Management of Orbital Manoeuvres for Satellite Constellations and Commercial Space Activities

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Abstract

On 2 September 2019, the European Space Agency's *Aeolus* Earth observation satellite was required to make an immediate axial shift — commonly known as a 'delta-V' manoeuvre — to avoid collision with SpaceX's *Starlink-44* satellite, which had lowered its orbital plane for system testing. Although SpaceX was notified of the imminent collision risk posed by changing *Starlink-44's* orbit to the same altitude of *Aeolus*, SpaceX refused to change position, thereby requiring ESA to fire *Aeolus'* thrusters to change orbit. On 3 December 2021 — two years after the *Aeolus* near-miss — the People's Republic of China filed a note verbale to UNOOSA, detailing two instances of performing delta-v safety manoeuvres for its crewed platform the *Tiangong* space station to avoid collisions with satellites. Central to the issues facing both *Aeolus* and *Tiangong* is one party having to take the burden of performing a delta-v manoeuvre to change course. Spacecraft are equipped with a finite supply of propellant, thereby providing a limited amount of delta-v safety manoeuvres that can be performed before the propellant is exhausted. Where a propellent is exhausted, or near exhaustion, a spacecraft's mission profile may be severely degraded, and it may have to be de-orbited. This paper will consider the liabilities of one party having to be compelled to frequently expend propellent to avoid collision due to a second party's action and propose regulatory solutions to mitigate undue propellant expenditure.

1. Introduction

On 31 January 1958 – just a few months after *Sputnik* – the United States of America became the second country to successfully launch a satellite into orbit with *Explorer 1*. In addition to reassuring the western public as to their

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aerospace competencies, *Explorer 1* also provided valuable cosmic radiation tests that would herald the way for future missions and further space activities.[1]

However, unbeknownst to either the public or the technical teams of 1958, *Explorer 1* would also serve to foreshadow future issues of satellite congestion when on St Patrick's Day, 17 March 1958, the launch of *Vanguard 1*, was delayed due to *Explorer 1* orbiting overhead, thereby posing a risk of a collision between the two US Satellites.

On 17 March 1958, *Vanguard 1* had in effect become the first satellite required to have its orbital trajectory impaired due to another satellite. This was a feat made perhaps more remarkable given that Vanguard 1 had not even managed to leave the Earth's surface, and the collision risk being raised at a time in space traffic management history when there were only three satellites in orbit.[2]

The foreshadowing continued for Project Vanguard in other key respects, namely: Vanguard's dimensions were similar to that of today's small-sats and cube-sats; it utilised solar panels for its power supply, it utilised miniaturised circuits for its operation, commenced the world's first global tracking system via the Minitrack global ground station network which saw facilities built in such as in far-away places including Woomera, Australia; and, it crowdsourced assistance from the public and amateur astronomers to help monitor the Vanguard constellation of satellites via Project Moonbeam.[3]

Vanguard 1 also became notable in another way – specifically to our colleagues in the International Institute of Space Law. Unlike either *Sputnik 1*; *Sputnik 2*; or, *Explorer 1* that came before, *Vanguard 1* is still in orbit – and will be so for another two centuries – making *Vanguard 1* the first piece of permanent space junk, and first residual risk to orbital manoeuvres, poetically perhaps, recreating its own interaction with *Explorer 1* on St Patrick's Day, 1958.

The issues faced by *Vanguard 1* on 17 March 1958 have only increased in frequency with time and the rise of satellite constellations of today that outpace the early constellations of the 1960s through to the original Iridium Satellite Constellation of the 1990s.

Particular amongst these issues is the use and conservation of propellant to allow for station keeping, transfer orbits, attitude and altitude control and more recently, considerations regarding active debris removal and space traffic management, in particular, for satellite constellations operating at differing orbits. This paper considers the roadmap to future issues and regulatory challenges and solutions to ensure that mission profiles are not significantly impacted due to propellant excessive discharge.

