Selected US Air Force Human Factors Research of Interest to FAA

March 2016

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Human Effectiveness Directorate (711HPW/RH)
Air Force Research Laboratory

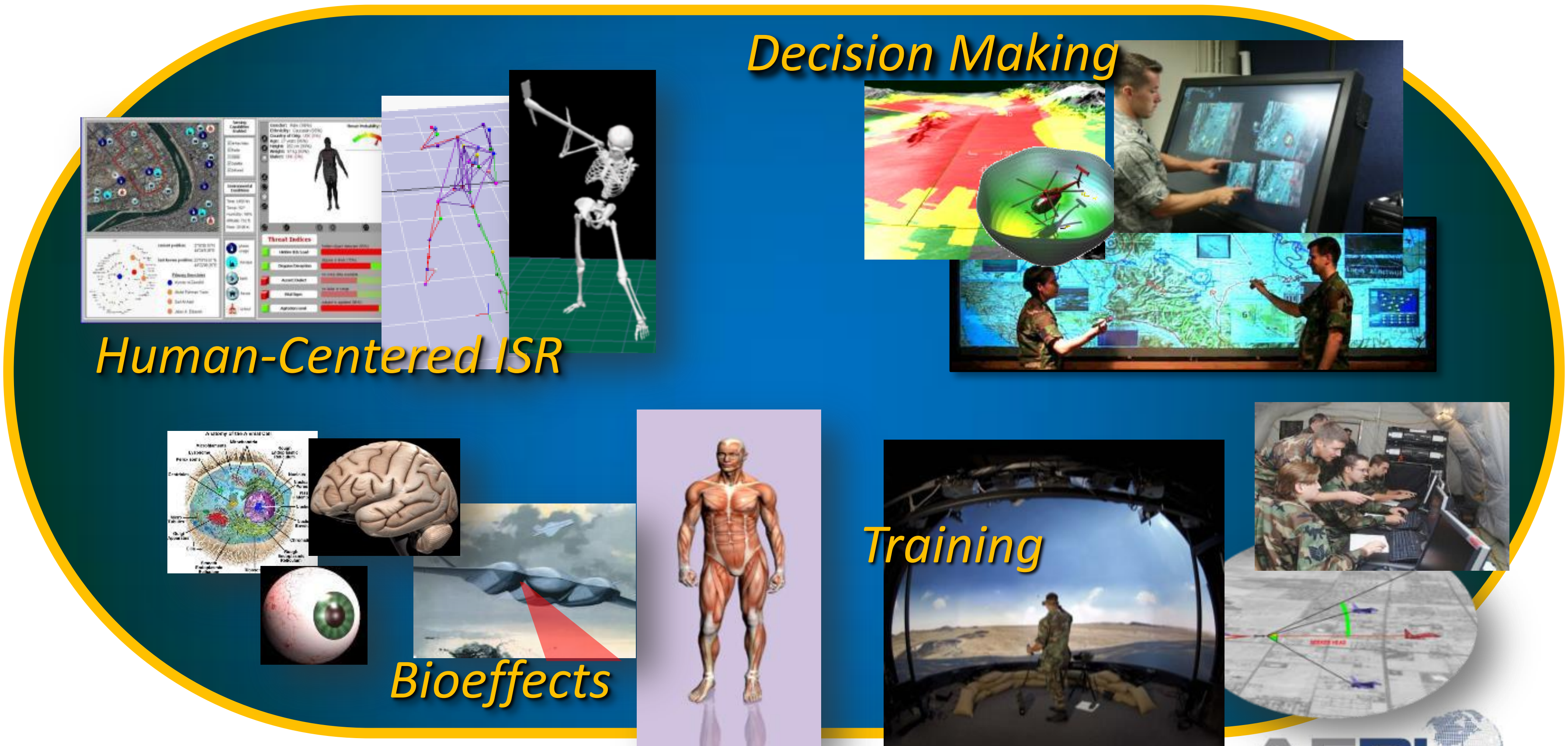
Integrity ★ Service ★ Excellence

711HPW/RH
Vision and Mission

Vision *- Lead the Air Force in Human-Centered Research*

Mission *– Discover Biological and Cognitive S&T to Optimize and Protect the Airman's Capabilities to Fly, Fight, and Win in Air, Space, and Cyberspace*

Organization *- RH is organized around its Core Technical Competencies*



Briefing Outline

1. Operator interface research enabling UAS detect-and-avoid capabilities

2. Other current 711HPW/RH activities related to FAA

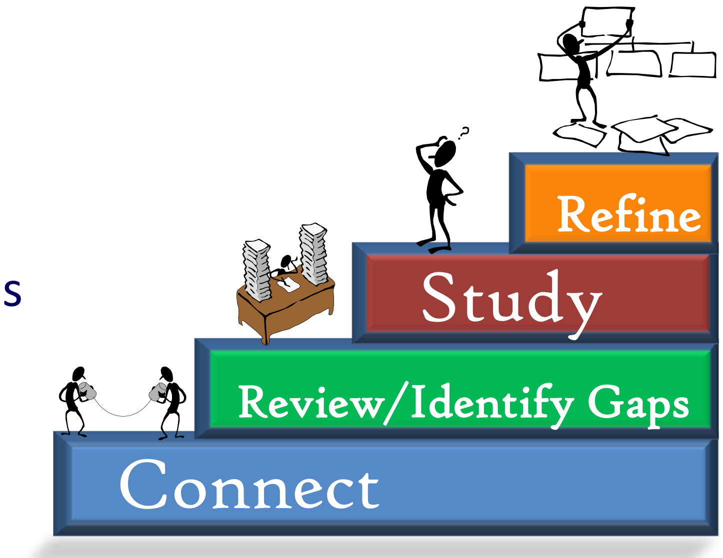
3. Human-machine teaming research supporting future systems

Briefing Outline

1. **Operator interface research enabling UAS detect-and-avoid capabilities**
2. Other ongoing 711HPW/RH activities related to FAA
3. Human-machine teaming research supporting future systems

Operator Interfaces Supporting UAS Detect-and-Avoid

- **Working with Common-Air Based Sense and Avoid (C-ABSAA) Program:**
  - Determine traceable HMI Requirements for USAF needs
  - Identify empirically backed HMI design concepts/strategies
  - Assist in developing a Common Operator Interface across Services
- **Approach:**
  - Strongly leverage existing work
    - Consensus-driven requirements and designs
    - Maximize traceability
  - Maximizing collaborative study opportunities
  - Execute targeted evaluations

