ROCKETRY CAPSTONE

WHAT STANDARDS CAN BE IMPLEMENTED IN THE LAUNCH VEHICLE INDUSTRY TO REDUCE WASTE?

A Thesis Prospectus
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The launch vehicle (LV) industry is entering a period of growth that hasn't been seen since the Apollo program. According to the space foundation, in 2022 the space industry was valued at $469 billion, with the majority 'coming in from the commercial sector (Space Foundation, 2023). SpaceX is poised to launch every 2.5 days in 2024, and smaller companies like Rocketlab and Relativity Space are on their heels in terms of technological innovation and projected growth. (Satellite Today, 2023b) According to a report by Deloitte, the aerospace industry is poised to grow by 15.7% each year after 2021. (Deloitte, 2021)
The telecommunications and defense industries increasing reliance on satellite technology is one of the main contributors to the growth in the industry. Furthermore, the use of satellite imaging has had an impact on environmental research, meteorology, aviation, urban development and the intelligence sector.

However, this expansion has held a light to the massive amounts of waste in the industry, with aerospace component manufacturing wasting 30-50% of materials used due to inefficient manufacturing methods. Another problem being encountered is space debris, where satellites and components that orbit around earth stay in stasis past their system's shutdown. As of 2013, there is over 300 million kilograms of debris, (Shan, Guo, & Gil, 2016) with NASA recommending that 5-10 large space debris objects be removed every year to counteract the growth. Space Debris is incredibly dangerous, not just because of potential collisions with crewed and uncrewed craft, but a concept known as the Kessler Syndrome. The Kessler syndrome occurs when the density of space debris in orbit is so high, that debris ends up colliding with itself, creating smaller fragments that then begin to orbit with a faster angular velocity around the earth, and colliding with more space debris. These fast moving objects create an incredibly dangerous environment that would make parts of lower earth orbit (LEO) inhospitable for any craft, crewed or non-crewed. (Riley, 2016)

Given these parameters, while satellite imagery is becoming a prevalent resource for a number of purposes, finding an alternative that doesn't result in as much waste during the device's production and post-mission would have significant benefits both financially and environmentally. This leads to my technical project, which is to design a rocket that deploys its payload near apogee (maximum altitude during flight). The intended payload will be a deployable glider that will circle around the launch zone and gather imagery using an onboard camera. I will use this as a proof of concept to demonstrate how unmanned aerial vehicles (UAV's) deployed from smaller LV's that don't need to stay in orbit as an alternative to constantly launching satellites for imagery.

BENEFITS OF UAV TECHNOLOGY

Satellite imaging is used as a resource in a number of fields, including agriculture, urban development, defense and security, and climate research. Furthermore, different satellite systems are equipped to gather data at different ranges depending on the use case. (Jacobsen, 2005) This means that UAV's can't be used in cases like tracking the size and movement of large storms like El Nino or monitoring the activities of a countries navy, (NASA, 2023)but it can be used in fields like urban development, monitoring crops for agriculture, and assisting with disaster response. (Nicolic et al, 2013)

The amount of strain placed on local infrastructure due to the increase in launches has been documented by the DoD, (Satellite Today 2023a) and in conjunction with the Space Force, has determined that over the next two years, launches at both DoD spaceports will grow by 100%-200%, with ‘commercial activity [already] accounting for 90% of the launches’. The expected growth is determined to be fueled by commercial endeavors, with smaller launch companies like Stoke Space beginning to move past the development stage for their multi-use rockets, more companies besides market leaders require a more expansive infrastructure to be in place to continuously meet launch goals. This increase in demand creates significantly more overhead for the DoD, both in terms of increased costs, as well as general resources like power, fuel and personnel, that interferes with the locality in which the spaceports operate. Given the small number of launch sites in America, and the current projected strain to be placed on them in the next few years, there is precedent to move to a more decentralized system to gain imagery from small launches with deployable UAV’s.

Another benefit of UAV’s is they require less computational resources to operate, with targeted data acquisition from these smaller missions means that there is less extraneous data being collected. Furthermore, by using the right imaging methods (infrared, optical, etc.) during collection, less post-processing or data filtering is required, leading to less time and energy being used during operation. (Manley, 2018)

Given the drawbacks of having lots of imaging satellites in LEO, deploying smaller LV's equipped with UAV payloads is a sustainable alternative. Additionally, space debris is eliminated, all parts of the system can be reused indefinitely, less resources are required to deploy, and specialized launch sites aren't required. Given these technical benefits of using UAV's for small scale satellite imagery, I believe that this is a suitable alternative to certain satellite imaging systems.

