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Institute of Aviation

PURSUING INNOVATION

CLEAN SOLID PROPULSION FOR SATELLITE DEORBITATION

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Space Technologies in Łukasiewicz Research Network – Institute of Aviation

- Satellite and **rocket systems**, including propulsion
- Suborbital flights and **microgravity research**
- IT solutions for **remote sensing** and space technologies
- **Rocket avionics** systems
- Propulsive **deorbitation** modules
- **Chemical propellants**
- **Optoelectronic and mechatronic** tools

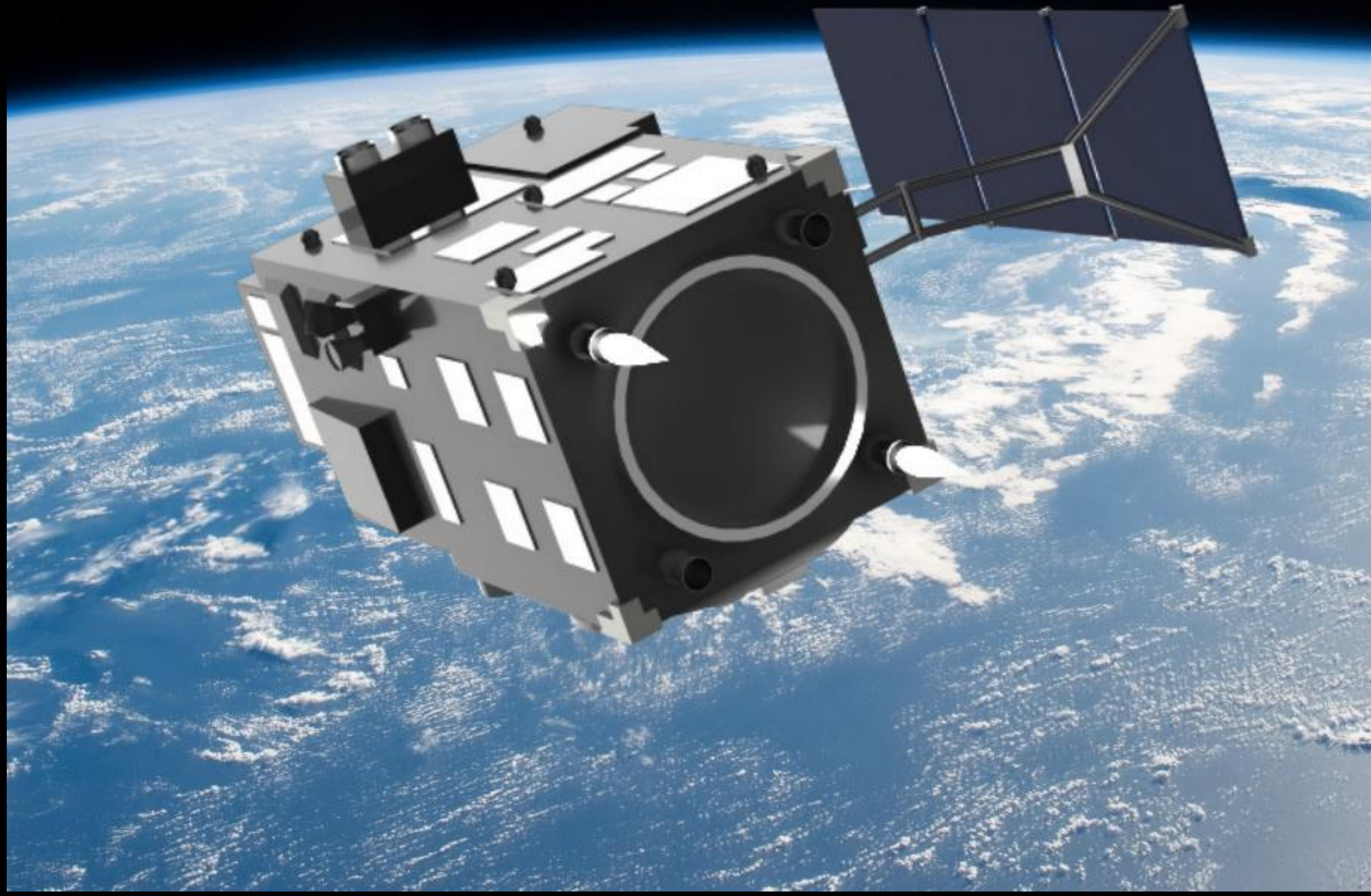
Deorbitation Solutions and Their Limitations

Chemical Propulsion Systems:

- Typically used for satellite deorbitation but often involve **complex, heavy** liquid engines and propellants feeding systems;
- Higher operational complexity due to the need for pressurization and propellant storage systems;
- Large systems with complex infrastructure – **lower reliability** in long-term storage.

