



A Comparative Ground Study of Prototype Augmented Reality Task Guidance for International Space Station Stowage Operations

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Outline

1. Motivation and Stowage Operations
2. Related Work
3. StowageApp
4. Evaluation: Pilot Study
5. Results
6. Discussion



Motivation: Life in Micro-gravity

Image courtesy of NASA



Image courtesy of NASA



Image courtesy of NASA



Image courtesy of NASA

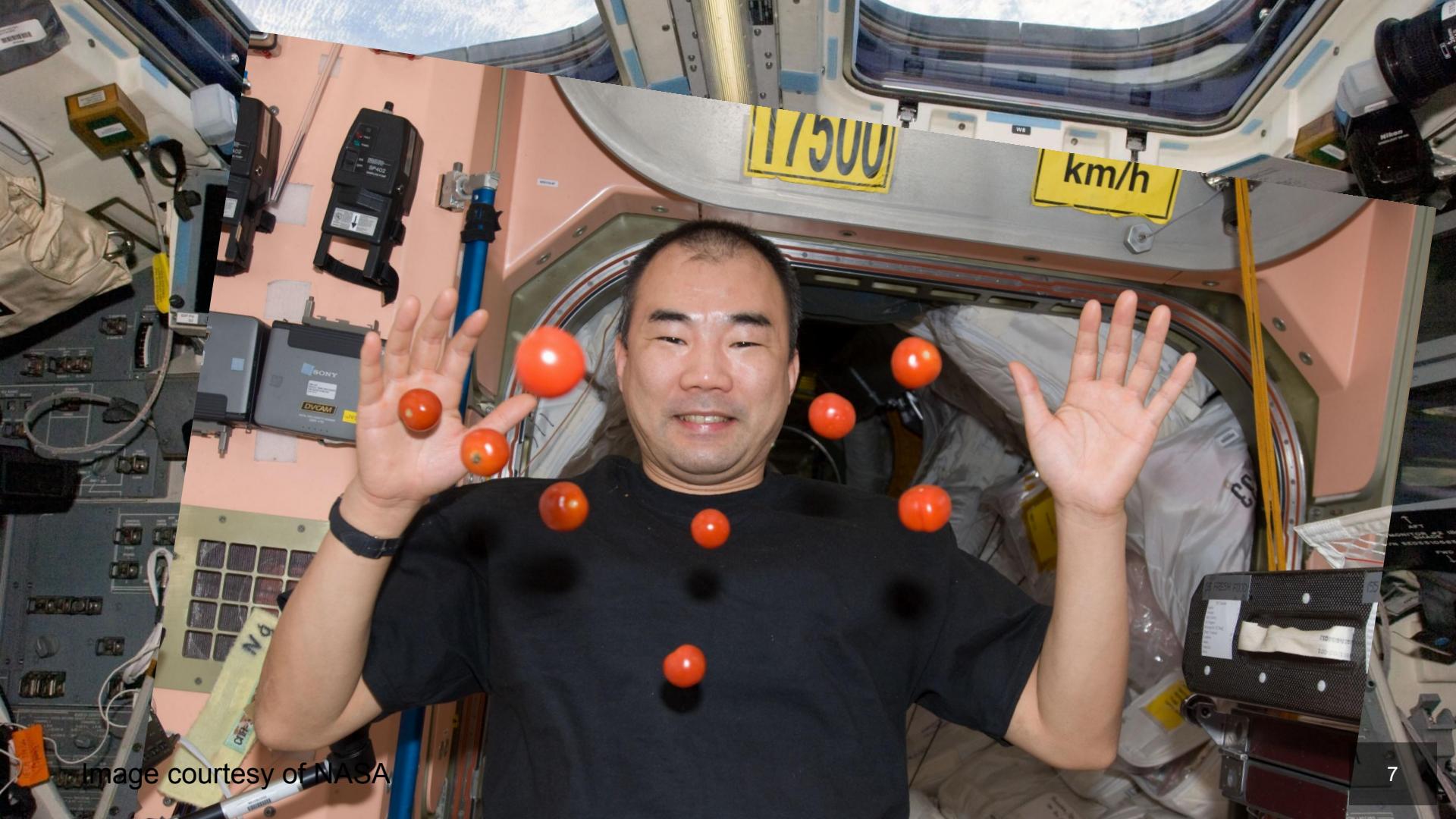


Image courtesy of NASA



Image courtesy of NASA

Stowage Operations

- Between visiting vehicle and International Space Station (ISS)
- Astronauts must follow cargo message instructions
- Typically takes 60 hours

Cargo Transfer Bag (CTB)



Image courtesy of NASA



Image courtesy of NASA

Stowage Operations

- Visiting vehicle ↔ International Space Station (ISS)
- Astronauts must follow cargo message instructions
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Image courtesy of NASA

How many hands do astronauts need?

- Hold and operate a tablet—two hands
- Hold and use a Cargo Transfer Bag—two hands
- Move in space—two hands

A photograph of a man wearing a dark VR headset and a black hoodie, standing in a large cargo bay. He is facing away from the camera, looking at a large white cargo pallet. In the upper right corner of the image, there is a semi-transparent black rectangular overlay containing a screenshot of a VR interface. This interface shows a green 3D model of a cargo bay with a green outline around a specific area. Inside this outlined area, the text "PMM1P2 B1" is displayed in white. There are also other labels like "4361" and "K14" in the background of the VR screen.

What is Augmented Reality?