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[1] Loff, Sarah, Explorer 1 Overview, NASA, 4 August 2017 https://www.nasa.gov/mission_pages/explorer/explorer-overview.html. (accessed 15 September 2023).

[2] p.37 Bloom, John, *Eccentric Orbits: The Iridium Story* Grove Press (2016).

[3] Green, Constance & Lomask, Milton, *Vanguard A History*, NASA (1970). pp 148 & 158.

2. Propellant Use Cases and Mission Profile

2.1. Mission Profiles

2.1.1. SOHO Mission 1995 – Ongoing

As noted in past IISL proceedings, reduction in the use of propellant can significantly impact positively on both mission profile and mission lifespan.[4] One such example of propellant conservation improving on mission performance is the ESA-NASA Solar and Heliospheric Observatory (*SOHO*), launched 2 December 1995, with a planned three-year mission profile to study solar activities.[5] *SOHO* presently orbits some 1.5m distance from Earth at a gravity-neutral position at Earth-Solar Lagrange Point 1 (ESL1). Due to ESL1s stable gravity field the use of propellant for *SOHO* remains nominal, allowing for *SOHO* to continue to limit the need of using its propellant, thereby allowing it to extend its mission performance – presently planned until 2025, some 27 years past its original design life.[6]

2.1.2. Iridium 1st Generation 1997–2021

In 1996, almost a year after the *SOHO* team were finalising for launch, Motorola's Iridium technical team were also making decisions that would subsequently allow for the Iridium satellite constellation to out-perform their original five-year design plans.

Being a post-Cold War telecommunications project designed by Motorola, the Iridium constellation detailed design and assembly was heavily influenced by Motorola's success in mass-market product delivery. As such, construction of the Iridium satellite constellation had relied heavily on technician-friendly assembly lines, batch-testing and incorporation of off-the-shelf parts such as the Apple PowerBook processor.[7] However, the acquisition by the Iridium project team of off-the-shelf componentry was not solely reserved to electronics but encompassed all elements of the satellite design including fuel tanks.

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[4] Green, T, Neumann, P, Grey, K, Sandlin, T, *Earth, Solar and Lunar Lagrangian Point Management in the Mitigation of Anti-Competitive Conduct and Management of Natural Monopolies in Commercial and Military Space Activities* 70th International Astronautical Congress, 62nd Colloquium on the Law on Outer Space, International Institute of Space Law (2019).

[5] National Aeronautics and Space Administration, 'SOHO Mission Overview', 3 August 2017, https://www.nasa.gov/mission_pages/soho/overview/index.html (accessed 2 October 2023). See also; Domingo, V., Fleck, B., & Poland, A. I., 'The SOHO Mission: an Overview' Solar Physics, Volume 162, Issue 1-2 (1995). http://articles.adsabs.harvard.edu//full/1995SoPh..162....1D/0000007.000.html (accessed 2 October 2023).

[6] Ibid.

[7] Ibid. n. 2, p. 148.

Iridium had originally intended to have a mission profile accommodating only 25 gallons of hydrazine – a propellant common at the time, and less so now – for orbital manoeuvres. Regrettably for the mission designers, no commercially available tanks were available in the 25 Gallon size. The next smallest the technical team could obtain were 200-gallon containers – some 175 gallons extra capacity than the mission profile required. Working on the design principle that 'extra fuel in orbit is more precious than life itself and atones for many sins' the project team realigned the fuel requirement to accommodate for the additional capacity of the tank.[8]

The consequence of selecting for a larger fuel tank – and taking advantage of its capacity – would have significance for the mission profile of the Iridium satellite constellation. The Iridium 1st Generation satellite constellation originally had a 5-year mission life planned when it began launching in 1997. However, Iridium constellation was only fully replaced with the successful launch of the final batch of its successor satellite constellation Iridium NEXT five months ago (at the time of this presentation) in May 2023 – some 26 years after it was first launched – and 21 years after its original design life.