Electric Propulsion Systems:

- More propellant-efficient but with **extremely low thrust** and long operation times;
- May not generate sufficient ΔV within a practical time for controlled re-entry, especially for larger satellites or rocket stages.



SRMs fill a specific gap – providing both the necessary thrust and simplicity for controlled deorbitation within a reasonable timeframe, something that other systems struggle to achieve efficiently in certain mission profiles.

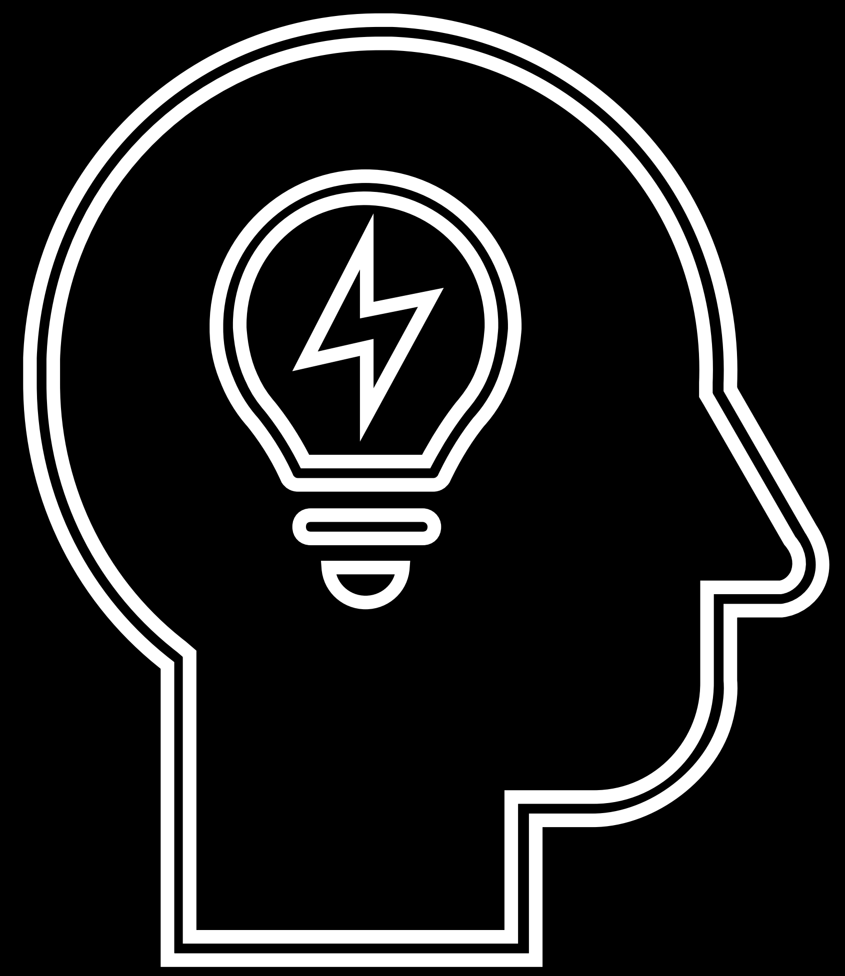
Advantages of Solid Rocket Motors for Deorbitation

- SRMs are **self-contained systems** that do not require complex infrastructure, reducing the risk of failure. This makes them **highly reliable** for end-of-life satellite deorbitation, where reliability is crucial.

- The SRM's ability to store propellant in a stable, solid form allows for **long-term storage** and quick, controlled activation when needed, a feature less common in liquid or electric systems.

- Traditional SRMs are often known for their high thrust and short burn times. However, the new low burn rate propellant allows for extended burn times and **controlled low-acceleration thrust**, which is essential for sensitive satellite equipment. This ability to provide smoother, longer burns is a significant advancement in SRM technology.

- **Advanced thermal insulation** allows the SRMs to handle extended burns without overheating or compromising satellite integrity.



