Lasers and Space Debris in a Global Context:

Players, their Activities, Planning and International Legal Guidelines and Regulations

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Players and their Activities

- ESA
- European Commission via Horizon 2020
- NASA
- CNES
- DLR
- UKSA
- Australia
- Japan/IZEST
- Various non-profit entities e.g. UN and affiliates
- Industrial companies
“Clean Space” initiative: space debris tracking and mitigation

Funding from TRP, GSTP, GSP ~ 10M Euros/yr

• **Eco-design** (e.g. design for demise = complete burn-up on re-entry)

• **Green technologies** (essentially “green” propellants)

• **Space debris mitigation** (investigate technologies that enable, simplify and make the compliance of missions with mitigation requirements e.g. drag augmentation devices and tethers)

• **Technologies for space debris remediation** (technology developments required for targeted de-orbit of spacecraft using advanced guidance, navigation and control sensors and techniques for docking and manoeuvring)
• ESA agreement with US Strategic Command to improve data exchange between the organisations

• ESA collaborates with Fraunhofer Institute on Tracking and Imaging Radar (TIRA) system for dedicated tracking campaigns and surveys on debris objects of diameters down to 2 cm at 1000 km range

• ESA’s space debris telescope on Tenerife uses a 1 m-diameter Zeiss optical telescope, to survey and characterise objects at high altitudes and can detect and track near-GEO objects up to magnitudes of +19 to +21 (equivalent to down to 15 cm in size).

• ESA’s detailed activities are in its Space Debris Brochure
Interesting ESA Statement

“Research will also be conducted into modelling the behaviour of the dynamic ever-changing space debris environment, as well as the development of technical means to collect measurements on man-made objects between 1 mm and a few centimetres in diameter – which remain invisible to current detection methods – within the most critical orbital altitudes between 800 and 1000 km.”

ESA in its documentation mentions laser methods for space debris tracking by multiple ground stations but rarely for remediation.

Footnote: ESA Problem = now-dead 8,000 kg ENVISAT at 700 km
European Commission Horizon 2020

• Recently (Nov 2014) the EC under Horizon 2020 issued a call which included an item:

  PROTEC – 1 - 2015: Passive means to reduce the impact of Space Debris
  Problem = Getting beyond EUSPEAK e.g. Specific Challenge / Scope/ Expected impact/ Type of action
  Apparent Subject =
  • Prevention, avoid adding new debris to the already large debris population.
  • Mitigation, specifically de-orbiting solutions for satellites and launcher upper stages at the end of their operational life.
  • Protection, i.e. shielding satellites from impact of small debris.

Funding = EUR 3 to 4 million

Problems = use of word “passive” (rules out lasers?), confusion w.r.t what ESA is doing and lack of detailed technical requirements

• CLEANSPACE study under FP 7 by Airbus et al on ground-based laser removal. Reported at this w/s
• Orbital Debris Programme Office, Johnson Space Center
• *Orbital Debris Quarterly News (ODQN)* is a quarterly publication of the NASA Orbital Debris Program Office
• Orbital debris models to describe and characterize the current and future debris environment
• Data sources = U.S. Space Surveillance Network, Haystack X-Band Radar, returned surfaces from Solar Max, Long Duration Exposure Facility (LDEF), Hubble Space Telescope (HST) and Space Shuttle spacecraft.
• Cooperation with ESA, COPUOS and Inter-Agency Space Debris Coordination Committee (IADC), and resulting guidelines accepted by COPUOS in June 2007 and endorsed by the United Nations in January 2008.
Mitigation Documentation

