



NEURO-VESTIBULAR EXAMINATION DURING AND FOLLOWING SPACEFLIGHT (VESTIBULAR HEALTH)

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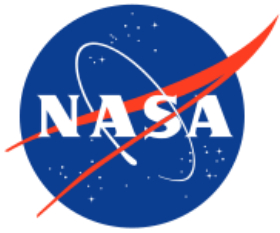
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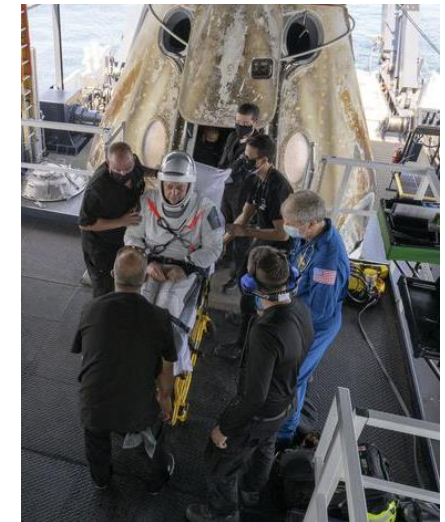


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Background

- Spaceflight-induced sensorimotor adaptations can cause neurological disturbances that are mediated by the vestibular system:
 - Space motion sickness, spatial disorientation, and cognitive impairment, as well as changes in head-eye coordination, vestibulo-ocular reflexes, and control of posture.
- Otolith-mediated reflex gains appear to adapt rapidly to g-transitions, but animal studies suggest that there are long-term structural modifications to the vestibular apparatus¹.
- What is the severity and mechanism of symptoms as a function of spaceflight duration?



¹Boyle et al., J Neurophysiol, 2001



Objectives



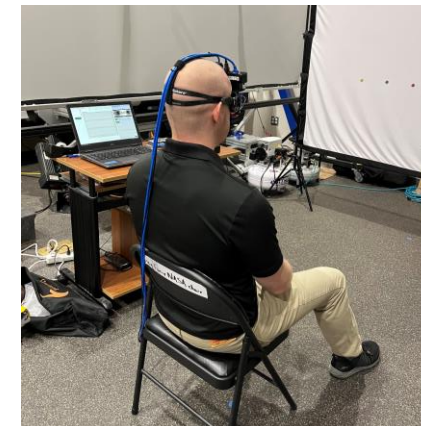
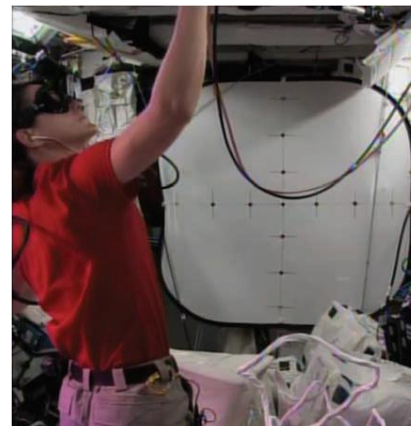
- Use well-established clinical and experimental procedures to:
 - Identify temporal trends of vestibular adaptation in orbit and after landing.
 - Differentiate between peripheral and central vestibular forms of vertigo and oculomotor disorders.



Methods

- Recordings of eye, head, and body movements, as well as subjective reports of perception of motion.
 - This includes characterization of temporal trends in central compensation for vestibular (otolith) asymmetry.
- Video eye measurement system (DX Falcon, Neurolign Technologies Inc, Toronto, CN).
- To date, 6 crewmembers (3F, 3M) have completed preflight, inflight, and postflight testing.
 - Mean flight duration: 219 ± 42 days (148-282 days)
 - 1 additional crewmember is still undergoing testing.

Preflight	Inflight	Postflight
Evaluation: Launch-200 Exam: Launch-90	Flight Day 1 (FD1), FD30, FD150, Return-30 Motion Sickness Questionnaire (MSQ): FD4	Return+0 (R+0), R+4, R+9, R+30 MSQ: R+4

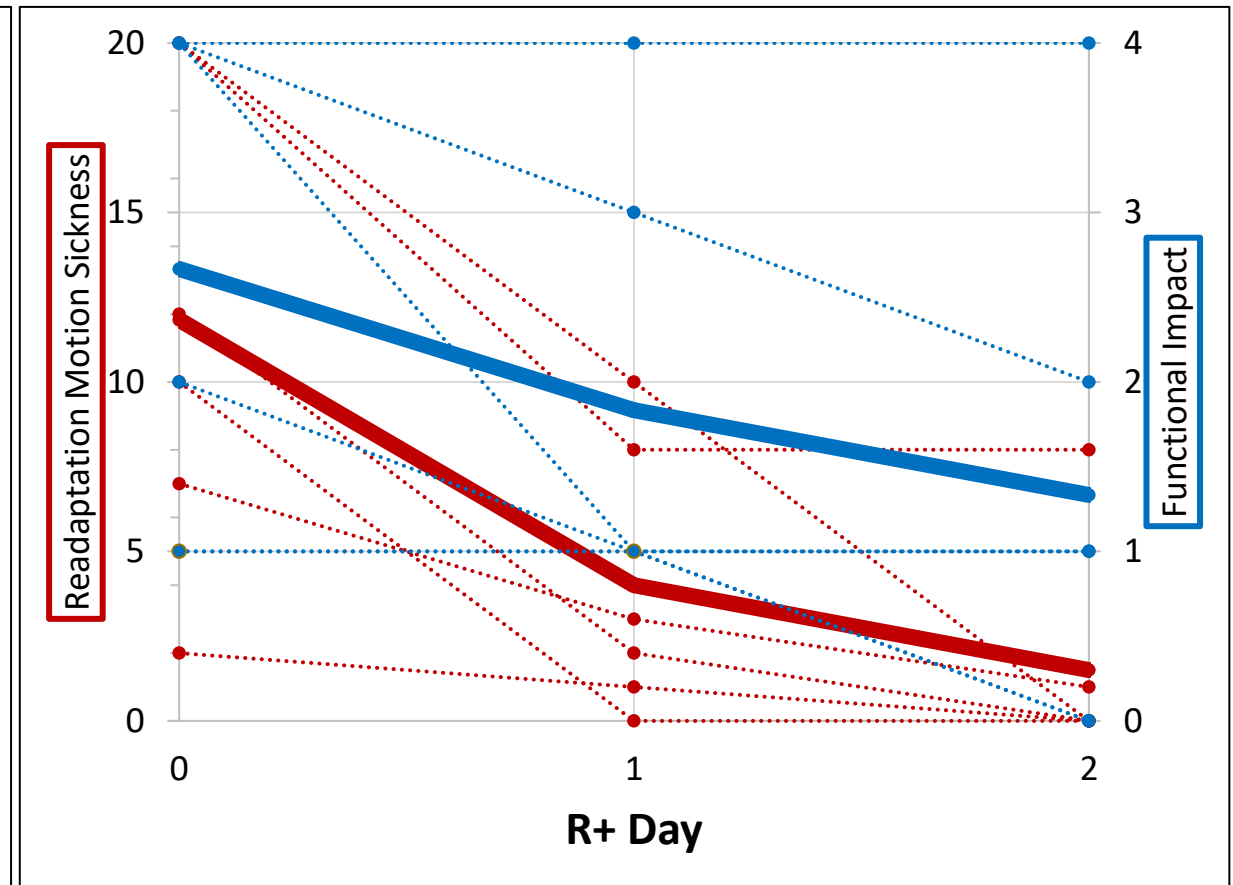
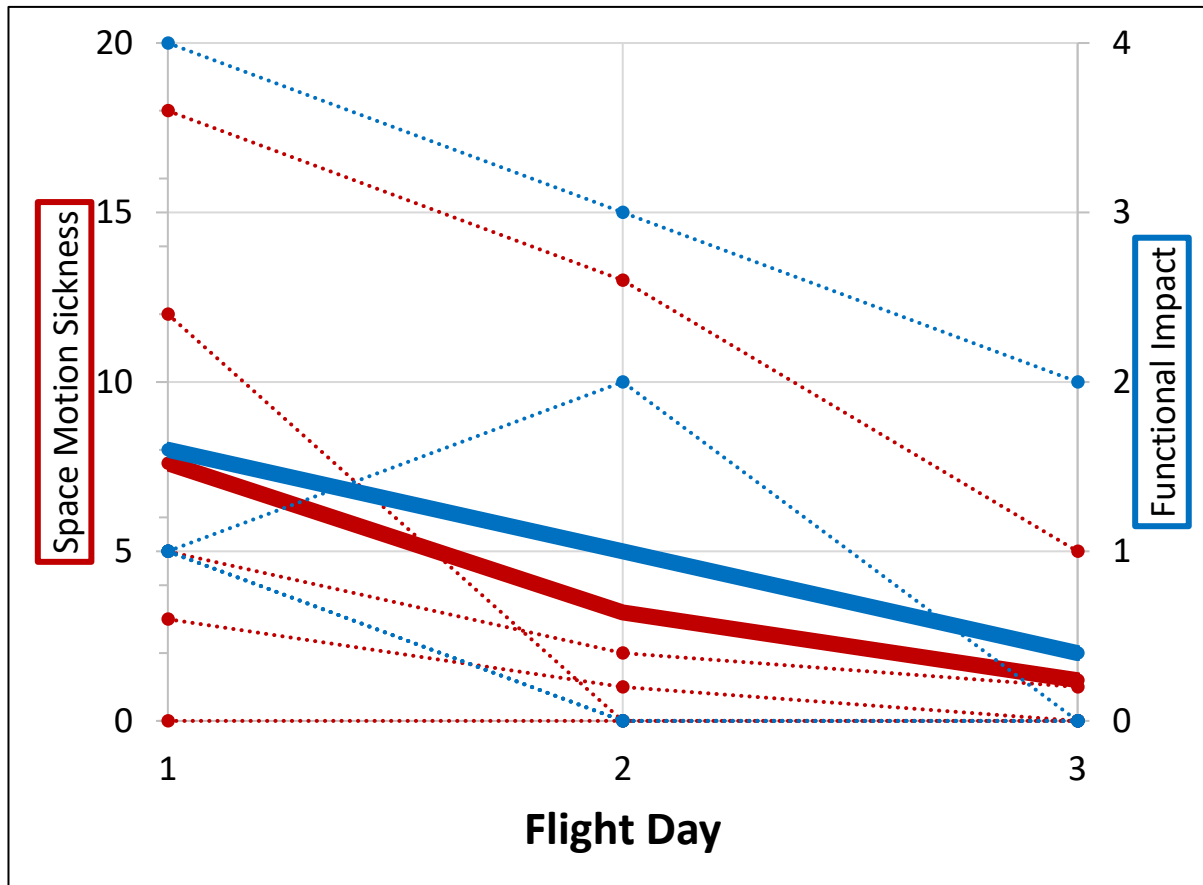




Preliminary Results – Motion Sickness

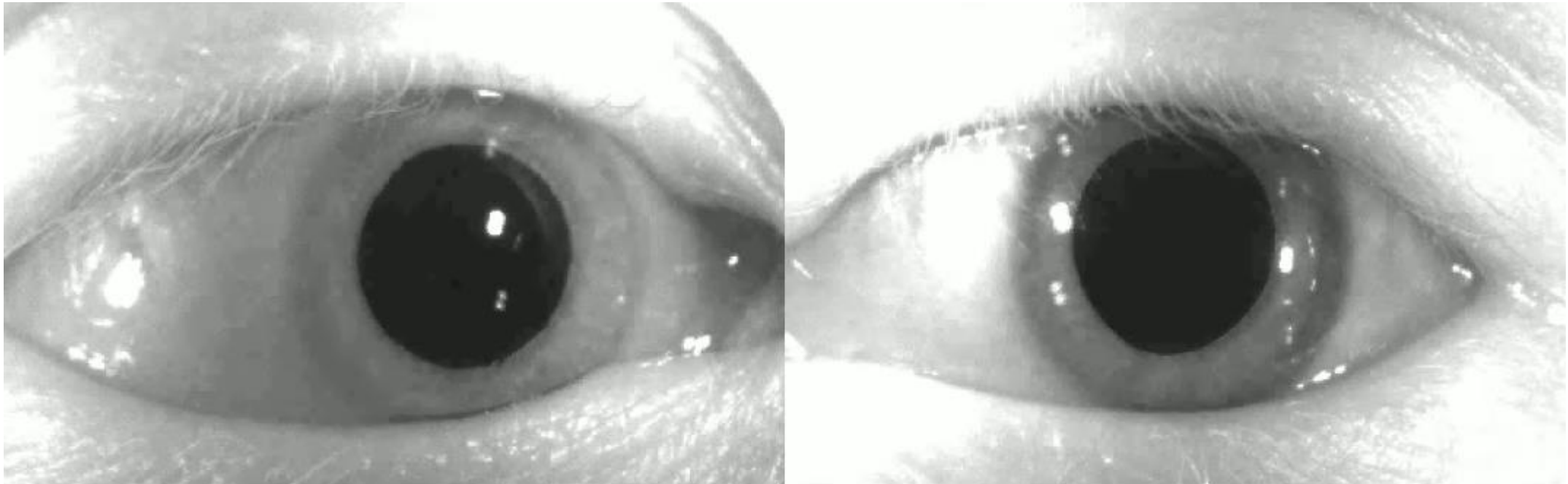


- Maximum level of motion sickness rated on a scale of 0-20.
- Severity of impact to the performance of functional tasks on a scale of 0-4.

