# A BRIEF HISTORICAL OVERVIEW OF SPACE DEBRIS MITIGATION RULES

CLEAN SPACE INDUSTRIAL DAYS

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# EARLY WORKS, INITIAL STANDARDS

## First concerns in early 70s', mainly at NASA level :

⇨ Brooks, David R.; Gibson, Gary G.; and Bess, T. Dale: Predicting the Probability That Earth-Orbiting Spacecraft Will Collide With Man-Made Objects in Space. [IAF Paper] A74-34, Sept.-Oct. 1974.

⇨ Brownlee,D.E. ; Tomandl,D.A. ; Hodge,P.W.
The Flux of Meteoroids and Orbital Debris Striking Satellites in Low Earth Orbit
Nature 323, pp 136-138, 1974

⇨ Bess,T.D.
Mass Distribution of Orbiting Man Made Space Debris
NASA TN D-8108 , Dec. 1975

3700 cataloged debris
900 tons in orbit

- First collision models
- First debris propagation models
- First orbital density models
- Comparison with micro-meteoroids
- Initial development of "EVOLVE" tool

↳ **However, no recommendations yet, just facts!**

# EARLY WORKS, INITIAL STANDARDS

## Early publications at international level:

⇨ Collision Frequency of Artificial Satellites: The Creation of a Debris Belt

DONALD J. KESSLER AND BURTON G. COUR-PALAIS

*NASA Johnson Space Center, Houston, Texas 77058*

- Early identification of potential problem (**1978**) [1]
- Potential cascading effect
- ⇨ **First recommendations!**
  - . to "deorbit" at end of mission,
  - . to avoid explosions and collisions

**5200 cataloged debris**
**1400 tons in orbit**

Various methods to stop or slow the formation of a debris belt should be studied. The model suggests that the most effective way would be to keep the number of large objects as small as practical. This could be accomplished by planning launches so that large objects can be caused to reenter when their usefulness is complete or by using the space shuttle concept to retrieve objects in orbit which no longer serve a useful function. Since it is impractical to retrieve the much larger number of large and small fragments, every effort should be made to prevent their production in space, either by explosion or by collision.

[1] Journal of Geophysical Research, June 1st, 1978, Vol 83, No A6

# EARLY WORKS, INITIAL STANDARDS

## Dissemination of the information at international level in early 80s':

⇨ Reynolds, R.C., Fischer, N.H., and Edgecombe, D.S.: A Model for the Evolution of the On-Orbit Man-Made Debris Environment. Proceedings of the NASA/JSC Orbital Debris Workshop, NASA Conference Publication 2360, 1982, pp. 102-132.

⇨ Kessler, D.J.: Orbital Debris Environment for Space Station. JSC 20001, 1984.

⇨

| | | |
|---|---|---|
| Kessler et al, ORBITAL DEBRIS (NASA CP 2360) | GENERAL | 1985 |

⇨

| | | |
|---|---|---|
| Shin-Yi Su, ORBITAL DEBRIS ENVIRONMENT RESULTING FROM FUTURE ACTIVITIES IN SPACE NASA IAA JOURNAL | GENERAL | 30.6.86 |

⇨ Kessler, D.J., Reynolds, R.C., and Anz-Meador, P.D.: Orbital Debris Environment for Spacecraft Designed to Operate in Low Earth Orbit. NASA TM 100-471, 1988.

⇨

| | | |
|---|---|---|
| ESA-SP-1109, SPACE DEBRIS The Report of the ESA Space Debris Working Group | GENERAL | Nov. 88 |

- General description of Space Debris environment
- Modelling
- First recommendations for Space Station

