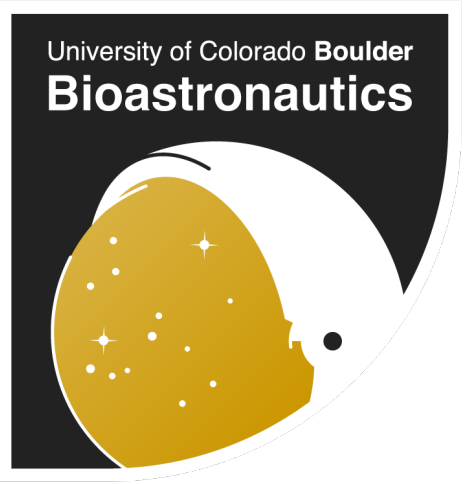
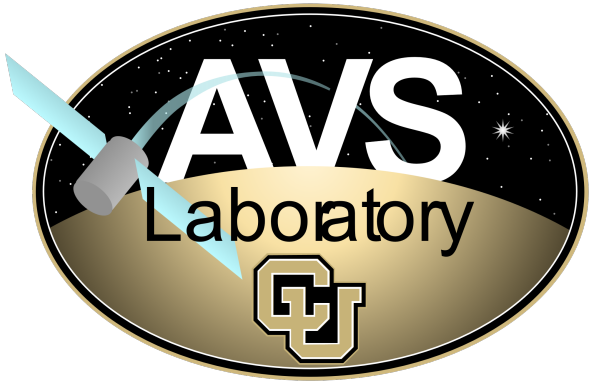


Integrated Virtual Reality Visualizations and Information Display to Understand Uncertainty in Training for Spaceflight Operations



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Disclosure Information

93rd Annual Scientific Meeting
Savannah Buchner

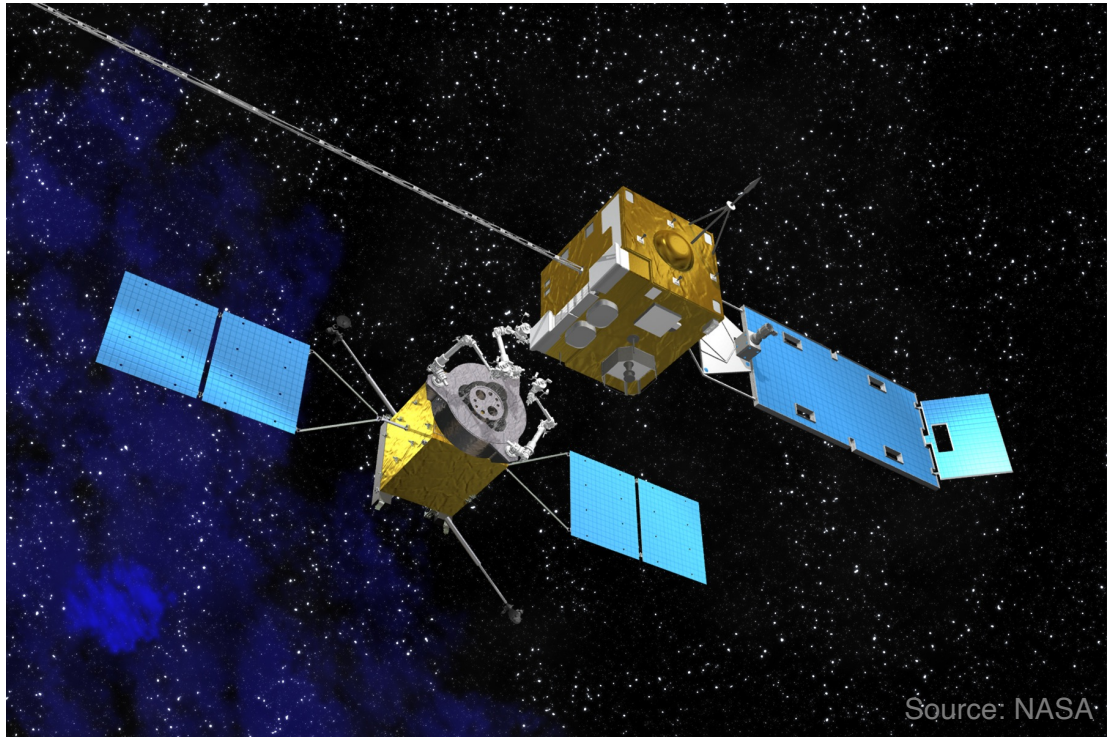
I have the following financial relationships to disclose:

