



# Team Coordination and UAV Operations

**Nancy J. Cooke**

Cognitive Engineering Research Institute  
National Academy of Sciences AFRL Associate  
ASU East

# Research Team Members

## **Sponsors**

Air Force Office of Scientific  
Research  
Air Force Research Laboratory  
Office of Naval Research

## **NMSU Faculty**

Peter Foltz

## **AFRL**

Dee Andrews

## **CERTT Developer: US Positioning**

Steven M. Shope

## **NMSU Graduate Students**

Olena Connor  
Janie DeJoode  
Jamie C. Gorman  
Preston A. Kiekel  
Rebecca Keith  
Harry Pedersen

## **ASU Students**

Pat Fitzgerald  
Christy Caballero  
Paulette Dutcher

## **ASU Faculty**

Nia Amazeen  
Tom Taylor

# Overview

## ❖ CERTT Lab and UAV Synthetic Task

- Focus on measuring team cognition
- The synthetic UAV task
- CERTT capabilities
- Task fidelity

## ❖ Findings relevant to coordination

- Acquisition and retention
- Dispersion
- Workload
- Expert teams
- Communication

## ❖ Conclusions & Future Directions

# CERTT Lab

## Cognitive Engineering Research on Team Tasks



### Unmanned Aerial Vehicle Synthetic Task Environment

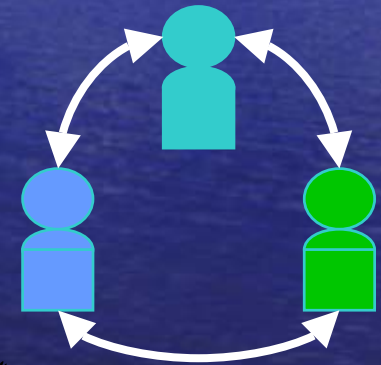
In our UAV STE three operators must coordinate in order to maneuver their UAV to take pictures of ground targets

# Team Cognition in Practice



# Team Cognition

- ❖ It is more than the sum of the cognition of individual team members.
- ❖ It emerges from the interplay of the individual cognition of each team member (PROCESS IS KEY)
- ❖ Further, for heterogeneous teams, individual cognition is also heterogeneous (AVERAGING INAPPROPRIATE)



vs.



**Team coordination IS team cognition.**

# The Synthetic Task

**Air Vehicle Operator**  
controls UAV airspeed,  
heading, and altitude  
and monitors air  
vehicle systems

**Payload Operator**  
controls camera  
settings, takes  
photos, and  
monitors camera  
systems

## **DEMPC**

navigator, mission  
planner, plans route  
from target to target  
under constraints



Based on a cognitive task analysis done on Predator operations at Indian Springs, NV

# CERTT Capabilities

- ❖ Four participant consoles
  - Integration of seven task applications over local area net
  - David Clark headsets for participants and experimenter
- ❖ One experimenter workstation
  - Video and audio recording equipment (including digital audio)
  - Intercom and software for logging communications flow
  - Embedded performance measures
  - Computer event logging capabilities
  - Ability to disable or insert noise in channels of communication intercom
  - Experimenter access to participant screens
  - Experimenter control capability of participant applications
  - Easy to change start-up parameters and waypoint library that define a scenario
  - Software to facilitate measurement of team process behaviors
  - Software to facilitate situation awareness measurement
  - Training software modules with tests
  - Software modules for off-line knowledge measurement (taskwork ratings)
  - Software for administering debriefing questionnaire
  - Software for administering NASA TLX, SART, and other scales
  - Capability for distributed simulation (across intranet and internet)



