Human Factors Issues in Unmanned Aerial System Training

CERI HF of UAVs 2007

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Research Team Members

Sponsored by:
National Aeronautics and Space Administration, California Space Grant Foundation

Project:
UAV Alliance, Research and Curriculum Development Partnership Project

CERI:
Nancy Cooke
Harry Pedersen

Arizona State University Polytechnic, Aeronautical Management Technology:
Laurence Gesell
James Hartman
Matthew Skinner

Arizona State University Polytechnic, Applied Psychology:
Weston Pack

Air Force Research Laboratory:
Dee Andrews
Patricia Fitzgerald

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Outline

- Our Task: Inventory and Assessment
- UAS Training Background
  - U.S. Army
  - U.S. Air Force
  - Civilian UASs
- Training Issues Identified & Research Agenda
  - Background
  - Simulation
  - Mitigating Constraints
  - Other ROVs
  - Team Training
  - Acquisition and retention
- Implications and Conclusions

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UAV Alliance, Research and Curriculum Development Partnership Project

- ASU Team's Task:
  - *To identify potential human factors of specific concern in UAS operator/pilot training*
  - *Propose follow-on tasks to demonstrate one or more research initiatives relating to the concerns identified*
- Sources include: Existing literature, operator interviews, training observations, CERI HF of UAVs Workshop series break-out sessions

The Bottom Line

Unmanned Aerial Vehicles

ARE NOT UNMANNED!

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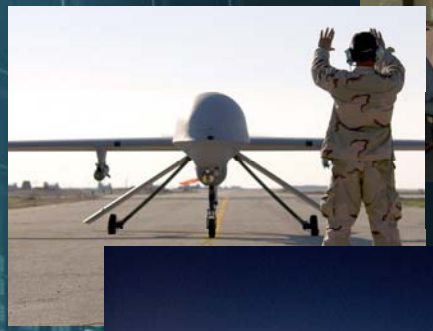

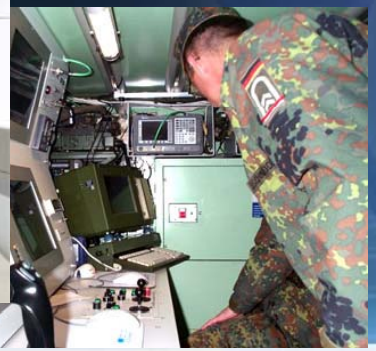

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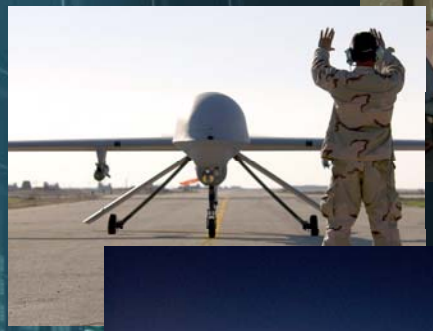

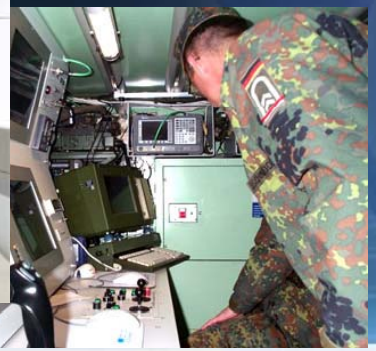

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Poses a Problem with the….

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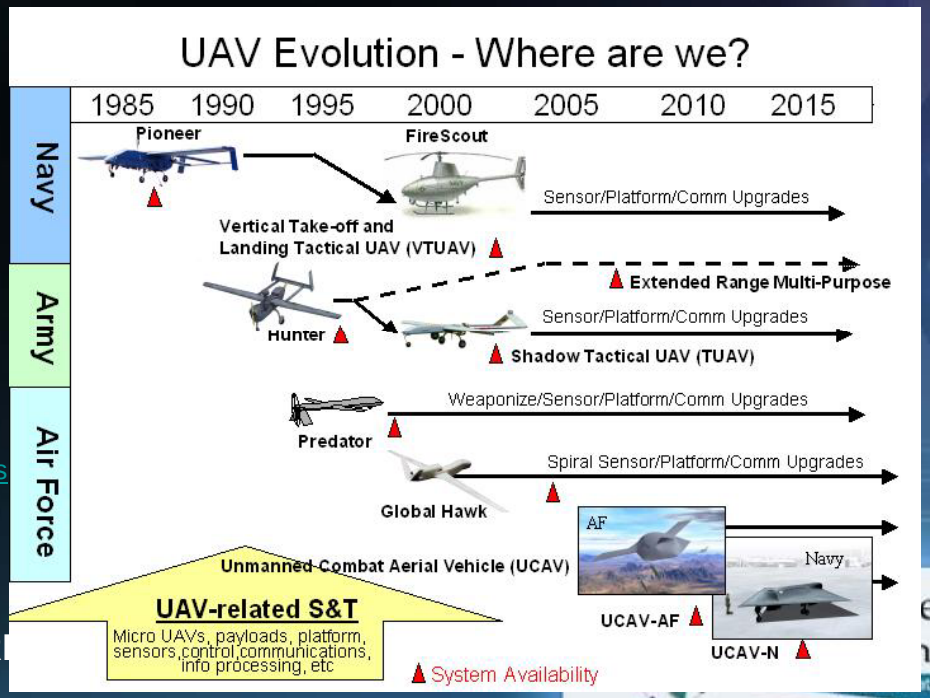
Recent Surge in Use of UASs

