# *Naturalistic Flight Deck*

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# Outline

- Crew Resource Management (CRM) - *Crew ⇉ Cockpit*
- Naturalistic Flight Deck (NFD) Goal
- NFD Agents
- Haptic Flight Control System (HFCS)
- Interface Paradigms 3 ⇉ *1*
- Progress since 2007
- Awareness and Engagement Experiment
- Team Composition
- Supporting Programs
- Future Plans

# CRM Crew ⇉ Cockpit

- CRM has been a great success
  - Train crews
    - How to work together
    - How to manage resources
    - How to cross-check
    - How to back each other up
- But CRM leaves out a critical member of the flight deck
  - This agent is
    - Not expressive or communicative
    - Unaware of the overall goals of the mission
    - Blindly obedient
    - Unaware of what other crew members are doing
    - Not adaptive or flexible
    - Gives up when faced with a problem
  - Usually the one flying the aircraft!
  - We can't retrain – we must redesign
    - *A single point solution won't cut it*
- *True <u>Cockpit</u> Resource Management*
  - *Redesign of Agents Roles and Responsibilities*
  - *Enable Clear Communication among agents*

# NFD Goal

- Develop a holistic flight deck design based on human factors, psychological and physiological principles.
  - Revolutionary target for evolutionary progress
  - Design decision traceable to principles
  - Relatively technology independent
  - Expandable as new airspace paradigms and technological breakthroughs emerge

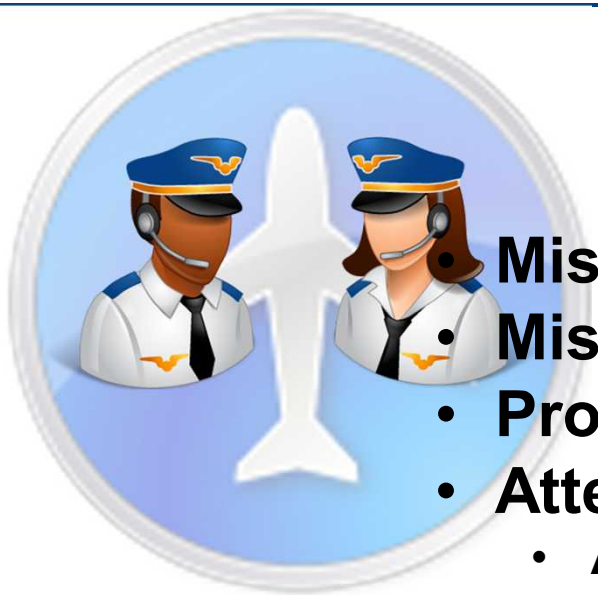
# NFD Agents

# Crew

## Crew

- Mission Manager
- Mission Monitor
- Troubleshooter
- Backup

# Crew Task Alerting & Planning

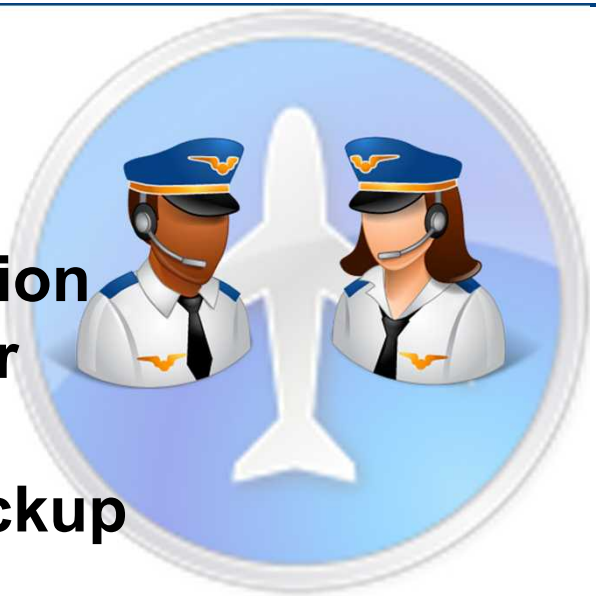


- Mission Planner
- Mission Monitor
- Prognosticator
- Attention Manager
  - Alerts and Alarms