SRM Engineering Model Development

Propellant Development:

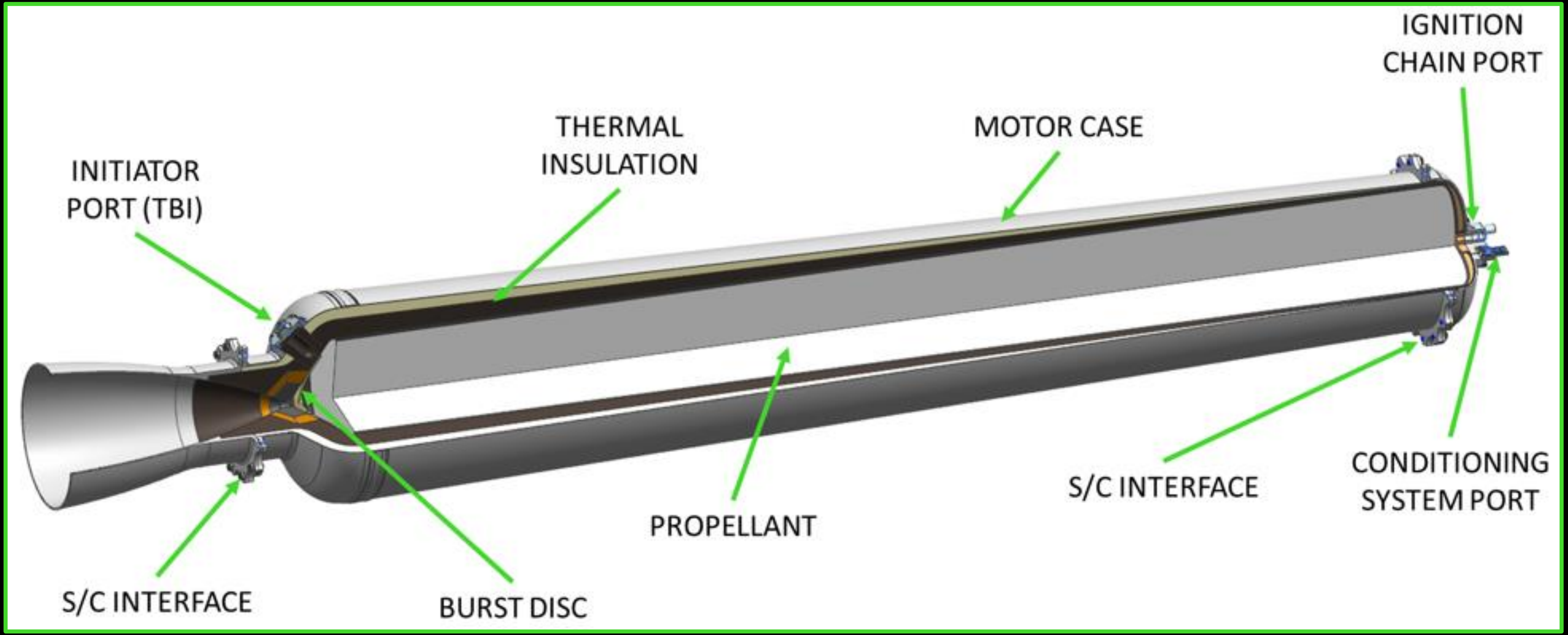
- Pre-qualification of new, **dedicated solid propellant**.
- Propellant optimised for low thrust and reduced space debris.
- Safety and storability tests conducted to ensure propellant compatibility.

SRM Design Phase

- Considerations for thermal insulation, **extended burn time**, and high ΔV manoeuvres.
- Deorbit **propulsion system** requirements:
  - Deorbiting a 1500 kg satellite from SSO
  - ΔV: 200 m/s
  - Propellant mass: 116 kg
  - 4 motor cluster, firing 2 at a time.
- **Motor** requirements:
  - Max thrust: 250 N
  - Burn time: >400 s
  - Specific impulse: >270 s

SRM Engineering Model Development

- **Design Approach:** End-burning grain geometry chosen for constant thrust and long operation time. Low thrust reduces chamber pressure, allowing lightweight motor body.
- **Thermal Management:** Double-layer insulation – ablative composite layer and a secondary low-conductivity material for mass optimization.
- **Environmental Resistance:** Design considers extreme temperature cycles, vibration, radiation, and vacuum exposure during storage and operation.

