

Symbology Development for Head-down Displays (SD-HDD)

Experiment B, for Merrill Pass, Alaska



Picture Courtesy of John Seaman, Alaska



Outline of Presentation

Aviation Safety Program: Synthetic Vision Systems – General Aviation

- Goals and Objectives
- Experiment Plan
- Independent Variables
- Area of Operations
- Testing Protocol
- Preliminary Results
- Summary

SD-HDD Objectives



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- Establish interactions between Guidance Symbolology and Terrain Portrayal concepts on a Primary Flight Display for:
 - *VMC-like terminal area operations in IMC in a terrain-challenged environment (Approach and Missed Approach)*
 - *Complex mountain pass maneuvers (En Route)*
 - *Over a range of specific minification factors*
- Develop recommendations for SVS-GA PFD symbolology and terrain texture
- Demonstrate application of SVS technology to advanced operational procedures
- Evaluate altitude and range estimations for different terrain texturing methods

● Part A

● Part B

● Part C

Experiment Plan



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- *Experiment A:* JNU terminal area simulations:
 - Instrument Approach like a VFR Pattern
 - Missed-Approach
 - Rare event on Missed-Approach
- *Experiment B:* Merrill Pass simulations:
 - Search & Rescue Mission at Fixed Altitude Above Ground
 - Rare event
- Two days of testing for each Evaluation Pilot



Experiment B: Independent Variables

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I) Merrill Pass Terrain Portrayal Concepts (TPC) with DEM=2 arc-sec:

1. *Baseline TPC: No terrain, Blue Sky Brown Ground*
2. *Minimal TPC: Constant Color Texture w/ Fish Net & Cultural Features & Obstacles*
3. *Medium TPC: Elevation Based Generic Texture & Cultural Features & Obstacles*
4. *Complex TPC: Photo Realistic Texture & Obstacles*

II) Merrill Pass Guidance Symbology Concepts (GSC):

- Guidance, No Tunnel
 - 1- *Pitch/Roll Flight Director*
 - 2- *Ghost plane*
- No Guidance, With Tunnel:
 - 3- *Unconnected-Boxes Tunnel*
 - 4- *Crows Feet Tunnel*
- Guidance, With Tunnel:
 - 5- *Crows Feet Tunnel & Ghost Plane*
 - 6- *Connected Tunnel & Guidance Box*
- No Guidance, No Tunnel:
 - 7- *TPC (BSBG/VMC-Baseline, all others IMC)*

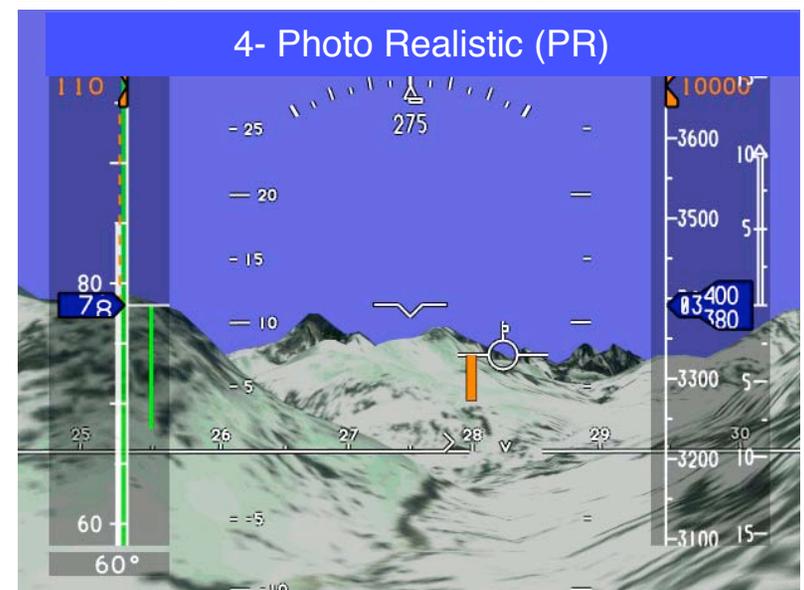
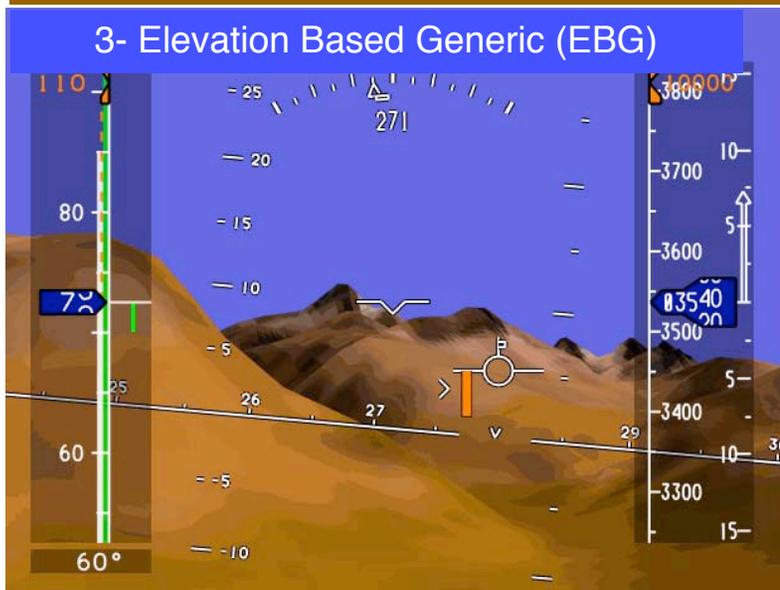
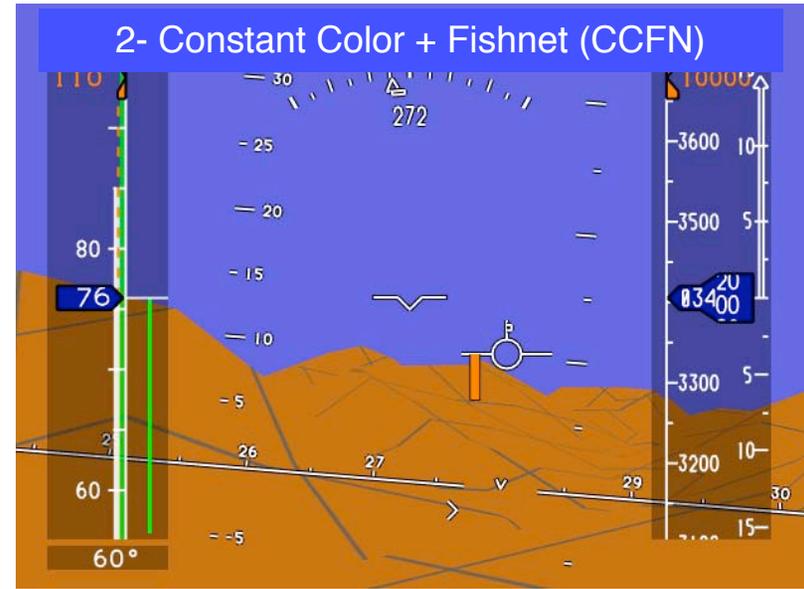
III) Evaluation pilots (18 Total, 15 to date) aeronautical experience:

1. GA VFR pilots (<400 hours, 4 to date)
2. GA IFR pilots (<1000 hours, 6 to date)
3. High-time Specialists (5 to date)

Merrill Pass Terrain Portrayal Concepts – DEM 2



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Guidance Symbology Concepts

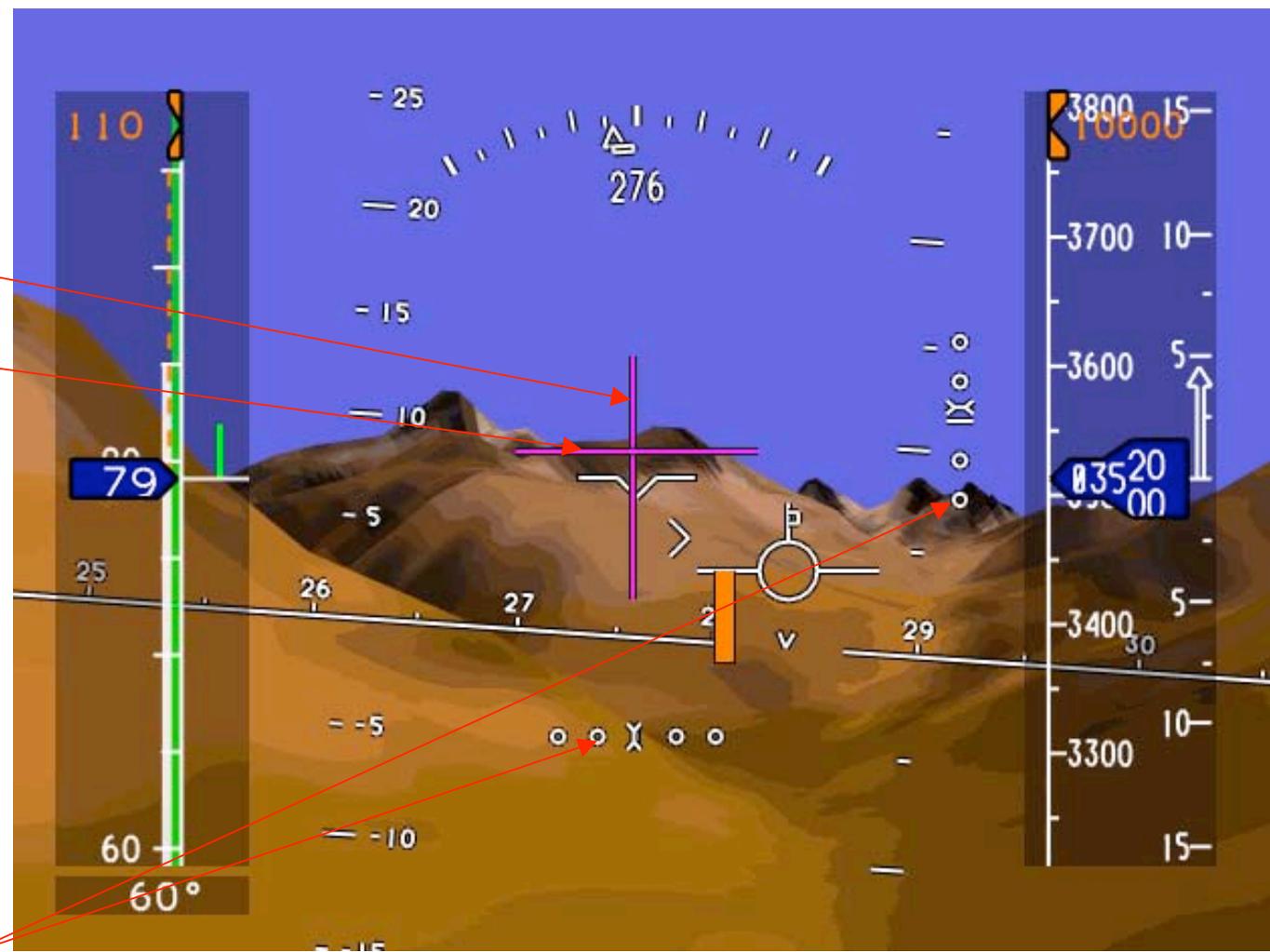
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1- Pitch/Roll Flight Director, No Tunnel