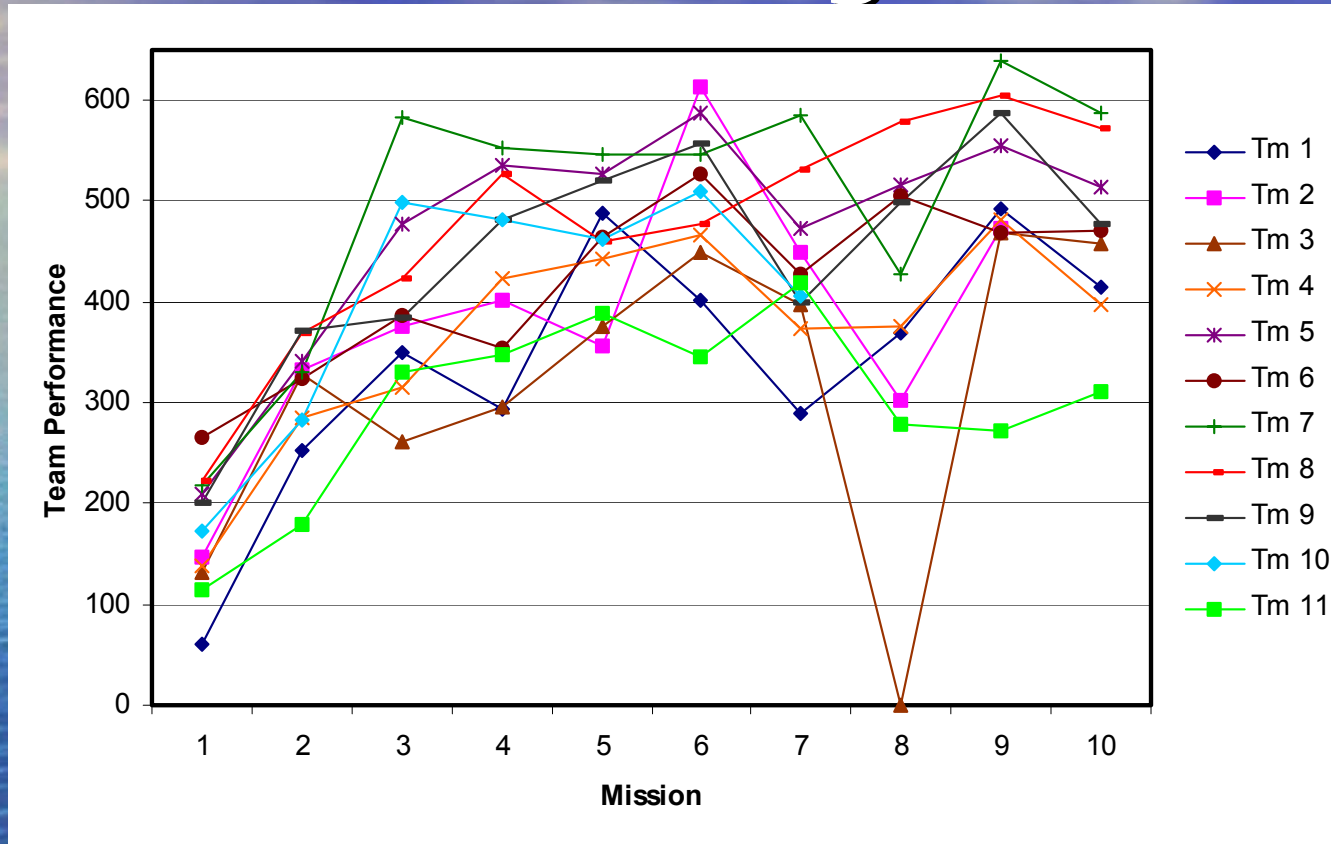
# Task Fidelity

- ❖ Task based on cognitive task analysis of Predator operations
- ❖ Task is faithful to the aspects of the operational task that pertain to team cognition
- ❖ Cognitive fidelity vs. physical fidelity
- ❖ Validity: face validity and expert benchmarking

# Five CERTT UAV Experiments

- ❖ **Three team members (AVO, PLO, DEMPC) maneuver UAV to take reconnaissance photos**
- ❖ **Independent Variables: knowledge sharing, workload, dispersion**
- ❖ **Primary Measures: performance, process, cognition (teamwork knowledge, taskwork knowledge, SA)**
  - **Experiment 1: 11 teams, 10 missions**
  - **Experiment 2: 18 teams, 5 missions, shared vs. unshared**
  - **Experiment 3: 20 teams, 7 missions, 5-7 high workload, distributed vs. co-located**
  - **Experiment 4: 20 all-male teams, 5 missions, 5th high workload, distributed vs. co-located**
  - **Experiment 5: Benchmarking, 5 “expert” teams, 5 missions, 5th high workload**

