UNITED NATIONS
Office for Outer Space Affairs

SKYROOT AEROSPACE

Promoting Space Sustainability

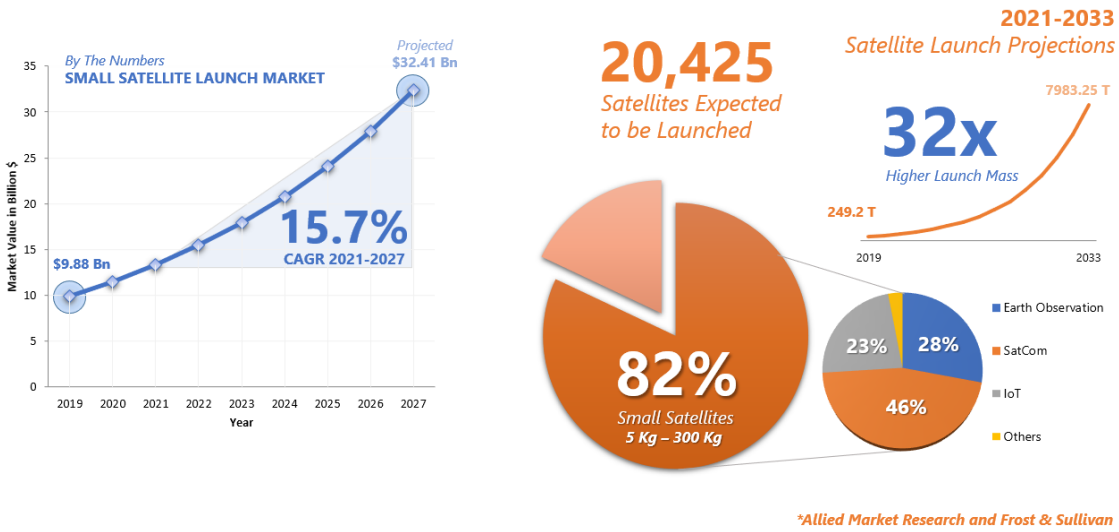
International Compliance of Private Launchers in Developing Nations

Skyroot Aerospace Pvt. Ltd.
16th June 2021

Implementation of the Guidelines for the Long-term Sustainability (LTS) of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space

Operational Case Study: The Story of Skyroot Aerospace and India's rise as a haven for New Space Activities

Since the advent of the Space Race, technological advancements have led to a NewSpace revolution, beginning with university nanosatellites comprising commercial off-the-shelf components which far exceeded the expected life in space, leading to an opportunity for all stakeholders, present and new, to access space on a pocket-friendly budget. This CubeSat revolution and miniaturization, coupled with the application of Moore's law and economies of scale, has culminated in a huge market potential over the next decade for small satellites globally.



2030 Market Insights: Allied Market Research, Frost & Sullivan

Even with an expectation of 20,000+ satellites to be launched with an estimate of 32 times the mass compared to the total mass launched in 2019, the international launch market has still not tapped this potential. The two major types of launchers and their benefits and challenges to satellite customers need to be understood to understand the cause of this gap:

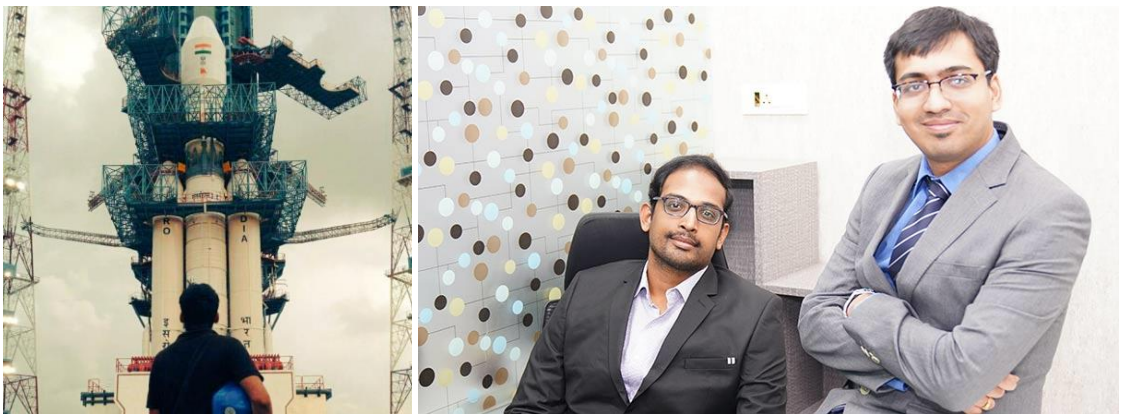
1. **Large Scale Launchers (Example: SpaceX):** They send huge masses of payloads to space, and are more inclined and optimized for large payloads, human missions and cargo transports. The smaller satellites are generally stowed in available space, require to book via a launch aggregator, are reliant on the comfort of the Large Launchers and the significantly larger payloads, which may lead to launch delays or extra efforts for entering the desired orbit with the desired parameters, projecting to huge decrements in profits and increased expenses due to the satellite company's operational timeline delays hence caused. The upside is an **extremely low and lucrative price tag per kg** of mass sent. Generally, the Smaller Satellites are *Ride-Share Payloads* as compared to the larger *Dedicated Payloads*.
2. **Small Scale Launchers (Example: RocketLab):** They have significantly lower payload capacities but can provide same altitudes as Large-Scale Launchers and **even extra features such as dedicated orbit insertion, phase change and desired altitude raising in space, more convenient integration, launch facilities on the logistical end and even priority on the satellite customer's mission architectures.** These do occur at a slightly higher price per kg compared to Large Scale Launchers but are significantly lower than the conventional Satellite Launch Vehicle average market price.

There are many upcoming companies around the world trying to enter into this new **"Dedicated Small Satellite Launcher"** market, but the companies with a successful development and testing record or a commercially positive operation are very few. Even for any one company at full operation now would only address less than 4% of the market demand and still make a huge profit. With more Technology Readiness Level increase for the range of technologies such as green and economic propulsion, reusable launch vehicles and mass production technologies being implemented, the very small increment in price compared to a Large Scale Launcher would drop and nearly match.

The factors that would define the expensiveness outside the technical parameters is the national advantages for business and operations. India is currently one of the strongest spacefaring nations, only behind US, China, Europe and Russia in terms of heritage. As a developing nation with a world-famous reputation for highly skilled human resources and low labour cost, and lower operational costs as compared to most developed countries and generally a supportive economic scenario for businesses and entrepreneurs and most economic activities, India is a top-level location to invest in space activities or most businesses. The Indian Space Research Organization (ISRO), India's pride and the entity responsible for India's progress in space, amongst other national agencies with the support of the Government of India, is globally known for its frugal innovation and successes in a short span since its *Inception*, even being able to successfully send an orbiter to Mars on a budget lower than *Interstellar* considerations, inspirational to all.
To add to the above benefits, in 2017, the Government of India released the Draft Space Activities Bill, which was a motivator for few entrepreneurs to brave up and venture out with their start-ups. ISRO having set the benchmark by developing the basic infrastructure for a spacefaring nation plans to expand

and rise to higher challenges, such as its own space station with the *Gaganyaan* mission, the *Aditya* mission to fly closer to the Sun, more progress in *Mangalyaan* and *Chaandrayan* for Mars and Moon respectively, and even the *Shukrayaan* aimed at Venus. If private companies enter in and actively participate in the opportunities in the Low Earth Orbit, more resources of the government can easily be redirected for the exploratory progress of the nation in space, in turn leading to spin-off technologies returning and growing the economy, as visible in the diversity and growth and technological advancement of the US after NASA and its activities, for instance. From nearly two dozen space start-ups after the draft bill, the number rose to more than 350 in the aerospace sector with a huge rise in start-ups involved in space directly or indirectly ranging from launch, satellite development, services, commercial support, education and other spin-off fields.

