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CHAPTER 10

ENVIRONMENTAL REGULATION

Introduction

Space presents a variety of environmental problems to which law must respond.[1] Not all will be treated in this Chapter. Radio matters are covered in more detail in Chapter 8, Radio and the International Telecommunication Union. The environment of the Moon and other celestial bodies is largely dealt with in Chapter 7 as is the detail of the Moon Agreement itself on contamination by its exploration. Here, moving from 'in' to 'out there' we cover generalities of Space Law before turning to the possibility of the contamination of the Earth from space, the polluting results of space activities (broadly the debris problem), and the protection of the Earth from asteroids, meteors and comets (planetary defence). But we must begin with some general observations.

General

It would be wrong to consider the law of the space environment as something separate, distinct and different from the concepts of terrestrial environmental law.[2] Of its nature space presents exceptional difficulties, but these are not sufficient to require unique concepts. Environmental space law is simply a specialised area of environmental law. Matters of law are involved. The Moon Agreement, with its paltry level of ratifications (13 as of 2008) cannot pretend to affirm propositions that bind other than its parties although many of its provisions are sensible. The Outer Space Treaty has a better legal status. It and the preceding UN Declaration of Legal Principles of 1963 were adopted without vote in the General Assembly. As we have argued in Chapter 3 the fundamental or basic principles expressed in the Principles and the OST now form part of customary International Law, and therefore also bind states which have neither signed nor ratified the 1967 Treaty. Article III of the OST, and para 2 of the 1963 Declaration state that the exploration and use of outer space is to be carried out in accordance with International

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[1] M. Williamson, *Space: The Fragile Frontier* (Washington, DC: AIAA, 2006) and his 'Space Ethics and the Protection of the Space Environment' (2006) 32 *J. Sp. L.* 217; B.K. Schafer, 'Solid, Hazardous, and Radioactive Wastes in Outer Space: Present Controls and Suggested Changes' (1988) 19 *Cal. W. Int. L.J.* 1-46 (with select bibliography).

[2] F. Lyall, 'Protection of the Space Environment and Law' (2000) 42 *Proc. IISL* 472-82; A.G. Apking, 'The Rush to Develop Space: The Role of Spacefaring Nations in Forging Environmental Standards for the Use of Celestial Bodies for Governmental and Private Interests' (2006) 16 *Colo. J. Int. Env. L.* 429-66; D. Tan, 'Towards a New Regime for the Protection of Outer Space as the "Province of All Mankind"' (2000) 25 *Yale J. Int. L.* 145-94. L. Viikari, *The Environmental Element in Space Law: Assessing the Present and Charting the Future*, (Leiden: Nijhoff, 2008) was published after this chapter was drafted.

Law.[3] The principles of general terrestrial environmental International Law are therefore relevant for space. What are they?

A considerable body of International Law now deals with environmental matters.[4] It is even argued by some that its basic principles have become customary law.[5] Certainly there are many environmental treaties, declarations and similar documents,[6] and there is relevant debate in the International Law Commission (ILC) on 'State Responsibility', on 'International Liability for Injurious Consequences Arising from Acts Not Prohibited by International Law' and on war crimes.[7] While it must be remembered that the function of the ILC is to consolidate and develop, but not to make law, its work is always of interest.[8]

One traditional starting point for discussions of state obligations in regard to the environment is the *Trail Smelter Arbitration*[9] which articulates the duty of a state not to

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[3] See Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies, (1968) 610 UNTS 205; (1968) UKTS 10, Cmnd. 3519; 18 UST 2410, TIAS 6347; (1967) 6 ILM 386; (1967) 61 AJIL 644; 'Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space', UNGA Res. 1962 (XVIII) 1963: (1964) 3 ILM 157. Cf. Part A, para 1.b of UNGA Res. 1721 (XVI), 20 December 1961; Preamble 'Believing' of UNGA Res. 1802 (XVII), 19 December 1962.

[4] P.W. Birnie and A.E. Boyle, *International Law and the Environment*, (Oxford: Clarendon Press, 1992); P. Sands, *Principles of International Environmental Law*, 2nd ed. (Cambridge: Cambridge UP, 2003); D. Hunter, J. Salzman and D. Zaelke *International Environmental Law and Policy*, 2nd ed. (New York: Foundation Press, 2002); T. Kuokkanen, *International Law and the Environment*, (The Hague: Kluwer Law Int., 2002).

[5] C.L. Carr and G.L. Scott, 'Multilateral Treaties and the Environment: A Case Study in the Formation of Customary International Law' (1999) 27 *Denv. J. Int. L. & Pol.* 313-35.

[6] P.W. Birnie and A.E. Boyle, *Basic Documents on International Law and the Environment*, 2nd ed. (Oxford: Oxford UP, 2002); P. Sands and P. Galizzi, *Documents in International Environmental Law*, 2nd ed. Cambridge: Cambridge UP, 2004); *International Protection of the Environment: Treaties and Related Documents*, B. Ruster and B. Simma, eds., 33 vols. (New York: Oceana, 1990-).

[7] 'Responsibility of States for Internationally Wrongful Acts', (International Law Commission, 2001). See A/Res/56/83, or http://untreaty.un.org/ilc/texts/instruments/english/draft%20articles/9_6_2001.pdf, or with commentary at http://untreaty.un.org/ilc/texts/instruments/english/commentaries/9_6_2001.pdf; See J. Crawford, *The International Law Commission's Articles on State Responsibility* (Cambridge: Cambridge UP, 2002); cf. S. Rosenne, *The International Law Commission's Draft Articles on State Responsibility,* (Dordrecht: Martinus Nijhoff, 1991).

[8] The codification of International Law has been the responsibility of the International Law Commission since it was set up by UNGA Res. 174(II) of 1947. Codification is not the same as consolidation, and involves improvement as well as articulation. Over the years the Commission has produced draft Codes, as well as draft treaties.

[9] The *Trail Smelter Arbitration* (US v Canada) 1938/41 3 RIAA 1905; (1939) 33 AJIL 182; (1941) 35 AJIL 684. Note the possibility of contamination of domestic territory during a space launch, *infra* n. 46.

permit the use of its territory to the detriment of another state. Other cases have followed, e.g. the *Corfu Channel Case* of 1949,[10] where again a state was found liable for a use of its territory that damaged another state. But environmental damage can be caused without the territory, property or personnel of another state being involved. Damage can be done to environmental objects or areas not owned by and beyond jurisdiction of any state. Terrestrial rules are therefore of interest, for space is beyond the limits of national jurisdiction: '[O]uter space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means' (Art. II, OST).

That states have a responsibility to ensure activities within their 'control do not cause damage to the environment of areas … beyond the limits of national jurisdiction' is a major part of Principle 21 of the Stockholm Declaration of 1972.[11] Its Principle 22 then requires that States cooperate in developing further International Law as to liability and compensation for damage caused 'by activities within the jurisdiction or control of such States to areas beyond their jurisdiction.' Similar language is found in a number of later agreements and Declarations.[12] To these one must add the work of the United Nations Environmental Programme (UNEP),[13] the UN Conference on Environment and Development (UNCED), Rio de Janiero, 1992 and Agenda 21, the action programme it adopted for a variety of environmental matters.[14]

All these are largely aspirations and intentions and are non-binding although they are often complied with. Matters might have been taken further had the ILC persevered on lines it considered during the long process that resulted in its Articles on 'State

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[10] The *Corfu Channel* Case, (UK v Albania), 1949 *ICJ Rep*. 1.

[11] 'The Declaration of the UN Conference on the Human Environment', Stockholm, 1972; http://www.unngocsd.org/documents/stockholm1972.pdf or http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97&ArticleID=1503; (1972) 11 ILM 1416. For the Conference Documents see http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97.

[12] Cf. 'The Rio Declaration on Environment and Development', (A/CONF.151/26) - http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm; the World Charter for Nature of 1982, UNGA Res. 37/7; (1983) 22 ILM 455. (111 states voted in favour, the US against, and 18 abstained on the ground that their sovereignty over their natural resources might be impaired). Cf. N.B. Robertson et al. eds. *Agenda 21 and the UNCED Proceedings*, 6 vols., (New York: Oceana, 1992-3); F. Lyall, 'Protection of the Space Environment and Law' (2000) 42 *Proc. IISL* 472-82. Cf. also Part XII (Arts. 192- 237) on the protection of the marine environment of the UN Convention on the Law of the Sea, Montego Bay, Jamaica, 10 December 1982, 1833 UNTS 3; 1999 BTS 82, Cm. 4524; (1982) 21 ILM 1261; US Tr. Doc. 103-39.. See also materials cited *supra* n. 6.

[13] UNEP was established following the 1972 Stockholm Conference on the Human Environment. It encourages and coordinates actions on environmental matters by national and regional non-governmental bodies.

[14] Agenda 21 is an action programme directed particularly to sustainable development and the proper use and management of environmental resources. See *Agenda 21 and the UNCED Proceedings*, 6 vols., N.B. Robertson et al. eds., (New York: Oceana, 1992-3). See also the Division for Sustainable Development of the UN Department of Economic and Social Affairs at http://www.un.org/esa/sustdev/documents/agenda21/index.htm.

Responsibility' of 2001, but these do not figure in the final text.[15] In 1996 an Art. 19 for the then Draft Articles did indicate state responsibility in respect of areas not under national jurisdiction.[16] It was suggested that an 'international crime' would be committed by the breach of any obligation recognised by the international community as 'essential for the protection of the fundamental interests of the international community' (Draft Art. 19.2), including obligations 'such as those prohibiting massive pollution of the atmosphere or of the seas' (Draft Art. 19.3). Draft Art. 19.4 then provided that an internationally wrongful act short of an international crime was an international delict.[17] However, the ILC was divided and departed from the concept of 'international crime' partly because of the way the concept of 'crime' was being developed within other international jurisprudence, including through the creation of the International Criminal Court and the work of the Tribunals for Yugoslavia and Rwanda. Notwithstanding, the ILC discussion of Draft Article 19 shows a willingness to consider damage to the environment beyond national jurisdiction as being of major importance. The Commentary to ILC Draft Art. 51 of the 1996 version of the Draft Articles indicates that the purpose of the introduction of a category of 'international crime' was to set apart or denote 'a category of wrongful acts to which, because of their seriousness, special consequences should apply'. Later ILC discussion used the term 'exceptionally serious wrongful acts'.[18] But it is doubtful whether 'damage' to the space environment or to a celestial body is so 'essential for the protection of the fundamental interests of the international community' that it should be categorised as a crime. However there is an argument that in appropriate circumstances such damage should be classed as an international delict should it be an 'exceptionally serious wrongful act'.[19]

Another interesting line of discussion is the ILC work on 'International Liability for Injurious Consequences Arising from Acts Not Prohibited by International Law'. This also might have produced ideas relevant for space. However, although it still centres on questions of prevention in order to achieve consensus within the Commission the ambit of those Draft Articles has been restricted to the 'Prevention of Transboundary Damage from Hazardous Activities' of 2001[20] and the 'Draft principles on the allocation

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[15] See n. 18 *infra*.

[16] Draft Articles on State Responsibility, 1996 YBILC II(2); A/52/10 - http://untreaty.un.org/ilc/texts/instruments/english/draft%20articles/9_6_2001.pdf or with commentaries at http://untreaty.un.org/ilc/texts/instruments/english/commentaries/9_6_2001.pdf.

[17] L. Berat, 'Defending the Right to a Healthy Environment: Toward a Crime of Geocide in International Law' (1993) *Boston U. Int'l L. J.* 327-48.

[18] 1998 YBILC II(2), paras 241 – 331, at the end of which Draft Art. 19 was agreed to be put aside 'for the time being'.

[19] The Chinese destruction of its weather satellite in 2007 comes to mind. See *infra* n. 130.

[20] 'Prevention of Transboundary Harm from Hazardous Activities' (ILC: 2001) (A/56/10) - http://untreaty.un.org/ilc/texts/instruments/ english/draft%20articles/ 9_7_2001.pdf or with commentaries at http://untreaty.un.org/ilc/texts/ instruments/ english/commentaries/9_7_2001.pdf.

of loss in the case of transboundary harm arising from hazardous activities' of 2006.[21] Both clearly refer to environmental harm done to the territory of another state or areas under its jurisdiction, not to areas beyond national jurisdiction.

Finally, at one stage in the ILC consideration of 'War Crimes' Art. 22 of the 'Draft Code of Crimes against the Peace and Security of Mankind' included 'employing methods or means of warfare which are intended or may be expected to cause widespread, long-term and severe damage to the natural environment' as one of the 'Exceptionally serious war crimes' (Draft Art. 22.2.d).[22] Further, Draft Art. 26 included the wilful causing of such damage as a crime in war or in peace for which an individual could be held guilty. But again in order to achieve consensus within the Commission, such matters did not persist into the final form of the Draft Code.[23]

The timidity or diffidence of the ILC notwithstanding, a general international duty towards the preservation and conservation of the environment, both within and outside areas of national jurisdiction is developing. In the Advisory Opinion of 1996 on the *Legality of the Use by a State of Nuclear Weapons in Armed Conflict* the ICJ stated:

> 'The Court recognises that the environment is under daily threat and that the use of nuclear weapons could constitute a catastrophe for the environment. The Court also recognises that the environment is not an abstraction but represents the living space, the quality of life and the very health of human beings, including generations unborn. The existence of the general obligation of States to ensure that activities within their jurisdiction and control respect the environment of other States or of areas beyond national control is now part of the corpus of International Law relating to the environment.'[24]

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[21] 'Draft principles on the allocation of loss in the case of transboundary harm arising from hazardous activities' (ILC; 2006) (A/61/10) - http://untreaty.un.org/ilc/texts/instruments/english/draft%20articles/9_10_2006.pdf or with commentaries at http://untreaty.un.org/ilc/texts/instruments/english/commentaries/9_10_2006.pdf.

[22] 'Draft Code of Crimes against the Peace and Security of Mankind' 1995) Report of the Special Rapporteur (A/CN.4/466). See (1991) YBILC 223-8 for discussion of Draft Art. 22. Cf. UNGA Res. 47/37, 1992, on 'Protection of the Environment in Times of Armed Conflict'. Cf. also H.A. Almond, Jr., 'War, Weapons and the Environment' (1988) 1 *Geo. Int. Env. L. Rev.* 167-97, and 'War, Weapons and the Environment' (1990) 3 *Geo. Int. Env. L. Rev.* 117-82.

[23] 'Draft Code of Crimes against the Peace and Security of Mankind' 1996; 1996 YBILC II.2, http://untreaty.un.org/ilc/texts/instruments/english/draft%20articles/7_4_1996.pdf.

[24] *Legality of the Use by a State of Nuclear Weapons in Armed Conflict*, Advisory Opinion, 8 July 1996, (1996) ICJ Rep. 226, para 29 (240); (1996) 35 ILM 809. At para 31 the Court also cites para 64 of its Order of 22 September 1995 in the *Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgement of 20 December 1974 in the Nuclear Tests Case (New Zealand v. France) Case*, 1995 ICJ Rep. 288. Para 64 of the Order dismissing that *Request* expressly states that it is made 'without prejudice to the obligations of States to respect and protect the natural environment' (Rep. at 306).

One year later, in a contentious case the Court quoted that statement, noting that it had 'recently occasion to stress … the great significance that it attaches to respect for the environment, not only for States but also for the whole of mankind'.[25]

The developing International Law on the environment is not confined to *post hoc* action. The 'Precautionary Principle' argues in favour of giving a hard content to international environmental duties to avoid or prevent problems. In such matters it is better to be safe than sorry. It is better to take precautions which may not be needed, than to fail to take them and risk unfortunate consequences. The Precautionary Principle originates in municipal Environmental Law but it is making its way in International Law.[26] It also has its echoes in relation to space.

Last we note the concept of the Global Commons - the idea that there are portions or aspects of the Earth, not subject to state sovereignty either at all (e.g. the oceans beyond territorial limits), or not so subject in the normal way (e.g. the atmosphere, notwithstanding that some of the atmosphere necessarily lies within the airspace of states).[27] Increasingly it is suggested that Global Commons are held in some sort of trust for the whole of mankind and are to be managed as such.[28] Space, being set aside from national sovereignty, would seem to be another obvious example.[29] If, in the future, the concept of Global Commons stands, a duty to respect and manage the environment of a global commons in space could be inferred from terrestrial International Environmental Law, even in the absence of a clear universal multi-lateral treaty to that effect.[30] Of course, the concept of 'global commons' links to that of the 'common heritage of mankind' which we discussed in Chapter 7 on the Moon and Other Celestial Bodies, but it is a different thing.