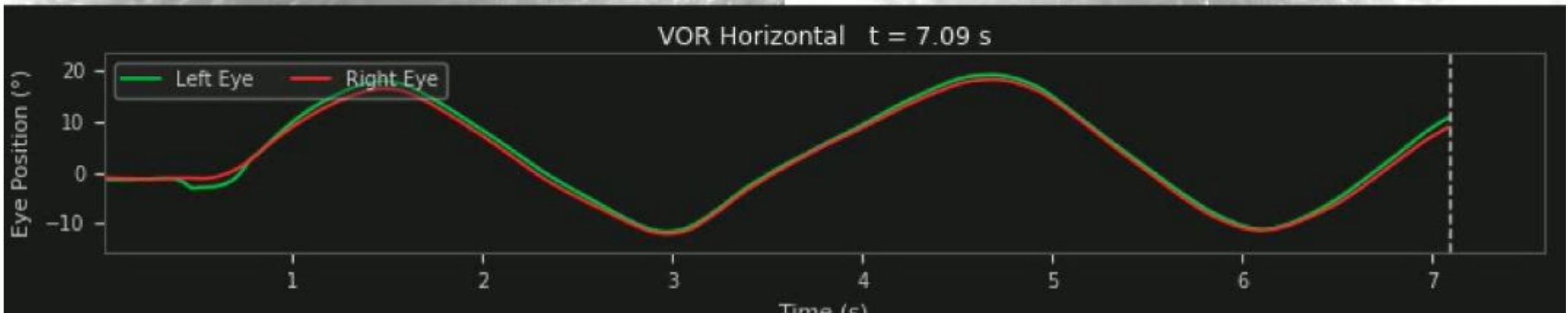




Preliminary Results – Vestibulo-Ocular Reflex

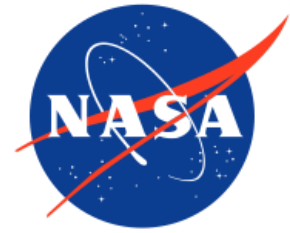


Non-crew
example

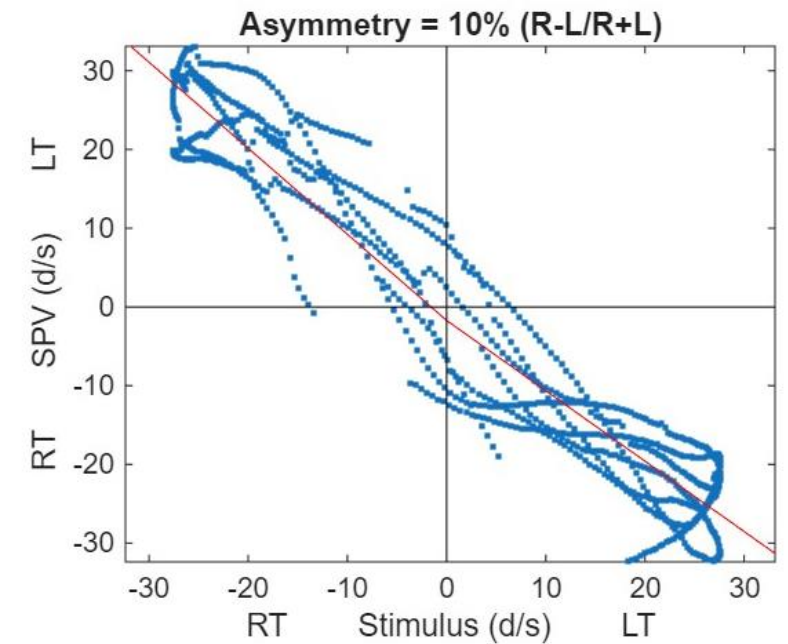
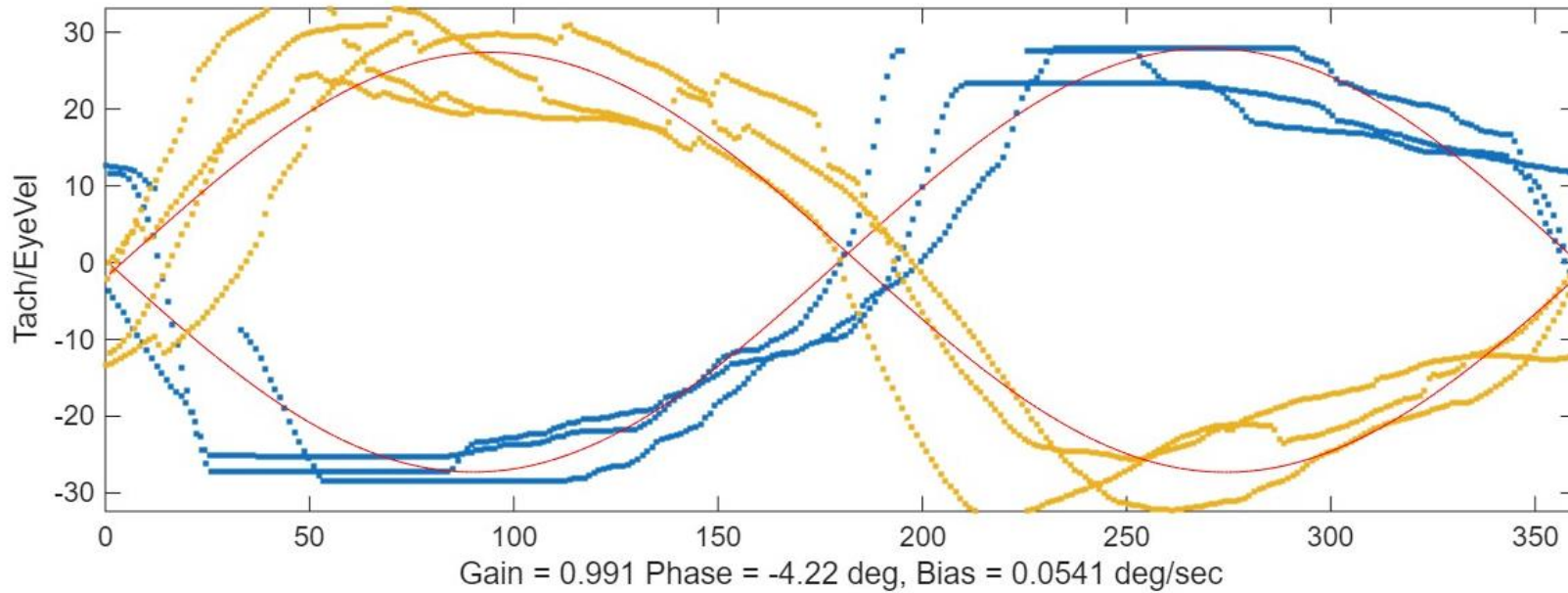




Preliminary Results – VOR Gain

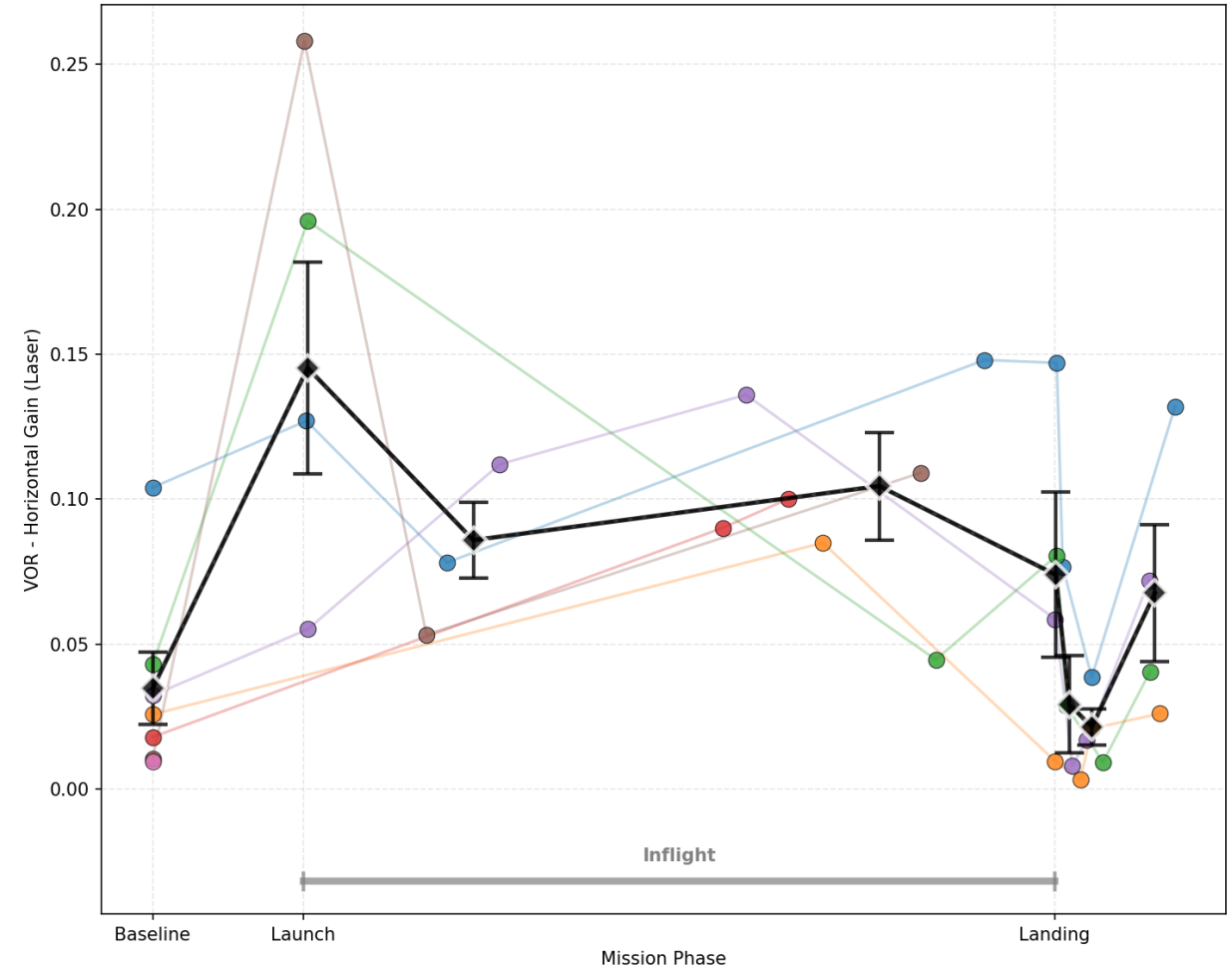
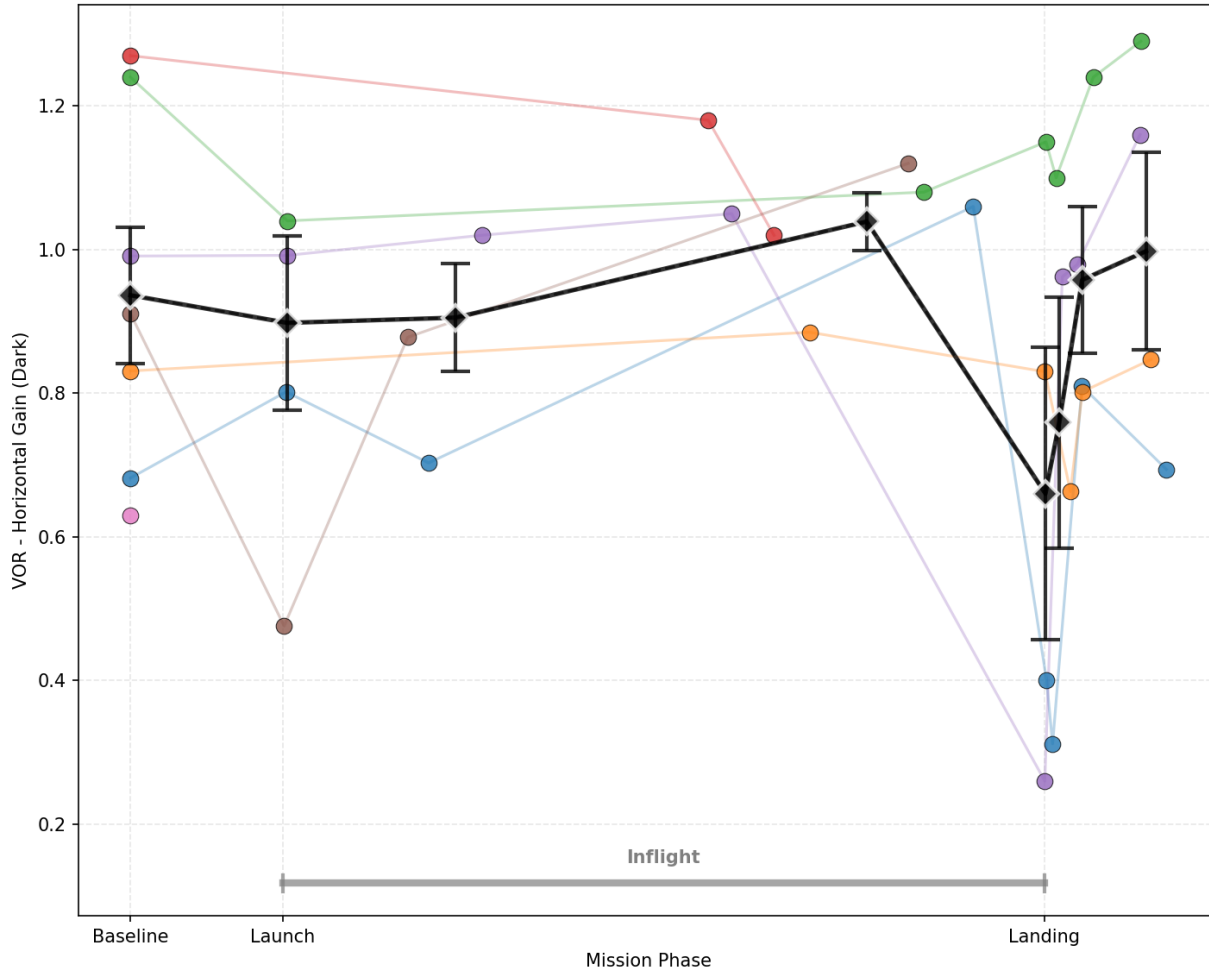
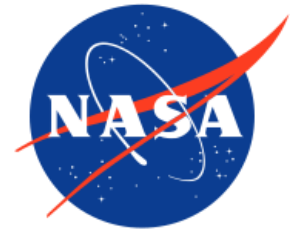


