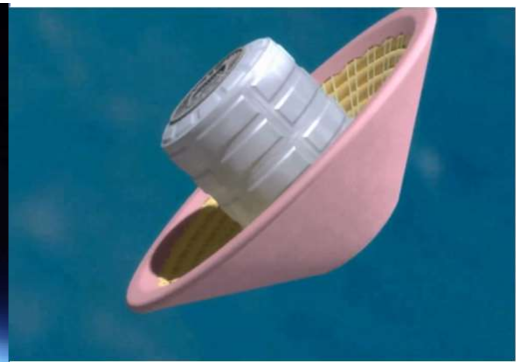
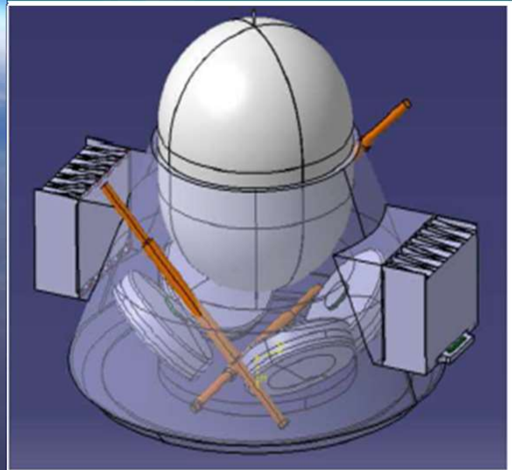
CSID 2021 : 22/09/2021

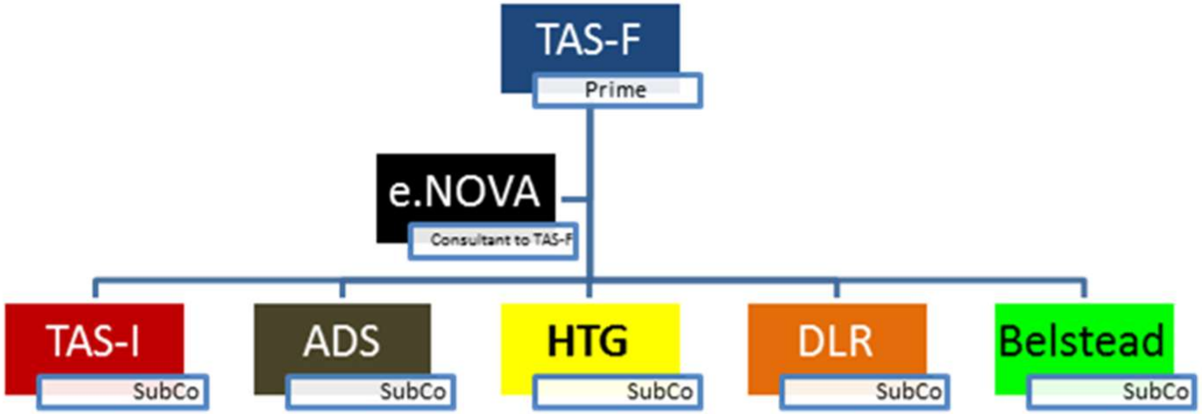
D4C: Design for Containment

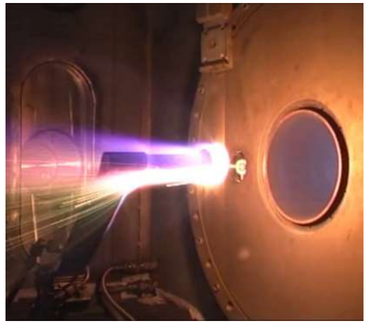
WP1000 : State of the Art - Technological concepts