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[25] *Case Concerning the Gabčikovo-Nagymaros Project (Hungary / Slovakia)*, 1997 ICJ Rep. at para 53, (1998) 37 ILM 168-242.

[26] H. Hohmann, *Precautionary Legal Duties and Principles of Modern International Environmental Law*, (London: Graham & Trotman; Dordrecht: Martinus Nijhoff, 1994); A. Trouwborst, *Precautionary Rights and Duties of States*, (Leiden: Martinus Nijhoff, 2006); P.B. Larsen, 'Application of the Precautionary Principle to the Moon' (2006) 71 *J. Air Law & Comm.* 295-306; L.D. Roberts, 'Ensuring the Best of All Possible Worlds: Environmental Regulation of the Solar System' (1997) 6 *N. Y .U. Env. L. J.* 126-60.

[27] We use the term in its technical legal sense. 'Global Commons' is also used freely (and sloppily) by some as a label for any global opportunity which they consider should be subject to little or no constraint.

[28] *Our Common Future: The Report of the World Commission on Environment and Development*, G.H. Brundtland, Chairman, (The 'Brundtland Commission') 1987, UN Doc. A/42/427, (Oxford/ New York: Oxford UP 1987); S.J. Buck, *The Global Commons: An Introduction* (London: Earthspan, 1998); J. Vogler, *The Global Commons: Environmental and Technological Governance*, 2nd ed. (London: John Wiley, 2000); cf. L.F.E. Goldie, 'Title and Use (Usufruct) - An Ancient Distinction too oft Forgot' (1985) 79 AJIL 689-714.

[29] Outer Space Treaty; Art. II; cf. V. Kopal, 'Outer Space as Global Commons' (1997) 40 *Proc. IISL* 108-16; L.D. Roberts, 'The Law of the Commons: A Framework for the Efficient and Equitable Use of the Lagrange points', (1990) 6 *Conn. J. Int. L.* 151-72.

[30] Cf. K. Gorove, 'Protection of the Global Commons: New Customary Law?' (1998) 26 *J. Sp. Law* 208-13; V. Kopal, *supra* n. 29.

The idea of a general duty as to the terrestrial environment that is not limited to the avoidance of direct harm to other states is therefore coming to be accepted. There is a common interest in the avoidance of harm to the planet on which we live. Some global environmental harm can only be remedied through a global approach.[31] The same logic applies to outer space, outer space debris being a case in point. Much of the current phraseology is anthropocentric, but we need not be so confined. Harm done to 'generations unborn' as the ICJ has put it,[32] could well include the degradation of the space environment, both near and far. The point is that terrestrial environmental law is applicable to the global environment as a whole, not just to those parts that lie within the jurisdiction of particular states. Environmental rights and duties go beyond that constraint and constitute obligations *erga omnes* (owed to everyone), although the idea of an international *actio popularis* (an action brought by one to enforce a duty owed to many or to the population as a whole) has not yet gained full acceptance in International Law.[33] Notwithstanding, states should exercise 'due diligence' in framing and enforcing their laws and regulations so as to secure the environment.[34]

How does all this apply to space?

Environmental Law and Space

Questions of the space environment arise in a number of different ways. When C. W. Jenks included a chapter on these sorts of problems in his *Space Law* he perceptively

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[31] Without entering into this debate, we note the mounting international concern as to 'global warming' and the efforts to mitigate the human contribution to this problem.

[32] *Supra* at n. 24. Note also the reference in MA Art. 4.1 to the interest of 'present and future generations' in the exploration and use of the Moon.

[33] See P. Sands, *supra* n. 4, at 150-4, 'International enforcement: Damage to the environment in areas beyond national jurisdiction'; A. de Hoogh, *Obligations Erga Omnes and International Crimes*, (The Hague: Kluwer, 1996); M. Ragazzi, *The Concept of International Obligations Erga Omnes*, new ed. (Oxford: OUP, 2000); C.J. Tams, *Enforcing Obligations Erga Omnes in International Law* (Cambridge: CUP, 2005).

Which state might be willing to bring court action to enforce such an *erga omnes* obligation is moot (in the UK sense of that word = unresolved). Again it is certain that some countries would not be prepared to be sued on an *erga omnes* basis: analogously cf. the US reaction to the Nicaragua Case of 1986 as manifested in various articles in (1987) 81 AJIL. Effective international judicial proceedings depend on the consent of parties. That said, although they did not proceed to a judgement, the Nuclear Tests cases of 1974 may be considered to have an *erga omnes* element, contamination of the high seas being an element of the complaints. See the *Nuclear Tests Case (New Zealand v. France)* 1974 ICJ Rep. 157 and the *Nuclear Tests Case (Australia v. France)* 1974 ICJ Rep. 253.

[34] 'Due diligence' has been a matter of discussion. Cf. Draft Art. 3 of the ILC 1998 Report, Ch. IV, on 'International Liability for Injurious Consequences arising out of Acts not Prohibited by International Law (Prevention of Transborder Damage from Hazardous Activities)', 'Prevention' and Commentary; www.un.org/law/ilc/ reports/1998/chp4.htm. Cf. also Birnie and Boyle, *supra* n. 4 at 92-4.

entitled it 'Space Cluttering and Contamination'.[35] We here deal with seven: astronomy, contamination, the Near-Earth environment, space traffic management, space debris, and planetary defence - the protection of the Earth from meteor, asteroid or cometary impact. Arguably the use of radio frequencies has an environmental aspect, but this is minimal within the parameters of this chapter, and, though mentioned below in relation to astronomy and orbital questions, we cover radio more extensively in Chapter 8.

Astronomy

The interests of optical and radio astronomy are often overlooked in discussions of space activities and space law.[36] Astronomy is, however, a valid use of space, which should be borne in mind. Radio astronomy is a 'service' for which provision is made in the Table of Allocations in the ITU Radio Regulations. Even so radio astronomy continues to be subjected to interference from terrestrial sources. We consider this particularly in Chapter 17 on SETI, and Chapter 8 on Radio and the International Telecommunication Union.[37] The institution of nationally and internationally protected radio 'quiet zones' would ameliorate some of these difficulties.[38] Optical astronomy encounters two major problems, light pollution from the ground and interference caused by the albedo of space objects and other debris.[39] We discuss the problems caused by orbiting objects and space debris below.[40] Light pollution from terrestrial sources is also a handicap for astronomers although major observatories are now placed well away from light sources. Amongst others Commission 50 of the International Astronomical Union (IAU) has a Working Group on 'Controlling Light Pollution'.[41] The International Dark-Sky Association (www.darksky.org) seeks the reduction of light pollution for a variety of environmental reasons, including the needs of astronomers, professional and amateur. In 2005 the Fifth European Symposium for the Protection of the Night Sky adopted the 'Declaration of Genk' calling for further action, including by the European Union.[42] The responsibility

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[35] C.W. Jenks, *Space Law* (London: Stevens, 1965) 280-2. UN OOSA maintains a useful Index of National Research on Space Debris, Nuclear Power Sources and Other Related Subjects: http://www.unoosa.org/oosa/en/natact/sdnps/sd_nps_docsidx.html.

[36] Cf. G. Lafferanderie, 'Space Law relevant to Astronomy' UN/ESA Basic Workshop. Bonn, 1996, http://www.seas.columbia.edu/~ah297/un-esa/paper-lafferanderie.html.

[37] For radio interference from satellite stations see *infra* at n. 103.

[38] F.G. von der Dunk, 'Space for celestial symphonies? Towards the establishment of international radio quiet zones' (2001) 17 *Space Policy* 265-74. Cf. Chapter 17, SETI, c. n. 55.

[39] 'Albedo' is the reflectivity of a body.

[40] *Infra* following n. 87.

[41] IAU Commission 50 deals with the 'Protection of Existing and Potential Observatory Sites', for both radio and optical observatories: see http://www.ctio.noao.edu/light_pollution/iau50/

[42] http://www.britastro.org/dark-skies/articles/genk.html. The Seventh Symposium, Oct. 2007, was to take up the matter again. See now the 8th Symposium, Darksky 2008 - http://darksky2008.kuffner-sternwarte.at/.

for such matters is, of course, that of municipal law and is perhaps best tackled at any planning stage.[43]

Contamination

Before we turn to the contamination of space, we would first note that contamination of the surface and atmosphere of the Earth can occur during or as a result of a launch or particularly of a failed launch.[44] Some launches occur into the areas of the High Seas. Resultant pollution should come under the head of damage caused to areas outwith national jurisdiction, but unfortunately the ILC has not proceeded with that topic.[45] Where a state launches its own satellites from its own territory pollution of that territory will be its own concern.. However, we note that during the continued use of the Baikonour Cosmodrome by Russia subsequent to Kazakhstan independence, there was pollution of the Kazakh steppes by rocket fuel and a resultant dispute.[46] This is a matter which non-territorial launching states, launch providers using foreign launch sites and commercial purchasers of foreign launches have to consider. We assume (but do not know) that relevant launch contracts either provide for compensation for any damage to launch-site territories or exclude liability. By contrast where contamination is caused to the territory of a non-launching state (to invent a label) liability will be incurred either under the Liability Convention, or in terms of Art. 5.4. of ARRA where material of a hazardous nature is incurred.[47]

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[43] Cf. 'Light Pollution and Astronomy' (UK) House of Commons, Committee on Science and Technology, Seventh Report (2002-3) (HC 747-I, Evidence at HC 747-II), http://www.publications.parliament.uk/pa/cm200203/cmselect/cmsctech/747/74710.htm. The Committee recommended a variety of measures to reduce light pollution in the interests of professional and amateur astronomers. The Clean Air and Environment Act 2005 ss. 101-103 made artificial light nuisance a statutory nuisance in England and Wales from 2006, but the exemptions are such that astronomy is not helped. Para 90 of the Guidance Note, 'Statutory Nuisance from Insects and Artificial Light' issued by the then Department for Environment, Food and Rural Affairs indicates that light pollution is not necessarily a statutory nuisance, and that the new offence is not a remedy for light pollution *per se*. Cf. also M.M. Taylor and D. Hughes, 'Exterior Lighting as a Statutory Nuisance' (2005) *J. Planning L.* 1131-1144.

US law on light pollution is sporadic and patchy. See K.M. Ploetz, 'Light Pollution in the United States: An Overview of the Inadequacies of the Common Law and State and Local Regulation', (2002) 36 *New Eng. L. Rev.* 985-1039: cf. the website of the American Astronomical Society (www.aas.org) (search 'light pollution'). The Declaration of Genk (*supra* n. 42), indicates that some European states have taken a variety of measures, but these also are patchy and not always effective.

[44] See 'Space Rocket Launch Sites around the World' - http://www.spacetoday.org/Rockets/Spaceports/LaunchSites.html#Hammaguir

[45] See *supra* at n. 20.

[46] M. Hošková, 'The 1994 Baikonour Agreements in Operation' (1999) 42 *Proc. IISL* 263-72. Kazakhstan suspended Russian use of the site until compensation was agreed.

[47] See Chapter 4, Space Objects, - 'The Return of Space Objects', 'Liability', and 'Practice'. The ARRA liability laid on a launching state is under the direction and

Looking outward from the Earth, space and celestial objects can be contaminated and contamination of the Earth from returning space objects might occur. Discussions on the contamination of and from space have their own jargon. 'Forward contamination' is contamination of space or celestial bodies by earth through our space activities. 'Back contamination' is the contamination of Earth from space by the return of astronauts or space objects that potentially might carry viruses or bacteria in to the Earth environment. There is also the contamination of Earth orbit, but we come to that in the next section.

Caution, not to say fear, as to the possibility of contamination arose early in the history of space. Indeed, the International Astronautical Federation discussed contamination at its Seventh Congress, Rome, 1956 – a year before Sputnik I. In 1958 having previously set up an ad hoc Committee on Contamination by Extraterrestrial Exploration (CETEX), the International Council of Scientific Unions (ICSU),[48] formed the international Committee on Space Research (COSPAR)[49] in part to coordinate anti-contamination action.[50] At first forward contamination was the major concern, especially given the early probes that were targeted to impact the Moon, and emergent plans for similar encounters with Venus and Mars, but when astronauts began to return from space back contamination rose in prominence.

The International Law on these matters is sparse, national regulation being in practice crucial through its role in implementing its generalities. The second sentence of OST Art. IX provides:

> States Parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter, and, where necessary, shall adopt appropriate measures for this purpose.

In that statement there is a curious tension between the duty to 'avoid … harmful contamination and … adverse changes', but only to adopt appropriate measures 'where necessary'. Further, it is noticeable that contamination *per se* is not excluded – only 'harmful contamination', and what constitutes that contamination is not defined. States

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control of the state that has found the relevant space object (but only if it so requires) to eliminate the possible danger of harm from hazardous materials. This duty applies not only to national territory but also if a contracting state finds a space object elsewhere than somewhere under its jurisdiction.

[48] ICSU is now the International Council for Science, but retains its old acronym - http://www.icsu.org/index.php

[49] For COSPAR see http://cosparhq.cnes.fr/ Its Charter is at http://cosparhq.cnes.fr/About/charter.htm

[50] 'Contamination by Extra-terrestrial Exploration' (1959) *Nature* 925-8; C.R. Phillips, *The Planetary Quarantine Program: origins and achievements, 1956-1973*, (SP-4902: NASA History Office, 1974) - http://history.nasa.gov/SP-4902/sp4902.htm; G.S. Robinson, 'Interplanetary Contamination: The Ultimate Challenge for Environmental and Constitutional Challenge? (2005)31 *J. Sp. L.* 117-63 at 121ff; L.I. Tennen, Evolution of the planetary protection policy: conflict of science and jurisprudence?' (2004) 34 *Adv. in Sp. Research.* 2354-2362.

are therefore left rather free in their implementation of the duty, albeit that the duty is one with which Art. VI requires them to ensure that their national activities comply. Precise implementation can be awkward, particularly when the OST is considered by a state to be non-self-executing and statutory authority is required. [51]

The other treaty which covers questions of contamination is the Moon Agreement of 1979. We consider the Agreement more fully in Chapter 7 but note here that its Art. 7.1 provides:

> In exploring and using the moon, States Parties shall take measures to prevent the disruption of its environment, whether by introducing adverse changes in its environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise. States Parties shall also take measures to avoid harmfully affecting the environment of the earth through introduction of extraterrestrial matter or otherwise.

Although the Moon Agreement is relatively ineffective through its failure to gain general acceptance, because it was adopted by the General Assembly (A/RES/34/68 of 5 December 1979) it is at least indicative of a generality of opinion as to matters of space contamination.[52]

In their implementation of duties as to non-contamination states have the benefit of the COSPAR Planetary Protection Policy which has been refined over many years. Its flaw that it is recommendatory only, not binding.[53] The Policy covers questions of biological contamination and deals with them in five categories of combinations of target body and space missions. An important factor in classification of forward contamination is whether the body may be of interest for understanding the process of chemical

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[51] Thus for the US see Robinson, *supra* n. 50; G.S. Robinson, 'Forward Contamination of Interstitial Space and Celestial Bodies: Risk Reduction, Cultural Objectives and the Law' (2006) 55 ZLW 380-99; cf. P.M. Sterns and L. Tennen. 'Current United States Attitude Concerning Protection of the Outer Space Environment' (1984) 27 *Proc. IISL* 398. See also L.D. Roberts, 'Ensuring the Best of All Possible Worlds: Environmental Regulation of the Solar System' (1997) 6 *N.Y.U. Env. L. J.* 126-60 at 157-60; D.A. Cypser, 'International Law and Policy of Extraterrestrial Planetary Protection' (1993) 33 *Jurimetrics* 315-39.

[52] Cf. M.S. Race and R.O. Randolph, 'The Need for Operating Guidelines and a Decision Making Framework Applicable to the Discovery of Non-Intelligent Extraterrestrial Life' (2002) 50 *Adv. Space Res.* 1583-91. Contamination was a matter which COPUOS was seised of, but ineffectively preferred to refer to the non-binding recommendations of COSPAR to which we are coming: Cypser, *supra* n. 51 at 317-21.

