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Committee on the Peaceful Uses of Outer Space

National research on space debris, safety of space objects with nuclear power sources on board and problems of their collisions with space debris

Note by the Secretariat*

Addendum

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* The present document contains replies received from Member States and international organizations between 25 November 2000 and 25 January 2001.

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I. Introduction

1. At its forty-third session, the Committee on the Peaceful Uses of Outer Space agreed that Member States should continue to be invited to report to the Secretary-General on a regular basis with regard to national and international research concerning the safety of space objects with nuclear power sources, that further studies should be conducted on the issue of collision of orbiting space objects with nuclear power sources on board with space debris and that the Committee's Scientific and Technical Subcommittee should be kept informed of the results of such studies.[1] The Committee also took note of the agreement of the Subcommittee that national research on space debris should continue and that Member States and international organizations should make available to all interested parties the results of that research, including information on practices adopted that had proved effective in minimizing the creation of space debris (A/AC.105/736, para. 96).

2. Information received by Member States and international organizations as at 24 November 2000 is contained in the note by the Secretariat of 27 November 2000 (A/AC.105/751). The present document contains information submitted by Member States and international organizations between 25 November 2000 and 25 January 2001.

II. Replies received from Member States and international organizations

United States of America

A. Background

1. The United States of America has pioneered the passivation of launch vehicle orbital stages since the early 1960s and has strongly encouraged other launch vehicle operators around the world to adopt similar measures. The need for orbital stage passivation is evident from the fact that more than 80 per cent of all orbital stage break-ups could have been prevented by passivation. Indeed, no passivated orbital stage is known to have suffered a major fragmentation.

2. As early as 1961, the United States recognized the potential benefit of passivating orbital stages and subsequently implemented fuel venting for Thor-Ablestar orbital stages. The hazards of uncontrolled venting of cryogenic propellants were identified in 1963 with the Centaur orbital stage, leading to simple design and operational changes. During the 1980s and 1990s, passivation measures became standard operating procedures on a number of United States' orbital stages belonging to the Delta, Pegasus and Titan launch vehicle series.

3. The most important element of orbital stage passivation is the depletion of residual propellants by either venting or burning. Both techniques are employed by various United States' orbital stages. One advantage of depletion burns is the opportunity to lower the disposal orbit of the vehicle, thereby reducing its orbital

[1] *Official Records of the General Assembly, Fifty-fifth Session, Supplement No. 20* (A/55/20), para. 99.

lifetime at no cost. The orbit of a Delta II second stage was lowered from its payload delivery orbit of 900 km to a disposal orbit of 207 km by 860 km, allowing the vehicle to re-enter in less than one year, rather than several hundred years without the manoeuvre. Similarly, altitude reduction via propellant depletion manoeuvres by Delta II second stages on Iridium and Globalstar missions greatly shortened their orbital lifetimes.

4. Experience with the Pegasus hydrazine auxiliary propulsion system (HAPS) orbital stage demonstrated the need also to vent high-pressure inert gases. Although very few orbital stage fragmentations are estimated to have been caused by malfunctioning batteries or range safety systems, due diligence dictates that those functions also be included in end-of-mission passivation plans.

5. In addition to finding techniques to impede the break-ups of orbital stages, the United States has introduced a variety of design changes to reduce the amount of mission-related debris associated with orbital stages. Explosive bolts used to separate launch vehicle stages or to release spacecraft from the final launch vehicle stage are now designed with catchers to prevent fragments from becoming orbital debris. Separation springs and payload hold-down clamps are now routinely retained with the orbital stage.

6. In 1997, the United States Government developed a set of orbital debris mitigation standard practices. The first two standard categories address mission-related debris and passivation:

> "*Guideline 1-1*. In all operational orbit regimes spacecraft and upper stages should be designed to eliminate or minimize debris released during normal operations. Each instance of planned release of debris larger than 5 mm in any dimension that remains on orbit for more than 25 years should be evaluated and justified on the basis of cost effectiveness and mission requirements."

