Human Systems Roadmap Review

Dr. John Tangney, SES
Director, Human and Bioengineered Systems Division, ONR
Chair, Human Systems Community of Interest

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Human Systems Community of Interest
Active Membership

**STEERING GROUP**

Dr. John Tangney (Navy)
Dr. Patrick Mason (OSD)
Dr. Laurel Allender (Army)
Dr. Kevin Geiss (AF)
Dr. Michelle Sams (Army)
Mr. Doug Tamilio (Army)
Mr. Maris Vikmanis (AF)
Dr. Marty Bink (Army)
Dr. Paul Chatelier (Navy)
CDR Joseph Cohn (OSD)
Ms. Rose Guerra (Army)

**WORKING GROUP**

Mr. Maris Vikmanis (AF)
Dr. Marty Bink (Army)
Dr. Paul Chatelier (Navy)
CDR Joseph Cohn (OSD)
Ms. Rose Guerra (Army)
Mr. John Lockett (Army)
LCDR Brent Olde (Navy)
Ms. Cheryl Stewardson (Army)
Ms. Josephine Wojciechowski (Army)

**SUB-AREAS**

- **Personalized Assessment, Education, and Training**
  Dr. Ray Perez (Navy)
  Mr. Rodney Long (Army)
  Dr. Leah Rowe (AF)
  Dr. Glenn Gunzelmann (AF)

- **Systems Interfaces and Cognitive Processes**
  Dr. Todd Nelson (AF)
  Dr. Susan Hill (Army)
  Dr. Micah Clark (Navy)
  Dr. Mark Derriso (AF)

- **Protection, Sustainment, and Warfighter Performance**
  Dr. Mike LaFliandra (Army)
  Ms. Karen Gregorczyk (Army)
  Dr. Peter Squire (Navy)
  Ms. Stephanie Miller (AF)
  Dr. Lloyd Tripp (AF)
  Dr. John Schlager (AF)

- **Human Aspects of Operations in Military Environments**
  Dr. Liz Bowman (Army)
  Dr. David Scribner (Army)
  Dr. Rebecca Goolsby (Navy)
  Mr. Eric Hansen (AF)
Vision:
Develop and deliver new human-centered technologies to quantify mission effectiveness and to select, train, design, protect, and operate for measurably improved mission effectiveness.

Goals – to enhance mission effectiveness
• Integrated simulations for mission training and experimentation
• Human-machine designs for mission effectiveness
• Assessment of (candidate) operator effectiveness
• Operating through battlespace stresses
• Mastering the PMESII* battle space

*Political, Military, Economic, Social, Infrastructure, & Information
# Human Systems Community of Interest

## Sub-Area Thrusts

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<td><strong>Ensuring Warfighter Safety and Survivability</strong></td>
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<td>• Understanding and Quantifying the Effects of Critical Stressors</td>
<td>• Exploiting Social Data, Dominating Human Terrain, Effective Engagement</td>
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<td>• Critical Stressor Mitigation Strategies</td>
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Operational Concept
Mission Effectiveness Quantification

**Capability:** Integrated, persistent Live-Virtual-Constructive (LVC) training environments incorporating adaptive training methods to accelerate Service, Joint, and Coalition Readiness

**Affordable Mission Realism – Integrated Forces – Quantified Effectiveness**
Ideas: Third Offset

Five building blocks

• **Autonomous Learning Systems**
  – Delegating decisions to machines in applications that require faster-than-human reaction times

• **Human-Machine Collaborative Decision Making**
  – Exploiting the advantages of both humans and machines for better and faster human decisions

• **Assisted Human Operations**
  – Helping humans perform better in combat

• **Advanced Manned-Unmanned System Operations**
  – Employing innovative cooperative operations between manned and unmanned platforms

• **Network-enable, autonomous weapons hardened to operate in a future Cyber/EW Environment**
  – Allowing for cooperative weapon concepts in communications-denied environments
Department of Defense’s Third Offset
Human-Machine Collaboration; Combat Teaming

Human Systems COI S&T Focus Areas that Address the Five 3rd Offset Elements

1. Learning Machines
   - Computational Models of Human Cognitive, Psychomotor, and Perceptual Capabilities

2. Human-Machine Collaboration
   - Intuitive, Multi-sensory, Adaptive Interfaces
   - Natural Language Interfaces

3. Assisted Human Operations
   - Intelligent, Adaptive Aiding

4. Human-Machine Combat Teaming
   - Trust Calibration and Transparency of System Autonomy
   - Metrics of Mission Effectiveness at Individual and Unit Level

5. Autonomous Weapons
   - Systems that can take action, when needed
   - Architectures for Autonomous Agents and Synthetic Teammates

… and Experiments Using Realistic Mission Scenarios
## Service Demand Signals

### Personalized Assessment, Education and Training
- Personalized, integrated assessments and training to improve performance, accelerate proficiency and increase affordability
- Enhanced warfighter performance through scenario based training & automated performance based readiness assessments
- Maintain air superiority over complex, evolving threats using adaptive training