**6300 cataloged debris in 1982**
**1600 tons in orbit**

# EARLY WORKS, INITIAL STANDARDS

## First major synthesis in Europe:

**SAFE DISPOSAL OF ORBITING SYSTEMS AND SPACECRAFT - INCLUDING THE PREVENTION OF DEBRIS CREATION**

7500 cataloged debris
2500 tons in orbit

- 1987 - 1989
- ESA Contract from Pr. Walter Flury to European Industry
- Study led by MBB-ERNO
- Covering all kind of satellite and launcher missions
- Recommendations, element per element, including Envisat…
- Identification of the “classical” mitigation measures:
  - . Passivation
  - . Deorbiting of large spacecraft
  - . No intended release of operational debris
  - . Long term integrity of systems
  - . End of Life operations to be performed part of nominal operations
  - . Debris avoidance (longer term)

1. Safe Disposal of space systems shall be performed at the end of its mission.

1a Space systems in LEO below 800 km and in GTO shall be designed for either a controlled destructive re-entry into the atmosphere (example: re-entry of PPF) or a retrieval (by another space system or by itself, examples: retrieval of APM, retrieval of EURECA) to earth, the latter one being the preferred

# EARLY WORKS, INITIAL STANDARDS

**First standard in Europe:**

⇨ System safety requirements for ESA space systems

- ESA-PSS-01-40 Issue 2, September **1988**
- Not devoted to Space Debris, but includes numerous associated requirements
  - . Controlled reentry for hazardous space systems, deorbiting
  - . Proper mastering of collision risks, passivation
- Probably too theoretical and not applicable

8600 cataloged debris

2700 tons in orbit

**II – 1.6.2** Means shall be provided to prevent the hazardous descent of debris as the result of a launch vehicle launch abort, or the uncontrolled de-orbiting or orbital decay of spacecraft, or space system elements that are likely to survive re-entry.

**II – 1.6.4** The creation of space debris in orbits that repeatedly intersect orbital paths used by space systems shall be avoided.

**II – 3.1.1.3** Orbiting spent stages shall have the capability of being safely de-orbited.

**II – 3.1.2.5** Residual propellants contained in spent or aborted stages shall be safely dispersed.

# NATIONAL STANDARDS

## NASA Standard (1995):

9000 cataloged debris

3800 tons in orbit

**Guidelines and Assessment Procedures for Limiting Orbital Debris**

- 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 Standard (1996) NASDA-STD-18:

(1) Preventing the space systems after the end of its mission from on-orbit breakup which generates a large amount of debris

(2) Transferring a post-mission spacecraft that has been operated on geostationary earth orbit (GEO) into higher orbit in order to preserve GEO environment

(3) Reducing the time during which the upper stage left on geostationary transfer orbit (GTO) would interfere with GEO to preserve GEO environment

(4) Minimizing objects released on orbit during operation of a space system

(5) Reducing the time during which a post-mission space system would interfere with useful orbit region

# NATIONAL STANDARDS

## CNES RNC-Q-40-512:

Applicable by decision of DG 18 June **1999**

Structured into 3 parts:

- Management
- Design
- Operations

11000 cataloged debris

4500 tons in orbit

## DLR RF-0S-001

Latest issue: (7) August 2012

## ECSS-Q-40-A

Evolution of the PSS-01-40 applicable to ESA (April 1996)

## Russian GOST –P - 52925-2008

General Requirements on Space Systems for the Mitigation of Human-Produced near-Earth Space Pollution (**2009**)

**South-Korea:** under preparation

15000 cataloged debris

5800 tons in orbit

## Relatively good coherence of standards at national level

↳ Decision to prepare International standards

# IADC - UNCOPUOS

## IADC (Inter-Agency Space Debris Coordination Committee):

- Initial meetings starting in 1987 between NASA and ESA
- Officially 1st IADC meeting in Moscow 1993
- 34 meetings so far; now once per year
- 13 countries (including ESA) today
- 4 Working Groups + Steering Group
  - WG1: Measurements
  - WG2: Environment and Data Base
  - WG3: Protection
  - WG4: Mitigation
- IADC Space Debris Mitigation Guidelines
  - 5 years convergence
  - Unanimously approved in **2002**, revised in 2007

**11000 cataloged debris**

**4900 tons in orbit**

## UN Guidelines:

- Elaborated by UNCOPUOS on the basis of IADC Guidelines
- Published in 2007
- No mention of 25-year rule

# THE MAKING OF ISO-24113

## European Space Debris Mitigation Standard EDMS(1998):

- 5 years work to prepare EDMS
- Vol.1 = Standard
- Vol.2 = Explanations and Guidelines for implementation
- Edition 1.7 ready for approval on July 1st, **2002**

  ↳ but, not allowed to write standards!

