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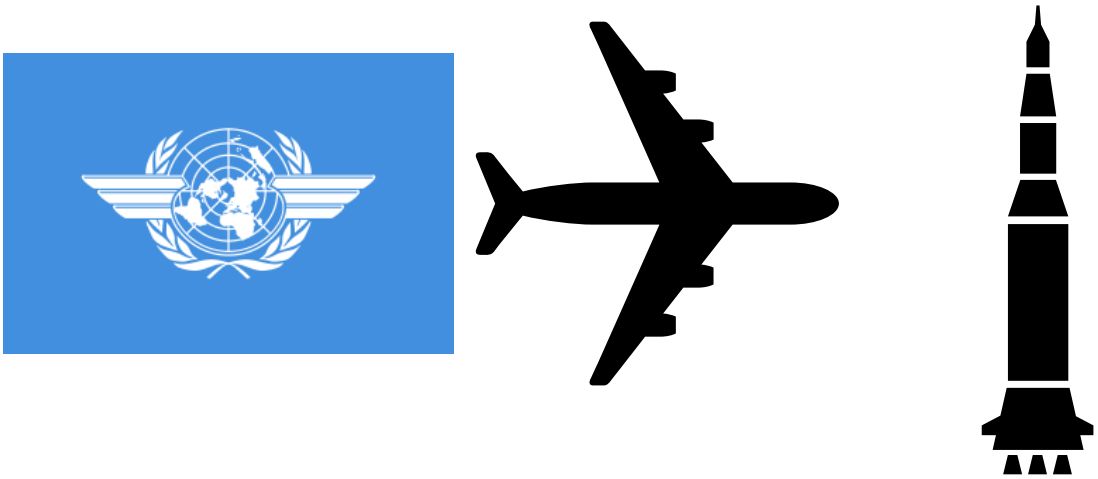

Managing Low Earth Orbital Issues:Integrating Air and Space Traffic Management for Aviation and NearSpace
by Dr Sanat Kaul Chairman, International Foundation for Aviation, Aerospace and Drones

1.Introduction: the proposition

This paper will examine and show why it is now necessary to regulate and integrate Air and Space Traffic Management upto Low Earth Orbit and what kind institutional framework is required for it. Second, it is proposed to show the urgency of this proposition. Third, how integration of Air and Near Space Traffic Management is becoming more feasible as technology is developing which is similar for both making it feasible and economically viable. Lastly, why it is not only possible but even obligatory for ICAO to take up this task.

A.The necessity and urgency to regulate Space Traffic

2.What is New Space

New Space has been described also as democratised space or a space where affordable commercial activity can take place.Travel into upper atmosphere and Low Earth Orbit ((LEO) in Outer-space will no longer remain an occasional launch when the Air Traffic Controller informs all aviation traffic to stay clear by issue of a Temporary Flight Restriction (TFR). With the coming of Space Tourism, Sub-orbital Flights, hypersonic aircrafts, high altitude balloons well as UAVs in near future there will be much greater requirement of better management of Upper AirSpace and New Space. With the existing operational Satellites of about 2666 circling the earth at various levels and in different orbits[1]we are expecting a huge number to join from the commercial space. In a few years commercial companies are expected to place about 20,000 satellites. Elon Musk has announced that his company Space X would be sending around 40,000 satellites in the next years[2]. Other billionaires like Jeff Bezoz has made similar announcements . All these satellites would be small and medium in size. All this traffic will make space traffic more congested, the task of Space Situation Awareness(SSA) more challenging and the need for a Space Traffic Management (STM) more urgent and demanding.
According to Space News: 'Private companies of all kind are sending payloads for research, technological, commercial and educational gains. Space tourists are lining up to buy tickets, entrepreneurs and high school students are putting up cubesats, and commercial satellites are providing everything from worldwide internet access to tracking a retailer's fleet of trucks or monitoring fishing and land development .... If we are not careful we face the potential "tragedy of the commons" where companies will focus on near-term business success rather than long term sustainability and shared

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[1] Who owns our orbit: just how many satellites are there in space ? World Economic Forum: www.weforum.org

[2] Bloomberg BusinessweekElon Musk's Next Big Thing Is 40,000 Satellites Beaming Broadband: 17th September 2020

safety of operations'[3] It goes on to say that while the US government actively supports space commercialisation, it is required to maintain an effective oversight, licensing and regulation of these companies. It must, therefore, help set international standards norms for all players. It further says that unlike Wild West , LEO is shared across all nations.

In an Editorial written in the Journal of Space Safety Engineering it has been stated, 'U.S. National Space Council should help to promote the dialogue and facilitate bringing together key international stake holders to address this topic. Stakeholders, including UN Committee on Peaceful Uses of Outer Space (UN COPUOS, UN Office of Outer Space(UNOOSA), UN International Civil Aviation Organisation (ICAO) plus relevant professional and trade organisations, including The International Astronautical Federation, the American Institute of Aeronautics and Astronautics, the International Astronautical Federation, the Satellite Industry Association, the Commercial Spaceflight Federation among others'[4].

3. Dangers of Space Debris: Space debris consists of a very large number of space objects of different sizes circulating in an orbit around the earth. Based on certain estimates there could be 100,000 of various sizes. has been considered that the single most factor for debris accumulation is non compliance with debris mitigation standards. Further, it has been calculated that failure of launch vehicles add up to 15% of debris. Therefore , we have reached the tipping point in space safety and removal of space debris is now an imperative need. As and when they come into earth's atmosphere , they tend to disentigrate, but not always.

All objects in low-Earth orbits (LEOs) are traveling at speeds of over 25,000 kilo-meters per hour, about 25 times faster than today's jetliners. Satellites share the same space as large and small debris, and everything is moving independently in arbitrary directions. Collisions can occur at relative speeds of up to 50,000 kilometres per hour. Today, there are roughly 2,612 operational satellites in LEO, 139 in MEO and a total of about 3,372 [5]most of which cannot change course on short notice. Many cannot manoeuver at all. Add to this are at least several million passive objects that are completely non-responsive regarding traffic management operations. As a result, we have control over less than 1 percent of a very dangerous population of extremely fast-moving objects all of which are sharing the same space. Clearly, a first step in achieving a complete and successful space traffic management system will be the remediation of the debris problem. Although the complete elimination of debris will not be possible, a sufficient amount of removal and control must be achieved safe operations for satellites operators. In other words, a programme of space debris elimination and control system should form a part of STM operations.

