A07

Brief Overview of the Current Status of Space Traffic Management

○Christophe Bonnal (CNES)

Following the drastic increase in orbital population observed since numerous years now, three key organizations have decided to join their efforts in order to come out with a good synthesis of the situation associated with clear recommendations to deciders, at international level.
IAF, International Astronautical Federation, IAA, International Academy of Astronautics and IISL, International Institute of Space Law, have signed a joint MOU on the subject of STM, Space Traffic Management, asking for a clear presentation of the situation, the lacks, and the solutions within a couple of years.
The most modern topic today is linked to STM, Space Traffic Management, with variants stemming from SST, Space Surveillance and Tracking, SSA, Space Situational Awareness, with variants linked to SEM, Space Environment Management which includes actions such as ADR Active Debris Removal of JCA Just-in-time Collision Avoidance.
A dedicated IAF Technical Committee, TC.26, has started to deal with this important global topic. Some 23 sub-topics have been identified, each with a dedicated working group specifically devoted to it, coming from a very wide span of geographical, gender and generation origins.
The paper will present the status of this international effort, detailing the current achievements and expected calendar.

Biography

Christophe Bonnal

Christophe Bonnal, Senior expert at CNES Launcher Directorate, in in charge of Space Debris topic since 1987. He currently chairs the IAA Space Debris Committee and the IAF TC.26 STM Committee. Member of IAA, AAE, AIAA, 3AF, he is French delegate to IADC, ECSS and ISO.

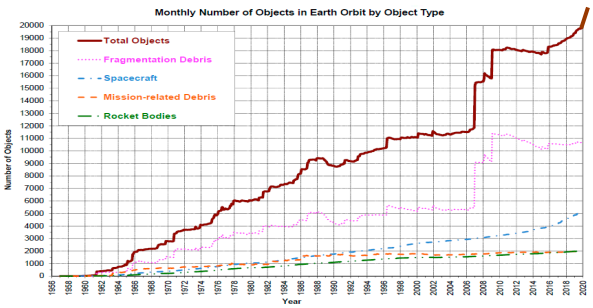
BRIEF OVERVIEW OF THE CURRENT STATUS OF SPACE TRAFFIC MANAGEMENT

JAXA Workshop – Feb. 24th, 2021

Christophe BONNAL AAE, IAA, AIAA, IAF, ISO, ECSS
CNES – Launcher Directorate – Paris, France

