Institute of Lightweight Structures
Aerospace Department
Technische Universität München, Germany

SMART reflectors

Leri Datashvili, Horst Baier

Large Space Apertures Workshop
Keck Institute for Space Studies, Caltech-JPL
Pasadena, CA, USA
10-11 November, 2008

Outline

- LDR groups by reflecting surface - overview
- SMART includes :
  - SAFIRS,
  - FLAME,
  - triax CFRS,
  - triax CFRS/P …
  - Deployments
  - Challenging spin-off
- Conclusions

Classes and Groups of Deployable Reflectors

Reflector size classes:

• Small deployable reflectors (SDR)	up to 4 m
• Medium deployable reflectors (MDR)	4 to 8 m
• Large deployable reflectors (LDR)	8 to 15 m
• Very large deployable reflectors (VLDR)	15 to 25-30m
• Super large deployable reflectors (SLDR)	above 25-30m

a general name – LDR – is still used for all classes

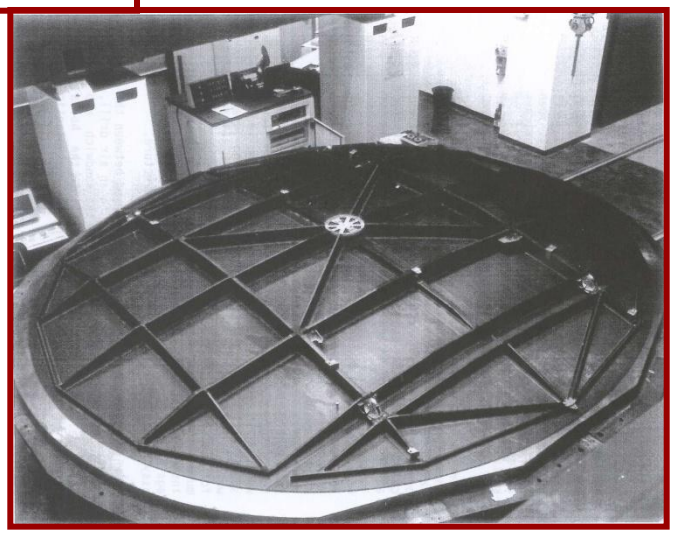
Reflecting surface types:

• Solid surface reflectors	MDR
• Flexible shell reflectors	MDR
• *Flexible shell-membrane reflecting surface*	*SDR - VLDR*
• Metal mesh surface reflectors	MDR - SLDR
• Membrane surface reflectors (infl.)	MDR - SLDR

LDR groups, overview

Solid reflectors

From Astrium



From Alenia

High accuracy, limited in size to medium LDRs due to packaging problems

LDR groups, overview

From Hughes

Flexible shell reflectors

Lower accuracy than for solid surfaces, limited in size to medium LDR due to packaging problems

LDR groups, overview

Medium to very large LDR

Mesh reflectors

From Georgian Institute of Space Constructions

From Astroaerospace

Lower accuracy than for shell/solid surfaces, due to pillowing effect

LDR groups, overview

- Medium to very large LDR
- Stowability similar to metal meshes
- Accuracy close to flexible shells/solids

NEW: Double curved flexible shell-membrane reflectors

SMART, Scaled Lab models from TU Muenchen

What is SMART ?

Shell Membrane Antenna Reflector Technology:

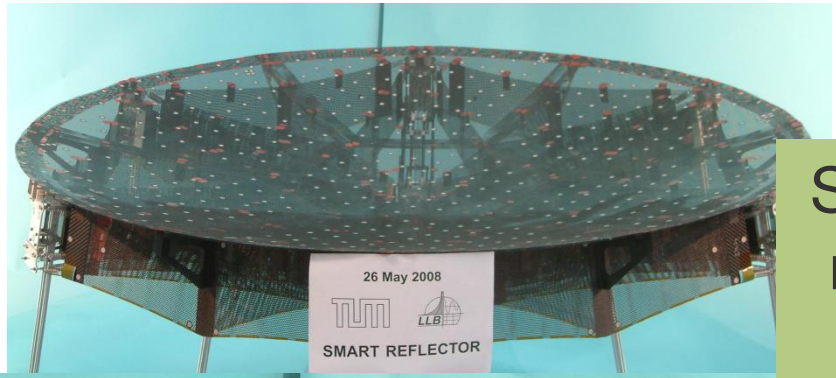
- LDRs
  - SAFIRS – structurally adaptive fiber reinforced surfaces
  - FLAME – flexible antenna membrane experiment
- Materials with carbon fiber reinforced silicone (CFRS):
  - Double curved tension-free reflecting surface
  - Tensioned rib-membrane CFRS/P
- Enabling technologies
  - Shaping,
  - shape-control
  - Reconfiguration …
- All – to achieve high (Ku, Ka) RF