Space Traffic Management is about safety of travel in space and, therefore, the issue of risk management from space debris also becomes a part of it. This involves collision avoidance which in turn involves Space Situation Awareness (SSA). This involves collection and dissemination of data.
Until an initial STM capability is established there must be an international system executing to bring the debris situation under control. This is a dire need. At the same time, new LEO space systems developers must prepare for a new set of requirements regarding hardware and procedures that will satisfy anticipated STM regulations. For example, every new spacecraft bound for LEO will have to be licensed by the STM authority and incorporate transponders that continuously report the vehicle's position/ speed etc to STM controllers. In order to respond to manoeuver commands, each spacecraft will have to be capable of executing rapid avoidance manoeuvres when commanded to do so. Such implementations will be expensive and add mass to each spacecraft. In fact, space operations will also become more complex but it is required.

B The progress so far on STM:

4.1 United Nations Committee on Peaceful Uses of Outer Space [6]
The United Nations Committee on Peaceful Uses of Outer Space (UN-COPOUS) has just celebrated its 60th year of existence . Formed in the year 1959 by United Nations General Assembly, it has been able to get five Space related Treaties successfully concluded within its first twenty five years: The Outer-space Treaty of of 1967, their main treaty, has been ratified by 108 number of countries followed by Rescue and Return Agreements of 1968, the Liability Convention of 1972, the Registration Convention of 1976 and finally the Moon Convention of 1979. However, after 1979 Moon Agreement it did not propose any new Space Law Treaty.

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[3] SPACENEWS 13May ,2021 https://space news.com/op-Ed-protecting-low-earth-orbit-from-becoming-new-wild-west/

[4] Journal of Space Safety Engineering: Editorial: Vol4, Issue 2, June 2018

[5] Data of satellites is based on report of UCS (Union of Concerned Scientists) Satellite Database and includes launches through 31December 2020.: ucsusa.org/resources/satellite-database

[6] The Committee on the Peaceful Uses of Outer Space (8) was set up by the UN General Assembly in 1959 to govern the exploration and use of space for the benefit of all humanity: for peace, security and development.

The UNCOPUOS therefore, has not been able to keep pace with the growth of Space activities. Since it remains a Committee of the UN, it is not fully empowered. With the huge growth of spacefaring activities there is now an urgent need to have binding regulation for safety, security and environmental protection. The growing and massive problem of Space debris is yet another issue which needs immediate resolution. The Inter-Agency Space Debris Advisory Committee(IADC) set up in 1993 by COPUOS began to address the issues of Debris based on the COPUOUS Working Group on 'Long Term Sustainability of Outer Space Activities(LTSOSA). There has been insufficient international agreement , enforcement and national regulatory mandate and therefore, IADC guidelines, UN-COPUOS guidelines as well as Consultative Committee on Space Data Systems have not proved to be effective enough.

The handicapp of UNCOPUOS as well as the United Nations Office of Outer Space Affairs (UNOOSA) is the it has no inherent power to ensure that states that agree to their policy actually implement it. What is required is that policies adopted in committee like COPUOUS are fully implemented and made into domestic law of each country. Since such a large number of new satellites are being sent into orbit, there is a dire need for fixing standards not only by an international body which are also incorporated in domestic laws of each country also.

4.2 Space Situation Awareness (SSA)

This is a major issue today. With this huge floating population of debris in the LEO, we are helpless spectators. Even to monitor the debris is a major task. At present the US Air Force is the major supplier of the information. This is because it built up its own SSA to keep a track of its own satellites. Over time it started keeping track through its special radars and optical sensors. It warns other countries of a possible collision when it realises and assess that a piece of debris will hit a satellite. As a matter of fact the International Space Station (ISS) has had to shift its position a number of times to avoid a piece of debris hitting it. Besides US Air Force, European Union and Russian Scientific Optical Network (ISON) etc are also doing their bit in SSA.

However, what we are anticipating is a huge increase in debris which is putting US Airforce also in a difficulty as they feel their primary duty is to keep a track of their own satellites. NASA Orbital Debris Program Office has developed an Orbital DebrisEngineering Model (ORDEM) to estimate the chance of of debris collision for objects of 10 microns and larger. Further, some private effort is also stepping in in providing data on SSA on commercial terms. Private operators will soon, perhaps, need to use the services of these companies to ensure that their satellites do not meet with an accident. New technology is being introduced to improve SSA. US has just implemented an S-Band radar system what they call the Space Fence. This is the world's most advanced Radar operating from the Republic of Marshal Island in the Pacific Ocean and provides detection, tracking and accurate measurement of space objects and debris. Germany has also developed a new radar for debris tracking involving 34 m dish radar at Wachtberg near Bonn in Germany. There are many optical tracking systems being installed in various locations. There is also The Space Data Association (SDA) started by SES,Intelsat and Inmarsat to prevent a possible collision using tracking information supplied by its members. The membership of SDA is growing. A number of private providers are growing in the arena of SSA like Analytical Graphics Limited (AGI) like ExoAnalytics, Rincon, Lockheed Martin, LeoLabs, Boeing, Schafer Labs and Applied Defense. With all these and more not only SSA capability will increase using S Band radar and optical tracking but timely alerts will be provided to avoid a possible collision[7] Meanwhile, in Europe's European Space Agency (ESA) has developed a similar model called ' MASTER'.

