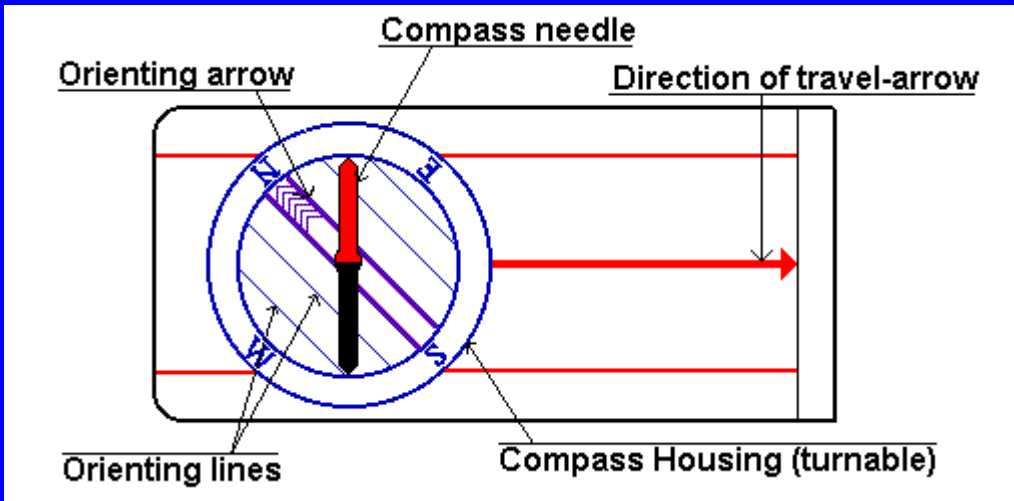
Challenges UAV operators face in maintaining spatial orientation

Lee Gugerty
Clemson University



Overview

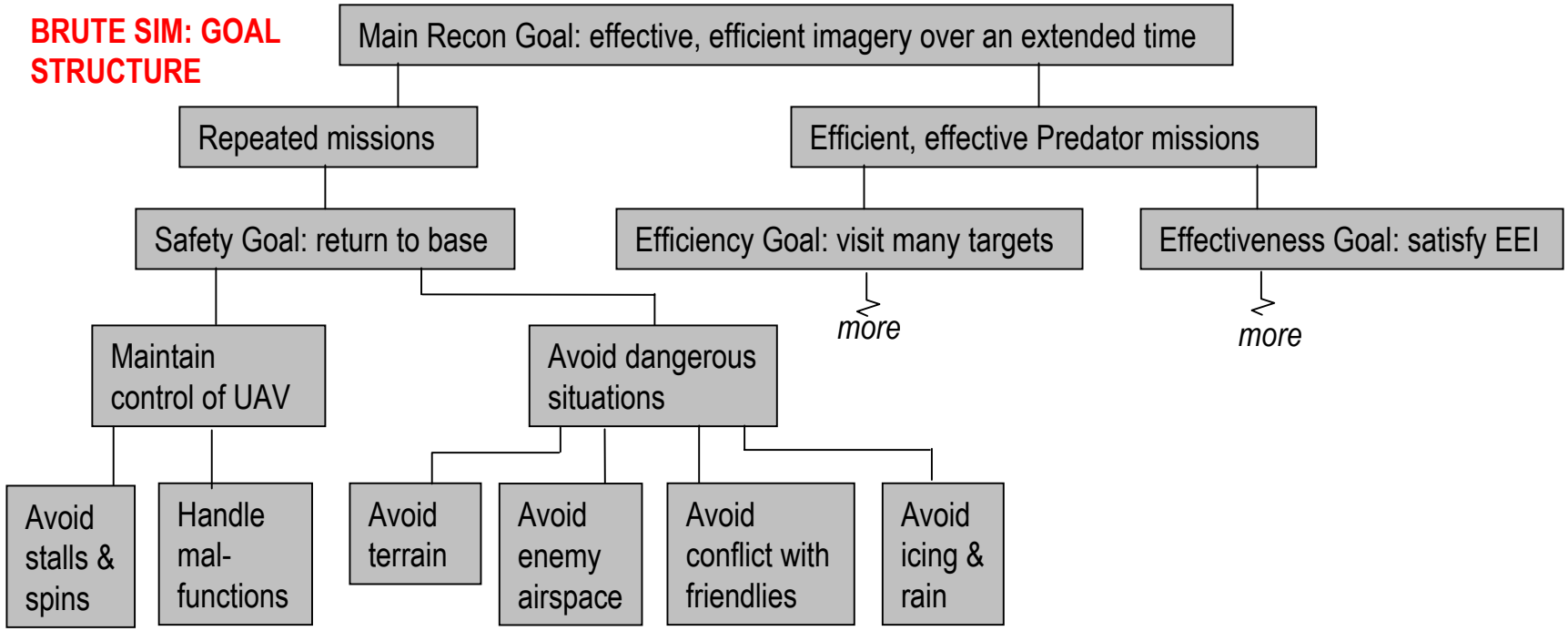
- Task analysis of Predator UAV operations
  - UAV synthetic task
  - Spatial orientation challenges
- Data on spatial orientation challenges
  - From experiments and protocol studies
- Applications
  - Training
  - Interface design

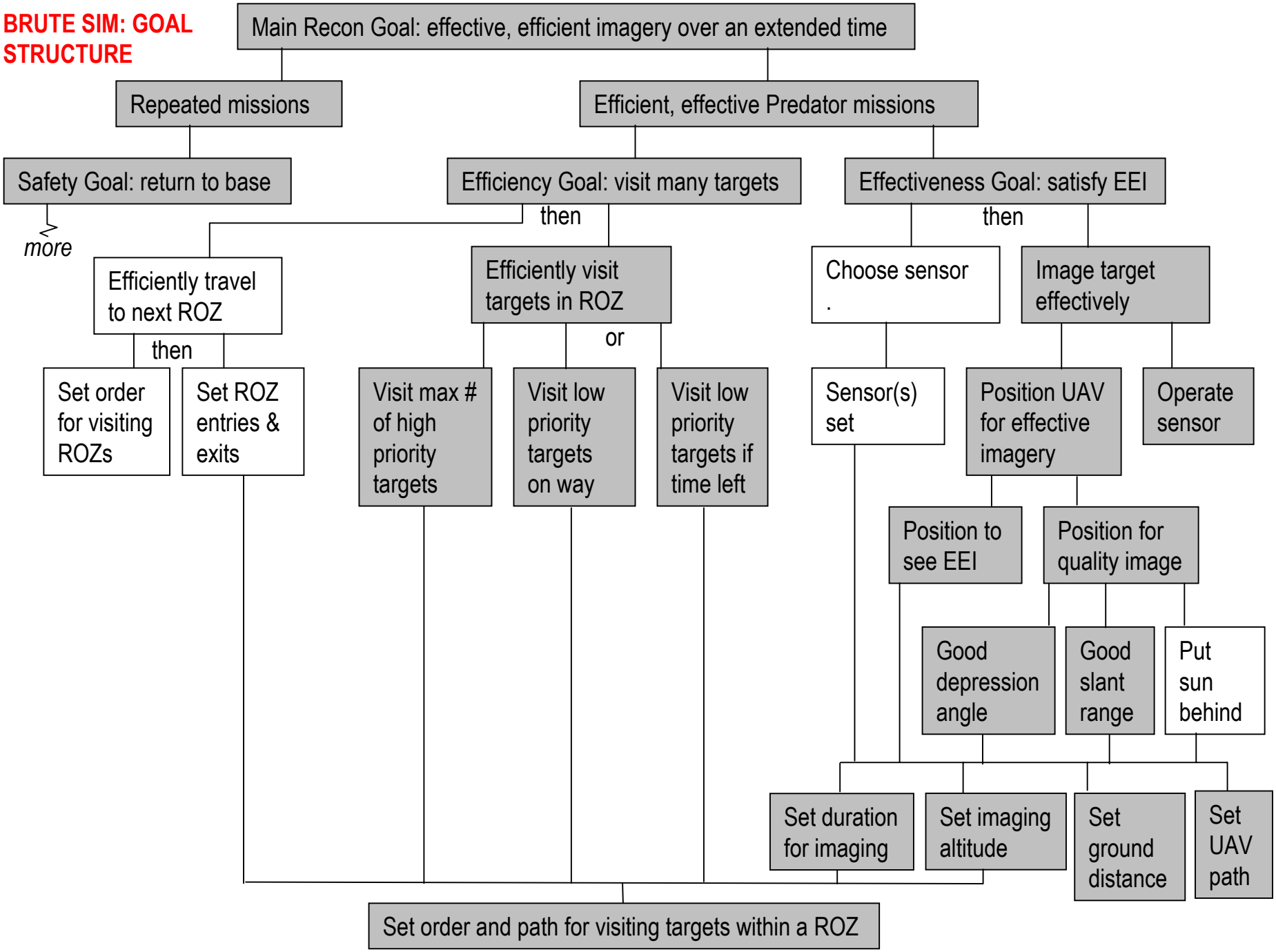
Cognitive Task Analysis

Predator UAV reconnaissance operations

- Structured interviews
- Air Force UAV trainers and UAV trainees
  - 7 pilots
  - 12 sensor operators / mission planners

BRUTE SIM: GOAL STRUCTURE




BRUTE SIM: GOAL STRUCTURE
Main Recon Goal: effective, efficient imagery over an extended time
Repeated missions
Efficient, effective Predator missions
Safety Goal: return to base
Efficiency Goal: visit many targets
Effectiveness Goal: satisfy EEI
more
then
then
Efficiently travel to next ROZ
Efficiently visit targets in ROZ
Choose sensor .
Image target effectively
then
or
Set order for visiting ROZs
Set ROZ entries & exits
Visit max # of high priority targets
Visit low priority targets on way
Visit low priority targets if time left
Sensor(s) set
Position UAV for effective imagery
Operate sensor
Position to see EEI
Position for quality image
Good depression angle
Good slant range
Put sun behind
Set duration for imaging
Set imaging altitude
Set ground distance
Set UAV path
Set order and path for visiting targets within a ROZ

Goal Constraints

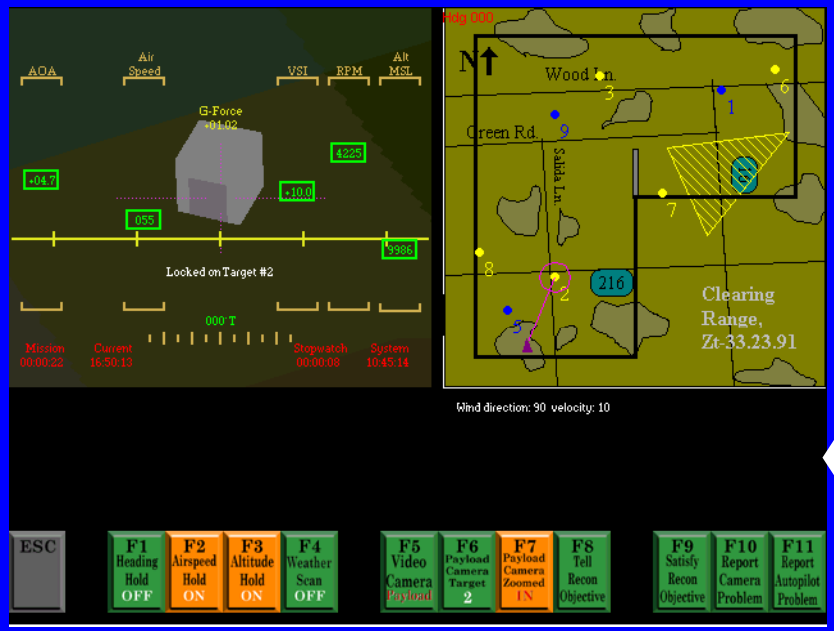
Constraints on Mission Planning (within restricted zones)

- Wind speed and direction
- Clouds occluding targets
- Clouds and storms in UAV's path
- Ad hoc targets
- Target layout
- ROZ entry and exit points
- Imaging altitude for individual targets
- Terrain height
- Shape of ROZ box
- Sensors needed for individual targets
- Target priority
- Time for occupying ROZ box
- Time for imaging individual targets
- UAV speed

