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The space sector has undergone a transformative shift from being predominantly governed by state agencies to a burgeoning market driven by commercial entities. This evolution has been catalysed by multiple factors, positioning the space industry as a robust and burgeoning market with substantial economic prospects.



ABSTRACT

The future of the space sector appears promising, marked by anticipated growth and continuous innovation. The convergence of cutting-edge technologies, heightened commercial engagement, and supportive governmental frameworks is poised to propel the expansion of space-related endeavours.

As this market matures, the space sector stands to become a cornerstone of the global economy, offering new avenues for exploration, investment, and economic advancement.

Characterized by rapid technological advancements, increasing commercial ventures, and significant investment opportunities, the space sector continues to redefine our engagement with outer space. It presents compelling prospects for businesses and investors prepared to navigate the complexities inherent in this transformative industry.





**LET'S US
GET INTO**

INTRODUCTION

AirLaunch is a pioneering company dedicated to revolutionizing the satellite launch industry with our innovative V1 launch vehicle. Our primary focus is on launching smaller satellites using our proprietary "pneumatic tube launch" method, which significantly reduces launch costs compared to traditional methods. This approach is expected to lower our cost per kilogram to orbit by 10-20% relative to our competitors. The V1 launch vehicle employs the pneumatic tube launch method for its initial ascent. The first stage is designed for mid-air recovery using our advanced 3-axis catch equipment, ensuring full reusability and further reducing launch costs.

Initially, the second stage of the rocket will be expendable. However, our long-term goal is to achieve full reusability across all stages of the vehicle, as we believe this is essential for making space exploration truly cost-effective. Full reusability is vital for the future sustainability of the space industry.

The V1 launch vehicle primarily serves to validate our launch and recovery techniques. Upon successful demonstration, we plan to develop larger, more efficient rockets that are fully reusable. We are confident that the future of the space industry lies in 100% reusable rockets, and AirLaunch aims to be at the forefront of this transformation.



USP

Why Choose AirLaunch?

In an industry crowded with experienced and skilled companies, you might wonder what sets AirLaunch apart from the competition. Our primary differentiators are our proprietary "pneumatic tube launch" method and our innovative first stage catch technique.

Launching rockets is notoriously expensive, with costs per kilogram to low Earth orbit (LEO) reaching \$2,700 for the Falcon 9 rocket. Given Falcon 9's 22,800 kg capacity, each launch totals \$61.5 million. If we could enhance Falcon 9's initial flight phase to achieve a 10% increase in capacity, it would result in a saving of \$6.1 million per launch.

Considering Falcon 9's 96 launches in 2023, this capacity increase could translate into an annual saving of \$585.6 million for Falcon 9 alone.

PNEUMATIC TUBE LAUNCH METHOD

Our pneumatic tube launch method utilizes large tanks of compressed air, released instantaneously, to propel the rocket to near supersonic speeds before it exits the launch tube. Upon exiting the tube, the rocket ignites its engines to continue its journey to orbit.

Using Falcon 9 as an example, accelerating the rocket to 500 km/h (approximately Mach 0.4) with ground support equipment could reduce the first stage burn time by 30 seconds from the average 170 seconds.



This represents a 17.6% or 69,463kg reduction in first stage fuel required, enabling a much heavier second stage payload with minimal additional cost per launch.



FIRST STAGE 3-AXIS CATCH PLATFORM

Our advanced 3-axis catch platform is designed to recover the first stage booster mid-air, ensuring full reusability. This system can capture the rocket within a 5-10 meter landing tolerance, providing a significant safety margin during early landings to ensure success.

Equipped with a range of sensors, the platform determines the rocket's exact location and velocity during its landing burn. The platform's four corner catch points move towards the rocket as it descends. The two-layered catch platform stabilizes and slows the rocket: the bottom layer makes initial contact and travels downward with the rocket, while the top layer brings the rocket to a complete stop without causing damage.

In summary, AirLaunch's unique pneumatic tube launch method and innovative catch technique significantly reduce launch costs and improve reusability. Our approach offers a compelling value proposition for customers seeking cost-effective and reliable access to space.



WHAT IS PNEUMATIC ENERGY AND HOW DOES IT PROVIDE SUCH SIGNIFICANT ACCELERATION?