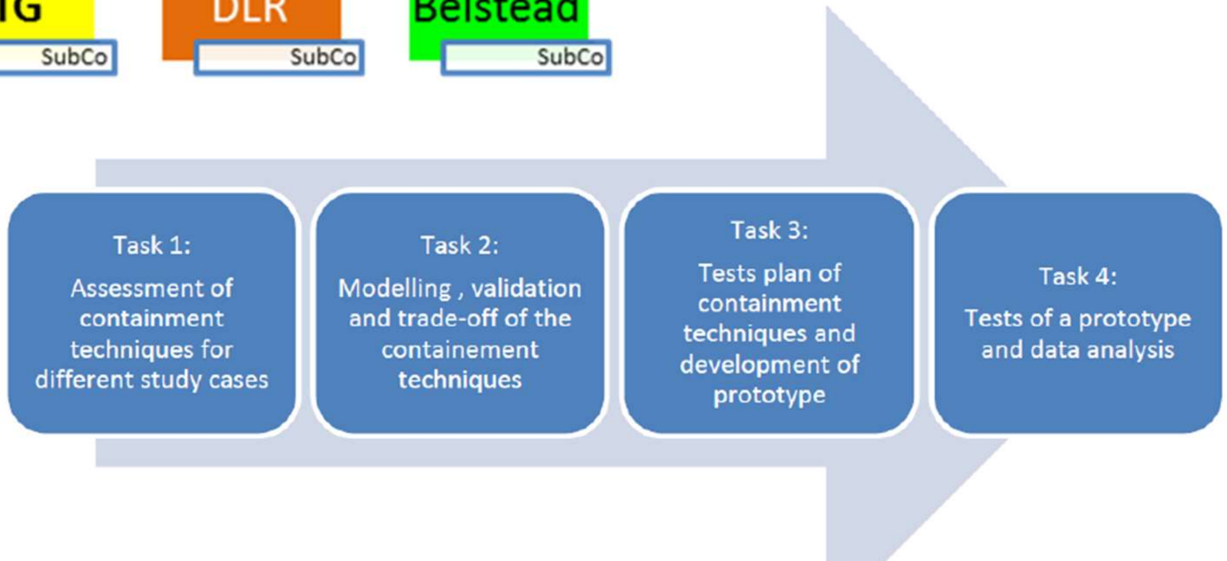




AO10323:
Containment Techniques to Reduce Spacecraft Re-Entry Footprint







__APPROACH__ **:**
DIVE (Method & Approach)
DRAMA (Analysis S/W)
ESTIMATE (Materials Database)

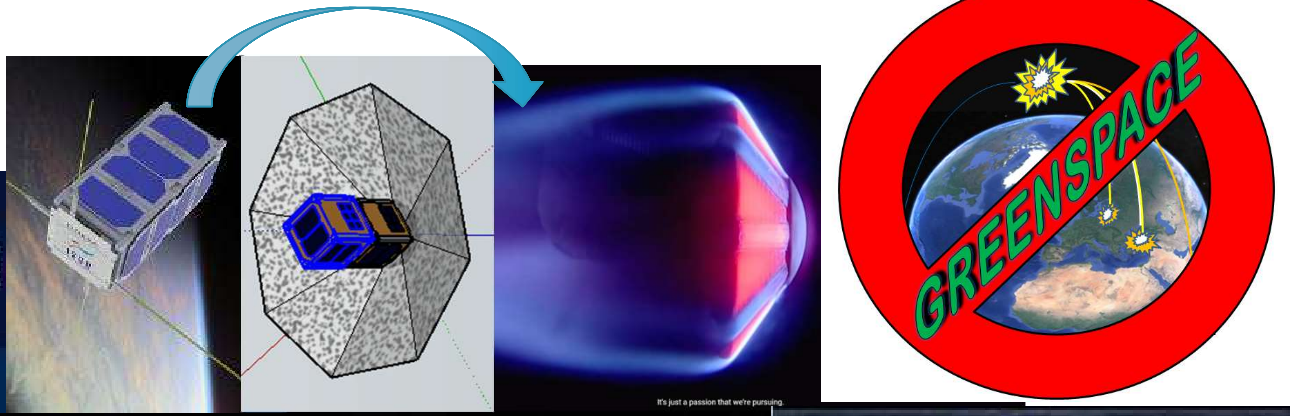
Methods to contain critical elements shall be investigated, assessed, traded-off and a prototype of the containment method(s) will be developed and tested.

e.NOVA :

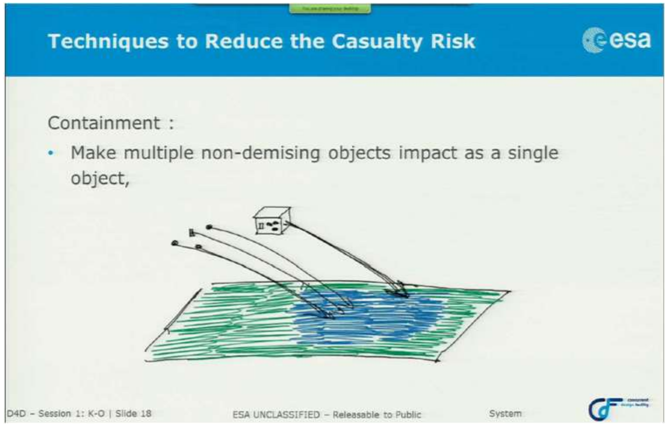
“Let’s Fly your Experiment, your Idea with our knowledge of the **NEWSPACE industry** “

GREENSPACE & NEWSPACE Topics

NO NEWSPACE without GREENSPACE



D4C " Design for Containment"
Task 1



STATUS : **Litterature (Previous Activities)**

Initial ESA CDF **Micra D4D** Webcast (2014)

APPROACH & SOLUTION :

D4D S/C TAS activity (2014-2016) => **RWA & Tank**

D4D S/C Airbus activity (2014-2016)) => **S2 MSI optical bench**

ALTRAN BB proposal : **Demise / Survive Block** (2015) => (Not selected)

D4D S/C OHB Activity => **Containment tether (2017**) => presented ESOC (2017)

D4D OP/L (TAS) : **Carbonsat**

D4D OP/L (Belstead/FGS) :

SECRET activity (Beck, Schleutker, Caiazzo, & Soares, 2019):

OUTCOMES & RESULTS :

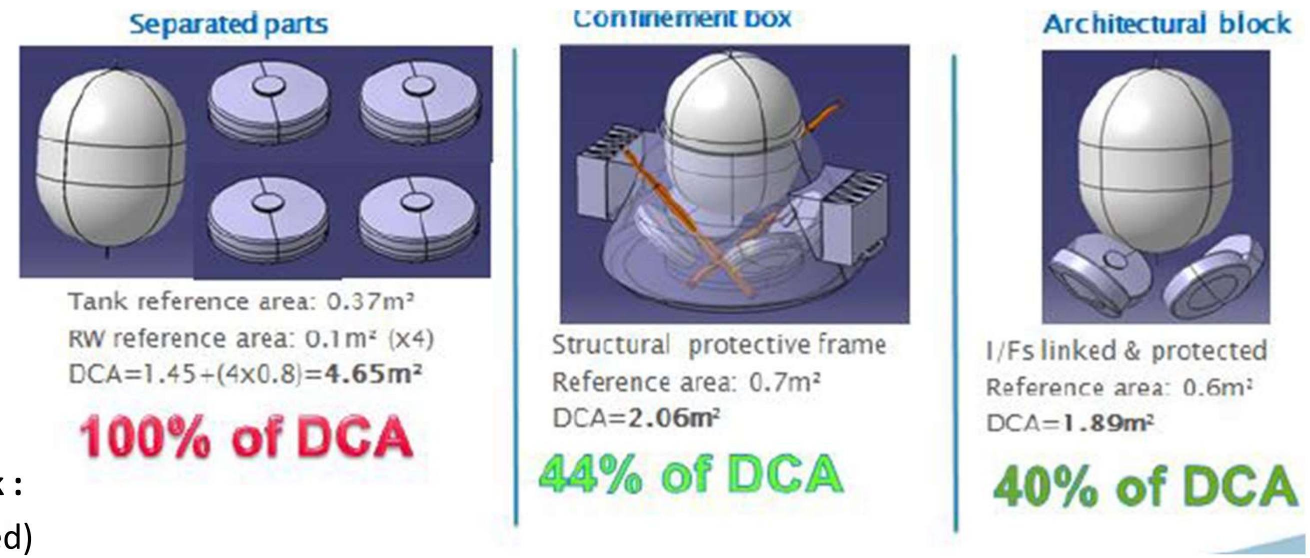
RD [1] N. Eggen, T. Soares, L. Innocenti: Containment methods for the atmospheric re-entry of satellites, First International Orbital Debris Conference (2019).
Link at: https://www.researchgate.net/publication/337898815_Containment_methods_for_the_atmospheric_reentry_of_satellites

RD [2] D. Riley, I. Pontijas Fuentes, J. Meyer, G. Proffe, T. Lips: Design for Demise: Systems-level techniques to reduce re-entry casualty risk, 7th European Conference on Space Debris (2017).
Link at: https://www.researchgate.net/publication/293824337_DESIGN_FOR_DEMISE_TECHNIQUES_TO_REDUCE_RE-ENTRY_CASUALTY_RISK

RD [3] J. Beck, I. Holbrough, J. Merrifield, S. Bainbridge, P. Doel: Demisability of Optical Payloads, ESA Clean Space Industrial Days (2017). Link at:
https://indico.esa.int/event/181/contributions/1420/attachments/1329/1554/2017_CSID_Beck_BRL_DemisabilityOfOpticalPayloads.pdf

RD [4] European Space Agency, ESA DIVE - DIVE - Design for Demise Verification Guidelines for Analysing and Testing the Demise of Man Made Space Objects During Re-entry, Issue 1 Revision 0, 2019.