Flight Director:
Roll Command

Flight Director:
pitch Command

CDIs=75ft per dot



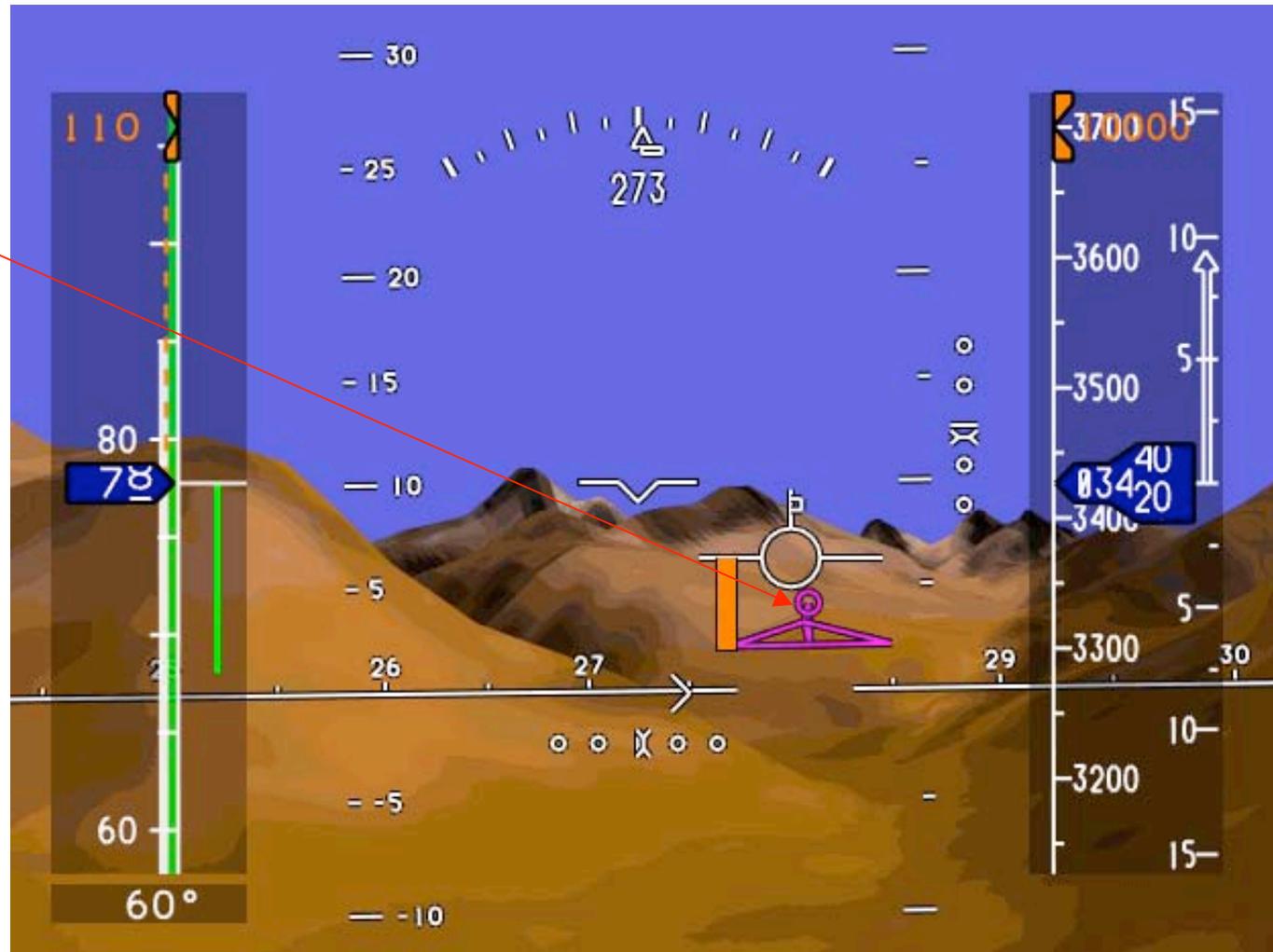


Guidance Symbology Concepts

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2- Ghost Plane, No Tunnel

Ghost plane will be 5 seconds ahead

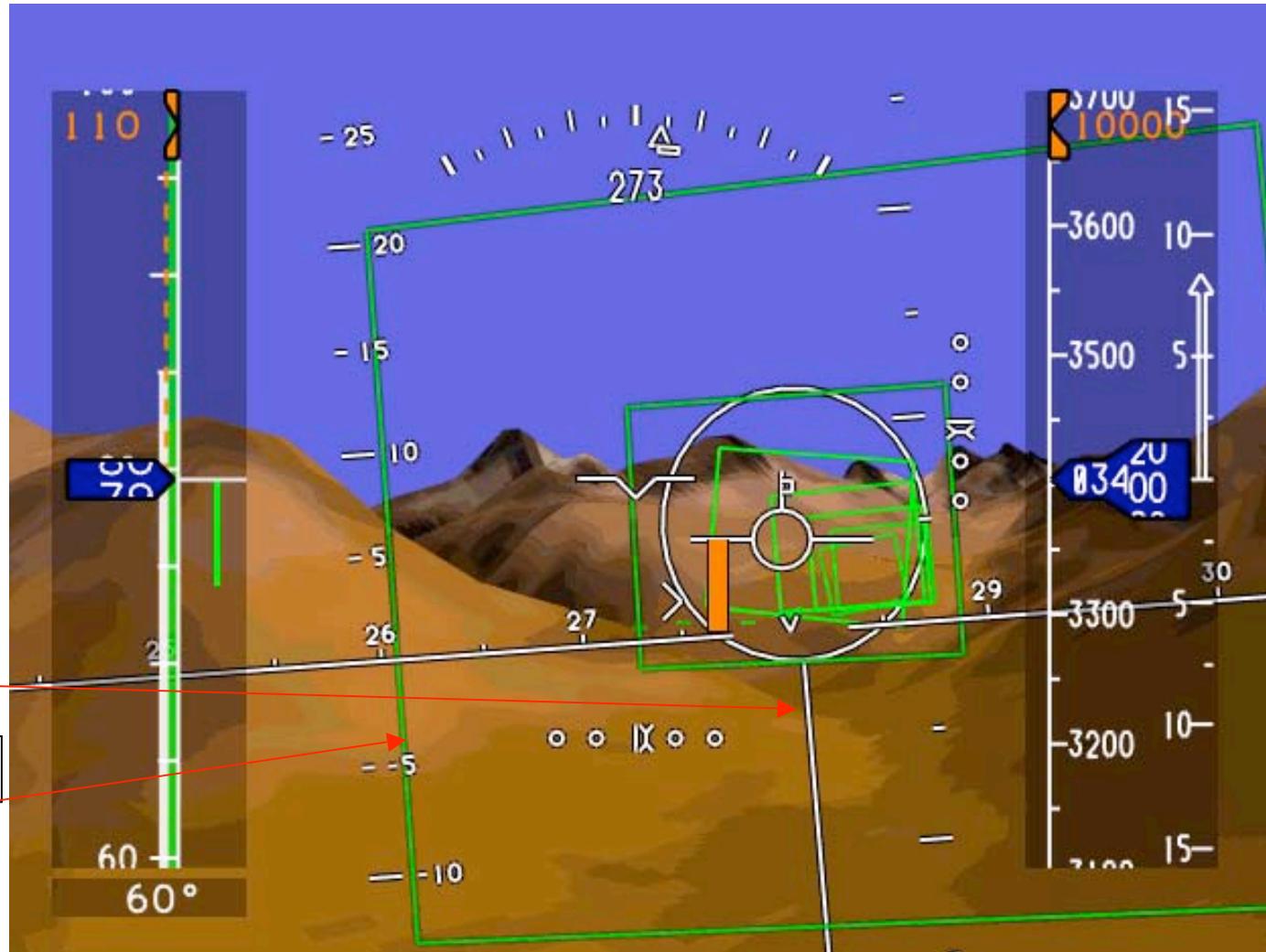




Guidance Symbology Concepts

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3- No Guidance, Unconnected-Boxes Tunnel



Tethered balloons

400' x 320' High



Guidance Symbology Concepts

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4- No Guidance, Crows Feet Tunnel