- UASs very successful in the military in “Dull, Dirty, and Dangerous” missions
- Growth has increased dramatically in the last decade
- Growth in UAS use expected to continue as more civil, commercial, and private sectors adopt them for
  - Search and rescue
  - Border patrol
  - Crop management
  - Communications relay



Source: http://www.defenselink.mil/news

But….

- Piloting tasks are significantly different from manned flight tasks
- Piloting environment is significantly different as well
- Focus of design often on physical airframe and not the human
- Numerous HF issues exist
  - ‘Soda Straw’ view
  - Ergonomic issues
  - Transfer issues
- Interface design is usually the first consideration

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Current U.S. Army Platforms

RQ-5 Hunter

RQ-7 Shadow

RQ-11 Raven

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Current USAF Platforms

RQ/MQ-1 Predator

RQ-4A Global Hawk

RQ/MQ-9 Predator B

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U.S. Army Training

- UAS training governed by the Army Aviation branch, formally Military Intelligence
- Enlisted personnel trained at Ft. Huachuca, Sierra Vista, AZ after basic training completed
- Training is divided into classroom, simulator, and flightline
- Four specializations:
  - Air Vehicle Operator
  - Mission Payload Operator
  - Flightline Operator
  - External Pilot

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USAF Training

- Rated pilots (officers) serve three-year career broadening tours
- Operators hold FAA commercial certificates with instrument ratings
- However, UAS training takes pilots away from manned aircraft

- Possible solution: Permanent UAS career track
  - Train IFR in training aircraft (Cessna 172 or T-1)
  - Move on to Predator/Global Hawk simulator training
  - Mission qualification training
- Potential cost savings: $685,051 (B-52) vs. $17,800 dedicated UAS
- UAS operators won't require survival training, retraining

- USAF currently exploring the above as a solution (Hoffman, 2005)

Civilian UAS Training

- UASs quickly transitioning from military applications to civilian
  - U.S. Border Patrol
- Various HF issues abound
  - Single operator workload
  - Lack of sensory cues
  - Automation issues
  - Communication and coordination…. Just to name a few
- Operation in NAS will require FAA standards and regulations
  - Studies by the FAA show that UASs are not flown—they are "commanded"
- Represents a great paradigm shift for HF, displays, and operator qualifications and training (McCarley & Wickens, 2005; Williams, 2004)

Should UAS Operators Be Rated Pilots?

- Status quo:
  - No FAA pilot certification processes or procedures for operation in NAS currently exist.
- Several schools around the world provide instruction to civilians
  - TAG Aerospace Inc. facility in South America
  - UAS Applications Center (NASA Ames) currently developing curriculum
- FAA is also now surveying existing literature to identify specific research questions regarding the impending integration of UASs into the NAS

Training Issues Identified

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Training Background-State of the Art

- Different branches of the military hold very different doctrines
  - USAF: Rated pilots, Officers with instrument ratings
  - U.S. Army: Enlisted personnel, no flight experience
- Evidence for rated pilots (Schreiber, Lyon, Martin, & Confer, 2002; Andrews, Fitzgerald, & Chubb, 2005)
- For civilians, FAA research has not reached a definite conclusion (Williams, 2005)
- CERI 3rd Annual HF of UAVs Workshop addressed what KSAs and MECs operators should posses
  - Do operators need a tactical background?
  - Should they be videogamers? If so, do they need flight training?
- FAA suggests strict currency requirements
  - UAS operation requires more cognitive processing (less procedural knowledge)

Training Background-Research Agenda

- *What KSAs and MECs are required for UAS operation? Is there common ground between all involved?*
- *Are there data to support videogamers as UAS operators? Can they be used as training tools?*
- *Should manned flight experience be a prerequisite? What can be done about negative transfer when transitioning to a UAS?*
- *What KSAs and MECs are required for instructors? How should instructors be trained? How should expertise be assessed?*