CTAP

# Haptic Flight Control System

- Tactical Execution
- Tactical Monitor
- Troubleshooter
- Emergency Backup



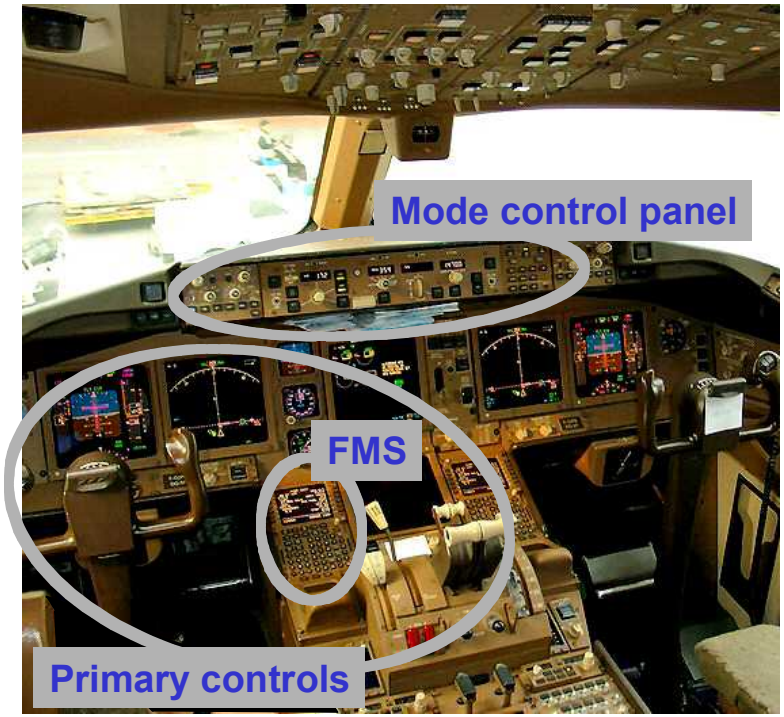
HFCS

# Haptic Flight Control System

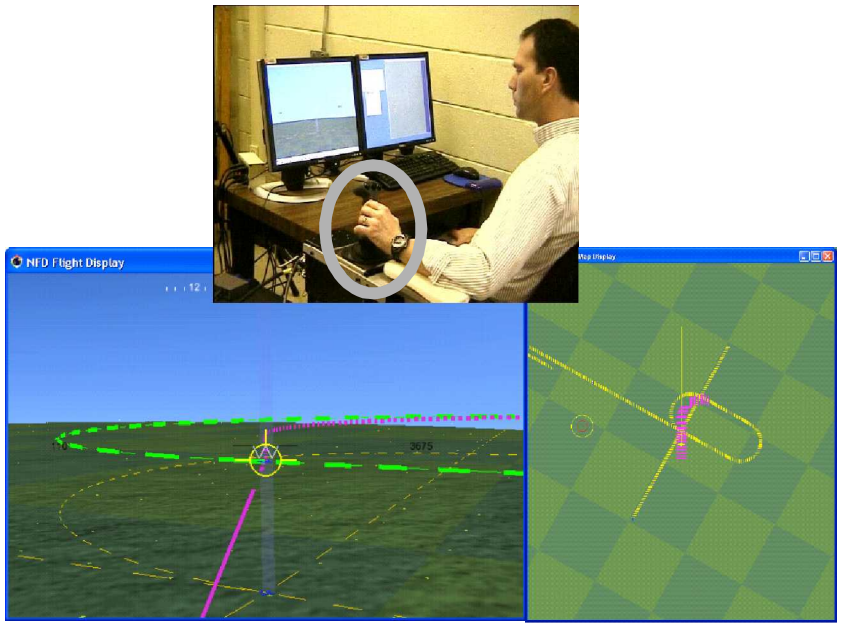
- Vehicle as a semi-autonomous agent:
  - Limited situation awareness and near-term action execution
  - Performs near-term maneuvering & control but not long-term preprogrammed sequences
  - Variable autonomy level (tight and loose rein control)
  - Self-preservation instinct & independent “will”
- Performs Inertial and Performance Behaviors
  - Airway segment following
  - Holding Patterns
  - Takeoff, landing
  - Econ Climb
- Multi-modal interaction with strong bi-directional, haptic component
  - Information encoding is largely analog / spatial rather than linguistic / abstract
  - Simple but flexible and robust communication
    - …not two monologues

# Interface Paradigms 3 ⇉ 1

**Current state of the art:**
Separate interface for
each automation level
*Three ways to move the aircraft*




**H-inspired:**
Single interface allows efficient
management of all levels
*One way to move the aircraft*



# Progress since 2007

- **Usability study – HFCS in turbulence**
  - Visual Motion Simulator
  - Motion (on/off), Turbulence (on/off)
  - 6 different terminal area tasks
  - 5 pilots
  - Cooper Harper Ratings and subjective comments and questionnaire
  - Subjects rated HFCS as easy and gave several design comments
- **Design for functional equivalence with FMS/Auto-pilot**
  - Ensure that all functions that can be accomplished in modern flight decks can be accomplished using HFCS
  - Implemented those functions that were missing
- **Awareness and Engagement Experiment**

# Awareness and Engagement Experiment

- **Compare Manual, *Segment-based Automation**, & Fully Automated**
  - Situation Awareness (Objective & Subjective)
  - Workload (Subjective)
  - Preference (Subjective)
  - Performance on Secondary Tasks (Objective)
  - Failure Detection (Objective)

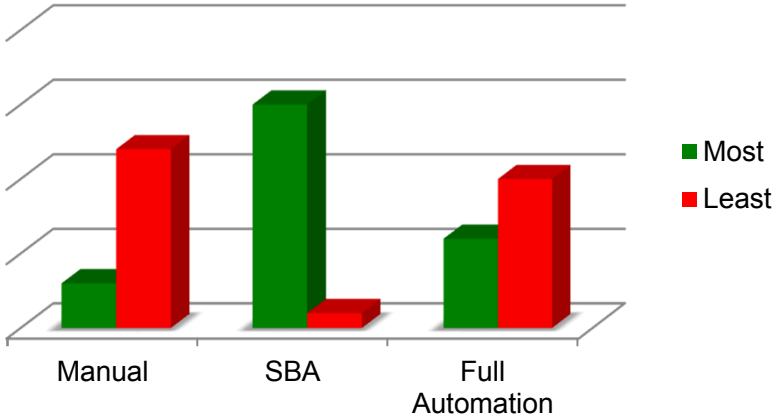
- **Experiment**
  - 24 non-IFR pilots with 50-300 hours (at least 12 hours in last year)
  - HAVS Lab - Workstation-based simulation
  - Plan and fly 4 flights (ranging from 1 to 2 hours)
    - Fictitious Airspace
  - Perform secondary tasks (Target Identification and Math)
  - Make Tactical and Strategic Changes
  - Failures introduced
  - Within Subject (each subject flew each condition)

**** Segment-based Automation (SBA) is a subset of HFCS.***

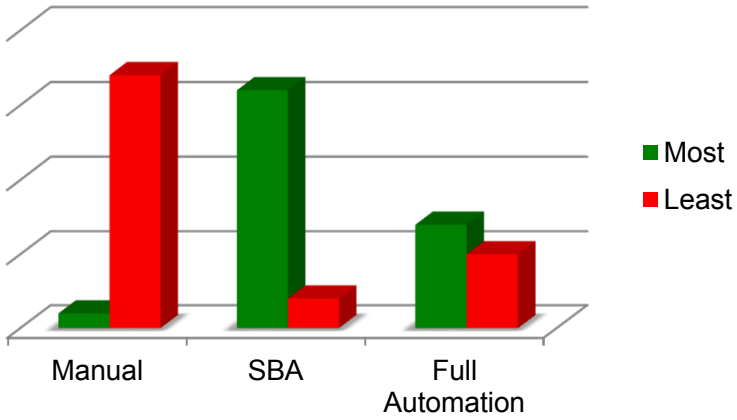
# Awareness and Engagement Experiment

- **Results** *(Statistically Significant)*
  - **The SBA condition improved flight progress situation awareness (Subjective) over that of full automation.**
  - **The SBA condition caused less Mental workload and Effort when compared to the Manual condition.**
  - **Subjects preferred SBA over both Full Automation and Manual**
    - **Just flying the aircraft**
    - **All tasks**
  - **Subjects detected a failure of the automation in the SBA condition sooner than they detected it in the Full Automation condition.**