600' x 350' High



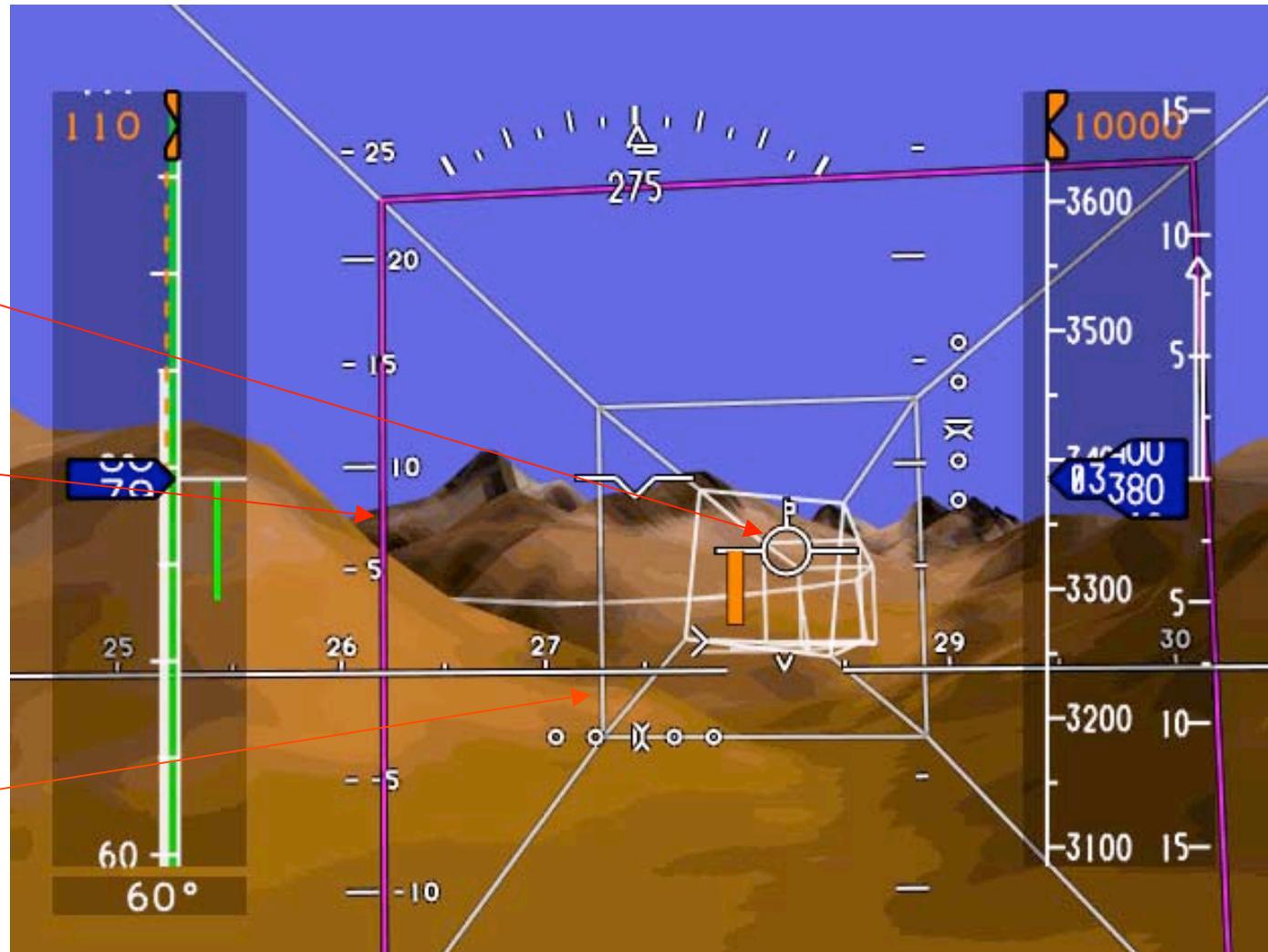
Guidance Symbology Concepts

5- Connected Tunnel with a Guidance Box

Predictor is similar to VV but 5 seconds ahead in Lateral direction

Guidance box (magenta) is 5 seconds ahead

300'x300' High





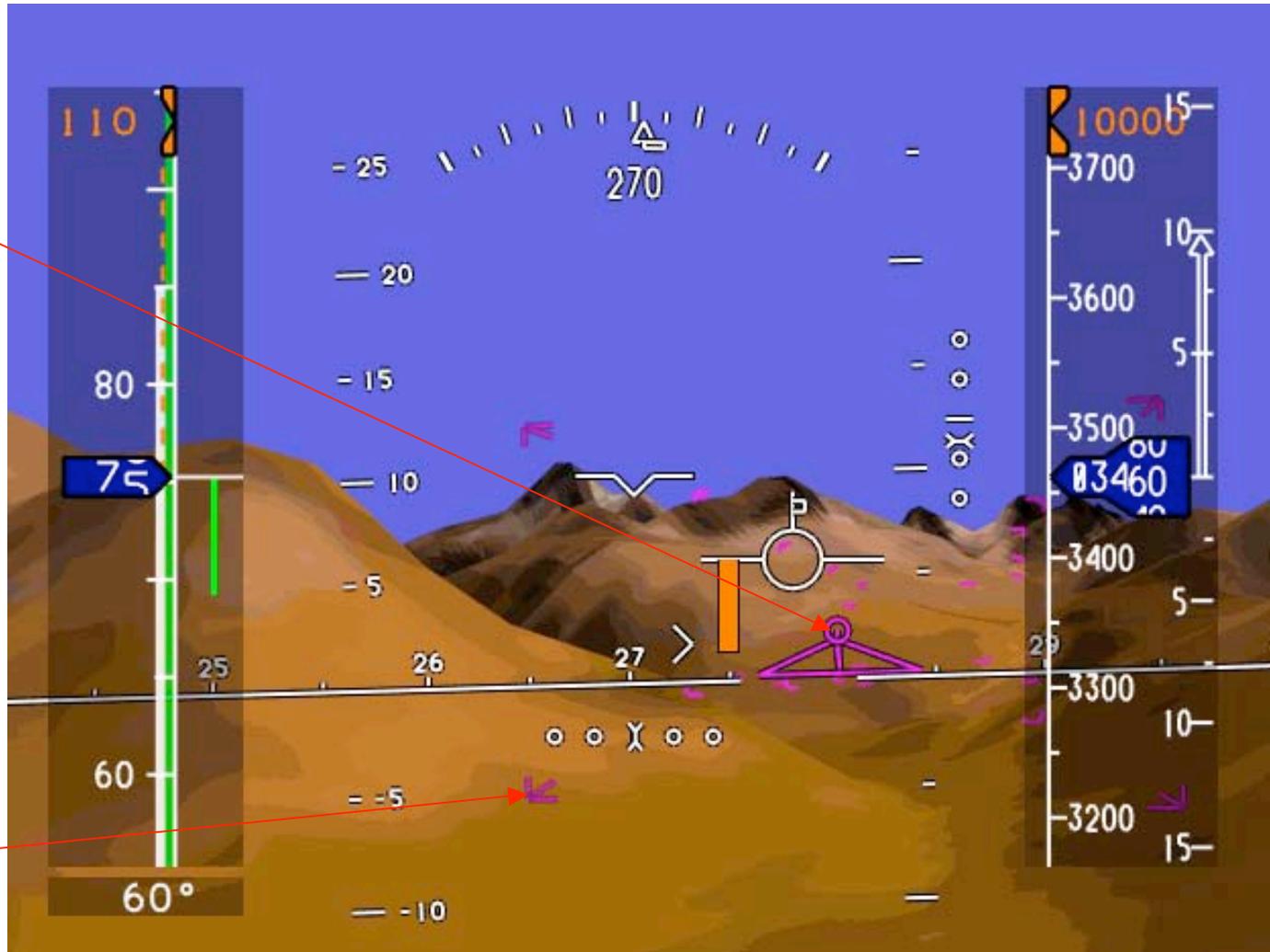
Guidance Symbology Concepts

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6- Crows Feet Tunnel with Ghost Plane

Ghost plane moves 5 seconds ahead

600' x 350' High

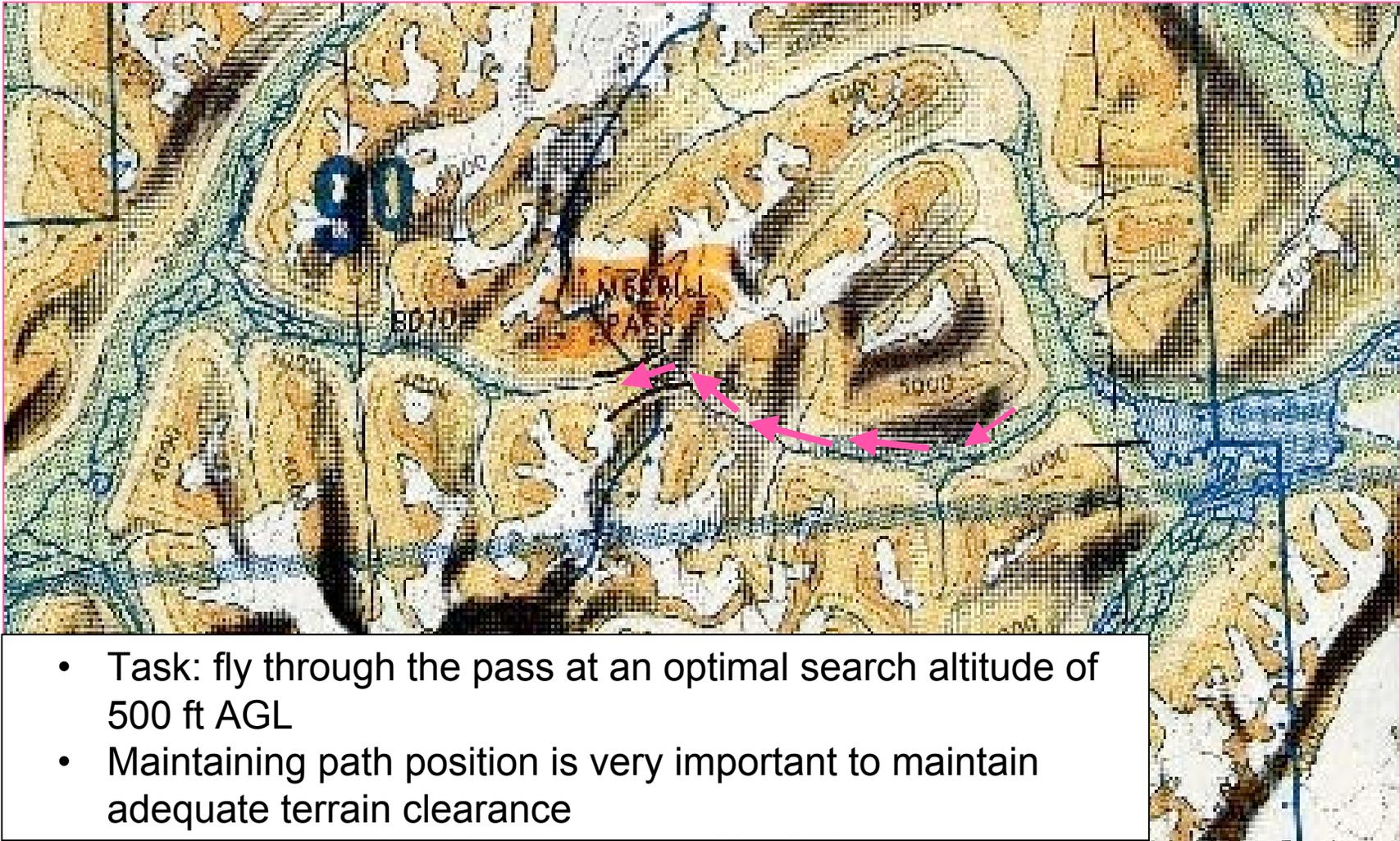


Flight Scenario in Merrill Pass Area



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Experiment Flight Path (5 minutes)



- Task: fly through the pass at an optimal search altitude of 500 ft AGL
- Maintaining path position is very important to maintain adequate terrain clearance

Testing Protocol



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- Training:
 - Part B: 1.1 hrs allotted
 - FAA/Jeppesen-style training syllabus (Test for PTS level skills)
 - Instruct EPs to use all available display information to minimize pilot flight technical errors.
 - Instruct EPs to avoid any hazardous terrain or flight situations when they occur and to communicate their intentions and take corrective action if necessary.
- Testing:
 - Day 1: Pilot Briefing, Overall Training, Data Collection
 - Day 2: Data Collection continued (w/Physio Data), Exit Interview

Testing Protocol, Cont.



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- Replicated runs (58)
 - 7 GSCs and 4 TPCs (28)
 - Predictor time mis/match for Connected Tunnel & Guidance Box run with EBG only
 - No guidance concepts preceded immediately by guidance run with same TPC (to obtain terrain perspective)
 - 2 replicates each
- Two extra runs
 - VMC BSBG (“With a selected Guidance Concept”)
 - Rare event with last-used TPC (“No Guidance, No Tunnel”) run at end
- Total of 60 runs per pilot



Rare Event Scenario in Merrill Pass

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Rare Event Scenario (RES) Protocol:

- 1) Unknown to the pilot, a gradual structural icing is introduced from the beginning of the scenario, intensifying with time.
- 2) RES is conducted with No-Guidance/No-Tunnel displays
- 3) Prior to RES the TPC in use will be flown with a guidance/tunnel concept

Rare Event Measures:

- 1) Time to recognition of the anomaly
- 2) Time to corrective action
- 3) Outcome of the action
 - a) Successful U-turn
 - b) Emergency off-field landing
 - c) CFIT
 - d) LVLOC

Dependent Measures



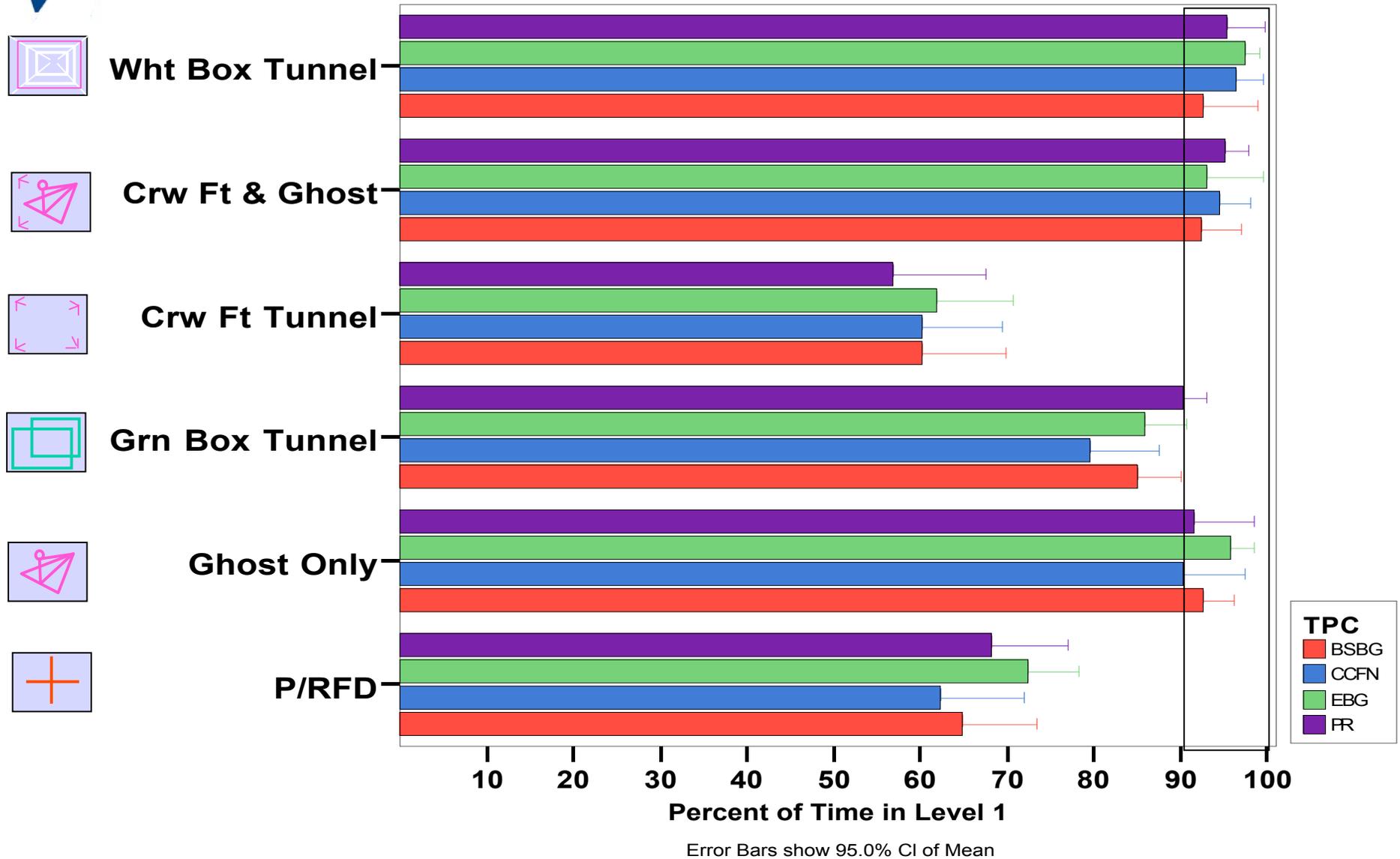
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- **Pilot/vehicle performance measures:**
 - Pilot control inputs, aircraft path errors & performance data
 - Here: Level 1 = 75'x75' = 1 dot on CDIs
 - Rare event measures
- **Pilot physiological measures:**
 - Skin Temp
 - Pulse Rate
- **Qualitative pilot questionnaires:**
 - NASA TLX (workload), SART (situational awareness) and Cooper-Harper (aircraft handling qualities) after each run
 - Modified SA-SWORD and Preference Questionnaires after each block and at the end of test
 - Ranking of the display combinations at the end of test
 - Audio/video of all communications