> "*Guideline 2-2*. All on-board sources of stored energy of a spacecraft or upper stage should be depleted or safed when they are no longer required for mission operations or post-mission disposal. Depletion should occur as soon as such an operation does not pose an unacceptable risk to the payload. Propellant depletion burns and compress gas releases should be designed to minimize the probability of subsequent accidental collision and to minimize the impact of a subsequent accidental explosion."

7. Passivation and the curtailment of mission-related debris is important for existing launch vehicles, as well as those still under design and development. Typically, the cost of passivation and debris mitigation measures is extremely small, if undertaken early in the design phase.

B. United States' orbital stages

1. Athena

8. The Lockheed-Martin Athena launch vehicle family, originally introduced in 1995 as the Lockheed-Martin launch vehicle (LMLV), is designed primarily to place payloads of less than two tons into low-Earth orbit (LEO). The Athena 1 consists of two solid-propellant stages and a liquid-propellant orbit adjust module (OAM). The

Athena 2 launch vehicle adds another large, sub-orbital solid-propellant stage to more than double the payload capacity.

9. Normally, the only stage left in orbit is the OAM. This small, mono-propellant hydrazine system is completely passivated with the elimination of any residual propellant and pressurant. Batteries are discharged within 90 minutes and any range safety systems are inhibited. In the event that the Orbus 21D solid-propellant motor of the Athena 1 second stage or the Athena 2 third stage reaches orbit, it is also passivated. Mission-related debris is limited to one object for the Orbus 21D stage and to two objects for the OAM.

2. BA-2

10. Beal Aerospace Technologies, Inc., has decided not to proceed with development of the BA-2 vehicle. However, the design was planned with orbital debris mitigation in mind and is included here for the sake of completeness. Beal Aerospace Technologies was developing a new, three-stage, all-liquid-propellant launch vehicle designated BA-2 and capable of inserting up to 5.8 tons into geostationary transfer orbit (GTO) or up to 17 tons into LEO. The third stage, powered by hydrogen peroxide and Jet-A kerosene, was to remain in orbit and be passivated. The residual main propellants, along with helium pressurants, were to be vented, while the residual hydrogen peroxide used by the attitude control system would be burned to depletion. The stage was to use solid-state batteries that would be fully discharged after payload delivery. No mission-related debris was anticipated.

3. Centaur

11. The Lockheed-Martin Centaur was the world’s first liquid hydrogen/liquid oxygen upper stage, completing its inaugural orbital mission in 1963. Today, the latest Centaur variants are carried by both the Atlas and Titan launch vehicle families for LEO and high-altitude missions. Complete passivation is executed after all Centaur missions. All residual main propellants and attitude control system propellants are eliminated, the former by venting and the latter by depletion burns. Batteries are discharged within 24 hours and range safety systems are disabled. Mission-related debris is limited to one to three objects per flight.

4. Delta

12. The Boeing family of Delta launch vehicles has been in use since 1960 and supports a wide variety of LEO, geostationary orbit (GEO) and deep space missions. Currently, Delta II- and Delta III-class launch vehicles are operational and the Delta IV launch system is under development.

(a) Delta II

13. The Delta II launch vehicle was introduced in 1990 with a LEO payload capacity of 5.1 tons and a GTO payload capacity of 1.9 tons. The second stage retained the passivation measures first instituted in 1981 for the previous generation of Delta launch vehicles. Following completion of the mission, the residual hypergolic propellants of the main propulsion system are burned to depletion, allowing the helium pressurant system to be partially relieved. The cold-gas

nitrogen attitude control system is blown down. Battery lifetime is nominally less than nine hours and the range safety system is disabled about one minute after the initial second-stage main engine burn. No mission-related debris is intentionally released.

14. On some Delta II missions, a third stage, using either STAR 37FM or STAR 48B solid-propellant motors, is employed, which naturally burns the main propellant to depletion. A hydrazine attitude control system is blown down after motor cut-off and no other fluids are present. Like the second stage, the third-stage electrical power system has a maximum nine-hour lifetime. No range safety system is carried. Up to five mission-related pieces of debris may be generated, depending on the need to despin the system prior to payload separation.

