Human Factors Evaluation of an Experimental Locomotive Crew Station

Matt Isaacs
Operations Research Analyst
Volpe Center

Transportation Research Board
Annual Meeting
January 2017

U.S. Department of Transportation
Federal Railroad Administration

OFFICE OF RESEARCH & DEVELOPMENT

Volpe The National Transportation Systems Center
Advancing transportation innovation for the public good

Rationale

- AAR-105 was principally developed before automation and computer displays.
- Adding displays has a limit and risks lowering out-the-window visibility.
- Advances in technology allow for more ergonomic designs.
- Engineers experience vibration and spend extensive time in a seated position.

Crewstation Requirements

- Capability for both seated and standing operation
- Ergonomic improvements
- Reconfigurable controls (to enable future iterations)
- Vibration dampening
- Ability to view and operate displays and controls from 180 degrees of chair rotation
- Enhanced comfort, including adjustability, headrest and footrest

Experimental Crew Station, standing position with arm up

Crewstation Requirements

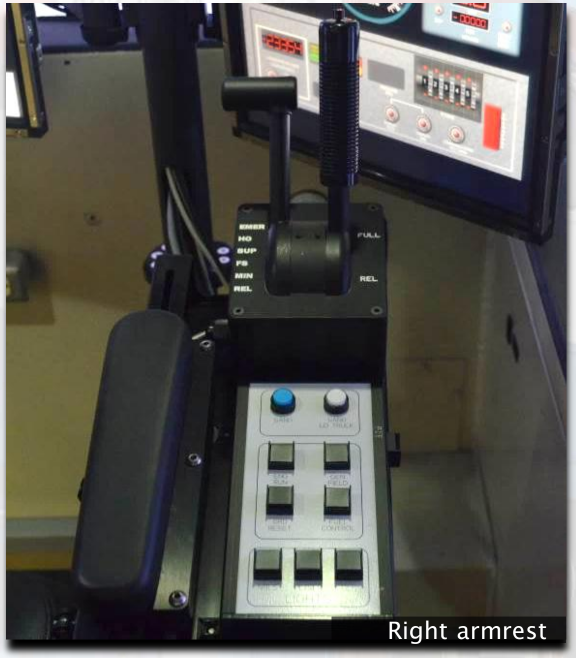
- Capability for both seated and standing operation
- Ergonomic improvements
- Reconfigurable controls (to enable future iterations)
- Vibration dampening
- Ability to view and operate displays and controls from 180 degrees of chair rotation
- Enhanced comfort, including adjustability, headrest and footrest

Experimental Crewstation in seated position

Crewstation Requirements

- Capability for both seated and standing operation
- Ergonomic improvements
- Reconfigurable controls (to enable future iterations)
- Vibration dampening
- Ability to view and operate displays and controls from 180 degrees of chair rotation
- Enhanced comfort, including adjustability, headrest and footrest

Left rmrest



Right armrest

Crewstation Requirements

- Capability for both seated and standing operation
- Ergonomic improvements
- Reconfigurable controls (to enable future iterations)
- Vibration dampening
- Ability to view and operate displays and controls from 180 degrees of chair rotation
- Enhanced comfort, including adjustability, headrest and footrest