- **NASA Procedural Requirements for Limiting Orbital Debris** - NPR 8715_006A
- NASA's policy to limit future orbital debris generation, responsibility within NASA organizations
- **NASA Technical Standard 8719.14**
  - Flight projects required to provide debris assessments and end-of-mission planning as part of project development
- **Debris Assessment Software & User's Guide**
  - Developed to assist NASA programs in performing orbital debris assessments as described in NASA Technical Standard 8719.14
- **U.S. Government Orbital Debris Mitigation Standard Practices**
  - U.S. interagency working group led by NASA and DoD for a work plan on debris environment and work with U.S. government agencies and other space faring nations and international organizations to design and adopt guidelines to minimize orbital debris
“No New Launches” scenario highlights eventual need for remediation of existing debris population (Chinese ASAT test in 2007 and Cosmos 2251/Iridium 33 in 2009)

If goal of remediation is to reduce risk to current operational spacecraft, remediation techniques need to focus on removal of small sized (but still damaging) debris

If goal is to control long-term growth of debris population, efforts need to concentrate on removal of large, massive objects such as intact rocket bodies and non-functional satellites

Any successful ADR concept must be technologically feasible, economically affordable, and politically acceptable to the international community

June 2010 National Space Policy for the United States of America directs NASA and Department of Defense to “Pursue research and development of technologies and techniques... to mitigate and remove on-orbit debris...” However, it should be noted that, currently, no U.S. government entity has been assigned the task of removing existing on-orbit debris
National Research Council and NASA

• In 2011 US the National Research Council looked at NASA's orbital debris programs for improvements
• NASA should lead public discussion of debris problem
• NASA should improve long-term modelling, better measurements, more regular updates of the debris environmental models
• NASA should join with other agencies to develop and provide more explicit information about the costs of debris avoidance, mitigation, surveillance, and response
NASA, Debris and Lasers

- Project ORION (Phipps, 1996) by NASA/USAF proposed using powerful laser beams to vaporize surface material on targets, providing enough recoil to de-orbit them.
- Project Orion lasers recently characterised by ODPO potentially “could be seen as weapons threatening other spacefaring nations.”
- Recently, Mason et al (NASA Ames/Stanford) suggested much less powerful and cheaper lasers using light pressure on debris.
- Medium-power commercially available laser of 5-to-10-kw constantly focused on a piece of debris located at e.g. Plateau Observatory (PLATO) in Antarctica.
- Example = ASTRO-F, a discarded lens cap of 80 cm and 5 kg from the Japanese Akari telescope in a near-circular orbit at 700 km. A laser at PLATO pointed at this for about two hours over two days could move it away from a dangerous orbit.
CNES clearly has done a lot of thinking about this.

Highest level priorities for CNES:
• Development by Toulouse Space Center of a predictive tool, with different modelling, enabling robustness studies
• Tool MEDEE will be soon available
• Potential need for Active Debris Removal (ADR)
• Recognised as international problem
• Sources of debris come from every space-faring nation
• No nation alone can solve the problem
• Emphasis is on large objects e.g. Ariane booster left-overs
• Bonnal work on laser mitigation methods, reported at this w/s
• Bonnal paper at IAF Workshop on Space Debris Removal – UN, Vienna – February 11th, 2013. Lots of ideas about active debris removal (ADR)
As for small objects operators’ main concern is short term risk induced by small debris and following example is given:

- Risk for Spot 5 (CNES)
- Mission loss 0.3% per year
- Main influence of objects < 5 cm
- Risk on Sentinel 1 (reference to TAS-I draft doc.)
- Mission loss 3.2% over lifetime
DLR

• Developing optical observation system with high-power laser. Tested in January 2012, at laser station in Graz (Austria)

• Graz laser station part of Space Research Institute of the Austrian Academy of Sciences

• Detection of more than 20 different launcher components at distances of 500 to 1800 kilometres and based on calculations performed by researchers at DLR Stuttgart