Synthetic Task - BRUTE

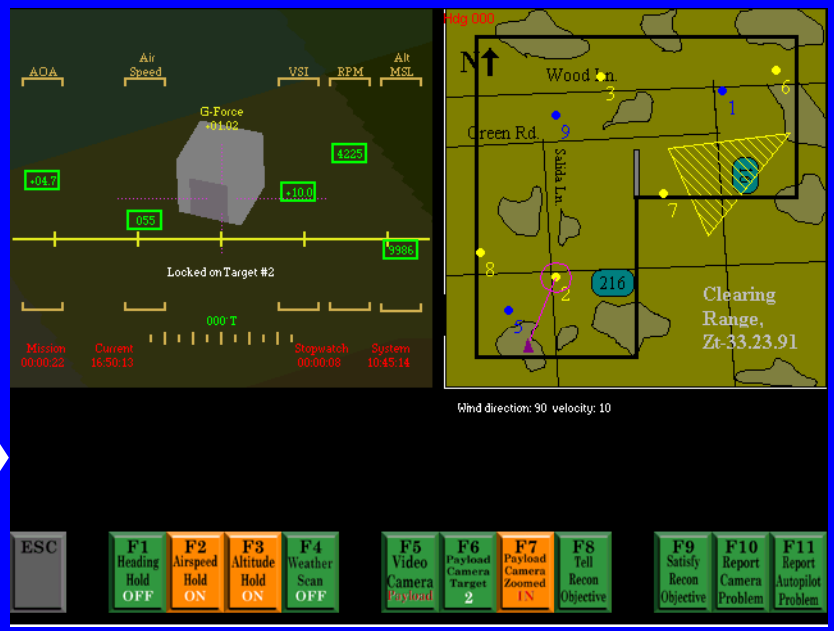
Basic Research UAV Task Environment

Pilot Station



Joystick flies aircraft

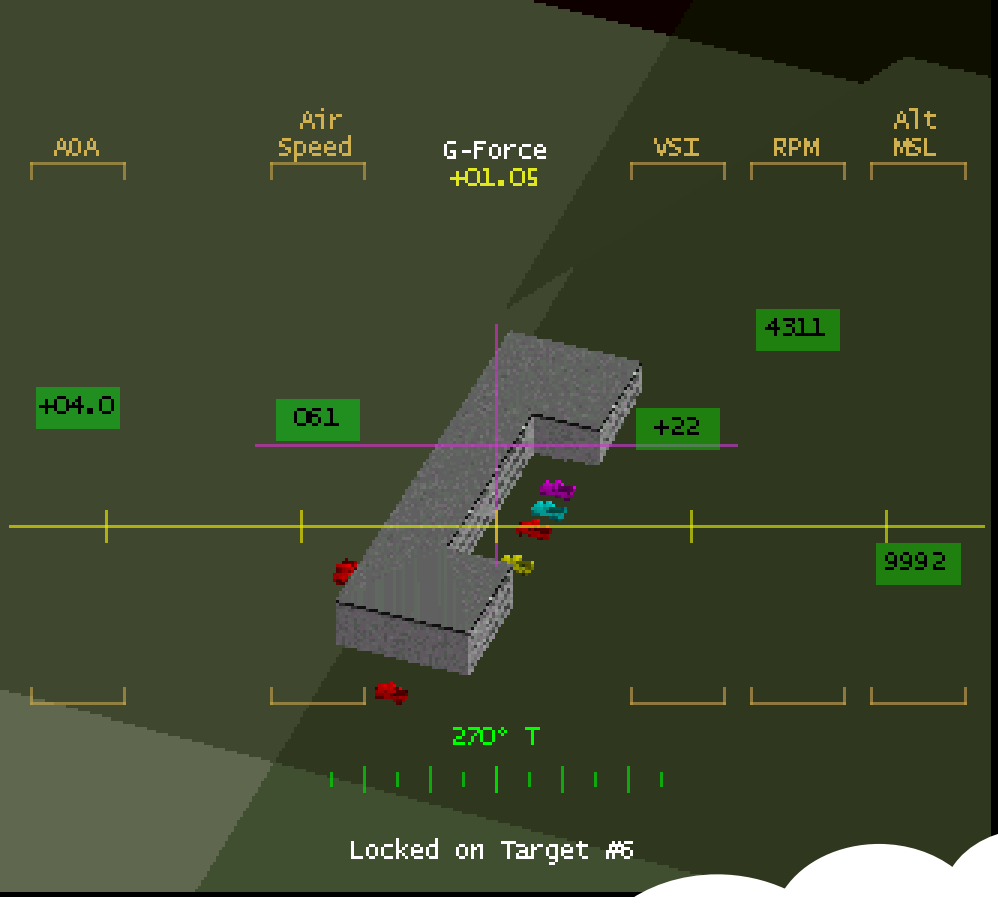
Camera Operator Station

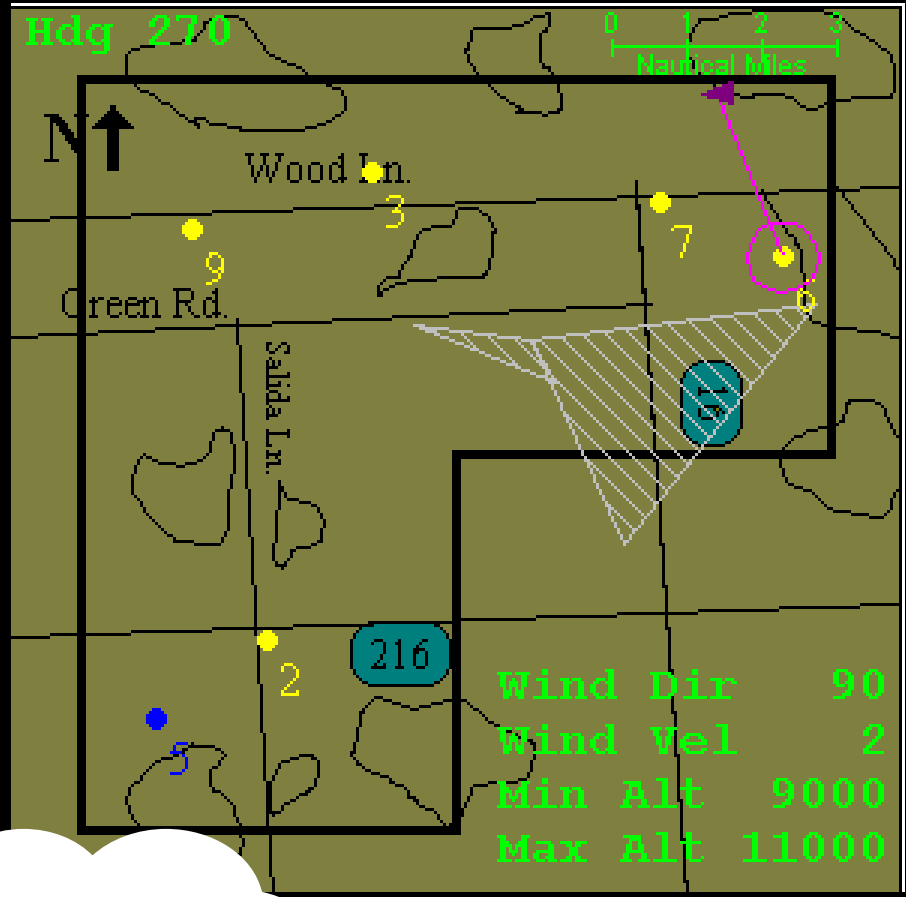


Joystick controls camera

Cognitive Task Analysis: UAV Spatial-Orientation Challenges

- Directing the aircraft and camera
- Using cardinal directions to locate targets





00:23:44

Points
Gained 0
Lost 0
Total 0

Should camera operator point camera right or left to view target 7 ?

ESC

F1 Heading Hold OFF

F2 Airspeed Hold OFF

F3 Altitude Hold OFF

Camera Payload

Camera Target 6

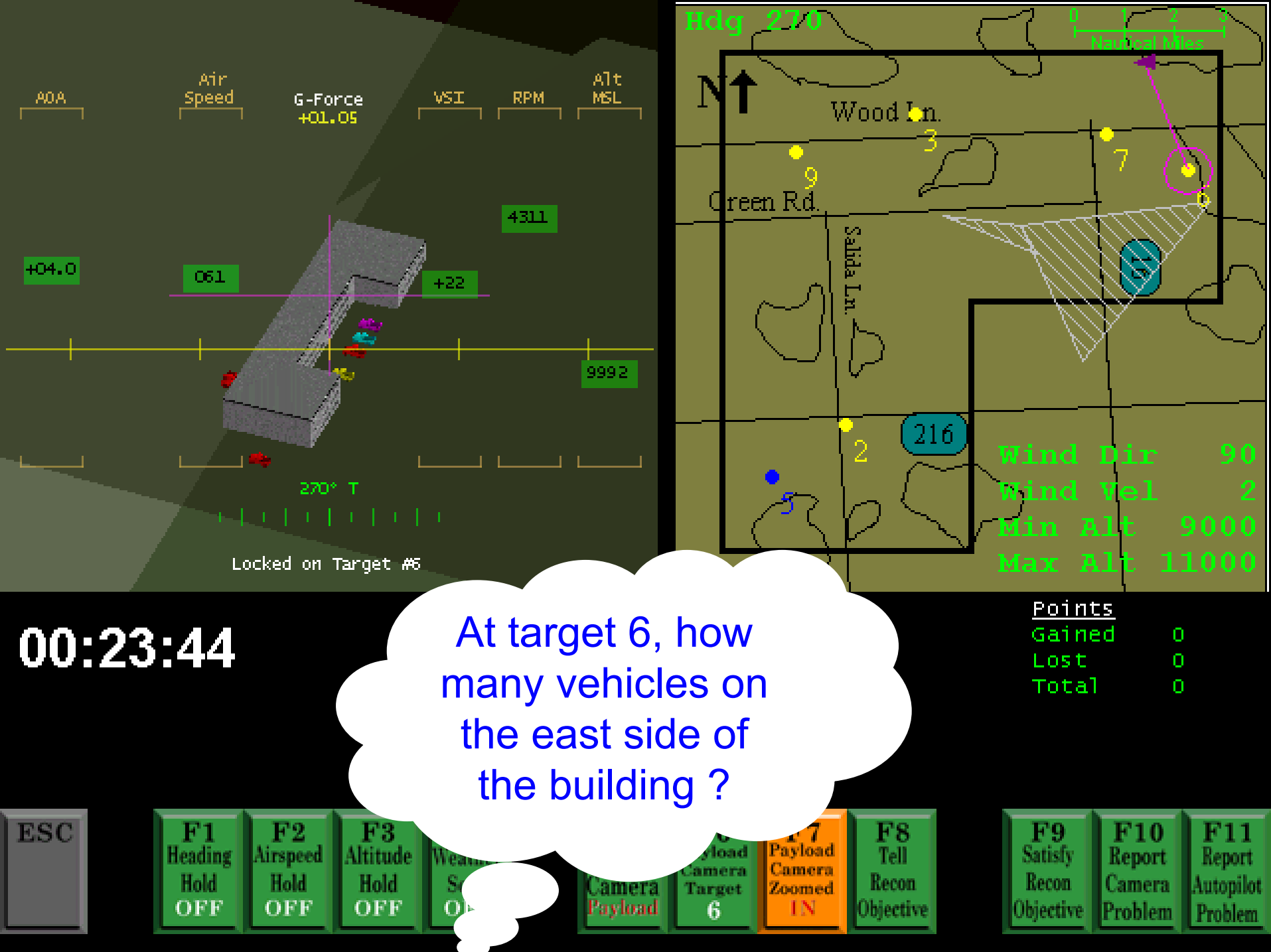
F7 Payload Camera Zoomed IN

F8 Tell Recon Objective

F9 Satisfy Recon Objective

F10 Report Camera Problem

F11 Report Autopilot Problem


AOA
Air Speed
G-Force +01.05
VSI
RPM
Alt MSL
4311
+04.0
061
+22
9992
270° T
Locked on Target #6
Hdg 270
0 1 2 3
Nautical Miles
N
Wood Ln.
Green Rd.
Salida Ln.
3
7
9
6
2
5
216
Wind Dir 90
Wind Vel 2
Min Alt 9000
Max Alt 11000
00:23:44
Points
Gained 0
Lost 0
Total 0
At target 6, how many vehicles on the east side of the building ?
ESC
F1 Heading Hold OFF
F2 Airspeed Hold OFF
F3 Altitude Hold OFF
Camera Payload
Camera Target 6
F7 Payload Camera Zoomed IN
F8 Tell Recon Objective
F9 Satisfy Recon Objective
F10 Report Camera Problem
F11 Report Autopilot Problem

Cognitive Task Analysis: UAV Spatial-Orientation Challenges

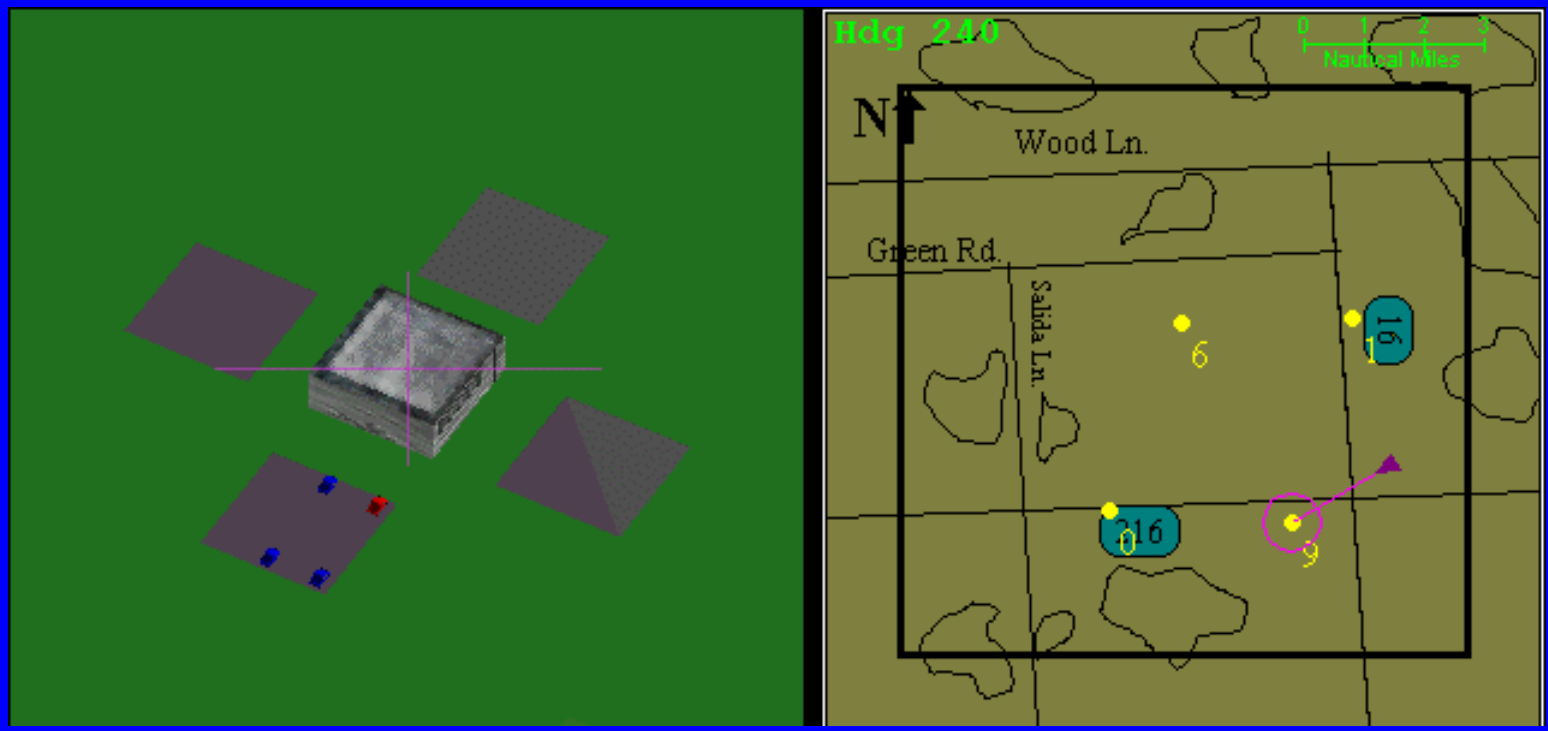
- Challenging spatial tasks:
  - Directing the aircraft and camera
  - Using cardinal directions to locate targets
- Little training
- Exacerbated by UAV characteristics:
  - Smaller visual field of view
  - Lessened vestibular & kinesthetic feedback