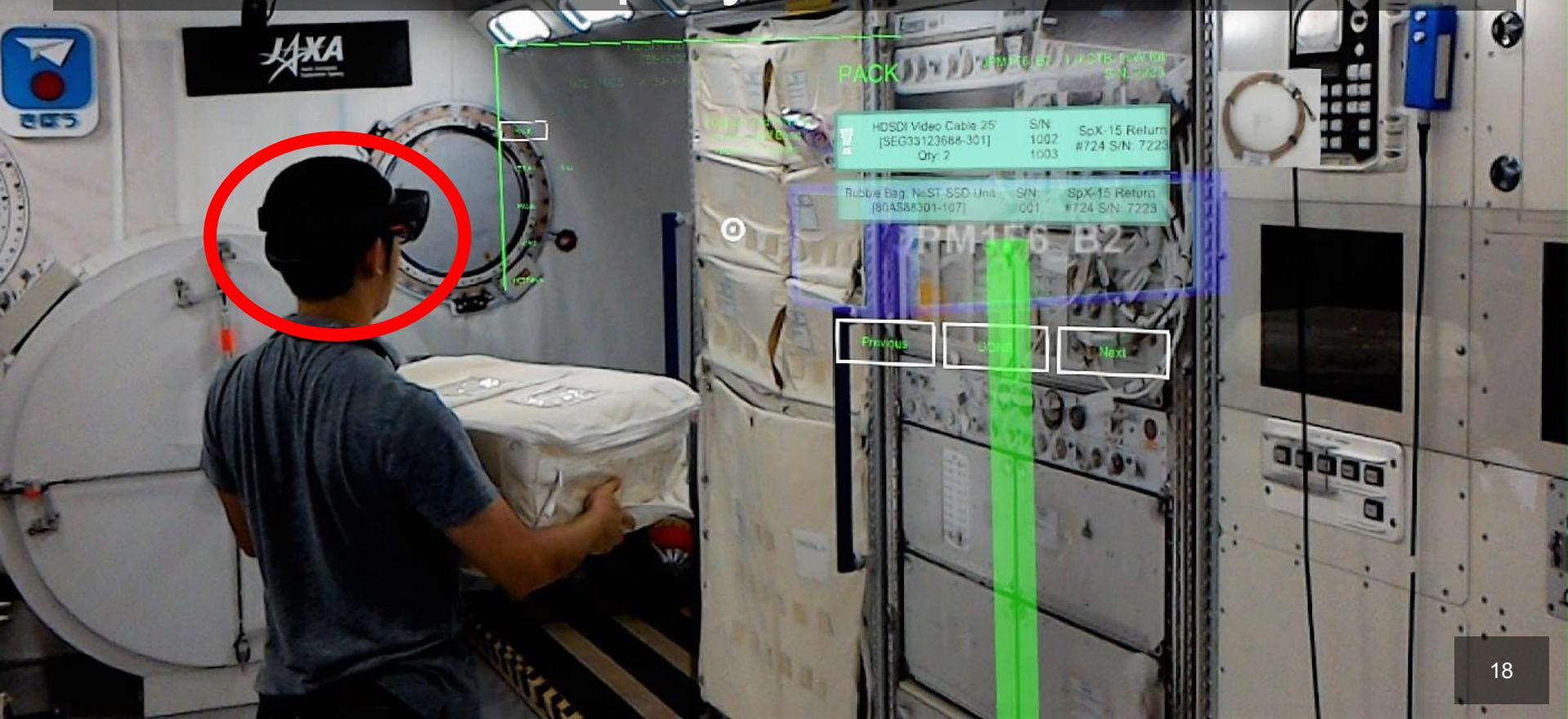
Related Work

- AR in warehouse order-picking
- Electronic procedures
- AR procedure task guidance
- 2D windows in 3D space
- AR pathfinding
- AR for spaceflight maintenance

