Integrating Cognitive States with Intelligent Systems for Optimal Human-Machine Teaming

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Measurement Enhances Human

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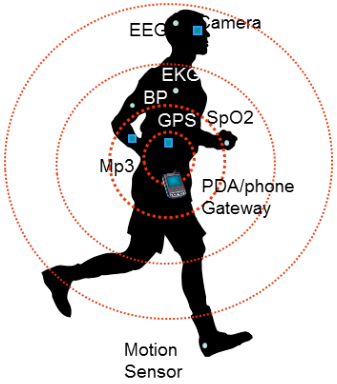

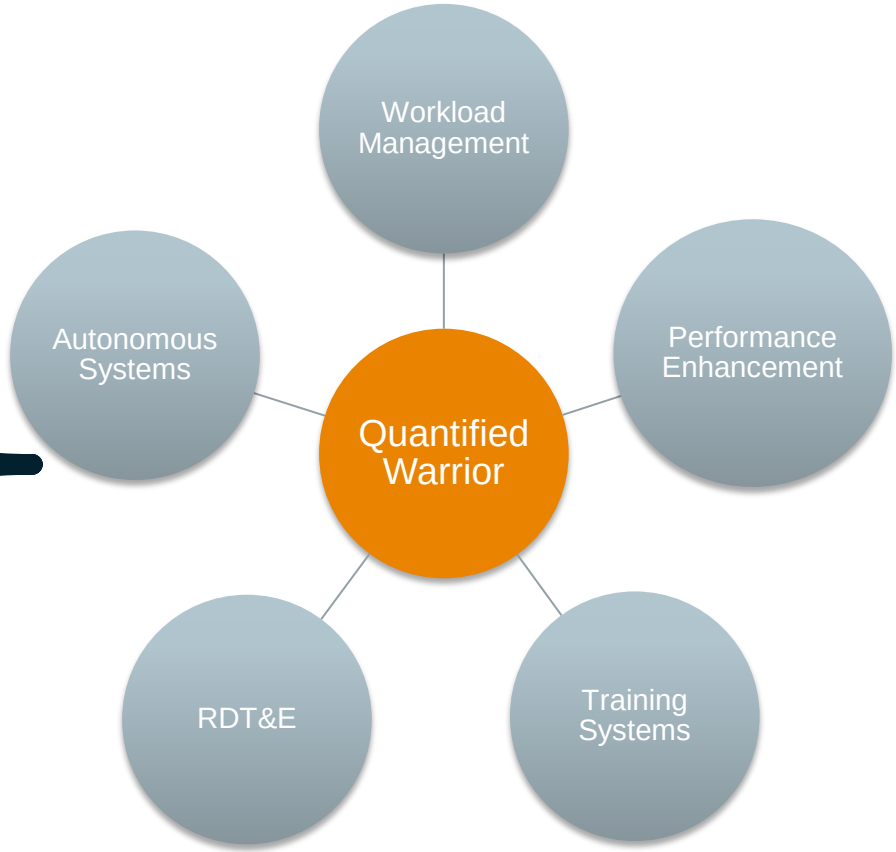

Challenge: Increasing Operational Demands…

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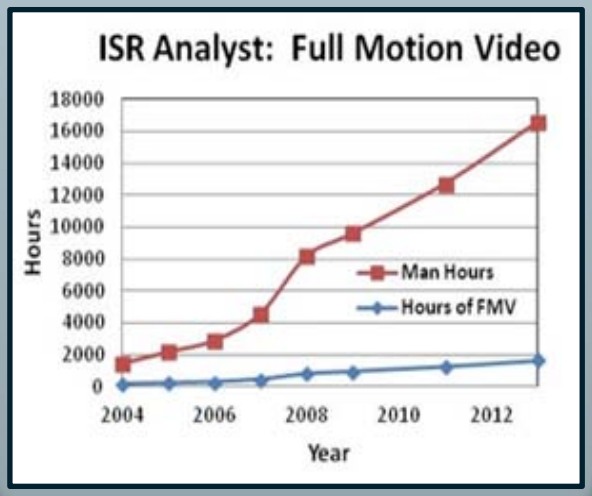
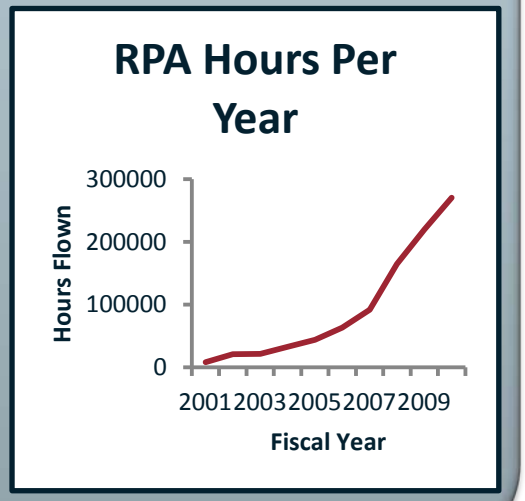
ISR Analyst