Overview

- Task analysis of Predator UAV operations
  - UAV synthetic tasks
  - Spatial orientation challenges
- Data on spatial orientation challenges
  - From experiments and protocol studies
  - Focusing on cardinal direction task
- Applications
  - Training
  - Interface design

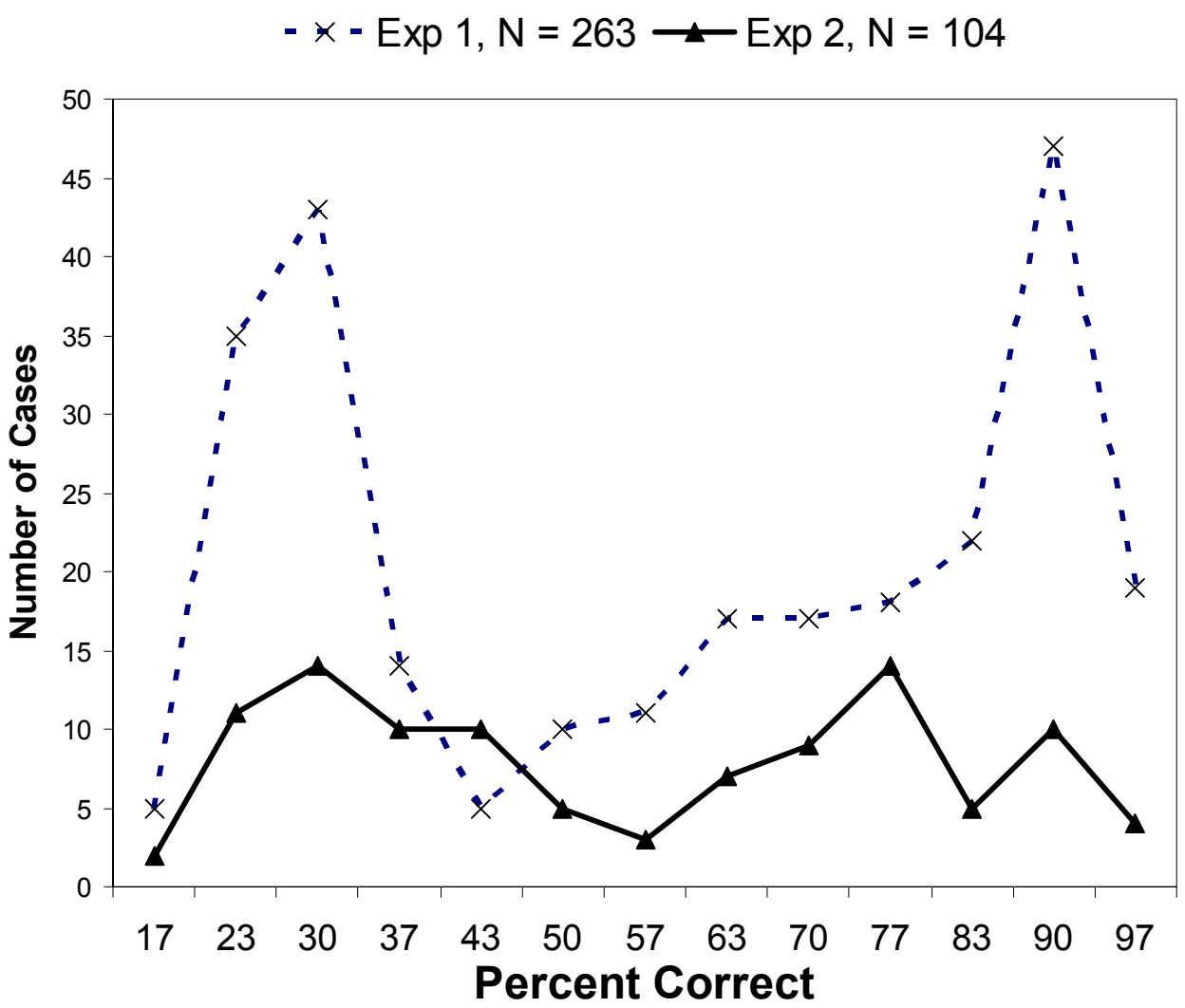
Data on UAV spatial orientation tasks

- Cardinal direction task - static



Is the parking lot with cars North, South, East, or West of the building?

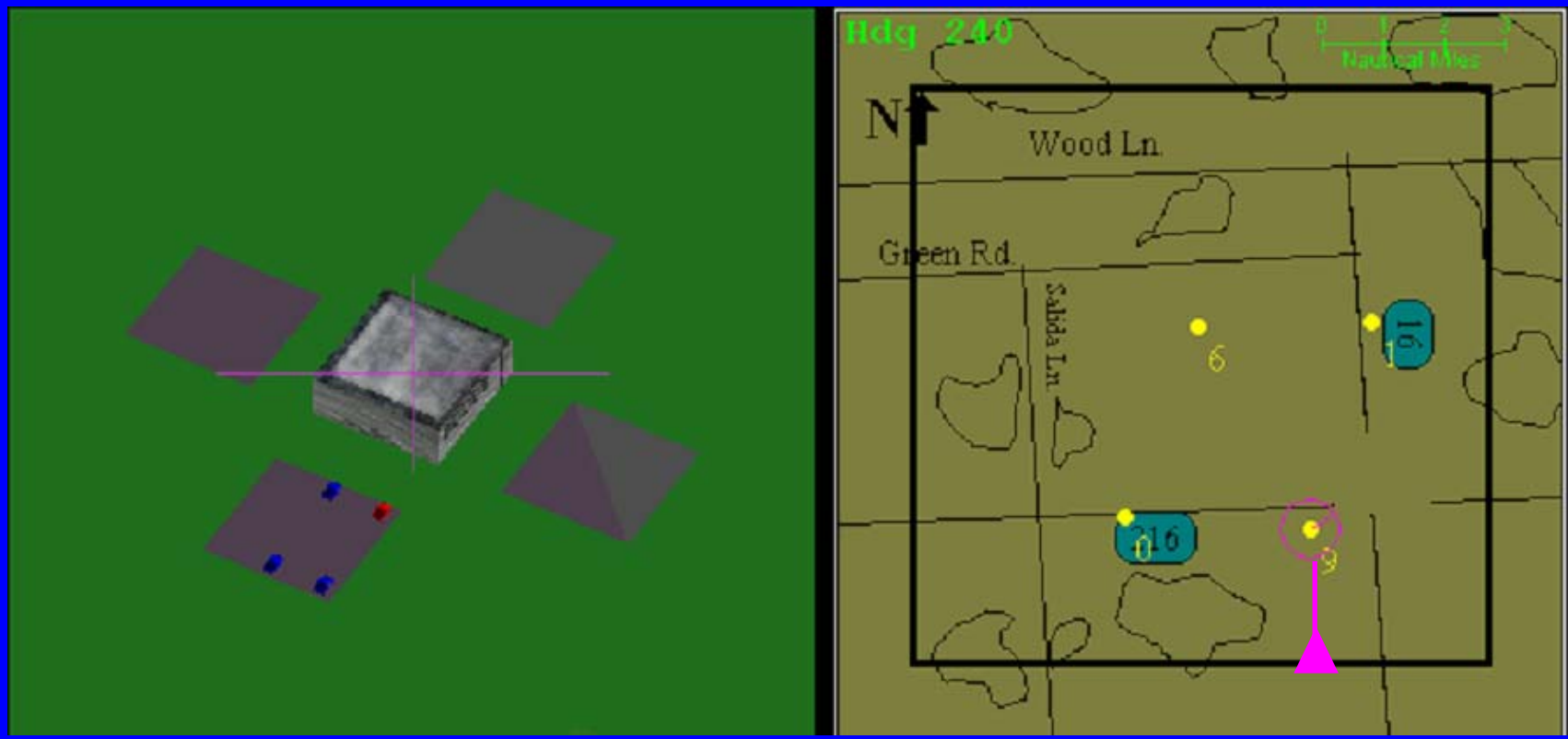
Cardinal direction task:
Histograms of accuracy for AF recruits



