Requirements for Debris Mitigation

IISL-ECSL Space Law Symposium 2014

Christophe BONNAL

CNES Launcher Directorate
IADC WG4 French Delegate
Chairman – IAA Space Debris Committee

Vienna, March 24th, 2014
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1. **IADC chronology**

1st ESA-NASA Orbital Debris Coordination Meeting in October 1987

- Held in Rolleboise (France)
- Exchange opinions, present study results, discussions and identification of contact points
- 6000 cataloged objects at this date
- Following sentence interesting to note:

> Ultimately regulations for the conduct of space operations could become necessary. As being premature, this point was not addressed in the meeting.

- **ESA side:**
  - Space Debris Working Group SDWG
  - Working Group on Re-orbiting of Geostationary satellites
  - Activities on Hyper-Velocity Impacts and monitoring of non-cooperative objects

- **NASA Orbital Debris program:**
  - Improved definition of the environment – Maintain orbital debris data base
  - Studies on damage potential and protection techniques
  - Estimate the hazard for future use of Space
  - Recommend approaches for control of debris and mitigation of its effects

7th Coordination Meeting on Space Debris ESA-NASA-Japan in February 1992

- **Inclusion of Japan in the Coordination Meeting**
- Held in Noordwijk (Netherlands)
- 6800 cataloged objects at this date
1. IADC chronology

9th Coordination Meeting on Space Debris ESA-NASA-Japan-RKA in April 1993

- Inclusion of Russian Space Agency in the Coordination Meeting
- Held in Darmstadt (Germany)
- 7130 cataloged objects at this date
- NASA draft “Orbital Debris Handbook Guidelines”
- ESA draft “Orbital Debris Preventative Requirements” in PSS-01-40
- NASDA “Debris Mitigation considerations of the H-II program”

2nd Meeting of the Inter-Agency Space Debris Coordination Committee in November 1993

- Held in Moscow (Russia) between ESA-NASA-Japan-RKA
- First Terms of Reference of the IADC
  - Review all ongoing cooperative space debris research activities between member organizations
  - Recommend new opportunities for cooperation
  - Serve as primary means for exchanging information
  - Identify and evaluate options for debris mitigation

- Four Working Groups:
  - WG1 – Measurements
  - WG2 – Environment and Database
  - WG3 – Testing and Shielding
  - WG4 – Mitigation

- 7500 cataloged objects at this date
- 2nd official IADC, but renamed 10th IADC afterwards
1. IADC chronology

13th Meeting of the IADC in February 1996

- Held in Darmstadt (Germany)
- Inclusion of CNSA (China), CNES (France), BNSC (UK) and ISRO (India) ⇒ 9 members
- Steering Group added to the Terms of Reference
- Numerous activities related to Space Debris mitigation
- Numerous practical examples of applications in space programs
- 1st invitation to present IADC activities to UNCOPUOS 1997 session
- 8005 cataloged objects at this date

20th Meeting of the IADC in April 2002

- Held in Guilford (United Kingdom)
- 11 members: ASI, BNSC, CNES, CNSA, DLR, ESA, ISRO, Japan, NASA, NSAU, RASA
- Approval by the Steering Group of the IADC Guidelines prepared by WG4 (AI 17.2)
  ⇒ 3 years convergence process
  ⇒ Unanimous approval of the 11 delegations
- Drafting of the IADC Guidelines Support Document (= Justification)
- Approval of the Work Plan for Action Item 18.4 devoted to Small Satellites
- 8890 cataloged objects at this date
2. **First Mitigation Standards**

**NASA Safety Standard 1740.14**

- Guidelines and Assessment Procedures for Limiting OD (August 1995)
- Following NASA Management Instruction (NMI) 1700.8 (April 1993)
- **Guidelines for:**
  - Depleting on-board energy sources after completion of mission
  - Limiting orbit lifetime after mission completion to 25 years or maneuvering to a disposal orbit
  - Limiting the generation of debris associated with normal space operations
  - Limiting the consequences of impact with existing orbital debris or meteoroids
  - Limiting the risk from space system components surviving reentry as a result of postmission disposal

**NASDA STD-18**

- **Space Debris Mitigation Standard (March 1996)**
- **Contents:**
  - Preventing the space systems after the end of its mission from on-orbit breakup which generates a large amount of debris
  - Transferring a post-mission spacecraft that has been operated on geostationary earth orbit into higher orbit in order to preserve GEO environment
  - Reducing the time during which the upper stage left on geostationary transfer orbit (GTO) would interfere with GEO to preserve GEO environment
  - Minimizing objects released on orbit during operation of a space system
  - Reducing the time during which a post-mission space system would interfere with useful orbit region; 25-years rule in LEO
2. First Mitigation Standards