- With vision occluded, crewmembers actively moved their heads to a 0.33 Hz tone while focusing on an imaginary wall-fixed target and then focusing on a visual suppression light that moved with their head.



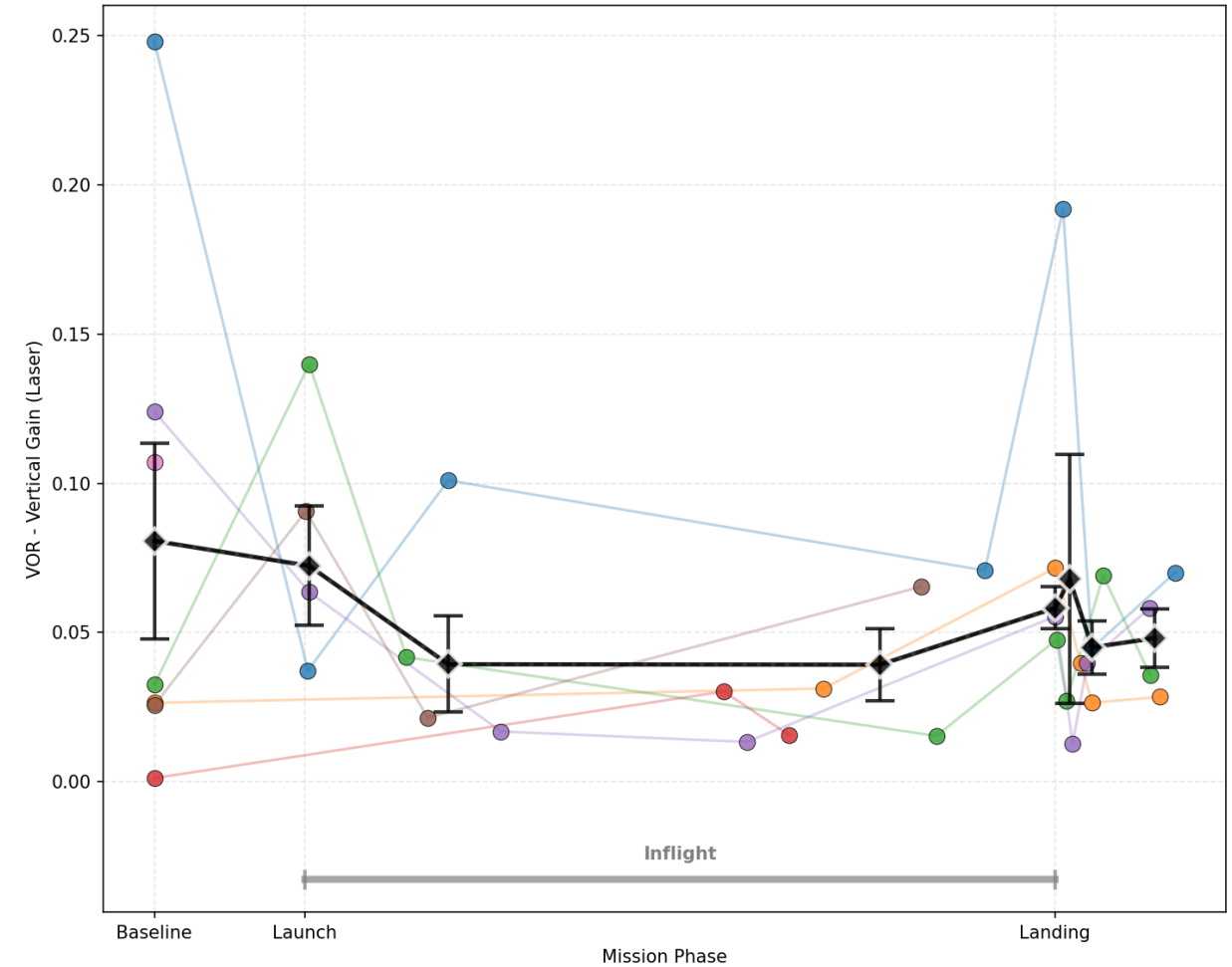
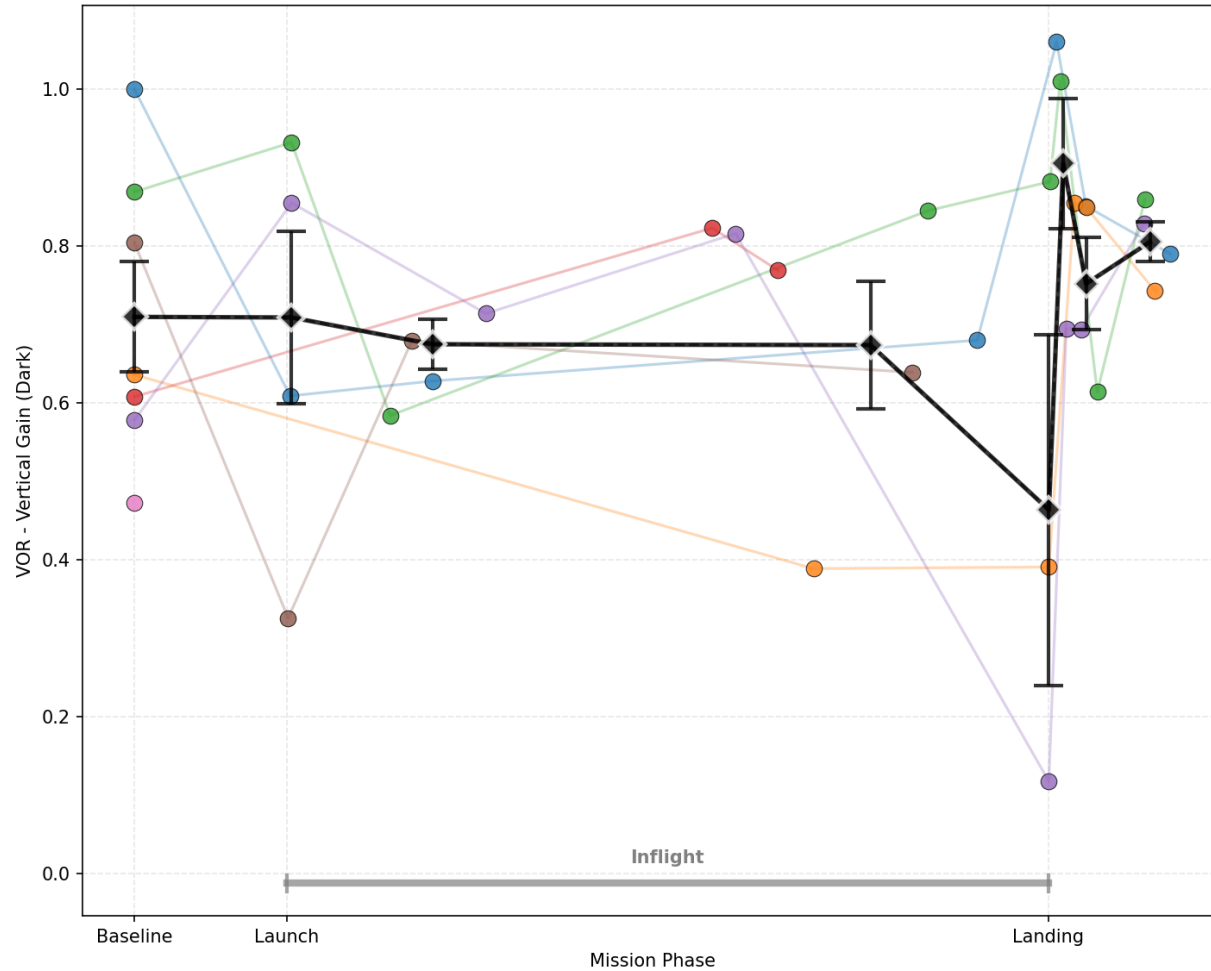


Preliminary Results – VOR Gain Horizontal





Preliminary Results – VOR Gain Vertical

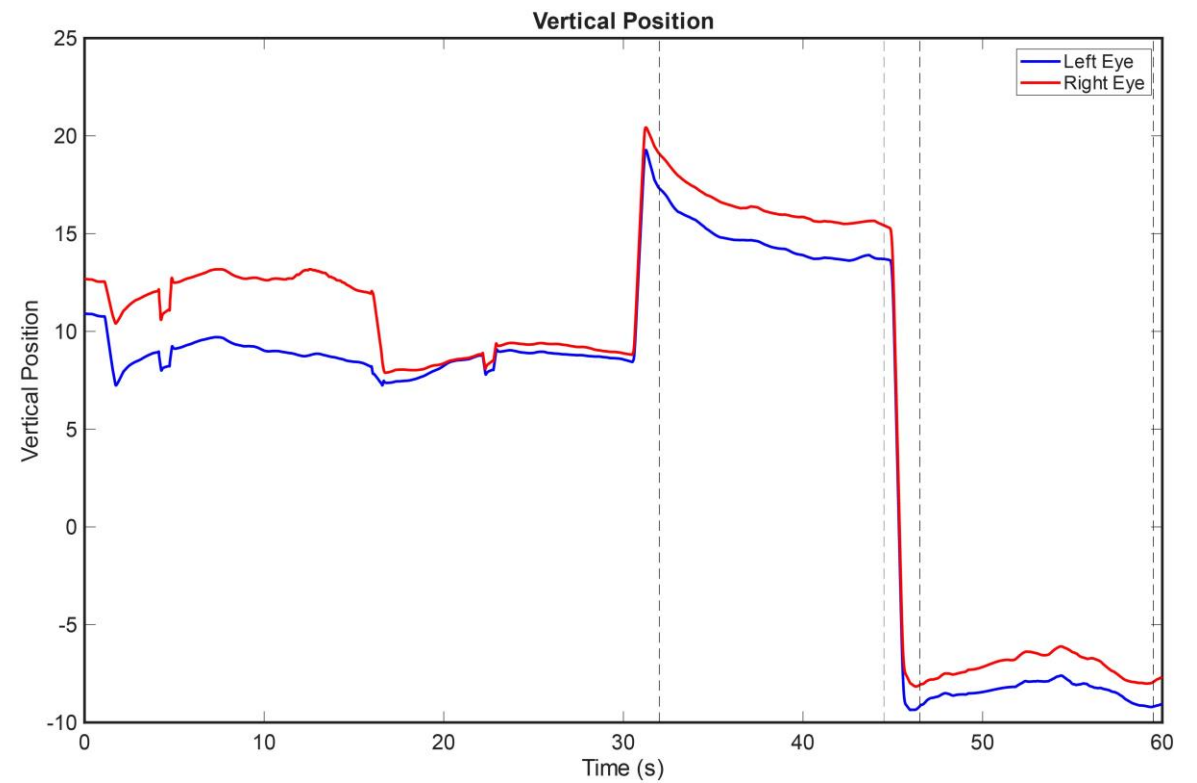
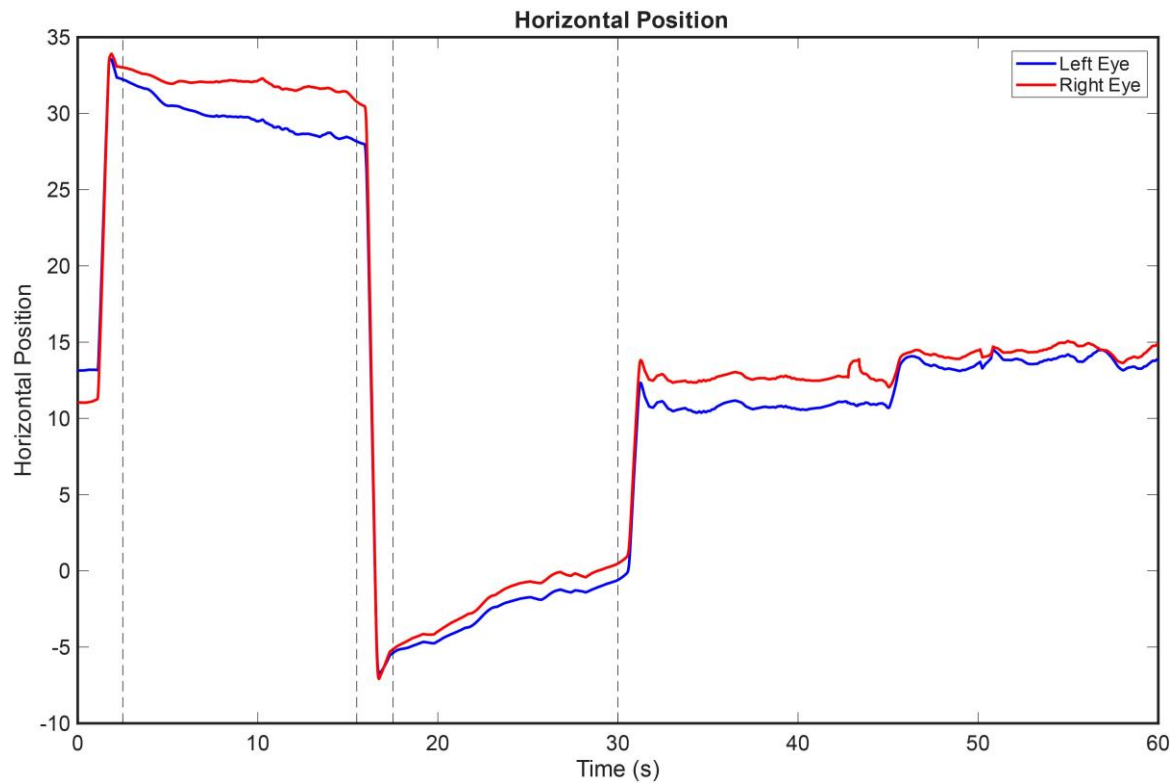