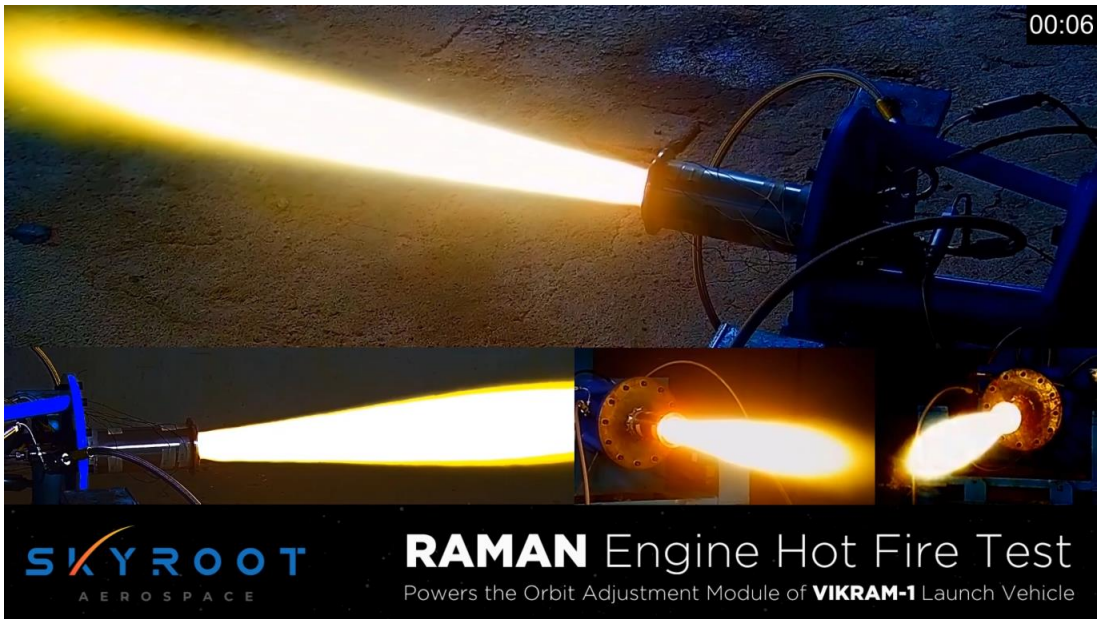
With an extremely supportive Government and Department of Space providing support such as Kerala Space Park dedicated for incubating Space Start-ups, Innovation Grants such as the ARISE-ANIC to foster and raise participation and incentivize innovation amongst space start-ups, and ISRO always providing a highly supporting ecosystem ranging from launch location and licensing, regulatory, and operational support such as telemetry and tracking and transport to list some, and the introduction of a new dedicated regulatory player named Indian National Space Promotion and Authorization Center (IN-SPACe) to support public-private collaborations and boost the Indian Space Ecosystem, India has risen from one of the most cost-effective space-friendly nations to arguably the best value-for-money location to cross Karman lines and beyond the horizon, truly paving the way for democratized space, affordable and accessible to all.



Pawan Chandana entering ISRO with a youngster's curious mind in 2012 and revolutionizing Private Rocketry with co-founder Bharath Daka today at Skyroot Aerospace with ISRO's training.

Skyroot Aerospace Private Limited, established in 2018 by Pawan Kumar Chandana and Naga Bharath Daka, two former ISRO scientists on a mission to support the nation's progress in space with their activities in the private sector, are on the verge of providing dedicated small satellite launches to satellite and other scientific payload customers from India and around the world, open to commercial, research and nearly any beautiful space dream that may be realized with their Vikram series of launch vehicles, currently successfully tested at the component level and nearly complete at systems level, aiming to have its first launch in 2022.

Successful Test fire of the Kalam Motor, qualifying the main three stages of Vikram-1 Launcher



Successful Test fire of the Raman Engine, qualifying the orbit insertion propulsion of Vikram-1

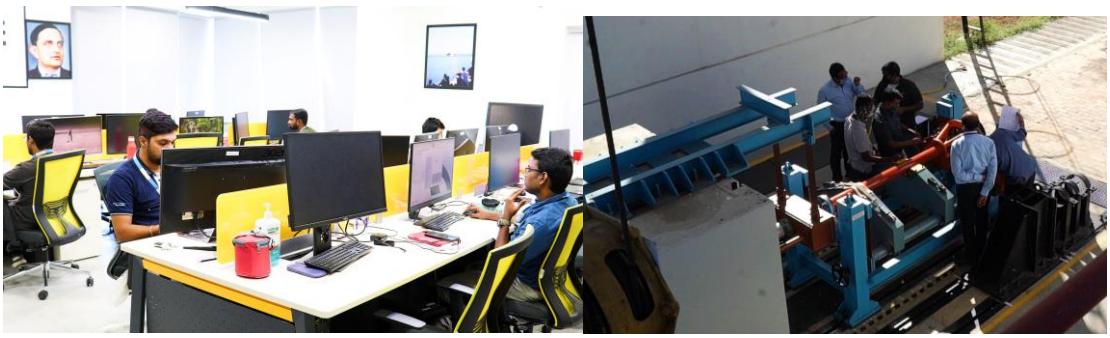
The indigenously developed launch vehicle using reliable technologies with a smaller size makes the price point very lucrative and affordable. With support from ISRO and the Government of India, Skyroot aims to launch and provide customers the best launch experience at a lucratively low-price tag. Skyroot is also the first Indian company to successfully 3D-print a Liquid Oxygen – Liquefied Natural Gas-powered engine in two days (generally takes a year or two), the next-generation fuel Musk and most Space Agencies worldwide has his bets on to revolutionize the economics of Martian Colonization in a green and pocket-friendly manner.

