International Academy of Astronautics

Inter-Agency Space Debris Coordination Committee

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

Table of Contents

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 Data base
  - 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**

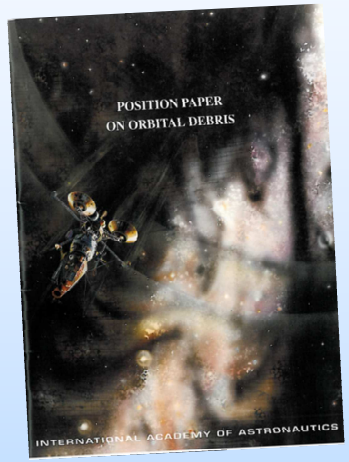
European Space Debris Mitigation Standard: EDMS (1/0)

- **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

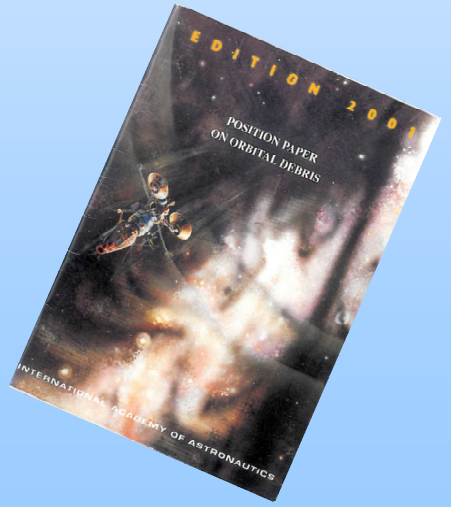
- **Recognition → Characterization → Mitigation → Remediation**
- **Compiled by Ad-Hoc Expert Group, then IAA Space Debris Committee**



IAA Position Paper on Space Debris (1993, Revised in 2001)

- **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

	Category I Immediate Low $/Little Technology Development Needed	**Category II** Secondary Mod $/Some Development Needed	**Category III** Long-Term High $/Significantly Technology Development Needed
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

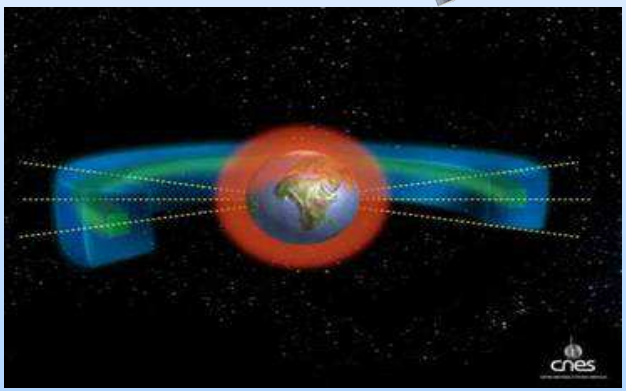


3. IAA Position Papers

IAA Position Paper on Space Debris Mitigation (2005)

- **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

Debris Mitigation Guidelines	Hardware Design	Mission Operations
Spacecraft	*Minimize debris releases* *Eliminate energy sources (after use)* *Remove from orbit*	
Launchers		



IAA Position Paper on Space Debris Remediation (2013)

IAA study on Orbital Debris Removal: Policy, Legal, and Economic Considerations

⇨ Ongoing

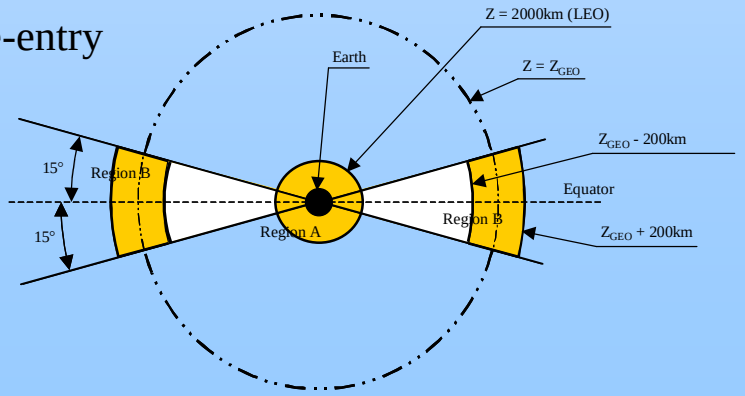
IAA Reference Report on Space Debris ⇨ Ongoing

