Cognitive Technologies for Teams 711HPW/RHCPT

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14. ABSTRACT
The mission of the Cognitive Technology for Teams (CTT) research program is to conduct research and development that enhances the Air Forces capability to support teams that are effective, resilient, and adaptable within the context of command and control (C2). The program provides science and technology leadership in two areas, a) the development and assessment of collaborative interfaces to extend the effectiveness of battle managers working within a network-centric framework, and b) the development of new metrics for assessing team workload and performance. To this end the program conducts applied research within two laboratories. The Collaborative Technology Testbed permits the systematic evaluation of advanced collaboration interface technologies, data visualization tools, and multi-modal interface technologies and their effects on team performance, communication effectiveness, shared situation awareness, and decision effectiveness. Experiments in this lab typically employ high-fidelity simulated work environments for human-in-the-loop experimentation. The Augmented Team Workload Assessment Lab is designed to explore the application of physiologic-based operator state assessment technology to the objective, online measurement of team states such as mental workload, stress, and fatigue. Research in this lab is focused on the development and validation of theory-driven, innovative subjective and behavioral metrics for characterizing individual and team workload; and development of robust physiological indices of team workload, with a particular interest in minimally invasive measures such as EEG, EOG, ECG eye movement data and cerebral hemodynamics. Current research directions for the CTT program will be discussed.

15. SUBJECT TERMS

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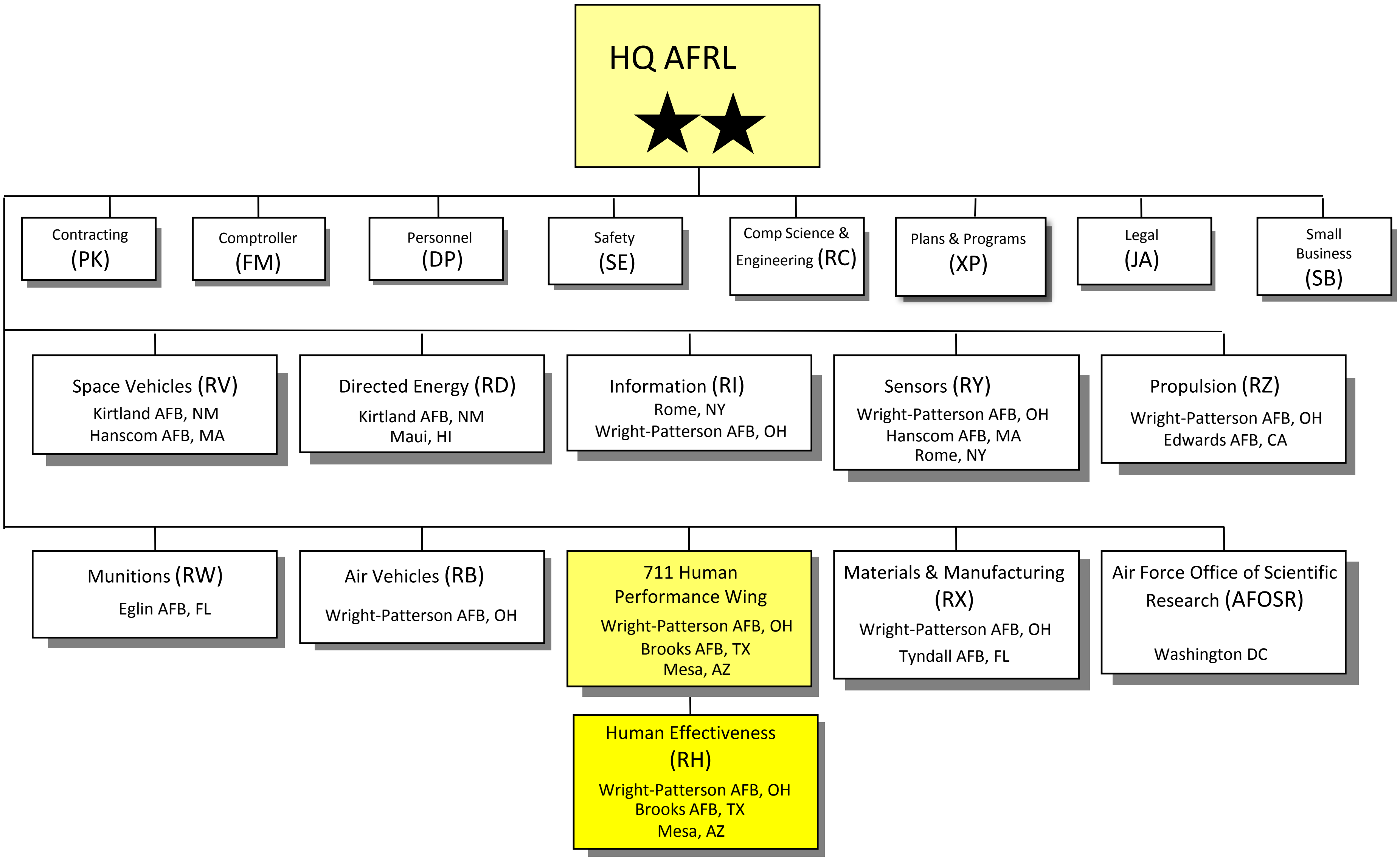
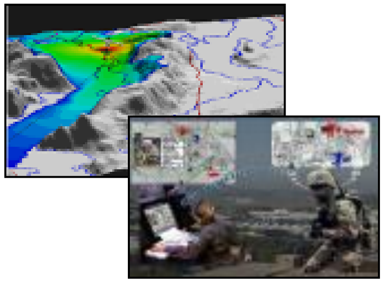
Air Force Research Laboratory Organization Structure