very poor performance for half the subjects

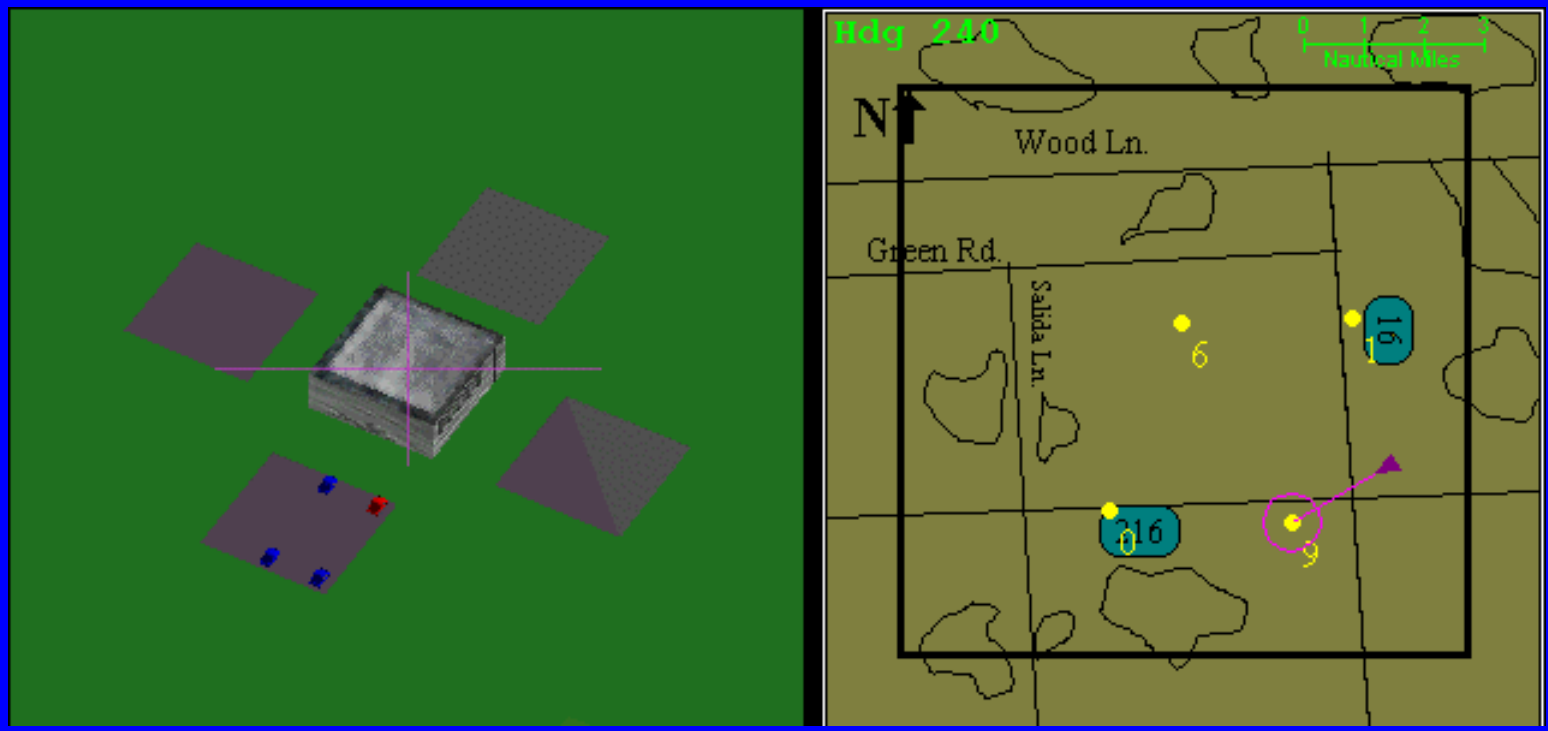
Effect of aircraft/camera heading

- EASY



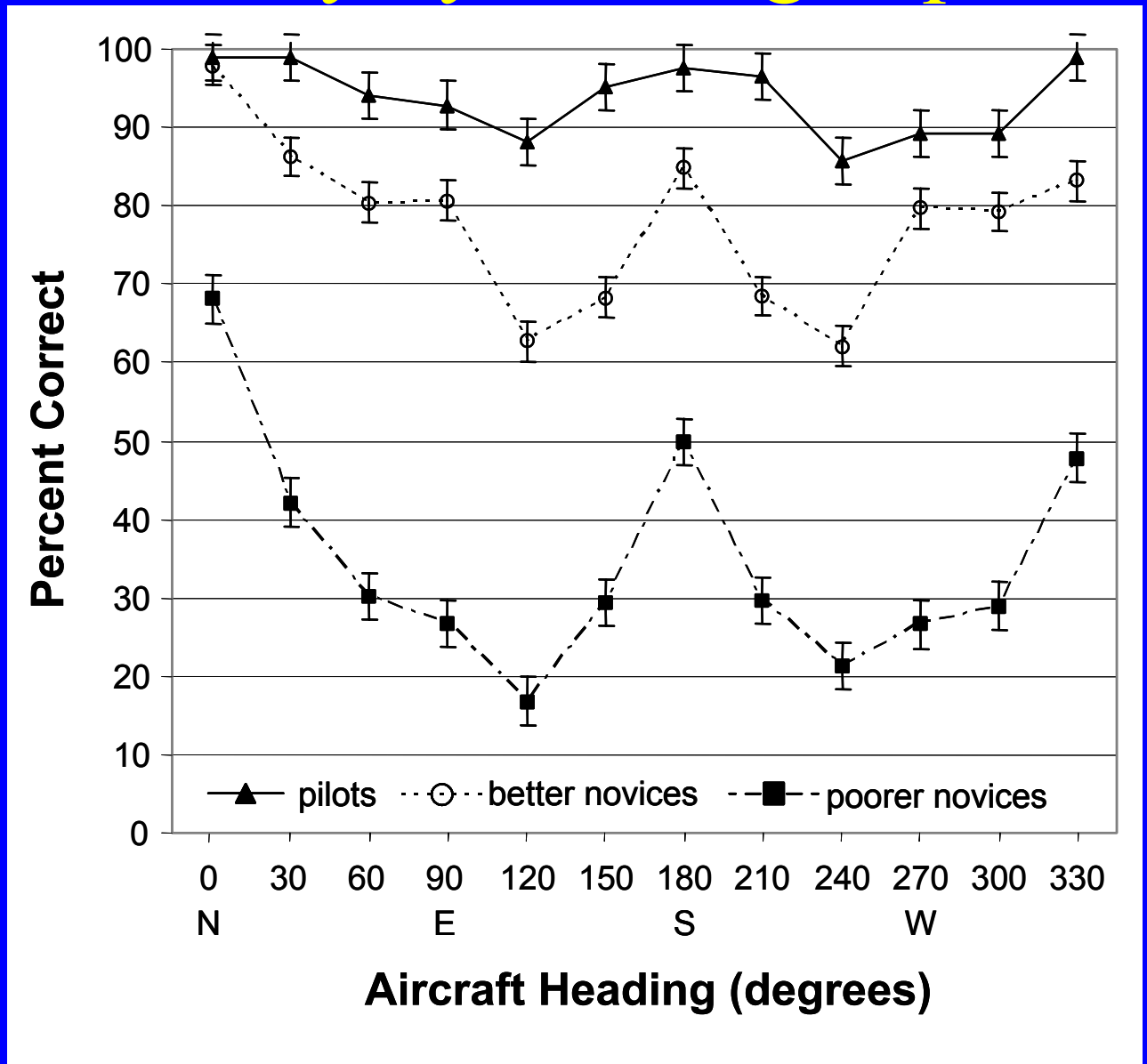
Effect of aircraft/camera heading

- HARD



Is the parking lot with cars North, South, East, or West of the building?

Cardinal direction task: Accuracy by heading expertise

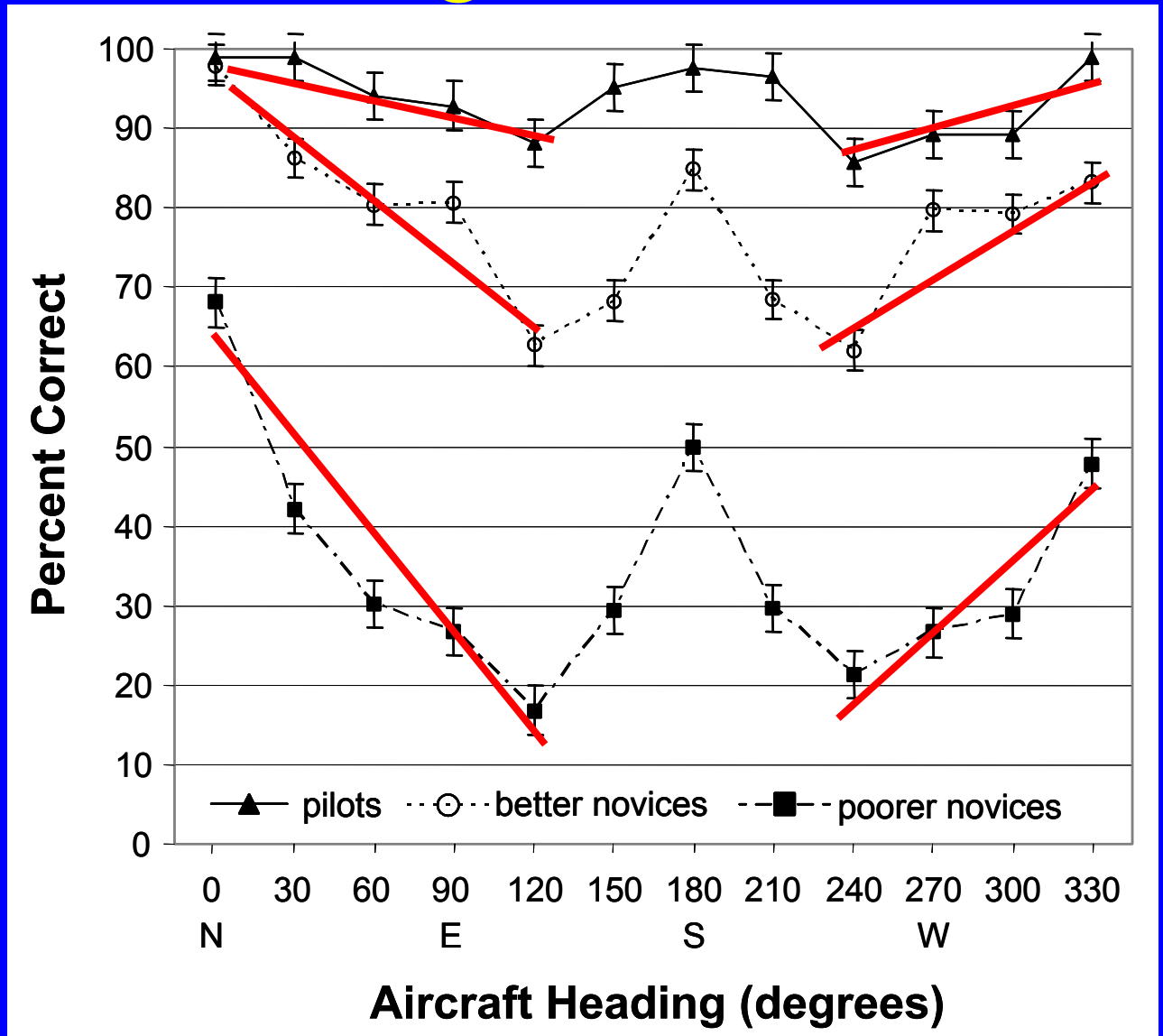


experts

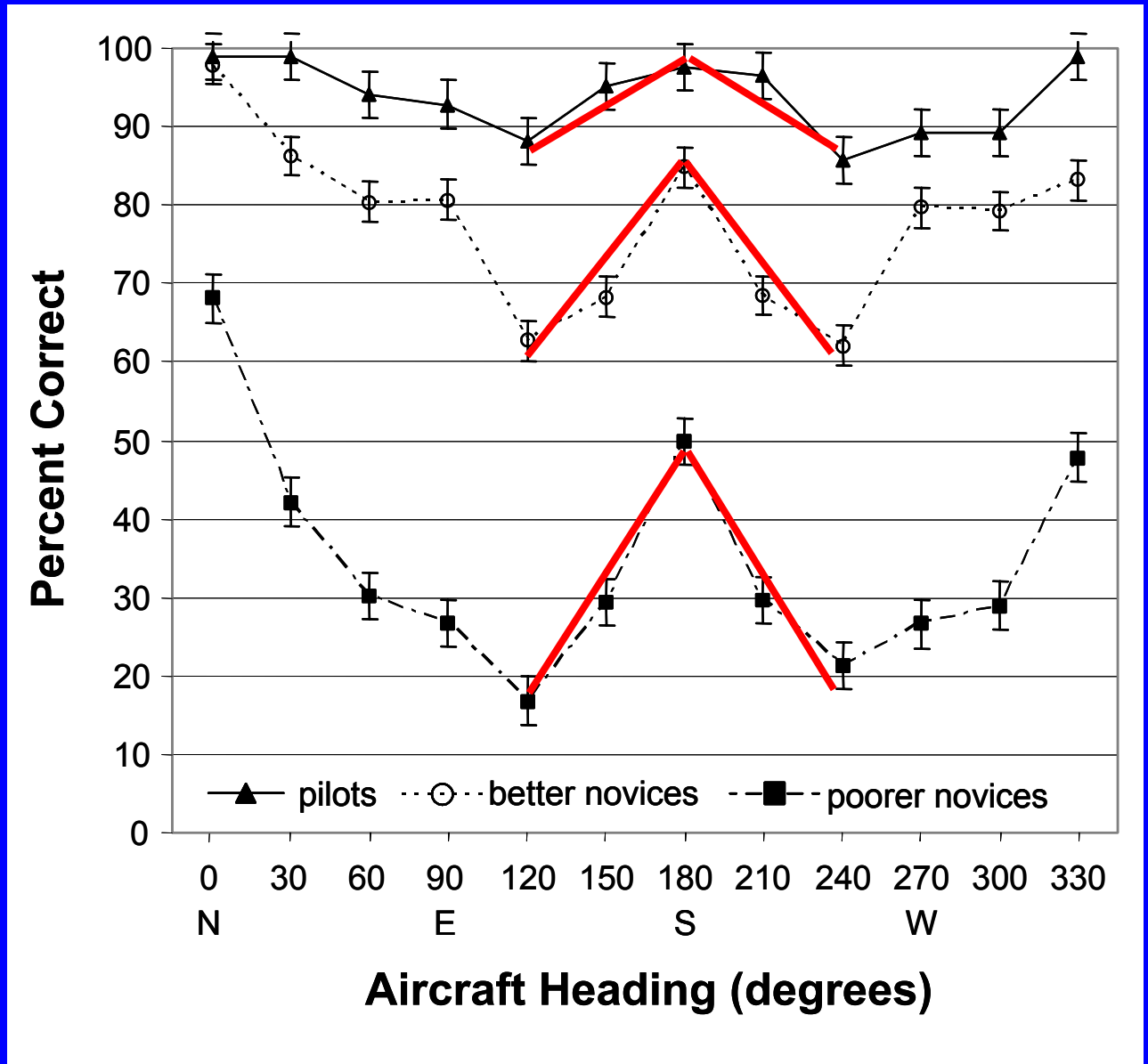
better novices

poorer novices

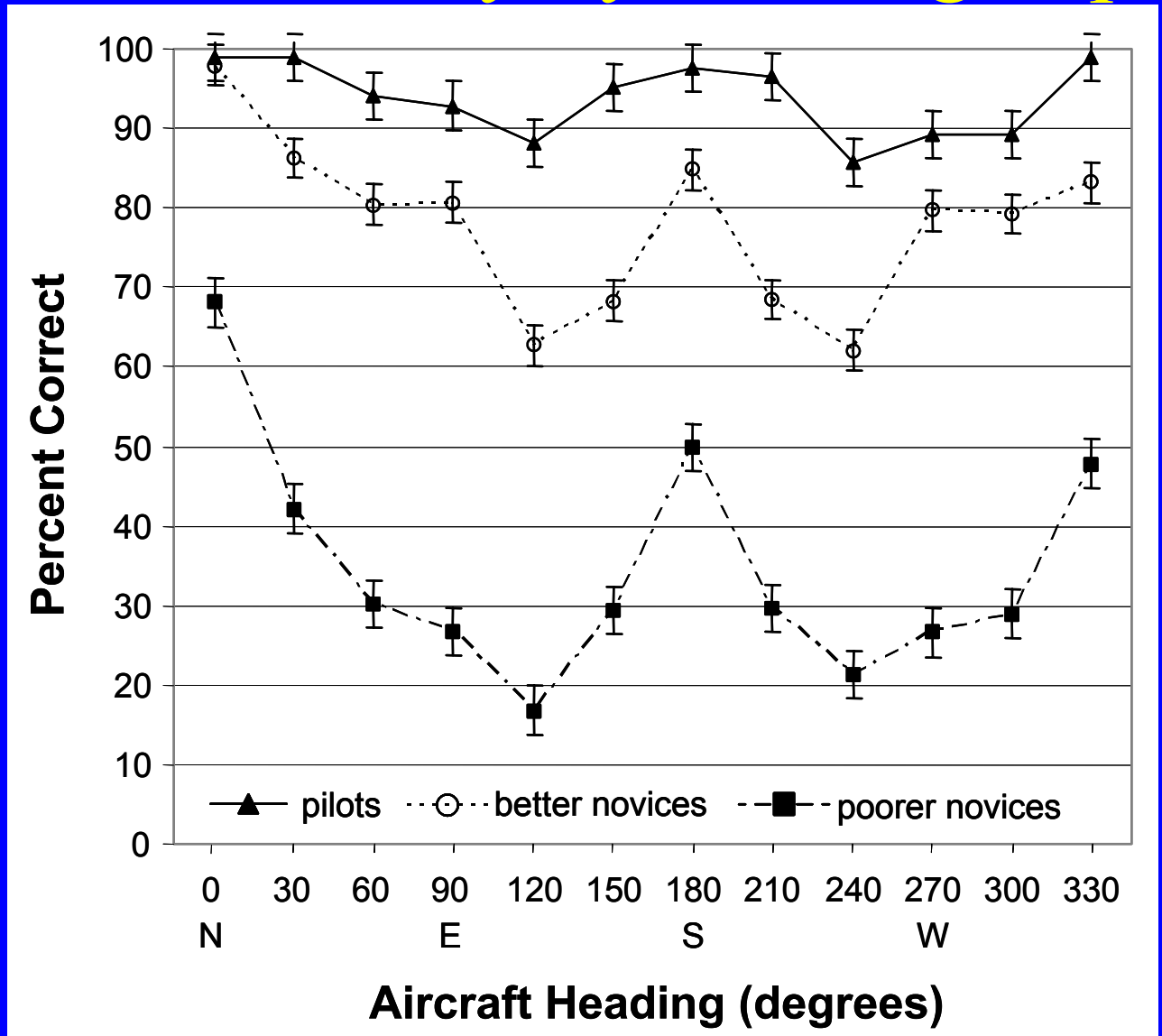
Cardinal direction task: Misalignment effects



