PROTECTION OF THE SPACE ENVIRONMENT: THE FIRST SMALL STEPS

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ABSTRACT

The development of the space environment - for industry, commerce and tourism - is a natural extension of our current business and domestic agenda. Unfortunately, this brings with it the ability to pollute, degrade and even destroy aspects of the space environment. This paper briefly reviews the evidence of mankind's pollution of the space environment in the first 45 years of the Space Age, and extrapolates the potential for further degradation into its second half-century. It also makes recommendations concerning the first steps towards a solution to the problem, including the formation of an international consultative body and consideration of a 'set of guidelines' or 'code of practice' as a precursor to more formal policies or legislation.

INTRODUCTION

It has often been said that mankind's desire for exploration is one of the aspects that set us apart from the other creatures with which we share the Earth. A natural extension of this is the desire to explore the space environment - a philosophy expressed concisely in the well-worn phrase 'space...the final frontier'. From this point of view, it is important for the long-term psychological well-being of the human race that we maintain the ability explore space.

Moreover, as the development of industry, commerce and tourism here on Earth has shown, our desire and ability to explore leads inexorably to a desire to develop and exploit. This strongly suggests, therefore, that exploration of the space environment will lead to its development and exploitation, and there is evidence that this is the case. Indeed, it has been suggested that, particularly as it becomes increasingly accessible, the space environment will become a natural extension of our current business and domestic environment (Williamson, 2001).

As previous papers - most notably those presented at an IAA/IISL Scientific-Legal Round Table in 1999 (see references) - have shown, this ability to explore and develop brings with it an ability to pollute, degrade and even destroy aspects of the space environment. This is, arguably, a natural extension of an ability we have developed and practised here on Earth.

It is these abilities, and their long-term effects, that compel us to consider protection of the space environment in much the same way as terrestrial environmental degradation has compelled others to call for its protection.

The task is a difficult one in either realm - terrestrial or extraterrestrial - because those who seek to develop and exploit the environment in question are usually those with the most to lose, particularly if protection means denial of their business income.

This is, by its nature, an emotive subject, which many will tend to shun because of its difficulty and potential to set different parts of the space community against each other. This would obviously be counterproductive. The only solution is to take an entirely pragmatic stance. As on Earth, the solution for protection of the space environment lies in convincing the 'polluters' and 'degraders' that it is in their long-term business interests to protect the environment they are developing and exploiting.

No-one is suggesting that protection of the space environment is easy, but then neither is space exploration - and mankind has managed to do that quite successfully. This paper attempts to make the first small steps towards a goal that would, arguably, constitute another "giant leap for mankind": the preservation of the space environment for future generations of space explorers and developers.

EVIDENCE

The evidence of mankind's pollution or degradation of the space environment, which includes the surfaces of the planetary bodies, has been presented in some detail in previous papers (Almar; Johnson; Williamson, 1999), and is summarised here. Although pollution and degradation are emotive and pejorative terms, and definitions of the terms may differ between observers, this discussion is not intended as an exercise in laying blame; it is simply an attempt to highlight a few historical facts.

For most observers, degradation of the space environment begins and ends with space debris, or man-made orbital debris - the inactive remnants or products of space hardware which remain in Earth orbit. This includes defunct satellites, launch vehicle upper stages, hardware jettisoned from manned and unmanned spacecraft, and even the combustion products of solid rocket motors in the form of tiny metallic particles.

The larger objects are tracked on a continual basis and the evolution of their orbital paths is well understood, but many other smaller objects remain undetectable. For example, objects in low Earth orbit (LEO) at least 10cm in diameter can, in principle, be tracked on a routine basis by the US Space Surveillance Network (SSN); indeed, about 10,000 objects are tracked, some 8,600 of which are officially catalogued. Objects greater than 1m in diameter can be detected in geostationary orbit (GEO), but the ability to detect them depends on many factors, including shape, material composition and the eccentricity of their orbit. About 2000 objects in GEO, including active and inactive satellites, are currently tracked by the SSN.