Design goals and concept capabilities

- Reflector aperture > 4m up to very large diameters (25 m)
- Circular / elliptical apertures
- Symmetric / offset configuration
- Shape accuracy 0.5 mm RMS and better
- Mass - << 1.2 kg/m^2
- Service Temperature range -165°C to +165°C and even wider

SMART/SAFIRS reflector – *"From Imagination To Reality"*

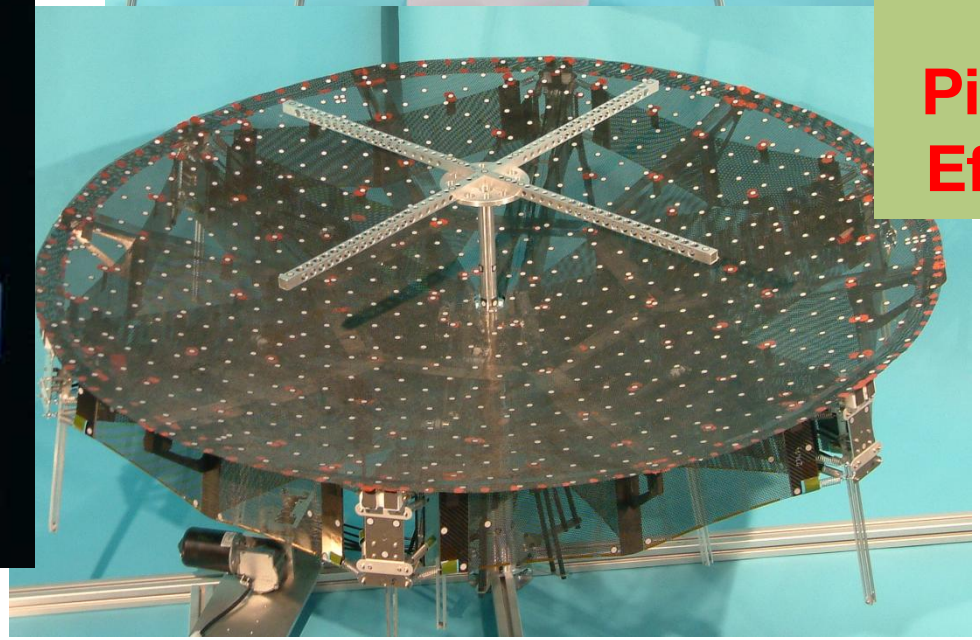
CAD model



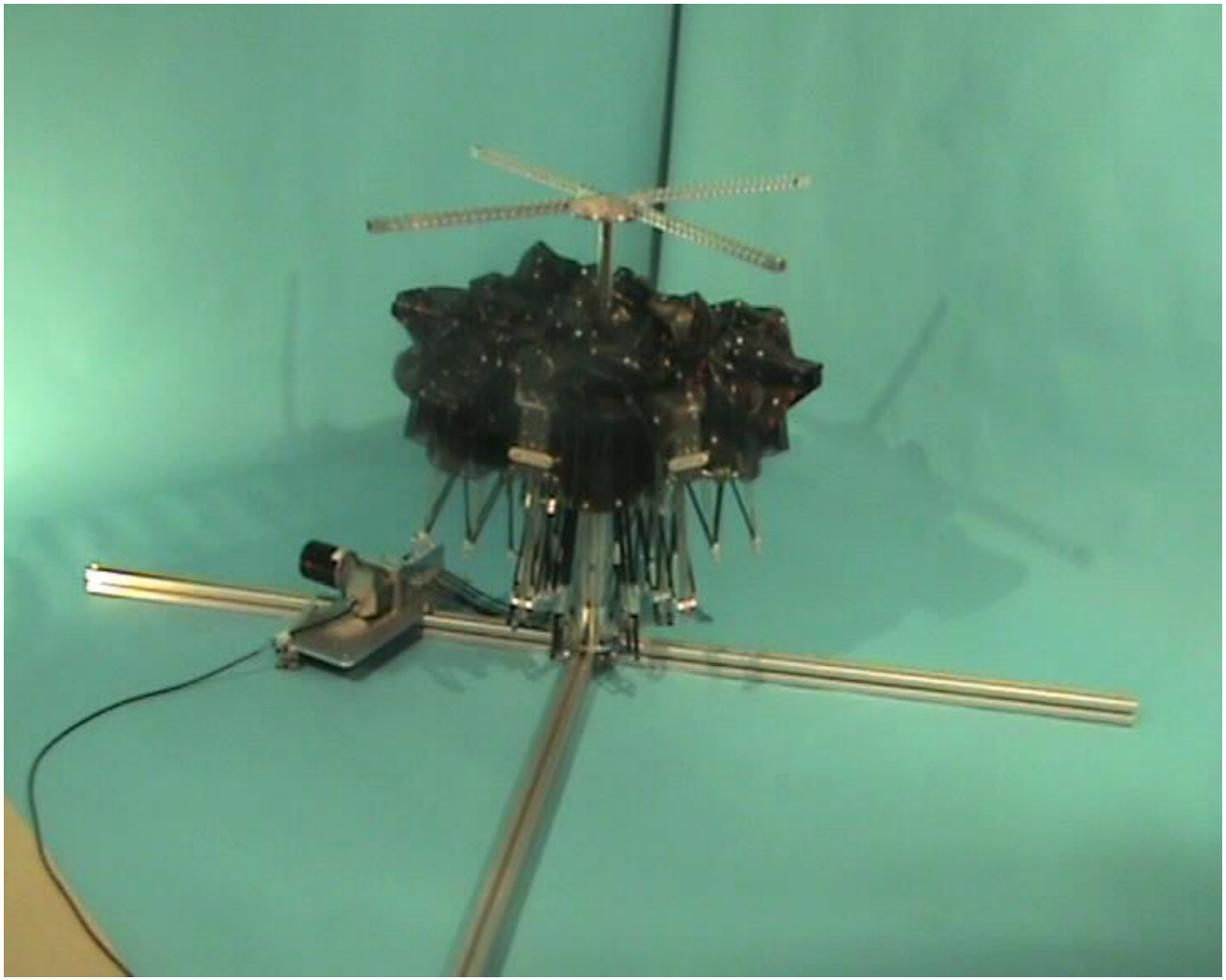
Scaled model

No Pillow Effect

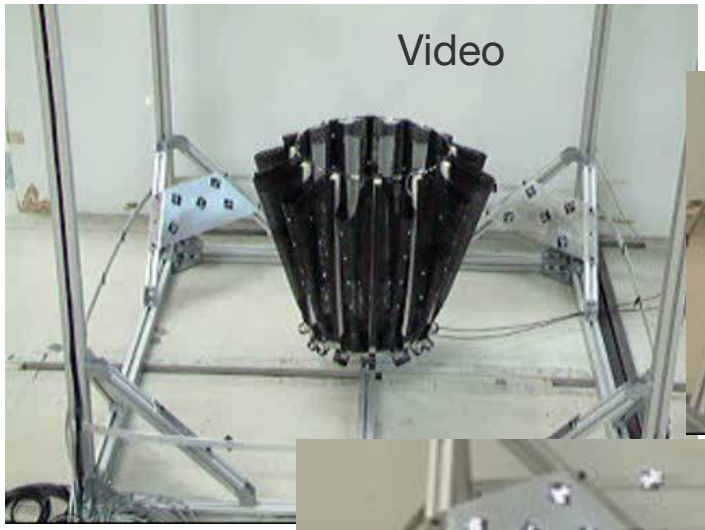
MAPSAR (CAD +)