Cardinal direction task: South reversal



Cardinal direction task: Accuracy by heading expertise



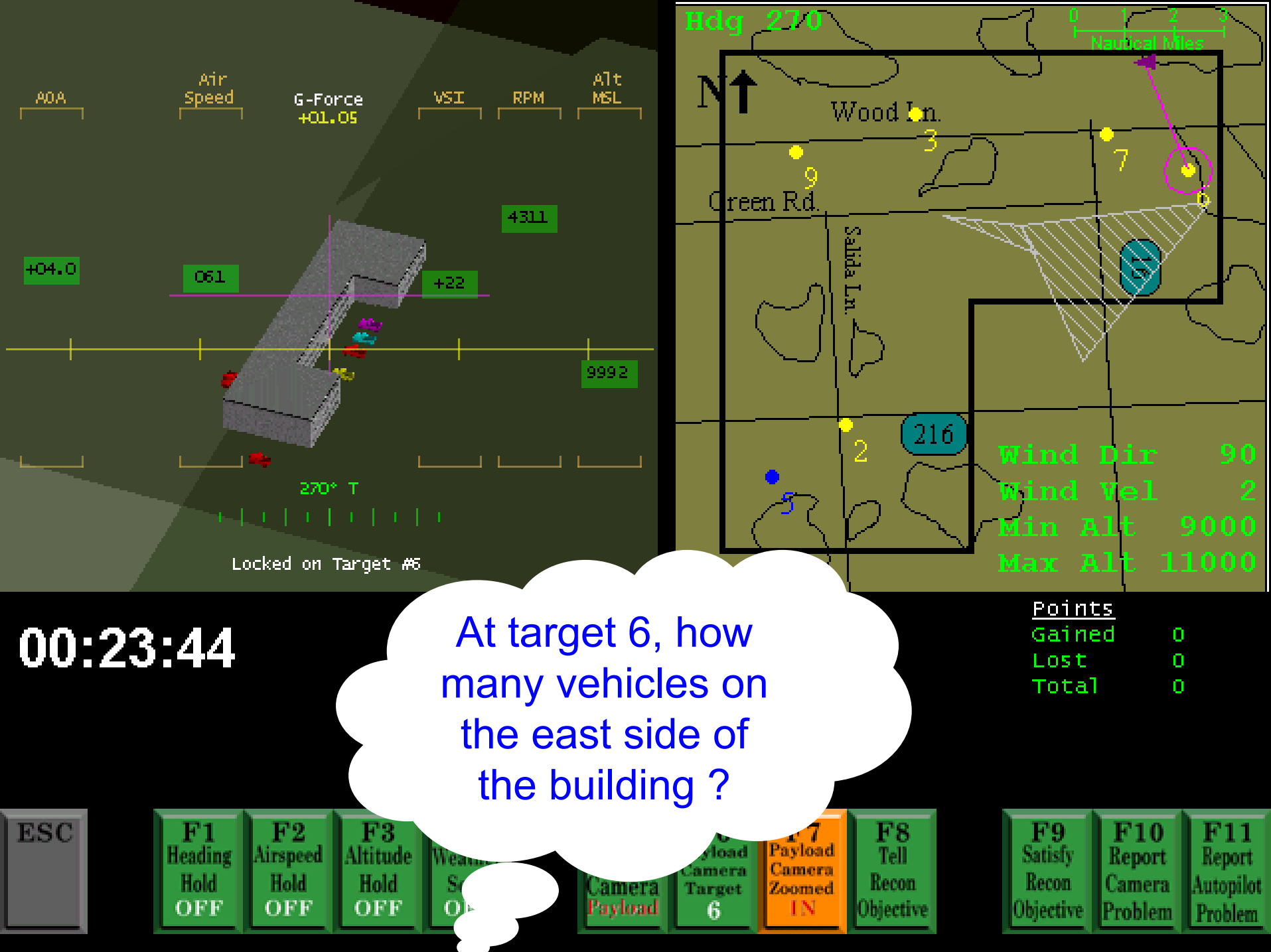
misalignment cuts accuracy by 10% to 70%

effects decrease with expertise

Misalignment effects with BRUTE UAV synthetic task

Task:

- plan route, visit targets, answer target questions
- some questions required cardinal direction judgments


AOA
Air Speed
G-Force +01.05
VSI
RPM
Alt MSL
4311
+04.0
061
+22
9992
270° T
Locked on Target #6
Hdg 270
0 1 2 3
Nautical Miles
N
Wood Ln.
Green Rd.
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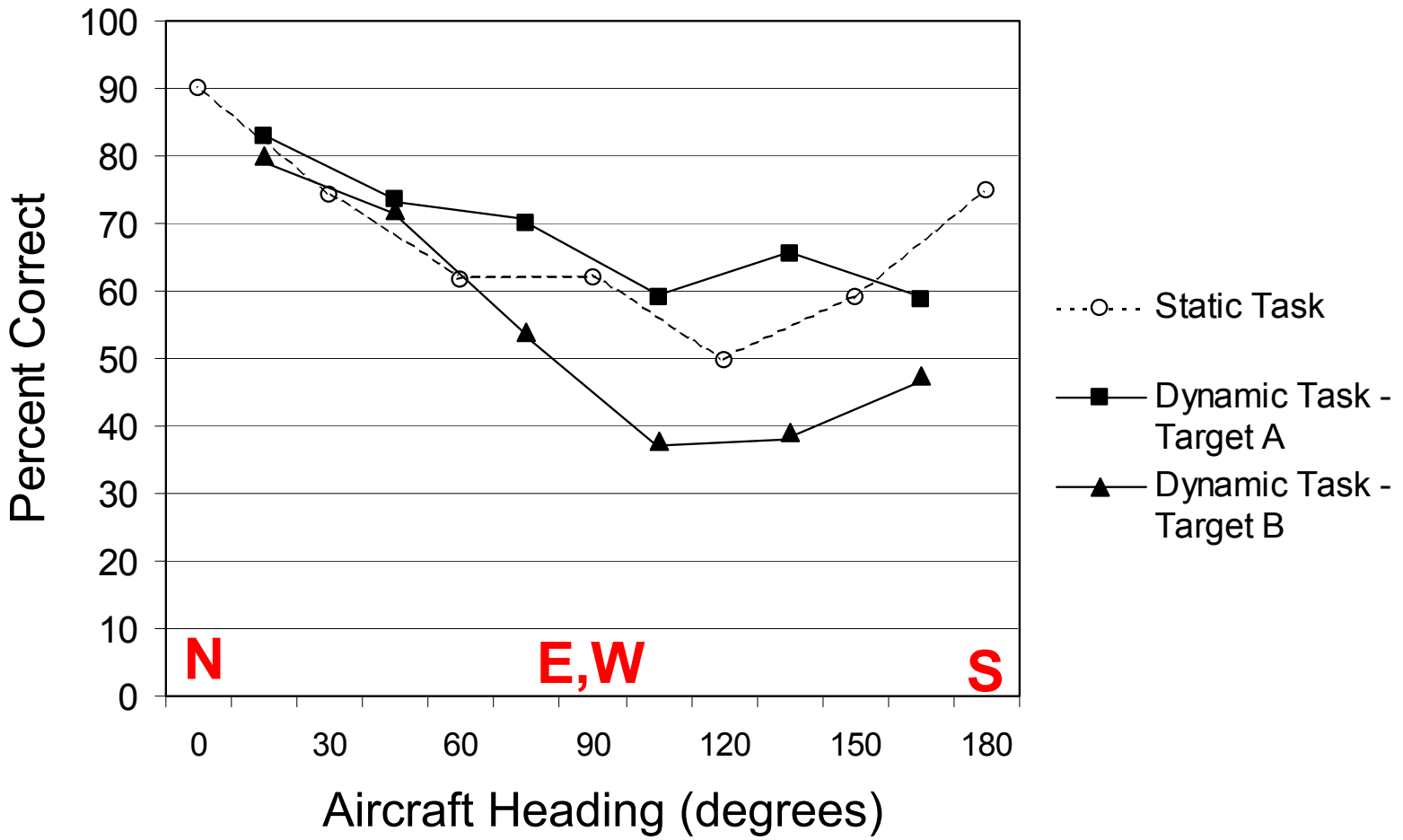
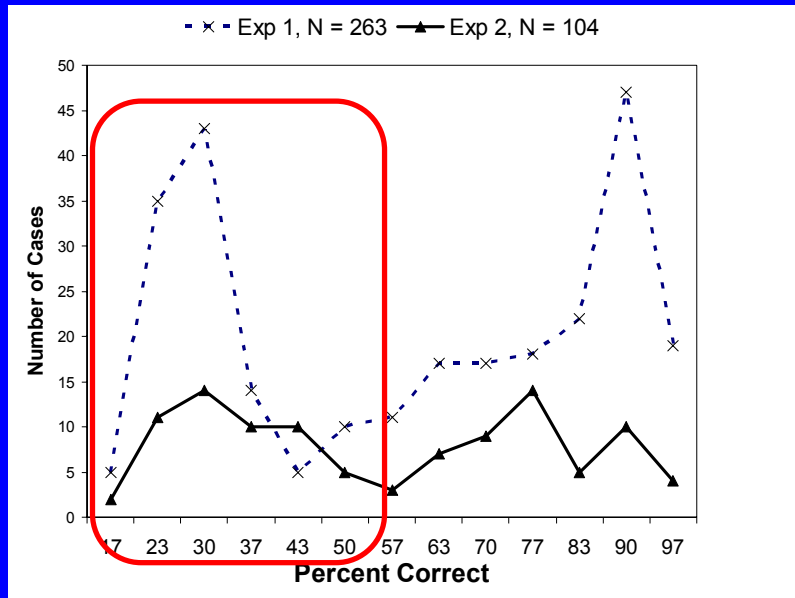
Effect of misalignment on cardinal direction accuracy with BRUTE



Data on UAV spatial orientation tasks

- Quantified effects of UAV spatial tasks
  - Direction of turn task
    - Misalignment ➔ slowing (1 s)
  - Cardinal direction task
    - Misalignment markedly decreases accuracy
      - up to a 70% decrease
      - also slows (e.g., doubles) RTs
    - Overall difficult task
      - Many novices close to chance



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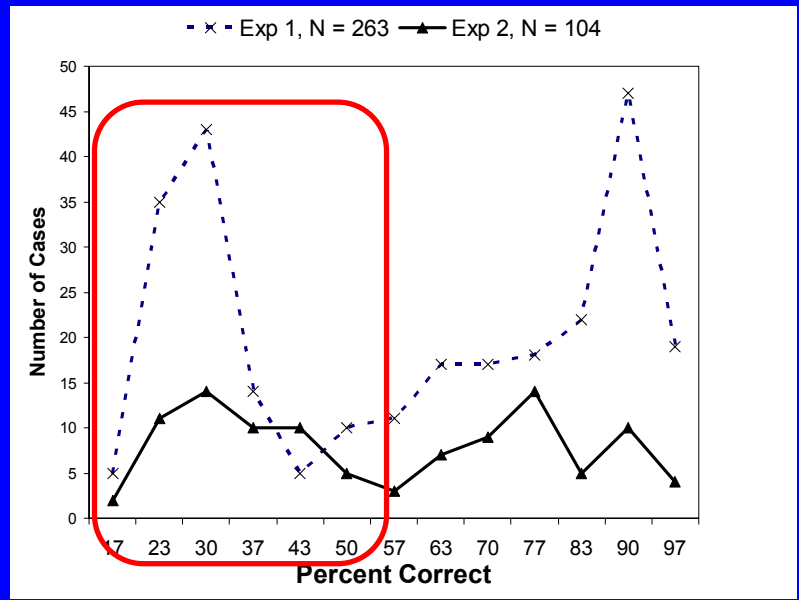
Need for training or interface aids, especially re misalignment