### System Interfaces and Cognitive Processing
- Achieve operational maneuverability through soldier-system integration
- Design systems to enable effective human machine interaction, including robotics & autonomous systems
- Enhanced interaction & trust w/autonomous systems; increased SA for operators; reduced analyst workload

### Protection, Sustainment and Warfighter Performance
- Greater force protection to ensure survivability across all operations and environments
- Maintain health & injury recovery; reduce noise induced hearing loss
- Agile Combat Support through countering aerospace physiology and toxicology threats, reducing cognitive workload

### Human Aspects of Operations in Military Environments
- Provide situational awareness; timely mission command and tactical intelligence human-agent teaming

#### Army Enduring Challenges
- Navy Vision/Objectives
- AF Core Mission/Challenges
Outreach Highlights

Federal, Industry and Academic Outreach

• Annual NDIA Human Systems Conferences
• Biannual Industry Research & Development Technology Interchanges
• Strong leverage of basic science research
• NASA participation in HS COI
• Cross Agency participation in National Science and Technology Council Network and Information Technology Subcommittees

International Engagement

• Singapore: HS COI workshop leading to MINDEF/DoD Human Systems roadmap
• India: HS COI Cognitive Sciences workshop led to multiple Project Agreements currently in negotiation
• Japan: February 2016 Team Visit to explore Trusted Human-Autonomy Teaming
• NATO: Leading strategically targeted activities in Science and Technology Organization Panels: Human Factors and Medicine, Info Systems, SAS
• TTCP: Strong Participation in Human Performance, C3I Groups
  • Restructured HUM to focus on transition opportunities
  • Leading the first TTCP Cross-Group Panels on Human Systems Land and Air
CoI-to-CoI Collaborations

- **ASBREM**
  - Human Performance Optimization Committee
  - Joint Biomedical Modeling and Simulation Initiative
  - Walter Reed Army Institute of Research (WRAIR) evaluating TAPAS as a contributor toward predictors of mental health & medical attrition

- **ASBREM, Sensors, CWMD**
  - Wearable Physiological Monitors

- **Autonomy**
  - Roadmap development: Human-Machine Teaming shared area
  - V&V Licensing Study
  - Executing Joint-Service Autonomy Research Pilot Initiatives

- **C4ISR**
  - Human-Computer Interaction (HCI) for Decision Making Subgroup - seedling proposal funded for 2 years in 2015 (Army, Navy, Air Force)

- **Cyber**
  - Cyber Selection and Training
  - Cyber Situational Awareness

- **CWMD**
  - Dark web concerns, social network analysis, and counter-terrorism research
Impact of Human Systems Community of Interest

$450M COI Budget Has Broad Impact in Several DOTMLPF Areas
Defense Innovation Marketplace

• **For Industry, the Defense Innovation Marketplace is:**
  
  – A place to learn about DoD R&E investment priorities and technology requirements.
  
  – A source allowing industry to align their IR&D efforts to better support the current and future needs of the warfighter.
  
  – A link to specific solicitations, upcoming R&E related events, Communities of Interest, and Technology Interchange Meetings; *improving visibility to DoD activities*.
  
  – A portal to securely share their IR&D projects with S&T/R&D and acquisition personnel they consider their target market.

• **For DoD, the Marketplace is designed to be:**
  
  – The place to post important, relevant and future needs, S&T/R&E priorities, events, presentation and solicitations.
  
  – A secure portal for registered and approved DoD S&T/R&D and acquisition personnel to gain *insight and visibility into industry IR&D investments*. 
SUB-AREA S&T THRUSTS
Personalized Assessment, Education, and Training
HUMAN SYSTEMS COI SUB-AREA: Personalized Assessment, Education, and Training

VISION
Measure and train for joint mission effectiveness.

TRAINING: Accelerate Individual Proficiency and Joint Force Readiness

Past: Skills for specific tasks/missions; slow update; same training for all
Near → Future: Competency-based for full spectrum; rapid updates; adaptive training accelerates learning

(Live + Virtual + Constructive) + Adaptive Training

• Integrated
• Personalized

PERSONNEL: Optimize Person-Service-Job Match

Past: Separate measures; same test for all; group probabilities of potential
Near → Future: Integrated measures & adaptive testing for more precise assessment of individual potential

(Cognitive + Non-cognitive + Physical) + Adaptive Testing

• Integrated
• Personalized
Thrust 1: First Principles for Training Design

Delivering the Mission

Ensuring measurable mission effectiveness
- Competency-based training will enable adaptive personalized learning that ensures mission effectiveness
- On-demand realistic training will increase warfighter agility
- LVC enables delivering this training beyond the individual to teams
- Reduction in training development and delivery costs can deliver more frequent tailored training