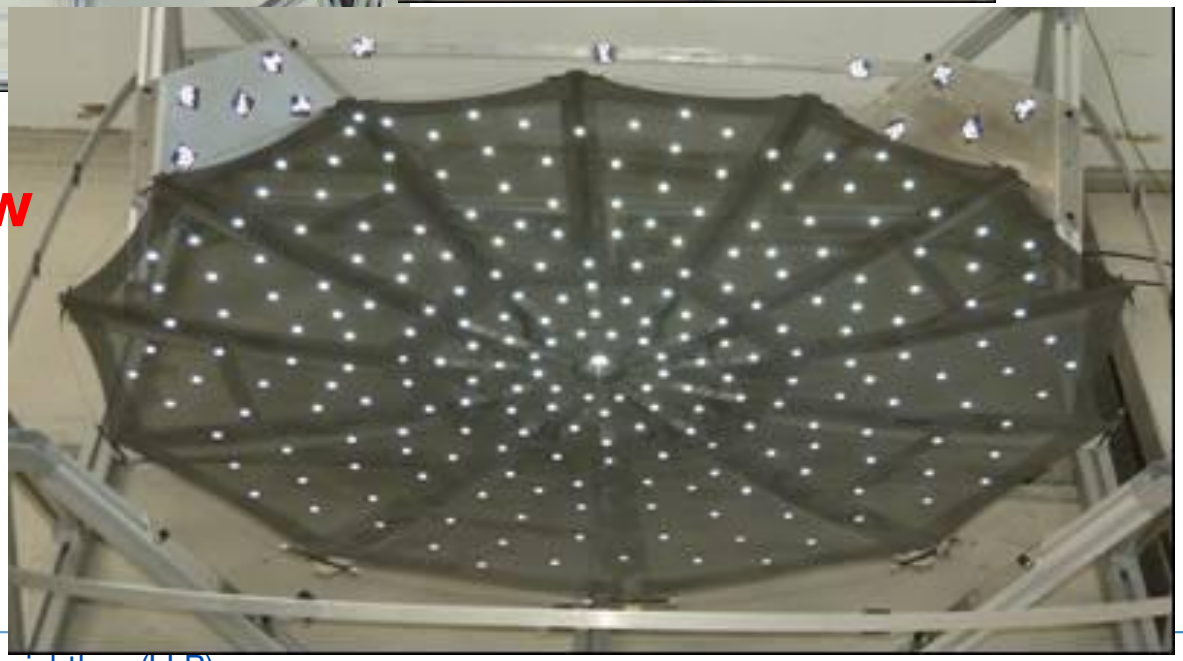
Deployment of the SMART / SAFIRS



Deployment of the SMART / FLAME



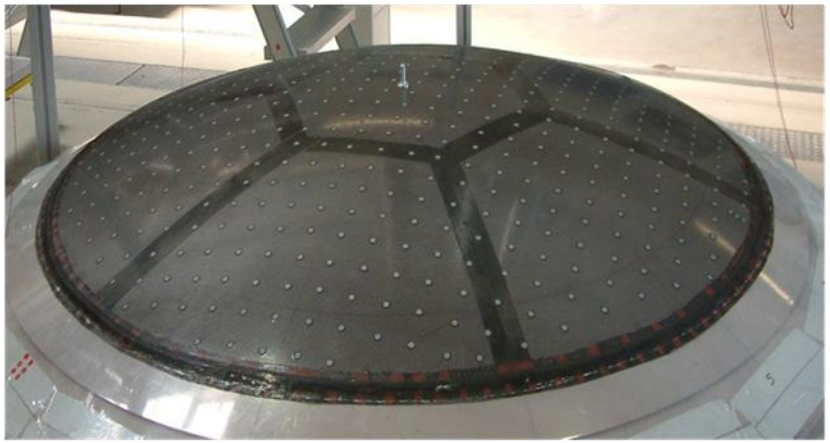
triax CFRS with umbrella type support structure

