

Early Stage Valuation and Investment Thesis
Case Study: MagDrive
Space Propulsion Technology

Executive summary

Current propulsion technology is limited to inefficient combustion rockets or low-thrust electric thrusters. Magdrive is a next-generation space propulsion system, developed in response to a lack of innovation in the industry over the past 40 years. Following their first in-orbit demonstration in 2024, the company will target the rapidly growing low Earth orbit, small satellite market.

Founded	2019	Industry	Satellite and space industries
Location	Harwell, Oxfordshire	Team Size	12
Product		Solar charged electric plasma thruster for space propulsion	

Founders and team

Co-founder and CEO	Mark Stokes, mechanical and deep learning engineer background
Co-founder and CTO	Dr Thomas Clayson, nuclear fusion plasma physicist
Electrical engineer	David Salmon
Mechanical engineer	James Bass
Marketing and operations	Chuong Van Dang
Mechanical and flight engineer	Charlie Clark
Experimental Physicist	Dr Savva Theocharous

The founders aim to grow the team to 20 by 2024, and are currently hiring experimental physicists.

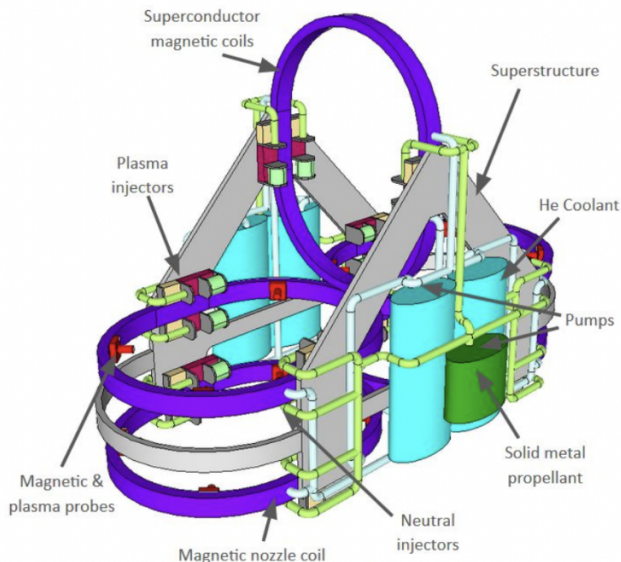
Team Strengths	Team Weaknesses
Team expertise from the automotive and defence sector; their unique hiring strategy of recruiting outside the space industry has led to innovative approaches in tackling space exploration challenges.	With limited experience in the space and satellite industry, they will need to rely on the support of their advisors such as the Satellite Applications Catapult, Westcott Incubator and European Space Agency.

Advisory board

Dr Dimon Bland	Plasma Physics
Dr Aaron Knoll	Spacecraft Engineering
Dr Chris Hobbs	Business Strategy, Satellite Applications Catapult
Essa Saulat	Oxford Accelerator
Michael Curtis-Rouse	Manufacturing for Space, Satellite Applications Catapult

Product

- Next-generation propulsion system that uses a miniature electric plasma thruster contained by a unique magnetic field topology
- The use of solid propellant eliminates complex pressure/cryogenic storage
- Enables thrust and efficiency ratios that are a leap ahead of existing electrical thrusters
- Allows for faster deployment and increased satellite lifespans.



The Magdrive thruster is composed of superconducting magnetic coils arranged in a configuration that creates a magnetic chamber (Figure 1). These coils store electrical energy and direct the hot plasma exhaust. The high-temperature results in high efficiencies and specific impulses, while magnetic confinement leads to a high plasma density, and thus, high-thrust.

Figure 1: CAD model of the Magdrive thruster for use in small satellites (Shared by founders)

Business model

Use case: Magdrive will start by selling thrusters directly to small satellite manufacturers and operators for use in deployment, orbital manoeuvres, and station keeping.

Satellites must have propulsion systems for deployment, obstacle-avoidance, and station-keeping.

Currently there are two main propulsion types:

1. **Chemical propulsion:** Such as Hydrazine, are inefficient, requiring heavy propellant which results in higher launch costs and shorter satellite lifetimes.
2. **Electric propulsion:** Such as Ion & Hall, increases efficiency which reduces required propellant mass and launch costs. But sacrifices thrust, making deployment slow and leaving satellites unable to avoid obstacles rapidly. Additionally, they require a constant power supply (i.e. solar power) and are impractical for low Earth orbit as they cannot be used when in the shadow of Earth.