Pneumatic energy, commonly used in industrial applications such as automated equipment and motor racing, operates through the use of compressed air. It's a relatively safe and clean energy source suitable for various environments. The acceleration force generated by pneumatic energy depends on the surface area it acts upon. For instance, an air gun in a factory with a 5 mm diameter nozzle operating at 5 bar pressure produces a force calculated as:

$$F(N) = P(Pa) \times A(m^2) = 500,000Pa \times \pi \times (0.0025)^2 = 9.8N$$

In contrast, our launch tube with a 12-meter diameter plate, at the same pressure, generates a force of:

$$500,000Pa \times \pi \times (6)^2 = 56,520,000N$$

This substantial force can only be achieved if we have sufficient pneumatic energy stored and can release it instantaneously.

Theoretically, the speed of air through our system should approach the speed of sound. Our goal is to accelerate rockets to speeds between Mach 0.5 and 0.8. Through first and second stage testing, we will determine efficiency losses due to friction and other factors, allowing us to calculate the exact pressure requirements for specific accelerations.

For example, if a satellite contains delicate components that cannot withstand acceleration forces over 5g, we can precisely calculate the necessary air tank pressure to limit acceleration accordingly. This precision ensures that we can safely and effectively launch payloads with varying sensitivity to g-forces.



PNEUMATIC TUBE LAUNCH DESIGN

The design of the pneumatic tube launch system is straightforward in concept, though its final implementation involves considerable complexity. The system comprises three main components:

- Launch Tube
- Launch Plate
- Air Tanks

Launch Tube

The launch tube is a long vertical structure, typically 100-150 meters in length. The longer the tube, the greater the achievable acceleration. Increasing the diameter of the launch tube exponentially increases the acceleration. The rocket begins at the bottom of this tube, positioned on the launch plate, and is accelerated upwards through the tube into the air.

Launch Plate

The launch plate, which matches the area of the launch tube, has a minimal gap between itself and the tube walls to prevent compressed air from escaping. The rocket is attached to this plate at the bottom of the tube. Upon release of the compressed air, the launch plate is propelled up the tube, catapulting the rocket into the air where it ignites its engines to continue its ascent to orbit.

Air Tanks

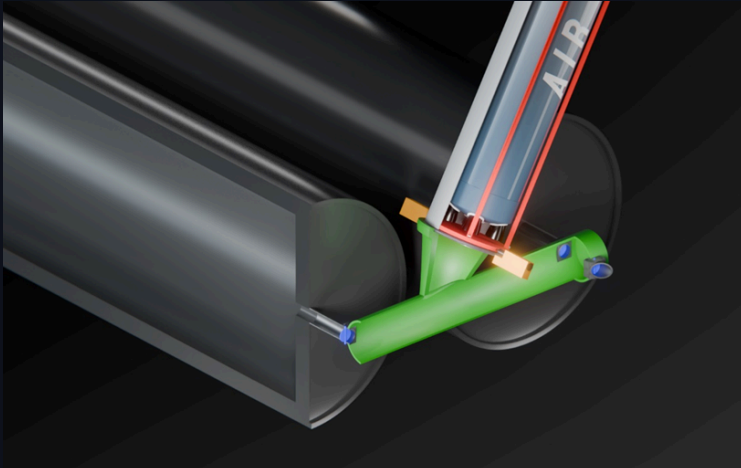
The air tanks are filled with pressurized air before launch. To prevent significant pressure loss as the launch plate ascends, the total capacity of these tanks needs to be 8-10 times the volume of the launch tube. A critical aspect of the air tanks is the launch valves, which are situated between the tanks and the launch tube.

The total open area of these valves must be slightly larger than the area of the launch plate to ensure that full instantaneous pressure acts on the plate, providing maximum acceleration. These tanks can be pressurized over hours or days and can release all their energy within seconds during launch. This design leverages the simplicity of pneumatic principles to achieve significant acceleration for rocket launches, combining efficiency with innovative engineering to reduce costs and improve launch capabilities.



PNEUMATIC TUBE LAUNCH DRAWING

Below is a simple 3D drawing of the pneumatic tube launch system.