- Grant/Research support from: SpaceWERX grant FX21S-TCSO1-0345

I will not discuss off-label use and/or investigational use in my presentation

Motivation

- For future on-orbit spacecraft operations, human operators will act as supervisors of autonomous systems
- The operator is separated both spatially and temporally from the spacecraft
  - Lack of environmental context compromises situation awareness (Chen et al., 2007)
- Operators are required to process complex data from many sources



Motivation

- It is important for operators to be able to understand the impact of their actions on future satellite states
- This includes understanding how small uncertainties in planned actions can impact future satellite states
  - i.e., imperfect thruster burns, noisy sensor readings
- There is a need for effective training

Virtual reality (VR) can allow for immersive, high fidelity, realistic simulations of the environment (Chen et al. 2007)

Background

- VR is a promising training modality for a variety of task types (Seymour et al. 2002, Wheeler et al., 2023) and for use in teleoperations (Chen et al. 2007)
  - Has been shown to induce realistic responses (van Dammen et al. 2022) and be a safe, low-cost training mechanism (Xie et al. 2023)
  - In teleoperations VR can improve situation awareness, lower workload, and improve collision avoidance (Elor et. Al, 2021, Wilde et al. 2014)

- There is limited research into remote supervisory tasks
  - For remote supervision, it was found that 3D visualizations improved SA, but VR might increase cognitive load (Lager and Topp, 2019)

Our objective is to develop an immersive VR display to improve operator performance interpreting uncertainty during on-orbit service, maintenance, and repair training.

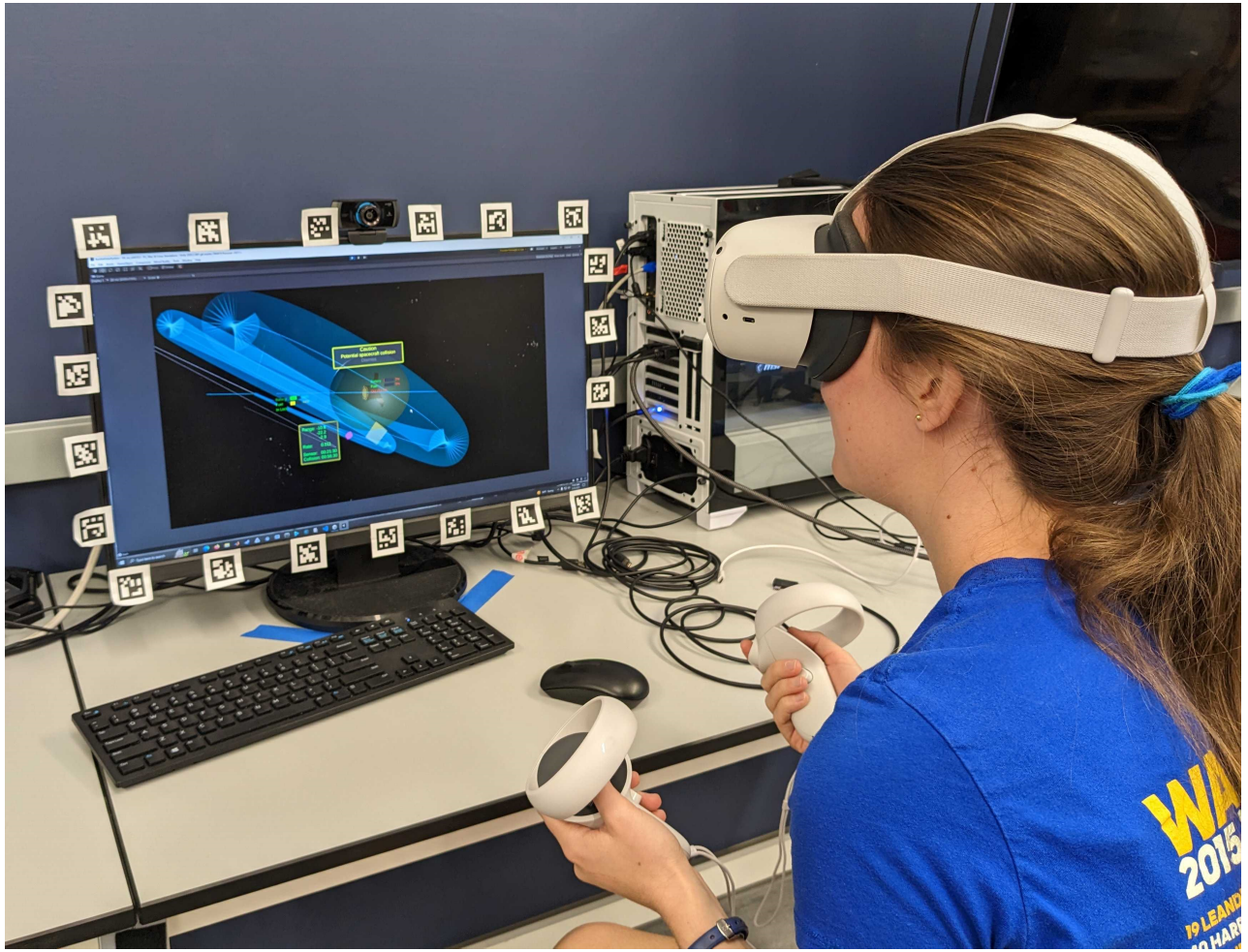
Our approach incorporates human-factors display deign principles integrated with physics-based orbital and satellite simulations. It will be compared to alternative display designs.