Preliminary Results – Gaze Nystagmus

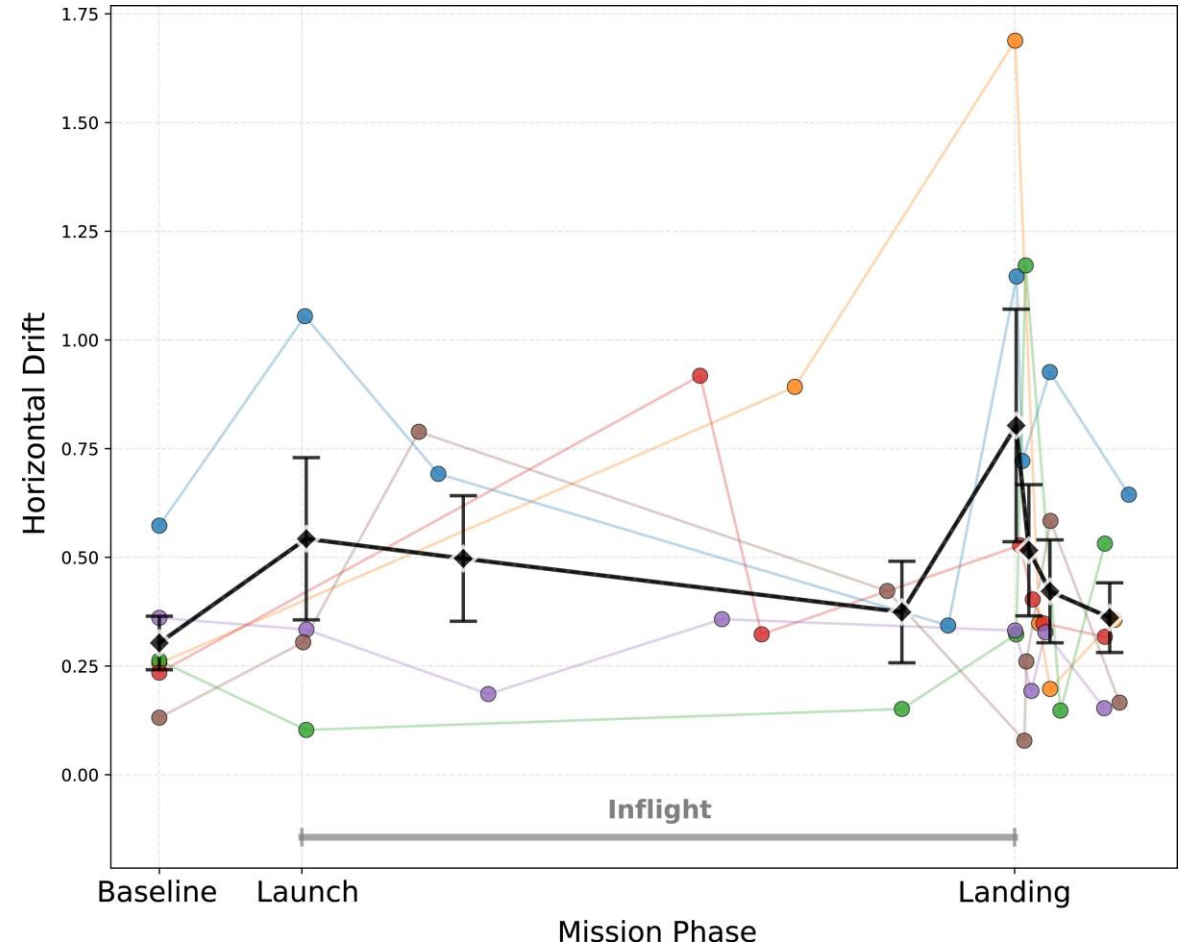
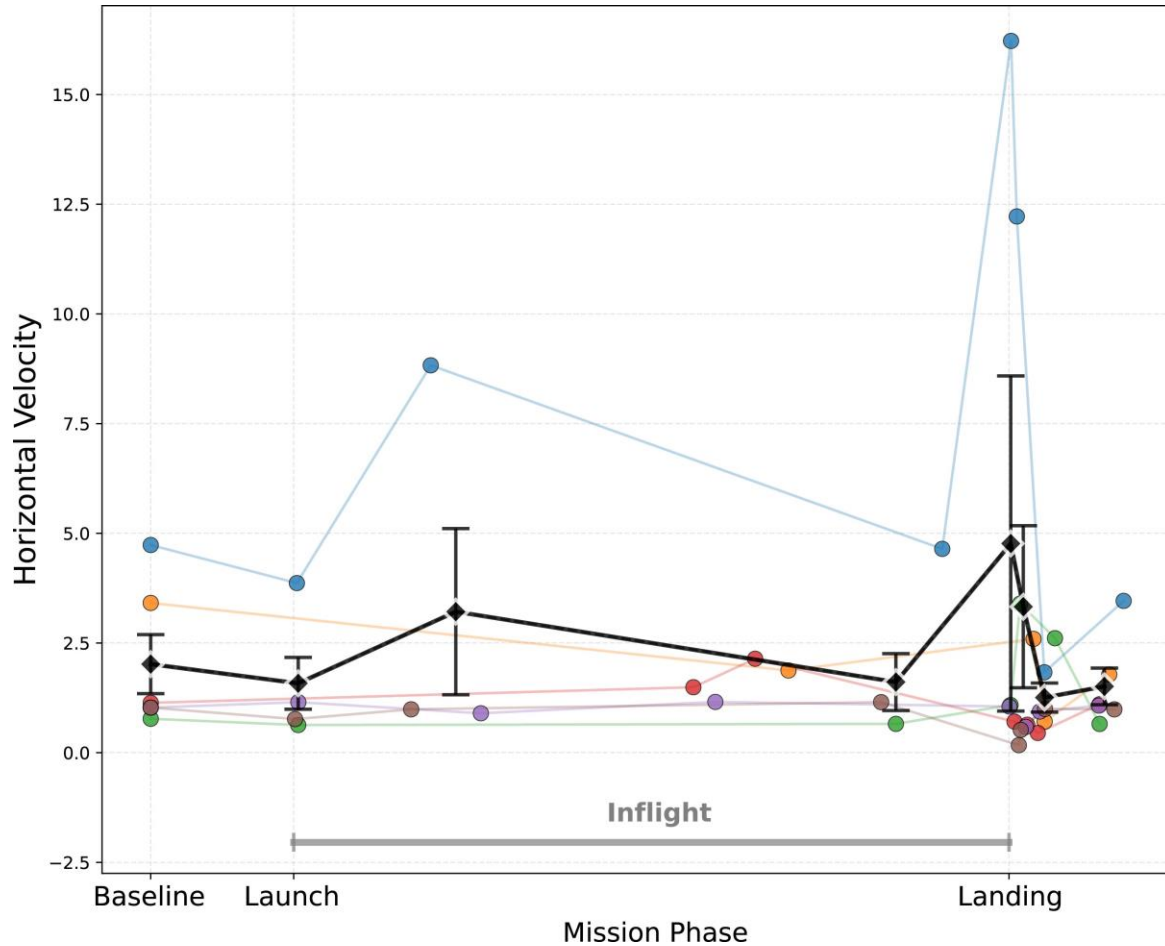
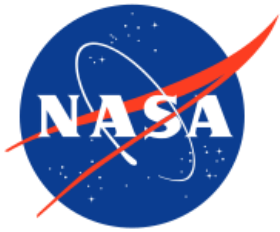


- Vision-occluded crewmembers were instructed to keep their heads still in a neutral upright position and hold their gaze on imaginary horizontal and vertical ± 15 -degree wall fixed targets for approximately 15 seconds.





