Update of the Technical Regulation associated to the French Space Operation Act (FSOA) And its technical implementation T4SC

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French Technical Regulation update

- **<u>Context</u>** :
  - Update of the French Space Operation Act (FSOA)
  - Need to adapt the contents of the associated Technical Regulation (TR) in particular due to the New Space environment
    - ✓ Increased space traffic
    - ✓ Diversification and multiplication of space actors
    - ✓ Development of innovative systems
  - Emergence of « **Space Traffic Management** » concept

- **<u>Aim</u>** :
  - Overcome the **risk related to debris** in orbit
  - **Limit debris generation** through preventive measures
  - Pushing technological developments : **vector of innovation**
  - Provide a **regulatory framework for new innovative activities** (e.g. On Orbit Servicing)

- **<u>Methods</u>** :
  - Work started in July 2020 with a feedback on the application of the current TR
  - Ensure coherence with International standards/regulations (e.g. FCC, ODMSP, ISO, IADC, WG ESA, …)
  - Close coordination with French Operators and Industrial partners
    - ✓ Official review, extended to international entities (e.g. FCC, FAA, Starlink, Oneweb, …)

TR envisaged evolutions perimeter

Feedback on the application of the current TR

- Removal of ambiguities, clarification of expectations, formalization of processes already in place, …

Consideration of the New Space perimeter

- In-Orbit Servicing, Constellations, Nanosatellites, …

Better consideration of the risk of collision

- Adapt the requirements to international rules, taking into account the current space environment in orbit, …

Identification and tracking of space objects

- Encourage the use of a system facilitating identification and tracking

Restriction of orbital lifetime

- Condition re-entry duration to the duration of the operational mission, …

Higher requirements on probability of successful disposal

- Comply with international guidelines (probability of 0.9 – IADC / ISO)

Focus on main modifications

- Disposal reliability
  - Dedicated requirement for constellations
  - Hardening because spontaneous fragmentation is the major source of increased debris

Single satellite :
- **0,85** (Disposal reliability including passivation and disposal maneuvers)

Single satellite :
- **0,90** (Disposal reliability including passivation and disposal maneuvers)

Constellations :
- Above **0,9** (Disposal reliability including passivation and disposal maneuvers)
- Progressive with an upper limit of **0,95**

- Collision probability
  - Previously only considered with respect to manned objects and geostationary spacecraft
    - ➢ Probability extended to any object larger than 1 cm
    - ➢ Objective to be reached under confirmation via dedicated analysis, a simple estimation will be required for a start
  - Previouly only covering the operational lifetime and 3 days following disposal
    - ➢ Probability extended to the entire orbital lifetime of the space object (for LEO spacecraft)

Objects of size between 1 and 10 cm

- Objects that are currently difficult to detect
- Purely statistical study
- Study on-going until end of the year to provide a dedicated methodology

Objects larger than 10 cm

- Objects taken into account in spacecraft collision avoidance process
- Take into account the methods for managing collision avoidance (in particular adjustment of the PoC threshold and target residual risk)

Focus on main modifications

- Collision management
  - Introduction of requirements to better regulate the risks of collision:
    - ✓ Ensure availability of collision avoidance maneuvers as soon as possible after injection (5 days for single satellites)
    - ✓ Prevent short-term collisions at separation between simultaneously injected objects (5 days), and with respect to manned objects (3 days)
    - ✓ Require coordination in case of collision risk between two maneuvering spacecraft
    - ✓ Limit the orbits accessible to non-maneuvering objects (prohibition above 600 km altitude)

- Devices for identification and tracking
  - Require unambiguous “identification” and knowledge of the object's orbit at the earliest and within 3 days after separation
  - Without necessarily imposing carrying additional on-board systems (e.g. use of SSA systems)

- Limitation of orbital lifetime

Single satellite or “small” constellation	Re-entry requirement in less than 25 years after disposal	Residual orbital lifetime after disposal or from separation for non-maneuvering objects: - 3 times the operational lifetime - Minimum 3 years, maximum 25 years
Large constellation	Not addressed in current version of the TR	Residual orbital lifetime after disposal : - 5 years for constellations with less than 1000 satellites - 2 years for constellations with more than 1000 satellites

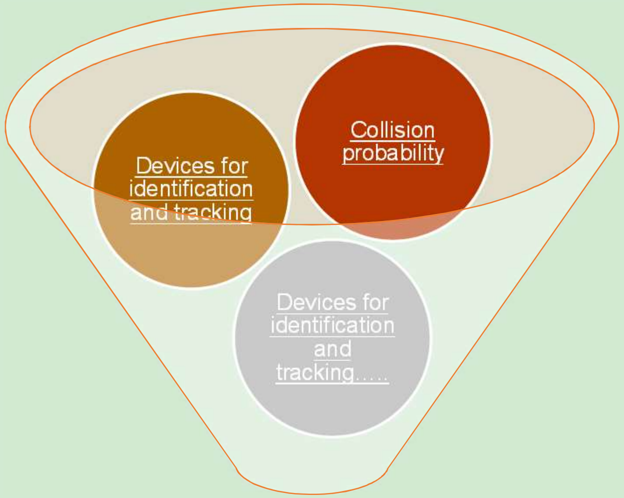
Focus on main modifications

- In-Orbit Servicing
  - Introduction of specific requirements broken down by mission phases
  - Mainly coming from ATV lessons learned and international guidelines (ISO 24330, ESA CPO, CONFERS, …)
  - Focused on limitation of debris generation, e.g.
    - ✓ Collection of intentionally created debris larger than 1mm in their largest dimension
    - ✓ Ensure that entry into safe mode of the Servicer does not induce a collision risk with the Client

