LEGAL ANALYSIS OF ROCKET FUEL EMISSIONS WITH THE EMERGENCE OF SPACE TOURISM AND ITS REGULATION

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ABSTRACT

The era of privatisation of space journey could be more exciting than before as it is based on the idea of access to space for all. Whilst the enthusiasm, commercialism in space journey brings with it certain discrepancies, especially the environmental back fall. Rocket fuel emissions are one of the causes of such environmental damage. It was not adequately addressed in the past because of its negligible percentage of contribution to the environmental damage. Private space agencies such as SpaceX, Virgin Galactic, Blue Origin and currently Skyroot Aerospace in India, dramatically set an era of privatisation in space journey. However, several countries around the world are lagging in enacting a proper legislation in addressing the rocket fuel emissions as an environmental issue as well as at the International plane. This is a concern for future particularly when the prices for space journey gets reduced causing eventual compromise on taking environmental precautions. Thus this researcher attempts to analyse if the present International Space Law and International Environmental Law could properly address the rocket fuel emissions and if not so come up with a draft treaty addressing the rocket fuel emissions.

Keywords: Rocket fuel emissions, environmental damage, privatisation, space journey, commercialism, legislations, regulations.

I INTRODUCTION

Reaching space was a long imagined fantasy of human species. At the onset of space tourism and reusable launch vehicles it is becoming a matter of tickets for space journey making civilians experience the beauty of space darkness. However, this will happen at the cost of earth environment including atmosphere. At present the launch rate of the rockets is meagre due to which the role of emissions out of rocket fuel in depleting ozone layer in the stratosphere have not exceeded 0.1%[1] and the environmental degradation around launch sites seem negligible[2]. With the emergence of privatisation and space tourism there is an expected increase of launch sites, proportional increase in launch rate and cheaper tickets for space transport[3]. When such a state of affairs arrive, it is usual that the benefits blind the negative consequences, among which the environmental degradation out of rocket fuel emission is no less serious consequence. It is no doubt that the International community have taken less measures in addressing such consequence and are excited about the introductory face of space tourism. The lesson from handling the issue of space debris was that the delay in recognising the issue left everyone nowhere but to start from that point to stop creating debris. It is high time to regulate the rocket fuel emission by recognising the environmental consequence at the earliest. This research attempts to legally analyse the present International Environmental Legal regime and International Space Law regime to know the status quo legality of rocket fuel emissions and its regulations. Also, this research attempts to analyse certain technical aspects to suggest for a regulatory framework in controlling and restricting the activities of the private entities involving in space tourism and transportation to combat the environmental consequence out of space tourism.

The researcher introduces the rocket fuel emissions and the associated environmental issues in the wake of space tourism in Chapter I. Chapter II deals about different environmental issues associated with rocket fuel emissions. The researcher studies about the International Environmental Law that acts as restrictions for rocket fuel emissions and how the Environmental principles are not sufficient to curb the rocket fuel emissions in the wake of Space Tourism is been dealt under Chapter III. The researcher attempts to come up with a

[1] Martin Ross and James A vedda. (2018). The Policy and Science of Rocket Emissions. Centre for Space Policy and Strategy.
[2] Nivedita raju. (2019). The Regulation Of Rocket Emissions. McGill University.
[3] Torres, A. I.. (2020). Reusable Rockets and the Environment. *UC Merced Undergraduate Research Journal*, 12(2). https://doi.org/10.5070/m4122048807

regulatory framework which could act as *lex specialis* on regulating rocket fuel emissions in the Chapter IV. The researcher would summarise the paper in the Chapter V with a conclusion.

II ENVIRONMENTAL ISSUES ASSOCIATED WITH ROCKET FUEL EMISSIONS

A) The Launch Stage:

(i) Successful launch and Environmental impacts: A rocket launch produces noise pollution, dust and emissions. In the preparatory stage of Rocket launch several hazardous materials are used such as acetone, chromate conversion coating, oils, solvents, paints, denatured alcohol, epoxy, flux, inks, lacquer etc. During the launch, the combustion of rocket propellants emit airborne exhaust emissions as well as creating hazardous waste water generation. Spilling of substances such as heptyl, UDMH[4] and other liquid hypergolic propellants[5] which are solid rocket fuels damages the *in-situ* on the surrounding land. Inadvertent releases of toxic air contaminants are possible as the result of improper handling of hazardous materials during payload processing, transportation and launch[6]. The adverse effects of launch activities cause serious health problems among people living below the rockets' flight path. For instance, the levels of endocrine disease and blood disorders in children are reported to be over twice the regional average. This is due to highly toxic propellants which are dumped onto the land located along the flight trajectories, by a rough estimation, dozens of litres of unburned fuel is sprayed over several square kilometres of land with every launch[7].