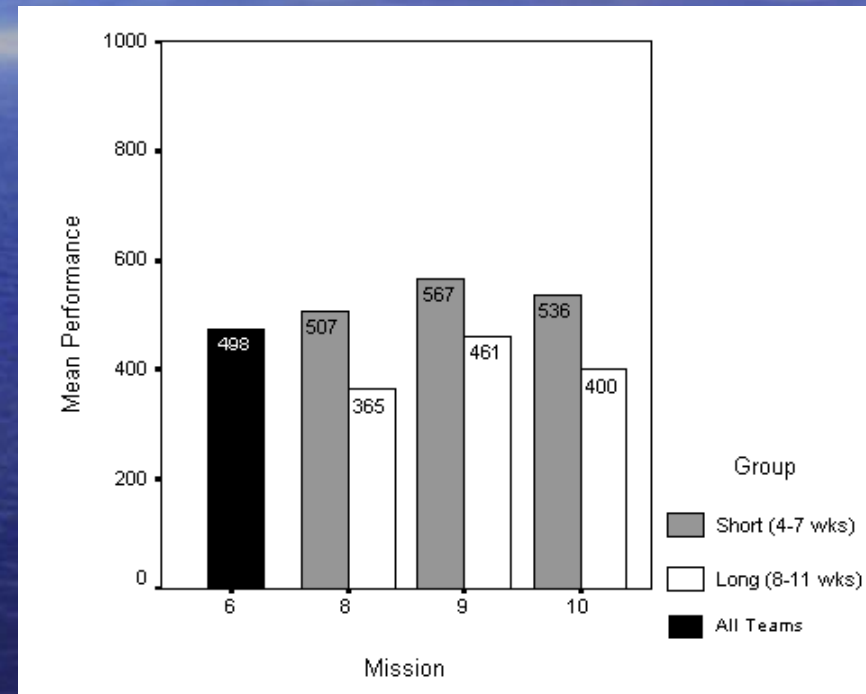
# Exp. 1 Acquisition and Retention Findings



- ❖ Asymptotic team performance after 4 40-min missions (robust finding)
- ❖ Process improves and communication becomes more standard over time; knowledge is more stable
- ❖ Skill loss after 7 weeks

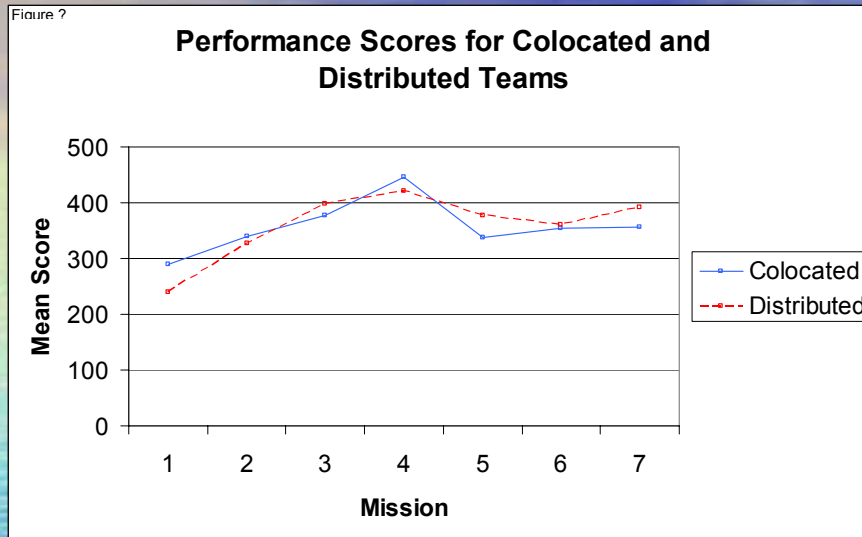
# Exp. 1 Acquisition and Retention Findings