The rocket booster sits on the red launch frame whilst being held down by the hydraulic release pins. Just before launch, the blue valves from the air tanks will open, flooding the green manifold with high pressure air. When ready for launch, the hydraulic pins will release, accelerating the rocket up the launch tube (launch speeds shown in the subsequent calculations section)

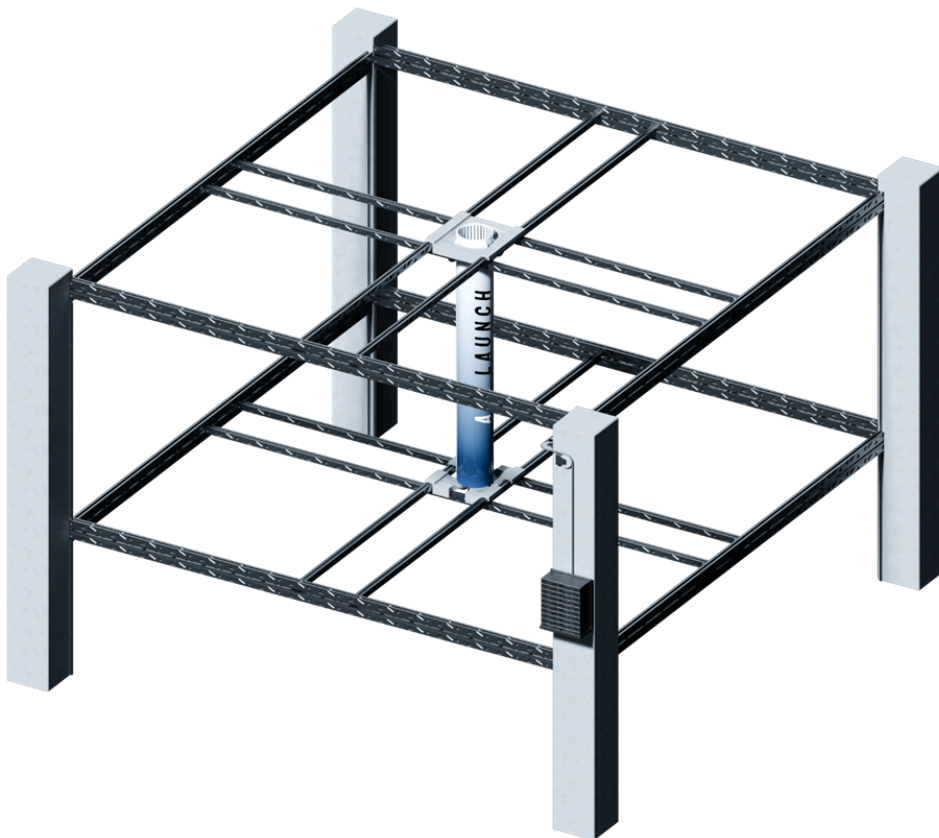


CATCH PLATFORM DESIGN

The design of the 3-axis catch platform is also a relatively straightforward idea that can offer considerable benefits over competitors. It can allow for some quite significant inaccuracies in landing position to still result in a successful catch.

The system comprises three main components:

- Booster stabilisation arms
- Vertical stabilisation rollers
- Catch Arms



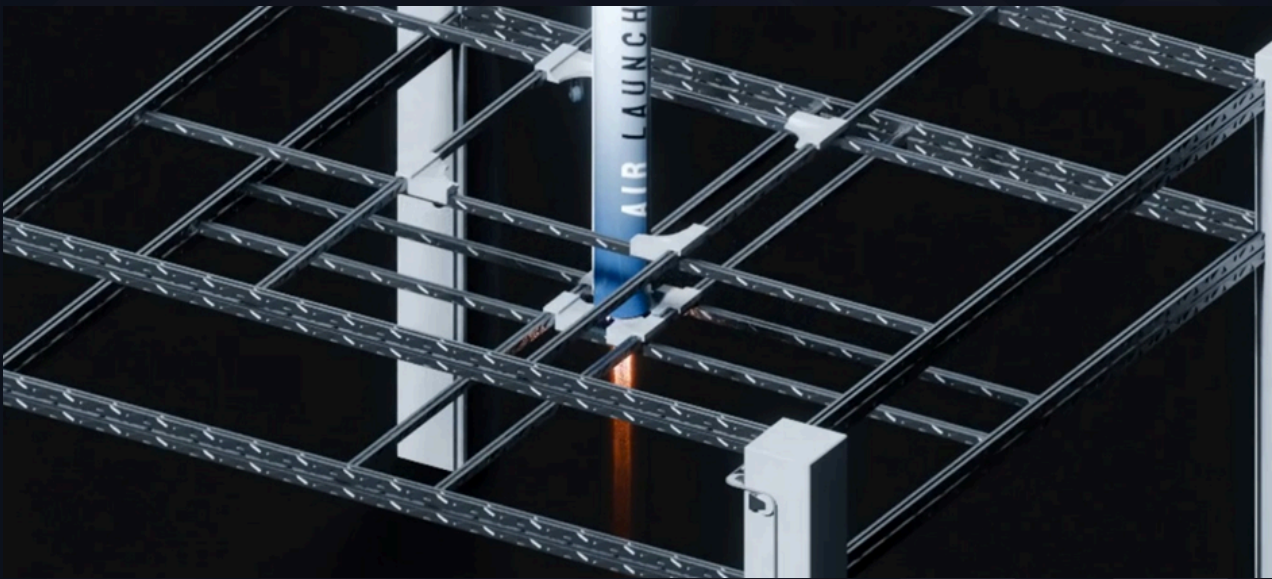
As the booster arrives at the catch platform, it will light its engines so that the last few meters of its journey towards the catch platform are at a slow and steady pace.



Booster stabilization arms

The booster stabilization arms serve as the initial point of contact with the booster. These arms are equipped with precise location sensors to accurately detect the speed and position of the booster as it approaches, allowing for seamless contact when the booster is within range.

Upon contact, the stabilization arms engage with the booster at the top of the frame, with this section of the frame designed to move downward in sync with the booster's descent. At this stage of the catch process, the stabilization arms will not bear any significant weight, as they will be descending at the same rate as the booster.



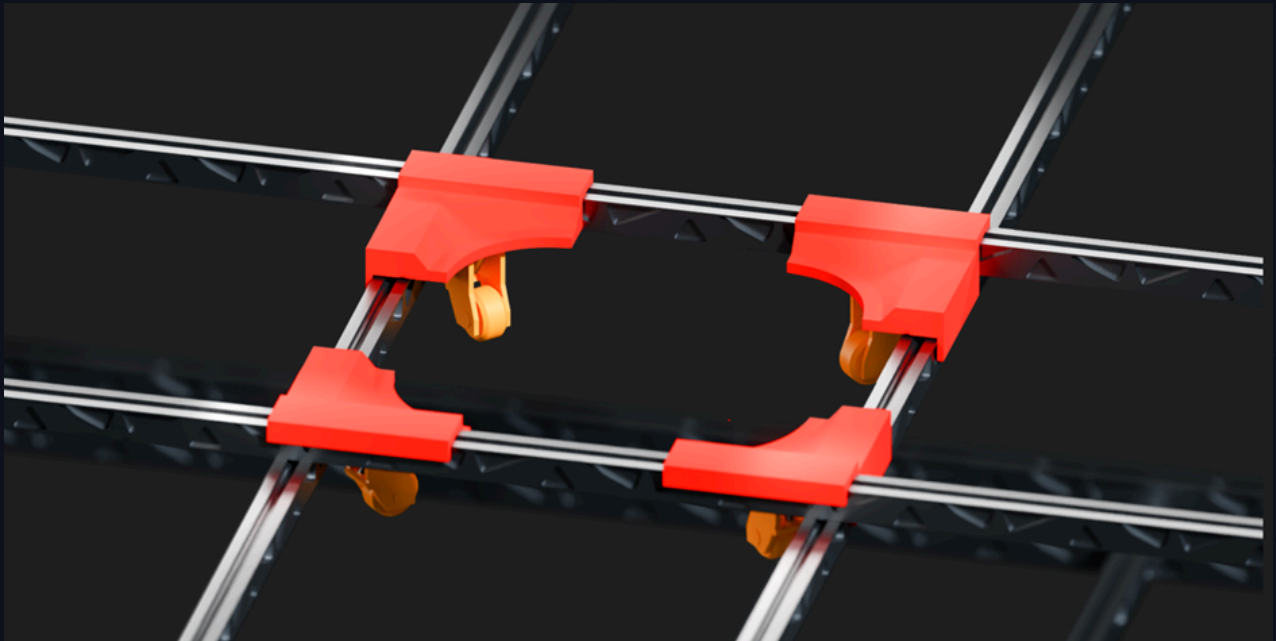
As the booster nears contact with the catch arms, the booster stabilization arms will begin to bear a significant portion of the booster's weight—up to 50%. This ensures that the load is evenly distributed across the two layers of the platform, enhancing stability and minimizing stress on any single component.