Therefore, launching to orbit is expensive as current thrusters are inefficient and require heavy fuel, which increases launch costs.

- Magdrive has invented a new electric plasma thruster, which combines the high-thrust of chemical rockets and high-efficiency of electric thrusters, delivering deep throttle and variable specific impulse.
- The thruster is smaller and cheaper than other options, so it makes fast and affordable space travel possible (can save 15 kg or £450,000 per satellite).
- Doubles as an energy storage system, allowing it to be charged with solar power and discharged rapidly for high-thrust manoeuvres even on the dark side of Earth

Market: The primary market is the US, with the potential to sell to Europe as a secondary market. Magdrive's technology is scalable from small satellites to large spacecraft and launch vehicles that the company will develop as part of its long term vision; to open up entirely new markets in deep space travel, asteroid mining and space-based manufacturing.

Product roadmap and timeline

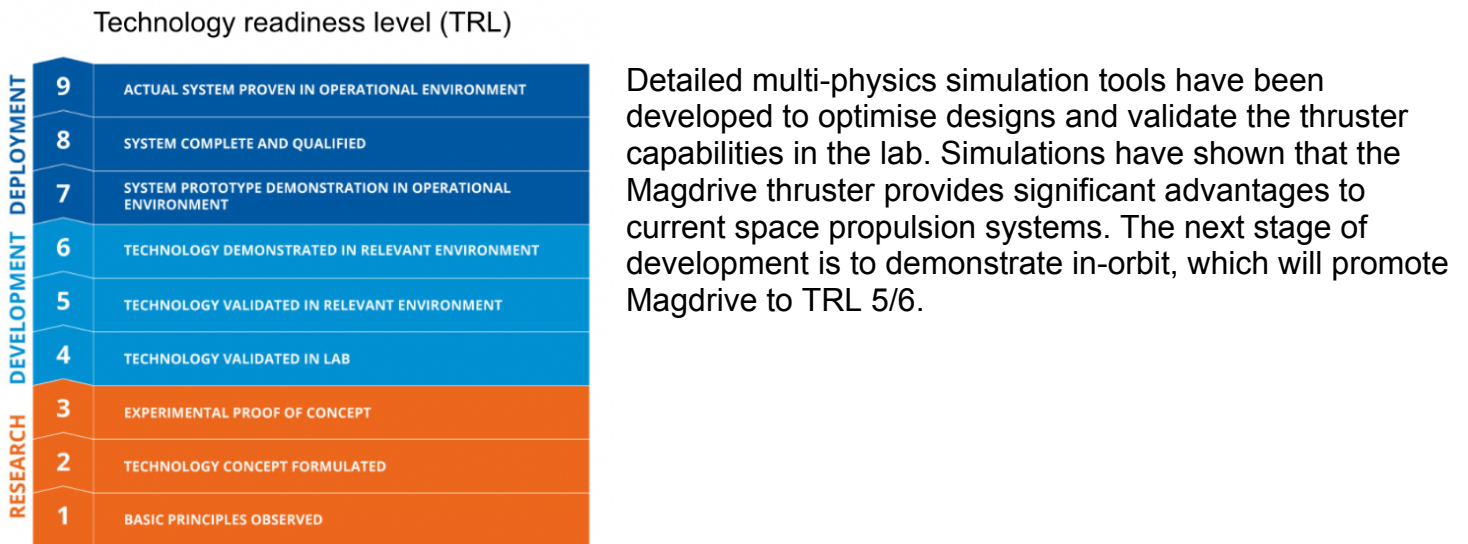


Figure 2: NASA TRL levels (TWI global, 2022)

Stage	Description	Investment Required	Duration	TRL
1	Simulations (Completed)	-	2 years	3-4
2	Laboratory tests (2023)	£200,000 (Grant acquired from Launch UK)	1 year	4-5
3	Flight model (2024)	~£500,000	1 year	6-7
4	First flight (2024-2025)	~£2,000,000	2 years	9
5	Satellite thrusters (2025+)	Additional Funding May Be Required	-	-
6	Space industries (2030+)	Additional Funding May Be Required	-	-

Figure 3: Product roadmap and timeline

Market

From 2011-2020, around 2,970 small satellites have been launched worldwide (Figure 4). The US as a target market accounts for 63% of the total smallsats launched.

