Space Debris Remediation – Common but Differentiated Responsibility*

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The topic of Space Debris in the context of long term sustainability of outer space activities for peaceful purpose, is gaining momentum and raising concerns, due to ever growing human made debris population in outer space. With the increase in the scope of outer space activities driven by vast application areas vis-à-vis increase in number of space-faring nations and related players, the situation warrants certain remediation measures beyond mitigation measures. Cleaning-up of the debris dumped all these years of space activities, is quite imperative. While the concept of Active Debris Removal (ADR), poses many technical challenges in terms of development, demonstration and implementation, it poses certain non-technical challenges to international space community relating to policy aspects, international consensus & collaboration, investment & economic viability and legal issues.

Legal challenges include a host of issues such as definitional issues on space debris vis-à-vis space objects, affiliation of ownership and responsibility of space objects/ debris originating from 'launching state', 'state-of-registry', abandonment of space objects & debris, liability issues in the course of disposal activities, enforcement of technology controls & safeguards, intellectual property protection, and on so on.

The provisions under UN Treaties on outer space activities such as Space Object, Launching State, State responsibility, Liability, Jurisdiction & Control, due regards and avoidance of harmful interference to others space activities, which indirectly address the problems of space debris could be taken support to address the legal issues associated with topic of ADR. Prevailing UN Guidelines on space debris mitigation are to be implemented by states through national policies and regulations on voluntary basis and hence they are non-binding soft law instruments. Nevertheless, some analogy could be drawn from the Law of

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Sea (Article 60 and Article 80 of UN Convention on the Law of Sea, 1982), and Nairobi International Convention on the removal of wrecks, 2007, which are very much comparable to the responsibility of a launching state or state of registry in respect of their inactive space objects like defunct spacecraft and rocket bodies and components thereof.
The economic dimension of the concept and operation of ADR and associated operational liability issues could be addressed through sharing of burden in an equitable manner. The principle of 'polluters pays' could be applied on the basis of Common but Differentiated Responsibility principle, amongst the space faring nations. ADR activities could be facilitated, monitored and governed by an international body under UN arrangement.

1. Introduction

The *res communis* nature of Outer Space, has offered, without discrimination, the Freedom of exploration and use of it, to every state, and apparently an inherent right too to dump debris of space systems by the space faring nations, unmindful of long term consequences. Since the launch of first space object in 1957, more than 4800[1] space launches have placed about 7,150 spacecraft in orbit along with associated rocket bodies. Dominant contributors are U.S. and then USSR and Russia. Presently, there are about 1071[2] operational spacecraft orbiting around the Earth. More than 100 countries own a spacecraft or have a share in one spacecraft. The life on Earth of a modern society obsessed with information and communication technology services, cannot afford to dispel the services of space systems, even for a short spell of time. Today, a country, which is not influenced by the space based services in some form or other can hardly be found. The dominant roles of space systems in the national security/ military services and beyond, as exercised and exploited effectively, in the recent past by space dominant nations, have also been witnessed by the global community. The Outer Space *sans* borders, the habitat for coexistence of all celestial bodies and human-made objects is subjected to varied environmental conditions due to natural / celestial events and human interventions, very frequently. These situations pose serious threats to the space objects regardless of their nationality or functional or positional status. It is hardly to be emphasized that, the situation of more dependence on space systems invariably invite more vulnerability too, which warrants a distributed architecture of space systems and services to ensure uninterrupted services.
The ever growing population of space debris is a major constituent that endanger the operational status of orbiting spacecraft including ISS. In order to

1 Data for the period 1957-2011:
Total No. of Launches: 5,196 (4769 ½ Success);
Total No. of Payloads carried: 7,120.
Source: <http://claudelafleur.qc.ca/Spacecrafts-index.html> DoA: Sep 3, 2013.

2 Union of Concerned Scientists (UCS) Satellite Database as of May 31, 2013.

sustain the long term of pursuance of outer space activities by the space faring nations for the benefits of humankind, as enunciated by the outer Space Treaty, space debris have to be limited undeniably. Space activities cannot afford to be limited; but to be undoubtedly sustained and expanded; whereas, creation of space debris too cannot afford to be sustained but can be certainly controlled. Thus the mission of mitigation came into effect in the last millennium, though the idea was introduced in the early 70s itself. After prolonged international debates of the topic of debris mitigation by space faring nations, in various forums such as IADC and Sub Committees of UNCOPOUS, the Debris Mitigation Guidelines were formulated and adopted through UN General Assembly resolution in 2007. As part of this initiative, various mitigation measures such as - Limiting the creation of orbital debris through passivation techniques, end of life disposal operations, proximity analysis and collision avoidance studies & measures were pursued by the space faring nations on voluntary basis.
Having pursued mitigation measures voluntarily in the last few years, which however proved to be not so effective, the system of management of orbital debris is forced to take the ultimate step of remediation measures. Even without any further launch, due to the prevailing debris population, collisions in the low earth orbit will continue to occur over next 200 years[3], a phenomena which could be explained by Kessler Effect.[4]