According to NASA estimates, the population of particles between 1cm and 10cm in diameter is greater than 100,000, while the number of particles smaller than 1cm probably exceeds tens of millions. Individual objects as small as 3mm can be detected by ground-based radars, providing a basis for a statistical estimate of their numbers, while assessments of the debris population smaller than 1mm can be made by examining impact features on the surfaces of returned spacecraft (albeit limited to spacecraft operating at altitudes below 600km).

Most orbital debris resides within 2000km of the Earth's surface, although the amount of debris varies significantly with altitude and is concentrated at around 800km, 1000km and 1500km. A good deal of theoretical work has been done concerning predictions of how these debris populations may evolve, largely based on the premise that a single collision can produce a cascade effect, producing more and more debris. Some have concluded that certain low Earth orbits may become unusable by the middle of the century (Eichler and Rex, 1989; United Nations, 1999). Interestingly, the first validated collision between two catalogued objects occurred in July 1996 when the French microsatellite Cerise was hit by part of an Ariane rocket.

Although there was originally a good deal of resistance towards warnings of the dangers of orbital debris, it is now widely accepted as a cause for concern. As a result, in order to reduce the probability of collision and the resulting accumulation of debris, geostationary satellites are now removed to a 'graveyard orbit' at the end of their operational lives and satellites in LEO are generally de-orbited to burn up in the Earth's atmosphere. Likewise, cleaner separation and deployment devices which do not produce debris have been developed, and propellant tanks are now 'passivated' by venting residual propellant to avoid subsequent explosions.

These procedures and technologies have not been developed to protect the space environment for its own sake; they are pragmatic and self serving measures which help to protect the orbital environment for future use, either for scientific or financial gain. Again, no judgement is intended; it is simply a fact.

Unfortunately, the same pragmatism has so far not been extended beyond Earth orbit, and there are no similar debris mitigation measures for spacecraft which orbit or land on other planetary bodies (including of course our own Moon).

In the early years of the Space Age, a large number of spacecraft and rocket stages were intentionally crashed onto the lunar surface, littering the surface with debris (Williamson, 1999). It began with the Soviet Lunas and American Rangers of the 1950s and 1960s, and continued into the early 1970s with the impact of Lunar Orbiters, Apollo lunar module ascent stages and Saturn V third stages. Interestingly, however, the potential danger posed by inactive orbiting spacecraft was realised in the case of the Lunar Orbiters, which were deorbited specifically to avoid 'potential interference' with the later (manned) Apollos.

While the catalogue of a few dozen impacts may be viewed as insignificant on a planetary scale, in the absence of a policy against impacts it has continued to the present day. The most recent example was the impact of

Lunar Prospector onto the Moon's south pole in 1999, designed as an attempt to produce a plume of water molecules from suspected polar ice deposits.

The only reason there have not been more intentional impacts is that no lunar missions were conducted between Luna 24's landing in August 1976 and the launch of Japan's Hiten/Hagoromo spacecraft in January 1990; and there were only two other missions in the 1990s (Clementine in 1994 and Lunar Prospector in 1998/99).

Likewise, the only reason the other bodies of the solar system are not littered with debris from manned and unmanned spacecraft is the dearth of missions. With the single exception of targeting the Galileo orbiter into Jupiter's atmosphere to avoid a possible contaminating impact with Europa, there is little indication that these bodies are afforded any protection against contamination when it comes to their scientific exploration. What hope then when they become the target of commercial exploitation?

EXTRAPOLATION

It is difficult to extrapolate the potential for further degradation of planetary orbits and surfaces into the second half-century of the Space Age (2007-2056), because no-one knows with any certainty what missions will be launched in that period. However, it is possible to predict the *likely* consequences of *currently expected* progress in space exploration and development.

For the most popular Earth orbits, the case has already been made and broadly agreed upon for debris mitigation measures. As a result, we expect to continue using low, medium and high altitude orbits for at least the next half-century without experiencing significant problems. However, this will depend on the continuation and improvement of those mitigation measures, since a single cascade event could make a given orbit unusable (perhaps for thousands of years).