Delivering Capability

Develop training technologies for large scale Live, Virtual and Constructive (LVC)
- Better models enable building more realistic synthetic agents to play blue or red forces

Deliver life long learning
- Continuous career field learning and management and persistent measurement

Key Technical Challenges

Develop ability to model individual expert behaviors
- Need pedagogical models/knowledge elicitation for training development (e.g., intelligent tutoring systems (ITS)).
- Need to validate high resolution metrics to measure mission effectiveness at individual and unit level.
- Need computational models of human cognitive, psychomotor, and perceptual capabilities for current and future missions

Program Overview
- Adaptive Training Research
- Joint and Coalition Training Research
- Augmented Reality for Training Research
First Principles for Training Design

Mission Need

- Improved readiness through the use of realistic training environments, tailored to the individual and team

Military Capabilities

- Large-scale LVC Training
  - Discovery engines to model individual expert behaviors
  - Higher fidelity behavior models (individual and teams)
  - Pedagogical models to guide training development and training authoring tools
  - Computational models of human cognitive performance
- Joint, Interoperable Training
  - Competency models to support scenario design and performance assessment
- Globally Persistent Coalition Ops
  - Autonomous models that support training and operations

Technical Goals

- High resolution, validated metrics for performance measurement & mission effectiveness
- Persistent readiness measurement and tracking in/ across mission contexts
- Secure, scalable, on-demand joint and coalition LVC events
- Continuous career field learning and management
- Autonomous models that support training and operations

S&T Focus

- Mechanisms of Cognitive Processing
- Cognitive Model and Scale Integration
- Integrated LVC Training and Assessment
- Multi-Level Modeling for Readiness Management
- Automated Knowledge Elicitation and Engineering

Shading Legend

- Dark: Funded
- Light: Not/partially funded

Participation Legend

- Army
- Navy
- Air Force

2016 2018 2020 2022 2025
## First Principles for Training Design

**Program Detail**

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<th>Mid/ Far-term</th>
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<tr>
<td><strong>Integrated LVC Training and Assessment</strong>&lt;br&gt;Develop, validate, demonstrate and establish processes, procedures, and environments to seamlessly integrate responsive training and assessment into Live, Virtual, and Constructive (LVC) operations across the Range Of Military Operations (ROMO)</td>
<td>Adaptive LVC Training for Enhanced Warfighter Readiness&lt;br&gt;Adaptive Training for C4ISR&lt;br&gt;Secure LVC Advance Training Environment.&lt;br&gt;Autonomous Models and Agents for Training &amp; Operations&lt;br&gt;Live Virtual Constructive Simulation &amp; Training&lt;br&gt;Live, Virtual, Constructive Training Fidelity</td>
<td>Seamless integration of live, virtual, &amp; constructive training environments; personalized training grounded in operationally relevant proficiency assessments; Range infrastructure to support LVC integration for 4&lt;sup&gt;th&lt;/sup&gt;/5&lt;sup&gt;th&lt;/sup&gt; gen aircraft; scalable, adaptive constructive agents that think and act like people to support training &amp; ops</td>
<td></td>
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<tr>
<td><strong>Cognitive Model and Scale Integration</strong>&lt;br&gt;Bridge the gap between high fidelity simulations of human cognition in laboratory tasks and complex, dynamic environments; Reduced development time/cost while increasing model complexity, adaptivity, and fidelity</td>
<td>Autonomous Models and Agents for Training &amp; Operations&lt;br&gt;Adaptive LVC Training for Enhanced Warfighter Readiness&lt;br&gt;Adaptive Training Research&lt;br&gt;Computational/Cognitive Models for ITS</td>
<td>Decreased costs and increased reusability of constructive agents for training; Trainable agents for personalized learning that keeps pace with ops tempo; Improved integration and interoperability with operational training systems</td>
<td></td>
</tr>
<tr>
<td><strong>Mechanisms of Cognitive Processing</strong>&lt;br&gt;More robust, valid, &amp; Integrated mechanisms that enable constructive agents that truly think and act like people</td>
<td>Autonomous Models and Agents for Training &amp; Operations&lt;br&gt;Virtual Human Research&lt;br&gt;Biorobotic Computational/Cognitive Modeling</td>
<td>Increased adaptivity in constructive forces for training; Enhanced validity; increased cognitive &amp; behavioral fidelity; agents that are language enabled &amp; situationally aware</td>
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</table>
Success Story: Joint Theater Attack Controller Training and Rehearsal System (JTAC TRS)

Operational Challenge

High fidelity simulation does not exist for Joint Terminal Attack Controllers

Problem: Lack of live air does not allow for training as usual, simulation required to supplement live training

Objective: Create validated high fidelity simulation environment that allows for transfer of training

Outcome: JTAC TRS training research results drove the requirements of the acquisition of the USAF operational training system over 32 systems to be fielded in US and Coalition locations