(ii) Launch failure and Environmental Impacts:

(a) Non-Radiological[8]:

[4] Heptyl and UDMH are the first class hazard substance as classified by World Health Organisation which is highly dangerous because of its high toxicity. Trofimov, I et al.. (2020). Analysis of rocket fuels and problems of their application on the example of Ukraine. *Technology Audit And Production Reserves*, 6(1(56)), 19-27. https://doi.org/10.15587/2706-5448.2020.218358

[5] Liquid hypergolic propellants include Hydrazine, monomethyl hydrazine, UDMH, Dinitrogen tetroxide and their combinations. Rarata, G. & Florczuk, W.. (2016). NOVEL LIQUID COMPOUNDS AS HYPERGOLIC PROPELLANTS WITH HTP. *Journal of KONES*. Powertrain and Transport, 23(1), 271-278. https://doi.org/10.5604/12314005.1213587

[6] After ignition of the 1st stage and first few seconds of lift off through launch vehicle ascent, the exhaust emissions would form a buoyant cloud at the launch pad. This high-temperature cloud would rise quickly and stabilize at an altitude of several hundred metres near the launch area. The Cloud would then dissipate through mixing in the atmosphere. The exhaust products would be distributed along the launch vehicle's trajectory as the vehicle moves through the atmosphere. NASA (2020). Draft Environmental Impact Assessment for Mars Mission. http://www.nasa.gov/agency/nepa/mars2020eis

[7] The Russian Use of Baikonur Cosmodrome. Viikari, L.. (2008). Preliminary Material. *The Environmental Element in Space Law*, i-xvi. https://doi.org/10.1163/ej.9789004167445.i-396.2

[8] Non-radiological means and includes those non-ionizing radiation such as ultraviolet light, radiant heat, radio

Unburned pieces of Solid propellants such as ammonium perchlorate and the quantity of liquid propellants will fall on the land and the nearby water bodies, thereby endangering the aquatic ecosystems. The ammonium perchlorate becomes ammonium ion and perchlorate ion after reacting with water. The ammonium ion if felt from low to medium, acts as plant nutrient which stimulates plant growth, by when felt high it becomes dangerous to the lives of the aquatic species and plants. Debris from the launch failures and spilling of solid propellants have the potential to adversely affect managed fish species and their habitats in the vicinity of launch site. The potential effects of an accident would include a localized fireballs, falling debris from explosion of the vehicle, release of unburned propellants and propellant combustion products, on pad or very low altitude explosions, death or damage to nearby biota and brush fires near the launch pad[9].

(b) Radiological consequence:

Radiological consequences include those effects arising out of radioactive substances which are otherwise called ionising radiation[10]. It seriously causes biological issues[11] such as fatal cancer and other hereditary diseases such as down- syndrome in children. Also it is carried in atmosphere for distances from the launch site measured in Source term[12].

B) The Atmospheric pollution:

Rocket engine exhaust emitted into the stratosphere during ascent to orbit adversely impacts the global atmosphere. Rocket exhaust has two main effects on the atmosphere. First, chemical reactions deplete the ozone layer. Secondly, the radiative forcing[13] which heats up the ozone layer resulting in its depletion[14]. There are other ancillary changes along with the above

waves and microwaves. Ford, J., & International Atomic Energy Agency, Division of Public Information, Vienna (Austria). (2004). Radiation, people and the environment. IAEA.

[9] *Supra.* 6

[10] Ionizing radiation includes cosmic rays, X rays and the radiation from radioactive substances. *Supra..* 8

[11] All the energy deposited in biological tissues by ionizing radiation is eventually dissipated a heat through increased vibration of the atomic and molecule structures. It is the initial ionization and the resulting chemical changes that causes harmful biological effects leading to development of cancers or inherited genetic defects. *Ibid* 10.

[12] Source Term is defined as the Quantity of radioisotope that is released from the fuelled clads and becomes airborne. Consequences associated with the material released in an accident are driven by the portion of the release that can become airborne and be transported away from the Impact Site. *Supra 8*.

[13] Radiative forcing is the process in which the particles from rocket fuel emissions being injected into the stratosphere get absorbed and reflect solar energy, changing the flow of radiation in the atmosphere, heating the stratosphere and cooling the surface. *Supra* 1.

[14] *Supra* 1.

consequences which include changes in the pattern of global circulation and cloudiness, including polar mesospheric clouds. The important emissions of concern with respect to global impacts are chlorine and alumina particles from solid rocket motors (SRMs) and soot particles (black carbon). Rocket launch currently injects approximately 10 gigagrams of BC and alumina particles into the stratosphere each year.

(C) Rocket fuel Emissions and Space tourism[15]:

Although rocket impacts to the global atmosphere are presently insignificant compared to other human activities, trends that include plans for airline-like operations, massive LEO communication satellite constellations, and space tourism indicate rocket impacts are likely to grow.[16] However, there prevails inaccurate information and research with respect to contribution of different fuels in damaging the environment including the atmosphere. Meanwhile, new fuels which are cost efficient such as methane[17], absorbs infrared radiation, have not been environmentally assessed in its usage. These concerns aside, there is a recommendation and use of Reusable rocket launch vehicles appreciated by the commercial space companies in the name of sustainability. Though it reduces the production of new launch vehicles, reusability will make the rocket launch much cheaper with cheaper tickets for tourism, along with cheaper maintenance resulting in environmental damage around the launch site[18].