In presenting to the Promoting Space Sustainability virtual event series on 9 February 2021 on the totality of the lifespan of the Iridium 1st Generation satellite constellation, alongside its successful deorbit, Iridium Communications provided a case study on the deorbiting program.[9]

In their case study, Iridium Communications noted that in the 1990s during the detailed design phase and launch of the 1st Generation Iridium constellation, active debris removals were only emerging as a topic of interest in industry and with regulatory authorities. The NASA & Inter-Agency Space Debris Coordination (IADC) guidelines were not a commercial standard, and the need for Iridium – one of the first Satellite constellations – to provide for additional propellant to deorbit was a prescient step in ensuring sufficient margin was provided for the operational requirements of end-of-life management. NASA & IDAC Guidelines require a 25-year re-entry orbit plan, however 'Iridium found many satellites had enough fuel remaining to reach altitudes low enough that Iridium set an aspirational goal of a four-week re-entry post-deboost phase'.[10]

Both the mission duration of 27 years as well as a four-week deorbit phase at end of life had been achievable. This was thanks to a larger than intended propellant allowance caused by a limitation on the types of fuel tanks on offer in 1996.

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[8] Ibid. p. 160.

[9] *Iridium Deorbit of Block 1 Constellation*, Iridium Communications, 9 February 2021 https://www.unoosa.org/documents/pdf/PromotingSpaceSustainability/PresentationsCaseStudies/CaseStudies/Iridium_Case_Study_Report.pdf (accessed 6 October 2023).

[10] Ibid. p. 2.

2.2. Propellant types & mission parameters

Classes of propellant for mission profile can vary depending on use case, costs, insertion mass and other elements central to both mission designers, regulators, as well as public interest groups for space operations. These may include three broad classes of propellant alongside emerging propulsion systems such as:

(a) Solid Propellant that will change into a gaseous discharge under correct conditions such as Ammonium Dinitramide;

(b) Mono propellants – that is – the use of a single chemical for the propellant, such as hydrazine used by Iridium; alongside more recently favoured less-toxic alternatives, such as hydrogen peroxide by mission designers;

(c) Electrical thrusters comprising either conventional solar-electric thrusters and/or nuclear-electric thrusters, which utilise a combination of noble gases such as xenon alongside a conductive metal or metalloid to create a hall effect to be used in conjunction with a gridded ion thruster; or,

(d) emerging propulsion systems, such as the Australian-built Neumann Thruster, which utilises a anode-cathode configuration with a conductive material capable of creating its own plasma, thereby leading to substantial efficiency gains in specific impulse while also improving the robustness of the system overall by reducing dependencies on additional materials to facilitate a reaction.

Despite the variation in propellants available to mission designers and project teams, the fundamental objectives of all choices in propellant remain the same: namely, to ensure insertion into available orbits is made possible, and remaining in those orbits until end of lifecycle and decommissioning. As such, propellants are available for the following mechanisms generally:

(a) transfer orbit – that is to say transferring from one orbit to another;
(b) apogee and perigee correction – to ensure that the orbit remains optimal and does not deform through orbital eccentricity into a highly elliptical orbit;
(c) attitude and altitude control to support reaction wheels and gyroscopes on the satellite to ensure the optimal positioning relative to the celestial body it is orbiting is maintained; and,
(d) evasive manoeuvres where there exists a risk of collision or near misses with another object in space.

Without adequate propellant, these manoeuvres may not be performed; or, many not be performed to an optimal level. This may place the mission longevity at risk of either impairment or outright discontinuation where propellant levels become critically low or fully exhausted.