Retention Interval Group	Mean (# of weeks)	Min	Max	N
Short (4-7 weeks)	5.86	4.71	6.57	4
Long (8-11 weeks)	9.63	8.71	10.86	5

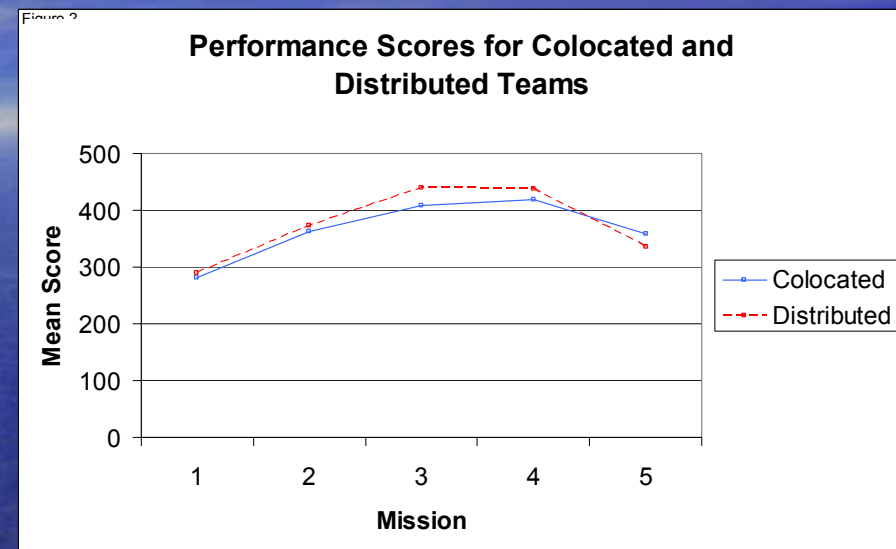


***The question of retention of C2 skill is of great practical importance, but little is known.***

# Dispersion IS NOT Detrimental to Team Performance



**Experiment 3**

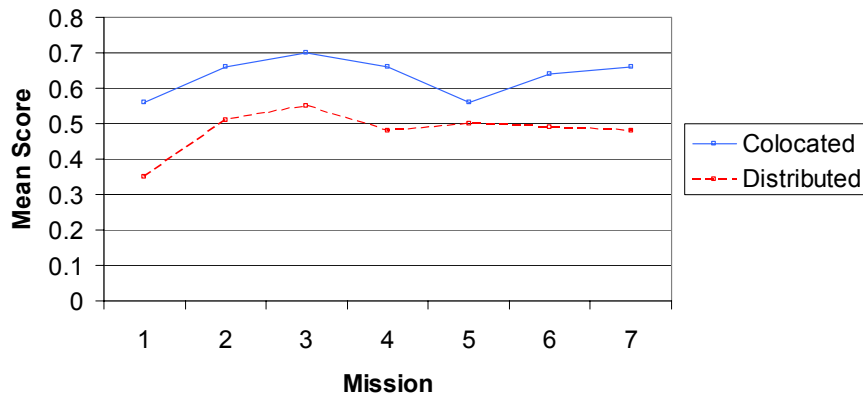


**Experiment 4**

- ❖ Team skill is acquired from Mission 1 –4
- ❖ Increased workload (M5 and later) is detrimental to team performance
- ❖ Distributed teams perform better than co-located under high workload (Exp. 3)

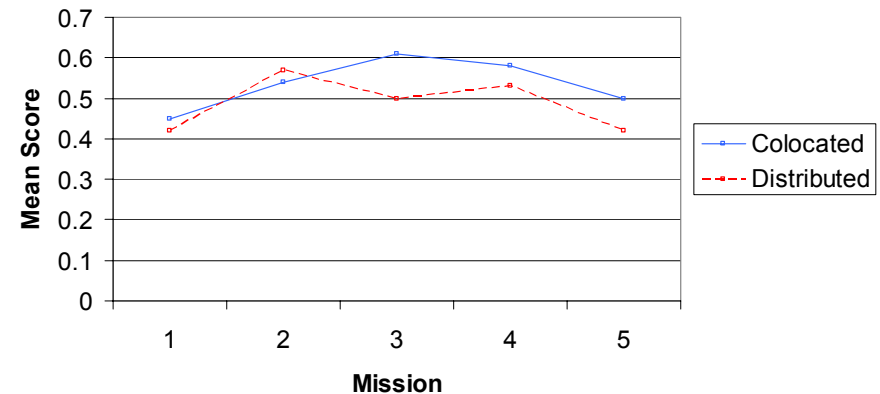
# Dispersion IS Detrimental to Team Process