Both ORDEM and MASTER provide an indispensable tool for insurance companies which insure satellites.These tools also estimate the chance of mission fatal occurrence. Based on these it has been calculated by Seradata's SpaceTrak launch and satellite data base that there have been 12 debris strike- related serious anomalies with spacecrafts largely in LEO and only two were under 10 kg mass[8]

Space Regulations for Commercial Satellites:US

The newly established National Space Council of the US Government established in 2017 has a working group on space traffic management which is streamlining regulation on commercial use of space. At the same time Federal Communications Commission (FCC) is also putting its conditions at the time of obtaining a licence for frequency use on debris mitigation[9]. The US has initiated a national STM policy with Space Policy Directive 3(SPD3). This will be in

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[7] A path forward to better space security: finding new solutions to space debris, space situation awareness and space traffic management by Joseph N. Pelton IAASS; Journal of Space Safety Engineering Vol 6 No2 June 2019

[8] Measuring space debris risk by Tim Fuller, Managing Director, Seradata Limited, UK ; Room the Space Journal #3(13)2017

[9] Space Traffic Management in the new space era by Theodore j

the civil domain and already the task has been given to the Commerce Department. The military will retain Space Situation Awareness (SSA) architecture consisting of both ground based sensors and radars as well as space based. Realising **the difficult problem of STM it has already designated its Federal Aviation Authority(FAA)/ Commerce Department with the responsibility of laying down rules for commercial space flights. Therefore, by twinning the role of aviation safety management and Outer Space commercial satellite safety management in a single authority, US has already started to bring the desired impact of integrating air and space traffic for the growing commercial space into a harmonious manner. US should, therefore, welcome an international approach to STM, as long as it does not interfere with Defense Space issue. This would be similar to Aviation where ICAO's mandate is only civil aviation and does not include State or military aircraft.**

4.3 **Space Safety: No consensus: Prof Joseph Pelton**

In a well written article[10] Prof Joseph Pelton points out that there are two broad issues of space safety. The first is that there is no broad international agreement on global space governance and the second is a lack of holistic approach on issues of space safety and security. Clearly UNCOPUOS has done its best to promote best practices or a code of conduct or model bye laws and regulations but have not yielded results . The 12 guidelines as approved by the Working Group on Long Term Sustainability's of Outer Space Activities (LTSOSA) in 2016 or 9 additional guidelines developed by UNCOPUOS IN 2018 with consensus on it by the 87 member COPUOS was a significant achievement. However, no consensus was reached on on space traffic management or debris removal.

International law, therefore, has no specific binding mechanism for regulating space activities and create space standards. The Space treaties are general in nature. All activities are to be conducted under national regulations while not violating the Space Treaties. However, there are no binding regulations in the space arena in which standards are laid out. In addition space debris or its related issues do no find any mention the these treaties. This is in contrast to what is happening in the arena of Airspace, where detailed regulations have be laid out which all member states are obliged to incorporate, as far as possible , in their national legislation. As the activities of states and its objects have increased substantially and the impact of its commercial satellites are making an impact on their GDP, it is important to adopt some kind of binding regulations for space activities. When sovereign states are obligated to harmonise the international regulations of an inter- governmental body to their domestic law then there is a obligation to implement by that country.

The US Government leads in Space activities , both civil and military. Under Space Policy Directive-3 (SDP-3) its views on having a Space Traffic Management is as follows:
" to maintain U.S. leadership in space, we must develop a new approach to space traffic management (STM) that addresses the current and future operational risks. The new approach must set priorities for space situation awareness (SSA) and STM innovation in science and technology (S&T), incorporate national security considerations, encourage growth of U.S. commercial Space sector, establish an updated STM architecture , and promote space safety standards and best practices across international communities"[11]

It is also becoming clear that US is also looking for a rule based STM which will be inclusive of SSA. Will US cooperate in building an international multilateral structure for STM and related activities. In the recent months NASA has floated the concept of multilateral cooperation through Artemis Accord for going to Moon and Mars, inviting other countries to join. In this it does give full assurance that Outer Space Treaty 1967 will be followed. However, without a full international cooperation for making of Standards and Regulations for STM the effort will be futile, especially if a major spacefaring nations stay out.

Europe today is getting ready for an operational space infrastructure as it has realised that 10% of EU 's GDP comes out of or depends on space based applications. They have calculated that €53.5 billion per year is the economic benefit from its space activities in gross value added terms. Therefore EU is looking towards a security of its space infrastructure. It is therefore also developing a European Space Situation Awareness (SAA) capability with 19 states and an independent GNSS Agency. The European Space Agency (ESA) has launched in 2009 an SSA programme to produce an independent data base DISCOS and a data exchange format. However, their commercial SSA market is small but coming up.

Japan has been been in favour of a global STM system. They also feel that in order to gain a larger consensus it is necessary to have a rule making process for global STM. While they feel that a start from national legislation is

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[10] A path forward to better space security by Prof Joseph N. Pelton: Journal of Space Safety Engineering Bol 6, no 2, June 2019

[11] The White House. (2018) Space Policy Directive 3: National Space Traffic Management Policy : https// www.whitehouse.gov/presidential-action/space-policy-directive-3-national-space-traffic-management-policy/.

possible, it may negatively effect the competitiveness of commercial space operations and therefore, a global rulemaking process is desirable from a point of view of international community as well as industry.[12]

China is becoming a major player in space activities. It has realised the importance of STM and has made certain legal and policy arrangements in this regards. China's Position Paper of 2016 on Long-term Sustainability of Outer Space Activities promotes multilateral effort for a STM instrument and believes that a system of STM must be based on the UN international legal regime on outer space.[13] China would consider under STM eight elements: SSA, private human space flights, debris mitigation and remediation, development of standards for space safety, traffic rules, practices for management of space resources, national space legislation, and organisational aspects.

4.4 Another issue for consideration is the working of the Committee on Disarmament of the UN which has remains deadlocked for years. Preventing arms race in OuterSpace is one of the issues. Therefore, it is a moot question whether we could include Defense satellites on STM issues as there may be some opposition if Defense satellites are included. Since Defense satellites are not many and commercial satellites are growing much faster, this issue is best left untouched for the present.