Preliminary Results – Gaze Nystagmus

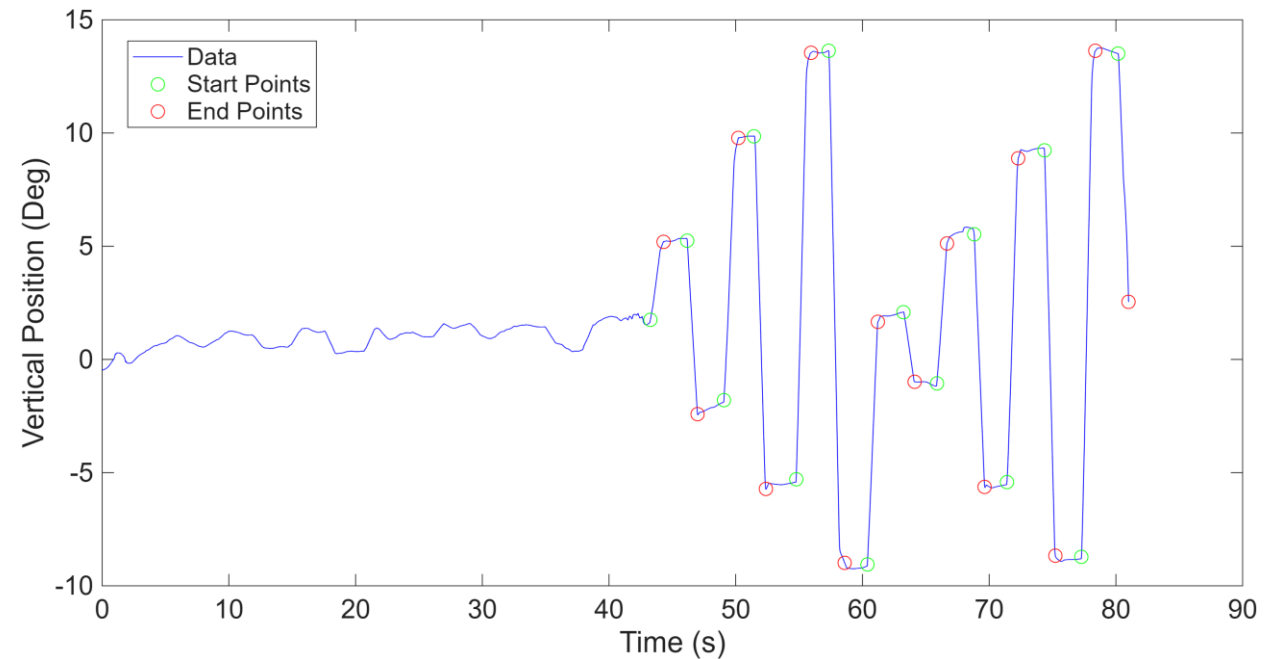
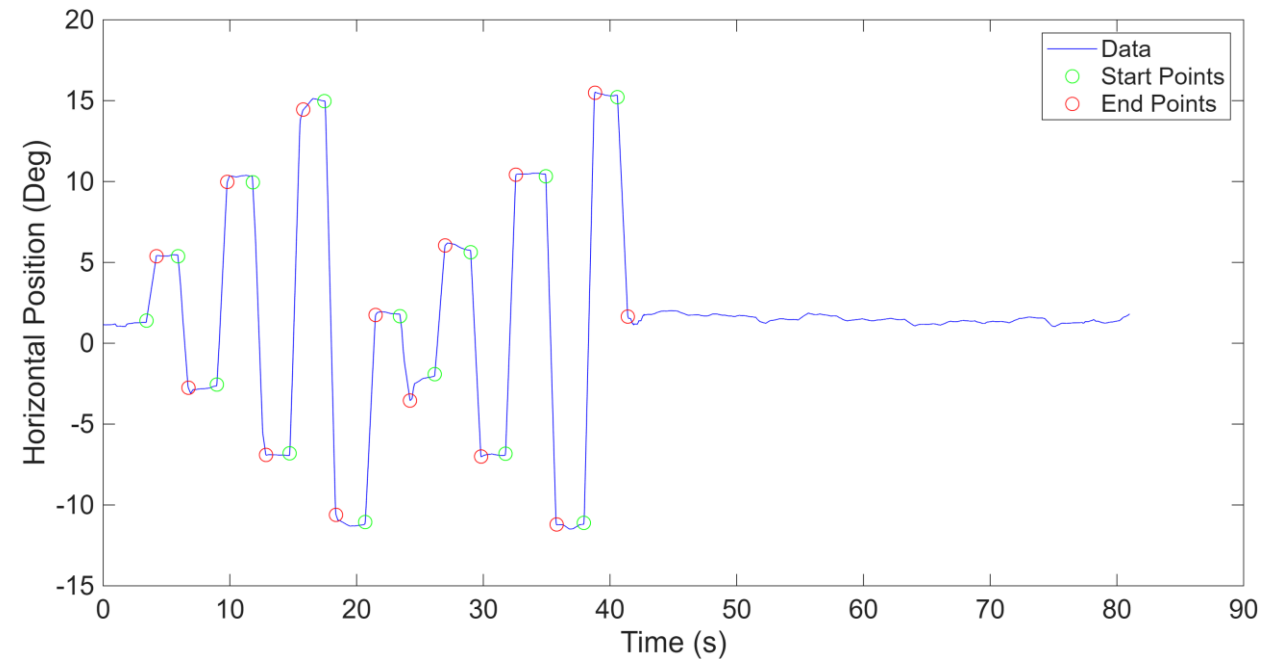




Preliminary Results – Active Saccades

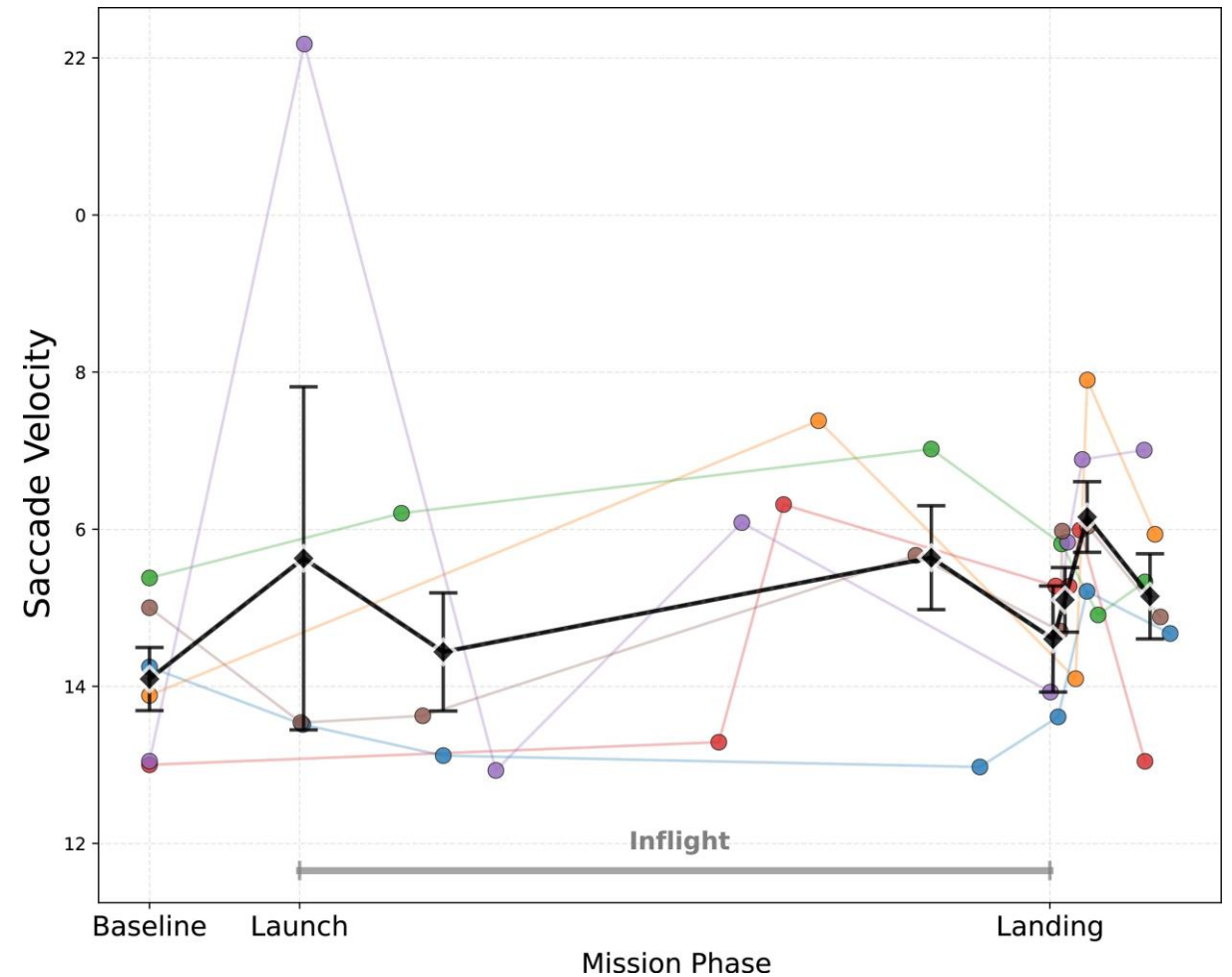
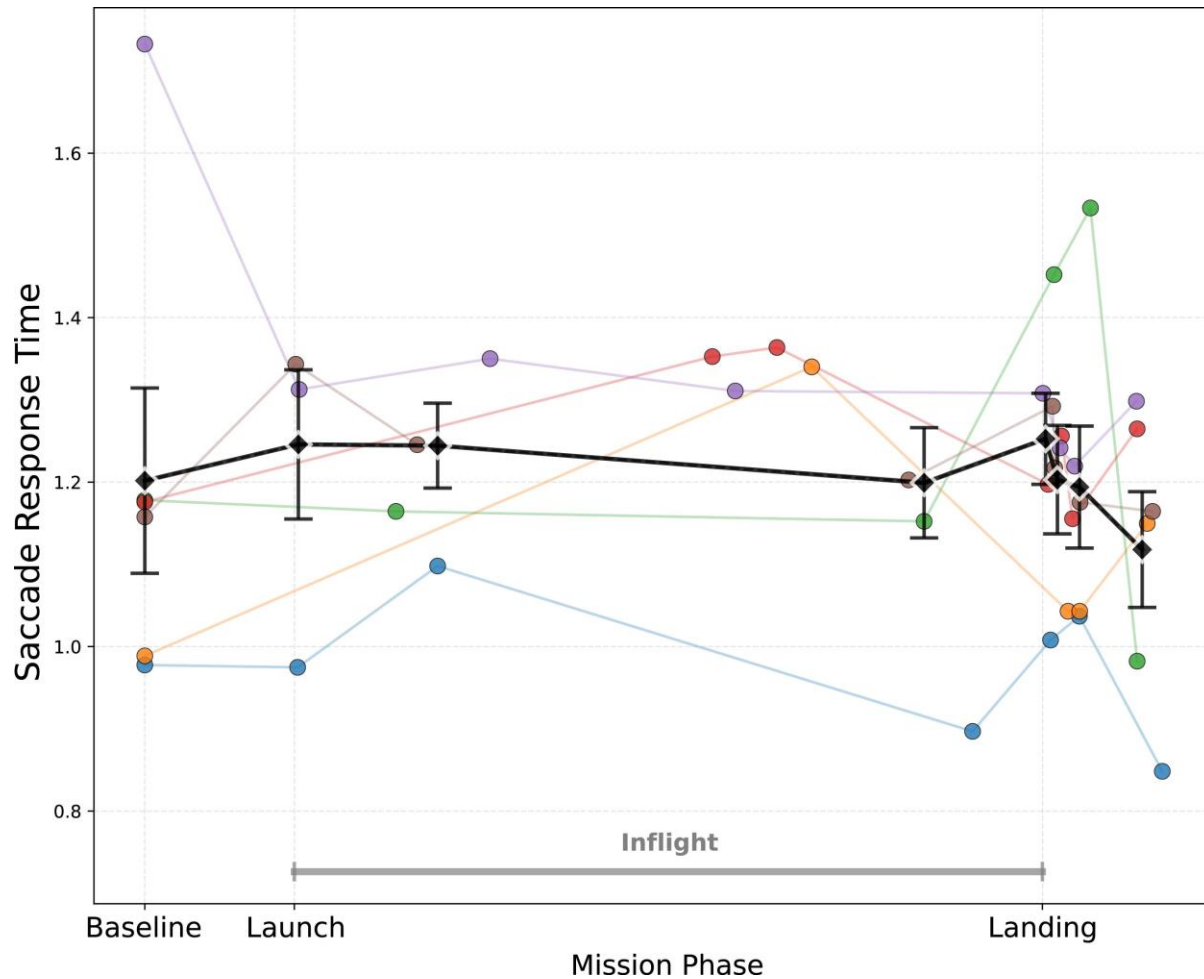


- Subjects were guided by an audio recording to capture 5-degree, 10-degree, and 15-degree visual wall targets while keeping their heads still in a neutral upright position



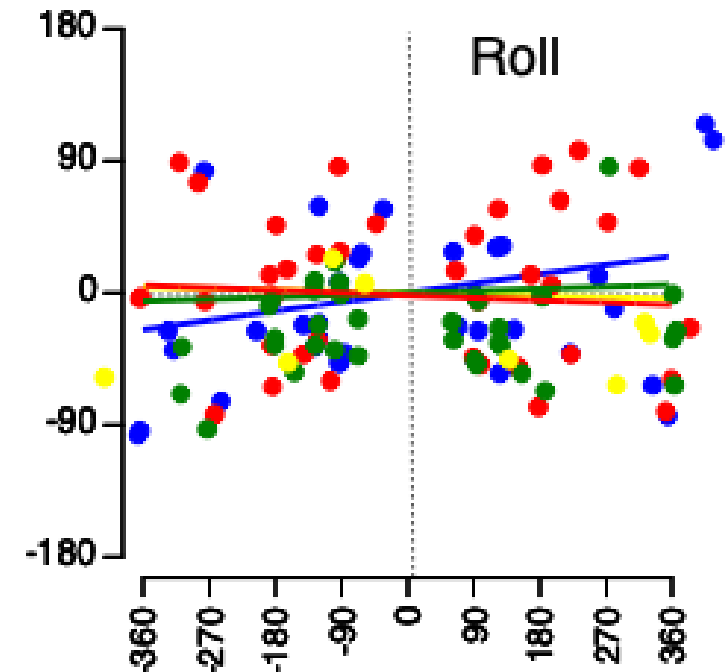
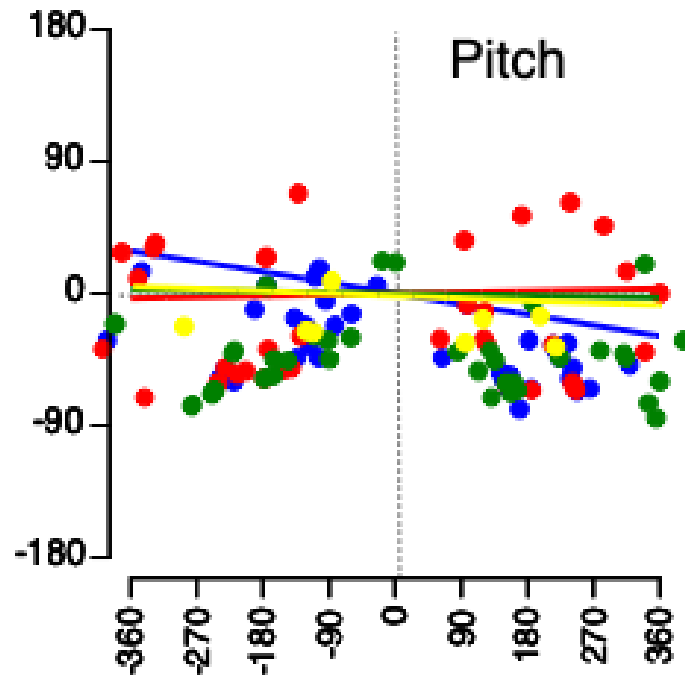
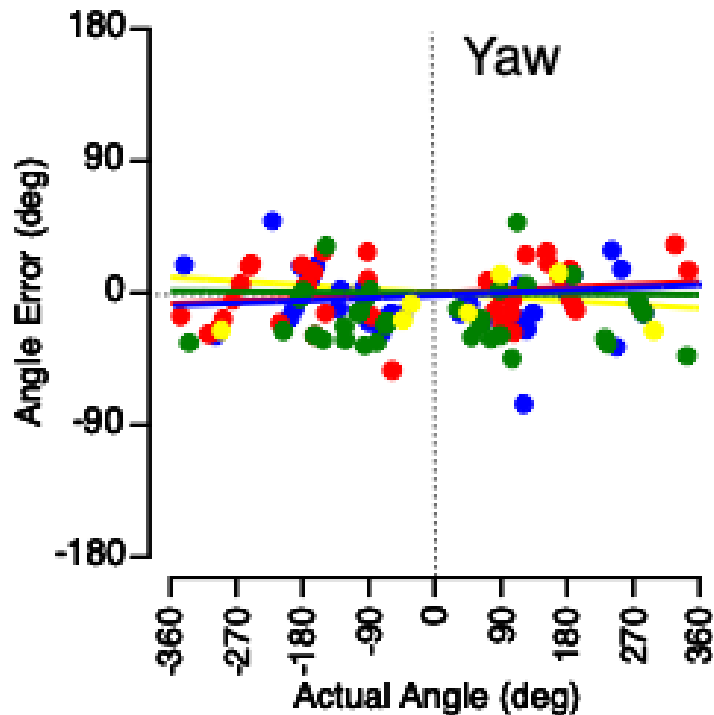