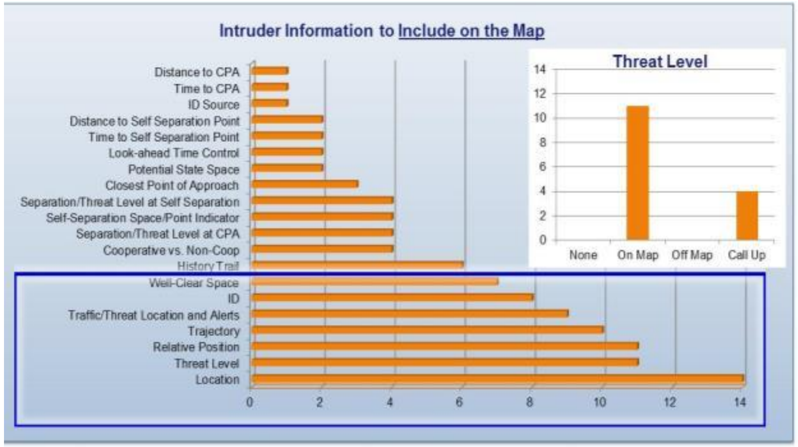


Initial Research Activities

➤ **Traffic Depiction Study**

Function	AFRL	CSD	FAA	NASA
Intruder Information				
Intruder Location	X	X	X	
Intruder ID (BASIC)	X	X	X	X
Vertical Velocity Indicator	X			
Vertical Rate				X
Route	X			X
4-D Information	X			
Range (graphical)			X	X
Range (numeric)			X	
Relative Range	X			X
Bearing (graphical)			X	X
Bearing (numeric)				
Azimuth				X
Heading			X	X
Heading numeric			X	
Altitude	X	X	X	X
Relative Altitude		X	X	X
Vertical Trend	X	X	X	X
Ground Speed	X		X	X
Relative Radial	X			
Air Speed	X			
Intruder History Trail	X		X	

➤ **Derivation of initial "Min Set" Info requirements (joint with NASA)**



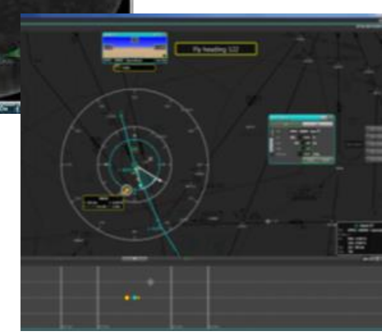
➤ **DAA Information Requirements Operator Survey**

Draper, Pack, Darrah & Moulton, (2014)

NASA/C-ABSAA Collaboration
(NASA Part Task 4 Evaluation)



- **Goal:** Evaluate SAA displays & algorithms with respect to self-separation & collision avoidance.
- **Joint Team:** NASA & AFRL
- **SAA Algorithm:** NASA's Auto-Resolver
- **Data Collection:** Feb-March 2014 (12 RQ-4 Pilots)
- **Design (2x2):**
  - Display Integration Level: Standalone vs Integrated
  - Display Information Level: Basic vs Advanced

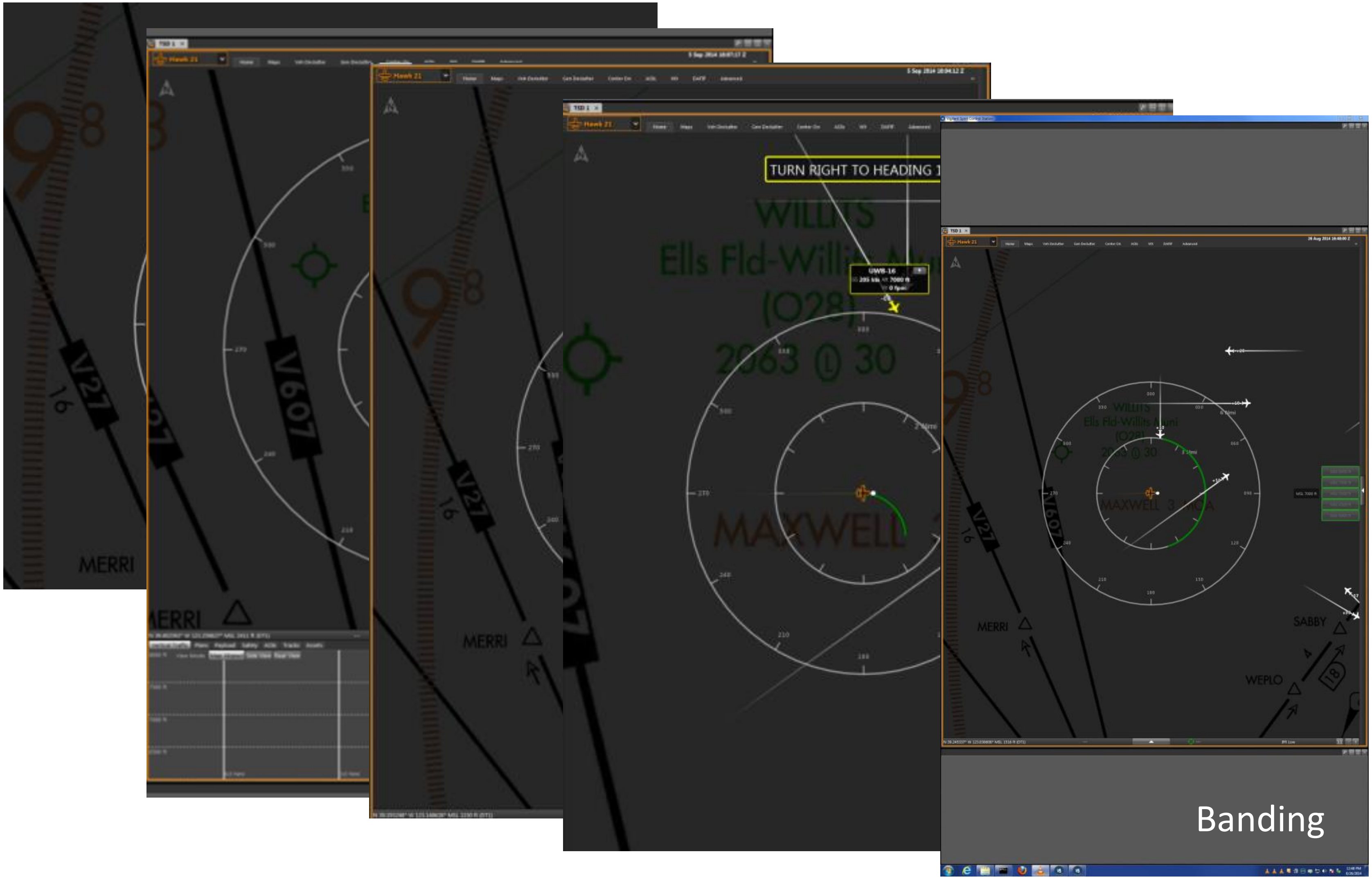
Maneuver Recommendation Study
Overview

- **Pilot Tasks:** Fly through controlled airspace while addressing DAA alerts as well as other mission related tasks
- **Scenarios:** 10 min, Mix of traffic encounters
- **Design:** 5 (Display Configuration) x 2 (Wx Presence)
  - Standalone Display Configurations
    1. *Informative Basic*
    2. *Informative Advanced*
    3. *Directive Text*
    4. *Directive Text + Vector*
    5. *Directive Text + Banding*
  - Constraint Presence
    1. *No Constraints*
    2. *Weather Constraint*