We therefore come to some understanding based on the discussion above that there is an informal international consensus on need for internationally acceptable rules of STM. Further such a consensus must also be legally binding on the states. What all should the concept of Space Traffic Management entail? For a successful STM it will necessarily need to include in it SSA and issues of Space Debris remediation as well as for automatic collision avoidance system.

C. Issues of Integration of Air and Space Traffic Management

5. AirSpace and OuterSpace : comparison and convergence issues

Space is getting busier than ever with 5-8% growth annually and over 80 launches a year. There are already *2666* satellites in operation. Private sector is entering commercial space in a big way having major plans for expansion like SpaceX and OneWeb building mega constellations of satellites. Airbus is planning Spaceplanes and Space tourism beginning to take shape withVirgin Galactic, Blue Origin, SpaceX Dragon2, XCOR. We could expect at a minimum about 20,000 satellites in the next five years. Some of these will be small and some medium and a few large. As price of a launch goes down , especially of small satellites, the incentive to send commercial satellites increases. Satellites of the size of a football are now being launched by students and are affordable. Further, as launch vehicles become reusable, the price comes down further. In a single launch the Indian Space Research Organisation's PVSL-C-37 carried 104 satellites.

While there is no legally separation between where Airspace ends and Outer Space starts, there are many thoughts going around like 100 kms vertical could be the limit of Airspace (based on Karman line proposal)[14]. The major legal difference between the Airspace and Outer Space is that while Airspace above a land territory (including territorial waters) of a country is the sovereign airspace of that country as per Article 1 of Chicago Convention of 1944, the Outer Space Treaty of 1967 defines Outer Space as the 'common heritage of mankind'. At the same time, under Art 12 of the Chicago Convention the Air Space over the High Seas is under ICAO and is also treated a 'Global Commons' or 'a common heritage of mankind' as it is open for all to use. Therefore, both Air Space over High Seas (70% of airspace) and Outer Space can be considered as "Global Commons". There is, thus, a great commonality between the Chicago Convention and Outer Space Treaty than generally accepted.

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[12] Law and policy for space situation awareness towards Space Traffic Management- A Japanese perspective by Yu Takeuchi: Journal of Space Safety Engineering Vol 6, No 2, June 2019

[13] Chinese perspective on an international regime of space traffic management.

[14] Broadly, most experts say that space starts at the point where orbital dynamic forces become more important than aerodynamic forces, or where the atmosphere alone is not enough to support a flying vessel at suborbital speeds.Historically, it's been difficult to pin that point at a particular altitude. In the 1900s, Hungarian physicist Theodore von Kármán determined the boundary to be around 50 miles up, or roughly 80 kilometres above sea level. Today, though, the Kármán line is set as "an imaginary boundary" that's 62 miles up, or roughly a hundred kilometresQ above sea level.

Article 28 of the Chicago Convention states that each contracting State shall provide in its territory navigational aids to facilitate international travel by air. However, since Airspace over High Seas is with ICAO, it has to provide the navigational facility. To overcome this responsibility, ICAO has divided the entire Airspace over High Seas into many Flight Information Regions (FIR). After seeking the acceptance of the adjoining littoral country it has allotted FIRs to them. But no sovereignty is passed on to the state. Currently Air Space Management by a country is at best upto about 30 kms vertical. But with an increasing number of satellites launches and that too from an increasing number of launch sites clear rules of the for ATM & STM need to be laid out.

Civil Aviation Navigation Services Organisation (CANSO), as association Air Navigation Service Providers or the voice of Air Traffic Managers, has stated in their presentation[15] at a Symposium by ICAO/ UNOOSA in 2017 that while aviation and space are fast growing industries, the need for cooperation between ATM and STM is now paramount. Clear rules need to be developed and agreed by all stakeholders, to accommodate the requirements of users in traditional airspace, as well as space-bound vehicles travelling to and from space.

According to DLR, A German Government Research Agency, within the next two decades commercial Space Traffic will develop into a global multi-billion-Euro market. This emerging market will mainly focus on Suborbital Space Travel (point-to-point connections and vertical ballistic joy rides), Suborbital Cargo Transportation and Satellite Deployment via air launch systems. With the growth of this promising market the need for a safe, efficient and globally (co)operating Space Traffic Management (STM) system will arise
A successful STM system requires the execution of all necessary managing and monitoring & control operations that are mandatory to ensure safe travel of manned and unmanned suborbital space vehicles through space and airspace. One key aspect along this path is the seamless integration of spacecraft into the global Air Traffic Management (ATM) system[16]

According to Marshal H **Kaplan**[17] the implementation and enforcement of space traffic management (STM) policies and regulations will be extremely complex and expensive for governments of spacefaring nations and all users of the near-Earth space domain. Compared to air traffic management, the challenges of managing low-orbital traffic will be orders of magnitude more sophisticated.
The underlying reasons include:

- High orbital speeds of near-Earth satellites, 25 times greater than jet aircraft
- Lack of the ability of satellite to responsively execute avoidance manoeuvres
- Difficulty of assessing real-time and precise collision probabilities
- Presence of millions of uncontrolled and dangerous resident space objects (RSOs) that share the most-congested region of space as operating satellites
- Complexity of reaching an agreement with all spacefaring nations regarding space traffic issues
- Development of regulations that are fair and balanced without excessively restricting space traffic and related operations
- Creation of centralised space traffic controller and enforcement systems
- Achieving satellite operator compliance related to additional onboard traffic management hardware, operational restrictions and licensing processes

5. The Challenges for STM: An enigma

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[15] Global Air Traffic Management and Space Traffic by Nico Voorbach, Director ICAO and Industry Affairs : CANSO at ICAO/UNOOSA Aerospace Symposium 29-31st August 2017

[16] Space Traffic Management: dlr.de

[17] | Space Traffic Management: implementation and enforcement by Marshall H. Kaplan — August 31, 2018
Marshall H. Kaplan, Ph.D., is a recognised expert in satellite and launch vehicle systems design and Engineering. He has participated in many new launch vehicle and satellite developments and has
" as Chief Engineer on two launch vehicle programs. Dr. Kaplan was a member of the National Research Council's Committee on Reusable Launch Vehicle Technology and Test Program. He has trained organisations that have won large space systems contracts for military and commercial applications. In his 40+ years of academic and industrial experience, he has served as Professor of Aerospace Engineering at the Pennsylvania State University, was the executive Director of a Space Research Institute and has presented space technology and systems courses in the U.S., Europe, Asia and South America. In addition to publishing over 100 papers, reports, and articles on space technologies, he is the author of several books, including the internationally used text, Modern Spacecraft Dynamics and Control. Dr. Kaplan is an AIAA Fellow and member of the Technical Committee on Space Transportation. He holds advanced degrees from MIT and Stanford University and is a Professor of the Practice in the Department of Aerospace Engineering at the University of Maryland.