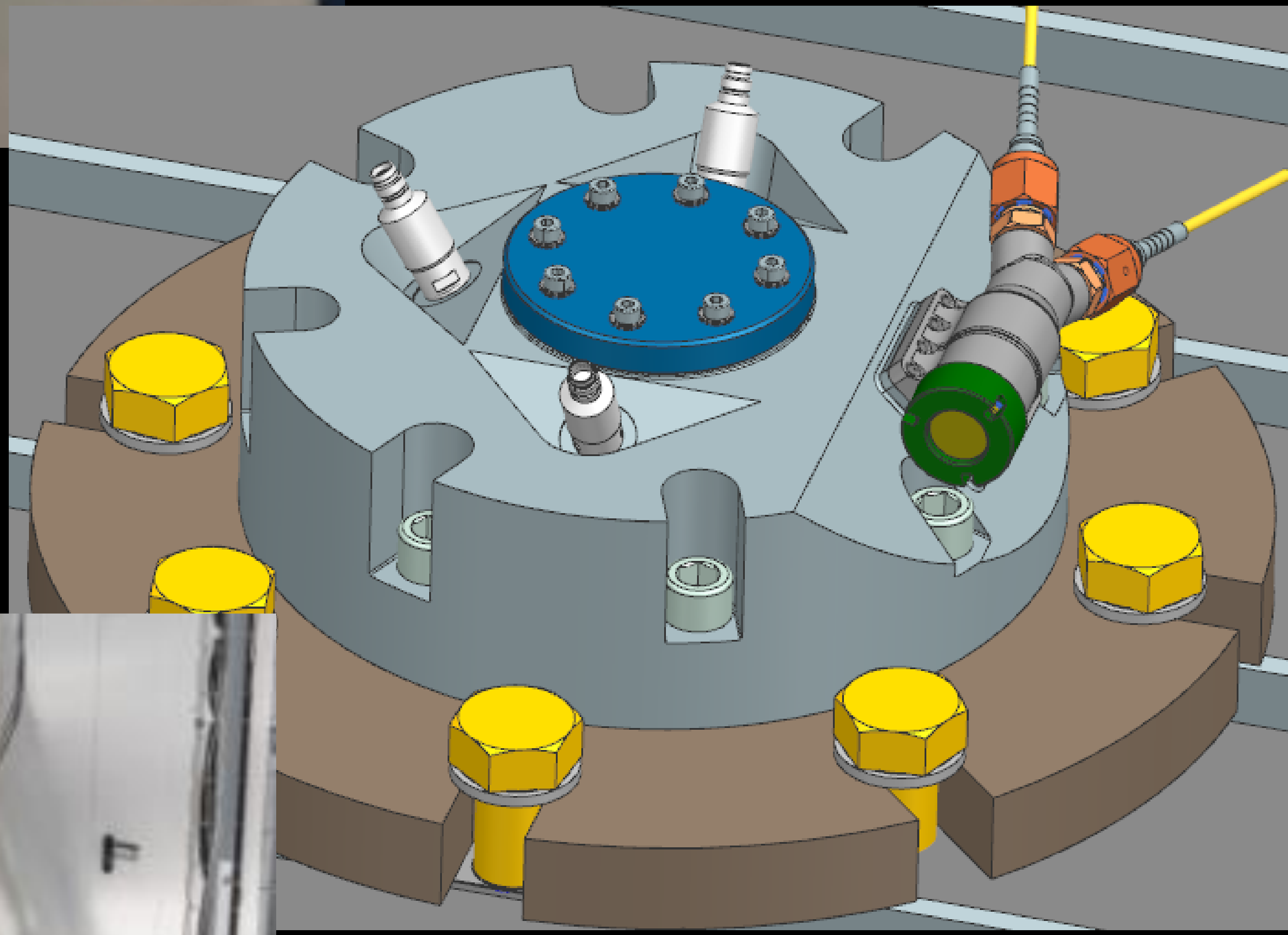


Adaptability of the Solid Propulsion System

- The **scalable design** of the SRM is a key innovation. By making the system modular, it can be adapted to deorbit satellites of various sizes and masses.
- Electric propulsion systems, while efficient, are often not scalable to the same extent, limiting their application to specific satellite sizes or mission types. Liquid systems require different engineering designs for varying payloads.
- Modularity allows the system to be applied across **different mission profiles**, catering to both small and large satellites, as well as rocket upper stages.

