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Large Deployable Antenna recent ESA developments and mission needs

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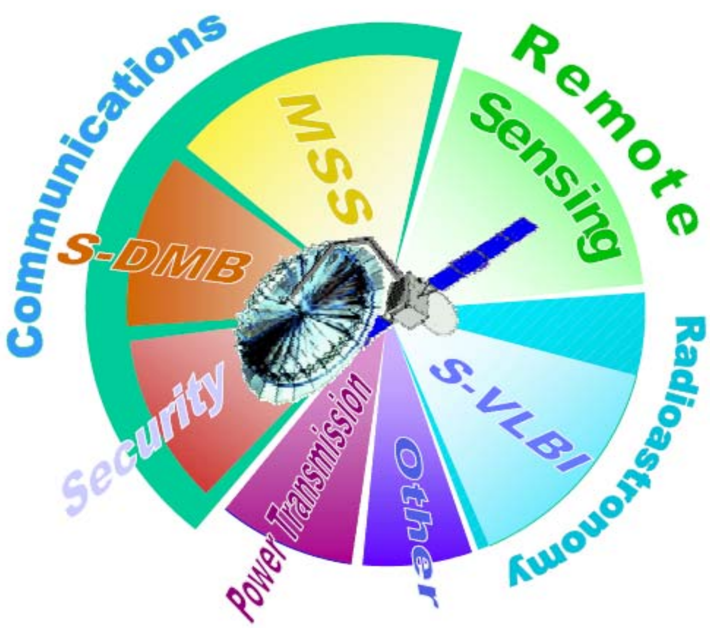
Content

- 1. Introduction
- 2. Space missions requiring large reflector antennas
- 3. Past reflector market share
- 4. ESA recently supported developments
- 6. Large Deployable Antenna way forward



European Space Agency

Introduction

The optimisation of antenna performance is a key issue in the design of satellite system and requires a coordination of multi-disciplinary activities supported by electromagnetic, thermo-mechanical and technological expertises.

Even if the today trends is toward the miniaturization of all RF equipments and platform, antenna size is expected to grow for higher sensitivity instruments and access to the end user with small terminal. One may consider:

- **Real apertures** such as reflector, reflectarray, membrane, arrays and lenses
- **Synthetic apertures** generated by a set of individual radiators or arrays in formation flying satellites.

Considering

- The already existing flight hardware for arrays (real and synthetic apertures)
- The fact that more than 80% of telecommunication space apertures are implementing reflectors and needs are identified for Earth Observation

Effort shall be put on making available large European space reflectors.

Introduction

European industry is very strong with space reflector that can be accommodated on the spacecraft in one piece:

- Single deployment Ultra Light Reflector in CFRP up to 3.8 m
- Double deployment Ultra stable Reflector up to 2.6 m
- Dual Grided Reflector up to 2.2 m

Europe has supported some developments to overcome these limits:

- Early study by Aerospatiale (1980') , MBB 5 m Deployable Mesh Antenna (1988)
- Foldable tips reflector by TAS (I)
- Membrane reflector based on Carbon Fiber Reinforced Silicon TUM
- Large Deployable Antenna up to EQM level (2007) by Thales Alenia Space (I) and EGS

Despite the efforts put in place, and the strong interest for Telecom and EO missions, the products maturity/availability prevent their implementation in the frame of a C/D phase.

Introduction

As identified in the 2009 Telecommunication Reflector harmonisation dossier roadmap called “Fill the gap for reflector technologies not available in Europe”, this presentation focuses on:

- All reflectors above 4 meters (the ones to be “deployed / built” in space due to launcher accommodation constraints)

Considering Large antennas as the ones above 4 meters allows:

- To cover a broaden set of missions and a larger market segment to achieve an earlier ROI.
- To identify possible technology/techniques synergies that may allow sharing design and testing NRE costs.

Presentation focused on mission needs and ESA supported R&D

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Space missions requiring large reflector antennas

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Telecommunication Well established and solid markets:

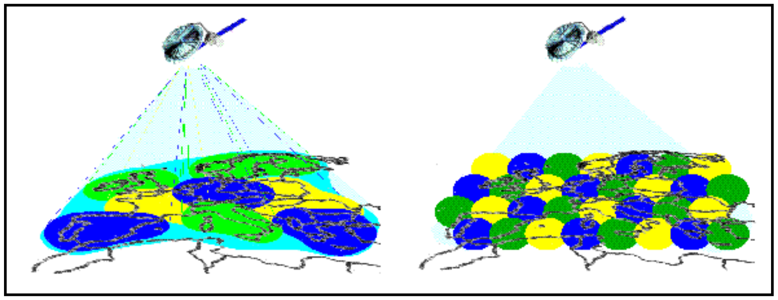
Fixed and broadcasting Satellite Services DTH/TV, FSS Ku Market including Government services and VSATs

⇒ **reflector diameter up to 5 m for linguistic European coverages**

Telecommunication Dynamic markets with capacity already in orbit:

Mobile interactive communication satellite services

=> **reflector diameter up to 25 m**



Mobile broadcast satellite services

=> **reflector diameter from 9 to 12 m**

Digital Audio Radio Service

=> **shaped reflector diameter from 4 m to 7 m**

Broadband Satellite services

=> **reflector diameter up to 5 m**

Space missions requiring large reflector antennas

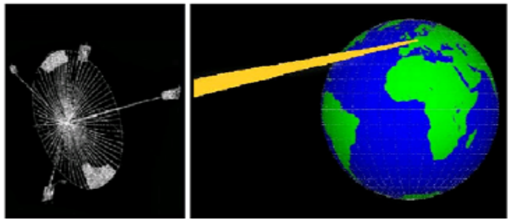
Telecommunication New applications under development in partnerships

Air traffic management satellite services as part of the SESAR Programme.
=> **Multibeam antenna with reflectors from 3.5 to 8 meters diameter operating at L-band from HEO or GEO**

Tactical communications based on UHF SATCOM services.
=> **Reflector diameter above 10 m at UHF band**

Emergency communication for high reliability and prompt response services to remote large areas of the globe in support of contingency operations.
=> **Reflector diameter above 10 m at UHF band**

Spectrum Monitoring and signal intelligence for intercepting, processing, and analyzing electrical communications and other signals. These systems can play an important role in civil security, military and peacekeeping operations.
=> Reflector diameter above 10 m up to Ka-band



SIGINT (Signal intelligence)

Space missions requiring large reflector antennas

Navigation

Future evolution of the Galileo system and mission could foresee the broadcasting of PRS (Public-Regulated Services) signals within spot beams steerable over the visible hemisphere from the MEO altitude.

The size of such spot beams is the subject of investigation in different system studies, but preliminary considerations ask for beam footprint size around 1500 km diameter.

=> **Reflector sizes between 3.5 and 7 m diameter** allowing level of power flux densities received on-ground between 10 and 20 dB higher than the baseline (global coverage).

Space missions requiring large reflector antennas

Earth Observation

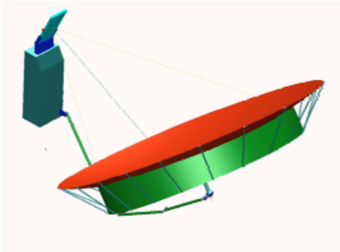
There are currently a certain number of missions in the feasibility study phase with an instrument concept based on a large deployable reflector.

