Test System Development for a Novel Plasma Propulsion Device

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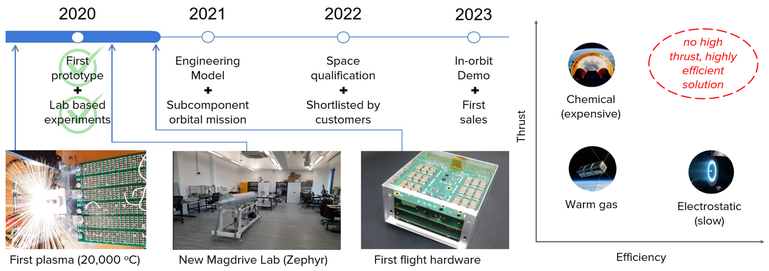
MAGDRIVE

The Magdrive Propulsion System

The Magdrive: A next generation in-space electric propulsion system based on the generation of super dense plasma and magnetic plume confinement. The system offers high levels of thrust, along with variable specific impulse that allows the user to achieve the high thrust required for responsive, rapid manoeuvres, or the efficient high specific impulse for long duration thrusts, all with one device.

Dry mass	1 kg	**Dimensions**	10x10x10 cm
Energy storage	6 kJ	**Max power**	2000 W
Total impulse	~100,000 Ns	**Gimbal range**	10^{o}
Specific impulse	2000 to 5000 s	**Thrust**	100 mN

Development: Multiple subsystems for an integrated prototype thruster are under development. This rapid development requires a constantly evolving testing environment, meaning the test system must be flexible and foolproof.



Test System Applications & Requirements

The primary use of the chamber is to provide an appropriate environment for the generation of plasma, ~1e-4 mBar, and maintain that whilst the thruster is firing.

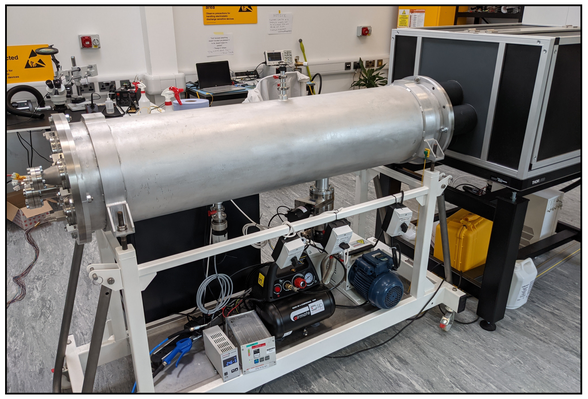
Other applications include:

- Measuring thruster performance
- Testing components' resistance to the vacuum environment
- Testing the functionality of a subsystem's operations and processes in vacuum
- Testing the appropriateness of materials under vacuum (outgassing)
- Spaceflight hardware bakeout

Derived from these applications, the driving system requirements are:

- Sufficiently strong vacuum for the generation of dense plasma
- Sufficient vacuum to demonstrate the viability of test articles for space operation
- Allowing for the measurement and observation of in-chamber events
- The ability to measure plasma properties
- Flexibility in design to allow for various test configurations
- The ability to rapidly pump down and configure test equipment

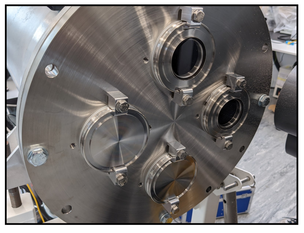
"Bertha" - Current Test System

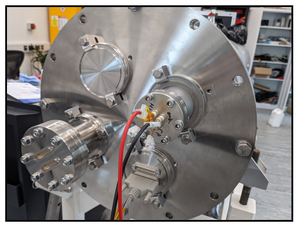


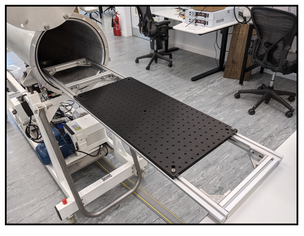
Our test system has been built up to consist of:

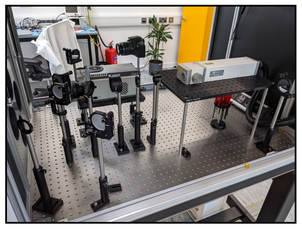
- **Vacuum System—**Chamber, mobile support, turbopump, backing pump, gauge
- **Adaptable Flanges** - large DN320 flanges to accommodate 4 x DN63 flanges
- **Sliding rail platform**—to easily move test assemblies in and out of the chamber
- **Pneumatic gate valve**— to protect the turbopump
- **Charge plate**— a charged aluminium plate to catch ions from the plasma
- **Diagnostics Bench**—A large stabilised bench for optical diagnostics
- **Black box—**an opaque box for laser safety

Chamber Specification	
Internal Volume	$0.1m^3$
Variable flange ports	8 x DN63ISO
Time to 10^{-4} mBar	~2 hours
Time to 10^{-6} mBar	~15 hours
Turbo pumping speed	80L/s



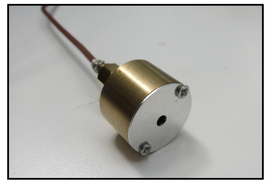






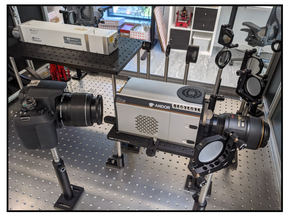
Experimental Plasma Diagnostics

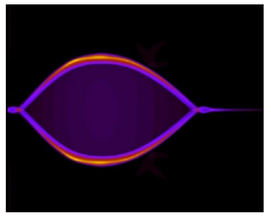
The diagnostic suite at Magdrive will initially be based around:



- **Plasma interferometry** to generate highly time-resolved (~5ns) density maps of the plasma.
- **Faraday Cups** to provide outflow velocity and plasma density – an array of these cups will also allow us to investigate the spatial profile of the plume.
- **Self-emission imaging** to generate highly time-resolved (<2ns) images of our plasma plume, as well as provide temperature estimates.
- **Electrical diagnostics** (in-vacuum Rogowski coils and voltage dividers) to allow us to accurately calculate the power deposited into our system.

This diagnostic suite will allow us to diagnose every stage of the plasma generation and evolution, and provide verification for parallel plasma simulations in FLASH that are currently in development.





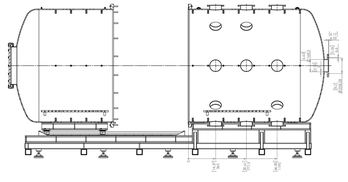
Future Developments

Improvements to the current system:

- **New turbopump -**Similar size—better efficiency
- **Infrared heat lamp -** for thermal cycling and improved bake-out
- **Helium leak detection system -** leak detection to enhance system performance
- **LN2/Cryogenic feedthrough** - for thermal cycling and cold trapping

Newly proposed system:

- **Larger chamber volume of $4.42m^3$**—larger and longer duration firing, easier test set-up
- **Chamber body rail system—**Easier access
- **Larger turbopump**—3200L/s,
- **Twin backing pumps—**allowing for more effective noise suppression
- **Cryogenic system -** localised cooling
- **Integrated control system**
- **Micro-newton Thrust Balance**



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