S&T Accomplishments

- First immersive environment to receive Joint Fires Executive Steering Committee accreditation for types 1, 2, and 3 daytime controls for training concurrency and deployment preparation (i.e., accredited to provide training for all US services and JTACs from 18 nations)

- JTAC TRS training research results drove the requirements of the acquisition of the USAF operational training system (over 32 systems to be fielded) and is the baseline for UK, Naval Strike and Air Warfare Center simulators; Deployed testbeds in New Zealand, Ft Benning, and USAFE

Return on Investment

Affordability: Supplement live training with simulator training, reduce live air requirements

Readiness: Experimentation results yielded significant increases in successful attacks, number of ground vehicles neutralized, and a decrease in time to complete mission

Warfighter feedback: “I’ve been that grunt that never had that air support, so I’ve been in situations where you’re getting shot at and you’re like, ‘This is it, I’m dying’. With this, we give hope” - Matt Hruska, Simulator Operator, ANG 169th Air Support Operations Squadron
Thrust 2: Personnel Selection and Assignment

Delivering the Mission
- Initial Military Training attrition is ~10% ($1.7B cost/yr).
- IMT attrition could be reduced to ~8% (saving ~.34B/yr) if current S&T product (TAPAS) was implemented to assess personality. IMT attrition could be reduced to 6% (saving $.68B/yr) with FY22 S&T products.
- Reduce negative behaviors for enlisted by ~5%.
- Increase satisfaction, performance, and retention in critical specialties by ~15%.

Delivering Capability
Maintain our competitive edge in Human Capital (Force of Future).
- Reduce attrition and negative behaviors with more precise assessments of candidates for initial entry & job assignment.
- Improve performance and retention with an emphasis on critical specialties (e.g., cyber) through advancements in talent assessment.

Key Technical Challenges
- **Predictor measures**: Existing measures lack individualized precision and are not integrated.
- **Outcome measures**: Performance and behaviors are difficult to measure and systematically obtain over a career.
- **Predictive models**: Existing models are stove-piped and based on group probabilities.

Program Overview
- Develop and refine specialized cognitive tests
- Leverage Training S&T competency assessments in realistic mission scenario
- Predictive analytical models based on predictors and longitudinal outcomes
Personnel Selection and Assignment

Maintain our competitive edge in Human Capital ("Force of the Future", SecDef 18 Nov 2015).

Reduce attrition and negative behaviors in the enlisted Force with more precise assessment of candidates for initial entry & job assignment.

Improve performance and retention in critical specialties through advancements in talent assessment.

Predictors: Increase precision and integrate measures.

Outcomes: Improve measurement of performance & behaviors.

Models: Integrate models for individual probabilities.

Predictors: Expand/refine non-cognitive measures (Tailored Adaptive Personality Assessment System)

Outcomes: Expand/refine behavior & performance data

Models: Expand/refine predictive analytic model for integrated cognitive + non-cognitive measures to predict attrition, performance, & behaviors.

Improve performance and behaviors with optimal talent management across a career

Compensatory models integrating all predictors for wide range of outcome data

Shading Legend
Dark: Funded
Light: Partially funded
White: Not funded

Participation Legend
- Army
- Navy
- Air Force
### Personnel Selection and Assignment Program Detail

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<tr>
<td>Predictors</td>
<td>Expand and increase precision of Tailored Adaptive Personality Assessment</td>
<td>Develop, refine, and validate Vocational Interest Inventories</td>
<td>More precisely and fully assess individual potential and risk.</td>
</tr>
<tr>
<td></td>
<td>Develop and refine specialized cognitive tests (e.g., Cyber, Strategic Thinking)</td>
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<tr>
<td>Models</td>
<td>Predictive analytical models based on predictors and longitudinal outcomes.</td>
<td></td>
<td>With enhanced Talent Management, improve performance, reduce attrition and negative behaviors.</td>
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**Predictors**
- Expand and refine non-cognitive measures (temperament, interests) and specialized cognitive assessments.

**Outcomes**
- Integrate the behavioral and competency data that define criterion job performance.

**Models**
- Expand and refine predictive analytic models for integrated personnel measures to predict attrition, performance, & behaviors.
Success Story: Enlisted Personnel Selection
Tailored Adaptive Personality Assessment System

**Operational Challenge**

*Increase precision of assessing individual potential, risk, and fit to a military career.*

- 26 personality dimensions such as optimism, excitement seeking, and non-delinquency
- Applicant chooses from statement pairs generated on-the-fly based on responses

**S&T Accomplishments**

- State of the art personality assessment
- Developed in partnership with industry
- 2009: Limited operational screening (Army)
- 2010-2011: Administered to recruits (Navy)
- 2014: Began selection for 5 specialties (AF)
- 2015: Administered to recruits (Marines)

**return on Investment***

**Readiness**

- Reduces attrition by 5%
- Reduces Initial Military Training re-starts by 3%
- Reduces conduct incidents by 5%

**Affordability**

(attribution cost – recruiting, training)

- Current implementation saves ~ $30M/year
- Expanded use can save ~ $50M/year

*Based on Army data for limited operational screening.