BIOMASS from ESA (also a DRA configuration is proposed);

DESDynI from NASA/JPL;

Tandem-L from DLR;

SMAP from NASA/JPL.



These missions employ the reflector for either active observations using Synthetic Aperture Radar (SAR) technique at P/L Band

=> **SAR Reflector diameter above 12 m at P-band**

=> **Interferometric bistatic SAR with diameter of 15 m at L-band**

Or passive instruments such as radiometer for SMAP.

=> **Reflector diameter of 6 m at L-band with conical rotation to provide a wide swath at a constant incidence angle.**

Space missions requiring large reflector antennas

Science deep space communication

Space exploration is getting an increasing attention and the communication aspects play a central role in securing its success.

Communications requirements derived from future human and robotic planetary exploration missions ask for extremely wide bandwidth links (1 Gbps considered for Mars orbiting data relay satellite).

An Earth orbiting satellite or a more futuristic space vehicle located at the Lagrangian point of the Earth-Sun system could operate as a relay station of the of the Deep Space Network (DSN).

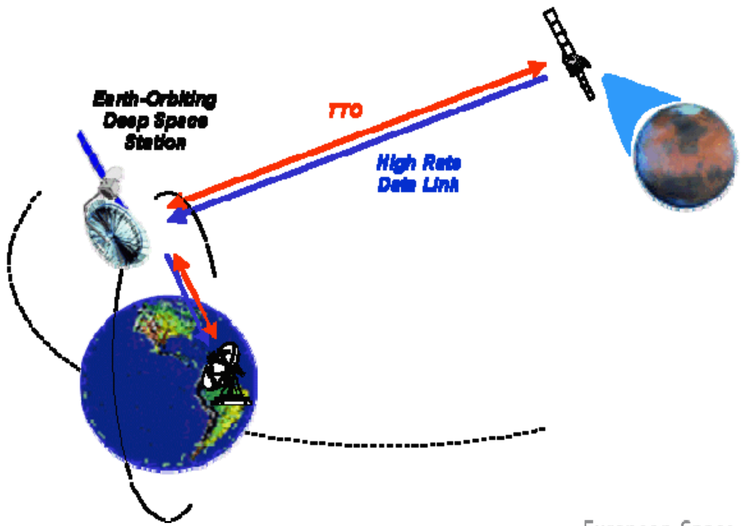
Required antenna gain

and very long distances

to outer planets ask for:

=> **Reflectors above 4 m**

operating at X and Ka-band



Space missions requiring large reflector antennas

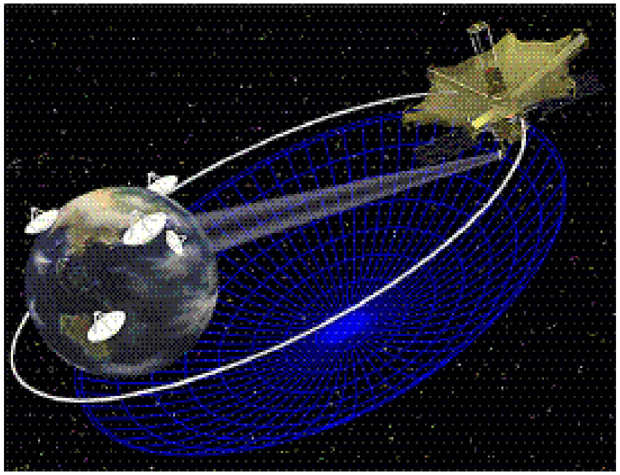
Radio Astronomy Missions Based on Space Very Long Baseline Interferometry

Current Earth based VLBI networks are limited by the finite size of the Earth diameter and thus the maximum baselines/resolution at a given frequency

The obvious choice is to realise a satellite based radio telescope, which co-observes with the terrestrial VLBI network. Initial studies were undertaken for the space VLBI program Quasat in the 80's by ESA.

=> Space reflector antennas

above 8 to 10 m operating up to Ka-band.



In the future, 10 to 25 m class is of interest

as well as stand alone functionality to

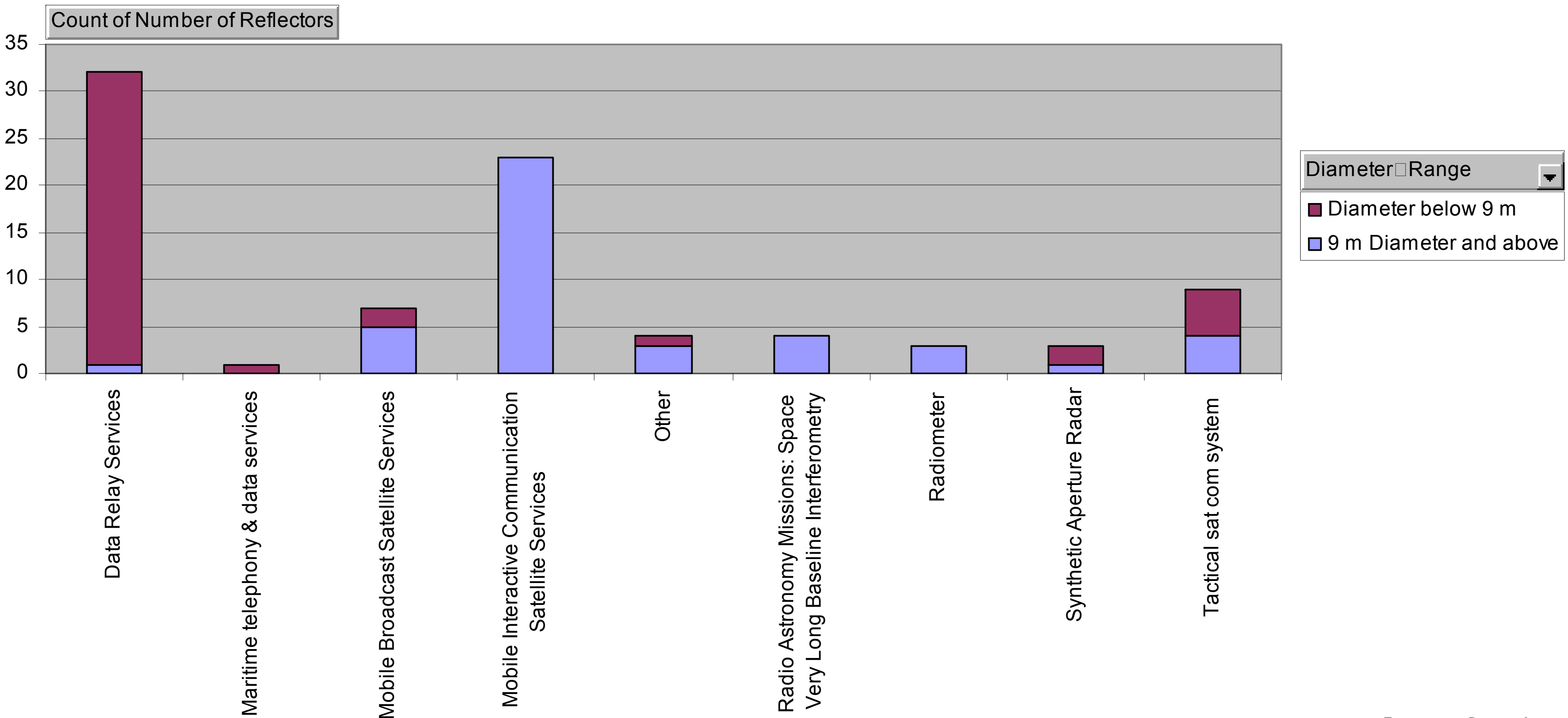
observe outside the atmosphere.