- **DAA Algorithm:** NASA's Auto-Resolver
- **Data Collection:** Aug-Sep 2014, Redstone and Wright-Patterson AFB
- **Participants:** 4 Army Pilots (Grey Eagle/Shadow), 5 Global Hawk Pilots & 6 Reaper/Predator Pilots

Maneuver Recommendation Study

Displays



Maneuver Recommendation Study
Summary

- **Banding Display** most effective in facilitating safe separation
  - Tended to result in fastest response times
  - No CA alerts

- Several features from the **Informative Advanced Display** were indicated as useful
  - Predictive CA Outlining
  - CPA Indications
  - Vertical Situation Display
  - CA Ring

Predictive CA Outline

VSD

- Revealed critical insights into information requirements associated with various **pilot subpopulations** that should be considered when designing future Detect and Avoid (DAA) displays

* Pack, Draper, Darrah, Squire & Cooks, 2015

Perspective Study
Overview

- **Pilot Tasks:** Evaluate a traffic scenario and verify the safety of a commanded maneuver with different levels of display misalignment present
- **Scenarios:** 6 different traffic engagements (subjects saw each engagement twice)
- **Design:**

No Adjustment Capability

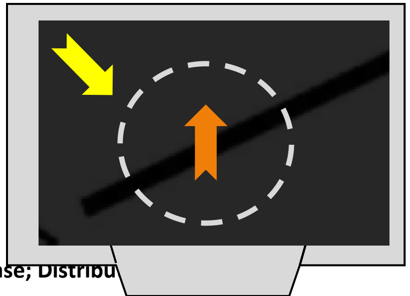
1. *Integrated*
2. *Aligned Standalone*
- *Standalone with offset:*
3. *Zoom Level*
4. *Orientation*
5. *Zoom Level & Orientation*

Adjustment Capability

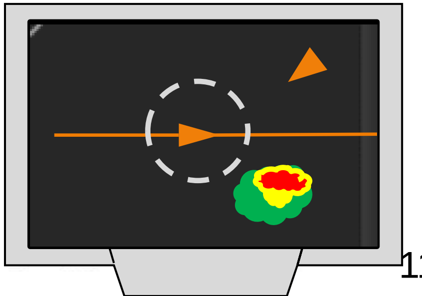
1. *Integrated*
2. *Aligned Standalone*
- *Standalone with offset:*
3. *Zoom Level (step)*
4. *Zoom Level (continuous)*
5. *Orientation*
6. *Zoom Level (step) & Orientation*
7. *Zoom Level (continuous) & Orientation*

- **Testbed:** Vigilant Spirit screenshots
- **Data Collection:** April-May 2015, Wright Patterson AFB
- **Participants:** 28 Subjects, 14 pilots & 14 UAS Students/Gamers

DAA Display



TSD



Perspective Study
Summary

- **Multiple misalignments** (zoom & orientation) with **continuous zoom** functionality required **more adjustments** and resulted in **longer response times**

- **Response times** were **shorter** among the **gamers/student** population

- Subjects **adjusted orientation** the **most** and reported **orientation misalignments** as the **most detrimental**

- Majority of pilots **suggested** a **link on demand zoom functionality** with the **TSD** as the **parent**

- Pilots **advocated** adding **NFZs**, **weather**, and **waypoint route** to DAA display

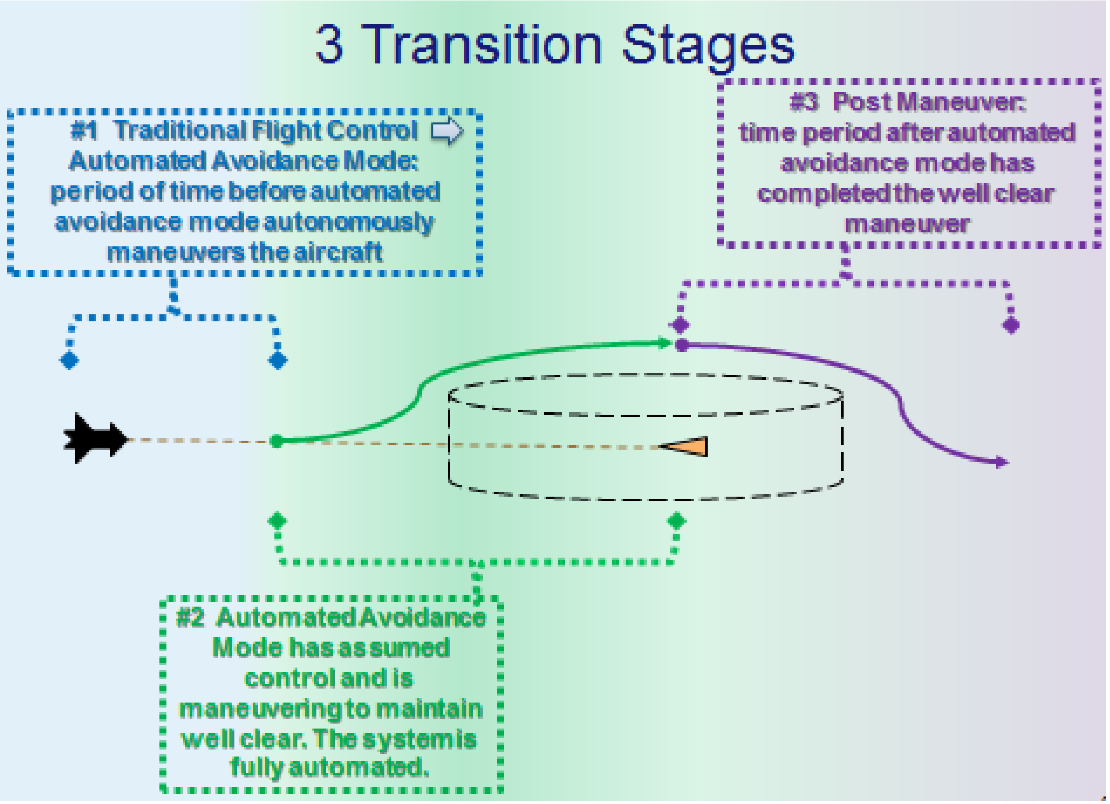
Pilots indicated a need for zoom and orientation adjustment capabilities on standalone display

Automation Focus Group
Overview

- **Purpose:** Gather feedback from operators on what informational elements are needed to facilitate the transfer of control from the pilot to an automated avoidance system
  - The information gathered directly affected the prototypes used in the JOCA Maneuver Study