2. Today's Space Environment

Outer space is dumped with 16602 trackable space objects, of which only 3612 are payloads and rest 12990 are rocket bodies and debris[5]. More than 21,000 orbital debris of size larger than 10 cm are known to exist in outer space. It is estimated that approximately 5,00,000 particles of size varying between 1 to 10 cm and about 100 million particles of size less than 1 cm are floating around[6]. Most congested region is between 760 to 860 kms altitude, which was influenced mainly due to intentional break-up of Fengyan 1C in 2007 by China and the accidental collision of Cosmos 2251 and Iridium 33 in 2009. Fengyun 1C destruction resulted in 3378 catalogued debris, whereas Cosmos 2251 and

3 J.C. Liou and N.L. Johnson- 'Risks in space from orbiting debris'-Policy Forum-Science-Vol 311, Jan 20, 2006.

4 A cascade effect of colliding objects in space,- each collision generating further space debris and so on- a syndrome proposed by Donald J. Kessler, NASA in 1978- Source: Wikipedia.

5 Satellite Score Box (as of July 2013, Catalogued by U.S. Surveillance Network)- Orbital Debris Quarterly News-Vol 17, Issue 3, July 2013.

6 Orbital Debris- FAQ- NASA Orbital Debris Program Office- <www.orbitaldebris.jsc.nasa.gov/faqs.html#3> DoA: Sep 03, 2013.

Iridium 33 collision resulted in 2251 and 598 catalogued debris respectively. Of these, more than 80 % are still in orbit as of January 2013[7].
Orbital break-ups of existing space space debris and Reentry of space objects are yet other dimensions of threat potentials posed by Space debris.
It is estimated that in order to stabilize the LEO population, five space objects per year need to be removed. If ten objects are removed, the trend would be reversed[8]. Removal could include Post Mission Disposal and active removal of spacecraft.

3. Active Debris Removal (ADR)

The idea of Active Debris Removal was articulated thirty years ago[9]. Nevertheless, the technical challenges and prohibitive high costs towards technology developments and demonstrations might have thwarted serious attempts. Nevertheless, as it has become quite imperative, the concept of Active Debris Removal (hereafter referred to as ADR) is gaining momentum among global space community. Besides technical challenges certain non-technical barriers relating to legal, policy and economic aspects are also to be overcome to effectively implement ADR systems. As per the report of the International Inter Disciplinary Congress on Space Debris Remediation and On-Orbit Servicing[10], following are some of the essential pre-requisites for the conduct of ADR and on-orbit servicing.

i. A cost effective technique
ii. A legal and policy framework to protect the parties involved and to deal with 'alternative use" concerns
iii. Available and willing target for removal or customer for servicing
iv. Someone to pay (Cost)
v. Accurate tracking and necessary assistance during operations
vi. Technical capability to locate, approach, connect de-orbit/ servicing device, control orientation and to move the target object to desired destination
vii. Safety aspects of the public on ground, at sea and in air

In this paper it is attempted to address the legal and policy aspects and how they can be supported by taking parallels with the international maritime laws towards evolving customary laws. Also as to how to manage the cost aspects

7 NASA Presentation to the 50th Session of STSC, UNCIOPUOS, 11-22, Feb. 2013, titled- 'USA Space Debris Environment Operations, and Modelling Updates'.
8 Tanja Masson-Zwaan – 'Space Debris remediation as a next step towards sustainability', IISL/IAA Space Law & Policy Symposium, June 23, 2012.
9 'Orbital Debris Conference', NASA Conference Publication 2360, (1985)- J.C. Liou, A note on ADR- Orbital Debris Quarterly-Vol 15, Issue 3, July 2011.
10 U.N. Document A/Ac.105/C.i/2012/CRP.16 dt. January 27, 2012- A report of the International Interdisciplinary Congress on Space Debris Remediation and On-Orbit Satellite Servicing.

on an equitable sharing manner by adopting Common but Differentiated Responsibility Principle.

4. Legal Issues on Space Debris

Before attempting on the topic of discussion, it is preferred to highlight a few prevailing legal issues on space debris, such as definitional issues on space debris vs space objects vis-à-vis liability, and state responsibility on space debris, as they have bearing on the subsequent topic of legal issues relating to ADR.