III INTERNATIONAL ENVIRONMENTAL LAW AND INTERNATIONAL SPACE LAW IN CURBING THE ROCKET FUEL EMISSIONS

A) International Environmental Law:

(i) The Precautionary Principle

(a) The Stockholm Declaration, 1972

This principle applies the concept of avoiding activities which cause harm to environments that fall under "a global commons", which includes outer space, Antarctica and the high seas within

[15] YAZICI, A. M. & TİWARİ, S.. (2021). Space Tourism: An Initiative Pushing Limits. *Journal of Tourism Leisure and Hospitality*, 3(1), 38-46. https://doi.org/10.48119/toleho.862636
[16] *Supra* 10.
[17] The global launch industry has so far used four propellant combinations (LOX/kerosene, LOX/hydrogen, SRM, and hypergolic).
[18] *Supra* 3.

its purview[19]. However, this 'no harm principle' could not possibly address the rocket fuel emissions within the territory of the launching state.

(b) Rio Declaration, 1992:

The actual wording of Principle 15[20], the words "shall be" have been incorporated, the qualifying phrase "according to their capabilities" significantly weakens the precautionary principle[21]. Because orbital and suborbital commercial space flights present unique dangers to the sensitive layers of the upper atmosphere, the precautionary principle dictates that the developing industry should be regulated sooner rather than later. International governing bodies and individual states should heed the warnings from anti-geoengineering climatologists who are concerned about the unforeseen consequences of injecting particles into the upper atmosphere[22].

(ii) The UNFCCC[23]:

There is a constant fear which seems reflected in Article 2 of the UNFCCC[24] that added regulation would come at the cost of industry and development. The same is reflected in the rocket fuel emissions, wherein the world community is excited by the commercial space transport and space tourism and the consequences are forgotten. On the other hand, they also fear that bringing in regulation may curb the space tourism industry.

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[19] Principle 21, "States have . . . the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction." The Stockholm Declaration, 1972.

[20] Principle 15, " Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". The Rio Declaration, 1992.

[21] *Supra* 2. Trail Smelter Arbitration, U.S.-Canada, Trail Smelter Arbitral Tribunal, Aug. 16, 1938, Reports of International Arbitral Awards, Vol. 3 1911-1937.

[22] Friedberg, J.. (n.d.). Bracing For The Impending Rocket Revolution: How To Regulate International Environmental Harm Caused By Commercial Space Flight. Colorado Law Scholarly Commons. https://scholar.law.colorado.edu/celj/vol24/iss1/7?utm_source=scholar.law.colorado.edu%2Fcelj%2Fvol24%2Fiss1%2F7&utm_medium=PDF&utm_campaign=PDFCoverPages

[23] UNFCCC defines "emissions" as "the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time" under Article 1(4) and defines of "greenhouse gases" was enumerated as "those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation" under Article 1(5).

[24] Article 2 sets out the objective of the UNFCCC, "to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Change, U. N. F. C. o. C. (2006). United Nations Framework Convention on Climate Change Handbook.

At the time that the UNFCCC was drafted, there were various factions discernible through the negotiations, beginning with a demarcation between developed and developing nations on the basis of who should bear primary responsibility for climate change. Article 3, which introduced the contentious concept of "Common but Differentiated Responsibilities" (CBDR), classifying countries into Annex I and non-Annex I states[25]. However, there is a concept of 'tragedy of commons'[26], wherein the mistake done by one party will result in suffering of all the parties. Thus there is demand for an international framework without such division in case of climate change and Environment[27]. Similarly, regulation of rocket fuel emission should be a concern of all and if not regulated at the initial stage the suffering would be on the part of all.

(a) The Kyoto Protocol, 2007: The purpose of the protocol is to reduce greenhouse gas emissions by the developed States. It introduced a concept called as "emissions trading"[28] which is otherwise a 'carbon market' in which buying and selling of carbon credits happen to show reduction in carbon emissions. However Kyoto Protocol proved to be failure as major developed countries[29] got withdrawn from the Protocol due to the differentiation as Annex I parties.