Percent Time in Level 1 for GSC x TPC



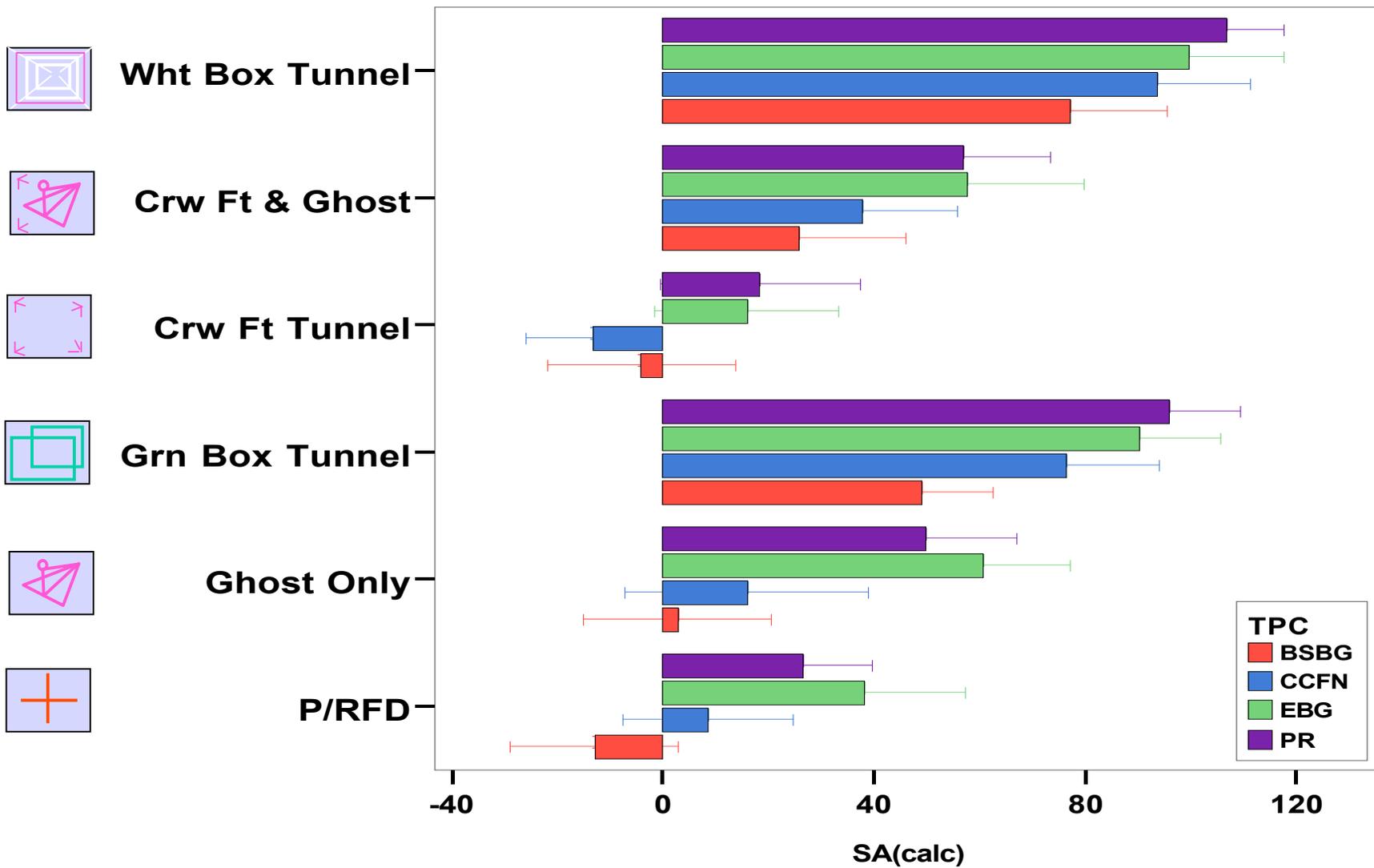
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Mean SART Scores for GSC x TPC



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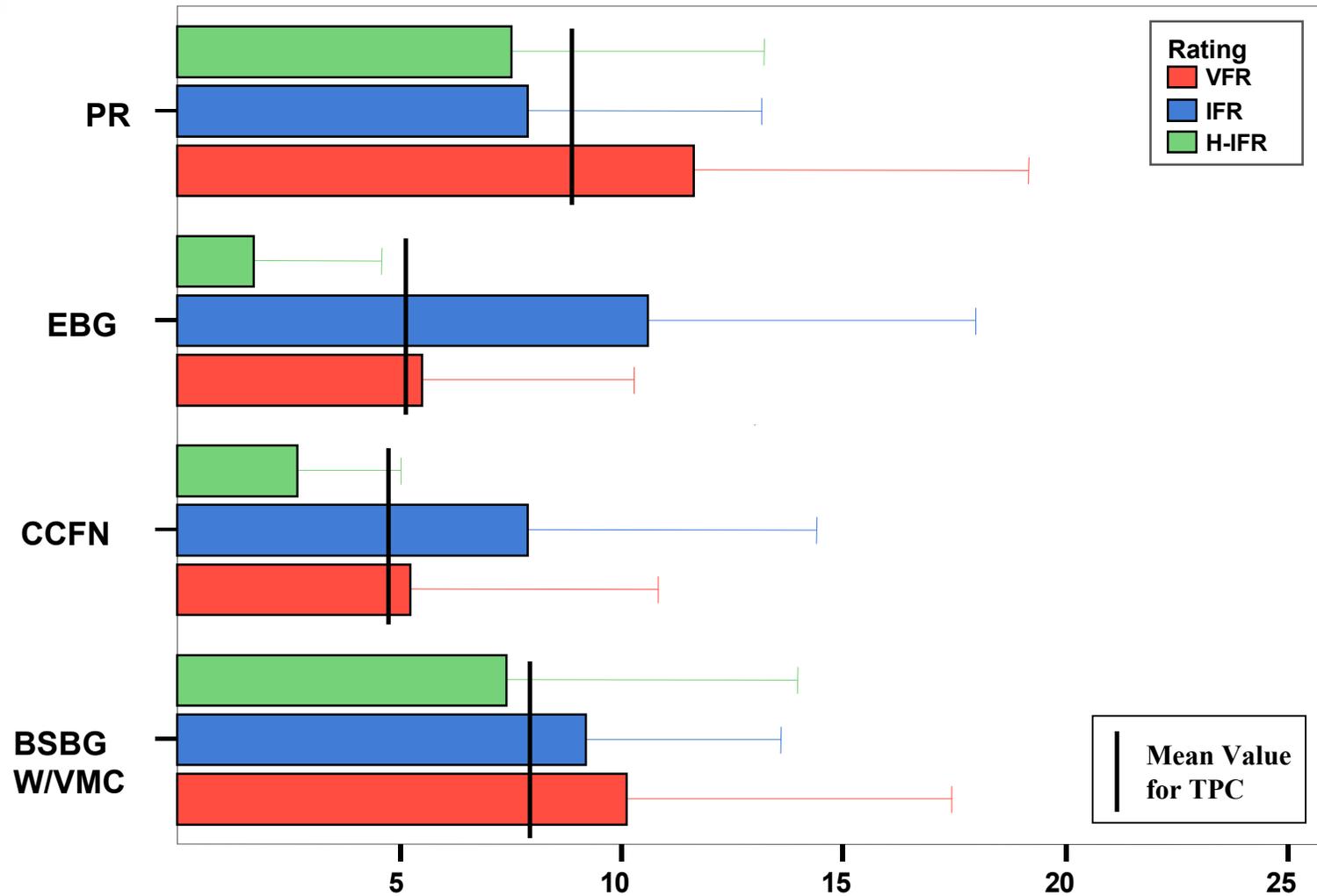


Error Bars show 95.0% CI of Mean

Percent Time in Level 1 for TPC x Pilot Category (No GSC Runs)



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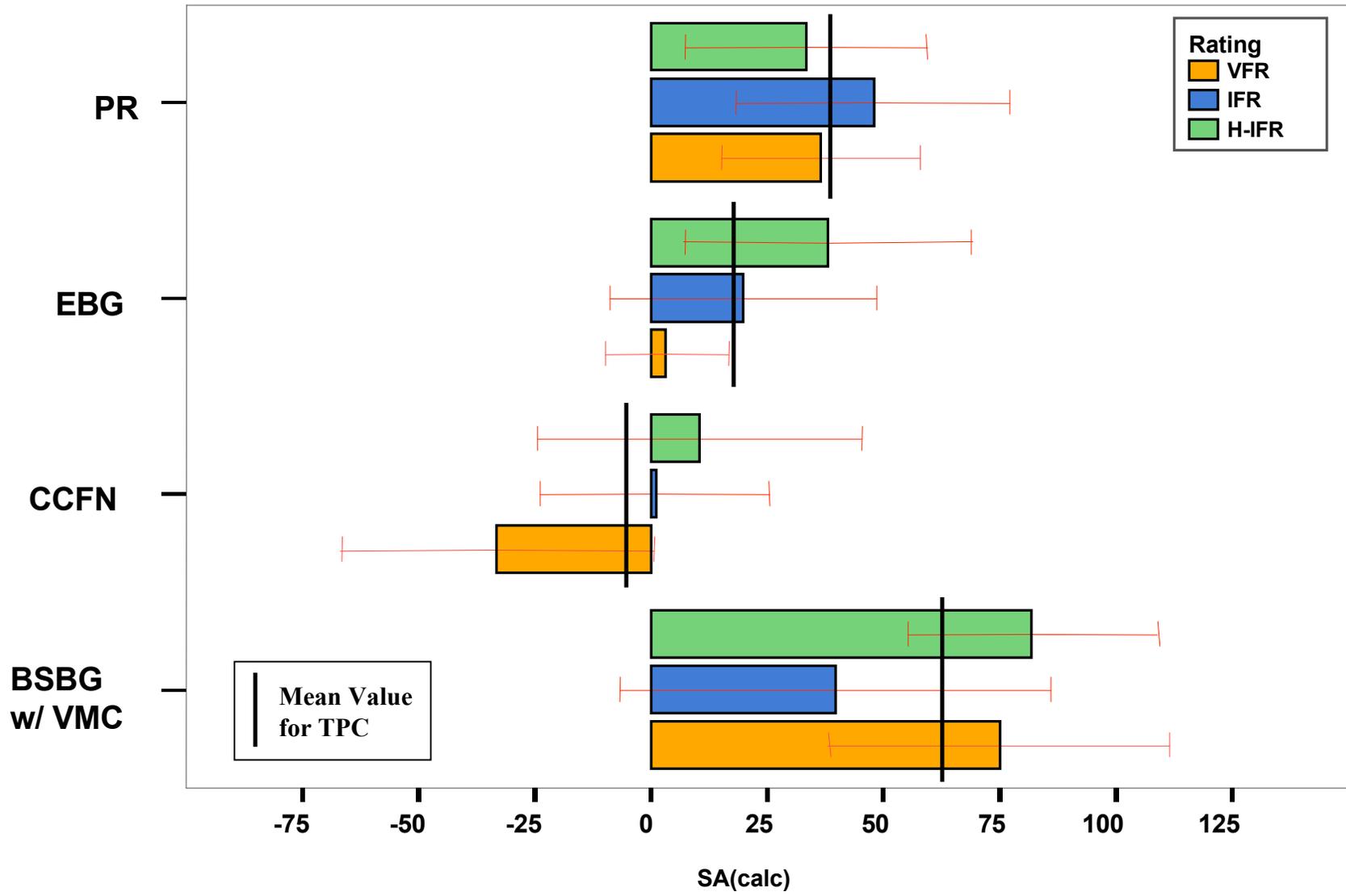
Percent of Time in Level 1