4.1. Space Debris vs Space Object and Liability

It is interesting to note that the term 'Space Debris' has not been referred to in any of the UN Treaties on Outer Space. The first definition, which was internationally accepted, was through Inter Agency Space Debris Coordination Committee (IADC) in 2002. It defines Space Debris as, 'All man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional'. Whereas, as per the Liability Convention and Registration Convention, a 'Space Object' includes component parts of a space object as well as launch vehicle and parts thereof. Thus logically it implies that Space Debris is a sub-set of Space Object, and gets differentiated by its non-functional status. But this simple interpretation, might not fully support when the liability issues are to be addressed.

Article VII of Outer Space Treaty, 1967 (OST), stipulates that a State Party is internationally liable for damage caused by its space object or its component parts on the Earth, in air space or in outer space. Article VII of OST empowers a State Party to exercise jurisdiction and control over its space object and further assign ownership on its space objects in unequivocal terms. But, in broader sense, the so called Component parts of space object should include, besides the spacecraft per se, any bigger and easily identifiable parts of a spacecraft such as fuel tanks, batteries etc., and smaller parts such as nuts & bolts, flakes of paint etc., which are not easily identifiable with respect to their ownership. Such objects, unidentifiable are generally unclaimed, rather abandoned by the Launching States and State of Registries. It is a fact that the IADC Space Debris mitigation guidelines were approved by the United Nations Committee on Peaceful Uses (UNCOPUOS) and adopted through a UN General Assembly Resolution in 2007, for implementation by the Member States. Nevertheless, the legal sanctity of the definition of the term, 'Space Debris' is still in ambiguity, as the UN Space Debris Mitigation guidelines, do not have legally binding effect as they are accepted and implemented on voluntary basis by the space faring nations.

Further the scope of the term Damage[11] as defined in the Liability Convention does not seem to be addressing the damages caused to the outer space environ-

11 Article I (a) of Liability Convention: The term 'damage' means loss of life, personal injury or other impairment of health; or loss of or damage to property of States

ment[12] per se, by the space activities, which contribute to creation of space debris in outer space.

4.2 State Responsibility on Space Debris

The extension of the ambiguous nature of the definitional aspect of the term space debris might leave loop holes with respect to liability issues too. The responsibility of a State with respect to legal issues posed by the creation of space debris cannot be ignored. Subsequent abandonment of non-functional spacecraft or components, which are grouped under Debris category, might not absolve the responsibility of a state.

Article VI of Outer Space Treaty (OST) 1967, obligates a State Party to bear international responsibility for national activities in outer space, regardless of whether such activities are carried out by government agencies are by non-governmental entities. Article IX of OST obligates a State Party to pursue the outer space activities under the guidance of the principle of cooperation and mutual assistance and to conduct the activities in outer space with due regard to the corresponding interests of other State Parties. Any breach of these international obligations, could be construed as causing an international wrongful act, for which a State is internationally responsible[13]. Further, with respect to on-orbit collisions, conjunctions due to space debris, on-orbit explosions of space objects or its component parts, a State Party is internationally responsible, as it has been empowered with right of exercising the jurisdiction and control over such space objects (regardless of their functional status). (Ref. Article VI &VIII of OST).

5. Legal Issues of Active Debris Removal

Having dealt on certain basis legal issues on space debris as a prelude, the topic of ADR is taken up. As mentioned in the earlier part of this paper, ADR system attracts a host of legal and policy issues for implementation. Declaration of a Space Object as a Space Debris, abandonment, technology controls & safeguards, protection of Intellectual Property Rights (IPR), possibility of dual use, accidental damages are a few legal issues taken up for discussion.

5.1 Declaration of a Space Object as Space Debris

As it has been already established that, barring the component parts and residual parts, a space object becomes a space debris only when it becomes non-

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or of persons, natural or juridical or property of international intergovernmental organisation.

12 Prof V. Kopal, 'Present international law principles applicable to space debris and the need for their supplement'- 1997ESASP.393 ©ESA.