Cyber Operator

RPA Operator



… Requires Increased Reliance on Intelligent Systems

Autonomous Systems and Human Performance

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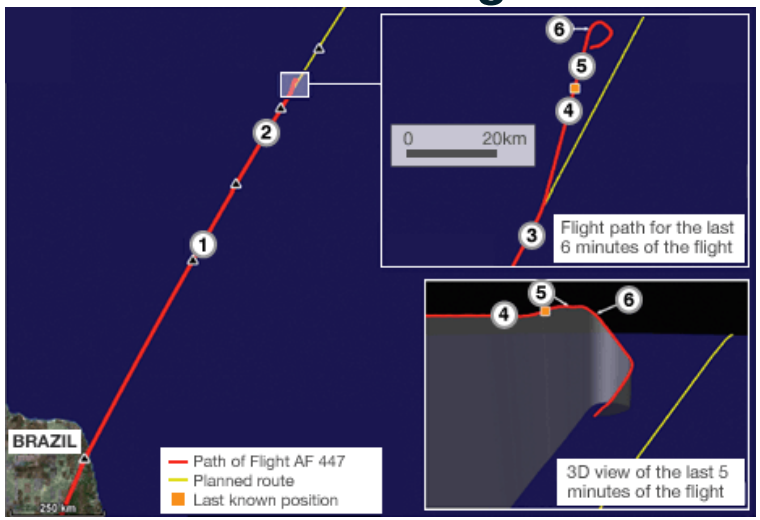
Final Minutes of Flight AF447*



1. 0135 GMT: The crew informs the controller of the flight's location

2. 0159-0206 GMT: The co-pilot warns of turbulence ahead before the captain leaves the cockpit for a rest break

3. 0208 GMT: The plane turns left, diverting from the planned route. Turbulence increases

4. 0210 GMT: The **auto-pilot and auto-thrust mechanisms disengage**. The plane rolls to the right. The co-pilot attempts to raise the nose. The **stall warning sounds** twice and the plane's speed drops. The co-pilot calls the captain

5. 0210 GMT: The **stall warning sounds again**. The plane climbs to 38,000ft

6. 0211-0213 GMT: The captain re-enters the cockpit. The plane is flying at 35,000 ft but is descending 10,000 ft per minute. The co-pilot says "I don't have any more indications", pulls the nose down and the **stall warning sounds again**

7. 02:14 GMT: Recordings stop

- Operational challenges
  - Mismatch between humans and the systems they use
  - Human “in-the-loop” vs “on-the-loop”
- Role of Autonomy in DoD Systems (DOD DSB, 2012)
  - Barriers preventing the adoption of autonomous systems
  - Outlined recommendations to overcome those obstacles
- Mission Need
  - Significantly enhanced methods for representing information about human operators to autonomous systems
  - Workload, engagement, stress, fatigue, and performance

*Source: http://www.bbc.co.uk/news/world-europe-13572569

Solution Objectives

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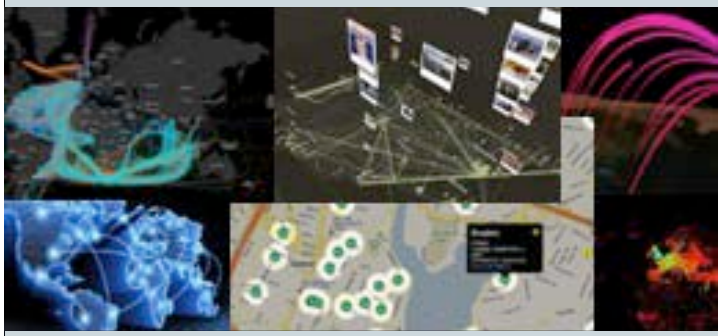
- Design common set of measures, analysis techniques, infrastructure, and transfer protocols to communicate the operator cognitive states to autonomous systems in real-time mission settings
- Develop tools, methods, and standardized interface protocols that will be a key enabling technology for the development of flexible, user-conscious autonomy
- Provide the technological basis for future advancements in flexible, human-system collaborations to enhance overall systems and mission effectiveness

