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IISL - 01-IISL -4.02

SPACE DEBRIS, A STATUS REVIEW AND FUTURE IMPLICATIONS

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ABSTRACT

The progress of space technology in recent decades has created a vast amount of space debris, which with the outlook of ever-increasing activities in both government and private sectors, is going to be of considerable concern. The projected increased activities will be fueled with the introduction of new launch systems, particularly reusable launch vehicles in the near future. Many space projects are also defined and carried out by multinational organizations or intergovernmental agreements.

In spite of many different international instruments with regard to space debris and a considerable amount of technical research that has been carried out in mitigation and modeling, still a clear picture of the future of legal and technical challenges does not exist. However, it is certain that the existing legal instruments are not necessarily adequate for the expected complex future of space activities.

A review of the present status of space debris and related legal instruments is presented. Some future issues are introduced, analyzed and discussed. A proposal is made for an international fund and an International Debris Regulatory Body.

INTRODUCTION

We are at the beginning of the new age of the benefiting from outer space, which can be characterized by privately financed, commercial driven activities rather than the traditional government funded and operated programs that were the hallmark of the "Old Space" era.

New space products and services are designed, priced and distributed in ways to satisfy direct consumer demands, such as the desire for satellite television services, where there are no local stations.

New space is the economic frontier of Earth. Space is to its investors today, what the New World was to its investors in the 1600's, i.e. a source of limitless potential, where untold fortunes awaited those investors who had the information, the capital and the desire to seize upon the opportunity. It is now common to see broadcasting companies spend as much as $1 billion to put one single satellite into orbit.

Because of the incredible commercial demand, more privately financed satellites are launched from Cape Canaveral than military and government satellites are launched.

International co-operation in space activities is a major part of the big picture of space activities, and will continue to grow considerably for a number of reasons[1]:

- Pulling financial resources from different international partners.
- Reduces overall cost of a given program to a nation, and increases the number of programs a nation can undertake or participate in.
- Access to foreign launch services increases mission flight opportunities for a given nation.
- International scientific participation in data analysis and international publication of

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research results enhances the scientific return of a research project.

A reduction data and information system to collect and distribute the data generated from global, regional and national satellites and in situ observations is required to obtain maximum scientific analysis of the data and to ensure international access to the data for use in policy decision making. This availability of data will result in a wider awareness of space benefits and will in turn increase demand for more space applications. The international participation in the generation, analysis and dissemination of data to potential users worldwide is of particular importance in this regard.

A VIEW OF THE SPACE INDUSTRY

In the development history of space industry, we are witnessing an era of increasing high volume of activities. Smaller and more frequent missions have made space more sensible and more easily understood by people from all sectors of the international society. The prospect of a future in space with frontiers of science, engineering and limitless sources of raw material has attracted a considerable amount of investment. This is backed by the fact that wealth and profit available from space show no limit.

To take advantage of this growing market, many countries have devoted budget for their space activities, which has been steadily increasing. Table (1) shows the budgets for some countries that in one way or another are involved in space activities. This table shows a steady spending in the global sense throughout a rather long period. Of course due to the advancement of technology and growing competition, which have helped to lower the prices, this actually shows a steady increase in investment in space industry. It should, also be noted, that many other countries are also providing budget for space technology development or applications by investing in different research and or service sectors.

Table (1) Space Program Budget (Million US$)

COUNTRY	*1977*[2]	*1998*[3]	*2000*[9]
Australia	NA	37	25.4
Austria	44	48	41.4
Belgium	169	163	NA
Brazil	96	139	45.6
Canada	185	262	22.2
Denmark	NA	34	20.6
European Space Agency	3119	3137	2900
Finland	24	43	NA
France	1544	1840	1600
Germany	712	851	669
India	303	357	NA
Italy	762	498	445
Japan	2001	NA	1900
Korea	NA	32	69.4
Netherlands	116	125	NA
Norway	30	31	45.4
Spain	156	120	132.9
Sweden	88	87	75.1
Switzerland	78	78	78
United Kingdom	320	296	254.4
United States	12730	13272	13600
TOTAL	22477	21450	21924.4

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Although the budget for space industry development is spent in different areas, the interest in the launching industry is of particular interest, mainly because access to all benefits of space needs launch services at some point. This interest has translated into several launch programs and launch vehicles. Table (2) shows the extent of this fact by providing some information on a number of launch programs, launch vehicles and their variants and a look at the near future plans.

