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Environmental Implications of Various Divisions of Rocket Launch Operations- A Review

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ABSTRACT: -

The main aim of this paper is to highlight the impacts of rocket launches on human health as well as on the environment by examining various operations such as manufacturing, handling, transporting, and storage of chemical propellants; launch operations; dropped stages; and launch failures. An exhaustive literature review on green propellants that are better for the environment had been carried out and related issues with effects and preventions had been discussed. Based on this review, a set of creativities to promote environmental friendly sustainability for the launch industry, leading to better and greener launch practices for future had been proposed.

Keywords: *- Environmental friendly sustainable launch, Eco-friendly rockets, Green propellants, Launch industry,*

I. INTRODUCTION

Whenever there is a discussion about the environment or the climate, a lot more about transportation industry is heard rather than the rockets or space launches. There is a simple reason to the fact. Each flight into space does have a small impact on the planet it leaves behind, but—for the moment, at least—these launches are very rare. Only a couple of rockets blast off every month around the world. As a result, space travel does not register on most environmentalists' radars. Rocket engines emit reactive gases that cause ozone molecules to break apart. They also discharge microscopic particles of soot and Aluminium oxide, which may increase the rate at which those gases wreak havoc. Each assortment of rocket fuel conveys its own particular balance of ozone-draining substances: Solid propellants, for instance, are more harming than liquid ones. To exacerbate the situation, rocket dump some of these noxious wastes straightforwardly into the upper and middle stratosphere, where they can begin causing harm promptly. They also affect the water bodies in the close vicinity of the launch site.

The pollutants from the present space launches contribute to a very small percentage of the overall global pollution but have significant effect in terms of a local level. For example, the processing, handling, and storage of chemical propellants all pose major risks to the local environment and people working with these propellants. Dropped stages from multistage rockets may contain considerable amounts of unburnt fuel that is toxic for people and wildlife. Launch failures can affect the local environment significantly and threaten human life. Therefore, it is important to identify the potential health risks associated with the launch industry; to seek greener technologies and propellants that are better for the environment.

An extensive literature review on five topics that are important in understanding the environmental impact of the space launch industry had been conducted in this study. These topics include; a) propellant and green launch technology, b) health and environmental effects of propellant and rocket exhaust, c) economics of the launch industry, d) space policy and environmental regulations, and, e) existing outreach programs regarding space launches and the environment. These five topics have been discussed in details based on the inputs and data available in open literature through various portals and web domains. The authors believe that it is important to consider all of these related topics to propose initiatives that are environmental friendly and yet practical and viable.

II. IMPORTANT TERMS

Sustainability came from the Brundland Report, published in 1987, which suggests a strong link between economic development and the environment. A sustainable activity considers the impact on future generations with respect to economic, environmental and social aspects at all phases during the project.

Green Propellant is a general name for a family of propellants that satisfy requirements such as low toxicity, low pollution, good storability, wide material compatibility and optimum performance. Presently, it is not possible to develop propellants that are harmless to lifeforms as well as the environment; therefore, green propellants should be viewed in the context of sustainability where the life cycles of green fuels are better for the environment than conventional propellants.

Green Technology is the application of science to preserve the environment i.e. minimizing the generation of pollution and risks to the ecological systems and human health. The concept of sustainability is central in the development of green technology.

Space Launch Industry or Space Activity stand for organizations dealing with the manufacturing, transporting, handling, and storage of rocket propellants and launch operations for orbital and sub-orbital flights. The environmental impact of the launch industry is limited to launch operations and dropped stages from multistage rockets.

III. LAUNCH TECHNOLOGY

Propulsion - Propellant selection for launch vehicle system is a trade-off between propulsion performance characteristics and hazard potential, such as toxicity and pollution impact. Through years of research and development, the number of propellants has been narrowed down to the following: kerosene, LH_2, and UDMH as liquid fuels with LOX or N_2O_4 as oxidizers. For solid propellants, HTPB is being used as the main binder, Aluminium as a fuel source, and Ammonium Perchlorate as the main oxidizer. Currently, greener propellants have the technical potential to replace traditional ones; especially in the case of liquid propellants. However, there is a compromise in performance, as well as additional costs, which have limited the adoption of greener propellants.

Analysis - Out of the various solid propellants used in the launch industry today, 33% contain AP as oxidizer. The use of AP releases chlorinated compounds into the atmosphere which can cause significant damage to the ozone layer. The UDMH/ N_2O_4 combination accounts for 26% of liquid propellants used by launch industry. These are highly toxic in nature and are very difficult to handle. Another 20% of rocket fuels are cryogenic which requires costly infrastructure for storage and handling. The applications of cryogenic propellants are limited to boosters or first stage due to their low density specific impulse.

