

POSITION PAPER

# XR Interoperability as a Prerequisite for Model-Based Systems Engineering in Human Spaceflight

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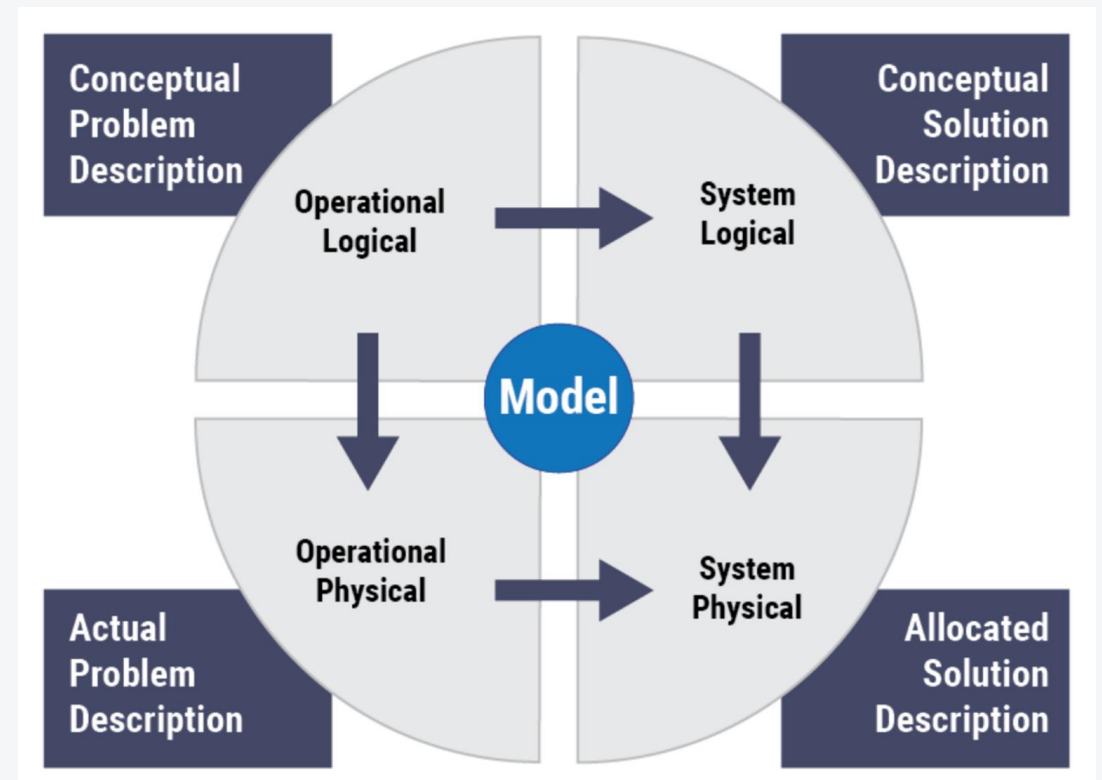
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# Model-Based Systems Engineering (MBSE)

## THE PROMISE:

Organize engineering projects around shared, continuously updated digital models - encoding technical, social, and organizational context into one coherent framework accessible to all relevant stakeholders. In theory, this improves flexibility, sustainability, real-time capability, adaptability, reliability and usability.



# Case study: Coordinating Artemis Is an Organizational Problem, Not Just a Technical One

The Artemis program aims to return astronauts to the Moon by 2028, with permanently inhabited lunar bases targeted for the early 2030s. It is an uniquely complex project to coordinate.