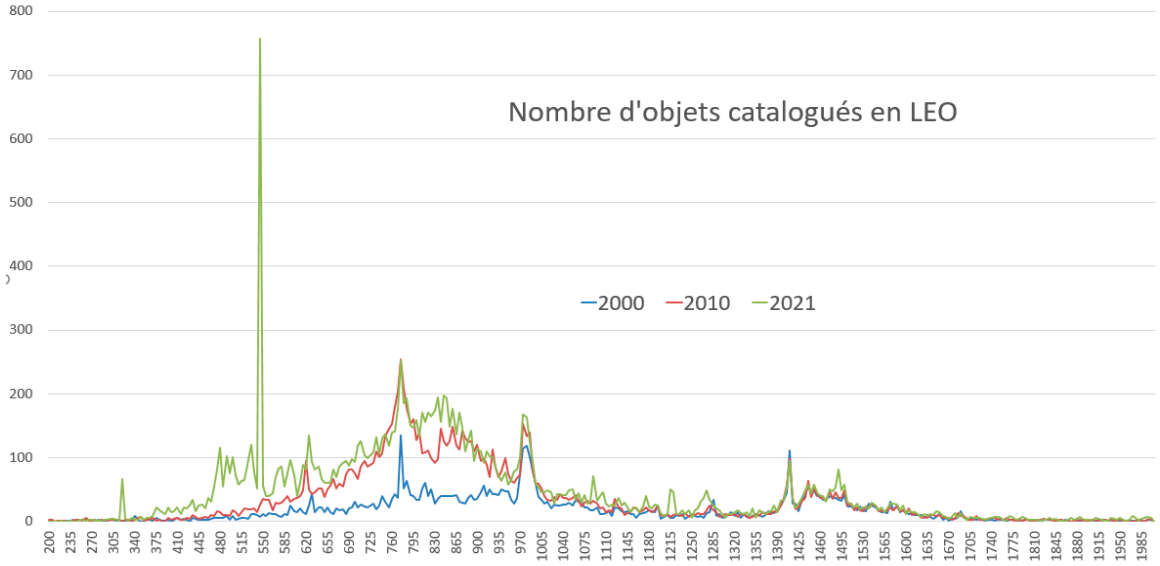
Context

- Rapid increase of the orbital population
  - 34000 objects larger than 10 cm (ESA Master)
  - 22300 cataloged objects (Space-Track)
    - ❖ ≅ 66% of the > 10 cm population
    - ❖ Collisional energy of a 10 cm Steel debris ≅ 500 MJ
  - ≅ 2700 active satellites including 2000 with propulsion
    - ❖ Active satellites ≅ 12% of the cataloged population
    - ❖ Maneuvering satellites ≅ 9% of the cataloged population
      ≅ 6% of the larger than 10 cm population



- Potentially critical evolution, even at short term
  - Large constellations of Telecommunication or Earth Observation satellites:
    - ❖ Already 1,021 Starlink in orbit; 12,000 for 1st generation; 42,000 for 2nd generation
    - ❖ OneWeb, Kuiper, … to come
  - Large number of small satellites, in general with no propulsion on board, as small as 0,25 U
    - ❖ 264 Flock from Planet
    - ❖ 69 Spacebee…

Context



Context

- Major concerns
  - Collisions: uncontrolled increase of the orbital population due to collisions between non-maneuvering objects.
    Risk of Kessler syndrome ⇨ Space Environment Management SEM
  - Collisions: loss of active satellites ⇨ Space Traffic Management STM (or Coordination STC)
  - Atmospheric reentry ⇨ SEM and STM

  ↳ All require a good knowledge and analysis of the orbital population:
  Space Surveillance and Tracking SST et Space Situational Awareness SSA
- Relatively unclear definitions at international level
  - Need identified since a very long time: Space Traffic Control (Nagatomo, 1971)
  - Numerous initiatives, past or ongoing:
    - ❖ International IADC, UN LTS
    - ❖ Standardization ISO WG3, ECSS ad-hoc WG
    - ❖ Academic world AIAA, IAA, SWF, EPSI, IAASS, SSC, WEF, AAE
    - ❖ National CNES, ESA, NASA, JAXA…
  - These groups are very well coordinated, often with the same experts, converge progressively and appear to be coherent

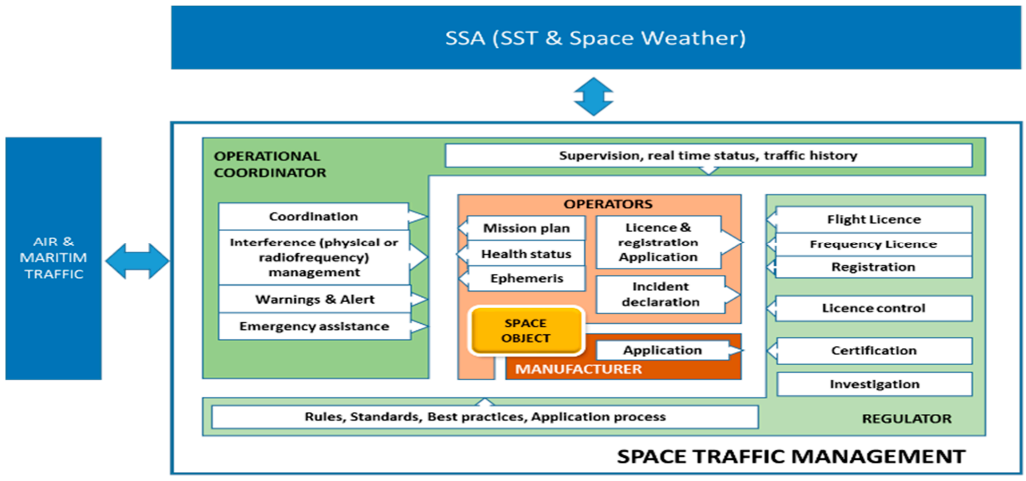
Space Traffic Management in France

- STM-STC is still an open question: the French Space Operations Act is under revision and will include a specific focus of the topic
- Definition of the Space Traffic Management: dedicated activity at CNES level
  - Numerous definitions in the literature: complex subject
  - We did a prospective approach at the horizon of 2030:
    - What are les main objectives of STM?
    - What would be the main services provided by the?
  - CNES Inter-Direction Working Group
    - Numerous meetings necessary to reach a convergence and some consensus
    - Presentation at IAC 2019
    - Publication in Acta Astronautica « *CNES technical considerations on space traffic management » AA 167(2020)296-301*