5.1 Space Debris not found in Airspace

Today, there are roughly 2666 operational satellites of which 1918 are in LEO[18] most of them cannot change course on short notice. Many cannot manoeuver at all. Add to this at least several million passive objects of all sizes that are completely non-responsive regarding traffic management operations. As a result, we have control over less than 1 percent of a very dangerous space debris which are sharing the same space. While the first step should be the remediation of the debris problem but it is easier said than done. We need a body which can undertake this job in a collective manner. Private companies are attempting new technology, but their contracting and execution needs to be done by a central body acceptable to all countries and stakeholders. Although the complete elimination of debris will not be possible, a sufficient amount of removal and control must be achieved in order to realise safe on-orbit operations for constellation operators. In other words, a permanent space debris elimination and control system is needed along with STM operations.

All objects in low-Earth orbits (LEOs) are traveling at speeds of over 25,000 kilometres per hour, about 25 times faster than today's jetliners. Satellites share the same space as large and small debris, and everything is moving independently in arbitrary directions. Collisions can occur at relative speeds of up to 50,000 kilometres per hour

During the transition period, from today's situation until an initial STM system is put in place, there is a most urgent need to bring the debris situation under control. While private effort at reducing debris by innovative technologies is going on, there is no system in place to employ this and finance it. Therefore, the new Space Management System will need the approval of all to manage it in an equitable manner. For example, every new spacecraft bound for LEO will have to be licensed by the STM Authority and install transponders that continuously report the vehicle's position/ speed etc to STM controllers. In order to respond to manoeuver commands, each spacecraft will have to be capable of executing rapid avoidance manoeuvres when commanded to do so. Such implementations will be expensive and add mass to each spacecraft. In fact, space operations will also become more complex. Side by side attempts at debris elimination or management should continue

5.3 **Code of Conduct(CoC) for Space activities: failure of UN COPUOS**

In absence of any acceptable Code of Conduct for Outer Space by way of a UN sponsored regulation, private initiatives have come up. On one end is the US and the other Russia and China together. However, since they have not been able to have a consensus on this issue, it is hanging fire for the last two decades. The issue of CoC concerns both civil and military satellites. It needs to provide freedom of access to all countries and also inherent right to self defence. In view of the non- binding nature of IADC and UNCOPUOS or even for enforcement or incentivisation of compliance, the use of these instruments for STM are not considered sufficient. There is a need for a binding instrument for regulation of space activities which will focus and ensure safety and sustainability.[19] In addition, as the civil- commercial space traffic is far outgrowing the military space traffic, it is prudent to concentrate on the civil STM, like in the case of Air Traffic, and the military will, hopefully, fall in line.

Meanwhile European Cooperation for Space Safety Standards(ECSS) is another initiative aimed at developing coherent, single set of user friendly technical standards for use in all European Space activities. At the same time International Organisation for Standards(ISO), with membership of 163 countries has also developed its standards for Space including debris management, re-entry etc. However, ISO standards are voluntary and generic, which does not serve our purpose.

Private non-profit institutions like International Association for Advancement of Space Safety(IAASS) or Safe World Foundation (SWF) have been making their own efforts by holding Conferences and producing papers on these issues.

5.4 Therefore, Space Traffic Management remains an enigma as it remains an unregulated activity without acceptable standard from an global point of view. Each spacefaring country decides its own safety norm, rules and regulation and so far there has been coordination between the countries. However, as space activities grow the need for a global regulator is deeply felt. The need for Standards and Recommended Practices, like in Aviation, is being felt for Space activities too, especially in the low earth orbit. In a recent incident when China's biggest rocket re-entered the Earth's

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[18] Geospatial World: geospatialworld.net/blogs/how-many-satellites -orbit-earth-space-traffic-management-is-crucial/

[19] Outer Space SARPs: A mechanism for implementing of space safety standards by Gilles Doucet: Journal of Space Safety Engineering vol6, No 2, June 2019

atmosphere on 9th May,2021 with most parts burnt up and disintegrated into the Indian Ocean near the Maldives. This uncontrolled object was about twenty tonnes in weight and could have caused damaged on earth. In this connection NASA of US stated that China failed to meet "responsible standards" regarding its space debris, hours after the country's largest and out of control rocket disintegrated. The point being made here is that since there are no standards as yet on safety of launch of satellites, the description "responsible Standards" become a vague concept. It is therefore, necessary that for purposes of safety that internationally acceptable standards are introduced by an internationally acceptable body at an early stage.

6.Space Traffic Management: some issues: Space Debris & SSA are a part of STM

Space Traffic Management is like Air Traffic Management but more. This is so because in the Low Earth Orbit there are over 100,000 pieces of debris over 1cm and over 100 million tiny fragments smaller than one millimetre[20] floating around which can be very harmful to spacecrafts, a situation not found in Airspace. Today United States Air Force(USAF) is monitoring about 20,000 space objects above 10cm. However, USAF is keen to hand over this job to some civil organisation in US, possibly FAA. Other countries that are also involved in Space Situation Awareness are Russia , EU and possibly China and now even some private companies supply data commercially.