13 As per Article 1 and 2 of Draft Articles on Responsibility of States for internationally wrongful acts, as adopted by the International Law Commission at its 53rd Session (2001).

functional. The non-functional status of a space object is not generally declared except for the geo-stationary satellites, which are constrained with fixed orbital slots and frequency bandwidth to be allotted by International Telecommunication Union (ITU). Since all the functionally active and non-active spacecraft are monitored and catalogued through Space Surveillance Networks (SSN), practically it is possible to identify the ownership of such space objects during their orbital life, and up-to their re-entry into earth's atmosphere. However, the functional status or utility aspects of a space object can be authentically and even legally declared by the State of Registry/ spacecraft owner only. In this regard, the UN General Assembly Resolution No. 62/101 of 17th December, 2007 entitled, 'Recommendations on enhancing the practice of States and international intergovernmental organizations in registering space objects', which was evolved for extension of the scope of application of the UN Registration Convention, could be taken support of. Paragraph 2 (b) of this resolution, expects the States to furnish additional appropriate information to Secretary General of UN with respect to geostationary orbit location, any change of status in operation (inter-alia, when a space object is no longer functional), approximate date of decay or re-entry etc. Except for geostationary objects and re-entry objects, details on functional status of other space objects are hardly known to international community. Obviously, declaring a space object as space debris could be an ultimate step to be taken by a State of Registry, after exhausting all possible attempts to retrieve a satellite, which would have either lost any or all of its operational systems, including onboard fuel and thus become either un-controllable or untrackable, or encountered with orbital collisions or impingements with space debris or exposure to solar flare or any other celestial events and thus become defunct.

Nevertheless, there are instances, where uncontrollable space objects, which obviously should have been lost or abandoned and hence fallen under space debris group, have been surprisingly retrieved and made to continue their operational life. The first such instance reported was, the case of Palapa B2 satellite launched for Indonesian Government in February 1984. Palapa B2 launched onboard Space Shuttle STS-41B, could not reach its intended geostationary orbital slot due to malfunction of onboard boost motor, and hence ended up in a intermediate lower orbit, which offered no functional use of it. This satellite, which was under insurance case, was purchased by a private agency namely Sattel Technologies of California, which subsequently retrieved the satellite from orbit with the support of NASA, through a Space Shuttle Contract in 1984 itself. The retrieved satellite got refurbished through its original manufacturer, namely Hughes Aircraft Company and got re-launched as Palapa B2-R in April 1990. Interestingly it was resold to same Indonesian Government[14].

14 Michael J. Listner, 'Addressing the challenges of space debris, Part 3: Policy'-The Space Review, March 11, 2013.

Another recent past example on Galaxy15[15] satellite of Intelsat can also be quoted. On April 5, 2010, the Galaxy 15, stopped responding to ground commands and lost its control, but strangely its C-Band communication transponders were active and sending signals. The problem was potentially caused due to a large geomagnetic storm. Due to its uncontrollable geo orbital motion (hence called as Zombiesat), Galaxy 15 was posing collision threats to other geo-stationary space objects, which was averted through the cooperation of owners of neighbouring satellites. Nevertheless, though a series of technical contingency measures performed by the manufacturer of this satellite, namely Orbital Sciences Corporation, communication with the satellite was re-established successfully. The spacecraft was fully recovered and has resumed its services in October 2011.

Most recently, on May 22, 2013, the GOES-13 of NOAA stopped producing imaging and sounding data, possibly due to a damage sustained due to a micrometeoroid hit on its solar array, which activated automatic shut down of instruments. The satellite was taken into safe mode and the attempts to recover the satellite, through back up plans resulted in successful recovery of the spacecraft's functions on June 10, 2013[16].

These practical examples would invariably discourage the satellite owners or operators to disown a space object at the first instance of functional failure of a sub-system or loss of control, as it would cause economic losses. Though they seem to be fit cases to be declared as uncontrollable space objects and hence become space debris, the successful retrievals have defeated this logic.

5.2 Abandonment

As discussed in the previous section, it might be difficult for a State of Registry or satellite owner or operator to make any declaration or undeclared abandonment of a space object and hence such practices have not been followed commonly. But with respect to space debris such practices of undeclared abandonment are quite common, as it does not offer any technical advantage or economic value but only invites liability issues. Nevertheless, it should be noted that the concept of Abandonment or loss of ownership does not arise at all with regard to space objects. As per Article VIII, *'a State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the earth…'*. Thus it can be construed that a State of Registry of a space object acquires a perpetual ownership over that space object. Even if the satellite is sold on-orbit, the new State which exercise

15 Brian Weeden, 'Dealing with Galaxy 15: Zombiesats and on-orbit servicing', The Space Review, May 24, 2010.

16 NOAA Returns a healthy GOES13 to normal operations as GOES East – source: <*www.nesdis.noaa.gov/news_archives/goes13_operational.html*>.

the jurisdiction and control, would automatically assume the role of State of Registry. Further, as per Article II and III of Liability Convention, a Launching State is absolutely liable to pay compensation for any damages caused by its space object on the surface of the earth or to aircraft flight or owns fault based liability in the event of damage caused to another space object in space, respectively. The Launching State status continues to prevail, unless the ownership or State of Registry is addressed or changed through launch service contracts or on-orbit sale/ ownership transfer contracts.