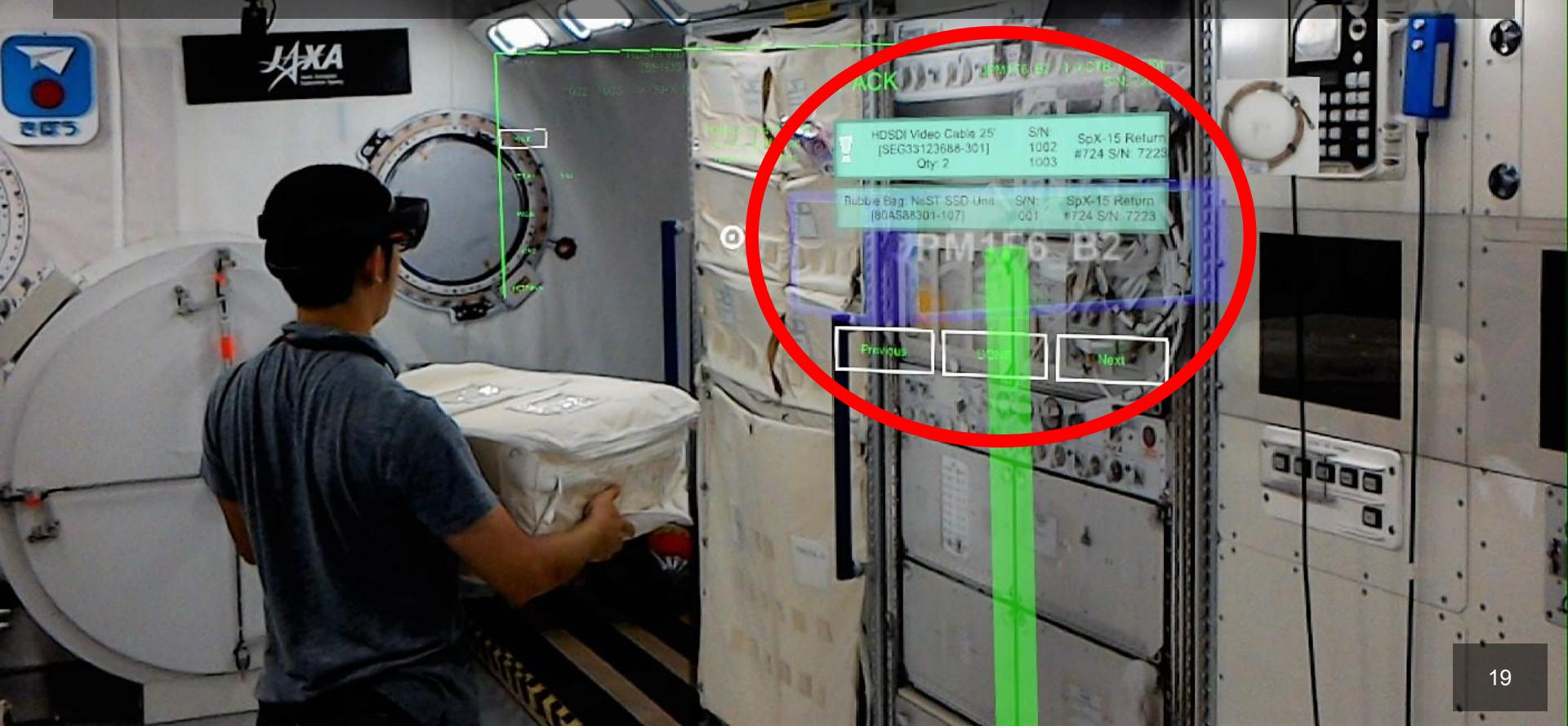
StowageApp



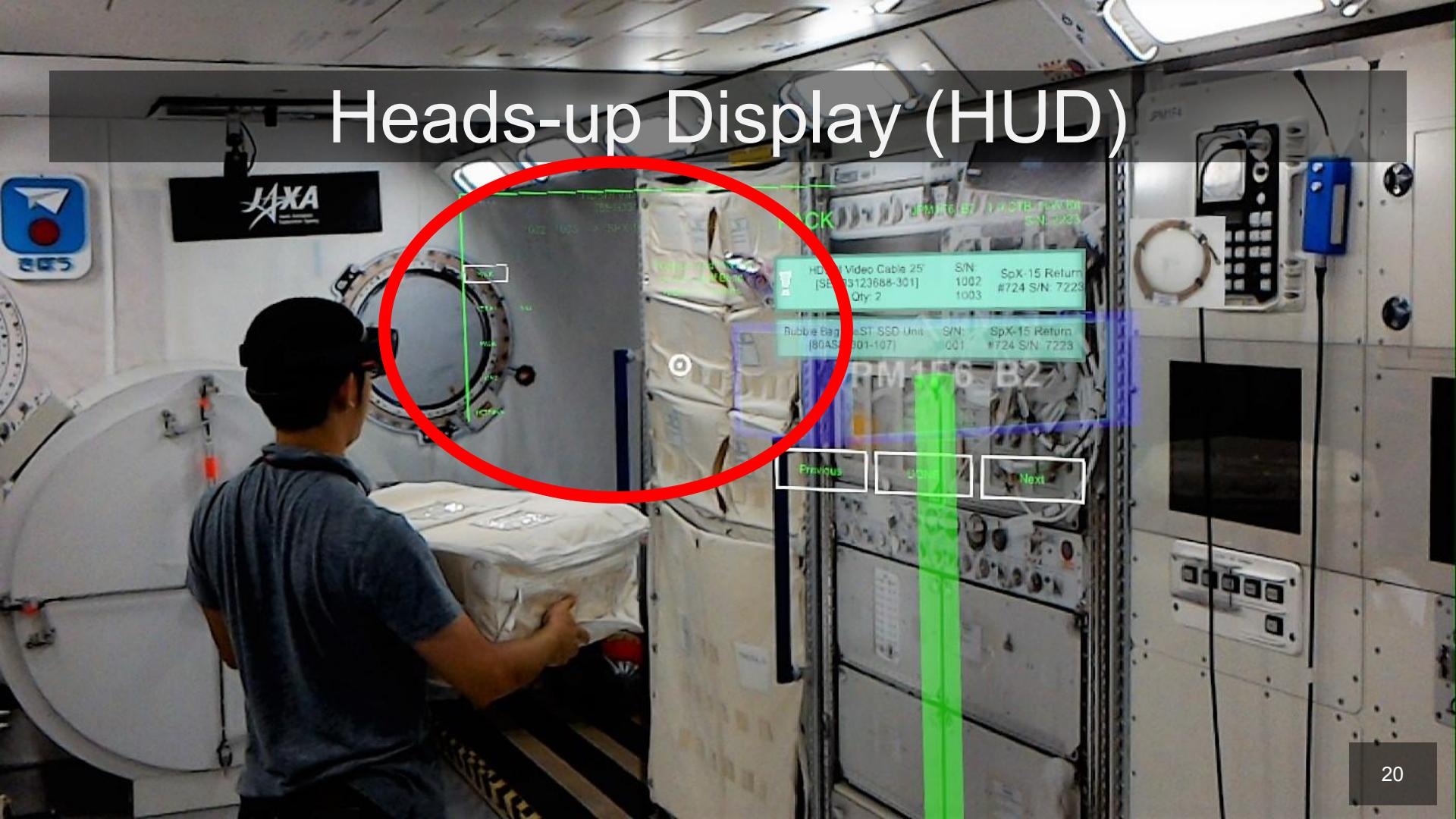
Head-worn Display: Microsoft HoloLens