6.1 Looking for the right fit for STM: ICAO for Space

It is felt that time is ripe to start a STM system. The issues are whether it should be a new institution or it can be a part of an existing institution. There has been discussion on the subject for many years. In a study published in 2011 by Professors R.S. Jakhu, T. Sgobba and P.S. Dempsey as Editors to a book titled ,The need for an Integrated Regulatory Regime for Aviation and Space: ICAO for Space.[21] This book has analysed the need for an institution for Space. After studying some other organisations like International Telegraph Union(ITU) and International Standards Organisations (ISO) they have come to the conclusion that ICAO is the most suitable existing institution for Space Traffic Management. The author was also consulted by them, which they have acknowledged. The author is also of the opinion that :

1. Time is ripe to build up an institution for Space Traffic Management as Space Traffic is becoming unsustainable
2. Issues of Space debris remediation or removal requires a group/ institutional/ collective approach.
3. Space Situation Awareness also needs to receive data from different sources under overall supervision of one institution
4. The proposed institution should be entitled to make Rules for Space flight up to LEO
5. DATA on space debris needs to be collected centrally from different sources

6.2 Extending the role of ICAO to Space Traffic Management

Now we come to role of ICAO in Air Traffic Management and consider the possibility and appropriateness of extending the same to Space Traffic Management. Here there are two issues. The first is the legal issue and second, the appropriateness of ICAO as an agency.

The Mandate of ICAO by its very name it is meant for civil aviation. The preamble to the Chicago Convention of 1944 document clearly mentions civil aviation. Further, the text of Chicago Convention mentions only aircraft and not any other mode of transport. Yet the Chicago Convention of 1944[22] which is the basis for setting up of ICAO, neither defines what an 'aircraft' is nor defines the 'upper limits of Airspace'. Perhaps, in 1944 there was no need to provide any such definitions. However, the Outer Space Treaty of 1967 also does not define the lower limit for start of Outer Space. Further, aircraft has been defined only in Annexes to ICAO which can be corrected/modified by the Council of ICAO to include aerospace objects. Therefore, on the legal side there may not be much difficulty for ICAO to take on the additional charge of Space Traffic Management in the upper AirSpace and even LEO. However, it would require work to open a new Annexure on Space and also amendments in various Annexes like safety, licensing etc. This is a matter of detail which can be easily sorted out once a decision is taken.

As Dr Assad Kotaite, the legendary former President of The International Civil Aviation Organisation for 30 years has stated in his book 'My Memoirs[23]

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[20] Technical Challenges of better Space Situation Awareness and Space Traffic Management by Daniel L. Oltrogge, Salvatore Afano: The Journal of Space Safety Engineering Vol6, No2 June 2019

[21] The need for an Integrated Regulatory Regime for Aviation and Space: ICAO for Space Editors R.S. jakhu, T Sgobba. P.S. Dempsey : published by Springer 2011

[22] The Convention on International Civil Aviation, drafted in 1944 by 54 nations, was established to promote ... Known more commonly today as the 'Chicago Convention'. See History of ICAO and the Chicago Convention at Icao.int

[23]Late Dr Assad Kotaite, President Emeritus of the of International Civil Aviation Organisation was the President of ICAO for 30 years and Secretary General for 6 years. Prior to that he was the Representative of Lebanon in ICAO. His memoirs: My Memoirs: 50 years of International Diplomacy and Conciliation in Aviation: page 216

‘Space: In September 1993, Russian Prime Minister Victor Chermomydrin joined American Vice- President Al Gore in announcing Plans for the International Space Station. The 72-metre by 108-metre Space Station has since been assembled as a series of interlocking modules, serving as a manned platform for scientific research, explorations and technological development, and perhaps above all as a symbol of world peace, as it orbits the planet every 92 minutes, at an altitude of 250 to 263 miles(402 to 424kilometres). The first Space Station partners were multilateral and government space agencies, but in 2012 the first commercial freighters began docking at the Space Station. I believe that this places us at the dawn of a new age of commercial passenger flights.
‘The first time that sub-orbital flights and space flights were mentioned at an ICAO Assembly was at its Thirty-Fifth Session, in September 2004, when I opened the Assembly with the following words: One hundred years from now, regular passenger flights in sub-orbital space and even in outer space could become commonplace. “Yet we have no precise definition as to where “air space” ends and where”outer space begins. There is no clear indication in international law as to the definition between air space and outer space which would clearly establish whether to apply air law or space law to sub-orbital flights. I believe that the time has come to examine how to apply to sub-orbital and outer-space flights the same kind of global management process that has worked so successfully for international air transport through Chicago Convention.
‘Sub-orbital flight is a natural extension of our current civil aviation- space vessels and space planes will have to fly through current air space to reach low orbit. Sustaining high speeds is no longer a problem: The problem is rather to find the way to enable passengers to endure these speeds in acceptable safety and comfort. I believe that commercial low-orbital flights will one day become widespread. Regulations and standards will need consideration. There is no need for a new agency to develop regulations: drawing on the principles of the Chicago Convention, ICAO is already well-equipped to examine all commercial and technological aspects of sub-orbital flights. New Annexes to the Chicago Convention may be required. The UN has a special Committee on the Peaceful Uses of Outer Space and ICAO has participated in its work”