**TAPAS**

Which of these statements is most like you?

- I am not one to volunteer to be group leader, but would serve if asked.
- My life has had about an equal share of ups and downs.

*(example statement pair)*
System Interfaces and Cognitive Processes
HUMAN SYSTEMS COI SUB-AREA: System Interfaces & Cognitive Processes

VISION

Warfighters teamed with machines through cognitively engineered interfaces that are intuitive to use, learn with experience about their users, and thereby enhance rather than disrupt the warfighter’s focus on accomplishing their primary mission

This will be achieved through:
1. Investigating science and technologies that facilitate intuitive and seamless human-machine teaming.
2. Developing the ability to provide intelligent and adaptive tools and aids that are sensitive to warfighter state and the operational environment.

Achieving this vision will enable:
1. Actively coordinated teams of multiple machines in concert with human teammates executing desired mission effects (*Force multiplier- more mission effects with fewer resources*)
2. Safe and effective human-machine systems successfully operating in complex, dynamic & contested environments (*Force protector-desired effects without risk to most valuable resources; the human*)
4. Coupling of real-time, closed loop quantification of both the warfighter and the machine to achieve unprecedented mission success (*Adaptive tools and aids ensure human-machine team is ready for unpredictable contested environment*)
## Thrust 1: Human-Machine Teaming

### Delivering the Mission
- Increased capability with smaller force structure across air, land, sea, space, and cyber
  - 1 MQ-9 Operator controlling 7 simulated MQ-9s
  - Reduced ISR PED Cell Operators from 5 to 3
- USTRANSCOM Global Mission Scheduling System
  - Reduced logistics and personnel footprint; reduced planned flying hours >2% saving $37M/yr
- Trusted synthetic teammates that provide recommendations for battlespace operations
  - Reduced manpower and training requirements
- Ability to operate safely in highly contested environments
- Reduced exposure to personnel

### Delivering Capability
Seamless human-machine interfaces enabling optimized weapon system and warfighter performance in all contested domains and mission environments:
- Demonstrate highly effective, agile human-machine teaming
- Create actively coordinated teams of multiple machines
- Ensure safe and effective systems in uncertain and dynamic environments

### Key Technical Challenges
- Immature intuitive, multisensory, adaptive interfaces
- Lack of robust and reliable natural language interfaces
- Absence of effective gesture control interfaces
- Fragile cognitive models and architectures for autonomous agents and synthetic teammates
- Insufficient degree of trust calibration and transparency of system autonomy
- Immature decision support tools

### Program Overview
- Cognitive Science and Artificial Intelligence
- Human Interaction with Adaptive Automation
- Human Insight and Trust
- Human Language Technology
Human-Machine Teaming

**Mission Need**

Actively coordinated teams of multiple machines in concert with human teammates executing desired mission effects.

**Military Capabilities**

Human-Robot Teaming
- Gesture/Limited Dialogue-enabled UGV for Logistics Connector Missions

Socio-Cognitive Architectures
- Integrated Intelligent Systems
- Mission-Specific Natural Language Dialogue
- Gesture/Non-Verbal Interaction
- Trust Calibration
- Multisensory Perception and Interfaces
- Interfaces to C2 Information Systems
- Mission Planning and Scheduling Tools

NATURAL USER-SYSTEM INTERACTIONS: REACTIVE INTERFACES
- Defense and Security
- Human-Robot Interaction
- Cognitive Architectures and Integrated Intelligent Systems

**Technical Goals**

Visualization and Decision Support for Agile C2 and Cyber
- Combined Speech/Gesture Interfaces
- Schema for Dynamic Management of Heterogeneous Autonomous Systems
- Unrestricted Natural Language Dialogue
- Natural User-System Interactions: Trustworthy Proactive Interfaces

**S&T Focus**

- Coently Based Visualization Techniques
- System Trust & Transparency
- Natural User-System Interactions: Reactive Interfaces
- Multi-User/Platform, Synchronized Autonomous Operations
- Seamless Teaming of Autonomous UAV with Manned Systems
- Hybrid Force Demonstration: Combined Air-Sea-Land Engagement

**Shading Legend**
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**Distribution Statement A: Approved for Public Release**
## Human-Machine Teaming Program Detail