[53] COSPAR Planetary Protection Policy, 2002, amended 2005 - http://cosparhq.cnes.fr/Scistr/Pppolicy.htm. Cf. J.D. Rummel et al., 'COSPAR's Planetary Protection Policy: A Consolidated Draft' (2002) 30 *Adv. Space Res.* 1567-71; I. Almar, 'What Could COSPAR do to Protect the Planetary and Space Environment/' (2002) 30 *Adv. Space Res.* 1577-81; P.M. Sterns and L. Tennen, 'The Future of Planetary Protection: Is there Reason for Optimism' (2006) 49 *Proc. IISL* 391-400. For a practical example see the environmental assessment for the New Horizons mission of 2006, *infra* at n. 64.

evolution or the origin of life. In Category I there is no such direct interest, protection of the target body is unwarranted and the policy imposes no protection requirements. In Category II there is significant interest in the target for such understanding, but the chance that contamination carried by a spacecraft could jeopardize future exploration is remote. Only simple documentation of the activity is needed. Category III missions are fly-by or orbital missions where the likelihood of an impact on the target body is small but there is either a 'chemical evolution and/or origin of life' interest or scientific opinion thinks there is a significant chance of contamination that could jeopardize a future biological experiment. Here documentation is to be more thorough, and 'clean room' and sterilisation procedures should be used in construction of the probe. Category IV missions involve planned landings. Documentation is to be more detailed, and the intended lander sterile.[54] The big change of attitude in the Policy rules comes in Category V with regard to any mission involving a return to Earth. In order to preserve the Earth-Moon environment Category V missions comprise all Earth-return missions. Documentation requirements are considerable as are the requirements as to the sterility etc of hardware and materiél. However, where a solar system body has no indigenous life forms the requirements are modified. For these 'unrestricted Earth-return' projects only the outbound Category I and II requirements are imposed. All other cases are classed as 'restricted Earth-return'. In these any destructive impact of a probe upon its return to Earth is absolutely prohibited so as to prevent the escape of material.[55] All returned hardware which has directly contacted the target body together with any unsterilised material or samples from the target body is to be contained, such containment persisting through post-mission analysis. Perhaps ominously, '[i]f any sign of the existence of a non-terrestrial replicating entity is found, the returned sample must remain contained unless treated by an effective sterilizing procedure.' Of course this last is a staple of science fiction. Terrestrial bacteria may have killed H.G. Wells' Martians in *The War of the Worlds* (1898): incoming biological material might reverse that outcome. Protection against contamination is essential, and as a matter of general environmental law is, of course, dictated by the Precautionary Principle.[56]

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[54] An annex to the Policy lists the solar system target bodies to which Category III and IV may apply.

[55] Cf. the crash of the returning element of the 'Genesis' probe in September 2004 - http://news.bbc.co.uk/1/hi/sci/tech/3638926.stm. See also the Genesis Mission home-page - http://www.genesismission.org. The 'Stardust' spacecraft successfully parachuted a capsule to Utah in January 2006 with material from its visit to comet Wild II. The spacecraft itself was sent into Sun orbit. See - http://stardust.jpl.nasa.gov/mission/details.html. See also B.C. Clark, 'Martian Meteorites do not Eliminate the Need for Back Contamination Precautions on Sample Return Missions' (2002) 30 *Adv. Space Res.* 1593-1600; A. Debus, 'Planetary Protection Requirements for Orbiter and Netlander Elements of the CNES/NASA Mars Sample Return Mission' (2002) 30 *Adv. Space Res.* 1607-16.

[56] For the US rules see NASA Policy Directive NPD 8020.7F on 'Biological Contamination Control for Outbound and Inbound Planetary Spacecraft', 1999 (expires 2009) assigning responsibilities for administering NASA's planetary protection policy. The Directive refers to OST Art. IX, and stresses the importance of compliance so that contamination in both directions is avoided. See also NASA Policy Directive NPD

Nuclear contamination of the Earth may happen through the crashing of a satellite which has a nuclear power source.[57] Indeed we already have the example of COSMOS 954 which came to earth in Canada in January 1978.[58] In addition the world has been alarmed by the 1986 Chernobyl nuclear accident,[59] and by memories of the nuclear bombing of Hiroshima and Nagasaki at the end of World War II. The possibility of a major disaster involving contamination by plutonium caused the Florida Coalition, a group of environmentalists, to try to stop the launch of the Galileo space-craft in 1989,[60] and the Ulysses Project space-craft in 1990.[61] In both cases the space-craft were to pass close to the Earth while building up the velocities necessary for their missions.[62]

7100.10D on 'Curation of Extraterrestrial Materials' (expiring 11 February 2008, but likely to be extended). For NASA NPDs and NPRs see http://nodis3.gsfc.nasa.gov. How the Memorial Spaceflights offered by Space Services Inc. (http://www.memorialspaceflights.com/services.asp) are regulated is unknown to us. See *infra* n. 128.

[57] We consider the use of space for the disposal of terrestrial nuclear waste unrealistic and dangerous: R. Dusek, 'Lost in Space: The Legal Feasibility of Nuclear Waste Disposal in Outer Space' (1998) 22 *Will. & Mary L. & Pol. Rev.* 181-218.

[58] 'Canada – Union of Soviet Socialist Republics: Claim for damage caused by Cosmos 954' (1979) 18 ILM 899-930; Protocol and Settlement, Moscow, April 2 1981, (1981) 20 ILM 689. Other nuclear batteries have ended up in the Pacific from the returning Russian unmanned resupply 'Progress' spacecraft that serviced MIR and now the ISS. The Cosmos 954 incident is outlined in Chapter 4 in relation to questions of liability

[59] International Atomic Energy Agency, Convention on Early Notification of a Nuclear Accident, 1986, (1986) 25 ILM 1370-6, and Convention on Assistance in the Event of a Nuclear Accident or Radiological Emergency, 1986, (1986 25 ILM 1377-86, together with the Documents of the related IAEA Special Session, (1986) 25 ILM 1387-1407, including reservations and application to incidents not covered by these agreements.; Cf. Tokyo Economic Summit, 'Statement on the Implications of the Chernobyl Nuclear Accident, (1986) 25 ILM 1005-6; International Atomic Energy Agency, 'Statement Summarizing Decisions Taken at the Special Session of the Board of Governors Concerning the Chernobyl Nuclear Accident' (1986) 25 ILM 1009. See also D. Goren 'Nuclear Accidents in Space and on Earth: An Analysis of International Law Governing the Cosmos-954 and Chernobyl Accidents' (1993) 5 *Geo. Int'l Env. L. Rev.* 855-95; M.S. Straubel, 'Space Borne Nuclear Sources – the Status of their Regulation' (1986) 20 *Valparaiso U.L. Rev.* 187-218.

[60] *Florida Coalition for Peace and Justice* v. *George Herbert Walker Bush, et al.*, Civil Action No. 89-2682-OG United States District Court for the District of Columbia, 10 October 1989; 1989 U.S. Dist. LEXIS 12003. S. Gorove, 'Recent Litigation Involving the Launch of Spacecraft with NPS on Board' (1993) 36 *Proc. IISL* 298-303.

[61] *Florida Coalition for Peace and Justice* v. *George Herbert Walker Bush, et al.*, Civil Action No. 89-2682-OG United States District Court for the District of Columbia, 5 December 1990; 1990 U.S. Dist. LEXIS 13345. S. Gorove, *supra* n. 60.

[62] A number of deep space missions use the fly-by technique to pick up speed. Sometime the Earth is used. New Horizons (n. 64) used Jupiter. The Messenger mission to Mercury used the Earth in July 2007, and will use Venus several times before arriving

However, in both cases the Coalition was unsuccessful. In 1997 a similar result attended an attempt to halt the Cassini Mission.[63] More recently it is instructive to peruse the Final Environmental Impact Statement for the New Horizons Mission published in 2005, the initial parts of which assess the potential dangers of an accident during the New Horizons launch.[64]

The possibility of nuclear contamination of the Earth by a crashing satellite certainly exists and should be planned for by national authorities. International provision comes in UNGA Res. 47/68 of 14 December 1992 on 'Principles Relevant to the Use of Nuclear Power Sources in Outer Space'.[65] The Principles are limited in their application to nuclear power sources 'devoted to the generation of electric power … for non-propulsive purposes' generally similar to those in use at the time of the adoption of the Principles (Preamble, 'Affirming'). While Pr. 11 makes room for the revision of the Principles, that has not yet happened, but we would hope that their general tenor would be complied with in the case of a crash with a more recently developed nuclear source on board.

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at Mercury in 2011. 'Deep Impact' passed some 10000 miles above Australia on 31 December 2007 on its way to its next mission.

[63] *Hawaii County Green Party, Florida Coalition for Peace and Justice, Plaintiffs* v. *William Jefferson Clinton, President of the United States, in his official capacity, et. al.*; 11 Oct. 1997; US District Court for the District of Hawaii; 980 F. Supp. 1160; 1997 U.S. Dist. LEXIS 16196. The US notified the UN as to the related environmental safety assessment in 1997: A/AC.105/677 – 2 June 1997.

[64] NASA, *Final Environmental Impact Statement for the New Horizons Mission*, July 2005: http://spacescience.nasa.gov/admin/pubs/plutoeis/ or its 2 vols. Vol. 1: http://spacescience.nasa.gov/admin/pubs/plutoeis/NH-FEIS_Vol1.pdf: Vol. 2: http://spacescience.nasa.gov/admin/pubs/plutoeis/NH-FEIS_Vol2.pdf. The related Record of Decision is at http://spacescience.nasa.gov/admin/pubs/plutoeis/NH-ROD.pdf. The Statement was compiled under the US National Environmental Policy Act (NEPA) (42 USC 4321 ff.) to assist in the decision-making process for the project. Launched in January 2006, New Horizons is to explore Pluto and the Kuiper Belt, arriving in 2015. Cf. the US notification to OOSA: A/AC.105/864. Environmental assessments for other NASA launches are in the US Federal Register of Environmental Documents at http://www.epa.gov/fedrgstr/EPA-IMPACT/ e.g. http://www.epa.gov/fedrgstr/EPA-IMPACT/2002/June/Day-18/i15348.htm. [The New Horizons probe is currently hibernating in transit from Jupiter to Pluto - http://pluto.jhuapl.edu/news_center/news/100907.htm]. Cf. also 'Environmental Assessment for ICESat' NASA Goddard Spaceflight Centre, Maryland, - http://icesat.gsfc.nasa.gov/publications/12538-r10.pdf; 'Environmental Assessment for the Sea Launch Project' ICF Kaiser Consulting for NASA - http://www.fas.org/spp/guide/ukraine/launch/2_99Bslea.pdf;

[65] 'Principles Relevant to the Use of Nuclear Power Sources in Outer Space', 14 December 1992. UNGA Res. 47/68; 1993 32 ILM 917. (1993) 32 ILM 917 at 921-6. N. Jasentuliyana, - 1, 'Multilateral Negotiations on the Use of NPS in Outer Space' (1989) 24 AASL 297-337; - 2, 'An Assessment of the United Nations Principles on the Use of Nuclear Power Sources in Outer Space' (1993) 36 *Proc. IISL* 312-21. See also *infra* at n. 80 and following.

In the Nuclear Power Principles much is the responsibility of the 'launching state' or the 'state launching' the space object. The definition of such is limited to the state exercising jurisdiction and control (presumably in terms of Art. VIII of the OST) over the space object at the relevant time,[66] but for the purpose of liability by Pr. 9 the 'launching state' is defined broadly as in Art. VII of the OST and the Liability Convention (Pr. 2.1). When a space object has a nuclear power source on board and there is a malfunction and a risk of the re-entry of radioactive materials,[67] 'as soon as the malfunction has become known' (Pr. 5.2) its launching state is to inform the UN Secretary General and any states that might be affected (Pr. 5.1).[68] The information required comprises the system parameters (roughly those required by the Registration Convention) but particularly includes 'information required for the best prediction of orbital lifetime, trajectory and impact region' (Pr. 5.1.(a)(iv)). Principle 5.1(b) then requires information to be supplied as to the type of the nuclear power source on board (whether it is a radioisotopic generator or a nuclear reactor) (Pr. 5.1.(b)(i)) and as to the 'probable physical form and general radiological characteristics of the fuel and any contaminated and/or activated components likely to reach the ground. The term 'fuel' refers to the nuclear materials used as the source of heat or power' (Pr. 5.1.(b)(ii)). Information is to be updated as frequently as practicable and with increasing frequency as the anticipated 're-entry into the dense layers of the atmosphere approaches' 'so that the international community will be informed … and will have sufficient time to plan for any national response activities deemed necessary' (Pr. 5.2).[69] Principle 6 goes on to require the launching state to respond quickly to requests for further information or consultations.

Other states are also to be involved. When under the Principles the launching state notifies the possible re-entry of a nuclear power source all states having monitoring and tracking facilities are expected to get involved. They are to keep the UN Secretary General and other states informed of any information they may have so as to allow potentially affected states 'to assess the situation and take any precautionary measures deemed necessary' (Pr. 7.1). Once the re-entry has occurred the launching state is to offer assistance in identifying the location of the impact, the detection of materials and their retrieval or clean-up (Pr. 7.2(a)).[70] As indicated in our discussion of the Liability Convention and of the Nuclear Power principles there, the acceptance of an offer is at the discretion of the affected state. However, in contra-distinction, if the launching state is requested to offer assistance, it is to provide it (Pr. 7.2.(a)). Other states and relevant

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[66] Interestingly this formulation allows for the transfer of responsibility for a satellite by change of its registry. See Chapter 4, Space Objects, at c. n. 50.

[67] The term used is 'risk', not 'significant risk' or 'minimal risk' or other modification of its level.

[68] M. Hošková, 'The Notification Principle in the 1992 NPS Principles' (1993) 36 *Proc. IISL* 304-11.

[69] The UN Secretary General is similarly to be kept informed (Pr. 5.3). An example of the Principles in action is the Russian notification of the launch of the Mars-96 probe on 15 November 1996 (A/AC.105/647) and its re-entry east of Australia on 16 November 1996 following a launch failure (A/AC.105/648).

[70] Principle 3 calls for nuclear sources to be placed in non-frangible containers, but it is realistic to have provision as to a clean-up were such to fail. See also ARRA Art. 5 regarding the clean-up of hazardous and deleterious materials.

international organisations with appropriate capabilities are also to offer their help (Pr.7.2.(b)). However, again it is for an affected state to accept or decline an offer.

Of course the possible crash of a nuclear power source in its territory is an emergency for which governments should have plans and procedures. There will be short and long-term risks to the population as well as potentially significant damage to property. Less-developed countries are less likely to have such procedures. Accordingly the last paragraph of Pr.7 states that in the implementation of Pr.7.2.(a) and (b) as to states helping each other, 'the special needs of developing countries shall be taken into account'. Principle 10 indicates that dispute as to the application of the Principles is to be resolved through negotiation or any other established procedures for the settlement of disputes in accordance with the UN Charter. There have been none such as yet.

Penultimately, there are, of course the questions of responsibility, liability and compensation. These are covered in Prs. 8 and 9, and we have dealt with such matters back in Chapter 4. Interestingly, for the purpose of liability under Pr. 9 the 'launching state' is defined broadly as in Art. VII of the OST and the Liability Convention, while in connection with other Nuclear Principles the term is restricted to the state exercising jurisdiction and control (presumably in terms of Art. VIII of the OST) over the space object at the relevant time (Pr. 2.1).[71]

Finally, under Pr. 11 the Principles were to be reopened for revision by COPUOS no later than two years from their adoption (in 1992). Revision has not occurred.[72]

The Near-Earth environment

We have just outlined questions of contamination of the Earth or celestial bodies. There are also questions of the contamination of the Near-Earth environment. Most current space activities take place in Earth orbit where space is becoming cluttered by the deliberate insertion of objects or materials. Debris is, of course, a major problem but we tackle that separately below.

The contamination of Earth orbital space, as opposed to the presence of debris, is possible. Regrettably, in the early years of space both the US and USSR deliberately detonated nuclear devices in orbit.[73] Apparently this affected the Van Allen radiation

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[71] Cf. Note Verbale of 29 July 2003 from The Netherlands: A/AC105.806 as to satellites 2002-019A and 2002-057A; http://www.unoosa.org/pdf/reports/ac105/AC105_806E.pdf, and Note Verbale of 18 February 2004 from The Netherlands: A/AC.105/824 as to the removal of 1988-040A from geostationary orbit - http://www.unoosa.org/pdf/reports/ac105/AC105_824E.pdf.

