Orbital Design and Orbital Data for Small Satellite Missions: Requirements from the Standpoint of Safety of Space Operations

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Why new requirements appear?

Space is becoming more and more congested

- Number of operational spacecraft already exceeds 1100 and continues to grow
- Just a few orbital regions are used for placement of spacecraft that results in increasing concentration of operational payloads in orbits having similar parameters (e.g. SSO)
- Nano- and picosatellites are usually being launched as secondary payloads to the same orbits as a ‘primary’ spacecraft despite of possible problems that can appear due to low observability of tiny objects on certain orbits
- Spatial density of distribution of traceable space debris objects is already high (if not critical) at certain regions of LEO
- Future small satellite projects suppose further miniaturization (femto-satellites) and possibility of launch of hundreds of extremely small payloads simultaneously
- Development of a variety of small-payload Nanosatellite Launch Vehicle (NLV) technologies begun and further increase of a number of orbiting small satellites expected

Joint efforts are required in order to minimize risks and increase on-orbit operations safety

What to do? (1)

Follow recommendations already adopted at the international level and implemented at the national level

Space Debris Mitigation Guidelines of the COPUOS (2007):

- Guideline 3: Limit the probability of accidental collision in orbit
- Guideline 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
- Guideline 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

IADC Space Debris Mitigation Guidelines (2007):

- 5.3.2 Objects Passing Through the LEO Region:
  Whenever possible spacecraft or orbital stages that are terminating their operational phases in orbits that pass through the LEO region, or have the potential to interfere with the LEO region, should be de-orbited (direct re-entry is preferred) or where appropriate manoeuvred into an orbit with a reduced lifetime. Retrieval is also a disposal option.
  A spacecraft or orbital stage should be left in an orbit in which, using an accepted nominal projection for solar activity, atmospheric drag will limit the orbital lifetime after completion of operations… This IADC and some other studies and a number of existing national guidelines have found **25 years** to be a reasonable and appropriate lifetime limit.

What to do? (2)

Prepare yourself to follow recommendations that are being developed by the international community

Guidelines for the Long-Term Sustainability of Outer Space Activities (in the development phase at the Scientific and Technical Subcommittee of the COPUOS).

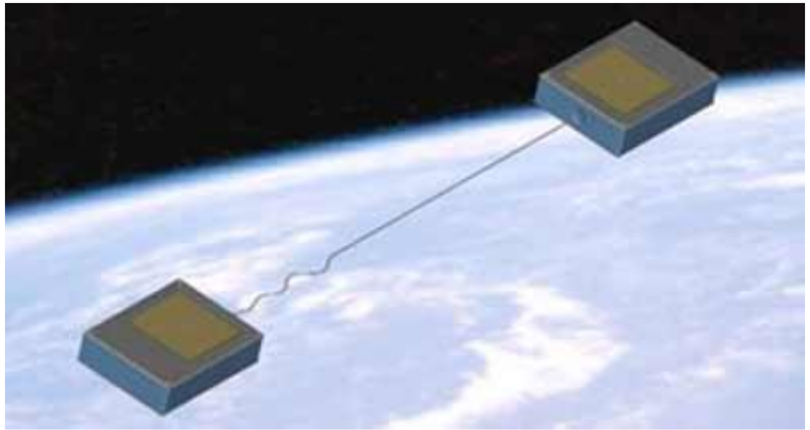
Inter alia, following topics being considered:

- Registration information on space objects
- Contact information and information on space objects and orbital events
- Use of standards when sharing orbital information on space objects
- Conjunction assessment during orbital phases of controlled flight
- Use of techniques and methods to improve the accuracy of orbital data for spaceflight safety

Avoiding collisions during operational lifetime of a spacecraft under your control. Practical recommendations (1).

1. Consider solutions to increase the accuracy of orbital data
   – implementation of on-board GNSS techniques
   – design modifications to improve traceability of a spacecraft (*in course and after the end of the mission*!) by space surveillance sensors. Consider possibility to increase the radar cross-section (RCS), e.g., by the deployment of dipole structures, and to increase the optical visibility, e.g., by the use of highly reflective surface materials

MEMS Picosat (2000-004H
The tether contains thin strands of gold wire to facilitate radar tracking



Avoiding collisions during operational lifetime of a spacecraft under your control. Practical recommendations (2).

2. Implement standard formats for orbital information representation

CCSDS 502.0-B-2 ORBIT DATA MESSAGE (CCSDS Recommended Standard).

Section 5 of the standard describes ORBIT EPHEMERIS MESSAGE (OEM). It can be recommended as the most universal format for the purposes of sharing orbital information.

3. Share orbital information (as precise as you can) for the current and predicted location of your spacecraft

Avoiding collisions during operational lifetime of a spacecraft under your control. Practical recommendations (3).