D4C " Design for Containment"
Task 1



STATUS :

ALTRAN activities (2012-2018)

-> e.NOVA Aerospace (2019-)

APPROACH & SOLUTION :

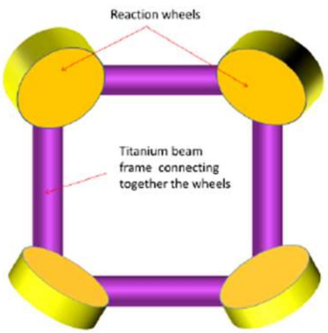
CLEANSAT Technological Building Block :

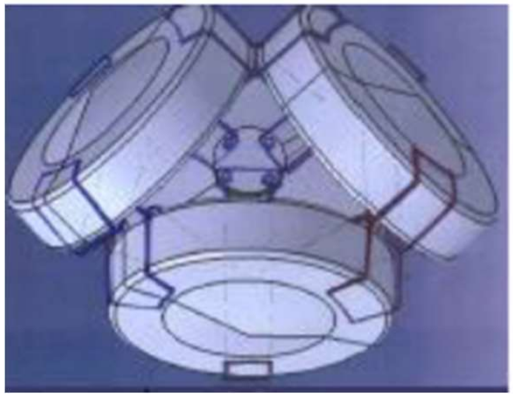
DEMISE/SURVIVE BLOCK (Not Selected)

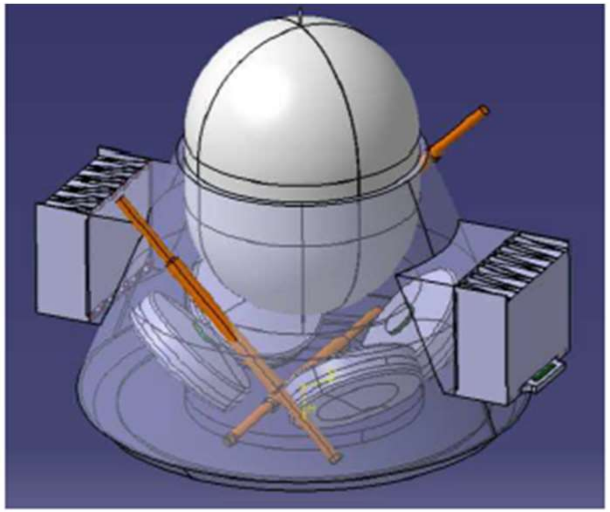
Reaction Wheels DEMISE: (ALTRAN BB11)

OUTCOMES & RESULTS :

DCA potentially reduced **up to >50%** **(TBC)**





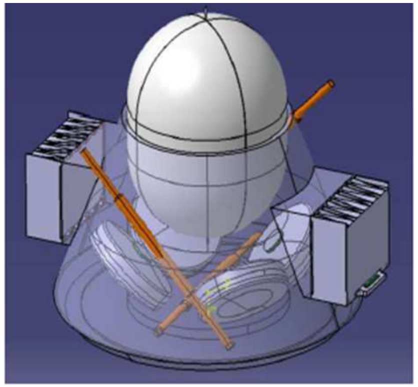


ThalesAlenia Space
a Thales / Leonardo company

e.NOVA

D4C " Design for Containment“
Task 1

Carbon-carbon impact



STATUS :

ALTRAN Research activities (2012-2018)

-> **e.NOVA Aerospace** (2019-)

The **central cone** of the Sentinel 3 satellite FEM were replaced by a **3.1mm NB41** carbon-carbon sheet with mechanical properties :
E = **200 GPa** . / Density = **1970 kg/m3** / Yield limit = **169 MPa**
Mass = same as original CFRP panels

APPROACH & SOLUTION :

Containement Box :

SVM Central Cone made out **C/C**

SYSTEM Impact Analysis /

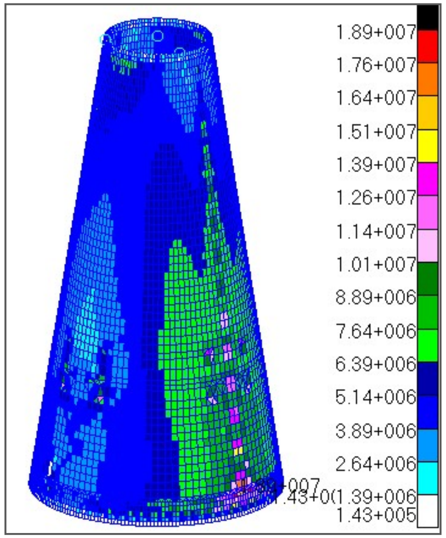
(S3 Analysis made @ iso-resistance S3 analysis)

OUTCOMES & RESULTS :

+1.0 Hz Lateral Modes
+ 1.5 Hz Axial Mode
Negligible Impact
on Modal Analysis
But More Stiffness

Displacements under 1g

		1gY	1gZ
Disp X – HComb	**1.13 µm**	1.34 µm	7.96 µm
Disp Y - HComb	-250.98 µm	**14.71 µm**	24.63 µm
Disp Z - HComb	-13.36 µm	-245.70 µm	**1.51 µm**
Disp X - C/C	**1.70 µm**	1.26 µm	6.88 µm
Disp Y - C/C	-190.30 µm	**11.1 µm**	25.17 µm
Disp Z - C/C	-10.16 µm	-183.42 µm	**1.41 µm**



D4C " Design for Containment"
Task 1

STATUS :