10000 cataloged debris

4200 tons in orbit

## European Code of Conduct ECoC (2003) :

- From Sept. 2003 to June 2004
- Replacement of all “shall” by “should”
- Major 3 days workshop with Industrials in December 2003
- Approval ASI-BNSC-CNES-DLR-ESA on 26 July **2004**
- Issue 2 in August 2005
- Volume 2 “Support to Implementation of ECoC”

11000 cataloged debris

4800 tons in orbit

## ↳ Used as initial text for ISO 24113

# ISO-24113

## ISO-24113 = High level standard:

- Lengthy process from 2005 to formal issue in February **2010**
- Family of “second level” standards
- Currently under revision

↳ Major evolution to include all “second level” standards

17500 cataloged debris

6000 tons in orbit

## Adopted by ESA through:

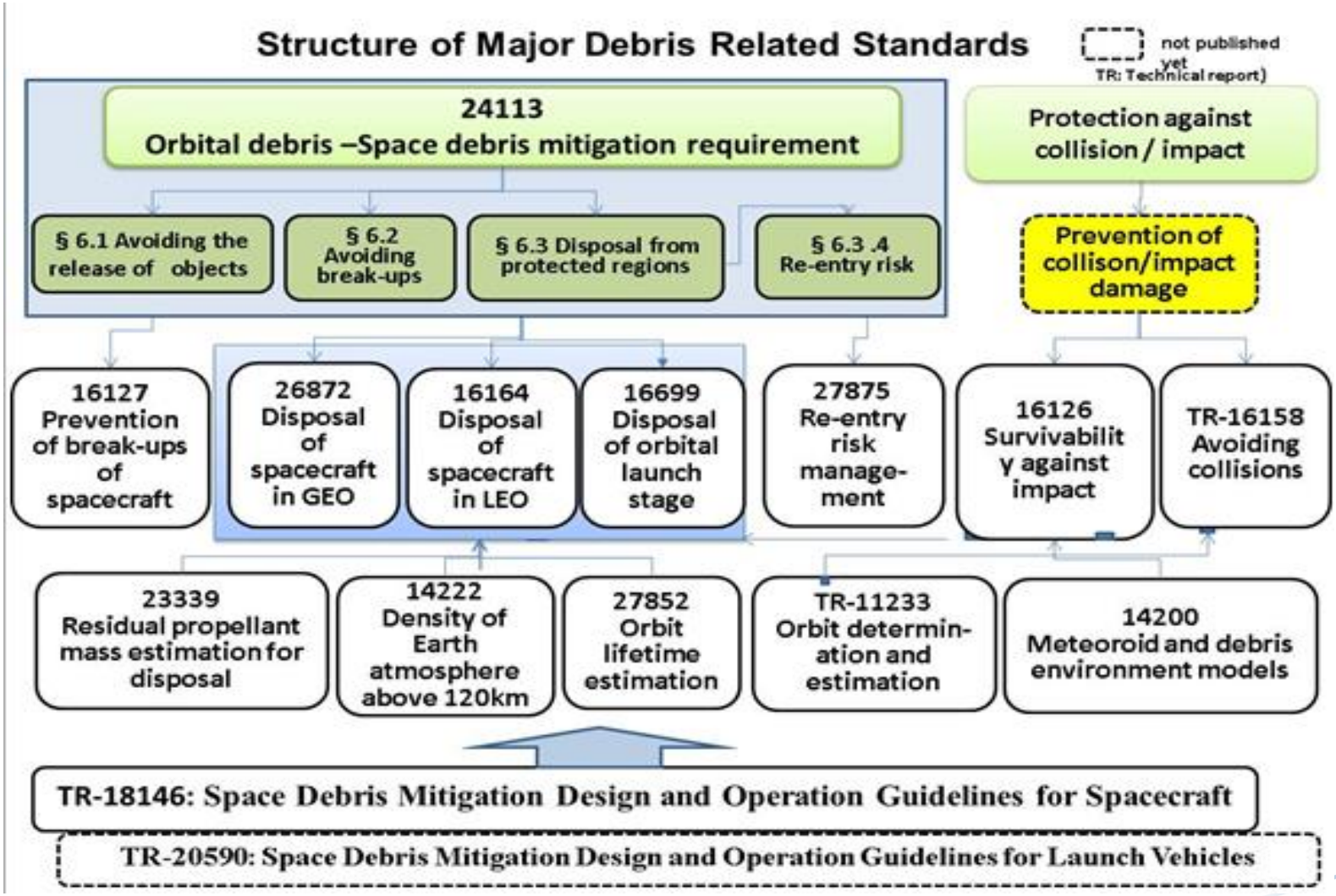
- ESA/ADMIN/IPOL(2008)2 dated 1 April 2008
  Space Debris Mitigation for Agency Projects
- Updated as ESA/ADMIN/IPOL(2014)2 dated 28 March **2014**
- ECSS-U-AS-10C 10 February 2012
  Adoption Notice of ISO 24113
- Evolution following current update of ISO-24113?

