



Symbology Development for Head-Down Displays (SD-HDD) Simulation

Experiment: Experiment A

NASA/GAMA/FAA SVS-GA Workshop

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NASA SVS-GA Team

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Outline of Presentation

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- **Goals and Objectives**
- **Experiment Plan**
- **Independent Variables**
- **Experiment Scenarios**
- **Dependent Variables**
- **Experiment Equipment**
- **Testing Protocol**
- **Preliminary Test Results**



SD-HDD Objectives

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

● Part A

● Part B

● Part C

SD-HDD Overview



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- ***Experiment A: JNU terminal area simulations***
 - Substantial terrain presence in IMC
 - Advanced operational procedures w/ precision guidance
 - Instrument approach w/ VFR-like pattern
 - Missed Approach
 - Engine failure rare event on Missed Approach (MA)
- ***Experiment B: Merrill Pass simulations***
 - Extreme terrain presence
 - Advanced En Route maneuver
 - Structural Icing rare event
- ***Experiment C: Minification Issues***



SD-HDD Experiment

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Experiment A: JNU terminal area simulations



Independent Variables

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- **Terrain Portrayal Concepts (TPC):**
 1. **Baseline TPC: No terrain, Blue Sky Brown Ground**
 2. **Minimal TPC: 60 arc-sec DEM, Constant-color Texture w/ Fishnet, Cultural Features, & Obstacles**
 3. **Medium TPC: 6 arc-sec DEM, Elevation-based Generic Texture w/ Cultural Features & Obstacles**
 4. **Complex TPC: 2 arc-sec DEM, Photo-realistic Texture & Obstacles**

- **Approach/MA Guidance Symbology Concepts (GSC):**
 1. **Minimal GSC: Pitch/Roll Flight Director**
 2. **Medium GSC: Boxes as tunnel sections, no guidance**
 3. **Complex GSC: “Crows-Feet” as tunnel corners, “Ghost aircraft” guidance**
 4. **Most Complex GSC: Connected boxes as tunnel, moving box/velocity predictor for guidance**

- **Evaluation pilots (21 total) in the following experience subgroups:**
 1. **GA VFR pilots: 9 subjects each w/ less than 400 hours**
 2. **GA IFR pilots: 6 subjects each w/ less than 1000 hours**
 3. **High-time pilots: 6 subjects**



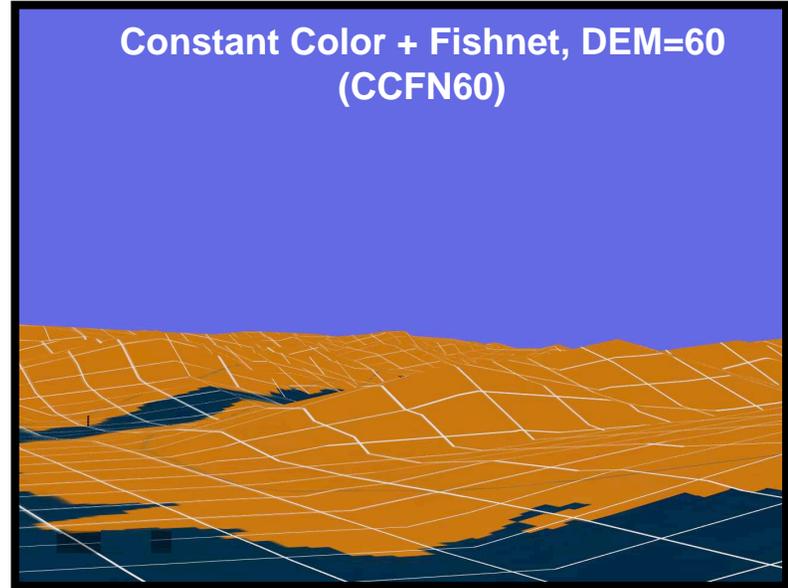
Terrain Portrayal Concepts

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No Terrain, Baseline (BSBG)



Constant Color + Fishnet, DEM=60 (CCFN60)



Elevation-Based Generic, DEM=6 (EBG 6)

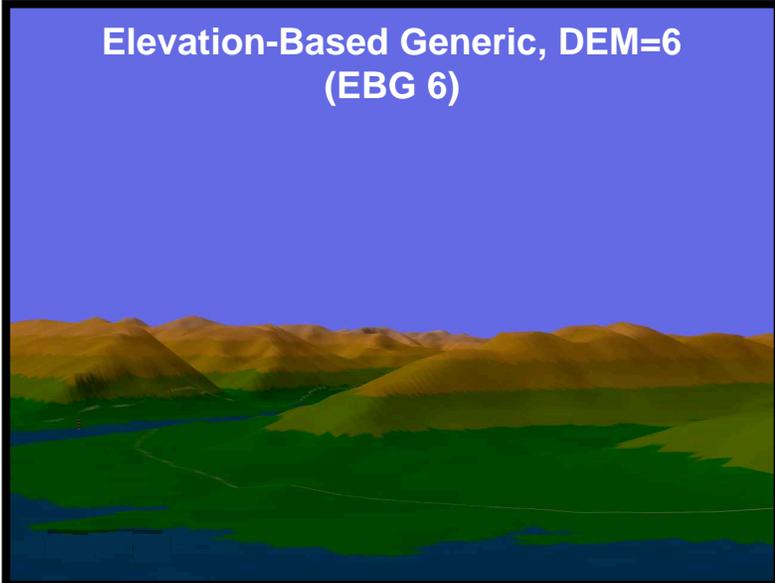
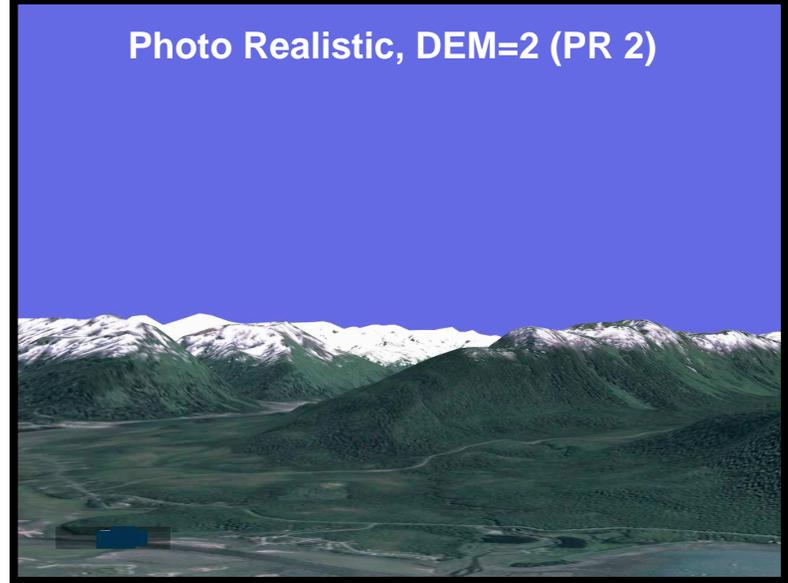


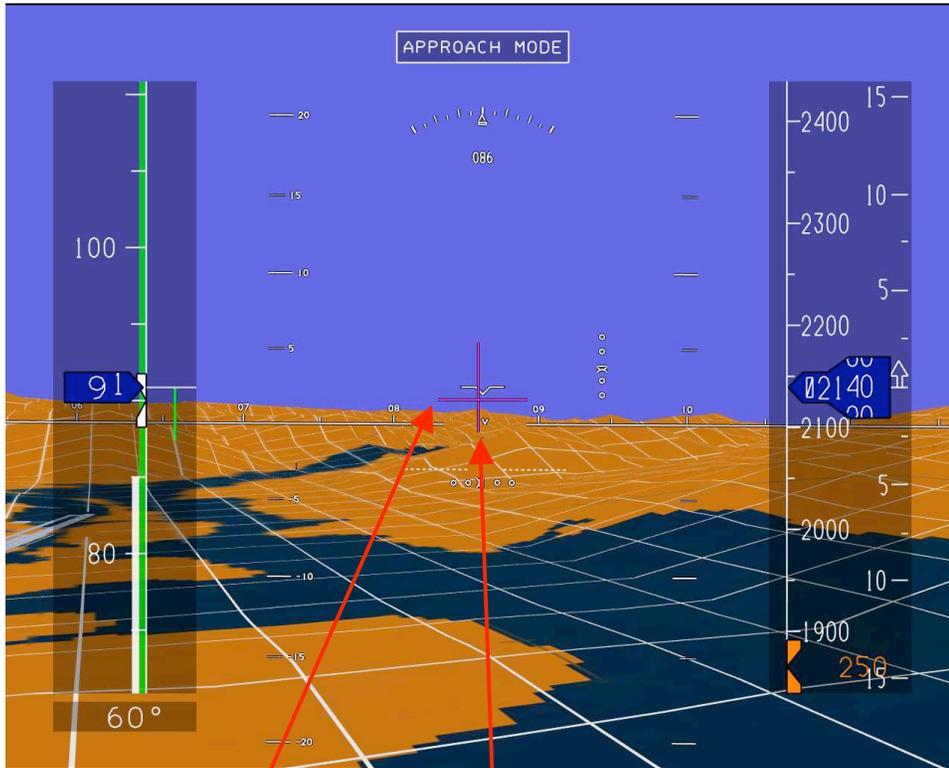
Photo Realistic, DEM=2 (PR 2)