Use of Simulation and Training-State of the Art and Agenda

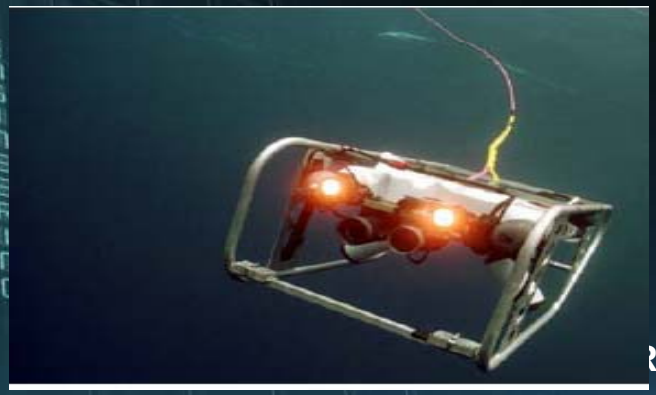
- Simulators are a valuable tool, benefits are numerous
- Interface development is a leading area of interest
- FAA very interested in areas such as attentional limits, training effectiveness, environmental factors in training
- UAS community interested in how much flight time is needed for operator *qualification—can simulation take the place of actual flight time?*
  - There may be a smaller need to train with the actual aircraft.
- Determination of KSAs can inform what should be trained, and address simulator effectiveness

Mitigating Constraints Through Training-State of the Art and Agenda

- How much hands-on time is needed to operator qualification?
  - All UASs are different and doctrines vary widely
  - Number of operators per system affects training
- Big issue: decreasing the system to operator ratio
  - State of art: 3:1 or 2:1, eventually: 1:1 and even 1:2, 1:3, and 1:4!
  - Additional vehicles lead to loss of awareness of system failures and poor flight instruction recall (Dixon & Wickens, 2003)
- Training with variable levels of automation will be necessary-an entire research agenda on its own!
  - Vigilance decrement, automation abuse, fatigue
- *What training will be needed for these issues? How can technology be used to provide adaptive training or mitigate constraints?*

Other Remotely Operated Vehicles- State of the Art

- Very little research on the relationship between UASs, and other ROVs
- Environment of other ROVs and UASs vastly different but similarities exist:
  - UUVs and UASs use real-time camera images to navigate
- Humans still play a pivotal role in ROV operations—*What can UAS training adopt from successes and failures with other vehicles?*



Team Training-State of the Art and Agenda

- Very little work being done in the training of team communication and coordination, and team training in general

- Research efforts at the Cognitive Engineering on Team Tasks (CERTT) Laboratory at CERI in Mesa, AZ has focused on the dynamics associated with UAS operation and the acquisition of team level skills

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The Cognitive Engineering Research on Team Tasks Laboratory

AVO

PLO

DEMPC

Original CTA by Gugerty, DeBoom, Walker, and Burns, 1999

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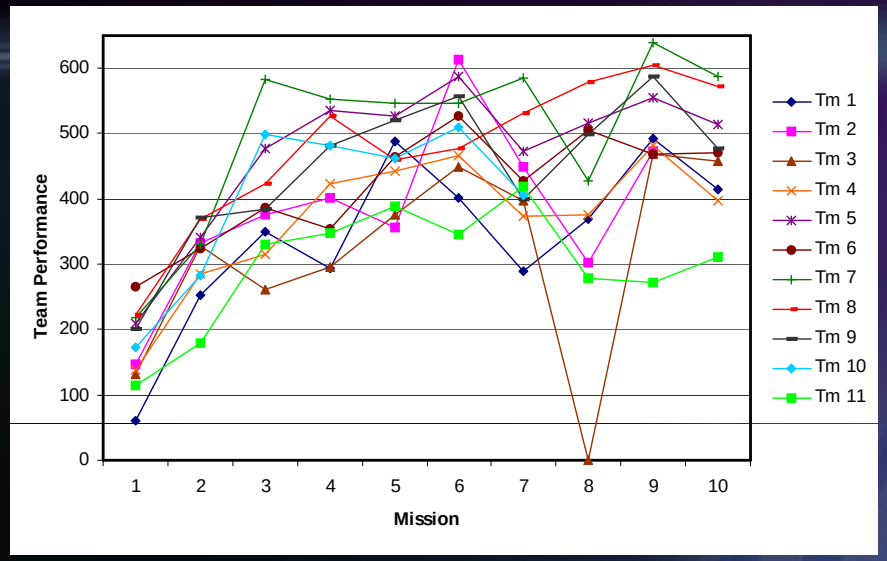
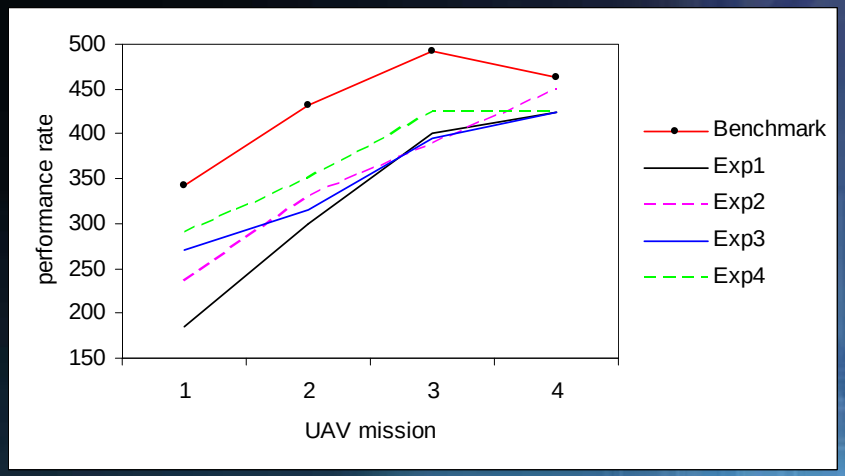
CERTT Capabilities