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<td>Supervisory Control Technology Integration and Demonstration</td>
<td>Soldier-centered Design Tools</td>
<td>Interfaces to C2 Information Systems</td>
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<td><strong>Multisensory Perception and Interfaces</strong></td>
<td>Multisensory Perception and Data Presentation Interfaces</td>
<td>Soldier Sensory Performance</td>
<td>Advanced Technologies for Battlefield Airmen</td>
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<tr>
<td><strong>Human-Robot Interaction</strong></td>
<td>Human-Robot Interaction</td>
<td>Human-agent Teaming, &amp; Shared Cognition</td>
<td>Human Interaction with Adaptive Automation</td>
</tr>
</tbody>
</table>
Success Story: Autonomy Research Pilot Initiative: Realizing Autonomy via Intelligent Adaptive Hybrid Control

**Operational Challenge**

Autonomous control of multiple unmanned systems for military operations

**Problem:** Current fielded systems fall far short of desired advanced, highly reliable autonomous cooperative behavior

**Objective:** Increase the robustness and transparency of autonomous control for multiple unmanned systems

**Outcome:** Agile and robust mission effectiveness across a wide range of situations, and with the many ambiguities associated with the “fog of war”

**S&T Accomplishments**

- Intelligent Multi-UxV Planner with Adaptive Collaborative Control Technologies (IMPACT) architecture designed
- IMPACT “DoD Virtual Lab” established (Year 1)
  - 1 operator x 6 vehicles (simulation)
- Developed tri-service “Base Defense” challenge scenario
- IMPACT operational user assessment conducted
- Co-development of R&D testbeds at ARL and SPAWAR
- Year 2 Goal: 1 operator x 12 vehicles (simulation)
- To date, 23 S&T publications produced
- To date, 8 academia collaborations established

**Return on Investment**

**Affordability**

- Reduction in logistics footprint for equipment and personnel
- Risk Reduction: Opportunities to transition IMPACT technologies to other DoD programs

**Readiness**

- Force multiplier: Autonomous control of multiple weapon systems with fewer personnel
Success Story: Improve Airlift Mission Planning Efficiency Global Mission Scheduling (GMS)

**Operational Challenge**

Support USTRANSCOM/AMC plan fuel efficient airlift

**Problem:** Current airlift mission planning tools are manual spreadsheet type tools causing inefficiencies to be unintentionally passed to execution (e.g. empty flights, underutilized cargo aircraft)

**Objective:** Improve airlift effectiveness through improved mission planning.

**Outcome:** Reduction in planned flying hours resulting in fuel cost savings.

---

**S&T Accomplishments**

- GMS Version 1 demonstrated in FY14
- GMS Version 1 delivered to AMC in FY15
- GMS Version 1 to be integrated into Consolidated Air Mobility Planning System in FY16
- GMS Version 2 plans to improve mission precision and fuel tradeoffs, and interoperability with USTRANSCOM planning systems
- GMS Version 2 funded through FY17 to demonstrate mission planning for Surfing Air Vortices for Energy Advance Technology Demonstration

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**Return on Investment**

**Affordability**

- Reduction in flying hours and fuel costs
  - Estimated reduction in planned flying hours >2%
  - Estimated fuel savings of 70M lbs. of fuel or $37M/yr. based on FY15 JP8 fuel rates

**Readiness**

- Efficient use of C-5 and C-17 aircraft
  - Improve pairing of aircraft with cargo to ensure aircraft are fully utilized.
Thrust 2: Intelligent, Adaptive Aiding

Delivering the Mission

• Maintain mission effectiveness despite fluctuating demands: No mission degradation in a high tempo environment
• Optimized human-machine teaming: Dynamic workload allocation to improve mission efficiency
• Provides shared situation awareness and transparency between the operator and the weapon system platform: Appropriate level of operator trust
• Optimized warfighter readiness and enhanced training: Identification of relevant biomarkers indicative of operator cognitive and physiological state

Delivering Capability

Enhance warfighter effectiveness by coupling humans and machines through the use of intelligent adaptive aids to protect from being overwhelmed by complexity and workload.

• Develop models of perception and cognition
• Assess the functional state of the operator
• Real-time measurement and assessment of warfighter performance

Key Technical Challenges

• Immature tools for individual and team functional state assessment
• Fragile cognitive models
• Operationalize minimally invasive sensor suites
• To Identify the appropriate biomarkers for determining operator performance
• Absence of effective gesture/non-verbal interfaces

Program Overview

• Applied Adaptive Aiding
• Molecular Signatures
• Perceptual & Cognitive Foundations of Soldier Performance
• Cognition, Performance, and Individual Differences
Intelligent, Adaptive Aiding