**Preferences**




**Flying**




**Combined**

# Team Composition

- **Skill Mix**
  - Automated systems design
  - Aviation operation concept and procedure development
  - Crew/vehicle interaction technologies
  - Flight management
  - Flight operations
  - Human/Automation Integration
  - Simulation and flight testing
  - Software development

- **Workforce**
  - 2.5 FTE (historical average)
  - 1 WYE (supporting research activities, automation development, and simulation infrastructure development)

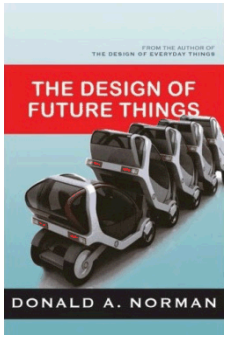
# Supporting Projects

- **Aviation Safety Program**
  - **Vehicle Systems Safety Technologies (VSST) Project:** *provides knowledge, concepts and methods to avoid, detect, mitigate and recover from hazardous flight conditions, and to maintain vehicle airworthiness and health.*
    - **Naturalistic Flight Deck (NFD)**: *explores concepts and methods to reduce apparent complexity and improve apparent consistency within the flight deck.*
- **Airspace Systems Program**
  - **Concept and Technology Development (CTD):** *facilitating the Research and Development (R&D) through developing and exploring fundamental concepts, algorithms, and technologies to increase throughput of the National Airspace System (NAS) and achieve high efficiency in the use of resources such as airports, en route and terminal airspace*
    - ***Single Pilot Operations (SPO):*** *explores concepts and methods to redistribute workload in reduced crew operations (e.g., single pilot, incapacitated pilot) among flight crew, ground crew (e.g., ATC, AOC) and automation.*
      **Currently in Planning Stage**

# Interested Parties

- Toyota Aviation
- Honeywell
- DLR
- Raytheon
- DARPA
- Emerald Sky
- Don Norman

***The Design of Future Things***



# Future Plans

- Interface Comparison Experiment (ICE)
  - HFCS compared with [Stick, Autopilot (MCP), FMS]
  - 12 Subjects

- Crew Task Alerting & Planning (CTAP) Development
  - Concept of Operations
  - Use Cases
  - Mockup

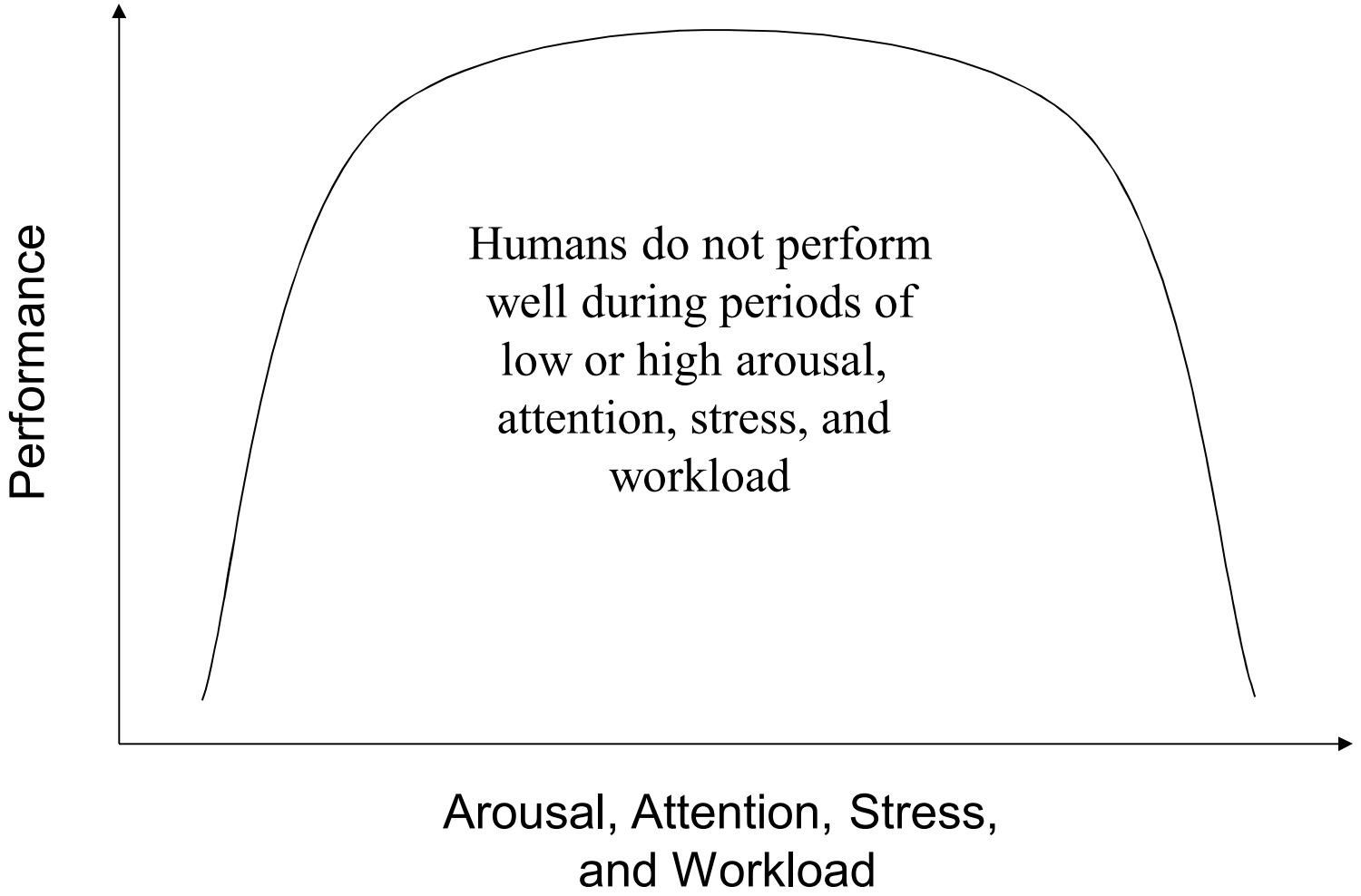
- ICE 2
  - Comparison in a higher fidelity environment
  - Research Flight Deck