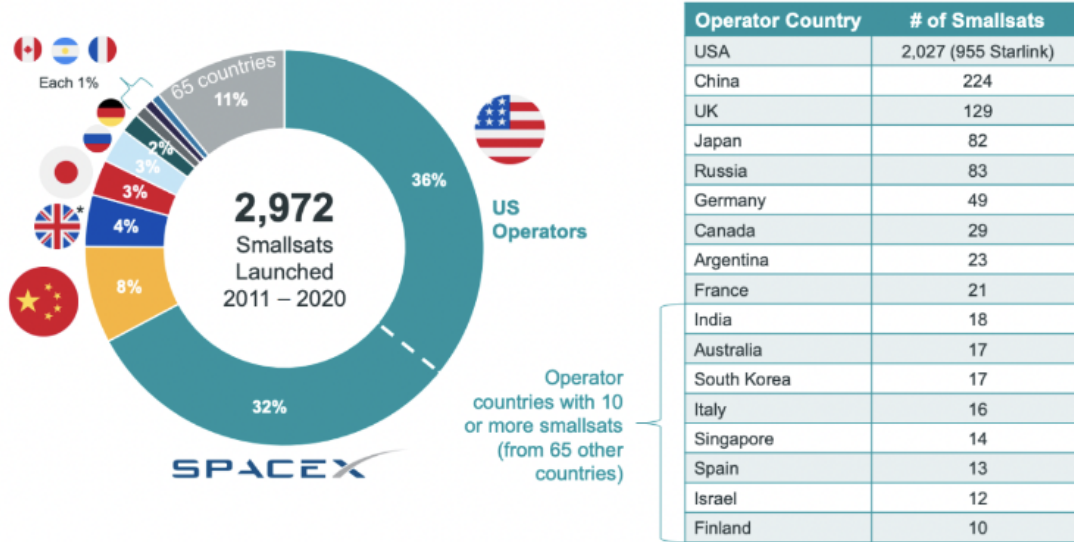


Figure 4: Small satellites launched worldwide by country 2011-2020 (Bryce tech, 2021)

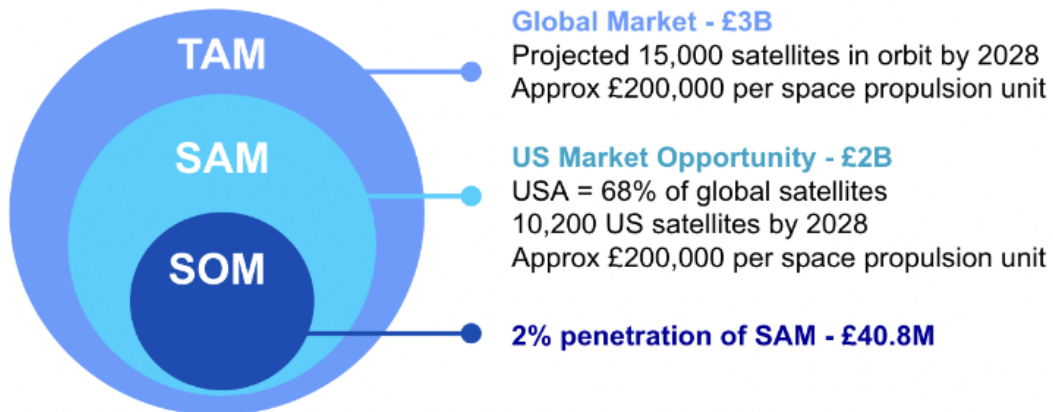


Figure 5: Market opportunity Sources: Global satellites in orbit by 2028 (WEF, 2020), USA satellite share (Bryce tech, 2021), Space propulsion unit price (Hofer and Randolph, 2013 and company estimates)

Projected global small satellite launches per year ^x	990
£ per space propulsion unit ^x	£200,000
USA % of global satellites ^x	68%
Approximate US satellite launches annually	673
US spending on thrusters (£)	£135 million
2% market penetration annual revenue yield	£2.7 million

Figure 6: Potential annual revenue projections, Sources: Launches per year (WEF, 2020)