All this has created a launch business activity that a decade ago was a luxury and political prestige for very few countries. To illustrate this, the number of launches for a similar period in 1997 and 1998 and 2000 is shown in Table (3). It can be seen that in 3 months in average every 2-3 days, one satellite has been put in orbit, and from this data and others, one can observe that a large number of countries are involved one way or the other.

Table (2) Launch Vehicles[4]

COUNTRY	*LAUNCH PROGRAMS*	*LAUNCH VEHICLES*	*LAUNCH VEHICLE VARIANTS*	*NEW LAUNCH VEHICLES 1998-2000*	*NEW LAUNCH VEHICLES PROPOSED*
Australia	6	8	8	-	6
Brazil	1	1	1	-	-
China	1	7	7	-	-
Europe	1	2	8	1	-
India	2	4	6	2	1
Israel	2	2	2	1	-
Italy	1	1	1	-	-
Japan	1	1	1	-	-
Russia	4	7	10	-	-
Ukraine	3	7	7	-	3
United States	13	20	38	8	7
TOTAL	35	60	85	14	17

Table (3) Comparison of Number of Launches

Country of Origin	Number of Launches		
	1/4-31/6/, 997[5]	1/4-31/6, 1998[6]	1/8-31/102000[9]
Brazil			1
China	1	2	2
Egypt	-	1	1
ESA			2
Europe			2
France	1	-	
India	1	-	
Italy			2
Ivory Cost	1	-	
Japan	2	1	1
Malaysia			
Norway	1	-	
Russia	6	11	6
Saudi Arabia			2
Spain	1	-	
Thailand	1	-	
United Arab Emirate			1
United States	18	25	10
TOTAL	33	40	30

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If in the 1960's and 1970's having a flagship airline was important for political or economical reasons. In this first decade of the twenty-first century, having a satellite orbit is important; probably more due to economical and financial returns. The attraction has mainly been in communications and TV broadcasting. Of course, education, disaster prevention, agricultural product forecasting and planning, etc. are among many other benefits that in the short and long run are going to bring about some financial and economical advantage.

The interest in the launch industry is well justified particularly when the programs for constellation deployment are considered. A total of 22 such programs is under way; Table (4) shows brief information of the current and planned constellations. When fully deployed, about 900 satellites will be put in orbit. This is not considering the spares. Considering this and replacement due to malfunction and normal life span, one can see the extent of activity and market for launch business. This has attracted attention of private investors to get actively involved in developing reusable launch vehicles. Five such programs are already under way.

Table (4) Constellation Status[7]

CONSTELLATION	OPERATOR	PRIME CONTRACTOR	ORBIT (Km)		NO. OF SAT.
Iridium	Iridium LLC	Motorola	780	BLEO	66
Global Star	Global Star LP	Space System /Loral	1414	BLEO	48
Ecco	Constellation	Matra Marconi Spaces	2000	BLEO	46
Ellipso Borealis	Ellipsat	Orbital Sciences	673x7515	BLEO	10
Ellipso Concordia	Ellipsat	Orbital Sciences	8060	BLEO	7
Signal	PKK Energiya	PKK Energiya	1600	BLEO	48
ICO	ICO Global COMM	Hughes	10355	MEO	10
Orbcomm	Orbocomm	Orbital Sciences	785	LLEO	28
Gonets D	Smolsat	AKO Polyot	1400	LLEO	36
Vitasat	VITA	Various	Various	LLEO	2
FAIsat	FACS	Final Analysis	1000	LLEO	26
SAFIR	OHB Teledata	OHB System	680	LLEO	6
Temisat	Telespazio	Kayser-Threde	938	LLEO	7
Courier (Konvert)	Elias Courier Complex	NPO Elas	700	LLEO	8
E-Sat	E-Sat (Ecostar)	--	--	--	6
Gonets R	Smolsat	AKO Polyot	1400	LLEO	45
Iris	Smolsat	OHB System	1000	LLEO	2
Leo One	SAIT Systems	--	950	LLEO	48
Celestri	Motorola	Motorola	1400	L/MEO	63
Skbridge	Skybridge	Alcatel	1457	L/MEO	64
Teledisc	Teledisc	Boeing	700	L/MEO	288
WEST	Matra Marconi Spaces	Matra Marconi Spaces	10000	L/MEO	9
TOTAL					873

LLEO = Little LEO   BLEO = Big LEO   L/MEO = LEO/MEO

The high cost of space projects has created an international cooperation environment. Not only investment in the service sector is internationally and multinationally financed, projects such as the International Space Station are now well-established international efforts.