- 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 and timing
  - 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)

Performance

- Task knowledge is stable by first mission
- Performance asymptotes by fourth mission
- High levels of workload are detrimental to team performance and process
- Performance and process changes with team-level experience and periods of nonuse
- Manipulations (dispersion, knowledge sharing, cross training) affect knowledge, but not performance
- Expert teams accelerate team skill acquisition





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Team Training Agenda

- UAS operations require teamwork
  - Even for 1:1 system as the individual must communicate with others
- Expert teams run in the lab exhibit transfer of coordination and communication skills
- *How should team training be incorporated into UAS operator training for maximum safety and efficiency?*

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Learning: Acquisition and Retention- State of the Art and Agenda

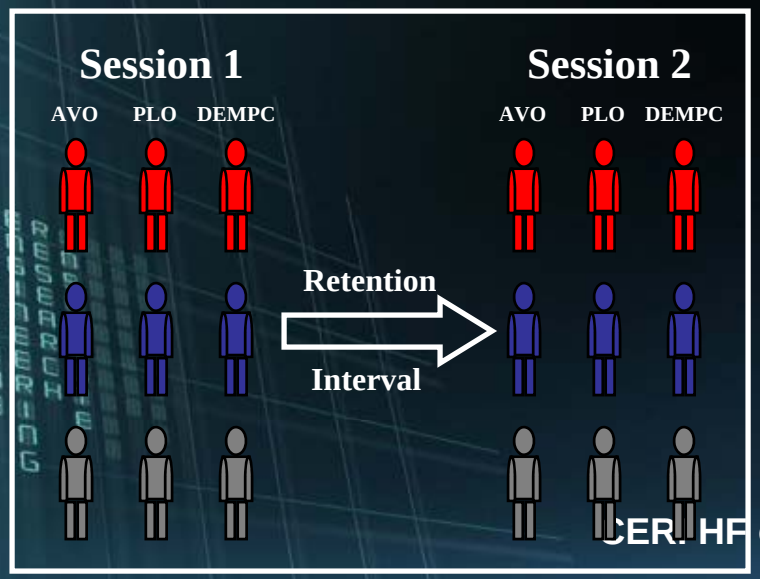
- Great interest to the military to keep training costs down
- No prior studies on UASs exist
- MA&D currently working on a study using overlearning and Predator UAS simulator
- However, no studies on team skill retention have been done
- *How quickly do teams learn and retain what they have learned? How long do they retain their skill? What factors influence?*

Acquisition and Retention of Coordination Skill

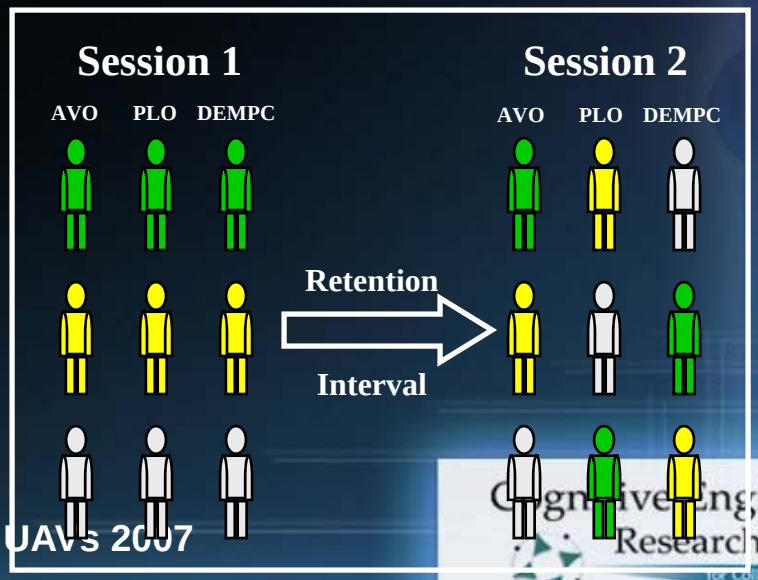
- 117 individuals divided into 39 3-person (unfamiliar) teams
- Conditions (retention interval and familiarity randomly assigned with scheduling constraints)
- Session 1: 5 missions
- Session 2: 3 missions

