Technologies For Space Care

T4SC

Tech4SpaceCare Initiative aiming to develop technological elements to ensure the sustainable use of space and the security of space operations in synergy with CleanSpace ESA activities

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Lot of activities have been done in CNES since 2010 in the frame of French Space Operation Act.

Establishment of an initiative that aims to:

- Focusing and centralize all the activities on the field of FSOA done in CNES with the objective to sustain the needs
- Keep watch on the subject
- Federate Technical activities inside CNES and French Space Industry
- Ensure the industrial and ESA point of contact

Maintain the sustainability of space

- Management of debris
- End Of Life
- Re-Entry safety : tools and technologies
- Protection of public health and the environment

Two main drivers

Re-entry Safety

Article 44.1 to 44.3 : Quantitative human safety objectives for return of a space object to Earth
Article 45 : Uncontrolled re-entry
Article 46 : Controled re-entry

Modeling

- Fragmentation
- Mecanical stress
- Benchmark
- Incertitude
- Methodology
- Wind tunnel
- Population

Design for Demise

- Joint test at hight temperature
- Advanced Studies : D4DLeO

Reentry Observation

- Avum rebuilding (GSTP)
- Mission definition (GSTP)
- Rentry Sat
- Advanced Studies : Experimentation for reentry observation demonstrator

Impact on environment (ex. reentry)

Space Sustainability

Article 40.1 to 40.7 :Space debris mitigation

End of Life

- Post Mission Disposal nominal or degraded mode
- Reliability vs Probability of PMD
- Equipment qualification
- Autonomous / Desorbitation
- Assisted natural re-entry
- ADR Compatibility & Maturity
- Passivation Measures

Mission extension

- Health Monitoring et Machine Learning
- EOF decision.
- Reliability

Protection/Vulnerability

- Hypervelocity impact : debris generation/spacecraft reliability
- Impact debris generation
- MMOD
- Protection
- Pressurized Tanks
- Battery

Action Items

- CNES R&T programm
- CNES Advanced studies (PASO)
- CNES FSOA plan
- Innovation cluster actions
- CNES support in CleanSpace activities (GSTP/TRP)
- CNES inkind resources
- Thesis funding

Building Blocks

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Art.40-1 : no generation of debris during the nominal operations												
Equation balistique liée au NIDA	<<											
IHV : Pressurized tanks												
Modélisation des impacts hyper vitesse												
Amélioration du moyen d'essais THIOT Ingénierie												
Evaluation of ballistic limits at high velocities												
Renforcement de panneaux NIDA												
Experimental characterization of the protection afforded by MLIs to debris and micro-meteorites												
Cloud model of fragments from a hyper-speed impact												
Impact simulation on metallic tanks with reactive fluid												
Art.40-3 : passivation of energy reserves and deactivation of means of energy production at end of mission												
Pasivation GEO												
Microperforator												
initiator with a long life												
Power system passivation												
Battery stress test												

Building blocks

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Art.40-6 : probability of success > 0,85 to perform the disposal maneuvers											
Gestion de panne tuyère transitoire de type bulle à partir d'informations du SCAO					■						
Health Monitoring					■	■					
System impact of taking into account 0.9 of PMD vs 0.85									■		

Art.44-1 : casualty risk < 10-4	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DEBRISK			■	■	■	■	■	■	■		
Aerothermal model for Debrisk reentry			■								
Wind tunnel			■	■	■	■					
Aerothermal effect of a hole in a tank during reentry					■						
Study of the effect of wake on atmospheric reentry							■	■			
Oxidation & emissivity of materials at high T °					■	■	■	■			
Evaluation of margins in DEBRISK models							■				
Resistance of satellite structures at high temperature						■	■	■			
Destruction of LEO satellite structures		■	■	■	■	■	■	■	■		
LOS Compatible Reservoir for Lower Earth Orbit Electric Satellites							■	■	■		
Development of "demisable" tanks made of composite materials							■	■	■		
Hight fidelity computation on spacecraft sub-system									■	■	
Mesh improvement and Spacecraft modeling with Pampero									■	■	
Improvement of aerodynamic spinning & damping moment during reentry									■	■	
Interaction between flow and surface for better modelisation									■		

Building blocks

Art.40-4 : to leave the protected area in less than 25 years Space sustainability