- Constellations
  - Introduction of specific requirements
    - ✓ Risks related to the high number of objects in orbit
      - Dedicated rules regarding Disposal reliability and Limitation of orbital lifetime
      - Avoiding threats to people: overall casualty risk over the entire large constellation below 10^{-2} (+ 10^{-4} per spacecraft)
      - Probability of intra-constellation collisions below 10^{-3} until natural re-entry or for 100 years
      - Ensuring sufficient separation within a constellation and between 2 constellations (adequate radial separation or robustness analysis to collision risks)
      - Imposing maneuvrability capacity for the satellites of a large constellation
    - ✓ Securing risks related to flight anomalies
      - Performing system tests in an intermediate orbit allowing a natural reentry in less than 5 years before reaching the operational orbit

- Mission Extension
  - Formalization in the TR of the mission extension process

The aim of Technologies For Space Care (T4SC) program is to develop technological solutions allowing the platforms to comply with the technical regulations of the LOS and their evolutions without harming the competitiveness of national industry.



Technical specifications

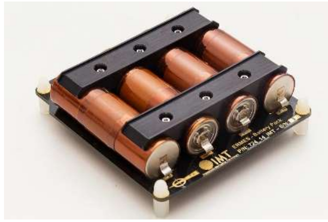
T4SC
Technologies For Space Care

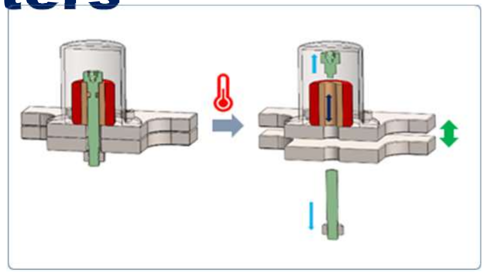
Set of coordinated actions using all the tools and skills available at CNES

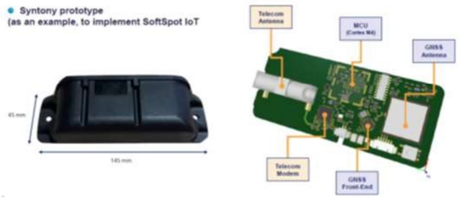
- Push the industry to evolve and develop on these specifications
- Mature these technologies
- Flight demonstration
- Low cost high reliability
- Available in same time as enforcement of the TR

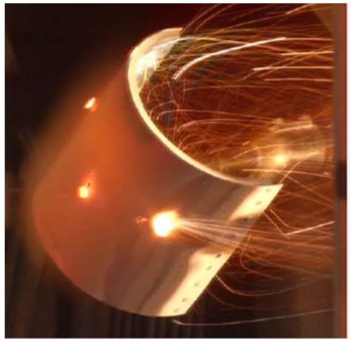
T4SC – technologies have been decomposed in 9 chapters

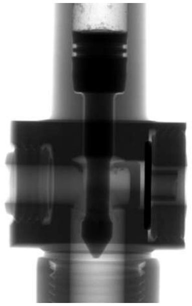
- **T4SC-1 : INCREASE SSA MEASUREMENT**
  - ON BOARD GNSS BEACON
- **T4SC-2 : IMPROVE PASSIVATION AT EOL**
  - AUTONOMOUS PASSIVATION SYSTEMS
- **T4SC-3 : PROTECT AGAIN HIGH VELOCITY IMPACT**
  - METALS AND FLUIDS BEHAVE ALIKE UNDER HYPERVELOCITY IMPACT.
  - EXTREME HYPERVELOCITY RESULTS IN VAPORIZATION OF THE IMPACTOR AND TARGET , MULTI-PHYSIC PHENOMENON
- **T4SC-4 : PREPARE ADR/IOS**
  - DOCKING SYSTEM
  - PROXIMITIES OPERATION SAFETY DEVICES
- **T4SC-5 : DECREASE ORBIT DURATION AFTER EOL**
  - SURFACE INTERACTION BETWEEN MATERIAL AND RAREFIED GAS , DRAG AUGMENTATION DEVICES, ELECTRODYNAMICS SYSTEMS
- **T4SC-6 : MINIMIZE RISK DURING REENTRIES**
  - REENTRY SCIENCE : PLASMA ,RADIATION, HYDRODYNAMICS, THERMAL, COMPRESSIBLE FLOW, DESIGN FOR DEMISE, DESIGN FOR CONTAINMENT
- **T4SC-7 : DEVELOPING ANTI-COLLISION**
  - MACHIN LEARNING THEORIES
- **T4SC-8 : IMPROVE MISSION EXTENSIONS AND FAULT DETECTION**
  - RADIATION EFFECT (SIMULATION, EXPERIMENTS) , EFFECT OF HIGH ENERGY PARTICLE ON EQUIPMENT
- **T4SC-9 : DARKENING LOW-EARTH ORBIT SATELLITE**
  - OPTICAL PROPERTIES OF MATERIAL / COATING











Thank you for your attention !