Competitive Landscape

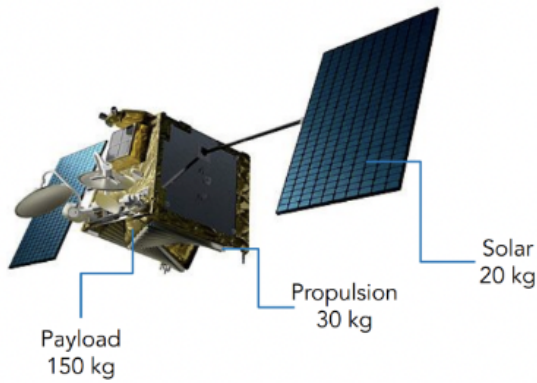
Due to diversification within the space propulsion industry, the power of competition in the market is immediate and direct. For example, Rocketjet Aerodyne provides launch vehicle propulsion, electric, solar and green propulsion.

- The Magdrive thruster's technical capabilities provide a competitive advantage for both thrust and efficiency.
- This addresses the immediate need for a significant increase in satellite lifetime through improved fuel density and efficiency.
- To maintain competitive advantage, Magdrive will need to demonstrate the thruster's capabilities in-orbit to sign a contract with a satellite manufacturer as soon as possible.
- As the business grows, the company will need to acquire greater control over the supply chain to consolidate market share against major competitors and prevent manufacturing bottlenecks. They plan to vertically integrate the development of superconductors and electrical components.

	Propulsion Type	Name	Founded	HQ	Funding	Employees	Deployment	Thrust	Efficiency
Electronic Propulsion systems	Hall-effect thruster	Aerojet Rocketdyne	1942	California, USA	Public 4.53B Mcap	4,352	In space	Low	High
	Hall-effect thruster	ThrustMe	2017	Paris, France	Private 4.1M EUR	31	In space	Low	High
	Hall-effect thruster	Sitael SpA	1994	Apulia, Italy	Private Unknown	295	In Lab	Low	High
	Hall-effect thruster	Thales Alenia Space	2007	Paris, France	Private 1.2B USD	7106	In space	Low	High
	Ion thruster	Ariane group	2015	Les Mureaux, France	Private Unknown	4,104	In Lab	Low	High
	Ion and Hall thrusters	Busek Co. Inc	1985	Massachusetts, USA	Private Unknown	57	In space	Low	High
Chemical propulsion	Ammonium dinitramide	NanoAvionics	2014	Vilnius, Lithuania	Private 67M USD	226	In space	High	Low
	Hydrazine	Rafael	1948	Israel	Private Unknown	2,161	In space	High	Low
	Hydrazine	Agile space industries	2009	Colorado, USA	Private 99M USD	59	In Lab	High	Low
Electric Plasma Propulsion	High density plasma	MagDrive	2019	Oxfordshire, UK	Private 4M USD	12	In Lab	High >100 mN/kg	High >2000 s

Figure 7: Competitor analysis, created in google sheets, data sourced via linkedin, crunchbase and company websites

Technical differentiation:



	Chemical (eg. Hydrazine)	Electronic (eg. Ion & Hall)	Magdrive
Deployment time	< 9 hours	36 days	8 days
Propellant mass	20 kg	0.8 kg	4.5 kg
Launch cost	\$ 615,000	\$ 70,000	\$ 135,000

(based on a \$30,000 per kg launch cost)

Figure 8: Technical differentiation, created in google drawings, data sourced from interview with founder

- Electric thrusters provide a small but continuous thrust when they receive solar power.
- Magdrive is able to store energy, allowing it to be slowly recharged with solar power and then discharged for a very rapid manoeuvre.
- This results in a significantly more efficient method of deploying satellites and also allows them to be used above the dark side of Earth (which is not possible with other electric systems), making Magdrive thrusters a potentially transformational technology for use in low Earth orbit.