Warfighter Interface Division



Battlespace Acoustics Branch *(RHCB)*

Leading the discovery, evaluation, and transition of revolutionary **auditory and communication technologies** that optimize warfighter survivability and lethality across the full range of battlespace environments

Supervisory Control Interfaces Branch *(RHCI)*

Conducting research to enhance the effectiveness of the **integration of crew and/or operators with intelligent and autonomous systems** to fully exploit the joint capabilities of the human-machine system.

Collaborative Interfaces Branch *(RHCP)*

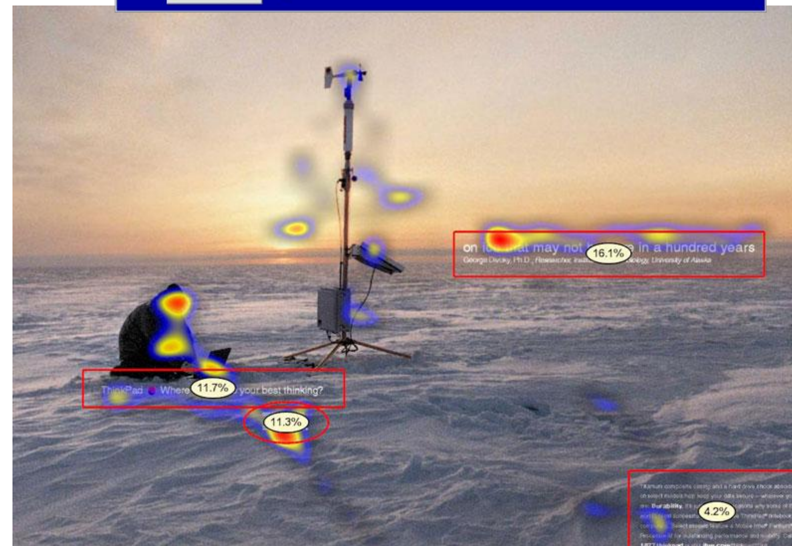
Leading the discovery of innovative technologies that optimize **human-to-human and human-to-machine collaboration** in a network-centric, distributed environment for **both teams and individuals** across all USAF domains