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**



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

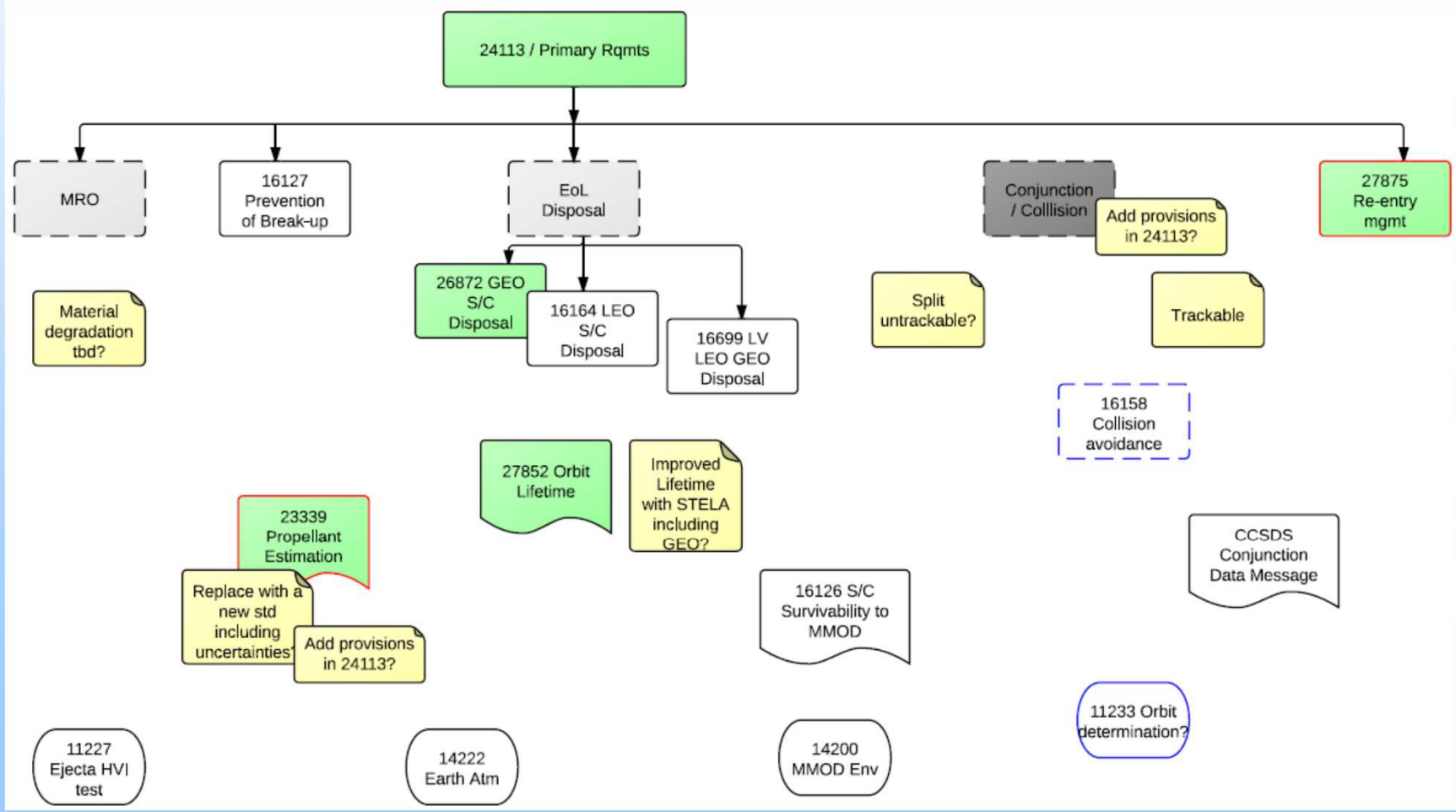
- **US FCC: Notice of Proposed Rule Making in the matter of Mitigation of Orbital Debris:**
  - First draft March 2002 – Final document June 2004

- **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.