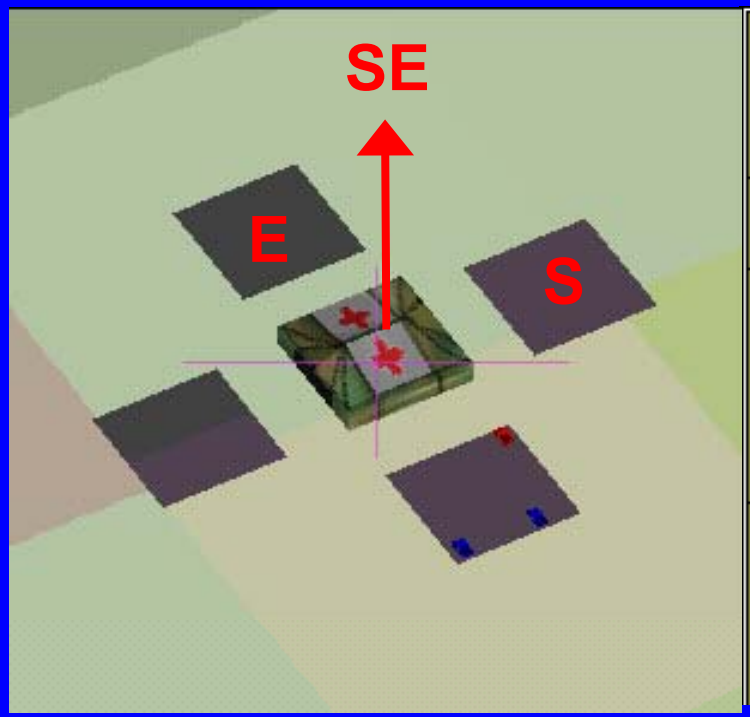
Mental strategies used on spatial orientation tasks

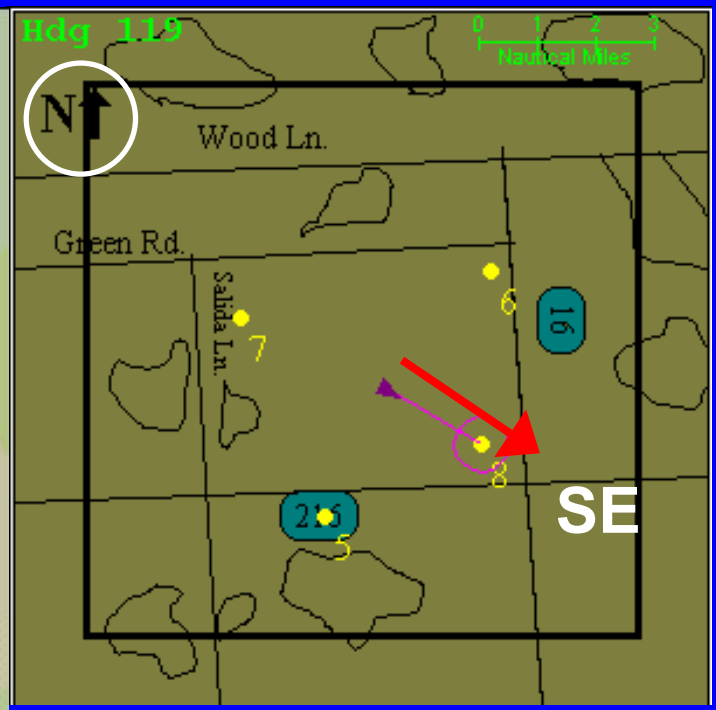
- Direction of turn task
  - Mental rotation (MR)
- Cardinal direction task
  - Specialized strategies
    - South reversal
  - General strategies
    - Mental rotation
    - Heading referencing

Heading Referencing

Is the parking lot with cars North, South, East, or West of the building?

Heading Referencing





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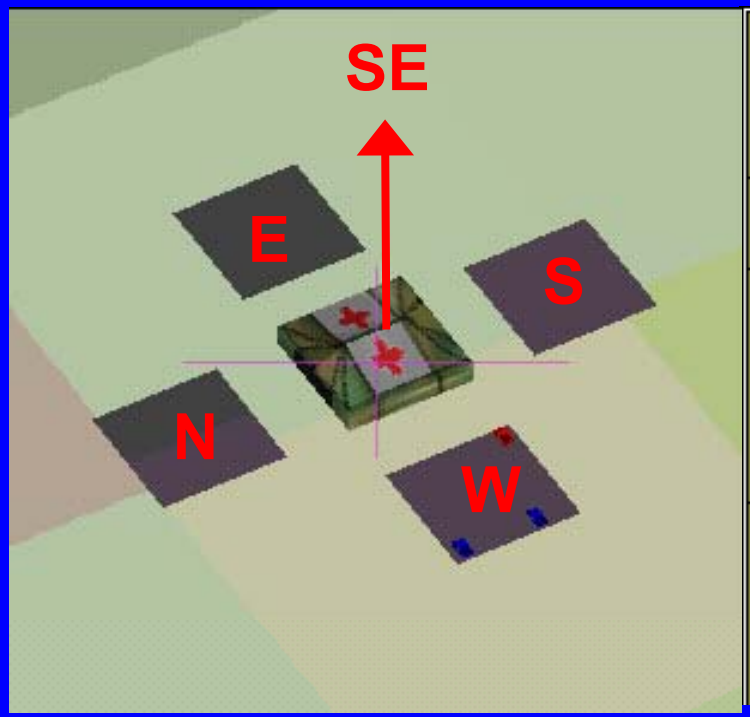

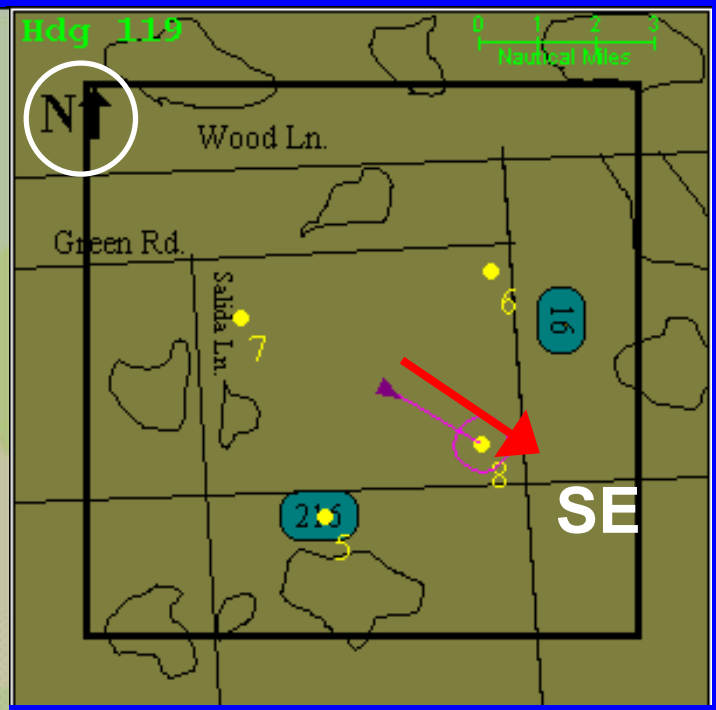

Is the parking lot with cars North, South, East, or West of the building?

Strategies from verbal protocols

	9 pilots	6 novices	
Map-first MR	1	1	*not much MR*
3D-first MR	2	0	
Heading referencing	6	2	*frequent heading referencing*
Heading referencing & map-first MR	1	3	

Data on UAV spatial orientation tasks

- Quantified effects of UAV spatial tasks and identified strategies
  - Direction of turn task
    - Strategy: Mental rotation
  - Cardinal direction task
    - Strategies: Heading referencing & some MR

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- Task analysis of Predator UAV operations
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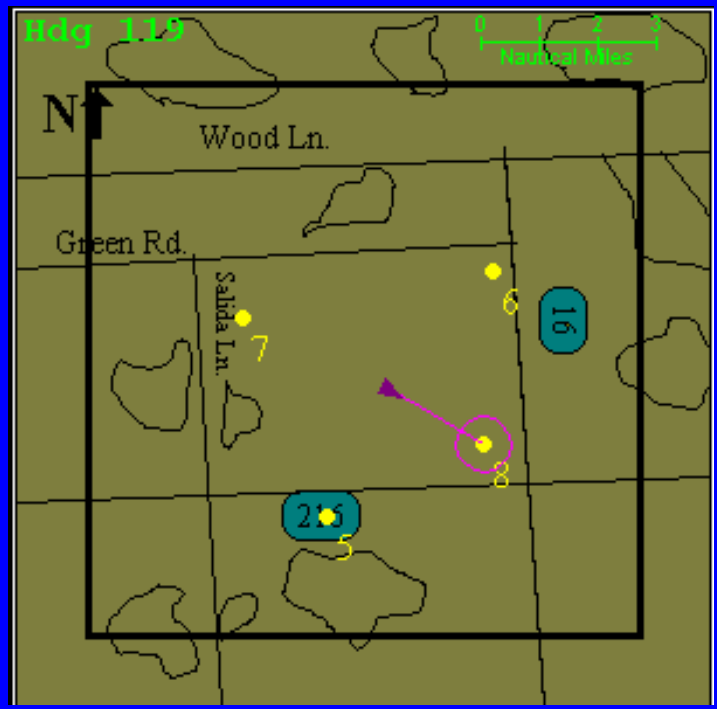
Training cardinal direction judgments

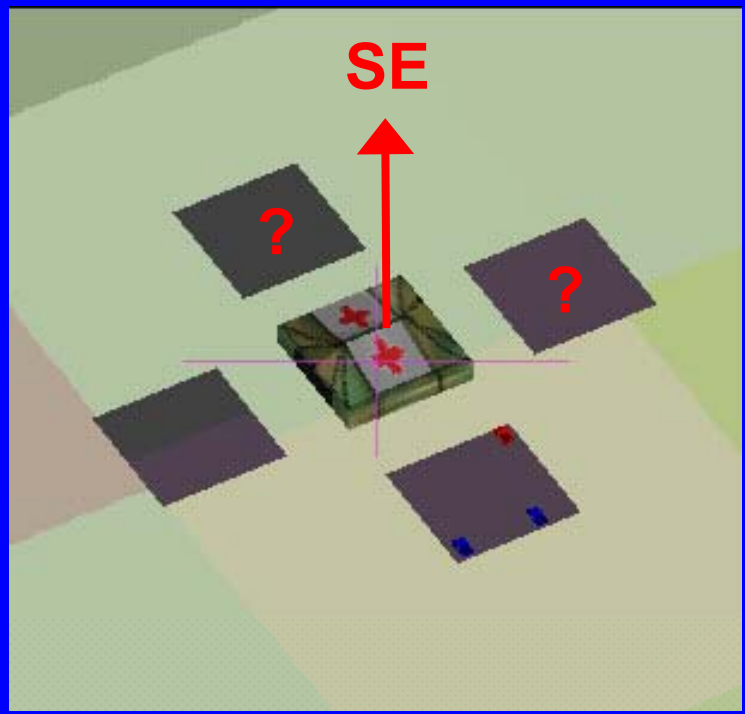
- Heading referencing a good candidate for training
  - Used by experts and better novices
  - amenable to part-task training
    - Step-by-step strategy