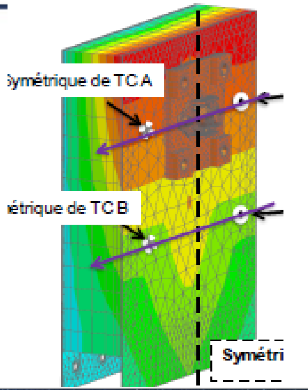
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Desorbitation from end-of-life survival mode of satellites in low orbit											
LEO autonomous desorption, in case of loss of ground control											
De-orbiting strategies leading to a controlled re-entry											
Desorbitation of satellites in electric propulsion											
Attitude control for very low-altitude satellites											
Defining an AOCS Mode for PMD in survival mode cont											new
Feasibility of Natural Assisted Reentry											

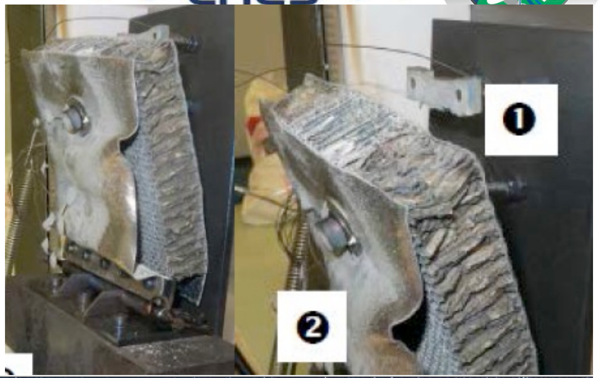
T4SC

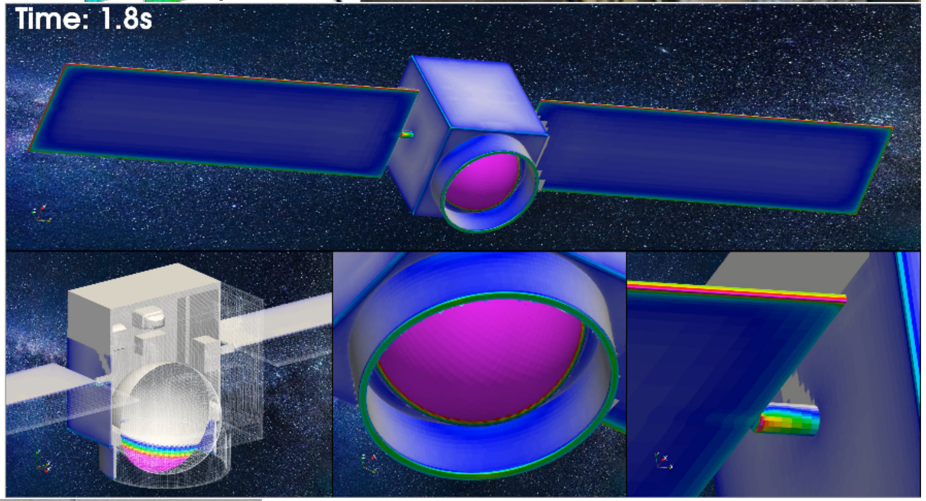
OVERVIEW of the activities conducted in CNES in 2018 in the frame on FSOA