Moreover, current mitigation measures for the higher orbits (e.g. graveyard boosts for geostationary satellites) simply delay the eventual solution. At the current launch rate of 20-25 geostationary satellites per year, between 1000 and 1250 spacecraft would be added to the GEO population over a 50-year period. Even assuming longer operational lifetimes for the newer satellites, this means that some 10-20 defunct satellites will be added to the graveyard each year (i.e. 500-1000 in 50 years).

The fact that these satellites are, almost by definition, abandoned and uncontrolled means that one day a collision will occur in a graveyard orbit, producing debris in orbits that will intersect the geostationary ring and threaten operational satellites. The probability of such a collision can only increase until the graveyard population is reduced.

At present, the technology to remove defunct satellites from high altitude orbits does not exist; nor are there any funded programmes to develop this technology. A significant part of any policy advocating protection of the space environment would, by necessity, include consideration of this matter.

At one point in the 1990s, it appeared that a similar if not greater potential for collision would be provided by the number of multi-satellite constellations planned for launch into low and medium Earth orbits (LEO and MEO). As it turned out, only two significant constellations - Iridium and Globalstar - were deployed, and they were commercial failures. However, a number of companies still have plans to deploy other constellations when market conditions allow, so the potential threat to LEO and MEO remains.

Current commercial applications apart, it is important - as with all aspects of space development - to realise that the situation does not remain static for long. Simply because most of our spacecraft are confined to Earth orbit today does not mean that this will always be the case. There are already plans to place a network of what, in Earth orbit, would be termed communications satellites in orbit around Mars. In the first instance, they would be used to transfer data from science stations on the surface, or flying in the Martian atmosphere, back to Earth; later they could serve as relay stations supporting a manned mission. There is no reason why areostationary orbit - the Mars equivalent of GEO - should not become an important resource in the future, eventually requiring the same protection as GEO.

Perhaps before that, similar orbits around the Moon may be developed for communications, lunar imaging and manned applications as they are today around the Earth. The example of the Lunar Orbiters quoted above shows that a precedent for protection has already been set.

At the beginning of the 21st century, we are still - by analogy - in the pre-commercial airline days of the 1920s; once the promised innovation of space tourism arrives, a Pandora's box of problems, issues and challenges will open, most of them concerned with the safety of fare-paying tourists. If measures are not in place by then to protect the usability of certain orbits, mitigate the production of debris, and maintain communications services to space stations, lunar shuttles and surface bases, there is little hope that space tourism will succeed.

PROTECTION FOR THE ENVIRONMENT'S SAKE

Protecting the space environment to maintain its qualities for commercial exploitation is surely the first line of attack in any pragmatic protection programme, since it addresses the primary concern of the commercial developer: continuity of income. However, it is also worth considering protection for its own sake. Too often, we hear of irreversible environmental degradation here on Earth. As we expand our influence into the solar system, we have the potential to carry our penchant for environmental degradation with us, as shown by historical evidence. The question must be one of balance: how much degradation is allowable in the name of progress?

While few space professionals would advocate a slash and burn philosophy in our exploration and development of the solar system, many would choose to turn a blind eye to the occasional pollution or degradation event in favour of budgets, project timelines or personal advancement. This is human nature; and it illustrates why protection of the space environment requires a human dimension.

This human dimension is effectively summarised in the term 'space ethics', a subject worthy of consideration in its own right (Pompidou, 2000), and covered in a parallel session of the 2002 World Space Congress (IAA.8.1 Ethical Issues Arising in Space Activities). Ethics can be defined as "the philosophical study of the moral value of human conduct, and of the rules or principles that ought to govern it". More practically, it represents "an approved code of behaviour" adopted, for example, by a group or profession. If a set of ethics is to be developed for space, it is important that what we refer to as the 'space community', or 'space profession', is intimately involved. Indeed, if it is not, the profession risks having the job done for it, for example by politicians and members of the general public, who for their own reasons may wish to place restrictions on space development, or ban it altogether. The terrestrial nuclear power industry, for example, has already suffered this fate, while widespread ignorance of 'nuclear matters' has led to a moratorium on the use of radioisotope thermoelectric generators (RTGs) in spacecraft.