The Government of India and ISRO are also supporting Skyroot in this endeavour as it successfully won the ARISE-ANIC grant for Green Propulsion. Skyroot has taken the pre-emptive consideration of adhering to the sustainable goals of the UN to provide a comfortable environment for its

launch customers, i.e, movement towards greener propulsion and environmental considerations, responsible use of orbit insertion modules and disposal of used stages to prevent hazardous incidents, economic and judicious use of existing propellants to minimize impact, and best practices and compliance followed according to the benchmarks set by ISRO, the Government of India and other successful and admirable space players and in a constant process of being pre-emptively adherent to the Space Activities Bill and other regulatory and licensing and insurance in formulation by Government of India, ISRO, IN-SPACe and other key entities, who ensure the opinions of all private players, including Skyroot, are taken into consideration, providing confidence to grow and proceed towards the aim of making space access reliable, economic and affordable to all, from India, for the world. For its efforts, Skyroot was recognized and awarded the National Startup Award in 2020 by the Startup India initiative of the Government of India.

Skyroot wins the National Startup Award 2020 for Space in Launch Vehicle Category

Today, more vigorously than ever, Skyroot strives, powered by its intense and inspirationally obsessed team who stop at nothing to overcome all challenges, to democratize space access and start taking payloads to space in 2022, with future visions of growing and supporting the global space economy in larger endeavours such as human space flight and journey beyond the stars.



#TeamSkyroot relentlessly defying all odds in-office and on-site.

I. Short description of the outer space activity

A National award-winning growth-stage start-up, founded by former ISRO scientists, Skyroot Aerospace is building India's first private small satellite launch vehicles. With dedicated anchor investors and a closely-knit world-class team of 70+ with a combined expertise of over 500 years in the rocket industry onboard, our mission is to offer reliable and economic launch services for satellite companies worldwide.

Its core product, industry-leading Space launch vehicles called the Vikram series — named after ISRO founder Dr Vikram Sarabhai in honour of his contributions to the Indian Space sector — consists of three launch vehicles developed especially for launching small satellites. The Vikram Series are based on upgradable architecture, for launching small satellites and offer affordable, reliable and responsive launches to Low Earth Orbit (LEO).

Vikram-1, Skyroot's flagship Launch Vehicle, is an indigenously built three-stage solid propellant launch vehicle with a 4th liquid propellant kick stage for control and orbit adjustment (called Orbit Adjustment Module – OAM), designed for launching multiple small satellites to wide range of Low Earth Orbits. It is designed for rapid launch and production capabilities using highly reliable and proven solid propulsion boosters, and liquid propellant orbit adjusting stage for increased mission flexibility. Vikram-1 has been designed and being developed by Skyroot Aerospace leveraging best of Indian heritage and acumen for building reliable launch vehicles, while keeping mass producibility and simple low-cost architecture as the key drivers to achieve a launch cadence and flexibility the Satellite operators need. With an adaptable design with feasible potential for a diverse range of launch facilities and support from ISRO and the Government of India, some of the auxiliary facilities provided to customers include, but are not limited to:

- Logistics coordination and support
- Provision of templates for deliverables
- Mission integration analyses [CLA, thermal, trajectory]
- Creation and management of interface control document and associated verifications
- Facilitation of range safety review process
- Provide required signals for Satellite deployment
- Satellite electrical interfacing
- Fairing temperature, humidity and cleanliness control assurance
- Satellite processing facilities with temperature and humidity control
- Installation of customer logo on Satellite fairing

- Mission operations support during launch and deployment
- Confirmation of separation and provision of state vector
- Post-flight report
- Mission feasibility analyses
- Provision of deployer and hardware testing
- Custom Satellite adapters
- Additional analyses cycles
- Early integration studies
- Provision of electrical harness and connectors
- Umbilical connection to EGSE
- Enhanced cleanliness controls
- Satellite transportation to launch site

Skyroot aims at the first launch of Vikram-1 in 2022 and welcome space enthusiasts worldwide to utilize this opportunity to reach for outer space at the lowest price tag.