- **Participants:** 18 Unmanned Pilots

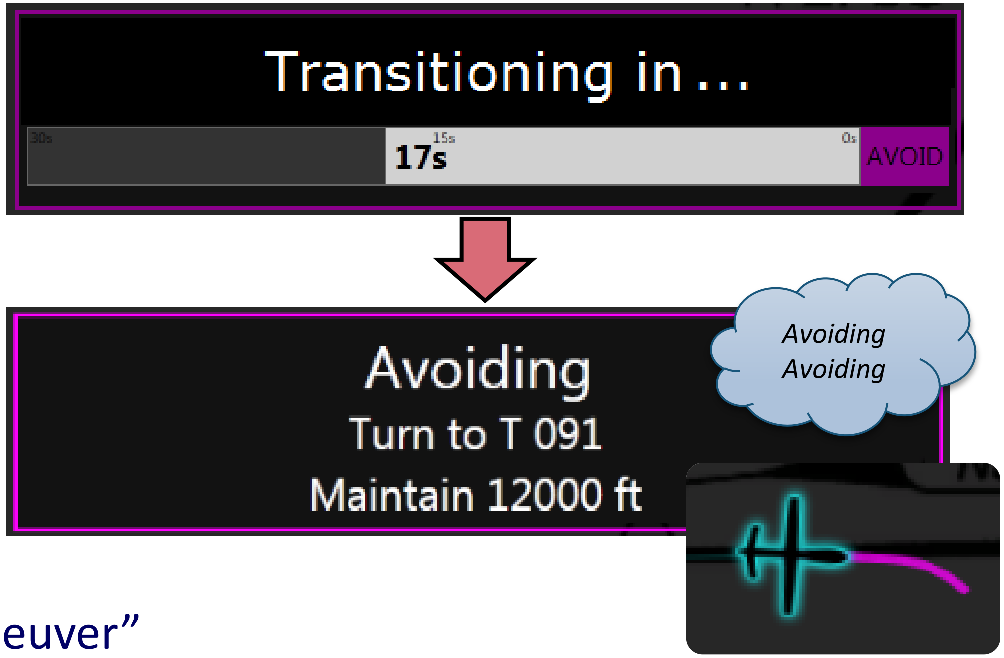
- **Method:** Focus Groups via Survey & Telecom



Automation Focus Group
Summary

Most Requested Elements (100%):

- System status indication through all phases of automation
- Timer to denote when automation will take over
- The maneuver parameters (heading/altitude)
- Depiction of intended flight path



Differences of Opinion:

- System action after “Avoidance Maneuver”
  - *Return to flight plan autonomously vs. hold heading & altitude (8 vs 10)*
- Acceptance of flight controls from autonomous system
  - *Visual message stating “complete” vs. a physical action (7 vs. 5)*
- Maneuver parameters
  - *Textual vs. Graphical (3 vs. 8, 2 both)*
- Override Implementation
  - *One-Click disengage vs. Normal entry into the FMS (13 vs. 4, 2 both)*

JOCA Maneuver Study

Overview

Purpose: Integrate JOCA (suggestive & directive) into Vigilant Spirit and study the display implications specific to JOCA's capabilities

JOCA: The Air Force Detect and Avoid Algorithm being developed in support of the C-ABSAA program

Goals:

- Decide what information should be provided to pilots on a DAA display when transitioning from traditional flight control to autonomous avoidance control
- Investigate what type of suggestive displays best compliment an autonomous avoidance system
- Investigate how different autonomy thresholds (Well Clear vs. NMAC) affect pilot performance
- Shed light on how the JOCA automated response compares to the pilots' response

JOCA Maneuver Study
Overview/Status

- **Pilot Tasks:** Fly through controlled airspace while addressing DAA alerts as well as other mission related tasks
- **Scenarios:** 6 - 15 mins, Mix of traffic encounters
- **Design:**

Observe Trials (3 x 1 within subject)

- *Well Clear Automation Threshold*
  1. *Banding Display*
  2. *Probe Display*
  3. *Dual Perspective Display*

Interact Trials (3 x 2 within subject)

- *Well Clear Automation Threshold*
  1. *Banding Display*
  2. *Probe Display*
  3. *Dual Perspective Display*
- *NMAC Automation Threshold*
  1. *Banding Display*
  2. *Probe Display*
  3. *Dual Perspective Display*

- **DAA Algorithm:** Bihrle's Jointly Optimal Conflict Avoidance (JOCA) Algorithm
- **Data Collection:** Nov 2015 - Jan 2016 (Beale AFB, Holloman AFB, Wright-Patt AFB)
- **Participants:** 8 Global Hawk pilots, 8 Reaper/Predator pilots, 6 manned pilots

JOCA Maneuver Study
Displays

Banding Display

Banding concept used in past studies. Color codes **ranges** of headings and altitudes based on safety while proving continuous **trend information**

Probe Display

Color codes **discrete** headings & altitudes based on safety while allowing for insight into a **secondary maneuver** via **pimento logic** & **probing mechanism**

Dual Perspective

Color codes headings, altitudes & **combinations** based on safety within a cockpit view while allowing for insight into a **secondary maneuver** via **pimento logic**

Way Forward

- Include AF missions in <u>military airspace</u>
- Expand technologies to encompass <u>multi-vehicle control</u> by single pilot
- Represent and account for <u>uncertainty</u> in airspace and in automated decision making
- Support upcoming DAA-related <u>flight tests</u> associated with USAF activities