Practical questions include the extent to which development of the lunar surface should be allowed. For example, strip mining the surface for helium 3 or other elements and materials would, by definition, disfigure the surface. Should we only sanction mines that are small enough to remain invisible from Earth and, if so, do we mean invisible to the naked eye or through a telescope? Or should we confine such development to the back side of the Moon? In which case, should the development remain invisible from naked eye observers in a lunar orbiting hotel, or not? Alternatively, should any scale of mining be allowed as long as the surface is returned to its former visual appearance after a given period?

Similar questions may be posed for other planetary bodies, and it is worth repeating the concern of astronomer Ivan Almar who has pointed out that a typical open cast mine on the Martian moon Phobos, which is smaller than a city the size of London, could destroy its unique groove system forever (Almar, 1999). These and many other specific questions are worth asking. However, it is not for individuals to decide on the answers - especially individuals with a financial interest in the outcome. This much we may learn from terrestrial experience. So, who will decide, on what information will they base their decisions, and how will those decisions be enforced?

RECOMMENDATIONS

The above discussion indicates that much, but certainly not all, of this subject is theoretical and dependent on actual progress in space exploration and development. However, it also argues that there is no time like the present to begin serious and organised consideration of the subject of protection of the space environment.

In a sense, the first small steps have already been taken. Individual space professionals have published articles and papers drawing attention to some of the issues, and the 1999 IAA/IISL Scientific-Legal Round Table made a more formal attempt to present the issues to the international space community.

While these attempts are laudable, they represented only a fraction of the effort required, firstly, to convince the space community of the need to consider protection and, secondly, to formulate a policy.

PROMULGATING IDEAS

The next small step in the process is, in fact, more of a continuing background task: that of spreading the word. Those with an interest in protection of the space environment, or those with particular expertise to share, should continue talking to their peers in industry, space agencies, etc, and promulgating the issues at conferences and in publications.

If the aims of the 'protection lobby' are to be realised, the discussion of the subject will require a good deal more collective knowledge, understanding and maturity than has been evident in similar discussions regarding the

Earth's environment. At present, that knowledge resides largely within a small subset of the professional space community. Thus there is a need for promulgation, both within and beyond that community. This will be no easy task, because there are many who will see this as another layer of bureaucracy and yet another restriction on progress.

The analogy with the terrestrial environmental movement has already been drawn; one could also compare the space protection lobby with the Luddite machine-breakers of the early 19th century. This would, however, be controversial and counterproductive, since the space protection lobby is not against the industrial development of space; it simply wishes to ensure that development takes place in a sustainable and environmentally-friendly manner.

By definition, most people with an interest in protection of the space environment are those with some knowledge of space science, technology, and so on; and most of them have a vested interest in the continuation of space exploration and development. One of the many challenges in communicating information and views on space protection to a wider audience will be that of demonstrating that the lobbyists are not latter-day Luddites.

FORMULATING POLICY

Small steps aside, significant progress in any subject is made by giant leaps, and the giant leap in protection of the space environment would be the formulation and agreement of a policy.

The first step towards that goal is the formation of an international consultative body to consider the relevant issues and raise awareness of the subject among the growing body of space professionals and practitioners. The question is, of course, under whose auspices should this body be inaugurated? Obviously, given the increasingly international nature of space exploration and development, it is important for the body to be as international as possible, ideally including representatives from all major spacefaring nations.

Given the forum in which this paper is presented, a first suggestion might be the formation of a working group under the joint auspices of the International Academy of Astronautics (IAA) and the Committee on Space Research (COSPAR). An alternative might be organised under the UN, possibly affiliated with the United Nations Committee for the Peaceful Uses of Outer Space (UNCOPUOS), which has already taken an interest in space debris. A third option might be a form of space agency/space industry forum. The pros and cons of these and other options may have to be discussed at some length before a decision is made.

