The Effects of Concurrent Bandwidth Feedback on Robotic Manual Control Tasks

An Experimental and Modeling Study

John Austin Karasinski

August 29th, 2018

Qualifying Examination

Outline

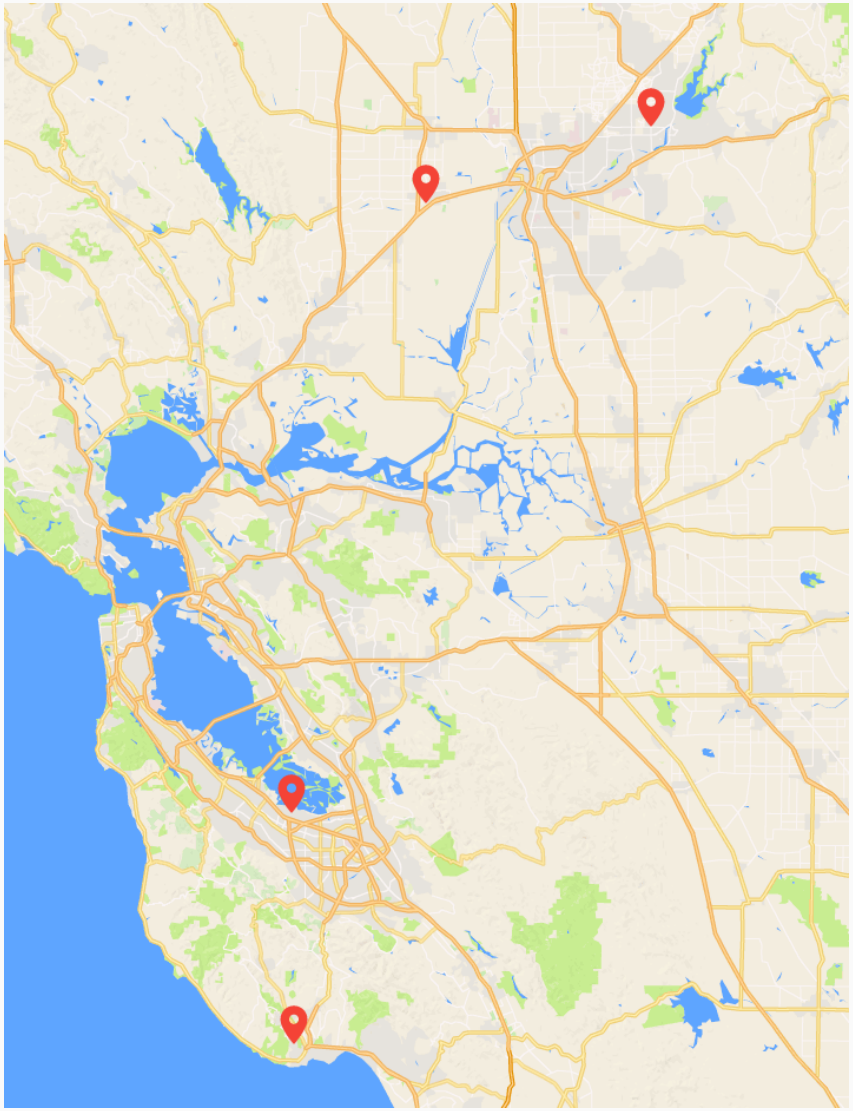
About Me

2012 B.S. Physics, UCSC
Software Engineer, MV

2013 Start at UC Davis

2016 M.S. MAE, UCD
Intern, ARC

2017 Link Fellowship
Pathways Intern, ARC



Introduction


Canada
SPACE

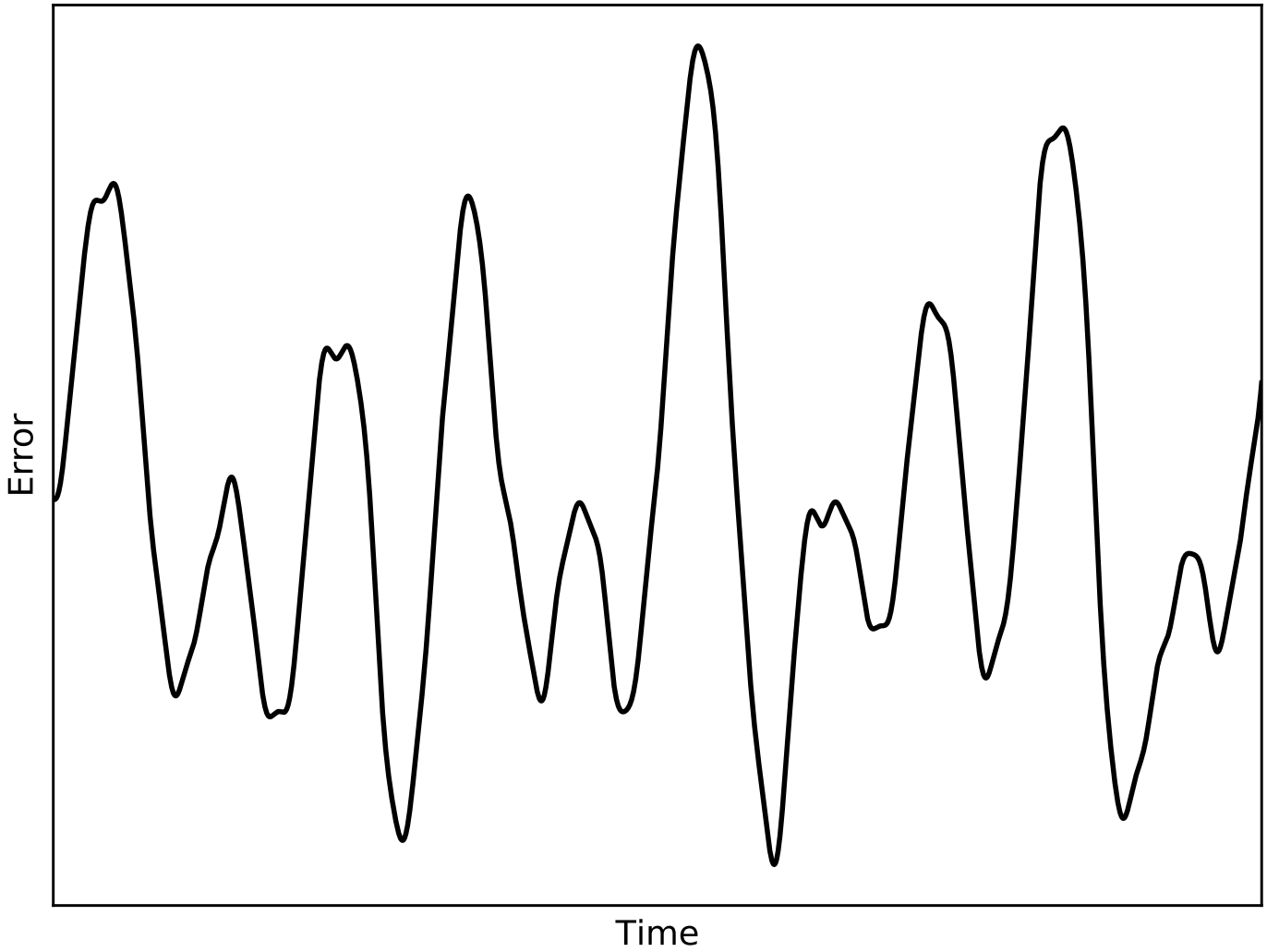
Goal

Measure, model, and predict the effects of concurrent bandwidth feedback on human performance in robotics manual control tasks.

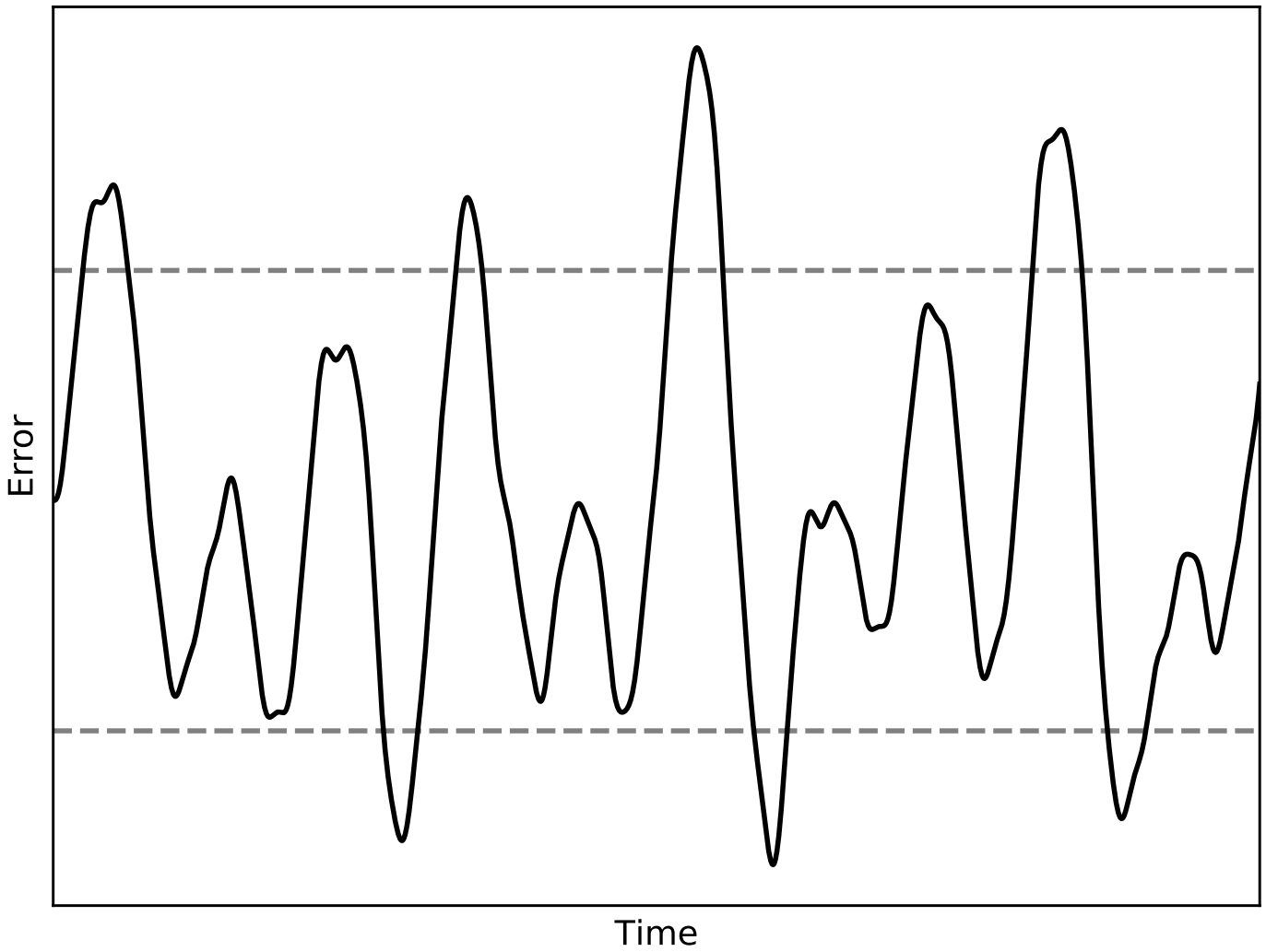
Concurrent bandwidth feedback

Concurrent bandwidth feedback is provided to an operator in real-time when a signal deviates out of a predefined range.

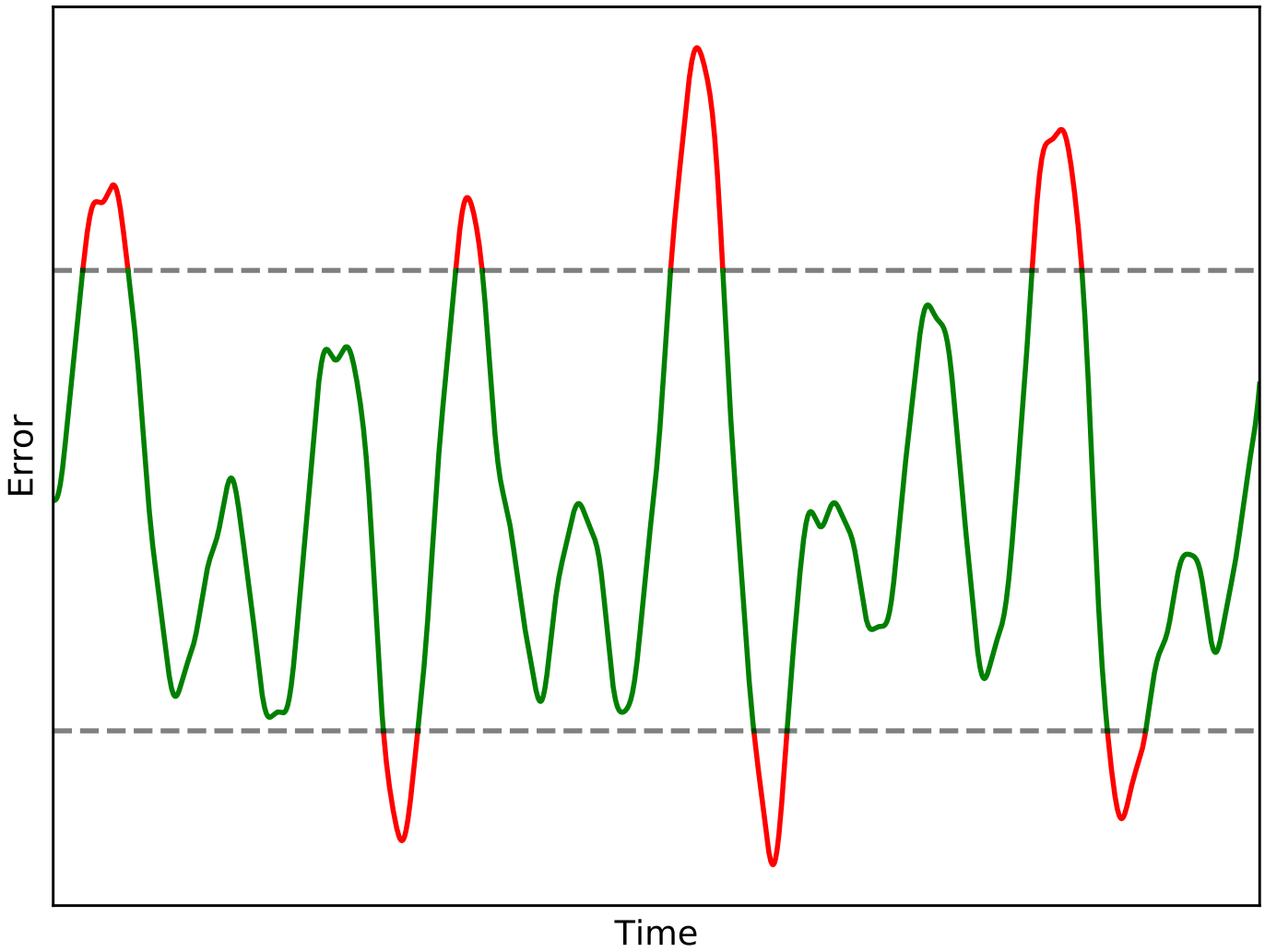
Concurrent bandwidth feedback



Concurrent bandwidth feedback



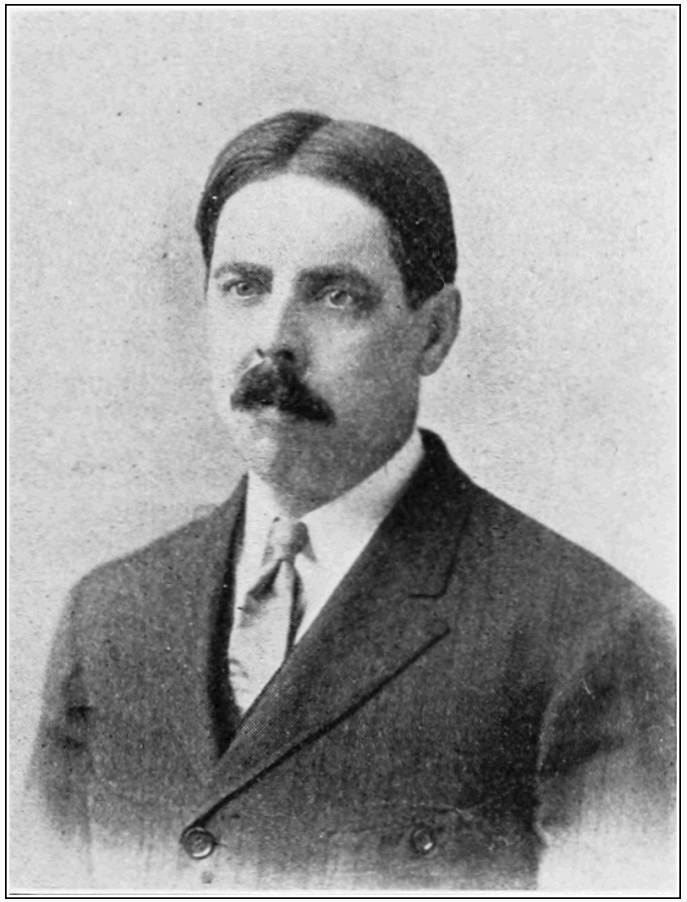
Concurrent bandwidth feedback



Background

Thorndike, 1927 [1]

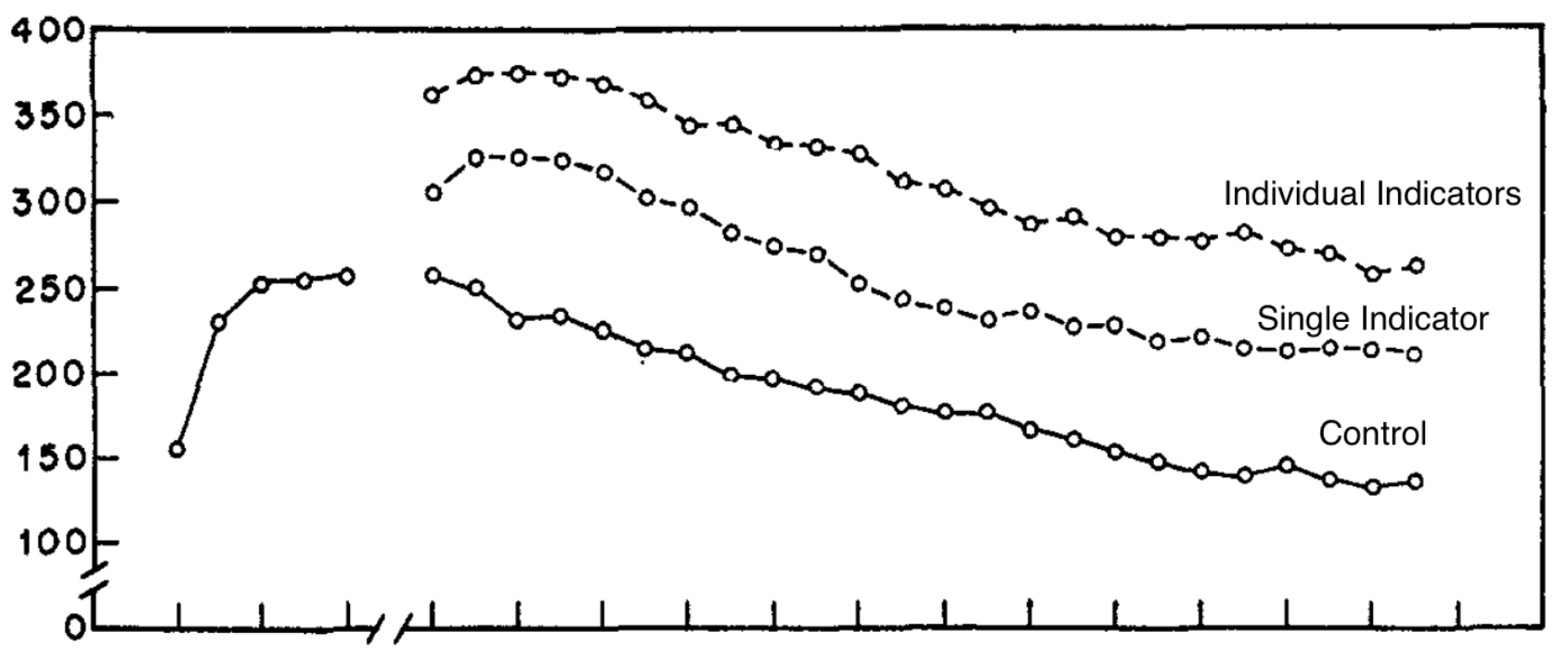
- Blindfolded line-drawing experiment
- Two groups of subjects:
  With, without bandwidth feedback
- Bandwidth feedback resulted in better performance, but was lost in retention
- Results consistent with guidance hypothesis