Error Bars show 95.0% CI of Mean

Mean SART Scores for TPC x Pilot Category (No GSC Runs)



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Error Bars show 95.0% CI of Mean



Subjective Rankings From Exit Interview

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Rank	Display Concept	Mean	Std Dev
1	EBG w/ Connected Box Tunnel	2.33	1.99
2	PR w/ Connected Box Tunnel	2.93	2.71
3	EBG w/ Unconnected Box Tunnel	4.53	3.44
4	PR w/ Unconnected Box Tunnel	5.20	3.59
5	CCFN w/ Connected Box Tunnel	6.47	3.02
6	EBG w/ Crows Feet Tunnel & Ghost AC	9.13	5.22
7	PR w/ Ghost AC	9.33	4.20
8	PR w/ Crows Feet Tunnel & Ghost AC	9.60	4.39
9	CCFN w/ Unconnected Box Tunnel	9.73	4.56
10	EBG w/ Ghost AC	9.87	5.19
11	BSBG w/ Connected Box Tunnel	12.47	5.15
12	CCFN w/ Ghost AC	12.73	3.90
13	CCFN w/ Crows Feet Tunnel & Ghost AC	13.00	4.24
14	BSBG w/ Unconnected Box Tunnel	13.93	4.99
15	EBG w/ Pitch/Roll Flight Director	15.20	6.00
16	PR w/ Pitch/Roll Flight Director	15.27	5.48
17	BSBG w/ Ghost AC	16.33	5.47
18	BSBG w/ Crows Feet Tunnel & Ghost AC	16.80	4.84
19	CCFN w/ Pitch/Roll Flight Director	17.40	4.73
20	PR w/ Crows Feet Tunnel	18.00	4.63
21	EBG w/ Crows Feet Tunnel	18.07	4.88
22	CCFN w/ Crows Feet Tunnel	20.00	4.11
23	BSBG w/ Pitch/Roll Flight Director	21.33	3.96
24	BSBG w/ Crows Feet Tunnel	22.60	2.38
25	EBG w/ No GSC	24.67	2.16
26	PR w/ No GSC	24.73	1.83
27	CCFN w/ No GSC	26.60	1.30
28	BSBG w/ No GSC	27.73	1.03

Legend	
	Guidance Only
	Tunnel Only
	Guidance & Tunnel
	No Guidance



Summary

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- Testing has been conducted to establish the interactions between GSCs and TPCs for advanced search and rescue/en route operations
- Extends previous SVS results for TPCs and GSCs (TP-HDD, SD-HDD Part-A)
- Preliminary results indicate:
 1. No interactions between TPC and GSC
 2. Most tunnel concepts outperformed P/RFD and were preferred to the P/RFD for this task
 3. EBG and PR texturing concepts are preferred to BSBG and CCFN
 4. Presence of SVS terrain does not adversely affect pilot performance and workload while improving SA
- Plans: Complete testing and data analysis (analyze safety level data for VMC vs IMC), publish conference papers and NASA reports



BACK-UPS

Dependent Measures, Cont.



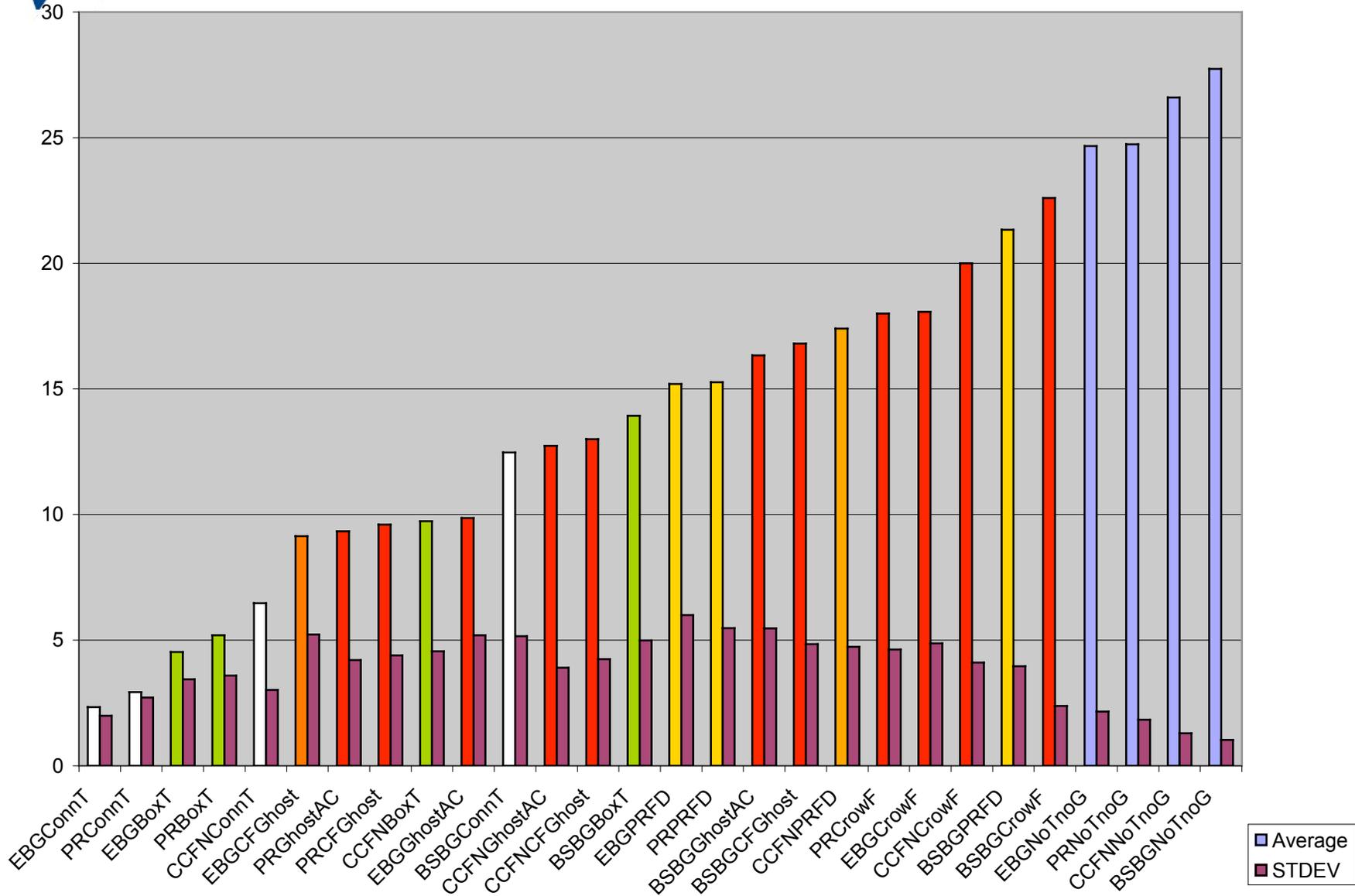
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- **Level 1 Time**
 - The percentage of time that EP remains within 75 ft lateral and 75 ft vertical distance from the center of the planned flight path.
- **Situation Awareness Rating Technique (SART)**
 - Widely used and easily employed subjective SA metric
 - Administered at the end of each data collection run
- **NASA Task Load Index (NASA - TLX)**
 - Highly tested and validated multi-dimensional subjective workload measure
 - Administered at the end of each data collection run
- **Subjective Ranking of Display Concepts**
 - Simple rank order of preferred combinations of terrain and guidance concepts as seen on the PFD
 - Administered at the end of 2nd day of data collection



Subjective Rankings From Exit Interview

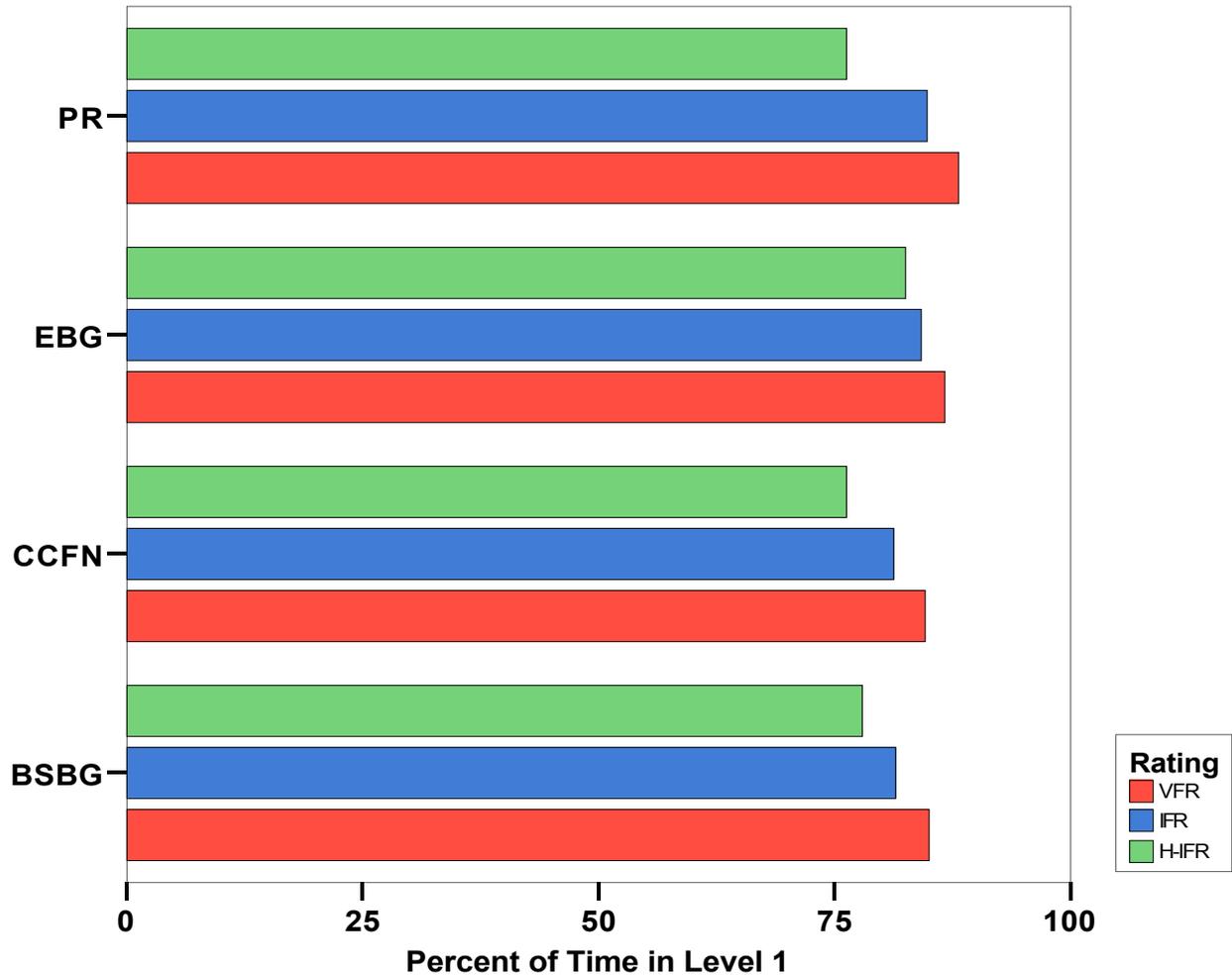
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Time in Level 1 Performance for 15 EPs