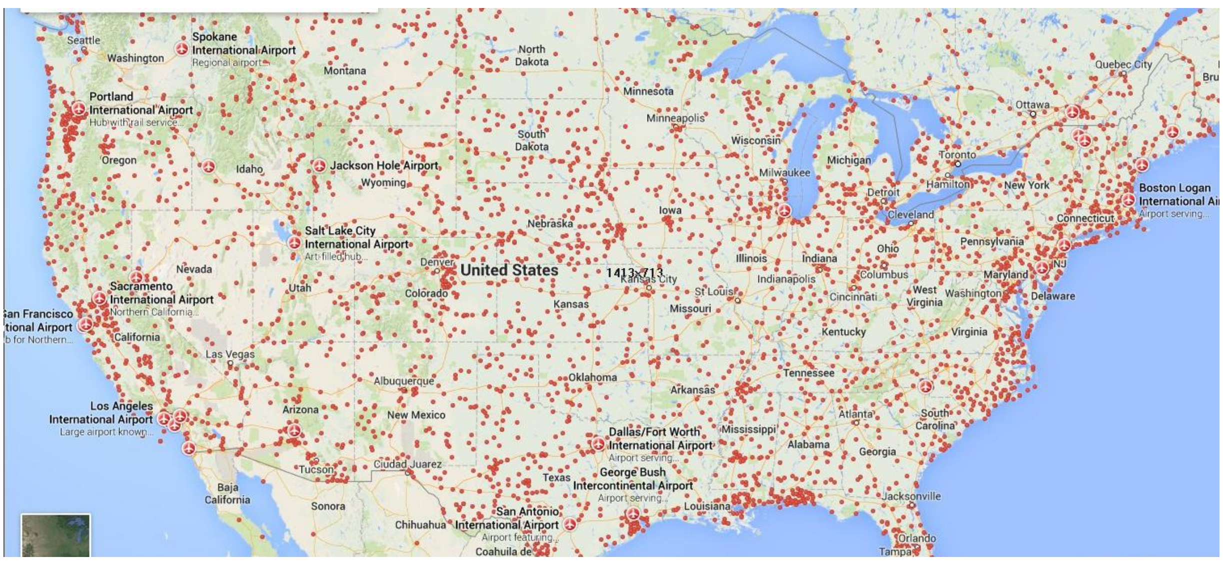

Figure 1. A map of airports in America (Airport)