17200 cataloged debris

6700 tons in orbit

# ISO-24113

## Current structure of the ISO Debris Standards:



# LAWS

## Numerous National Regulations related to Licensing [1]:

- US Commercial Space Launch Act: 1984
- UK Outer Space Act: Initial regulation in 1986
- South Africa Space Affairs Act in 1993
- Argentina: Establishment of the National Registry of objects launched into outer space" in 1995
- Russia: Decree and statute on licensing space operations in 1996
- Australia: Space Activities Act in 1998
- Brazil: Space Agency Administrative Edict in 2001.

↳ **In general, indirectly related to Space Debris**

## French Space Operations Act (FSOA):

- First Law directly related to Space Debris (2008)
- Cancells and Replaces the French Standard RNC-CNES-Q-40-512
- Declined into two "Application" documents:
  - Technical Regulation RT ("Flying" segment = Launchers and Satellites)
  - Operations of the Guiana Space Center Installations REI = Ground segment
- All Space Debris Mitigation rules included in RT
- Partial waiver regime up to 2020 for transitory phase

[1] Addressing Orbital Debris Through National Regulation R. Crowther

# FUTURE

## Need for a good harmonization of mitigation rules:

- Currently the various standards are relatively coherent
- However, some strong discrepancies: i.e. FAA rules are currently weak
- A comprehensive survey of what is effectively specified is necessary

  ↳ Every commercial manufacturer or operator should play with the same rules, for fair competition

## Current evolutions of mitigation rules under study at IADC level:

- Expected number of human casualties per re-entry $\leq 10^{-4}$
- Probability of successful disposal operations $\geq 90\%$
- Probability of break-up during operational phase $\leq 10^{-3}$
- GTO apogee altitude
- Maximal duration in GEO region = 25 years
- Zone above 2000 km no longer acceptable as graveyard when coming from LEO
- Minimum size of debris to be considered? (no consensus yet, under study)
- Specific rules concerning Mega-constellations? (potentially none, under study)

  ↳ What is the process to have these evolutions taken into account in the various National or International standards?

# FUTURE

## Most promising way for the future appears to be ISO-24113:

- Approved at international level
- Prepared by Industrials + Operators + Agencies
- Potentially universally rendered applicable to any contract in the future
  - Manufacturing (launchers and satellites)
  - Space operations
- Currently under heavy revision; probably a lengthy convergence process…

## Need to apply correctly these rules:

- Unfortunately, Mitigation Rules are not yet applied in a satisfactory level **today**
- Need for a good dissemination of information:
  - Workshops, congresses, conferences, publications…
  - IAA Position Papers

  ↳ **Let us do now what we say we will do…**

17500 cataloged debris
7000 tons in orbit