Understanding strategies guides training and interface development

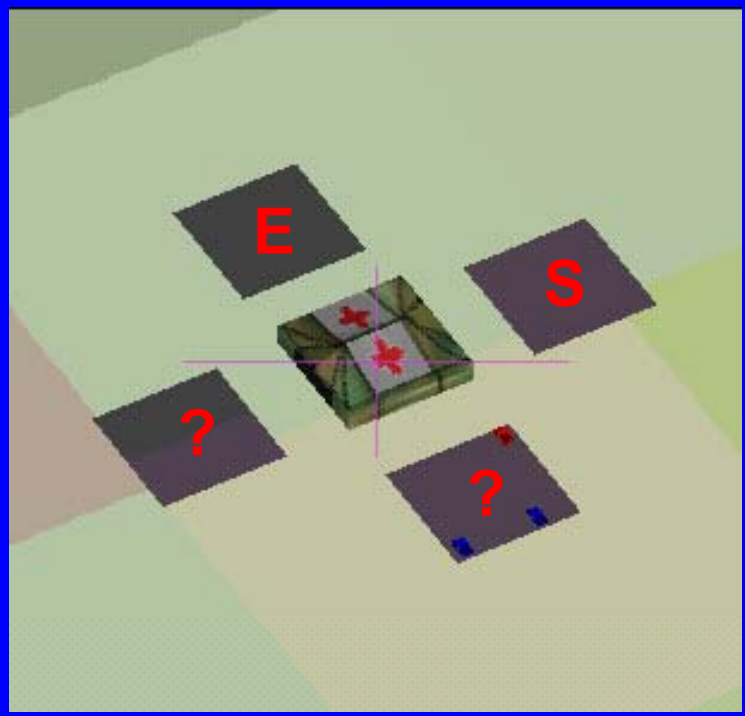
Heading referencing step 1: map reading



Heading referencing step 3: from reference direction to nearby bearings



Heading referencing step 4: from known bearings to other bearings



Training cardinal direction judgments

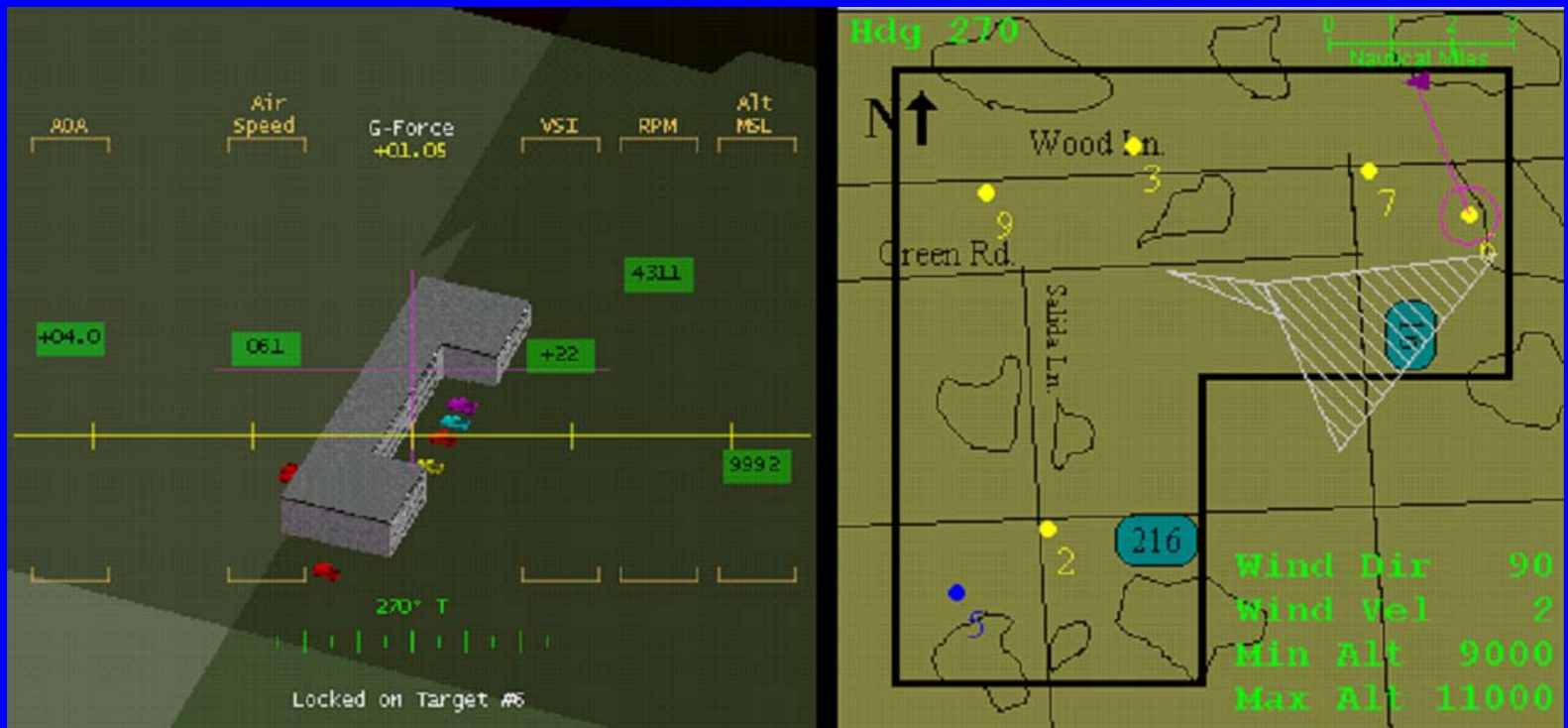
- Part-task training of heading referencing
  - Then integrate part tasks

Training cardinal direction judgments

- Part-task training of heading referencing
  - Then integrate part tasks
- Use of eye-tracking to monitor strategies
  - Then provide real-time feedback
- Use of structural alignment theory

Structural alignment theory:

- Analogy, metaphor … & cardinal direction judgments involve:
  - Comparing, matching elements, aligning elements in disparate representations
    - Eg, comparing 2 models helps find objects in 1 model

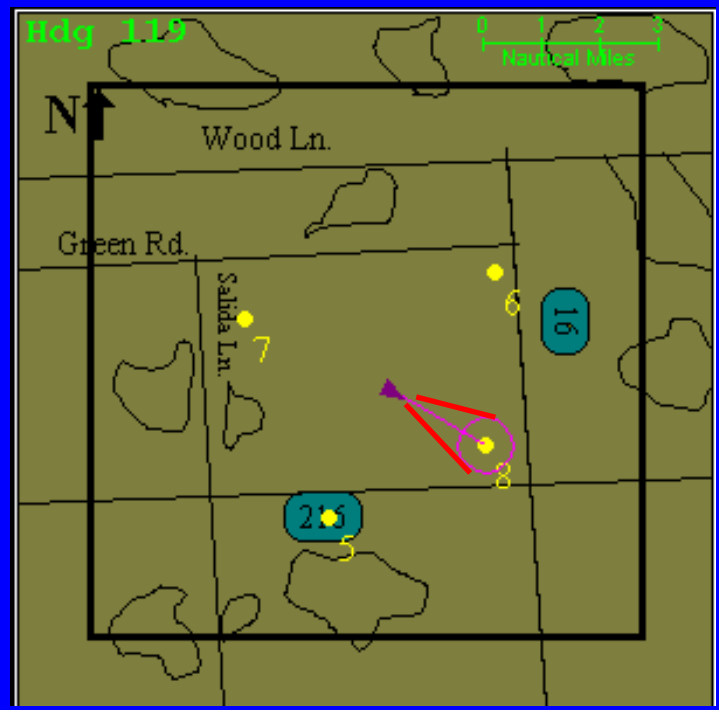


Training cardinal direction judgments

- Part-task training of heading referencing
  - Then integrate part tasks
- Use of eye-tracking to monitor strategies
  - Then provide real-time feedback
- Use of structural alignment theory
  - Training in matching & comparing displays (e.g., maps, 3D views)

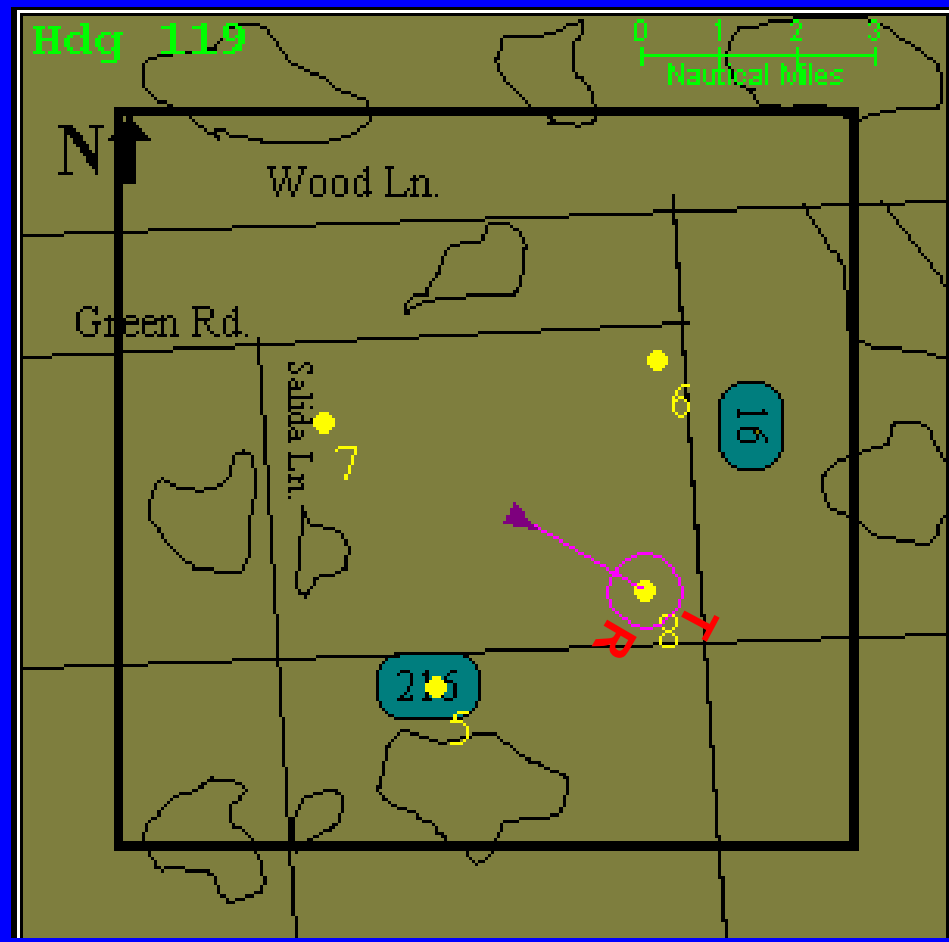
Interface aids for direction of turn task

- Rotating (track-up) map
  - But lack of global (survey) knowledge
- Aretz' wedge
  - Provides local (egocentric) and global knowledge
  - In use in Predator

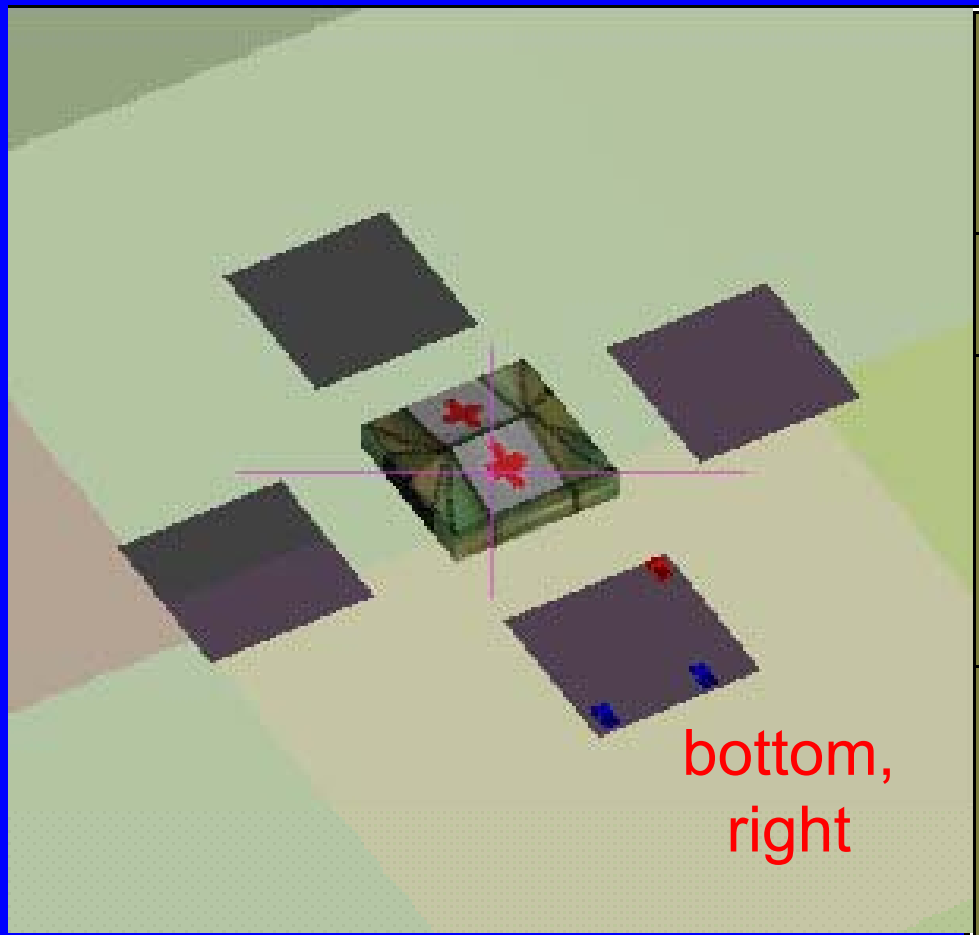


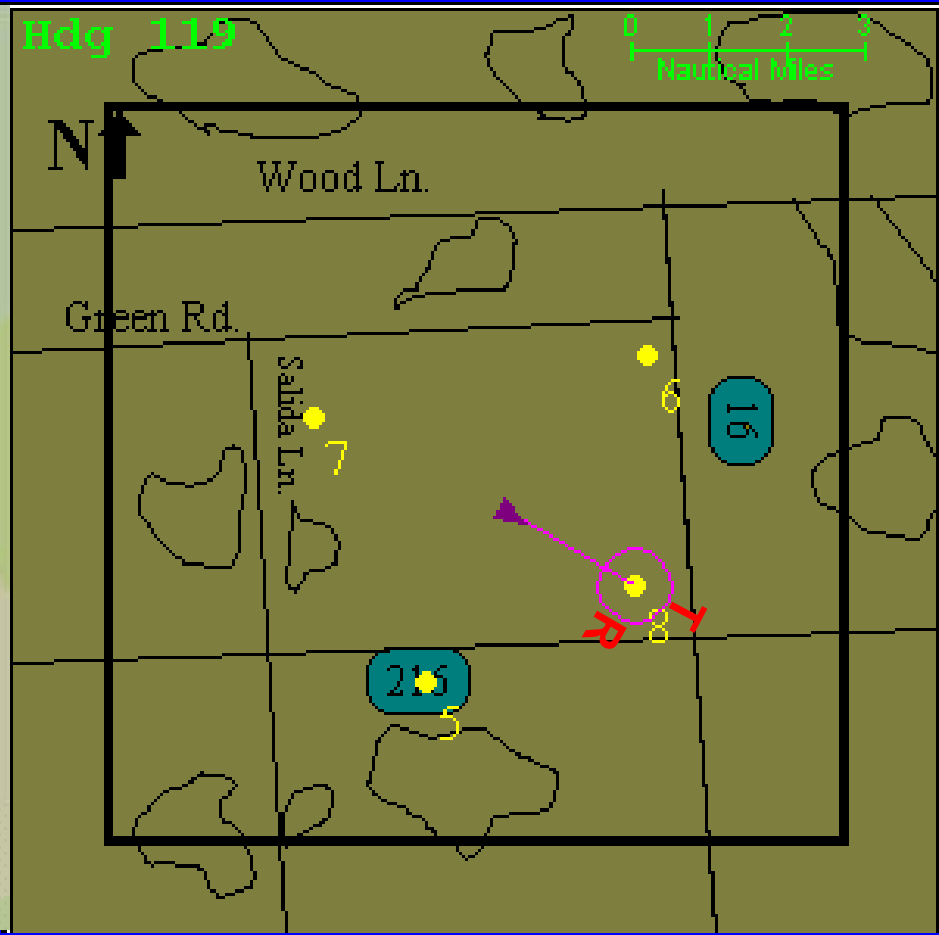
Interface aids for cardinal direction task