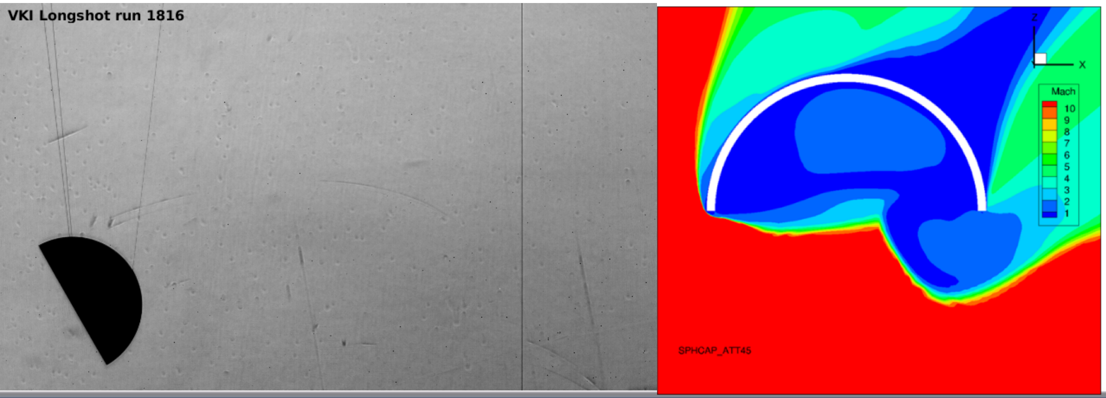
Re-entry Safety :Modeling

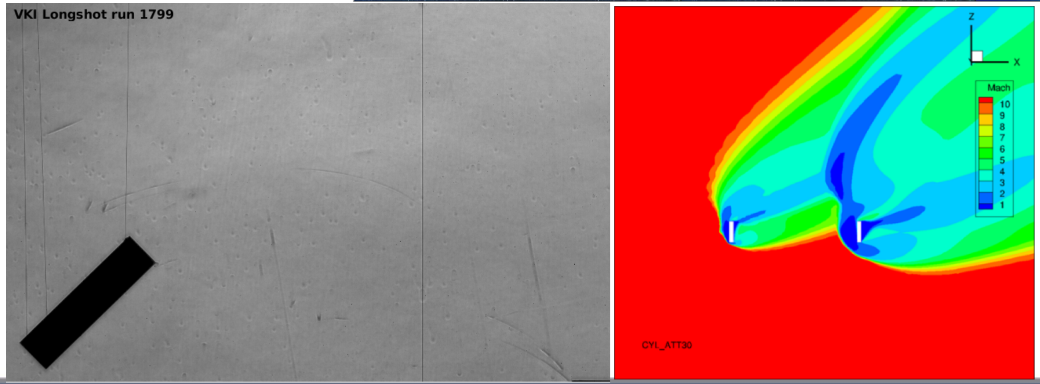
- Fragmentation : Mecanical & Thermal joints experimental & numerical tests (ADS/ArianeGroup)
- Mecanical stress : Implementation and adaptation of PAMPERO (Rtech) for mecanical computation in complex vehicle
- Wind tunnel : Wind tunnel test (VKI) for complex shape knowledge improvement and implementation in DEBRISK
- Incertitude :Improvement of aerodynamic spinning & damping moment during reentry(R-S18/PF-0002-098)