6.3 ICAO was set up as an intergovernmental rule making body for civil aviation in 1944 and subsequently absorbed as an Agency of the United Nations. Over the years it has created 100,000 Standards and many more Recommended Practices(SARP)s as well as detailed Procedures for Air Navigation Services(PANS) and Regional Supplementary Procedures (SUPPS). While it does not possess disciplinary powers, it does a mandatory audit of safety and security of its member countries. An adverse report is sufficiently damaging for the airlines of that county and no country wants a bad report. The effective power of ICAO lies is acceptance of each member contracting state to its Standards. It has an elaborate method of making Standards and Recommended Practices better known as SARPs. ICAO has an elected Council of 36 member states, elected every three years, who approve the SARPs. It also has an elected 19 member Air Navigation Commission (ANC) appointed by the Council and proposed by the member States who are selected on the basis of their technical expertise . Air Navigation Commission recommends to the Council adoption of a SARP. Members of the Air Navigation Commission are expected to be independent of their State in giving their views. The key challenge facing the ANC is to improve aviation safety and air navigation efficiency, integrate more air traffic and introduce new technology with increase in air traffic.
The making of SARPs and PANs (Procedures for Air Navigation) are the core aspect of ICAO mission which leads to a harmonised global aviation safety and efficiency. The development of a SARP/PAN follows a transparent multi-stage process which takes approximately two years for it to get approved by the Council and join an Annexe. The ANC sends a proposal to the Council. The Council has to adopt the proposal with two third voting in its support. Two weeks after adoption of the proposal an interim letter is sent to states with a time period of 3 months to reply . The replies to the letter is collated in ICAO secretariat. If majority of States are in favour it is sent back to the Council for its formal approval and it becomes a Standard or Recommended Practice as the case may be. If there are differences filed by some States they are published in the supplement to Annexes under Article 38. As a result of this long procedure, all member States get sufficient time to consider the making of a SARP or filing their difference. Because of the nature of the consultative procedure, the differences generally get ironed our during the process.

However, there are many reasons for filing a difference but generally technical. It, therefore, provides space to Member State to file the difference which is duly taken care of. Generally filing of differences is due to technical nature of the SARP and not any other reason.

On the issue of navigation facilities to airlines of foreign countries each country was obliged by ICAO to provide Air Navigation Service to all commercial aircrafts flying over or landing on its territory. However, this obligation was not extendable over Airspace over high seas which were global commons and were under jurisdiction of ICAO. To overcome this problem ICAO allotted a Flight Information Region(FIR) to each adjoining country over High Seas. Thus , without having any of its own equipment for Navigation or Surveillance, ICAO was able to get each member country to manage not only its territorial Air Space but also AirSpace which is over the High Seas without any cost to it, notwithstanding that AirSpace over High Seas in part of Global Commons and not sovereign to that State. Of course, those countries that are given to regulate the Airspace over High Seas charge for their services from the airlines and is generally a source of profit also.
In the case of Space Traffic Management, satellites generally take off vertically from a country (except for sea launches) and go up OuterSpace without violating any other countries’ AirSpace. But sub-orbital flights may take-off as an aircraft might might pass through other countries.

7. The Outer Space Treaty(OST) of 1967 has unfortunately not created any organisations like ICAO, which the Chicago Convention of 1944 did. It is surprising that OST which came up 23 years after the Chicago Convention, did not think of proposing any institutional framework for Space travel. However, 54 years after the OST it appears that commercial space travel will picks up soon and therefore the need for an institutional framework is being felt urgently. While Air and Space travel are quite different, both require framing of rules and regulations by an intergovernmental institution preferably under the United Nations. Forming a new institution would be cumbersome, costly and will take a long time for consensus amongst States to reach. However, if there is an existing institution which could do the same, perhaps deliver better, and quicker, it would help all. ICAO has the experience of 77 years of ruling making called SARPs, after getting near consensus of 193 member States (which is the same as that of United Nations). This procedure is time tested and has made air transportation the safest mode of travel today. The compliance with SARPs and its subordinate legislation of PANs and SUPPs make it a formidable legal system. On top of this are the regular audits carried out by a team of inspectors constituted by ICAO to conduct a physical on site inspection of each of its member's facilities and registers to confirm compliance with SARPs. It is a great deterrent for a country to get a bad report. Therefore, the question that comes up is whether if ICAO is entrusted with the job of making SARPs for Outer Space, will they be able to do it? As mentioned earlier this question has been examined under the auspices of the International Foundation for Advancement of Space Safety along with the Institute of Air and Space Law of McGill University, Montreal, Canada. It formed a Working Group of eminent experts and produced the report in 2011 titled: The Need for an Integrated Regime for Aviation and Space: ICAO for Space?[24]The group studied the international organisations like International Telegraph Union(ITU/International Maritime Organisation IMO) and came to the conclusion that ICAO meets all the requirements which others do not.

D. ICAO for Space

7.1 If selected for purposes of STM, ICAO will need to make some modifications in its administrative structure.While the President, the Secretary General and the elected Council will remain as it is, they will a need to have a ' SpaceNavigation Commission' on lines of Air Navigation Commission' to assist the Council of ICAO in making of SARPS's for Space Travel. There will be a necessity to bring in a new Annexe on Space issues, especially on management and remedial action on 'Space Debris'. The Council, which represents all countries of the UN, could also take up pending issues like Code of Conduct for Space vehicles. On the issue of licensing of Space crafts, licensing of astronauts or special requirements for space passengers, safety of space vehicles etc either the existing Annexes can cover issues of Space or a separate Annexure is made , both of which are possible by the Council itself. A remedial action for removal of Space Debris could be undertaken by ICAO jointly with other countries and associations which are involved in it.

ICAO and funding for STM
7.2 ICAO is funded by contributing of contracting States. Proportion of contribution of each State is decided by a set formula in ICAO which takes into account various attributes of each member State like its GDP, its use of Aviation etc and has never been questioned. A similar formula can be followed for raising additional resources needed for Space portion and it is not like to be high.In fact, there would not be a cheaper and better option than to give ICAO the charge of Space Traffic Management. This is so because besides the physical building of ICAO given by the host country - Canada, the entire professional staff of ICAO has domain expertise in making SARPs for Aviation and can be a great advantage to help drafting SARPs for Space regulation. The Space Navigation Commission proposed to be set up in ICAO could follow the excellent procedures adopted by its Air Navigation Commission. Some addition Staff from the UN Office of OuterSpace based in Geneva could be merged with ICAO. Similarly the Inter-Agency Space Debris Coordination Committee(IADC) could be brought into ICAO. At the same time UNOOSA and COPUOS should continue dealing with OuterSpace issues beyond LEO.