The next-generation technology Skyroot is building today will unlock potential or latent demand for sustainability interventions, space-based research, data analytics, and telecommunications.

II. Connection with the LTS Guidelines

With the operations in the Indian ecosystem, recently privatized and fully supporting private participation, understanding of the LTS Guidelines provides Skyroot an opportunity to understand and provide maximum comfort zones for international customers, while adhering to the Indian regulations and policies under development and maintaining compliance to UNOOSA's guidelines as a responsible space player. Some connections inferred, limited by the author's capacity in all aspects and not representing the opinions of any organizational entity, are listed below:

A. Policy and regulatory framework for space activities

- **Guideline A .1 — Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities:** India is pre-emptively developing IN-SPACe as a regulatory agency to support the national growth in the space sector for both private and public entities for ensuring each player operates in the space ecosystem responsibly and judiciously, providing more confidence to Skyroot for operating in the ecosystem.

- **Guideline A .2 — Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities:**
  2(a) Skyroot engages only in peaceful uses of outer space with its Vikram series of launch vehicles.

2. (b) The Orbit Adjustment Module's Design and Operations are done with responsible disposal methods in mind after operations and minimize space debris formation.
2. (c) (d) Skyroot strives to move towards eco-friendly and green propulsion and responsible use of space, as demonstrated by its R&D activities towards LOX-LNG propulsion and Orbit Insertion efforts of high precision and deorbit strategies for the Orbit Adjustment Module and careful release of spent stages to ground.
2. (f) (g) (h) (i) Skyroot is constantly striving to ensure maximum compliance to licensing, regulatory, and insurance standards and follows best practices to ensure safety to all connected stakeholders in all angles. Skyroot also invites any and all entities interested in developing technologies or running programs to advance the cause of bettering human lives to utilize its launch capabilities.

- **Guideline A .3 — Supervise national space activities:** Skyroot, in adherence to best practice, aims to comply with the policy, regulations and standards to be put forth by IN-SPACe and the other agencies of the Government of India and regularly participates in the opportunities provided to contribute its opinions to provide a hassle-free experience to all customers.

- **Guideline A .4 — Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites**
  1,2,3,4,5. Skyroot's launch vehicles do not use extremely penalizing bandwidth or spectrum to provide comfortable use for customers and adhere to ITU and Government of India's rules and regulations on the same and aims to use its capabilities judiciously.
  6. As iterated above in A.2., Skyroot takes into consideration the responsible use of space to prevent space debris formation and aims to utilize its rocket stages and terminate mission after completion accordingly and in a safe and judicious manner.

- **Guideline A .5 — Enhance the practice of registering space objects:** Skyroot aims to adhere to the best practices performed by launch vehicle operators reinforced by the Government of India to ensure maximum safety and probability of mission success.

B. Safety of space operations

- **Guideline B .1 — Provide updated contact information and share information on space objects and orbital events**
- **Guideline B .2 — Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects**

As a private company and to adhere to the Right to Privacy and maintain proprietary status for Skyroot as well as Private customers, there are limitations to the data permitted to release from the company. Yet, in

adherence with government rules and regulations full cooperation will be provided to the best ability by providing data required for regulatory, licensing and other relevant purposes.

- **Guideline B .4 — Perform conjunction assessment during all orbital phases of controlled flight**
- **Guideline B .5 — Develop practical approaches for pre-launch conjunction assessment**

Intended Conjunction is not an activity currently in the capability or interest of Skyroot's launch vehicles, although if at all in any remote sense orbit insertion may come under the umbrella of definition, Skyroot aims to provide pre-flight and post flight reports covering all possible scopes of assembly, integration, tests and Trajectory and performance reports along with other relevant flight data to customer and other regulatory entities as to be required by law in future. Addressing unintended conjunction, Skyroot aims to adhere to best practices to avoid hazardous incidents of any manner.