[72] A.D. Terekhov, 'Review and Revision of the Principles relevant to the Use of Nuclear Power Sources in Outer Space' (1993) 36 *Proc. IISL* 336-48.

[73] The three US 'Operation Argus' explosions were conducted over the South Atlantic between August and September 1958, with 'Starfish' occurring in 1962. The three USSR tests over Siberia were in October/November 1962. Radiation from 'Starfish' destroyed three satellites: D.P. Stern, 'Birth of a Radiation Belt' http://istp.gsfc.nasa.gov/Education/wbirthrb.html. See also M.W. Mouton, 'Artificial Radiation: the Starfish Experiment' in M.W. Mouton, 'The Impact of Science on International Law' 119 *Hague Recueil* 1966-III, 183-260 at 236-8; A.G. Haley, *Space*

belts before they could be examined in their pristine condition. The position as to nuclear explosions is now regulated for its parties by the Nuclear Test-Ban Treaty of 1963, Art. I of which prohibits nuclear tests *inter alia* in space.[74] The absence of France from the Nuclear Test Ban Treaty has provoked questions whether this prohibition has passed into customary International Law,[75] but we would hope that non-parties to the Treaty would refrain from such actions. The UN General Assembly has unanimously called on states to refrain from placing in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction or from installing such weapons on celestial bodies,[76] and OST Art. IV makes similar provision. Unfortunately the UN Comprehensive Nuclear Test Ban Treaty of 1996 has not yet been brought into force.[77] By its Art. 1.1 states party undertake not to carry out any nuclear weapon tests or any other nuclear explosion and to prohibit and prevent any such explosions at any place under their jurisdiction or control. This language would encompass nuclear explosions in space, on the moon or on any other celestial bodies.

Law and Government (New York: Appleton-Century-Crofts, 1963) at 11-12, 267-71 and . 326.

[74] Treaty Nuclear Weapon Tests in the Atmosphere, in Outer Space or Under Water, Moscow, 5 August 1963, 480 UNTS 43; 14 UST 1313, TIAS 5433; 1964 UKTS 3, Cmnd. 2245; (1963) 57 AJIL 1026; (1963) 2 ILM 883 - http://www.state.gov/t/ac/trt/4797.htm; M.W. Mouton, 'Nuclear Bomb Tests' in M.W. Mouton, 'The Impact of Science on International Law' 119 *Hague Recueil* 1966-III, 183-260 at 242-49; 'X', 'Nuclear Test Ban Treaties' (1963) 39 BYIL 449-56; E. Schwelb, 'The Nuclear Test Ban Treaty and International Law' (1964) 58 AJIL 642-70. Cf. the *Nuclear Tests Case (New Zealand v. France)* 1974 ICJ Rep. 157 and the *Nuclear Tests Case (Australia v. France)* 1974 ICJ Rep. 253, and next note.

[75] Cf. Paras 105.2.A and B of the Decision, and the Opinion (particularly paras 27-9), the Separate Opinions, Declarations and Dissenting Opinions in the *Legality of the Threat or Use by a State of Nuclear Weapons in Armed Conflict*, Advisory Opinion, 8 July 1996, (1996) ICJ Rep. 226; (1996) 35 ILM 809.

[76] 'Question of General and Complete Disarmament' UNGA Res. 1984 (XVIII), 17 October 1963. Cf. the series of Resolutions on the 'Prevention of an arms race in outer space', e.g. UNGA 61/58, 6 December 2006 and UNGA 62/20, 5 December 2007.

[77] UN Comprehensive Test Ban Treaty, 1996, (1996*)* 35 ILM 1439-78, US Senate Doc 105-28. As at June 2008 178 states had signed, of which 144 had ratified it, but to come into force it requires to be ratified by the 44 states listed in its Annex 2. These are the states which possess nuclear power or nuclear reactors. As at June 2008 41 of these had signed and 35 ratified. D.S. Jonas, 'The Comprehensive Nuclear Test Ban Treaty: Current Legal Status in the United States and the Implications of a Nuclear Test Explosion,' (2007*)* 39 *N.Y.U. J. Int. L. & Pol.* 1007-46. As noted in our text above, this treaty prohibits nuclear explosions anywhere. It would also set up monitoring stations and an organisation to implement its provisions, including verification of compliance, which may be its stumbling block. (See the Preparatory Commission for the Comprehensive Test Ban Treaty Organisation (CTBTO) - http://www.ctbto.org/). A future problem might be the effect of the treaty on nuclear propulsion systems for space-craft as these develop.

While most satellites are powered by solar cells and batteries, some use nuclear power sources.[78] These are either nuclear reactors (usually used for long-range missions) or radioisotope thermoelectric generators (RTG) producing heat which is converted to electricity – in effect nuclear batteries. That said, the Nuclear Power Principles (some of which have been outlined already and to which we return to in the next paragraph) specifically state that in order to minimise the quantity of radioactive materials in space and the accompanying risks, nuclear sources should only be used when a mission cannot reasonably use a non-nuclear power source (Pr. 3 preamble). As we will see below, for the further protection of the Earth the Principles also require that after use earth orbiting satellites with nuclear power sources are to be stored in high orbits (Prs. 3.2.(a)(iii) with 3.2.(b); Pr. 3.3.(a)).[79]

The previous section considered the potential contamination of the Earth from the crash of a nuclear powered satellite. An explosion on board any nuclear powered satellite in orbit may result in nuclear debris in space. The Nuclear Principles (UNGA Res. 47/68, 14 December 1992) therefore set goals and guidelines in an attempt to secure the safety of nuclear power sources generally.[80] Adopted almost fifteen years after the COSMOS 954 episode of 1978, the Principles recognise that nuclear power sources are 'particularly suited or even essential' to some space missions. The Preamble states that they apply only to non-propulsive nuclear power sources used to generate electricity, leaving open the interesting possibilities of propulsion by ramjet, fission, fusion, gas, electric, photon and other methods involving nuclear materials (Preamble, 'Affirming'). It also recognises that the proper use of nuclear power sources in space requires a thorough analysis of risks to safety and appropriate assessments (Preamble, 'Recognising further'). The Principles were intended to deal with systems comparable to those in use at the time of their adoption (Preamble, 'Affirming') and therefore the need to revise and update them is also recognised (Preamble, 'Recognising') but, although Pr. 11 called for COPUOS to re-examine the Principles two years after their adoption, as noted this has not so far happened.

Principle 1 re-states the generality that nuclear power sources in outer space are to be used in accordance with International Law including the UN Charter and the OST. Principle 2 then goes on to define terms to establish the meaning of various terms. As we have seen a distinction is made between the 'launching state' for the purpose of liability in terms of Pr. 9, and its use elsewhere in the Principles. For liability the term is defined broadly as in Art. VII of the OST and in the Liability Convention (Pr. 2.2). Otherwise the 'launching state' is defined as the state having jurisdiction and control over the space object at the relevant time (Pr. 2.1). Principle 2.3 then deals with other terms and phrases

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[78] S.A. Mirmina and D.J. Den Herder, 'Nuclear Power Sources and Future Space Exploration' (2005) 6 *Chic. J. Int. L.* 149-76; J.J. MacAvoy, 'Nuclear Space and the Earth Environment: the Benefits, Dangers, and Legality of Nuclear Power and Propulsion in Outer Space' (2004) 29 *Will. & Mary Env. L. & Policy Rev.* 191-233.

[79] See *infra* n. 84 and following n. 121.

[80] Principles Relevant to the Use of Nuclear Power Sources in Outer Space, 14 December 1992. GA Res. 47/68; 1993 32 ILM 917. (1993) 32 ILM 917 at 921-6. Cf. V. Kopal, 'The Use of Nuclear Power in Space: A New Set of United Nations Principles?' ((1991) 19 *J. Sp. L.* 103-22, Jasentuliyana, *supra* n. 65, Hošková, *supra* n. 68 and Terekhov, *supra* n. 72.

used in the Principles. 'Foreseeable' and 'all possible' are restricted to a probability of occurrence which is credibly possible for the purpose of safety analysis, and the terms are not absolute. Redundant safety systems for each component in order to achieve 'defence in depth' are not necessarily required. 'Defence in depth' against a malfunction does, however, require design of equipment and its operation so as to prevent or mitigate the effect of a malfunction. Finally, making a nuclear reactor 'critical' does not include zero-power testing,

Principle 3 is the major core of UNGA Res. 47/68. Radioactive materials in space are to be limited, and when used, severely controlled. Its introductory paragraph specifically states that 'in order to minimise the quantity of radioactive materials in space, and the risks involved' the use of NPS in outer space is to be limited 'to those space missions which cannot be operated by non-nuclear energy sources in a reasonable way.'[81] Principle 3 then sets out general goals for safety and protection from radiation together with measures as to nuclear reactors and radioisotope generators. Under Pr. 3.1 generally the highest standards of design and manufacture are to be adopted for space objects with nuclear power sources on board. These should meet the standards set by the International Commission on Radiological Protection.[82] A distinction is made between low-probability accidents and others as to levels of radiation exposure, but these levels are under constant review (Pr. 3.1), A general concept of 'defence-in-depth' is to be applied including the possibility of correction of malfunctions (Pr. 3.1.(d)) and the reliability of safety systems through redundancy,[83] physical separation, functional isolation and adequate independence of components.

Nuclear reactors are the subject of Principle 3.2. Only enriched U235 is to be used on space missions (Pr. 3.2.(c)). Devices using U235 may be operated on interplanetary missions or in what is defined as 'sufficiently high' orbits round the Earth or in low earth orbit provided that the devices are stored in a 'sufficiently high' orbit at the end of the mission (Pr. 3.2.(a)). All satellites with nuclear reactors are to have means to ensure that they can be safely and controlledly disposed of into a 'sufficiently high' orbit – colloquially a graveyard, junk or disposal orbit (Pr. 3.2.(f)).[84] 'Sufficiently high' is defined as an orbit so high that the orbital lifetime will outlast the decay of the fission products on board the satellite to approximately the activity of the actinides. Such an orbit would be well beyond the geostationary orbit. In the calculation of the relevant altitude the period for the radioactivity of the reactor itself to reduce to acceptable levels

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[81] Global positioning satellites run on nuclear batteries. Deep space probes may use a nuclear furnace.

[82] Based in Stockholm, and a registered charity in the UK, the International Commission on Radiological Protection is an independent non-governmental advisory body: http://www.icrp.org/

[83] Although as per Pr. 2.3, above, not necessarily for all components,

[84] M. Meija-Kaiser, 'Taking Garbage Outside: The Geostationary Orbit and Graveyard Orbits' (2006) 49 *Proc. IISL* 469-77. In the IADC Guidelines on Debris Mitigation of 2002 (*infra* nn. 110, 141) Guideline 5.3.1 recommends the use of graveyard orbits beyond the GSO for spent GSO satellites to protect the GSO. See generally Guideline 5 on Post-Mission Disposal for all orbits. Some Russian satellites have at end of mission been boosted out of orbit on trajectories that end in the Sun. For the relevant ITU recommendation see n. 91. See also Chapter 9, Orbits, at n. 8.

before re-entry is also to be considered (Pr. 3.2.(b)). Apart from zero-power testing (Pr. 2.3) a reactor must not be made critical before reaching either the operating orbit of the space-craft or an interplanetary trajectory (Pr. 3.2.(c)) and the design and construction of the reactor should be such that it cannot become earlier critical under any circumstances including explosion, re-entry, impact or the incursion of water (Pr.3.2.(d)).

Radioisotope thermoelectric generators (RTGs) are treated similarly. They may be used on interplanetary missions 'and other missions leaving the gravity field of the Earth' (which presumably means to the Moon, or extra-solar missions. Earth orbital missions are also competent provided that at the end of the mission the satellite is placed in a 'sufficiently high orbit'. Ultimate disposal will be necessary (Pr. 3.3.(a)). As with reactors, an RTG container is to be such that it can withstand atmospheric re-entry and will not fracture on impact with the ground so that the impact area can be completely cleared of radioactivity by a recovery operation (Pr. 3.3.(b)).[85]

Obviously such provisions make for the safety of use of nuclear power sources. This is augmented by the specific requirement that, prior to a mission, a launching state carry out a thorough safety assessment of design and construction as well as of the operational systems, and that procedure is to involve designers, manufacturers and contractors as well as any state which would be a 'launching state' as defined in the Liability Convention (Pr. 4.1 and 2). In accordance with OST Art. XI the result of the assessment and 'to the extent feasible' the time of the intended launch are to be made publicly available, and the UN Secretary General it to be informed of how states may obtain the results of the assessment (Pr. 4.3).[86]

Of course, despite all such Principles, accidents may happen. We have dealt with the procedures as to the notification of a malfunction, re-entry and liability in the case of a crash on Earth in the immediately previous section. As to how the Principles may work in practice, see the NASA Final Environmental Impact Statement for the New Horizons Mission of 2006 referred to above.[87]

Space Objects in Orbit

The major use of Near-Earth space is the orbiting of satellites. When their function is at an end they effectively become debris which is considered separately below.

Various orbital configurations are in regular use. To repeat data from Chapter 9 most satellites are in Low Earth Orbit (LEO) (c. 100-500 km/65-310 m.) taking some ninety minutes for each orbit. These vary from tracks more or less over the equator to polar orbits. Such orbits are roughly circular, their low and high points (perigee and apogee) being comparable. These orbits are lower than the Van Allen radiation belts. A Highly Elliptical Earth Orbit (HEO) has a wide variation between perigee and apogee. Such orbits in their apogee phase remain visible from a point on earth for up to twelve hours, and are used *inter alia* by communications satellites (e.g. the Russian Moliyna

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[85] The phrasing may reflect the fact that the RTG on COSMOS 954 did fracture. Specific mention is made of the possibility of a crash on return from a highly elliptical orbit where the re-entry velocity would be very great.

[86] Thus the US notification to the UN in terms of Pr. 4 for the 'New Horizons' mission is at A/AC.105/864. Cf. n. 64 *supra*.

[87] *Supra*, n. 64.

series). A Medium Earth Orbit (MEO) or Intermediate Circular Orbit (ICO) is between 2000 km and 35000 km (1240- 21750 m.) and a satellite in MEO takes anything from two to twelve hours to complete an orbit. MEOs are used mainly for global positioning satellite configurations, though they are also used for some communications satellites.[88] A geosynchronous orbit is one in which a satellite returns to the same position each day. Of these the most well-known is the Geostationary Orbit (GSO), an eastwards circular orbit some 35786 km/22236 m. above the equator. The GSO is used for communications and remote sensing (mainly meteorological) satellites.[89] A 'parking orbit' may be in LEO or MEO and is used temporarily after launch before a satellite or space probe is put on its final trajectory. Finally, a 'graveyard' 'disposal' or 'junkyard' orbit is normally higher than the geostationary. It is used for satellites which have reached the end of their useful life, and which it would be too expensive or difficult to de-orbit to Earth. As noted above, defunct satellites with radioactive power sources on board are to be placed in a 'sufficiently high' orbit to remove them from causing problems in the immediate future.[90] ITU Radiocommunication Sector Recommendation S.1003-1 (01/04) 'Environmental protection of the geostationary-satellite orbit' would have states ensure that at the end of their useful lifetime geostationary satellites are relocated to a 'supersynchronous graveyard orbit' which does not intersect with the GSO.[91]

Satellites come in two main forms, passive and active. As we will see, considered simply as objects active satellites have the same potential as passive satellites for interfering with other uses of space, but we first deal more particularly with passive satellites as such.

Passive satellites do not possess radio facilities except perhaps for the reception of signals for their initial deployment. They are deliberately placed in low earth orbit for a variety of purposes. Thus 'Project West Ford' (1961-63) involved the insertion of small dipoles (2 cm. long copper needles) with the intention of their being used to reflect radio transmissions. Some clusters of Project West Ford needles are still in orbit, and may still cause problems.[92] Other launches were of balloons. 'Echo 1' (1960) (30 metres in diameter) and 'Echo 2' (1964) (41 metres in diameter) were large metallised polymer balloons inflated in orbit to act as passive radio reflectors as well as for geodetic purposes

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[88] A satellite in a suitable MEO will provide communications facilities for the North and South Polar areas. The LEO or GSO will not.

[89] See Chapters 8, Radio, 9, Orbits, and 13, Remote Sensing.

[90] *Supra* n. 84.