• When operational, possible to locate objects measuring down to 10 centimetres

• Apparently no laser space debris remediation system contemplated by DLR

• Graz Participation reported at this w/s
UKSA

• ESA’s new Clean Space Initiative shared with leading UK space firms and researchers at Harwell in October 2013.
• Satellite Application Catapult centre (Harwell–Oxford campus) hosted event, organised by UK Space Agency
• Airbus Defence and Space at Stevenage developing harpoon to help capture derelict satellites
• UK involvement includes Space Insight's Starbrook - optical sensor system for space surveillance, and RAL STFC's Chilbolton Observatory – a meteorological radar experimental facility
• Univ. of Strathclyde and RAL study on short pulse reflectivity and energy coupling for space debris removal presented at this w/s
AUSTRALIA

- Established a Cooperative Research Centre (CRC) for Space Environment Management based at Mt Stromlo. High-technology consortium of aerospace companies, universities and space agencies. CRC team members are:
  - The Australian National University [Australia]
  - Lockheed Martin [USA]
  - EOS Space Systems [Australia]
  - NASA Ames Research Center [USA]
  - National Institute of Information and Communications Technology [Japan]
  - Optus [Australia]
  - RMIT University [Australia]
- EOS/Lockheed Martin agreement to establish a laser space debris tracking and mitigation system and operated on a commercial basis as services to commercial satellite operators
- Presentation at this workshop
A proposed collaboration between Japanese researchers, IZEST and others for a staged implementation of an orbiting debris remediation system comprised of a super-wide field-of-view telescope (EUSO) and a novel high efficiency fibre-based laser system (CAN).

Proof of concept stages will operate from the International Space Station (ISS) where the EUSO 2.5m telescope has been designed for operation as a detector of ultra-high energy cosmic rays.

Project envisages:

1) Proof of principle demonstration of the detection by a mini-EUSO and operation of 100-fibre CAN laser technology as an ISS based prototype.

2) Technical demonstrator of debris-removal that consists of the EUSO telescope for the detection and a 10,000 fibre CAN laser for tracking and impulse delivery for debris re-entry.

3) A free-flyer mission dedicated to debris remediation in a polar orbit with the altitude near 800 km.

Project described at this workshop.

Additionally a concept for a free-flyer has been proposed in a paper by Soulard, Quinn, Tajima and Mourou in 2014, Act. Astro.
UNITED NATIONS

• UN body responsible is Committee on Peaceful Uses of Outer Space (COPUOS). Scientific and Technical Subcommittee responsible for Space Debris Mitigation creates Guidelines of COPUOS. Latest version published in 2010 as follows:
  1: Limit debris released during normal operations
  2: Minimize potential for break-ups during operational phases
  3: Limit 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 low-Earth orbit (LEO) region after end of mission
  7: Limit long-term interference of spacecraft and launch vehicle orbital stages with geosynchronous Earth orbit (GEO) region after end of mission

• Absence of any recommendations referring to the active removal of existing space debris. COPUOUS defers now to IADC.
Inter-Agency Space Debris Coordination Committee (IADC)

- International governmental forum for worldwide coordination of activities related to issues of man-made and natural debris in space
- IADC member agencies include the following:
  - ASI (Agenzia Spaziale Italiana)
  - CNES (Centre National d'Etudes Spatiales)
  - CNSA (China National Space Administration)
  - CSA (Canadian Space Agency)
  - DLR (German Aerospace Center)
  - ESA (European Space Agency)
  - ISRO (Indian Space Research Organisation)
  - JAXA (Japan Aerospace Exploration Agency)
  - KARI (Korea Aerospace Research Institute)
  - NASA (National Aeronautics and Space Administration)
  - ROSCOSMOS (Russian Federal Space Agency)
  - SSAU (State Space Agency of Ukraine)
  - UK Space Agency
- “Support to the IADC Space Debris Mitigation Guidelines, IADC 04 06, Rev 5.5 May 2014”
- No mention of the use of lasers for tracking or mitigation of space debris is mentioned in this extensive document
Industrial Companies