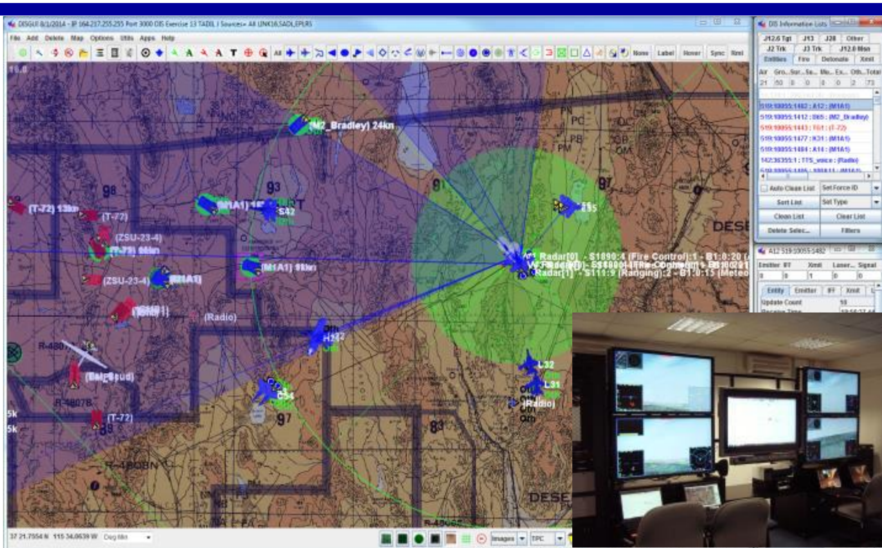
Briefing Outline

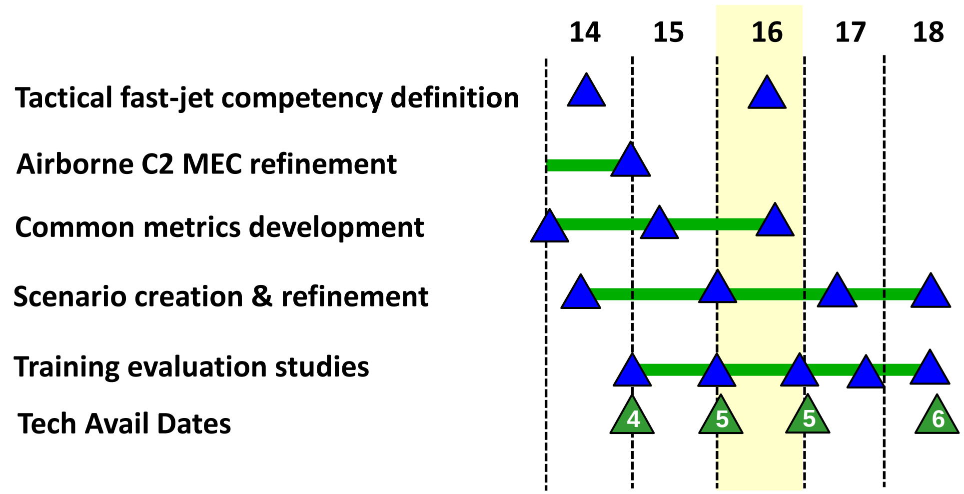
1. Operator interface research enabling UAS detect-and-avoid capabilities

2. **Other ongoing 711HPW/RH activities related to FAA**

3. Human-machine teaming research supporting future systems

Competency-Based Team Training





Program Goal

Create and validate an integrated individual & team training, coordination & performance measurement environment.

Benefits to the Warfighter

- Mission/cross-mission, competency-driven scenarios & metrics
- Common and co-located team training & measurement environment
- Unique capability to spec out/derisk approaches for improved

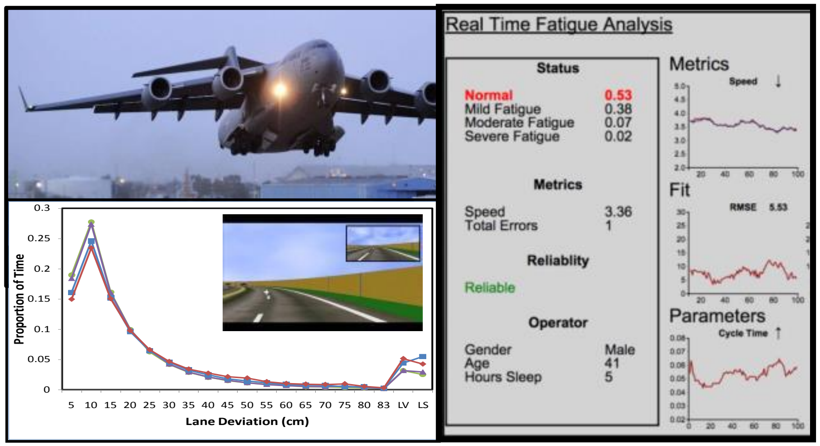
Description

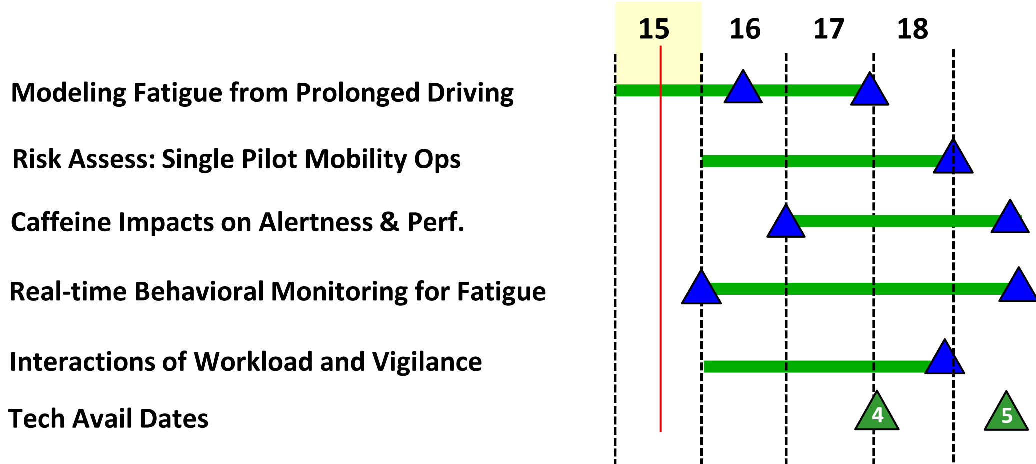
- Current tactical training is stovepiped
- Team-level interaction across fast-jet and airborne command and control systems rarely happens in other than expensive live flight events
- Limited metrics at the individual, mission team & cross-team levels of analysis
- Create mission-specific & cross-mission common environment, scenarios, metrics & feedback tools

Technical Approach

- Define Mission Essential Competencies for mission areas
- Create scenarios that address common competency gaps inside & across missions
- Define and validate mission performance metrics at individual, team & team-of-teams levels of analysis
- Create common planning, after action review & feedback mechanisms at each level
- Demonstrate persistent training & assessment capability

Simulations of the Impact of Fatigue on Cognitive Processes





Program Goal

Develop simulations of the impact of fatigue on human cognition and behavior that can be used to inform policy decisions for Fatigue Risk Mitigation (FRM) and monitoring systems for real-time fatigue assessment

Benefits to the Warfighter

- Task and domain specific performance predictions, allowing quantitative Analysis of Alternatives (AOA) for FRM using simulation
- Real-time, unobtrusive monitoring systems for fatigue, based upon behavioral performance