Preliminary Results – Active Saccades



Preliminary Results – Movement Perception

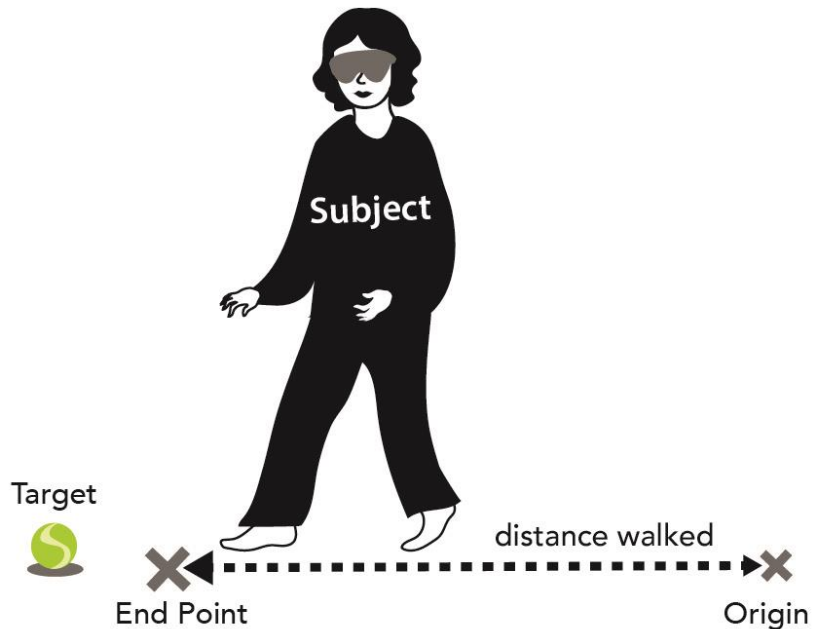
- Body movement perception was assessed in microgravity with vision occluded during passive rotations and translations initiated by an inflight operator.



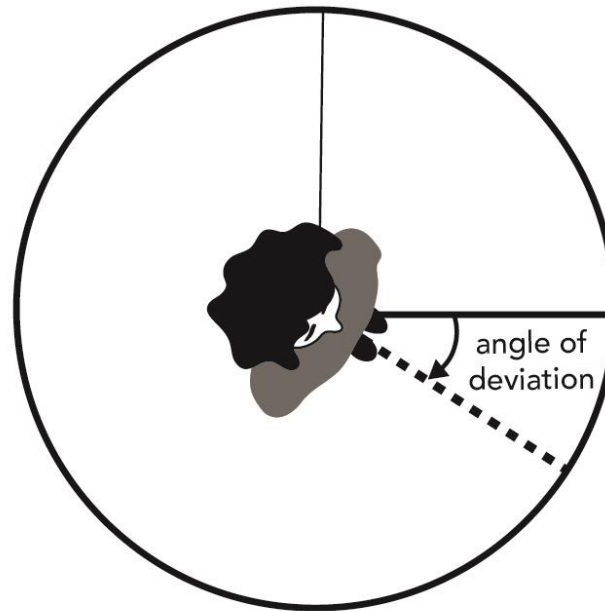
Preliminary Results – Movement Perception

- Body movement perception was assessed on the ground during active movement tests with eyes closed.

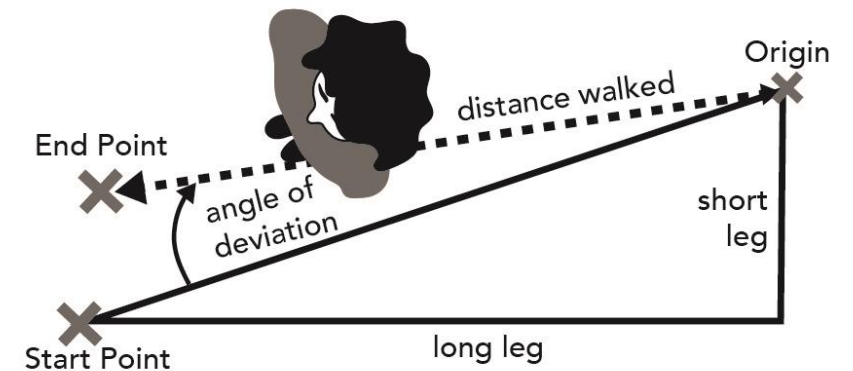
Egocentric Distance



Egocentric Rotation

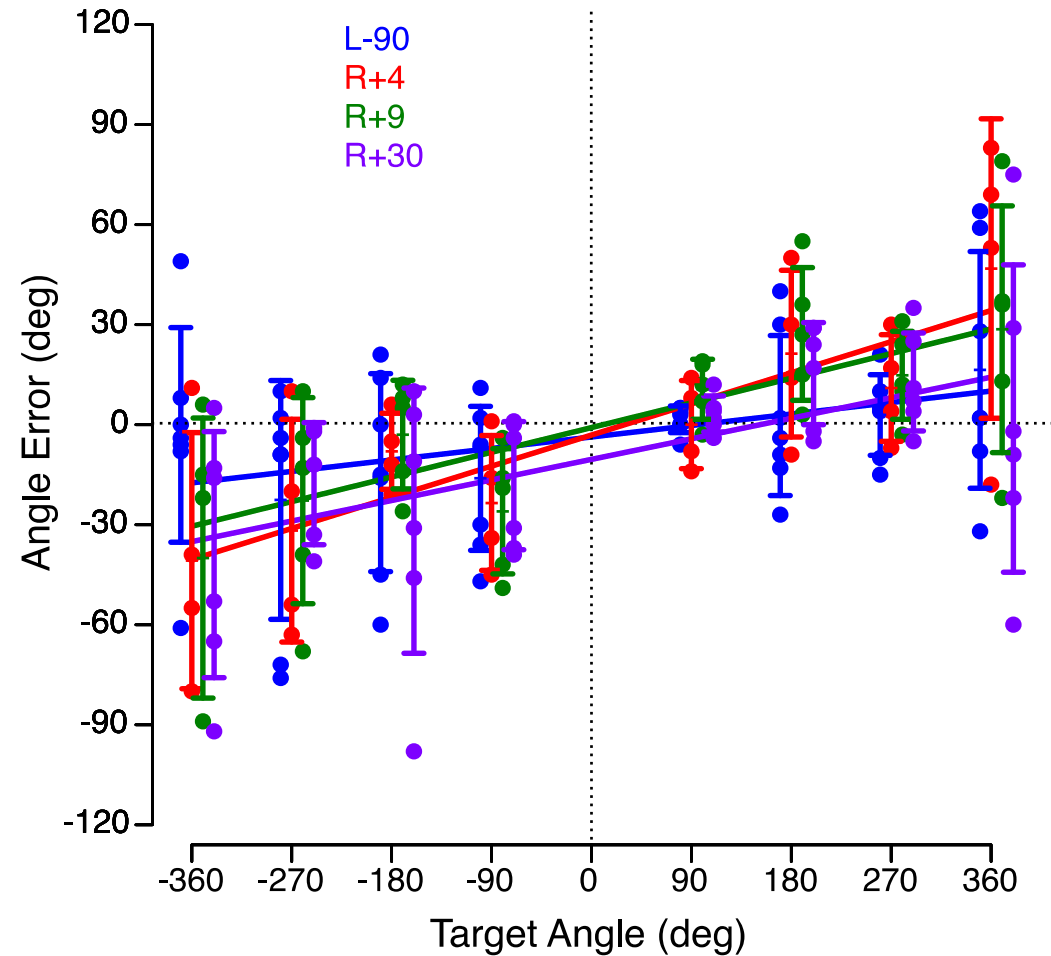
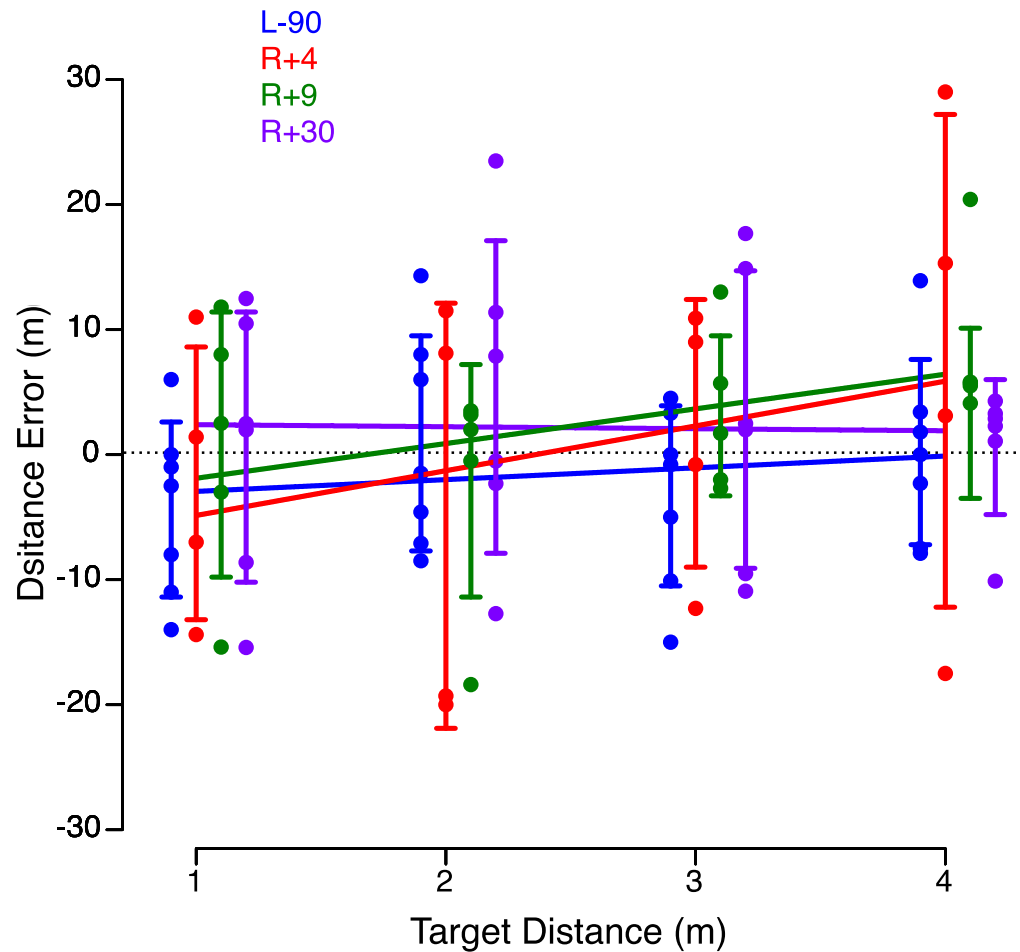
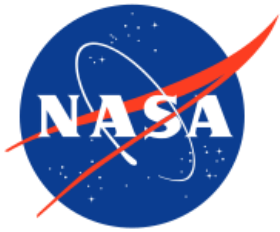