Mission Need

Military Capabilities

Technical Goals

S&T Focus

ENHANCED WARFIGHTER EFFECTIVENESS BY USING ADAPTIVE SITUATIONAL AIDS AND TOOLS FOR MISSION SUCCESS

COUPLING OF REAL-TIME, CLOSED LOOP QUANTIFICATION OF THE WARFIGHTER AND MACHINE TO ACHIEVE UNPRECEDENTED MISSION SUCCESS

WARFIGHTER STATE ASSESSMENT / PREDICTION

MISSION & TASK DRIVEN ADAPTIVE AIDING

Task and Behavior-Driven Assessment Systems

Minimally Invasive Sensor Suites

Identification of Biomarkers for Cognitive & Physiological State Assessment

Physiological, Behavioral, and Cognitive Sensing & Assessment

Molecular Signatures

Applied Neuroscience

Gesture/Non-Verbal Interaction

MODELS OF COGNITION, PERFORMANCE AND PHYSIOLOGY

NEURALLY INFORMED DISPLAYS WITH INDIVIDUAL DIFFERENCES

Natural User-System Interactions: Trustworthy Proactive Interfaces

Computational Models of Operators’ Beliefs, Desires, Intentions and Other Mental States

Human-System Co-Adaptation

Socially-Guided Machine Learning

Shading Legend

Light: Not funded

Dark: Funded

Participation Legend

GREEN: Army

BLUE: Navy

Cyan: Air Force

2016

2021

2026
## Intelligent, Adaptive Aiding

### Program Detail

<table>
<thead>
<tr>
<th>S&amp;T Focus Area</th>
<th>Near-term</th>
<th>Mid/ Far-term</th>
<th>Operational Opportunities</th>
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</thead>
<tbody>
<tr>
<td><strong>Gesture/Non-Verbal Interaction</strong></td>
<td>Gesture and Non-verbal Interaction</td>
<td>Human-machine interaction using gestures and/or other non-verbal means to communicate/execute mission intent.</td>
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<tr>
<td><strong>Applied Neuroscience</strong></td>
<td>Applied Computational Neuroscience</td>
<td>Real-time, omnipresent-sensing technology, signatures of brain networks that capture changes in task performance and brain-based technologies to aid the operator and optimize team performance.</td>
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<tr>
<td></td>
<td>Translational Neuroscience</td>
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<td>Molecular Signatures</td>
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<td>Soldier-focused Neuro-technologies</td>
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Success Story: Enhanced Battlefield Airmen Effectiveness
Advanced Technologies for Battlefield Airmen

Operational Challenge

*Improve survivability / lethality of Battlefield Airmen*

**Problem:** Current equipment interfaces are not intuitive or ergonomically effective, requires intensive training and has resulted in fatal errors.

**Objective:** Address operational challenges faced by the Joint Terminal Attack Controller and Pararescue Jumper (PJ).

**Outcome:** Intuitive, airman-centered equipment/interfaces.

S&T Accomplishments

- 30+ technology transitions from 2004 – Present
- Reduced total weight carried by battlefield airman by 50%
- Optimized ergonomic fit of equipment to the operator
- Mass casualty health monitoring – 1 PJ for 5 patients

“This [BATDOK] increases our capabilities and effectiveness in a mass-casualty incident”
- Lt Col Stephen Rush, 106th Rescue Wing, Flight Surgeon

“Sirs, just got out of an after actions/lessons learned briefing from one of our ST guys that just returned from theater, SSgt Gutierrez. Wanted to pass on his praises of the MR-1 and PRC-152 specifically; he made multiple comments on how both of these pieces of gear made him more combat effective”.
- Capt Joe Gross, 720th OSS

Return on Investment

**Affordability**
- Reduction in the number of pieces of equipment carried into the field

**Readiness**
- Increased lethality
- Increased survivability
- Decreased time to execute a mission
Protection, Sustainment, and Warfighter Performance
VISION

Warfighters capable of fighting through stress to complete their mission while protected from threats in their environment.

This will be achieved through:
1. Understanding the factors that influence individual performance
2. Developing the ability to measure performance in the operational environment
3. Developing strategies to mitigate the effects of critical stressors on performance

Achieving this vision will enable:
1. Warfighter protection aligned to mission specific threat, environment, and region allowing for optimal performance while maintaining protection
2. Increased ability to perform at a higher stress level without a performance decrement or increase in injury potential
3. The ability to measure performance in training and operational environments
4. New technology capable of measuring current Warfighter state and predicting current and near term performance, resulting in 20% increase in task performance
5. Load mitigation strategies resulting in 25% decrease in metabolic cost
Thrust 1: Understanding and Quantifying the Effects of Critical Stressors

Delivering the Mission
- Real-time data analysis and performance prediction will enable improved resilience by providing critical information on Soldier readiness.
- Understanding the underlying mechanisms through which critical stressors influence performance will enable greater performance.
- Understanding individual differences in the effect of critical stress on performance will enable greater Warfighter resilience.

Delivering Capability
- Developing technology capable of objectively measuring warfighter performance in operational environments will enable real-time monitoring of Warfighter performance.
- Understanding the underlying mechanisms through which performance is influenced will provide a pathway to optimizing Warfighter performance.
- Model individual responses to critical stressors will enable the leveraging of individual variability as a means of improving Warfighter performance.