Armrest adjusters

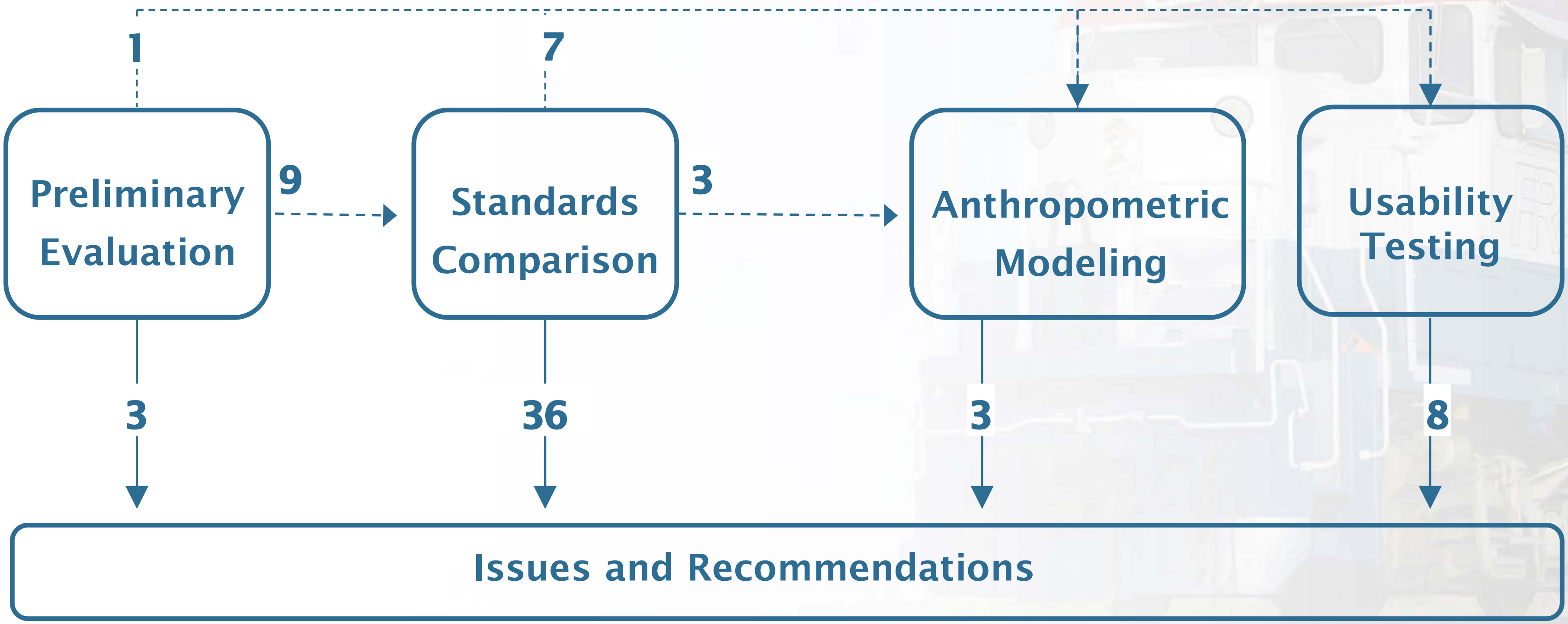
Roles

- FRA: Provide basic requirements for the crew station and fund construction and analysis.

- QinetiQ North America: Build crew station according to FRA specifications; integrate with CTIL.

- Volpe: Evaluate the crew station using the CTIL simulator and human factors evaluation processes, making recommendations for improvement and noting areas of cab design that need further research.

Evaluation Process



Evaluation Process

Preliminary Evaluation

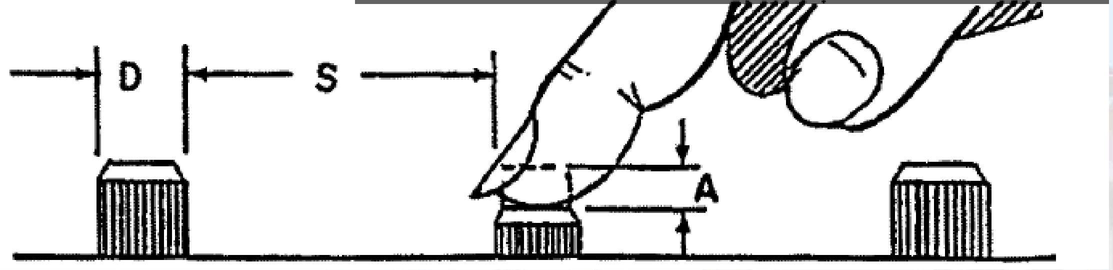
- Gain a high-level understanding of potential problems, and help focus later activities
- Evaluations made using general usability practices
- Full integration of ELCS into CTIL allowed evaluators to interact with the prototype