Development of Physics Simulation

- A satellite servicing mission profile was developed using Basilisk, a high-fidelity physics-based spacecraft simulation tool
  - Simulation includes a servicer satellite entering proximity operations around a dead target satellite
- Uncertainties are introduced through imperfect thruster burns and noisy sensor readings
- Propagation of uncertainties can lead to potential collisions

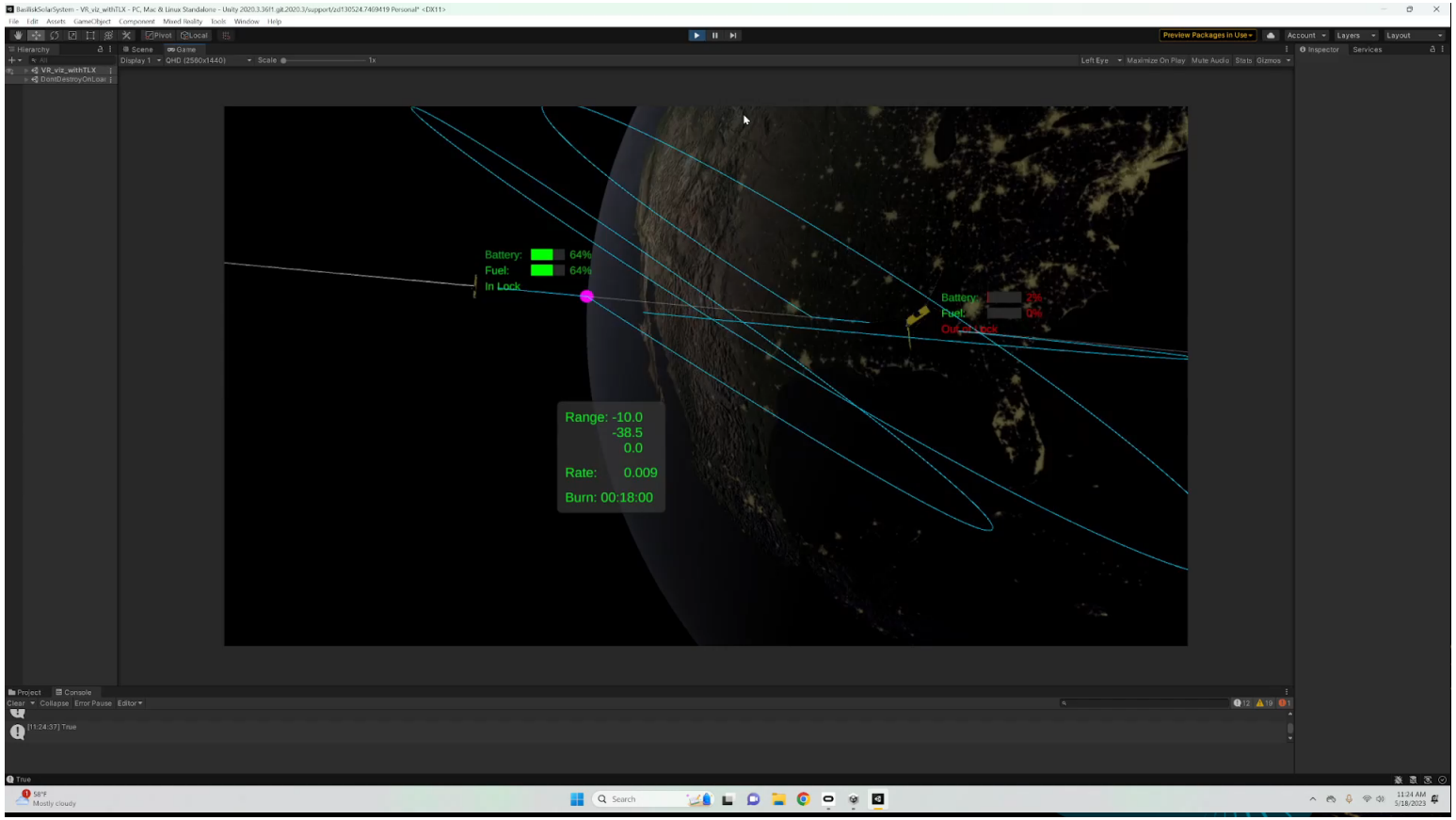
Virtual Reality Display Design

- Display design utilized human factor approaches
- Combined principles from:
  - Traditional 2D aerospace displays
  - Heads up displays
  - Virtual reality displays



Virtual Reality Display

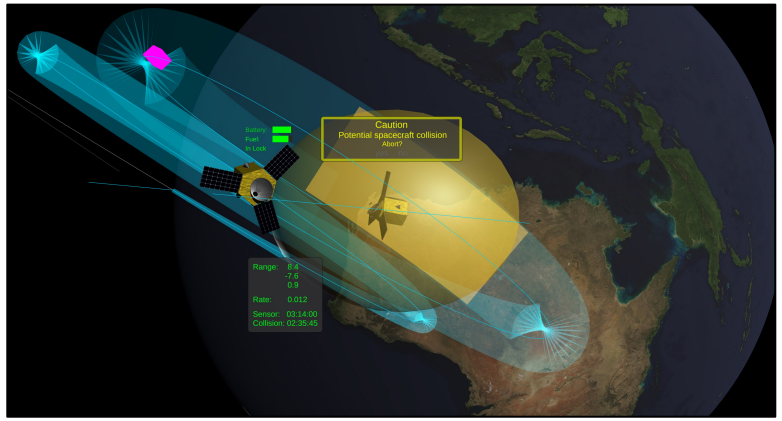
- Data, such as orbits and uncertainty, are visualized immersively
- Critical information is in text-based heads-up display
- Information shown can be customize by the operator

