Composite Structures for Launchers : Challenges in Design, Dimensioning and Qualification for Gain of Costs and Adaptation to Market

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Sommaire

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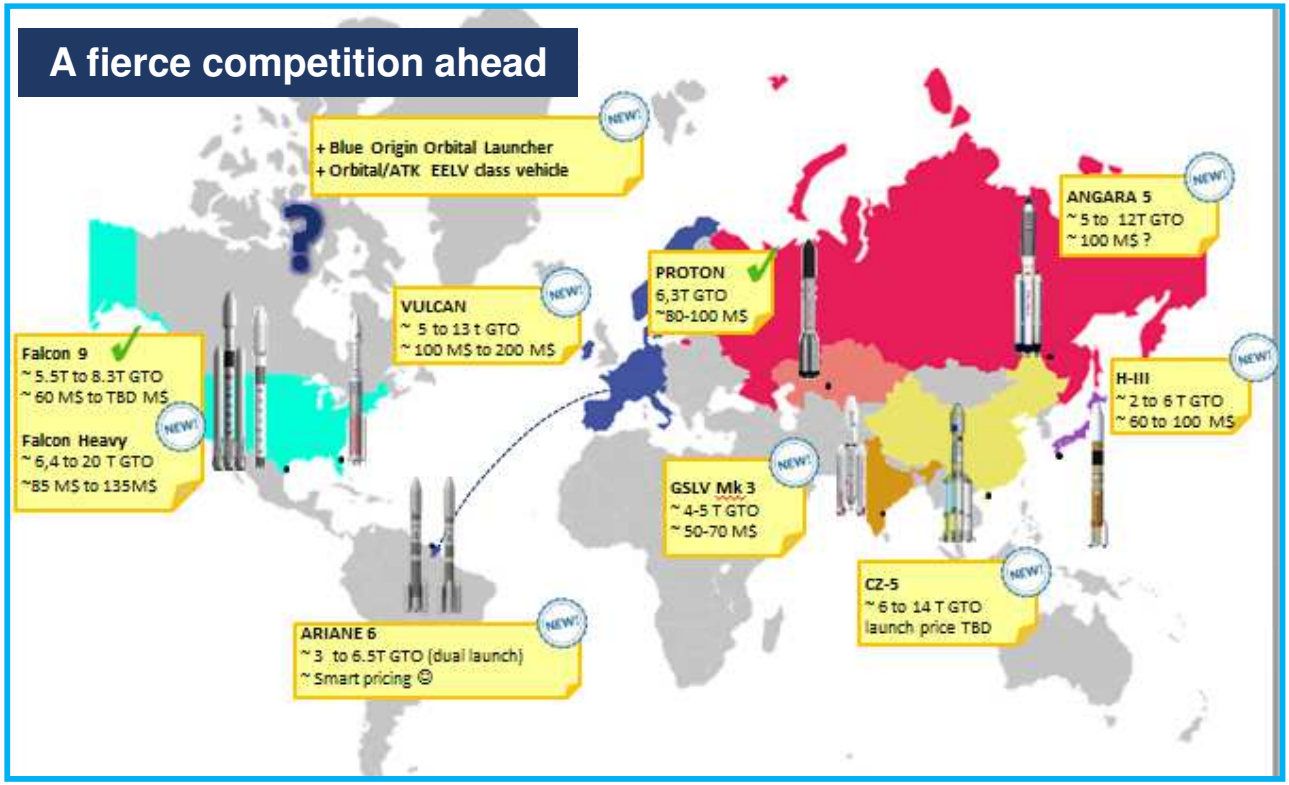
Among its prerogatives, the French space agency works to :

- **Orient the french space policy on launchers**
- **Promote french industry and academy**

We collaborate with laboratories or industrials to develop the launchers technologies of tomorrow.

The current context

A fierce competition ahead

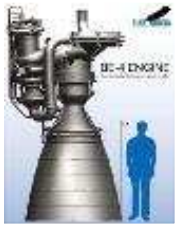


To remain competitive with new comers

Private competitors jostle the whole sector

A NEW PARADIGM FOR THE LAUNCH SERVICES SECTOR:

- Reduced Supply chain
- Process Innovation
- Optimization of production facilities
- Simplicity in the design, cost oriented technologies choices
- spiral method and rapid prototyping



REUSABILITY

COST OPTIMIZATION

FAST DEVELOPMENT

MANNED FLIGHT

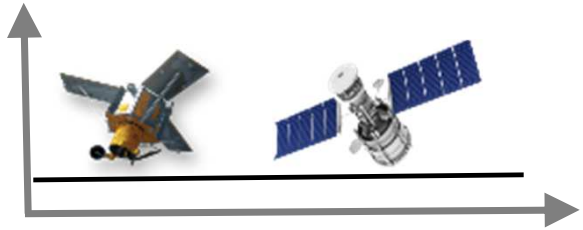
➡ A culture of cost awareness at all company levels
➡ Focus on technical and economic optimization of the entire system

Prospective look into next decade: commercial space evolution/revolution?