Vertical Stabilization rollers

The vertical stabilization rollers move toward the booster, making contact shortly after the booster stabilization arms. Although the rollers can move horizontally to engage with the booster, they are fixed to the top layer of the catch platform and cannot move vertically.

As the booster descends through these rollers, they apply a controlled amount of pressure, helping guide the booster in the desired direction, if necessary.





These rollers are attached to the red catch arms so that they can ensure the booster is in perfect position for when the final contact is made.

Catch Arms

The catch arms serve as the final stop for the booster. By the time the booster reaches this level of the platform, the booster stabilization arms will have secured the bottom, and the vertical stabilization rollers will have corrected its angle. As a result, the booster arrives at the catch arms in the precise position required for a secure capture.





The catch arm layer will incorporate a dampening mechanism to prevent shock loading during contact. As the booster engages with the catch arms, the booster stabilization arms will simultaneously bear a significant portion of the weight, ensuring an even distribution of the load across the system

Benefits

The advantages of this booster catch method, compared to current competitor landing techniques, include:

- No need for landing gear on the booster, reducing overall booster weight.
- The system can accommodate landing inaccuracies of 5-10 meters.
- The catch platform stabilizes the booster and corrects its angle prior to the final capture.
- The booster is secured from both the bottom and top, ensuring full support for a controlled and stable landing.



CALCULATIONS

To illustrate the scalability of our launch method, let's use the Falcon 9 as an example, even though our rockets will be smaller in scale.

For 8-meter Diameter Launch Tube

Given parameters

- Falcon 9 mass (m): 549,000 kg
- Launch plate diameter (D): 8 meters (D = 8 m)
- Launch plate area (A):

$$A = \pi \times \left(\frac{D}{2}\right)^2 = \pi \times (4)^2 = 50.24 \text{ m}^2$$

- Air pressure (P): 10 bar = 1,000,000 Pa

Force (F):

$$F = P \times A = 1,000,000 \times 50.24 = 50,240,000 \text{ N}$$

Acceleration (a):

$$a = \frac{F}{m} = \frac{50,240,000}{549,000} = 91.5 \text{ m/s}^2$$

Net Acceleration (subtracting gravity):

$$\text{Net Acceleration} = 91.5 \text{ m/s}^2 - 9.81 \text{ m/s}^2 = 81.7 \text{ m/s}^2$$

Velocity after 2 seconds:

$$v = a \times t = 81.7 \text{ m/s}^2 \times 2 \text{ s} = 163.4 \text{ m/s}$$

Distance traveled:

$$d = \frac{1}{2} \times a \times t^2 = \frac{1}{2} \times 81.7 \text{ m/s}^2 \times (2 \text{ s})^2 = 163.4 \text{ m}$$

This is an exit speed of 588 km/hr if we have a launch tube of 163.4m in length. Increasing launch tube length will add further acceleration to the rocket.

For 12-meter Diameter Launch Tube

Given parameters

- Launch plate diameter: 12 meters ($D = 12\text{ m}$)
- Launch plate area (A):

$$A = \pi \times \left(\frac{D}{2}\right)^2 = \pi \times (6)^2 = 113.04\text{ m}^2$$

Force (F):

$$F = P \times A = 1,000,000 \times 113.04 = 113,040,000\text{ N}$$

Acceleration (a):

$$a = \frac{F}{m} = \frac{113,040,000}{549,000} = 205.9\text{ m/s}^2$$

Net Acceleration (subtracting gravity):

$$\text{Net Acceleration} = 205.9\text{ m/s}^2 - 9.81\text{ m/s}^2 = 196.1\text{ m/s}^2$$

Velocity after 1.5 seconds:

$$v = a \times t = 196.1\text{ m/s}^2 \times 1.5\text{ s} = 294.15\text{ m/s}$$

Distance traveled:

$$d = \frac{1}{2} \times a \times t^2 = \frac{1}{2} \times 196.1\text{ m/s}^2 \times (1.5\text{ s})^2 = 220.725\text{ m}$$

This is an exit speed of 1058km/hr but would require a launch tube length of 220.7m.