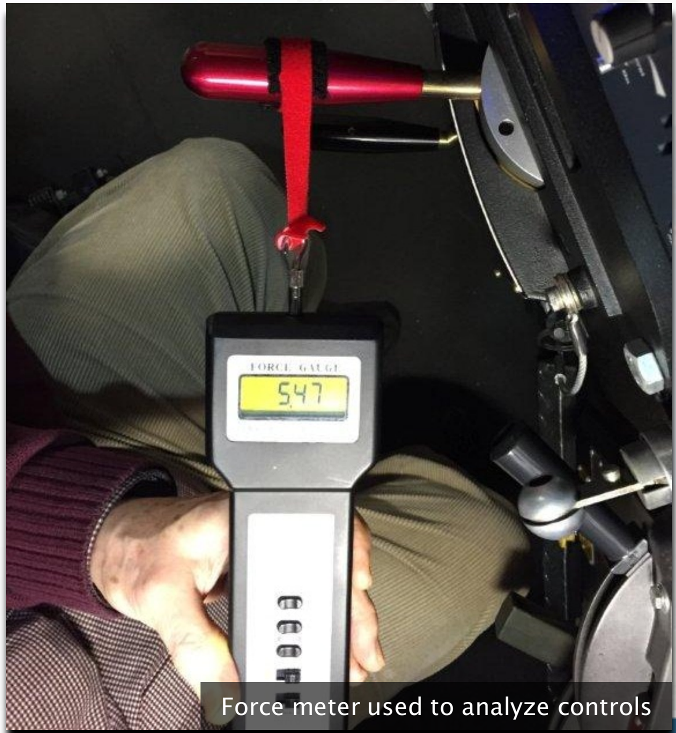
Evaluation Process

Standards Comparison

- Used military human factors standard MIL-STD-1472G (DoD, 2012) to address every feature of the design
- Evaluated both the experimental control station and the AAR-105
- Also measured egress space, control forces, clearances and heights

MIL-STD-1472G drawings showing critical aspects of buttons





Force meter used to analyze controls

Evaluation Process

Anthropometric Modeling

- Created CAD models of all designs
- Used CTIL's RAMSIS software to model:
  - Clearances
  - Reachability
  - Viewing angles
  - Comfort level of key positions
- RAMSIS provides representative users for virtual testing. Sizes used:
  - 95th percentile male
  - 50th percentile female
  - 50th percentile male


RAMSIS being used in an automotive contexts (human-solutions.com)

Evaluation Process

Usability Testing

- Put engineers through 7 scenarios in CTIL simulator based on concerns raised in earlier phases
- 4 freight engineers, 4 passenger engineers
- CTIL enabled collection and analysis of quantitative data and recording of user actions and comments
- Usability measured using System Usability Scale (Bangor, Kortum & Miller, 2008)

Recreation of a two-handed behavior exhibited by engineers during usability testing

Evaluation Process

Usability Testing

Used binomial probability to sort patterns of behaviors in to three groups using $\alpha < .05$:

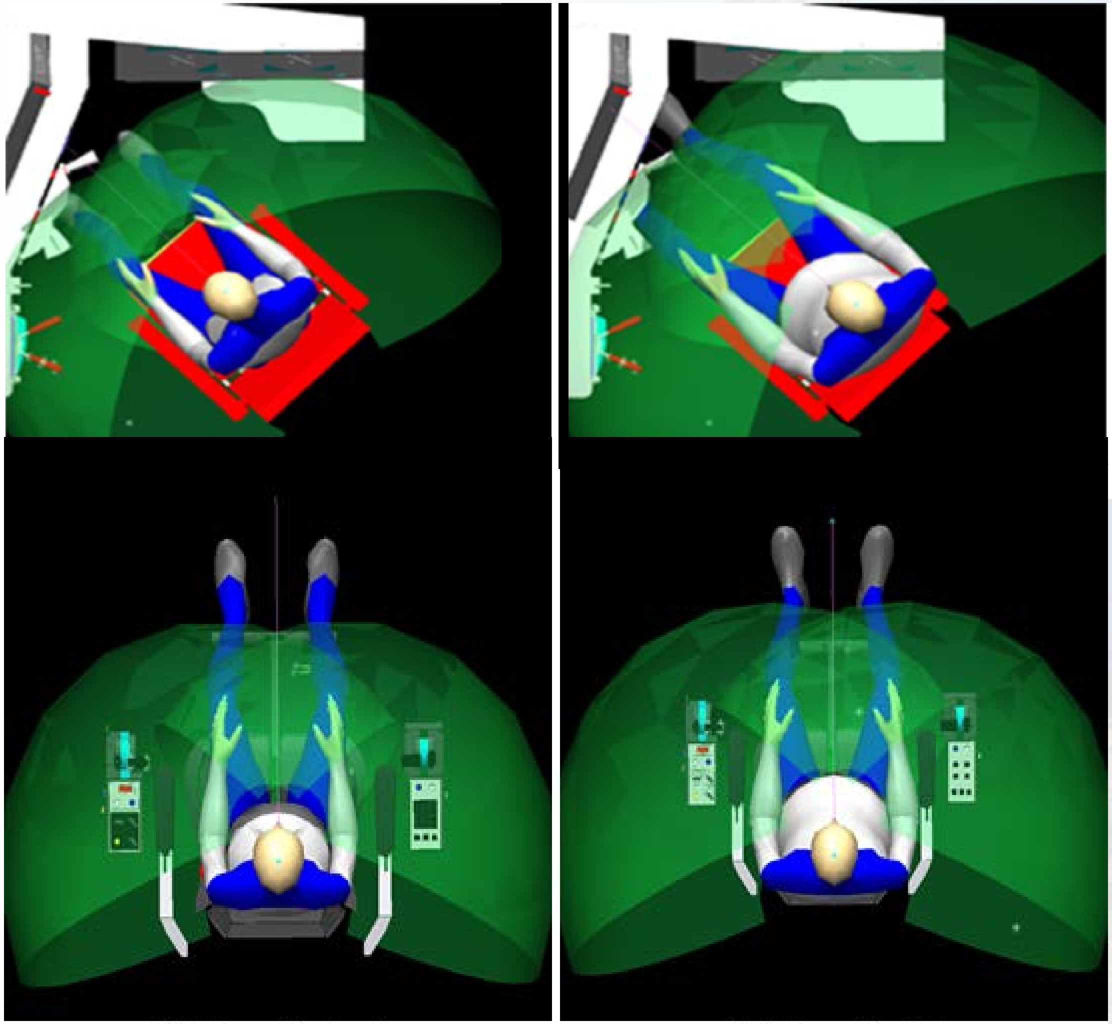
- Small Minority (5%): three of eight participants (p=0.006).
- Substantial Minority (20%): five of eight participants(p=0.010).
- Majority (50%): seven of eight participants (p=0.035).

One-tailed probability matrix for a sample size of eight

Population Behavior Rate	Probability of Subject Failures								
	0 subjects	1 subject	2 subjects	3 subjects	4 subjects	5 subjects	6 subjects	7 subjects	8 subjects
5%	1.000	.337	.057	**.006**	.000	.000	.000	.000	.000
20%	1.000	.832	.497	.203	.056	**.010**	.001	.000	.000
50%	1.000	.996	.965	.855	.637	.363	.145	**.035**	.004