Familiarity	Retention Interval: 3-6 weeks	Retention Interval: 10-13 weeks
Intact	10 Teams	9 Teams
Mixed	10 Teams	10 Teams

Intact Condition



Mixed Condition



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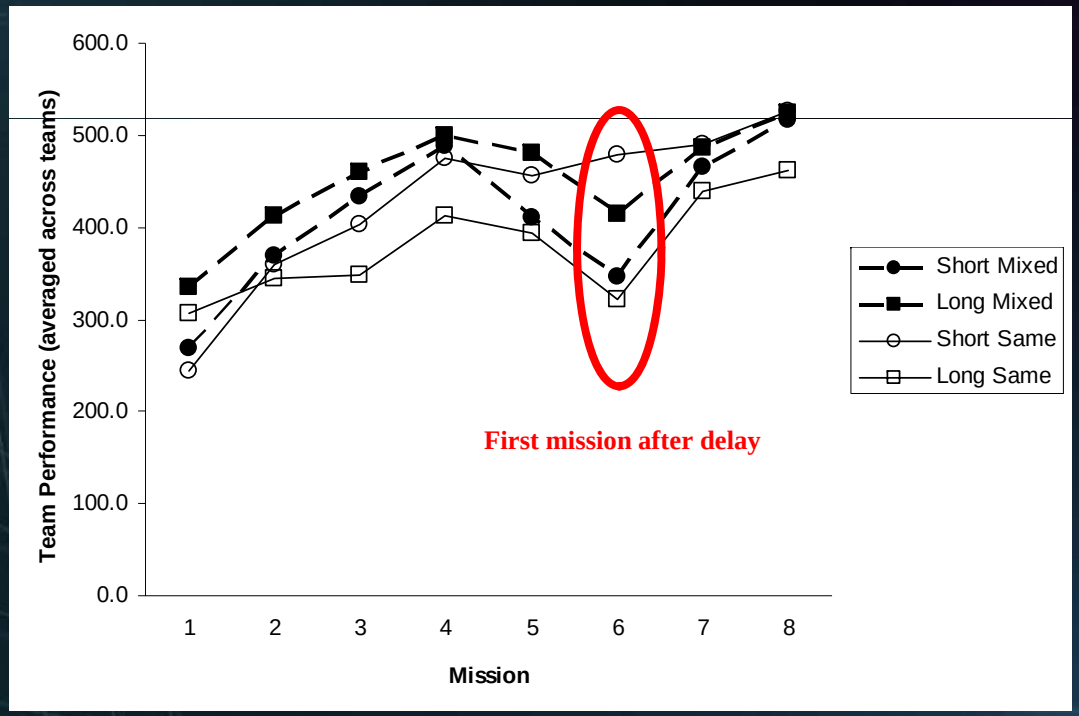
Mixed Teams Performed Better

- Teams that experience the long retention interval perform worse upon returning for Session 2 compared to short-interval teams
- Mixed teams displayed larger decrement, but performed better during last mission
- Same-short and Mixed-long teams showed best SA performance
- Team composition impacts retention more than interval length



Mean Performance Scores Based On Current Data Collected
(N = 39 Teams)

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Implications for UAV Operations

- Training research is needed to provide guidance for training standards to:
  - Keep pace with increased demand for trained UAS operators
  - Overcome the historically high mishap rates seen in UAS operations
- Effects of manned flight experience and videogaming experience must be established
- KSAs and MECs must be established
- Research will eventually make UASs the cost-effective platforms they were originally intended to be

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Thank You!

hpedersen@cerici.org

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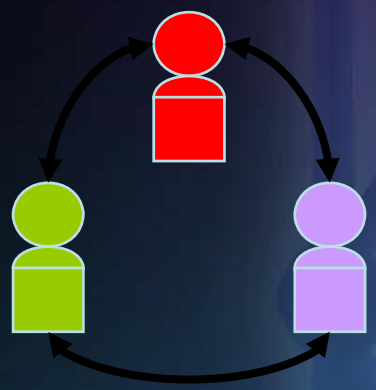
Team Cognition