Test Campaign Preparation

- **Mechanical and thermodynamic properties testing**
- **Ignition system testing**
- **Environmental testing**
  - Mechanical **vibrations** tests
  - Life cycle tests
  - **Radiation** testing
  - Storability testing
- **Hot-firings**
  - **Performance** verification
  - Solid particle size measurement



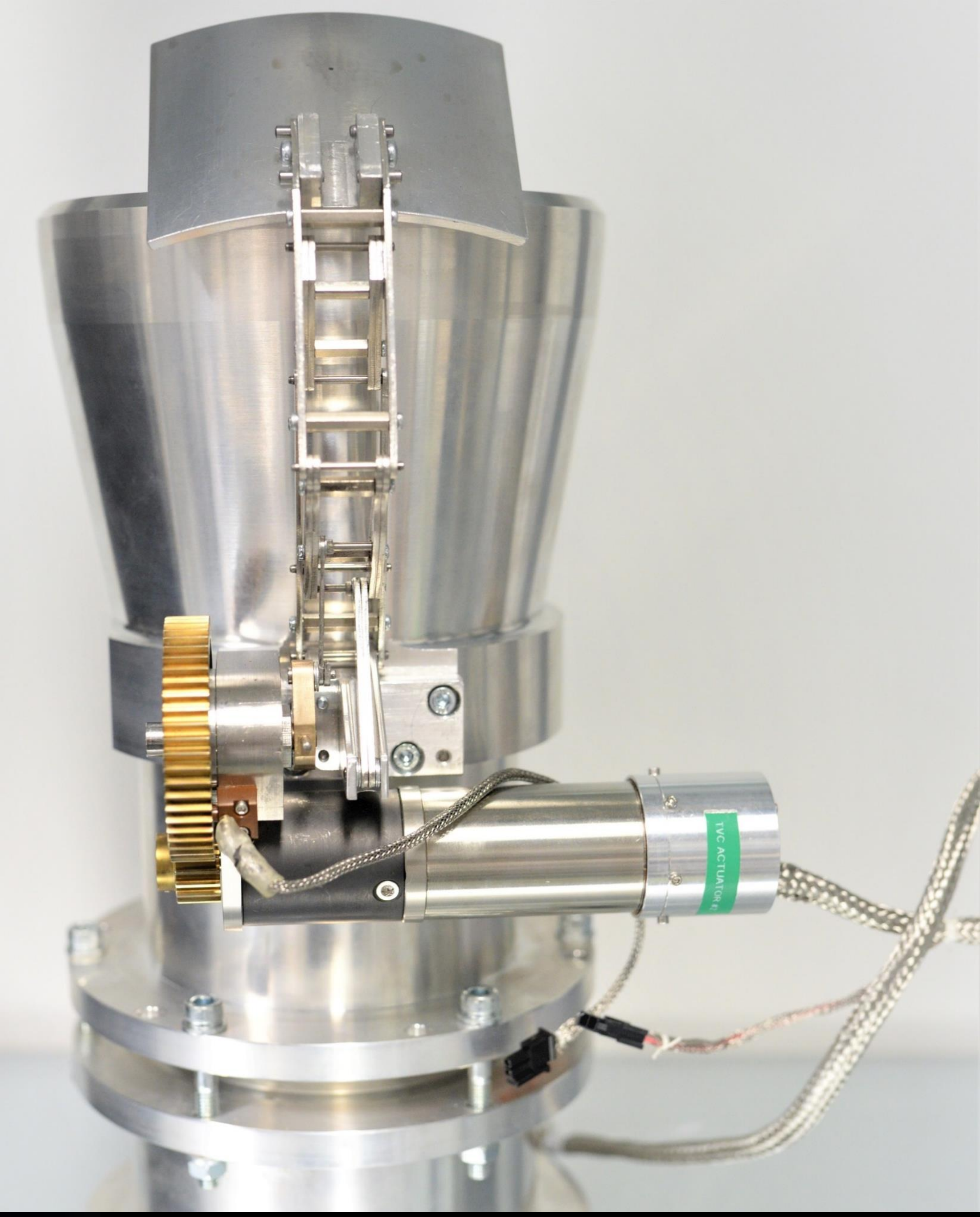
Thrust Vector Control (TVC) System

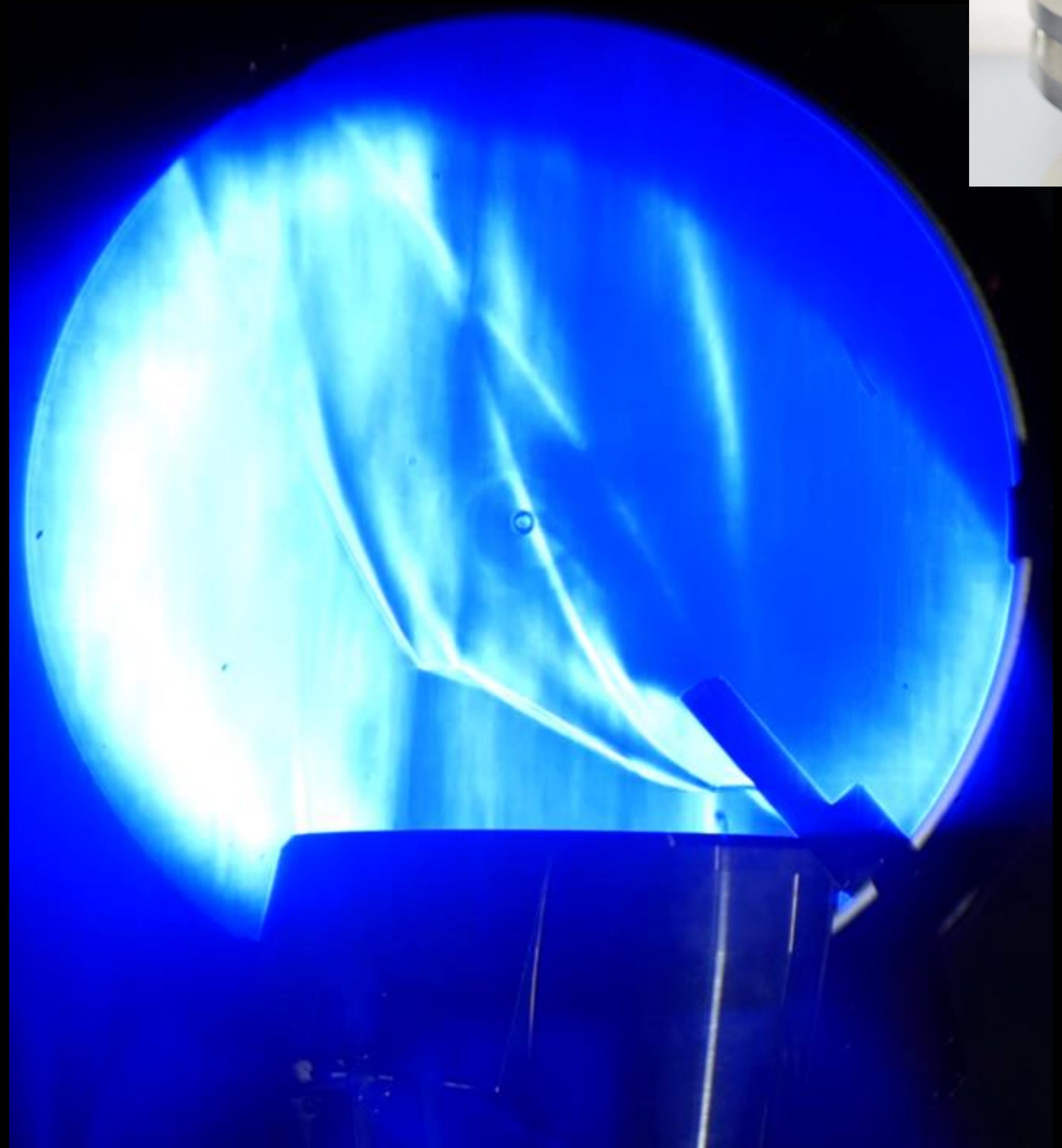
- A common challenge with SRMs is achieving precise control during deorbitation manoeuvres due to the inherent nature of solid propulsion **(once ignited, it cannot be stopped)**.

- Integration of a TVC system is an approach **to enhance precision and control**, allowing the SRM to adjust the direction of thrust dynamically during the deorbitation process.

- **External flap system** chosen for its compactness and minimal impact on SRM design, with some trade-offs in axial thrust reduction.

- **Cold-gas tests** executed in the vacuum chamber confirmed the performance.