Description

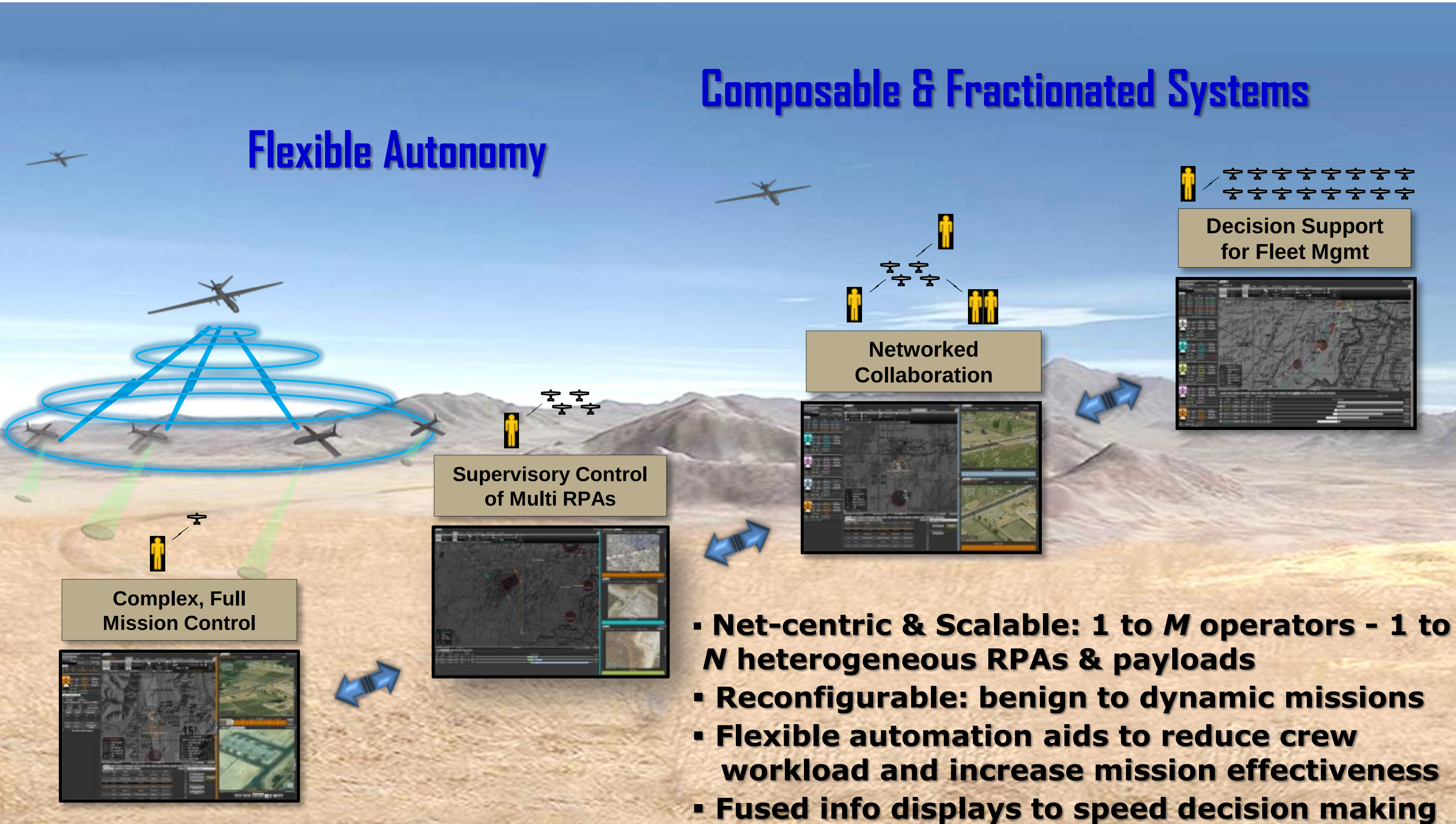
- Current models of fatigue are limited to informing schedule manipulations to reduce fatigue levels in operators
- Develop models that simulate the human mind, including the impact of fatigue, to allow FRM to consider the entire human-machine system in identifying ways to reduce risk & ensure operational success

Technical Approach

- Integrate software models that think and act like people with quantitative models of the impact of sleep, circadian rhythms, workload, and time on task on alertness
- Validate the models in carefully controlled laboratory contexts
- Use the models to:
  - Inform AOA in system design, training, & policy decisions
  - Monitor operators to detect signs of fatigue

Multi-Role Control Station

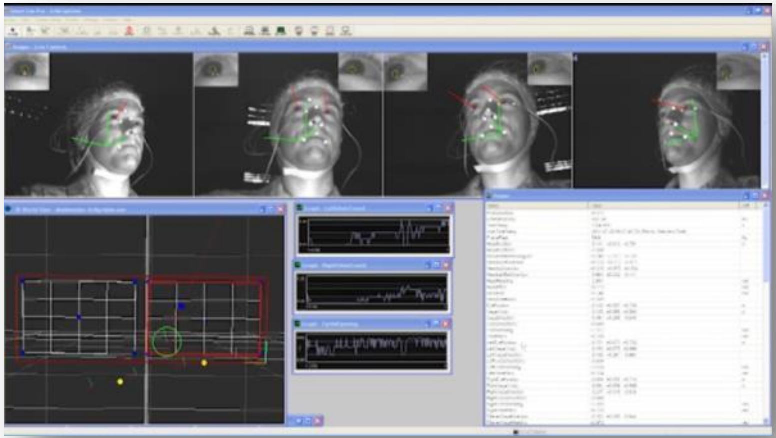
M – N Spectrum of Control Capability



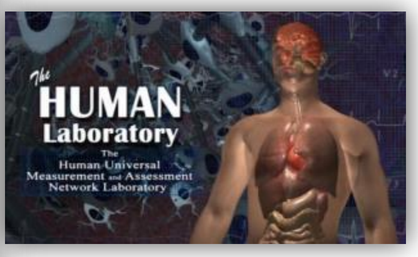
- **Net-centric & Scalable: 1 to *M* operators - 1 to *N* heterogeneous RPAs & payloads**
- **Reconfigurable: benign to dynamic missions**
- **Flexible automation aids to reduce crew workload and increase mission effectiveness**
- **Fused info displays to speed decision making**

Human State Measurement & Assessment

Human State Sensing foundational for humans and machines to work as a team



- Develop measurement techniques for stress, workload, attention.
- Correlate human cognitive tasks to performance
- Long Term vision: Provide the machine data about the human's state so the machine can aid mission performance



Other Activities

- AFRL Representative to Federal Interagency Committee on Aviation Noise (FICAN)
  - Review and update information on aviation noise issues
- Selection methods for UAS/RPA training
  - Manned pilot training methods are effective
  - Improvements being investigated: Person-environment fit (work interests), Task prioritization/ time sharing, Personality
- AFRL/RH support to RTCA SC-228
  - Contributing human factors data from empirical evaluations

Briefing Outline

1. Operator interface research enabling UAS detect-and-avoid capabilities

2. Other ongoing 711HPW/RH activities related to FAA

3. **Advanced human-machine teaming research supporting <u>future</u> air systems**

Autonomy-Capable Systems

Need to change the dialogue from "Autonomous Systems" to "Autonomy-Capable Systems" that can be operated on multiple levels of human interaction

~~Autonomous Systems~~ → Autonomy-Capable Systems

- Fully Autonomous
- Human Supervised
- Human Tailoring
- Human Operated

Human Interaction with Increasingly Autonomous Systems

Research human-automation interaction & design human-machine interfaces to enhance operator decision making and ensure flexible, robust mission operations.