Legally, any abandonment of objects in international areas such as high seas, outer space, Antarctica, deprives the due rights of other states to use such common places. Further they pose series of threats to the functioning of objects of other states. Again Article-IX of Outer Space Treaty could be invoked in this regard too- Exploration and use of outer space to be guided by the principle of co-operation and mutual assistance and to conduct the activities with due regard to the corresponding interests of all other State Parties; seeking international consultations, if it is believed that the activities of a State Party in outer space might cause harmful interference to the activities of another State. Article-I ensures the right of exploration and use of outer space to all states without any discrimination. Article- II prohibits appropriation of outer space by means of use or occupation. Article-III obligates to adhere to international law including Charter of UN, while carrying out outer space activities.

'Abandonment' being a topic of contention, notably, it might challenge another concept, namely On-Orbit Satellite Servicing (OOS), which is considered to be a sibling to ADR, and also gaining momentum Research efforts are being pursued by leading space faring agencies on OOS concept. It is obvious that, If any space object is apparently abandoned or unattended by a State of Registry due to a faulty sub-system, even then it might attract salvage interests. A state having proven ADR or On-Orbit Satellite Servicing technology might attempt to salvage that abandoned space object, even without the permission of that space object. And if it proves to be successful, it would certainly raise legal issues relating to ownership, jurisdiction and control and technology exposure/ theft etc., between the erstwhile owner and the guardian. End part of Article VIII, conveys that - … Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return. This provision makes the case of the owner of that retrieved space object stronger.

6. Policy Issues:

6.1 Technology Controls, Safeguards

The entire spectrum of space technology pertaining to space launch vehicles and its sub-systems, satellites and their payloads for remote sensing, communication and navigation and tracking, command and control networks etc., are generally not available are shared for commercial gains or on cooperative basis, by the states, due to the dual-use nature of such technologies. Multi lateral

export control regimes such as Missile Control Technology Regime (MTCR), Wassenaar Arrangement for export control of conventional arms and Dual use technologies limit the proliferation of space technologies. Acquisition of such items commercially, upon establishing credibility on end-use applications through undertakings, obligates the recipient countries/ agencies also to abide by such prohibitive norms on sharing or transfer of technologies to third countries. It might appear to be contravening the Article-I of Outer Space Treaty, which provides for right of exploration, free access to all areas of celestial bodies, freedom of scientific investigation and international cooperation in such investigations. Nevertheless, Article- III compensates this dilemma, which obligates a State party to pursue outer space activities in accordance with the Charter of United Nations, in the interest of maintaining international peace and security and promoting international cooperation and understanding.
In the context of Active Debris Removal, a technologically capable state can always either recover or eliminate the space object or space debris of another state on the pretext of protecting its own space object. Such capable states might engage its non-governmental entity also to perform such operations. In case of any unauthorized recovery of space objects, there exists a possibility of gaining access to the classified technologies of one state by another state or its agencies. This situation causes unauthorized proliferation of dual-use technologies. Also, any recovery of space object of one State by another state through ADR technology could jeopardize the research and commercial interests of the owners of the Intellectual Property Rights over the technological elements/ sub-systems.
As mentioned in earlier paragraph, ADR capability of one State poses a threat to another space faring state. ADR systems could be used as space weapons too, during conflict times. Apparently, a geo-political imbalance might result in. Also, it is possible that while performing ADR operations, some accidental damages might be caused to other space objects and also might produce counter effects of increasing the debris population, if unsuccessfully or inefficiently attempted. Under such circumstances quite a few liability issues might arise on the part of the agency engaged in ADR process, the owner of the space debris, which was intended to be moved/removed, claims from the affected parties of damage sustained space objects etc. In order to circumvent these issues, compulsory insurance on ADR actions, becomes imperative.

7. Analogy from Law of Sea

Outer Space, being a latest entrant to the group of common international space, regulation of activities in that area could take advantage from the law of sea. Especially the UN Convention on Law of Sea (UNCLOS) 1982[17] and Nairobi International Convention on the removal of wrecks, 2007[18] are having provisions relating to abandonment of structures in High Seas and removal of wrecks in the Economic Exclusive Zones.

17 Supra note at 12.
18 Martha Mejia-Kaiser, 'Removal of non-functional space objects without prior consent'- IAC-07-E.6.3.10- AIAA.