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Note that a decade ago, such projects were national prestige and its undertaking was considered a political gain.

Even the Mir space station, which once was off limit to non-Soviets, was offered to other nations for co-operative activities in its last years of service. Russian space officials tried rather hard to attract international financial support to extend the life of the aging station.
In other activities smaller and less expensive missions have attracted considerable attention from public, scientific and political centers. The mission to Mars by NASA was a successful well publicized example of such projects.

Sales of remote sensing images, has enjoyed a growing market, better resolutions and lower prices are assuredly expected. Newcomers like India to this market will both benefit from it and help create a wider product base and lower prices for the benefit of the consumers.

This was a brief overview of some of the space activities, which are instrumental in creating debris in Earth orbit.

DEBRIS IN EARTH ORBIT

Space activities have resulted in putting a wide range of objects in space. Functional spacecraft either operational or stand by are the objects that serve a purpose. However, like any other technological development, space technology has had its own adverse effect on the environment, mainly by creating debris in Earth orbit, which are man made objects that serve no purpose. The following categories can be recognized for debris in Earth orbit:

Rocket bodies; upper stages of rocket bodies that have been part of the vehicle launching the satellite into orbit. These can cause fragmentation debris of an explosion due to remaining residual fuel.

Mission related objects; in normal operations in space, small objects may be released intentionally or unintentionally. Solid rocket fuel releases aluminum oxide particles.

Fragmentation objects; the most populous component of space debris is fragments from collision or explosion. Satellite breakup for any reason creates a considerable amount of debris.

Nonfunctional spacecraft, satellites that have depleted all fuel, have lost a critical component, have come to the end their mission, or simply have been put out of commission. These objects pose a greater potential threat for collision. When in GEO drifting and colliding with functional spacecraft is a problem, and when in LEO losing altitude and gaining velocity can cause breakup or high velocity collision with other spacecraft.

Even though knowing the exact population of debris in Earth orbit is not possible due to its highly dynamic nature, for mission planning and other purposes some are catalogued and or tracked.

The debris population has been increasing and all signs show that this is going to continue in the future. Even though the exact number for debris population is unknown, Figure 1 shows an estimate for different sizes of debris. More than 8500 pieces are catalogued by USSPACECOM.

Figure 1. Number of objects in low Earth orbit(less that 2000 km)[10]

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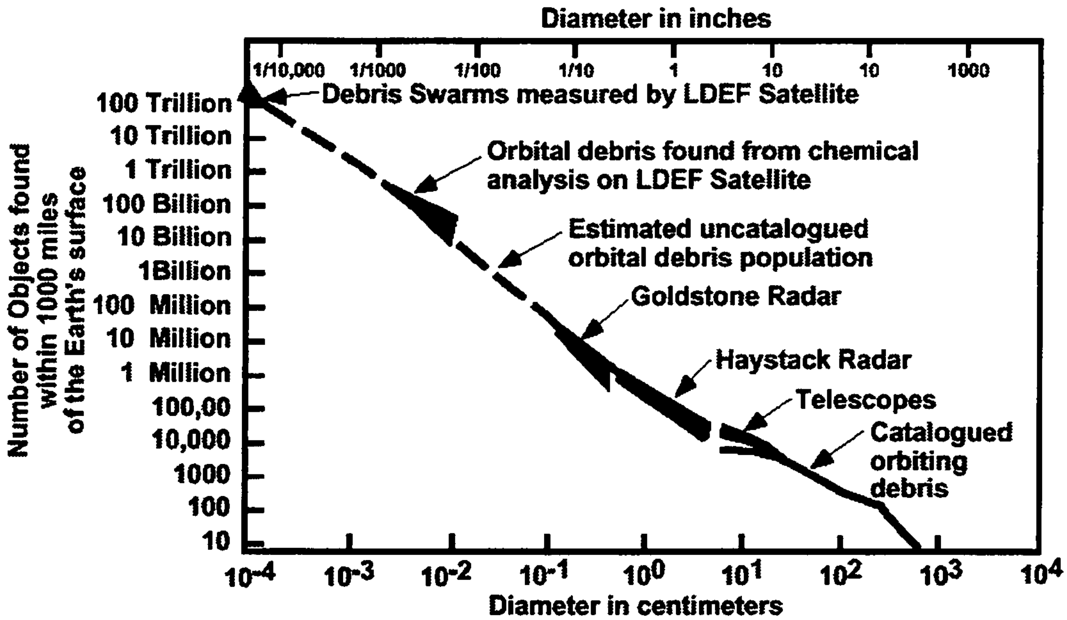