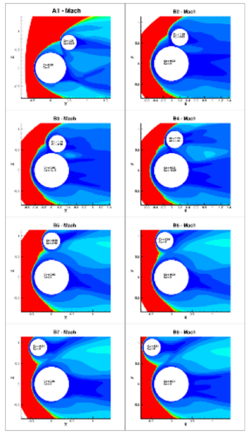






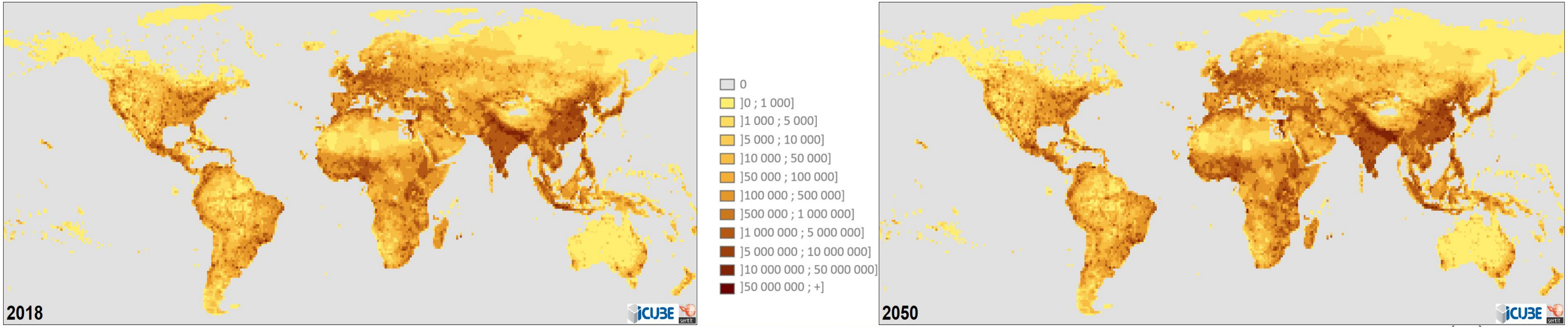


Re-entry Safety :Modeling

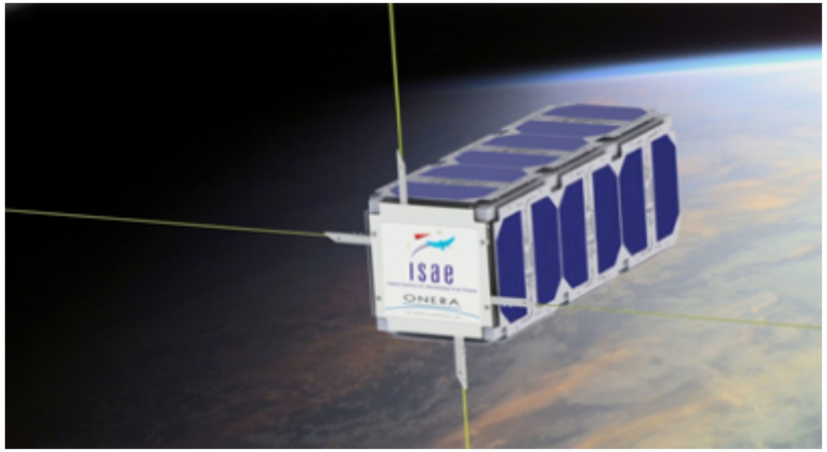


- **Risk of atmospheric reentries on aircrafts**
  - Qualitative and quantitative arguments to compute the risk for aircrafts to be hit by a space debris in its re-entry phase
  - The vulnerability of aircrafts is mitigated by already existing protections to external hazards (PRAs).
  - Update of air traffic density map using ICAO database Use of Electra tool to compute the risk
- **Study of the effect of wake on atmospheric reentry (R-S14/PF-0002-060)**

- **Population model** : major contributor in probability assessment of human risk => improvement of population model by mergin and extrapolate UN World Population Prospects and GPW.



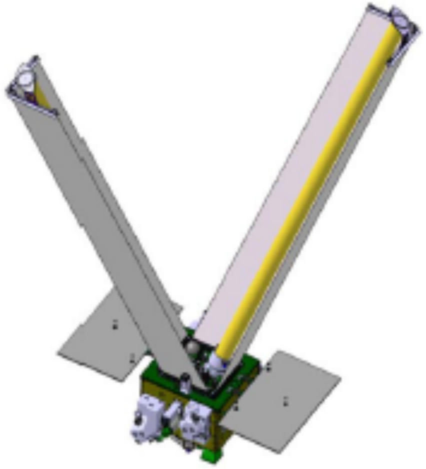
Re-entry Safety :Reentry Observation



- Advanced Studies : Experimentation for reentry observation demonstrator coupled with Assisted Natural Reentry
- Futur activities envisaged
  - Exploitation of Rentry Sat data: ISAE project with the help of Janus Program in CNES