Space missions requiring large reflector antennas

Synthesis of Mission Needs

Strong request for Telecommunication

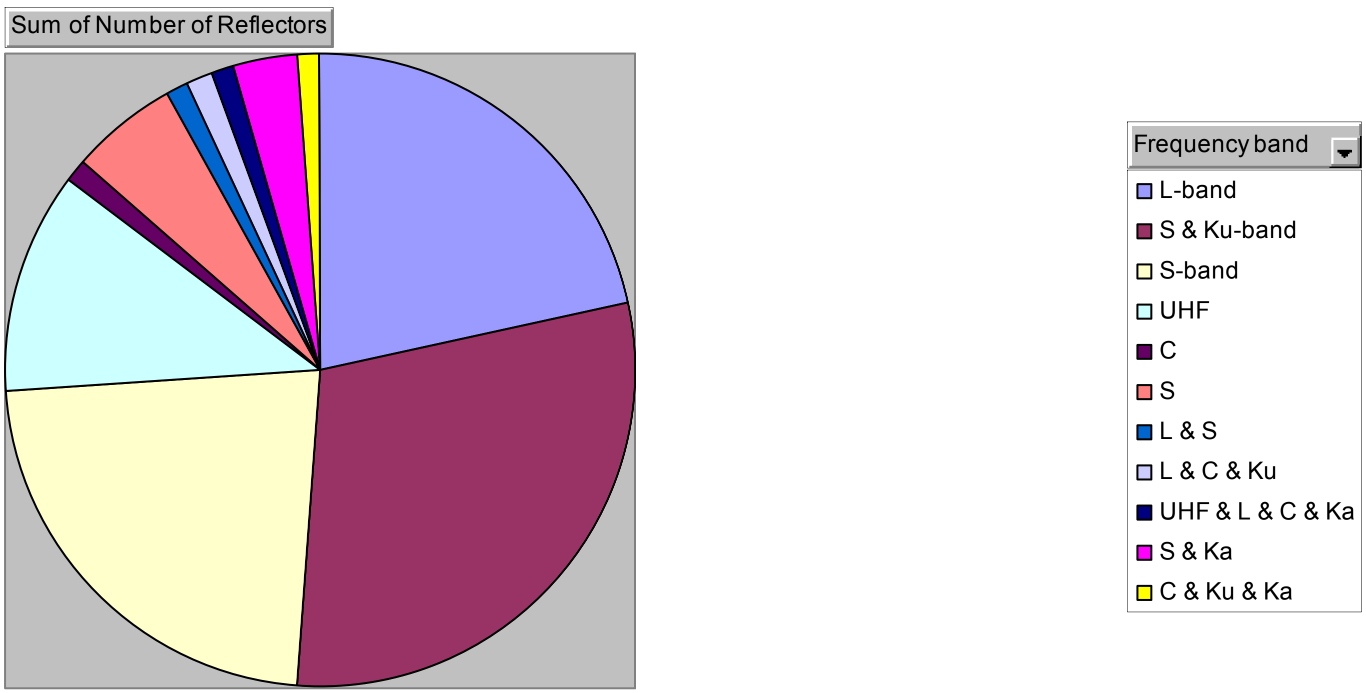
Wide reflector diameter range depending on the mission



Past reflector market share

Large Reflectors sorted by Operating Frequency

Major requests for S-band and frequencies below



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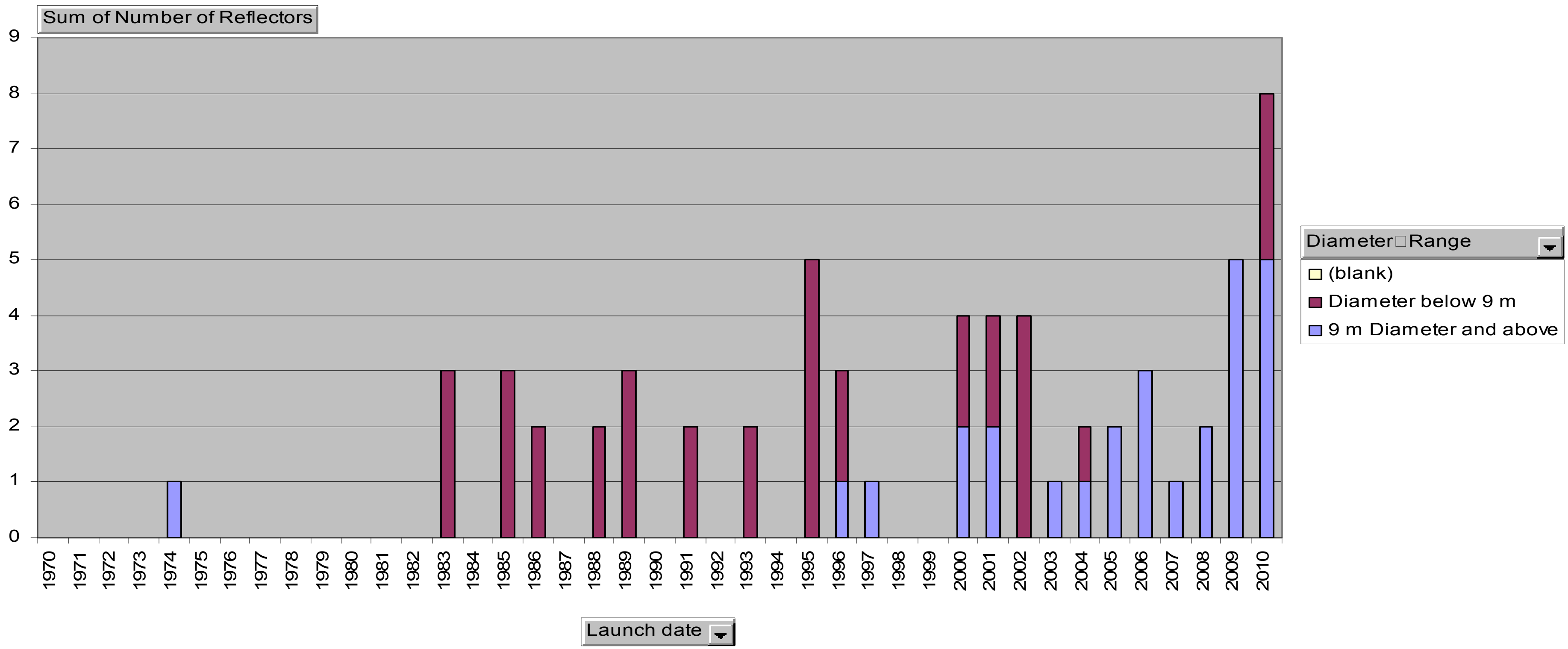
Past reflector market share

Large Reflectors sorted by Launch date

- World market situation (more than 100 flight objects identified)
- Strong market evolution from one reflector every two years to more than 5 reflectors per year