[91] This Recommendation was first adopted in 1993 as ITU-R S.1003 (04/93). The revision of 2004 incorporates IADC originating protocols for the calculation of the new orbit. See also n. 84 *supra*. L. Perek, 'Planetary Protection: Lessons Learned' (2002) 45 *Proc. IISL* 462-5 at 464 notes that only 2 out of 14 GSO satellites at the end of their life in 2001 had been relocated. In 1996-2001 some 50 spent satellites had been left in GSO.

[92] J.C. Mandeville and J-M. Perrin, 'Interaction between electromagnetic radiations and West Ford needle clusters: Models and application' (2006) 58 *Acta Astronautica* 587-604; R.M. Goldstein et al., 'Radar observations of space debris' (1998) 46 *Planetary and Sp. Sc.* 1007-13; M.W. Mouton, 'Project West Ford' in M.W. Mouton, 'The Impact of Science on International Law' 119 *Hague Recueil* 1966-III, 183-260 at 238-42; A.G. Haley, *supra* n. 73, at 268-9.

(the measurement of the Earth).[93] The Echo balloons re-entered the atmosphere respectively in 1968 and 1969. PAGEOS I, in orbit from 1966 to 1975 was another geodetic project.[94] In the NASA Explorer series, Explorers 9 (1961-64), 19 (1963-81), 24 (1964-68) and 39 (1968-81)[95] were launched to measure atmospheric density as was another Mylar balloon launched by the US Department of Defence (1971-91). China has launched two balloons also to measure atmospheric density (both 1990-1991), while one Russian balloon apparently remains in orbit (1991-). Passive satellites have been suggested for other physically larger projects and not always for scientific purposes. In the 1990s Russia considered orbiting large reflectors in low earth orbit to illuminate portions of the northern hemisphere in winter. The possibility also exists of passive satellites being used for advertising.[96] In the remote past it was suggested that vapour released from a pod in a crater of the Moon could by appropriate masking, be made to configure in the space of an advertisement for a well-known (US) soft drink. That was perhaps extreme, but the fact is that advertising in space has potential. An IAU background paper submitted to COPUOS in 2001 noted proposals to put materials in orbit for advertising (or celebration) purposes including a 'Ring of Light' to celebrate the bicentennial of the French Revolution and the centennial of the Eiffel Tower in 1997, a 'Star of Tolerance' to consist of two large tethered balloons in low earth orbit to celebrate the fiftieth anniversary of UNESCO also in 1999, the 'Space Billboard', a one square kilometre reflector to be in low earth orbit, and a similar project to advertise the Olympic Games in Atlanta in 1996.[97] As early as 1961 the International Astronomical Union (IAU) was concerned about the effect on its members' activities of all space

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[93] D.C. Elder, *Out from Behind the Eight-Ball: A History of Project Echo* (Washington DC: Am. Hist. Soc., 1995) (not seen). A 'reflecting satellite' is 'a satellite intended to reflect radiocommunication signals' (ITU RR 1.181).

[94] Geos I and II (1965-75) (Explorer series nos. 29 and 36) and some other early experiments allowed triangulation of a flashing or strobing beacon carried by the satellite. Technical advance, particularly through GPS programmes, has rendered such procedures obsolete. Geos I and II should not be confused with later GEOS programmes which provide earth observation from geostationary orbit.

[95] Dates are of launch and decay.

[96] D.E Tomlinson and R.L. Wiley, 'People Do Read Large Ads: The Law of Advertising from Outer Space' (1995) 2 *Global Leg. Stud.* 2; (1995) 47 *Fed. Comm. L. J.* 535. Russia has displayed an identifiable soft drink container in space, and for $5m has displayed an advert for a pizza product on the side of a Proton launcher.

[97] See: 'Obtrusive space advertising and astronomical research: Background paper by the International Astronomical Union', COPUOS, A/AC.105/777, 18 December 2001; discussion of the topic by COPUOS Legal Sub-Committee A/AC.105/786, paras 135-42. At para 138 the Sub-Committee 'noted with appreciation' that in 2000 the US banned the commercial launch of material for use in obtrusive space advertising. See 49 US Code § 70109a, added by Pub. L. 106-391, title III, Sec. 322(b), Oct. 30, 2000, 114 Stat. 1598; and rules at (US) Federal Register, 31 August 2006, 51968-72, 'Miscellaneous Changes to Commercial Space Transportation Regulations: 14 CFR Parts 404, 413 and 420'. 'Obtrusive space advertising' is defined in 49 US Code § 70102.(9) as 'advertising in outer space that is capable of being recognised by a human being on the surface of the earth without the aid of a telescope or other technological device'.

objects whether active or passive.[98] An IAU paper of 2001 notes that some space activities necessarily affect the work of astronomers but their 'benefit to national or international interests' may be 'perceived to outweigh their adverse effects'. Nonetheless, 'obtrusive space advertising' should be controlled, and preferably proscribed.[99] 'Obtrusive space advertising' would not include the display of advertising on the side of a launch vehicle, as has been done by Pepsi on the Russian Proton launches.

Both passive and active satellites can affect visual astronomical observations, as can the larger pieces of space debris. The passage of a sun-illuminated object or a strobing beacon across the field of a photographic plate can ruin an observation. The object need not be that large - what is important is its albedo.[100] The satellites of the Iridium constellation are themselves small, but 'Iridium flares' are visible to the human eye.[101] We would also note that any development of a solar power array system in orbit would necessarily affect visual astronomy, and perhaps radio astronomy might also be affected by the micro-wave down links from the satellites. In that any 'catcher' of solar radiation is bound to be very large, interference with some astronomy is unavoidable.[102]

Apart from their mere existence in Earth orbit, active satellites affect the use of space through their radio emissions.[103] Active satellites are 'active' because they require radio for tracking, telemetry and tele-command as well as frequencies for the data and

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[98] Of the passive satellites noted above, the Echo balloons were of magnitude 1, while PAGEOS was magnitude 2. Their progress across the sky affected some astronomical observations.

[99] IAU paper *supra* n. 97 at paras 22 and 33-5. Tomlinson (*supra* n. 96) was of the view that all space advertising should be banned, while his co-author, Wiley, although permitting it, would favour its regulation: see D.E. Tomlinson, 'The Better Means of Preserving Free Expression: Thoughts on Vigilance, Responsibility, Stewardship, Journalism Education, and the Demise of Value Systems' (2000) 23 *U. Ark. Little Rock L. Rev.* 81 at 110. Cf. IAU 'Resolution on the Protection of the Night Sky', IAU Gen. Ass. XXIII, 1997: '*Considering that* Proposals have been made repeatedly to place luminous objects in orbit round the earth to carry messages of various kinds and that the implementation of such proposals would have a deleterious effect on astronomical observations, *and that* the night sky is the heritage of all humanity, which should therefore be preserved untouched, *Requests the* President to take steps with the appropriate authorities to ensure that the night sky receive no less protection than has been given to the world heritage sites on earth.': http://www.aas.org/light/lightpollresolution.html. J.H. Heubert and G. Block, 'In Defence of Advertising in Space' (2006) 49 *Proc. IISL* 479-89, argue in favour of no regulation – basing their view on concepts of property and free speech that are derived mainly from the US. As to US rules see *supra* n. 97, but these only apply to US-licensed launches.

[100] Cf. *supra* n. 98.

[101] P.D. Maley and J.C. Pizzicaroli, 'The visual appearance of the Iridium satellites' (2003) 52 *Acta Astronautica* 629-639. The website Heavens Above, http://heavens-above.com/ provides data on expected Iridium flares for requested locations.

[102] See Chapter 9, Orbits, - 'Solar Power'.

[103] Reference point, n. 37.

other communications which they receive and transmit. In the ITU Radio Regulations an active satellite is a space station, defined as 'a station located on an object which is beyond, is intended to go beyond, or has been beyond, the major portion of the Earth's atmosphere' (RR S1.64). More particularly it is 'a satellite carrying a station intended to transmit or retransmit radiocommunication signals' (RR S1.80). Radio frequencies are a limited natural resource to be used 'rationally, efficiently and economically' and the part of the radio spectrum best suited for use by satellites is only a portion of the whole.[104] It is therefore important that appropriate measures are available to terminate its radio emissions when the satellite has served its function.[105]

Whether passive or active satellites are concerned, their impact or effect on the environment of space is a matter clearly within the responsibility and competence of states that licence space activities (OST Art. VI). In the consideration of whether to license a space activity 'due regard to the corresponding interest of other states' (OST Art. IX) should figure. So should any 'potentially harmful interference' to the interests of other states' although that particular factor triggers only consultations with affected states and does not operate as a bar (Art. IX OST).[106] Active satellites have to be processed through the ITU procedures outlined in Chapter 8. Both active and passive satellites should also go through the procedures for national and international registration that are outlined in Chapter 4.

Space Traffic Management

In the light of the above it is clear that in the future a proper system of space traffic management would be desirable. This would have several aspects. First, as discussed in Chapter 6 on the boundary question, the transit of spacecraft through state airspace on launch or re-entry would require to be coordinated with relevant air-traffic control. Second, above controlled airspace measures would be required to ensure the safe launch and re-entry through areas used by LEO communications satellite systems such as Iridium and others.[107] Finally, there is the question of the use of orbits. Various orbits are better suited for certain purposes than others: polar and near-polar orbits are useful for certain types of remote sensing, the geostationary orbit is excellent for

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[104] ITU Constitution Arts. 44.1 and 2. See Chapter 8, Radio.

[105] Originally such measures might be tele-command, short battery life, or a timing device. Now tele-command is required by Art. RR 22.1 of the ITU Radio Regulations: 'Space stations shall be fitted with devices to ensure immediate cessation of their radio emissions by tele-command, whenever such cessation is required under the provisions of these Regulations'. Some early US satellites could not be switched off and continued to broadcast on space-ideal frequencies long after their experiments had been hopelessly corrupted by solar and other radiation thus rendering those frequencies unusable for a number of years.

[106] See Chapter 3, The Outer Space Treaty..

[107] Iridium Satellite LLC (http://www.iridium.com/) provides world-wide communications using a sixty-six (at 2007) satellite system in LEO. It is used *inter alios* by the US Department of Defense. Polar coverage is available. Teledesic, Orbcomm, Globalstar and ICO-Communications all had similar plans in the 1990s. Cf. Maley, *supra* n. 101.

telecommunications and direct broadcasting. It would make sense were the use of these orbits rationalised so that the best can be got from space. We are not yet at the stage that this matter is wholly crucial, but it will become so.[108] At that stage the sensible step would be to go to a world regulatory organisation, which is an increasingly urgent step. The surrender of some control of its activities to an international regime or body will not be welcomed in certain quarters.

Space Debris

Over the years much has been discussed and written on space debris, technical reports have been compiled and guidelines elaborated. Suggestions and views have been diverse.[109] At present the debris problem is a result of what may be termed the civilian or peaceful use of outer space although military launches and spacecraft also produce debris. We therefore deal largely with that 'civilian' area. However, at the end of this section we will have to say something about the possibilities of debris resulting from military action.

On 22 December 2007 the UN General Assembly resumed discussion of the Report of the Committee on the Peaceful Uses of Outer Space (A/62/20) and by UNGA Res. 62/217 approved the COPUOS endorsement of a set of voluntary guidelines for the mitigation of space debris. [110] While this does not bring to an end the long debate over space debris it will probably result in a moratorium on the discussion whether space debris should be a matter of law or of voluntary practice. Voluntary practice rather than legal duty will remain the *modus operandi*, except in-so-far-as one might suggest that the

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[108] P.B. Larsen, 'Outer Space Traffic Management: Space Situational Awareness Requires Transparency' (2008) 51 *Proc. IISL* (forthcoming); C. Contant-Jorgenson, P. Lala and K-U. Schrögl eds. *Space Traffic Management*, IAF Cosmic Study (Paris: IAA, 2006); - http://www.iaaweb.org/iaa/Studies/spacetraffic.pdf; C. Contant-Jorgenson, P. Lala and K.-U. Schrögl, 'The IAA Cosmic Study on space traffic management', (2006) 22 *Space Policy* 283-8. Cf. L. Perek, 'Traffic Rules for Outer Space' (1982) 25 *Proc. IISL* 37; P. van Fenema, 'Suborbital flights and ICAO' (2005) 30 *Air and Sp. Law* 396-411; K.-U. Schrögl, 'Space Traffic Management' ESPI Flash Report #3, October 2007 - http://www.espi.or.at/images/stories/dokumente/flash_reports/stmflashrep3f2.pdf. See also Chapter 6, The Boundary Question, *ad. fin.*– 'Space Traffic Management'.

[109] For earlier materials see H.A. Baker, *Space Debris: legal and policy implications* (Dordrecht: Nijhoff, 1989) and his 'Liability for Damage Caused by Space Debris' (1988) AASL 183-225; IAA Cosmic Study 'Orbital Debris' (1993) 31 *Acta Astronautica* 168-91; Schafer *supra* n. 1; COPUOS Scientific and Technical Subcommittee, 'Technical Report on Space Debris' A/AC.105/720, 1999.

[110] COPUOS Report to the 2007 General Assembly (A/62/20), para 118 and Annex. (For space debris see paras 116-128) and 'International cooperation in the peaceful uses of outer space' UNGA Res. 62/217 para 26. This para was part of the Resolution adopted without vote: some states voted against para 47 on the endorsement of the work plan for the UN SPIDER programme: see OOSA note - http://www.unoosa.org/oosa/SpaceLaw/gares/gavotes.html#ARES_62_217. L. Perek, 'Space Debris at the United Nations' (2002) 2 *Space Debris* 123-36 narrates proceedings within the UN to its date.

creation of space debris is 'potentially harmful interference' with the activities of other states contrary to OST Art. IX. The Guidelines, each accompanied by the footnoted explicatory comment, are:

1. Limit debris released during normal operations[111]
2. Minimize the potential for break-ups during operational phases,[112]
3. Limit the probability of accidental collision in orbit,[113]
4. Avoid intentional destruction and other harmful activities,[114]
5: Minimize potential for post-mission break-ups resulting from stored energy, [115]

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[111] COPUOS comment: 'Space systems should be designed not to release debris during normal operations. If this is not feasible, the effect of any release of debris on the outer space environment should be minimized. During the early decades of the space age, launch vehicle and spacecraft designers permitted the intentional release of numerous mission-related objects into Earth orbit, including, among other things, sensor covers, separation mechanisms and deployment articles. Dedicated design efforts, prompted by the recognition of the threat posed by such objects, have proved effective in reducing this source of space debris.'

[112] COPUOS comment: 'Spacecraft and launch vehicle orbital stages should be designed to avoid failure modes which may lead to accidental break-ups. In cases where a condition leading to such a failure is detected, disposal and passivation measures should be planned and executed to avoid break-ups. Historically, some break-ups have been caused by space system malfunctions, such as catastrophic failures of propulsion and power systems. By incorporating potential break-up scenarios in failure mode analysis, the probability of these catastrophic events can be reduced.'

[113] COPUOS comment: 'In developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system's launch phase and orbital lifetime should be estimated and limited. If available orbital data indicate a potential collision, adjustment of the launch time or an on-orbit avoidance manoeuvre should be considered. Some accidental collisions have already been identified. Numerous studies indicate that, as the number and mass of space debris increase, the primary source of new space debris is likely to be from collisions. Collision avoidance procedures have already been adopted by some Member States and international organizations.

[114] COPUOS comment: 'Recognizing that an increased risk of collision could pose a threat to space operations, the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-lived debris should be avoided. When intentional break-ups are necessary, they should be conducted at sufficiently low altitudes to limit the orbital lifetime of resulting fragments.'

[115] COPUOS comment: 'In order to limit the risk to other spacecraft and launch vehicle orbital stages from accidental break-ups, all on-board sources of stored energy should be depleted or made safe when they are no longer required for mission operations or post-mission disposal. By far the largest percentage of the catalogued space debris population originated from the fragmentation of spacecraft and launch vehicle orbital stages. The majority of those break-ups were unintentional, many arising from the abandonment of spacecraft and launch vehicle orbital stages with significant amounts of stored energy. The most effective mitigation measures have been the passivation of spacecraft and

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,[116]
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.[117]

All this is a long way from the relative insouciance of the early days when various launch elements – spent boosters, cones, explosive bolts - were simply abandoned to go where they might.[118] But it remains a fact that for the present the mitigation of space debris is a matter of voluntary action, not of clear legal duty. It remains another fact that precise measures for the mitigation of space debris will remain a matter of discussion for many years to come. How did we get here from there?