- Industrial entities that appear to be involved in space debris area are:
  - Airbus Defence and Space, Stevenage for harpoon to help capture derelict satellites
  - Airbus Defence and Space, Bremen, studies for ESA on capture mechanisms
  - Thales Alenia (France) through its involvement in the ICAN project on the purely optical side.
  - Lockheed Martin (US)
  - EOS Systems (Australia) (Note: EOS has a subsidiary in Germany)
  - Photonics (US)
  - Tether Applications (US)
  - Amplitude Technologies (France)
  - TOPTICA Photonics AG (Germany)
  - MPB Communications Inc. (Canada)
  - Airbus Defence and Space (France) on CLEANSPACE study for EC
Regulatory Aspects and Regimes

REGULATIONS FROM INTERNATIONAL ORGANISATIONS
- UNITED NATIONS (UN)
- INTER-AGENCY SPACE DEBRIS COORDINATION COMMITTEE (IADC)
- INTERNATIONAL TELECOMMUNICATION UNIT (ITU)
- INTERNATIONAL ORGANISATION FOR STANDARDISATION (ISO)

SPACE AGENCIES
- EUROPEAN SPACE AGENCY (ESA)
- NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NATIONAL GOVERNMENTS
AUSTRALIA | FRANCE | UKRAINE
AUSTRIA | GERMANY | UNITED KINGDOM
BELGIUM | JAPAN | UNITED STATES
CANADA | NIGERIA |
UNITED NATIONS (UN)

• **Regulation:** Space Debris Mitigation Guidelines of the UN Committee on the Peaceful Uses of Outer Space (UN COPUOS).

• **Main Principles (Guidelines):**
  - Limit debris released during nominal operations
  - Minimize potential for break-ups during operations
  - Limit probability of accidental collision in orbit
  - Avoid intentional destruction and similar activities
  - Minimize potential for post-mission break-ups resulting from stored energy
  - Limit long-term presence of spacecraft/launch vehicle stages in LEO and GEO regions after end of mission

**Applicability:** Guidelines are not legally binding under public international law—but in resolution 62/217 of 22/12/2007, UN invited Member States to implement those voluntary guidelines through relevant national mechanisms “to the greatest extent feasible”
INTER-AGENCY SPACE DEBRIS COORDINATION COMMITTEE (IADC)

- **Main Principles**: Guidelines cover overall environmental impact of space missions with focus on:
  - Limitation of debris released during normal operations,
  - Minimization of the potential for on-orbit break-ups
  - Post-mission disposal
  - Prevention of on-orbit collisions.
- **Applicability**: Guidelines are non-binding. Organizations encouraged to use them when establishing mission requirements for future spacecraft or during operations of existing spacecraft.
- **Note**: IADC Space Debris Mitigation Guidelines used as foundation for COPUOS Space Debris Mitigation Guidelines, (previous slide) and as basis of the ISO standard 24113 “space systems – space debris mitigation”.
INTERNATIONAL TELECOMMUNICATION UNION (ITU)


• **Main Principles**: Guidance about disposal orbits for satellites in GSO and defines a protected region above, below and around the GSO.

• **Recommendation 1**: As little debris as possible should be released into the GSO region during the placement of a satellite in orbit.

• **Recommendation 2**: Every reasonable effort should be made to shorten the lifetime of debris in elliptical transfer orbits with apogees at or near GSO altitude.

• **Recommendation 3**: Before exhaustion of its propellant, GSO satellite at end of life should be removed from the GSO region such that it remains in an orbit with a perigee no less than 200 km above the geostationary altitude.

• **Recommendation 4**: Transfer to graveyard orbit to be carried out so as to avoid radio frequency interference with active satellites.

• **Applicability**: ITU-R S.1003.2 is addressed to member states of the ITU and is not legally binding.
INTERNATIONAL ORGANISATION FOR STANDARDISATION (ISO)


• **Main Principles**: Requirements to ensure that spacecraft and launch vehicle orbital stages (hardware) designed, operated and disposed of that prevents them from generating debris throughout orbital lifetime. ISO standard 24113 defines two protected regions: LEO region (up to 2000 km) and GEO region (35786±200 km), latitude sector: 15° South ≤ latitude ≤ 15° North). Technical requirements:
  
  • 1) Hardware designed not to release space debris into Earth orbit during normal operations. Any debris released remaining outside GEO protected region and limit presence in LEO protected region to a maximum of 25 years after release.
  