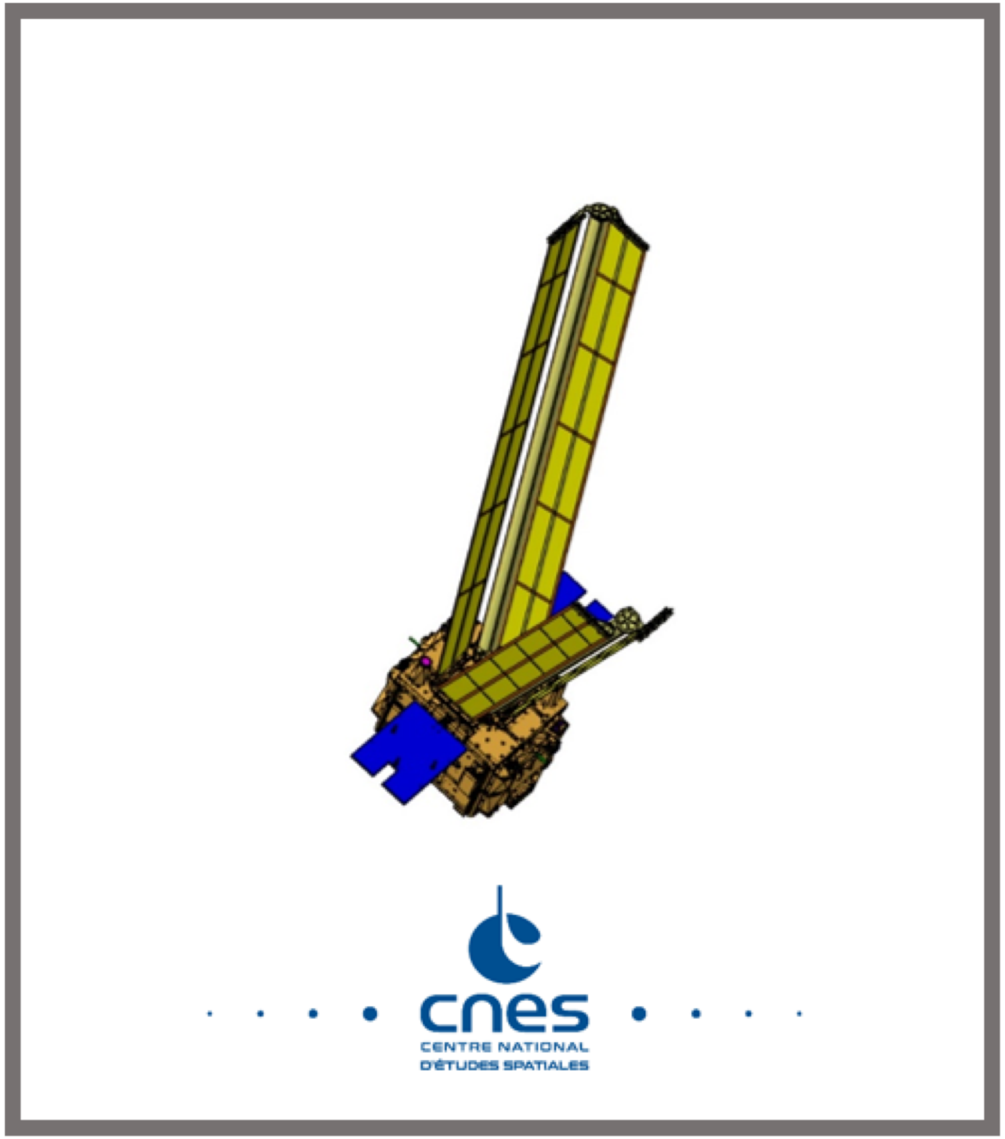
Space Sustainability : End of Life

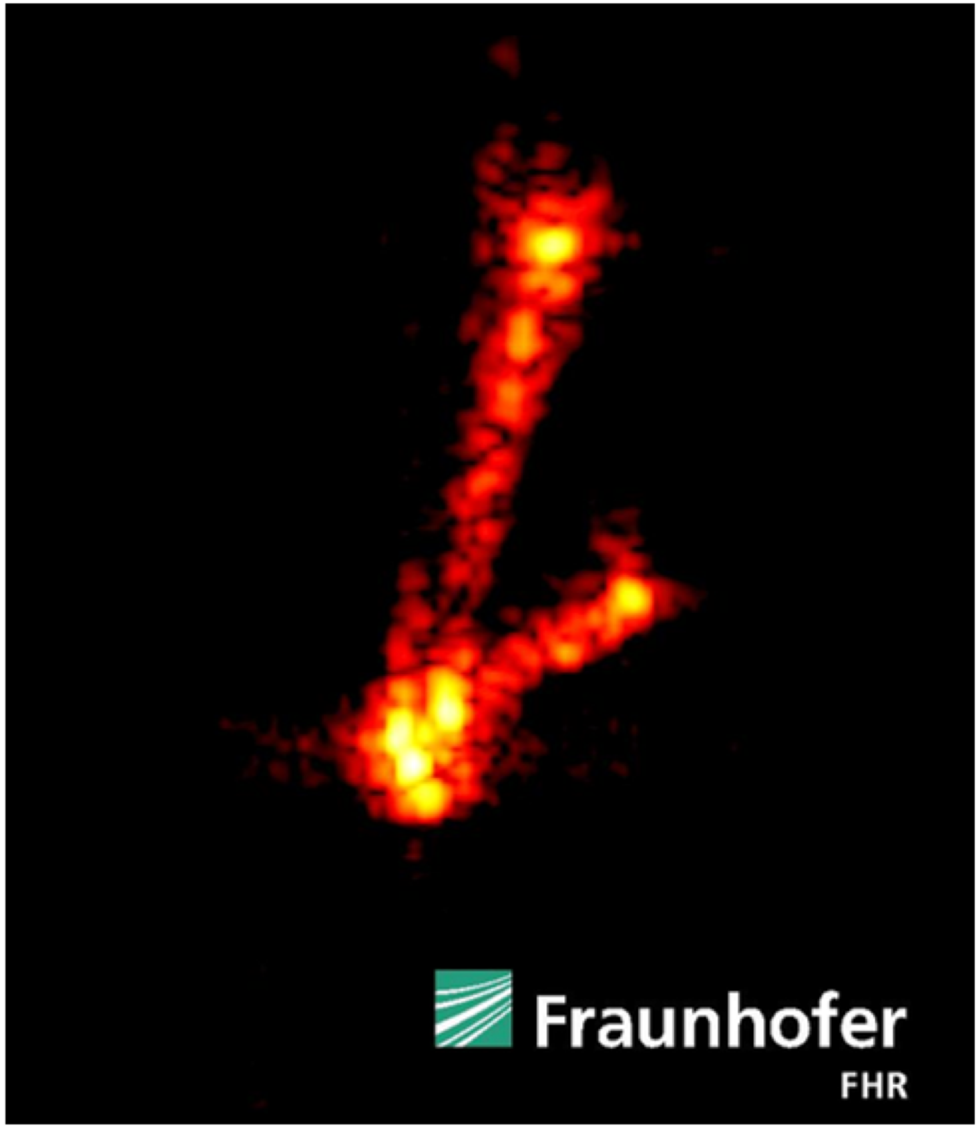
- Internal study to conclud of the Feasibility of Natural Assisted Reentry (R-S18/BS-0005-041)
- Internal study to Defining an AOCS Mode for PMD in survival mode (R-S18/PF-0002-095)
- Studies on System impact of taking into account 0.9 of PMD vs 0.85 (TAS and ADS)
- Success of Microscope IDEAS system which has been deployed 16 october 2018