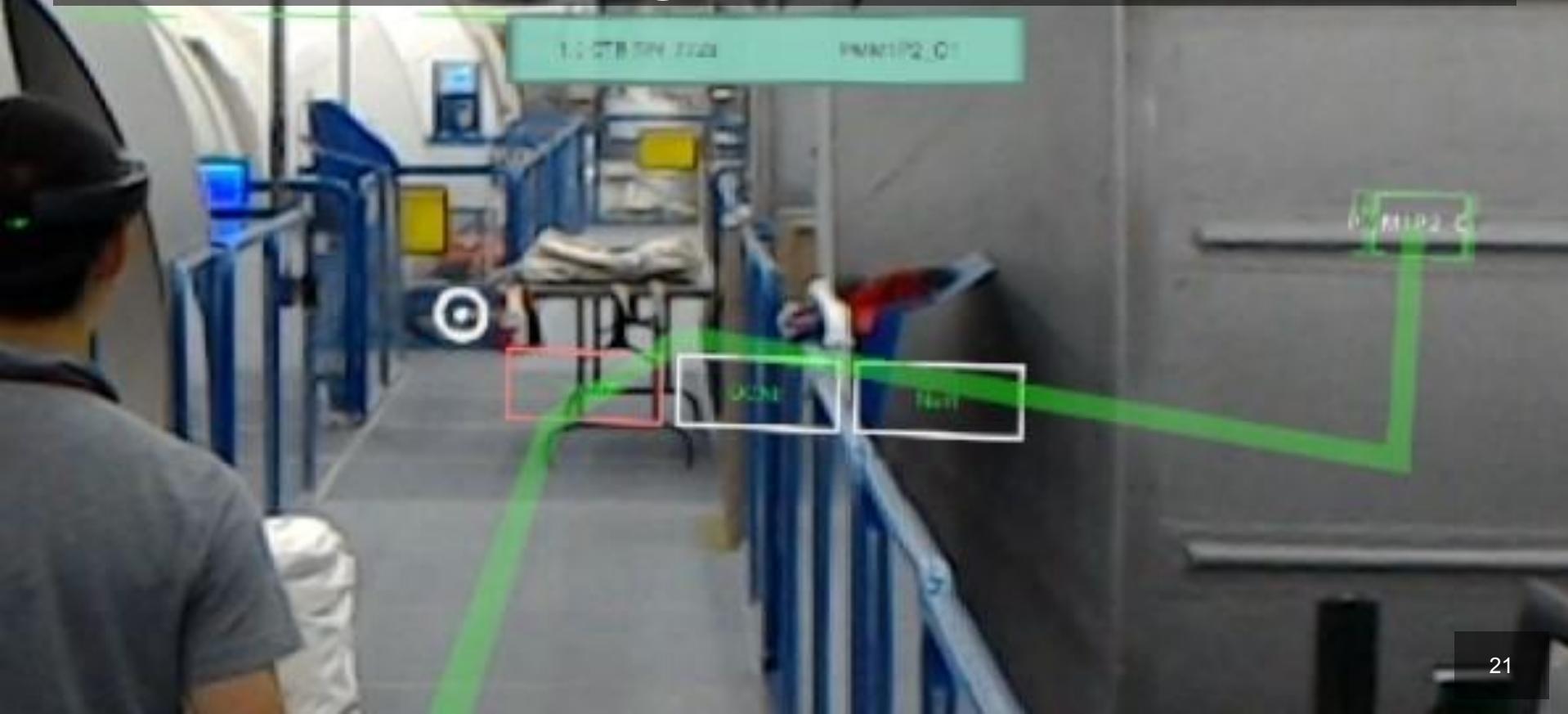
2D Window in 3D World: The Main Panel



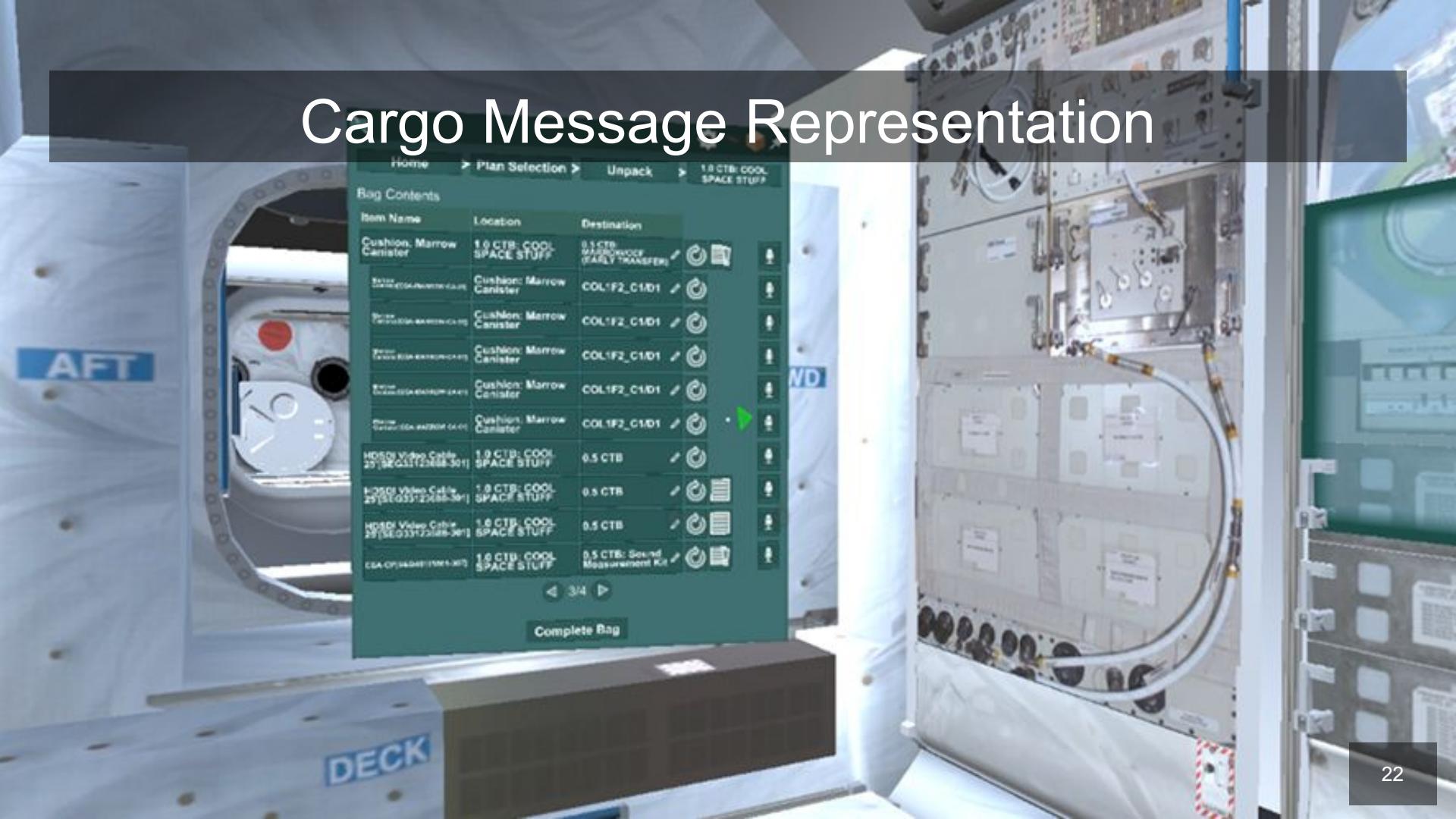
Heads-up Display (HUD)