Adaptive Learning



Contextual Visualization

Intuitive HMI/HRI

Solution Strategy: Quantified Warrior

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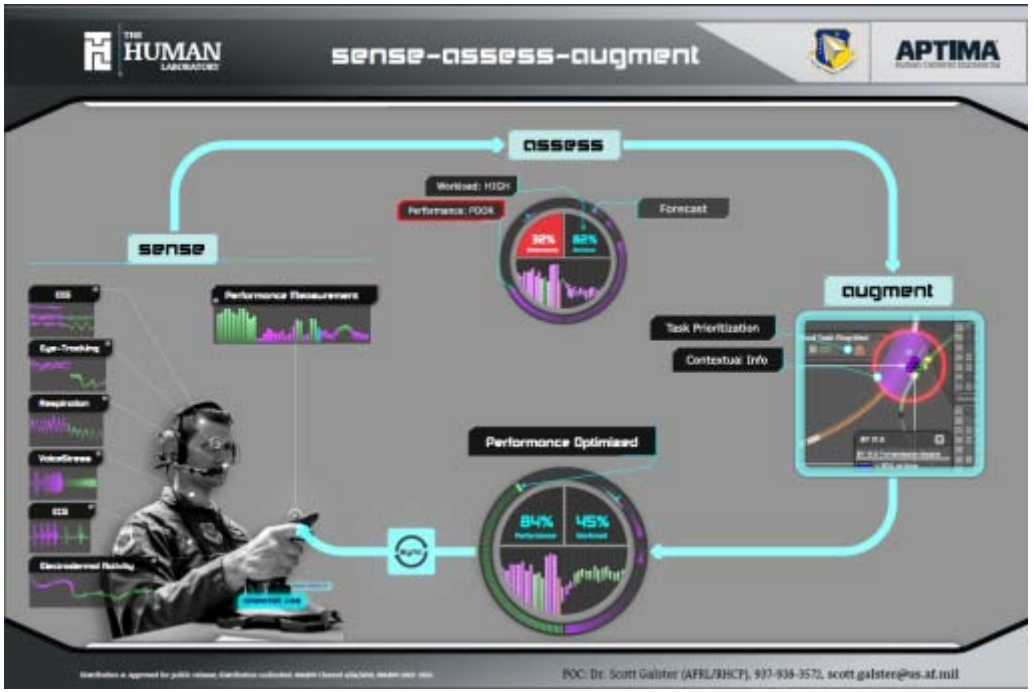
- Sense-Assess-Augment Taxonomy (Galster et al, 2014)
  - Adopted by 711th Human Effectiveness Directorate at AFRL
- **Sense and Assess** the state of warriors/operators/trainees
  - Unobtrusive sensors
  - Actionable assessments
- **Augment** human-machine interfaces, interactions, tasks
  - Machine learning of augmentation policy

Applicable across LVCG domains



Applied Neuroscience
Sense Technologies

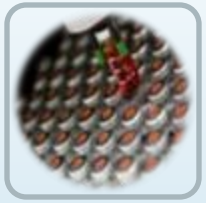
Off Body

- **Eye tracking/Oculometrics**
  - Vigilance, Arousal, Trust, Cognitive Load, Fatigue
- **Cardiac Activity**
  - Stress, Team Synchronicity, Cognitive load, Arousal
- **Voice Patterns**
  - Stress/Anxiety, Team Synchronicity
- **Facial Expressions**
  - Emotional/Affective State
- **Thermal Imaging**
  - Workload, Stress/Anxiety
- **Interface Pressure Sensors**
  - Stress/Anxiety, Cognitive Load
- **Metrics of Mission Performance**
  - Cognitive Load

On Body

- **Galvanic Skin Response**
  - Stress
- **Cardiac Activity**
  - Stress, Team Synchronicity, Cognitive load, Arousal
- **Respiration**
  - Cognitive Load, Arousal
- **Skin Temperature**
  - Workload, Stress/Anxiety
- **EEG**
  - Cognitive load
- **EMG**
  - Stress/Anxiety
- **fNIRS**
  - Cognitive Load
- **Accelerometers**
  - Team Synchronicity, Arousal