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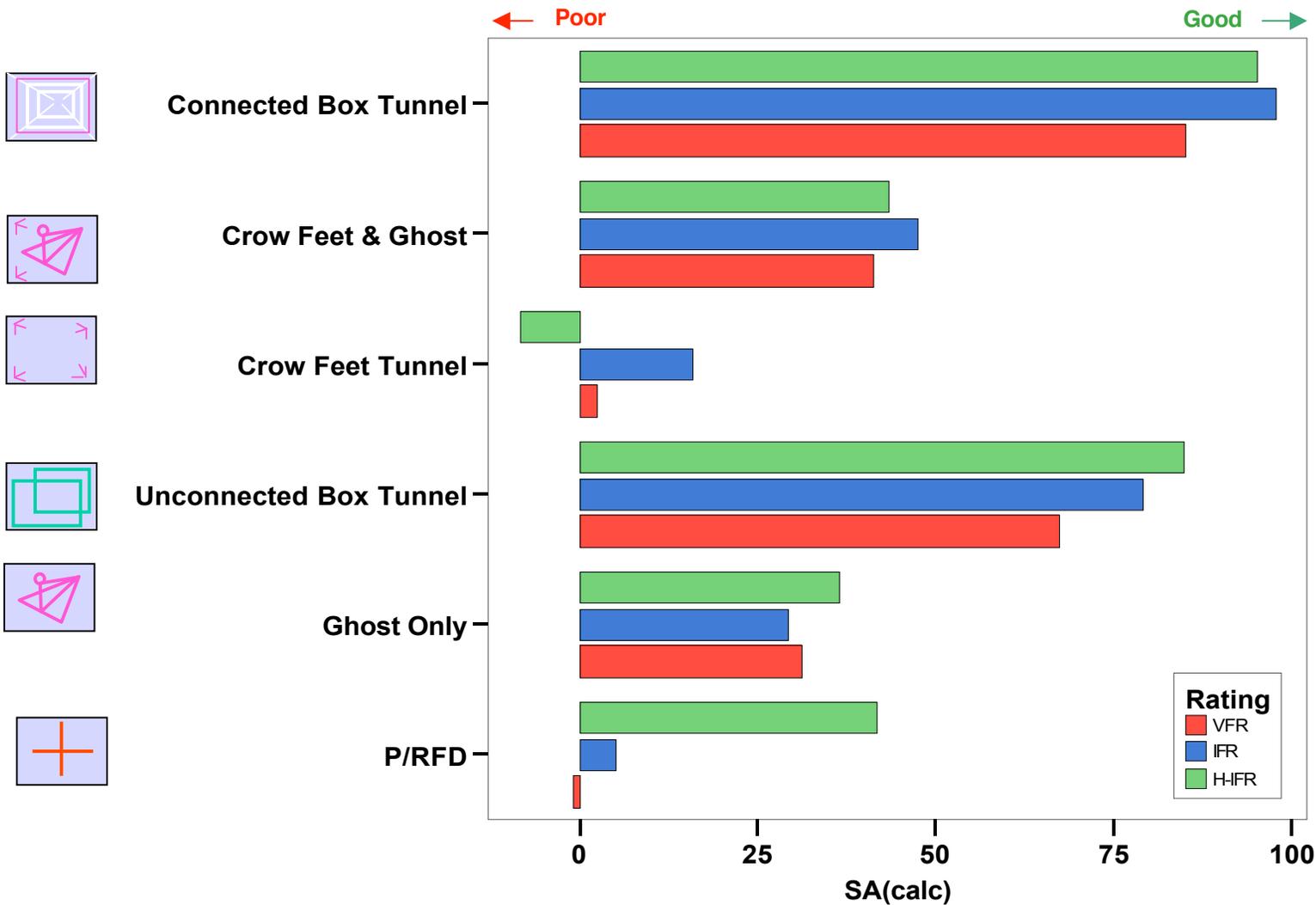


Univariate ANOVA: Not Significant



Mean SART Scores for 15 EPs

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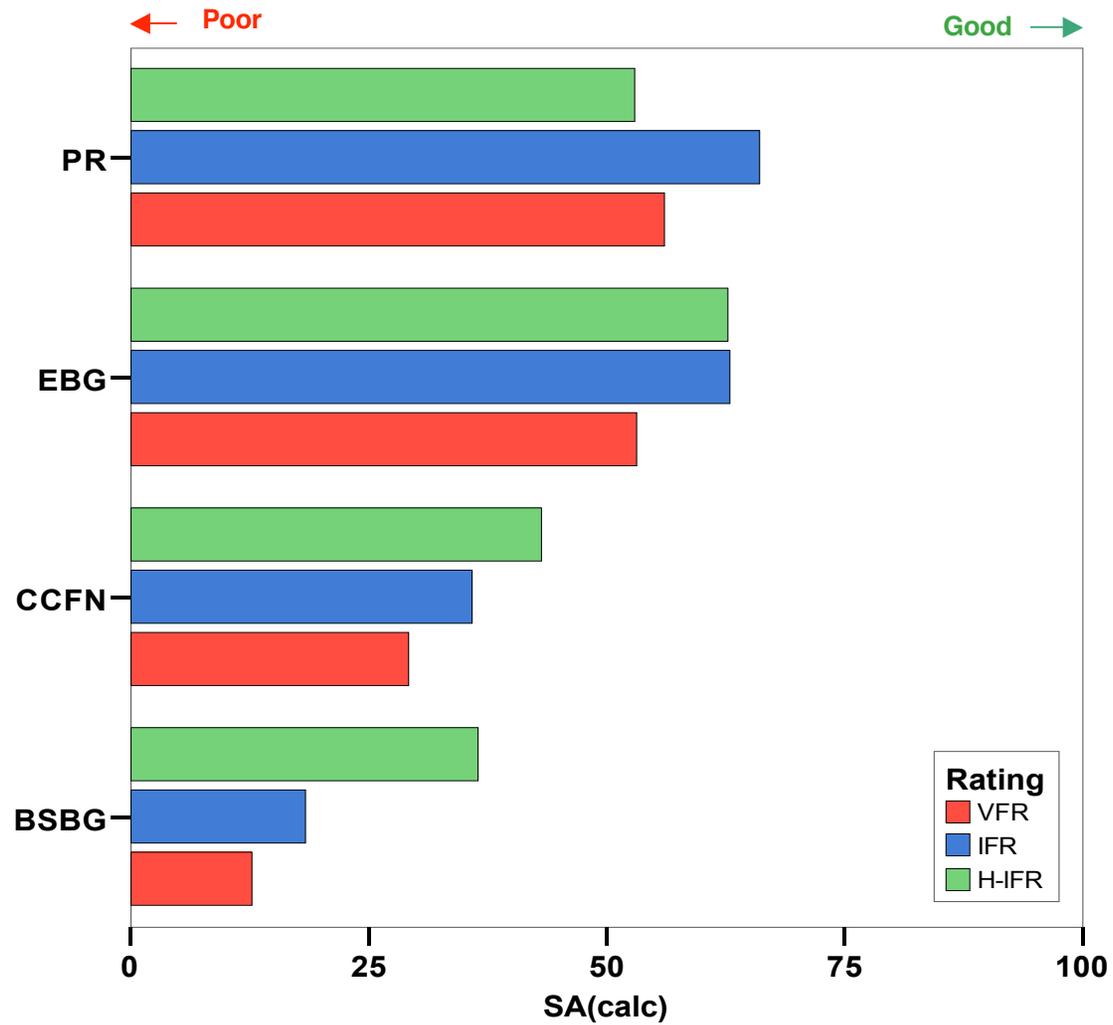


Univariate ANOVA: $F(10,676) = 2.28$ ($p < .01$)



Mean SART Scores for 15 EPs

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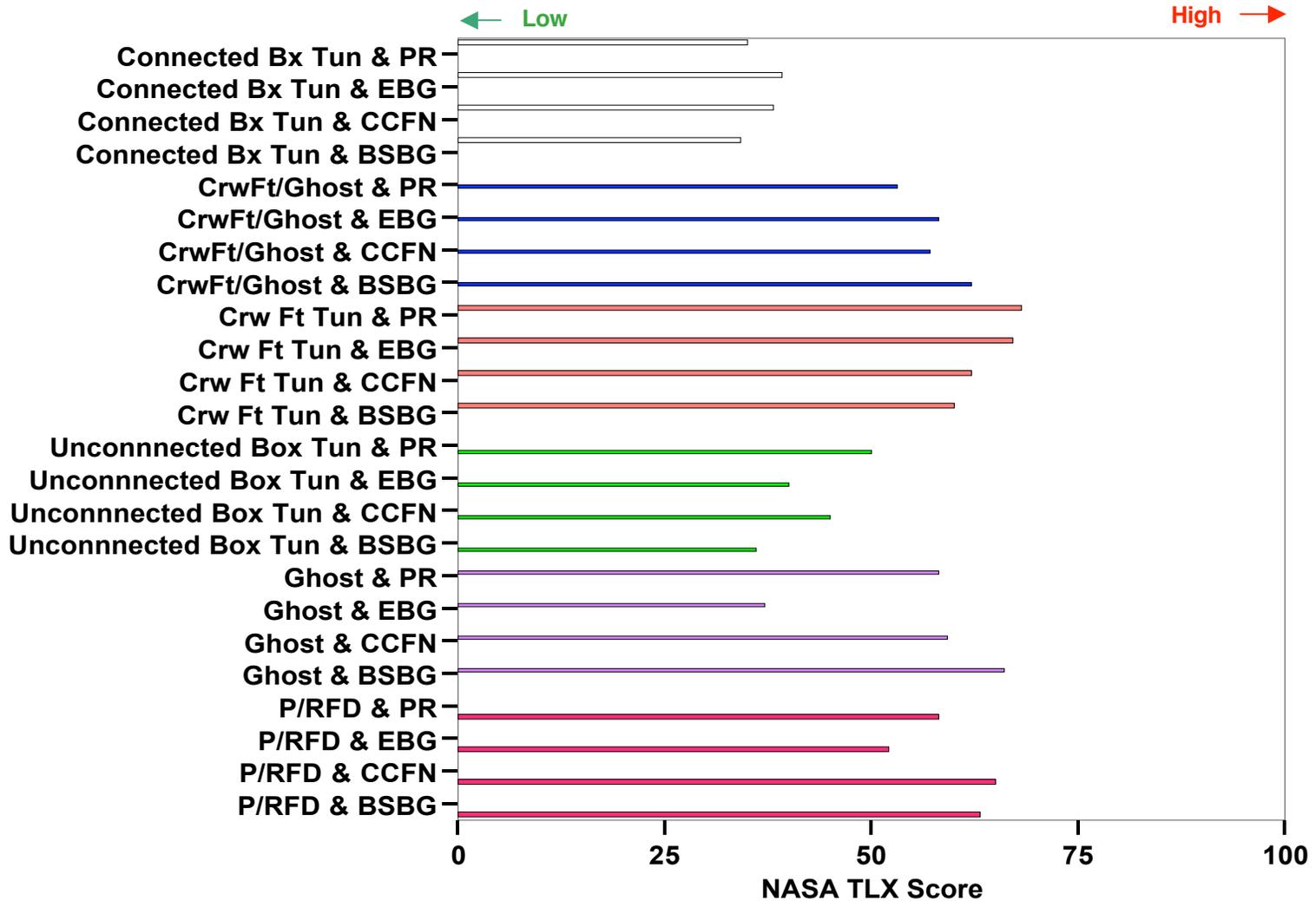
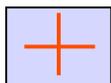
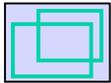