Pathfinding and Localization



Cargo Message Representation

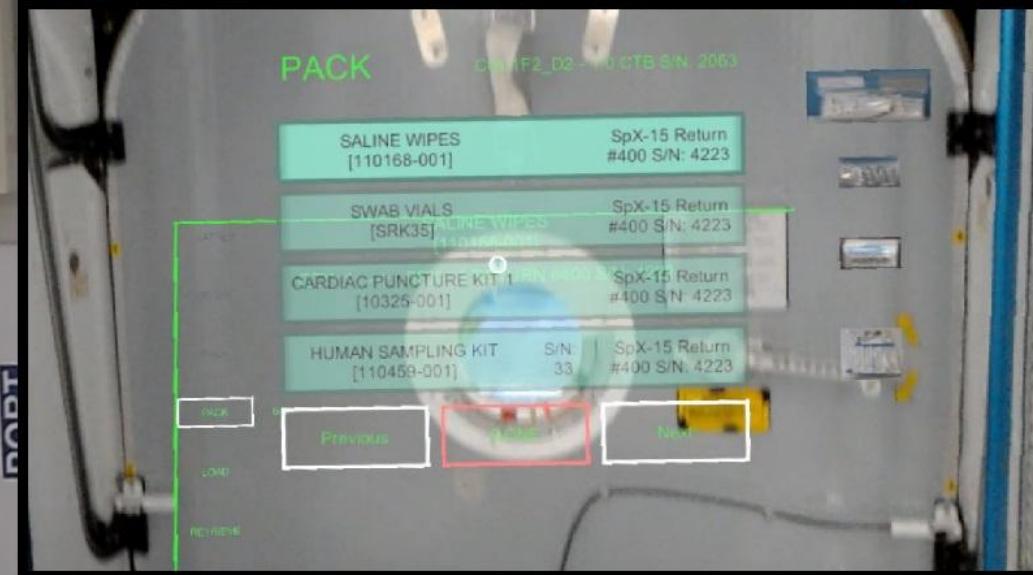


Bag Contents			
Item Name	Location	Destination	
Cushion: Marrow Canister	1.0 CTB: COOL SPACE STUFF	0.1 CTB: COOL SPACE STUFF (EARLY TRANSFER)	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
SHURE T5WHDGK-AWTRM-01	Cushion: Marrow Canister	COL1F2_C1/D1	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
SHURE T5WHDGK-AWTRM-02	Cushion: Marrow Canister	COL1F2_C1/D1	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
SHURE T5WHDGK-AWTRM-03	Cushion: Marrow Canister	COL1F2_C1/D1	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
SHURE T5WHDGK-AWTRM-04	Cushion: Marrow Canister	COL1F2_C1/D1	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
HDSDI Video Cable 25 [SEG3312588-30]	1.0 CTB: COOL SPACE STUFF	0.5 CTB	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
HDMI Video Cable 25 [SEG3312588-30]	1.0 CTB: COOL SPACE STUFF	0.5 CTB	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
HDSDI Video Cable 25 [SEG3312588-30]	1.0 CTB: COOL SPACE STUFF	0.5 CTB	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>
CSA OP/4404P/PW1-30	1.0 CTB: COOL SPACE STUFF	0.5 CTB: Sound Measurement Kit	<input checked="" type="checkbox"/> <input type="radio"/> <input type="radio"/> <input type="radio"/>

Complete Bag



OVHD



Cargo Message Representation

- Work with Inventory and Stowage Officers (ISOs) to model cargo message execution flow
- Refine granularity of cargo message representation
- Implement, demonstrate, get ISO feedback
- Repeat

Evaluation: Pilot Study

Pilot Study

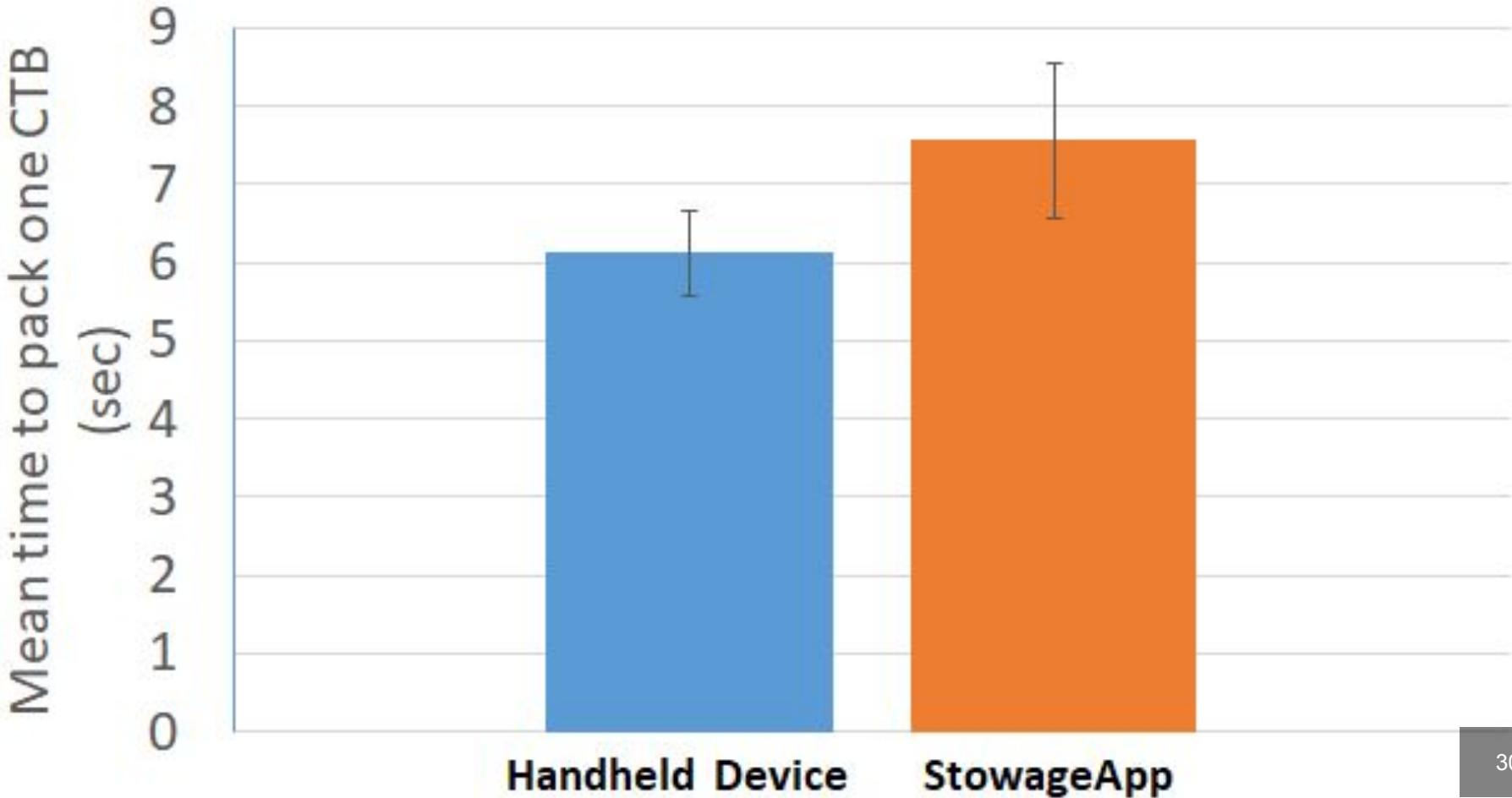
- Compare performance of cargo message on handheld tablet device to StowageApp
- Participants perform a mock stowage operation
- Conducted in full-scale ISS mockup at NASA Johnson Space Center (JSC)
- $N = 9$, 2 hr. per session, within-subject pilot study