4. Perform conjunction assessment in an appropriate way

Preliminary recommendations that are included into one of the draft LTSSA guidelines indicate following appropriate steps:

- improving the orbit determination of relevant space objects
- screening current and planned trajectories of relevant space objects for potential collisions
- determining whether an adjustment of trajectory is required to reduce the risk of collision, in coordination with other operators and/or organizations responsible for conjunction assessment, as appropriate
- in the case you are unable to perform conjunction assessment, seek support, via State authorities, as necessary and in accordance with the relevant applicable regulations, from appropriate around-the-clock conjunction assessment entities

DO NOT USE any orbital information you were able to find if it does not include description of a motion model which should be used to work with this information and/or no information on accuracy is provided! For example, TLE data are NOT APPROPRIATE to perform conjunction assessment.

Avoiding collisions during operational lifetime of a spacecraft under your control. Practical recommendations (4).

5. Share conjunction assessment results (especially in case of unavoidable close conjunctions)

6. Consider appropriate coordination with other spacecraft operators via designated points of contact (including, but not limited to, cases of collision avoidance manoeuvres)

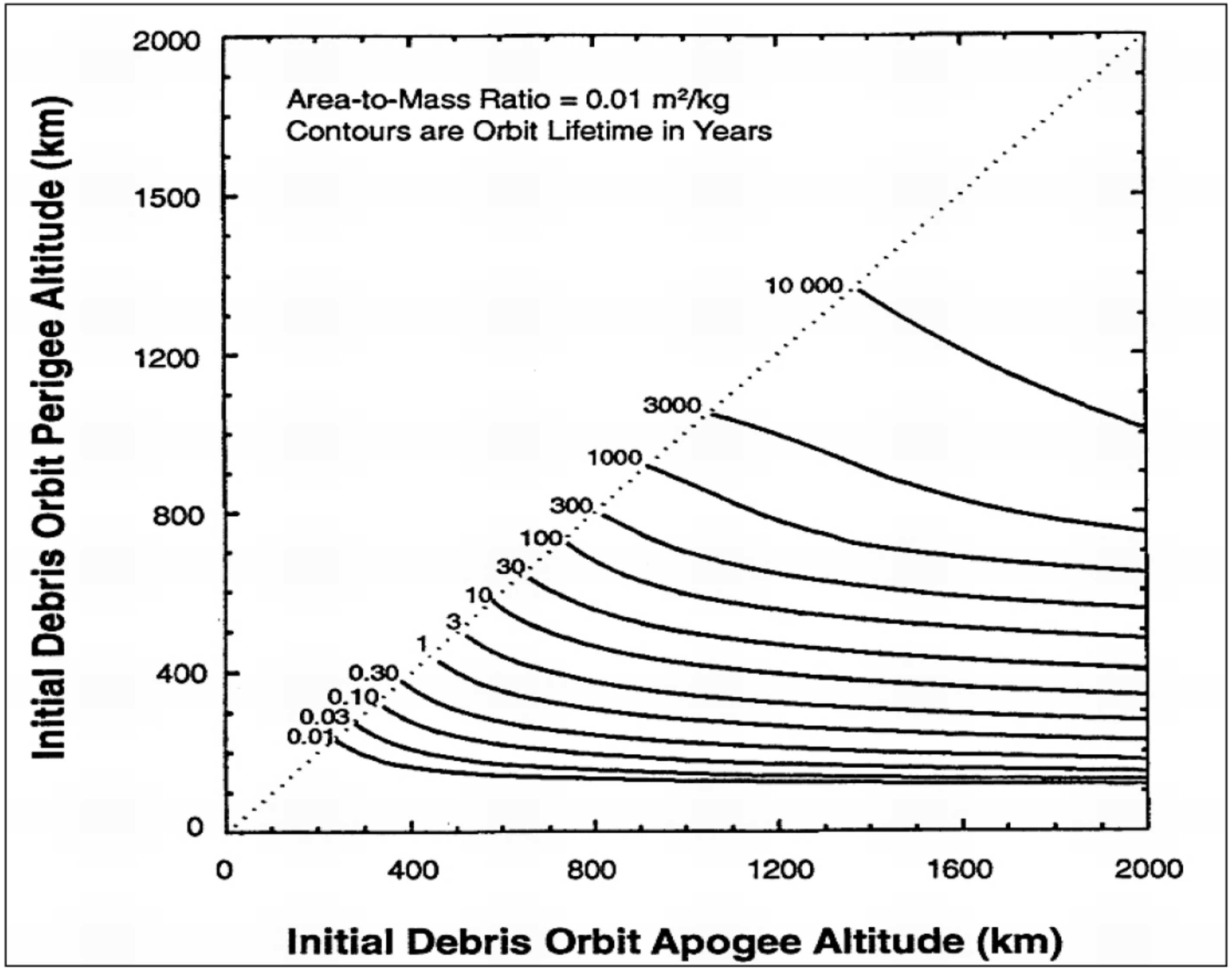
Minimizing orbital lifetime of a spacecraft after the mission termination. Practical steps (1).