INTERFACE

Adaptive & Adaptable
Naturalistic interaction
Spectrum of control
Automation transparency

INTEGRATION

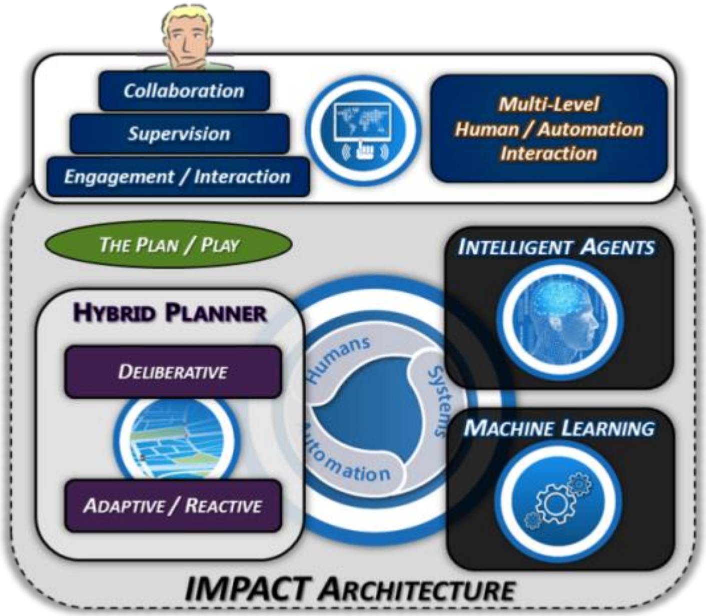
Technology Interactions
Optimized augmentations
Mission-level performance

INTELLECT

Context reasoning
Information integration
Situation monitoring

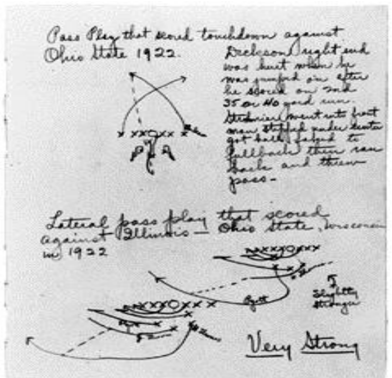
Intelligent Multi-UxV Planner with Adaptive Collaborative/Control Technologies (IMPACT)

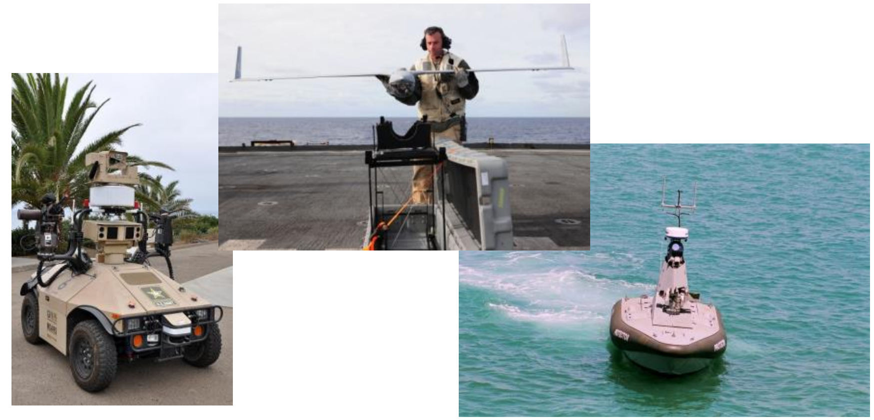
- **Tri-Service Collaboration**
- **Goal: Maximize team agility to unexpected events**
- **Scenario:**
  - Base perimeter security
  - single operator control of 12 heterogeneous UxVs