Battlespace Visualization Branch *(RHCV)*

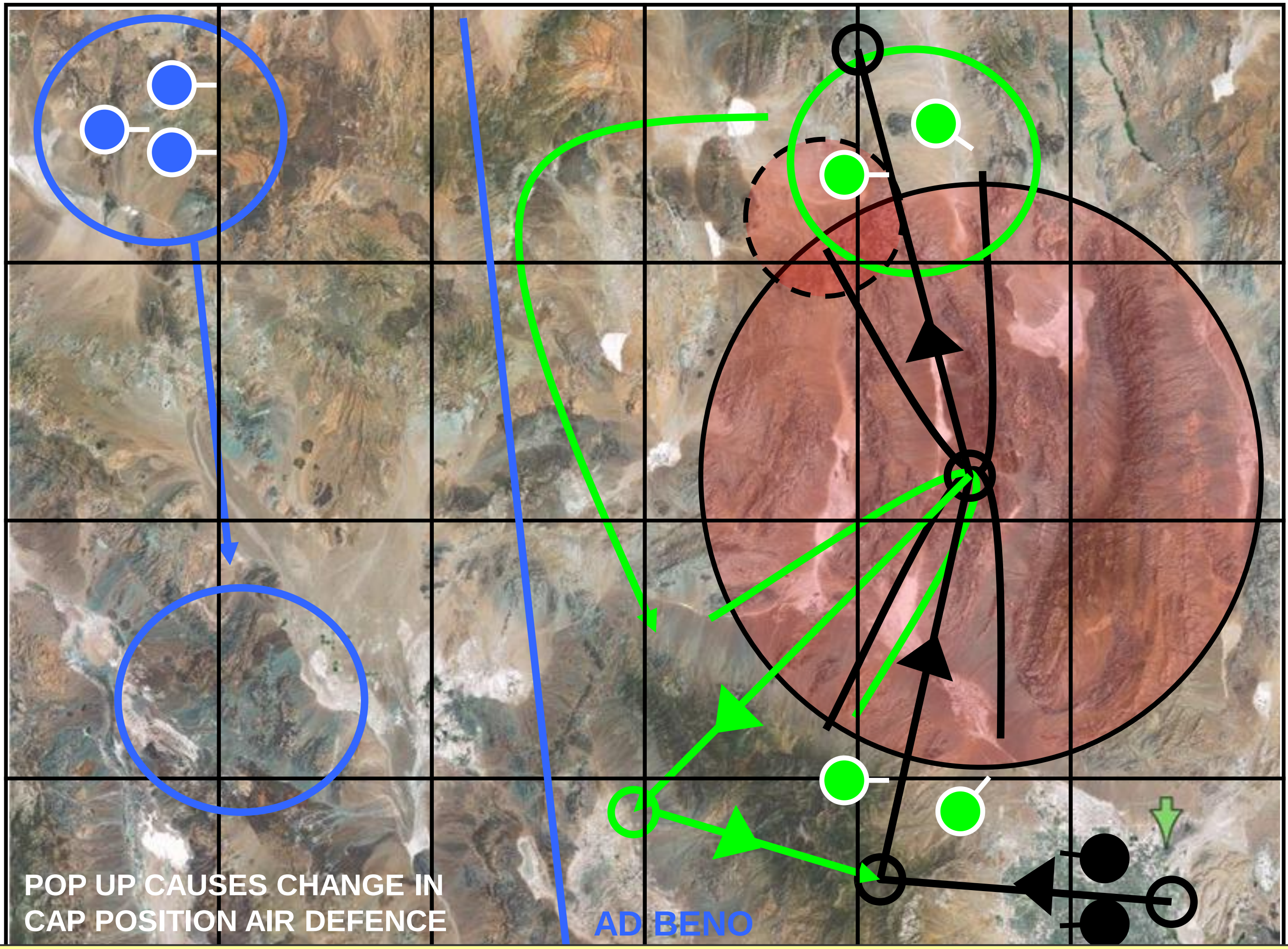
Advancing the science and technology associated with the **collection, optimization, display, and assimilation of visually complex information** to enable accurate and effective decision making across the battlespace domains

Collaborative Interfaces for C2 Program Goals

- **Collaborative Tools for Tactical C2 (FY 05-09)**
  - Design Tools – with multi-modal collaborative interface technologies
  - To Enhance: Performance Efficiency, Decision-Making, Situation Awareness, Workload
- **Augmented Team Workload Assessment (FY08-12)**
  - Develop Metrics to Assess: Team Cognitive Workload and Situation Awareness
  - To Enhance: Distribution of Workload, Situation Awareness, Efficiency & Effectiveness of Decision-Making, Speed of Command
- **Other Studies/Research Areas**



DRAW Use Case 1:
Dynamic Replanning



Can operators quickly communicate information changes (e.g. new EoB info that changes plan), and insure safety and success?

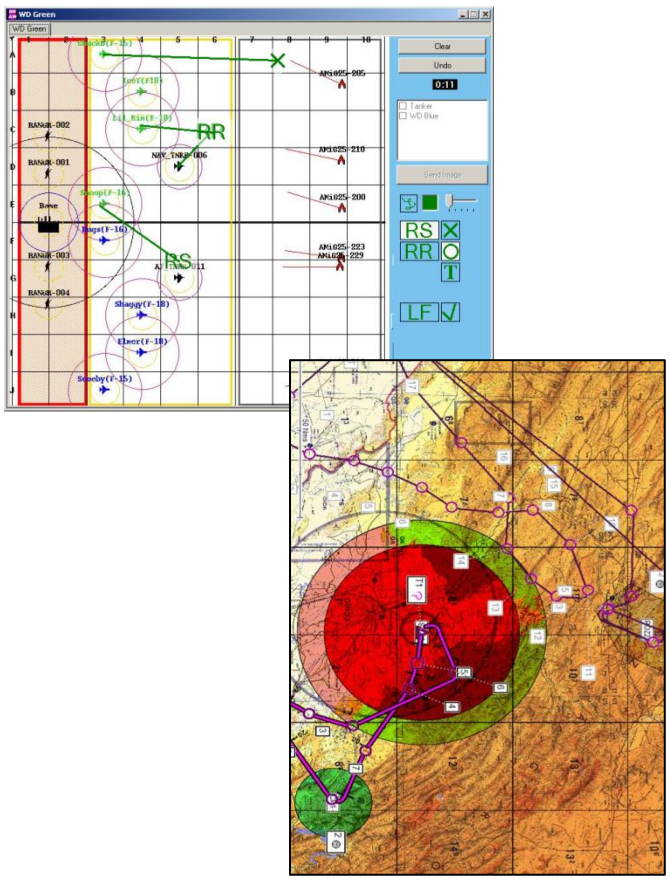
Experiment Players

- **C2:**
  - **Tactical – E-3**
  - Operational – CAOC (White Force)
- TST Strike Package:
  - **Strikers – GR-4s**
  - SEAD – F-16CJs