- **Guideline B .6 — Share operational space weather data and forecasts**
- **Guideline B .7 — Develop space weather models and tools and collect established practices on the mitigation of space weather effects**

Receiving highly accurate and actionable space data is beneficial to Skyroot to provide maximum launch cadence accurately with minimized scopes of delays or cancellations due to weather, as it is one of the largest reasons of launch delays and cancellations. With the supportive environment in India data will be provided by national agencies but with computational studies the accuracy of extrapolated data always increases with more quantity of raw data to evaluate, which, if accessible internationally via a database curated by UN (possibly with support from UN-SPIDER and other sub-agencies utilizing weather data), it could revolutionize the accuracy of launch window estimations and in turn make launches more successful to further support users of such data such as launch operators.

- **Guideline B .8 — Design and operation of space objects regardless of their physical and operational characteristics:** As a small satellite launcher, being able to track existing small satellites prior to insertion of payloads, collision avoidance of trajectory, and awareness of successfully and unsuccessfully deorbited objects of smaller scale is accurately possible only with relevant measuring instrumentations, whose technology is yet to be developed as by definition of Space Debris any object below 5 cm is difficult to track and constitute a large segment of the currently identified space debris, and the side length of a typical nanosatellite is in the centimetre range, directly relevant to the customers.

- **Guideline B .9 — Take measures to address risks associated with the uncontrolled re-entry of space objects:** As iterated in A.2, A.4.6, B.4 and B.5, Skyroot aims to operate in the safest manner possible, including the mission phase of stage re-entry. The telemetry and tracking facilities ISRO and the Government of India supports Skyroot with is also intended to prevent any and all such hazardous incidents caused by uncontrolled re-entry. Skyroot also aims to redundantly track the stages using alternative methods.

C. International cooperation, capacity-building and awareness

- **Guideline C .1 — Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities:** As a commercial entity, Skyroot is open to international customers and operate in accordance with the laws and regulations to be prescribed and brought in effect by the Indian Government, and international laws as and where applicable. Hence, international organizations are welcome to utilize Skyroot's facilities and expertise as an Indian Private company to further the advancement of humankind in space from India.

- **Guideline C .2 — Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange:** If at all there is any non-proprietary data generated by Skyroot which is legally allowed to be shared and does not compromise customer privacy, which contributes to the long-term sustainability of outer space activities, Skyroot, as a responsible space entity, would gladly oblige to provide the data conditional to the activity being in adherence to the Indian Government laws and the company policy.

- **Guideline C .3 — Promote and support capacity-building**
- **Guideline C .4 — Raise awareness of space activities**

As a commercial and payload agnostic launch provider, Skyroot understands the infinite plethora of opportunities to utilize each ride to space with a Vikram launch vehicle, from both a commercial and an intergovernmental/interorganizational perspective. As iterated above, Skyroot welcomes any and all such opportunities with support from the Government of India, ISRO and other entities of the State and would execute it in adherence to the regulations and policies laid out by the Indian authorities involved. Skyroot would also be willing to support any humanitarian efforts utilizing space in the best of its capacity, along with the capacity development opportunities for students of India and the world to catalyse the technological innovations and advancements for tomorrow.

D. Scientific and technical research and development

- **Guideline D .1 — Promote and support research into and the development of ways to support sustainable exploration and use of outer space**

- **Guideline D .2 — Investigate and consider new measures to manage the space debris population in the long term**

  If at all there is any non-proprietary data generated by Skyroot which is legally allowed to be shared and does not compromise customer privacy, which contributes to the cause of space debris monitoring, management and mitigation, Skyroot, as a responsible space entity, would gladly oblige to provide the data conditional to the activity being in adherence to the Indian Government laws and the company policy. With a dedicated R&D wing, Skyroot would also collaborate for any activity whose end product or conclusions would catalyse the advancement of space activities to the best extent possible as a private company.

III. Lessons learned

As a start-up growing in the Indian ecosystem to serve the international market, a clearer understanding of the LTS guidelines of the UNOOSA is a required exercise to ensure the compliance of activities at an international scale. The understanding of best practices and policies formulated and recommended also provide guidelines to the scope of activities, their effects and awareness as to the possible mitigation options for any unforeseen incidents. In an industry such as Space, where the complexity is so severe even a millisecond difference in the computer clock can cause mission failure, any well-articulated guideline is an eye opener to the perspective of the organization documenting and releasing the same, and as an international organization, the guidelines of the UNOOSA are an indirect indicator of the years of experience and trial and error leading to policy formulations based on best practices of most space players worldwide to generate effective and efficient performance and result in all activities of space undertaken at not just national but a global scale, much required insight for a private participant in the global space sector adherent to all applicable laws to ensure convenience to customers in the long term.