Even this is only a start, however. One needs only to look at the body of space law - and the disappointing fact that certain major spacefaring nations have not ratified the Moon Treaty ("Agreement Governing the Activities of States on the Moon and Other Celestial Bodies", adopted by the United Nations General Assembly on 5 December 1979) - to realise that well-meaning work on behalf of the international space community is not always appreciated. Another example is the International Telecommunications Union (ITU), which aims to coordinate the use of the radio frequency spectrum and geostationary orbital positions, among other things, to avoid harmful interference. Although, in most cases, this works well - since an interferer will generally also suffer interference - the ITU can only make recommendations; it has no legal powers of enforcement.

Any future 'International Space Protection Union' may have to function under the same restrictions. The key to success will be to get as many parties with vested interests 'on side' as soon as possible. Thus, to represent the science community, one might seek to gain backing from major space agencies, such as NASA, ESA and the future combined Japanese space agency. To represent industry, one might seek the support of national space industry associations or, better still, the leading prime contractors themselves. However, to make the organisation as democratic as possible and to allow a broad-based 'ownership' of the ideas, issues and eventual policies, one would have to accept representations from a much wider field.

This is important because we appear to be on the cusp of a true commercialisation of space: witness in-space burials, tourists on the International Space Station and plans to send teleoperated 'theme-park' rovers to the Moon. There is no point in formulating policies to which only the industrial prime contractors will adhere; there has to be a way to include the smaller operators.

Of course, this raises the issues of legislation, policing, conviction and punishment. If an operator or developer ignores the policies and breaks the rules, will there be a mechanism to cope with this? Unfortunately, experience regarding the Moon Treaty and the ITU suggests not.

Despite this, it is too early in the process to declare defeat. Despite the limitations of current space law and policies - and however little they have been tested in the hostile environment of space commerce - space exploration and development has continued unabated for the past 45 years and shows little sign of ceasing.

So, assuming the formation of an international consultative body goes to plan, what should it do? The first small steps should surely include the following:

- formation and enactment of a policy to maintain and expand the constituency of the body, specifically regarding its international nature
- formation and enactment of a policy to obtain funding and other support from key space-related organisations
- formation and enactment of a policy to ensure the promulgation of ideas among the space community and the media
- consideration of a 'set of guidelines' or 'code of practice' as a precursor to more formal policies or legislation.

Although the last point is the *raison d'être* for the body, the preceding points are also important. Their importance can be illustrated by considering the ramifications of omitting them:

- if the body is not international in nature it will be considered by those outside as partisan, and however well-meant its eventual policies they will be ignored.
- if the body cannot secure at least some regular funding, it will be unable to operate a secretariat or provide expenses to those members unable fund their activities in support of the body.
- if the body does not appoint an experienced promulgator - a press and public relations officer, for example - the ideas and issues considered by the body will remain 'in-house', much as they are today.

NEXT SMALL STEPS

Detailed suggestions concerning the content and coverage of the guidelines or code of practice will undoubtedly be made in due course, as one of the next small steps towards the goal of protecting the space environment. In formulating these guidelines, it will be important to recognise the need to strike a balance between unbridled exploration and development, and a stifling regime of rules and regulations. It is not in the nature of mankind to open a new frontier and then close it again without fully exploring its potential. Specifically, it is not in mankind's best interests to place a moratorium on space exploration and development.

The challenge for 21st century space practitioners will be to find a way to explore, develop and exploit the unique properties of the space environment - including the surfaces and orbital spaces of the planetary bodies - without degrading or destroying the environment which holds so much promise for the future of mankind.

CONCLUSION

As the space frontier becomes accessible to a wider variety of individuals, corporations and other bodies, the requirement for protection of the space environment grows. If the space environment is to remain available for the study of and use by successive generations of explorers and developers, we must make the first steps towards protection now. In another twenty years or so - when the second generation of lunar explorers is making footprints on the surface - it may be too late.

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