Guidance Hypothesis

If consistent feedback during the acquisition phase of learning is provided, “the subject comes to rely on that source of error information to maintain performance, and thus does not deal effectively with the other cues in the task that are important”.
-Salmoni et al., 1984 [2]

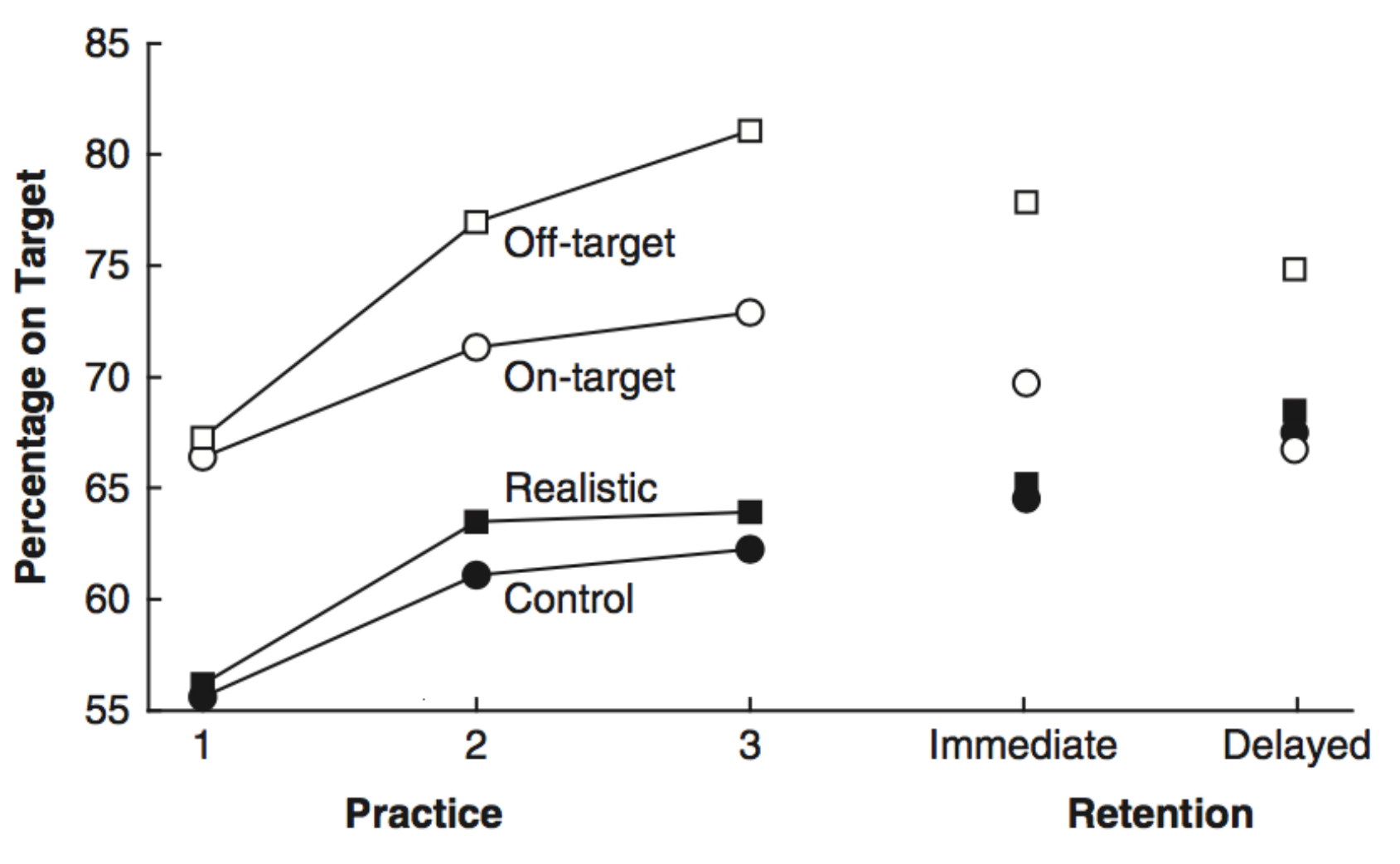
Payne and Hauty, 1955 [3]



Training Start 4 hours

de Groot et al., 2011 [4]

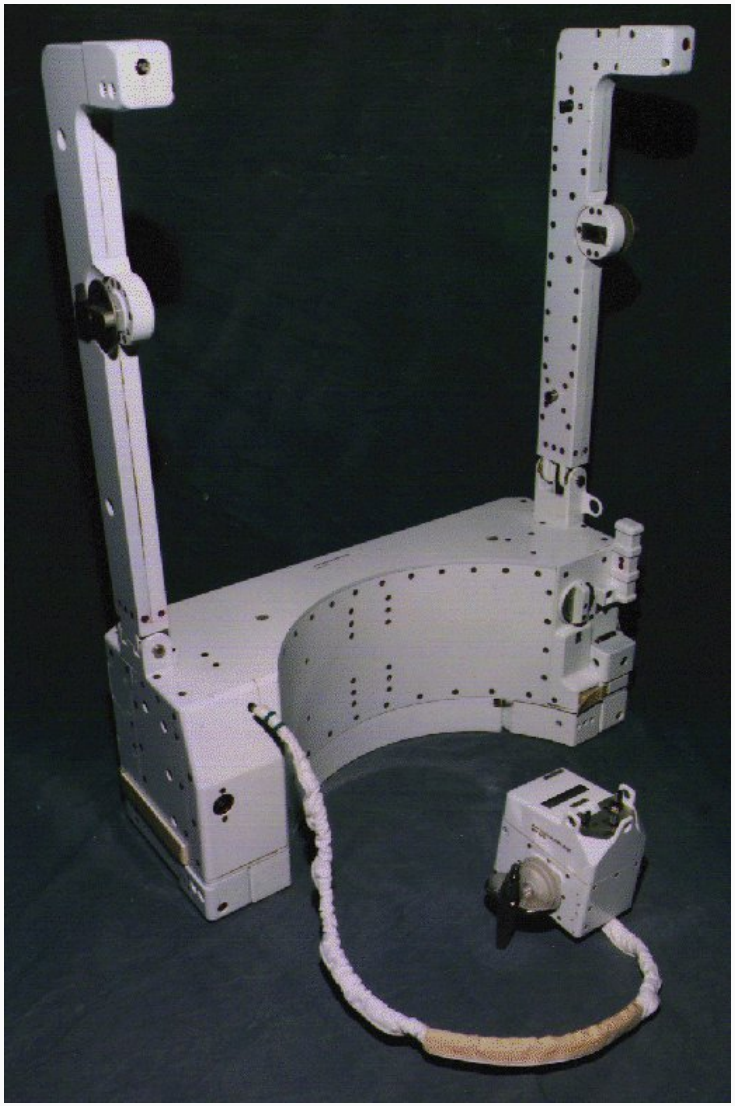
de Groot et al., 2011 [4]



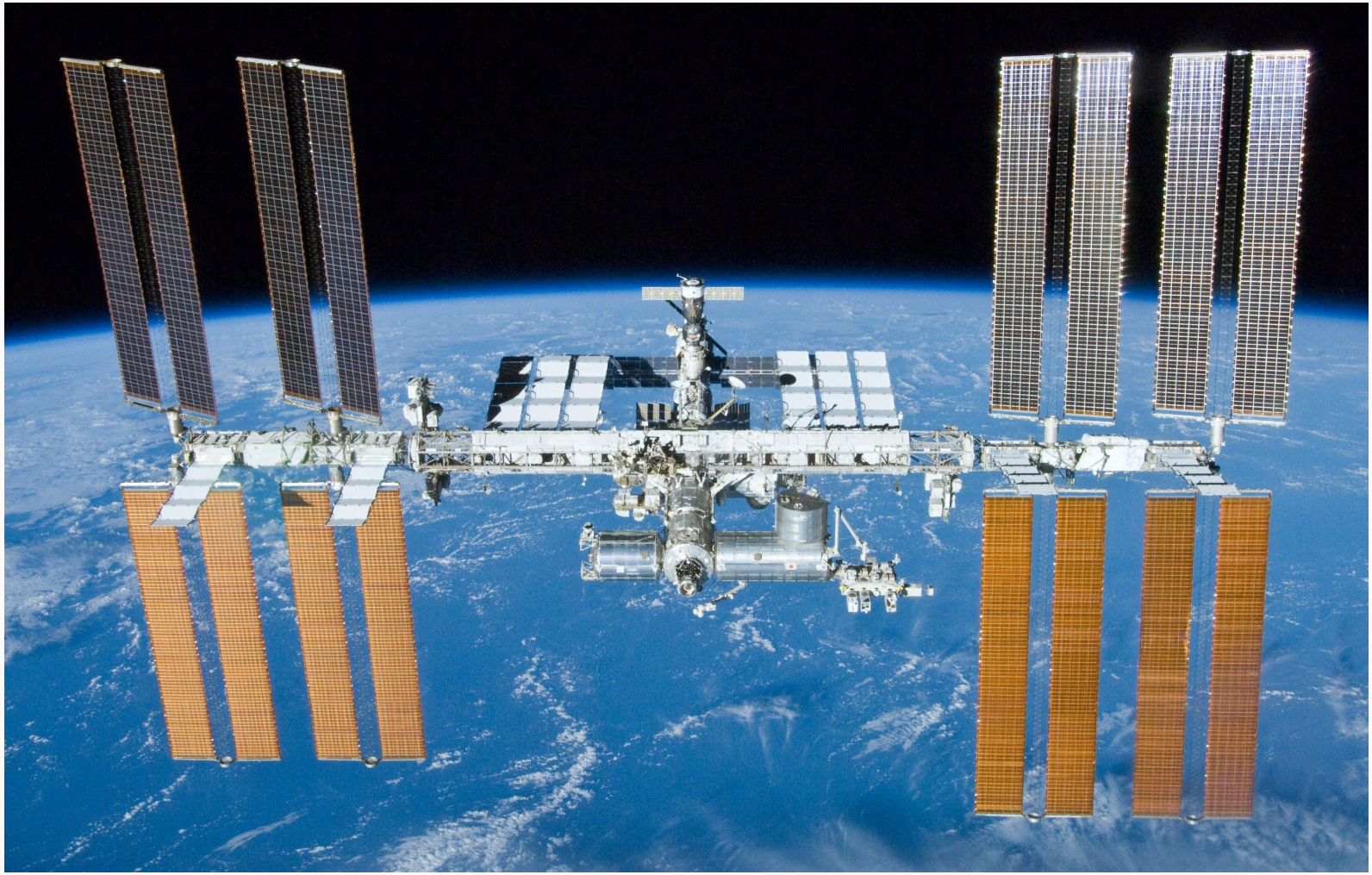
Karasinski, 2016 [5]

- I investigated feedback strategies in my Masters thesis
- Simplified Aid for EVA Rescue (SAFER)
- I developed a novel, operationally relevant task