Critical Incident Scores for Colocated and Distributed Teams



Experiment 3

Critical Incident Scores for Colocated and Distributed Teams



Experiment 4

- ❖ Team process improves from Mission 1 –4
- ❖ Increased workload (M5 and later) is detrimental to team process
- ❖ Co-located teams demonstrate better (or different) team process than distributed teams

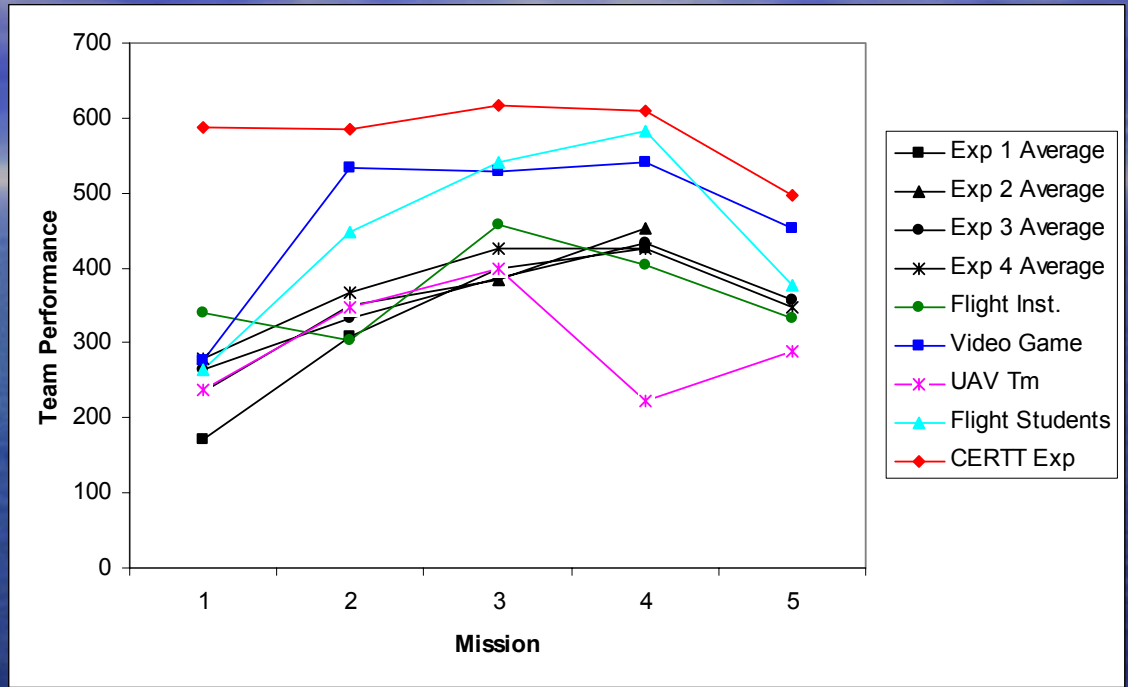
# Workload

- ❖ **High levels of workload are detrimental to team performance and process**
- ❖ **Under high workload teams get fewer photos per minute**
- ❖ **Co-located DEMPCs tend to perform better and perceive greater workload than distributed DEMPCs**
- ❖ **Working memory capacity is correlated with superior DEMPC performance**

# Exp. 5: Benchmarking Study

## Five Expert Teams

- 1) Flight Instructors
- 2) Video Game Team
- 3) UAV Design Team
- 4) Flight Students
- 5) CERTT Experimenters