Univariate ANOVA: Not Significant



Mean NASA-TLX Scores

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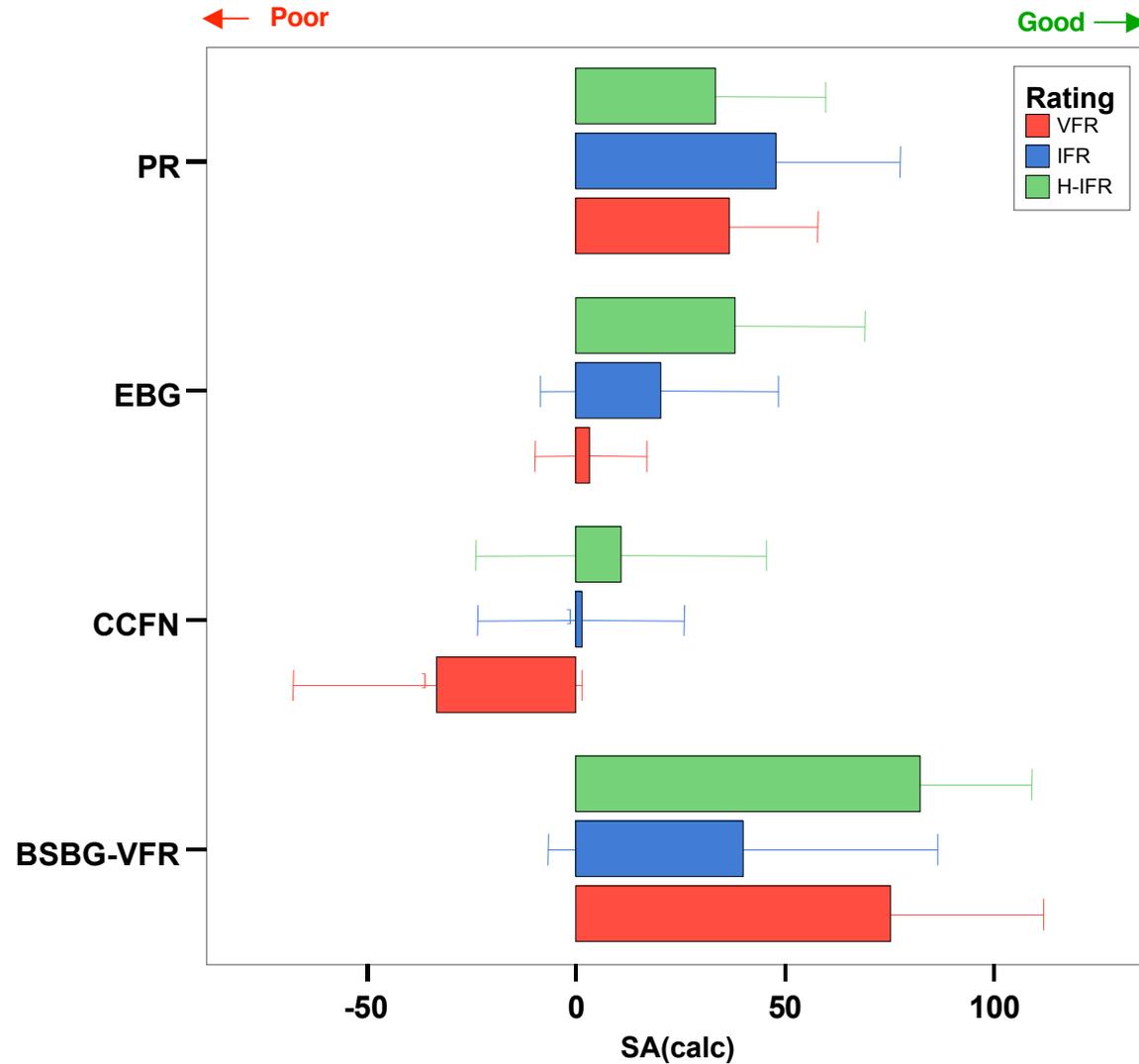


Univariate ANOVA: $F(23,696) = 10.44$ ($p < .01$)



Mean SART Scores for NoG/NoT

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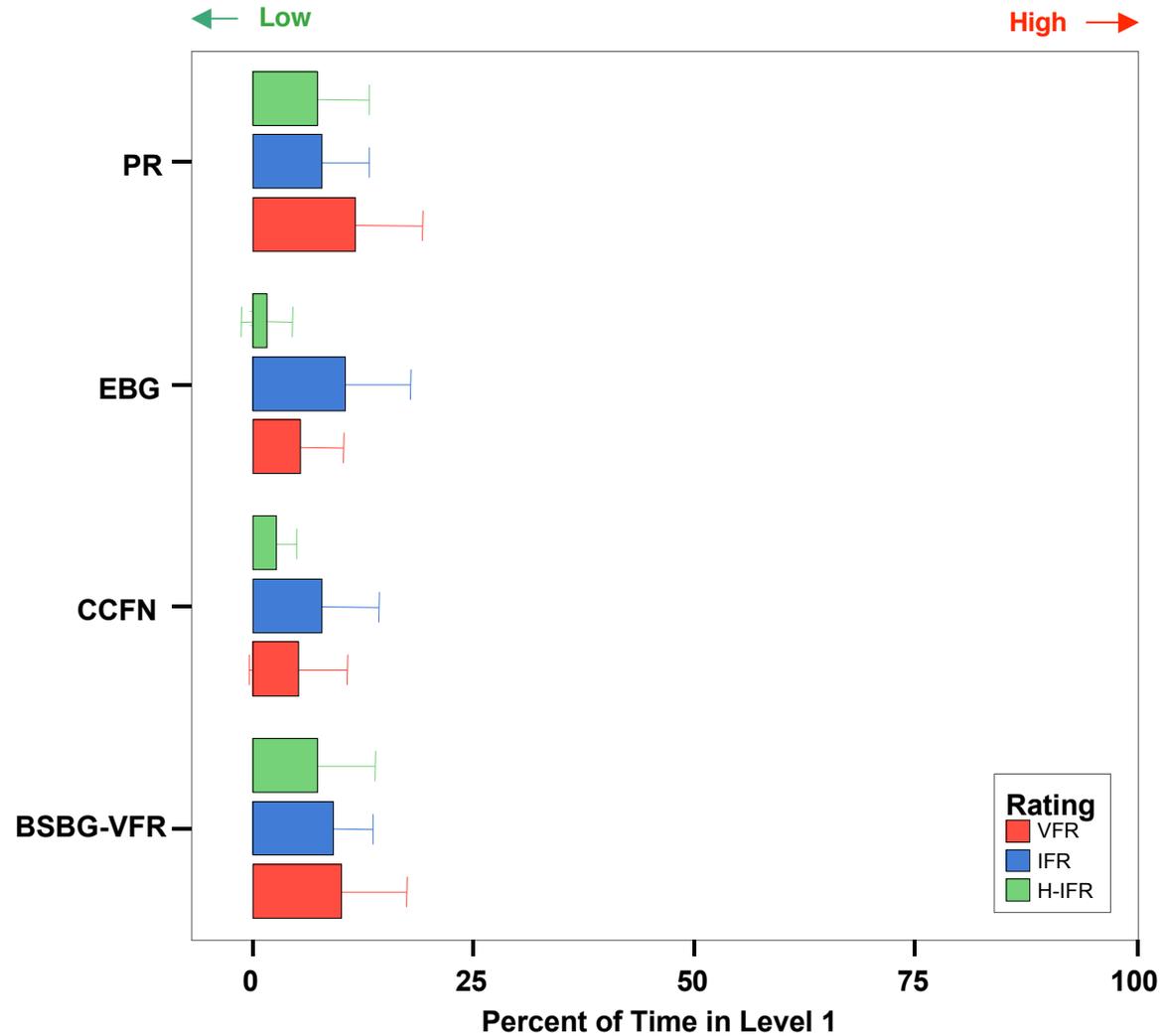


Univariate ANOVA: $F(3,108) = 13.77$ ($p < .01$)



Mean Percent Time in L1 for NoG/NoT

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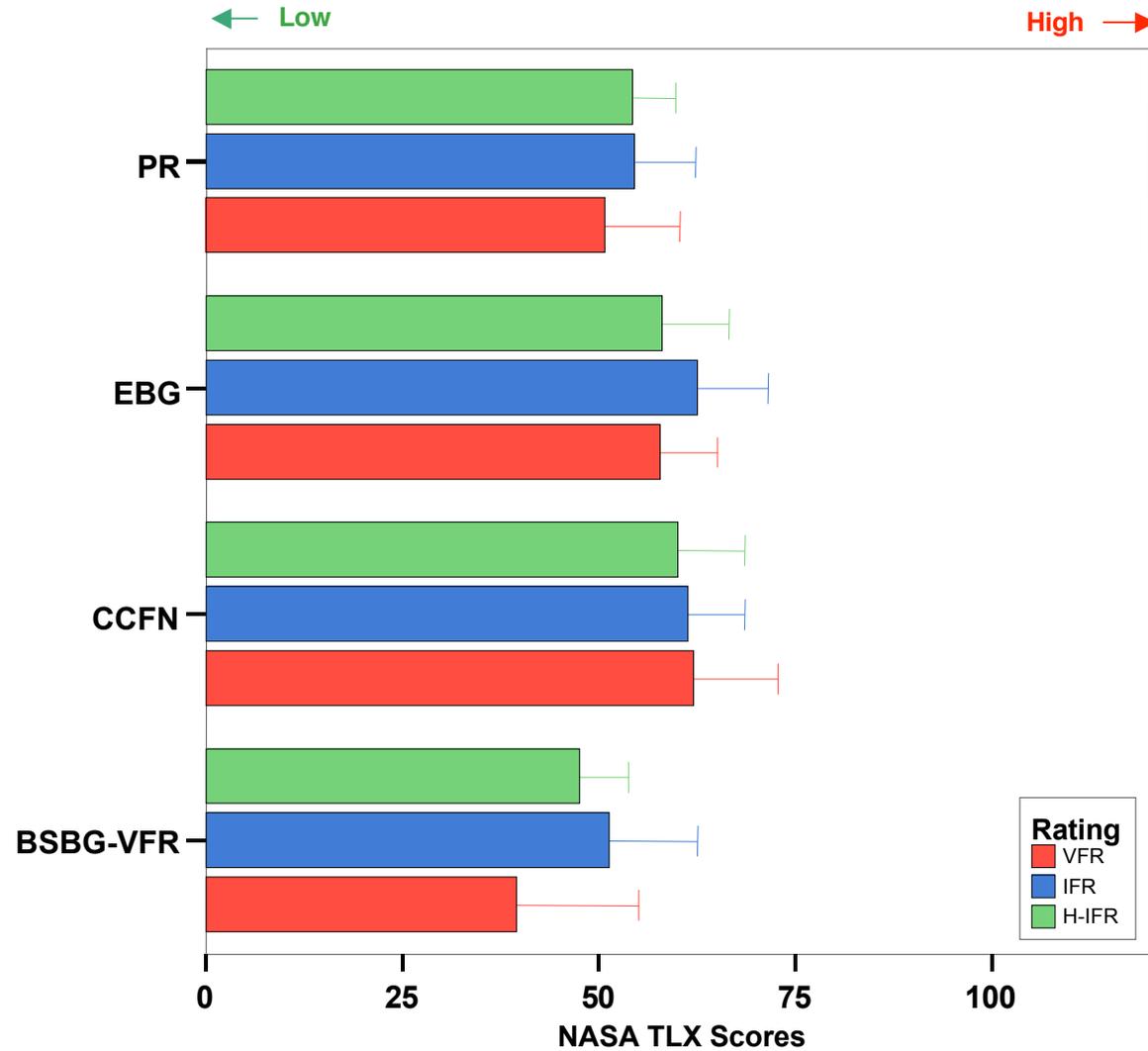