- High level objectives of STM
  - Coordination and optimization of the use of orbital space,
  - Safety of populations and ground installations, and of active satellites in orbit,
  - Identification of conditions necessary for a sustainable use of space,
  - Definition of common rules for a shared space,
  - Management of the physical interferences in orbit:
    - Coordination of actions for proximity operations, servicing, maintenance, Active Debris Removal ADR
    - Collision Avoidance CA
    - Other interferences, including Radio Frequencies RF, astronomical observations perturbations…

Publication in Acta Astronautica

- Two main domains of responsibilities very distinct: Regulation and Coordination



UNCOPUOS

- Remarkable work: 21 high level requirements covering the complete domain

UN COPUOS Guidelines on Long-term Sustainability of Outer Space Activities

A. Policy and regulatory framework for space activities
- Guideline A.1 Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities
- Guideline A.2 Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities
- Guideline A.3 Supervise national space activities
- Guideline A.4 Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites
- Guideline A.5 Enhance the practice of registering space objects

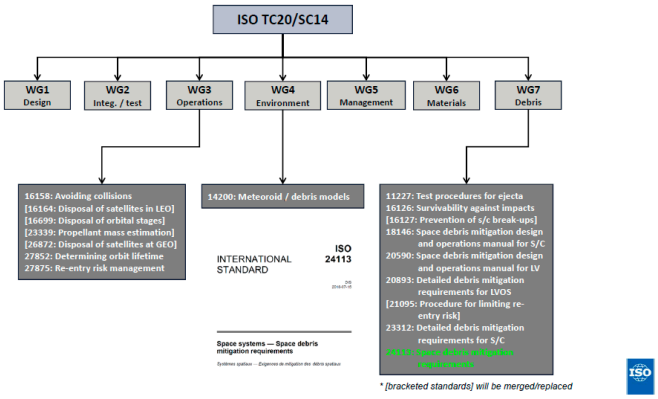
B. Safety of space operations
- Guideline B.1 Provide updated contact information and share information on space objects and orbital events
- Guideline B.2 Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects
- Guideline B.3 Promote the collection, sharing and dissemination of space debris monitoring information
- Guideline B.4 Perform conjunction assessment during all orbital phases of controlled flight
- Guideline B.5 Develop practical approaches for pre-launch conjunction assessment
- Guideline B.6 Share operational space weather data and forecasts
- Guideline B.7 Develop space weather models and tools and collect established practices on the mitigation of space weather effects
- Guideline B.8 Design and operation of space objects regardless of their physical and operational characteristics
- Guideline B.9 Take measures to address risks associated with the uncontrolled re-entry of space objects
- Guideline B.10 Observe measures of precaution when using sources of laser beams passing through outer space

C. International cooperation, capacity-building and awareness
- Guideline C.1 Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities
- Guideline C.2 Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange
- Guideline C.3 Promote and support capacity-building
- Guideline C.4 Raise awareness of space activities

D. Scientific and technical research and development
- Guideline D.1 Promote and support research into and the development of ways to support sustainable exploration and use of outer space
- Guideline D.2 Investigate and consider new measures to manage the space debris population in the long term