(b) Paris Agreement, 2015[30]: The significant aspect is that the agreement also stipulated that the parties' nationally determined contributions (NDCs) were legally binding, with these NDCs expected to "represent a progression over time." Thus we could see that the principle of CBDR has been diluted. The Paris Agreement hence strikes a balance between mitigation and adaptation, with Article 7(4) stating that "greater levels of mitigation can reduce the need for

[25] Nanda, A. D. (2011). India's environmental trump card: How reducing black carbon through common but differentiated responsibilities can curb climate change. *Denver Journal of International Law & Policy*, 39(3), 523–544. https://digitalcommons.du.edu/cgi/viewcontent.cgi?article=1192&context=djilp

[26] SEMCHENKO, M et al.. (2007). Challenging the tragedy of the commons in root competition: confounding effects of neighbour presence and substrate volume. *Journal of Ecology*, 95(2), 252-260. https://doi.org/10.1111/j.1365-2745.2007.01210.x

[27] United Nations Office for Outer Space Affairs [UNOOSA]. (2018). Guidelines for the Long-term Sustainability of Outer Space Activities (A/AC.105/2018/CRP.20). https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf

[28] The Protocol therefore does not recognise private entities, and employs a State-specific approach to track emissions units held and traded willingly on a national basis. See Article 12 & Article 17, The Kyoto Protocol, 2007.

[29] Phillipson, M. (2001). THE UNITED STATES WITHDRAWAL FROM THE KYOTO PROTOCOL. *Irish Jurist* (1966), 36, 288–304. http://www.jstor.org/stable/44013850

[30] The treaty reflected States' commitment to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels."

additional adaptation efforts[31].

(c) Montreal Convention:

The Montreal Protocol does not specifically address emission sources such as rockets (and aircraft) that emit directly into the stratosphere. Compounds are identified for global phase-out based on a calculated Ozone Depletion Potential (ODP), a metric that compares a compound's ozone depletion (per unit mass) to the ozone depletion caused by a standard compound. However, ODP is strictly defined only for gases released at the Earth's surface, so rocket emissions cannot formally be assigned an ODP for assessment. The impacts of rocket emissions on stratospheric ozone are occasionally assessed in the Montreal Protocol's Quadrennial Scientific Assessment of Ozone as "small" without a clear definition of "small"[32]. The Montreal Protocol has been amended to include substances that were not directly included under the UNFCCC framework (Kigali Amendment)[33]. This facilitated the regulation of hydrofluorocarbons (HFCs), which are "short-term climate forcers" that remain in the atmosphere for shorter periods of time, such as black carbon and methane. As Chapter II has presented the negative effects of black carbon emitted by certain rockets, the mechanics of this Protocol can assist in framing a new instrument for rocket emissions.

(iii) The 1979 Convention on Long-Range Transboundary Air Pollution and the Gothenburg Protocol:

The Convention provides in its preamble the precautionary principle enshrined under Article 21 of The Stockholm Declaration. The Gothenburg Protocol[34] is worth mentioning as it directly targeted reduction in fine-particulate matter which includes black carbon. However its target

[31] The role of US as a second largest carbon emitter raised alarms when it withdrew from the Paris Agreement under the Former President Donald Trump. However with the new administration under President Joe Biden, US re-entered the Paris Agreement obligations. Deb Niemeier. (2025, June 30). Why the US rejoining the Paris climate accord matters at home and abroad — 5 scholars explain. *The Conversation*. https://theconversation.com/why-the-us-rejoining-the-paris-climate-accord-matters-at-home-and-abroad-5-scholars-explain-153783?utm_medium=article_clipboard_share&utm_source=theconversation.com

[32] *Supra* 1.

[33] Kigali Amendment to the Montreal Protocol agreed by the Twenty-Eighth Meeting of the Parties, 15 October 2016, (entered into force 1 January 2019).

[34]The Protocol sets national emission ceilings for 2010 upto 2020 for four pollutants such as sulphur (SO2), Nitrogen Oxides (NOx), Volatile Organic Compounds (VOCs) and ammonia (NH3). United Nations Economic Commission for Europe. (2024, June 3). Revision of Gothenburg Protocol under the UNECE Air Convention will strengthen efforts to reduce air pollution in Europe and North America [Press release]. https://unece.org/environment/news/revision-gothenburg-protocol-under-unece-air-convention-will-strengthen-efforts

date had come to an end by 2020 itself. The scope of the Gothenburg Protocol is more limited as the Protocol introduced regulation to curb pollution of short-lived climate forcers on an international scale, but only binds State Parties. Major contributors to these pollutants such as India and China are excluded from the purview of this instrument, indicating a limit to how effectively it can achieve global reductions.

B) International Space Law:

For the purpose of convenience, the International community have adopted the 100km Karman line theory of delimitation of the airspace from outer space. In order to address the environmental issue associated with stratosphere, one need to understand whether stratosphere comes within the realm of outer space for the application of Outer Space treaty. Stratosphere which approximately extends up to 50-80 km from Earth's surface[35], it does not essentially fall within outer space. However, under the definition of the term 'environment', outer space is also included[36], which indeed makes the Environment related provisions in International Space Law applicable to stratosphere, air, land and water on Earth[37].

(i) The Outer Space Treaty, 1967: There are certain provisions in the Outer Space Treaty that are concerned with Rocket Fuel Emissions. Article III which makes Space activities, laws, rules subject to International Law and UN Charter which was dealt under the previous head of International environmental law; the terminologies 'due regard', 'potentially harmful interference' and 'harmful contamination' are of significance under Article IX[38], which has not been defined though. What does it mean to pay 'due regard?' The explanation was given by

[35] Balasubramanian, A. (2011). Atmosphere- Documentary [Educational Video]. University of Mysore. https://www.researchgate.net/publication/310021347_Atmosphere-_Documentary

[36] The Limited Test Ban Treaty, 1963; The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, 1974 included outer space within the application of the term "environment modification techniques."