Presently, the only remedy available to allow for management of propellant usage is to increase the amount of propellant available to a satellite when it originally launches, such as the Iridium 1st Generation satellites of the late 1990s who utilised commercially-available 200 gallon fuel tanks as part of their designs. Alternatively, favourable locations such as EL1 where SOHO has been stationed since 1996, may also assist in providing for reduced dependency on propellants used. However, increased propellant increases both the mass and volume of a satellite, thereby increasing the costs for mission as well as increasing proportionately the barrier to entry for emerging space actors such as developing nations, NGOs and small-to-medium enterprises.

Whereas some work has been undertaken to undertake on-orbit servicing, these applications are presently nascent and foreseeably will take some time to become ubiquitous. Even where on-orbit servicing may become available, it should be noted that frequent and otherwise avoidable discharge of propellant for orbital manoeuvres would require frequent on-orbit servicing as part of a preventative maintenance plan, which would still foreseeably result in increased costs and a higher barrier to entry for satellite operators.

As such, the only effective remedy available to mitigating the risk of reduced propellent is to conserve the finite volume of propellant available to both the satellite and mission teams.

2.3. Satellite Constellations and Congestion of LEO

2.3.1. Past Work on Space Traffic Management of Satellite Constellations

As part of their assessment of space traffic management in Low Earth Orbit (LEO) and the rise of satellite constellations in 2018, Green, Neumann and Grey noted that “[t]he universe is infinite, but those volumes of it that are economically useful to humanity are not.”[11]

Central to their consideration was the emergent issue of the rise of what is dubbed ‘NewSpace’ actors, being the disparate class of low-cost satellite commercial activities focused on business-to-business and business-to-customer facing goods and services in lieu of the former business-to-government facing goods and services that had dominated commercial space activities from the period from Vanguard-1 in the latter part of the 1950s through to the Iridium 1st Generation constellation of the mid 1990s.

At the time of writing in 2018 during the forecast SpaceX StarLink constellation of 12000 satellites as well as the proposed OneWeb

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[11] Green, T, Neumann, P, Grey, K, “Mitigation of Anti-Competitive Behaviour in Telecommunication Satellite Orbits and Management of Natural Monopolies”, 69th International Astronautical Congress, 61st Colliqum on the Law of Outer Space, International Institutre of Space Law, Bremen, Germany, pp 301-314, at p. 304 (2018).

constellation of up to 1980 satellites, Green, Neumann and Grey remarked that:

> [a]s one constellation populates its orbit shell with spacecraft, that shell becomes more problematic to operate in, due to space traffic management concerns. Over time, orbital perturbations will disrupt the orderliness of the constellation's initial condition, making collisions more likely. If another constellation begins operating in the same orbit shell, even if the satellites orbit in different planes from that of the first constellation, the collision risk at points where the planes intersect increases.[12]

Predictions made at IAC 2018 would become topics of discussion by IAC 2023. Now some five years post the commencement of launching of the Starlink satellite constellation, problems have begun to emerge in the management of the finite areas of space that remain of commercial interest to humanity.

Several notable examples have already emerged that demonstrate risks of collision avoidance, and the overreliance of propellant to avoid collisions with emerging satellite constellations. These include the near-miss between *Aeolus* & *Starlink-44* collision on 2 September 2019 wherein ESAs climate change monitoring satellite *Aeolus* was required to undertake propellant-expending manoeuvres following Starlink-44 changing its altitude outside of its original orbital plane.[13] SpaceX had been notified of the near-miss risk created by its change in orbital altitude, but refused to change course, placing the burden to out-manoeuvre on ESA.[14]

A repeat near-miss would occur again on 1 July 2021, this time with the *Tiangong* (天宫空间站), a platform designed and managed by the Chinese Manned Space Agency (CMSA) for crewed flight. In this instance, *Starlink-1095* also dropped its orbit to perform system testing, posing a collision risk

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[12] Ibid.

[13] Wall, Mike, 'European Satellite Dodges Potential Collision with SpaceX Starlink Craft' *space.com* 4 September 2019 (online) https://www.space.com/spacex-starlink-esa-satellite-collision-avoidance.html (accessed 2 October 2023). See also; 'ESA spacecraft dodges large constellation' *European Space Agency*, 3 September 2019 (online) https://www.esa.int/Space_Safety/ESA_spacecraft_dodges_large_constellation (accessed 2 October 2023).