1. Consider selection of appropriate orbital parameters at the mission design phase

- for spacecraft having $C_d A/m \sim 0.01 m^2/kg$ the ~650 km altitude circular orbit experience a median orbit lifetime of 25 years
- perturbations due to SRP and atmospheric drag are equal at ~800 km with the drag prevailing at lower altitudes and SRP prevailing higher

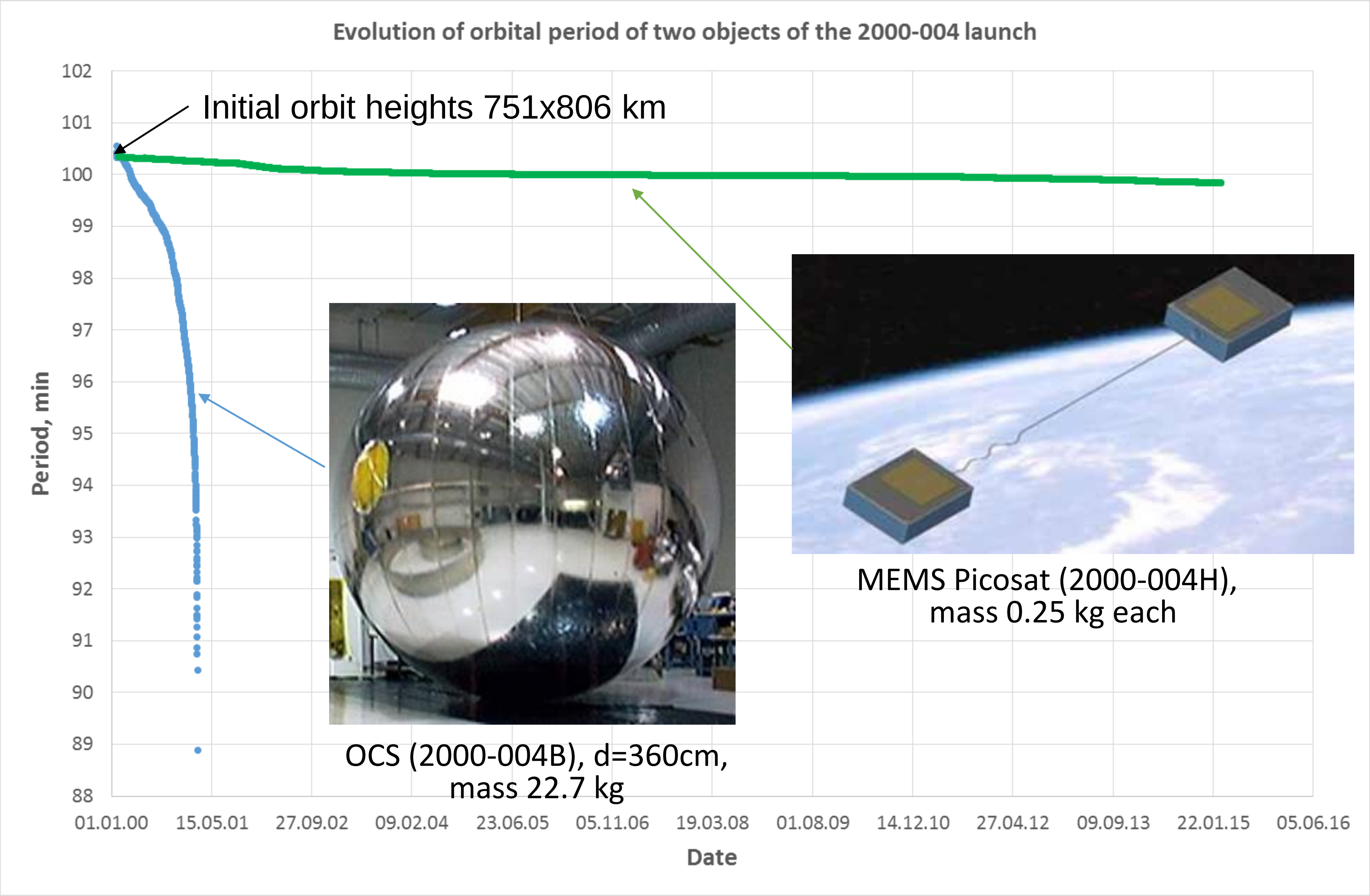
ISO Standard 27852, “Space systems — Estimation of orbit lifetime.”