Biomarkers



- **Brain Derived Neurotrophic Factor**
  - Memory/Learning
- **Neuropeptide Y**
  - Memory/Learning, Stress Resilience
- **Cortisol**
  - Anxiety
- **Orexin A**
  - Vigilance, Arousal
- **Oxytocin**
  - Interpersonal Trust, Anxiety
- **Epinephrine**
  - Anxiety, Arousal
- **Norepinephrine**
  - Anxiety, Arousal
- **DHEA**
  - Anxiety, Emotional State
- **Cytokines**
  - Inflammation/stress

Enabling Technology for Sensor Fusion

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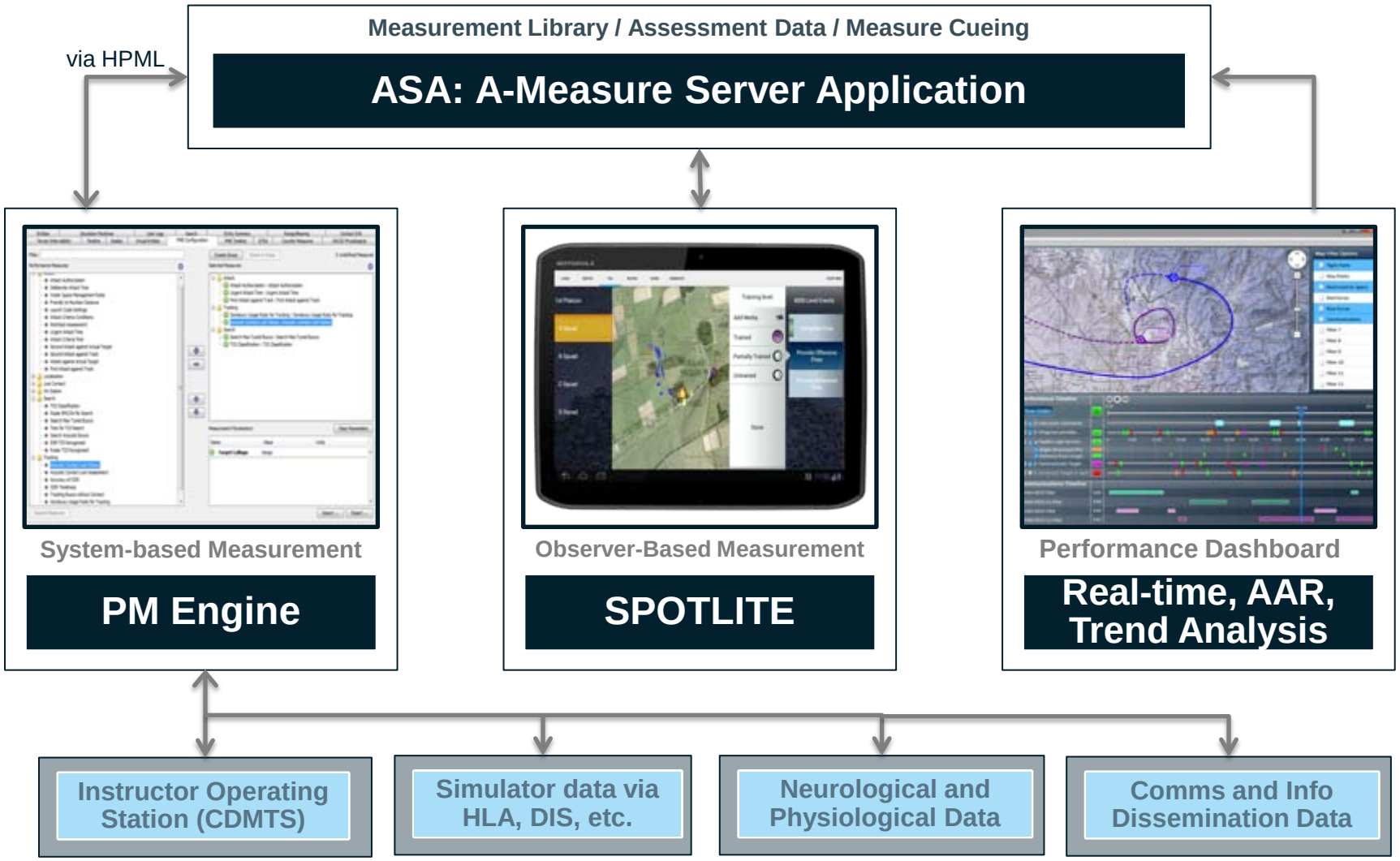
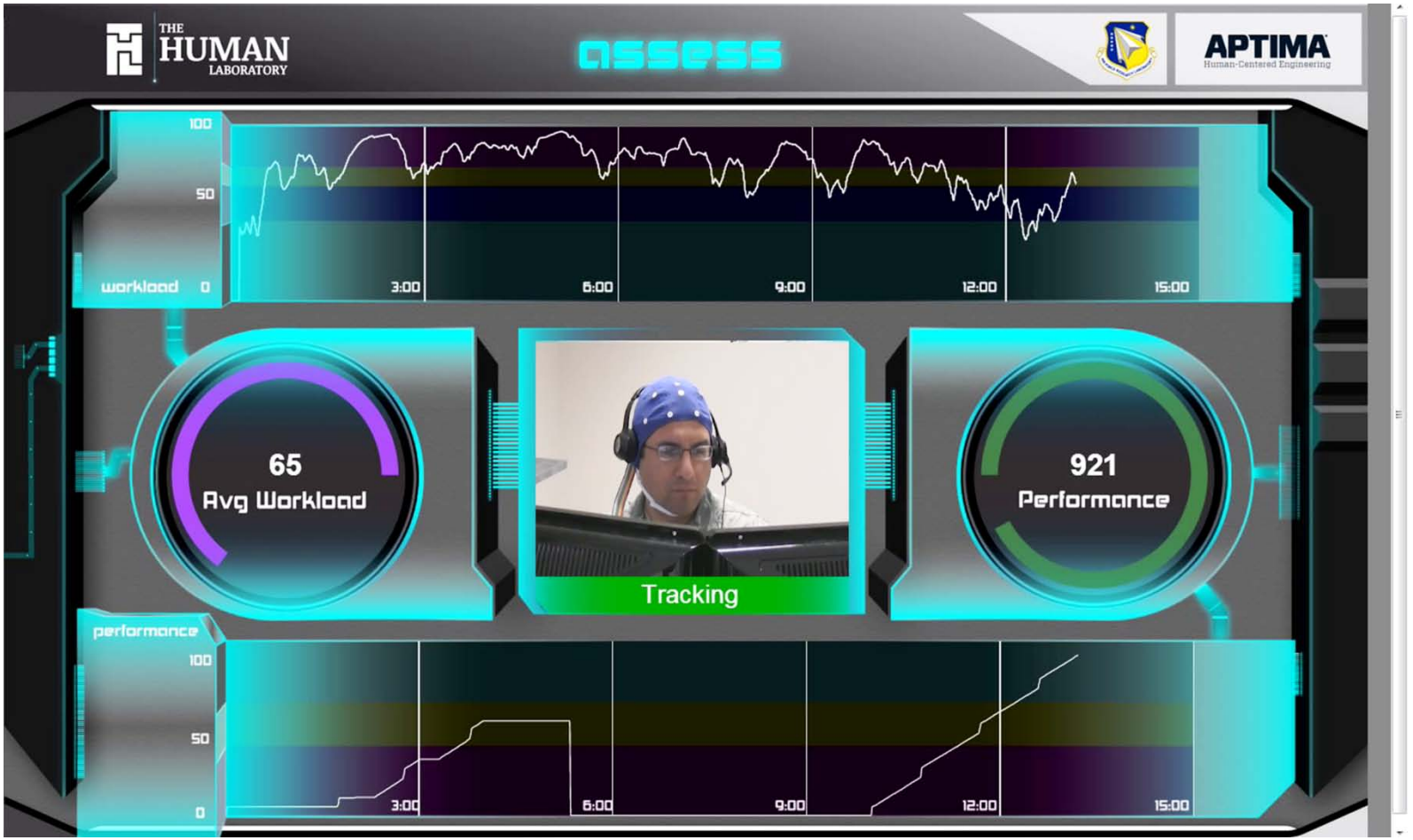


