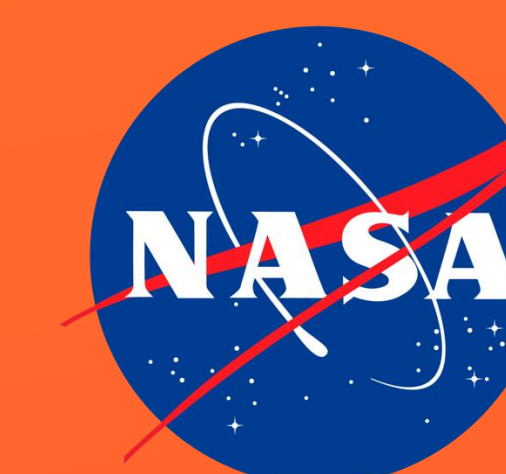


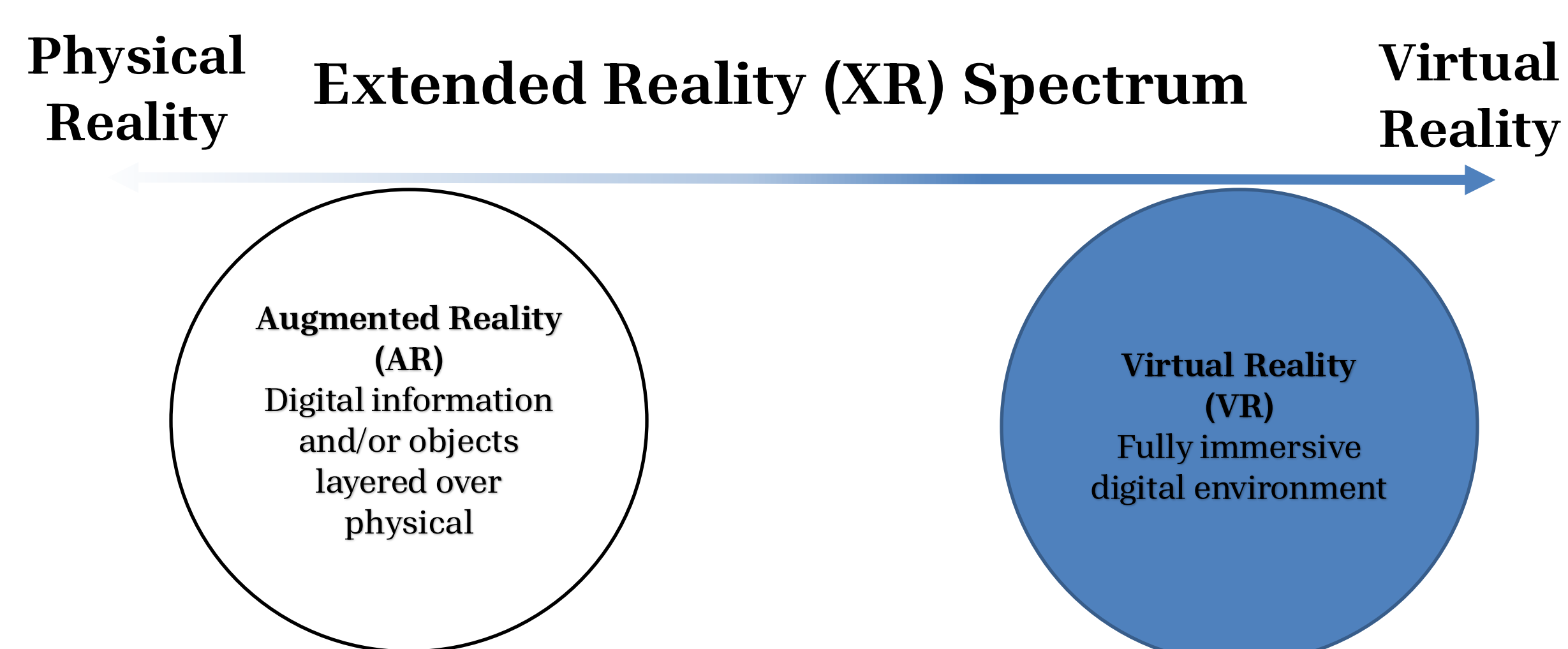
AN ANALYSIS OF EXTENDED REALITY MOCKUPS FOR USE IN VERIFICATION: PHASE 2



Ian Robertson¹, Shu-Chieh Wu², John Karasinski³, Kevin Arango⁴, Ryan Amick¹, Ryan Lange⁴
KBR¹, San José State University², NASA Ames Research Center³, Aegis Aerospace⁴