[37] Article IX of the Outer Space Treaty, 1967 provides, "States Parties to the Treaty shall pursue studies of outer space, including the Moon and the other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth".

[38] Article IX stipulates that a State must conduct its activities with due regard to the "corresponding interests of other State Parties" as well as conduct the exploration of outer space in a manner that avoids harmful contamination.102 Furthermore, the provision requires States to undertake consultations if it has "reason to believe" that the activity of another State may cause potentially harmful interference with the peaceful exploration and use of outer space.103 Much to the chagrin (or delight) of space law scholars. *Supra* 2

the Chicago Convention, 1944[39], The UNCLOS, 1982[40] and The Cologne Commentary[41] as "the performance of an act with a certain standard of care, attention or observance"[42]. Accordingly, State Parties to the Outer Space Treaty have an obligation to ensure that the emissions from their rocket launches do not contribute to environmental damage of the stratosphere. This provision is based upon the precautionary principle under International Environmental Law[43]. This precaution of 'due regard', is however with respect to the interests of the other States and not with 'Environmental concern'. This rejects the idea that pollution caused by rocket fuel emissions within the boundaries of a State is controlled by this provision, although one could possibly argue that disturbance in the stratosphere[44] and the 'environment' as such is the global concern[45]. The provision speaks of both forward[46] and backward 'harmful contamination' in which the latter provides for an 'earth-oriented' conception of the re-entry of space vehicles that may potentially contaminate the Earth. One could rationally come to the conclusion that rocket fuel emission and its consequences are not covered by the term 'harmful contamination'. Even if one interprets and fit rocket fuel emissions within the framework of 'harmful contamination' remotely, the liability does not get automatically provoked. There needs to be a proof of 'damage' and 'attribution' to a particular State[47]. Looking into the definition of 'damage' under the Liability Convention, 1972, '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 juridical or property of international intergovernmental organization', which could not properly be invoked because the definition seems ambiguous about a State Party being liable and compensating the people within its territory and the workforce in the operation of

[39] Article 3 (d) of the Convention on the International Civil Aviation, 1944 as, "The contracting States Undertake, when issuing regulations for their state aircraft, that they will have due regard for the safety of navigation of civil aircraft.

[40] Preamble of The United Nations Convention on The Law of Seas, 1982. Also See Article 87(2), UNCLOS, 1982 which states "these freedoms shall be exercised by all States with due regard for the interests of other States in their exercise of the freedoms of the high seas".

[41] Hobe Stephan, Schmidt-Tedd Bernhard, . (2009). Cologne commentary on space law Vol. I Outer space treaty. Deutsche: Carl Heymanns Berlag.

[42] *Supra* 2.

[43] Principle 12 of the Stockholm Declaration, 1972 and Principle 2 of the Rio Declaration, 1992.

[44] Nanda, V. P.. (n.d.). Stratospheric Ozone Depletion: A Challenge for International Environmental Law and Policy. *University of Michigan Law School Scholarship Repository*. https://repository.law.umich.edu/mjil/vol10/iss2/7

[45]'Prohibition activities affecting the environment' is the *erga omnes* obligation. Barcelona Traction, Light and Power Company, Limited (Belgium v. Spain), Preliminary Objections, Judgment, [1964] I.C.J. Rep. 6.

[46] Forward contamination o include the introduction of such items, substances and energy into outer space which results in endangering the health of cosmonauts, causing hindrance for legitimate outer space activities, and causing damage to outer space objects. *Supra* 42.

[47] Sucharitkul, S. (1996). State responsibility and international liability under international law. *Loyola of Los Angeles International and Comparative Law Journal*, 18(4), 821–854.

space object[48][49]. This probably ends up nowhere, but to the conclusion that rocket fuel emissions are not included within the term 'harmful contamination'. Also rocket fuel emissions are intangible and are not immediate to recognise the damage, even in case of cross-border contamination. It takes an accumulative realisation that a harmful contamination had occurred. The term 'harmful interference' is much linked with Avoiding potentially harmful interference was more linked to the critical issue of the use of outer space for peaceful uses[50]. Therefore Rocket fuel emissions and its regulation could not be fitted within Article IX of the Outer Space Treaty, 1967.

(ii) The Liability Convention, 1972: As previously stated the definition of 'damage' does not include rocket fuel emissions[51]. Article II also does not include damage by rocket fuel emissions by the plain reading of the provision which includes only two categories of damage caused on (i) the surface of the Earth, or (ii) to aircraft in flight, or (iii) to another space object[52]. Although, with the definition given under Article I(d), Space object also includes those component parts of a space object as well as its launch vehicle and parts thereof in order to make the launching State liable, which however is made inactive because of Article VIII and the intangible nature of damage caused by Rocket fuel emissions, to be included within this realm.