Measurement of Performance

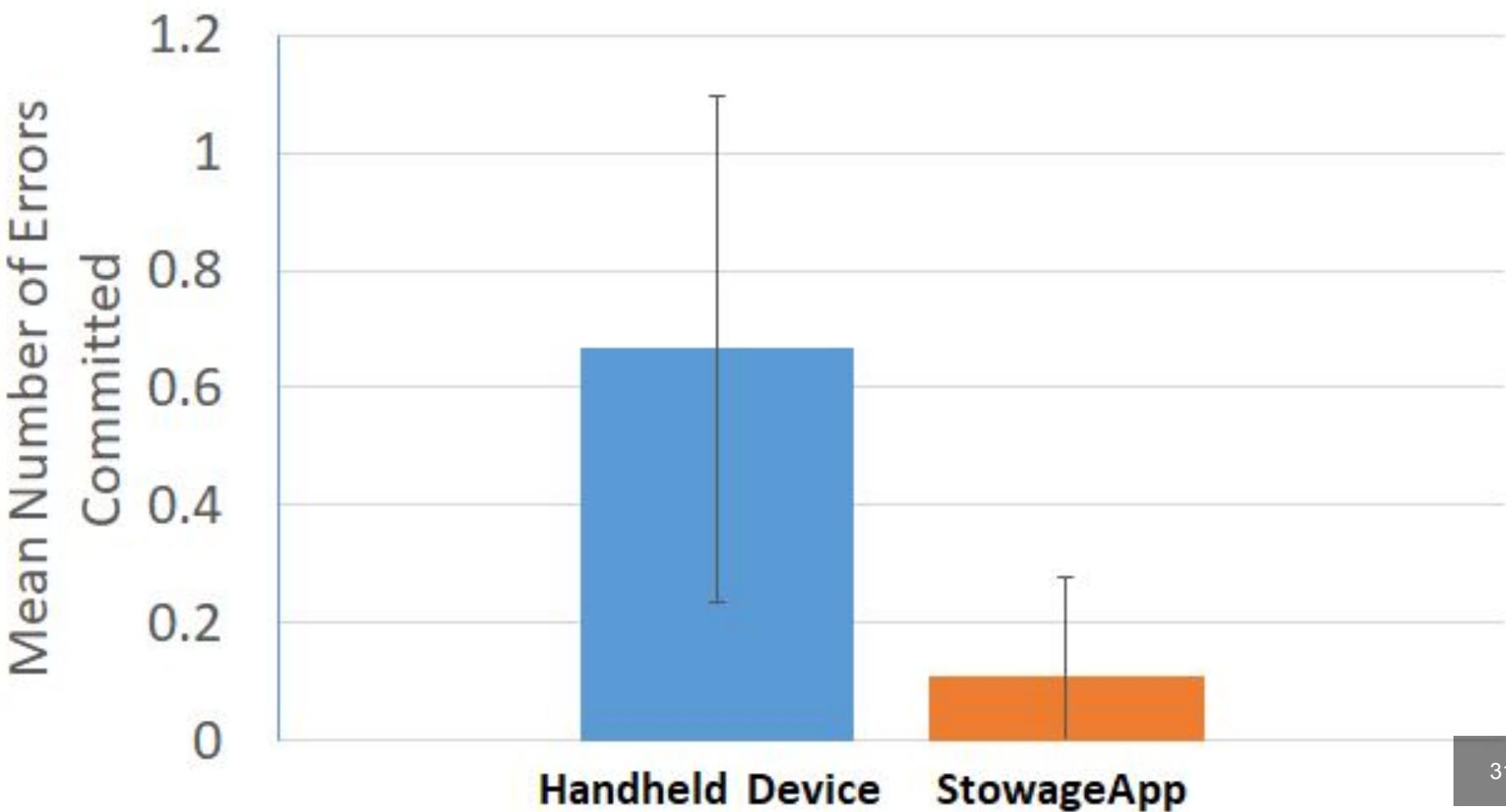
- Task completion time
- Number of errors committed
- NASA Task Load Index (TLX) perceived workload assessment survey
- User preference of method

