

Motivation

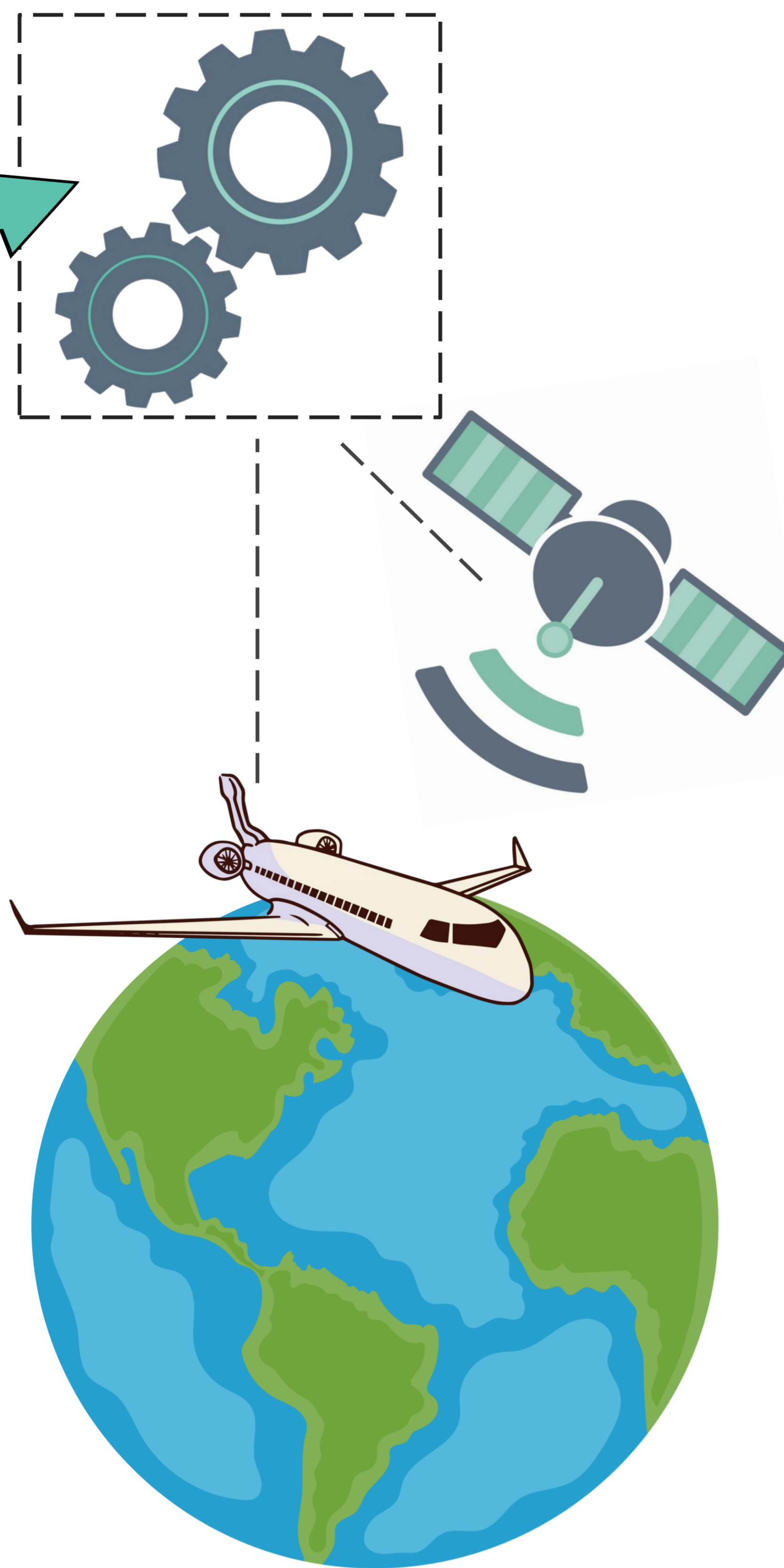
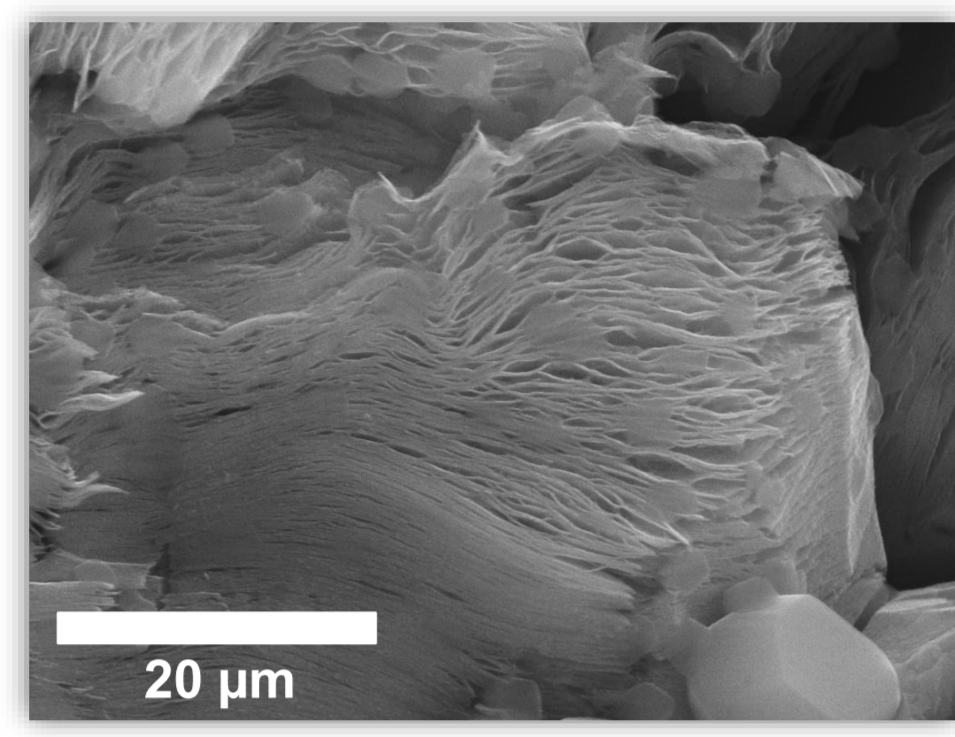
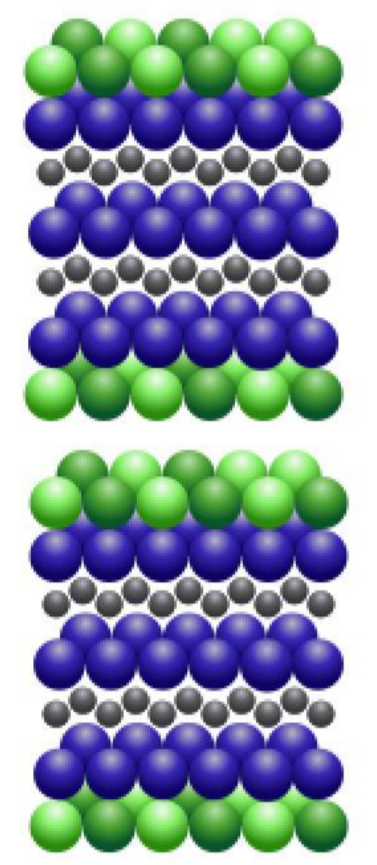
In aviation, technical failures account for nearly **20% of accidents**, affecting safety and operational costs, while failures such as the Kepler space telescope reaction wheel highlight the high cost of component malfunction in space systems.