Considerations

- Friction and Pressure Losses: Friction and pressure losses along the launch tube are expected to reduce speed by 15-25%. This will be determined during testing but improved designs can reduce these losses.



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- For example, early iterations of the launch tube will likely have the launch plate guided up the launch tube on some form of rails but advanced designs might adapt maglev principles to reduce friction.
 - G-Forces: The first set of parameters results in a force of 8g on the rocket, while the second set produces close to 20g. Launch pressures must be tailored to the rocket's maximum stress tolerance but the rocket will be designed with high g-force in mind so that we can achieve maximum tube exit velocity.

These calculations demonstrate the potential scalability and efficiency of our pneumatic tube launch method, highlighting its capability to significantly reduce launch costs and improve payload capacity.





LAUNCH PROCEDURE OPTIONS

There are two options available for the launch procedure:

Option 1

The rocket begins at the top of the launch tube, positioned on the launch plate, where it connects to all necessary ground support equipment for engine chilling and purging. Approximately 1-2 minutes before launch, the support equipment retracts, and the launch plate lowers to the bottom of the tube in preparation for launch.

Option 2

Ground support equipment is situated at the bottom of the launch tube and can retract into the side of the tube mere seconds before launch.

In both options, the rocket must autonomously initiate engine startup procedures independent of ground support equipment. Starting engines during the initial tube launch phase, under high g-force conditions, optimizes launch efficiency. Failure to do so results in a 10-20% loss of acceleration between tube exit and engine ignition. Importantly, neither option necessitates a water deluge system or pad heat protection, as the rocket clears the pad before engine ignition. This approach significantly benefits the environment and local surroundings





CURRENT MARKET LANDSCAPE

In the current space launch market, several notable competitors exist alongside our planned venture:

SpaceX:

SpaceX stands out as a prominent competitor. Our primary advantage over SpaceX lies in our significantly more efficient launch technique. Additionally, our innovative 3-axis catch platform eliminates the need for landing legs on the rocket, mitigating potential engine damage and operational complexities associated with ground landings. Unlike SpaceX's approach of using a launch tower for Starship booster recovery, which poses challenges and risks if not perfectly executed, our catch platform offers greater tolerance for landing inaccuracies.

SpinLaunch:

SpinLaunch is pioneering a novel approach by accelerating rockets using a centrifugal accelerator to speeds up to 5000 mph before launching into space. However, this method imposes extreme loads, up to 5000G, limiting the types of payloads that can be feasibly launched to specialized satellites designed to withstand such forces.

Virgin Orbit:

While Virgin Orbit is no longer operational, their concept involved launching rockets from a Boeing 747 aircraft near the speed of sound. Challenges included the complexity and cost associated with launching from an aircraft, as well as the prolonged disconnect period of the rocket from ground support equipment before launch, which contributed to operational difficulties and ultimately led to the closure of the project.

Strategic Differentiation

Our approach not only addresses these challenges but also offers a clear strategic advantage in terms of efficiency, operational flexibility, and environmental impact.

By focusing on innovative launch techniques and robust recovery systems like the 3-axis catch platform, we aim to redefine the standards of cost-effectiveness and reliability in the space launch industry.





CHALLENGES TO OVERCOME

As we advance our launch capabilities, several key challenges must be addressed:

High G-Forces Endurance:

Rockets and payloads must withstand higher-than-usual G-forces during the initial seconds of launch (10-20G).

While SpinLaunch is confident in producing satellites capable of enduring 5000G, this may still restrict approximately 20-30% of payloads during full-pressure launches. Adjusting launch pressures (for delicate payloads) can mitigate this impact, albeit at reduced efficiency for specific missions.

Autonomous Engine Ignition:

Engines must reliably ignite without reliance on ground support systems. Ensuring all engines are equipped for in-space relights or landing burns minimizes dependency and operational risks associated with ground infrastructure.

Engine Ignition Under High G-Forces:

Ideally, engines should commence ignition sequences within 1 second of exiting the launch tube to optimize performance. Delays up to 4 seconds result in velocity losses of up to 141 km/hr (15-20% depending on launch speed).