Ftr C2

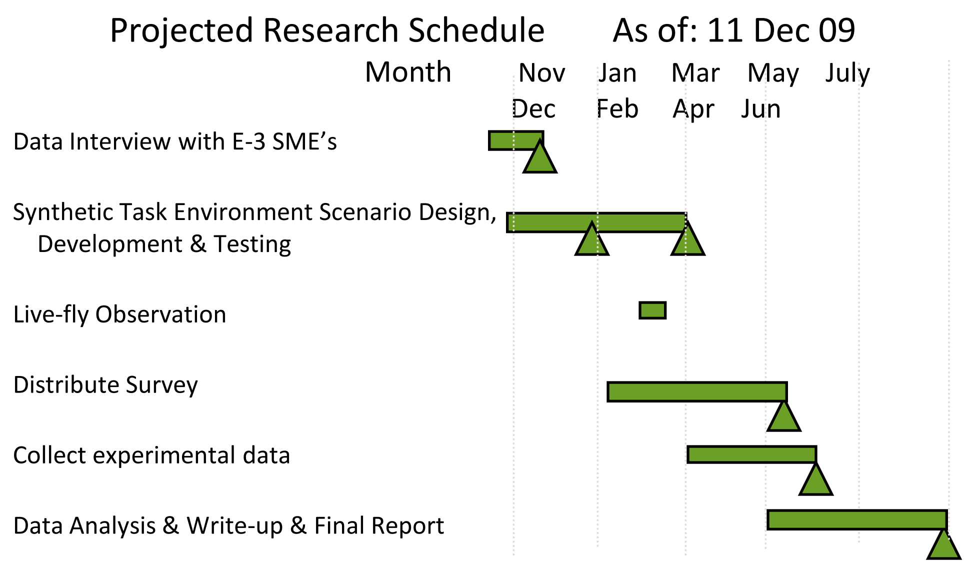
TST Coord

Experimental Factors



- Joint Warrior-based scenario
  - TST and intel injects via WF
- US & UK operator participation
  - 1-5 Mar, Farnborough, UK
- Experimental focus:
  - Interflight coordination for support
    - ROE & SEAD asset dependencies
  - Quickly communicating changes
    - DRAW tool (US)
  - Dynamic mission replanning
    - Mission management tools (UK)
  - Resulting TTPs

Chat Communication Study



Description

Chat communication study to assess the impact chat communication may have on communication processes, shared understanding, and sensemaking behaviors; all of which impact communication and coordination effectiveness.

Approach

Three major components:
1. Operational Chat Survey
2. Live-fly Observation (if permissible)
3. Empirical (Lab) Study

Benefits to the Warfighter

Greater insight into the impact of chat communication can help:

- Enhance implementation to maximize strengths and minimize weaknesses
- Focus future training
- Make smart decisions on best practice of deploying technology

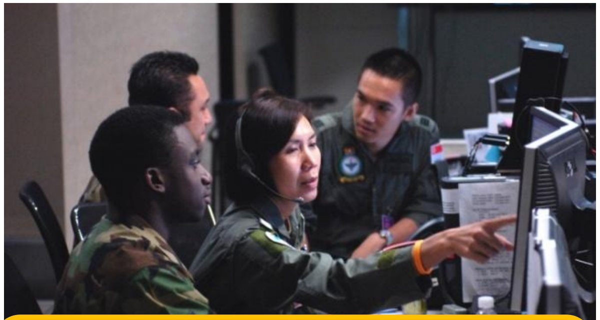
Chat Communication Study

Three Components of Study:

1. Operational Survey
   - Objective: understand current practices, procedures, issues, usage, concerns, and operator requirements.
2. Field Observation (contingent on opportunity)
   - Objective: understand chat usage and difficulties and domain challenges
3. Experimental Study
   - Objective: empirically test the impact chat technology on how teams of operators use this tool to solve problems, coordinate, and communicate

2x2 Experimental Design

	Voice	Keyboard
Transient	Voice Only	Chat Only (messages disappear)
Permanent	Voice + Archival Chat Log	Chat + Archival Chat Log



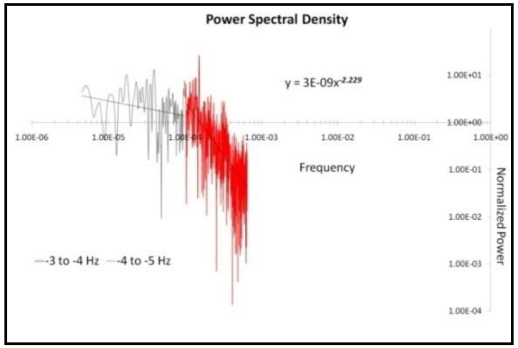
Communication = a means to solve complex problems

Team Resource And Cognitive Effectiveness (TRACE) Monitor

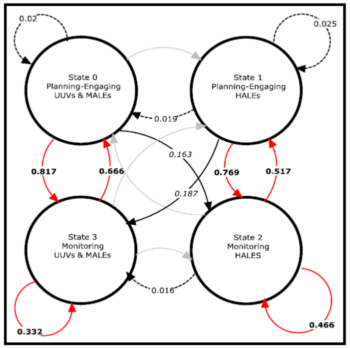
Objective: Develop near-real-time behaviorally- and neurophysiologically-based measures of team fitness (operator functional states).