# Questions?

# Backup Charts

# Meaningful Crew Involvement

## Yerkes Dodson Law

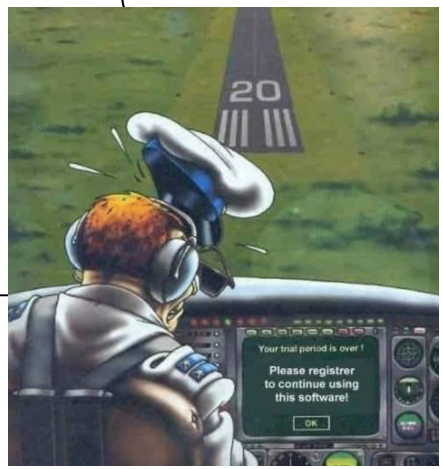


# Meaningful Crew Involvement

## At their worst

Performance

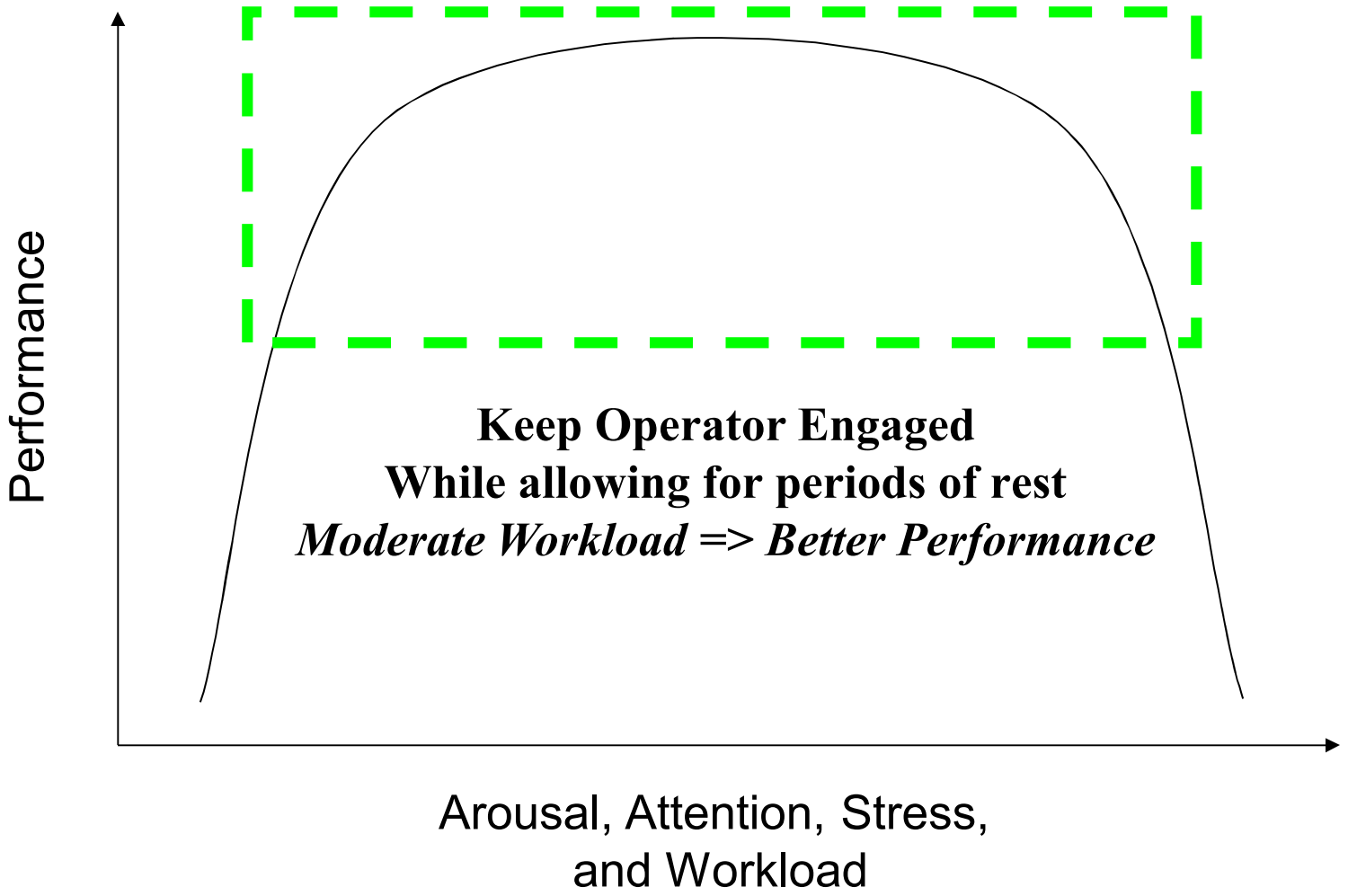
Piloting a modern aircraft is
Hours of Boredom
Punctuated by
Moments of Terror




Arousal, Attention, Stress,
and Workload

# Meaningful Crew Involvement

## NFD Goal



# Single Point Solutions won't cut it

## The interfaces between flightcrews and modern flight deck systems

"Based on our investigations and examination of the evidence, these concerns represent more than a series of individual problems with individual, independent solutions. These concerns are highly interrelated, and are evidence of aviation system problems, not just isolated human or machine errors. Therefore, ***we need system solutions***, not just point solutions to individual problems. To treat one issue (or underlying cause) in isolation will ultimately fail to fundamentally increase the safety of airplane operations, and may even decrease safety."