(b) Delta III

15. The newest generation of Delta launch vehicles, the two-stage Delta III, was first flown in 1998. The second stage is an entirely new design, relying on liquid hydrogen and liquid oxygen rather than the hypergolic propellants of Delta II. The maximum payload capacity to LEO is 8.3 tons and to GTO is 3.8 tons. Residual main engine propellants and helium pressurant are vented at the end of the mission. Residual hydrazine in the attitude control system is burned to depletion. Stage batteries are designed for only a three-hour lifetime and the range safety system is disabled after the initial second-stage main engine firing. An automated destruction system lanyard segment may be released during flight, as well as parts of a graphite epoxy stiffening ring.

(c) Delta IV

16. The Delta IV launch vehicle, now under development, will replace the single-variant Delta III with a family of five variants exhibiting payload capacities of 8.6-25.8 tons and GTO capacities of 3.9-10.8 tons. The second stages of the Delta IV will be similar to those of the Delta III, though larger. The Delta IV will inherit the same passivation procedures employed by the Delta III and potential mission-related debris will be the same.

5. Inertial Upper Stage

17. The Boeing Inertial Upper State (IUS) is a powerful, two-piece, solid-propellant assembly that has successfully flown with the Space Shuttle and the Titan 3 and Titan 4 launch vehicles, beginning in 1982. It has been used primarily to deliver payloads from LEO to GEO, but has also placed the Magellan, Galileo and Ulysses spacecraft on interplanetary trajectories.

18. The lower part of the IUS employs an Orbus 21 motor, while the upper segment carries the smaller Orbus 6 motor. As with other solid-propellant systems, the main propellant is burned to depletion. The residual hydrazine of the attitude control system is burned to depletion on some missions but may be left on others. Battery lifetimes range from 30 minutes to eight hours. Range safety systems are inhibited prior to IUS first-stage ignition. Some multi-layer insulation (MLI) may come off the IUS first-stage exit cone during operation.

6. Minotaur

19. The Minotaur launch vehicle, developed by the Orbital Sciences Corporation, combines the first two stages of the Minuteman II ballistic missile with the second and third stages of the Pegasus launch vehicle to produce an orbital payload capacity of 640 kg to LEO. The Minotaur debuted in 2000 with successful missions in January and July. Only the Minotaur fourth stage, the Orion 38, is left in Earth orbit. This solid-propellant system burns its main propellant to depletion and vents any attitude control system residual propellant (nitrogen). Batteries are limited to four hours and no range safety system is carried. One piece of mission-related debris may be produced.

7. Pegasus

20. Orbital Sciences Corporation’s Pegasus launch vehicle, first launched in 1990, is unique with its airborne launch platform. Pegasus can lift payloads of up to nearly 500 kg into LEO. The standard and XL variants of Pegasus can leave one or two stages in Earth orbit. One is the same as the Minotaur fourth stage (serves as the Pegasus third stage) and is passivated in the same manner. On some Pegasus missions a fourth stage, HAPS, is carried. That stage was redesigned after its first two missions to improve the vehicle and to permit more complete passivation. Residual hydrazine is burned and residual nitrogen used for attitude control is vented. The helium pressurant is not vented, but its pressure is reduced well below maximum operating pressures. Batteries are limited to lifetimes of four hours and no range safety systems are carried. One piece of mission-related debris may be produced.

8. Taurus

21. The Taurus launch vehicle combines the first three stages of Pegasus with a larger initial stage (designated Stage 0) of either a Peacekeeper ballistic missile first stage or a Castor 120 solid-propellant motor. The maiden flight of Taurus occurred in 1994 and the launch vehicle can lift up to 1.4 tons into LEO. The final stage of Taurus is the Orion 38 and it is passivated as on Minotaur and Pegasus missions. One piece of mission-related debris may be generated.

9. Titan

22. Like Atlas and Delta, the Titan space launch vehicle has been in service for the United States since the 1960s. Two main variants are currently offered by Lockheed-Martin, the Titan II and the Titan IV.

(a) Titan II

23. The Titan II was first used during 1964-1966 by the Gemini man-in-space programme. Using refurbished ballistic missiles, Titan II returned to space flight in 1988 with a capacity of approximately 2 tons to LEO. Since most Titan II payloads perform their own orbital insertion manoeuvres, to date only two recent-era missions have left a second stage in Earth orbit. Before the second such mission, in 1999, the Titan II second stage was modified to permit more thorough passivation. Now all propellants and pressurants are eliminated after payload separation. The maximum lifetime of the electrical power system is 90 minutes and the range safety

system is inhibited at the end of the mission. Up to two pieces of mission-related debris may be left in orbit.