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## Multidisciplinary

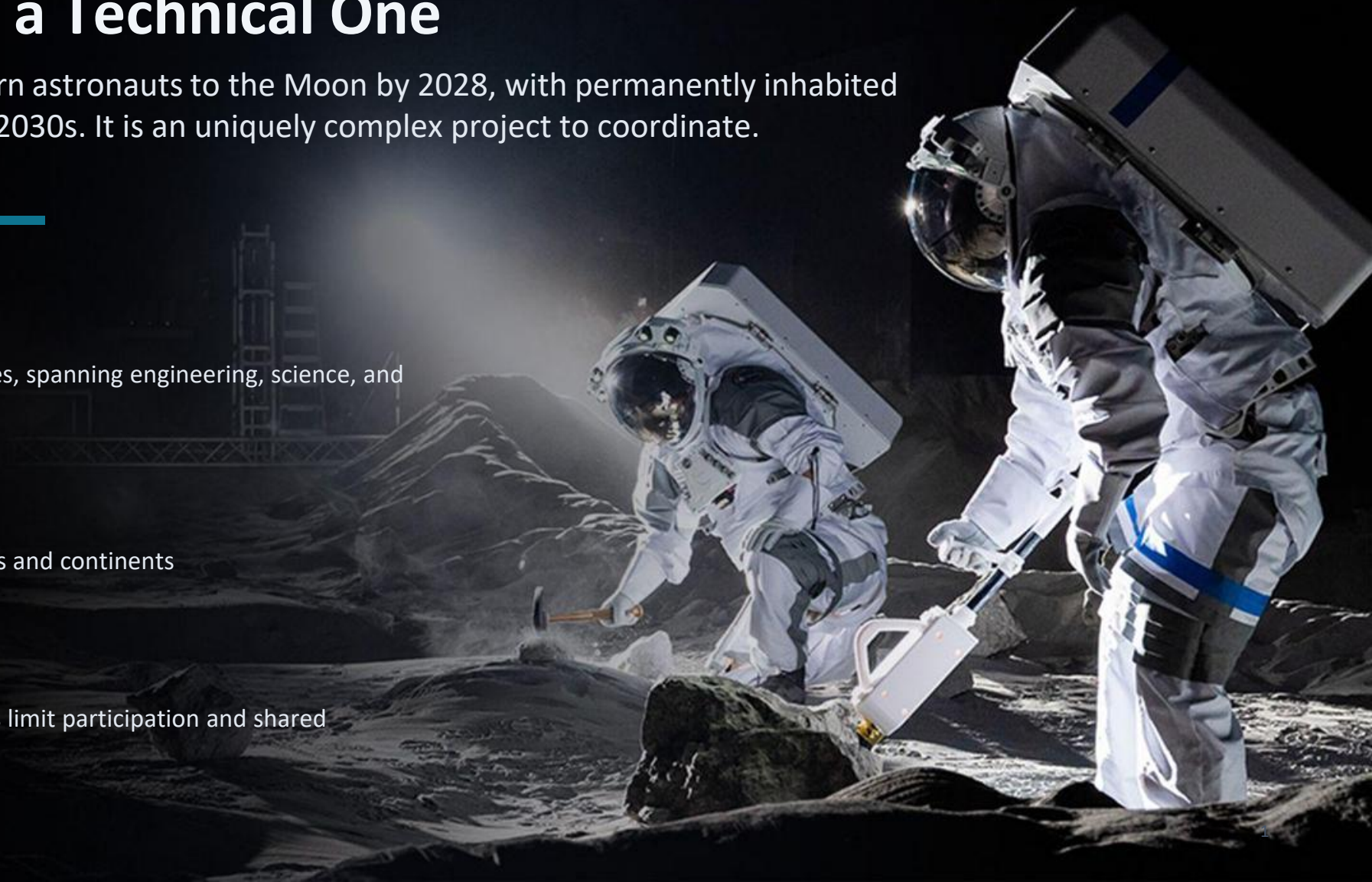
Industry, academia, and government agencies, spanning engineering, science, and operations

## Geographically dispersed

Stakeholders distributed across organizations and continents

## Slow to coordinate

Rigid processes and long development cycles limit participation and shared understanding



# XR as a Unifying MBSE Medium

*A shared 3D scenario can be understood by an astronaut, an engineer, and a program manager - without requiring any of them to first learn any specialized modeling language.*

XR visualizes complex, spatial, systemic data — and supports real-time collaboration among geographically dispersed teams, directly addressing space engineering's key bottleneck.