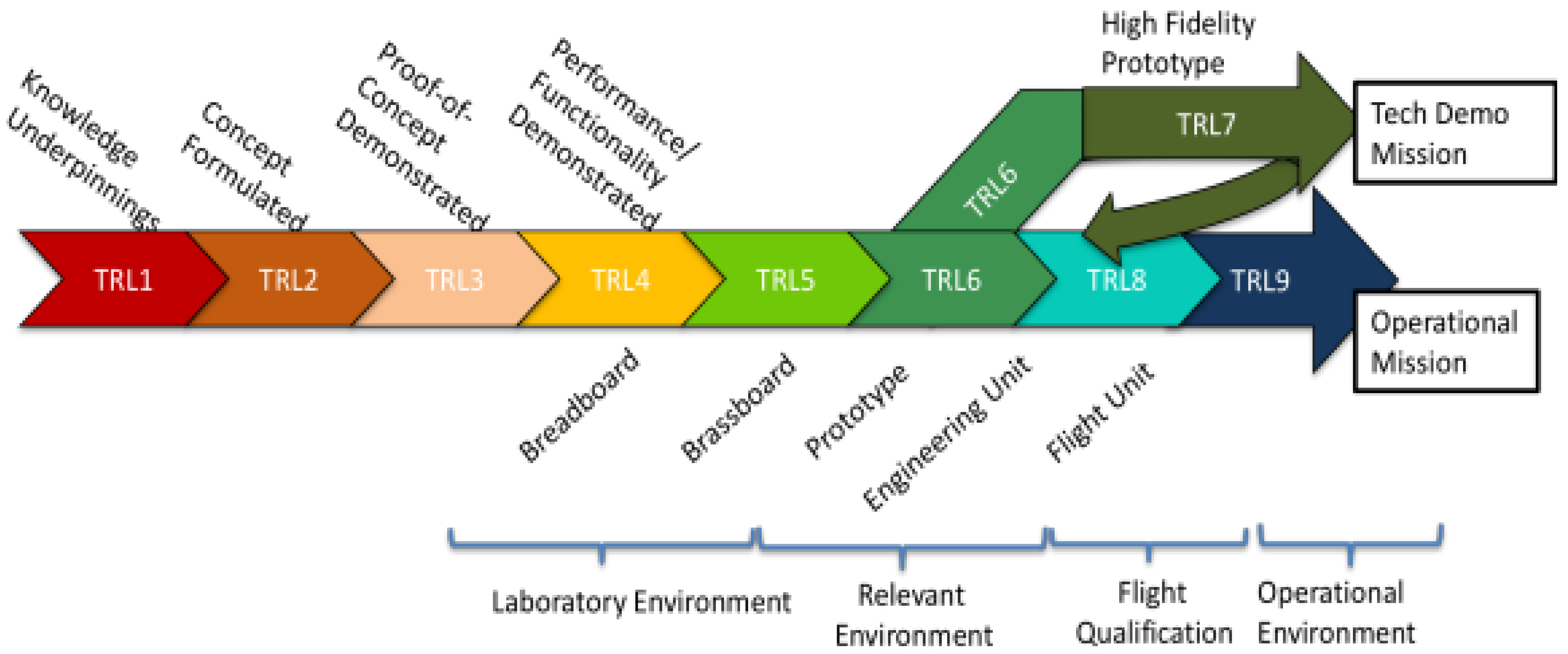


Space Debris Mitigation

- The system's alignment with **International Space Debris Mitigation Guidelines** is innovative because SRMs were traditionally not considered the "cleanest" propulsion systems. Through advanced design, aluminium-free propellant, and precise control TVC mechanisms, this innovation contributes to **safer, cleaner deorbitation** methods.

- The development of this SRM addresses the challenge of finding propulsion systems that comply with **ESA Clean Space** initiatives, **pushing the boundaries** of what is considered environmentally acceptable in space propulsion.

Future Work



- One of the key challenges moving forward is **qualifying the motor and TVC system** beyond Technology Readiness Level (TRL) 6.
- Achieving higher TRL levels will require the integration of these systems into **real-world mission conditions**, which presents a significant technical challenge.
- The next phase of development will also involve **further refinement of the TVC system**, with a focus on minimizing thrust losses while maintaining precise control.
- These steps will help to transition the motor and its systems into a fully operational, **flight-ready solution**, contributing to effective space debris mitigation and sustainable space activities.

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Conclusions

Key Takeaways:

- Novel **clean solid propulsion** system with advanced TVC capability.
- **Scalability** and modularity for various satellite missions.
- **Successful initial tests** and ongoing development plans.
- The system's potential to revolutionize **controlled satellite deorbitation** and its alignment with global efforts for space sustainability.

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