Reentry

Systems

APPROACH

TPS Evolutions

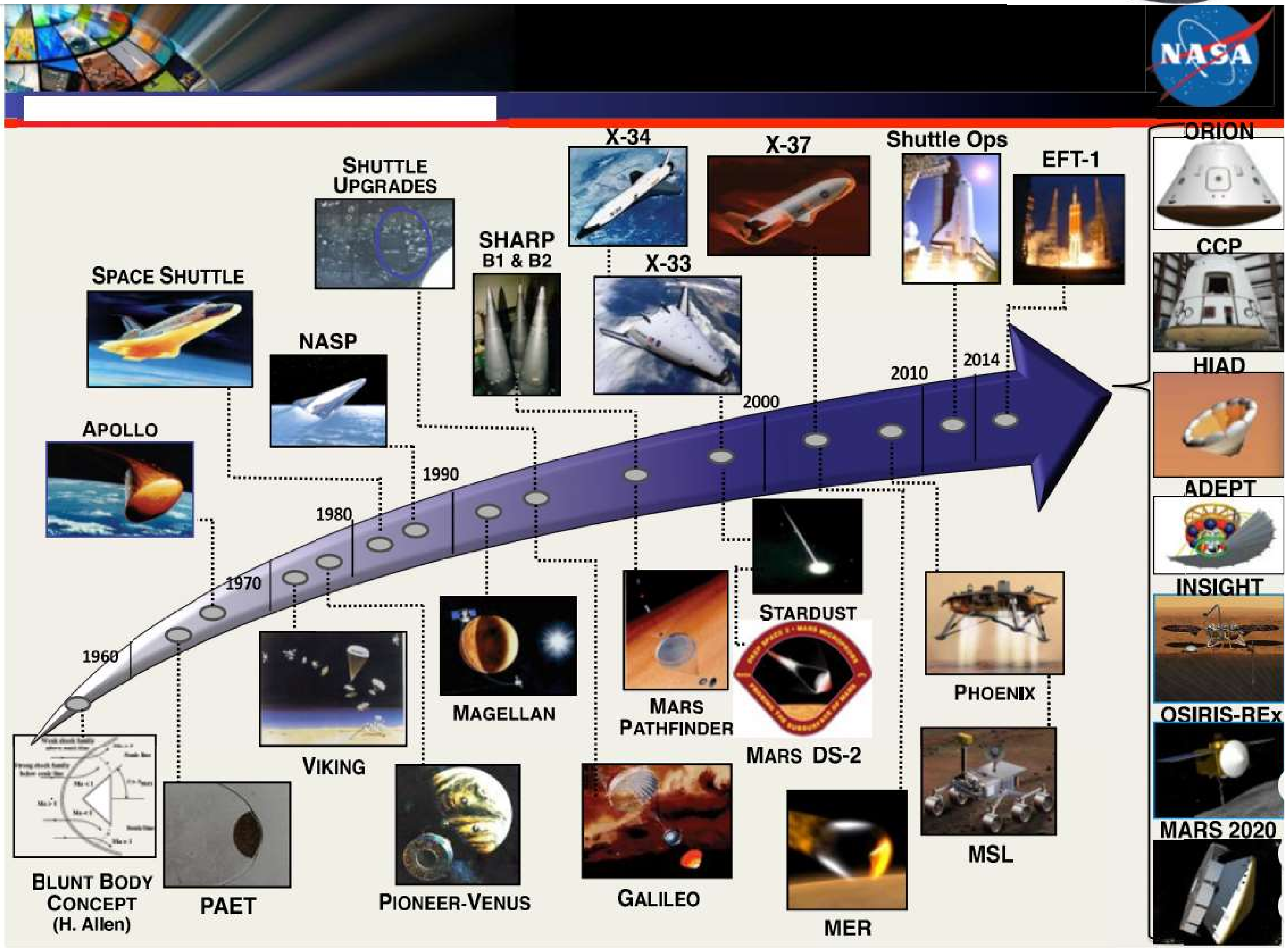
OUTCOMES

Ablative

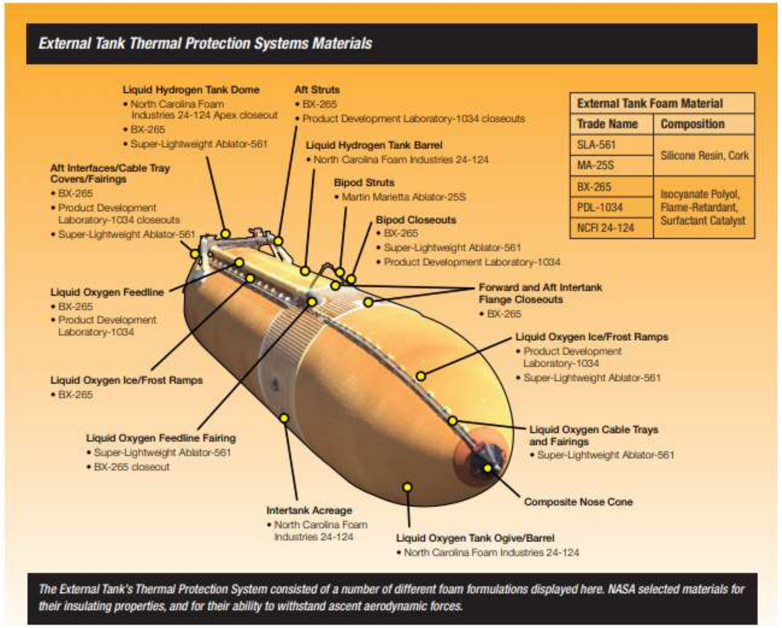
Reusable

-> Deployable

-> Inflatable



D4C " Design for Containment"
Task 1



STATUS : **TPS State of the Art**

APPROACH & SOLUTION :

Ablative Materials

Aerogels

OUTCOMES & RESULTS :

NASA Legacy

Avcoat

PICA

Foams

EU - H2020

ASTERM

PROSIAL

NORCOAT…

aspen aerogels®

DATA SHEET

Pyrogel® 2250

FLEXIBLE INSULATION FOR HIGH TEMPERATURES

Pyrogel® 2250 is a flexible aerogel nanoporous insulation blanket designed for high-temperature applications including transportation, power generation, thermal and fire protection, and tube bundles and small diameter tubing.

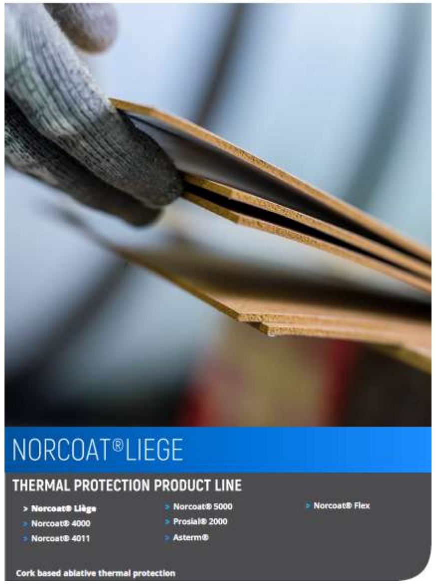
Using patented nanotechnology, Pyrogel® 2250 combines a silica aerogel with reinforcing fibers to deliver very low thermal conductivity, high temperature resistance, and good flexibility in an environmentally safe product.

Pyrogel® 2250 provides excellent thermal performance up to 392°F (200°C), while offering many advantages including low dusting, high tensile strength, high compressive strength, and hydrophobicity.