Background

At NASA, there is growing interest in using extended reality (XR) technologies for conducting Spaceflight Program verification activities.



Problem

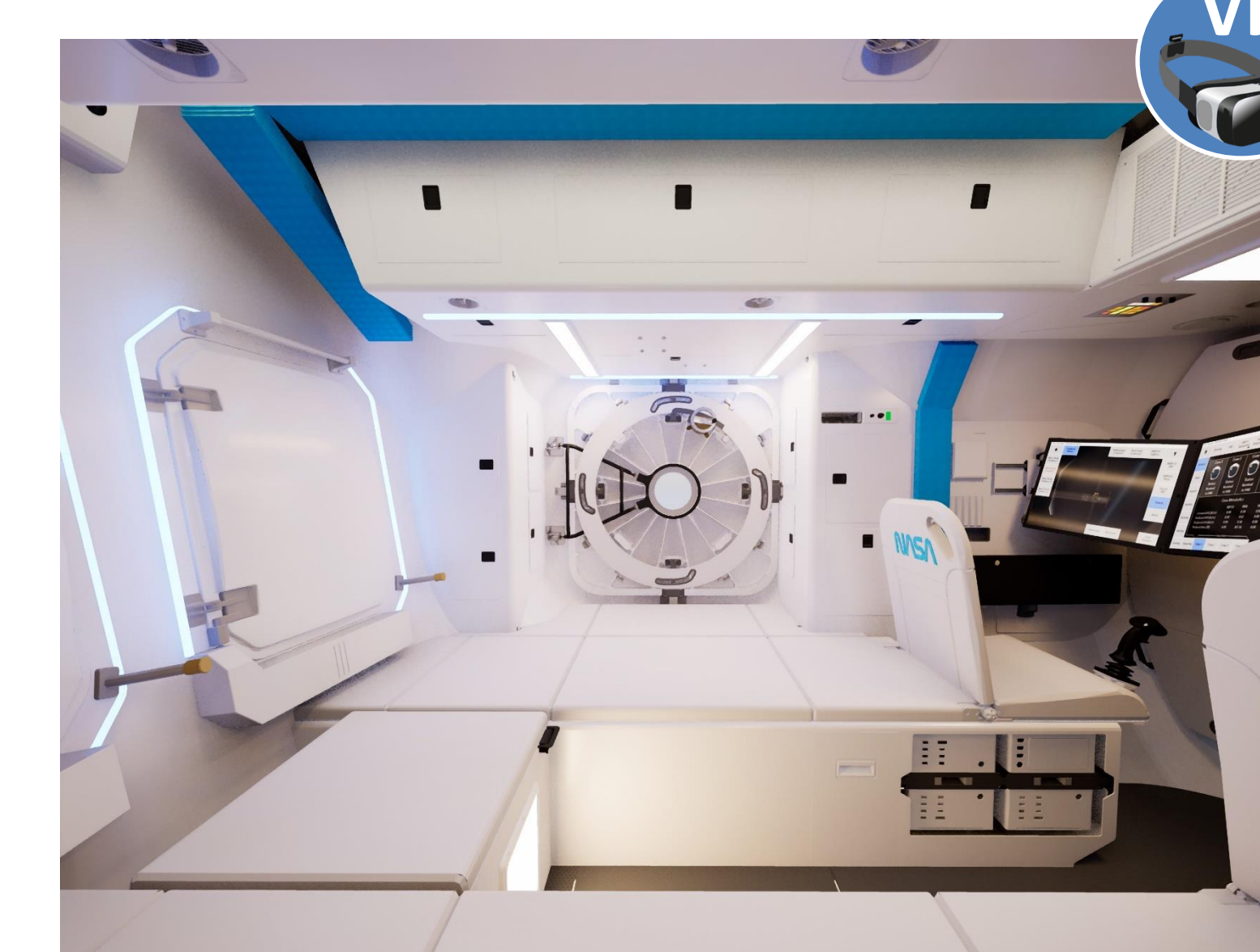
- There is little evidence concerning the validity of XR mockups for verification.
- Cost savings, alone, is not justification enough for the adoption of new approaches.
- XR technologies introduce new testing considerations and ill-defined terms, making evaluation difficult.