Although the Outer Space Treaty in article IX does not use the term space debris, it does establish the principle of cooperation and mutual assistance for activities in outer space, including the moon and other celestial bodies.

The Liability Convention, adopted by the UN General assembly in 1972, is the major instrument dealing with space debris. It defines the liability of launching state in case of damage due to space activities. Damage is defined as loss of life, any personal health impairment and injury, loss and damage of property of states and persons on the surface of the Earth, in the air or in space.

Many legal and technical organizatios such as ILA, IFA, AIA, IISL, AIAA, NASDA (Japan), NASA (USA), RKA (Russia), and ESA cooperate on exchange of information for research on space debris through the Interagency Space Debris Coordination Committee.

The ITU Radiocommunication assembly adopted a recommendation on debris in GEO in 1993. The recommendation was to generate as little debris as possible, shorten the life of debris generated, and transfer the satellite out of orbit after decommisioning.[11]

The UNCOPUOS technical subcommittee in its February 1994 meeting agreed on a work plan for measurement and effect of space debris on environment, modeling of space debris environment and risk assessment, debris mitigation measures.

The 66th Conference of the Internatioanl Law Association held in Buenos Aires in 1994 adopted the Draft Instrument on the Protection of the Environment from Damage[12].

Space debris and its legal implications continue to attract considerable amount of discussion. As human society advances in space, and builds space establishments such as the International Space Station, concern about debris becomes more important.

Multinational activities and ever increasing involvement of private sector certainly are going to introduce new challenges to the space law community. The protection of envronment both on Earth and in space will be of greater concern, as well.

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Since, we are beyond the point that only government supported research and development is the main activity in space, we have to make new approaches to the subject.

INTERNATIONAL DEBRIS FUND AND REGULATORY BODY

Nowadays the debris in Earth orbit is created for the major reason of financial rewards. Although research and military purposes still, have their considerable share in the matter. We should note that creating debris and polluting other environmental resources is actually using and destroying what belongs to the future generations. In Course of history human being for different reasons such as survival, advancement and development have brought considerable damage to Earth environment. Activities in space have had its own polluting effect and mainly in form of debris in Earth orbit, which has become a major concern over the years. In the early stages of space activities, the main source of space debris was research activities. Today, the picture is totally is different, commercial activities has grown considerably and prospect is that this growth is going to continue. TV broadcasting, communication, remote sensing, GPS and education along with research activities have made the space part of the every day life on Earth. This means that millions of people are using the technology and are sharing the benefits and thus partly responsible towards producing the debris.

The dynamic nature of the debris in Earth orbit, the fact that at this time it seems that generating debris is inseparable part of space activities, and as it was explained every user, which includes the vast majority of the inhabitants of Earth, call for a global collaboration and coordination effort for long term action in studying, research and controlling debris and its effects.

Here, we propose that every user of space technology should pay towards this goal. An International Debris Fund can be established for this purpose. The amount collected from each user can be minimal not to be disturbing to the space customer base.

An International Debris Regulatory Body (IDRB) can be set up to manage the fund for coordinating and conducting research about debris and related subject at national and international level. This can add to financial resources already available by some countries. IDRB can help to coordinate the activities among different agencies, as well. This approach can also help to create more awareness among users about debris and its effect on present and future human life and environment.

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