Physical Properties

Thickness*	0.08 in (2 mm)
Max. Use Temp.	392°F (200°C)
Color	Black
Density*	10.7 lb/ft³ (0.17 g/cc)
Hydrophobic	Yes
Material Form*	57 in (1,448 mm) wide x 450 ft (137 m) long rolls
Chloride content	Less than 35 ppm when tested using ASTM C871
Tensile Strength (stress at maximum load, typical value)	317 psi per modified ASTM D5034, single layer specimen at 1 in width

* Nominal Values



D4C " Design for Containment"
Task 1

STATUS :

TAS Group Experience

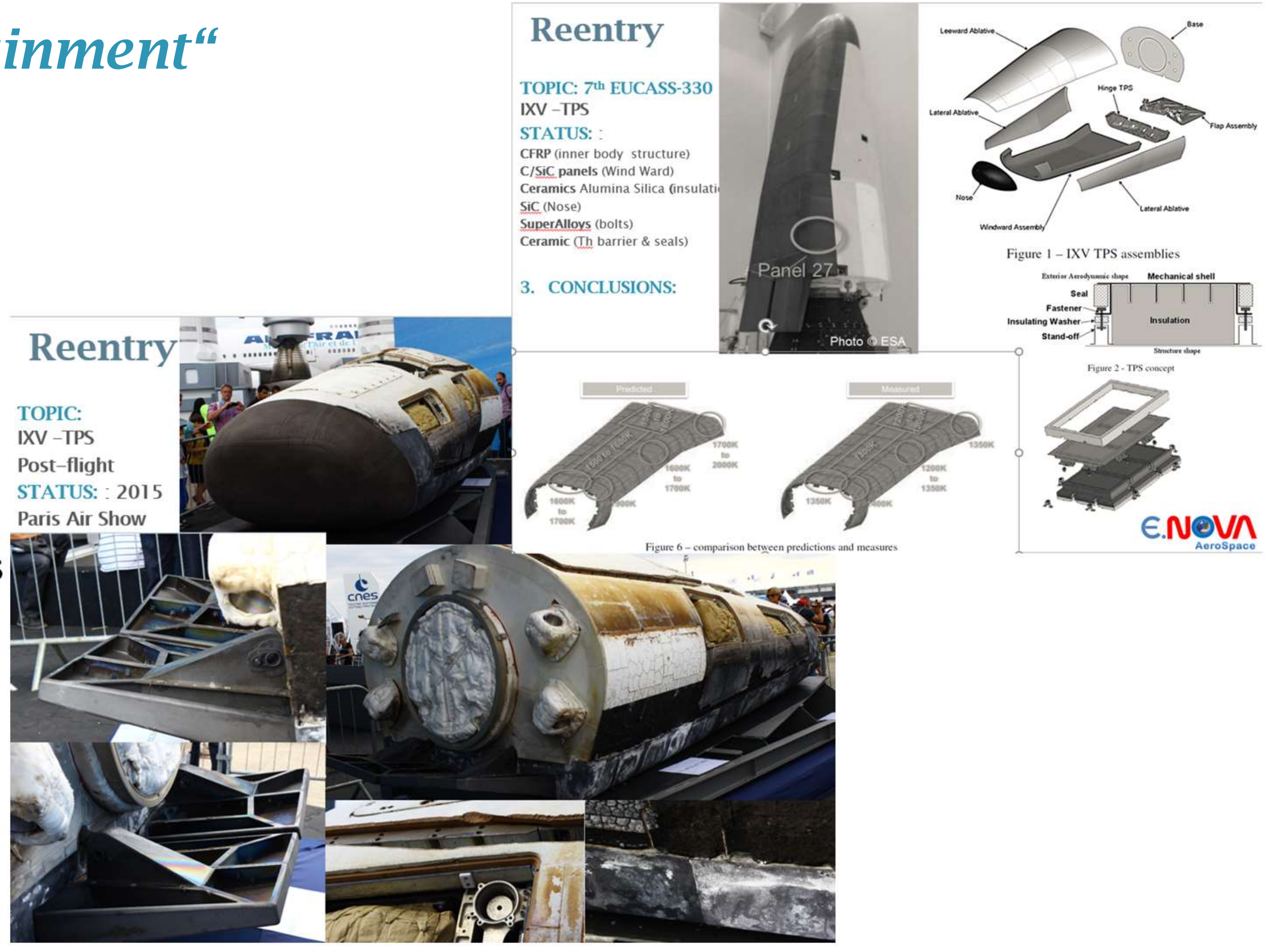
Optical Instruments

Stable Structures

APPROACH & SOLUTION :

Reentry Body Techniques & Technos

Reusable TPS : C/C, SiC etc…



OUTCOMES & RESULTS :

Expert , IXV Legacy -> Space Rider

IXV

ESA, prime Thales Alenia Space, launched 11.02.2015, successfully recovered

EXPERT

ESA, prime Thales Alenia space, spacecraft * completed in 2013, launch on hold

Figure 1-8 TAS successful experience in re-entry containment vehicle

D4C " Design for Containment"
Task 1

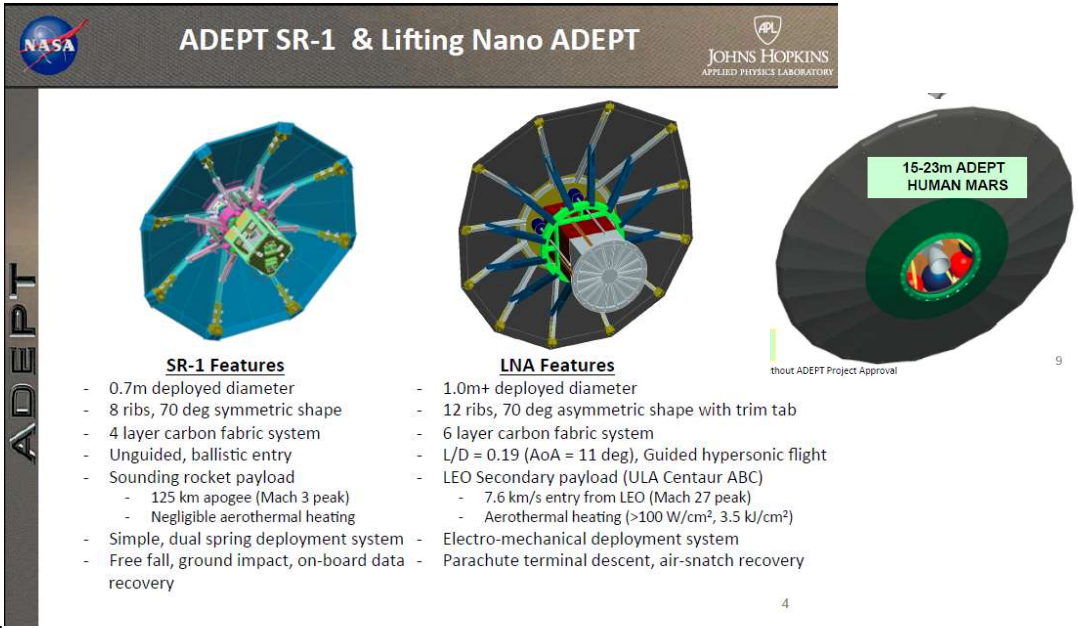
STATUS :
Reentry Kits / Deployable Shield / F-TPS

APPROACH & SOLUTION :
IAD: Inflatable Aerothermal Decelerator

DAD: Deployable Aerothermal Decelerator

OUTCOMES & RESULTS :
NASA Legacy:

EU H2020 initiative (EFESTO)



Reentry

1. **TOPIC:** Inflatable Decelerator (IRDT)

Inflatable Reentry Descent Technologyy

1. **STATUS:**

HIAD: Hypersonic Inflatable Aerodynamic Decelerator

SIAD: Supersonic Inflatable Aerodynamic Decelerator

IRVE –3&4: Inflatable Reentry Vehicle Experiment

3m / 10 foot Inflatable Heat Shield

LSDS: Low Density Supersonic Decelerator

Inflatable heat shield M<3,5

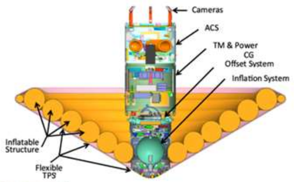
Supersonic parachute 30,5m

THOR: Terrestrial HIAD Orbital Reentry

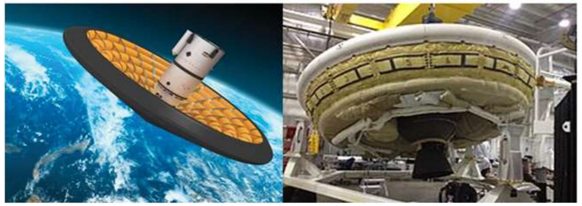
3,5m diameter

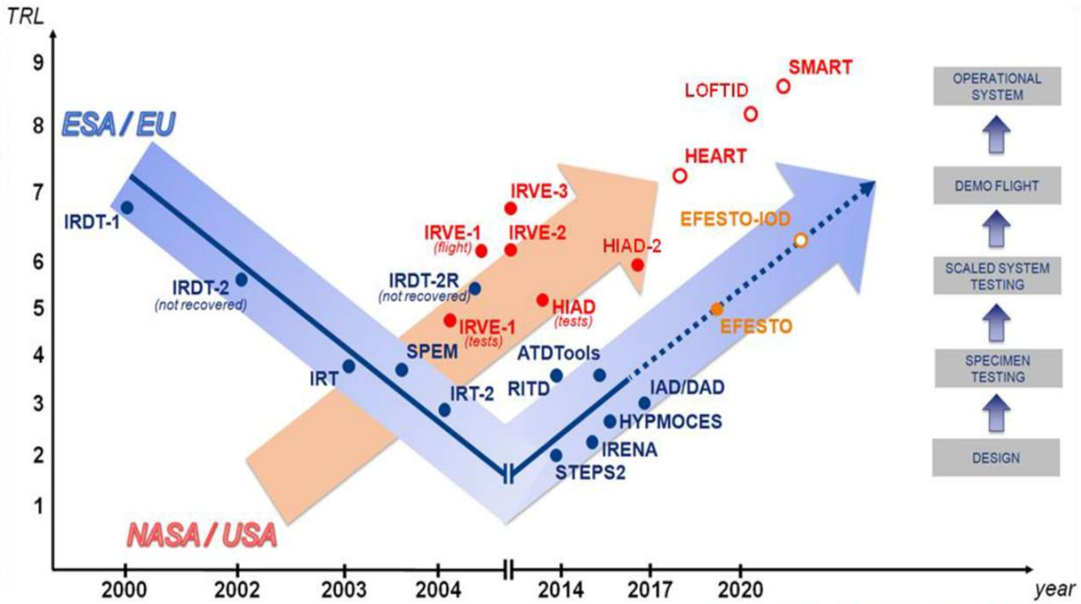
HEART:

3. **CONCLUSIONS:**



Deployed (3m [118"] diam)





D4C " Design for Containment“
Task 1

STATUS :

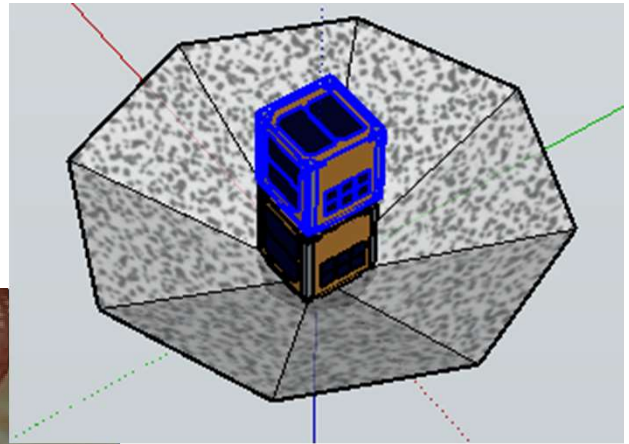
Reentry Kit / Deployable Shield

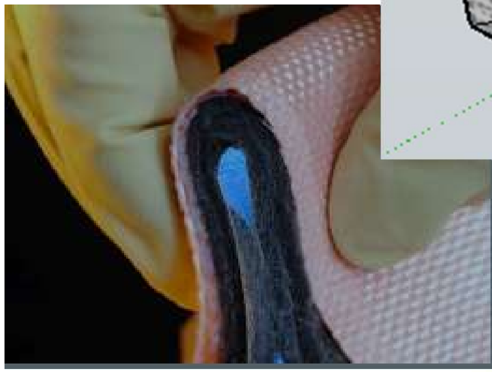
APPROACH & SOLUTION :

IAD: Inflatable Aerothermal Decelerator

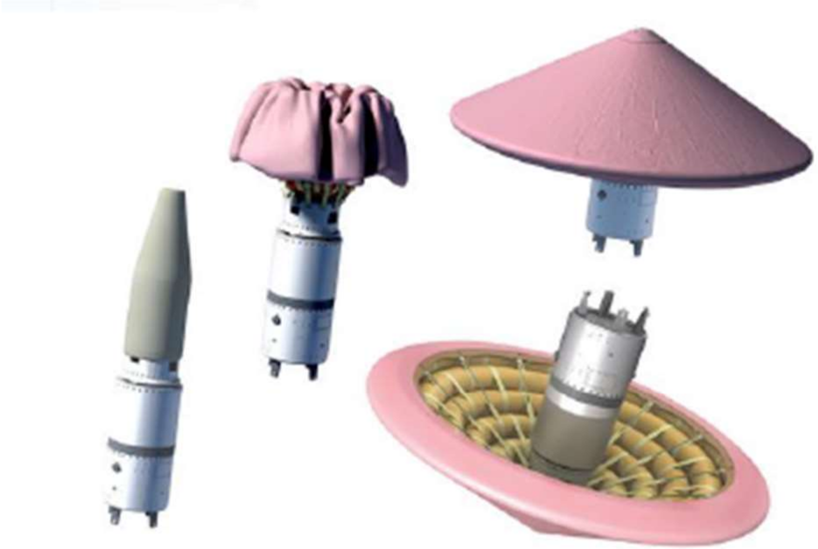
DAD: Deployable Aerothermal Decelerator

OUTCOMES & RESULTS :