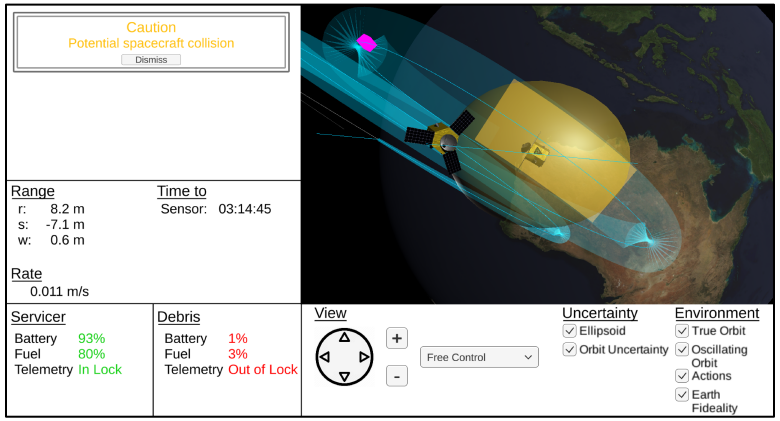


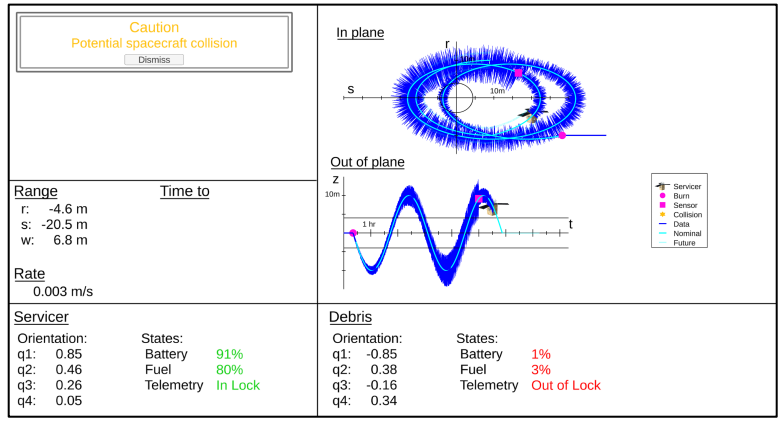
Methods

- Three display designs with various amounts of visualization and immersiveness
- All have the same information available to the operators
- Display designs are based on human factor approaches
- Subjects were randomly assigned to one of the display modalities

