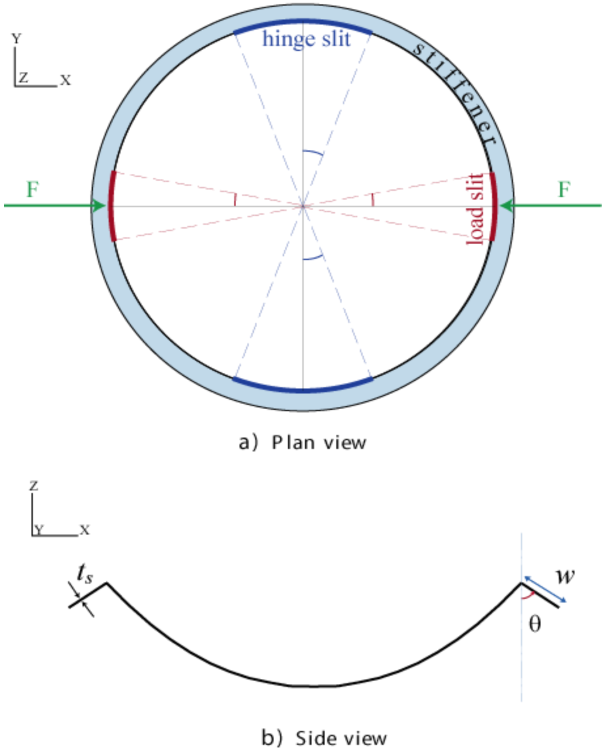
- **Low outgassing**
- **Wide range of service temperatures**
- **RT cure**
- **Flexible above -100°C**
- **Low and q/isotropic CTE**
- **No micro-cracks**
- **10-12 GHz reflection loss small**



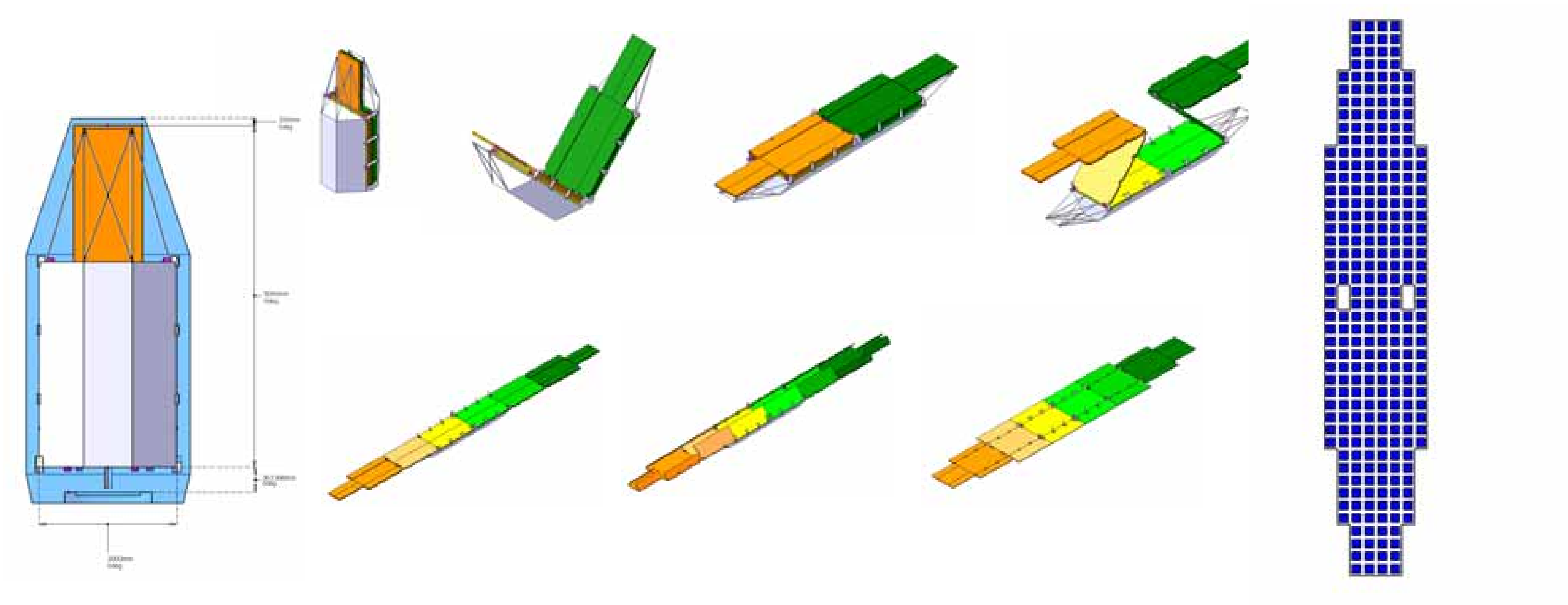
Other reflector concepts

Stiffened Spring-Back Reflector (DSL Cambridge University, Tan & Pellegrino)





STEP phased array P-band SAR antenna (A. Thompson et al.)



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