Funding

	February 2020	October 2020	January 2021	December 2022	Planned 2024	% Ownership
Raised	£ 100,000	£ 1,400,000	£ 1,300,000	£ 250,000	£ 3,000,000	
Type	Grant funding	Pre-seed round	Seed round	Grant funding	Series A	
Shares	1,000	820,000			902,000	
notes		800:1 split				
Clayson	600	480,000			480,000	53.2%
Stokes	400	320,000			320,000	35.5%
Founders Fund (all)		20,000			20,000	2.2%
2024 Capital					82,000	9.1%
Pre Money		£ 56,000,000			£ 30,000,000	
Post Money	£ 100,000	£ 57,400,000			£ 33,000,000	
price per share (post split)	£100.00	£70.00			£36.59	

Investors / Grant Providers

- Entrepreneurs First
- Innovate UK
- Founders Fund (lead)
- 7percent Ventures (participation)
- Luminos Ventures (participation)
- Founders Fund (lead)
- Outsized Ventures (formerly Luminous)
- Launch UK
- New 2024 Capital

Figure 9: Cap Table

Magdrive has raised £3 million to date across grants and two funding rounds. With publicly available information from Companies House we can see that in October 2020 outside investors took 20,000 shares (2.4%) in exchange for £1.4 million, giving the company a £57.4 million post money valuation.

Unfortunately, the next two rounds were limited in detail. However, for the prospective 2024 Series A raise, we know Magdrive is looking for £3 million at a £30 million pre-money value. Assuming this is raised from new outside capital, and current investors do not follow on to retain their current ownership, 82,000 new shares will need to be issued working off of the October 2020 capital structure.

Investment thesis

How much do you want to invest:	£1,000,000
What is the total size of the round:	£3,000,000
What is the name of this round:	Series A
What is the pre-money valuation:	£30,000,000
Post-money valuation:	£33,000,000
Dilution in this round:	9.1%
Your post-round ownership %:	3.0%

Drivers

Internal factors:

- The founders are highly passionate and driven to deliver their vision.
- A team with highly technical capabilities to develop superior technology.
- The founders plan to continue development of Magdrive long-term with no plans to sell to larger organisations, however this material and technologically heavy venture likely will require an industry major partnership to continue advancement - so a nearer-term exit is possible
- Their development efforts to future-proof superconductor technology through vertical integration will yield further improvements to the thruster in terms of weight, energy storage and thrust and mitigates reliance on supply chain partners.

External factors:

- Satellites increasingly deployed for weather forecasting, military communications, missile warning, and navigation
- Small satellite launches are becoming less expensive, lower costs result in more frequent launches.
- Currently, **5,465** total satellites in orbit, (72%) of active satellites fall into the small satellite category (NanoAvionics, 2022) and this number is expected to increase to 15,000 by 2028.
- To further reduce costs and maximise lifetimes, operators want low-weight propulsion systems, such as electric thrusters, but with faster deployment.
- NASA aims to launch spacecraft that use high-performance and non-toxic fuel (Caldwell, 2021). Magdrive's solid metal propellant meets this requirement.
- Several companies are looking towards deep-space operations but current propulsion technology is limited. The Magdrive thruster will open up this entirely new marketplace.
- Future vision for deep space mining has attractive growth prospects, as it provides resources for Earth, refuelling in space, and manufacturing in space. Magdrive will have the opportunity to expand in this field, using its propulsion technology to return resources to Earth.