[14] Wall, Mike, 'European Satellite Dodges Potential Collision with SpaceX Starlink Craft' *space.com* 4 September 2019 (online) https://www.space.com/spacex-starlink-esa-satellite-collision-avoidance.html (accessed 2 October 2023).

with *Tiangong* (天宫空间站).[15] Becoming aware of the risks to the crewed platform, CMSA was required to organise manoeuvres for the *Tiangong* (天宫空间站) to avoid collision with Starlink-1095.[16]

Three months following the *Tiangong* (天宫空间站) & *Starlink-1095* near-miss, *Tiangong* (天宫空间站) would again be required to undertake evasive manoeuvres when *Starlink-2035* once again posed a near-miss instance.[17]

In all these occasions a requirement was placed on one party over the other to undertake propellant expenditure to avoid a collision, thereby placing limitations on future manoeuvres and foreseeably impaired mission profiles where sufficient propellant is expended. Consideration will now be given to liabilities applicable.

3. Liability Convention 1972 (UN)

3.1. Current Mechanism of the Liability Convention

The *Liability Convention 1972* (UN) (the 'Convention') is the guiding legislative mechanism for establishing a liability regime for restitution where property damage has occurred either in space; or, on the Earth's surface, as a result of a space object. The Convention much like its counterpart mechanism the *Outer Space Treaty 1967* (UN) (OST) manages proprietary rights in space, however, unlike the OST which focuses on prohibitions on the propertisation of space and celestial bodies, and the management of space for peaceful and scientific uses, the Convention is focuses on providing a mechanism for where artificial space objects may cause damage either in space or on Earth, such as via re-entry.

Unlike the OST which is focused on the activities of nation states, the Convention provides for recognition of property rights for individuals as well as non-nation state private entities via Article I(a), which accommodate for the definition of 'damage' to extend to both natural and artificial persons. Additionally, Articles II & III of the Convention provide for remedies where property is damaged either in space or on the Earth's surface, either through collision or uncontrolled re-entry.

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[15] Lan, Chen, 'The Starlink-China space Station near-collision: Questions, solutions and an opportunity', *The Space Review* (online) 28 February 2022 https://www.thespacereview.com/article/4338/1 (accessed 2 October 2023). See also, Jones, Andrew, 'China's space station maneuvered to avoid Starlink satellites', *SpaceNews* (online) 28 December 2021 https://spacenews.com/chinas-space-station-maneuvered-to-avoid-starlink-satellites/ (accessed 2 October 2023).

[16] Ibid.

[17] Ibid.

Compensation claims can be brought forward via the operative clause of the Convention via:

- Articles IV where damages can be awarded where several states have been involved in contributory negligence;
- Article VIII which allows for a state to intercede on behalf of a claimant being either a natural or artificial individual;
- Article XIV which provides for powers to establish a Claims Commission to manage arbitration and awarding damages where settlement cannot be reached; and,
- Article X which sets out the limitation period in which a claim for damages against a launching state can be brought.

3.2. Current Interpretation of the Convention

The mechanisms within the Convention in its current drafting could foreseeably accommodate for claims for excessive discharge of propellant to be recoverable where an individual – being either natural or artificial; or, State could demonstrate that this would degrade or impair the overall mission profile of their satellite.

This may be achieved through either a broad or narrow interpretation of the current drafting of the convention. The present drafting of Article 1(a) of the Convention defines damage as:

The term “damage” means loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or judicial, or property of international intergovernmental organisations.

Where the definition ‘loss of or damage to property of States or of persons’ element of ‘damage’ is interpreted sufficiently broadly enough to include the expenditure of propellant as property to undertake unscheduled orbital manoeuvres to avoid collisions.