Assess

- Extract meaningful **human-focused parameters** that are standardized and communicated so that system designers can fully utilize the state from the human operator



Human State Assessment is a Big Data Problem

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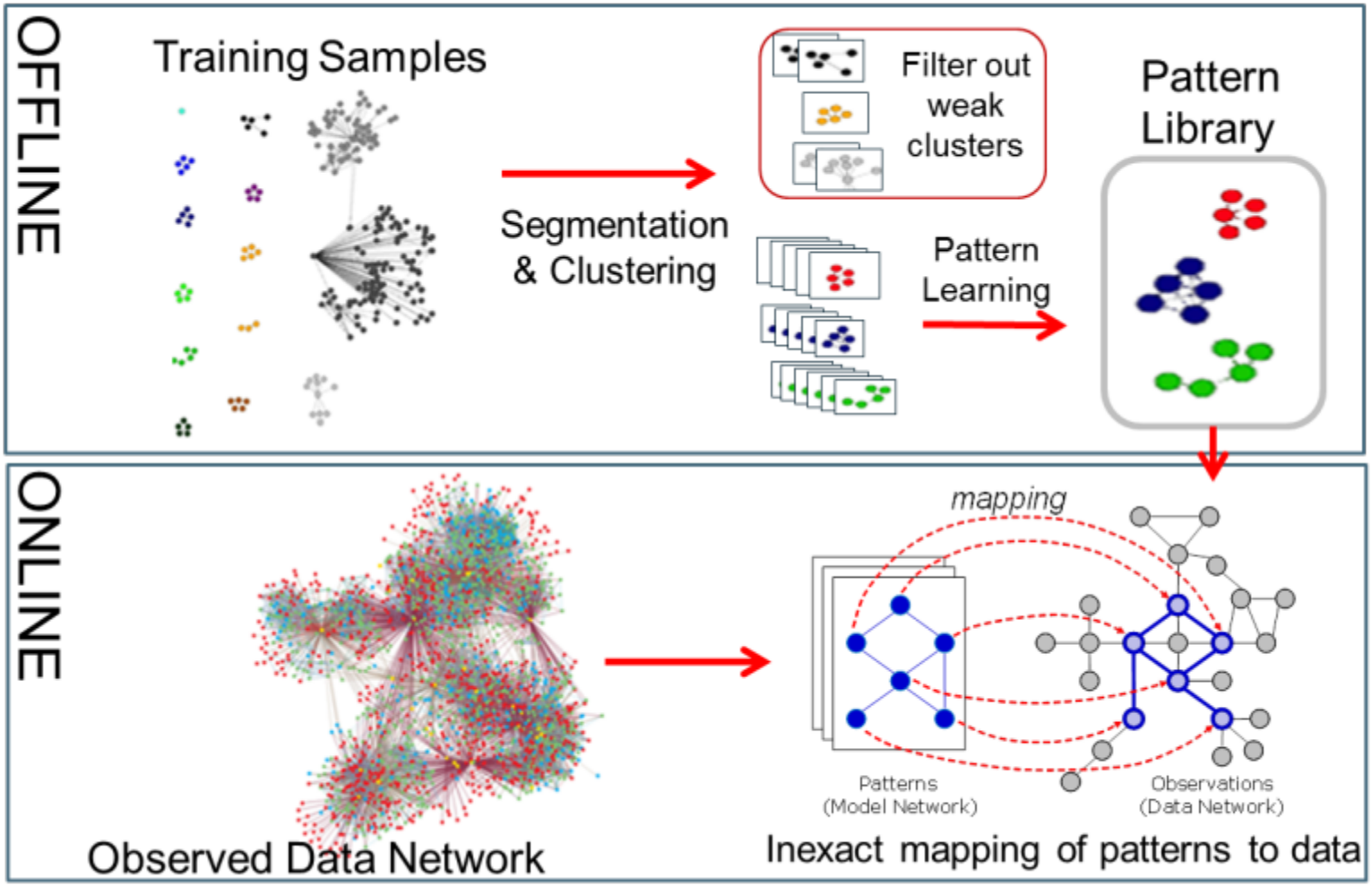