Small Size Satellite					
Designaion	-	Minisat	Microsat	Nanosat	Picosat
Mass, kg	<1000	< 500	< 100	< 10	< 1

- **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**

International Academy of Astronautics

Inter-Agency Space Debris Coordination Committee

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

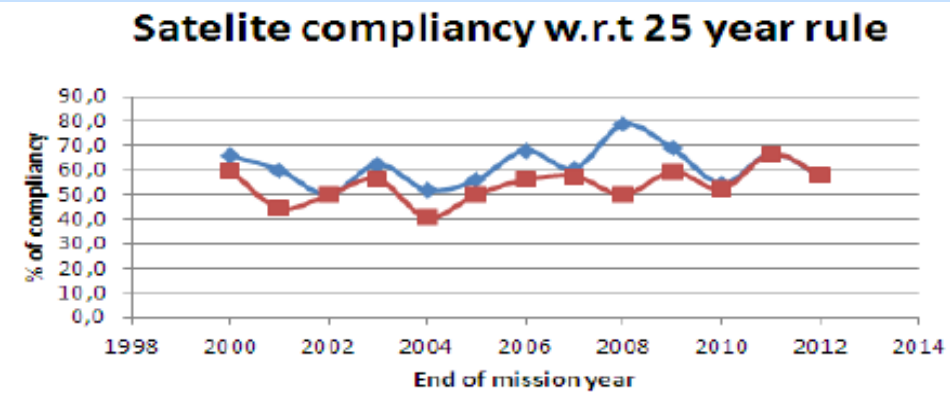
- Future launches of Small Sat will not produce operational debris.
- Accidental explosions or self-destruction events of Small Sat will be absent.
- Repositioning maneuver is not planning.
- In case of small, mini- and micro- sat the procedures of re-orbiting and de-orbiting will be in according with 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.

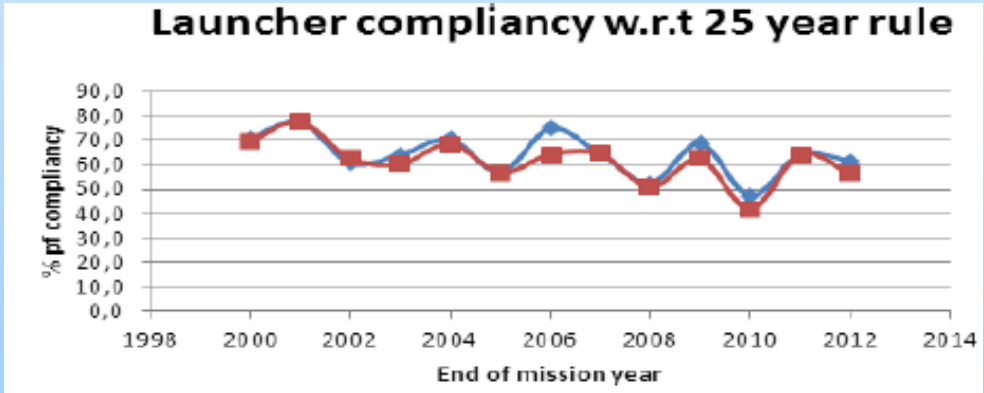
- **Final Report issued in March 2003 (226 pages):**
  - A small satellite, whatever its size, is a satellite and its design and operation shall be compliant with the applicable Rules, Guidelines, Laws, Codes of Conduct…
  - No dedicated regulatory needs
  - When small sats have no propulsion on-board,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





From V. Morand – JC. Dolado-Perez & DA. Handschuh CNES – 5th End of Life Workshop – Paris, January 2014

- **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