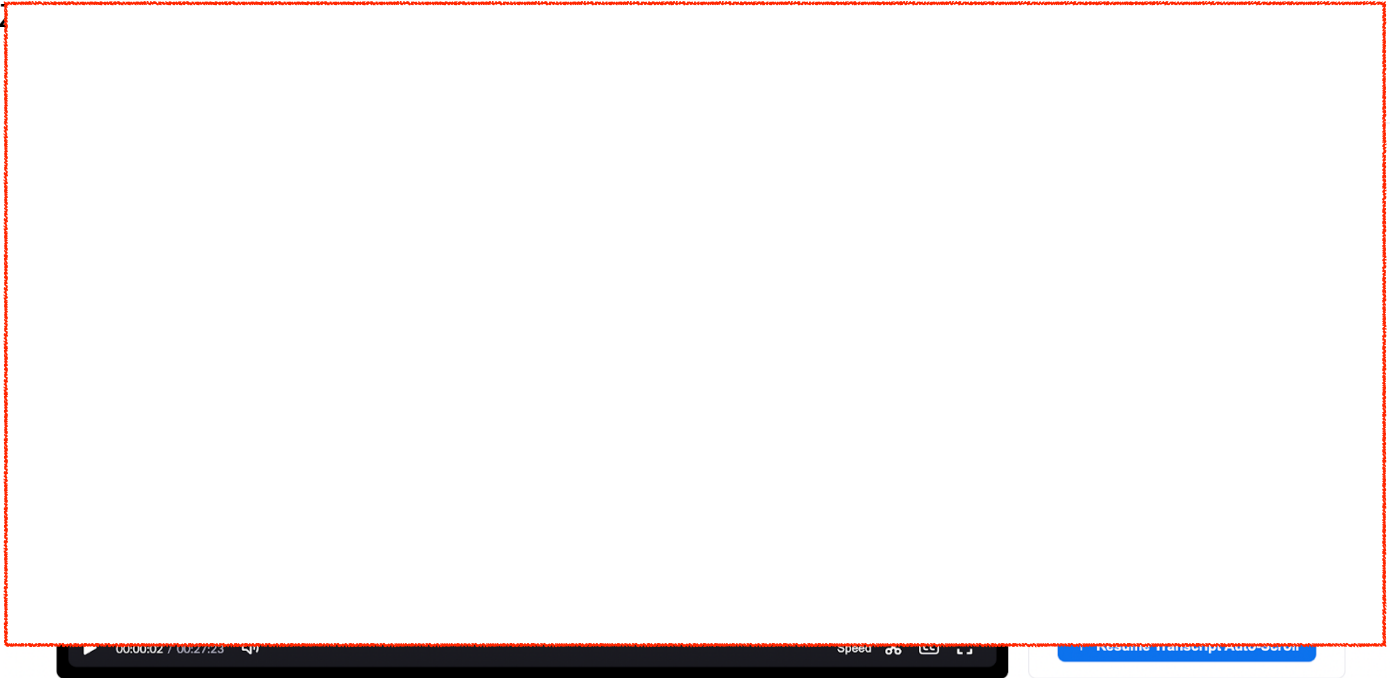
Concerns:

- Technology has not been deployed in any in-orbit demonstrations
- Space hardware is expensive; satellite operators are conservative with hardware choices, and less likely to select unproven technology
- Competition from other startups and established companies is a significant risk to the business. Incumbents have larger teams and capital which could fund faster advancement or attract away talent
- No patents currently held, although Magdrive are exploring the process. The long development timelines, foreign competition and possible applications to military technology may make patents ineffective. Magdrive plans to keep IP as trade secrets.

To conclude, I have confidence in Magdrive's solid leadership and external partnerships, as well as their "middle-market" niche in low-earth orbit, which outperforms current propulsion systems. Additionally, the large and mature aerospace market they are in could lead to strategic acquisitions, an exit opportunity as an investor.

Appendix

* Content has been hidden due to confidentiality



Communications with investors: After the interview with the founder, I set up an introductory email to an investor in the industry. This received interesting feedback, and following permissions from both parties the email is attached below. This highlights the importance of TLR levels and the timeline at which the company can meet their TLR targets for an investment decision.