*FAA Human Factors Team 1996*

# NFD Concept of Operations

# Principles and Guidelines

## *A few examples*

- What we call *Human Error* is actually the negative effects of normal human behavior that is not accounted for in design
- *Human Error* is present even in fully automated systems
- Function allocation based on human role rather than *Fitts List*
  - Changes Information and Control Requirements
- Deliberate use of design metaphors
  - Human, Animal, Body, Tool
  - Function, Interface, Behavior
- Design acknowledges its role in attention and engagement management
- Workload and Situation Awareness managed at *appropriate* levels rather than minimized or maximized

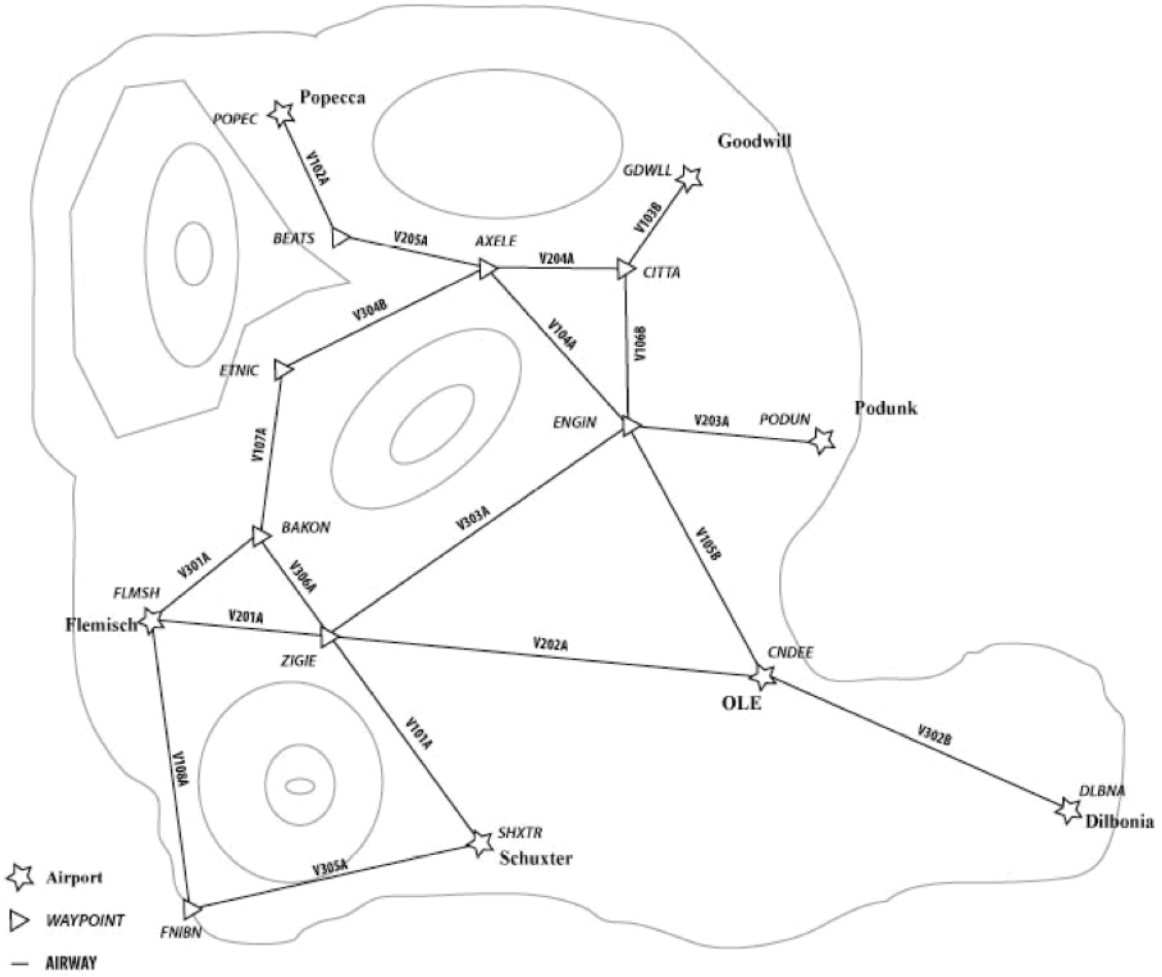
# Error Countermeasures in Design

- **Reducing Error Potential**
  - Memory Aids
  - Information Management
  - Task Management
  - Reducing Complexity
- **Increasing Error Saliency**
  - Mission Status
  - Speed Bumps and Rumble Strips
  - Prognosis & Forecast
- **Increasing Error Tolerance**
  - Modeling
  - Remediation and Explanation
- **Increasing Operator Proficiency**
  - Improved Training
  - On the Job Training
  - Simulation
  - Procedures