Space debris is not specifically dealt with in the OST because its importance was not recognised at the time the Treaty was negotiated.[119] Although for many years space debris has been an increasing problem, its prevention, mitigation and removal has been sporadic and slow. Conceptually terrestrial international environmental law and the ruminations of the ILC could be built on.[120] The duty to protect the environment of areas

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launch vehicle orbital stages at the end of their mission. Passivation requires the removal of all forms of stored energy, including residual propellants and compressed fluids and the discharge of electrical storage devices.'

[116] COPUOS comment: 'Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in a controlled fashion. If this is not possible, they should be disposed of in orbits that avoid their long-term presence in the LEO region. When making determinations regarding potential solutions for removing for removing objects from LEO, due consideration should be given to ensuring that debris that survives to reach the surface of the Earth does not pose an undue risk to people or property, including through environmental pollution caused by hazardous objects from LEO, due consideration should be given to ensuring that debris that survives to reach the surface of the Earth does not pose an undue risk to people or property, including through environmental pollution caused by hazardous substances.'.

[117] COPUOS comment: 'Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the GEO region should be left in orbits that avoid their long-term interference with the GEO region. For space objects in or near the GEO region, the potential for future collisions can be reduced by leaving objects at the end of their mission in an orbit above the GEO region such that they will not interfere with, or return to, the GEO region.'

[118] One regularly screened TV shot is of the jettison of an intermediate stage of a Saturn V rocket.

[119] M. Lachs, 'The Treaty on Principles of the Law of Outer Space, 1961-1992' (1992) 39 *Neth. Int. L. Rev.* 291-302 at 298. Thus M.S. McDougal, H.D. Lasswell and I.A. Vlasic, *Law and Public Order in Space*, (New Haven and London: Yale UP, 1963) 533-4, 620-5, and 733-4 write of the legal effects of collisions between spacecraft, but not about problems of debris, (which is not indexed in the book).

[120] See text at n. 15 ff.

beyond the jurisdiction of states should extend to Earth orbit.[121] There is a harbinger of such a duty in the relocation of some spent satellites to orbits remoter than the geostationary. It is regular practice so to push older defunct geostationary satellites into graveyard orbits if not to send them on a sunwards course, thus making available their former geostationary slots.[122] The 1992 UNGA 'Principles Relevant to the Use of Nuclear Power Sources in Outer Space' dealt with above shed further light.[123] Principles 3.2 (a)(ii), 3.2.(b) and 3.3 speak of 'high' orbits into which a satellite carrying a nuclear power source should be placed at the end of its mission, there to stay until the nuclear fuel and its containment chamber have decayed to safe radiation levels. Again various space debris mitigation guidelines indicate that other satellites and launch vehicles should be de-orbited once their operational phase is complete or else their orbits relocated so as to avoid the LEO region. But such satellites and objects are not debris. They remain identifiable space objects which are the responsibility of (as well as being under the jurisdiction) of their state of registry (OST, Arts. VI and VIII) and they should remain controlled at least until parked. The point about much space debris is that it is not always readily identifiable, and certainly is not really under the control of whichever state was responsible for the initial launch that produced it. There can be exceptions, spent boosters, spent manoeuvring stages, launcher cones and shrouds, for example, appear some entries in the UN 'Register of Objects Launched into Space' (ST/SG/Ser.) and are identifiable. But, lacking propulsion or tele-command facilities these are no longer controllable. Nor are the many fragments that are in orbit.[124]

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[121] Cf. Resolution 5 of the Sixty-Sixth ILA Conference, Buenos Aires, 1994, which annexes an 'International Instrument on the Protection of the Environment from Damage Caused by Space Debris', *International Law Association, Report of the Sixth-Sixth Conference*, (London: Int. Law Assoc., 1995) 7-15, with Report and Final Text of the Space Law Committee of the ILA, M. Williams, ed., at 304-25.

[122] See *supra* text at n. 91.

[123] See *supra* at nn. 65 and 78.

[124] See the early pages of: J.P. Lampertius, 'The Need for an Effective Liability Regime for Damage Caused by Debris in Outer Space' (1992) 13 *Mich. J. Int. L.* 447-68; C.D. Williams, 'Space: The Cluttered Frontier' (1995) *J. Air L. & Comm.* 1139-89; J.M. Seymour, 'Containing the Cosmic Crisis: A Proposal for Curbing the Perils of Space Debris' (1998) *Geo. Int. Env. L. Rev.* 891-914. Cf. T. Beer, 'The Specific Risks Associated with Collisions in Outer Space and the Return to Earth of Space Objects – the Legal Perspective' (2000) 25 *Air & Sp. L.* 42-50; J.-C. Liou, 'Collision activities in the future orbital debris environment' (2006) 38 *Adv. in Sp. Res.* 2102-6; J. Bendisch et al., 'The MASTER-2001 Model' (2004) 34 *Adv. in Sp. Res*. 959-68; C.S.L. Keay, 'Pollution Potentials in Interplanetary Space' (1998) 21 *Adv. in Sp. Res.* 1603-6; R. Walker and C.E. Martin, 'Cost-effective and robust mitigation of space debris in low earth orbit' (2004) 34 *Adv. in Sp Res.* 1233-40.

A 'space object' such as a glove, a camera, a tool bag, [125] even a golf-ball[126] retains some identifiability, but *ex natura* most space debris is fragmentary and hence responsibility for it is indeterminate. Some materiel has been deliberately jettisoned in space.[127] Yet other material has been lofted briefly into space for memorial purposes. [128] Even if some debris does not long persist in orbit, it represents a danger for space-craft. Material in lower orbits travels at least at 7 km per second so the kinetic energy of a collision can be considerable.[129] There is also a risk that one collision will produce many fragments that then trigger others – a 'cascade' – with the resulting creation of a belt of debris in a particular orbit which could imperil any space object crossing that orbit.[130]

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[125] White lost a glove on the first space-walk, Collins a camera from Gemini-10. Stefanyshyn-Piper lost her tool bag on a Shuttle spacewalk on 18 October 2008.

[126] In November 2006 a Russian, Mikhail Tyurin, hit a golf-ball from the ISS, the event being videoed and used as publicity for Element 21, a Toronto manufacturer of golf equipment. The ball was likely to remain orbit for only some three days.

[127] Garbage and urine have been jettisoned from various space vehicles. The Early Ammonia Servicer, the size of a piano, was dumped from the ISS in summer 2007 (Atlantis launch) in accordance with the ISS Jettison Policy adopted in autumn 2006. It re-entered the atmosphere on 2 November 2008 over Alabama with unconsumed debris falling into the sea between Australia and New Zealand: http://www.spaceflightnow.com/news/n0811/03eas/, http://www.msnbc.msn.com/id/27479972/ http://www.msnbc.msn.com/id/2747997. Cf. N.L. Johnson, 'The new jettison policy for the International Space Station' (2006) 38 *Adv. Sp. Research* 2077-83. For predictions of re-entries see http://www.aero.org/capabilities/cords/reentries.html. Normally ISS garbage is packed into an unmanned re-supply Russian 'Progress' vehicle and is destroyed along with it on its atmospheric re-entry usually over the Pacific. The 17 ton ESA Automated Transfer Vehicle 'Jules Verne' on such a planned re-entry burned up over the South Pacific on 29 September 2008 - http://cosmiclog.msnbc.msn.com/archive/2008/09/29/1464747.aspx.

[128] Space Services Inc. has sent the ashes of various persons into space, including those of Timothy Leary ('druggies' guru of the 80s), Gene Roddenberry ('Star Trek') and James Doohan ('Scotty' in Star Trek). Destinations offered include a brief entry to space, earth orbit, lunar orbit or surface, and deep space: http://www.memorialspaceflights.com/.

[129] Before starting a return to Earth the Shuttle heat-shield is inspected to see that it has developed no holes through collision with debris. The 14th ISS Mission in May-June 2007 installed a variety of shields intended to protect vulnerable parts of the ISS from damage through collision with space debris. Cf. the 'Final Report of the International Space Station Independent Safety Task Force', February 2007, www.nasa.gov/pdf/170368main_IIST_%20Final%20Report.pdf; and *Protecting the Space Shuttle from Meteoroids and Orbital Debris*, (Washington DC: National Academies Press, 1997) - http://books.nap.edu/catalog.php?record_id=5958.

[130] A number of articles cited in this chapter outline cascade problems. China's destruction of its own 1999 Feng Yun 1-C polar orbit weather satellite on 11 January 2007 has produced such a debris-ridden belt round the earth on more or less the same orbit as the former satellite. 817 fragments had been confirmed within a month and there may well be many thousands large enough to cause trouble:

The threat to space-craft and to astronauts from space debris is therefore very real. Space debris is monitored by the radar facilities of a number of states, and their results are coordinated through the US Air Force Space Command. Satellites and the Shuttle have altered orbit to avoid debris, but collisions have occurred.[131] Science acknowledges that more will happen.[132] The debris field round the Earth continues to grow, worryingly

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http://www.cnn.com/2007/TECH/space/01/18/china.missile/index.html; see also http://www.space.com/news/070202_china_spacedebris.html and http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=931. On 19 February 2007 the Breeze M upper stage of a Russian Proton launcher exploded almost one year after its launch, its propellant not having been fully exhausted into space: http://news.bbc.co.uk/go/pr/fr/-/1/hi/sci/tech/6398513.stm. 1111 fragments have been tracked. The destruction of US-193 on 21 February 2008 as it was about to re-enter denser atmosphere appears not to have caused major debris problems (see Wikipedia, 'USA 193). Cf. the Center for Orbital and Reentry Debris Studies, Aerospace Organisation: http://www.aero.org/capabilities/cords/; and the 1992 report 'On Orbit Collision Hazard Analysis in Low Earth Orbit Using the Poisson Probability Distribution' Karman Sciences for the (US) Office of Commercial Space Transportation: http://www.faa.gov/about/office_org/headquarters_offices/ast/media/poisson.pdf. F. Walsh, 'Forging a Diplomatic Shield for American Satellites: The Case for Re-evaluating the 2006 National Space Policy in Light of a Chinese Satellite System' (2007) 72 *J. Air L. & Com.* 759-99

[131] A number of satellites have ceased functioning and that this has been because of a collision with debris or a meteorite has been occasionally assumed. Thus in March 2006 the Russian Express-AM11 satellite failed on being hit by another object: http://news.skymania.com/2006/04/collision-knocks-out-satellite.html. Although the data was only published in 2008, the first known instance of a collision between identified objects is that a Russian non-functional navigation satellite, Cosmos 1934 (1988-023A, US Satellite Number 18985) and debris from Cosmos 926 in December 1991: http://www.spaceref.com/news/viewsr.html?pid=16201. On 16 July 1996 the UK Cerise satellite was hit by a fragment of Ariane V-16. Its stabilisation boom was halved by the impact but the satellite continued to function: http://www.satobs.org/seesat/Aug-1996/0110.html: http://www.tbs-satellite.com/tse/online/sat_cerise.html. Cf. M.N. Sweeting et al. 'CERISE microsatellite recovery from first detected collision in low Earth orbit' ((2004) 55 *Acta Astronautica* 139-47. In January 2005 the US rocket body (1974-015B, US Sat. No. 07219) collided with a fragment (1999-057CV, US Sat. No. 26207) from the third stage of a Chinese CZ-4 launch vehicle, which had exploded in March 2000: http://www.spaceref.com/news/viewsr.html?pid=16201. That report includes the statement that 'Currently, hundreds of close approaches (i.e. passes within less than one kilometre) between catalogued objects occur on a daily basis.' In August 2008 the ISS was lowered in orbit by a mile to avoid debris from a Russian launcher - http://www.msnbc.msn.com/id/26441443/.

[132] See for example, the *Proceedings of the First Conference on Space Debris*, Darmstadt Germany, 1993 (ESA SD-01); of the *Second Conference on Space Debris*, Darmstadt, Germany 1997, (ESA SP-393: SD-02); and of the *Third Conference on Space Debris*, Darmstadt, Germany, 2 vols. 2001, (ESA SP-473). Cf. IAA 'Position Paper on Space Debris Mitigation, Implementing Zero Debris Creation Zones' 15 October 2005:

in respect of telecommunications since the geostationary orbit is a 'debris cluster area' which gravity will not cleanse within any foreseeable period. The issue therefore arises as to the steps to be taken to limit the problem. Obviously steps have to be taken, but, for lawyers the question is whether binding legal obligation is the best route. There is the Liability Convention,[133] but its Art. 3 makes liability for damage caused by a space object elsewhere than on the surface of the earth or to aircraft in flight dependent on proof of fault. There is a case for a mutual insurance fund to meet damages claims caused by orbital debris to be contributed to by the space active.[134] There may be a case to encourage dedicated salvage firms to tackle the recovery of spent satellites through the grant of subsidies from a consortium of space agencies and commercial space users. But in the interim, basically the creation of space debris has to be lessened.

When COPUOS was discussing the Report that went to the 2007 UN General Assembly there was argument over its endorsement of its annexed Guidelines on the mitigation of space debris.[135] Some delegations were of the view that a set of guidelines which were voluntary and legally non-binding was not sufficient, and disadvantaged the developing countries. They therefore argued for the Legal SubCommittee to develop a legally binding framework (para 123). Others thought the guidelines should be presented to the Assembly as a draft resolution so as to stress their importance, as well as drawing attention to the effectiveness of COPUOS in space matters (para 125).[136] Yet others thought the guidelines would need to be reviewed as they did not cover all debris-producing situations (para 128).

Of course, *ex facie* the best way in which to achieve International Law in precision is through the articulation of the required rules in a formal treaty, accepted by as many states as possible, and certainly in this case including all states which are space-competent.[137] We will suggest in our final chapter that a legally binding instrument dealing with space debris would be a welcome development while recognising that

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http://www.iaaweb.org/iaa/Studies/spacedebrismitigation.pdf. Cf. R.E. Glickman, 'Estimating Collision Probability for Coincident Satellite Constellations' AIAA-96-3635-CP - http://pdf.aiaa.org/preview/1996/PV1996_3635.pdf; S. Alfano, 'Satellite Collision Probability Enhancements' (2006) 29 *J. Guidance, Control and Dynamics* 588-92 - http://www.centerforspace.com/downloads/files/pubs/JGCD.V29.N03.pdf - and their citations; T. Yasaka, 'Space Debris Protection: A Standard Procedure in Future' (2003) 53 *Acta Astronautica* 527-31.

[133] Convention on the Registration of Objects Launched into Outer Space, 14 January 1975; 1023 UNTS 15; (1978) UKTS 70, Cmnd 7271; TIAS 8480; (1975) 14 ILM 43. See *supra* Chapter 4.

[134] M.J. Sundahl, 'Unidentified Orbital Debris: The Case for a Market-Share Liability Regime' (2000) 24 *Hastings Int. & Comp. L. Rev.* 125-54.

[135] Report of the Committee on the Peaceful Uses of Outer Space to the 2007 General Assembly (A/62/20). Cf. the Report of the Scientific and Technical Subcommittee, 44th Sess. 12-23 February 2007, A/AC.105/890, and earlier reports.

[136] See Chapter 2 as to the effectiveness of a UNGA Resolution. The 'advertising' value of the proposal is uncertain.

[137] Cf. K-H. Böcksteigel, 'ILA Draft Convention on Space Debris' (1995) 44 ZLW 28-34. Schafer, *supra* n. 1, at 31-9 suggested a UN Office of Outer Space Environmental Protection.

another space treaty may be unlikely. Short of that the next best is a set of Principles elaborated through the Committee on the Peaceful Uses of Outer Space, and then adopted, preferably without vote, by the General Assembly of the United Nations.[138] But a legal duty to use space for the benefit of all is already enshrined in OST Art. I, and having regard to the 'interests of other states' and the avoidance of 'harmful interference' with the activities of others is already incorporated in OST Art. IX. There have been calls for these rather vague statements to be supplemented or crystallised so that they may be used to lessen the problem of space debris.[139] Apart from the difficulty of getting a comprehensive agreement on a treaty text,[140] a major problem would be one of enforcement. While such would constrain a responsible launch authority, and might constrain an irresponsible launch authority a little, how would one attach either a civil or criminal penalty to conduct which does not mitigate space debris? A decision, whether advisory or in a contentious proceeding, of the International Court would not seem either appropriate or effective. In sum it may be better to rely on the self-interest of space agencies and authorities. Space debris is a major problem. Effective efforts to diminish its impact remain recommendations and non-binding practices as these are applied in national requirements.[141] The main international protagonist in this has been the eleven member Inter-Agency Space Debris Coordination Committee.[142] Through the European Space Agency (ESA) European launching states have adopted a similar set of guidelines and procedures.[143] Continuing the policy of its predecessors,[144] the US has an extensive

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[138] See previous note.