Alternatively, even with a narrower interpretation of what constitutes property for satellite manoeuvres, restitution for loss of propellant may be achieved either through two approaches which are as follows:

(a) The first approach to satisfy the definition of damage for the Convention may be satisfied where loss of propellant is seen recognised as being undertaken through coerced discharge to avoid collision.

(b) The second approach to meeting the definition of ‘damage’ for the purposes of the Convention may be satisfied by demonstrating that the mission profile of the impacted party was degraded as a consequence of discharging additional propellant.

Under either a broad or narrow interpretation of Article 1(a) past examples of near-misses caused by satellite constellations, such as the *Aeolus* & *Starlink-44* near-miss caused by *Starlink-44*, the ESA through their State bodies could seek damages against SpaceX via the launching country. Similarly, the CMSA, operator of the Tiangong may also seek restitution from SpaceX via their launching countries for the near misses caused by *Starlink-1095* & *Starlink-2035* respectively.

3.3. Amendments to the Convention to Accommodate for Propellant Discharge

Alternatively, greater clarity as to what does and what does not constitute damages may also be gained through amendment of Article 1(a) to broaden the scope of damages to also include impairment alongside 'damage' and 'loss'. Such an amendment would allow for recognition of mission impairment due to change in orbit and reduced propellant allowance.

This amendment to broaden the definition of damage to also encapsulate impairment of operations may be sufficient in meeting the criteria of damage where it can be difficult to demonstrate either tangible or intangible damages to objects in space to the satisfaction of the present drafting of the Convention

3.4. Convention Remains Untested

Notwithstanding the robustness of the drafting of the Convention in its present form, or the proposal for a minor amendment to support the current drafting, both administrative and jurisprudential challenges continue to be faced by the fact that the convention remains an untested instrument, without any precedent having been developed through its operation despite the Convention having been in force for 51 years.

In addition to this, there remains a disinclination to rely on the Convention, or rely on the Convention fully by State actors against launch countries despite multiple instances where the Convention would have been the optimal mechanism to seek remedies for infractions.

For example, in 1977 the USSR launched and operated *Kosmos 954* which crashed into the northwest territories of Canada. The remediation cost undertaken by the Canadian government approximated $14m (CAD) to dispose of the radioactive *Kosmos 954* crash site.[18] Costs for this remediation were settled with the USSR outside of the Convention's mechanism for which the USSR agreed to pay $3m (CAD) in restitution - or significantly less than half of the costs.[19] In analysing the application of the Convention to the

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[18] Cohen, Alexander F, 'Cosmos 954 and the International Law of Satellite Accidents' (1984) Vol. 10:78 *Yale Journal of International Law*, p. 80, https://core.ac.uk/download/pdf/72839474.pdf (accessed 2 October 2023).

[19] Ibid.

Kosmos 954 crash, almost a decade later in 1984, one commentator noted bluntly that ‘Canada and the U.S.S.R. seem to have ignored most of the provisions of the Liability Convention during the Cosmos 954 incident’.[20]

Meanwhile, in 1979 *Skylab* re-entered earth’s atmosphere in an uncontrolled deorbit, breaking up over the township of Esperance, Australia, and littering debris over a wide population area. The mechanism used cost recovery and remediation was not the Convention, but a littering fine, issued by the Shire of Esperance for $400 which remained unpaid by NASA.[21]

More recently, the 2009 *Iridium 33* and *Kosmos 2251* collision was again waived from the Convention’s application. The opportunity to once again apply the Convention had not gone unnoticed by the legal community. As one commentator put it ‘the recent collision between the *Cosmos 2251* and the *Iridium 33* satellite, the first time since the *Cosmos 954* disintegrated over Canada that the Liability Convention stands a chance of officially being invoked’ to explore its regulatory potential.[22]

Further to this, contemporaneous legal commentators observed, perhaps controversially, that although *Kosmos 2251* posed a navigation hazard, as it was no longer responding to commands, the Russian Federation was exempt from liabilities as *Iridium-33* was able to manoeuvre and therefore avoid the collision.[23]

Together, these three notable instances, amongst others, have led some to refer to space activities as the new ‘wild west’. This is due to the failure of States to engage with the mechanisms available through the Convention, which together have caused the Convention to remain untested, as well as setting a precedent within the international community of an expectation of either no, or limited responses where fissile materials deorbit into pristine wildernesses, space stations impact on populated areas, and no recompense exists for space debris that impact existing and future missions.