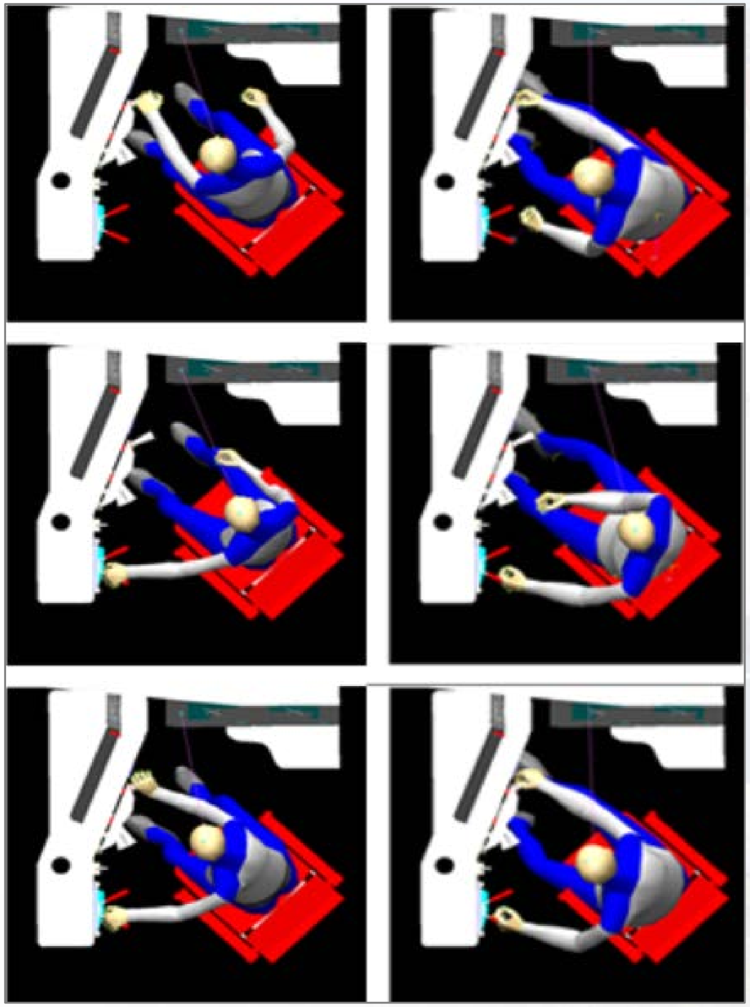
Reachability

- Even with an adjustable chair, most controls are at the edge of reach extents if engineer wants to use back support.
- Experimental crew station places controls well within reach extents for all users



AAR-105: Body Positions

- Controls oriented to user, but not plane of motion
- Two areas of focus for engineer means twisting and reaching.
- Controls require exerting high force far from the body
- Moving seat closer to the throttle means moving away from the automatic brake



Throttle

Automatic Brake

Both

50th Female

95th Male

Comfort Comparison

- "Most comfortable" body positions for each task were measured using RAMSIS Body Discomfort score
- Score based on 1-8; 8 is most *un*comfortable
- Derived from an ergonomics study in which drivers rated discomfort in different areas of the body for different positions (Meulen, 2006)
- Differences greater than 1 considered significant

Discomfort Type	50th Percentile Female		95th Percentile Male	
	AAR-105	Experimental crewstation	AAR-105	Experimental crewstation
Neck	**5.1**	**2.3***	**4.6**	**2.2***
Shoulders	**3.5**	**2***	**4**	**2.3***
Back	**2.8**	**1.7***	2.4	1.8
Buttocks	**2.3**	**1.3***	2.3	1.4
Left Leg	**3.5**	**2.1***	2.7	2
Right Leg	**3.5**	**1.9***	2.4	1.7
Throttle Arm	**5.2**	**1.7***	**3.9**	**2***
Other Arm	2.8	1.9	1.8	2
Overall Discomfort	**6.1**	**3.3***	**5.1**	**3.5***