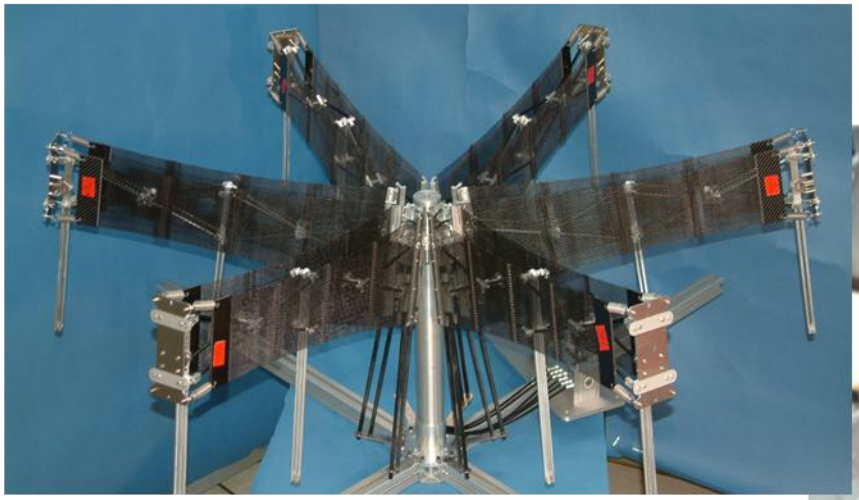


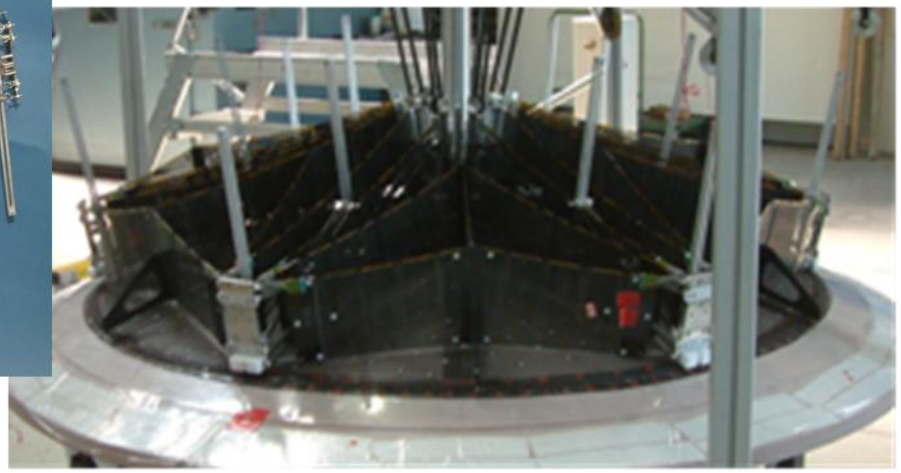
No Pillow Effect

C-band 6 to 8 m deployable reflector under considerations

Manufacturing and assembling procedure of SMART







Deployment, repeatability !!!

Gravity compensation !!!

New flexible shell-membrane composite material

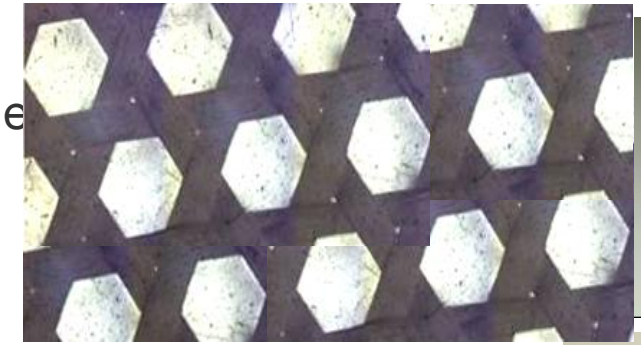
- For reflecting surfaces
- For tensioned membrane structures

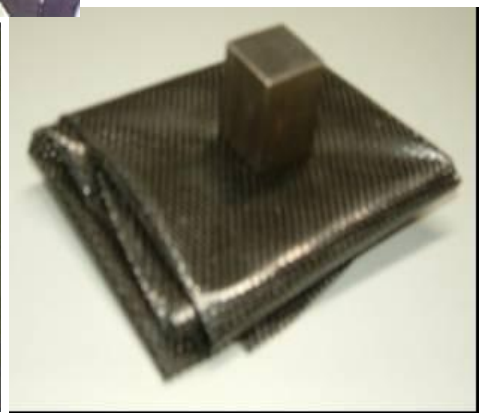
made of
triaxially woven carbon fibre fabric reinforced silicone