Aircraft and satellites rely on mechanical components that must operate reliably under **extreme conditions**, including vibration, temperature extremes, vacuum, and long maintenance-free lifetimes. **Solid lubrication** is critical to reduce wear and ensure smooth performance.

MXenes are a highly promising next-generation solid lubricant, offering sustainable, high-performance solutions for **aerospace and space** applications.

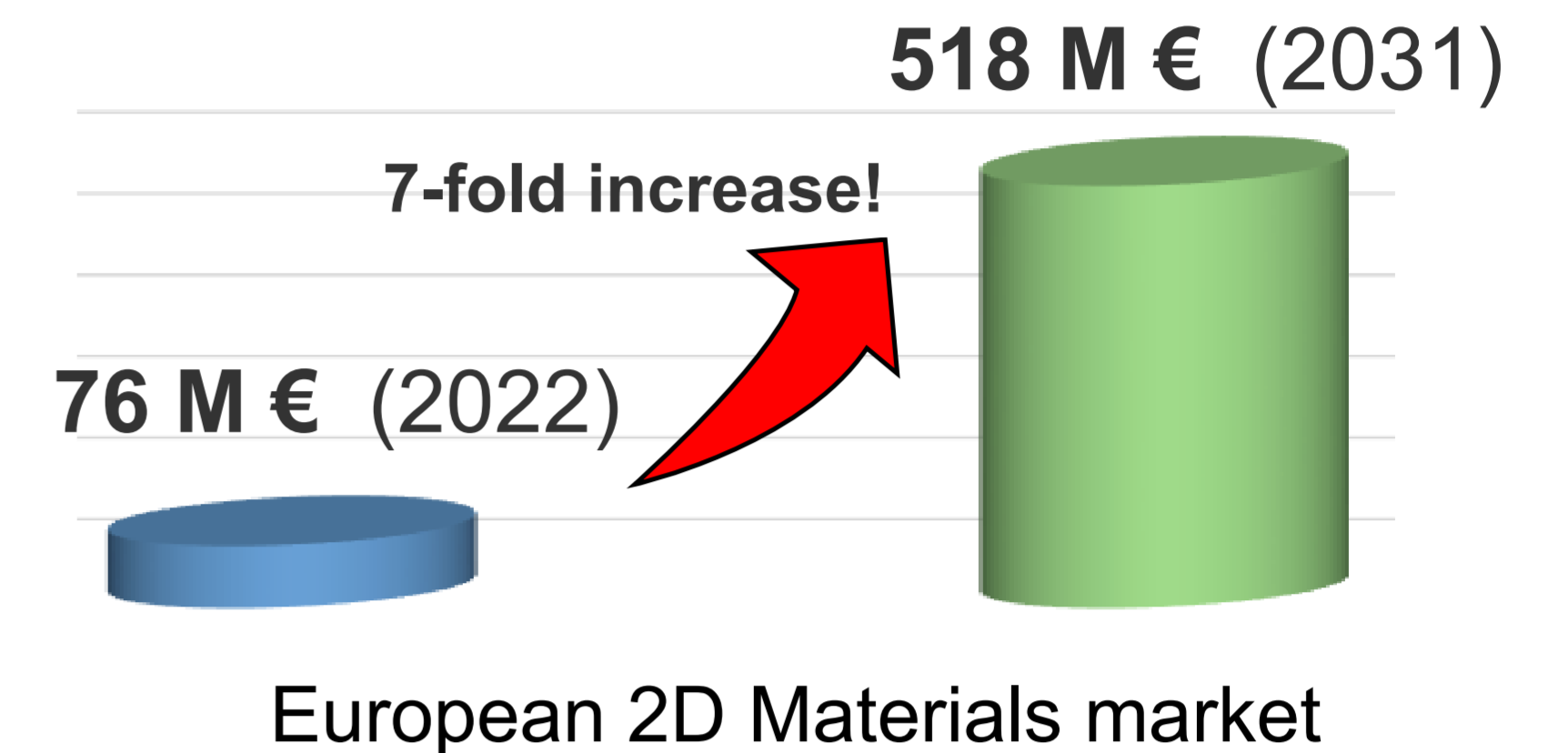
Green MXenes Production [1]

- Electrochemical & chemical synthesis
- ▲ $Ti_3AlC_2 \rightarrow Ti_3C_2T_x$
- ▲ **Non-toxic** & environmentally friendly process
- ▲ Cost-effective, simple & scalable setup