INSTITUTIONAL SPACE

today → tomorrow

➡ A stable demand for the number of classical satellites



COMMERCIAL SPACE

today → tomorrow

20-25 per year

COMMERCIAL SPACE

???
per year

Global space services

Smallspace boom ?

Tourism/private infra ?

Orbital services ?

HTS/Obs in LEO / constel for > 10s of Tb/s ?

HTS in GEO > 2 Tb/s !

New ways of working for CNES

Blue Origin new launcher plant (Dec 2016)

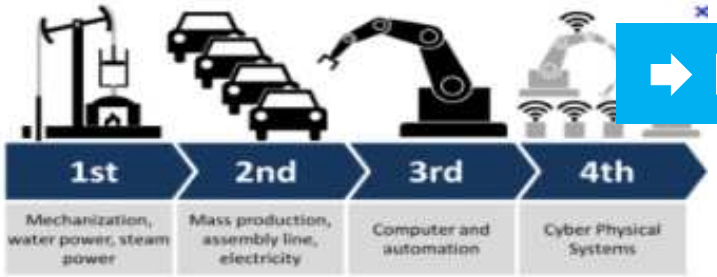
➡ Being reactive, working agile !

- New management & collaborative process
- Modular conception
- Launch flexibility

Falcon Transporter/Erector purchased for 37K$

➡ Frugal innovation and development

- Spin-in from other industry
- Quick prototyping (Additive Manufacturing)
- Development reduced from 10 to 5 years



➡ Digital revolution for rocketry !

- Industry 4.0
- Hardware empowered by software

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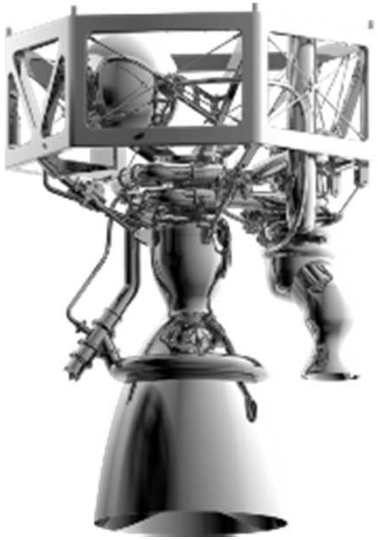
LOX/Methane potential benefits with Prometheus engine

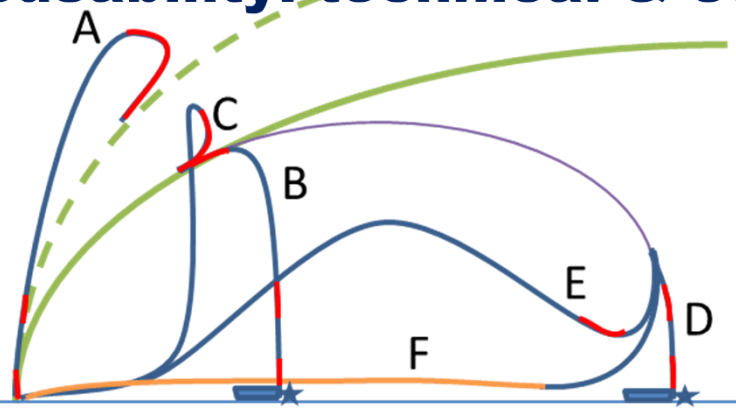
PROMETHEUS



LOX/CH4

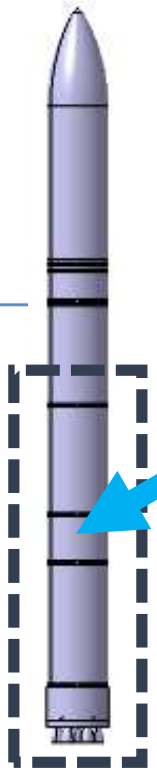
- ⊕ Less demanding than LH2
- ⊕ Low coking & soot (950 K)
- ⊕ Denser than H2
  (2.5 times, 80% of Kero bulk density)
- Cryo, but semi cryo (90 K)
- Medium ISP ~ 350s

Reusability: technical & economical issues



➔ A TECHNICAL CHALLENGE

➔ AN ECONOMICAL CHALLENGE



First stage reused = ~50% of launcher cost

+

Cost of refurbishment to be considered

Options for the future of Ariane

Main objectives for European Launchers:

➡ To remain competitive with new comers

➡ To anticipate market evolutions

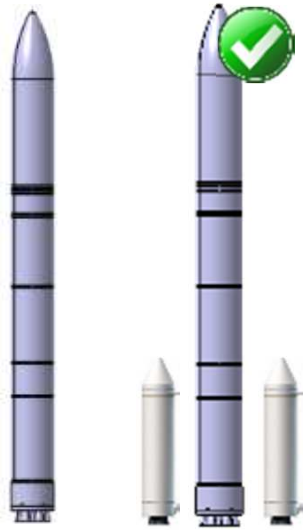
Standardization

Reusability options

Technical and economic studies made on different concepts

Low cost propulsion

A6 Prometheus



With / without Solid boosters

Fly back concept

Liquid boosters

Ariane Next actual concept of interest

GLOBAL
- …

AVIONICS
…

1ST STAGE RECOVERY & REUSE
- Semi-reusability strategy

PROMETHEUS
- …

STANDARDIZED TANK
- LOX and CH4
- …
- Composite cryo tank
- …

Optional boosters (0 / 2 / 4)
- …
- …

GROUND SEGMENT
- …

CH4 production

Technologies for futures Ariane – Composites materials

Materials
- New resins
- Thin-plies
- CNT
- TP vs TS

Process
- Bonding
- Hybrid assemblies
- Automatisation
- Machine learning

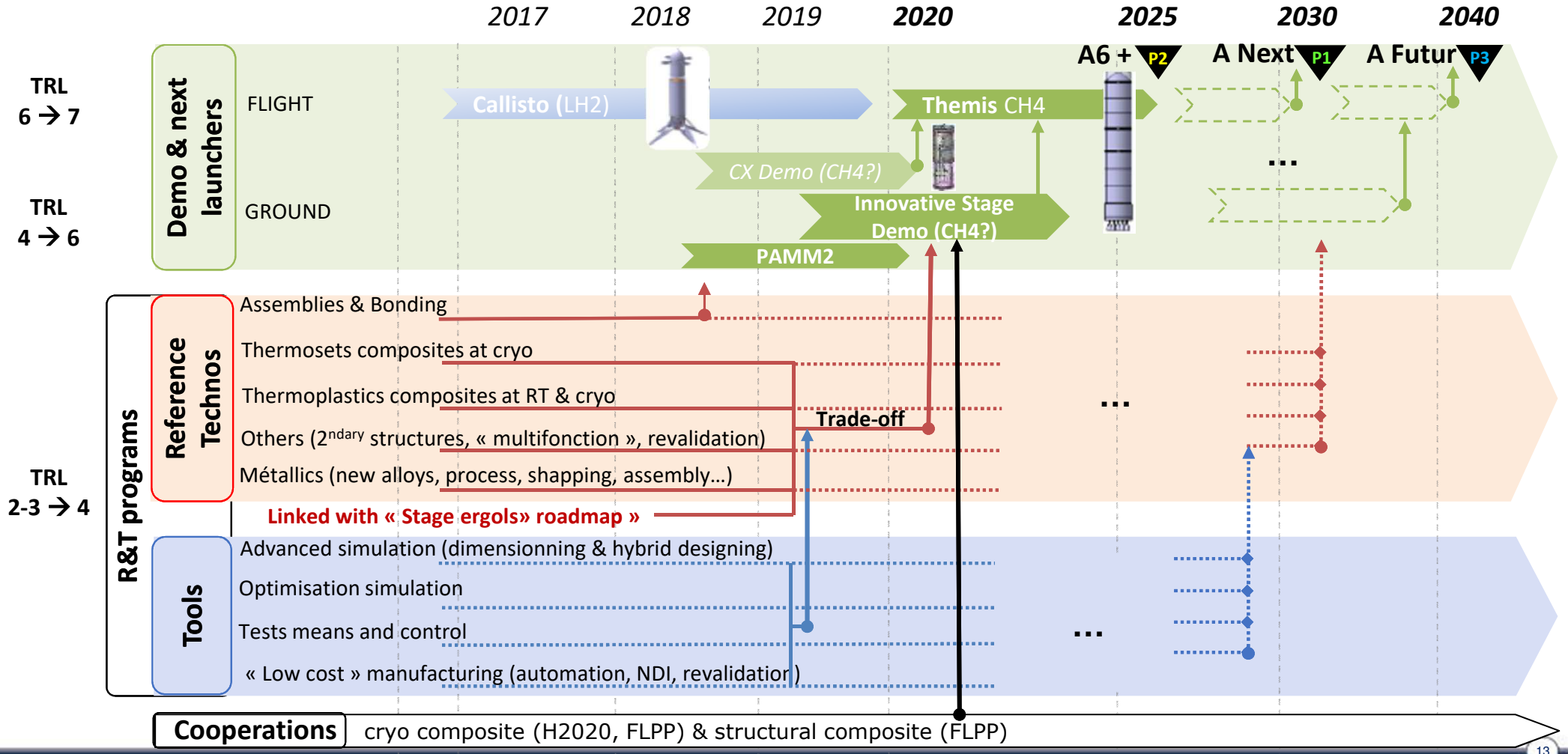
Functionnalisation
- Thermal insulation
- Equipment fixation
- Stiffening solutions
- Damping
- Sensors
- Energy storage