Results

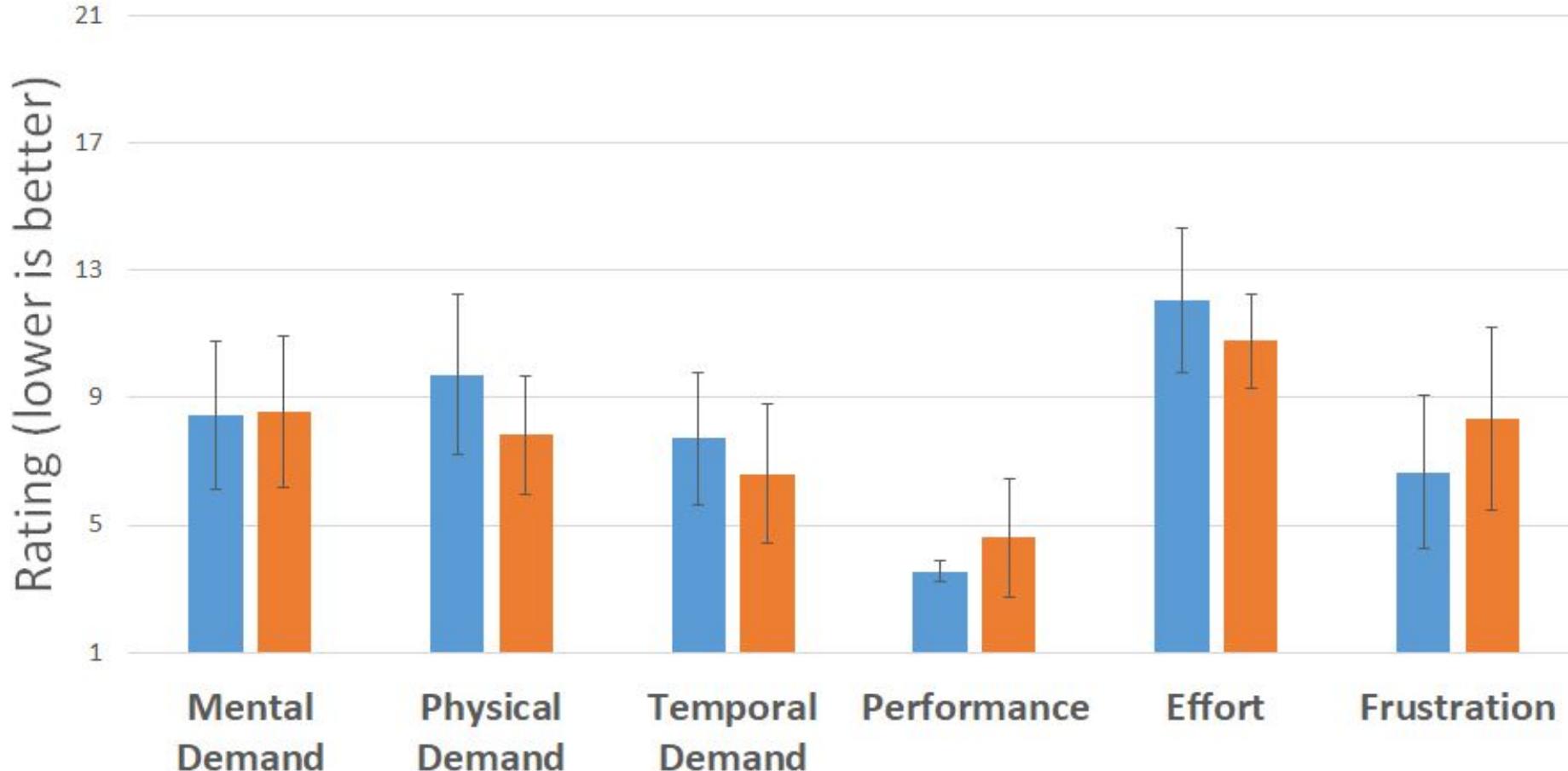
Completion Time



Errors Committed



NASA TLX by Method



Summary of results

- For all tests, $\alpha = 0.05$
- No significant difference in task completion time
 - 2-tail t-test of equal variance ($p > 0.075$)
- No significant difference in error
 - 2-tail t-test of unequal variance ($p > 0.09$)
- No significant difference in responses to any NASA TLX category
 - Wilcoxon signed rank tests (see paper for p-scores)
- 8/9 users preferred StowageApp

Discussion

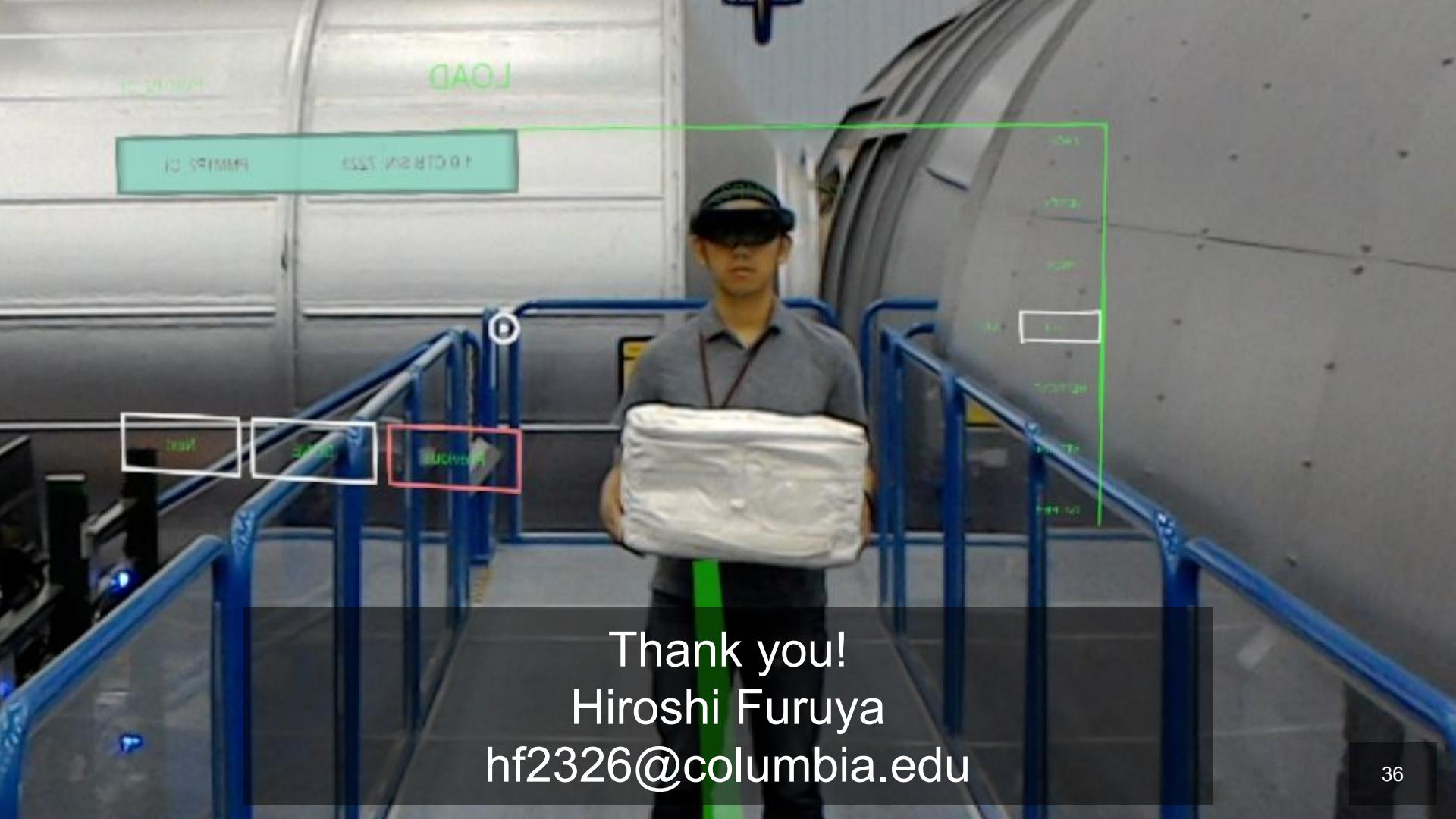
- Sample size too small
- Interpreting errors is difficult
- Need to better simulate stowage operations on ISS
 - Can you just put down a tablet?
 - Rules to enforce during a formal user study