Strong Market Potential

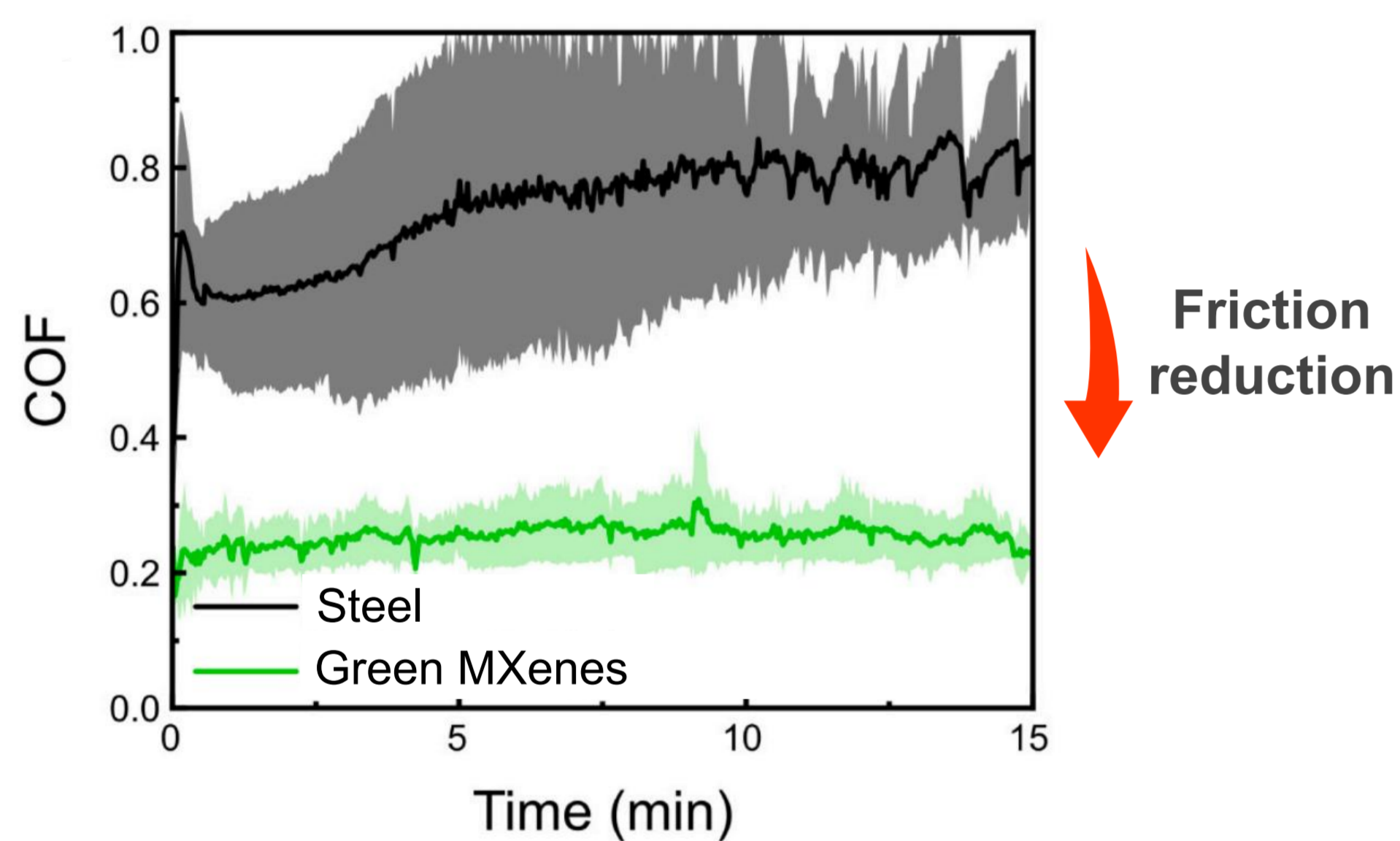
- Europe's 2D materials market is booming



- **Critical bearings, actuators, and gears**
- Aerospace: high-reliability, safety-critical systems
- Space: maintenance-free mechanisms for satellites and exploration
- Aerospace bearings
 - ▲ USD 12 B (2023) → **USD 22 B (2032)**;
- Space-grade bearings
 - ▲ USD 673 M → **USD 1.3 B (2033)**

Eco-Friendly Solid Lubrication [2]