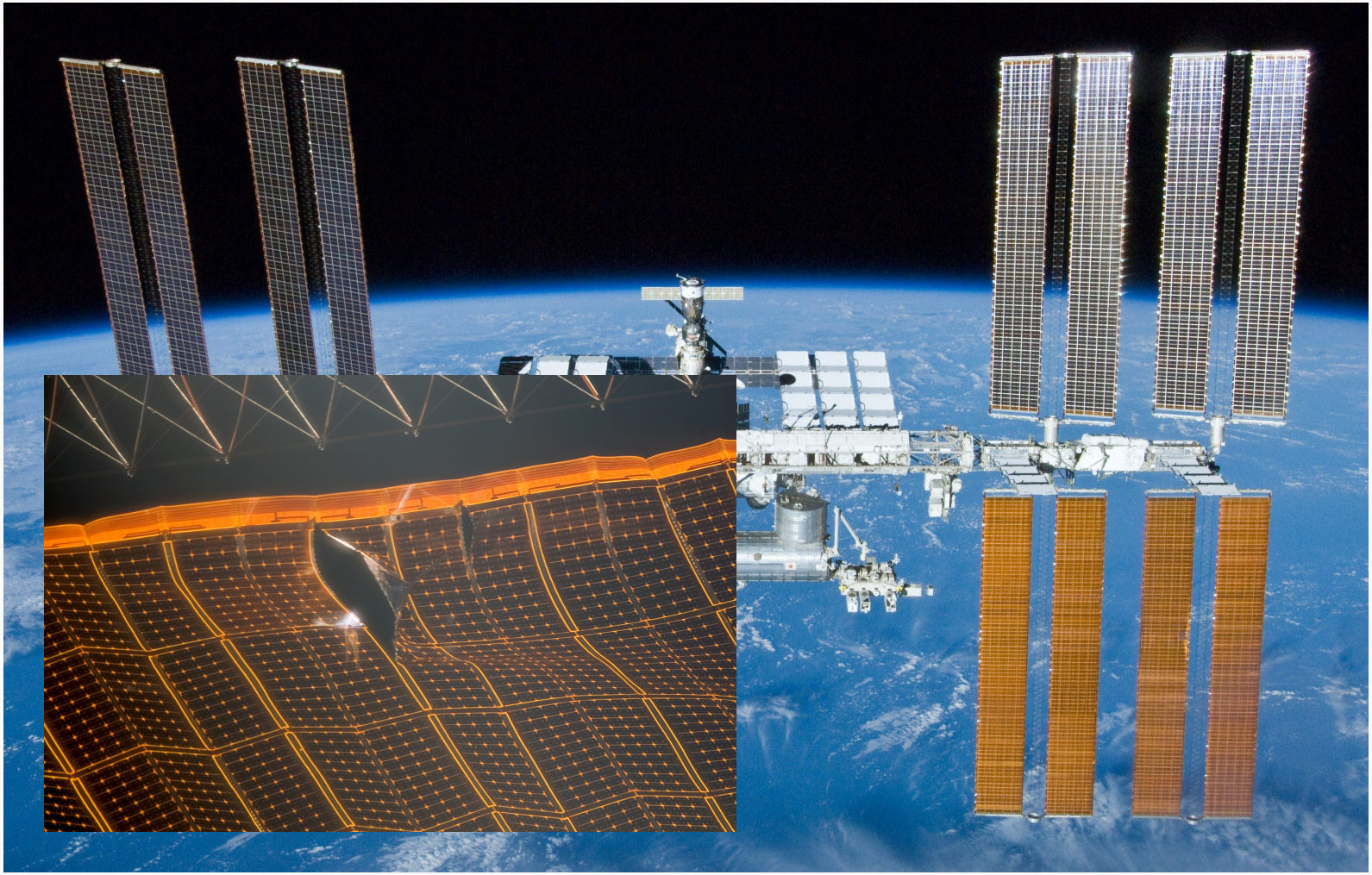
SAFER



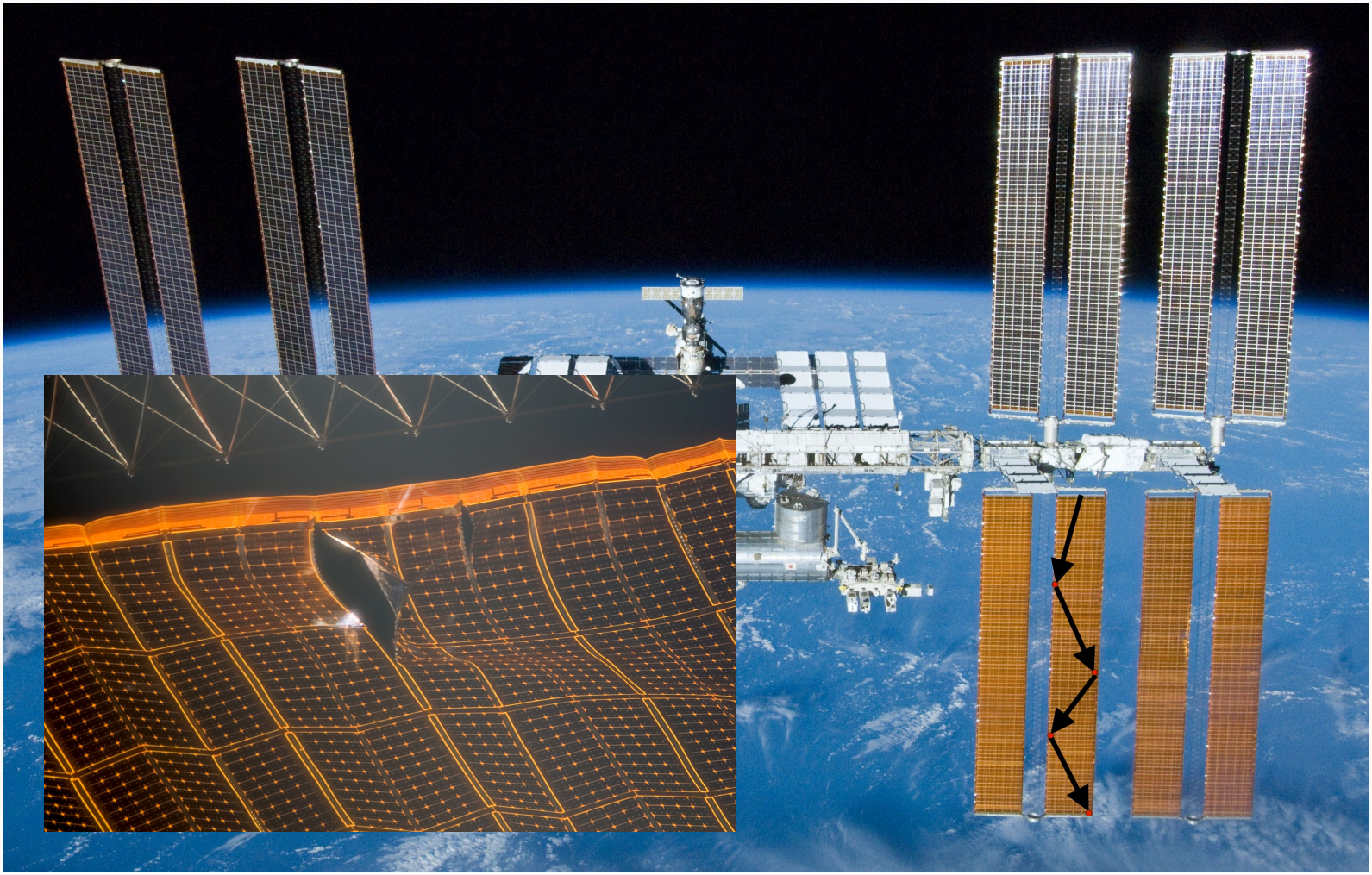
International Space Station



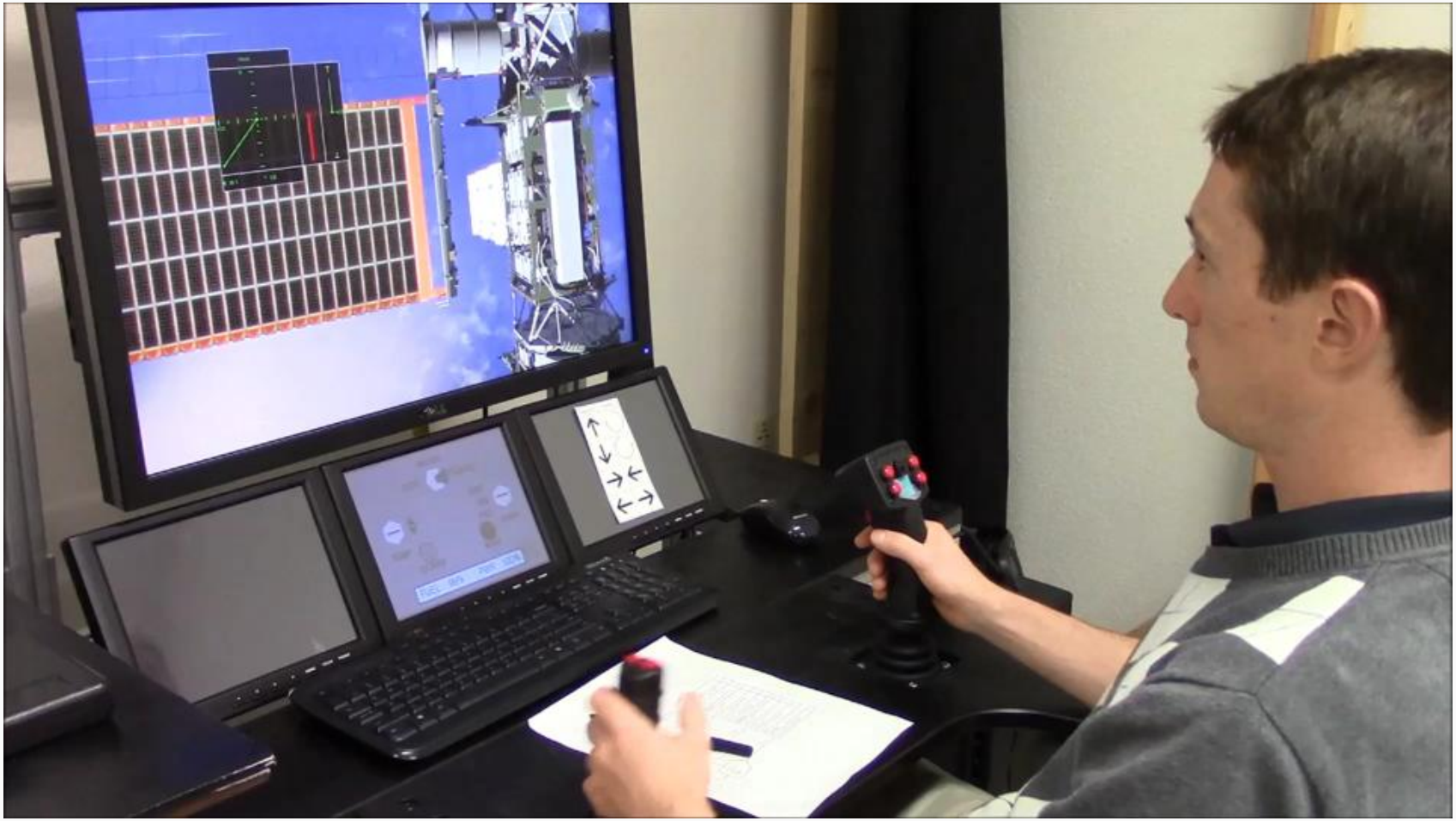
International Space Station



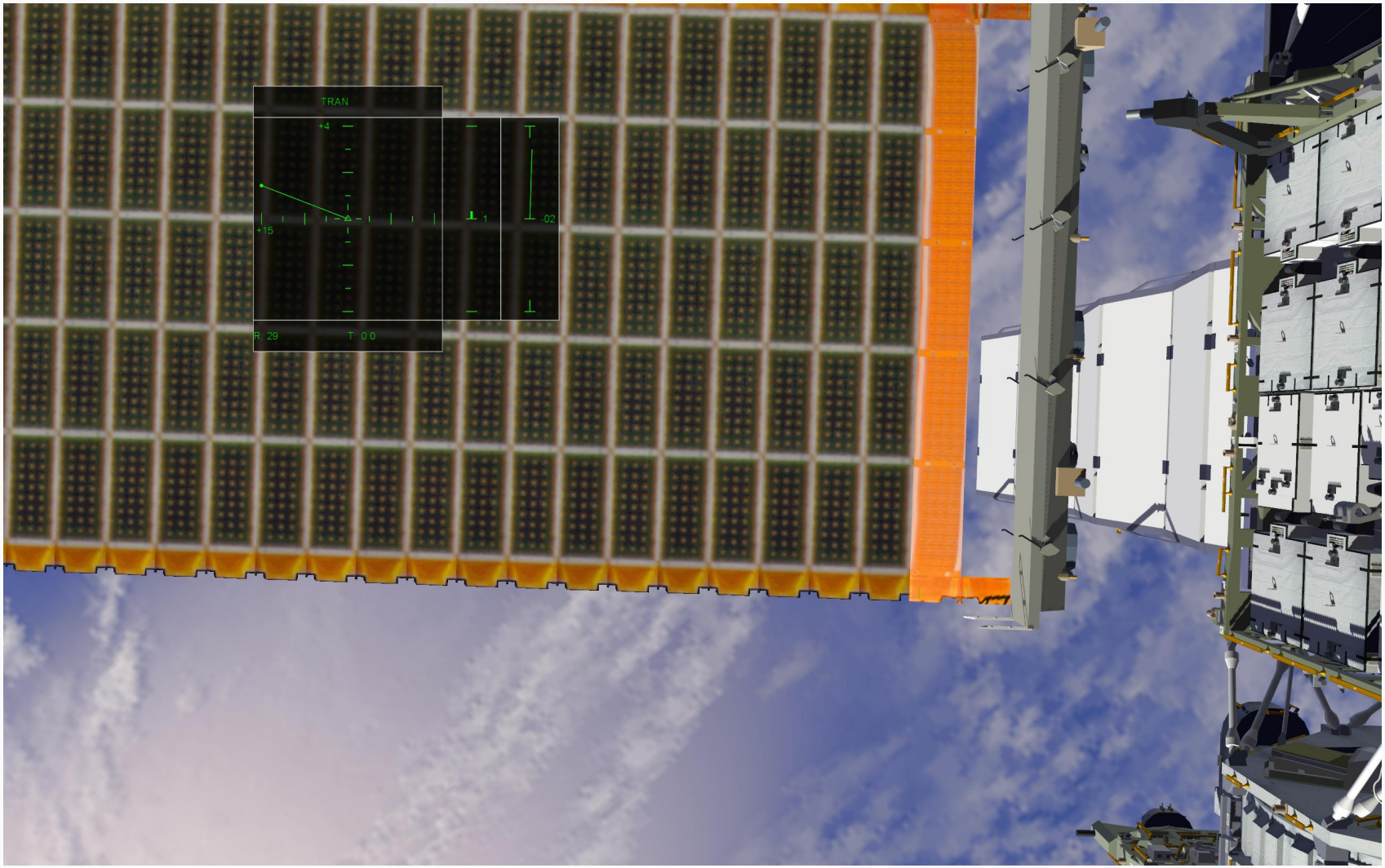
International Space Station



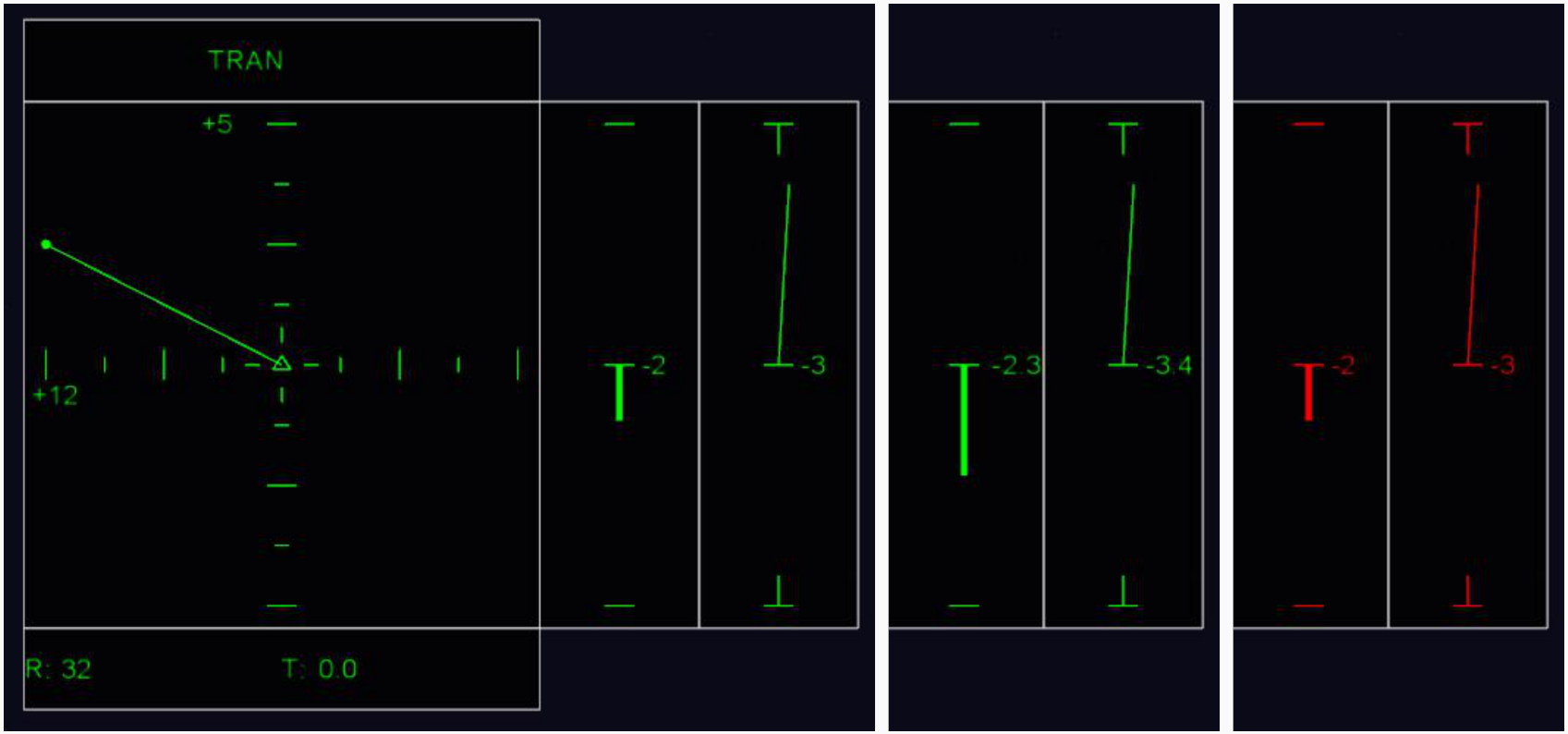
Flying SAFER



SAFER Guidance Display

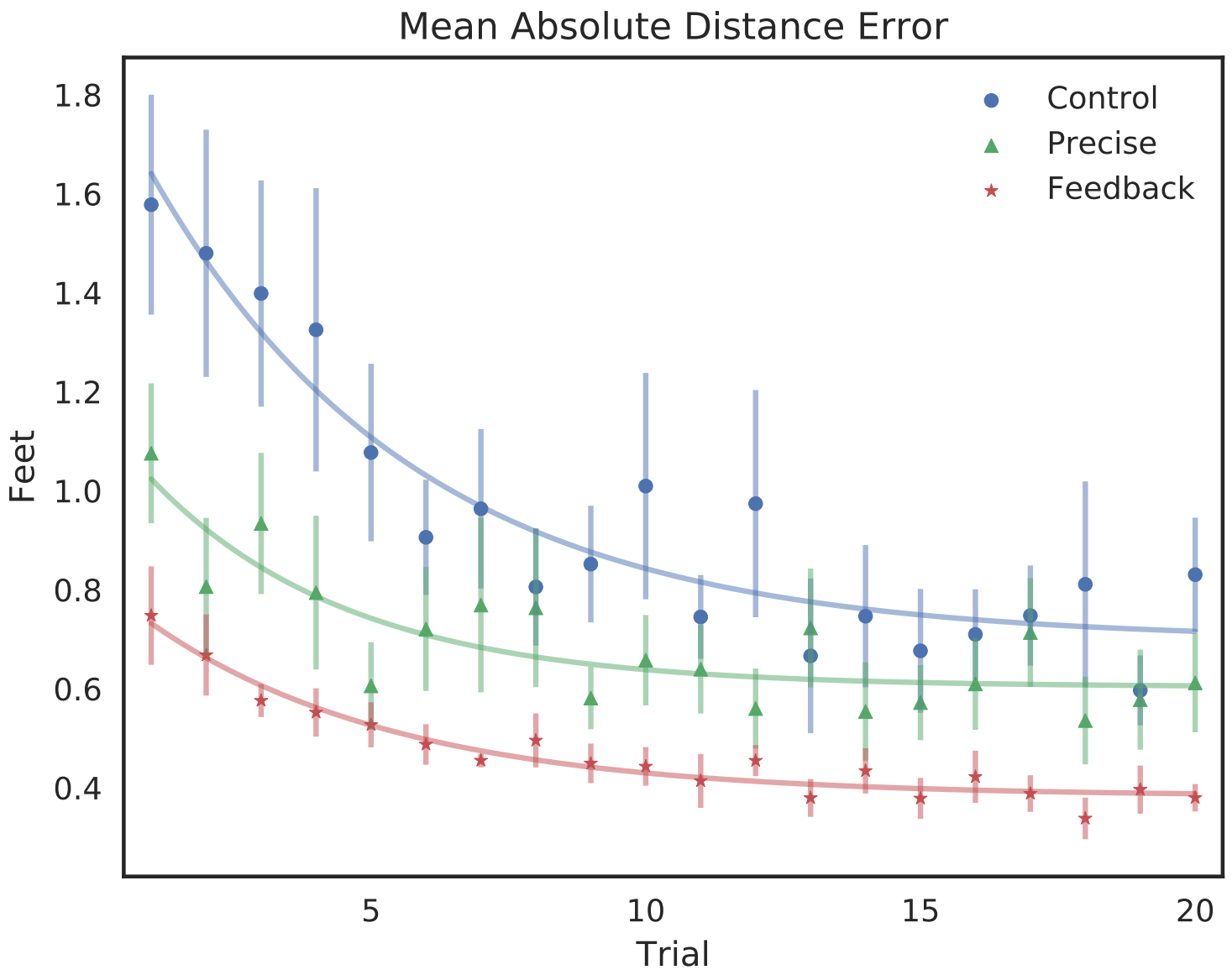


SAFER Groups

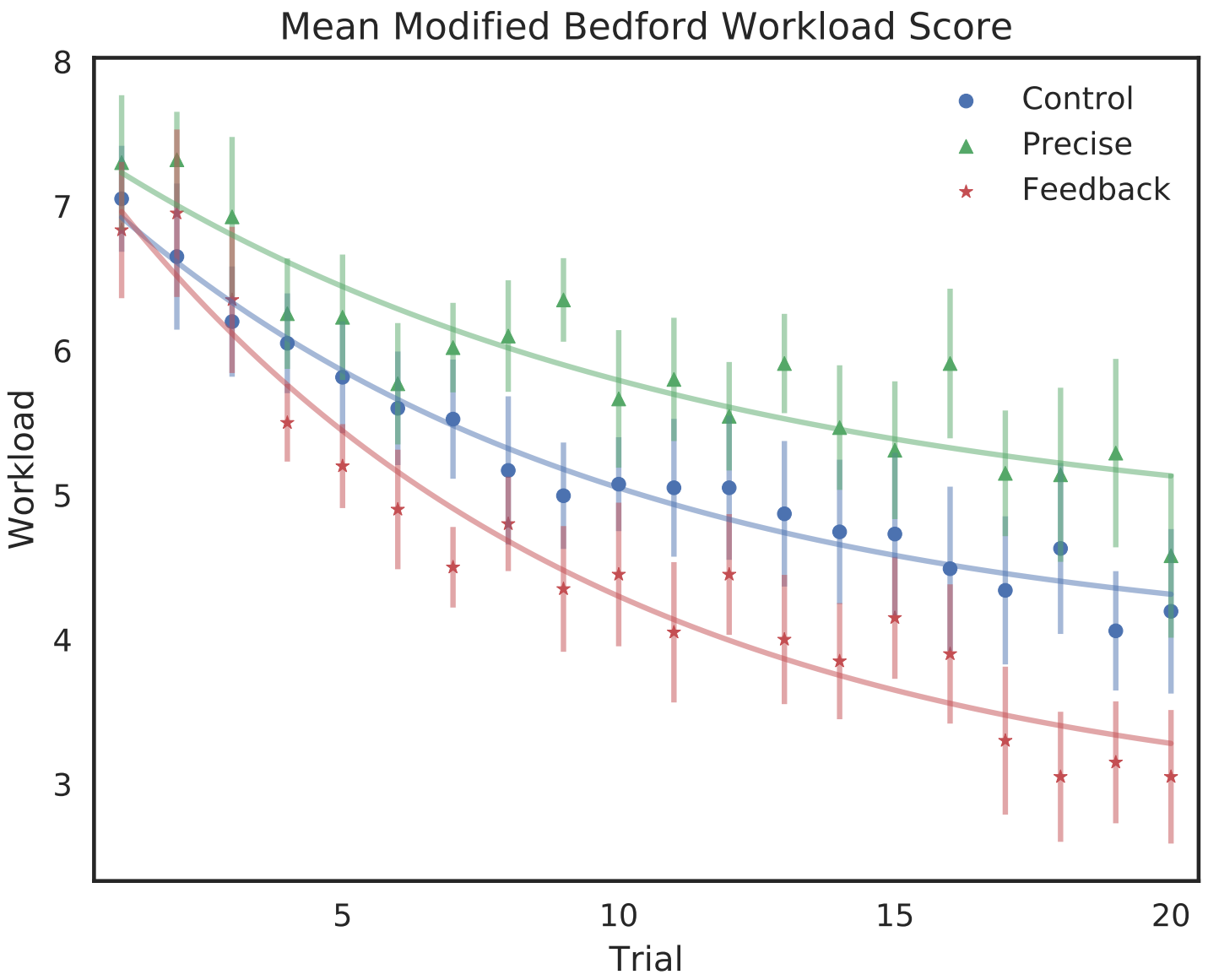


Control Precise Feedback

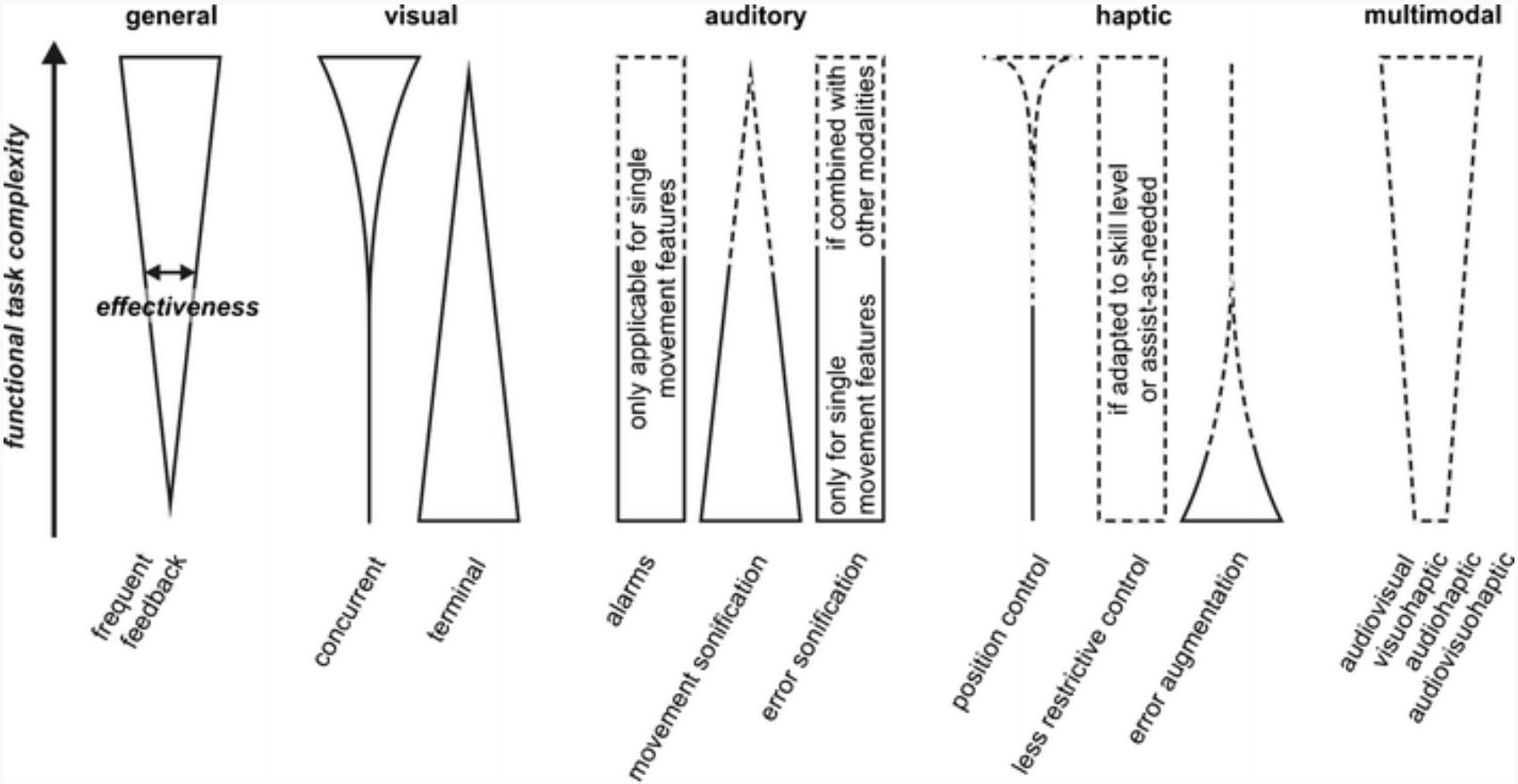
SAFER Performance



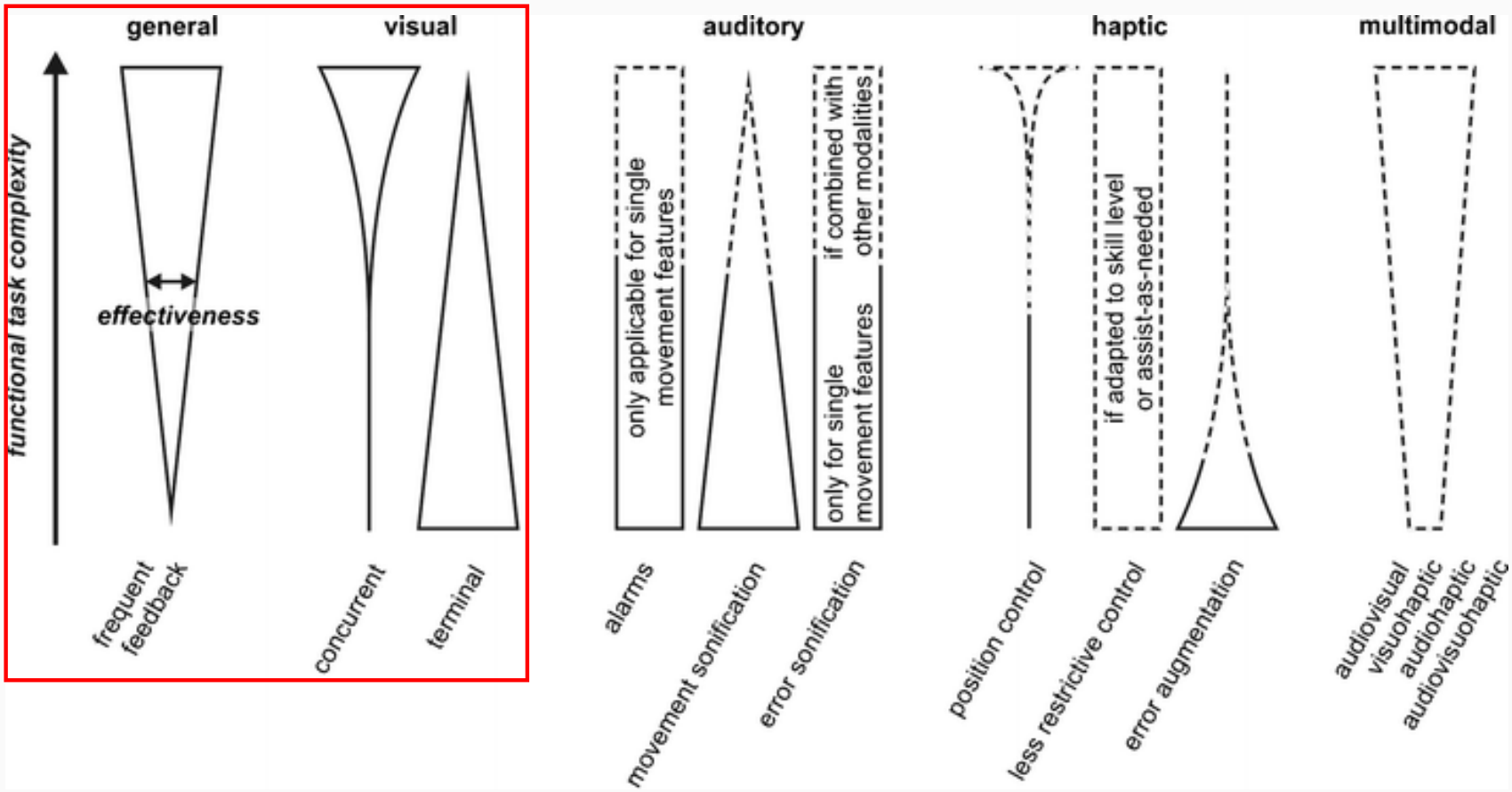
SAFER Workload



Sigrist et al., 2013 [6]



Sigrist et al., 2013 [6]



Open Questions

- What is the effect of concurrent bandwidth feedback on increasingly complex tasks?
- Can feedback be removed after training without reducing performance?
- Can we develop a model of human performance which includes the effects of concurrent bandwidth feedback?
- Can we use this model to identify optimal bandwidths or operational limits?

Proposed Research

Research Aims

Aim One Feedback effects in a three-axis manual tracking task

Aim Two Feedback effects in a robotics track and capture task

Aim Three Extend Structural Model to include feedback effects