(C) The Problem of Establishing International Responsibility when it comes to Rocket fuel emissions:

To apply the ASR[53] to damage caused by rocket emissions, there would have to be proof that a particular State has acted in a manner that constitutes an internationally wrongful act through a breach of the "no-harm" rule in international environmental law. The onus is on the State bringing the claim to provide evidence of the same. Further, there is the standard requirement for a causal link which proves that the defendant State's act resulted in the injury caused to the applicant State. It is also pertinent to note that damage *per se* is not required to invoke international responsibility under the ASR. A State can invoke responsibility of another State

[48] Article VIII of the Liability Convention, 1972; Diederiks-Verschoor, I. H. P. & (jurist.), V. K. (2008). An Introduction to Space Law. *Kluwer Law International* B.V.
[49] However, the term Space object under Article 1(d) includes component parts of a space object as well as its launch vehicle and parts thereof.
[50] *Supra* 26.
[51] *Supra* 33.
[52] Article II of the Liability Convention, 1972, "A launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight".
[53] Verma, S. K. (2012). An introduction to public international law (3rd Ed.). Satyam Law International.

that has breached its international obligations (although the commentary specifies that these obligations would have to be "collective obligations", i.e. they must apply between a group of States and have been established in some collective interest). Notably, the ILC cites "the environment" as a possible example for the application of this provision.

Both the international legal regimes thus had not sufficiently addressed the rocket fuel emissions and its regulations as it is important to notice the peculiar nature of Rocket fuel emissions and its consequences which are intangible and the possibility of establishing International Responsibility and International Liability seems difficult as the effect of rocket fuel emissions are not immediate and are cumulative. Therefore *lex specialis* is required with the introduction of space tourism to regulate Rocket fuel emissions, before it is too late.

IV REGULATORY FRAMEWORK OF ROCKET FUEL EMISSIONS

A) Schemes in existence:

In creating a mechanism for rocket emissions, it is necessary that the new regulation is effective. It is thus relevant to understand how emissions regulations can sometimes fail in achieving an overall reduction. There are two schemes existing which are on the path of curbing emissions. They are Emissions tax[54]by the States and the Cap and trade scheme[55]. A fundamental difference between carbon taxes and cap-and-trade lies in authority; while States retain power to impose and allocate taxes, control is transferred to the polluting entities in a trading scheme. This particular feature would require significant discussion within the rocket emissions context, given the number of commercial ventures planned for outer space, coupled with the fact that States are still responsible for the acts of their non-governmental entities[56].

Meanwhile command-and-control regulation has been criticised for clumsiness, inflexibility and tendency to encourage litigation but it is the contention here that these standards are necessary to any new conversation on emissions within a specific sector. This is because the very act of setting minimum standards for certain industries to avoid contributing to pollution is a progressive measure in itself. Evolving a regulatory mechanism applicable to rocket

[54] The tax structure conceptualised by Pigou required that externalities were wholly internalised in the cost of a product, thus reducing environmental damage. IMF & OECD. (2021). Tax policy and climate change: IMF/OECD report for the G20 Finance Ministers and Central Bank Governors, April 2021. International Monetary Fund.
[55] Profeta, T. & Daniels, B.. (2005). Design Principles of a Cap and Trade System for Greenhouse Gases. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1261011
[56] *Supra* 43.

emissions, however, will require additional considerations specific to the global space community. To establish a suitable mechanism, at the outset there is a need to acknowledge the divide between space-faring and non-spacefaring nations[57] and take distributive justice into consideration. By comparing the working of ICAO[58] and IMO[59] in the reduction of emissions provides an idea of how an international organisation if established to regulate the rocket fuel emissions should actually work. However, one could tell the mechanism of ICAO was much focussed on offsetting emissions, in other words, carbon neutral development, whereas the intention of IMO was well established to reduce the emissions. Thus for the Rocket fuel

[57] Distributive Justice of John Rawls, the arguments favouring a separation of distributive justice from climate change are founded on the premise that international climate change agreements are not the appropriate forum for wealthy nations (which have been responsible for the majority of historical emissions) to compensate poorer nations which disproportionately suffer from the effects of climate change. However, it is possible for its application in case of scientific and technological transfer from the space-faring nation to non-space faring nation. Moeller, J. F.. (n.d.). DISTRIBUTIVE JUSTICE AND CLIMATE CHANGE: THE WHAT, HOW, AND WHO OF CLIMATE CHANGE POLICY. *ScholarWorks at University of Montana.* https://scholarworks.umt.edu/etd/10699