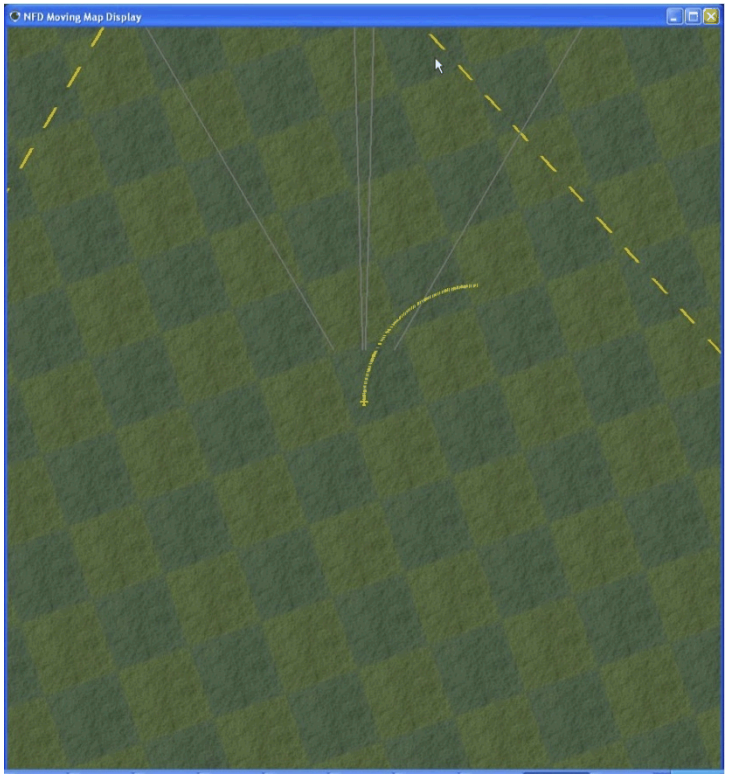
# Role of the Pilot

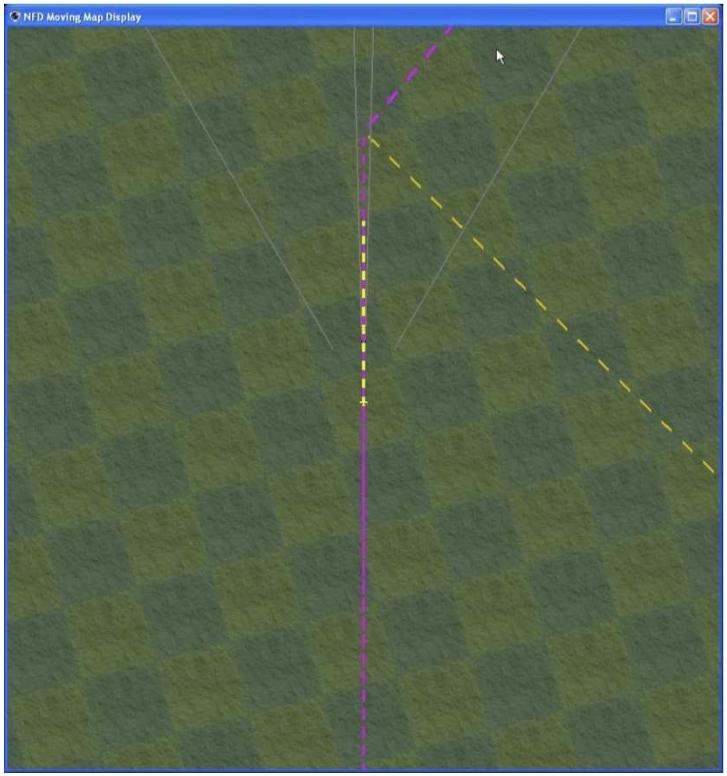
- Manager
  - Strategic perspective
  - *Not just leftovers*
- Monitor
  - Things the automation can't see or when automation makes wrong decisions
  - *Humans poor monitors of highly reliable systems*
- Troubleshooter
  - Override automation or develop new solutions
  - *"Someone's got to pull the circuit breakers!"*
- Backup
  - Reversion
  - Tactical intervention