Recommendations

In the field of solid propellants, alternative oxidizers, such as AND, HNF, etc. could replace currently used AP. This could help to reduce the environment effects of launches. Further research into the use of semi-cryogenic propellants could help to replace conventional propellants with greener alternatives, especially in the booster and first stage.

IV. HUMAN HEALTH AND THE ENVIRONMENT

There are both human health and environmental risks associated with rocket launch operations. These activities can be divided into three categories: pre-launch, successful launches and failed launches.

Pre-launch – Hazardous and toxic chemical compounds (for example ammonia and sodium hypochlorite) used in the manufacturing of propellants can cause acute or chronic bodily harm. A preliminary analysis showed that in the manufacturing of the propellants for the Ariane 5 launch vehicle, about 20,000 tons of CO_2 per vehicle is released into the atmosphere, contributing to the greenhouse effect.

Successful Launches - Plumes from a rocket launch releases chemicals such as aluminium oxide and hydrochloric acid into the atmosphere that can be harmful if inhaled at the high concentrations typical around the launch site. The exhaust products can also contaminate the ground and water. When stages are dropped as part of a successful launch, a major concern for people living within the impact area is the danger of being struck by falling rocket debris.

Failed Launches - In the case of a failed launch, apart from the explosion itself, effects on human health and environment will be amplified mainly because of the larger quantities of unburned fuel dispersed on the surface of the Earth and in the water bodies. This fuel can be highly toxic to humans, wildlife and aquatic life.

Recommendations – The authors propose the development of systems to allow monitoring the detailed analysis of launch activities on human health and ecological systems to quantify the effects of both orbital and suborbital launches.

V. BUSINESS AND ECONOMICS OF GREENER LAUNCH ACTIVITIES

Launch Business: Today and Tomorrow – To evaluate the influence of introducing green technology to the launch industry, an analogy with the US automobile industry in the 1970s was made. Based on this study, more restricted environment regulations would mandate space industry to invest in R&D for green technologies. However, the introduction a new rocket using green propellants should increase the insurance rates for the initial flights since the technology is unproven. According to an analysis, designing a completely new rocket with green propellant could cost about EUR 7.7B, which is slightly higher than a rocket using conventional fuel. These major investments will be necessary as the number of people interested in a greener environment is increasing. The development of the sub-orbital flights may provide a good opportunity to introduce greener propellants to the launch industry.

Recommendations – To promote a greener space industry, the authors would like to recommend that the research and development budgets at space agencies and launch companies need to be increased. In particular, increasing the resources for developing greener solid propellants. It is believed that a greener solid propellant can be retro-fitted to existing launch systems without major modifications. This technology would provide an optimum return on investment and environmental benefits. An increase in the R&D budget will also stimulate interest in the space industry as well as increase the number of research opportunities for other stakeholders. The development of environmental performance metrics will be a boon. They could be used as a marketing tool to promote the sustainability of the launch industry for space tourism.

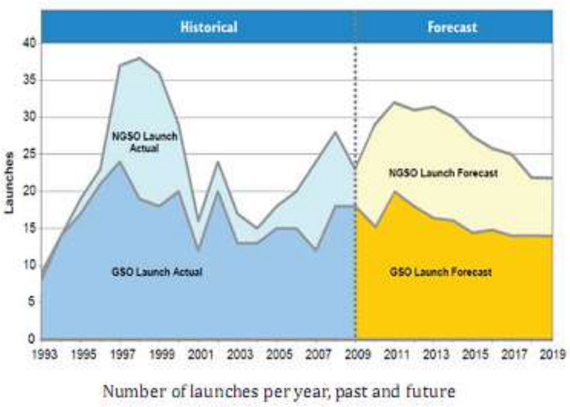

Figure 1: Data of number of Launches in 3 decades

VI. SPACE POLICIES AND ENVIROMENTAL REULATIONS

Treaties – Several international agreements aimed at protecting the environment: the 1979 *Geneva Convention on Long-Range Transboundary Air Pollution* (also known as the Air Pollution Convention); the 1987 *Montreal Protocol on Substances That Deplete the Ozone Layer* (Montreal Protocol); and the 1997 *Kyoto Protocol to the United Nations Framework Convention on Climate Change* (Kyoto Protocol). These treaties do not have sections tailored towards space launch activity.