[139] Cf. V. Kopal, 'Present International Law Principles Applicable to Space Debris and the Need for their Supplement', in *Proc. Second European Conference on Space Debris*, Darmstadt, 1997, [ESA SP-393] (Noordwijk: ESA, 1997) at 739-747; and M. Benkö and K-U Schrögl, 'Space Debris in the United Nations: Aspects of Law and Policy', ibid. at 749-57. Cf. *Proceedings of the First Conference on Space Debris*, Darmstadt Germany, 1993 (ESA SD-01) - Legal aspects at 673-707; *Proceedings of the Second Conference on Space Debris*, Darmstadt, Germany 1997, ESA SP-393 (SD-02) – Legal Aspects at 739-62; *Proceedings of the Third Conference on Space Debris*, Darmstadt, Germany, 2001. 2 vols. (ESA SP-473) - Legal Aspects at vol. 2 853-881. S. Mirmina 'The Ballistic Missile Defense System and its Effects on the Outer Space Environment' (2005) 31 *J. Sp. L.* 287-313. See also *supra* n. 121.

[140] Mirmina, *infra* n. 141, at 652-4.

[141] For the UNGA/COPUOS endorsed Guidelines (COPUOS, A/62/20 and UNGA Res. 62/217: see *supra* following n. 110. Cf. S. Mirmina, 'Reducing the Proliferation of Orbital Debris: Alternatives to a Legally Binding Instrument' (2005) AJIL 649-62.

[142] The Inter-Agency Space Debris Coordination Committee current members are the space agencies of China, France German, India, Japan, Italy, Russia, the UK, Ukraine, the US, with ESA: http://www.iadc-online.org/. For its Guidelines - http://www.iadc-online.org/docs_pub/IADC-101502.Mit.Guidelines.pdf.

[143] The five signatory European 'Code of Conduct for Space Debris Mitigation, 2004': ESA/IRC(2004)20, Appendix A: cf. http://www.esa.int/SPECIALS/ESOC/SEMZPBW797E_0.html.

[144] US Space Policy, 2006, (G.W. Bush) para 11, (2007) XXXII AASL 475-86, www.ostp.gov/html/US%20National%20Space%20Policy.pdf. Cf. para (7) of the section on 'Intersector Guidelines' of the US Space Policy, 1996 (Clinton)

set of rules, regulations and procedures.[145] India has also implemented measures in its space programme.[146]

We will have to wait and see whether the mitigation of the creation of debris m space by voluntary compliance with the international guidelines, and with national rules is effective.[147] Certainly some debris will continue to be added to the existing plethora. The unasked question, therefore, is what should be done about existing debris. Its removal was raised at the 2007 COPUOS meeting.[148] There are some current discussions of the technicalities.[149] However, the problems, particularly of smaller fragments, seem

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www.fas.org/spp/military/docops/national/nstc-8.htm. The 1988 US National Space Policy 1988 was the first to include a provision as to debris: 'Presidential Directive on National Space Policy 1988, *Space Law: Selected Basic Documents* (2nd ed.), Committee on Commerce, Science, and Transportation; US Senate, 95th Cong. 2nd Sess., December 1978 (USGPO), 449-68.

[145] NASA http://orbitaldebris.jsc.nasa.gov/mitigate/safetystandard.html; NASA Safety Standard 1740.14 of August 1995 'Guidelines and Assessment Procedures for Limiting Orbital Debris' - http://orbitaldebris.jsc.nasa.gov/library/NSS1740_14/nss1740_14-1995.html; and the NASA 'Procedural Requirements for Limiting Orbital Debris' NASA NPR 8715.6, 17 August 2007 - http://www.orbitaldebris.jsc.nasa.gov/library/NPR_8715_6.pdf, read along with NASA Technical Standard 'Process for Limiting Orbital Debris', 28 August 2007 (expiring 28 August 2012) NASA STD-8719.14. – http://www.hq.nasa.gov/office/codeq/doctree/871914.pdf, the related 'US Government Orbital Debris Mitigation Standard Practices' - http://www.orbitaldebris.jsc.nasa.gov/library/USG_OD_Standard_Practices.pdf and the NASA Debris Assessment Software: http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html. Cf. (US) FCC requirements contained in *In the Matter of Amendment of the Commission's Space Station Licensing Rules and Policies; Mitigation of Orbital Debris* IB Docket No. 02-34; IB Docket No. 02-54, 18 FCC Rcd 10760; 2003 FCC LEXIS 2858; 29 Comm. Reg. (P & F) 201, Adopted April 23, Released 19 May, 2003, and *In the Matter of Mitigation of Orbital Debris*, Second Report and Order; IB Docket No. 02-54, 19 FCC Rcd 11567; Adopted 9 June, released 21 June 2004. See also NASA's 'Orbital Debris Quarterly News' – http://orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html.

[146] V. Adimurthy and A.S. Ganeshan, 'Space debris mitigation in India' (2005) 58 *Acta Astronautica* 168-74.

[147] S.A. Mirmina, 'The Regulation of Orbital Debris through National Measures' (2004) 29 *Air & Sp. Law* 137-43. For earlier compliance with national rules cf. F. Alby et al., 'Debris assessment for Skybridge constellation' (2003) 53 *Acta Astronautica* 219-28.

[148] Report of the Committee on the Peaceful Uses of Outer Space to the 2007 General Assembly (A/62/20) para 128.

[149] E. Carlson et al., 'Space Debris Removal System' 1990 - http://www.tsgc.utexas.edu/archive/design/debris3.html; Y. Ishige et al., 'Study on electrodynamic tether for space debris removal' (2004) 55 *Acta Astronautica* 917-29; IADC paper, C. Pardini et al., 'Benefits and Risks of Using Electromagnetic Tethers to De-Orbit Space-craft' (IAC-06-B.6.2.10) October 2006, - http://www.iadc-online.org/index.cgi?item=docs_pub. See also the ESA Space Debris Conferences,

immense. The other question of 'debris' in its wider formulation relates to the remains of scientific probes. What should happen with apparently abandoned items? We know that such is not formally 'abandoned' (OST Art. VIII) but will anyone actually retrieve it or clean it up? It remains the responsibility of its 'owner' state. Were it sought to establish a legal duty in relation to the debris and abandoned machinery which may be left in orbit or on the Moon and other celestial bodies, probably other steps would have to be sought.[150] The duties as to the decommissioning of oil platforms on the continental shelf might provide an analogy.

Finally, as indicated at the start of this section, there is the question of space debris resulting from military action in space. We discuss the military use of space more fully in Chapter 16. Here we simply observe that by OST Art. III, and now by international custom, the UN Charter and international law apply in space, and this includes the provisions of UN Charter Chapter VII on 'Action with respect to Threats to the Peace, Breaches of the Peace and Acts of Aggression'. There the use of force is generally prohibited, but Art. 51 preserves the 'inherent right of self-defence' subject to conditions. Exactly what 'self-defence' means - its application and constraints in the modern world - is a matter of contention as we indicate in Chapter16. Of course were an all-out war to happen, rules would be ignored. However, a more limited conflict could be subject to environmental considerations. In that connection we note that OST Art. III, may imply that military uses of space that do not promote 'international peace and security' are prohibited, [151] Even so space debris would be created for example by the defence of a satellite system by anti-satellite measures (ASAT). We would hope that so

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supra. n. 132. On the 'orbital tether' system see also - http://www.space.com/businesstechnology/technology/technovel_tether_041117.html; http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=252; http://www.technovelgy.com/ct/content.asp?Bnum=698. In fiction A.C. Clarke foresaw the importance of orbital clean-up in *The Fountains of Paradise* (1978).

[150] We use the term 'abandoned' colloquially. Under OST Art. VIII a launching state retains jurisdiction and control over an object entered on its registry of objects launched into outer space. In law such objects cannot be abandoned to become *res nullius* or *res derelicta* (OST Art. VIII). A small plaque beside the replica of the Viking I Mars Lander in the Smithsonian Air and Space Museum in Washington DC, affirms the US property right in the Lander located on Mars, NASA having transferred its ownership to the Smithsonian – http://www.nasm.si.edu/exhibitions/GAL100/viking.html. Viking I landed on 20 July 1976, and remained active until November 1982. On 11 December 1993, at Sotheby's New York as part of a sale of Russian space memorabilia, the Lunokhod-1 lunar rover, launched 10 November, landed 17 November 1970 on the Mare Imbrium Sea of Rains) was sold for US$60,000 (estimate US$%5000). The location of the object was stated as 'resting on the surface of the Moon'. Sotheby's and the consignor of the object for the sale undertook no obligation to deliver possession. Only the current title rights of the owner were sold, without assurance as to the claims of others, including possible salvagers. See P.D. Nesgos, UN COPUOS Symposium on Commercial Activities in Space, March 1994, (1994) 37 *Proc. IISL* 305-14 at 305-6. See also Sotheby's Auction Catalogue 'Russian Space History' December, 1993.

[151] S. Mirmina, 'International Law Implications of the Ballistic Missile Defense System and Its Effects on the Outer Space Environment', (2005) 31 *J. Sp. L.* 287.

far as possible such debris would be minimised, bearing in mind the duties under OST Art. IX to have 'due regard to the … interests of all other States Parties to the Treaty'. More particularly Art. 35.3 of the Additional Protocol I to the Geneva Conventions of 1949 prohibits 'widespread long term and severe damage' to the natural environment.[152] The Convention on the Prohibition of Military and Any Other Hostile Use of Environmental Modification Techniques would also have a role in protecting the space environment.[153] Of course the question would arise as to how breach of such obligations might be prosecuted. One avenue might be through the Liability Convention, absolute liability being normally involved by its Art. II for damage caused to the surface of the earth and aircraft in flight, and liability based on fault for damage elsewhere by Art. III. Space debris resulting from hostilities in space causing damage to a neutral in space would be subject to the second of these as the deliberate action would establish fault (*dolus*).[154] Convention Art. VI.1 and 2 would deal with any question of exoneration, and could apply as between states taking mutual hostile action, though not eliding their liabilities towards non-combatants.

Planetary Defence.

Over recent years concern has grown about the possibility of a comet, asteroid or meteor colliding with the Earth.[155] A Near Earth Object (NEO) could pose a major threat. Every day small meteorites enter the atmosphere and burn up. Every so often a meteorite reaches the surface of the earth infrequently causing minor damage. Less frequently a major disaster may occur when a large object, an asteroid, comet or meteor, enters the atmosphere at high speed and either breaks up explosively at height or hits the surface.[156] It is these last that are the major matters of concern. The craters on the Moon show that meteor and asteroid impacts occur, and, although the atmosphere provides protection from minor objects which burn up, it is now known that the surface of the Earth also has

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[152] Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977; 1125 UNTS 4; UN Doc.A/34/144, (1977) 16 ILM 1391-1441 - http://www.icrc.org/ihl.nsf/FULL/470?OpenDocument.

[153] UN Convention on the Prohibition of Military and Any Other Hostile Use of Environmental Modification Techniques, 10 December 1976; 1108 UNTS 151; 31 UST 333, TIAS 9614; UNGA Res. 31/72; (1977) 16 ILM 88-94. See M. Bourbonniere, 'A Legal Regime for Keeping Outer Space Free of Armaments', 27 AASL 109 at 128-21.

[154] We note that in its Advisory Opinion on *Legality of the Threat or Use of Nuclear Weapons*, 1996 ICJ Rep. 226 at 261 (para 89) the ICJ held that 'international law leaves no doubt that the principle of neutrality, whatever its content, … is applicable … to all international armed conflict, whatever types of weapons may be used.'

[155] J.S. Lewis, *Rain of iron and ice: the very real threat of comet and asteroid bombardment* (Reading, Mass: Helix Books, 1995). Cf. P. Jenniskens, *Meteor Showers and their Parent Comets*, (Cambridge: Cambridge UP, 2006). For law articles see *infra* n. 185.

[156] The mid-August Perseid meteors come in at about 60 km/37m a second – some 133,300 mph. See also http://lifeboat.com/ex/asteroid.shield.

a history of asteroidal and meteor collisions.[157] The explosion of a meteorite over or near Tunguska in Siberia in 1908 showed that an area may be devastated,[158] and the final proof by the late E.M. Shoemaker that Meteor Crater in Arizona was caused by an asteroid or meteor and not by volcanic activity established that surface impact events could occur on Earth despite the protection of the atmosphere.[159] Theories as to the demise of the dinosaurs involve the impact of large objects.[160] These have been boosted by the discovery of the Chicxulub Crater centred on the Yucatán Peninsula and extending into the western Gulf of Mexico.[161] Another collision crater has been recently identified in north-west Scotland.[162] The collision of the fragments of the Shoemaker-Levy-9 comet with Jupiter in 1994 aroused much interest not to say excitement, and apprehension has been fanned by such films as *Meteor* (1979), *Asteroid* (1997), *Armageddon* and *Deep Impact* (both 1998).[163] The asteroid Apophis continues to cause a little concern for April in 2036, a previous threat for 2029 having dissipated on further more accurate tracking.[164] Threats of collision with the Earth by asteroids and comets are graded on the 'Torino Scale'.[165]

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[157] See the Earth Impact Database maintained by the University of New Brunswick, Canada. - http://www.unb.ca/passc/ImpactDatabase/

[158] W.K. Hartman, '1908 Siberian Explosion' - http://www.psi.edu/projects/siberia/siberia.html ; C. Chyba et al., 'The 1908 Tunguska Explosion: Atmospheric Disruption of a Stony Asteroid". (1993) 361 *Nature* 40-44;

[159] D.M. Barringer in 1903 suggested an asteroid origin for Meteor Crater and until recently the crater was known as the Barringer Crater.

[160] The Cretaceous-Tertiary extinction (the K-T event) was about 65.5 million years ago. Apparently M. W. DeLaubenfels, "Dinosaur Extinctions: One More Hypothesis," (1956) 30 *J. of Palaeontology*, 207-218 first suggested asteroid impact as a possible cause and in 1980 L. and W. Alvarez, F. Asaro and H. Michels, basing their argument on the world-wide occurrence of a layer of iridium (not explicable other than by debris from an asteroid impact) also theorised that the K-T event might have been caused by the impact of an asteroid:

[161] But see 'The Chicxulub Debate': http://geoweb.princeton.edu/people/faculty/keller/chicxpage1.html for argument that the Chicxulub meteor did not cause the extinction of the dinosaurs.

[162] K. Amor, SP Hesselbo et al., 'A Precambrian proximal ejecta blanket from Scotland' (2008) 36 *Geology* 303-6.

[163] Cf. L. Niven and J. Pournelle, *Lucifer's Hammer* (1977); A.C. Clarke, *The Hammer of God* (1993).

[164] The winners of the Planetary Society 'Apophis Mission Design Competition' that sought proposals for tracking and accurately measuring the asteroid were announced in February 2008 - http://www.planetary.org/programs/projects/near_earth_objects/apophis_competition/winners.html.

[165] For the 'Torino Scale': see http://neo.jpl.nasa.gov/torino_scale.html. It runs: 0 (White) – No hazard; 1 (Green) – Normal (a pass near the Earth, but with no danger); 2-4 (Yellow) – Meriting attention by astronomers; 5-7 (Orange) – Threatening; 8-10 (Red) – Certain collision, 8 causing localised damage, 9 causing unprecedented regional damage, and 10 causing global climatic catastrophe threatening the future of civilisation.

At present there is no international obligation on states either to investigate such matters or to take steps to deal with any threat. Article V para 3 of the OST requires Parties to inform the UN Secretary-General of phenomena discovered in outer space that might constitute a danger to life or health of astronauts. It would stretch the language unduly to interpret these words to include danger to Earth itself from asteroids, comets or meteors. Under OST Art. VIII States are required to avoid causing harmful contamination in outer space, or 'adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter'. They are also to avoid causing harmful interference to the space activities of others. Although one could argue that these obligations could cover the case where the orbit of an asteroid is altered (say by mining or even scientific probe) resulting in collision with a satellite or the Earth, [166] threats or dangers from objects proceeding in their natural orbits or trajectories are not covered. Principles X and XI of the Remote Sensing Principles of 1986 refer to the protection of the environment of the Earth and averting harmful phenomena and impending disasters, but these Principles relate to the sensing of the Earth from space, not to 'sensing' as it were 'outwards' to determine the existence of potential threats from outside.