Minimal Guidance Symbology Concept



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Pitch-command Flight Director

Speed-on-pitch command Flight Director:

Roll-command Flight Director

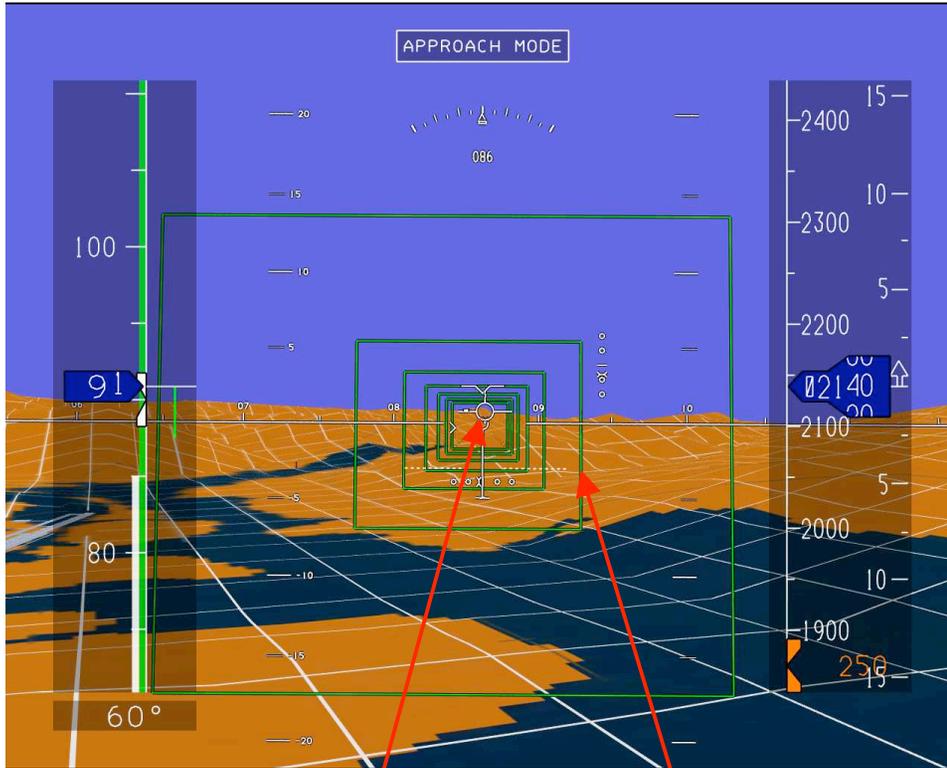
Pitch/Roll Flight Director



Medium Guidance Symbology Concept



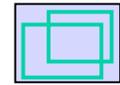
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Waypoint Balloon

Green Guidance Boxes

Box Tunnel/No Guidance



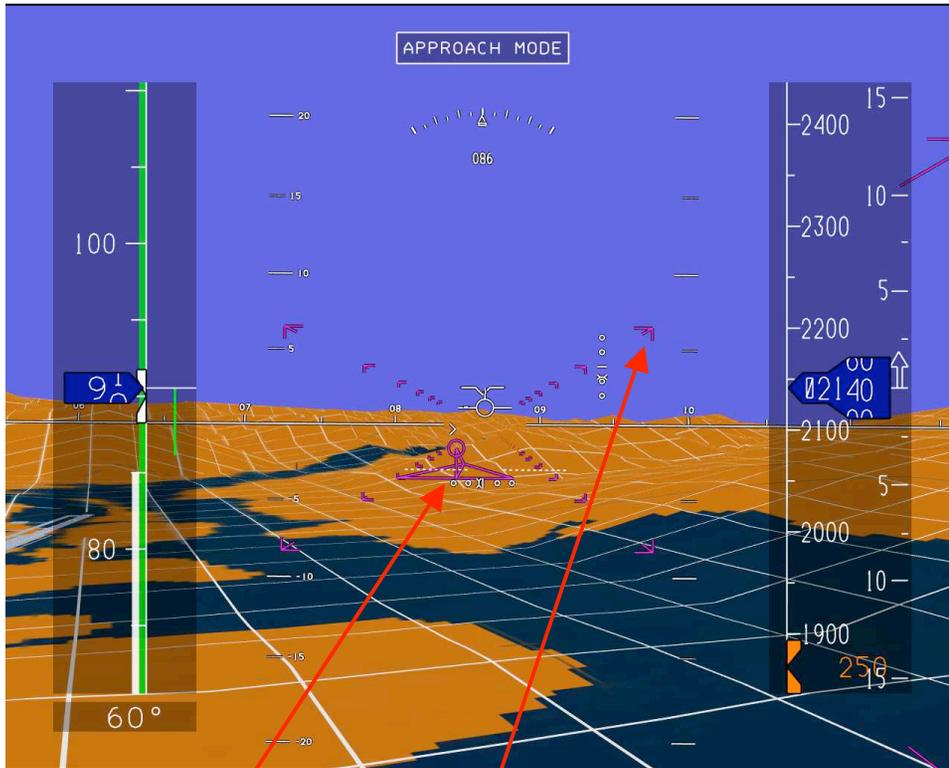
- Box Dimension - 400' Wide x 320' High
- Approach tunnel narrows down linearly from start of descending turn to the MAP



Complex Guidance Symbology Concepts



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Crows-Feet Tunnel/ Ghost Aircraft Guidance



- Box Dimension - 600' Wide x 320' High
- Approach tunnel narrows down linearly from start of descending turn to the MAP



Flight path
ghost plane
5 seconds
ahead

Crows-Feet
as tunnel
corners

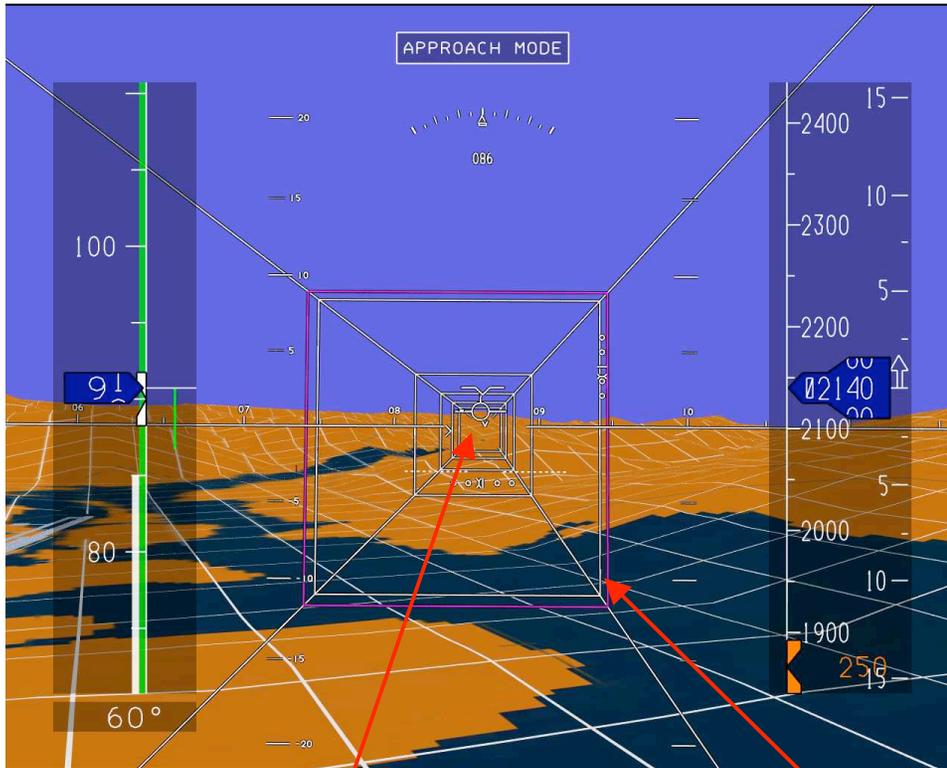
Sidewall
T-bars

Speed-on-pitch
command
Guidance Circle

Most Complex Guidance Symbology Concepts



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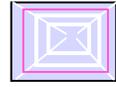