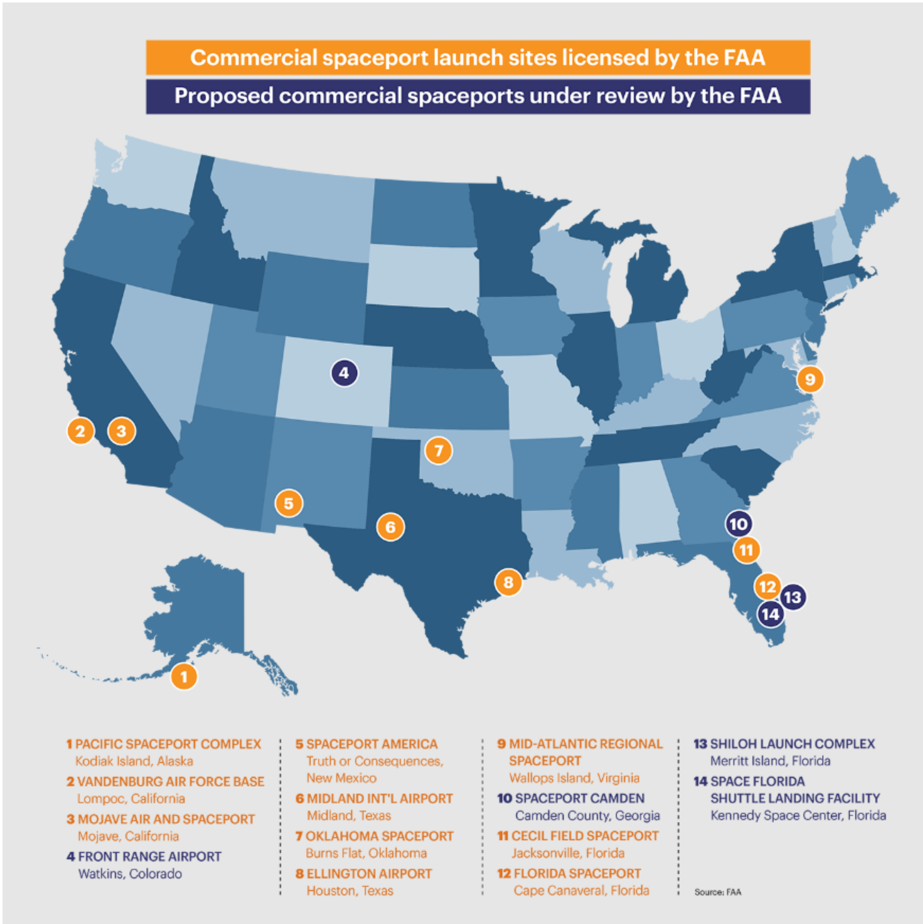

Figure 2. A map of spaceports in America (FAA, 2018)

INFRASTRUCTURE AND SOCIETY

In The Ethnography of Infrastructure (Star, 1999) Star presents infrastructure as a system that influences both human and nonhuman actors, as well as being reactive and proactive in how it ports into the socio-political values of its users. Tonkiss' definition of technological infrastructure takes it from a more literal standpoint, by outlining it as a societal tool that allows for the collective consumption and collective disposal of resources. (Tonkiss, 2015). Tonkiss then shows how infrastructure can change based on temporal cultural values, an example being the Sami, an indigenous population in northern Scandinavia, having to move their pasturing animals from certain regions and grazing paths due to the necessity for the instalment of satellite antenna and other telecommunication equipment. While this change did affect the infrastructure used by the Sami to maintain their livestock (Ojani, 2023) it did allow the region to maintain standards in terms of their telecommunication infrastructure systems, with Tonkiss even stating that the local privatization of infrastructure can subvert systems further from their embodiment of standards'.

This risk of decentralizing infrastructure systems does seem to contradict with the proposed technical solution, however, Geels' multilayered perspective theory (MLP) (Geels, 2002) gives a framework in which we can understand how to facilitate small instances of technological transfer while reducing its potential consequences. MLP is a concept that has roots in Actor-Network-Theory (ANT), (Latour, 1992) but applies it to larger technological systems instead of individual artifacts by creating a series of layers in which the system can be analyzed. Geels first talks about the sociotechnical landscape, which can be explained as the cultural, political and environmental factors that shape and constrain technological systems for long periods of time. Within this landscape, a 'patchwork' of technical regimes can exist, Rip and Kemp's 1998 paper best describes technological regimes, "A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures" (Kemp et al, 2001)

The final layer is arguably the most relevant to this prospectus, the niche layer, in which technology transfer can be initialized. Smaller technological innovations on a technical regime level might not be adopted across an entire infrastructure immediately but can grow on the niche layer over time before being adopted into smaller regimes. From there, should the innovation be able to fit in the technical regime and embed itself in the sociotechnical landscape, then technological transition has occurred.