Notwithstanding the lack of legal obligation, various organisations have appreciated the potential dangers and taken steps at least to assess and evaluate them. Initial efforts were varied, inadequately financed, and often amateur. Such were the several 'Spaceguard' projects.[167] A number of observatories have of their own initiative

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The Torino Scale was first proposed in 1999 and revised in 2004. Apophis is 700-1000 feet / 215-305 metres wide. Detected only on 11 October 2007, Asteroid 2007 TU24 went past the Earth on 29 January 2008 at 334,000 miles /500,000 km out (1.4 LD, i.e. 1.4 times the Lunar Distance). Asteroid 4179 Toutatis (c. 2.9 x 1.5 miles / 4.7 x 2.4 km) went past at c. 4.0 LD on 29 September 2004. Asteroid 2002 MN (diameter 80 metres / 260 feet) was noticed only on 17 July 2002 after it had passed the Earth two days earlier at some 120,000 km/ 75,000 m. (0.3 LD) out. Asteroid 2008 BC15 was discovered on 30 January 2008 and passed Earth one day later at 0.8 LD. On 9 December 1994 Asteroid 1994 XL1 passed by at some 65000 miles / 105,000 km. Asteroid 2008 TC3 was detected on an Earth-impact course on 6 October 2008 and entered the atmosphere above the Sudan on 8 October, exploding some tens of miles releasing the equivalent of about 1 kilotont of TNT. The Spaceguard system (*infra* n. 167) was involved in its tracking: see Wikipedia '2008 TC3'). For 'Potentially Hazardous Asteroids' (PHAs) see the NASA Near Earth Objects Program - http://neo.jpl.nasa.gov/neo/pha.html (which indicated on 29 January 2008 that there were 931 known PHAs) and - http://cfa-www.harvard.edu/iau/lists/PHACloseApp.html.

[166] While such an occurrence could be categorised as caused by negligence, the Liability Convention could not be appealed to since it deals only with damage caused by space objects that have been launched from Earth. But proof of negligence in a claim or action on these facts under normal rules of International Law seems unlikely.

[167] 'Spaceguard' may have taken its name from the 'Project Spaceguard' in A.C. Clarke, *Rendezvous with Rama* (1972) that detects the incoming object, Kali. Today ESA hosts the Spaceguard Central Node which brings together efforts which are coordinated by the Spaceguard Foundation: see www.spaceguard.esa.int or

undertaken work to find and catalogue Near Earth Objects (NEOs), particularly those which might cause trouble. There has also been formal governmental action, including surveys by government funded observatories.[168] In 2000 a Task Force set up by the British National Space Centre noted the inadequacy of current knowledge, the problems of disaster management (if needed) and questions of possible mitigation or avoidance, as matters requiring governmental discussion and action.[169] This view was supported by a Position Paper of the American Institute of Aeronautics and Astronautics (AIAA) in 2004.[170] The European Space Agency has also taken an interest in NEOs, funding a variety of studies, but most of these are still in a preparatory phase.[171] It has also published a report on the priorities for NEO risk assessment and their reduction.[172] This stressed the importance of finding NEOs and of investigating their physical characteristics since that might well affect how any threat each posed might be mitigated.[173] The report went on to explore various rendezvous mission concepts including SIMONE, ISHTAR and DON QUIXOTE as well as the potential of three observatory missions. In 2004 the Canadian-developed NEOSSAT (Near Earth Object Surveillance Satellite) was announced. This is a small satellite which from low earth orbit will track both near earth objects and satellites in other low earth orbit.[174]

Much has been done in the US. In 1990 the US Congress funded NASA activities in the area, and this stimulated interest resulting in a number of conferences and

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http://www.esa.int/SPECIALS/NEO/SEMS58OVGJE_0.html. The Spacewatch Foundation also tracks comets and asteroids - http://spacewatch.lpl.arizona.edu/.

[168] E.g. Australian 'Project Wormwood': www.ips.gov.au/IPSHosted/neo/index.html.

[169] Report of the Task Force on Potentially Hazardous Near Earth Objects, (London: BNSC, 2000), http://www.nearearthobjects.co.uk/report/pdf/full_report.pdf. Cf. the (UK) Near Earth Objects Information Centre - http://www.nearearthobjects.co.uk/. Cf. also *Near Earth Objects* - http://www.bnsc.gov.uk/assets//channels/resources/publications/pdfs/Near_Earth_Objects.pdf. and http://www.nearearthobjects.co.uk/report/resources_task_intro.cfm.

[170] AIAA Position Paper, 2004, 'Protecting Earth from Asteroids and Comets' (Reston, VA: AIAA, 2004) - http://www.planetarydefense.info/resources/pdf/Asteroids-Final.pdf

[171] See http://www.esa.int/SPECIALS/NEO/ and its links.

[172] Space Mission Priorities for Near Earth Object Risk Assessment and Reduction: Recommendations to ESA by the Near-Earth Object Mission Advisory Panel (NEOMAP), July 2004: http://www.esa.int/gsp/NEO/doc/NEOMAP_report_June23_wCover.pdf.

[173] A metallic asteroid would be different from a rocky one, and the degree of cohesion of a conglomerate object would also be of interest.

[174] NEOSSAT: Near Earth Object Surveillance Satellite - http://www.neossat.ca/. A.R. Hildebrandt et al., 'The Near Earth Object Surveillance Satellite (NEOSSAT) Mission Enables an Efficient Space-Based Survey (NESS Project) of Interior-to-Earth (IEO) Asteroids, (2007) 38 *Lunar & Planetary. Science* - http://www.lpi.usra.edu/meetings/lpsc2007/pdf/2372.pdf; A.R. Hildebrand et al., 'The Near Earth Object Surveillance Satellite (NEOSSAT) Mission Enables an Efficient Space-Based Asteroid Survey at Low Solar Elongations' (2008) *Asteroids, Comets, Meteors* - - http://www.lpi.usra.edu/meetings/acm2008/pdf/8293.pdf

papers.[175] In 2004 a Washington conference on 'Protecting Earth from Asteroids' sponsored by the American Institute of Aeronautics and Astronautics (AIAA) and The Aerospace Corporation produced a White Paper with recommendations for future studies, which was supported by the AIAA Position Paper already referred to.[176] The work was continued by another meeting in April 2007 and a further White Paper.[177] This noted the progress that had been made, but stated that while most 'civilisation killer' objects (some one kilometre and larger) had been identified, lesser objects of some 140-300 metres in diameter could cause serious damage over a large area and loss of life. Such might impact without warning. Search should be therefore undertaken. It was also a matter of concern that there was no agreed approach to such a disaster, or to methods by which it might be avoided or mitigated. The White Paper then went on to lay out the technical background behind its discussion and recommendations. Perhaps as a result or perhaps coincidentally, shortly after this White Paper was published in 2007 NASA reported to the US Congress on 'Near-Earth Object Survey and Deflection: Analysis of Alternatives'.[178] This recommended that the NEO Survey should be modified in order to identify and track by the end of 2020 ninety percent of all potentially hazardous objects greater than 140 metres which pass within 0.05 AU of the Earth.[179] This would be done in conjunction with other agencies. The report also outlined the advantages and disadvantages in respect of different strategies for the avoidance of a NEO impact,

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[175] A list of relevant papers is available at 'Planetary Defence Resources' maintained by The Aerospace Corporation: http://www.aero.org/conferences/planetarydefense/resources.html Cf. 'Preparing for Planetary Defense: Detection and Interception of Asteroids on Collision Course with Earth' - The (US) Air University,-- http://www.fas.org/spp/military/docops/usaf/2020/app-r.htm. Cf. also J.M. Urias et al. *Planetary Defence: Catastrophic Health Insurance for Planet Earth*, A Research Paper presented to Air Force 2025, Oct. 1996: http://www.fas.org/spp/military/docops/usaf/2025/v3c16/v3c16-1.htm

[176] 'The Planetary Defense Conference: Protecting Earth from Asteroids, February 2004, White Paper' - http://www.planetarydefense.info/resources/pdf/conference_white_paper.pdf. For the AIAA Position Paper of 2004 see *supra* n. 170.

[177] 'Summary and Recommendations from the 2007 Planetary Defense Conference' - http://www.aero.org/conferences/planetarydefense/2007papers/WhitePaperFinal.pdf. See also the Conference papers - http://www.aero.org/conferences/planetarydefense/2007papers.html.

[178] 'Near-Earth Object Survey and Deflection: Analysis of Alternatives' Report to Congress, NASA March 2007 – http://www.nasa.gov/pdf/171331main_NEO_report_march07.pdf. See also http://neo.jpl.nasa.gov/neo/report2007.html.

[179] An Astronomical Unit (AU) is the average distance between the Earth and the Sun (c. 93,000,000 miles / 149,600,000 km). A distance of 0.05 AU (46,500,000 miles / 74,800,000 km) is roughly twenty times the distance of the Earth to the Moon (0.0026 AU- 241,000 miles / 387,000km).

including nuclear explosions, the non-nuclear impact of a controlled missile, and various methods of deflection by a 'controlled push'.[180]

Internationally, 'Near Earth Objects' came on the UN scene with the holding of a major conference in 1995.[181] The topic entered the COPUOS agenda in 2005 when the General Assembly approved the amended three-year work plan adopted by the Committee (UNGA Res. 60/99). Accordingly the topic was discussed by the Scientific and Technical Sub-Committee of COPUOS in 2006 on the basis of various national reports and several presentations.[182] It noted that mitigation measures would require international coordination (para 149) and commended the US for its efforts in identifying objects of near-Earth objects more than one kilometre in diameter, and its investigation of methods and systems to identify objects down to 140 metres (para 151).[183] The Sub-Committee concluded by agreeing that efforts to track such objects should be 'continued and expanded' at both national and international levels (para 152). To further its work on NEOs the Sub-Committee set up an inter-sessional working party, which reported in 2007. This group now has a programme of monitoring international progress on cooperation in NEO studies on the basis of national reports, and of drafting (and perhaps agreeing on) in 2009 and 2010 of international procedures for the handling of threats.[184]

The question therefore arises what sort of international procedures might be adopted.[185] We already are developing measures to cope with terrestrially originating

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[180] Cf. C. Maccone, -1 'Planetary Defense from the Nearest 4 LaGrange Points plus RFI-free Radioastronomy from the Farside of the Moon: A Unified Vision' (2002) 50 *Acta Astronautica* 185-199; -2 'Planetary Defense From Space: Part 1 Keplerian theory' (2004) 55 *Acta Astronautica* 991-1006; S Konyukhov and N. Slyunyayev, 'Conception of the Creation of Space Rocket Complex as Necessary Link for Anti-Asteroid Protection of the Earth' (2002) 50 *Acta Astronautica* 629-32.

[181] J.L. Remo, ed., *Near-Earth Objects: The United Nations International Conference, 1995*, 822 *Annals N. Y. Acad. Sc.*, (New York, 1997); J.L. Remo, 'Policy Perspectives from the UN conference on near-Earth objects' (1996) 12 *Space Policy* 13-17.

[182] Report of the Scientific and Technical Subcommittee on its Forty-Third Session, Vienna, 20 February - 3 March 2006, A/AC.105/869.

[183] The US has so far identified 816 such objects (ibid., para 151).

[184] Report of the Scientific and Technical Subcommittee supra n. 182, paras 115-125 and Annex III. Cf. Report of the Committee on the Peaceful Uses of Outer Space, 2006, A/61/20 paras 144-5 and 178.

[185] M.B. Gerrard and A.W. Barber, 'Asteroids and Comets: U.S. and International Law and the Lowest-Probability, Highest Consequence Risk' (1997) 6 *N.Y.U. Env. L.J.* 4-49; L.I. Covert, 'Before Celestial Bodies Collide – Enhanced Dialogue and Coordination: Precursors to a Treaty for Effective New Earth Object (NEO) Response' (2003) 46 *Proc. IISL* 276-86; E.R. Seamone -1, 'When Wishing on a Star Just Won't Do: The Legal Basis for International Cooperation in the Mitigation of Asteroid Impacts and Similar Transboundary Disasters' (2002) *Iowa L. Rev.* 1091-1139; -2 his 'The Duty to "Expect the Unexpected": Mitigating Extreme Natural Threats to the Global Commons Such as Asteroid and Comet Impacts with the Earth' (2003) 41 *Colum. J. Transnat'l L.* 735-94; and -3 his 'The Precautionary Principle as the Law of Planetary Defense: Achieving the Mandate to Defend the Earth against Asteroid and Comet Impacts While There is Still Time' (2004) 17 *Geo. Int'l Envt'l L. Rev.* 1-23; J.L. Koplow, 'Assessing The Creation Of

disasters. These are not appropriate fully to cope with threats from space.[186] First, it would be wise to establish a formal international programme for the detection of incoming threats.[187] It may not be sensible to rely on existing national programmes, or even on international programmes such as that of ESA. The survey currently being carried out by NASA is unduly dependent on funding decisions of the US Congress, which may be erratic. The same could apply to ESA activities. A formal international organisation would be a better solution, with funding either from its members or from the United Nations itself. The UN funds peace-keeping forces. The creation and running of a survey and monitoring agency would cost much less, particularly were its operation to be contracted out to an existing agency or entity.[188] Second, the preparation of means of diverting an asteroid, meteor or cometary threat should not be delayed until an actual object is detected. Time might be too short adequately to deal with the crisis – missile or other technology has to be prepared.[189] Certainly as can be seen from materiél cited in this section, thought has been given to what might be done. A formal organisation (not necessarily one separate from the 'survey organisation') should therefore be established with the function of bringing into being several of the potential methods of diverting an incoming threat, or its mitigation (given a suitable composition[190]). Again elements of this undertaking could be contracted out. But the cost of diverting an incoming asteroid or comet would be much greater than that of simply looking for such things. A central organisation should therefore be established both to provide a channel for appropriate funding and to determine when appropriate measures are activated.[191] It is tempting to suggest an analogue of the former INMARSAT could serve. Funding should come from the UN, the World Bank and the International Monetary Fund, as well as from non-donors to these latter agencies. Since all are under threat, all should bear a portion of the cost of its avoidance. Attention will also need to be given to questions of liability. If an incoming object is diverted, but notwithstanding hits the Earth, or if the object is broken

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A Duty Under International Customary Law Whereby The United States of America Would Be Obligated to Defend A Foreign State against the Catastrophic but Localized Damage of an Asteroid Impact' (2004-2005) 17 *Geo. Int'l Envt'l L. Rev.* 273-306.

[186] Certainly such as the 'Disasters Charter' organisation might be able to help once a disaster has taken place: 'Charter on Cooperation to Achieve the Coordinated Use of Space Facilities in the Event of Natural or Technological Disasters' (2000) http://www.disasterscharter.org/main_e.html. See Chapter 13, Remote Sensing.

[187] In 2008 at least one internet site, 'The Tracking News', reports information derived from a variety of sources as to comets and asteroids and assessments of the risks they pose - http://www.hohmanntransfer.com/news.htm.

[188] Cf. the 'Project Spaceguard' which first picks up the track of the incoming starship in A.C. Clarke, *Rendezvous with Rama* (1972). Cf. also the 'Spaceguard Foundation', *supra* n. 167.

[189] As noted *supra* n. 165, Asteroid 2002 MN (diameter 80 metres / 260 feet) was spotted on 17 July 2002. It had passed the Earth two days earlier. Asteroid 2007 TU24 which passed the Earth on 29 January 2008 was detected only on 11 October 2007. Asteroid 2008 BC15 was discovered on 30 January 2008 and passed Earth one day later.

[190] A cometary 'snowball' could (might?) be broken into inoffensive parts by a kinetic impact.

[191] Koplow, *supra* n. 185, discusses whether the US might act alone.

up and parts still cause damage, where might liability (if any) lie?[192] Concepts of terrestrial international environmental law may have an unusual role to play.

[192] Cf. R.L. Schweikrt, 'The Near-Earth Object (NEO) Protocol' (2006) 49 *Proc. IISL* 574-9 at 578.