CNES MPM-51-00-12

- Exigences de sécurité - Débris spatiaux (Space Debris – Safety Requirements) (March 1999)
- Approved by CNES DG (Gérard Brachet)
- 3 sets of Requirements:
  • Management Requirements (Space Debris Manager for each program, Mitigation Plan)
  • Design Requirements (Limitation by design of debris generation, casualty risk)
  • Operational Requirements (Passivation, Protected Zones, 25-year rule, GEO rule)

ESA Space Debris Mitigation Handbook

- 1st Issue: April 1999
- Not a Standard, but included numerous guidelines and techniques for limiting the number of debris

European Space Debris Mitigation Standard: EDMS (1/0)

- Prepared by 5 European Agencies: ASI, BNSC, CNES, DLR, ESA
- 1st official issue: September 2000
- Derived from the CNES Standard: basically same content
- Led to the European Code of Conduct April 2004
3. IAA Position Papers

Four documents as catalysts for forward-thinking

- Recognition → Characterization → Mitigation → Remediation
- Compiled by Ad-Hoc Expert Group, then IAA Space Debris Committee


- Three families of options:
  - Category I: should do immediately - require minimal technology development or cost
  - Category II: consider later - require moderate technology development and/or cost
  - Category III: consider later - require significant technology and cost

<table>
<thead>
<tr>
<th>Category I</th>
<th>Category II</th>
<th>Category III</th>
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</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>Secondary</td>
<td>Long-Term</td>
</tr>
<tr>
<td>Low $/Little Technology Development Needed</td>
<td>Mod $/Some Development Needed</td>
<td>High $/Significantly Technology Development Needed</td>
</tr>
</tbody>
</table>

**Actions**

- 1. No deliberate breakups
- 2. Minimize operational debris
- 3. Vent LEO rocket bodies (R/B)
- 4. Minimize GTO lifetimes
- 5. Reorbit dead GEO payloads (P/L)
- 6. Separate kick motors into super-synchronous orbit (SSO)
- 7. Vent GEO rocket bodies and move to SSO

- 1. Removal within 3 months of all R/B’s and defunct P/L’s in LEO if lifetime exceeds 10 years
- 2. Removal of all R/B’s and P/L’s in GTO and highly elliptical orbits within 10 years
- 3. Reorbit R/B’s and P/L’s outside of LEO into a disposal orbit
- 4. Deorbit hardware into oceans to reduce ground hazard

- 1. Develop propulsive deorbit capability
- 2. Develop drag augmentation systems for removal
- 3. Develop grappling and detumbling devices plus tethers for removal
- 4. Develop laser removal
- 5. Develop effective sweepers that can avoid collisions
3. IAA Position Papers


- Implementing Zero Debris Creation Zones
- Proposed two space regimes to protect through zero debris creation mandates
  LEO: Up to 2000km
  GEO: ± 200km altitude and ± 15° latitude

<table>
<thead>
<tr>
<th>Debris Mitigation Guidelines</th>
<th>Hardware Design</th>
<th>Mission Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacecraft</td>
<td>Minimize debris releases</td>
<td>Eliminate energy sources (after use)</td>
</tr>
<tr>
<td></td>
<td>Remove from orbit</td>
<td></td>
</tr>
<tr>
<td>Launchers</td>
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</tbody>
</table>

IAA Position Paper on Space Debris Remediation (2013)
IAA study on Orbital Debris Removal: Policy, Legal, and Economic Considerations
⇒ Ongoing
IAA Reference Report on Space Debris ⇒ Ongoing

Thanks to Darren McKnight (IAA) for the help with these charts...
4. IADC Guidelines

IADC Space Debris Mitigation Guidelines

- First Issue: October 2002
- Approved by consensus by the 11 IADC delegations
- 3 fundamental principles:
  - Preventing on-orbit break-ups
  - Removing spacecraft and orbital stages that have reached the end of their mission operations from the useful densely populated orbit regions
  - Limiting the objects released during normal operations.
- Content:
  - Definition and content of the Space Debris Mitigation Plan
  - Any release of debris should be minimised in number, area and orbital lifetime
  - The potential for break-ups during mission should be minimised
  - All space systems should be designed and operated so as to prevent accidental explosions at end-of-mission
  - Intentional destructions, which will generate long-lived orbital debris, should not be planned or conducted.
  - Passivation at end of mission
  - Risk at reentry: casualty risk and information in case of controlled re-entry
  - Post Mission Disposal:
    - GEO rule for re-orbitation
    - LEO 25-year lifetime reduction rule
  - Prevention of on-orbit collisions
- Revised in 2007
- Support Document under finalization

<table>
<thead>
<tr>
<th>Region A</th>
<th>Region B</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°</td>
<td>15°</td>
</tr>
<tr>
<td>Z = Z_{GEO} + 200km (LEO)</td>
<td>Z = Z_{GEO} - 200km</td>
</tr>
</tbody>
</table>