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[20] Ibid. p. 78.

[21] Wynne, Emma ‘When Skylab fell to the earth’ ABC Goldfields, *ABC News* (online), 9 July 2009, http://www.abc.net.au/local/photos/2009/07/09/2621733.htm (accessed 2 October 2023). See also; Wall, Mike, ‘40 Years Ago, NASA's Skylab Space Station Fell to Earth’ *Space.com* (online) 11 July 2019 https://www.space.com/skylab-space-station-fall-40-years.html# (accessed 2 October 2023).

[22] von der Dunk, Frans G, ‘Too-Close Encounters of the Third Party Kind: Will the Liability Convention stand the Test of the Cosmos 2251-Iridium 33 Collision?’, 60th International Astronautical Congress, 52nd Colloquium on the Law on Outer Space, International Institute of Space Law, p. 1 (2009). https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1027&context=spacelaw (accessed 2 October 2023).

[23] Jakhu, Ram S, ‘Iridium-Cosmos collision and its implications for space operations’ in Kai-Uwe Schrogl, et al (eds.) *Yearbook on Space Policy: 2008/2009*, Springer, Wien New York (2010), pp. 254-275, at pp. pp.256-257 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2801684 (accessed 2 October 2023).

As such, the Convention, although designed specifically for the purposes of management of damages undertaken by space objects either in space, or on the Earth's surface, may not be the optimal solution to the emergent issue of propellant use for near miss and collision avoidance posed by the emergence of satellite constellations in recent years.

For this reason, alternative mechanisms such as the International Telecommunications Union (ITU) management may be considered.

4. ITU & Alternative Dispute Resolution

Alternative approaches to dispute resolution may also be advantageous and administratively more expedient than amendments or application of the Convention.

This may include such regulatory bodies as the ITU, which already have some involvement in existing orbital matters such as Geostationary Orbit (GEO). For example, Recommendation ITU-R S.1003 requires transfer to a graveyard orbit for all satellites in GEO and includes requirements related to a sufficient amount of propellant to be available to accommodate the transfer from GEO to graveyard orbit at end of life.[24]

Further attention has been given to ITU involvement in the regulatory field recently. Following UN Resolution 76/55 Transparency and confidence-building measures in outer space activities which adopted the Report of the Committee on the Peaceful Uses of Outer Space, the ITU passed Resolution 186 at Bucharest in December 2022.[25]

Resolution 186 related to the Strengthening the role of ITU with regard to transparency and confidence-building measures in outer space activities and specifically identified satellite constellation management as a key priority.[26] The key focus of ITU Resolution 186 was to support UN Resolution 76/55 via further support of Articles 15 & 16 of the ITU Radio Regulations which manages specifically interferences and international monitoring of radio stations respectively.

Although the key focus of Resolution 186 is specific to management of transmissions in support of both UN 76/55 and Article 44 of the Constitution

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[24] International Telecommunication Union, 'Recommendation ITU-R S.1003-2', *Environmental protection of the geostationary-satellite orbit*, (2010) https://www.itu.int/dms_pubrec/itu-r/rec/s/R-REC-S.1003-2-201012-I!!PDF-E.pdf.

[25] UN Resolution 76/55 'Transparency and confidence-building measures in outer space activities', United Nations General Assembly, 13 December 2021 https://documents-dds-ny.un.org/doc/UNDOC/GEN/N21/383/46/PDF/N2138346.pdf?OpenElement (accessed 2 October 2023).