* Difference greater than 1

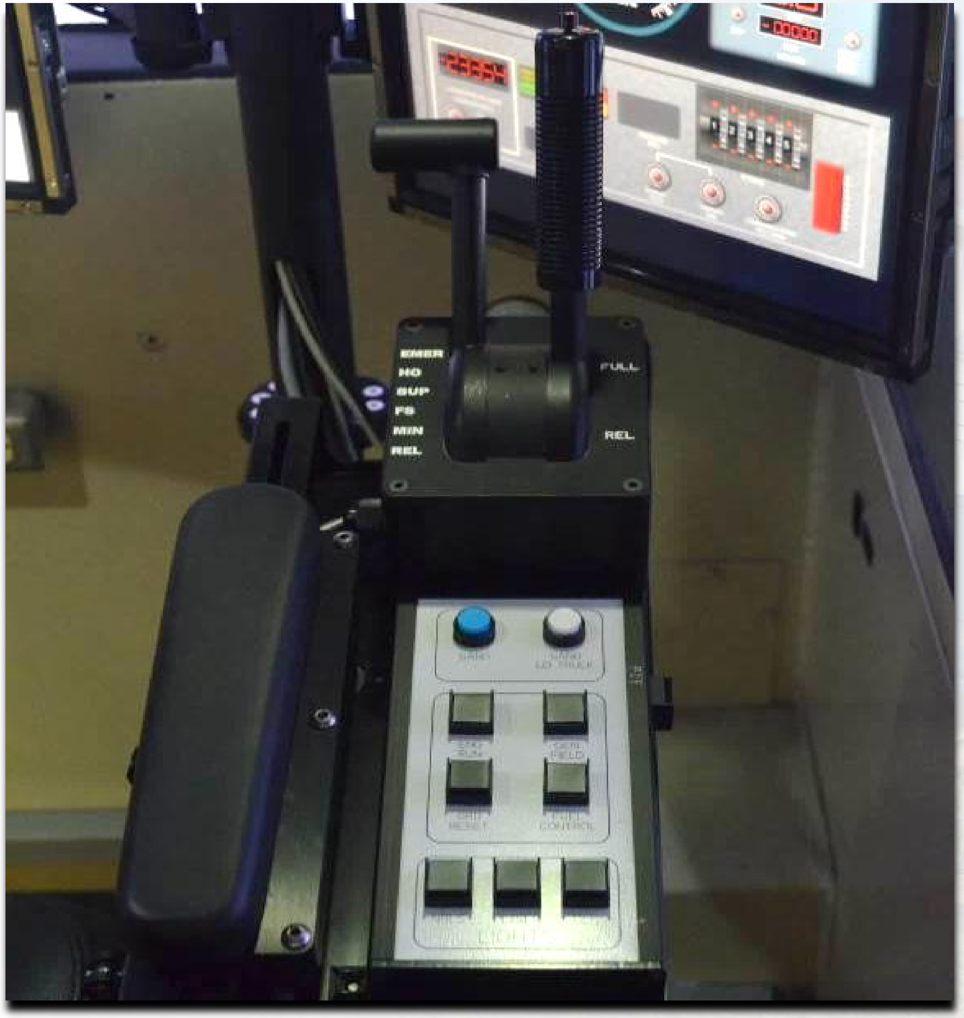
Example Issue 1:Automatic Brake

Preliminary Evaluation

- The detents on the automatic brake are regularly spaced, unlike current brake designs.
- The "service range" appears small:
  - NYAB: 3.28 inches from minimum to release.
  - ECS: 1.76 inches from minimum to release

Standards Comparison

- Found three standards recommending against combining regular controls and emergency ones.
- Found one standard cautioning against enabling accidental actuation.



Example Issue 1:Automatic Brake

Usability Test

- Eight engineers were asked to make four automatic braking applications using a non-moving simulated train.

Findings based on usability test performance data for over-braking

Task	Failures	Expected Frequency Based on Probability Matrix
Minimum service application	0 out of 8	Not significant (less than 5%)
Full service application	0 out of 8	Not significant (less than 5%)
15 pound application	4 out of 8	Small minority (greater than 5%)
20 pound application	5 out of 8	Large minority (greater than 20%)

- Comments from engineers echoed this performance:

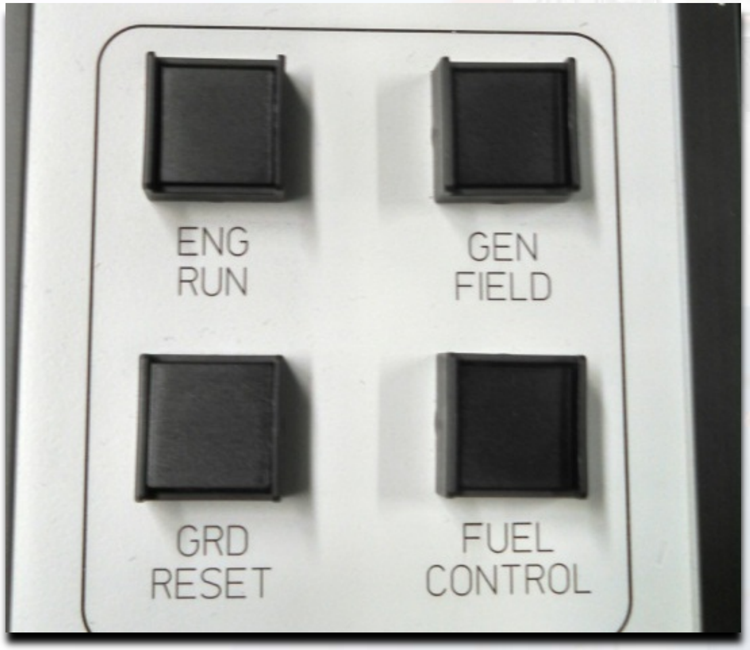
"I think I had to look down a couple of times. Between the minimum and the full service it just seemed a little short."

"For only going five pounds it seemed you go a very long way. And [now] that's full service…20 pounds in less distance than what you go to minimum."

Example Issue 2: Push-buttons

Preliminary Evaluation

Which of these functions are active and inactive? Which buttons stay active when released?



Example Issue 2: Push-buttons

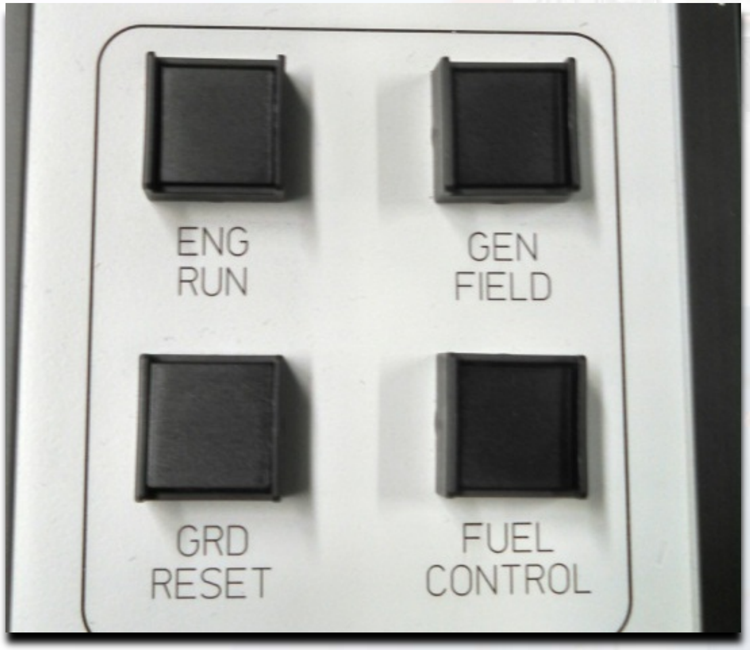
Preliminary Evaluation

Which of these functions are active and inactive? Which buttons stay active when released?

Example Issue 2: Push-buttons

Usability Test

When presented with a "stopped engine" scenario, 7 of 8 engineers were unable to find the problem of a Fuel Control button being placed in the "off" position, despite looking directly at the button panel in all cases (expected majority).



Example Issue 3: Upward Visibility

- Standards Comparison: “Upward visibility shall extend to not less than 15 degrees above the horizontal.”

- Anthropometric Analysis

Degrees of upward visibility using experimental crewstation

Test Case	CTIL Seated	CTIL Standing
95th Percentile Male	none	none
50th Percentile Male	1.13°	none
50th Percentile Female	4.38°	5.25°

Follow-on Work

- How do different AAR-105 control configurations affect key postures?
- Identify near-term and/or low-cost ergonomics upgrades to current designs.
- Conduct a time motion study to understand control use frequencies in various types of operations.
- Evaluate desktop-style configurations

Awkward wrist position in CTIL's AAR-105 control stand