Regulations – About environmental launch regulations, each space agency has its own set of policies. In the United States, NASA and the FAA have created a set of regulations to comply with NEPA. NASA also established an EMS to address environmental issues. In Europe, ESA has created a Coordination Office on Sustainable Development which addresses environmental, economic, and social sustainability. Both CNES and NASA have certified their spaceports with ISO:14000 standards. Under the China Environmental Protection Law, all organizations in China, including the launch industry must undertake plans for environmental protection and take effective measures to prevent and control environmental pollution.

Recommendations - All current and future spacefaring nations should ratify the existing international environmental treaties. It is also required of these nations to come together and draft an international agreement for space sustainability which seeks to protect the environment as nations undertake space activities. It is also recommended that all space agencies adopt environmental management systems with external third-party audits to ensure compliance with national environmental regulations as well as adopt best practices that are environmentally sustainable. These recommendations can be realized through the formation of the SSDB,

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and the expansion of ICAO to include space activities.

VII. EDUCATION, OUTREACH AND PUBLIC AWARENESS

The authors have identified the state of current outreach programs available at space

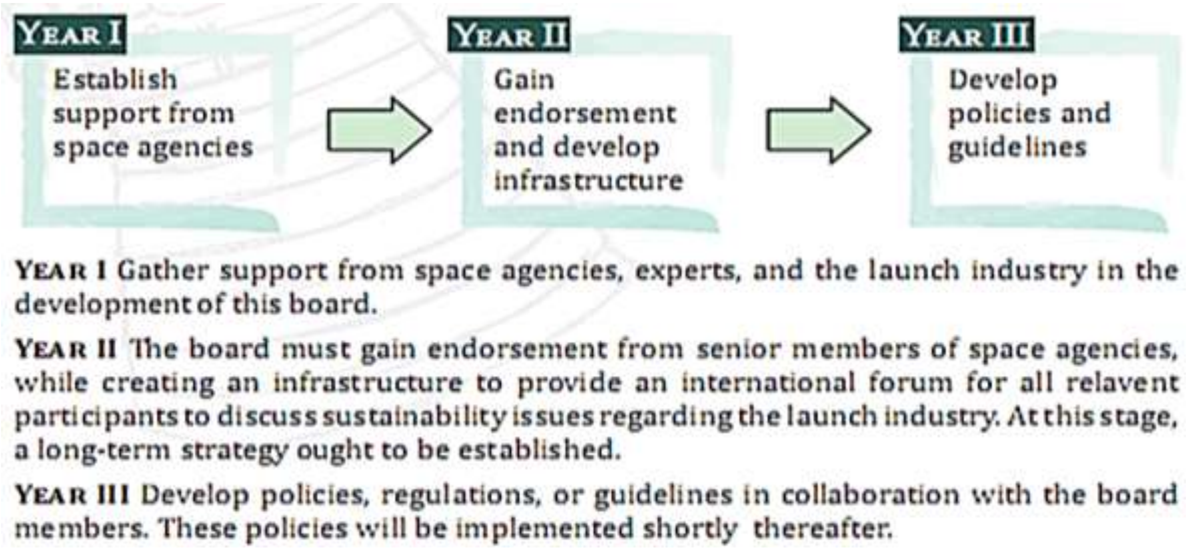

Figure 2: Flowchart for the concept of Greener Space

agencies, private space companies and international organizations. Since the concept of greener space is relatively new, it has not been the focus of space agency educational outreach programs. Although NASA and ESA have outreach activities in the area of environmental management. In the commercial sector, private space companies address environmental issues in their publications, indicating it is important to them. As an example, Virgin Galactic emphasizes in their marketing that the carbon emissions per passenger, per trip into suborbital space, will be less than a one-way flight between Europe and the USA. After identifying gaps within the above information sources, an initial survey was conducted to determine the public's interest in supporting green initiatives in the launch industry. Preliminary results suggest that those who purchase environmental friendly products are willing to pay up to 25 percent more for green space services, which indicates that existing techniques to market green products can be adapted to market a green space industry.

VIII. CONCLUSION

Based on the various discussions and facts presented in this paper, the authors would like to propose a scheme (as depicted in the Figure above) which can be worked out for better and greener rocket launches and in turn reduce the effects of rocket launches on the environment globally. This scheme will serve as a step-by-step process for the space industries to carry out launches in future without affecting the ecological balance and producing any further damage to the environment.

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