Triax (TWF) CFRS

Triax CFRS Flexible Shell-Membrane

- CFRS flexible shell-Membrane made out of **Triax carbon fibre fabric reinforced silicone**
  - Low outgassing
  - Wide range of service temperature (-180°C to +200°C and more)
  - RT cure
  - Low shrinkage at cure
  - Flexible above -100°C
  - Low and q/isotropic CTE
  - Sufficient bending stiffness
  - Double parabolic curvature
  - No prestress needed
  - No micro-cracks (thermal cycling)



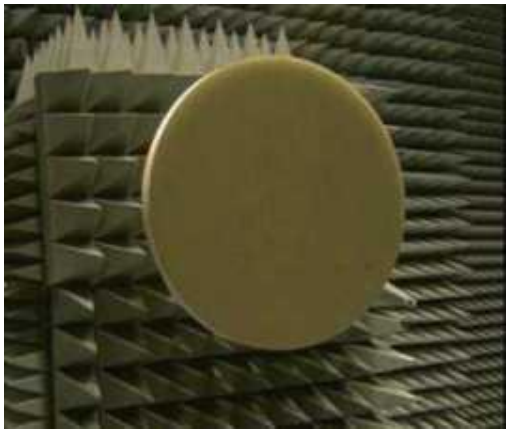


- No systematic errors like pillow effect due to bending stiffness (double curvature)
- Flexible enough for free type of stowing
- Elastically returns to stress free mould shape in Zero-Gravity
- Low mass (140g/m²)
- Materials space qualified

Flexible Shell Membrane Technology – sample and component testing

RF tests:
Up to
12GHz is ok

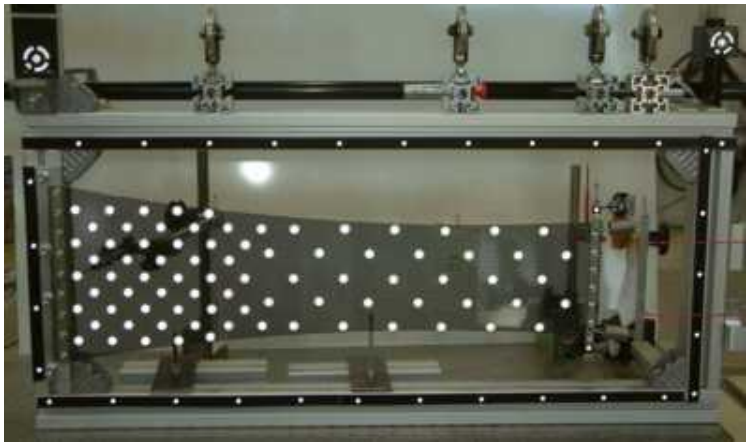
PIM is ok



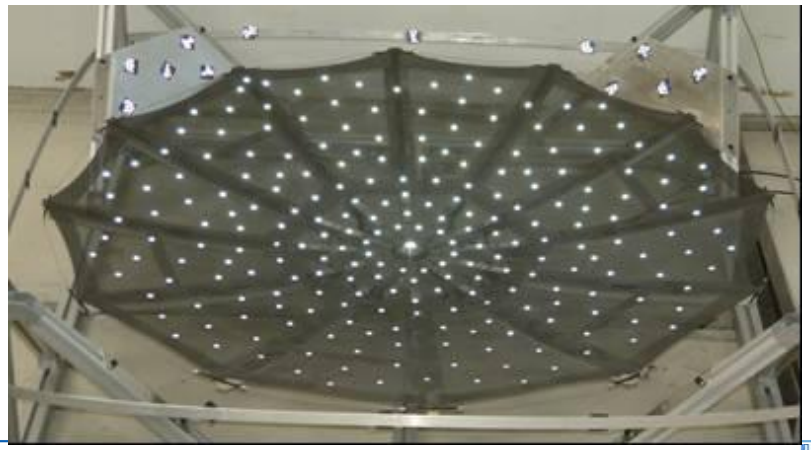
CTE measurement
- 0.36*10^{-6} /K
for -105°C to +200°C