  • 2) Combustion-related products shall be avoided into the protected regions; No pyrotechnic products larger than 1 mm.
• 3) Intentional break-ups to be avoided; probability of accidental break-up of hardware shall be no greater than $10^{-3}$. Deplete on-board sources of stored energy during disposal.

• 4) Probability of successful disposal of hardware shall be at least 0.9 at time of disposal.

• 5) Hardware in GEO protected region, shall be manoeuvred in a controlled manner during the disposal phase to an orbit that lies entirely outside the GEO protected region.

• 6) Hardware in LEO protected region, shall limit its post-mission presence in the LEO protected region to a maximum of 25 years from end of mission.

• 7) For hardware (or any part thereof), the maximum acceptable casualty risk shall be set in accordance with norms issued by approving agents.

• **Applicability**: Applicable worldwide but (apparently) not legally binding.
EUROPEAN SPACE AGENCY (ESA)


• **Main Principles**: Primary objectives of the Code:
  • a) Prevent on-orbit break-ups and collisions of spacecraft,
  • b) Facilitate removal from useful densely populated orbit regions and subsequent disposal of spacecraft and orbital stages that have reached end of mission
  • c) Help limit objects released during normal spacecraft operations.

• Code presents fundamental mitigation, safety and protection measures
  • 1) management measures,
  • 2) design measures including end-of-life measures,
  • 3) operational measures including end-of-life measures,
  • 4) impact protection measures and
  • 5) re-entry safety measures. It does not cover the launch phase safety.
EUROPEAN SPACE AGENCY (ESA) (2)

- **Applicability**: Application of Code is on voluntary basis.
- **Notes**: Code formally adopted by Italian Space Agency (ASI), UK Space Agency (UKSA), the French Space Agency (CNES), the German Aerospace Agency (DLR) and ESA
- Code is consistent with IADC Space Debris Mitigation Guidelines, while providing greater technical detail and explanations
- **ESA-Specific Regulation**: “Space Debris Mitigation for Agency Projects”, administrative instruction of the ESA Director General, entered into force on 01 April 2008
- **Main Principles**: Administrative instruction for procurement of space systems and launch services for ESA programmes. Defines minimum set of requirements (management, design, operational)
- **Applicability**: Binding for all ESA staff involved in ESA’s relations with third parties.
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)


- **Main Principles**: In 1995 NASA was the first space agency to issue a comprehensive set of orbital debris mitigation guidelines. In 1997, the U.S. Government developed a set of *Orbital Debris Mitigation Standard Practices* based on NASA guidelines.

- Four different objectives, each with mitigation standard practices

  1) **Control of Debris Released during Normal Operations**: 
     - Spacecraft and upper stages (hardware) to be designed to eliminate or minimize debris released. Release of debris larger than 5 mm after 25 years on-orbit to be justified.

  2) **Minimizing Debris Generated by Accidental Explosions**:
     - Hardware design to demonstrate (a) no credible failure mode for accidental explosion, or (b) design/operational procedures to limit probability of such failure modes.
     - On-board sources of stored energy to be depleted or safed after mission or disposal.
3) **Selection of Safe Flight Profile and Operational Configuration**:

- During design/mission profiling probability of collision with known objects to be estimated and limited.
- Design will limit the probability that collisions with debris smaller than 1 cm diameter will cause loss of control to prevent post-mission disposal.