[58]"The MBM would be an emissions trading scheme with a baseline implemented in a phased manner, with three phases beginning with 2021 to 2023, then the second from 2024 to 2026 and the third from 2027 to 2035. The legal character of CORSIA itself is dubious. This is because CORSIA derives its strength from the Annexes to the Chicago Convention and Assembly Resolutions. Neither of these are de jure hard law instruments. The 40th Assembly at ICAO adopted Resolutions 17, 18 and 19 regarding the environmental impact of aviation. The progress made is undeniable, evident from the new CO2 standards confirmed to take effect from 1 January 2020 for certain aircraft types in Resolution 17. The Assembly also evidenced ICAO's commitment to **ensuring fuel-efficient routing of international flights**, including through the Global Air Navigation Plan (GANP) and the continued the pursuit of a framework to **support alternative fuels**. The three Market-based schemes for the reduction of emissions which the ICAO is working are: (i) offsetting, which operates through creation of emissions units that allow States to quantify the reductions they have achieved in alternative sectors; (ii) offsetting with revenue generation, which would mean that in addition to offsetting, revenue would be generated by applying a fee to each tonne of CO2, for instance, through a transaction fee; or (iii) an emissions trading regime (cap and trade)". International Civil Aviation Organization. (2016). Resolution A39-3: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). 39th Session of the Assembly, Montreal, September 27–October 6, 2016. https://www.icao.int/environmental-protection/Documents/Resolution_A39-3.pdf

[59]Annex VI revised as Technical Code for Nitrogen (NO) Emissions, which became effective in 2010. The regulations under Annex VI identify emission control areas (ECAs) that require the introduction of regulation for emissions of sulphur oxide, beginning with the Baltic Sea, North Sea and English Channel. IMO also permits new ECAs to be identified and demarcated by further amendments to Annex VI. This demarcation of ECAs thus imposed a new mandate on vessels, requiring them to shift to fuel oil that complies with a lower rate of sulphur oxide emission before said vessel would enter the ECA. Similarly, the Annex also introduced an emissions target for nitrogen oxides under Regulation 13 and through Regulation 14, the MEPC resolved to implement a new fuel oil standard of a lower limit of 0.50% sulphur content which would enter into force and apply to all vessels on 1 January, 2020. In 2003, the IMO Assembly adopted Resolution 23 which acknowledged the need for market-based measures to regulate emissions in international shipping. International Maritime Organization. (2005). Annex VI: Regulations for the prevention of air pollution from ships (MARPOL, the International Convention for the Prevention of Pollution from Ships). https://www.imo.org/en/about/conventions/pages/international-convention-for-the-prevention-of-pollution-from-ships-(marpol).aspx

emissions the regulation should concentrate on 'decarbonisation' than 'carbon neutrality'.

B) REGULATORY FRAMEWORK:

Preamble,

Recognising the era of space transportation and the role of private entities in the participation of space transportation to the orbital and sub-orbital regions and the necessity of them being made accountable under International Law like the States in order to prevent the environmental damage arising out of rocket fuel emissions,

Taking into consideration that, notwithstanding the precautionary measures to be taken by States, International organisations, International intergovernmental Organisations, Non-Governmental Organisations and private entities involved in the launching of space objects, damage is also caused by rocket fuel emissions,

Recognizing the need to elaborate effective international rules and procedures concerning liability for damage caused by space objects and to ensure, in particular, the prompt payment under the terms of this regulation of a full and equitable measure of compensation to victims of such damage,

Believing that the establishment of such rules and procedures will contribute to the strengthening of international cooperation in the field of reduction of rocket fuel emissions and its consequences on the environment, in the furtherance of sustainable access to space,

Have agreed on the following:

Article I

For the purpose of this regulation,

(a) The term 'damage' means loss of life, personal injury or other impairment of health; loss or damage to property of States or of persons, natural or juridical, tangible or intangible, or property of international intergovernmental organisation and non-governmental organisation.

Damage includes 'environmental damage' due to the rocket launch from the preparation

of launch , failure and in case of successful launch, such as, depletion of ozone depletion in the Stratosphere, spillage of radiological and non-radiological propellants on the environment and other such similar effect.

(b) The term 'Rocket fuel emission' means and include introduction of chemical substances into the land, water and the atmosphere by the process of combustion of rocket fuel propellants in order to propel the rocket into the outer space from launch site which causes damage to the environment.

(c) The term 'decarbonisation' means moving to an economic system which reduces the CO2 emissions with the ultimate aim of carbon free economy.

(d) The term 'space tourism' means and include travelling to orbital or suborbital regions of space without of any intention of scientific research, but only for the purpose of leisure through spacecraft or rockets.

Article II

On the basis of the principle of sustainable access of all to space and the principle of equity, there should be transfer of technology from the developed nation, in the context of rocket launch, to developing nation ensuring the long term sustainability of access to space.

Article III

With the recognition that access to space should not affect the overall peaceful enjoyment of the environment which is the common concern of all, under the era of space tourism, the private entities and non-governmental organisations, like States and Intergovernmental Organisations, shall be internationally responsible for acts which are in violation of provisions of this regulation and internationally liable for any damage according to the regulation through rocket fuel emissions and make sufficient remediation for the caused damage along with further acts of mitigating effects of rocket fuel emissions.