With regard to the legal issues of abandonment of space objects, Article-60 of UNCLOS 1982, which deals on 'Artificial islands, installations and structures in the Exclusive Economic Zone' and Article-80 on 'Artificial islands, installations and structures on the Continental Shelf' are taken support of, to draw an analogy. Article-60, provides inter-alia- '*Any installations or structures which are abandoned or disused shall be removed to ensure safety of navigation, taking into account any generally accepted international standards established in this regard by the competent international organization. Such removal shall also have due regard to fishing, the protection of the marine environment and the rights and duties of other States. Appropriate publicity shall be given to the depth, position and dimensions of any installations or structures not entirely removed*'. Article-80 concurs with the provisions of Article-60, with respect to artificial islands; but applies to their location in the Continental Shelf.
Whereas, provisions of Nairobi International Convention on the removal of wrecks, 2007, sufficiently address most of the legal issues of ADR system. Definition of Wreck as per Article 1.3, reads as –'*Wreck, following upon a maritime casualty, means: (a) a sunken or stranded ship; or (b) any part of a sunken or stranded ship, including any object that is or has been onboard such a ship; or (c) any object that is lost at sea from a ship and that is stranded, sunken or adrift at sea; or (d) a ship that is about, or may reasonably be expected, to sink or to strand, where effective measures to assist the ship or any property in danger are not already being taken*'. The definition of Space Debris could be fine tuned in this line as per international acceptance. Further, 'Reporting Wrecks' (Article-5), Determination of Hazards (Article-6), Removal of Wreckage without the consent of Article 9. 6 (b) & Article-7 Liability of Owner (Article-10), Compulsory insurance for financial security (Article-12) are very relevant to Active Debris removal system. Possibly, an international convention on ADR, on the lines of Nairobi Convention on Wrecks, may have to be formulated to support and sustain ADR system.

8. Technological and Cost Aspects of ADR Systems

Possible ADR techniques vary with respect to size of the debris and their orbital locations. Detailed attempt on these topics is beyond the scope of this paper. Nevertheless, in order to capture the simplicity or complexity of various ADR techniques, it is chosen to provide a brief account.
For objects of size less than 10 cm diameter, simple orbit lowering techniques to facilitate their re-entry into earth's atmosphere and subsequent decay are followed. These inter-alia include, use of space based lasers to remove or reduce the momentum of smaller objects thereby lowering their orbits. In view of the potential high cost of operation of these systems, it would be advisable to adopt conventional approach of mitigation techniques only like post mission disposals, thereby avoiding susceptible collision and fragmentations[19].
With regard to removal of large debris in LEO (> 10 cm objects) or GEO (>1 m objects) which are potential source for the creation of massive amounts of

19 Supra note at 10.

additional debris, various concepts such as – momentum exchange or electro dynamic tether (for Leo), attaching de-boost motor, inflating balloon (for Leo) or adding device to the object to increase drag, deploying reusable tug that grapples and moves etc.[20], are considered. But these techniques are high technology oriented and hence they warrant sufficient expertise in handling robotic technology based missions, which include a host of technologies relating to location of objects, close monitoring, tracking and rendezvous, capturing and dragging and disposal. It is understood that demonstration of a full-fledged system is yet to be deployed in orbit.

Further, most of the governmental and non-governmental agencies of major space faring nations that are engaged in space systems manufacturing have been investing good amount of resources in terms of human capital and investments on infrastructure towards realizing Active Debris Removal systems. Obviously, one would be inclined protect the intellectual worth of these technologies. Today, quite a number of patents have been filed by these agencies on ADR concepts and systems[21]. While some of the concepts have been realized individually, full-fledged systems encompassing various sub-techniques of ADR, still await successful on-orbit demonstrations. These patents have commercial values. Obviously, the investor States / agencies, would expect to exploit them commercially through controlled business contractual environment only.

As can be seen from the above paragraphs, the technological complexities involved in realizing robotic missions, call for huge investments towards infrastructure, technology developments and demonstrations, protection and exploitation of IPRs, which might prohibit developmental or demonstration efforts. Nevertheless, in the common interest of the entire humanity to sustain and reap long term benefits of space technology and systems and space applications, innovative cost sharing methods should be conceived through international cooperation and consensus. Cost sharing by all states on equitable basis may appear to be logical. Since, the subject of discussion is to address the remedial measures to a international wrongful act of a State (unmindful creation of debris in outer space) of civilian nature, it would be apt to institute financial penalties on the offender state, which could be used through a Common Trust Fund *(discussed in the next chapter)* to compensate the damages caused by debris to another State and to invest on remedial measures. Thus, 'Polluter Pays' principle appears to be a rationale approach. At this juncture,

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20 Supra note at 10, 17.