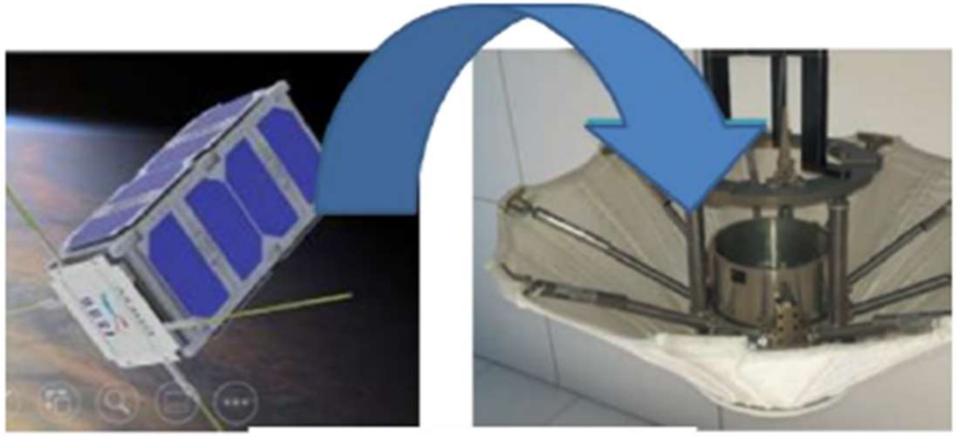




Pyromeral Systems
www.high-temperature-composites.com



a) NASA inflatable heat shield surviging Mach 20 ... emperature above 537°C.



E.NOVA

b) deployable containment heat shield proposed by E.NOVA

Figure 1-9: Example of “full” containment solutions

ThalesAlenia Space
a Thales / Leonardo company

ifth Institut Français du Textile et de l'Habillement

D4C " Design for Containment"
Task 1

STATUS :

APPROACH & SOLUTION :

**Wire Link &
Net Cage**

OUTCOMES & RESULTS :

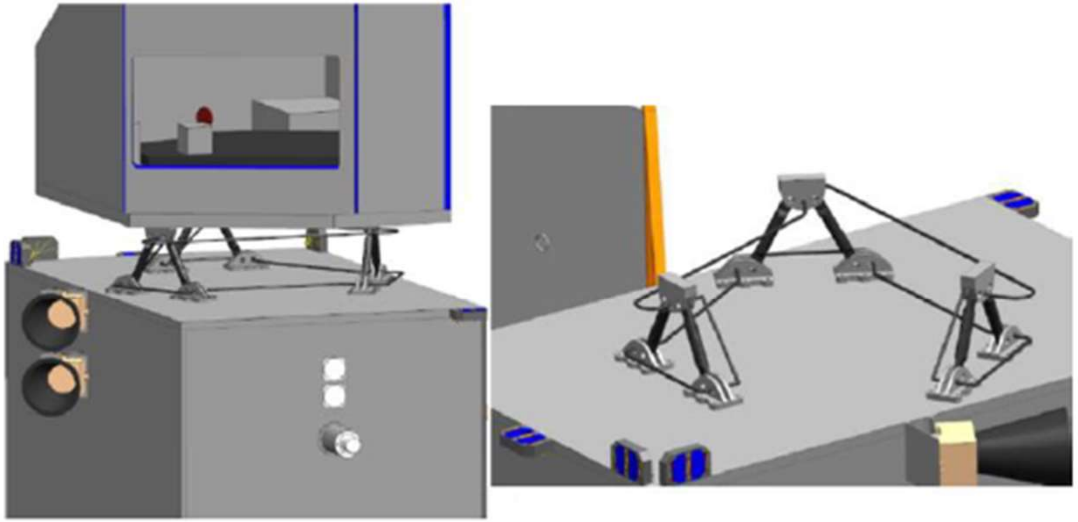


Figure 1-10 tethered feet on carbonsat solution proposed by deimos to reduce number of falling distinct parts (one instead of 3)

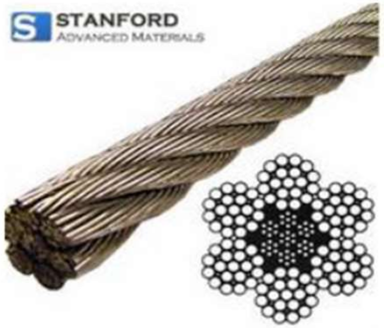


Figure 1-13 Tungsten rope delivered by Stanford

Figure 1-11 Thin wire made in molybdenum alloys by Plansee

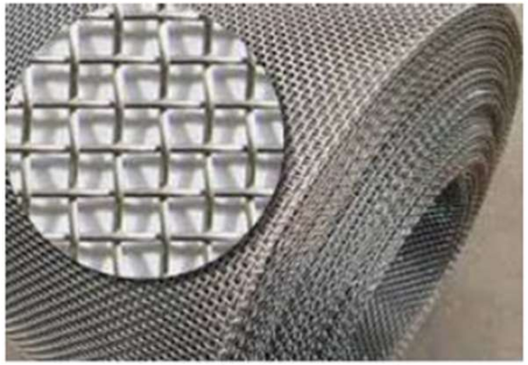


Figure 1-12 View of molybdenum mesh to encapsulate together not demisable elements

ThalesAlenia Space a Thales / Leonardo company

E.NOVA

D4C
Design for Containment
Task 1

STATUS :

SMA (Shape Memory Alloys)

APPROACH & SOLUTION :

Auto-Thermo activated Mechanisms

⇒**Need TPS** (Max OPS T° TBC)

OUTCOMES & RESULTS :

D4C Techniques/Technos

"Magic Rope " => Attach Elements **(DCA=??)**

"Magic Spring" => Reduce DCA

SPRING			
Mass (Kg)	1	1	1
Margin	5	5	5
Force (N)	1.976	1.976	1.976
T° (°C)	**400**	**600**	**700**
Stress (Mpa)	340	130	60
Dia Wire (mm)	1	1	1.5
Dia Spire (mm)	100	100	100
Material	TiNi	TiNi	TiNi
Density (Rho)	6.5	6.5	6.5
Rope length (m)	1	1	1
Wire Length (m)	7	7	7

STATUS :