Proposed Research

Experiment One

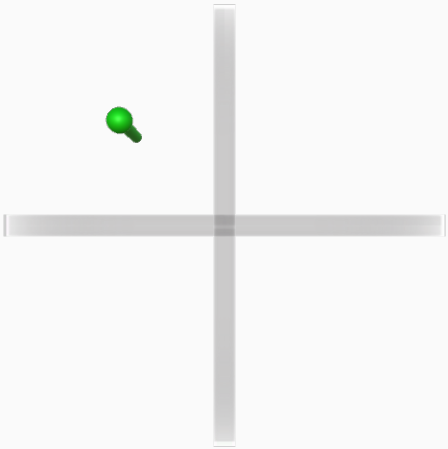
Motivation

- Link Foundation Modeling, Simulation, and Training Fellowship
- Measure the effects of feedback, 3D displays on performance and workload in robotics training
- Use a conceptually simple task, validate our modeling effort

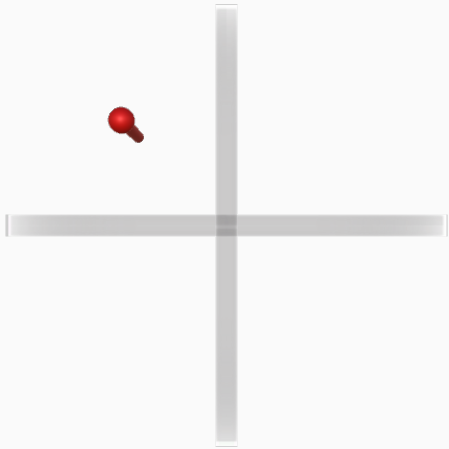
The Task

I developed a three-axis compensatory tracking task as an analog to a robotic arm track and capture task.

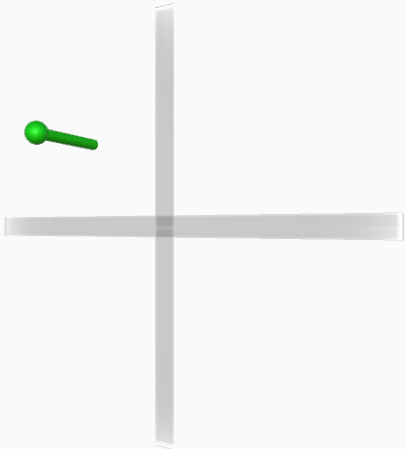
Three-axis tracking task designs



(a) Baseline

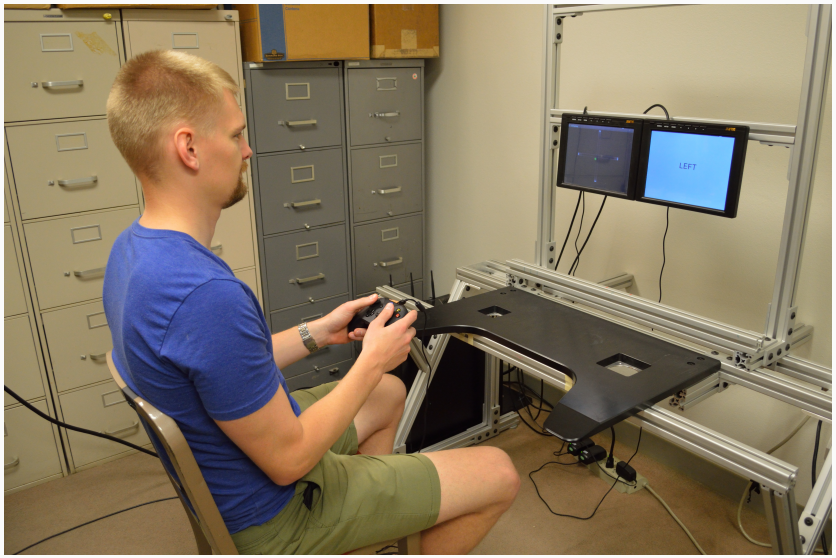


(b) Feedback

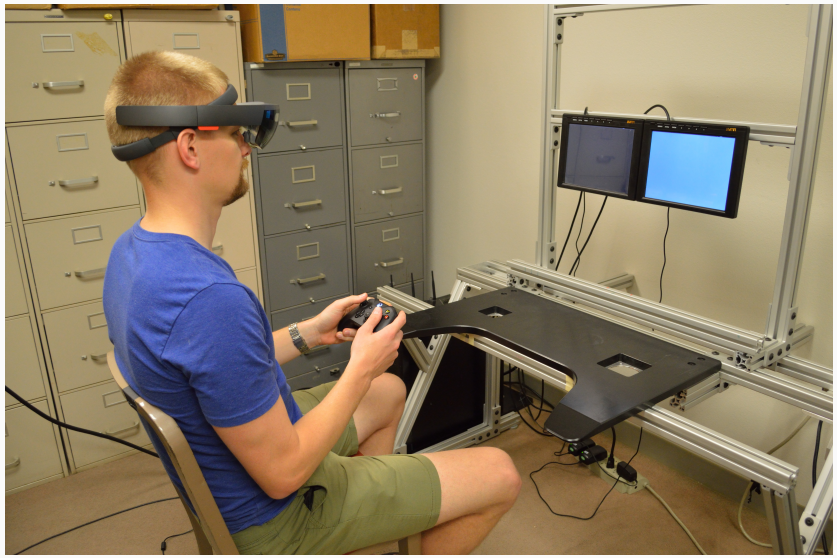


(c) Rotated

Three-axis tracking groups

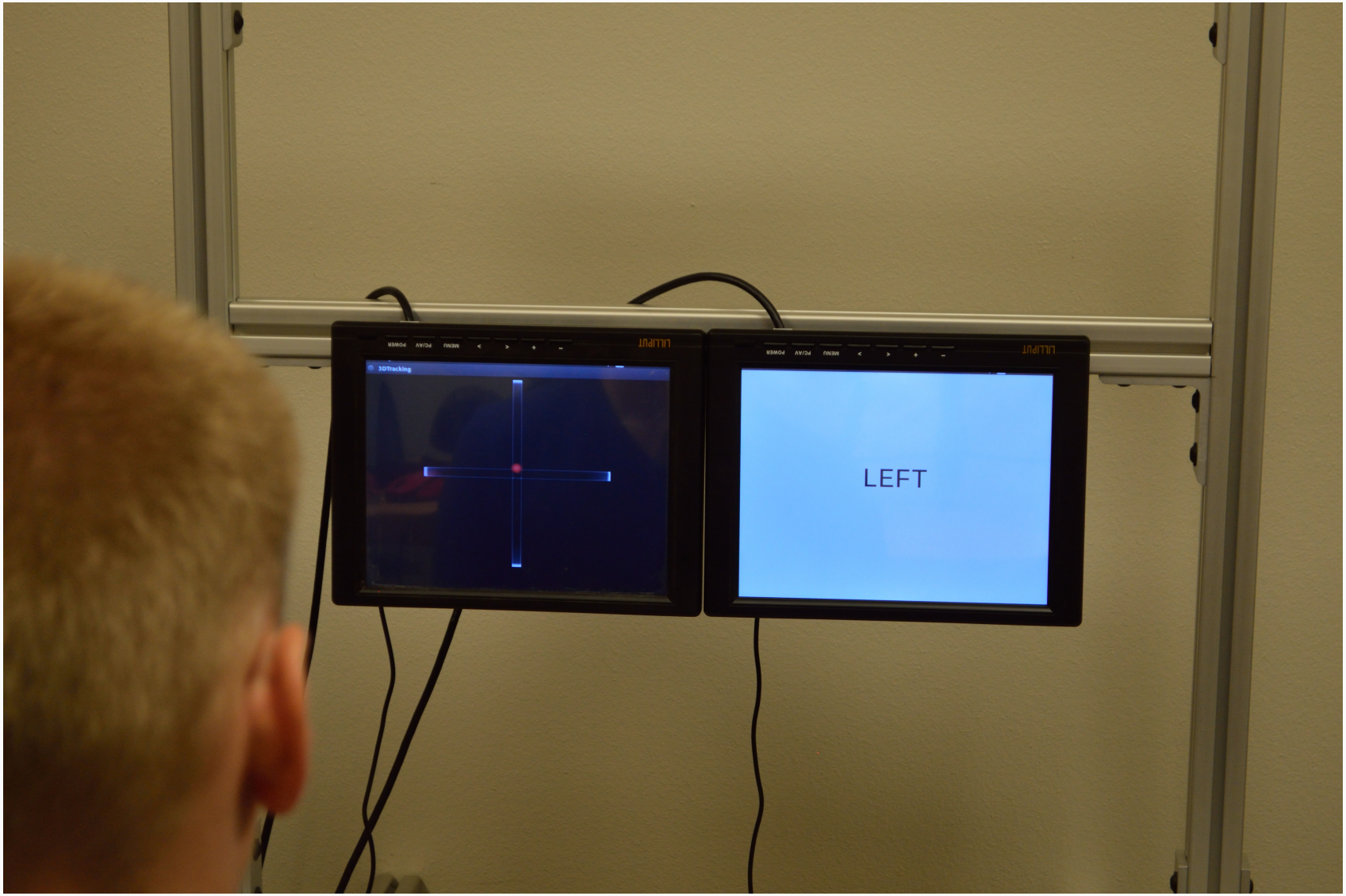


(a) 2D Group



(b) 3D Group

Three-axis tracking



Experiment Design

- 24 subjects
- Two groups (2D vs 3D)
  - Each subject in only one display group
- Three designs (Baseline, Feedback, or Rotated)
  - Each subject evaluated each design
- Three orders (Start in Baseline, Feedback, or Rotated)

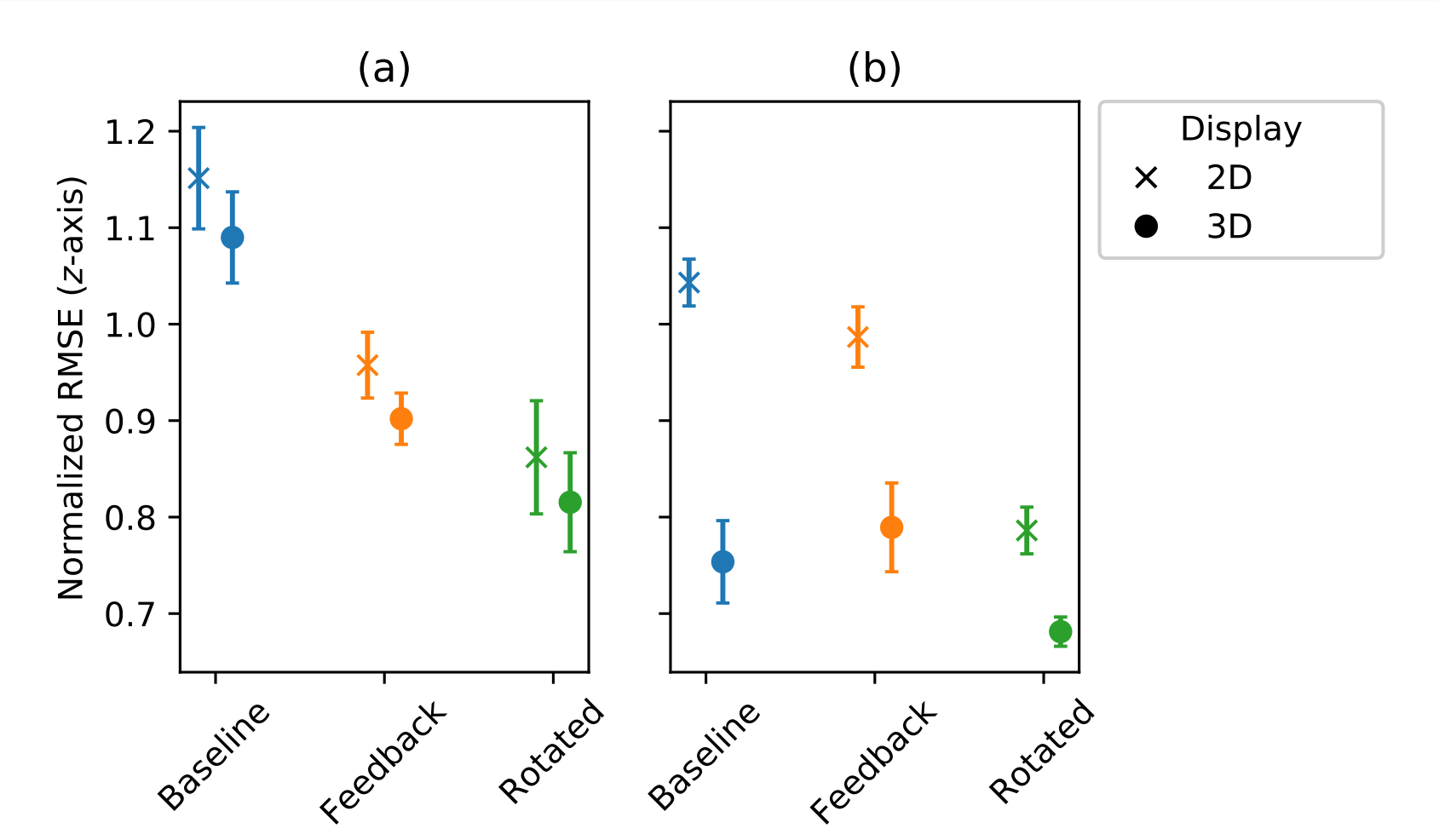
Hypotheses

H1 Feedback will improve performance in the *z* axis for both display types, and decrease workload.