Cryogenic Ergols Storage
- Damage Tolerancy
- Permeability
- Lox Inflammability
- …

Health Monitoring
- Ground (production, qualification, MRO)
- Flight

Methods & simulations
- Design (laws & criterias, optimisation, probalistic approaches,…)
- Tests / Models dialogue
- Virtual Reality

CNES-DLA roadmap for futures stages



Advanced methods – R&T CNES & Arianegroup

2 differents Thematics

Advanced methods
for
Composite Structures

ONERA
THE FRENCH AEROSPACE LAB

arianeGROUP

Advanced methods
for
bonded junctions

I2M BORDEAUX

iRDL
Institut de Recherche Dupuy de Lôme

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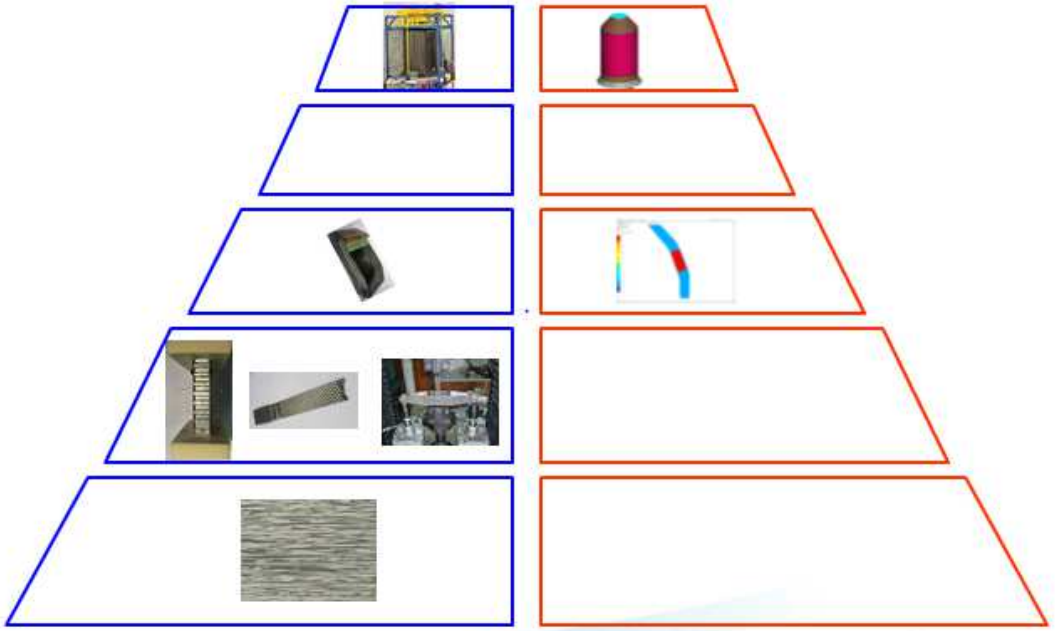
Advanced methods
for
Composite Structures

Context

We use a classical qualification methodology



Building block approach → Example pf SYLDA justification Pyramid

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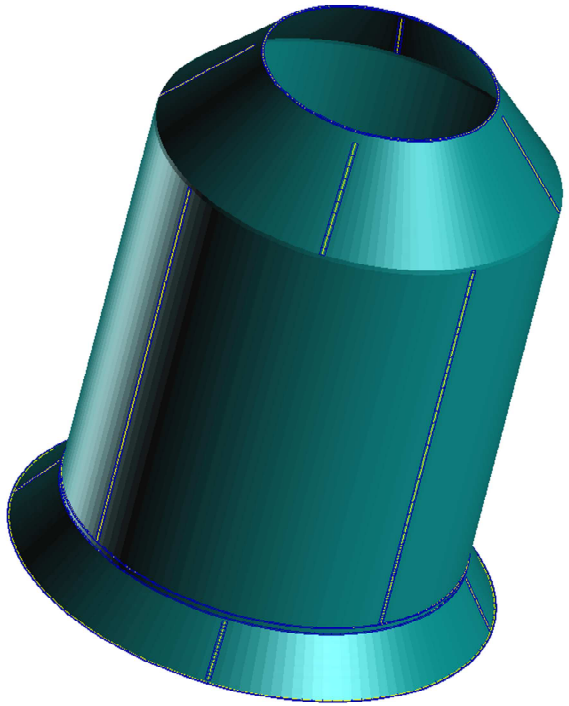
Advanced methods
for
Composite Structures

Context



Analysis :
Robust but **working on conservatism & accuracy** could offer opportunities