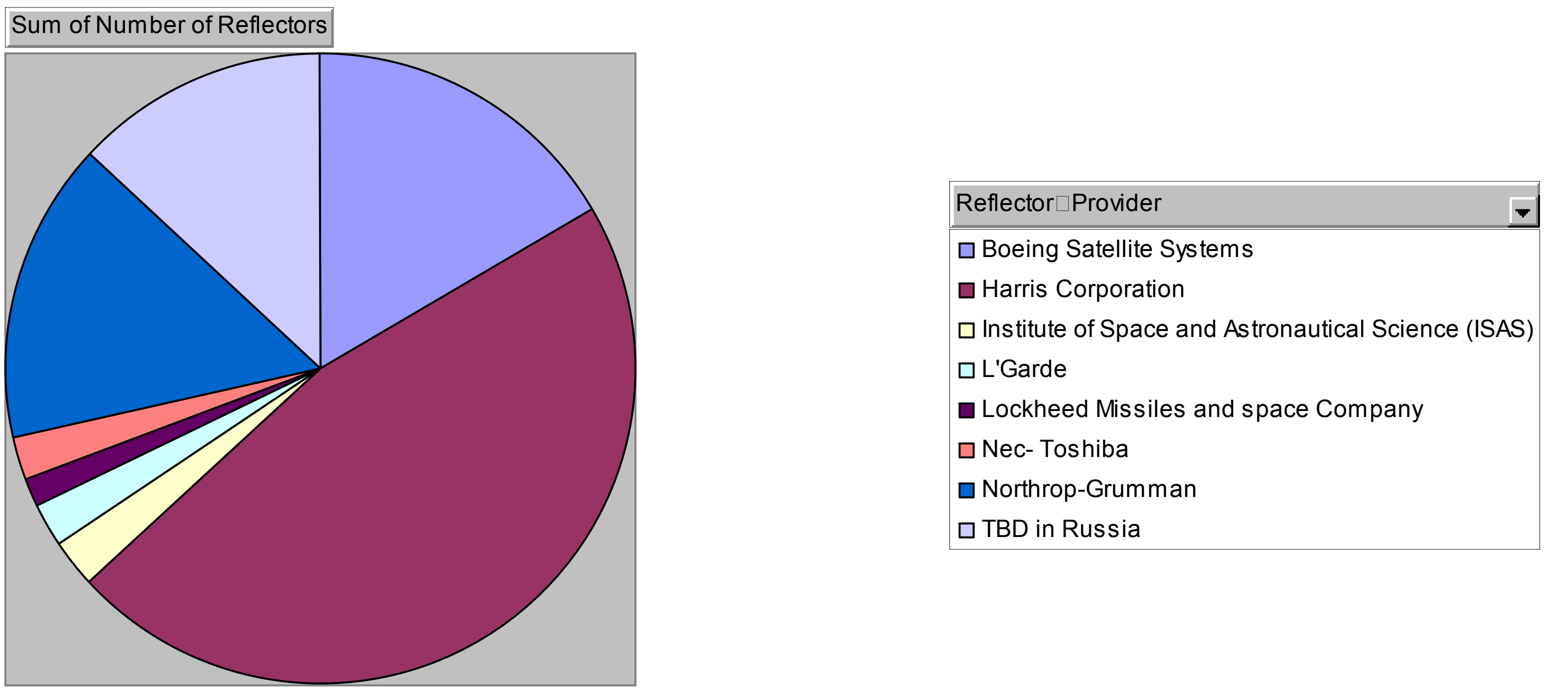


European Space Agency

Past reflector market share

Large Reflectors sorted by Provider

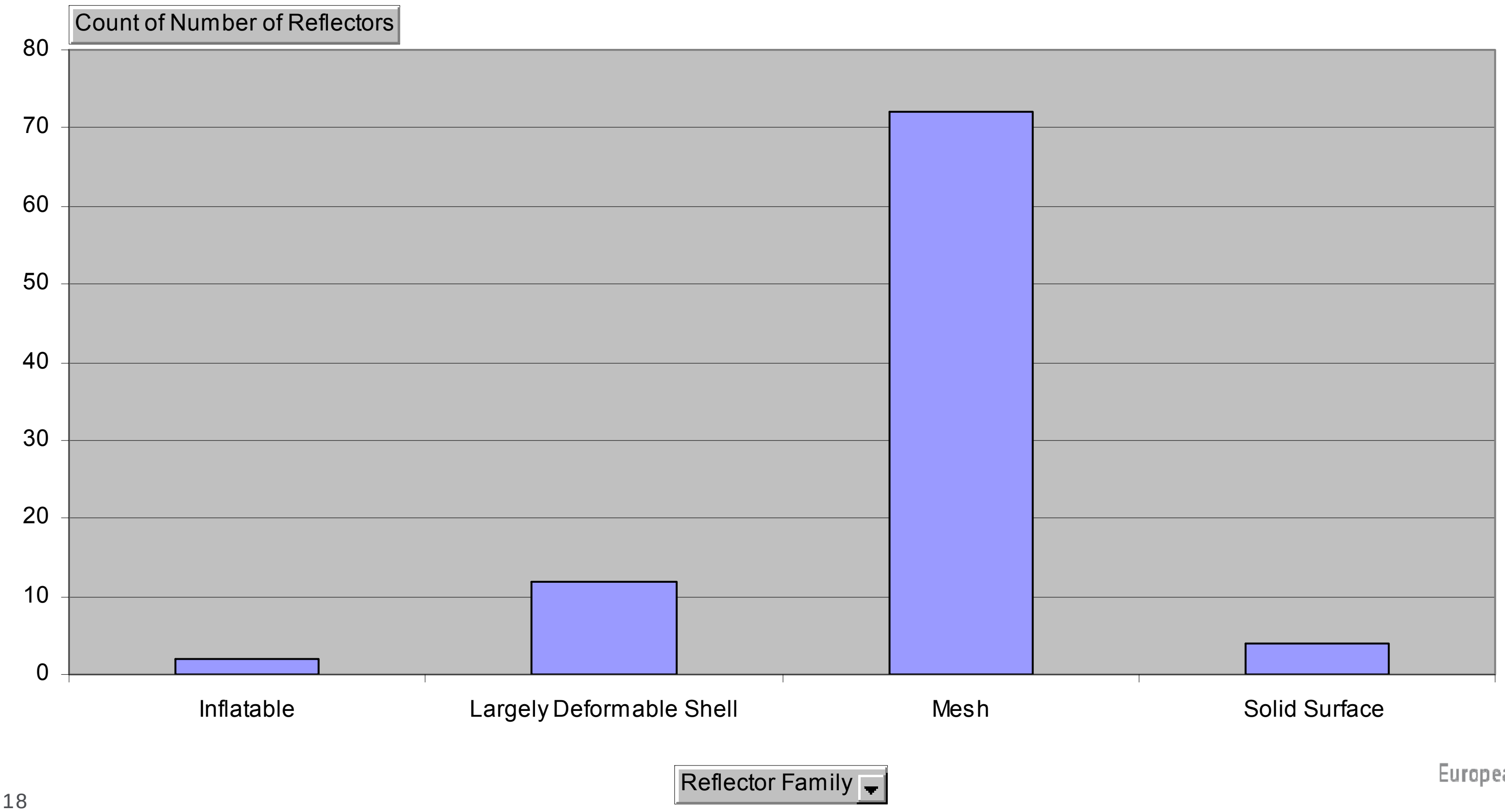
- Quasi monopoly of US providers
- Strong position of Harris Corporation