21 A few are listed; for details refer to the respective patent numbers.

1. *Disposal/recovery of orbiting Space Debris - WO 1994005546 A1*
2. *Device for removing space debris and method for removing space debris - WO 2013065795 A1*
3. *Method for clearing space debris - US 20120286097 A1*
4. *Method for clearing space debris -WO 2011068193 A1*
5. *Device for Trapping Space Debris -US 20120286100 A1*
6. *Space Debris Removal - US 20120241562 A1*
7. *Orbit debris removal and asset protection assembly -US 8403269 B2 etc.*

it may be worthwhile to recall a novel approach adopted in the formulation of Kyoto Protocol, namely, 'Principle of common but differentiated responsibilities', which is elaborated in the next section.

9. Principle of Common but Differentiated Responsibilities – Case of Kyoto Protocol

The United Nations Framework Convention on Climate Change, which adopted the Kyoto Protocol, has followed the Principle of Common but Differentiated Responsibilities (CDR Principle) in respect of fixing differential caps on emission of Greenhouse gases by the States. This CDR principle had been very effectively articulated in the negotiation process, got accepted and adopted as a protocol obligation and being implemented in Climate Change programmes. The innovative mechanisms such as- Differential caps on green house gas emissions, cluster of countries as single entity, Clean Development Mechanism (CDM) Joint Implementation (JI) projects/ mechanism (JIM), and Carbon Credits & Trading etc., were the key factors of the CDR principle, which oversaw the success of Kyoto Protocol adoption and implementation[22].
The pollution of environment of the Mother Earth with green house gases can be well compared with the pollution/ contamination of environment of celestial space with space debris.

10. Principle of Common but Differentiated Responsibilities – Case of Active Debris Removal

Space Debris Mitigation Guidelines of the United Nations Committee on Peaceful Uses of Outer Space (UN COPUOS), which was adopted in 2007, obligates the implementation of the guidelines by all states on voluntary basis through their national mechanisms. These guidelines do not differentiate the responsibilities of states with respect to their launch capabilities, number of launches made vis-à-vis quantum of debris generated in outer space. Also the new entrants, who are on the learning curve, are not given any concessions. Thus there was a general opinion that an appropriate legal regime for Debris mitigation should be evolved, which directed to look at Kyoto Protocol to take support and it's Principle of Common but Differentiated Responsibilities to rely upon.
The logic of applying CDR principle to space debris mitigation was effectively argued by Dr. M.Y.S. Prasad et.al., in fixing state responsibility on debris mitigation, vide a paper entitled *'Common But Differentiated Responsibility – A Principle to maintain space environment with respect space debris'*, presented in 58th International Astronautical Congress (IAC-2007). The basic tenets of

22 Dr. M.Y.S. Prasad, and Dr. Rajeev Lochan- 'Common But Differentiated Responsibility – A Principle to maintain space environment with respect space debris'- IAC -07-E.56.3.07.

Table 1 Distribution of Number of launches made for the period 1957-2011[a]

Total Number of launches made: 5196				
Russia	**USA**	**Europe**	**China**	**Others (incl. Japan, India)**
59.90%	**29.90 %**	**4.27%**	**3.19%**	**2.74%**

[a] Spacecraft Encyclopedia, Claude Lafleur- <*http://claudelafleur.qc.ca/Spacecrafts-index.html*>

Table 2 Distribution of Number of spacecraft launched by states for the period 1957-2011[a]

Total Number of spacecraft launched: 7120				
Russia	**USA**	**Europe**	**China**	**Others (incl. Japan, India)**
56.20%	32.50 %	4.27%	5.60%	2.80%

[a] ibid

Table 3 Quantum of see debris created in LEO by States as of 2011[a]

Type	CIS/ Russia	USA	China	Others
By Number	39%	28.4%	27.7%	4.8%
By mass	62.4%	23.4%	4.2%	10%

[a] Orbital Debris Quarterly News –Vol. 15, Issue 2, April 2011- Page 4

the extrapolation of CDR Principle to Space Debris Mitigation were – *'the debris population is proportional to number of launches carried out by each country in the past; hence large responsibility lies with the countries that have performed more number of launches, than the countries that have performed less number of launches or countries that are yet to perform any launches'*.
In this context, it is worthwhile take a quick look at the following data presented in tables 1, 2 & 3, on number of launches made and number of space objects placed, and quantum of debris created in low earth orbits by number and by mass, by major space faring nations.
Various mechanisms proposed by the authors of the above mentioned paper include – i) To limit the future space debris generation, fixing launch quota caps, ii) Rewarding with 'Debris Credits' on implementation of mitigation guidelines, iii) exchange of Debris Credits between countries on need basis, iv) provision of fixed quota of Debris Credits for countries which are yet take up space activities, v) Creation of a Trust Fund to compensate damages caused to victims, with the contributions of funds by countries proportionate to the debris generated by them, vi) Special treatment for countries willing to share their knowledge and technology in the area of space debris etc.