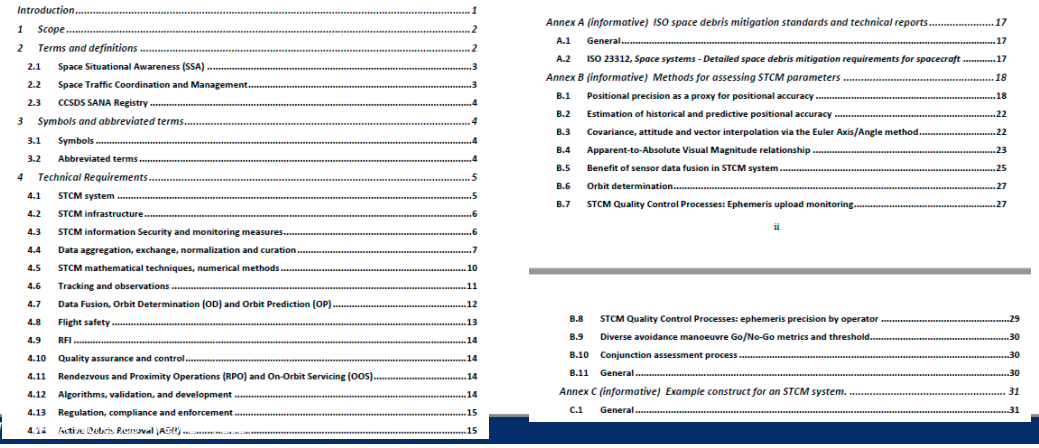
Current standardization activities

- ISO TC20/SC14 – WG3 et WG7
  - TC20 = Aircraft and Space Vehicles
  - SC14 = Space systems and Operations
  - WG3 = Operations and Ground support - WG7 = Orbital debris
- ECSS (European Cooperation for Space Standardization)
  - Two “mirror” working groups in preparation of European position in ISO, one on STM, the other on debris



Current standardization activities

- Preparation of a Standard dedicated to STCM within ISO WG3 (Space Traffic Coordination & Management)
  - NWIP (New Work Item Proposal) #5847 dated May 22nd, 2020
  - Prepared by Dan Oltrogge (AGI, Comspoc)
- Technical content very oriented towards "ground support tools", inspired from US…
  - Numerous meetings at ECSS level but globally negative vote of ISO members on Nov. 18th, 2020
  - Important recall of the independence and individual responsibility of States: No international management
  - New proposal under preparation, limited to Space Traffic Coordination



On-going IAF – IISL - IAA activities

- MOU signed between:
  - IAF (International Astronautical Federation) ⇨ Mostly industrials, operators, manufacturers… (750 member entities)
  - IISL (International Institute of Space Law) ⇨ Legal aspects
  - IAA (International Academy of Astronautics) ⇨ Academic, members are individual experts not representing their entity
- Final goal: preparation of a reference report providing status on STM and suggesting improvements

  IAF, IISL and IAA join in a cooperative initiative to develop comprehensive approaches and proposals for STM to be addressed to decision-makers on national and international level in order to promote the safe use of outer space.
- Creation of a Technical Committee dedicated to the topic within IAF: TC26 on Space Traffic Management
  - Structured following 5 major themes, themselves subdivided into 23 thematic sub-groups
  - 104 active members to date coming from 21 countries
    Good participation of all the key actors identified in previous pages
  - Very good contribution from US, Russia, China, but also India, Japan, ESA and all the European countries…
  - In priority 9 sub-groups (underlined in the list on the right)
    - Prepare an intermediate report for mid-March 2021
    - Final draft report from these 9 expected by October 2021
    - Then Kick-off of the remaining sub-groups
  - Final final report expected to be published by IAC 2022 in Paris

1	Terminology - Common understanding and Definitions
2.1	Improving the knowledge - New technical means of space objects monitoring
2.2	Improving the knowledge - Improve trackability and identification of small objects
2.3	Improving the knowledge - Data fusion - Merging of information
2.4	Improving the knowledge - Improvement of orbital data precision and accuracy
2.5	Improving the knowledge - Improvement of the UN registration
2.6	Improving the knowledge - Shared Catalog
2.7	Improving the knowledge - Hazards associated with reentry
3.1	Space capacity management
3.2	Management of RF interferences
3.3	Improvement of the collision avoidance process
3.4.1	Future operations - Spacetugs, IOS, IOM, IOR
3.4.2	Future operations - Massive constellations
3.4.3	Future operations - Sub-orbital activities
3.4.4	Future operations - Ground support activities such as spaceports
3.4.5	Future operations - Transits through airspace
3.4.6	Future operations - Impact of constellations on Astronomical observations
3.5	Future operations - Preparation of future activities
3.6	Future operations - Traffic from orbit to Moon (and Mars)
4.1	Technical regulations - Current references
4.2	Technical regulations - New activities
4.3	Technical regulations - Effective compliance to Technical Regulations
5	Outreach