Acknowledgments

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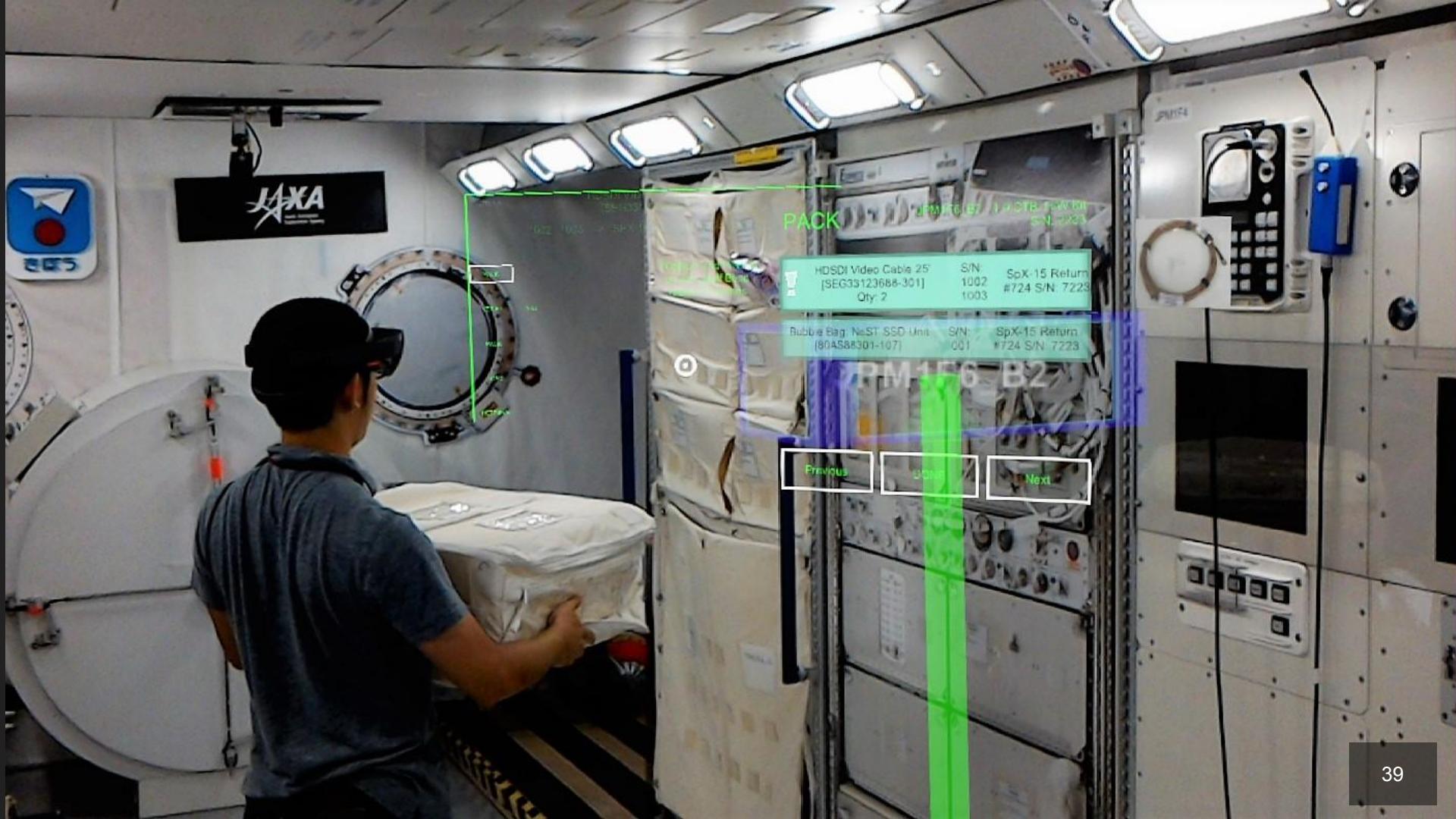


Thank you!
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Backup Slides

Design Decisions

- 2D virtual panel does not respect physical boundaries
- Virtual panel egocentric and exocentric behavior
- HUD cannot display detailed procedure instructions





LOAD

1.0 CTB: SpX Return Items
SN: 1122

JPM1F6_A1
JPM1F6_A1

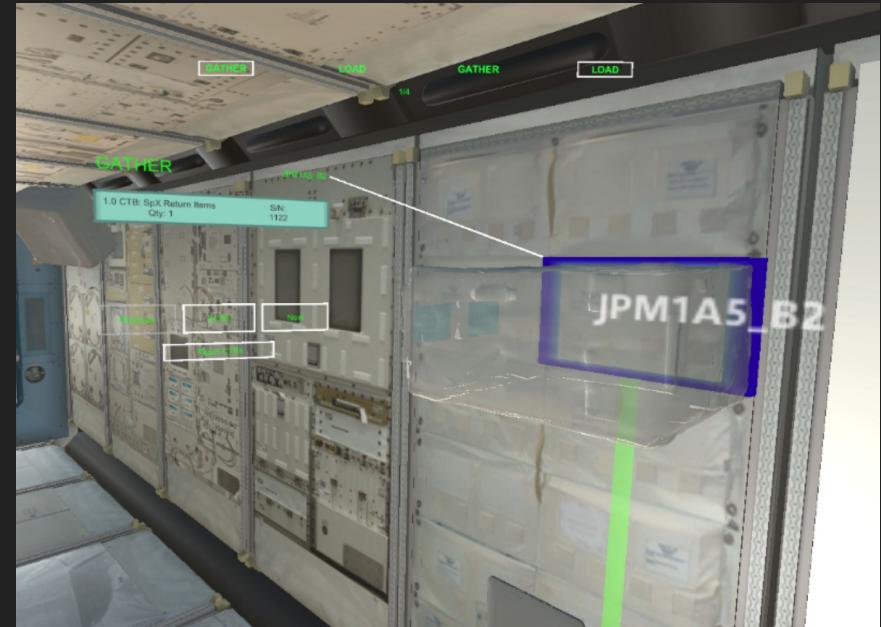
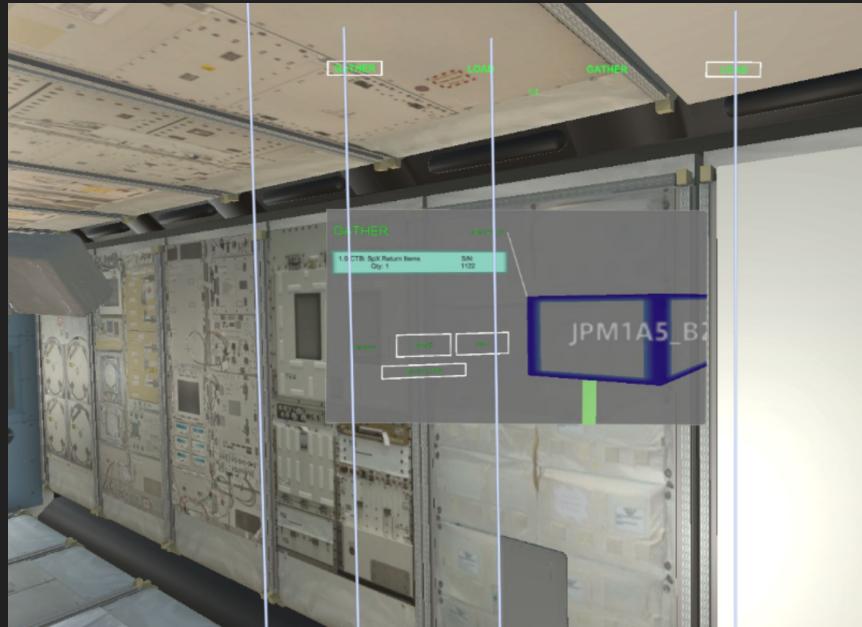
Previous

DONE

Next

Reset CTB

HoloLens Application vs AR Tool of the Future



AFT

Previous Interaction: Pin to physical environment





Current: Billboarding, dog-leashing



Simple Cargo Message Representation Model