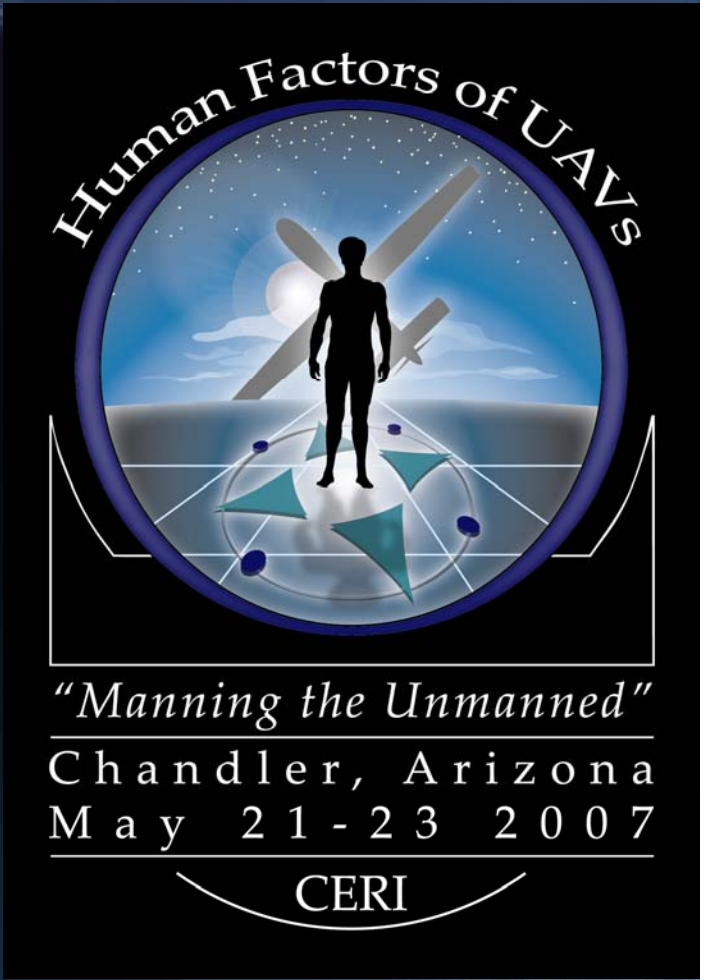
- Is more than just the sum of the cognition of individual team members
- Emerges from the interplay of cognition from individuals (via process)
- For heterogeneous teams, cognition is also heterogeneous

- A team is two or more individuals that interact interdependently toward a common goal who have each been assigned specific roles (Salas et. al. 1992)
- We measure team cognition because of the importance of teams in today's dynamic and stressful environments
- Team coordination is team cognition



CERI HF of UAVS Workshop

- May 21-23, 2007 at the Crowne Plaza San Marcos Golf Resort, Chandler Arizona
- Sponsors: Air Force Office of Scientific Research, Air Force Research Laboratory, L-3 Communications, Research Integrations Inc., Human Factors and Ergonomics Society
- Please see www.cerici.org for more information



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Performance

- 5 Experiments completed, IVs: 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**

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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

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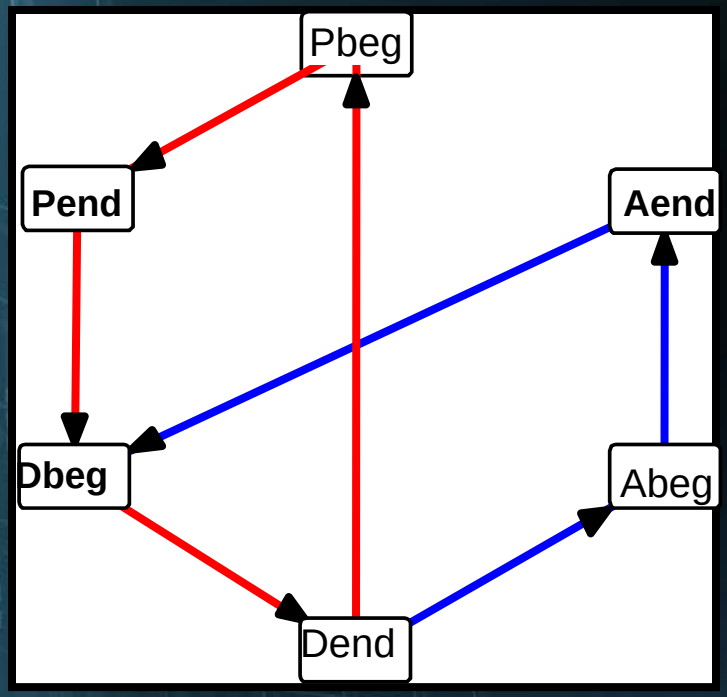
Communication