Article IV

It is the obligation of each State Party to do ensure sustainable development, and therefore each State party should compel through legislation to conduct Environmental Impact Assessment

by the private entities before each launch. The State Parties shall maintain the record of such Reports and it should be assessed by a competent Authority in order to give approval for the Launch. On the other hand private entities and other non-governmental organisation, shall have an obligation under this regulation to conduct Environmental Impact Assessment before each launch, in order to ensure such assessment is made even in the absence of any domestic legislation coming into place. Also, the private entities registered in a State should abide by the environmental laws of that State.

States should also maintain a registry to record the number of launches in each launch site along with details of the private entities if any, their mode of propelling the rocket towards the space, usage of rocket fuels, if any and the number of launches each private entity had done successfully. Along with it the data regarding the number of rocket launch failures and the level at which it was failed and the data regarding the spillage of any hazardous waste due to such rocket failure that would lead to possible environmental damage provided the rocket fuel emissions are measured in terms of carbon footprint of each launch.

Article V

In the membership of this regulation, the companies and Non-governmental organisations, like States and Intergovernmental Organisations under International Law, which are involved in space tourism shall also become a member of this regulation undertaking the obligations under this regulation for the sustainable development of rocket launch.

Article VI

Local Radiation Protection Authority by each State Partes shall be appointed consisting of fifteen to twenty members, being experts from rocket science, sustainable development and environment and law with different panels sitting locally, which shall function to review and authorize the proceeds of the rocket launch. In order to get clearance they should be submitted with the Environmental Impact Assessment report of each launch. The Authority shall in the exercise of its function check the regulatory limits for radiation exposure as well as reviewing and differentiating ionising radiation and non-ionising radiation and decide for clearance. There shall also be a monitoring Authority called as Launch Site Radiation Safety Personnel who monitors the radiation effects in the environment, human health and property. In their functioning these Authorities may incorporate a system of Radiological Protection which has

been developed to protect people from exposure to sources of radiation. Also these the monitoring Authority shall come up with hazardous material management plans and hazardous waste disposal plans in a sustained manner.

These local Authorities shall report the number of proposals and clearances along with failed missions to the National Radiation Protection Authority, who in turn as a matter of coordination and international cooperation provide such data to the International Regulatory Authority for Rocket Fuel Emissions.

Article VII

There shall be an International Regulatory Authority for Rocket Fuel Emissions which would consists of members from different expertise from different parts of the world with the purpose of protecting all life forms from the harmful effects of Rocket Fuel Emissions. Their function shall be to make recommendations, condemn the contaminating acts beyond limitations, fix regulatory limitations for radiation, and maintain the reports of all launch of the States Parties to this regulation. These functions they do as a representative of environment affected by human activities.

Article VIII

Any disputes between the members of this regulation, shall settle their disputes peacefully through arbitration, mediation, conciliation and other judicial methods to solve the issue.

V CONCLUSION

"The thread of the paper is long term sustainable access to space for all"[60]

Protection of Environment has become the common concern of all, wherein each individual is affected by the ill effects of environmental damage caused by any other individual at any place on Earth. This is in other words called as 'tipping point', wherein states come to a realisation that its high time to regulation or prohibit a particular act which acts as source of environmental damage and that it becomes irreversible anymore. But that tipping point will already be late in an attempt to reverse back the situation, however with the possibility of prohibiting and

[60] EarthSky. (2022, October 9). Launches: SpinLaunch plans a slingshot to space! https://earthsky.org/space/spinlaunch-slingshot-to-space/

regulating 'hereafters' to avoid any further worst scenarios. Such that, the accumulation of carbon particles on the stratosphere leading to depletion of ozone layer is already been an alarmed scenario, but the role of rocket fuel emissions as the source of introduction of carbon particles in the stratosphere has not been scientifically much researched upon to give the accurate information of contribution each particles rocket fuel emission in depleting ozone layer. Also one should not be quite when it comes to environment of the particular launch within a State, because pollution to environment at any place affects the entire family, For example. Climate change. Therefore, it is equally condemnable when the environmental damage occurs within one's own territory or people or lives. In the chapter I, the author introduces the research problem and issues, in the Chapter II the scientific part to understand how the rocket fuel emissions at different stages of launch up to stratosphere have caused damage to the environment, human being and other life forms. Chapter III dealt about the International Environmental law and International Space Law in addressing the rocket fuel emissions and the researcher has come to the conclusion that both restricts with its abstract notion without any focus of area, however with these principles the researcher realises the need of lex specialis regulation in addressing the rocket fuel emissions. Secondly, the researcher attempted to bring in the concept of international responsibility and liability on the part of private entities and NGOs participating in the space tourism, because the very establishment of the industry amounts to global concern for environment. Chapter IV is the contribution of the researcher wherein it has been attempted to come up with the regulatory framework in addressing the rocket fuel emissions and finally Chapter V leaves with the conclusion note summarising the entire research perspective.

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