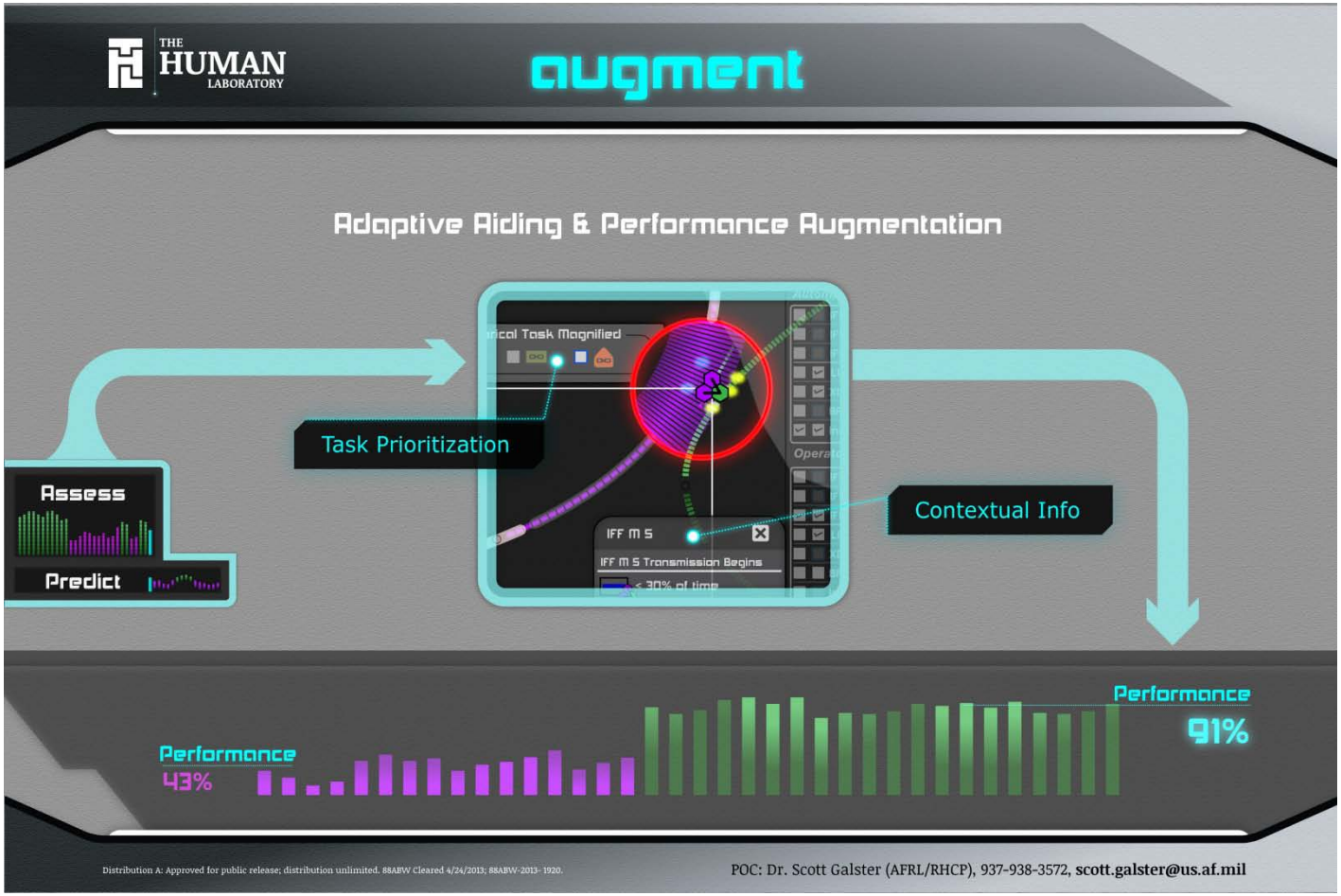
Step 1: Learn *patterns* from training samples using machine learning

Step 2: Find variations of learned patterns in data via optimized stochastic search

Leverage evolving techniques from the cyber and intelligence domains

Augment

- Standardize how autonomy receives cognitive states:
  - What structure does the data have? Is it always in this format? How do I get the data?