Past reflector market share

Large Reflectors sorted by technology

Predominance of mesh technology



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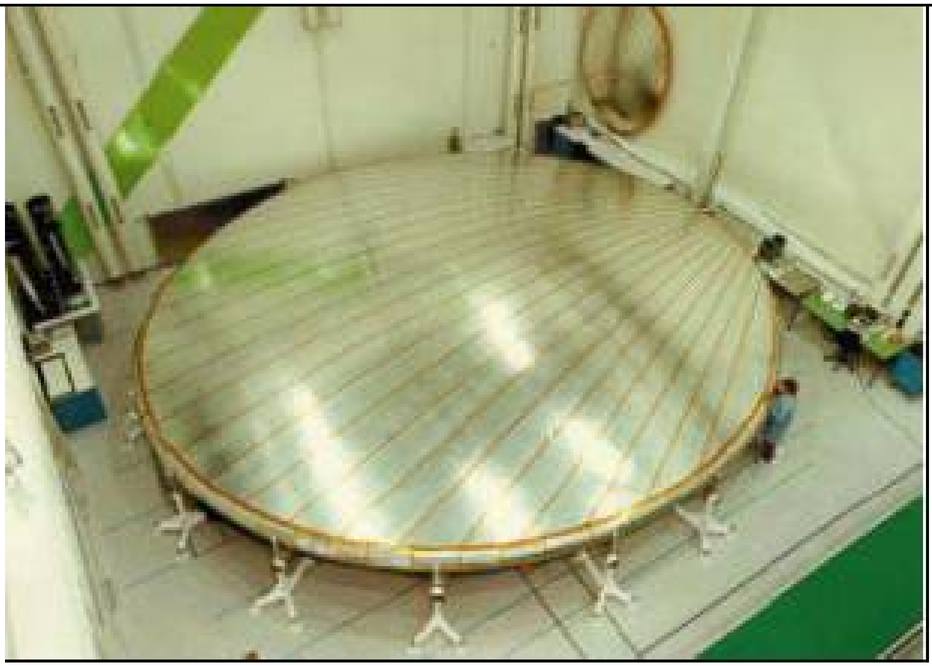
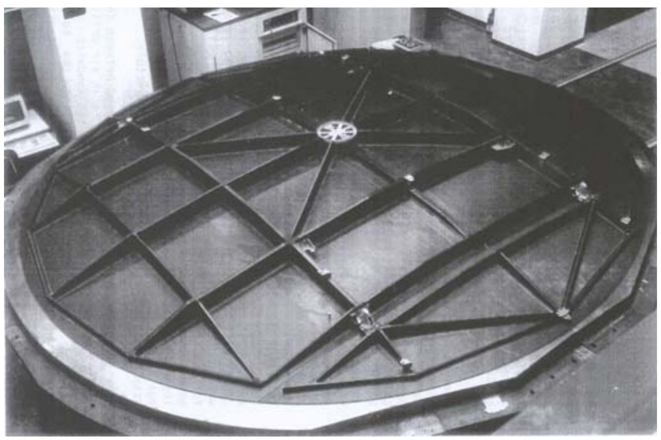
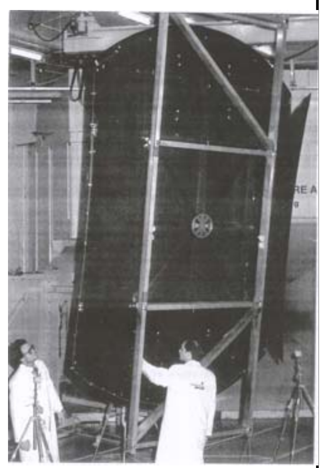
ESA recently supported developments

Background

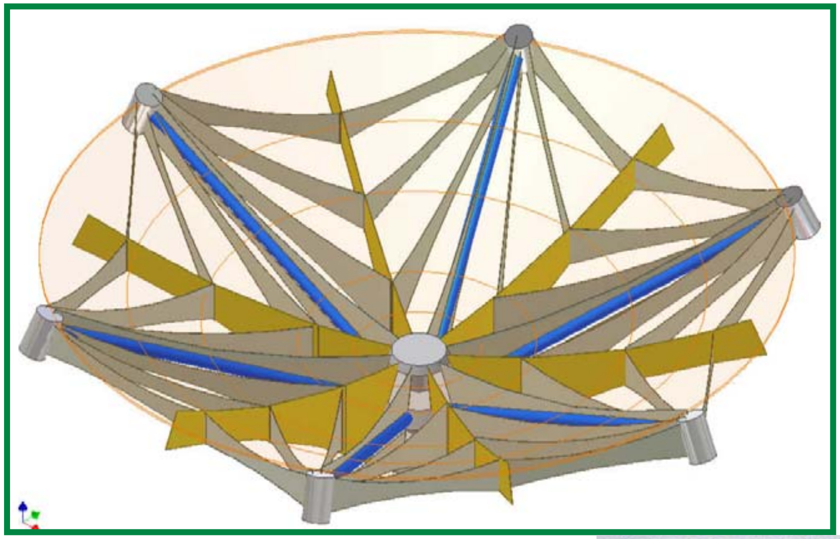
Unfurlable mesh reflector, 5 m, MBB 1986.	Contraves 12 m inflatable antenna
	

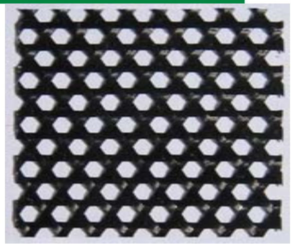
Background

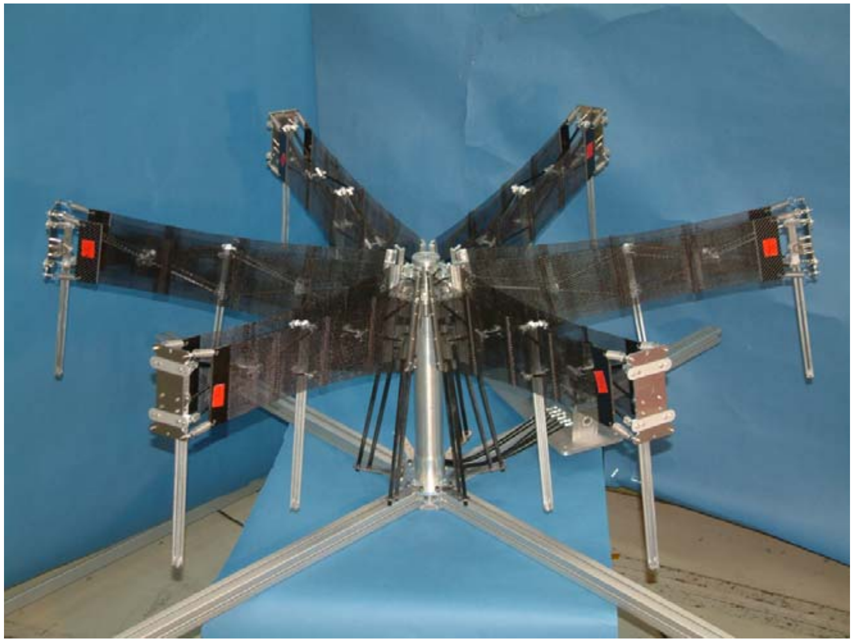
Alenia's 3.7 meter foldable tip antenna reflector	Collapsible Ribs Tensioned Surface (DSL Cambridge University, ESA patent)
 	