Approach

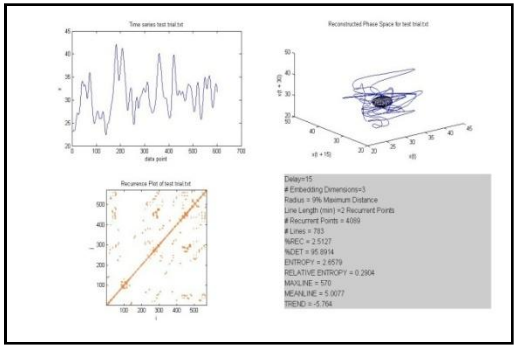
- Leverage advanced mathematical techniques to recognize patterns in team behavioral and physiologic data associated with effective or impaired team performance
  - Statistical modeling of team communication and behavior using Hidden Markov Models (HMMs)
  - Applying nonlinear data analytic techniques (recurrence quantification analysis, cross-recurrence quantification, fractal analysis, etc.) to identify chaotic, emergent patterns in team communication and physiologic data
- Apply online, neurophysiological measures to diagnose likely drivers of team performance impairments (extreme workload, inequitably distributed workload, stress, fatigue, etc.)
  - Potentially useful measures have been derived from EEG, ECG, eye-gaze tracking, and cerebral hemodynamics and oximetry



Fractal analysis of human inter-beat interval data



HMM of operator UAV control (from Boussemart, Las Fargeas, Cummings, & Roy, 2009)



Cross-recurrence analysis of eye-gaze data

TRACE Monitor

Relevance

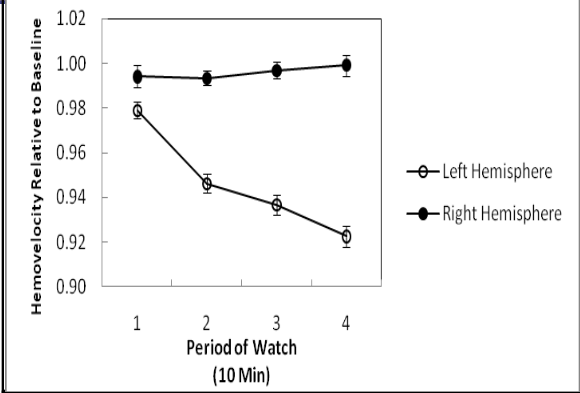
- Future network-centric CONOPs require rapidly formed, distributed teams for missions such as time-sensitive-targeting (e.g., Alberts & Hayes, 2003).
- Distributed teams may not have the opportunity to develop shared mental models that support good team performance & SA (Salas et al., 1995)
- TRACE will allow remote mission commanders and adaptive aiding tools to perceive and anticipate team "mental" fitness, allowing them to better direct team resources and improve performance & SA

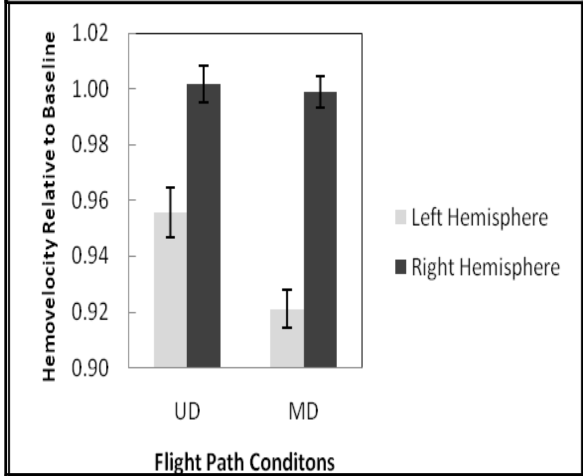
Payoffs

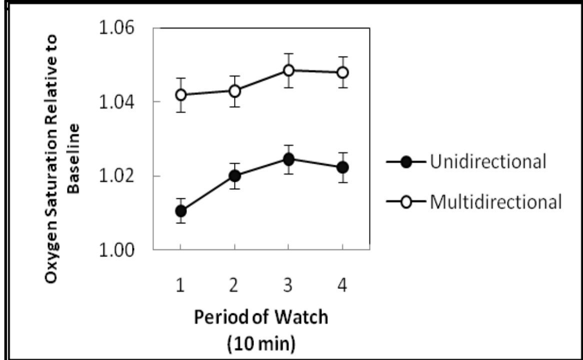
- Monitoring and diagnostic tools for dynamic assessment, management, and mitigation of teams, improving performance and SA
- Provides critical metrics for understanding human-unmanned systems
  - Such systems operate differently than human teams in many respects (e.g., issues of trust, complacency, communication, etc.)
  - TRACE provides additional/novel approaches to understand teams, team processes
- A diverse suite of validated team process metrics, allowing more accurate appraisal of team effectiveness
  - Allows us to treat teams as emergent systems, not simply collections of individuals