Path Integration



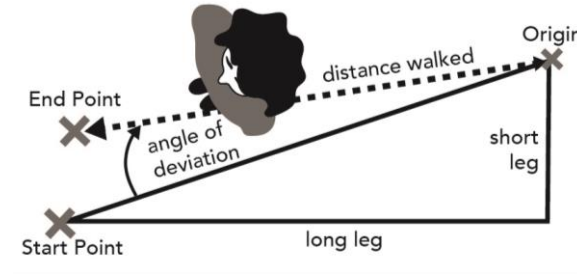


Preliminary Results – Movement Perception

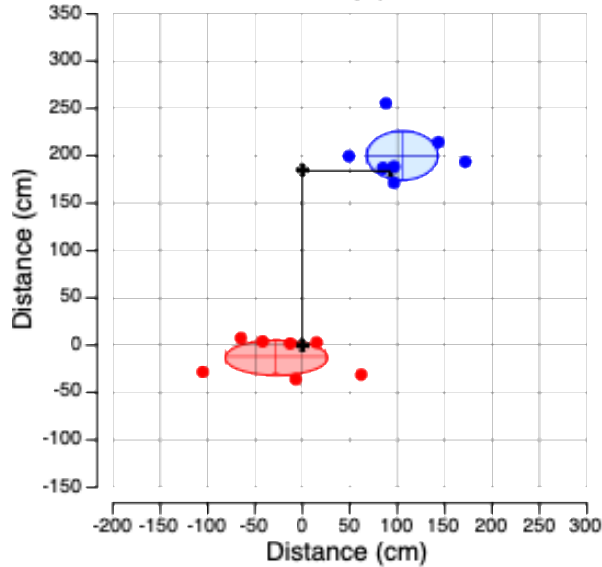




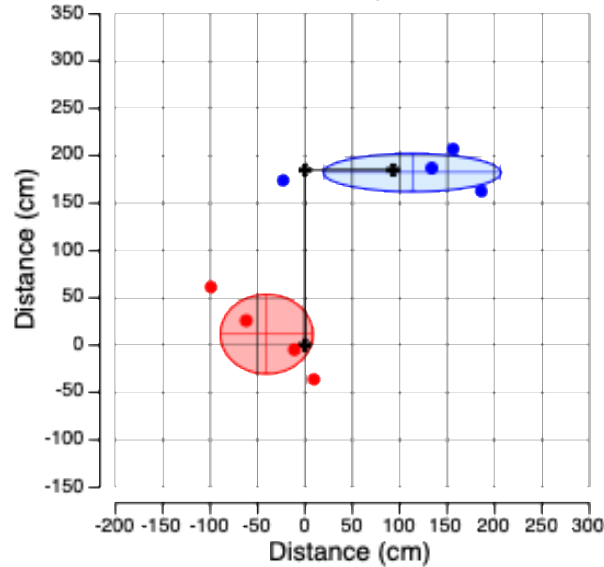
Preliminary Results – Movement Perception



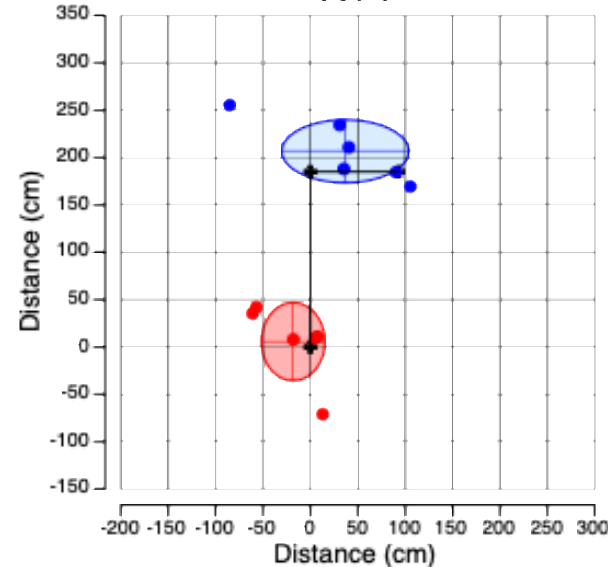
L-90



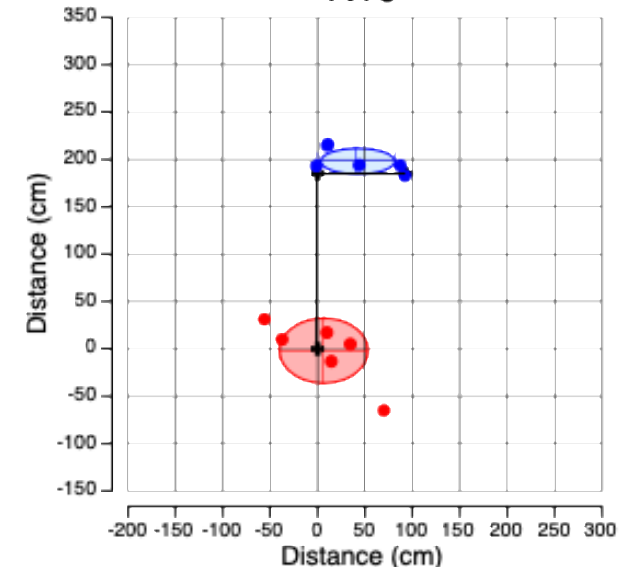
R+0



R+4



R+9





Next Steps

- Expected to complete final data collection in ~August 2026.
- Small-n statistical analyses
- Prediction analyses based on preflight vestibular asymmetries¹
- Comparisons with healthy ground control subjects and patients with bilateral vestibulopathy^{2,3}
- Supplemental data sharing from Standard Measures:
 - Sensorimotor Tests
 - Sleep Questionnaires
 - Cognition Tests

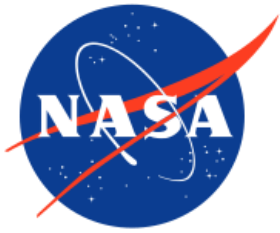
¹Macaulay et al., Brain Sci, 2023

²Clement et al., Front Neurol, 2023

³Kuldavletova et al., PLoS ONE, 2025



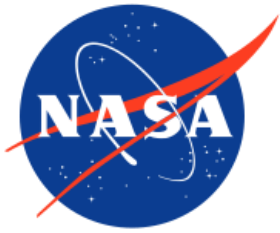
Relevance



- Characterize temporal changes, determine when countermeasures may be needed, and understand the etiology of vestibular syndromes.
 - Countermeasures will be proposed based on vestibular rehabilitation modalities currently used in patients with vestibular disorders.
- Further comparisons will be made with the same measures collected on 4 Artemis II crewmembers via the Standard Measures project.
 - If the observed symptoms are more deleterious after one type of mission than the other, then specific countermeasures/strategies may be needed for each design reference mission.

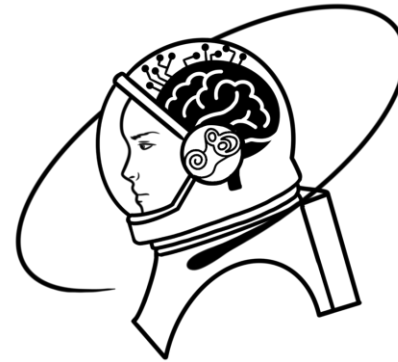


Thank You!



Acknowledgement: This work is supported by NASA's Human Research Program Human Health Countermeasures Element.

NASA
Neuroscience



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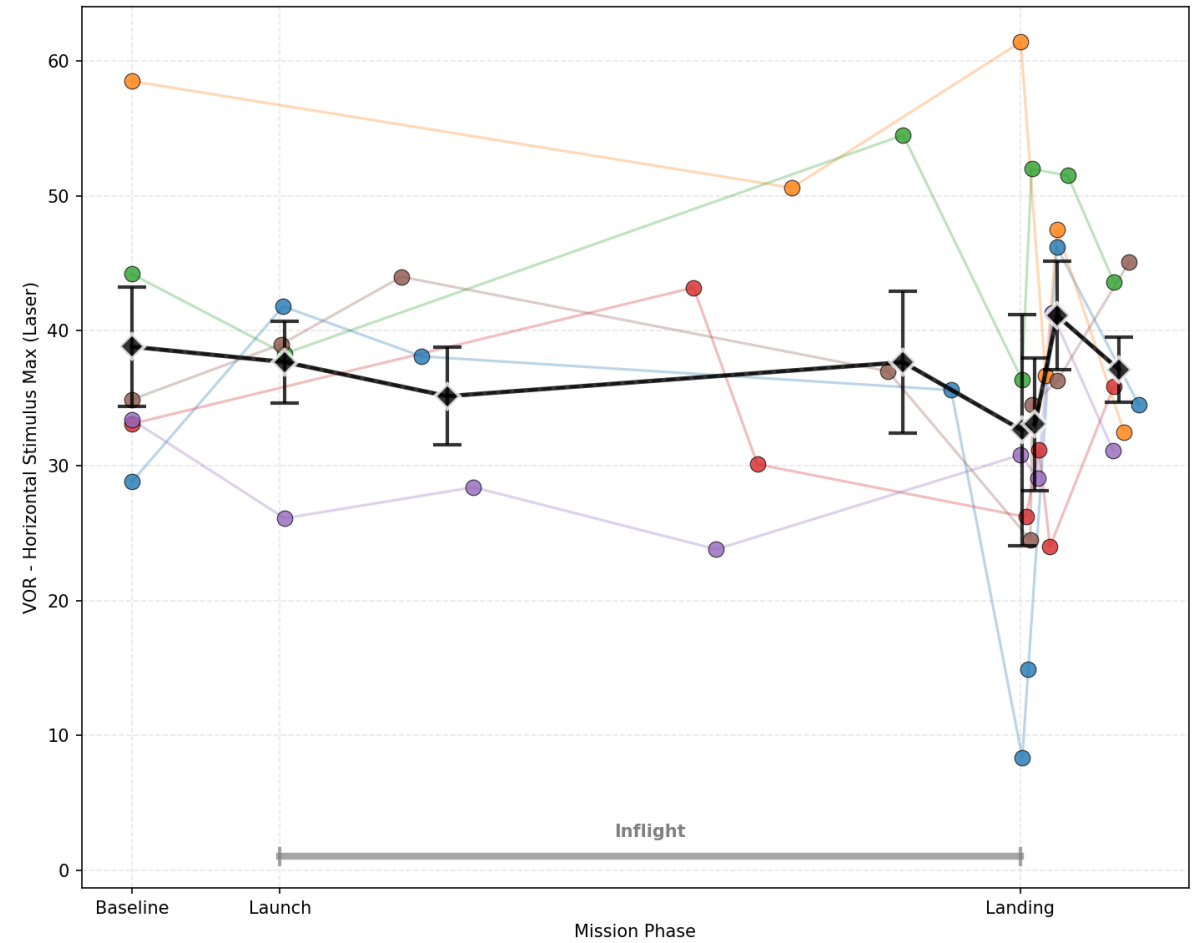
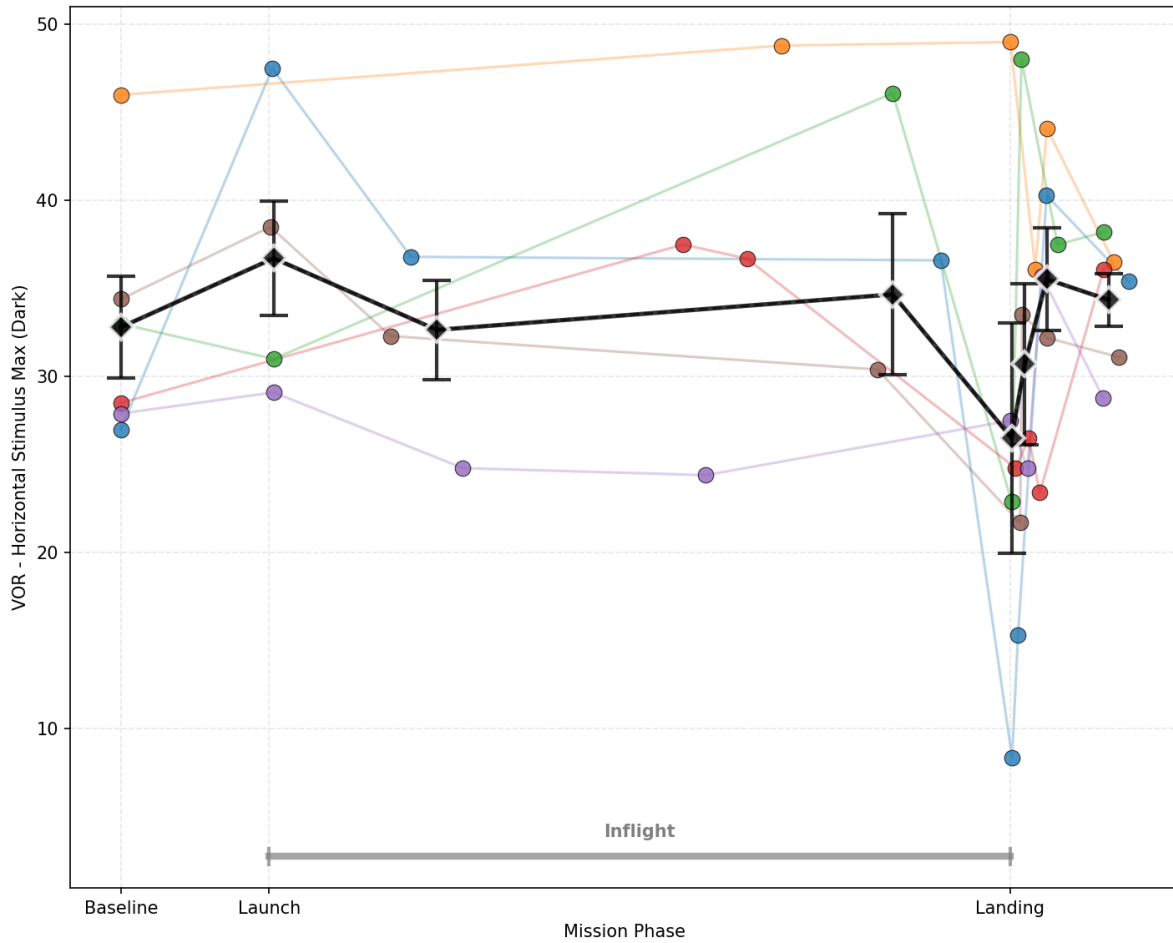
Backup