- Aretz' wedge
  - In use in Predator;
  - but doesn't help cardinal direction judgments, so
- Integrate egocentric info into map view
  - Consider "egocentric" labels



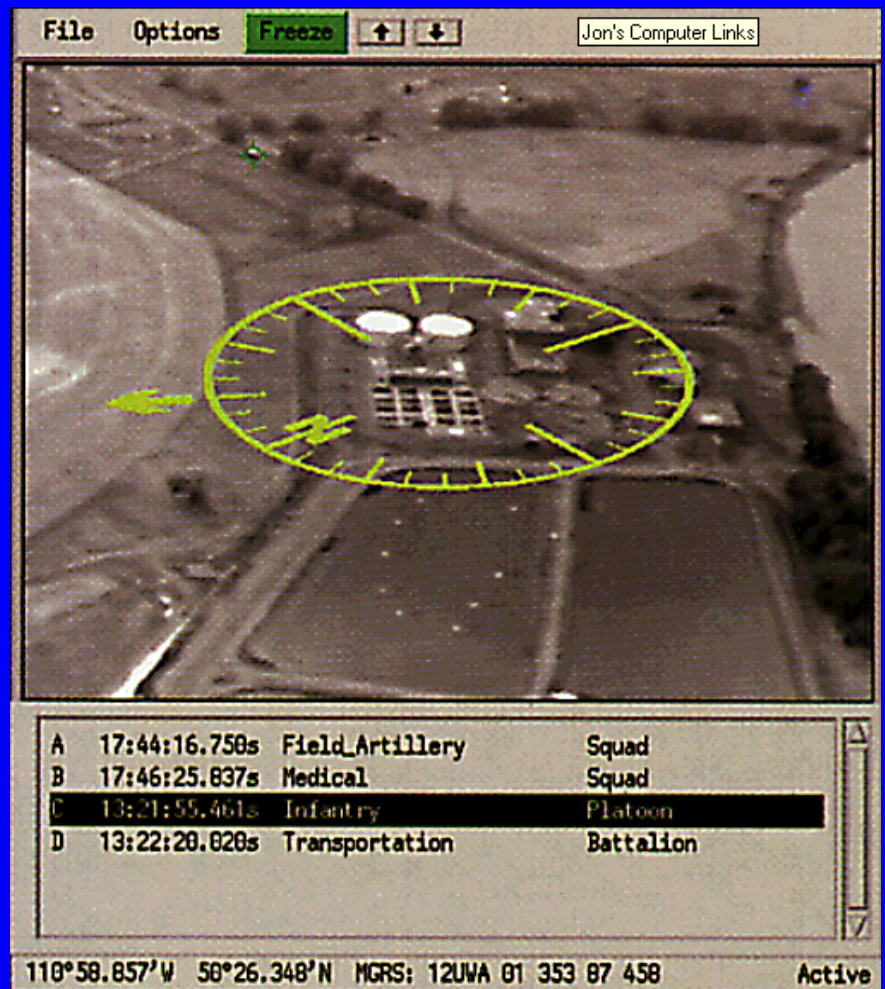
Interface aids for cardinal direction task





Interface aids for cardinal direction task

- Integrate exocentric ref direction in 3D view as in heading referencing
  - E.g., VCS Video display with compass rose overlay and aircraft direction arrow



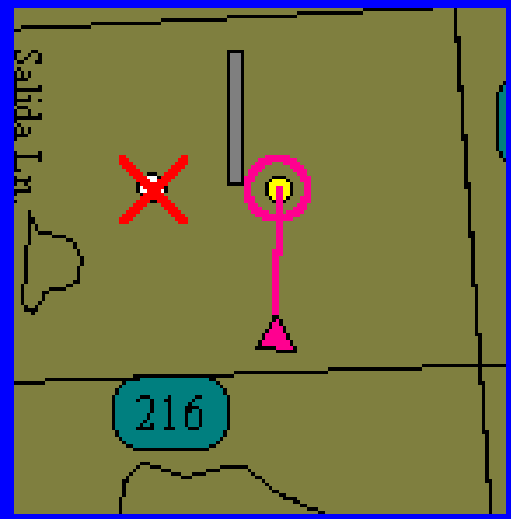
Questions?

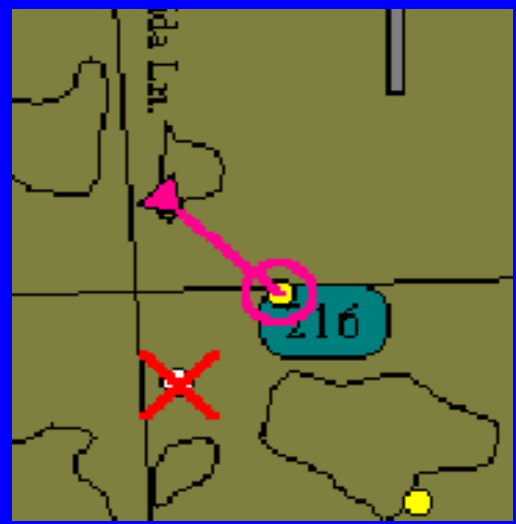
Predator Operations

Pilot and Sensor-Operator Stations

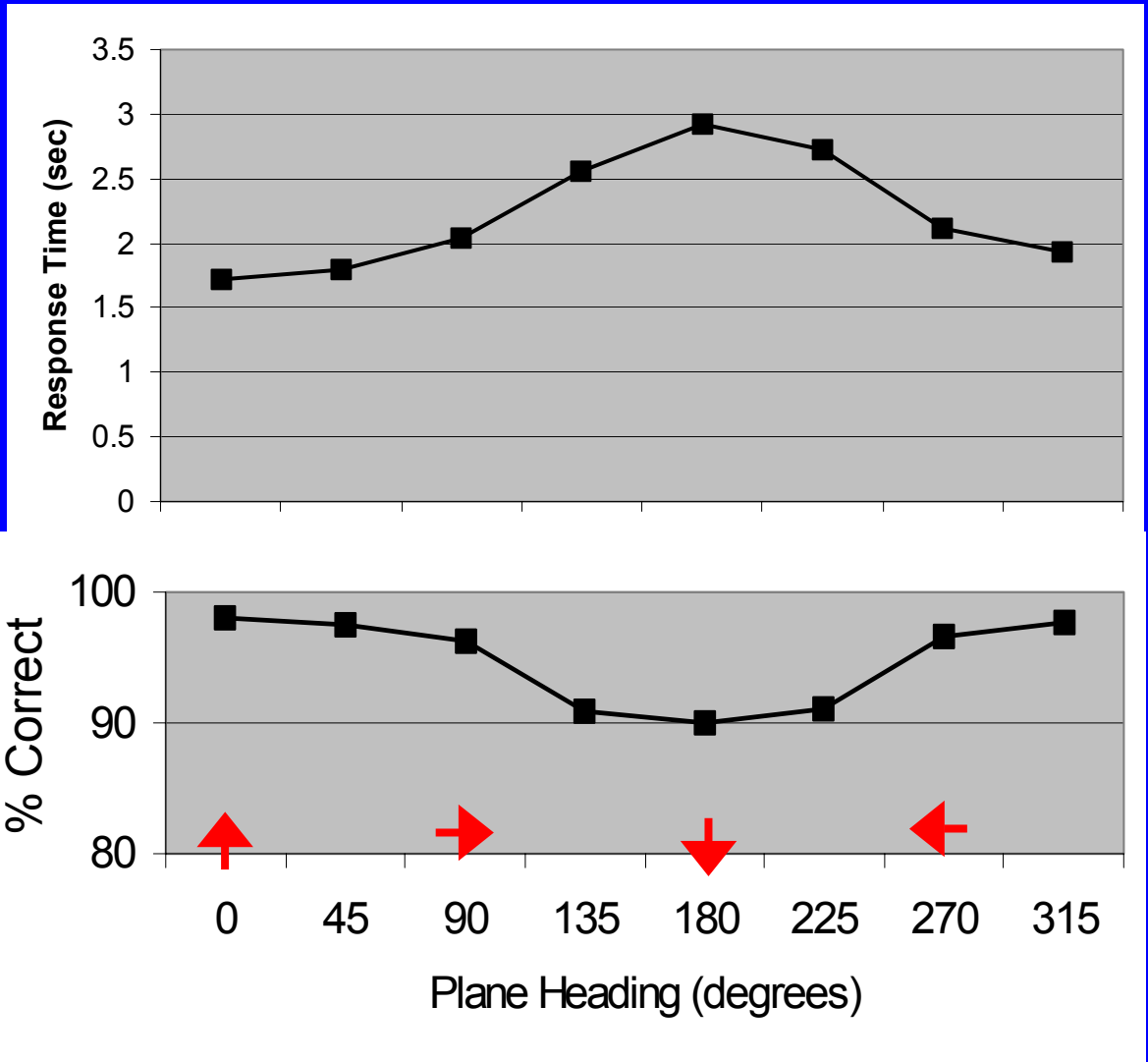
Data on UAV spatial orientation tasks

- Direction of turn task
  - Egocentric forward ALIGNED with top of map ➔
  - Egocentric forward MISALIGNED with top of map ➔





Direction of turn task
Effect of ref. frame misalignment



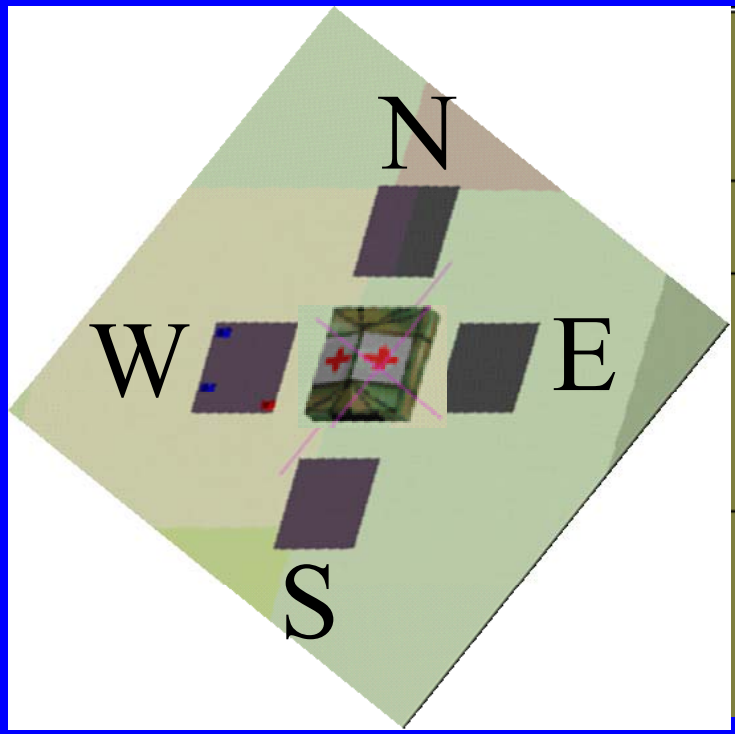
1 s slowing

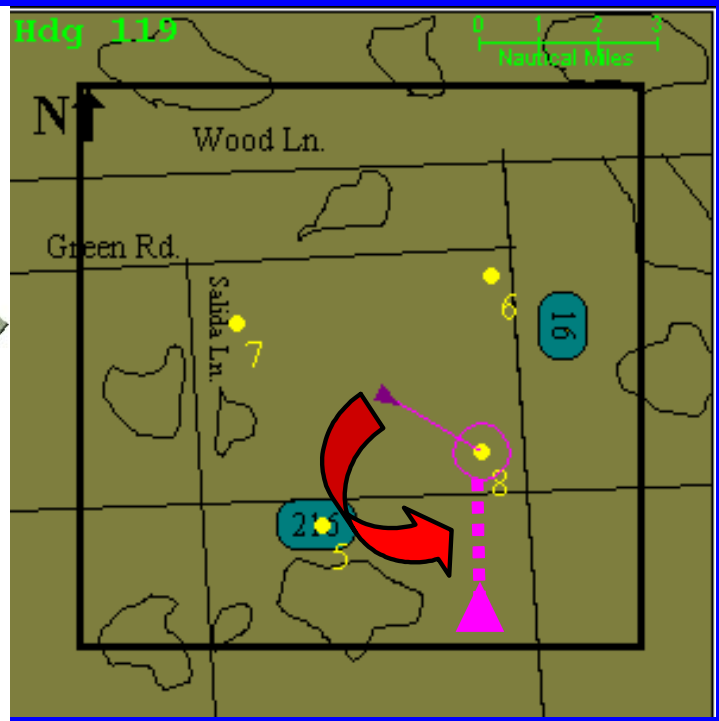
slight accuracy decrease

Map-first mental rotation

Is the parking lot with cars North, South, East, or West of the building?

Map-first mental rotation





Is the parking lot with cars North, South, East, or West of the building?

3D-first mental rotation

Close to tent & to the right

Is the parking lot with cars North, South, East, or West of the building?

3D-first mental rotation

Close to tent & to the right

Is the parking lot with cars North, South, East, or West of the building?

Heading Referencing

Is the parking lot with cars North, South, East, or West of the building?