Orbital lifetime as a function of altitude



Jehn, R., 2007, ‘The Space Debris Problem’, Lecture at the International Space University. Summer Session, Beijing, China, 2007

Illustration of the AMR (BC) importance



Minimizing orbital lifetime of a spacecraft after the mission termination. Practical steps (2).

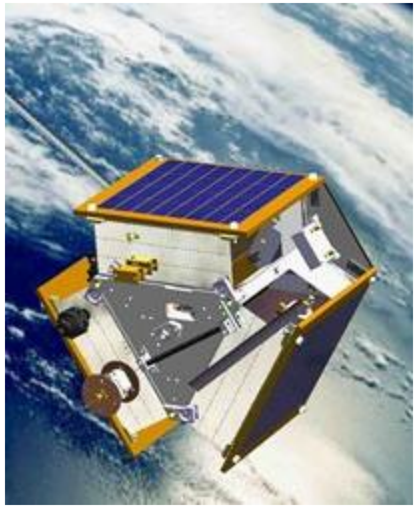
2. Consider possibility of spacecraft design modification to install extra component(s) for de-orbiting (decreasing orbital lifetime to 25 years or less)

Drag augmentation devices

- balloon drag device
- deployable membrane
- etc.

Electric propulsion systems

Chemical propulsion systems



SNAP-1, 6.3 kg, butane propulsion system

Minimizing orbital lifetime of a spacecraft after the mission termination. Practical steps (3).

Balloon drag devices efficiency

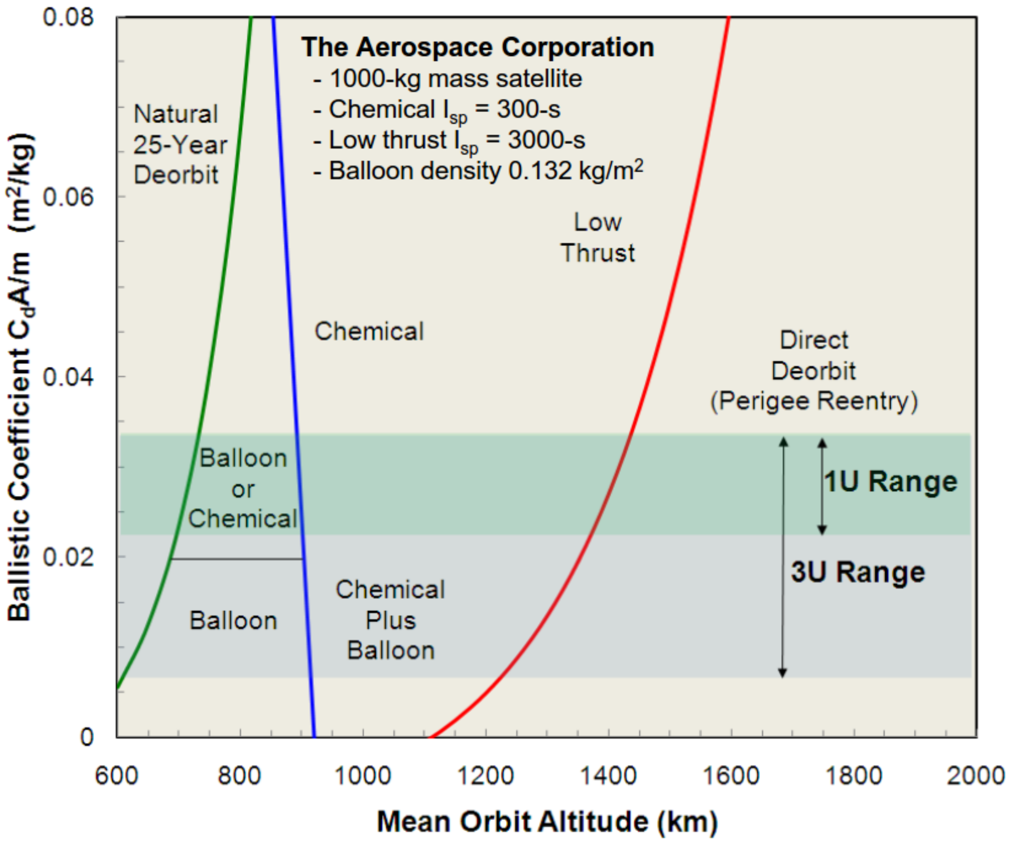


Chart from: *CubeSat Balloon Drag Devices: Meeting the 25-Year De-Orbit Requirement, Jerry K. Fuller, David Hinkley, and Siegfried W. Janson, The Aerospace Corporation, April 24, 2010*

Recommended references

1. Space Mission Analysis and Design, edited by Wiley J. Larson and James R. Wertz, 3rd edition, 1999

2. Fundamentals of Astrodynamics and Applications, David A. Vallado, 4th edition, 2013

3. Applied Orbit Perturbations and Maintenance, Chia-Chun “George” Chao, 2005