Phase I - Completed

- Focus of this phase was to evaluate VR and capture perspectives among NASA personnel.
- Conducted comparative analysis of pros and cons of XR mockups to physical.
- Empirically evaluated evidence for the use of VR mockups for verification.
- Laid ground for a framework for adopting XR technologies for verifications.

Phase I Testing

V&V HITL tests conducted in a VR model of the Habitable Airlock were compared to tests performed in the physical mockup.



Key Takeaways: VR mockups lack tactile feedback and must be carefully constructed to yield accurate/comparable results. The best current use case may be for single-system demonstrations. **Mixed reality mockups may address these shortcomings.**

Phase II - In Progress

- Builds upon the results of Phase I, with an emphasis on the use of Mixed Reality technologies to blend physical & virtual elements.
- Interviews with SMEs and Partners will capture current uses and practices with regards to XR technologies for product development and testing.
- Use of MR environments will be compared with findings from VR and PR mockups.
- The framework from Phase I will be matured.

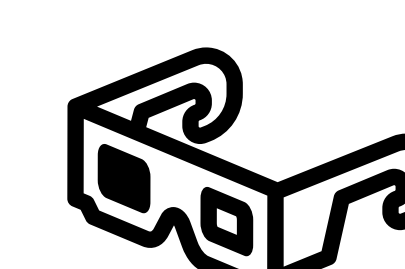
Current Work



Best Practices

Problem: XR technologies introduce need for new measures and considerations

- Common measurements for subjective measures such as **immersion**, **presence**, and **cybersickness**.
 - Can we recommend a standard battery as part of a “XR development toolkit?”
 - Identify if/how these measures contribute to maturing XR mockups for use in verification.
- How much training is needed to make XR hardware “transparent?”
- What do NASA partners do to evaluate their XR mockups/scenarios?



Physical Reality-Mixed Reality-Virtual Reality Comparison

Problem: There is still little evidence regarding the use of XR mockups for verification.

- Phase 2 Goals include:
 - Collect data to compare pros/cons of XR mockups
 - Field XR Development Toolkit
 - Validate XR for Verification Framework



XR for Verification Framework

Problem: Verification mockups require high fidelity for relevant aspects of scenario.

- **Fidelity is ill-defined:** Identify and define relevant fidelity dimensions for verification.
- **Fidelity is hard to evaluate:** If possible, find way to evaluate fidelity without the need to compare to physical reality.
- **How to validate?** Identify the best path forward for providers to demonstrate XR mockups are valid for use in verifications.

Potential XR Mockup Use Cases

XR Mockup Type	Physical Reality	Augmented Reality	Mixed Reality	Augmented Virtuality	Virtual Reality
Description	• Mockup and scenario are completely physical	• Elements are primarily physical • Digital elements are superimposed on physical • Low integration between digital and physical elements	• Elements are a blend of physical and digital • Digital and physical elements are highly integrated	• Elements are primarily digital • Physical elements are supplementary to digital • Low integration between digital and physical elements	• Mockup and scenario are completely digital
Example		PR mockup + AR overlays to act as interface mockups	Low fidelity PR mockup + VR overlay to add visual details	VR mockup for reach assessment + Brassboard for hardware operation	VR mockup for volume evaluation