Initiating engine startup post-tube exit reduces acceleration efficiency but can be optimized to minimize losses, aiming for a 2-second ignition delay to reduce velocity loss to 70 km/hr.

Efficient Launch Plate Deceleration:

Efficiently decelerating the launch plate at the end of the launch tube is critical to maximizing acceleration distance. This engineering challenge will be addressed during stage 2 testing, evaluating various methods to optimize plate deceleration within minimal distance constraints.

Addressing these challenges through rigorous testing and iterative refinement will strengthen our capability to deliver efficient, reliable, and cost-effective launch solutions in the competitive space launch industry.





STAGE 1 RESEARCH AND DEVELOPMENT – SMALL- SCALE HORIZONTAL LAUNCH TUBE TESTING



The initial stage of our research and development focuses on validating the performance of compressed air as a launch method through practical testing. This involves launching various masses along a 50-meter horizontal launch tube using a 2-inch diameter pipe to bridge theoretical concepts with real-world applications.

This stage will also involve the detailed design of the 3-axis catch platform so that a better CAD model can be produced for the stage 2 fundraising. Additional parts of stage 1 will include logo/website design as well as a small marketing campaign to improve the chances of stage 2 full funding.

Objectives

- Evaluate the effectiveness of compressed air propulsion.
- Study friction effects and material/design impacts.
- Collect velocity data using pressure sensors along the launch tube.
- Determine efficiency factors by assessing energy loss due to friction and pressure.
- Inform future scalability decisions based on empirical data.

Testing Equipment

- Generator with fuel (4-6 kW)
- Air compressor (10 bar)
- Air receiver tank (minimum 1000L capacity)
- 3-inch pneumatic ball valve (ensuring unrestricted pressure flow)
- 3-inch pneumatic butterfly valve (assessing pressure release dynamics)
- 50-meter launch tube
- Various launch projectiles (different designs/materials)
- 10 pressure sensors (response time <10 ms)
- Software for data acquisition and analysis



Logistics and Timeline

- Testing location conducive to experimental needs.
- Estimated cost: £160,000–£180,000.
- Duration: 12–18 months.

Key Performance Indicators

- Achieve an efficiency factor exceeding 75%.
- Attain a minimum tube exit velocity of >600 km/hr.

Critical Success Factors

- Rapid release of pneumatic energy.
- Minimization of friction between projectile and tube.
- Reduction of pressure loss during propulsion.

By rigorously testing these factors in a controlled environment, we aim to gather essential insights that will inform subsequent phases of development towards scalable and efficient launch technologies.

These foundational tests are pivotal in bridging theoretical projections with practical outcomes, setting a robust foundation for future advancements.





STAGE 2 RESEARCH AND DEVELOPMENT – LARGE- SCALE VERTICAL LAUNCH TUBE TESTING

Stage 2 of our research and development initiative focuses on scaling up our launch method with a 24-inch vertical launch tube, establishing a permanent testing facility for comprehensive experimentation.

Objectives

- Evaluate operational dynamics of larger-scale launch tubes.
- Test various launch plate designs and stabilization methods.
- Develop effective systems to halt the launch plate at the tube's exit.
- Investigate robust launch valve designs capable of rapid, full-area release within 0.1 seconds.
- Prototype a small-scale model of the 3-axis catch platform to validate functionality and sensor efficacy.
- Initiate rocket design phase to integrate findings into vehicle development.

Facility Requirements

- Permanent test facility for vertical launch tube operations.
- Comprehensive infrastructure for launch plate stabilization and control.
- Dedicated research team for concurrent system design and testing.

Technological Focus

- Optimize launch tube mechanics for efficiency and safety.
- Refine launch valve performance to meet scalability demands.
- Validate 3-axis catch platform functionality and sensor integration.

Financial Projection

- Estimated cost: £4-6 million.
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Strategic Milestones

- Demonstrate operational viability of launch and catch systems.
- Attract investor interest for phase 3: launch vehicle development.

Stage 2 represents a critical advancement phase, laying the groundwork for scalable and efficient launch technologies. By meticulously testing and refining key components, we aim to establish a robust foundation for subsequent phases, ensuring readiness for full-scale vehicle development and commercial deployment.