Model Cognitive State & Contextual Relationships for Autonomy Understanding

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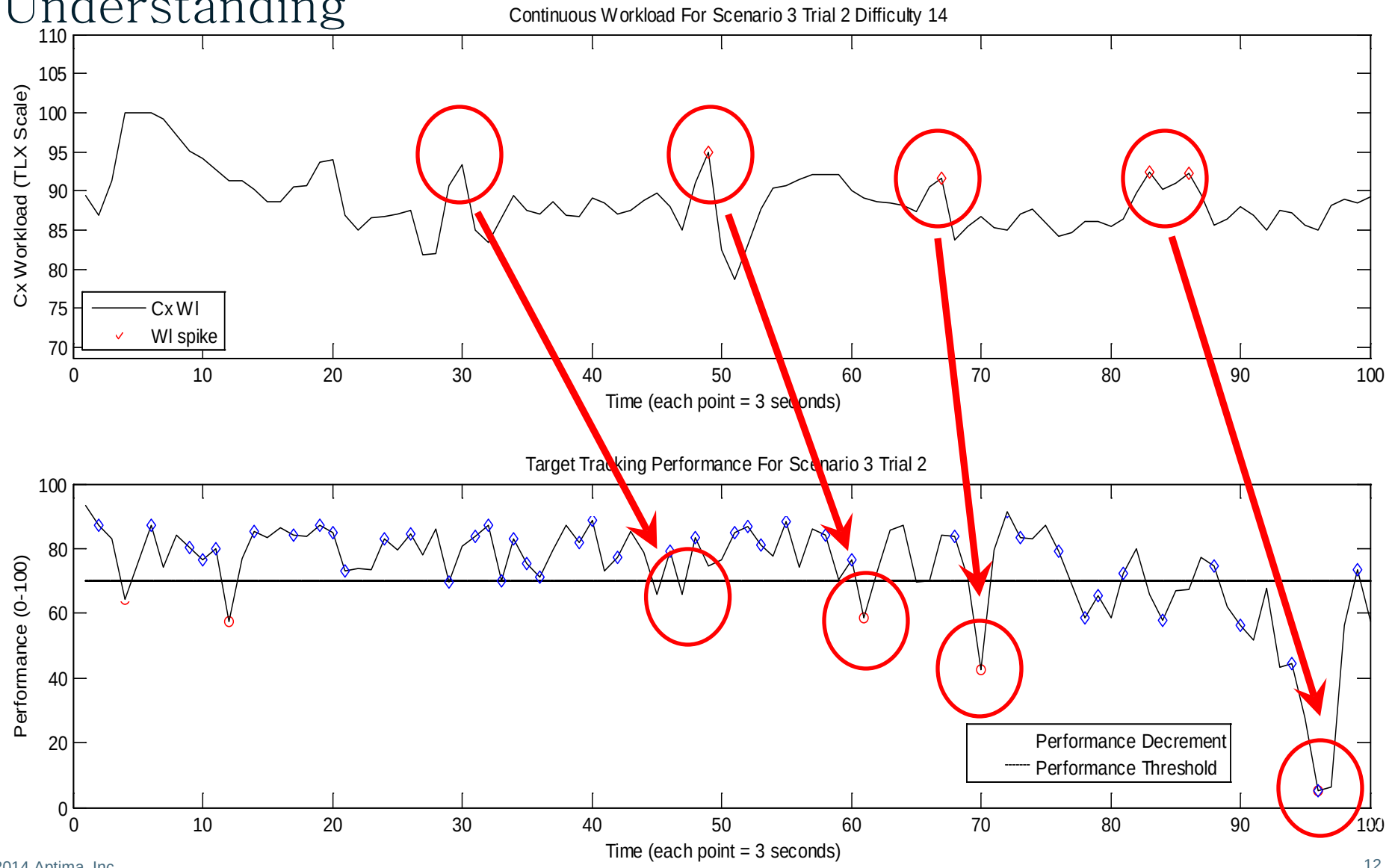

Optimized Human-Autonomy Teams

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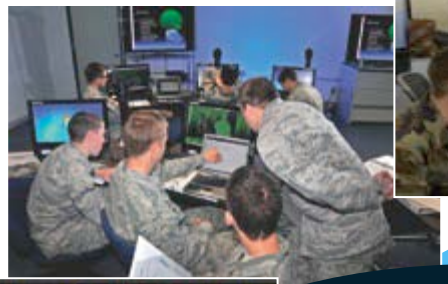

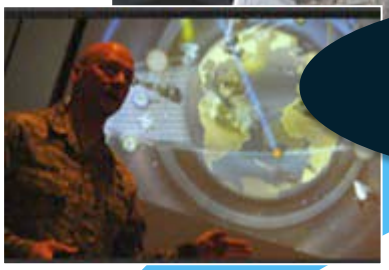


OPERATIONS

UNIT DEVELOPMENT

TRAINING

- Errors
- Terror attacks
- Cyber attacks
- RPAs lost
- Casualties

- Errors
- Efficiency
- Effectiveness

- Time to train
- Personnel
- Attrition rate
- Efficiency
- Effectiveness

Reduce casualties and costs

Contact Information

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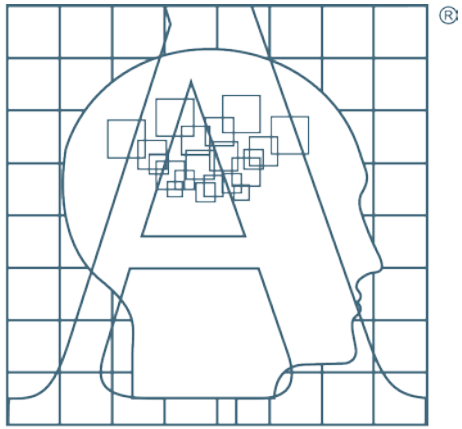

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