Univariate ANOVA: Not Significant



Mean NASA-TLX Scores for NoG/NoT

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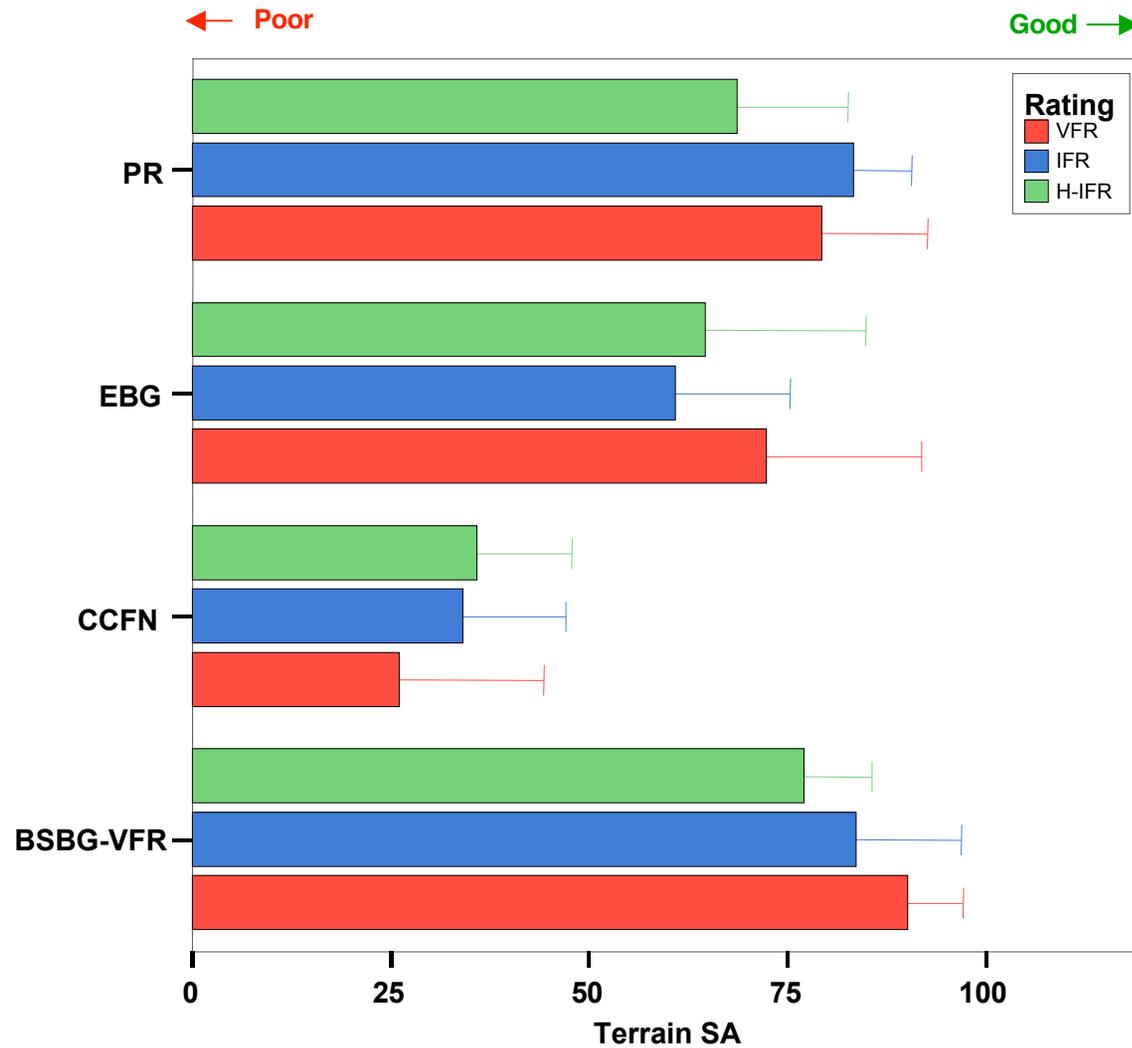


Univariate ANOVA: $F(3,108) = 8.15$ ($p < .01$)



Mean Terrain SA for NoG/NoT

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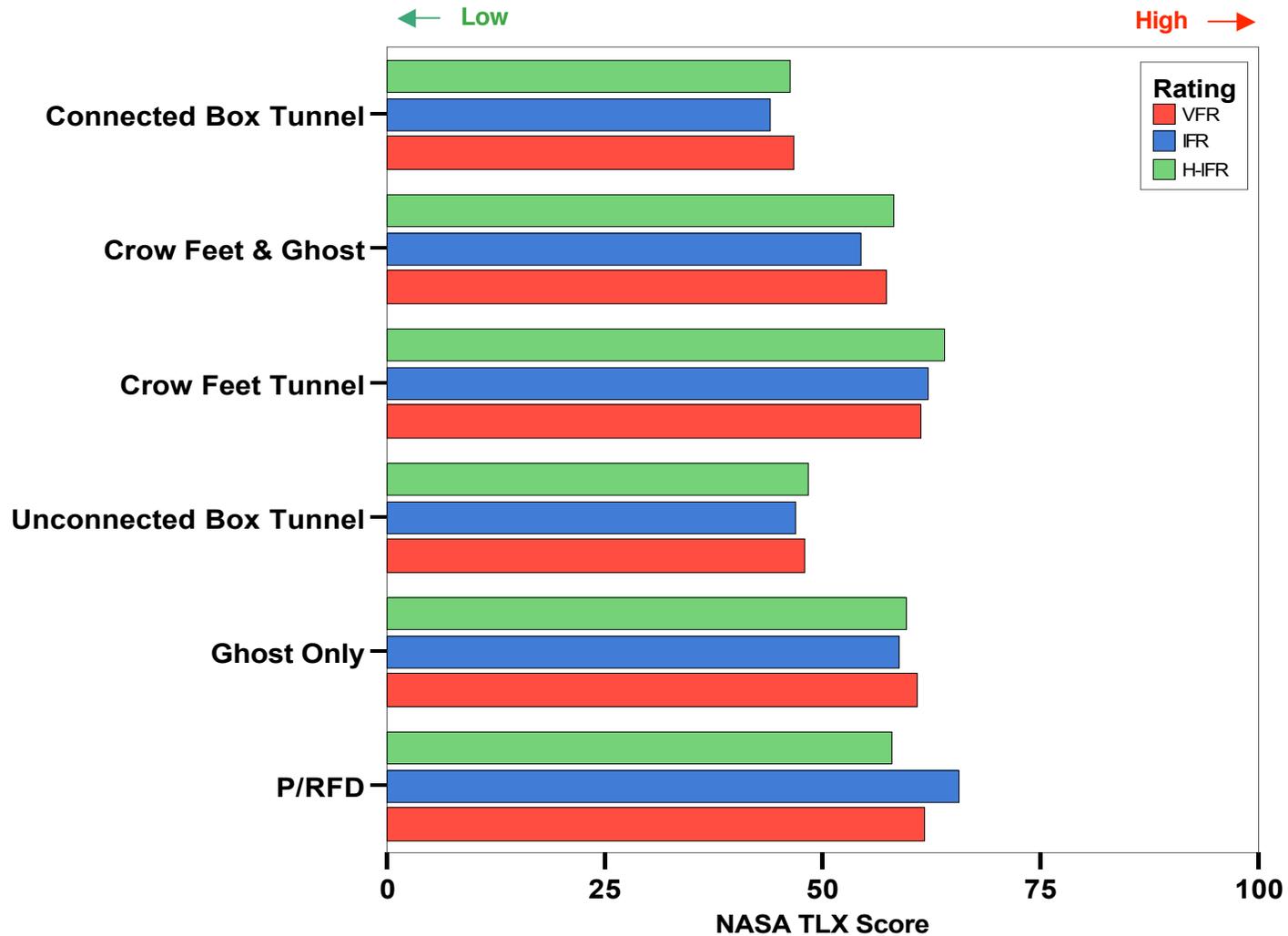


Univariate ANOVA: $F(3,108) = 41.18$ ($p < .01$)



Mean NASA-TLX Scores for 15 EPs

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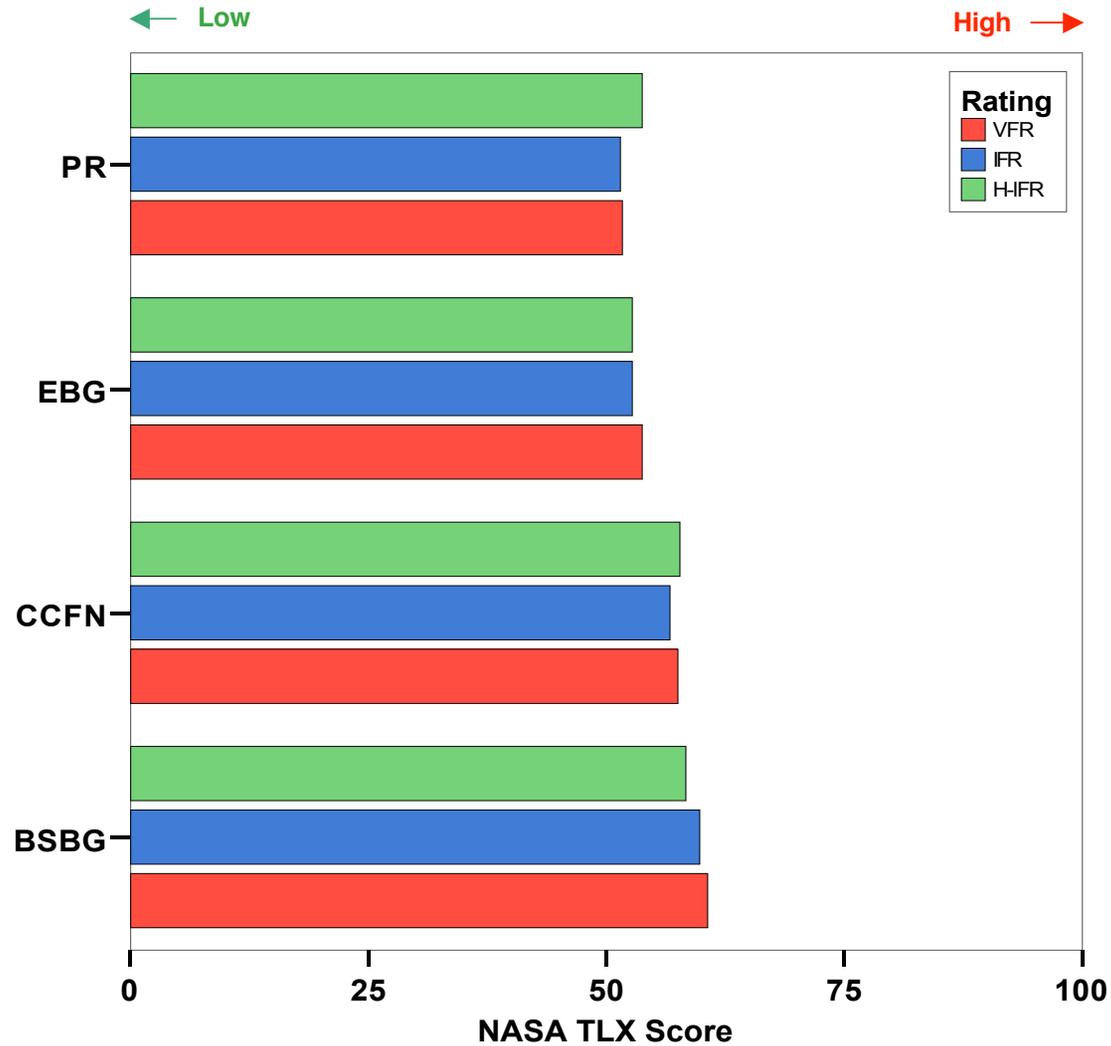


Univariate ANOVA: Not Significant



Mean NASA-TLX Scores for 15 EPs

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Univariate ANOVA: Not Significant



Tunnel/Guidance Concepts

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9- Guidance & Tunnel, Old Connected Tunnel with a Guidance Box

Predictor is similar to VV but 5 seconds ahead in Lateral direction

Guidance box (magenta) is 4 seconds ahead

In a Turn