Satellite with IDEAS in deployed configuration

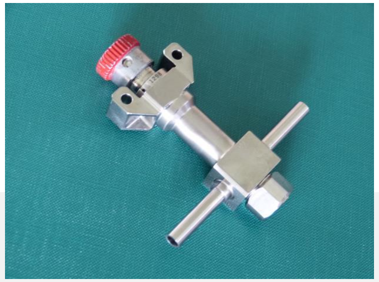
oom in folded configuration

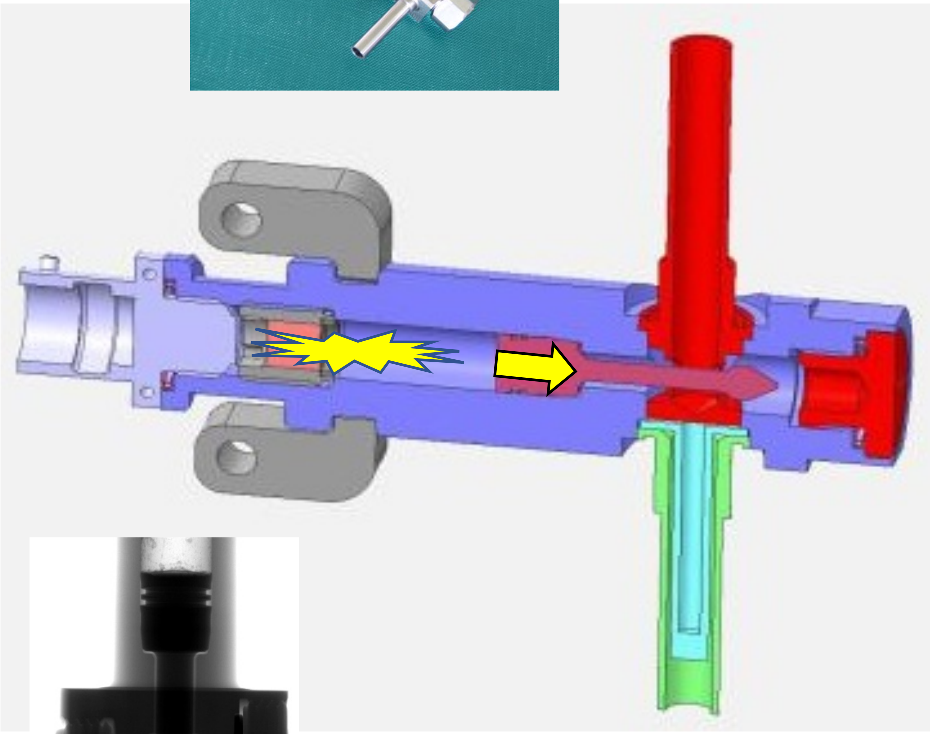


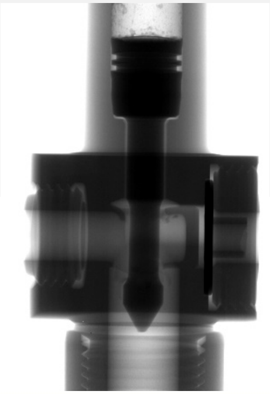


<u>Satellite MICROSCOPE du CNES avec ses 2 ailes de désorbitation déployées</u> (17/10/2018)
Modèle CAO (à gauche) et image radar capturée par le système TIRA du Fraunhofer Institute (à droite)

Space Sustainability : End of Life







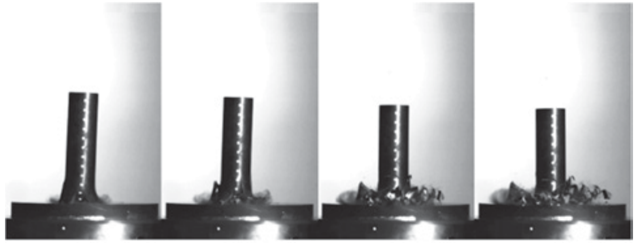
Equipment qualification

Depletion of the fluids

- **CNES has developed and qualified the microperforator, the more feasible and cheapest system in short terms**
  - it punches the tubing with a projectile and releases the pressurization gas
  - It is CNES qualified and it has been tested with propellant and vapors with success

Space Sustainability : Protection/Vulnerability

Hypervelocity impact : debris generation/spacecraft reliability



- **Debris cloud model (Impetus) :**
  - Numerical work:Get the description of the characteristics of the debris cloud generated by an Hyper Velocity Impact.
- **MLI efficiency against MMOD threat (Thiot Ingénierie)**
  - Experimental work :Evaluation and update of standard MLI ballistic limits with stand-off at high velocities (up to 10 km/s)
- Battery

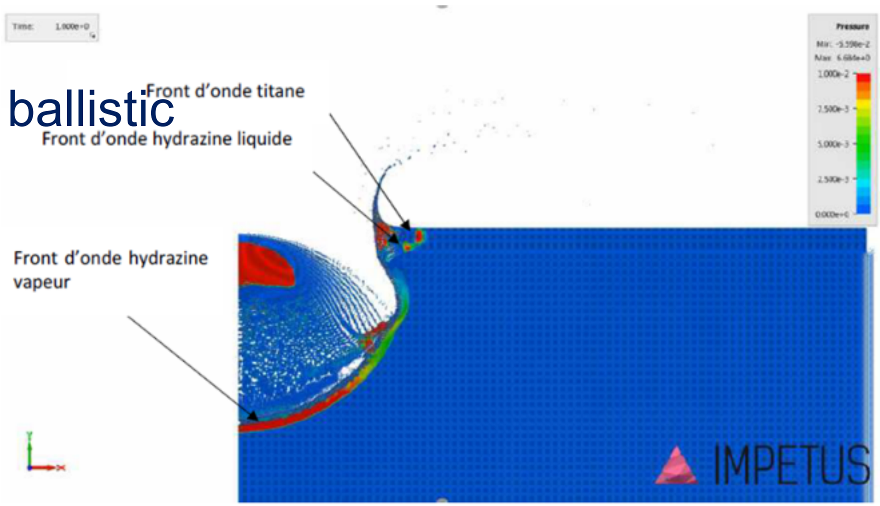


Figure 11 Modèle 2D axisymétrique Impetus t=0,68µs et 1µs

To be continued...

- Tech For Space Care will continue and emphasis the SRL activities that made CNES very active and concern on this topic.
- The French Space Law will be totally applicable without transient measure anymore at the end of 31st December 2020
- Increasing contributors in the space domain must push all the community to take the space sustainability as the keystone of the future beneficial activities