H2 3D will improve performance in the *z* axis, but not affect workload.

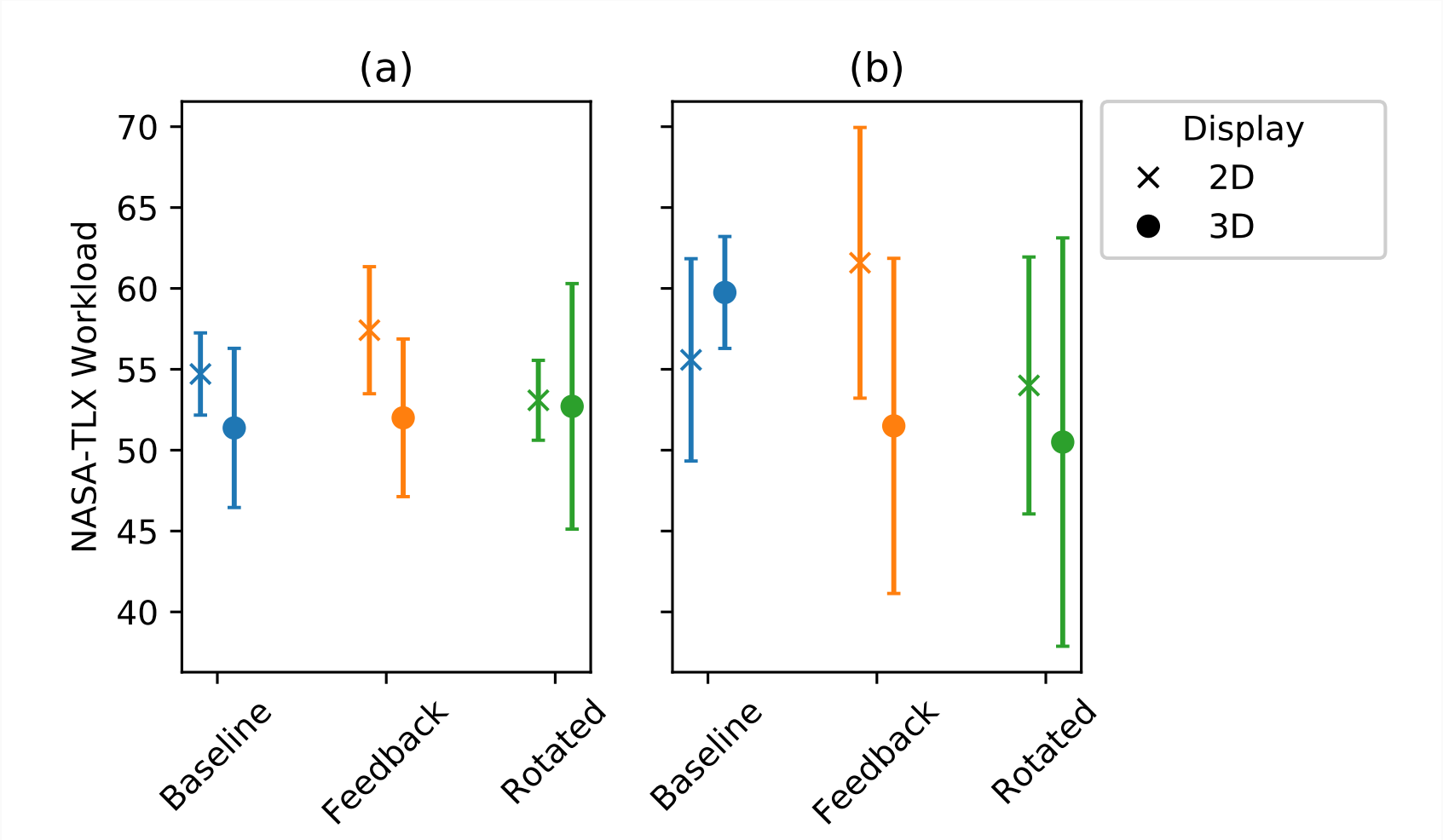
H3 Rotating the display improves performance in the *z* axis for both display types, and decrease workload.

Performance Analysis



(a) Started without Feedback, (b) Started with Feedback

Workload Analysis



(a) Started without Feedback, (b) Started with Feedback

Result Summary

Significant effect of design Rotated > Feedback > Baseline

Significant effect of device 3D > 2D for well trained subjects

Significant effect of order Early feedback $\rightarrow$ Better performance

No significant workload effects

Proposed Research

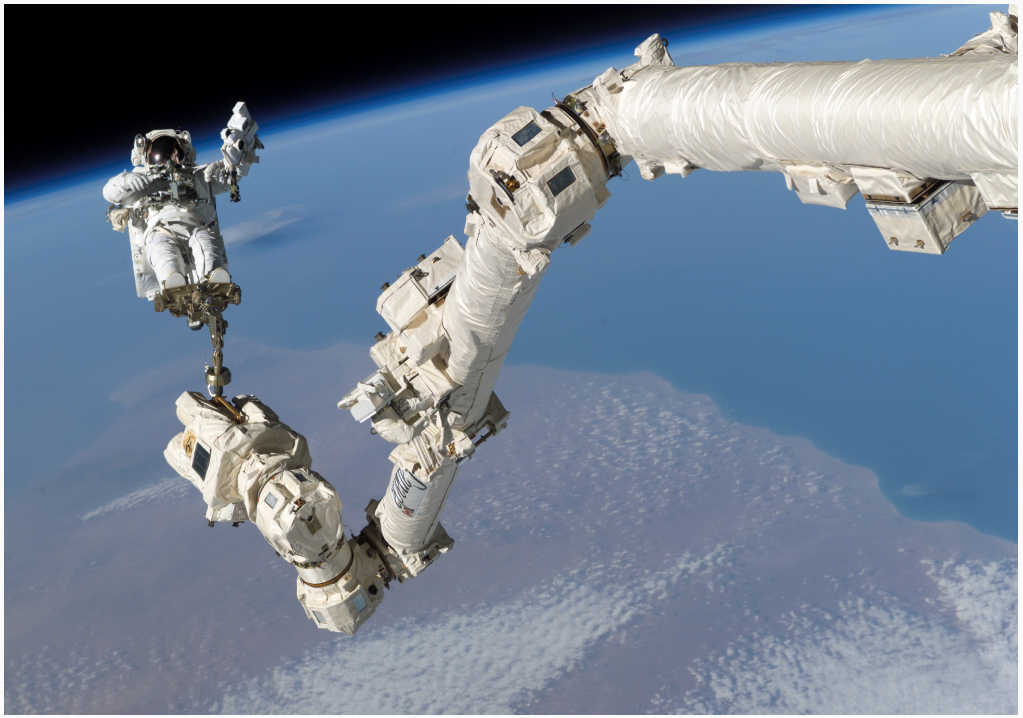
Experiment Two

Canadarm2

- Launched 2001, 7 DoF, 60 feet long, 4000 lb

Canadarm2

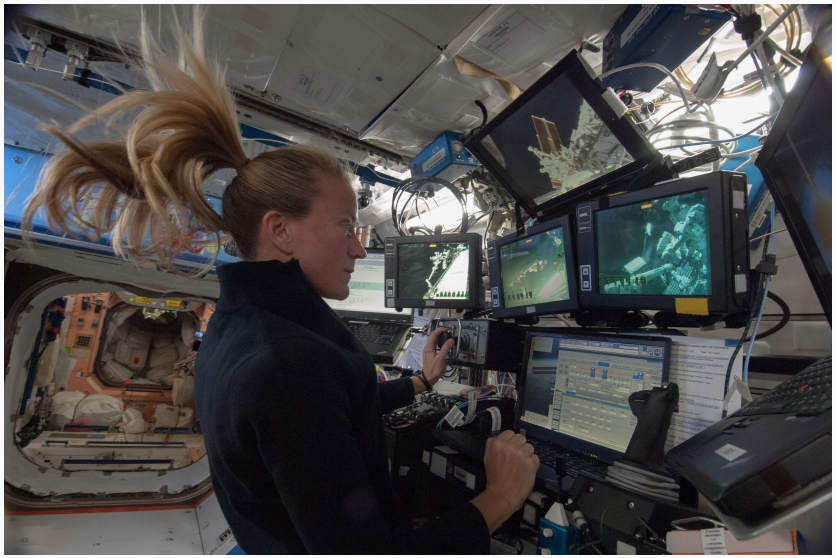
- Launched 2001, 7 DoF, 60 feet long, 4000 lb
- Astronaut EVA Assist



Canadarm2

- Launched 2001, 7 DoF, 60 feet long, 4000 lb
- Astronaut EVA Assist
- Grappling visiting vehicles

RWS on ISS



(a) Node Module

(b) Cupola

Track and Capture Scenario

- Vehicle arrives at capture point
- ISS and vehicle in two separate, nearby orbits
- Operators must capture a vehicle drifting in six dimensions

The Task

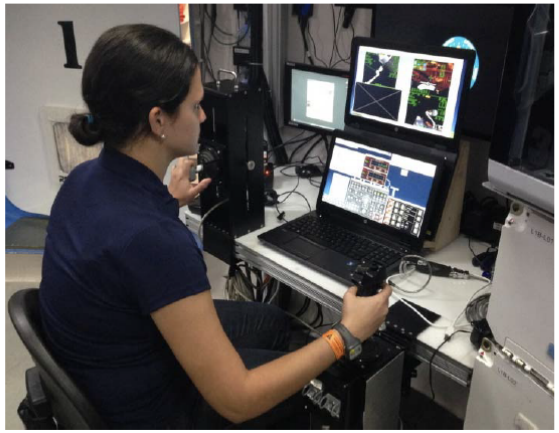
The Task

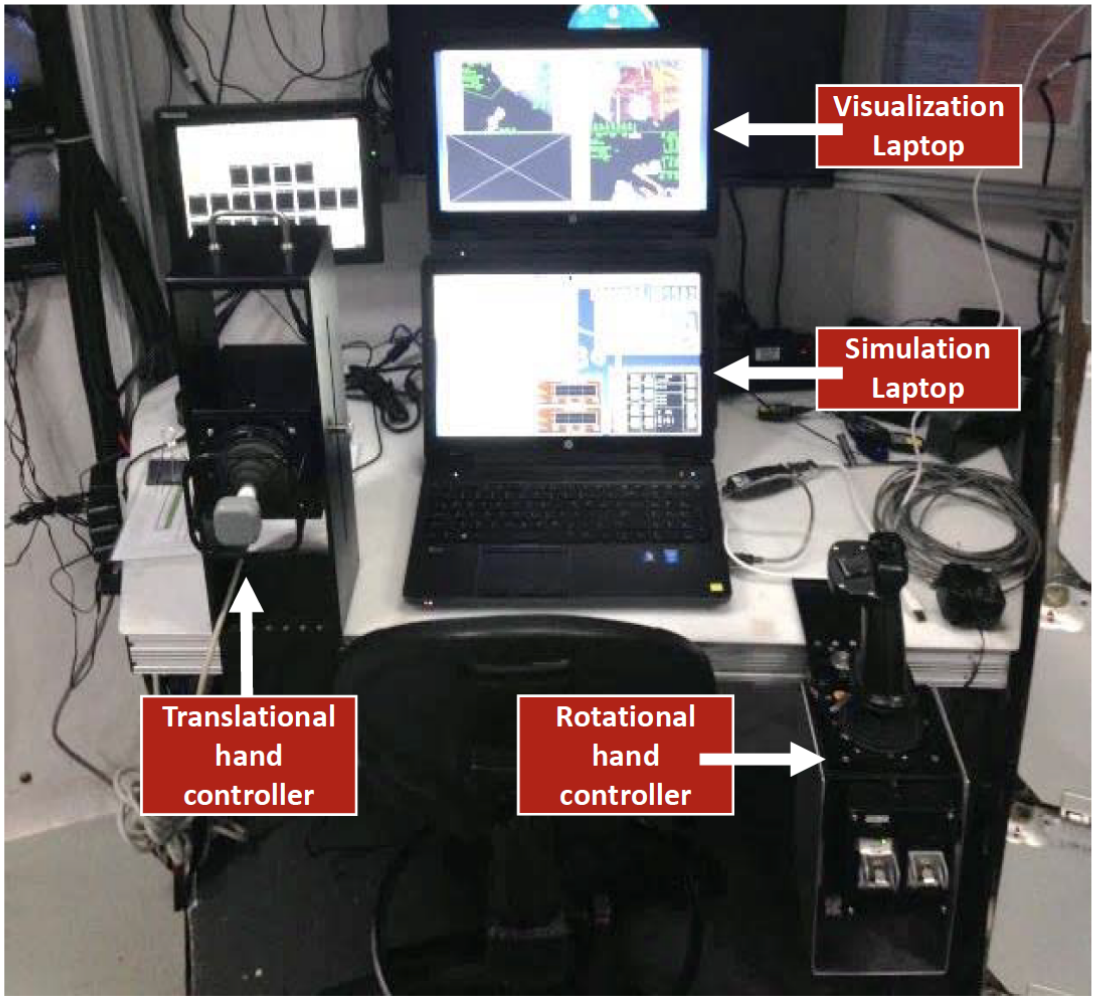
The Task

The Task

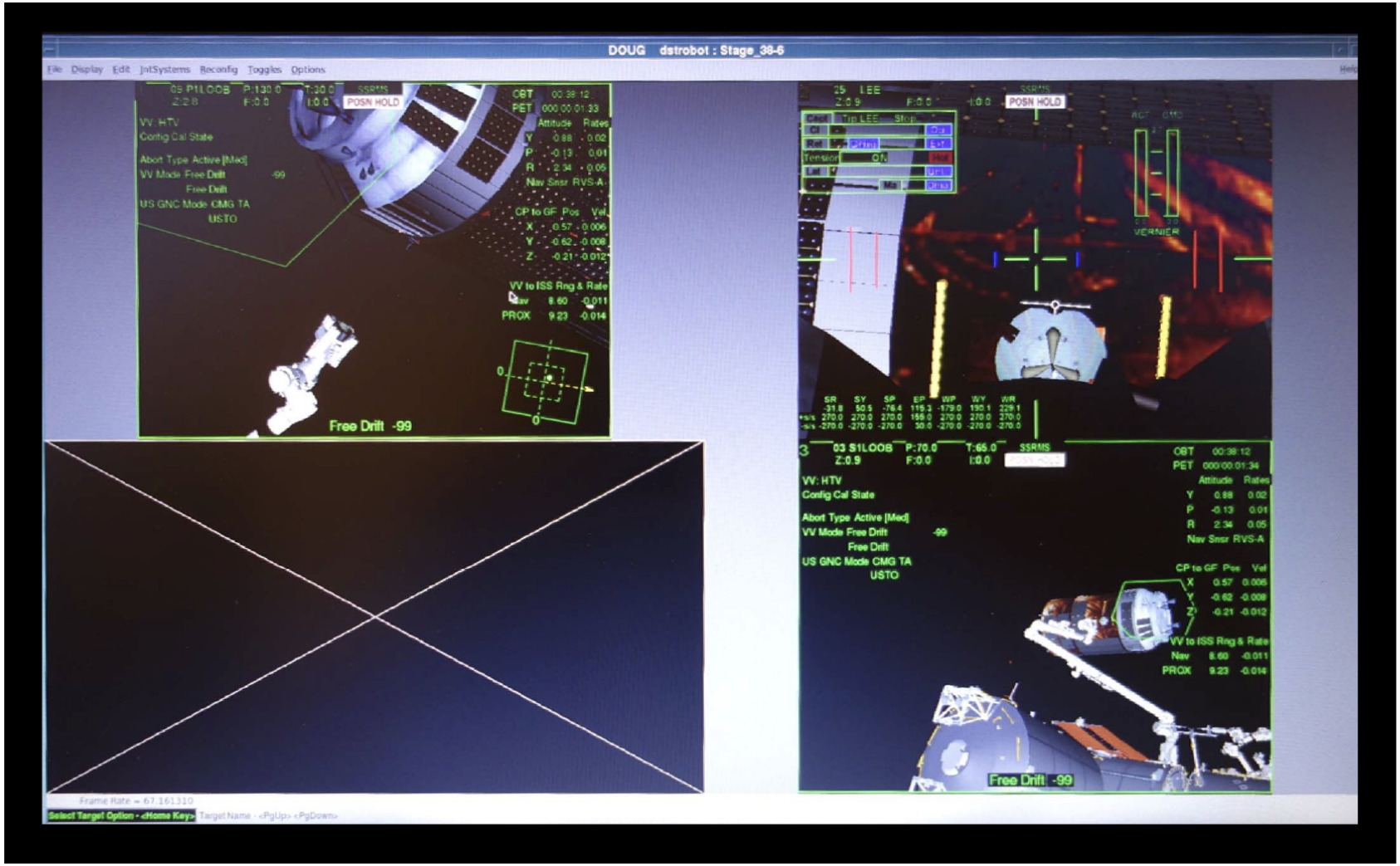
ROBoT Workstation

Installed on Level 1 of the habitat module





ROBoT Visualization



ROBoT Performance Reports

Track & Capture Pop-Up Evaluation Tool

File Options

Overview | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Run #6 | Run #7 | Run #8 | Run #9 | Run #10 | Run #11

tctool_20160422_114155.data

T&C Performance Score

Pass/Fail Criteria:

Alignment/Reversals = 2.9	MARGINAL (Close to tolerance)
Grapple Fixture Hits = 0	PASS
Efficiency = 75.78	PASS
Capture Attempts = 1	FAIL (Over the pin, but poor alignment)
Capture (Cable Tension) = 1	PASS
OVERALL	FAIL

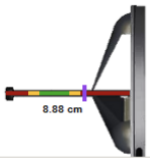
The T&C Alignment/Reversals Score is based on these weighted factors:

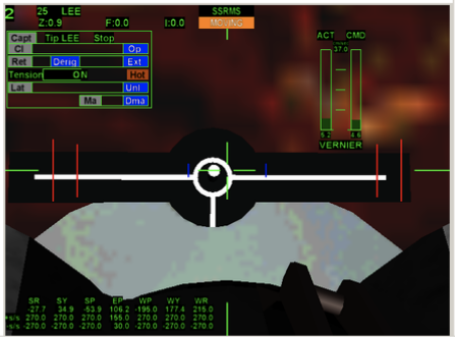
Alignment at trigger pull
Alignment at 1 pin
Alignment at 2 pin
Alignment at 1m
Reversals

Alignment/Reversals Score: 2.9

Alignment Errors	P/Y (d)	Roll (d)	x (cm)	y/z (cm)
Trigger	4.35	0.02	8.88	1.39
1 Pin	4.66	2.33	49.18	5.78
2 Pin	4.83	1.78	73.63	1.58
1.0m	5.00	1.96	99.74	5.48

Distance From GF
Base Plate At Trigger Pull (79 seconds)





Track & Capture Pop-Up Evaluation Tool

File Options

Overview | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Run #6 | Run #7 | Run #8 | Run #9 | Run #10 | Run #11

20160422_112707

Overall T&C Performance Score

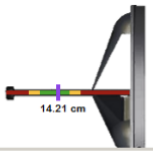
Pass/Fail Criteria	Run Number 1	2	3	4	5	6	7	8	9	10	11	12
Alignment/Reversals												
Grapple Fixture Hits												
Efficiency												
Capture Attempts												
Capture (Cable Tension)												
OVERALL												

Alignment at trigger pull
Alignment at 1 pin
Alignment at 2 pin
Alignment at 1m
Reversals

Alignment/Reversals Score: 1.5

Alignment Errors	P/Y (d)			Roll (d)			x (cm)			y/z (cm)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Trigger	0.86	6.50	2.88	0.02	2.08	0.69	8.88	17.69	14.21	0.45	4.03	2.17
1 Pin	1.34	7.01	3.43	0.05	2.33	0.87	49.01	49.27	49.15	0.50	7.82	3.96
2 Pin	1.43	6.82	3.64	0.07	1.78	0.95	73.49	73.91	73.76	0.04	11.16	4.87
1.0m	1.49	6.94	3.87	0.16	5.09	1.84	99.15	100.00	99.73	1.86	18.22	7.53

Average Distance From GF
Base Plate At Trigger Pull

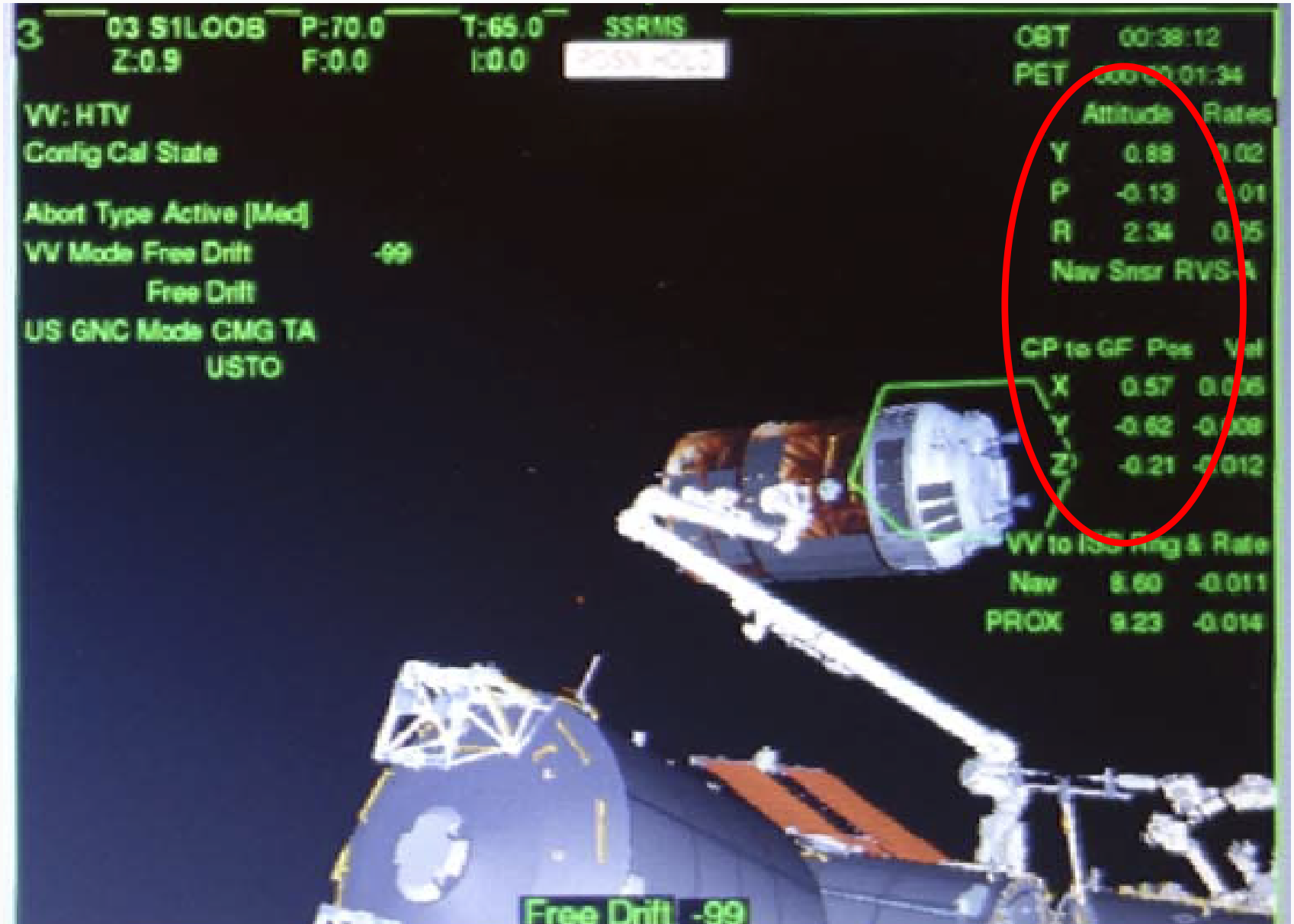


Trigger Statistics	Min	Max	Avg
Distance From GF (cm)	8.88	17.69	14.21
Elapsed Time(seconds)	29.00	86.00	50.00

Experiment Two

- Only terminal feedback is currently available without a trainer
- Terminal feedback is ineffective for complex tasks
- Provide feedback concurrently with task execution

ROBoT Treatment Group


03 S1LOOB
Z:0.9
P:70.0
F:0.0
T:65.0
SSRMS
OBT
PET
VV: HTV
Config Cal State
Abort Type Active [Med]
VV Mode Free Drift
Free Drift
US GNC Mode CMG TA
USTO
Attitude
Rates
Y
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R
Nav Snsr
CP to GF Pos
X
Y
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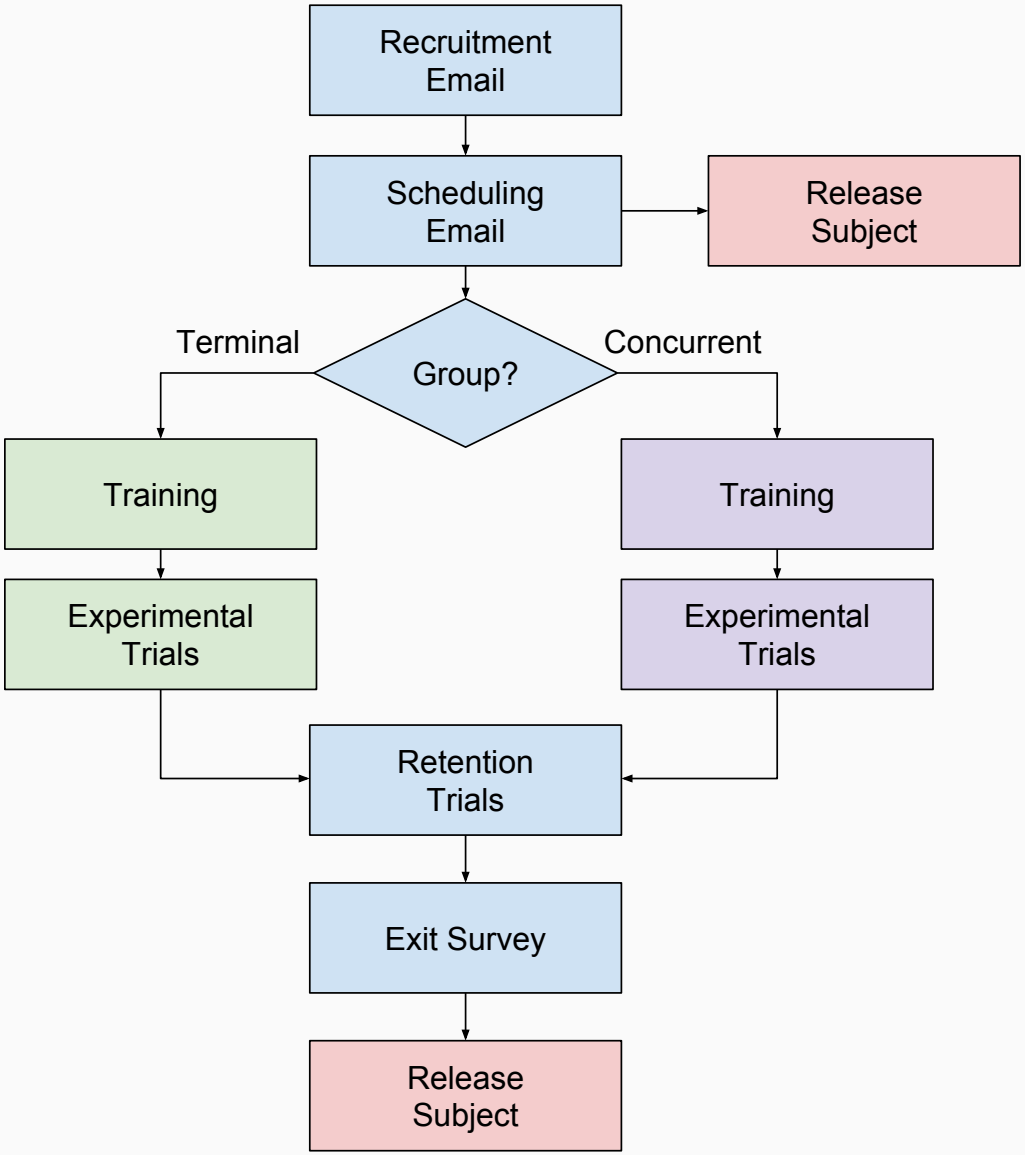
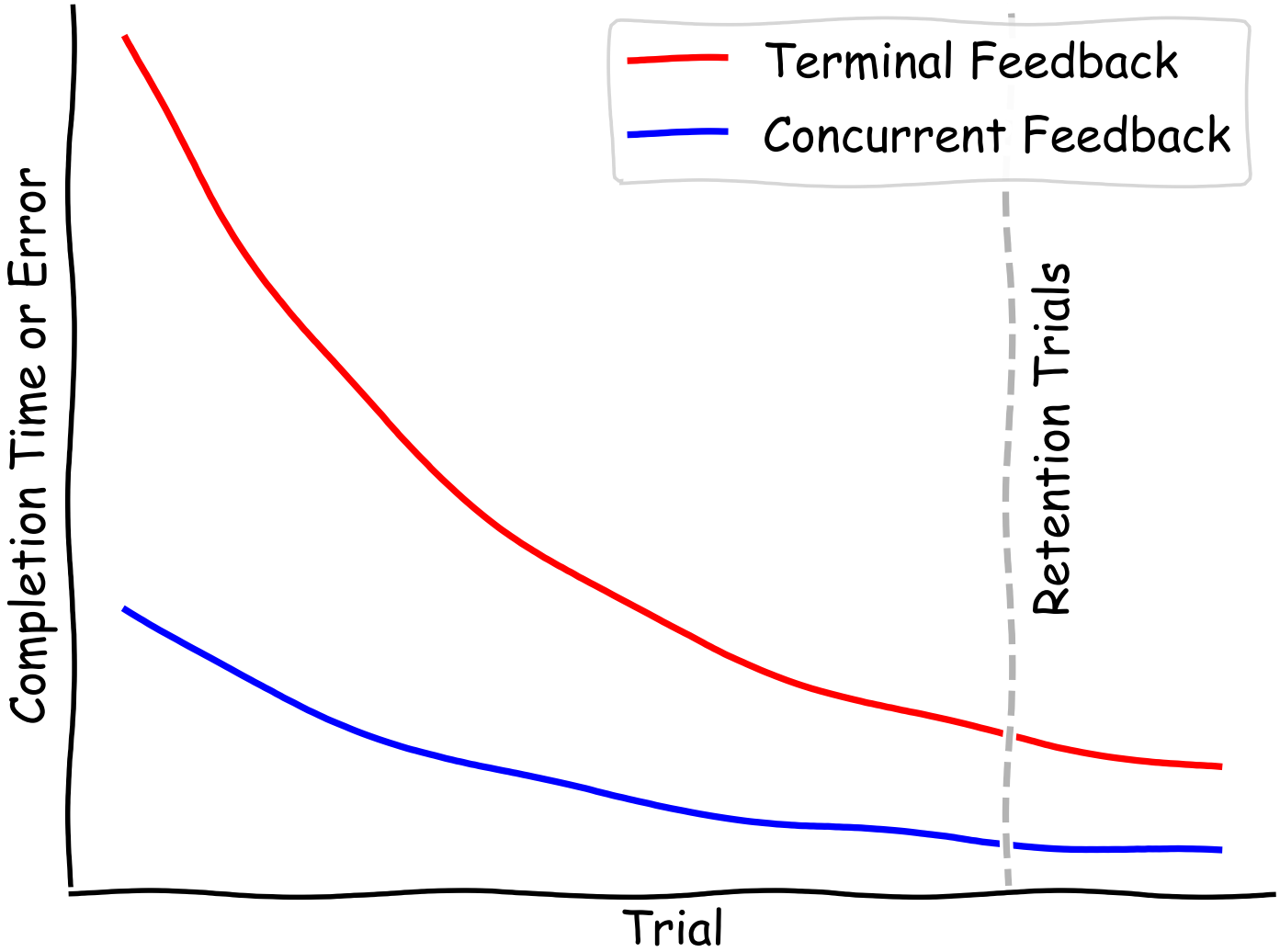
Nav
PROX
Free Drift -99