4) **Post-mission Disposal of Space Structures**. A spacecraft or upper stage may be disposed of by one of three methods:

   a) Atmospheric re-entry option: Structure in orbit no longer than 25 years after mission. If disposal by re-entry, risk of human casualty to be less than 1 in 10,000.

   b) Manoeuvring to a storage orbit: At end of life structure may be relocated to i) Between LEO and MEO: ii) Between MEO and GEO: iii) Above GEO: iv) Heliocentric, Earth-escape.

   c) Direct retrieval

**Applicability**: Standard Practices intended for US Gov.-operated or -procured space systems, including satellites as well as launch vehicles.

• **Main Principles**: Refines earlier orbital debris mitigation documents and expands their applicability. New requirements/Refinements:
  
  • **Routine conjunction assessments for all manoeuvrable NASA spacecraft in LEO and GEO**
  
  • **Prompt notifications of intended or unintended debris generation**
  
  • **Preparation and maintenance of formal end-of-mission plans**
  
  • **Human casualty risk limitations from re-entering debris to be calculated explicitly**
  
  • **Minimum kinetic energy threshold for potentially injurious re-entering debris is set at 15 Joules**
  
  • **Disposal of GEO spacecraft and launch vehicle orbital stages to ensure vehicles do not come within GEO + 200 km after end of mission**
  
  • **Spacecraft in LEO to remain for no more than 25 years after end of mission or 30 years after launch, whichever occurs sooner.**

• **Applicability**: NPR applicable throughout NASA and its contractors/partners
AUSTRALIA

• **Regulation**: Australia’s Satellite Utilization Policy, April 2013.

• **Main Principles**: Australian Government adheres to UN Space Debris Mitigation Guidelines. Participates in negotiation of International Code of Conduct for Outer Space Activities,

• **Applicability**: Australia’s Satellite Utilization Policy is a statement of Australia’s objectives and direction for civilian space activities. *It is not a legal document.*

• **Earlier Regulation**: Guidelines for Applicants seeking to apply for an Overseas Launch Certificate, 1998.

• **Main Principles**: Guidelines specify that an applicant for an overseas launch certificate to provide a debris mitigation strategy that addresses Space Debris Mitigation Guidelines of COPUOS

• **Applicability**: Binding regulation for Australian nationals carrying out space activities
AUSTRIA


• **Main Principles**: Austrian Outer Space Act is legal basis for Austrian space activities. Article 5 of Austrian Outer Space Act is entitled “Mitigation of Space debris” and provides that: “The operator has to make provision for the mitigation of space debris in accordance with the state of the art and in due consideration of the internationally recognized guidelines for the mitigation of space debris”.

• **Applicability**: the Outer Space Act is an Austrian federal law, and is therefore compulsory and applicable to space activities carried out:
  • a) On Austrian territory,
  • b) On board vessels registered in Austria
  • c) By a natural person with Austrian citizenship or legal person located in Austria.
BELGIUM

• **Regulation**: Law of 17 September 2005 on Activities of Launching, Flight Operation or Guidance of Space Objects.

• **Main Principles**: Belgian law allows the Minister the possibility to impose on the Operator the compliance with standards and norms adopted by intergovernmental bodies and/or relevant non-governmental organizations. For that purpose, a specific agreement has been concluded between the national authority (BELSPO) and ESA.

• **Applicability**: The Law applies to any activity which is carried on by an Operator from the Belgian territorial jurisdiction. The Operator is defined as he who exercises the ultimate authority over the activity.

• The Law doesn’t make any distinction in its application whether the Operator is of Belgian nationality or foreign nationality.
CANADA

• **Regulation:** Canadian Client Procedures Circular (CPC) for Licensing of Space Stations – 2014

• **Main Principles:** The Government of Canada, implements a licensing regime for all Canadian satellites in using above document.

  • Section 3.3.3 Space Debris Mitigation Plan of CPC-2-6-02 requires that applicants for space station spectrum and radio licenses submit a Space Debris Mitigation Plan as part of their applications.

  • Canadian law distinguishes between geostationary satellites and non-geostationary satellites.