Recent Developments

The SMART concept (TAHARA study TRP and Tech. Assess.) and SAFIRS (ITI) demonstrator developed by Technische Universität München- Lehrstuhl für Leichtbau (TUM-LLB) [D]







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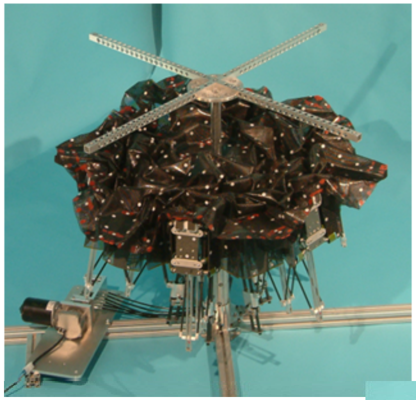

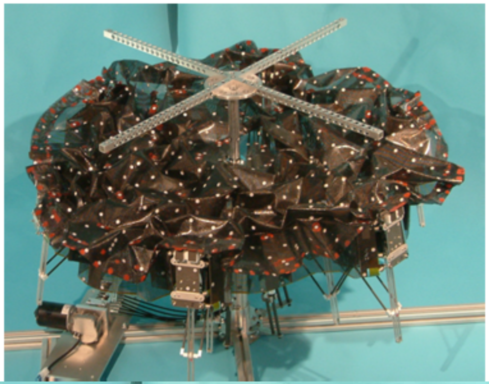

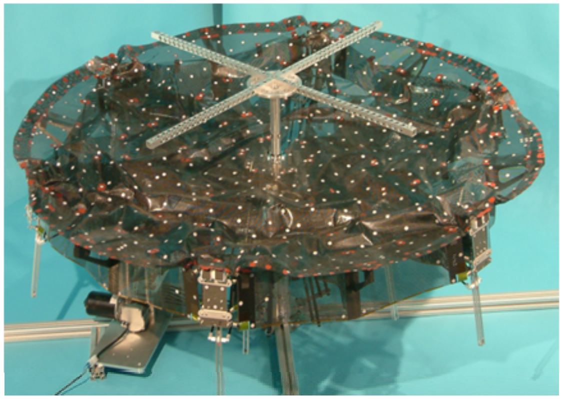

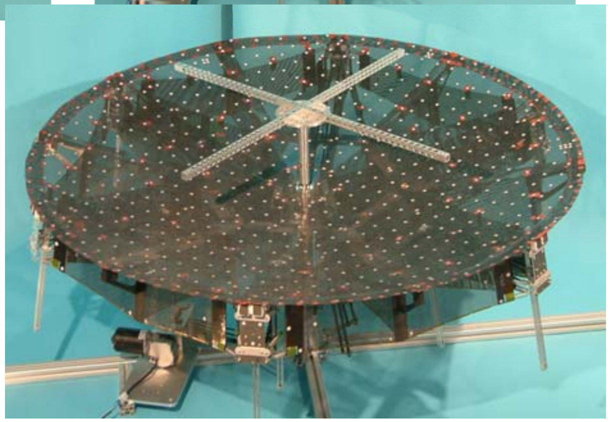

Recent Developments

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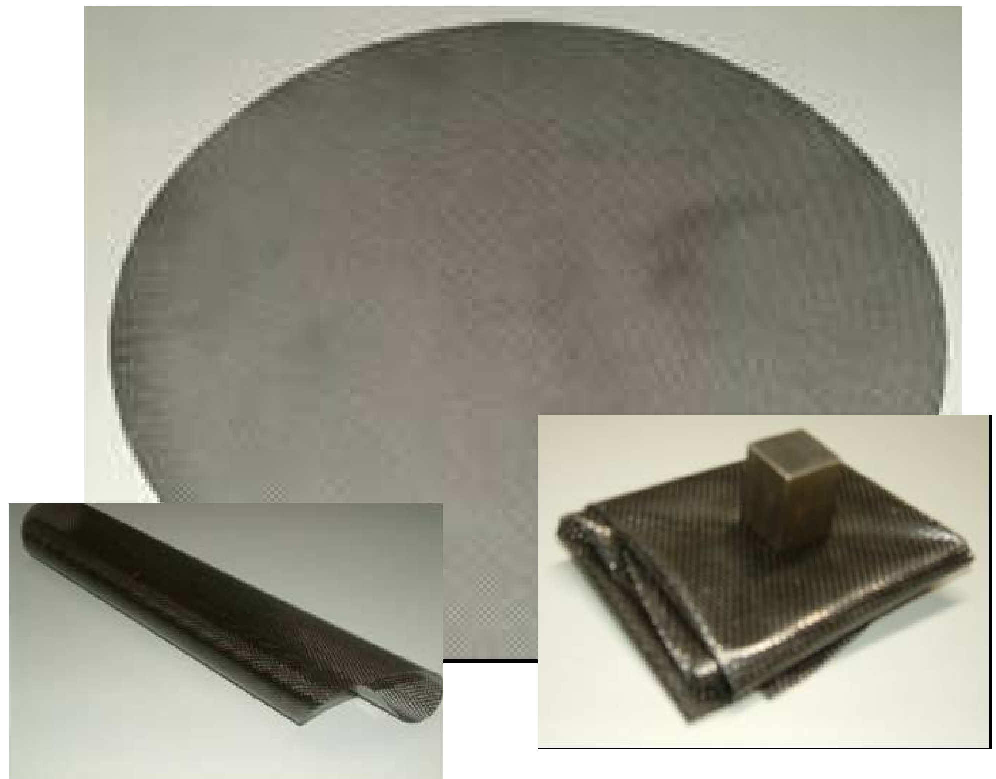
Carbon Fibre Reinforced *Silicone* flexible shell-Membrane made out of Triax carbon fibre fabric reinforced silicone