- 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 for flow

Procedural Networks-ProNet

- Can detect certain communication patterns such as conflicts:

BEFORE



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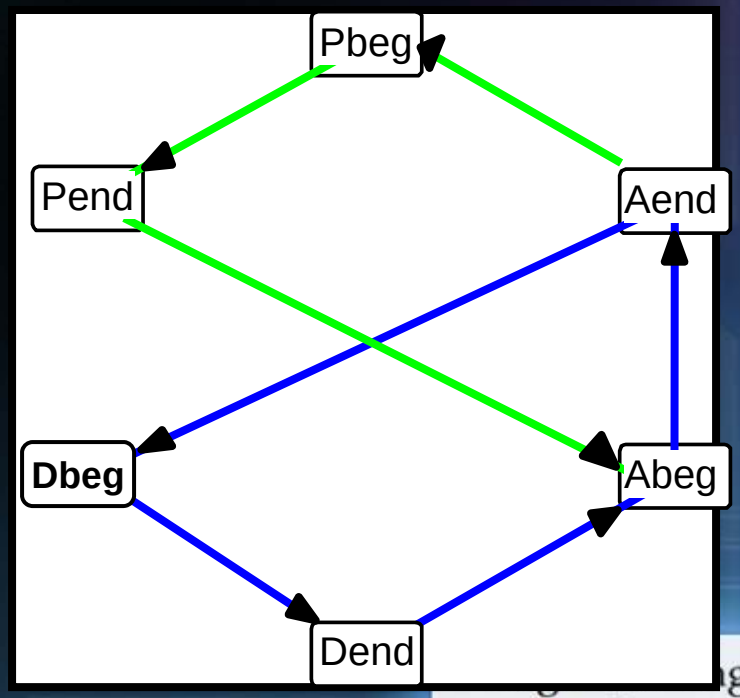

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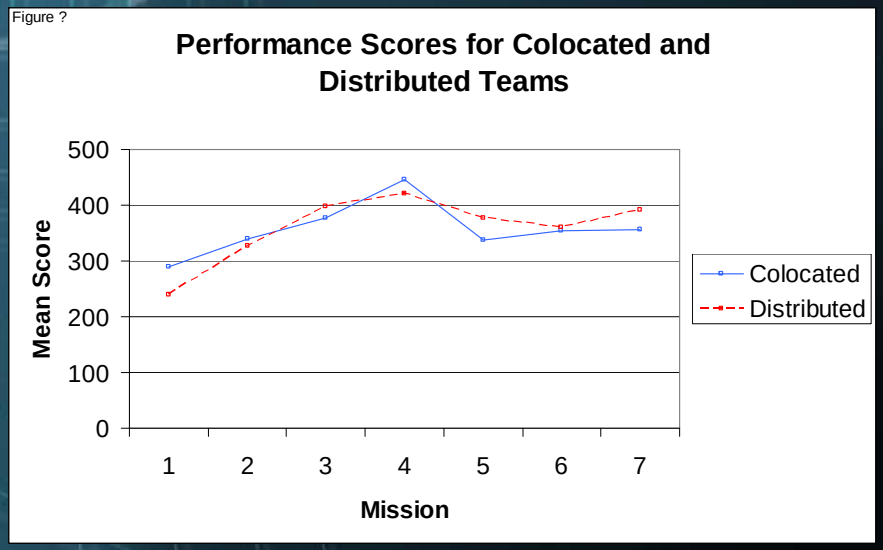
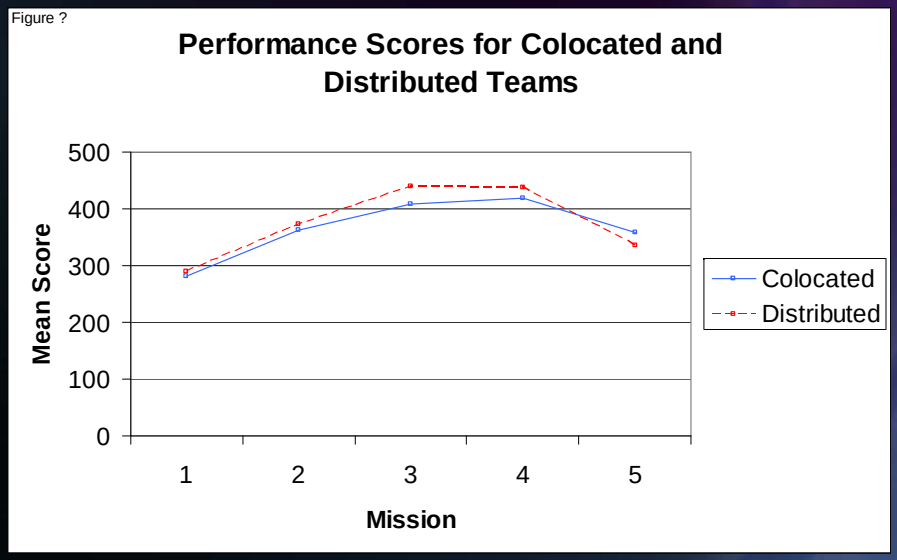
Various Findings