Experiment Two Flowchart



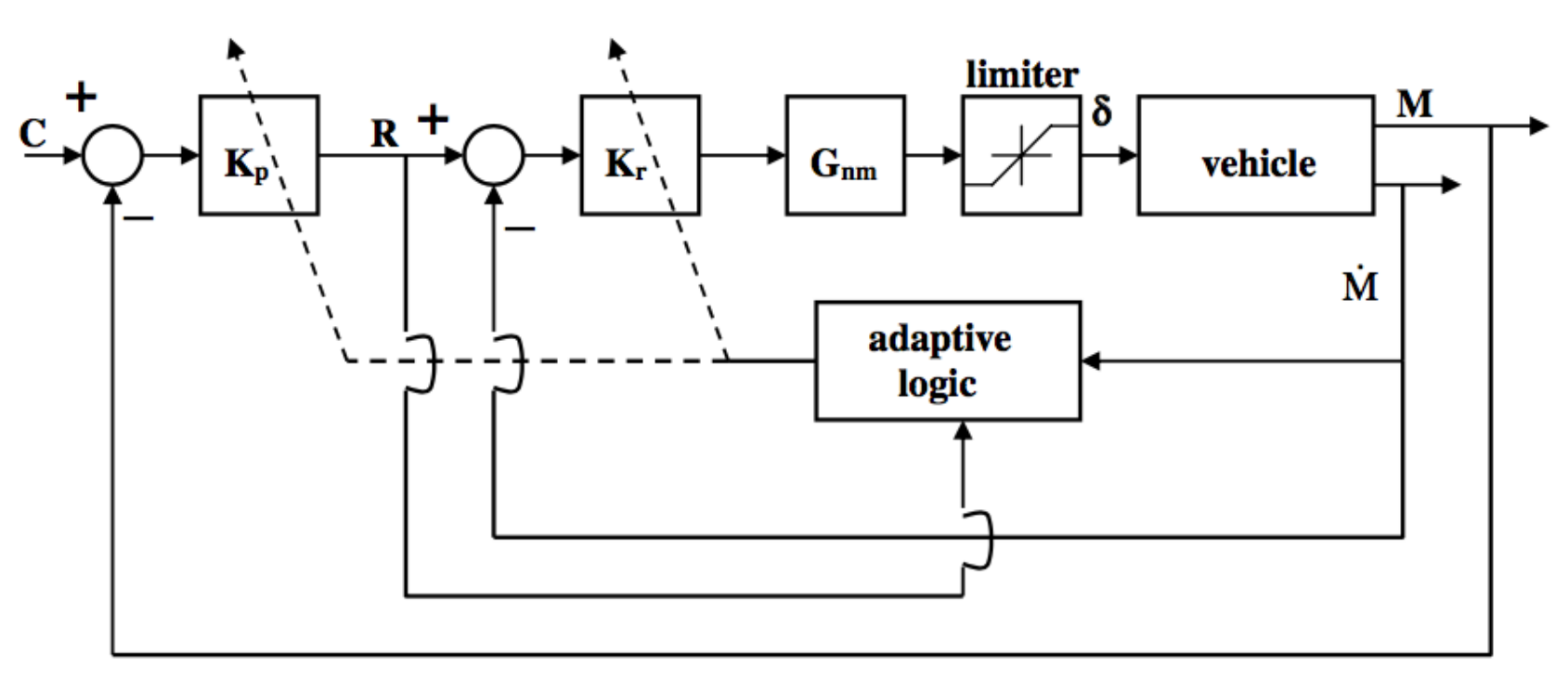
Predicted Results



Proposed Research

Modeling

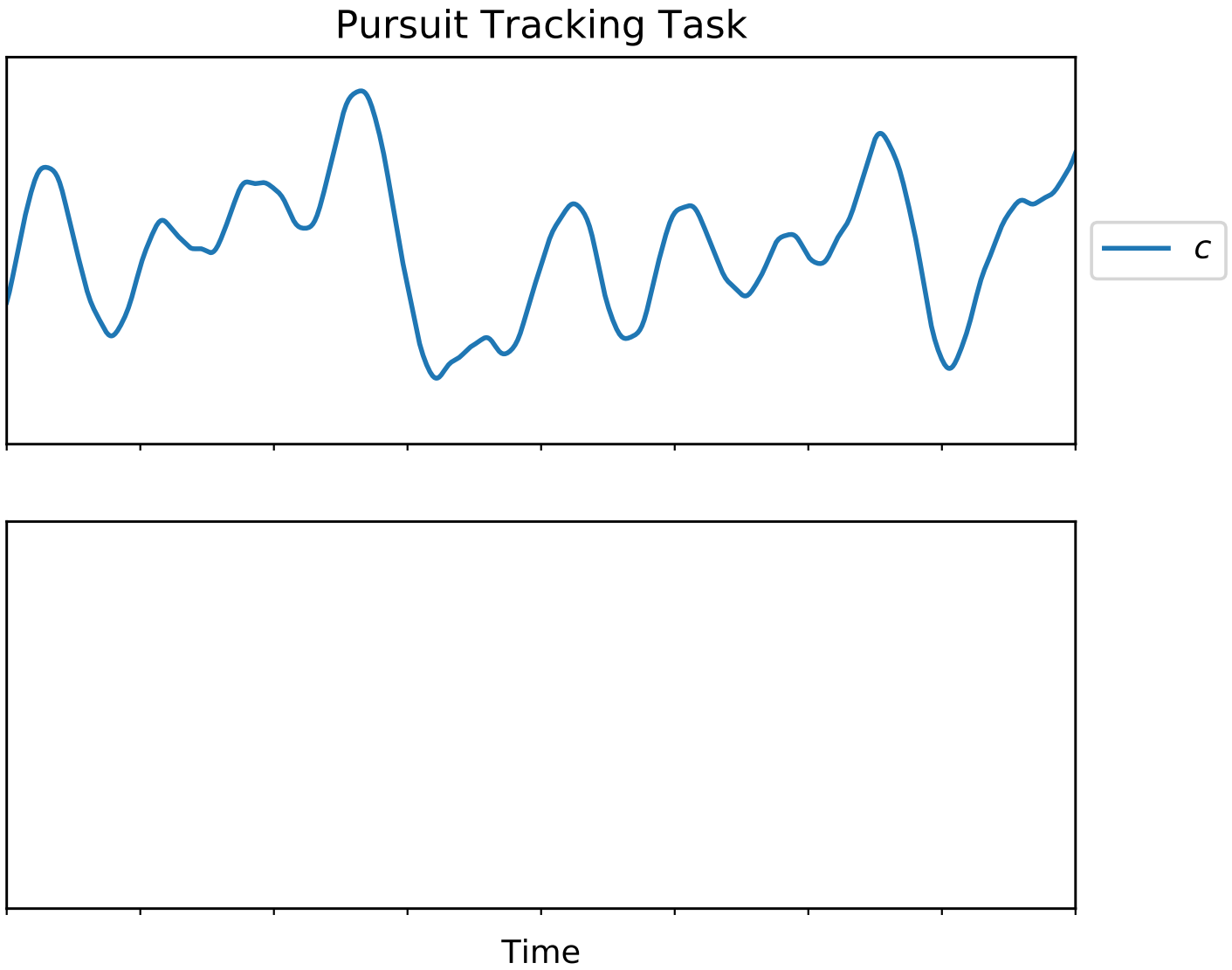
Hess Simplified Pursuit Model, 2009 [7]



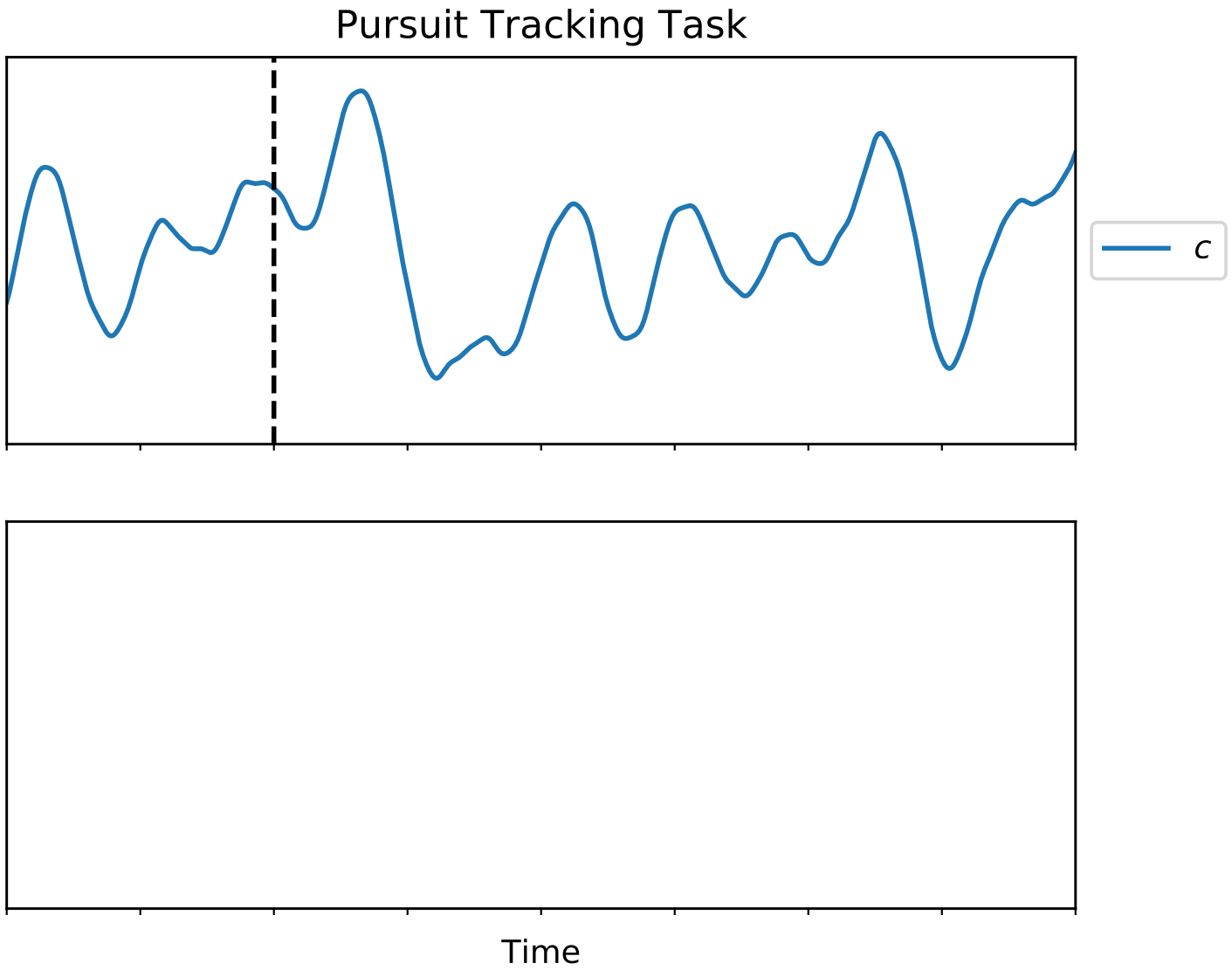
Current Adaptation

- Current model adapts based on inner rate loop caused by changed vehicle dynamics
- Preliminary replication results
- Sudden change of vehicle dynamics
  - $\frac{1}{s} \rightarrow \frac{e^{-0.065s}}{s^2}$