Experimentations :
Cost & time consuming / **Deeper data exploitation** could offer opportunities

Advanced methods – R&T CNES & Arianegroup

Advanced methods
for
bonded junctions

Context :

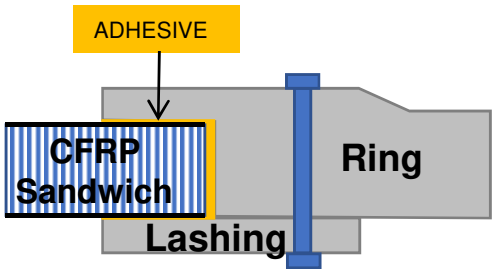
Adhesive have been used for long time on launchers

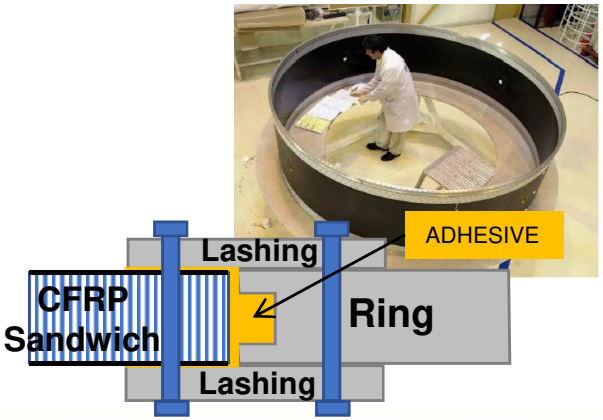
Ariane 4 (1988-2003) – SPELDA

Ariane 5 – ACY 2624

Ariane SYLDA 5

….





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Advanced methods
for
bonded junctions

Context & Objectives

- Performant but **complex to implement**
- **Implies mastering of whole chain** : design, justification, process, control

Cost reduction opportunities :

- G**iving more robustness** to the design & the process
- Editing **a clear handbook** = confidence.

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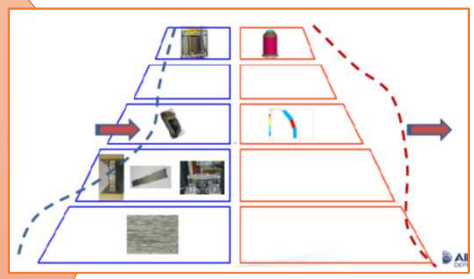
Common objectives:

To reduce development duration & cost



To improve the prediction capability of mechanical simulations

To better know **the real structural margins**

Advanced methods for **Composite Structures**

Advanced methods for **bonded junctions**

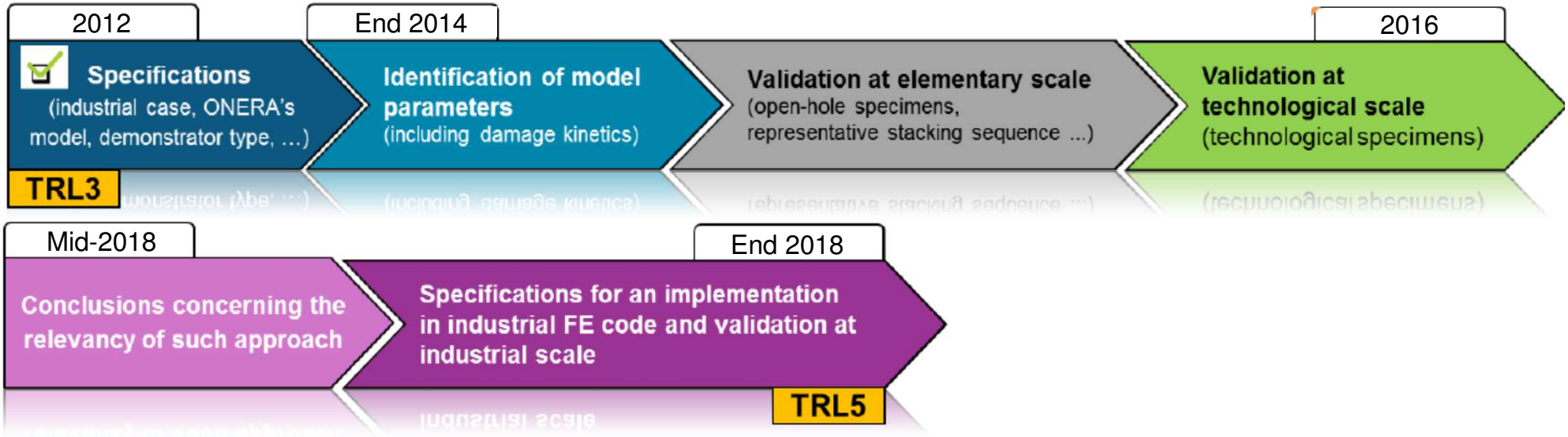
CNES & AGS share a common roadmap

Advanced methods – R&T CNES & Arianegroup

Advanced methods
for
Composite Structures

Activity : Advanced method for composite structures justification

Industrial transfer from ONERA : Model identification procedure in FE code, computation strategy for industrial use