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Topics for consideration by the TC

1. Terminology

Common understanding and definitions

Definition of the commonly used terms
Numerous definitions are currently used, slightly different: concepts of Management, Coordination, Control, Synchronization, Regulation, Harmonization, even Environment

[Related to UN LTS #C1]

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Topics for consideration by the TC

2. Improving the knowledge of the orbital population, including functional and non-functional space objects (1/5)

1. New technical means of space objects monitoring

Radars, telescopes, lasers
both ground- and space-based
Including private, e.g. private optical networks and monitoring satellite constellations
↳ Potential recommendation: study and promote additional systems, such as in-orbit sensors, laser detection from ground or from orbit, etc.

[Related to UN LTS #D1 and #D2]

2. Improve trackability and cataloging of small spacecraft

[Related to UN LTS #B8, #D1 and #D2]

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Topics for consideration by the TC

2. Improving the knowledge of the orbital population, including functional and non-functional space objects (2/5)

3. Data fusion - Merging information coming from various sensors

- ↳ Potential recommendation: develop and share methodologies at international level

[Related to UN LTS #B1 and #B3]

4. Improvement of orbital data precision and accuracy

- Improved mathematical models of motion
- Improved computational means and filters
- Use of star background
- Laser ranging from ground or orbit
- Representation of uncertainties
- ↳ May be one of the top priorities

[Related to UN LTS #B2]

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Topics for consideration by the TC

2. Improving the knowledge of the orbital population, including functional and non-functional space objects (3/5)

5. Improvement of the UN registration

- Currently rather poor despite regulation
- Stress the need to record end of operations
- Consider insufficiency, for STM purposes, of the information recommended currently for use in the registration process and identification of space objects

↳ Potential recommendation: unified (accepted worldwide) system of the space objects identification and identity confirmation

↳ Could there be a systematic pre-registration prior to any launch?

[Related to UN LTS #A5 and #C4]

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Topics for consideration by the TC

2. Improving the knowledge of the orbital population, including functional and non-functional space objects (4/5)

6. Shared catalog

. Question of protection of the data: legal solutions?

. Question of maintenance (integrity of data, control of completeness for certain blocks of information, e.g. orbital launch list, payloads etc., common rules for naming/ID assignment for referencing purposes etc., responsibility)

. Question of military systems

. Merging (data fusion, not just using individual outputs) information coming from various independent SSA centers

. Question of the reference source for such catalog (or multiple sources?)

↳ Possibility of cross-correlation of information coming from such “independent” centers due to use of the same batches of measurement information?

[Related to UN LTS #B1]

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Topics for consideration by the TC

2. Improving the knowledge of the orbital population, including functional and non-functional space objects (5/5)

7. Hazards associated with reentry disposal

. Radar and other measurement campaigns to assess and verify reentry hazards prediction models

. Design-for-demise approaches for minimizing reentry hazards

. Design-for-demise concepts

. Flight-verification of Design-for-Demise approaches

. Models predicting hazards to aircraft

[Related to UN LTS #B9]

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Topics for consideration by the TC

3. Use of such information (1/4)

1. Space capacity management

Space Sustainability quantification
Space Traffic assessment
Capacity coordination

- Potential recommendation: additional LTS guidelines to be considered by COPUOS

[Related to UN LTS #A4 and #C3]

2. Management of RF interferences

[Related to UN LTS #A4]

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Topics for consideration by the TC

3. Use of such information (2/4)

3. Improvement of the collision avoidance process

1. Probability evaluation and common understandings
2. Specific problematic associated with electric propulsion on large constellations
3. Maneuver coordination
4. Assessment prior to a launch

- Potential recommendation: sharing at ISO level through dedicated technical standards

5. Thresholds for Collision Avoidance,
6. Data exchange protocols

- Potential recommendation: harmonization at international level (IADC, ISO)

[Related to UN LTS #B1, #B3, #B4 and #B5]

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Topics for consideration by the TC