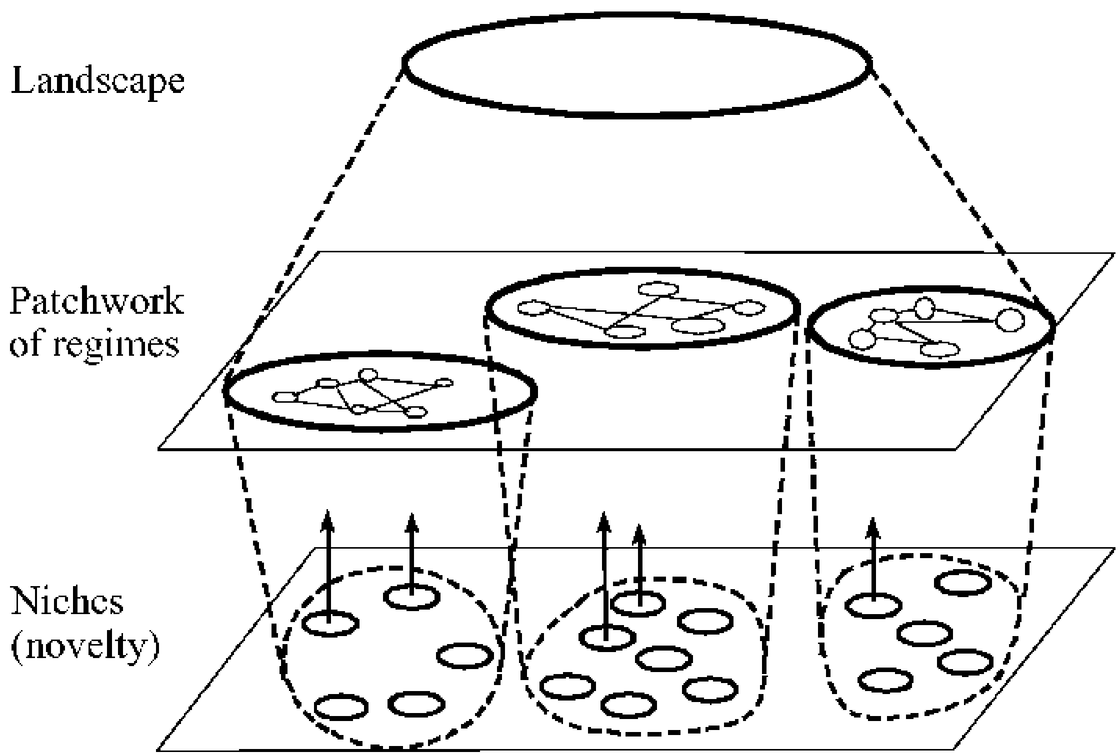

Figure 3. Layers in MLP (Geels, 2002)

Given the projected growth of the aerospace industry, and our need to keep certain satellite imagery systems in place for utilities like GPS and major meteorological research, it makes no sense to try to remove the infrastructure in place completely. But by targeting a certain sublayer of satellite imaging infrastructure, not only can we attempt to directly minimize the consequences associated with technological transfer, but we can ensure that the proposed changes maintain an embodiment of standards with the current infrastructure in place. Looking forward to my thesis, I believe the main sociotechnical relationships will be between end users who have a need for small scale satellite imaging alternatives, current imaging technologies in place, my proposed technical solution of using UAV's, and any aerospace regulatory organizations. There are many more stakeholders that are already affected by our current infrastructure, including those that live near launch sites, as well as the stakeholders of all the equipment in LEO that may be damaged by the predicted increase in space debris. (DoD, 2023)

PROPOSED RESEARCH METHODOLOGY

Given the problems faced in the industry and my current technological solution, I have decided that the research question my thesis will attempt to answer as: To what extent can a decentralized system of small-scale LV's equipped for imaging and data collection replace our current satellite imaging infrastructure? Not only will this set an effective precedent for how the LV industry can reduce waste by switching to an alternative system, but it will also allow me to determine a realistic scope for my technical project's end solution.

To find a conclusive answer, I plan on doing a literature review of STS-related papers that pertain to infrastructure, as well as looking at case studies involving the evolution of transportation infrastructures. From here, I intend to define both the socioecological landscape and existing technological regimes that pertain to satellite imagery. By defining these first two layers as clearly as possible, I will be able to create a verifiable basis to determine if technological transfer can occur by seeing if using small LV's equipped with UAV's is a sustainable 'niche' in line with MLP.

My plan for looking at case studies is to find all those that discuss the change in transportation infrastructure during periods of technological transition, and I plan on using RK Yin's methodology (Yin, 2012) to assist in my review of them. Using both methods, I hope to ascertain how effective a decentralized system would be, and how far it could replace current use cases that we apply to satellite imagery.

CONCLUSION

Returning to my initial problem; What standards can be implemented in the launch vehicle industry to reduce waste? I believe that my formulated research question will give me sufficient evidence to propose my technical project's product as an adequate solution to reduce waste in the LV industry. Not only will it reduce the waste seen in LEO, but also the computational strain of having to dissect large swathes of data before going through the resource intensive process of post-filtering to gain meaningful insights.

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