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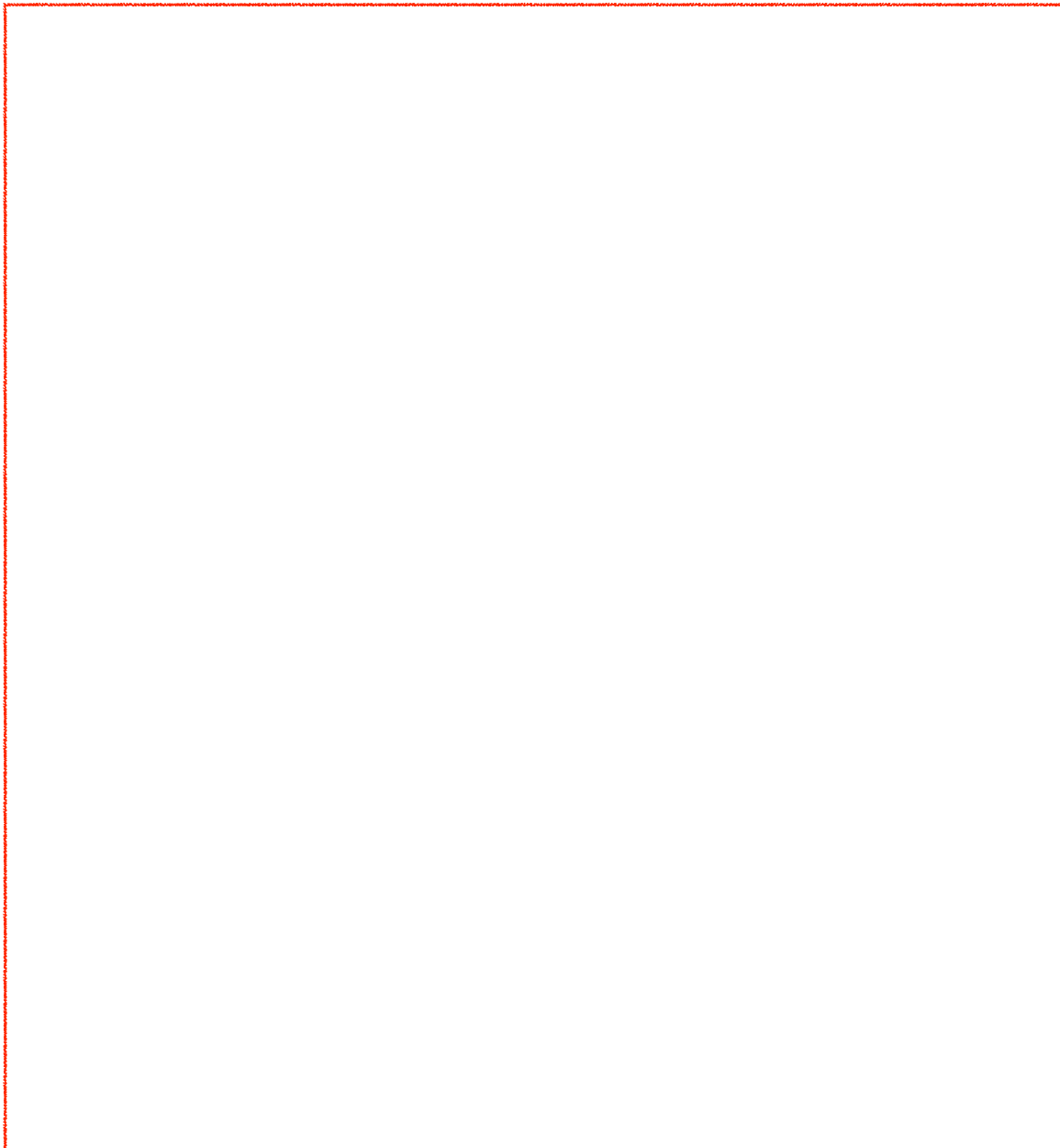
Either way, I will aim to come back to you at the end of the week with a response from our Spacecraft Propulsion team.

Hope this helps and let me know if you'd like to send them any comments back or get in touch with them.
Have a great week!

Just got off the phone with our space propulsion guys. Some notes here below.

Hope these details help the guys. Would be interested to hear their comments on my feedback.

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SWOT analysis and mitigants

Strengths	Weaknesses
Unique team expertise in military, defense and engineering	Team lacks direct experience in the space/satellite industry
Higher thrust, efficiency and propellant density	Team have no prior experience in fundraising
Enables better cost saving to customers than competitors	Magdrive is yet to be proven in-orbit
Technology is scalable to large satellites and launch vehicles	Significant capital is required
In top 10 global startups to join 2022 AWS Space Accelerator	Reliance on superconductor manufacturers in supply chain
Opportunities	Threats
Satellite operators need to reduce launch costs	Attraction of talent away to larger organisations
Large incumbents are slower to innovate	Incumbents have larger teams and amount of capital
Industry trend: rapidly increasing satellite deployment	Competitors that have proven technology in-orbit
Companies are looking to deploy in deep space	Satellite operators will not select unproven technology
Plans to vertically integrate supply chain (superconductors)	Currently no patents and is currently exploring this option

Risk	Probability	Risk Severity	Mitigants
Funding	Moderate	High	Strong network and advisory team Conservative capital allocation Funding rounds planned
Competition	Low	Moderate	React and adapt to the market need Continue to develop superior technology
IP	Low	High	NDA's implemented Secure and incentivise team (share options)
Regulatory	Low	Low	Adjust to any compliance/regulation introduced
Team	Low	Low	Hiring planned

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