It is hardly to be emphasized that the same logic as adopted for Space Debris Mitigation could be very well applied to for Active Debris Removal system too. In addition to all the aforesaid mechanisms, a mechanism for sharing of costs towards management of ADR system through an institutional arrangement *(which is explained in the next section),* has to be addressed. The scope of the Trust Fund can be enhanced to address the cost of overall management of ADR system too, besides compensating the potential damages caused due to debris.
The performance factor of a space faring nation can be assessed as Net Aggregate Value, based on other factors such as - the number of launches made, number of spacecraft placed in orbit vis-à-vis quantum of debris created; type of mission-civil/national, commercial or military; nature of launch-experimental or proven or modified/upgraded; first -time launcher; type of orbits reached-LEO, Polar, GEO or others; type of payloads- remote sensing, communication, scientific/ exploration/ inter-planetary etc. While varied ratings could be assigned to each factor, some discount ratings could be considered for certain factors like- non-commercial, experimental, exploratory/ scientific, first-time missions etc. Value of these ratings could be determined on consensus basis by all stakeholders. The Net Aggregate Value could be directly linked to the contributions to be made by a state to the Common Trust Fund, to manage the overall ADR system. Higher the value, higher the contributions.
Further, another incentive concept, known, the 'Debris Credits' proposed earlier for debris mitigation could be augmented to address ADR too. Debris Credits awarded to a country could be attributed to various factors such as - implementation of debris mitigation guidelines, ADR technologies developed on its own funding, Number of defunct satellites (under its custody) voluntarily identified/ offered for removal, quantum & nature of debris removed, the complexity and success of removal operations, Sharing of knowledge on ADR technologies developed by it, support & participation in ADR operations of other states etc. Debris Credits earned by a country could be adjusted against its pro-rata contribution to be made to the Common Trust Fund.
This approach is expected to maintain a balance between a polluter 'who pays' and a contributor 'who gains'.

11. Organizational Aspects of ADR System

It has been articulated that ADR system has to address inherent technical complexities and legal and policy aspects, towards successful implementation in the interests of global community. Beyond these there could many challenges from stakeholder countries and their agencies with regard to cooperation and participation towards implementation of ADR operations. Hence, an organizational system with an authority has to be instituted for the overall management of debris mitigation aspects and debris removal system. Its functions could inter-alia, include – Implementation of the proposed international convention on ADR *(dealt under section 7 of this paper)*, overseeing of implementation of debris mitigation guidelines, assessment of risks posed by orbital debris population, based on technical inputs from IADC and other countries having space debris monitoring and analysis capabilities, decision making with regard to

identification of critical debris to be removed and suitable ADR operation to be carried out, initiation of actions called thereupon with states/ agencies concerned, authorization of suitable agencies to carry out ADR operations, addressing risk managements including insurance aspects, conduct of periodic review meetings, carrying out out-reach programmes towards popularizing the ADR system amongst international space community, award of 'Debris Credits', management of Common Trust Fund, possible dispute settlement at institutional level etc.
Considering above mentioned points, with respect to overall management of Debris mitigation and ADR system, it is proposed that an empowered intergovernmental institutional arrangement, ideally under the auspices of UN-COPUOS would serve better. The system of establishment/ composition and management of this set up could be adopted in accordance with the UN system.

12. Conclusion

Exponential growth of Space Debris population in outer space, especially in Low Earth Orbits is a matter of major concern to the global space community towards sustaining outer space activities for the benefit of entire humanity. Management of space debris ought to take the next step, as Remediation. Active Debris Removal is a viable solution but has inherent risks in terms of maturing the technologies, managing prohibitive costs, and addressing certain legal and policy issues.
Having dealt with various aspects of legal and policy challenges associated with Active Debris Removal system, it is inferred that pursuance and implementation of ADR process is not an impossible task. Nevertheless, addressing the issues articulated, taking analogy from maritime law for legal course and adopting the CDR principle for apportionment of responsibilities including financial burdens, setting up a common institutional mechanism etc., warrant higher levels of international cooperation on the basis of mutual understanding and trust.
Further, a few incidents of successful retrieval of space objects should give effect to formation of customary international law on Active Debris Removal / On-Orbit Satellite Servicing processes. This would strengthen the case of evolving a legal regime through an appropriate legal instrument on Debris Removal from outer space. Forming an institutional mechanism under UNCOPUOS to oversee the entire spectrum of debris mitigation and ADR activities, would certainly support the success of the mission.