Velocity Predictor w/
5-sec prediction

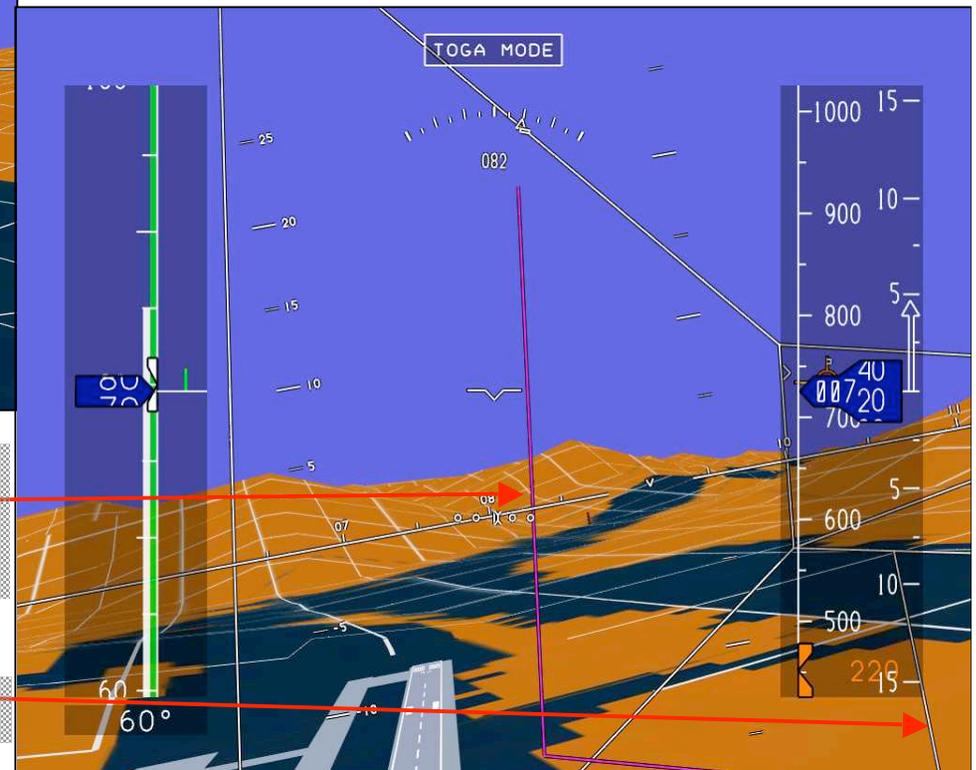
Guidance box
(magenta) 4 sec
ahead

Goal posts

Connected Boxes Tunnel / Guidance Box and Predictor



- Box Dimension - 300' Wide x 300' High from beginning to end

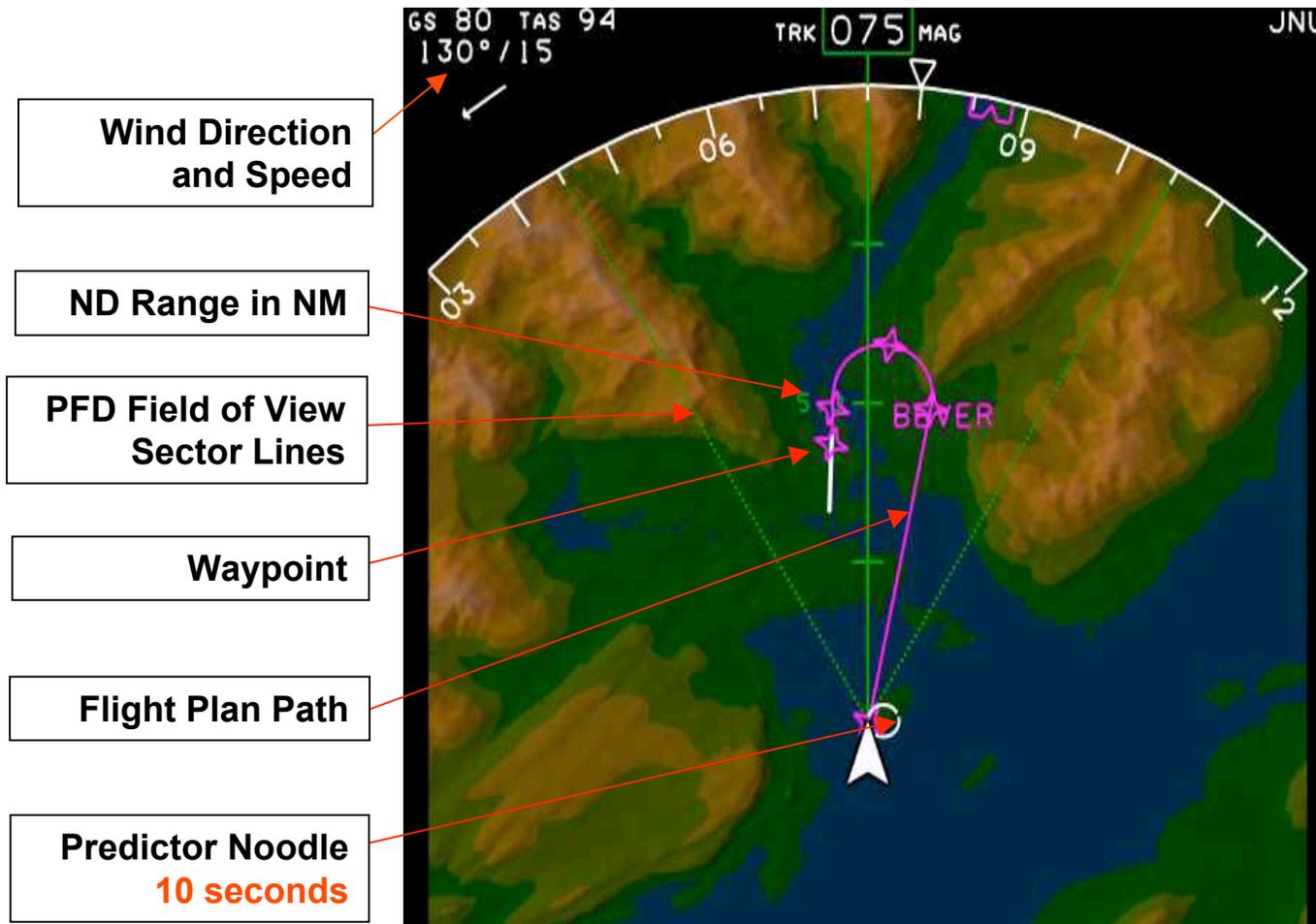




Navigation Display

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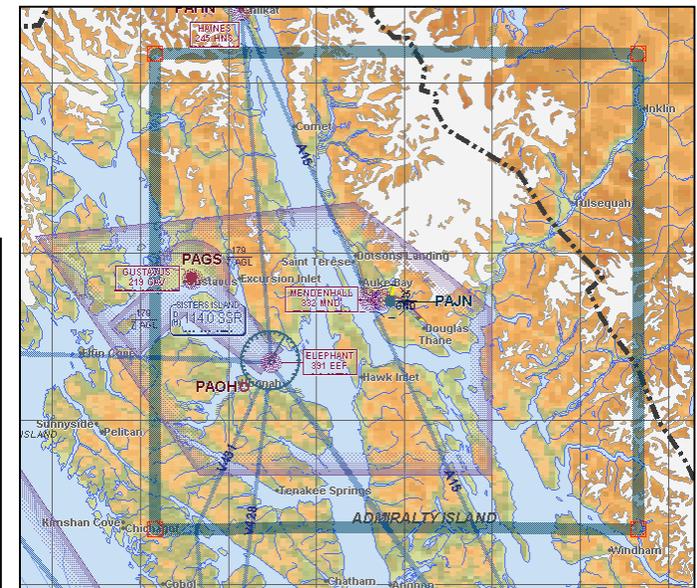
Strategic Map, Top Down View of Terrain