# A&E Airspace

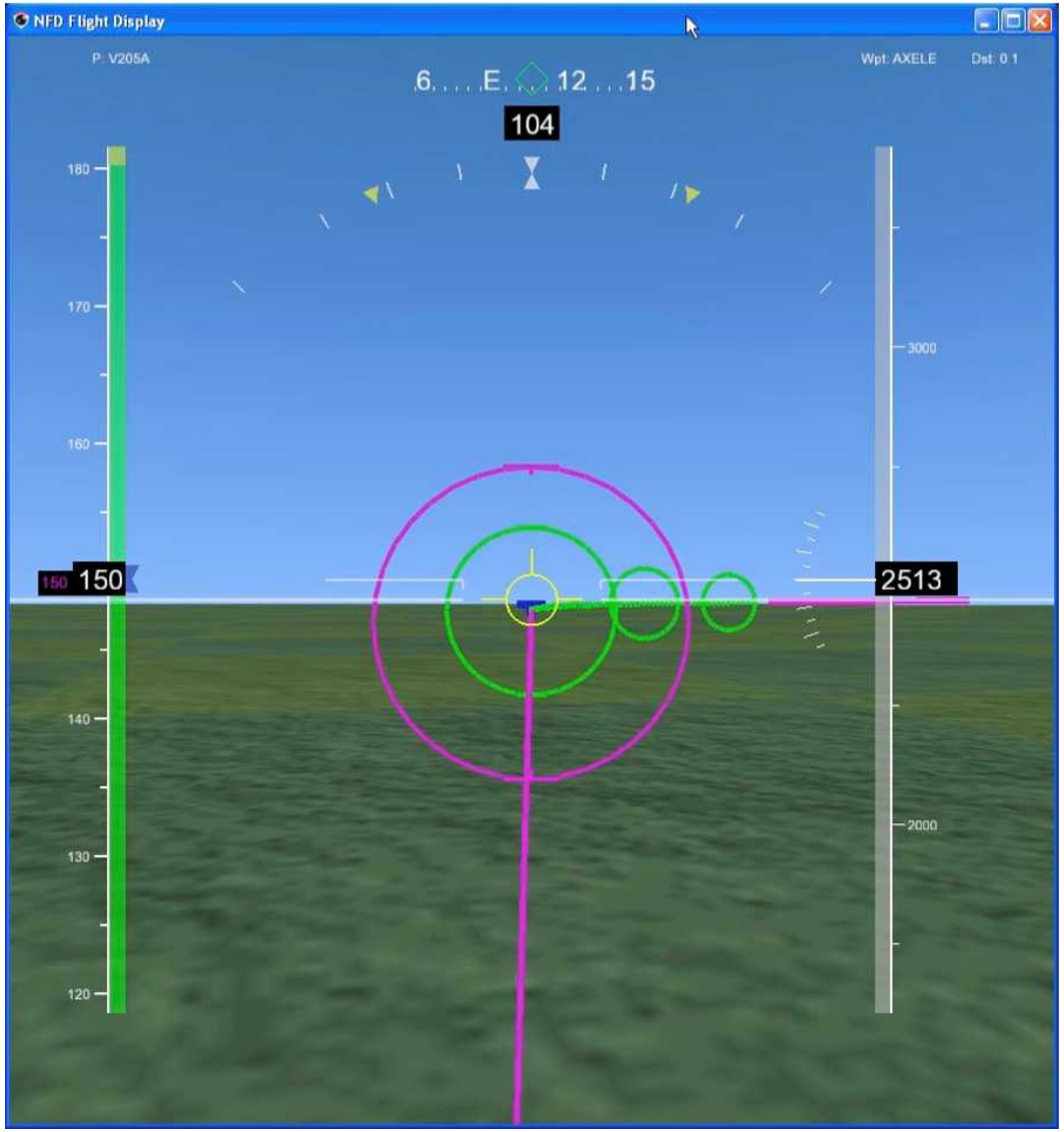

Popecca
POPEC
V102A
Goodwill
GDWLL
V103B
BEATS
V205A
AXELE
V204A
CITTA
V304B
V104A
V106B
ETNIC
ENGIN
V203A
PODUN
Podunk
V107A
BAKON
V303A
V105B
V301A
V306A
FLMSH
Flemisch
V201A
V202A
CNDEE
ZIGIE
OLE
V101A
V302B
V108A
DLBNA
Dilbonia
SHXTR
Schuxter
V305A
FNIBN
Airport
WAYPOINT
AIRWAY