- Team performance consistently reaches asymptotic levels after four 40-minute missions.
- Taskwork knowledge is relatively stable after initial task training and teamwork knowledge tends to develop with mission experience.
- We find a significant effect of the workload on team performance, such that an increase from 9 to 20 targets and additional route constraints results in fewer photos per minute.
- The dispersion manipulation affects team cognition; dispersed teams tend to have less taskwork knowledge than co-located teams.
- Dispersed teams with better team process and team knowledge have higher team performance scores.
- Expert teams (made up of individuals that communicate and coordinate with each other on a regular basis) show accelerated team skill acquisition on the UAV-STE.

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)

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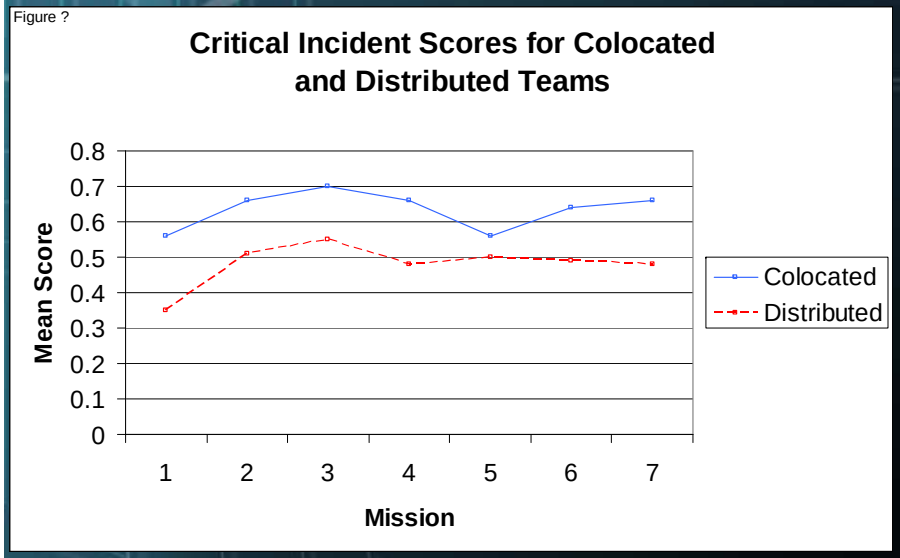
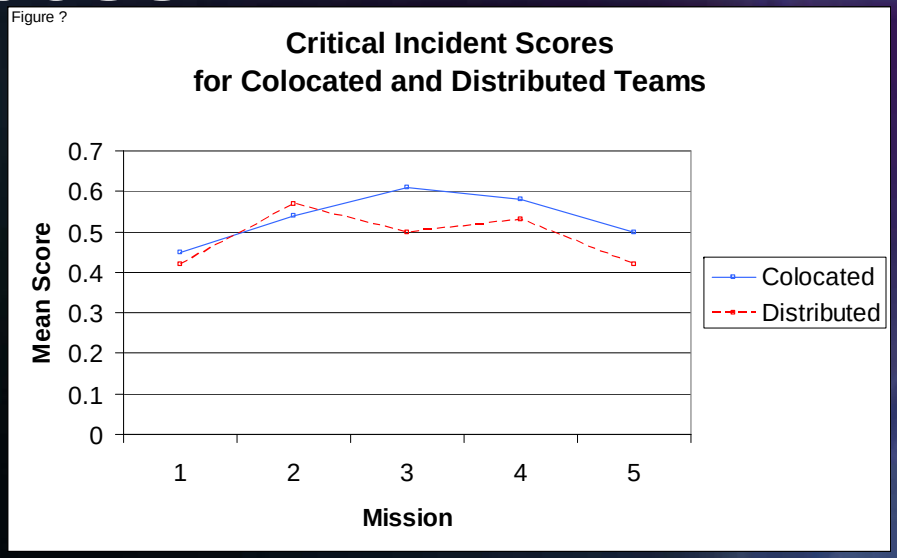
Dispersion IS Detrimental to Team Process





Experiment 3 **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

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