Z = 200km (LEO)
5. **IADC Guidelines follow-up**

**UNCOPUOS Guidelines for Space Debris Mitigation**

- Working group started in 2002 following IADC Guidelines
- Final approved document in February 2007
- 7 guidelines:
  1. Limit debris released during normal operations
  2. Minimize the potential for break-ups during operational phases
  3. Limit the probability of accidental collision in orbit
  4. Avoid intentional destruction and other harmful activities
  5. Minimize potential for post-mission break-ups resulting from stored energy
  6. Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission
  7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission

- **Globally coherent with the IADC Guidelines:**
  
  ⇒ But unfortunately no mention of the 25 years rule
  ⇒ Would benefit from a clarification on this point
5. IADC Guidelines follow-up

Laws, Standards, Guidelines, Code of Conducts, Recommendations…

- **Russian Orbital Debris Standard GOST R:**
  - Official title: General Requirements on Space Systems for the Mitigation of Human-Produced near-Earth Space Pollution
  - Prepared in 2007
  - “Classical” requirements: No debris generation, passivation, GEO rule, LEO 25-year rule

- **French law on Space Operations:**
  - Prepared in 2008
  - Active since December 2010
  - Numerous aspects associated to Space Debris
  - Certification process at every launch of french spacecraft, or launch from French Guiana

- **ESA/ADMIN/IPOL(2008)2:**
  - Official set of Requirements for ESA since April 2008
  - “Classical” requirements: No debris generation, passivation, GEO rule, LEO 25-year rule

- **US FCC: Notice of Proposed Rule Making in the matter of Mitigation of Orbital Debris:**
  - First draft March 2002 – Final document June 2004

- Etc…
5. **IADC Guidelines follow-up**

**ISO standardization**

- High level standard ISO 24113
- Second level documentation for requirements implementation or scientific data
6. Regulatory needs for very small satellites

IADC Action 18.4

- Proposed in June 2000 in Colorado Springs (USA)
- Goal:
  To assess the impact of small satellites (and small satellite constellations) on the long-term evolution of the space debris environment in LEO, by examining current and planned small satellite traffic, and to discuss disposal practices for small satellites.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Small Mass, kg</th>
<th>Size Minisat</th>
<th>Satellite Microsat</th>
<th>Nanosat</th>
<th>Picosat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass &lt; 1000</td>
<td>&lt; 500</td>
<td>&lt; 100</td>
<td>&lt; 10</td>
<td>&lt; 1</td>
<td></td>
</tr>
</tbody>
</table>

- Work Plan:
  • Phase 1  Survey on the technology of small satellite design and operation
  • Phase 2  Modelling of the debris environment due to different small satellite launch traffic, operational lifetimes and mitigation measures
  • Phase 3  Observation and tracking of nano- and pico-satellites
  • Phase 4  Produce a report on the influence of small satellites on the space debris environment

- Numerous contributions during 3 years:
  • 9 delegations involved in a detailed questionnaire + simulations
  • Important simulation work from WG2

- Note: Study led long before emergence of Cubesats – Hardly no satellite smaller than 50 kg at that time
6. Regulatory needs for very small satellites

IADC Action 18.4

Summary of the Study:

III. SUMMARY: Influence of Small Sat on Space Debris Population

- Future launches of Small Sat will not produce operational debris.
- Accidental explosions or self-destruction events of Small Sat will be absent.
- Repositioning maneuver is not planning.
- In case of small, mini- and micro-sat the procedures of re-orbiting and de-orbiting will be in accordance with national and IADC recommendations.
- Femto-, pico- and as a rule nano-sat will be designed without propulsion system. Their re-orbiting will be achieved as a result of passive deceleration in upper atmosphere.

Final Report issued in March 2003 (226 pages):
- A small satellite, whatever its size, is a satellite and its design and operation shall be compliant with the applicable Rules, Guidelines, Laws, Codes of Conduct…
- No dedicated regulatory needs
- When small sats have no propulsion on-board, they shall be left on an orbit reentering in less than 25 years

- 8391 cataloged objects at this date
7. Conclusion

Wide range of regulatory documentation

- **Diverse types:**
  - National Standards, Codes of Conduct, Laws, Guidelines
  - International Guidelines: IADC, UN
  - International Standards: ISO

- **No dedicated rules for small-micro-nano-pico satellites**

- **Improvable application of the mitigation rules:**
  - Roughly 50 to 60% of LEO objects are compliant with the 25-year rule (Requirement = 90%)
  - Among which vast majority of naturally compliant due to orbit

- 16918 cataloged objects today...

  ⇒ Need to be more rigorous at international level on the application of mitigation rules
Thank you for your attention

Any question is welcome

Christophe.bonnal@cnes.fr