Cerebral Hemodynamics

- **Transcranial Doppler Sonography (TCD)**
  - **Utilizes ultrasound signals to monitor intracranial arteries**
  - **When a particular area of the brain becomes metabolically active, by-products of this activity will increase**
    - This results in increased blood flow to the region to remove the unwanted by-products
- **Near-Infrared Spectroscopy (NIRS)**
  - **Utilizes tissue absorption of near-infrared wavelengths to measure cortical oxygen saturation levels or regional saturation of oxygen (rSO_2)**



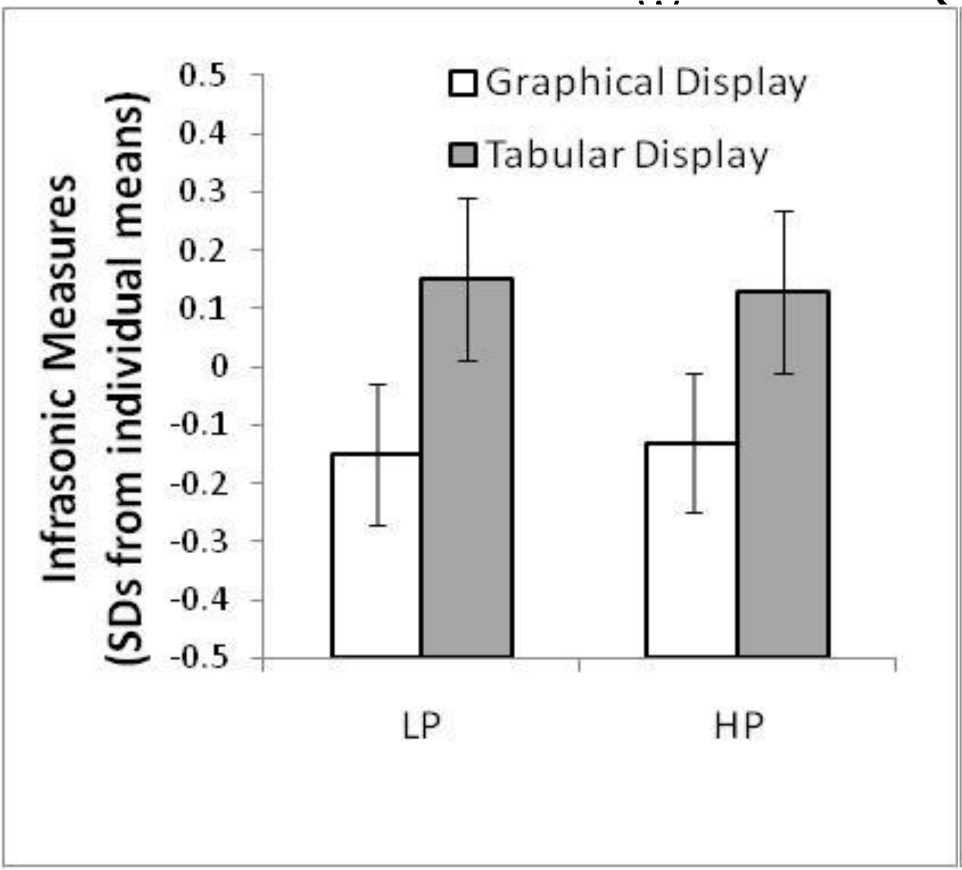


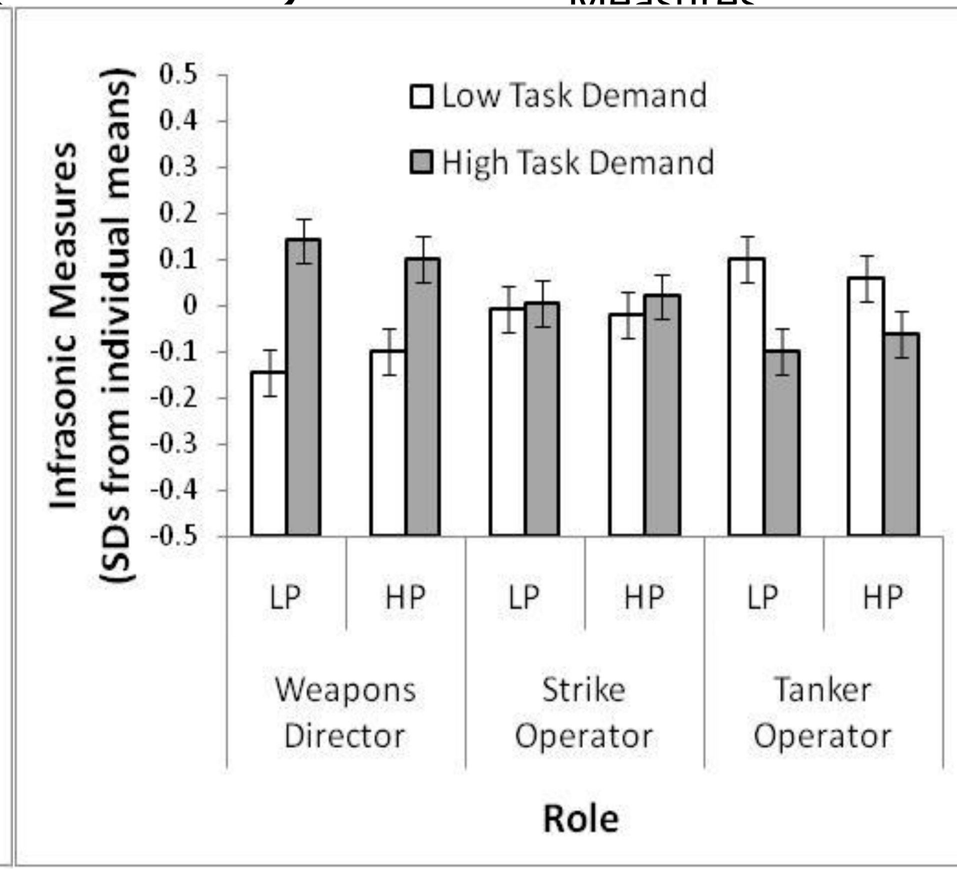


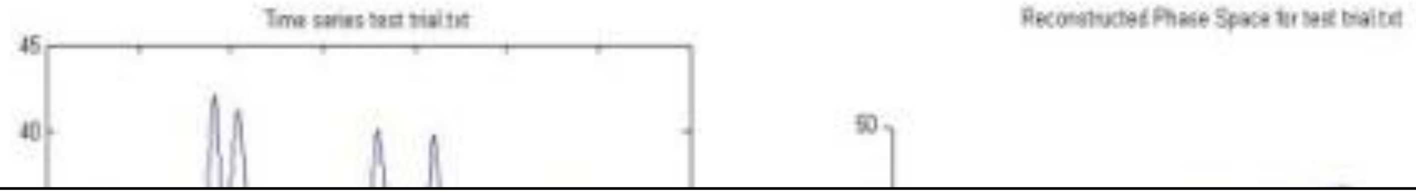
Voice Stress Analysis

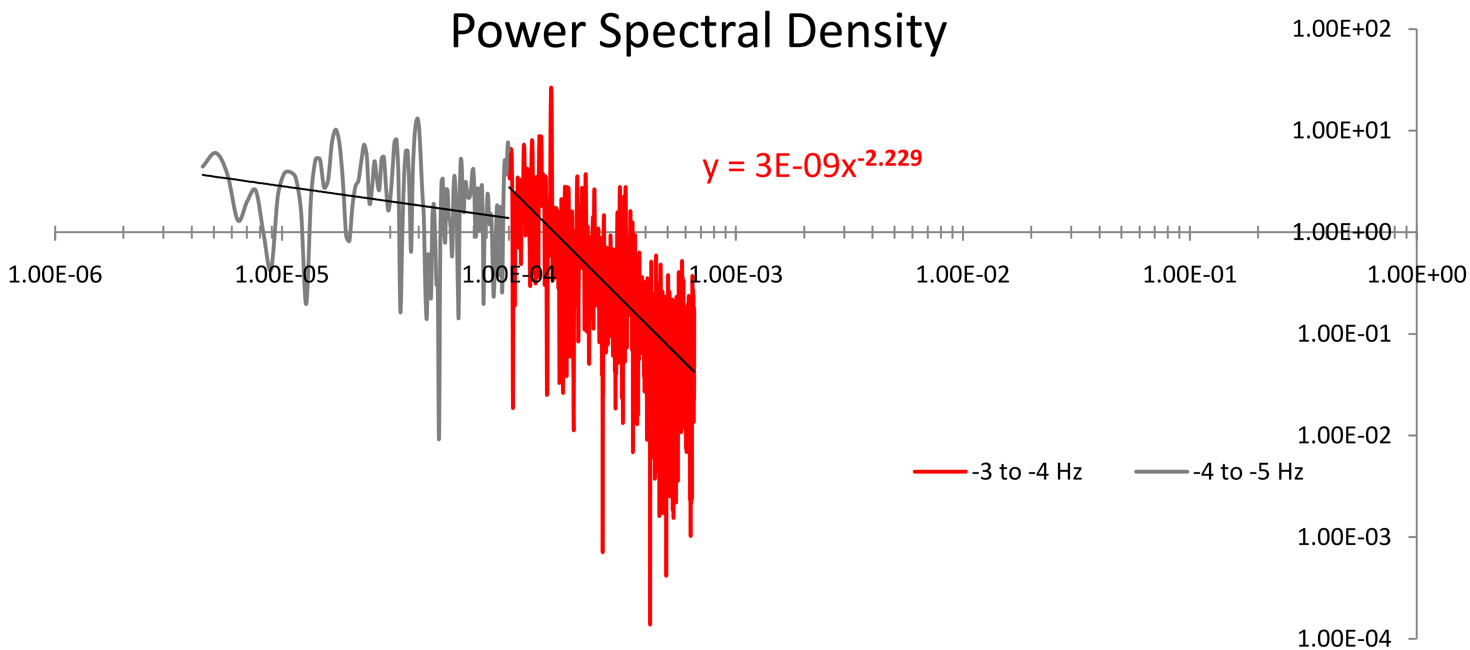
Measures:

Low Power Algorithm → Infrasonic Stress Measures





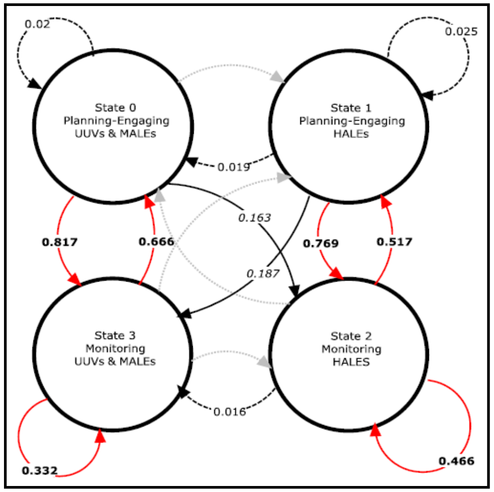




Fractal analysis of human inter-beat interval data

Sensitivity & Diagnosticity in Predicting Team Performance

- **HMM development extracts patterns of behavior from large corpora of training data**
  - **Future prediction is based on statistical likelihoods of a chain of behavior derived from patterns learned in training**
  - **Provide a novel means to monitor and predict individual and team performance**
    - Uncertain if predictive accuracy is improved using separate HMMs for each team member, or using a single "team" HMM
    - HMM prediction under different levels of task demand
- **EEG-based measures of workload are particularly promising (Gevins & Smith, 2003)**
  - **Central assumption is that changes in brain activity reflect ongoing mental work (Tsang & Vidulich, 2006)**



RHCPT Team

Research Scientists

- Gregory Funke, Ph.D.
- Benjamin Knott, Ph.D.
- Lt Connie Ambrose
- Becky Brown
- April Courtice*
- Matthew Funke*
- Maj Chris McClernon, Ph.D.
- April Rose Panganiban*
- Sheldon Russell*

Software Engineers

- Allen Dukes
- Brent Miller
- Jim Hyson
- Matt Middendorf

Program Managers

- Sam Kuper

***students**

RHCPT Collaborators

- **AFRL**
  - RHCPA
  - RHCB
  - RHA
  - RHXS
  - RHCI
  - RISA
- **International Partners**
  - DSTL & QinetiQ, UK
  - DSTO, AUS
- **Academic Partners**
  - Massachusetts Institute of Technology (MIT), Humans and Automation Laboratory (HAL)
  - University of Cincinnati
  - Wright State University
  - West Point
  - University of Central Florida
- **Industry**
  - Boeing

Questions?

RHCPT Spaces and Projects

- **CTT Lab**
  - **SDO Program – Sam Kuper**
  - **Dynamic Cyber Security – Janet Peasant**
  - **MATRIX Experiment**
    - DRAW & UK PA – Allen Dukes
    - WCAS & MMC – Brent Miller
    - SPO Chat Study – April Courtice
    - Nonlinear Analysis – Sheldon Russell
- **Workload Lab**
  - **Voice Stress Analysis**
    - Algorithms and Metrics – Chris McClernon, Matt Middendorf
    - Nonverbal Voice Stress Analysis – Mike Harter
  - **BioRadios & EEG – Becky Brown, April Rose Panganiban**
- **DART Lab**
  - **Change Blindness Research – April Rose Panganiban, Becky Brown**
- **BMC2 Lab**
  - **Transcranial Doppler Sonography Research**
    - TCD and Vigilance Research – Matt Funke
    - Removal of Voice-Related Artifacts from TCD Recording – Connie Ambrose
  - **Overview of TRACE Research**
    - FaceLab Demo – Allen Dukes
    - TRACE Workload Scale and Exchange Interfaces – Jim Hyson