3. Use of such information (3/4)

4. Use for future operations

1. Spacetugs, In Orbit Servicing, In Orbit Manufacturing, In Orbit Recycling
2. Massive constellations, including such aspect as use of AI in on-board control systems for autonomous decision making (without involvement of ground control services), especially in case of collision avoidance
3. Sub-orbital activities
4. Ground support activities such as spaceports
5. Transits through airspace (launch and controlled/uncontrolled re-entry)

6. Impact of Constellations on Astronomical observations
Question at STAC astronomy committee on how we could limit light interference to astronomy observations by satellite constellations

[Related to UN LTS #A4, #B8, #D1 and #D2]

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Topics for consideration by the TC

3. Use of such information (4/4)

5. Preparation of future activities

1. ADR: Removal of the relevant debris from crowded orbits to avoid statistical collisions
2. JCA: Nudging of a debris to avoid a predicted collision
3. LDTM: Cataloging and maintenance of precise orbits of large orbital debris and light nudging to avoid further critical situations

➢ Potential recommendation: identify a shared position at international level (IAA studies, IADC tasks, National studies, …)

[Related to UN LTS #D1 and #D2]

6. Traffic from orbit to the Moon (and in the future to Mars)

How to minimize perturbations to the natural environment and useless debris left at the surface?

[Related to UN LTS #A4]

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Topics for consideration by the TC

4. Technical regulations (1/3)

1. **Current references**
   - ↳ Can be based on ISO?

   Converged at international level since more than 10 years
   Coherent with IADC and National Standards established 20+ years ago
   Already applied by ESA and China
   Strong similarities with other International Standards and Laws
   Dedicated WG on STM within ISO WG3

Numerous new ongoing activities

ISO standard for collision probability calculation and impact risk assessment
- Inclusion of a threshold in the standard

ISO standard for the casualty risk calculation
- Inclusion of a threshold in the standard

[Related to UN LTS #A1 and #C1]

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Topics for consideration by the TC

4. Technical regulations (2/3)

2. But new activities required

Shall include elements related to Space Tugs, IOS, ADR, JCA, LDTM
Shall include sub-orbital
Can include criteria for risk based evaluations, and acceptance, of certain operations
May include Spaceports
Open to extension of the domain to Moon and Mars

[Related to UN LTS #A1]

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Topics for consideration by the TC

4. Technical regulations (3/3)

3. Major question: why are the Mitigation Rules so badly complied to?

Immature on-board technology for mitigation? Impact on performances?
Examine how changes to debris mitigation guidelines reduces STM burdens

↳ Potential recommendation: Education: Systematic inclusion of ISO in any contract

↳ Potential recommendation: Naming & Shaming (Naming already done at IADC level…)

↳ Potential recommendation: Compliance file prepared before any space operation, transparent follow-up by the launching state

[Related to UN LTS #A3]

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Topics for consideration by the TC

5. Outreach

Need to improve the dissemination of information

How to pass efficiently the messages and reach consensus over the proposed actions?

Who should we address, when, where, at which step of discussion: An essential link to operators is required, as they will be affected most.

This might require some dedicated fora / workshop with discussions on this topic as sole focus.

[Related to UN LTS #C4]

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Congress – Conferences – Symposia – Colloquium - Workshops…

- Very dynamic activity at international level
- Numerous congress or similar on the topic:
  - International Astronautical Congress IAC
    - 11 sessions every year, covering all the Space Debris topics, but also SST-SSA-SEM-STM
    - Numerous associated publication in Acta Astronautica
  - International Association for the Advancement of Space Safety
    - Covers well all the Space Debris field, mainly under the Safety aspects
    - Well implicated in the Regulation aspects
    - Good publications in Journal of Space Safety Engineering JSSE
  - IAA
    - International congress every two years devoted to SSA-STM
    - STM Conference organized every two years at University of Texas
  - ESA Space Debris Conference in Darmstadt
    - Every 4 years since 1993
    - Reference conference on the topic of debris in its "wide" understanding, including SST-SSA-SEM-STM
  - International workshops organized by CNES, each every two years
    - Collision Avoidance
    - End of Life of Satellites
    - Modeling and Remediation
  - International workshop organized by JAXA every two years, covering all domains
  - Very high number of Webinars and similar since mid-2020, always with the same speakers and messages…

Thank you for your attention

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