STAGE 3 COMMERCIAL SCALE DEVELOPMENT OF ROCKET

Stage 3 marks the full-scale development phase of our business, encompassing the comprehensive creation, testing, launch, and catch of the rocket.

Objectives

- Rocket Development: Advance from prototype to full-scale rocket production.
- Testing and Validation: Conduct rigorous testing to ensure reliability and performance.
- Launch Operations: Execute commercial launches utilizing our innovative launch method.
- Catch System Deployment: Implement and validate the 3-axis catch platform for reusable rocket recovery.

Key Activities

- Prototype Refinement: Iteratively refine rocket designs based on data from previous stages.
- System Integration: Integrate launch and catch systems into a cohesive operational framework.
- Regulatory Compliance: Obtain necessary permits and certifications for launch operations.
- Market Entry: Enter the commercial space launch market with competitive pricing.
- Customer Engagement: Secure contracts and partnerships for satellite deployment and other payloads.

Infrastructure and Resources

- Establish production facilities for rocket assembly and integration.
- Expand testing facilities to support full-scale rocket testing and validation.
- Recruit skilled personnel across engineering, operations, and support functions.

Financial Commitment

- Allocate resources for scaling operations and ensuring financial sustainability
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- Budget for ongoing research and development to refine technology and enhance capabilities.

Strategic Goals

- Achieve successful commercial launches with high reliability and customer satisfaction.
- Position as a leader in cost-effective and reusable space launch solutions.
- Expand market presence and capitalize on growth opportunities in the space industry.

Stage 3 represents the culmination of our technological advancements and strategic planning, marking a significant milestone in revolutionizing space access through innovative launch and recovery solutions.





THE TEAM

Currently, the team for Stage 1 consists of myself, James Borland, collaborating with several trusted electrical and mechanical contractors whom I have established relationships with over the years. Based in Belfast, I hold a degree in aerospace engineering from Queens University Belfast and bring a diverse background in engineering roles across various industries.

Professional Background

- **Aerospace Expertise:** Previous roles include manufacturing engineer for a company specializing in composite aircraft and missile components.
- **Mechanical Precision:** Experience as a mechanical engineer in precision electrical component manufacturing.
- **Current Role:** Currently engaged as a manufacturing engineer with a focus on project engineering in the medical PVC manufacturing sector.
- **Project Management:** Certified in Prince 2 foundation and practitioner project management, involved in numerous CAPEX projects annually ranging from £20k to £3m.

Skills and Expertise

- **Technical Proficiency:** Well-versed in pneumatic systems, pumps, valves, and project management.
- **Strategic Insight:** Strong understanding of engineering fundamentals, facilitating confidence in the potential of the pneumatic tube launch method.
- **Team Leadership:** Prepared to manage and coordinate all aspects of Stage 1 and Stage 2 initiatives.

Future Plans

- **Expansion Strategy:** Stage 2 will involve significant team expansion to support testing needs and initiate rocket design efforts.
- **Collaborative Approach:** Intend to recruit specialized talent to complement and enhance our capabilities in rocketry and aerospace engineering.

As we progress through the stages of development, my focus remains on leveraging my expertise and expanding the team strategically to achieve our ambitious goals in revolutionizing space launch technologies.





CONCLUSION

In conclusion, the future of the space industry hinges on reusability and efficiency. SpaceX's successful vertical landing of the Falcon 9 was a groundbreaking achievement, marking the beginning of reusable rocketry. However, achieving full reusability, as SpaceX is pursuing with the Starship launch vehicle, promises to revolutionize the economics of space travel with potential cost reductions exceeding tenfold.

As SpaceX continues to advance toward full reusability, the viability of single-use rockets in the commercial space sector diminishes significantly. The prospect of paying significantly more for traditional launch services when SpaceX offers a reusable alternative becomes untenable for many companies.

While SpaceX has demonstrated what's possible, it has also set a clear trajectory for the future of the space industry. Our focus on developing and proving innovative launch and catch methods presents a unique opportunity to establish a competitive UK-based company. By achieving one of the most competitive costs per kilogram to orbit, we aim to contribute to reshaping the global space launch landscape.

In this pivotal moment, the potential impact of our advancements could not be clearer. By demonstrating the effectiveness of our approach, we aspire to play a pivotal role in the ongoing evolution toward a more accessible and sustainable space industry.