  • For geostationary satellites, the applicant must submit a plan for de-orbiting their satellite(s) in compliance with Recommendation ITU–RS.1003-2, *Environmental Protection of the Geostationary Satellite Orbit*.

  • For non-geostationary satellites, the applicant must submit a plan for de-orbiting their satellite(s) in accordance with best industry practices.

• **Applicability:** The space debris mitigation requirement is applicable to all satellites licensed in Canada.
CANADA (2)


- **Main Principles**: Regulations set out requirements to be identified in a Disposal Plan. Chief requirements are:
  
  - a) method of disposal proposed for each satellite and reliability of that method;
  
  - b) probability of loss of human life
  
  - c) amount of debris (including hazardous materials) expected to reach the surface of the Earth,
  
  - d) assessment of space debris expected to be released from each satellite during normal operations and measures proposed to mitigate production of debris.

- **Applicability**: The Act and its regulations are mandatory in Canada, and also apply to following persons with respect to their activities outside Canada:
  
  - a) Canadian citizens, permanent residents, corporations incorporated under the laws of Canada etc.

• **Main Principles**: Regulation applies to launchers, launcher stages, satellites, orbital systems and all space objects in general. Technical Regulation contains technical requirements related to the mitigation of space debris in two parts:

  • Part 1 Dedicated to launch systems
  • Part 2 Dedicated to orbital systems

• **The space object must be designed, produced and implemented**

• (a) in such a way as to minimize the production of debris during nominal operations, including after its end-of-life and its component parts

• (b) so that, after the end of the launch phase, its components placed in orbits passing through protected region are de-orbited by controlled atmospheric re-entry
FRANCE (2)

• (c) so that components are no longer present in a protected region 25 years after end of launch but only if impossibility of meeting requirement (b) is duly proven

• (d) so that, after end of launch phase, its components stationed in an orbit in or passing through protected region, are placed in an orbit which does not interfere with this region for more than 1 year. This orbit must be such that, under the effect of natural disturbances, launcher or its components do not return to protected region within 100 years following end of operation

• (e) The probability of successfully completing disposal manoeuvres must be at least 0.9

• Applicability: The scope of the FSOA covers:
  • Launch and return operations carried out from French territory
  • Launch and return operations carried out by a French operator from a foreign country
  • Procurement of a launch by a French entity
  • Control of space objects in outer space by a French operator
  • As a law, it is mandatory for concerned space operators.
• **Regulation**: Product Assurance and Safety Requirements for DLR Space Projects: April 2012 (Issue 7.0)

• **Main Principles**: In implementing a particular space mission, requirements contained in *DLR Requirements* are tailored to respective projects according to mission characteristics. The aim is to:

  • *(a)* Ensure application of relevant requirements, their verifiability and their practicability during the development, production and operation phases of a space project.

  • *(b)* Tailor requirements to form part of the project requirements in the invitation of tenders as well as of the contractual agreements with the respective contractors.

  • *(c)* Allow non-compliance with any of tailored requirements on basis of a waiver. Waiver shall provide rationale and justification for deviation and requires formal approval by DLR.

• **Applicability**: *Product Assurance and Safety Requirements for DLR Space Projects* are mandatory throughout all phases of all space missions of the DLR Space Administration.
• **Regulation**: JAXA-Management Requirements (JMR-003B), revised in 2011.

• **Main Principles**: JMR-003B includes the following requirements:
  - Preventing on-orbit break-up of a space system after end of mission
  - Transferring dead satellites in Geostationary Earth Orbit (GEO) into a higher orbit in order to preserve GEO environment
  - Reducing orbital lifetime during which orbital stage left in Geostationary Transfer Orbit (GTO) can interfere with GEO region
  - Minimizing number of objects released in orbit during operation
  - Reducing orbital lifetime during which a completed space system can interfere with useful Low Earth Orbit (LEO) region
  - Preventing human casualties on ground caused by impact of space systems removed from orbit as well as in orbit caused by collision with manned system during space systems launch
  - Minimizing damage caused by on-orbit collision

• **Applicability**: JAXA applies the standard to all of its space projects including contractors who design its spacecraft and launch vehicles
NIGERIA and UKRAINE

• **Nigeria**
  • **Regulation**: National Space Research and Development Agency Act 2010 No.9 A 1255.
  • **Main Principles**: Law of 2010 established National Space Research and Development Agency. Particular emphasis is placed on the mitigation of space debris by a licensee.
  • **Applicability**: Act is applicable to all space activities within Nigeria by both citizens and non-citizens.