Specimen

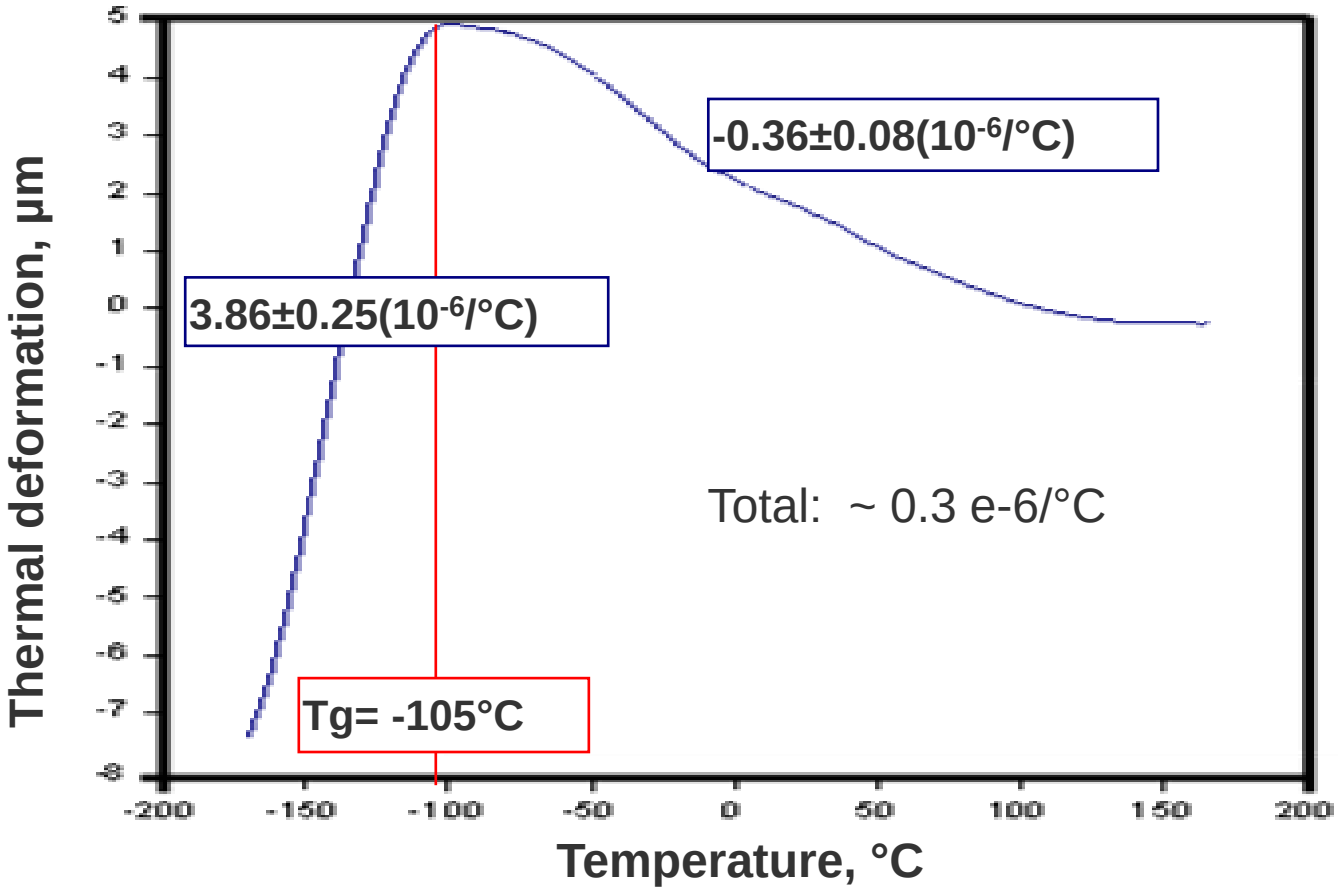
Triax CFRS/P Membrane rib testing



Shape measurements during manufacturing, in 1g and 0g



CTE of the triax CFRS



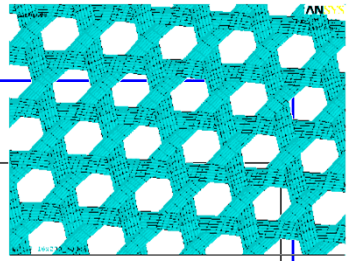
Average of all measurements

Silicone-free holes in triax

Quasi-Isotropic for thermal loads

Triax CFRS and CFRP mechanical analyses and tests

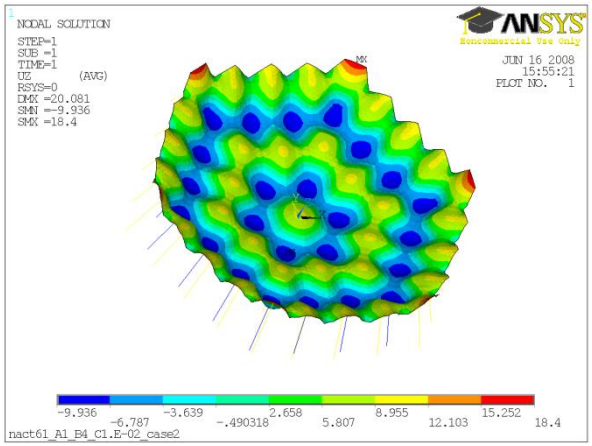
FEM: simple beam model



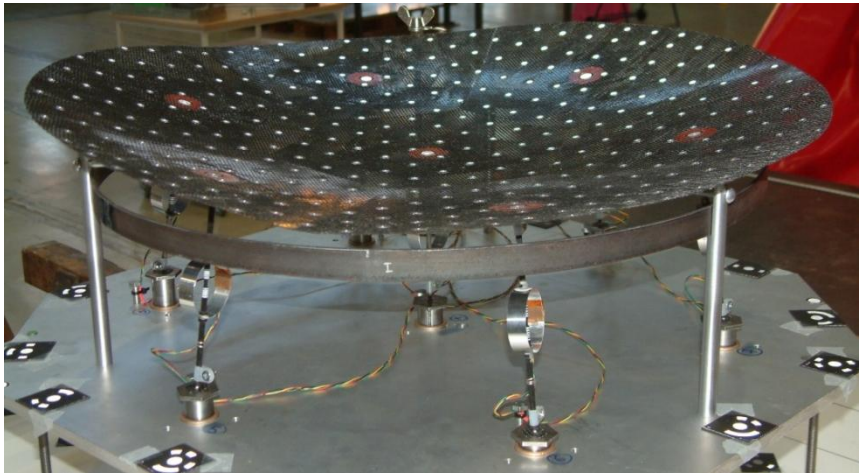
w/L=1/2, constant

Challenging Spin-off

- **Reconfiguration of surfaces based on high flexibility of the triax CFRS**



FEM simulation of
Reflector reconfiguration



Reflector lab model with
a reconfigured shape

Conclusions

- Shell Membrane Antenna Reflector Technology (SMART) is being developed
  - **CFRS reflecting surface has been created and characterized for space conditions. It can be used up to at least 15GHz with already selected and investigated materials**
  - **A hybrid triax CFRS/P composite material for tensed membranes has been created**
  - **Two reflector scaled models (SAFIRS and FLAME) based on CFRS RS have been built and tested for accuracy and deployment in laboratory and 0g conditions**
  - **Manufacturing technology has been improved and several important design updates have been made.**
- Theoretical and experimental investigations proved:
  - **SMART / SAFIRS reflector can be applied successfully for up to X-band RF in space,**
  - **SMART / FLAME can be applied even for higher frequencies.**

Acknowledgements

- This work has been supported by ESA / ESTEC under supervision of **Dr. Cyril Mangenot** and **Dr. Julian Santiago-Prowald**.

- Support of LLB staff is gratefully acknowledged.

Thank you very much for the attention