Scenario: Juneau Area

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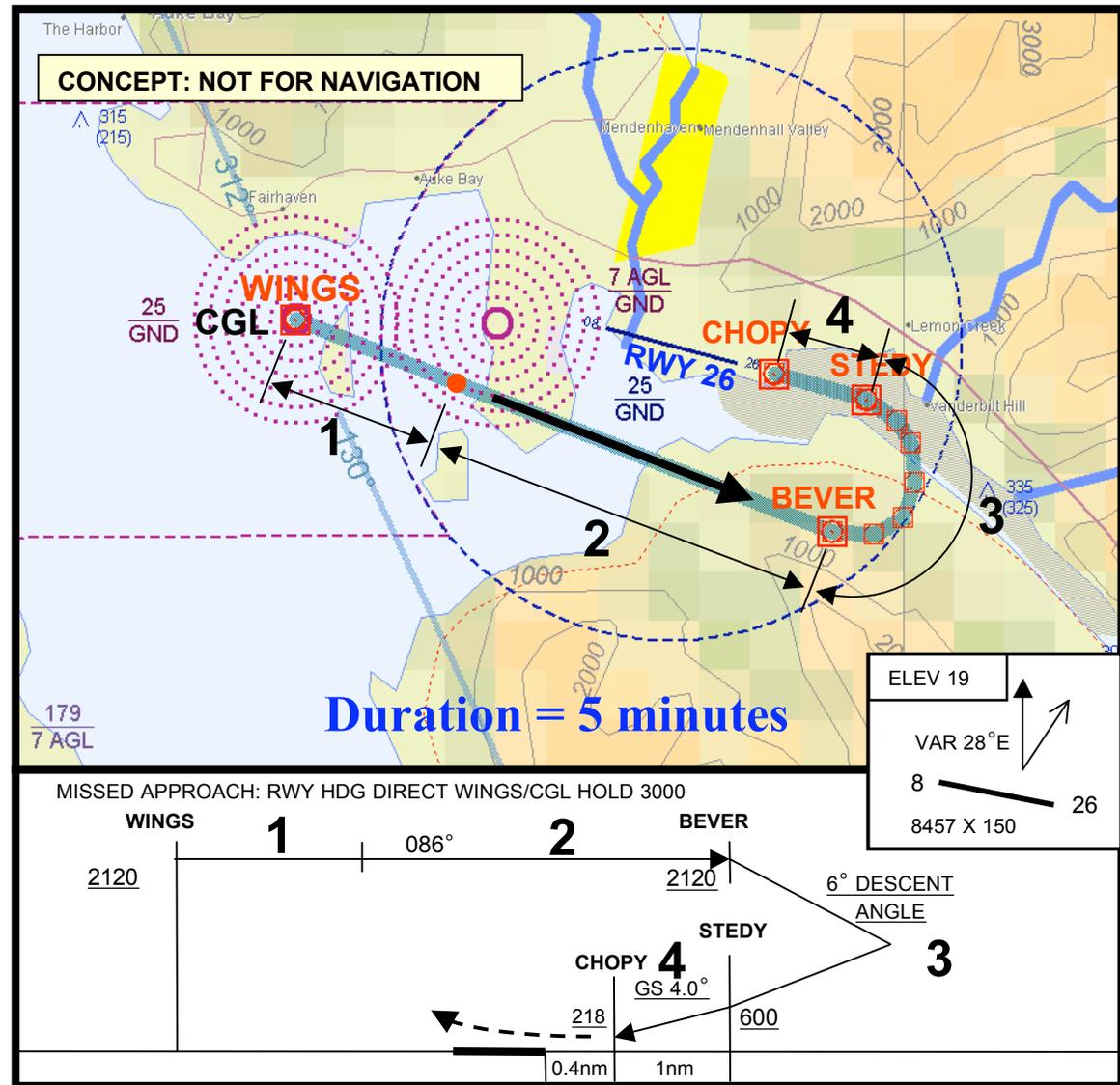
- Main mode of transportation is GA type aircraft with low service ceiling
- When cloudy, low freezing levels exist
- Surrounded by high mountainous terrain
- Accessible only by air and sea



Approach Scenario at Juneau, Experiment A

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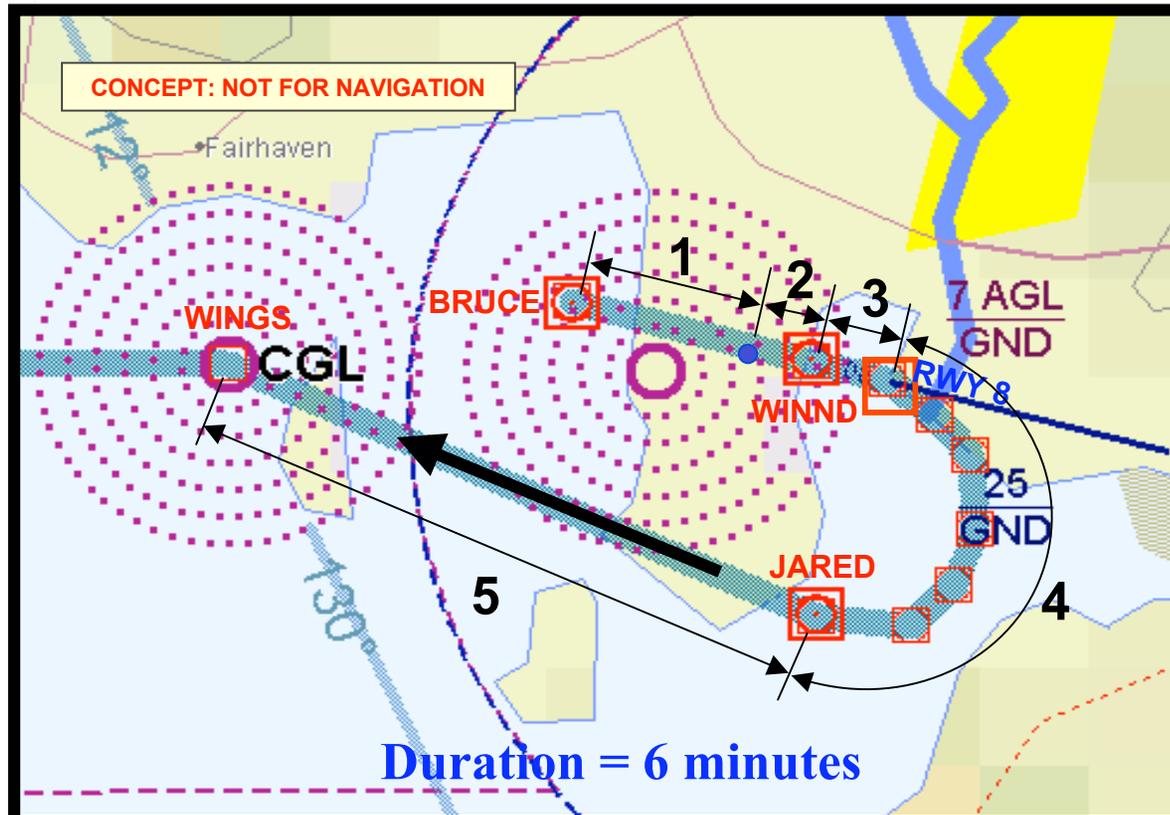
- **Four Segments:**
 - 1) Straight and level VMC
 - 2) Straight and level IMC
 - 3) 6-degree descending turn
 - 4) 4-degree final
- **Meteo. Conditions:**
 - _ Transition from VMC to IMC at 1 minute
 - _ IMC = 1-mile visibility
 - _ Light turbulence
 - _ Variable wind between 10 and 20 kts



Missed Approach Scenario at Juneau, Experiment A

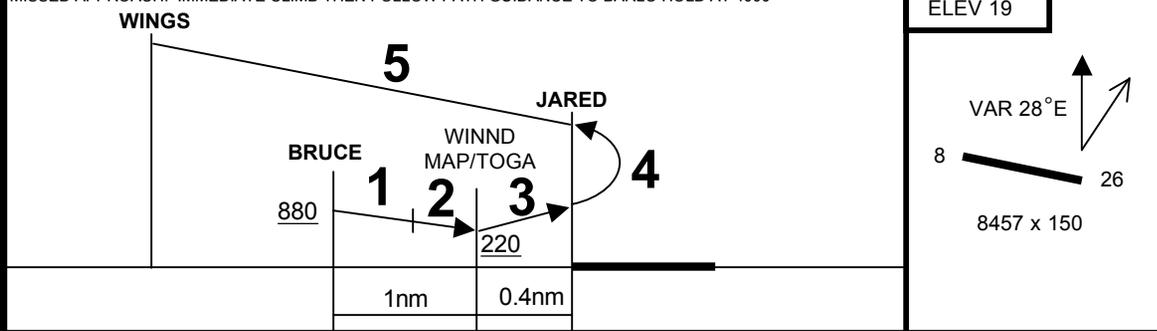


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- **Five Segments:**
 1. Final Approach VMC
 2. Final Approach IMC
 3. TOGA straight climb
 4. Climb and Turn
 5. Straight Climb
- **Conditions:**
 - _ Transition from VMC to IMC at 1 minute
 - _ IMC is 1-mile visibility
 - _ Light turbulence
 - _ Variable wind between 10 and 20 kts