[26] International Telecommunications Union, *Collection of the Basic texts adopted by the Plenipotentiary Conference*, ITU Publications (2023), pp. 784-86, https://search.itu.int/history/HistoryDigitalCollectionDocLibrary/5.23.61.en.100.pdf (accessed 2 October 2023).

of the International Telecommunication Union, it should be noted that mechanisms may already exist that can accommodate specific management of LEO satellite constellations that align with the existing Recommendation ITU-R S.1003 for propellant management for geostationary satellites.[27]

If the mechanisms available to the ITU are interpreted under the following approach provided – or an approach with a similar effect to the one provided – then it is reasonably foreseeable that adequate mechanisms exist for alternative dispute resolution and arbitration by ITU in management of near-miss and collision avoidance going forward. First, Article 44(2) of the Constitution notes that:

> … Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries.[28]

The present drafting of Article 44(2) accommodates for orbital management alongside spectrum management via their associated orbit, providing sufficient administrative scope for the ITU to provide regulatory oversight not just to GEO but foreseeably LEO, MEO, Lagrange Points or any other areas of space wherein transmission activities may take place that are regulated by the ITU.

The second element allowing for ITU oversight for dispute resolution for propellant management and mission impairment is accommodated within the Radio Regulations as detailed in Article 44(2) of the Constitution as well as referred to in Resolution 186. This deals specifically with the previously mentioned Articles 15 & 16 that manages interferences and international monitoring of radio stations respectively. Of interest is Article 15 §3(a) which notes that the location of transmitting stations should be located with particular care. Further to this, Article 15 §25 accommodates for when harmful interference occur as a result from space stations, the aggrieved satellite operator or ground station operator may seek information on the position of the space station if not otherwise known.

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[27] Ibid. n. 19.

[28] International Telecommunications Union, *Constitution of the International Telecommunications Union*, p. 49, at [195], https://www.itu.int/en/council/Documents/basic-texts/Constitution-E.pdf (accessed 20 January 2024).

Finally, 'interference' is further defined under Chapter 1, Section VII paragraph 1.166 of the Radio Regulations as to include

> [t]he effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

Electromagnetic induction can occur in a manner of ways, including both through indirect means but within close proximity, as well as direct means including physical contact between two objects – such as may occur in a near-miss or collision. For the purposes of the definition of interference for the Radio Regulations, it is reasonably foreseeable that electromagnetic induction may occur wherein a near-miss was not avoided, and where one party had to undertake orbital maneuvers to avoid said collision and foreseeable induction.

Additionally, it may also be possible to broaden the interpretation of interference by revisiting Article 15 §3(a) which requires interference to be managed via location of transmitting stations being positioned with particular care relative to one another. Under a revisited application of the rules, it is reasonably foreseeable that orbital mechanics, including near miss events, are within the remit of the ITU. As such, any maneuvers undertaken to avoid collision and reduce proximity would be undertaken in accordance with the Regulations and may make available appropriate means for recovery of any loss caused as a result of overcoming a party's negligent behaviour.

Additionally, although the current drafting is ostensibly with regards to mitigating radio interference between broadcasting stations, it is also apparent that reduced access to propellant due to continued collision avoidance with satellite constellations would foreseeably also interfere with the lifespan and mission profile of the satellite transmitting. As such it could be argued that interference – were it to include both current and future use, could also be achieved by demonstrating degrading the mission profile of the transmitting satellite via limiting its operational lifespan due to excessive propellant expenditure undertaken due to collision avoidance measures.

5. Conclusions

Recent recognition by industry, government, the international and professional community as to the practical issues posed by space traffic management are of value in reducing risk and improving management of the space domain in areas of interest to human activities.

Notwithstanding this, further work will need to be undertaken in exploring the correct governance approach to ensuring best-practice continues going forward.