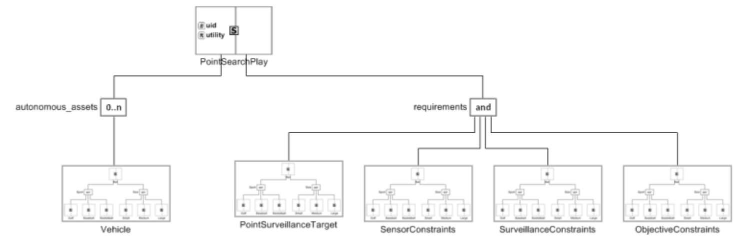


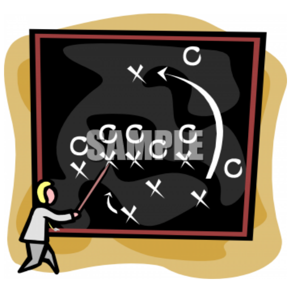
"Play Calling" Approach

Borrowing from Sports Analogies



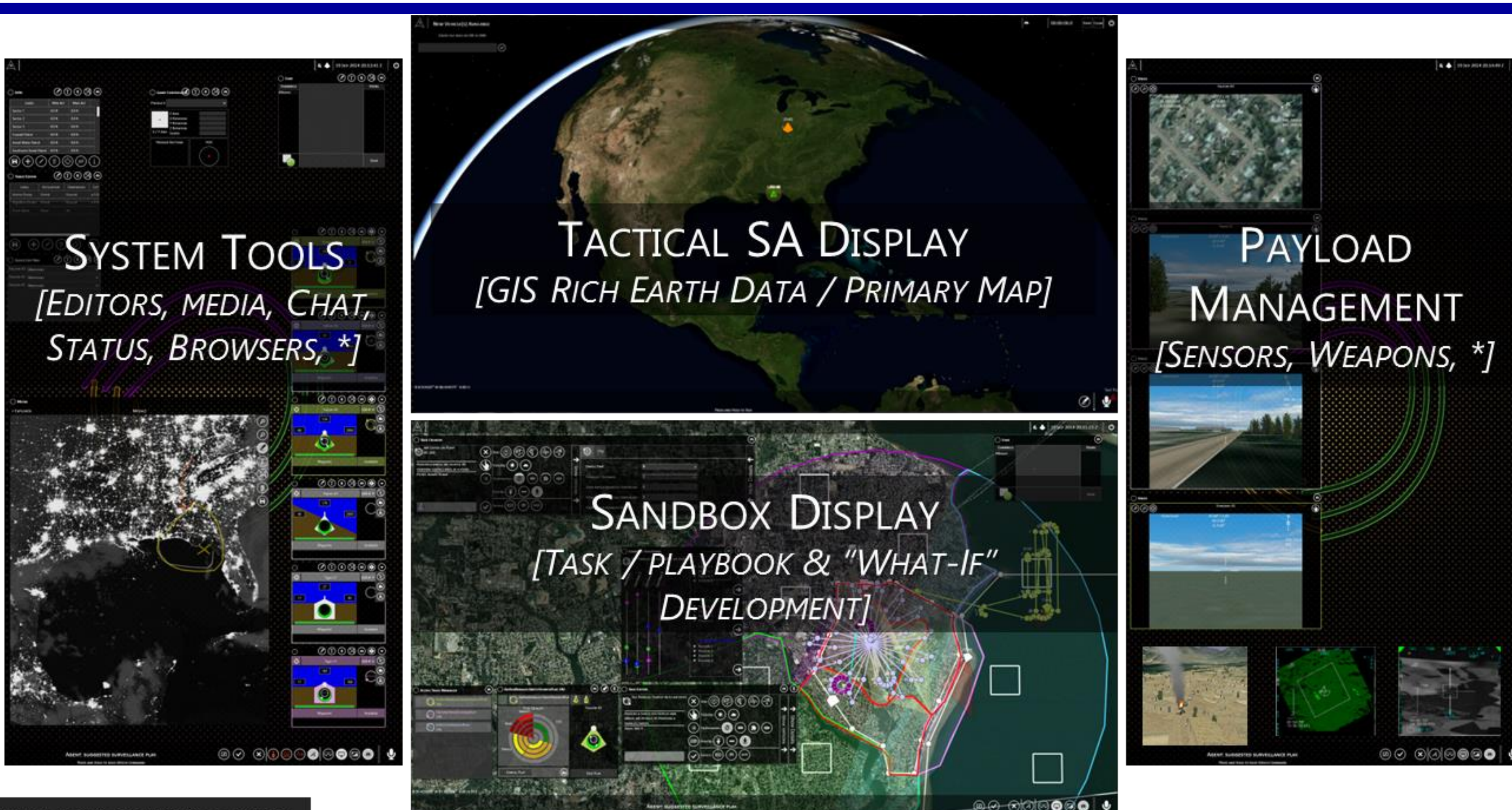


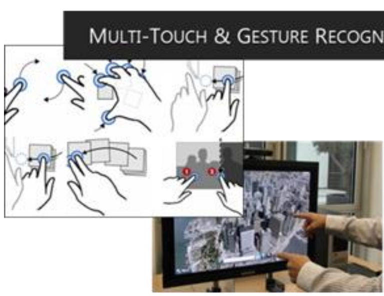




The Plan… **…must be made to fit reality**

IMPACT Integrated Testbed Capability





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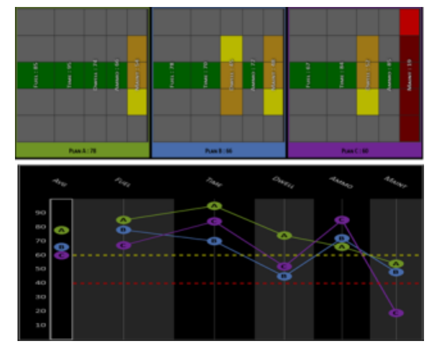
Increasing System Agility
Many Methods

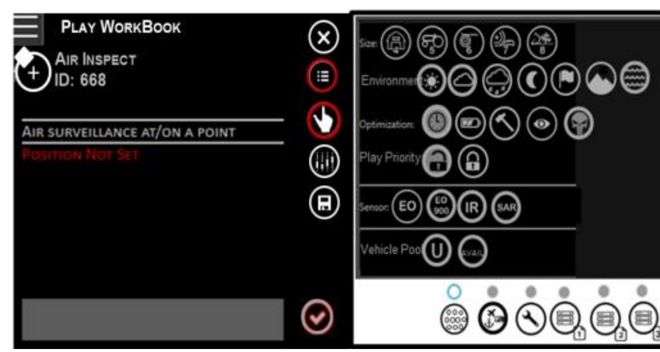
- Novel ***human-autonomy interfaces*** for play calling, full-spectrum control & adaptable to operator's needs & mission conditions

  "Graphical, intuitive, naturalistic interaction"



- ***"Course of action" evaluation*** tools to allow comparisons of different solution options

  "Multiple candidates & multiple heuristics to compare"



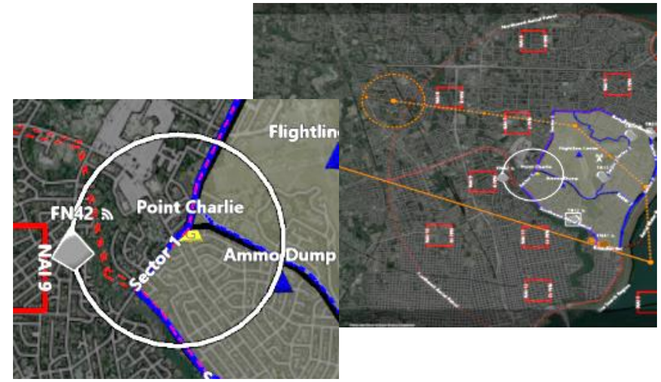
- ***Intelligent Agents*** to recommend assets for a desired play, identify new tasks/opportunities, and monitoring existing plans

  "Offer ideas/options, support actions, always monitoring"

Methods to Increase System Agility

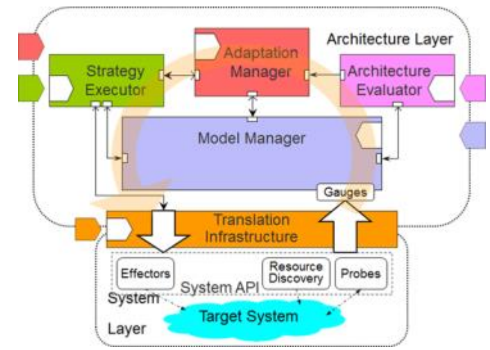
- ***Refactored collaborative control algorithms*** interact with Agents to rapidly solve complex resource & path planning problems

  "Transparent reasoning, increased customization"



- ***Autonomics play monitoring*** monitors plan execution & advises on key mission parameters

  "Soon to add automated repair strategies"



- ***Task manager*** to monitor & dynamically balance workload across human-autonomy team

  "Adapts to human direction with learning over time"

Manned-Unmanned Teaming Research

- **Develop Autonomy Technologies for air combat in a future highly contested or A2AD environment**
  - OCA, DCA, SEAD
- **Mixed team of manned and unmanned aircraft**
  - Heterogeneous (fractionated) capabilities
  - Inter-team Communication
- **Develop a "Tactical Battle Manager" to plan and coordinate actions of multiple aircraft**
  - Dynamic, uncertain, adversarial environment
  - Maneuver and system, weapon employments
- **Discover new tactics through machine learning**

Questions?

Citations

Draper, D. H., Pack, J. S., Darrah, S. J., Moulton, S. N. (2014). Human-machine interface development for common airborne sense and avoid program. Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting, Chicago, IL , October 27-31.

Fern, L., Rorie, C., Pack, J., Shively R., Draper, M. (2015) An evaluation of detect and avoid (DAA) displays for unmanned aircraft systems: The effect of information level and display location on pilot performance. *Proceedings of the 15th AIAA Aviation Technology, Integration, and Operations Conference*, Dallas, TX, June 22-26.

Pack, J. S., Draper, D. H., Darrah, S. J., Squire, M. P., Cooks, A. (2015). Exploring performance differences between UAS sense-and-avoid displays. Proceedings of the Human Factors and Ergonomics Society 59th Annual Meeting, Los Angeles, CA, October 26-30.

Federal Interagency Committee on Aviation Noise (FICAN)

Department of Defense:
U.S. Air Force
U.S. Army
U.S. Navy

Department of Interior:
National Park Service

Department of Transportation:
Office of the Secretary of Transportation
Federal Aviation Administration

U.S. Environmental Protection Agency

National Aeronautics and Space Administration

Department of Housing and Urban Development

- Effects of Noise on People
  - Hearing loss
  - Physiological effects
  - Annoyance
  - Speech Interference
  - Sleep Interference and Awakenings
  - Effects on Learning
- Aircraft Noise Modeling Tools
  - The Aviation Environmental Design Tool (AEDT) developed by the FAA
  - NOISEMAP is the primary noise model used by the Department of Defense to predict cumulative noise around airports.
- Land Use Compatibility