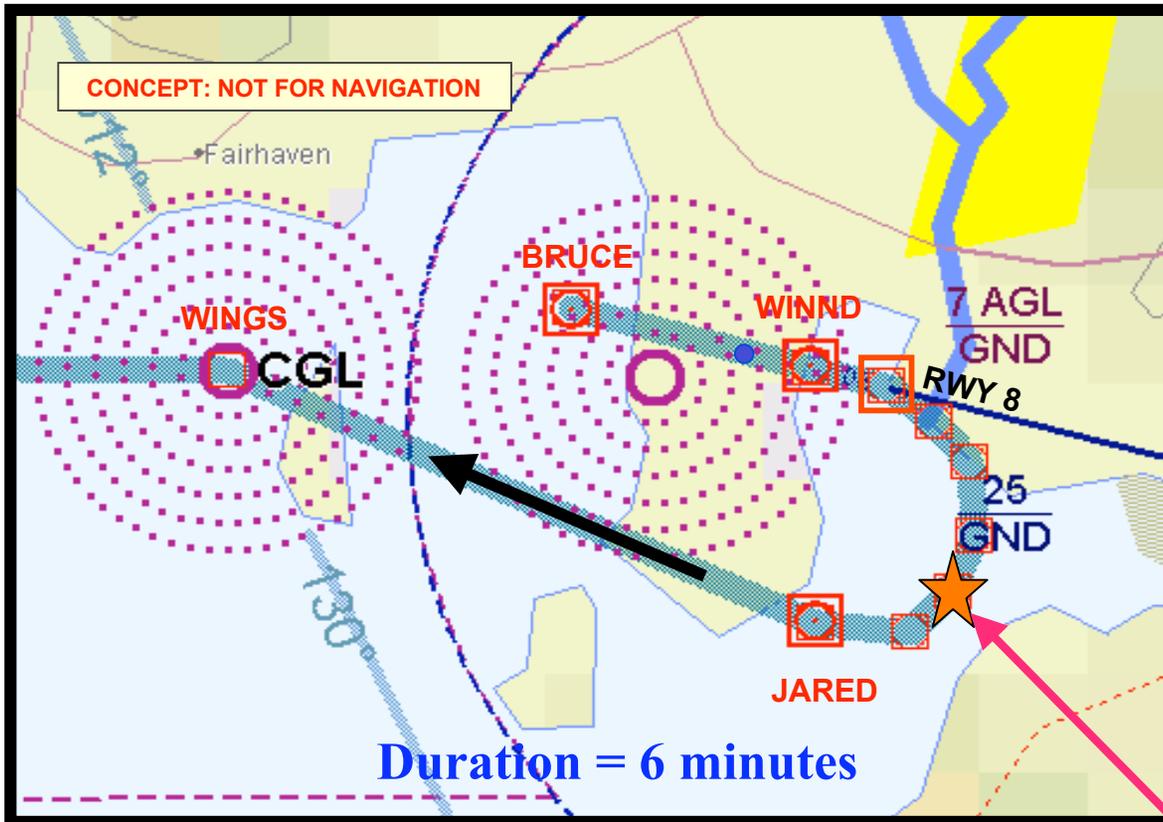
MISSED APPROACH: IMMEDIATE CLIMB THEN FOLLOW PATH GUIDANCE TO BARLO HOLD AT 4000



Rare Event Scenario at Juneau, Experiment A



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- **Conditions:**
 - _ Same flight plan as scenario 2
 - _ Unknown to EP, engine power reduced to 35% two minutes into the flight
- Each pilot experienced only one rare event
- 6 minutes or stopped after CFIT / landing

Partial Engine Failure

Dependent Measures



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- **Pilot/vehicle performance measures:**
 - Pilot control inputs, aircraft path errors / **L1 performance**
 - Time to recognition of partial engine failure during Rare Event
- **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 for all communications**

 = **Already analyzed**



Dependent Measures for L1 Performance

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- **Level 1 performance:**
 - **Measured % time within L1 performance**
 - **Approach**
 - **One segment from 65 sec into the run (5 sec into IMC) to 250 sec (near the end)**
 - **Criteria**
 - **IAS error: within 10 knots**
 - **Vertical deviation: within 30 ft (1 dot on V-CDI)**
 - **Lateral path deviation: within 100 ft (1 dot on H-CDI)**
 - **MA**
 - **One segment from 65 sec into the run (after Missed Approach initiated) to 300 sec (the end of the run)**
 - **Criteria**
 - **IAS error: within 10 knots**
 - **Lateral path deviation: within 100 ft**

General Aviation WorkStation (GAWS)



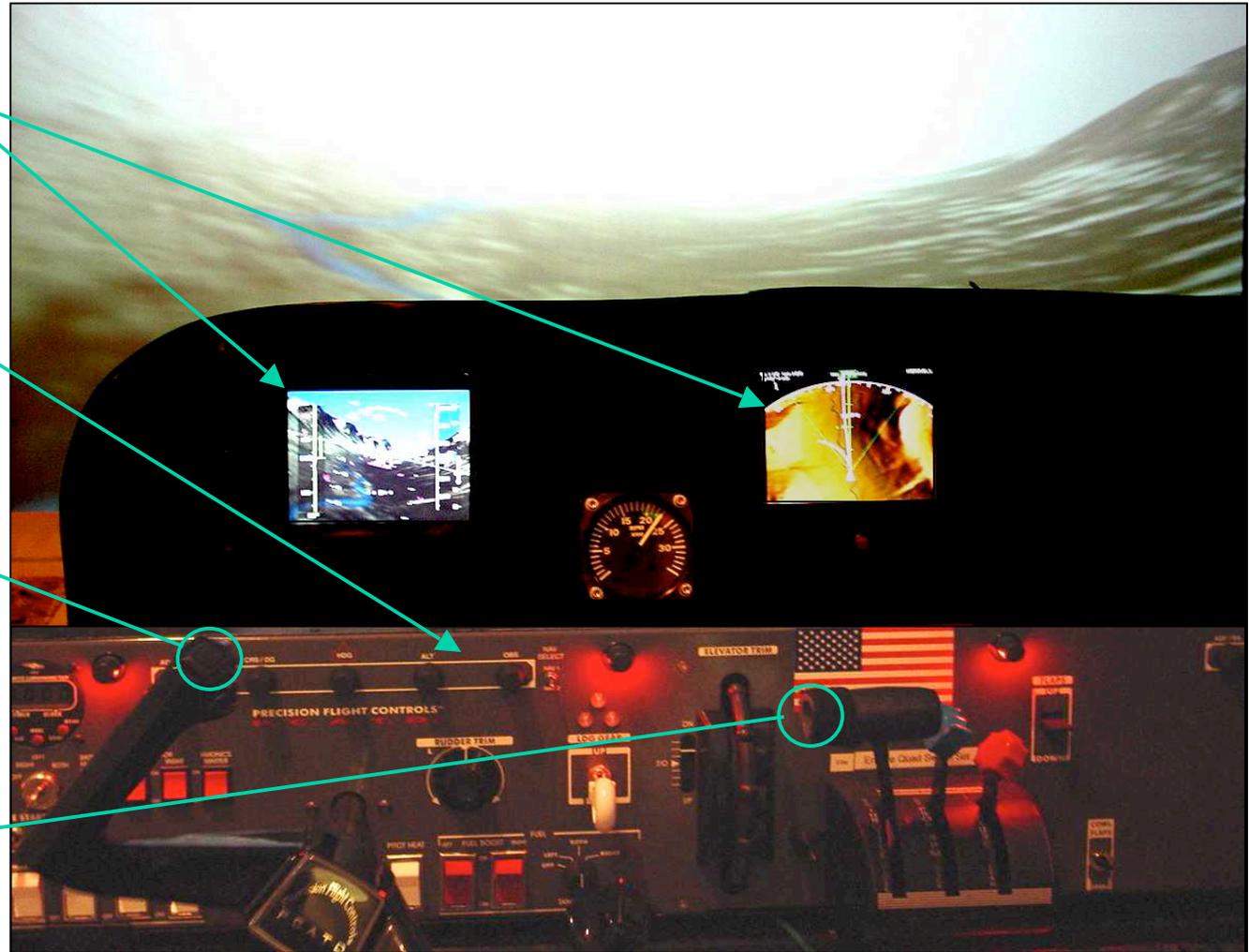
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**COTS 6" VGA
Monitor for the
PFD and ND**

PFC Console

**FOV Selector
Switch on the
Control Yoke**

**TOGA / Approach
/ En Route
Selector Switch
on the Throttle**



Testing Protocol



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- **Training:**
 - 2.5 hrs allotted
 - FAA/Jeppesen-style training syllabus to
 - test on Pilot Test Standard level skills for Pilot Performance Level
 - Instruct EPs to
 - use all display information to minimize pilot flight technical errors
 - just like real flying, avoid hazardous terrain or flight situations
 - communicate their intentions and take corrective action when encountering hazardous situations
- **Testing:**
 - Day 1: briefing, overall/approach trainings, approach runs w/ run questionnaires, block questionnaires at the end
 - Day 2: MA training, MA runs w/ run questionnaires, physio. data, 1 rare event, block questionnaires, exit interview