- **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**



Recent Developments

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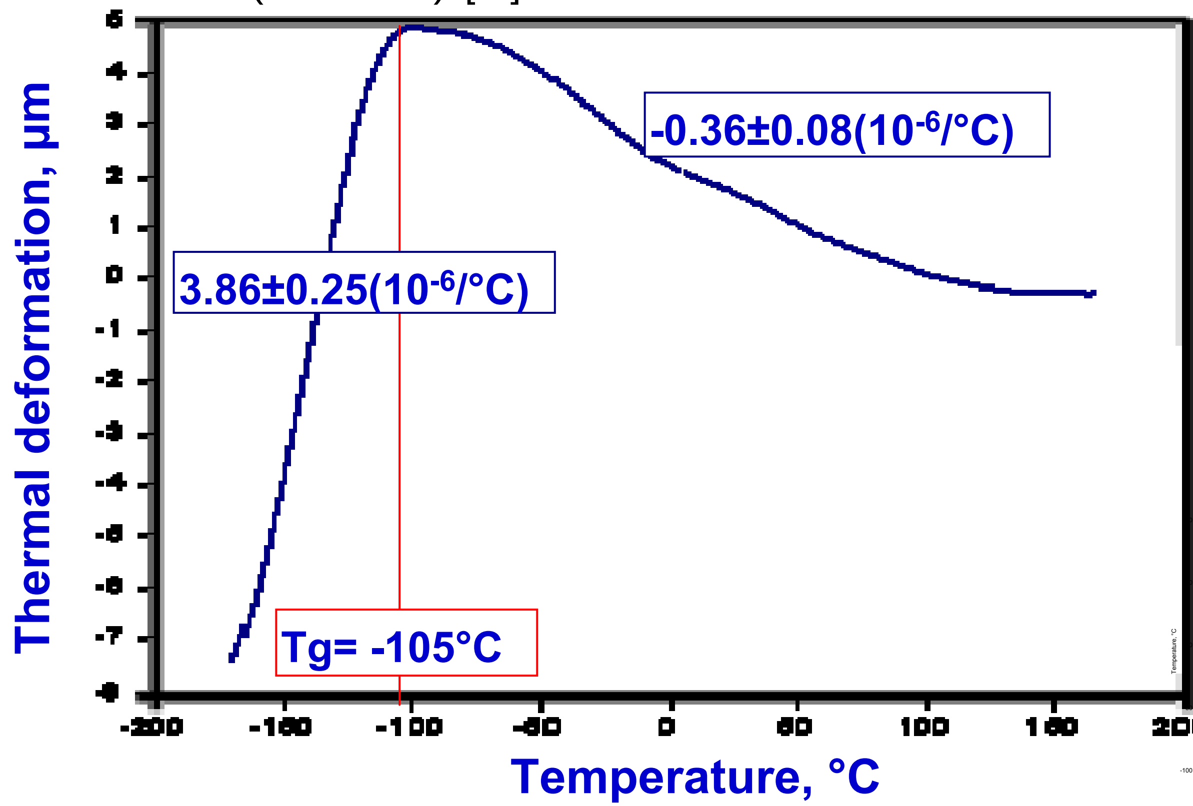
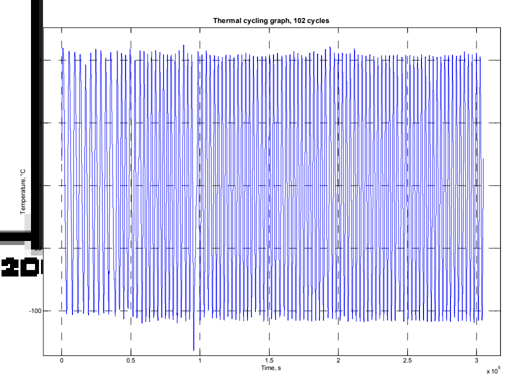


Average of all measurements

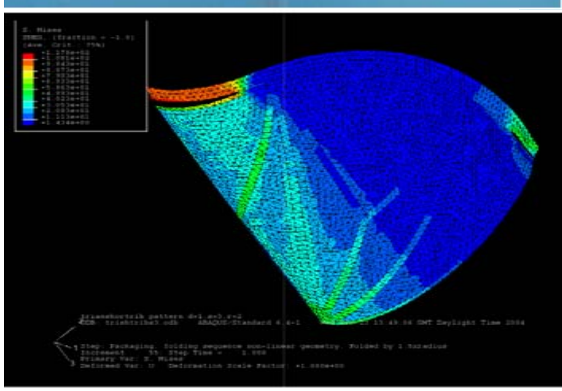
Silicone-free holes in triax

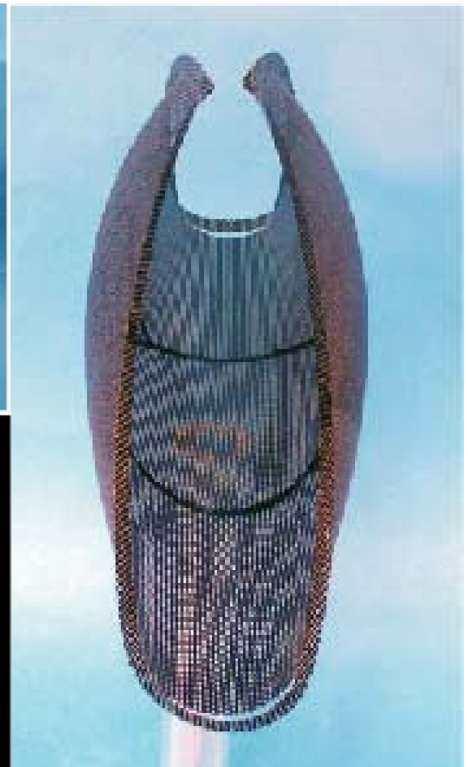


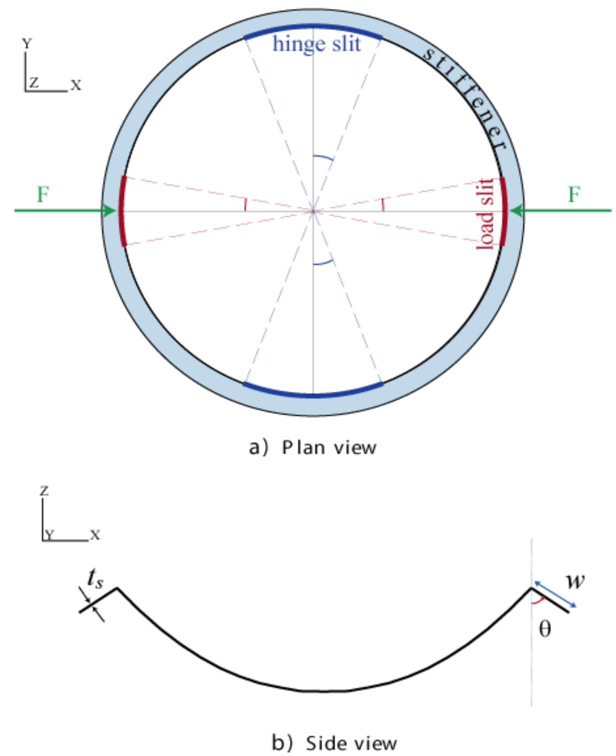
ESA recently supported developments

Recent Developments

TAHARA study: Stiffened Spring-Back Reflector (DSL Cambridge University)