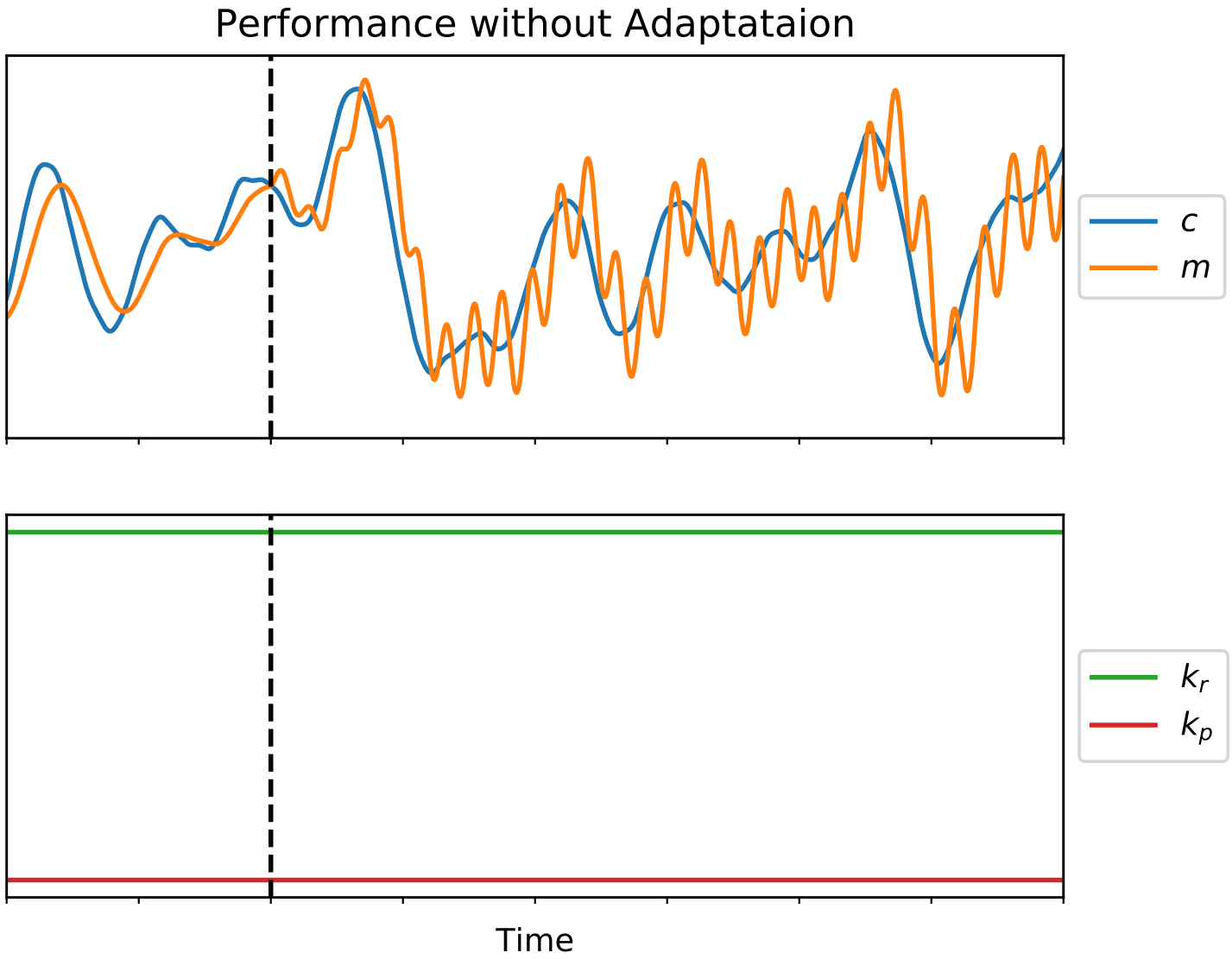
Effects of Adaptation



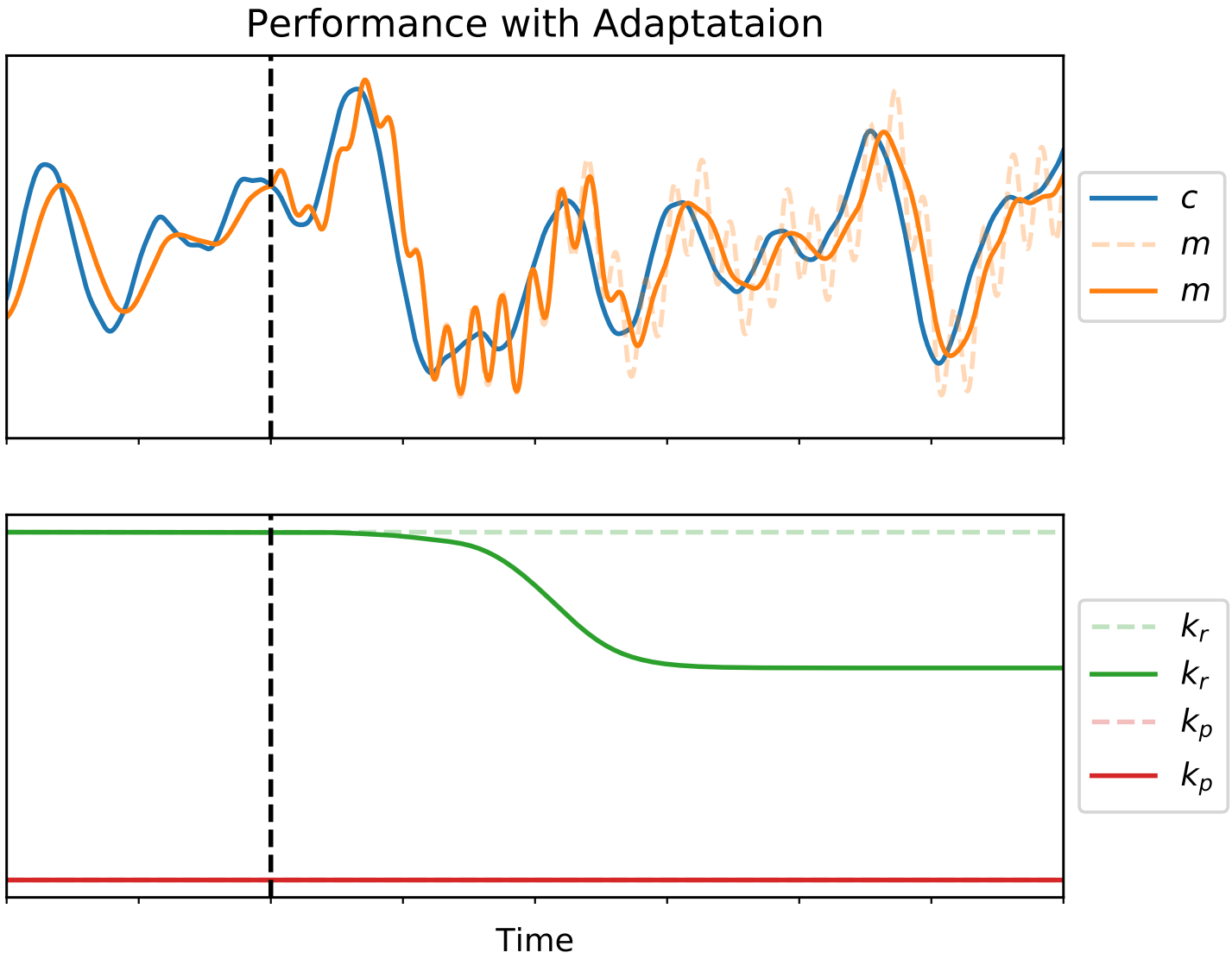
Effects of Adaptation



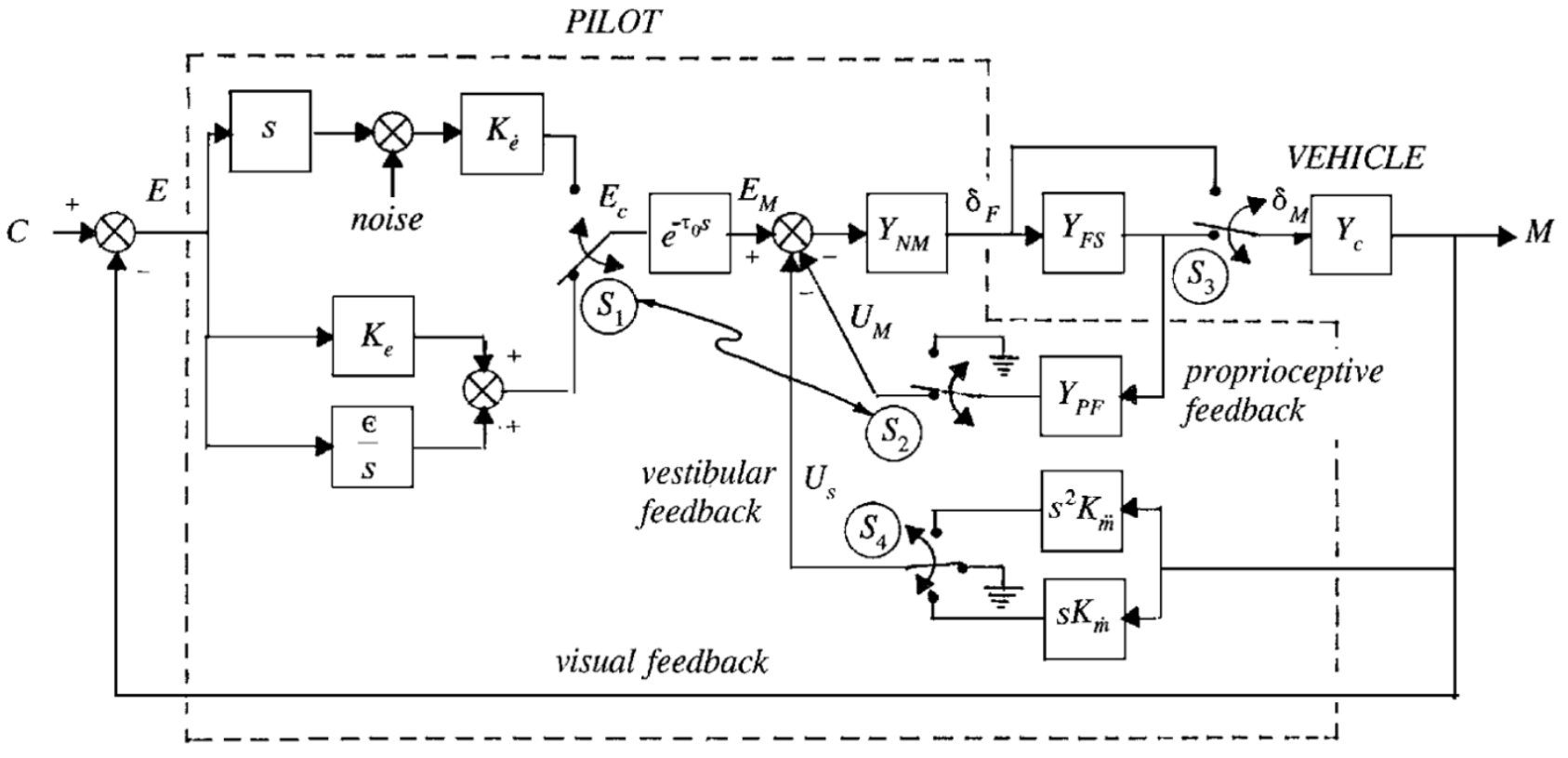
Effects of Adaptation



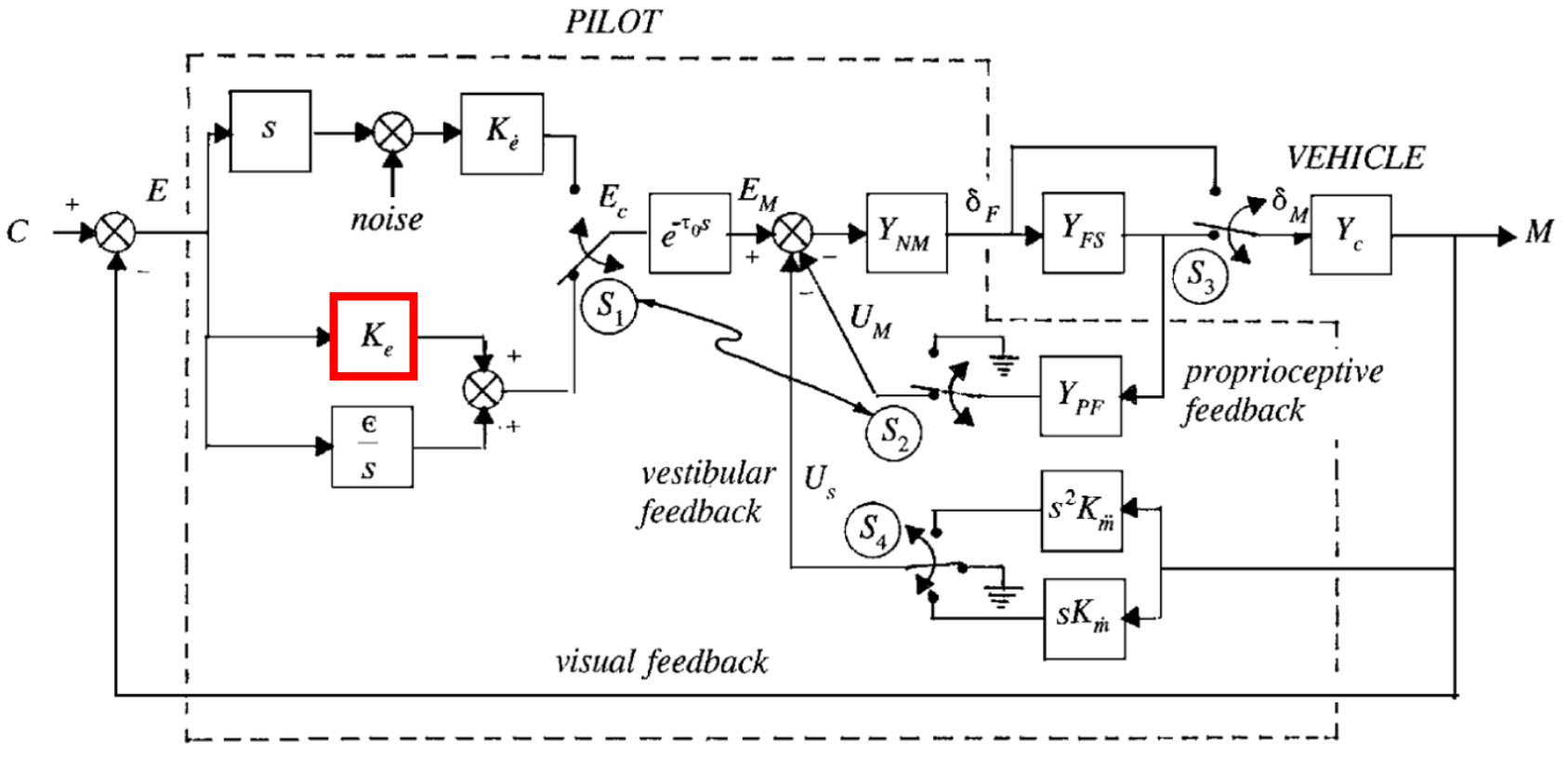
Effects of Adaptation



Hess Structural Model, 1997 [8]



Hess Structural Model, 1997 [8]



Proposed Modification

- Respond to concurrent bandwidth feedback
- Trigger adaptation when feedback is active
- First approach to place adaptation logic around K_e

Using the Modified Model

- Predict which tasks can be improved
- Identify the optimal bandwidth for peak performance
- Customize the feedback to the individual

Timeline

Timeline

		2018				2019				2020		
		W	S	SS	F	W	S	SS	F	W	S	SS
Aim 1	Design experiment, develop software, and submit IRB											
	Recruit subjects, collect data											
	Analyze data											
QE												
Aim 2	Design experiment, develop software, and submit IRB											
	Recruit subjects, collect data											
	Analyze data											
Aim 3	Develop model of human performance with CBF											
	Validation of model against previous studies											
	Use model to predict performance											
	Analyze data											
Dissertation												

Timeline

		2018				2019				2020		
		W	S	SS	F	W	S	SS	F	W	S	SS
Aim 1	Design experiment, develop software, and submit IRB											
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Dissertation												

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- Human/Robotics/Vehicle Integration and Performance Lab
- NASA Ames Human Systems Integration Division
- Qualifying Examination Committee
- Professor Robinson


Canada
SPACE

Backup Slides

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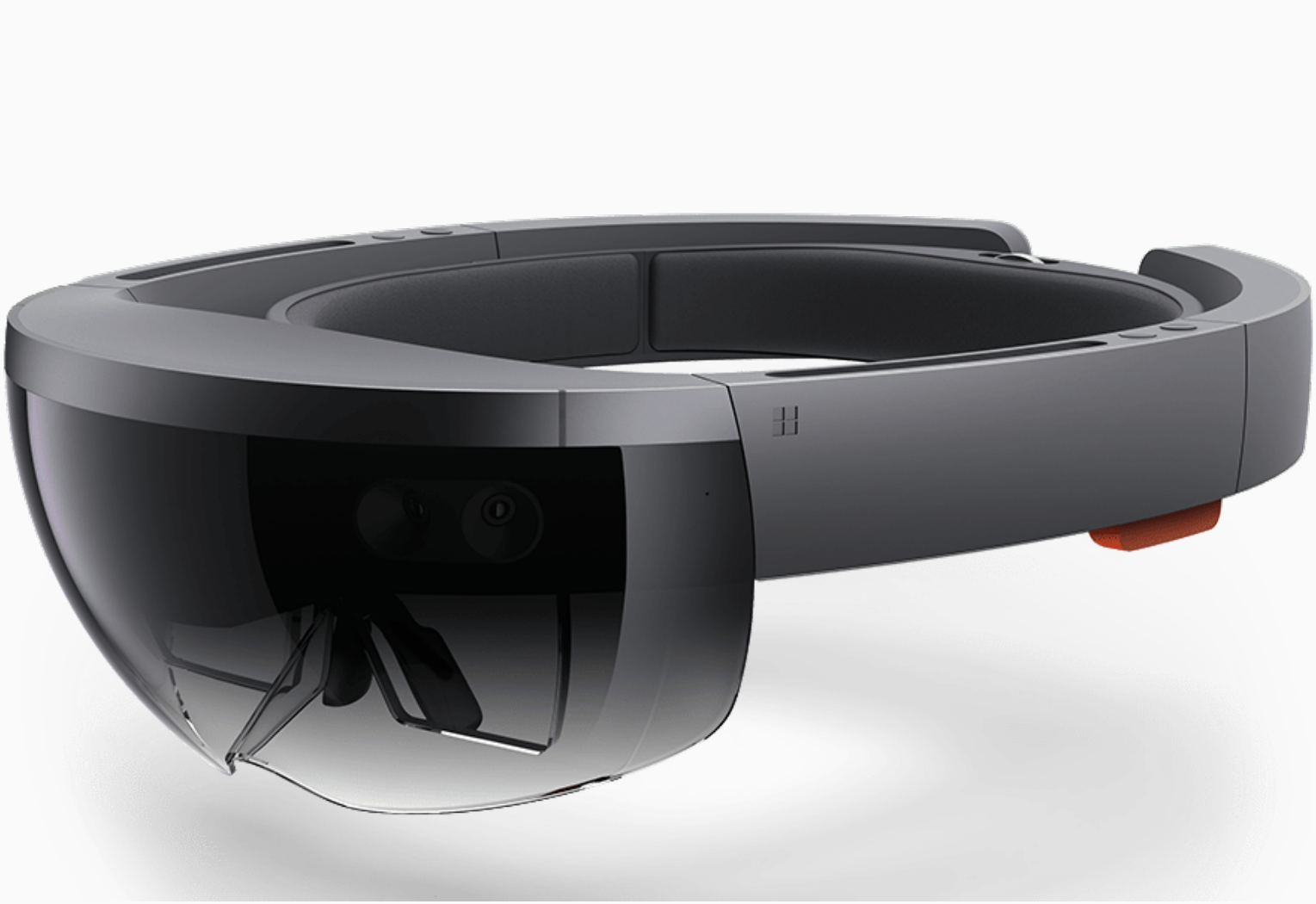
What is feedback?

“Feedback is information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way.”
- Ramaprasad [9]

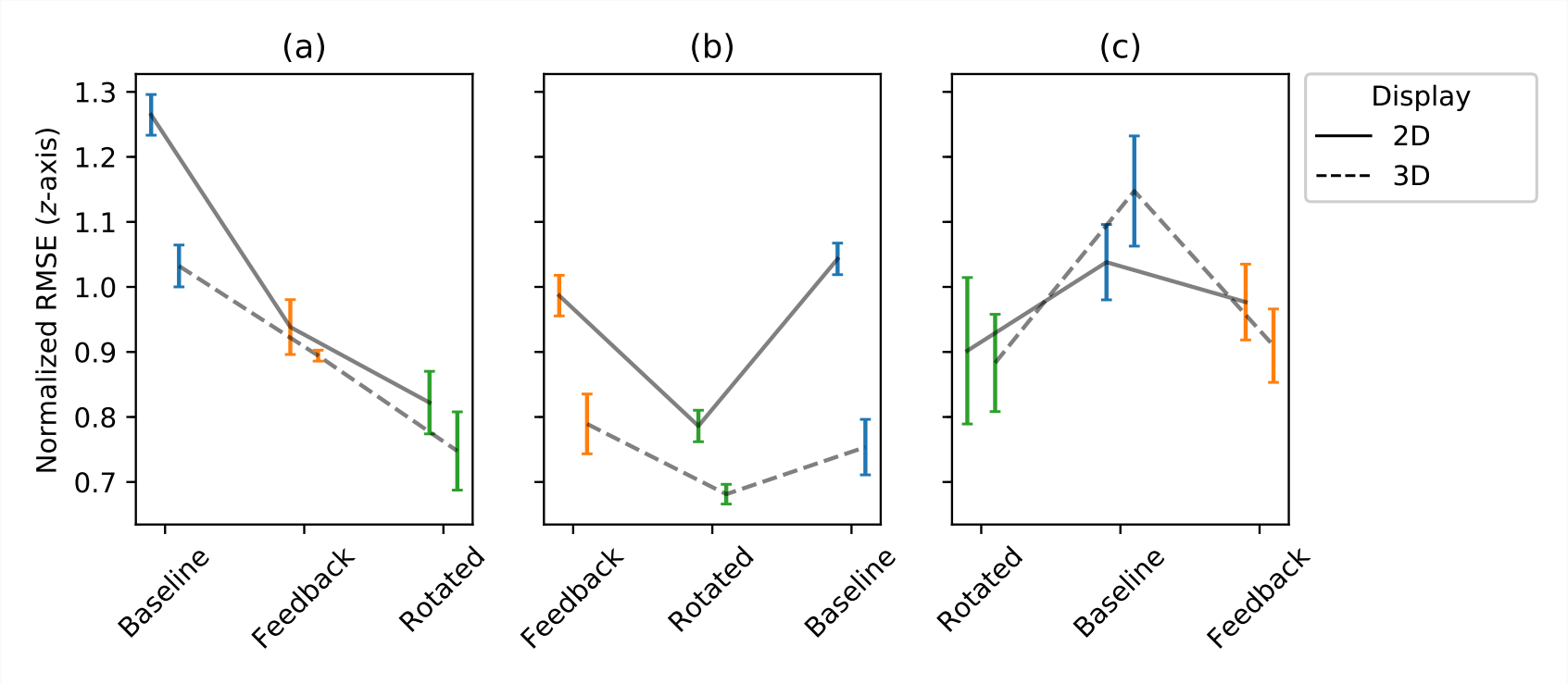
Controller

Microsoft HoloLens

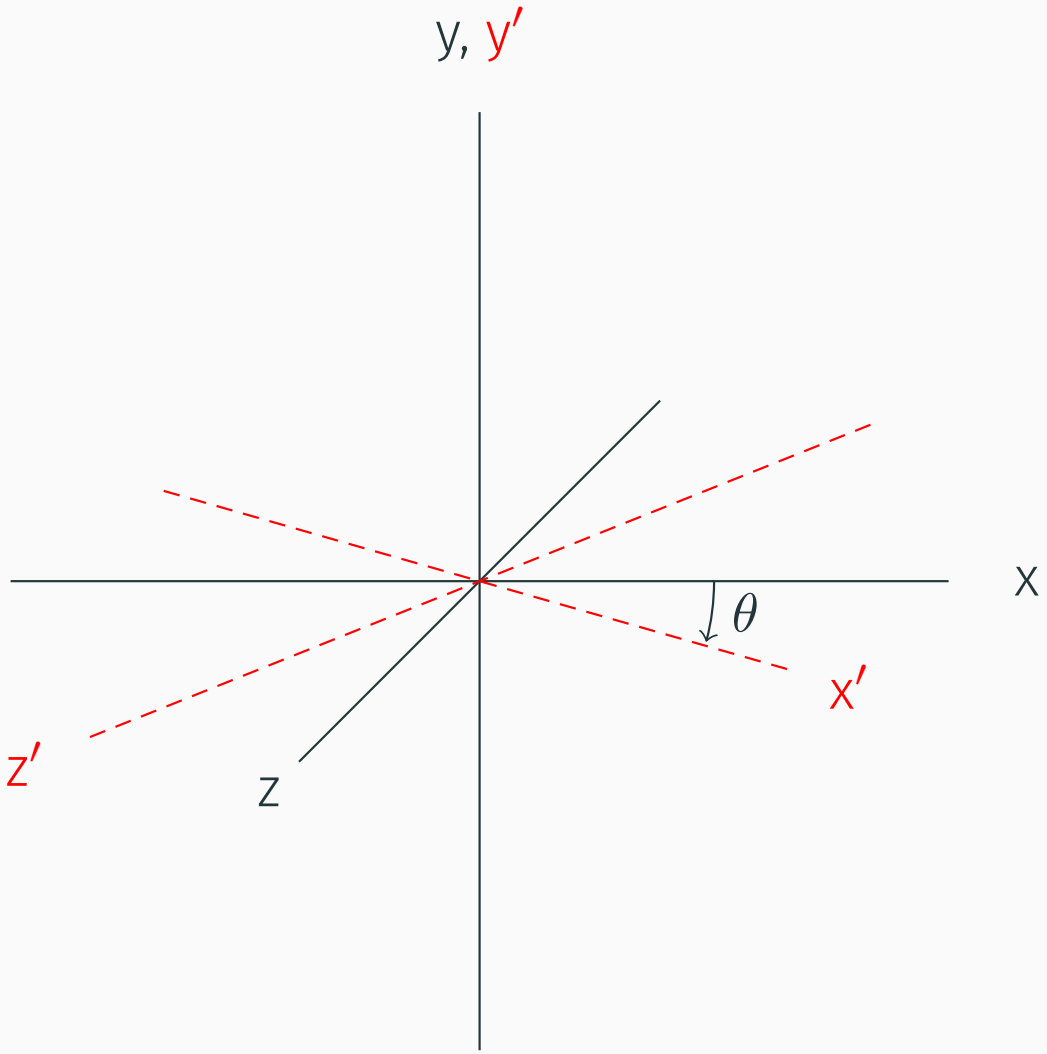


Augmented Reality Guidance

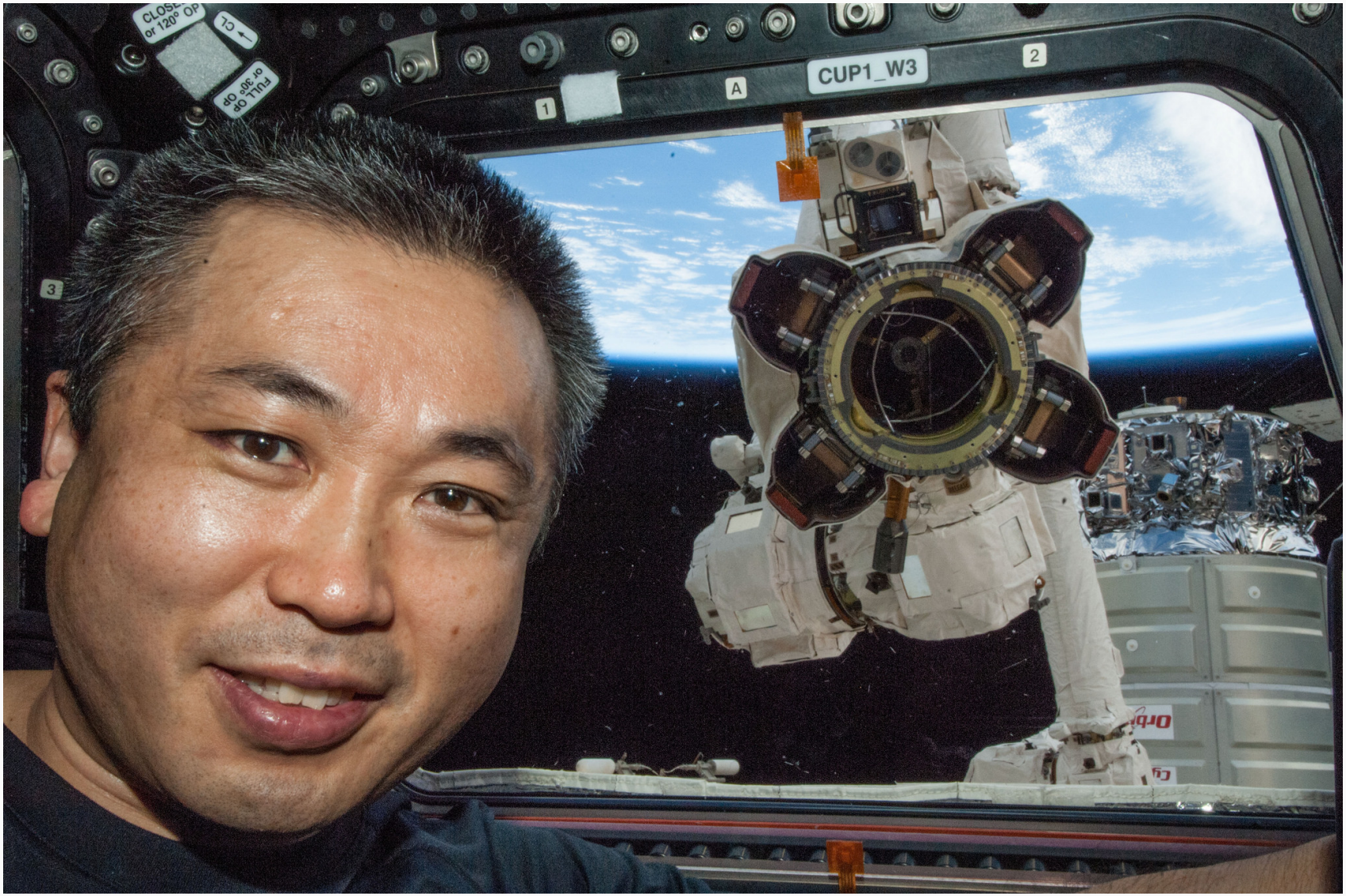
Performance Analysis by Starting Design



Three-axis tracking rotated design



Cupola Provides an Extra View



Experiment Two Hypotheses

Compared to existing terminal feedback techniques, concurrent bandwidth feedback will

- improve performance.
- cause subjects to more quickly reach their peak performance.
- decrease workload.

Experiment Two Estimates

- 10-15 subjects in each group
- 30 minutes of context and training
- 1-2 hours of trials
- 1-2 months from recruitment to end of subject testing

McRuer's Pilot/Vehicle System, 1974 [10]