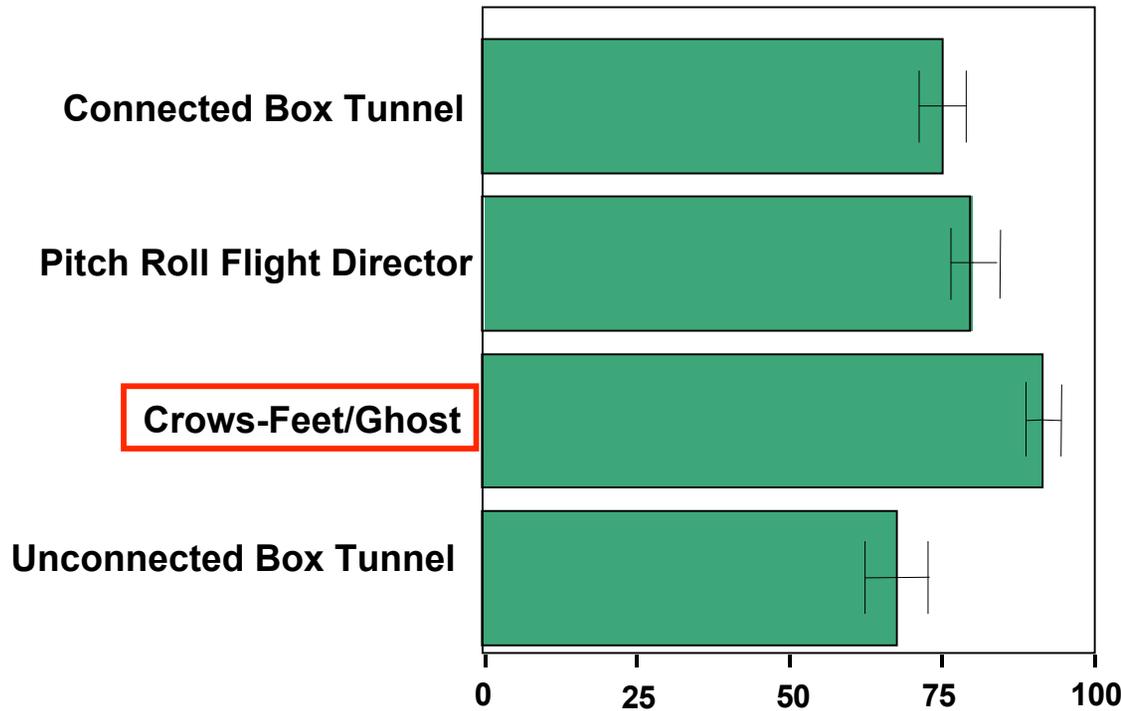


L1 Performance by GSC

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Approach

→ Better L1 performance

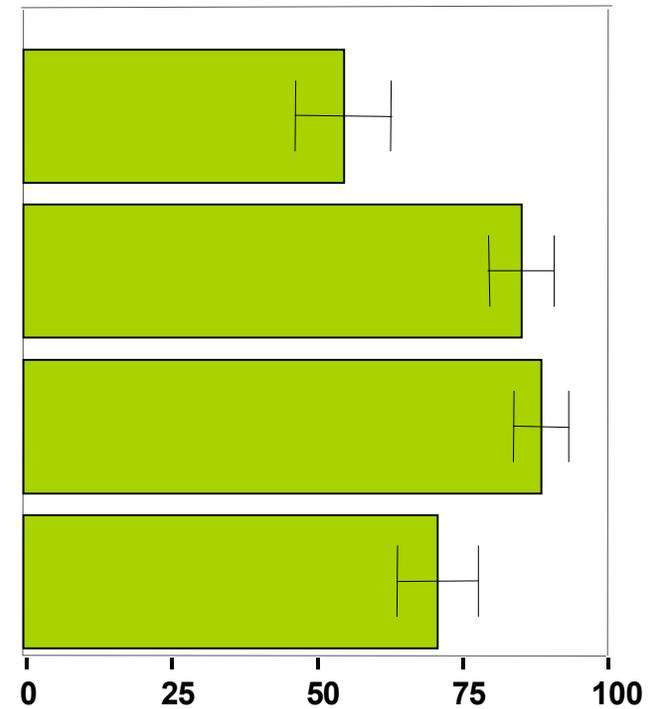


L1 Performance (% Time in L1)

$F(3, 320) = 24.842 (P < 0.01)$

Missed Approach

→ Better L1 performance



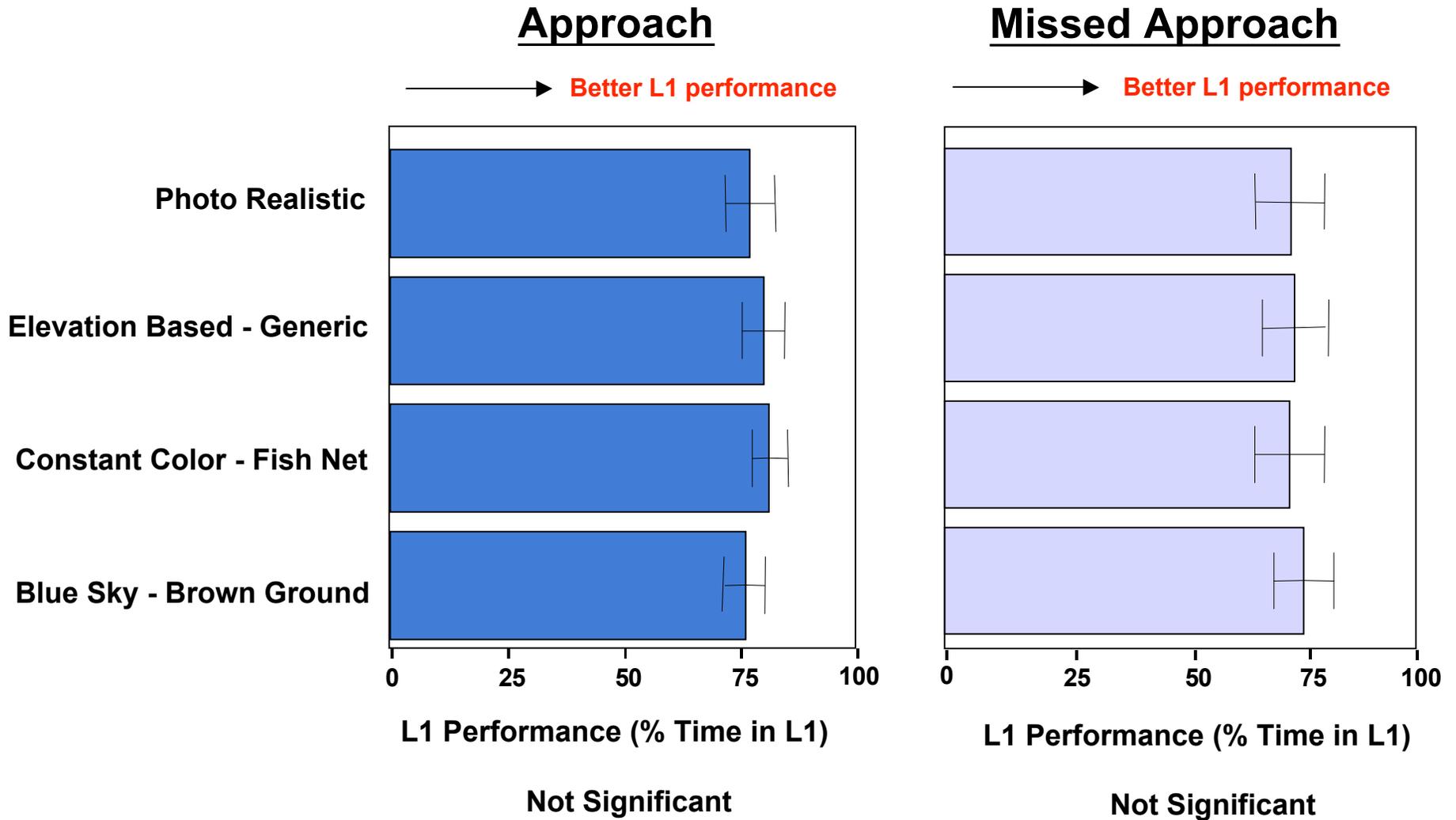
L1 Performance (% Time in L1)