• **Ukraine**
  • **Main Principles**: Main technical activities on limitation of space debris generation stated in industrial standard URKT-11.03:
    • Minimization of space debris generation during standard operations
    • Minimization of possibility of space objects breaking in orbit
    • Removal of spacecraft and launch vehicles from orbit after mission’s completion
    • Prevention of space objects collisions in near-Earth space
  • **Applicability**: Requirements of standard are compulsory for all actors
UNITED KINGDOM

• **Regulation**: Outer Space Act 1986 (OSA).
• **Main Principles**: OSA provides necessary regulatory oversight to:
  • (a) consider public health and safety and the safety of property
  • (b) evaluate environmental impact of proposed activities
  • (c) assess implications for national security/foreign policy interests
  • (d) determine financial responsibilities and international obligations.
• In assessing a mission proposed by a licence applicant, UKSA assessors will require applicants to demonstrate compliance with existing norms in relation to measures such as the IADC Space Debris Mitigation Guidelines, UN COPUOS Space Debris Mitigation Guidelines etc.
• **Applicability**: OSA is a mandatory, statutory instrument applying to UK nationals (i.e. personal rather than territorial).
UNITED STATES (non NASA)

Commercial remote sensing satellites subject to regulation by both NOAA and the FCC.

- **NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION**
  Requirements on:
  - Atmospheric re-entry, Manoeuvring to a storage orbit and direct retrieval

- **FEDERAL COMMUNICATIONS COMMISSION (FCC)**
  - Requires Disclosure of Orbital Debris Mitigation Plans from all new operators submitting applications for a license

- **FEDERAL AVIATION ADMINISTRATION (FAA)**
  - Only federal agency with authority to license commercial space transportation activities out of and into US launch sites but has no ability to mitigate creation of orbital debris

- **DEPARTMENT OF DEFENSE (DOD)**
  - Through its Joint Space Operations Center (JSpOC), has only legislative authority and capability to share space situational information, including notification of impending collisions and near collisions to cooperating space operators, but lacks enforcement authority. Applies to all military or military-affiliated satellites operating under the Department of Defense and the US Air Force.
Conclusions on Players and their Activities

### Presence of Usual Suspects

- UN/COPUOS/IADC
- NASA
- ESA
- EC (Taiwan/SK/Indo)
- CNES
- DLR
- UKSA
- Canada
- Australia
- Japan

### Absence of Others

- Russia
- China
- India
- Others
Conclusions on Players and their Activities (2)

• General agreement on seriousness of problem
• Universal concern on SSO orbits but little concrete action (e.g. now-dead Envisat)
• Distinguish between Mitigation and Remediation and meaning of these words
• Confusing situation in Europe (ESA, EC, National agencies) and US (various federal agencies)
• Little perceived interest in use of lasers (technical feasibility, weaponisation?)
• Surprisingly little from GSO operators
Conclusions on Regulatory Aspects

- Generally COPUOS/IADC guidelines accepted but these have low level technical detail (aspirational)
- Slow integration of these guidelines into national law, leaders are F, B, UK, Austria, Canada, Australia
- US situation legally complicated (NASA, NOAA, FCC, FAA, DOD, USAF)
- EU legal situation unclear, lead apparently with ESA
- Apparently no legal liability of offending entities
- Operators/Players must carry out own avoidance manoeuvres
- No guidelines, not to say laws, regarding use of high power lasers for remediation