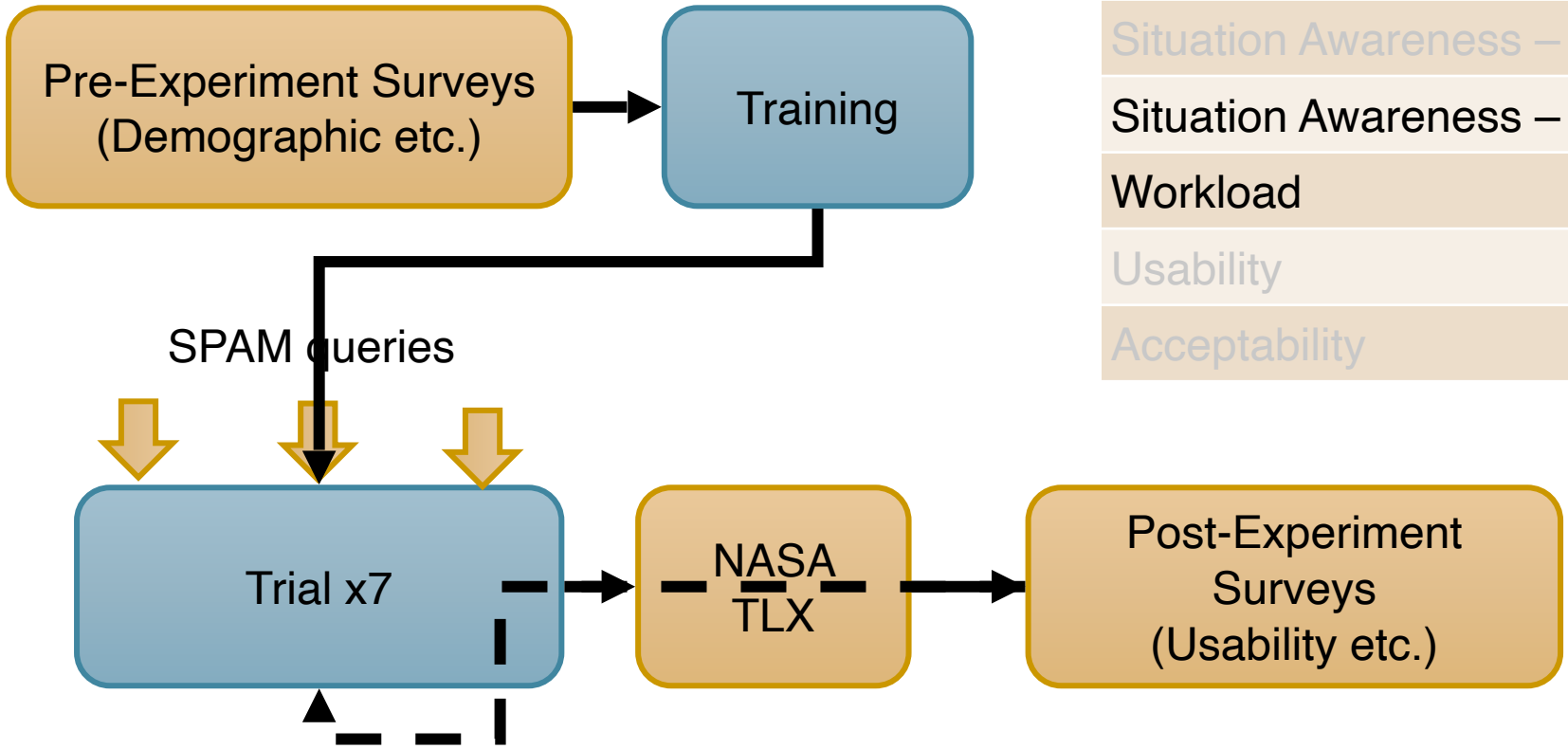
	VR
Visualizations	✓
Immersiveness	✓







Experiment Design



Variable	Method
Situation Awareness – Level 1	Callouts
Situation Awareness – Level 2/3	SPAM
Workload	NASA TLX
Usability	SUS
Acceptability	Subjective Questionnaire

SPAM – Situation Present Assessment Method (Durso et al., 2004)

- Multidimensional subjective workload assessment tool (Durso et al., 2004; Loft et al., 2015)
- Operators respond to queries while having access to their display

Selected Results

- These are preliminary results and may not reflect trends after subject testing is finalized

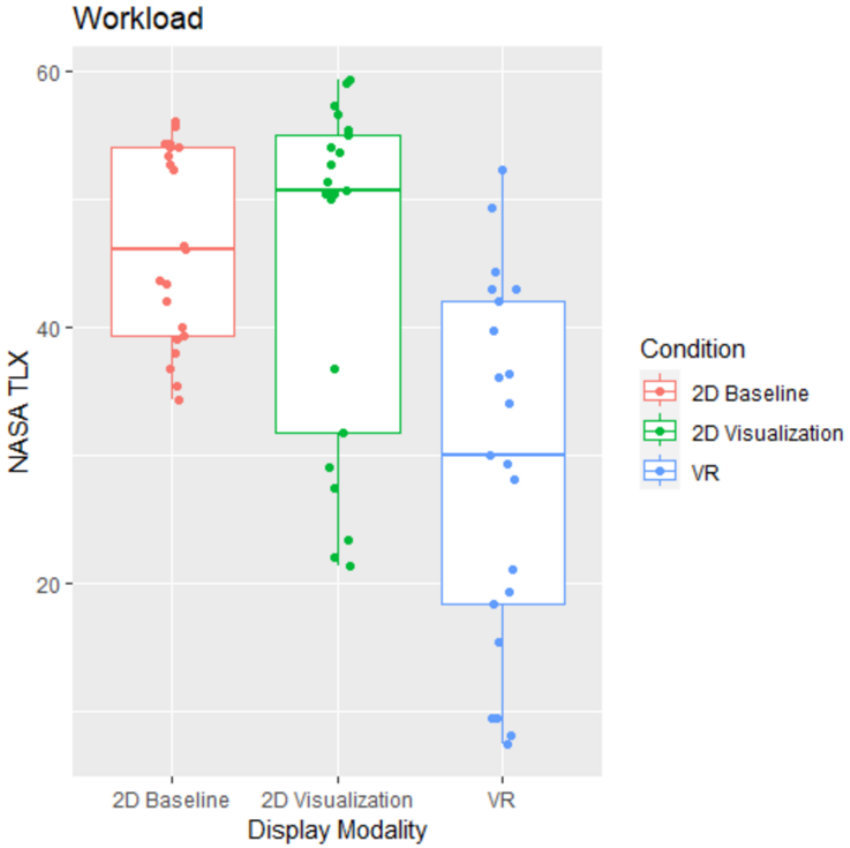
Situation Awareness (SA) (Endsley, 1996)

- Level 2: Comprehension
- Level 3: Projection

- Higher percent correct corresponds to higher SA
- Trends that visualization and immersiveness improve the ability to answer queries correctly

Selected Results

- These are preliminary results and may not reflect trends after subject testing is finalized



- Lower TLX corresponds to lower workload
- Immersiveness may improve perceived mental workload over the entire trial.

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Conclusion

- Designed an immersive VR display that utilizes existing heads up display principles as a potential training modality for complex, remote supervisory operations
- The study is undergoing human subject testing to compare the effects of immersiveness and visualization an operator's understanding of uncertainties for remote operations

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Thank you