$F(3, 287) = 22.407 (P < 0.01)$



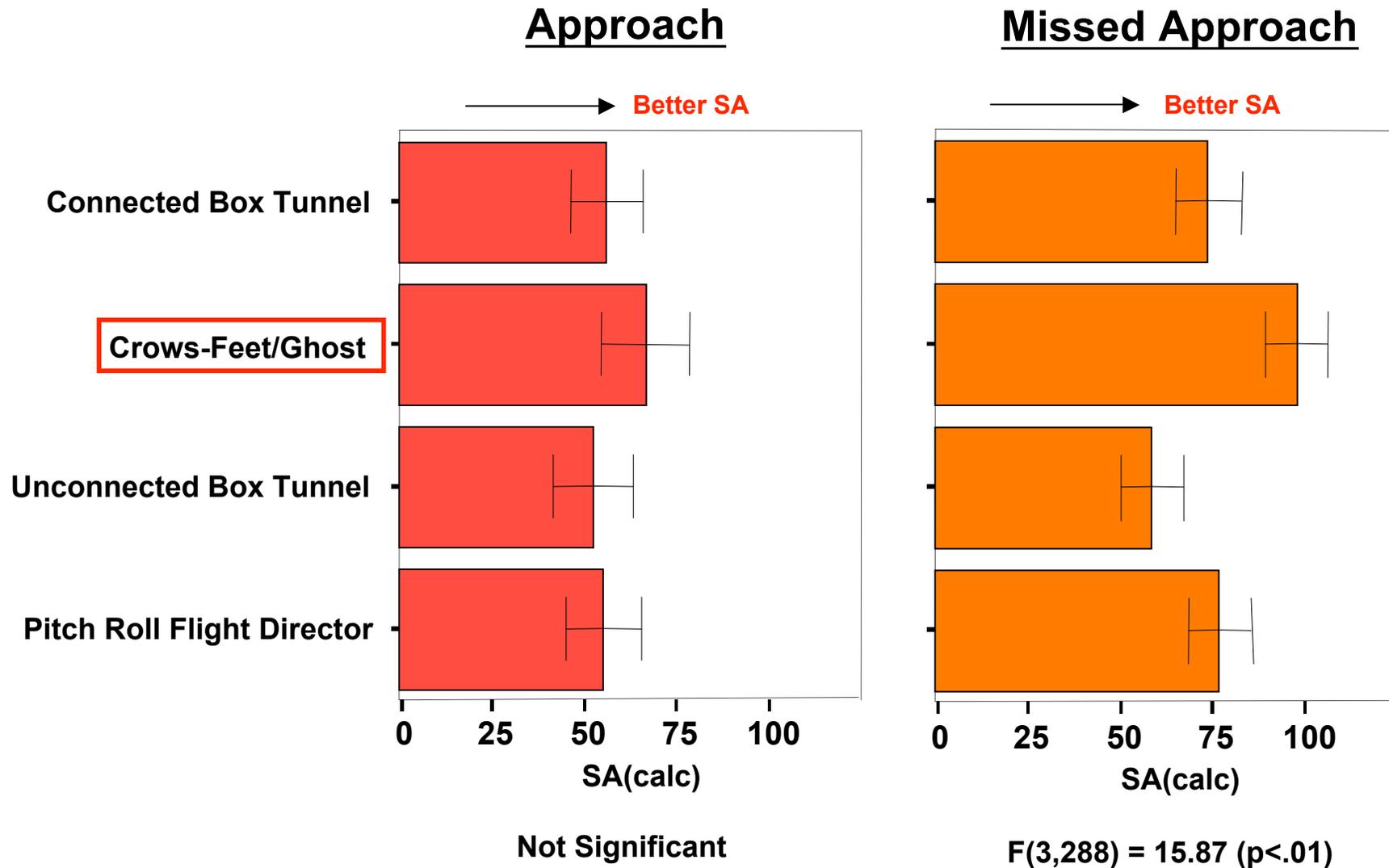
L1 Performance for by TPC

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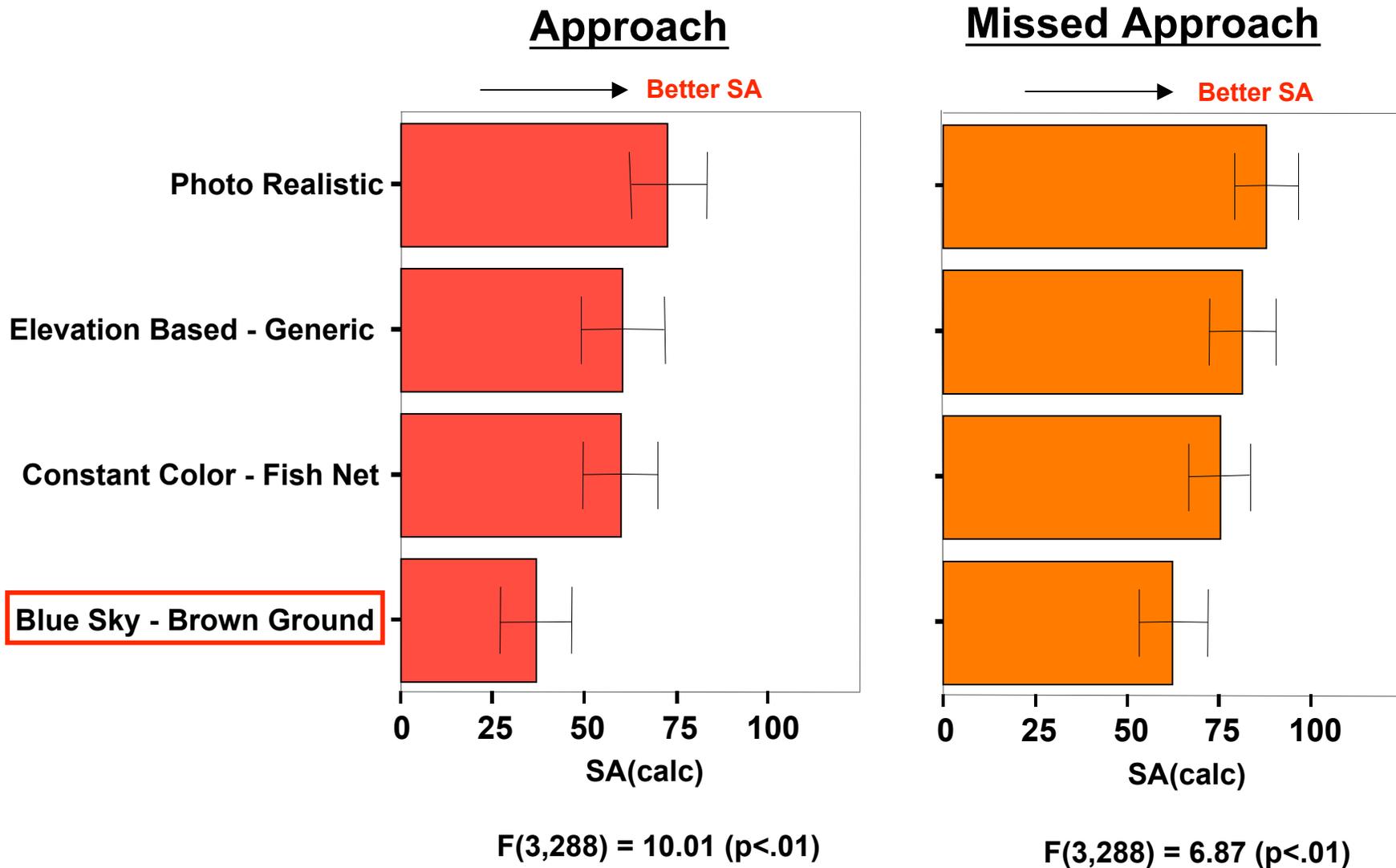
Mean SART Scores by GSC