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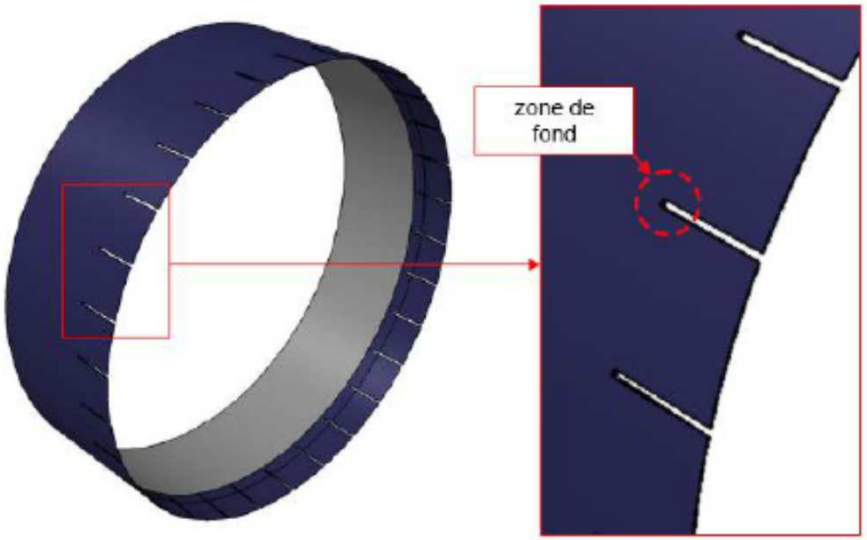
Advanced methods
for
Composite Structures

Activity : Advanced method for composite structures justification

Case study :



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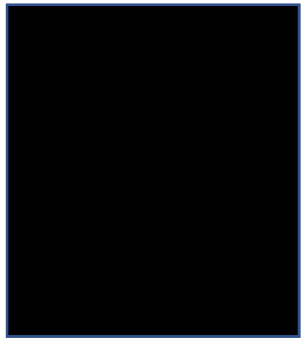
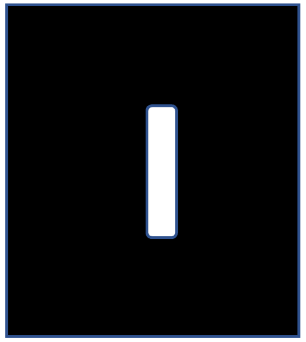
Advanced methods
for
Composite Structures

Activity : Advanced method for composite structures justification

Breadboards: 2 configurations tested in compression for performance assessment



Skirt field



« Notch »

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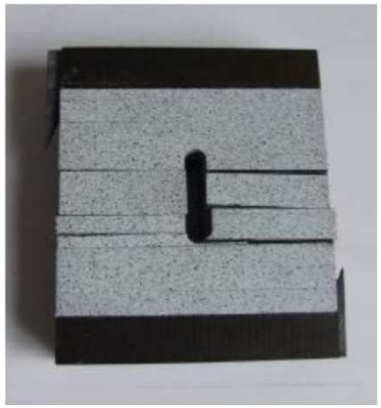
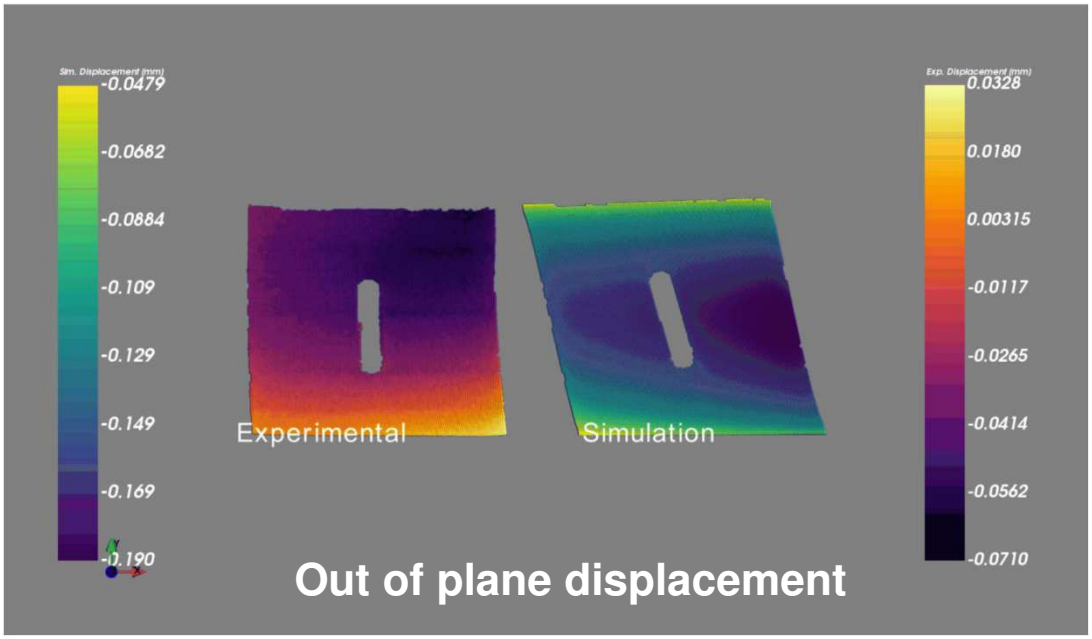
Advanced methods
for
Composite Structures