# A&E Map Displays

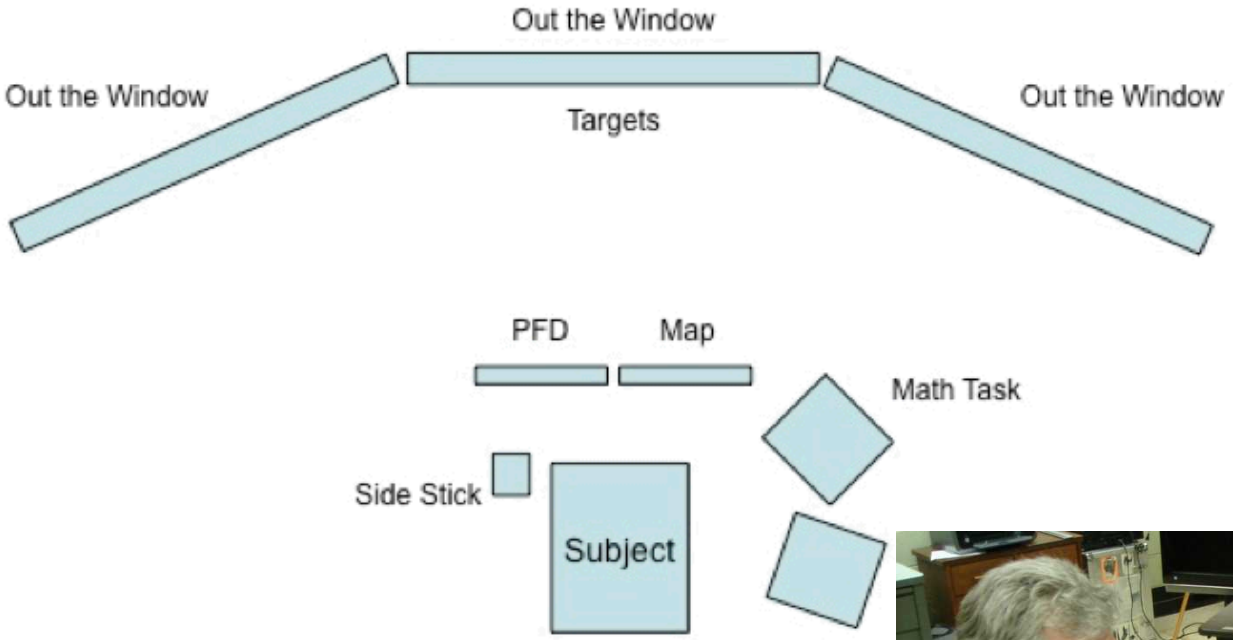


# A&E Primary Flight Display

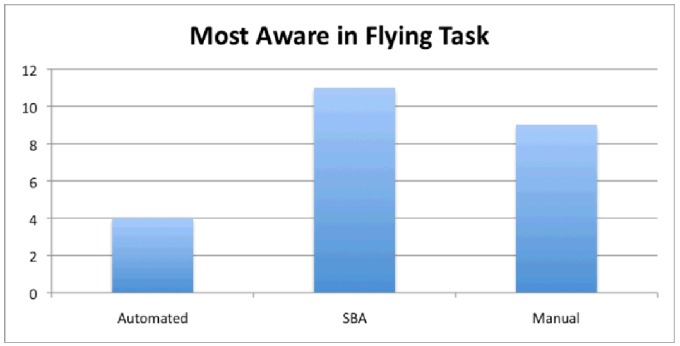


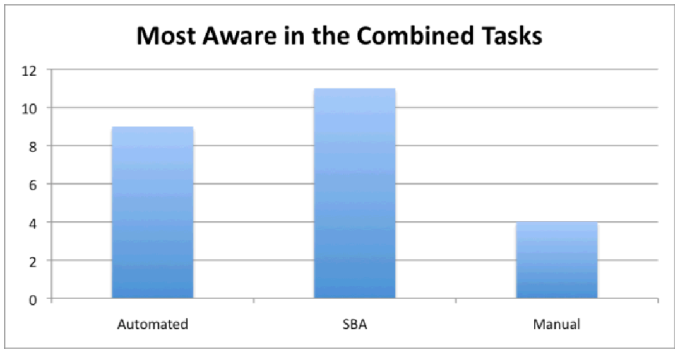
# A&E Lab Layout

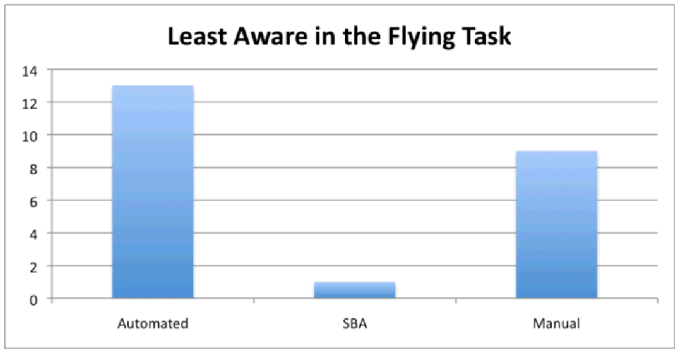


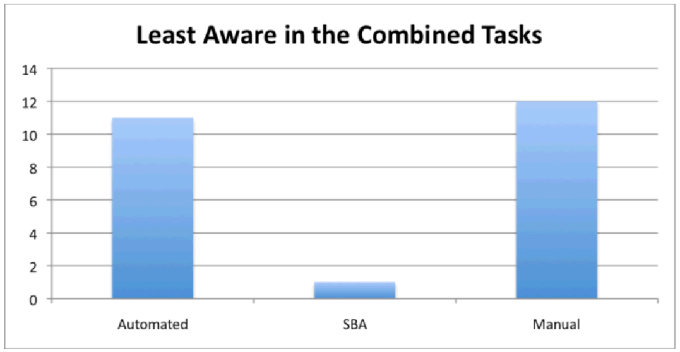

# A&E Experiment Results

## Subjective Awareness

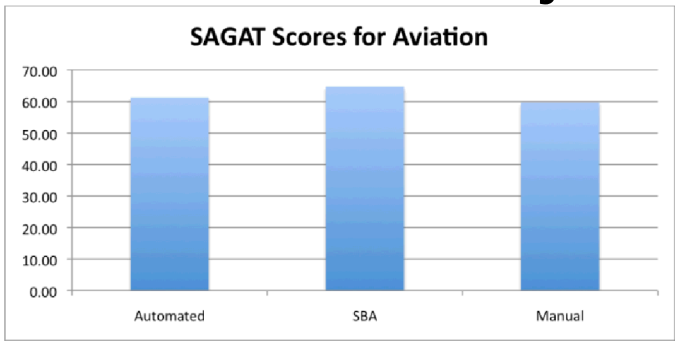


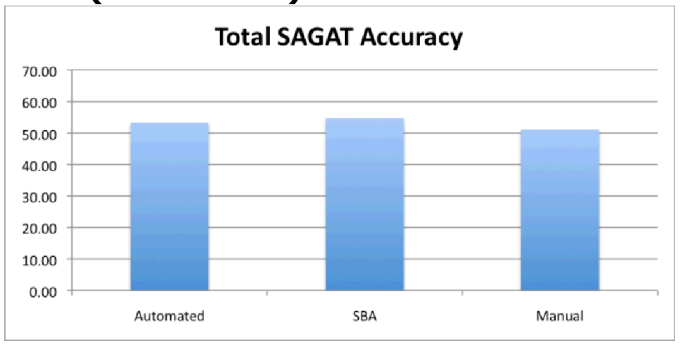



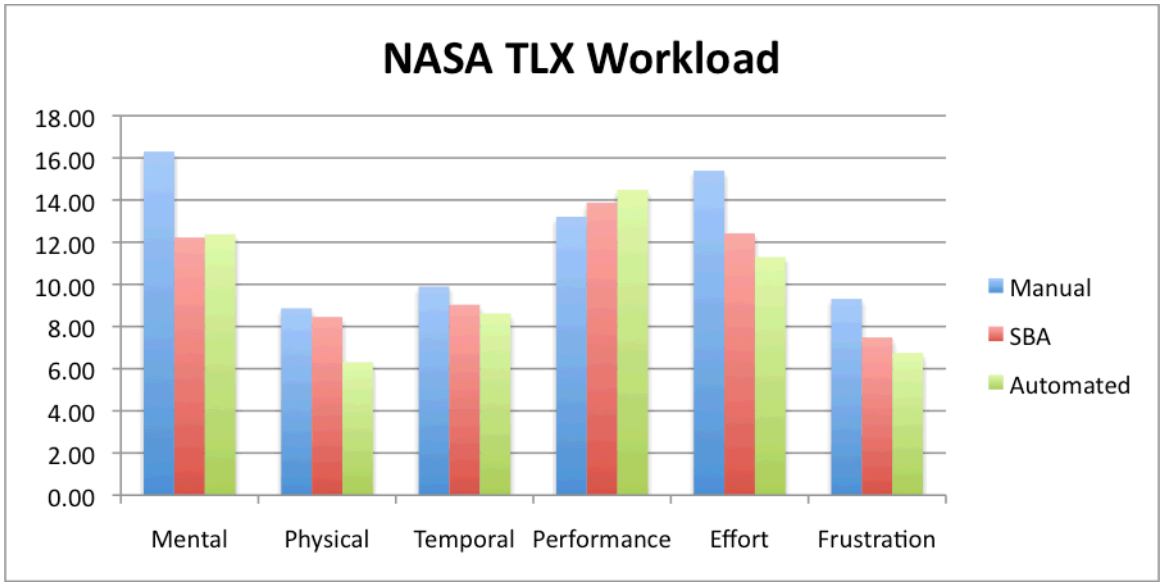

## Objective Awareness (SAGAT)



# A&E Experiment Results

## Subjective Workload



# A&E Experiment Results

## Secondary Task Performance