Mean SART Scores by TPC

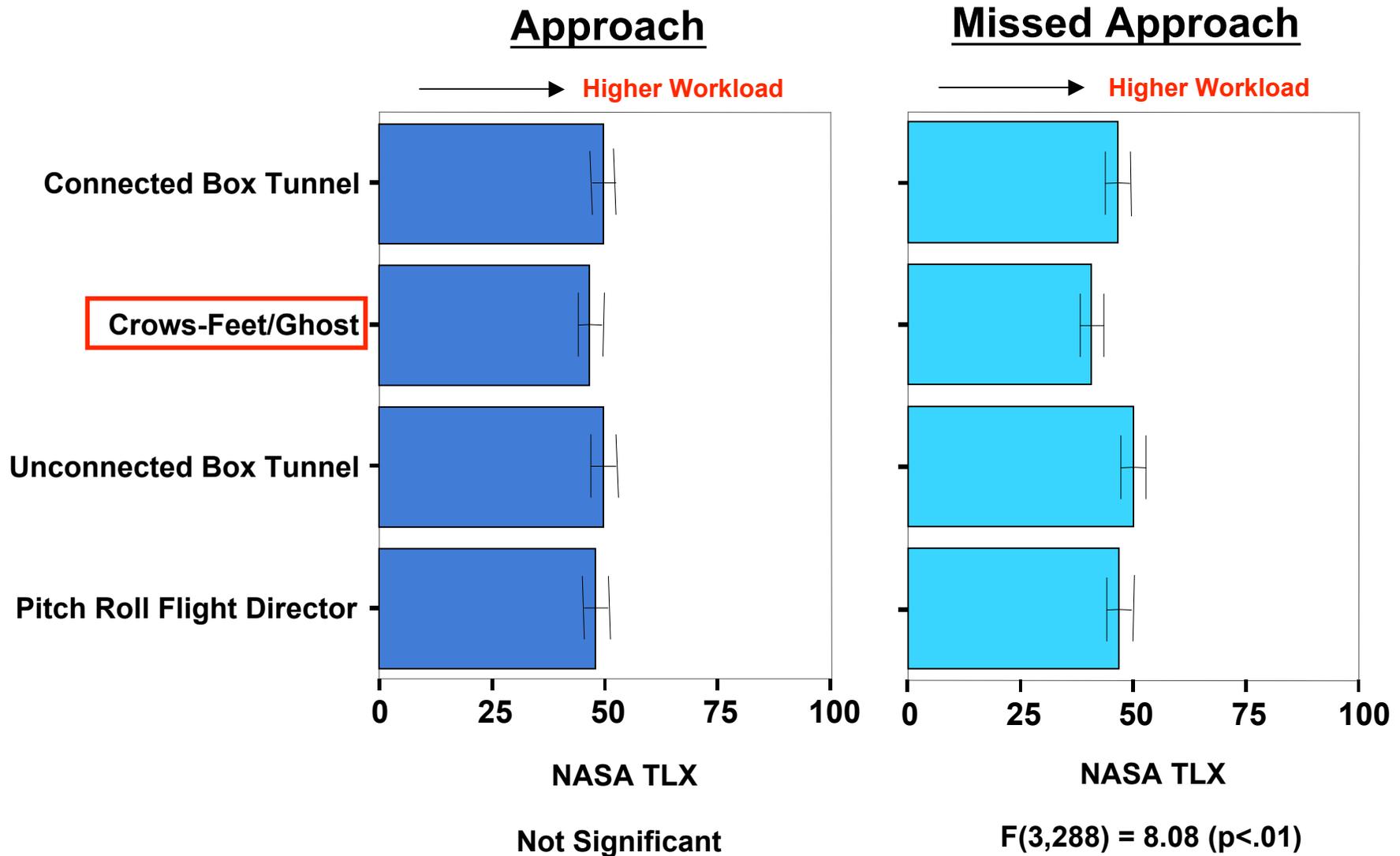
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Mean NASA-TLX Scores by GSC

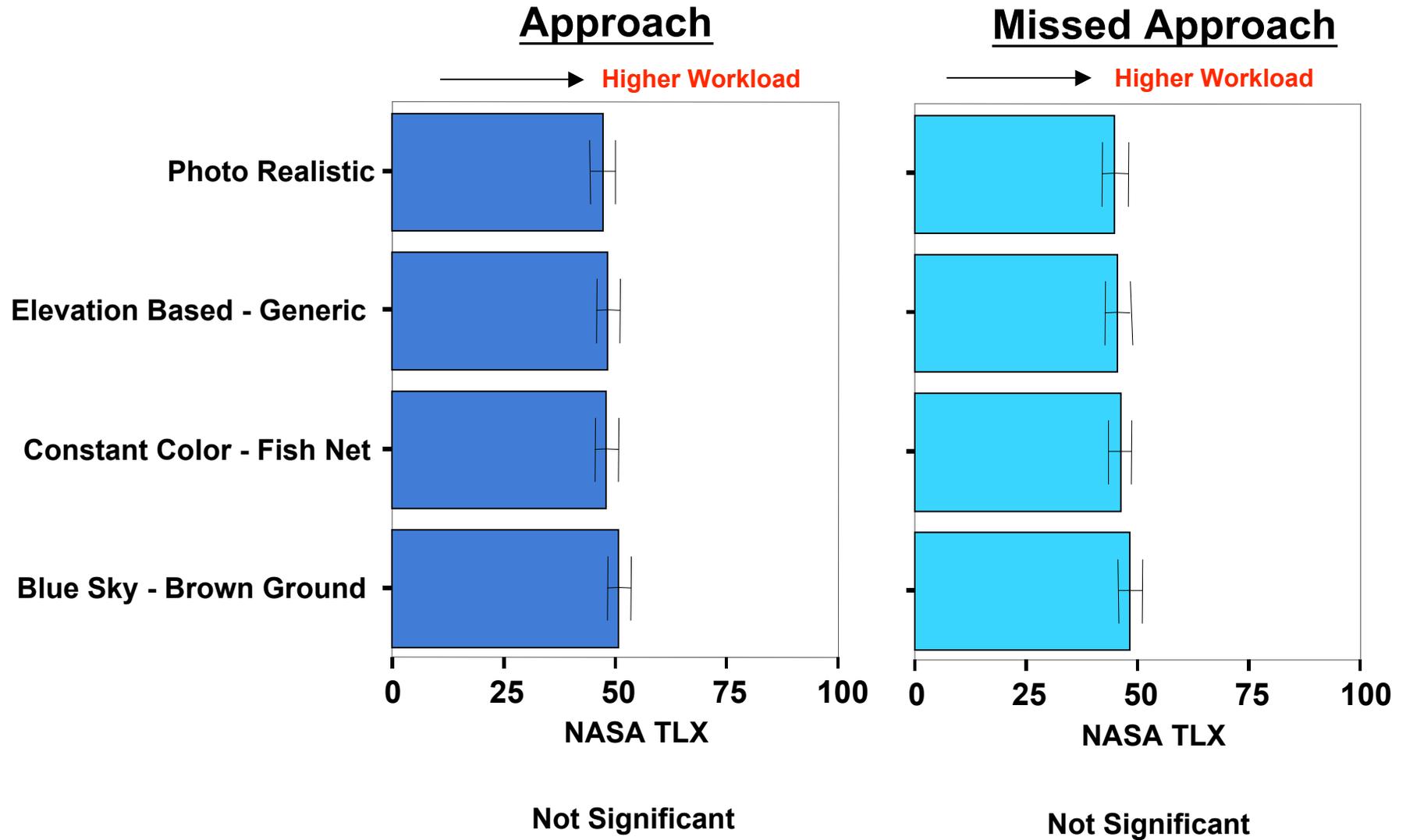
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Mean NASA-TLX Scores by TPC

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Subjective Rankings – Overall Preference

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Rank	Display Concept	Mean	Std. Dev.	Min	Max
1	Overall - PR w/ Crow Feet/Ghost	2.71	2.12	1	9
2	Overall - EBG w/ Crow Feet/Ghost	3.24	1.37	1	6
3	Overall - PR w/ P/RFD	4.10	3.06	1	11
4	Overall - EBG w/ P/RFD	4.76	3.08	1	10
5	Overall - CCFN w/ Crow Feet/Ghost	5.48	3.06	1	10
6	Overall - CCFN w/ P/RFD	7.24	3.25	3	14
7	Overall - PR w/ Connected Box Tun	7.20	3.12	2	15
8	Overall - PR w/ Unconnected Box Tun	8.00	3.00	2	14
9	Overall - EBG w/ Connected Box Tun	8.57	2.44	3	13
10	Overall - EBG w/ Unconnected Box Tun	8.90	3.10	3	16
11	Overall - CCFN w/ Connected Box Tun	10.19	2.96	2	15
12	Overall - CCFN w/ Unconnected Box Tun	10.71	2.57	4	13
13	Overall - BSBG w/ Crow Feet/Ghost	11.57	3.34	4	14
14	Overall - BSBG w/ P/RFD	13.19	2.18	7	16
15	Overall - BSBG w/ Connected Box Tun	14.90	1.14	11	16

Friedman's Non-Parametric Test	
N	21.00
Chi-Square	214.49
df	15.00
Asymp. Sig.	0.00

Summary of Observations



- **GSC**
 - **Crows-Feet/Ghost** had the best L1 performance in the Approach scenario
 - **Crows-Feet/Ghost** was similar to the **PRFD** in L1 performance in the MA scenario
 - None of the GSCs provided significantly better SA in the Approach scenario
 - **Crows-Feet/Ghost** had significantly better SA in the MA scenario
 - None of the GSCs provided significantly lower workload in the Approach scenario
 - **Crows-Feet/Ghost** had the lowest workload in the MA scenario
- **TPC**
 - **BSBG** had significantly lower SA in both the Approach and MA scenarios
 - None of the TPCs provided significantly better L1 performance or lower workload in both the Approach and the MA scenarios

Summary



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- **Conducted Testing to establish the interactions between GSCs and TPCs for advanced approach and missed-approach operations**
- **Extended previous SVS results from TP-HDD for TPCs and GSCs**
- **Preliminary results indicate:**
 1. **No interactions between TPC and GSC**
 2. **GSCs do affect pilot performance**
 3. **Crows-Foot Tunnel/Ghost Plane is better than PRFD for these maneuvers**
 4. **Presence of SVS terrain improves SA and does not adversely affect pilot performance and workload**
 5. **EBG and PR texturing concepts are preferred to BSBG and CCFN**
- **Plans: Complete data analyses, publish conference papers and NASA reports**



SD-HDD Experiment

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Experiment B: Merrill Pass simulations