Activity : Advanced method for composite structures justification

Tests and first comparisons





Advanced methods – R&T CNES & Arianegroup

Advanced methods
for
Composite Structures

Activity : Advanced method for composite structures justification

Coming work:

- **Modification of limits conditions on simulations to be representative of tests**
- **Comparison between analysis and tests**
- **Conclusions on performances**

Other activities for composite structures launched in 2018:

- Inverse methods for the identification of material constitutive laws
- Hybrid test : real time simulation / test interaction
- Probabilistic uncertainties for test predictions
- New methods for sandwiches structures sizing

Advanced methods – R&T CNES & Arianegroup

Advanced methods
for
bonded junctions

Activities for Bonded junctions:

- R&T “Technologies liaisons collées pour application lanceurs” : 2014-2018
  - Axis 1 = Improvement of pre-sizing and justification approaches for bonding (IRDL)
  - Axis 2 = Robustness - stability of debonding defects (I2M)

- Next activity should work on demonstrations at higher scale and initiate a handbook.

Equipped tank cover plate – R&T CNES & CETIM

Context

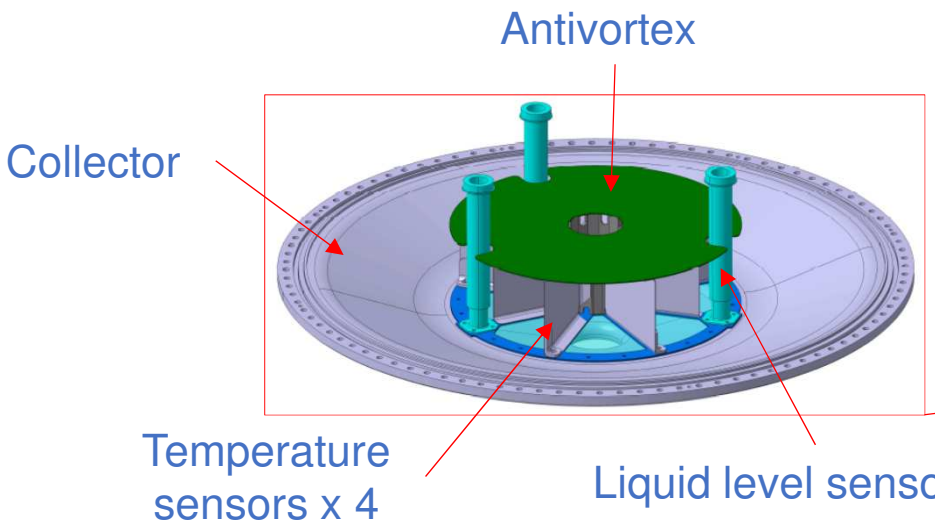
- Stages with composite cryotanks could lead to high gains in mass and cost.
- Crash program experimentation

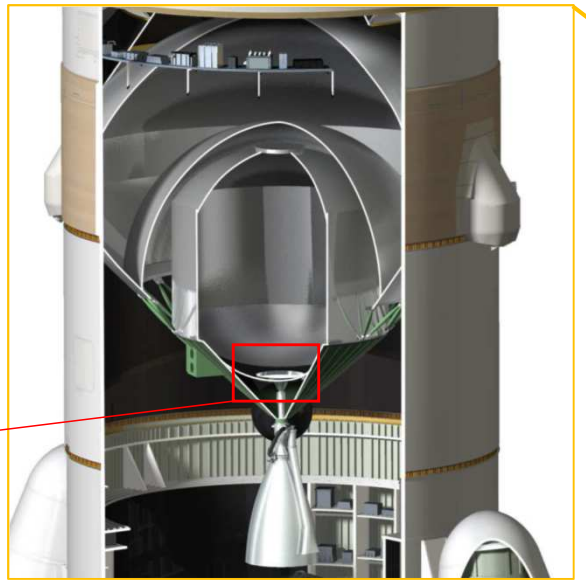
- Thermoplastics have shown good behavior at cryogenic temperature.
- CETIM have strong experience in TP automated process (QSP)

Equipped tank cover plate – R&T CNES & CETIM

Objectives

- **Redesign** in Thermoplastic composite a tank collector and its equipments inspired from Ariane 5 cryoliquid tank, and **manufacture & test a subscale model** to demonstrate possible gains in performance and industrialisation.