(b) Titan 4

24. The Titan 4 launch vehicle has been operational since 1989 and can be flown in a two-stage configuration or with an additional stage of Centaur or IUS. When left in orbit, the Titan 4 second stage is passivated in a similar manner to the Titan 2 second stage. A maximum of three pieces of mission-related debris may be produced.

European Space Agency

The Council of the European Space Agency adopted the following resolution on space debris policy on 20 December 2000:

"Resolution for a European policy on the protection of the space environment from debris

"*Council*,

"*Recalling* the resolution adopted on 29 June 1989 (ESA/C/LXXXVII/Res.3 (Final)), on the Agency's policy vis-à-vis the space debris issue, which already emphasized that "the problem of space debris has become worldwide one of the major issues regarding the environmental protection of outer space and has reached a level which requires serious considerations especially for manned missions",

"*Sharing* the worldwide concern at the growing amount of debris in various orbital regions and *recalling* the Declaration adopted in Vienna at the July 1999 Unispace Conference on Space and Human Development, and in particular chapter 3 thereof,

"*Considering* that the resulting problems and risks call for specific measures to be taken as a matter of urgency, in collaboration with the various players concerned and at the highest level, to ensure that outer space continues to be accessible and usable for the benefit of all countries, in accordance with the Outer Space Treaty of 10 October 1967,

"*Noting* the growing recognition of these risks and *encouraged* by the progress made by the Agency through its studies and implementations (such as the ESA Handbook on Debris Mitigation, the ESA MASTER Model, the DISCOS database and the ESABASE/DEBRIS risk analysis tool) and its Space Debris Advisory Group (SDAG), by the space agencies of Member States and by the Inter-Agency Space Debris Coordination Committee (IADC), which contribute collectively to a better understanding of the basic technical issues allowing the formulation and understanding of specific measures to reduce these risks,

"*Having regard* to the work of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), and in particular its technical report A/AC.105/720 (1999),

"W*elcoming* the technical measures already taken in the framework of the Ariane Launcher Programme (development and production), "*Reaffirming* its support for the International Relations Committee in the attention it consistently gives to that issue and *supporting* a European-focused initiative in that field,

"1. *Supports* the action being taken by the Agency to arrive at a more reliable assessment of the risks created by space debris, as a basis for specific measures, the application of mitigation measures and its efforts to pursue international cooperation within the IADC and ensure the public is properly informed.

"2. *Invites* the Member States and the Agency to further intensify their effort to coordinate and inform in the framework of their respective programmes and that of the IADC, and vis-à-vis the international organizations concerned (the UN and ITU in particular).

"3. *Invites* the Director General and the Member States to coordinate the establishment and use of their space debris monitoring systems in order to increase the European contribution to global space debris monitoring efforts.

"4. *Invites* the Director General and the Member States to expeditiously work, in collaboration with the other partners in the IADC, on the elaboration of technical standards for safety and debris prevention.

"5. *Invites* the Director General and the Member States to ensure that account is taken of space debris risks and space debris preventative measures at the time programme proposals are drawn up.

"6. *Invites* the Director General to make appropriate provision in the general budget and in the programme budgets for the annual resources required to implement the present resolution and to set up, for the sake of visibility, a separate output for this purpose.

"7. *Invites* the Member States to take measures in order that legal and economic aspects connected to space debris be studied in the most efficient ways, in particular within the UNCOPUOS and to present/support initiatives; *invites* the Director General to arrange for studies, in liaison with the ECSL and IISL in particular, of the legal and economic questions raised in this connection by the advent of privatization in the conduct of the use and exploitation of outer space and to introduce appropriate provisions in international agreements and in contracts.

"8. *Invites* the Director General to present to Council annual reports on implementation of the present Resolution and to bring the latter to the attention of the various players involved, including the United Nations (COPUOS), the ITU, other international organizations as appropriate and the members of the IADC, in an adequate form."