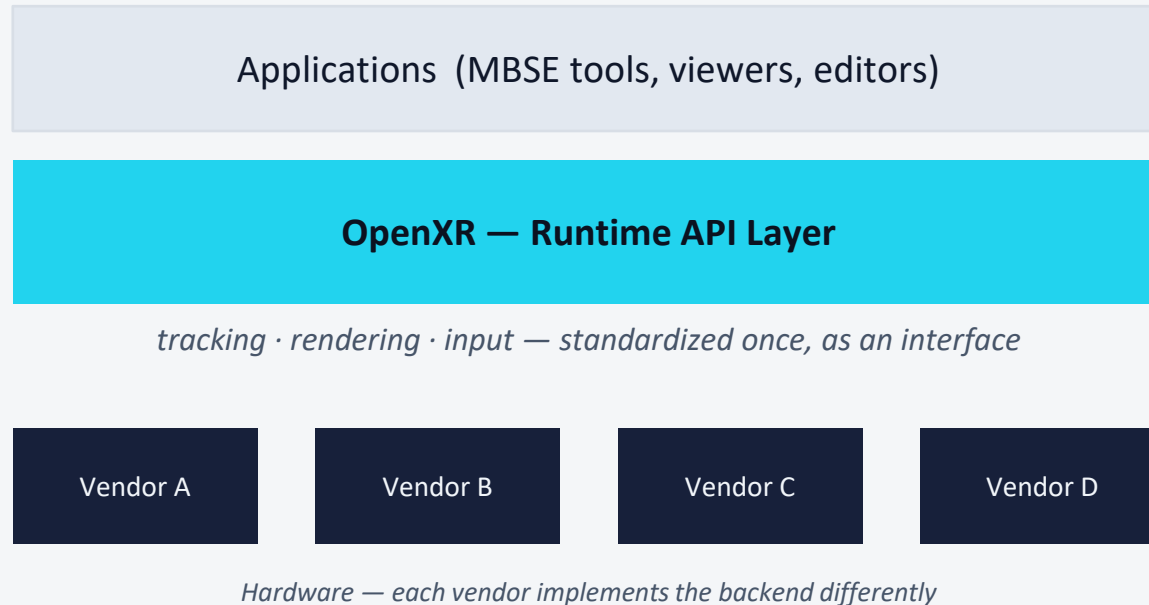
# Is XR Mature Enough to Deliver On This?

The viability of XR-based MBSE in the space sector rests on one big assumption: that XR is sufficiently interoperable to serve as a unifying medium.

If XR tools and content turn out to be just as fragmented and vendor-locked as existing MBSE tools, XR-mediated MBSE will do little to resolve the interoperability problem it set out to solve.

**So: is there precedent for successful, broad XR standardization?**

# OpenXR: One of the Few Standardization Successes in XR



## Developed by the Khronos Group

An industry consortium of 100+ members — also behind OpenGL, WebGL, glTF, and Vulkan.

## What it does NOT standardize

App stores, development environments, and distribution channels stay operator-controlled.

## Why vendors adopted it

A common interface widens the pool of applications on their devices — standardization grows the market for everyone.

# Important Gaps Remain

1

## Network Protocols

For multiplayer synchronization — real-time shared sessions across dispersed teams

2

## Spatial Computing APIs

Models that behave consistently across hardware and vendors

3

## Avatar Systems

Cross-platform representations so stakeholders can recognize and interact with one another

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*Without progress here, any XR-mediated MBSE workflow stays dependent on individual vendors — the same lock-in that limits conventional MBSE today.*

# Why the Space Sector offers an Interesting Case Study

*Multiplayer synchronization and cross-platform avatar systems are service-like, involving ongoing operational delivery rather than a one-time interface, and their providers monetize the service itself rather than the hardware beneath it. Standardization here works against the business model rather than with it. The uncomfortable consequence is that the capabilities an Artemis-scale MBSE workflow most depends on are precisely the ones the market is least inclined to standardize.*

-> A shared agenda and deliberate coordination are needed!

# Q1

## What Needs to Be Standardized First?

- Not all gaps are equally urgent - spatial computing APIs are a natural early target, while network protocols may be the most immediate problem for real-time distributed sessions.
- Avatar systems may matter more for sustained, trust-building collaboration over a project's lifetime.

# Q2

## How Should Standardization Be Pursued?

- OpenXR's success depended on a specific structural configuration — hardware vendors each benefited from broader application portability.
- Service-like gaps offer no such natural shared incentive.
- Who is the “Khronos-equivalent” coalition for space engineering, when the commercial motive to standardize is absent?
- Can existing standards bodies host this work — or do space agencies and industry need a joint dedicated effort to supply the incentive the market won't?