8. A new Technology is introduced for Air Navigation : ADS-B[25]:
Automatic Dependent Surveillance Broadcast (ADS-B) is a GNSS based technology that enables aircraft broadcast signals including flight related information i.e., identification, position, altitude, velocity and other relevant information i.e. surveillance on a regular basis to ATCs as well as to other aircrafts. This technology ensures that a moving object in air regularly transmits its position and other details to all other aircrafts and ATCs via the aircraft's Mode S transponder. However, for accuracy ADS-B also requires ground stations. US has already constructed over 640 ground stations as FAA had announced use of ADS-B (IN) as a compulsory equipment on all aircrafts by 2020. Australia is also doing the same. Terrestrial-based ADS-B infrastructure, therefore, becomes an alternative (or add-on) to radars but not a complete

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[24] The Need for an Integrated Regime for Aviation and Space: ICAO for Space? Springer/ ESPI 2011

[25] · ADS-B is a system in which electronic equipment onboard an aircraft automatically broadcasts the precise location of the aircraft via a digital data link. The data can be used by other aircraft and air traffic control to show the aircraft's position and altitude on display screens without the need for radar : see airservicesaustralia.com

solution to global Air Traffic Management as it is not available over high seas or polar regions where there are no ground stations

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8.1 Common technology for Air and Space

The traditional method of providing navigation in aviation to aircrafts is by radars. This is a II World War technology and is not effective over high seas or polar regions or even difficult terrains. This is because radars are ground based and cannot be installed on high seas or difficult terrain like Polar regions. The new technology of Global Navigation Satellite System (GNSS) based on satellites is avialble free of charge from its suppliers i.e. the US GPS, the Russian GLONASS , the Chinese Beidou and the European Galileo . This technology is available free to all aircrafts but with the help of Augmentation satellites WAAS (US), EGNOS(EU), GAGAN(India) and MSAS (Japan) they are able to navigate more accurately in all parts of the earth.

GNSS systems are working in Near Space right upto International Space Station and with the ADS-B over Satellite technology at high altitudes both existing radar and sensors for space surveillance technology and GNSS based ADS-B over Satellite for satellites with transponders can synergise for SSA collision avoidance in the LEO.

Therefore, technically also managing AirSpace and Near Space Traffic Management will become easier within the ICAO requirement of *Communications*, Navigation and Surveillance/Air Traffic Management (CNS/ATM). Merging the responsibility of Air and near Space traffic management in air space and near space can, therefore, be best left to ICAO with minor tweaking of the Annexes to Chicago Convention. In Space Situation Awareness the technology being used is both ground and space based radars and sensors. With this technology the prediction errors in Low Earth Orbit(LEO) are frequently greater than the estimated distance between objects when compared to say ADS-B over Satellite. With merger of the two technologies it is possible that accuracy of potential conflict will improve.

Resolving the High Sea Riddle: 'ADS-B over satellite'

The riddle of missing of Malaysian Airlines aircraft MH 370 over High Seas could not have been solved as neither Radars nor ADS-B could track keep a track of it because they both need ground stations and there is none over high seas. This riddle was subsequently solved by the German research organisation DLR as it found a solution to the above problem when it successfully provided the proof of concept with a transponder on a satellite as a hosted payload and thereby showed that ADS-B works equally well if not better in space as a hosted payload on a satellite and needs no ground stations and also covers high seas.Subsequently, a company has been launched called Aireon with NavCanada and Air Navigation authorities of a few countries with Inmarsat which used 66 new Next Gen Satellites of Inmarsat to host a payload of Aireon transponders. With this ADS- B is now commercially launched as a Servive Provider to many navigation authorities and is providing excellent service of each aircraft equipped with its transponder over the entire globe including high seas and polar regions. Each aircraft equipped with ADS-B transponder as hosted payload is broadcasting every couple of seconds its position, speed , direction, altitude and its unique number to all aircrafts in the region as well as the Air Traffic Control through its Mode S transponders.

For the present tracking of satellites and debris is being done with radars and sensors. While this has to continue, if all new satellites whether big or small, could be made to put on a transponder capable of broadcasting its position, speed altitude and its number every very few seconds, it will add greatly to Space Traffic Management. This is now possible with ADS- B-over-Satellite. It has been shown in a published paper that GNSS with satcom network dramatically improve space situational awareness. Further, the same study has determined that collision prediction accuracy can be greatly improved for spacecraft who carry on board GNSS transponders[26]. The accuracy and the convenience of such GNSS based hosted payloads can totally change the tracking of new satellites in the LEO. Second, because of this new innovative strategy of using GNSS based hosted transponders on small or big satellites, the false alarms raised by old technology of radars, lidars and optical telescopes can be reduced for collision avoidance measures and thereby save propellant of the satellites.

Simply put, ADS-B works wherever it is placed, be that on an aircraft, or on a space vehicle, or on a stratospheric balloon, or on a remotely piloted system.

8.2 Therefore a GNSS based satellite constellations has the capability to provide a global coverage at any possible flight level, avoiding limitations imposed by terrestrial ADS-B because of lack of ground stations over high seas and polar regions. If a transponder is put on all new satellites, Space Traffic Management will improve for tracking satellites with transponders. This could be implemented by receiving ADS-B signals or any other similar signals, which are broadcasted regularly by each equipped aircraft, spacecraft or even a balloon giving information on its position, speed, direction etc and will be available to both ATM and STM control centres.

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[26] GNSS with satcom networks to dramatically improve space situation awareness by Charles F. Radley and Thomas M Eubanks : Journal of Space Safety Engineering Vol7, No3 September 2020°

Conclusion : Examining the need to introduce Space Traffic Management as early as possible and to integrate it with AirTraffic Management upto LEO not only desirable but urgently needed. The fact that an Agency of the United Nations exists doing similar work in Airspace, fully competent by having proved itself in the last 77years of its existence by making Aviation the safest form of travel in the world today. This is the most convenient and the best alternative available without a doubt. It will be the cheapest alternative also. Further, it will be acceptable to all countries due to its existing membership of all UN members.