TEAM	Process	Teamwk	Taskwk
FI Instruc			
Video	X		
UAV			
FI Student		X	X
Exp		X	X



# Team Communication

- ❖ Communication is a predominant form of team interaction in command-and-control
- ❖ Real-time, embedded in the task
- ❖ Observable; Think aloud “in the wild”
- ❖ Rich, multidimensional (amount, flow, speech acts, content)
- ❖ Reflects team cognition at the holistic level; for us this *is* team cognition

# Team Communication

- ❖ We focus on flow and content
- ❖ Differences in communication patterns correspond to team performance differences
- ❖ Better performing teams display more consistent patterns of communication than poorer teams
- ❖ Automated communication analysis methods make this approach practical

# Conclusions

- ❖ **The UAV-STE provides a semi-controlled realistic environment for the study of team cognition**
- ❖ **The UAV-STE provides a fertile ground for developing and testing measures of team cognition**
- ❖ **Our UAV-STE data suggest that much team cognition occurs in the push and pull of information among team members**

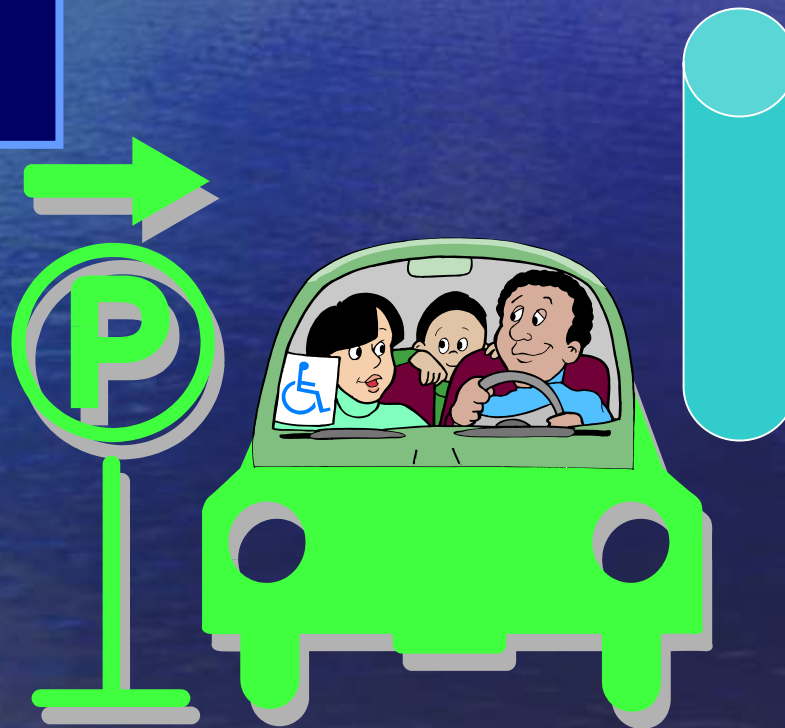
# Future Directions

- ❖ **Acquisition and Retention Studies and Models**
- ❖ **Dynamical Systems models of coordination**
- ❖ **Additional cognitive task analyses of UAV systems**
- ❖ **Command-and-control in emergency response**
- ❖ **Assessment and diagnosis of team performance via communication**
- ❖ **A new measure of coordinated situation awareness**

# Team Situation Awareness

## An Example

**coordinated  
perception  
and action**



# Team Situation Awareness

## A Holistic/Ecological Measure of Team SA

- ❖ Change is introduced (communication breakdown, enemy in area, storm) that will impact mission
- ❖ 2-3 team members are presented cues regarding change
- ❖ Team members need to perceive cues in a coordinated way (i.e., connect the dots) to identify the change
- ❖ Team members coordinate to take action relevant to the change (e.g., change altitude, communicate indirectly)

# Questions or Comments?

email:

[ncooke@asu.edu](mailto:ncooke@asu.edu)

website:

[www.certt.com](http://www.certt.com)

**Cognitive Engineering Research Institute**

**Mesa, AZ**

[www.cerici.org](http://www.cerici.org)