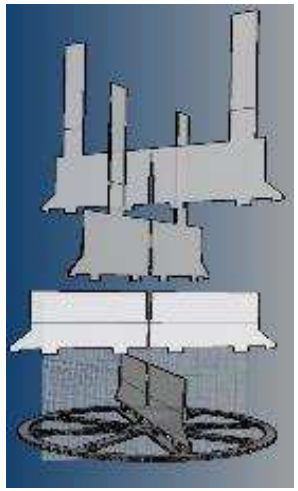




Equipped tank cover plate – R&T CNES & CETIM

New design

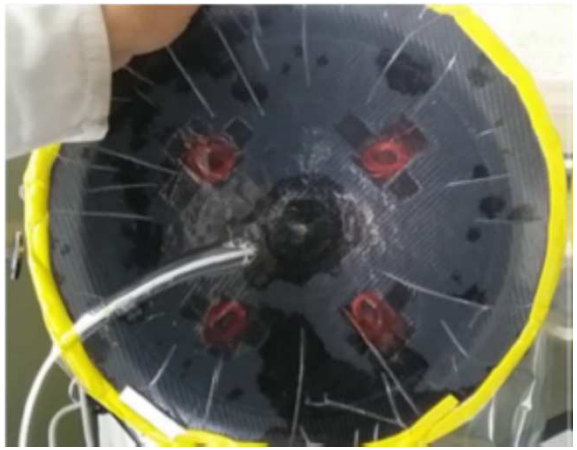
- More integrated
- More automatable
- 40% Lighter

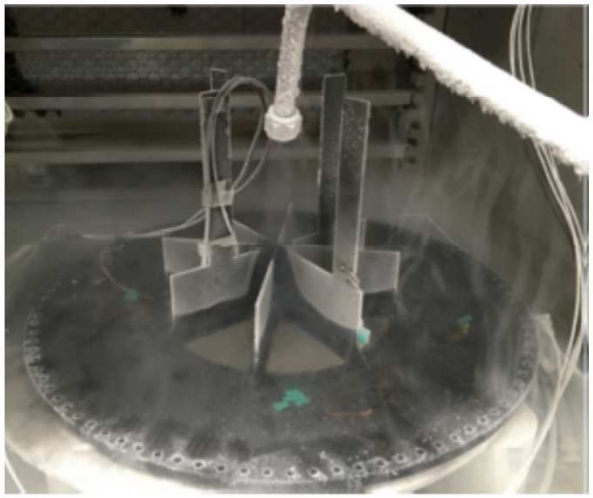


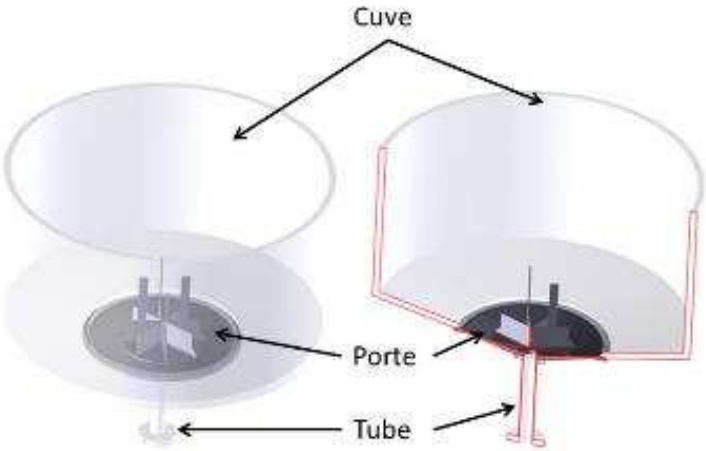
Equipped tank cover plate – R&T CNES & CETIM

Preliminary Tests

- Permeability
- Antivortex
- Liquid nitrogen







Equipped tank cover plate – R&T CNES & CETIM

Coming work

Second iteration

- Deeper inspection of the 1st article
- Improve design adding junctions permeability and mechanical strength
- Manufacture and test a 2nd article

Conclusion

- ✓ New comers change paradigm (reusability, cost optimization, fast development)
- ✓ CNES wants to impulse new ways of working : reactivity, fast development, digital revolution
- ✓ And work on the Ariane next generation : reusable, low cost engines (LOX/CH4), standardisation.
- ✓ Regarding composite technologies reusability, composite cryotank and ways of cost reductionare identified as priority.
- ✓ CNES pay lot of attention on simulation for cost reduction but also to accompagny technologies