Preliminary Results – VOR Horizontal



Head movement stimulus

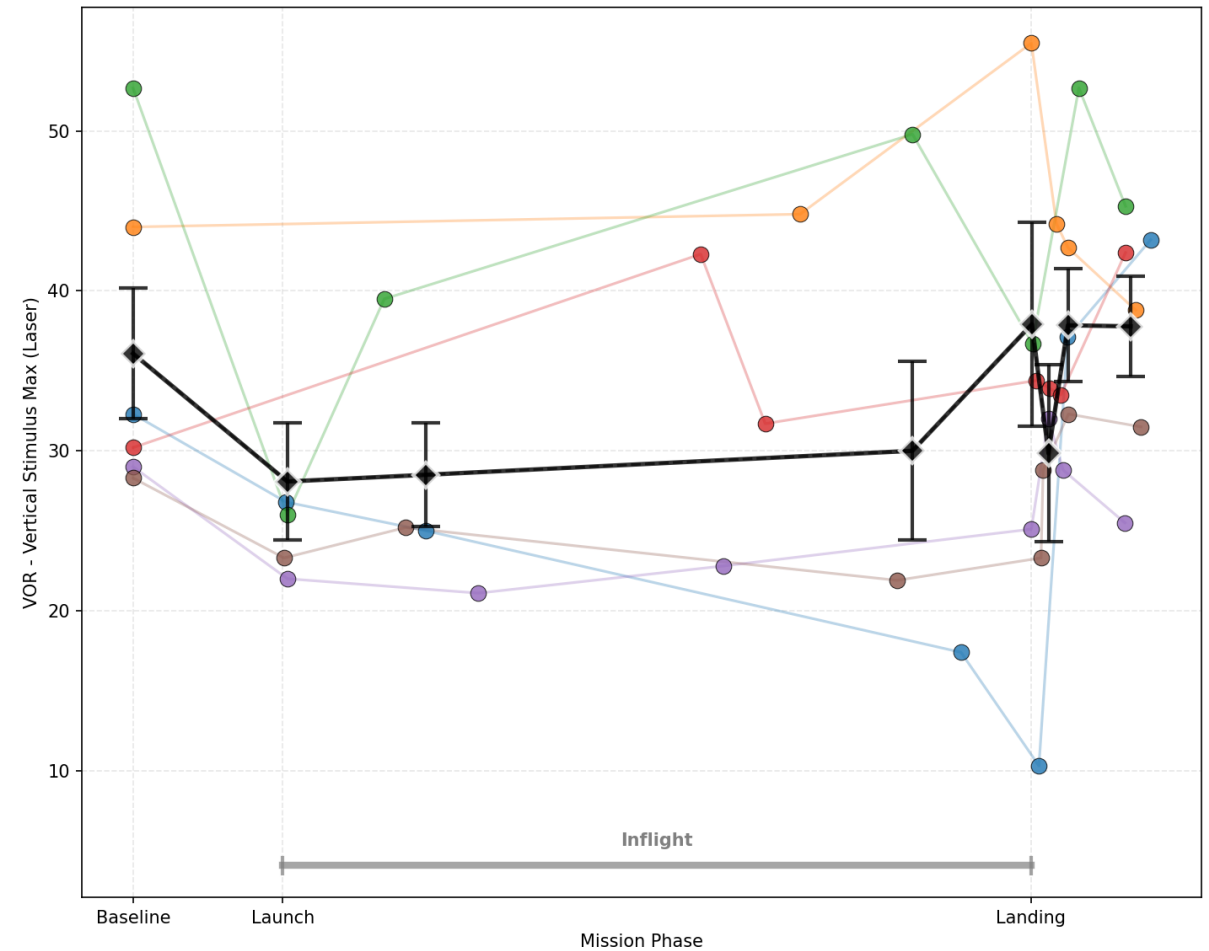
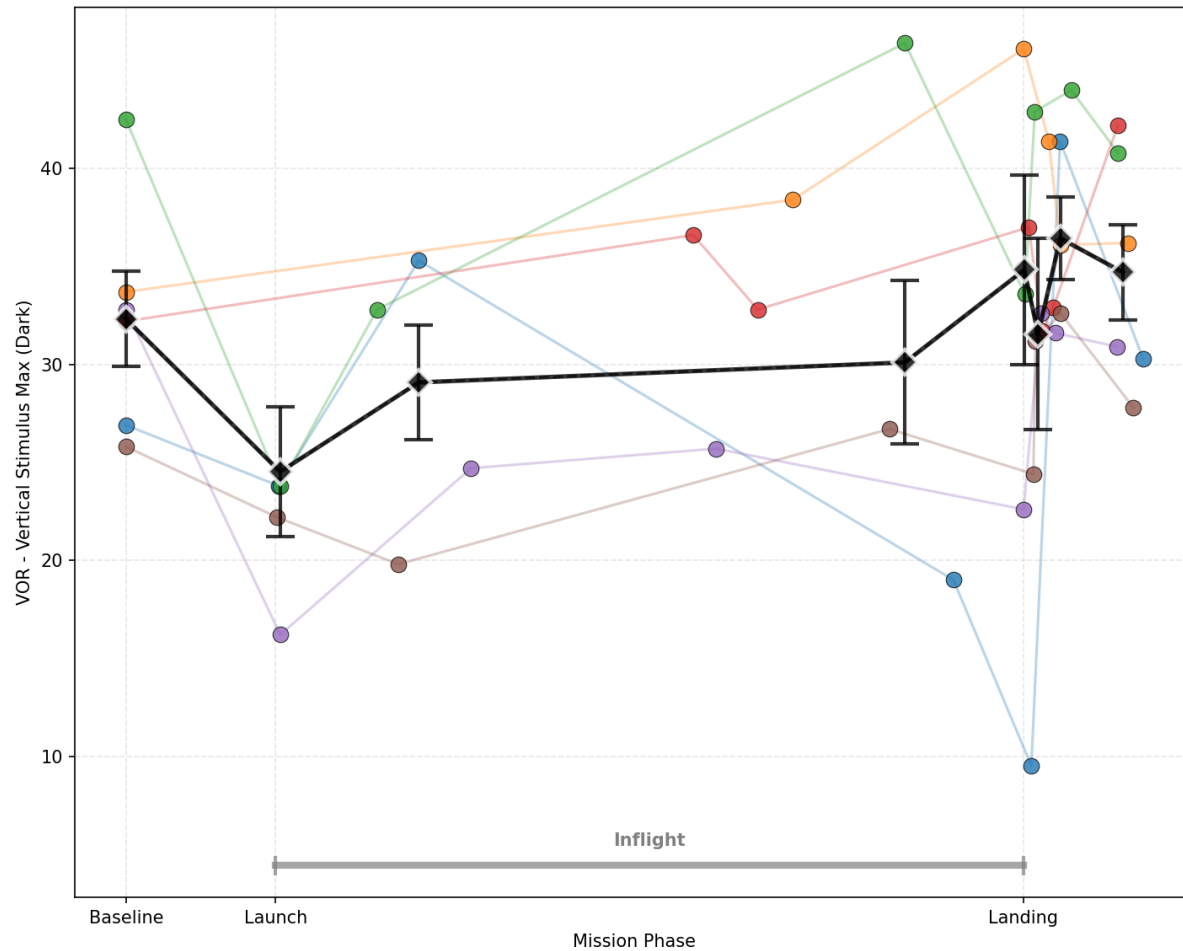




Preliminary Results – VOR Vertical



Head movement stimulus

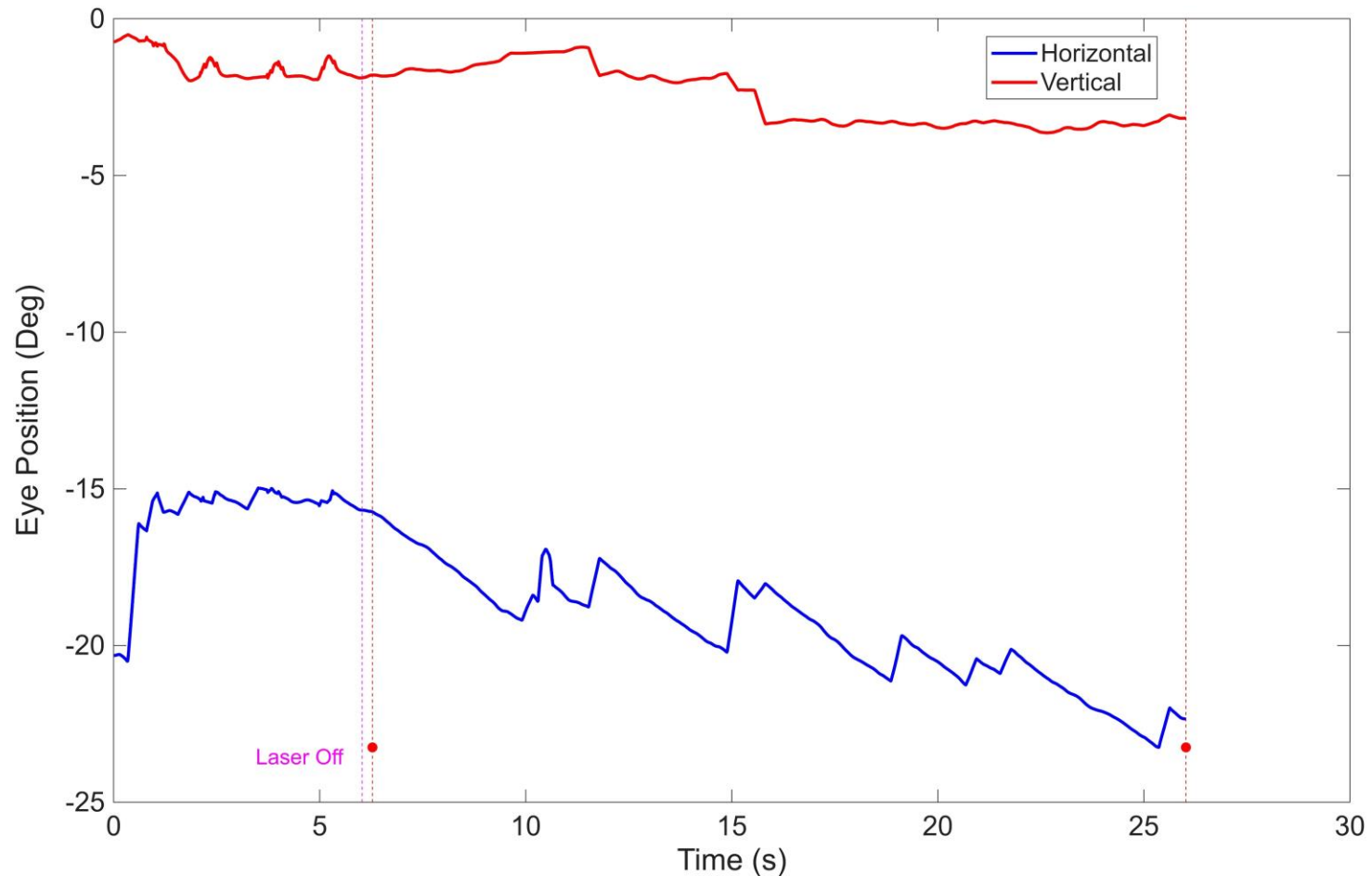




Preliminary Results – Spontaneous Nystagmus



- Vision-occluded subjects were instructed to look at a laser fixation in the center of their field of view and then continue to hold their gaze for approximately 20 seconds after the laser dot disappeared.





Preliminary Results – Spontaneous Nystagmus