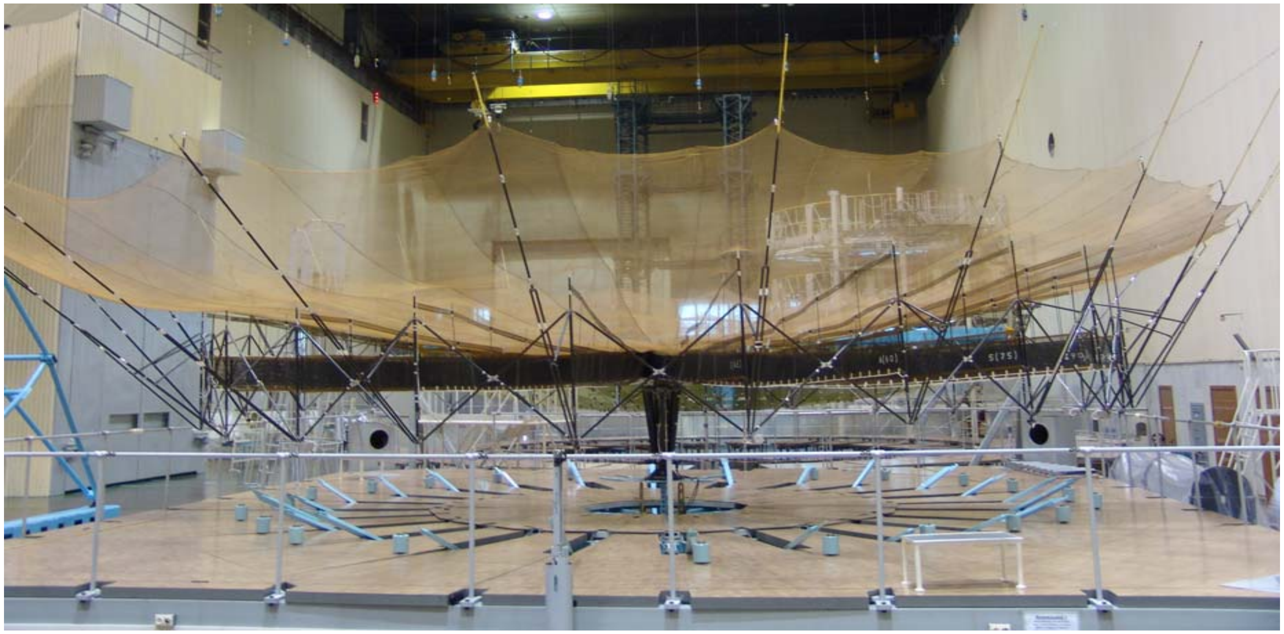






The 12 m LDA Programme

- EQM Reflector developed under ESA Telecom ARTES 5 programme
- Reflector: 12 m diameter, 6.3 m focal length, 3 m offset clearance
- Unfurlable support structure
- Trimming mechanism
- Arm: 4 hinges, 4 limbs, 2 hold-downs



Courtesy of Thales Alenia-Space, NPO EGS and RSC ENERGIA)

ESA recently supported developments

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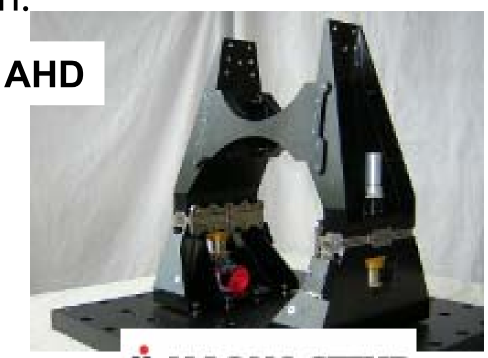
- **THALES ALENIA SPACE ITALIA: Prime Contractor**, System & RF designer of the overall system,
- **NPO EGS (Russia/Georgia): reflector dish (LDR) development**
- **RSC ENERGIA (Russia): LDR manufacturing & testing**
- **SENER (Spain): reflector trimming mechanism** (RTM) development and qualification
- **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.

ThalesAlenia Space
A Thales / Finmeccanica Company

RTM

AHD



MAGNA STEYR
SPACE TECHNOLOGY

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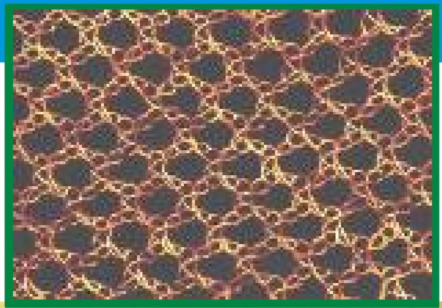
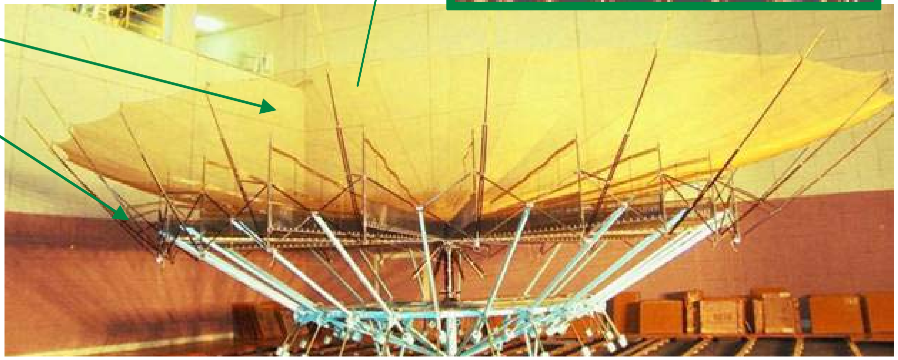
The reflector (LDR) consists of:

- 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

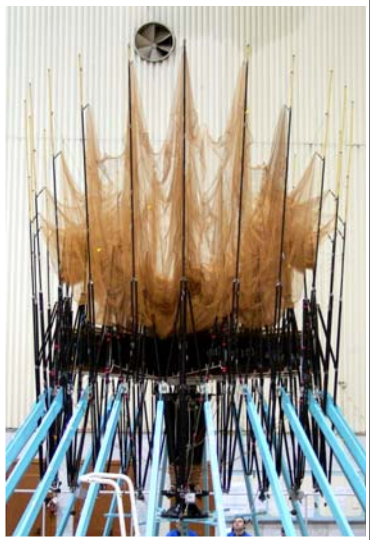




- Radial Ribs connect the central interface to the force ring and provide a solid reference to the mesh profile

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

ESA recently supported developments

LDR stowed	LDR semideployed	LDR fully deployed
		

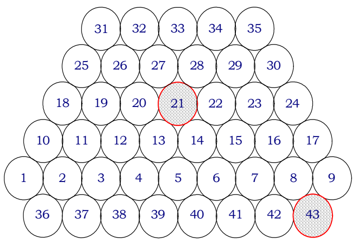
12 m LDA Programme

- 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**

LDR Qualification

ESA recently supported developments

12 m LDA Programme

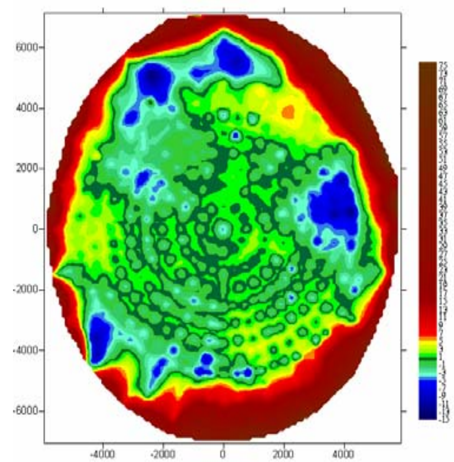


The mesh shape accuracy has been measured with a **laser radar instrument**.

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)

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Large Deployable Antenna way forward

ESA collaborative effort between Application directorates and Technology/ quality Management directorate to establish a way forward for Large Reflector Antennas requiring to be "built-in" space. On-going tasks include:

- Identification of missions/markets benefiting from the development large reflectors.
- Critical review of state of the art and patent situation. Non-dependence status.
- Lesson learnt from previous European developments (technical, programmatic)
- Investigation of enabling technologies with modularity and growth potential.
- Identification of candidate reflector concept(s) to cover the full domain addressed
- Elaboration of a development plan for the selected concepts including identification of required testing techniques and facilities.
- Ways to ensure the availability over time and use of the reflector(s).
- Estimation of ROM cost at completion and identification of possible funding sources for NRE activities.

Presentation of ESA findings expected by May 2010

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