# Q3

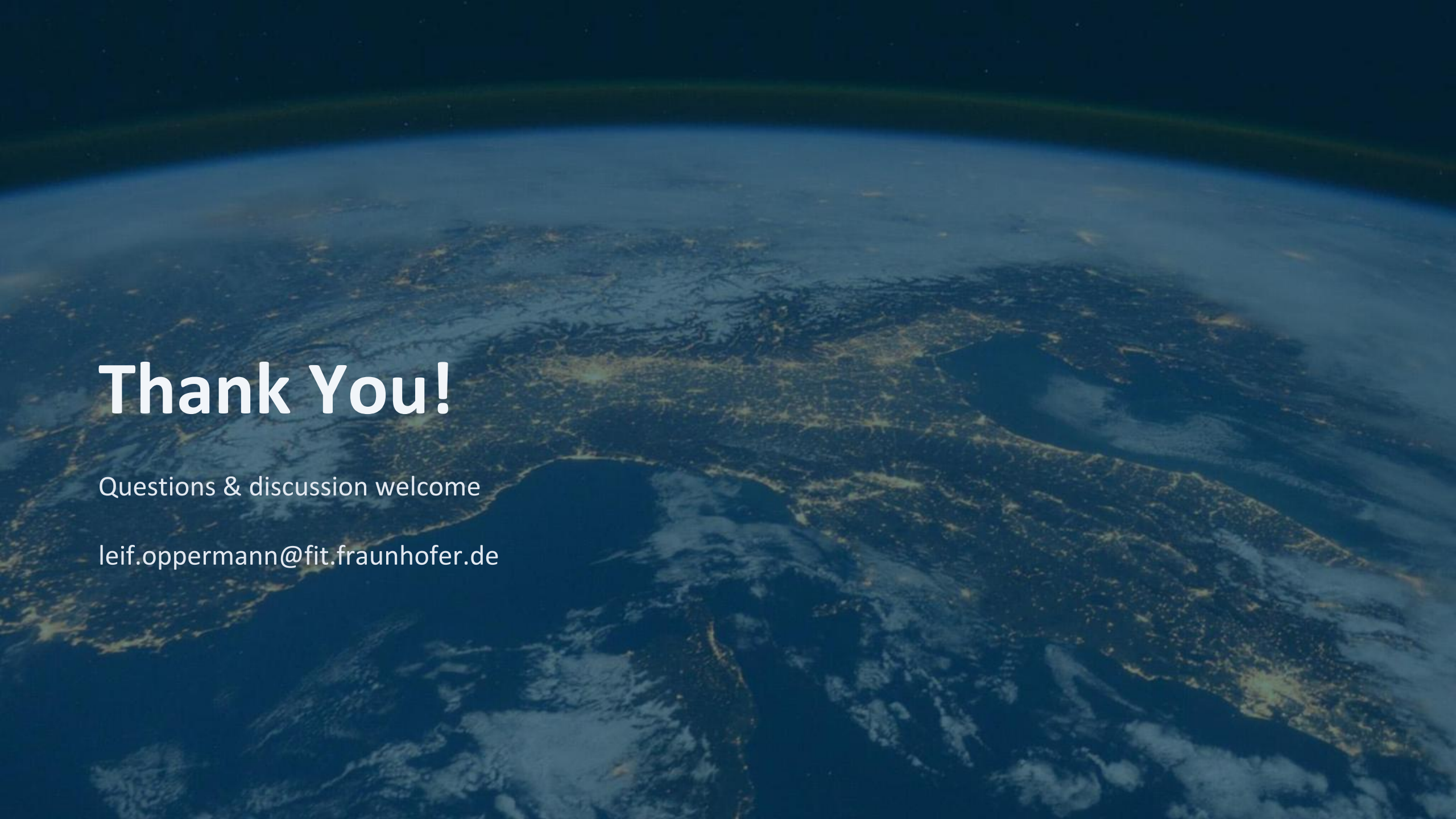
## What is Feasible in the Space Domain?

- Space engineering involves obstacles that general-purpose XR standardization hasn't faced: security classifications, export control regimes, strict safety certification etc.
- These may cut in unexpected directions — absence of a commercial distribution model could make some gaps easier to standardize than in the consumer market.
- Classification requirements could make others harder.
- Can general XR standards simply be extended — or are space-specific extensions and parallel standards needed?

# Why This Matters

- Large-scale space programs need better tools for coordinating diverse, dispersed, fragmented teams. MBSE hasn't been able to supply them alone.
- XR offers a promising path — but only if the ecosystem closes the gaps in network synchronization, spatial computing, and avatar representation.
- OpenXR proves XR standardization is achievable — but only because hardware vendors shared an incentive. The capabilities Artemis-scale MBSE depends on most fall largely outside that incentive structure.

*Articulating and pursuing this research agenda is a necessary next step — for human spaceflight coordination, and for the XR community at large.*



# Thank You!

Questions & discussion welcome

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