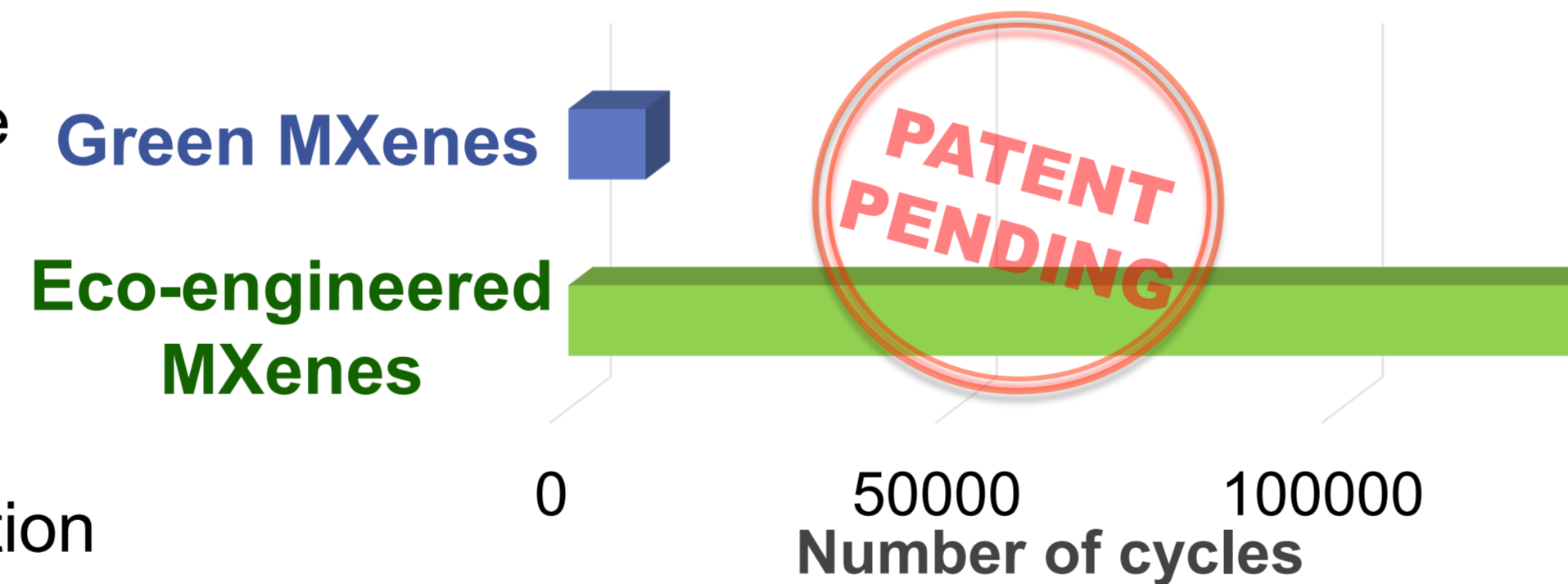
- **Layered MXene structure** enables smooth sliding
- Up to 4x lower friction compared to steel
- Alternative to MoS₂-based solid lubrication



Designed by rawpixel.com / Freepik

Exceeding NASA Benchmarks! [3]

- Chemical engineering for superior performance
- World record in MXenes solid lubrication
 - ▲ **>100,000 cycles** in solid lubrication tests
 - ▲ Superior material protection & reliability
- Solid lubrication delivering consistently low friction



Key Advantages

- **Safety & Reliability**
 - ▲ Reduced failure risk of critical components
- **Environmental benefits**
 - ▲ Elimination of hazardous liquid lubricants
 - ▲ Reduced waste generation
- **Economic benefits**
 - ▲ Lower production complexity and simplified qualification pathways
 - ▲ Reduced lifecycle and maintenance costs enabled by durable solid lubrication and extended component lifetime

Collaborators

AC2T research GmbH: Manel RODRÍGUEZ RIPOLL
TU Wien: Markus OSTERMANN, Edoardo MARQUIS, Markus VALTINER, Carsten GACHOT, Pierluigi BILOTTO



Acknowledgement

The work of Marko PILJEVIĆ is funded by Province of Niederösterreich via the "Gesellschaft für Forschungsförderung Niederösterreich m.b.H.", through its FTI PhD Funding Programme (grant number FTI22-D-018). The work is supervised by Carsten GACHOT, Markus VALTINER and Pierluigi BILOTTO financed by TU Wien and Markus OSTERMANN financed by CEST Kompetenzzentrum für elektrochemische Oberflächentechnologie GmbH and by TU Wien. Work of Edoardo MARQUIS is financed by TU Wien.

References

- [1] Ostermann, Piljevic et al., Pulsed Electrochemical Exfoliation for an HF-Free Sustainable MXene Synthesis. *Small* 2025
- [2] Piljevic et al., Electrochemically synthesized MXenes as sustainable solid lubricants: Mechanistic insights into tribofilm formation and interfacial dynamics, *Carbon* 2025
- [3] Piljevic et al., Patent application pending

Contribution to SDGs

No water pollution	6 CLEAN WATER AND SANITATION	7 AFFORDABLE AND CLEAN ENERGY	Green chemicals for material production
Advanced 2D materials for aerospace	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	11 SUSTAINABLE CITIES AND COMMUNITIES	Eliminate hydrofluoric acid disaster risk
Sustainable production and application	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	13 CLIMATE ACTION	Reduce the release of harmful gases