Already Tested in **PWT @ DLR**

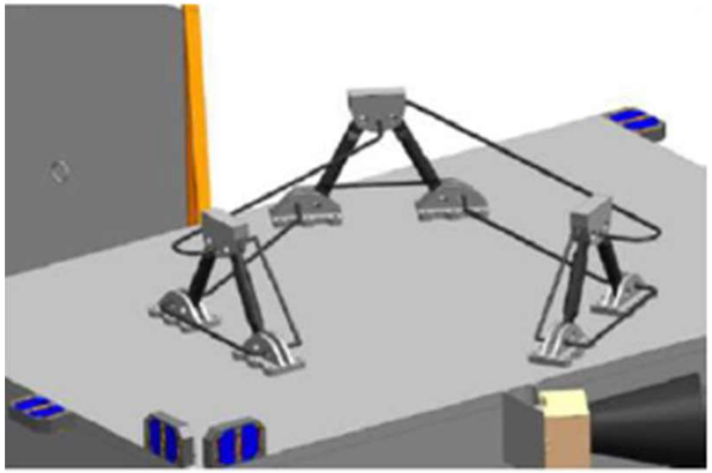
⇒**ESA D4D Activity**

Design for Dismantlement & Break-up (OHB Awarded)

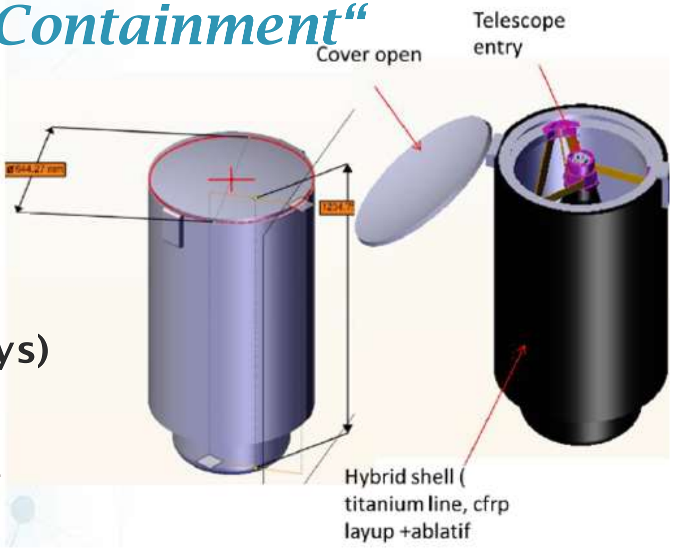
Full Success Techno

The most accurate and reliable

Overall ranked **3rd/31 technos**



D4C " Design for Containment"
Task 1



STATUS :

SMA (Shape Memory Alloys)

APPROACH & SOLUTION :

Auto-Thermo activated Mechanisms

⇒Need TPS

(Max OPS **T°=600**°TBC)

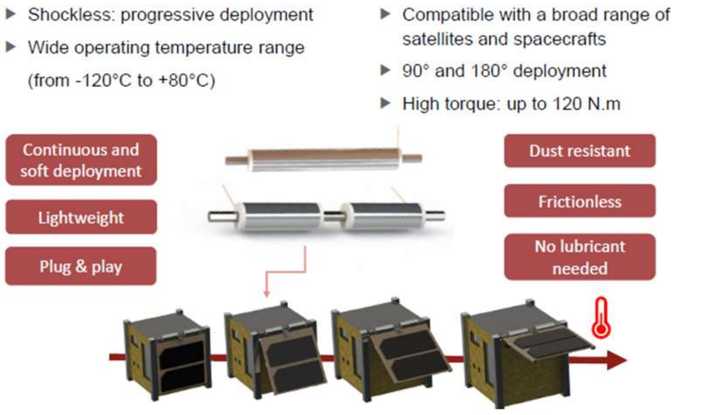
OUTCOMES & RESULTS : **D4C Techniques/Technos**

"Foldable Structures"

⇒ Close Box Mechanisms

"SMA Torque Hinge "

=> Fold Baffle & Close Box



	HECTOR® (SINGLE)	HES190	HES118	HES290	HES218	HES390	HES318
Dimensions	Total length (mm)	90		180		270	
	Fasteners length (mm)	2 x 10	2 x 5	2 x 15	2 x 10	2 x 25	2 x 15
	Operational length (mm)	70	80	150	160	220	240
	Diameter (mm)	12.8	9.7	21.1	13.8	28.4	18.0
Rotation	Nominal deployment angle (°)	90	180	90	180	90	180
	Maximal deployment angle (°)	110	220	110	220	110	220
	Deployment accuracy[1] (°)	2	4	2	5	2	4
	Reproductibility (°)	1	2	1	2	1	2
Mechanical	Maximal torque (N.m)	6	1	56	8	118	29
	Torsional stiffness (hot) (Nm/°)	1,7	0,2	17	1,2	53	4,3
	Torsional stiffness (cold) (Nm/°)	0,2-1,7	0,02-0,2	1,8-17	0,1-1,2	5,8-53	0,5-4,3
	Mass (g)	32	11	292	82	941	280
Electrical	Power (W)	32	11	145	41	469	140
	Nominal voltage[2] (V)	8	8	16	16	110	28
	Nominal current (A)	4	1,5	9	2,5	4,5	5
	Actuation duration (s)	300	300	600	600	600	600

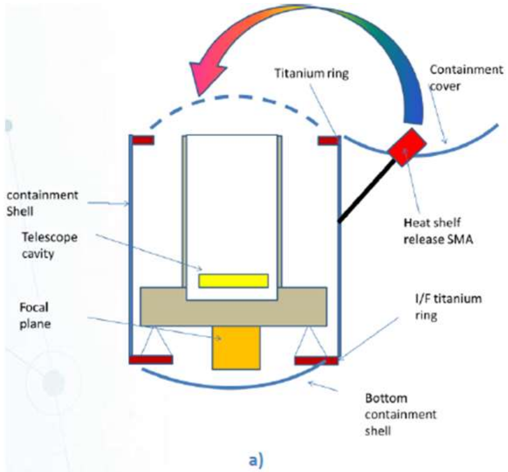


Figure 1-23 Example of (a) HR optical payload containment by a shell with close up cover and (b) Nimesis Self ignited SMA bolt release already qualified

CONTAINMENT METHODS

///Regroup

- Architecture change
- Adaptative change

///Protect

- Protection Upgrade
- Protection Addition
- Heat Shield Implementation

///Attach

- Specific attachment
- Interface change
- Design change

///Encapsulate

- Partial Encapsulation
- Total Encapsulation

D4C " Design for Containment"
Task 1

PROS :

Switch from Controlled Reentry

⇒To NON Controlled Reentry

Propellant Capacity /2 or /3
Propulsion system : as Usual (Simple)
S/C reliability : no EOL disposal

S/C 2tons -> 1ton

S/C price decreased (NRC& RC)

Switch L/V =>Soyuz/AR6 -> VEGA

L/V Price : /2

CONS :

Low TRL
Innovations Needed
Technological Developments

More surviving Mass ?
Higher kinetic Energy

Better 1 lethal impact Twice the Energy
Than 2 lethal impacts half the Energy
=> See limits in Sheltering effects

CONCLUSION :

With just some technological developments

=> COULD BE a GAME Changer :

If S/C can switch to Controlled -> Non Controlled Reentry