Key Technical Challenges
- Sensors needed that are non-invasive, don’t influence performance, and provide meaningful data.
- The underlying mechanisms by which specific stressors influence performance are poorly understood.
- The influence of human variability on the effects of stress on warfighter performance is poorly understood. Some people perform better with stress, others perform worse.
- High fidelity models that predict performance and injury are lacking

Program Overview
- Determinants of hazardous biomechanics
- Omnipresent Real-World Assessment
- Bioeffects: toxic particles, nanomaterials, directed energy exposures
Understanding and Quantifying the Effects of Critical Stressors

Mission Need

Improved readiness through quantifying and understanding the effects of critical stressors on individual warfighter state and performance

Real time monitoring of Warfighter performance
Optimized warfighter performance based on understanding critical stressors
Understanding and leveraging individual variability in response to stress

Define and validate operationally relevant test capabilities, metrics and measurement methods
Near term performance prediction based on real-time data
Integrated sensors and advanced models enabling near term performance prediction
Modeling of individualized response to critical stressors on warfighter performance

Develop sensors capable of real-time performance monitoring

Technical Goals

Physical Performance and Individual Differences
Real-Time Data Analysis and Performance Prediction
Warfighter Assessment in All Environments

S&T Focus

Participation Legend
- Army
- Navy
- Air Force

Shading Legend
- Dark: Funded
- Light: Not/partially funded

2016 2019 2021 2023 2026

Distribution Statement A: Approved for Public Release
Understanding and Quantifying the Effects of Critical Stressors

Program Details

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<td>Effects of operational environment on pilot toxicology</td>
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<tr>
<td><strong>Physical Performance and Individual Differences</strong></td>
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<tr>
<td>Understanding the effects of physical stress and of individual variability on the effects of that stress on performance.</td>
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<td>Advanced Research focusing on Individual Differences</td>
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<td><strong>Real-Time Data Analysis and Performance Prediction</strong></td>
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<td>Developing the ability to predict near and far term performance decrements before they happen.</td>
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<td>High resolution, wearable kinematic sensor and real-time algorithms development</td>
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<td>Real-time IMU feedback to improve Warfighter Performance</td>
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<td>Sustainment Technologies for Enhanced Performance of Soldiers (STEPS)</td>
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<td>Real-Time Bioeffects analysis</td>
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<tr>
<td><strong>Warfighter Assessment in All Environments</strong></td>
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<tr>
<td>The development of metrics and tools for quantifying Warfighter states in any environment.</td>
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<td>IMU Arrays for Warfighter Kinematic Measurement</td>
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<td>Omnipresent Real-World Soldier Assessment</td>
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<td>Aerospace Toxicology Human on a Chip</td>
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<tr>
<td>Integrated Sensor Suite Development</td>
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</table>

An understanding the individualized effects of critical stressors on physical performance will enable greater warfighter resilience.

Real-Time information on Soldier state and impending performance decrements will provide critical information on Soldier readiness.

The ability to collect information on Warfighter state in the operational environment. This information can be used to prevent performance decrements.
Success Story: Warrior Web – Physical Augmentation

Operational Challenge

Provide Dismounted Warfighters with physical augmentation tool to reduce effects of heavy load carriage

Problem: Dismounted Warfighters are carrying heavy physical loads, resulting in increased fatigue, which in turn is leading to decreased performance and increased injury.

Objective: DARPA Warrior Web is designed to provide light weight physical augmentation to reduce the effects of heavy physical loads.

Outcome: This is the first time a decrease in metabolic cost has been shown on a military population using physical augmentation.

S&T Accomplishments

• Built and demonstrated component technologies
• Army researchers at have shown that SOME Soldiers exhibit decreased metabolic cost when walking with Warrior Web.
• This is the first time a decrease in metabolic cost has been shown on a military population using physical augmentation

Return on Investment

Readiness

• Decreasing metabolic cost is expected to lead to decreased fatigue and increased physical and cognitive performance.

Warrior Web has been featured in several ‘non-industry’ media venues, such as NHK Japan’s Future Technology mini-series (>10,000,000 viewers), and Science Magazine (Oct 2015)
Thrust 2: Critical Stressor Mitigation Strategies

Delivering the Mission
- Physical augmentation to reduce metabolic cost by up to 25%
- Modeling and Simulation tools capable of predicting physical stress on the Warfighter to within 5%.
- Optimized load configurations and route planning leading to a 10% reduction in metabolic cost and 10% increase in operational performance.

Delivering Capability
- Develop methods of lessening the effects of critical stressors on Warfighter performance
- Understand the underlying mechanisms by which physical augmentation and protection technologies affect performance. Set system requirements.
- Provide the tools (M&S, route planning, etc.) necessary to understand the relationship between new technology, mission requirements and operational effectiveness.

Key Technical Challenges
- Tools to model effects of augmentation on physical performance and injury potential are still in development.
- Route planning tools require high fidelity models of human physiological response to critical stressors.
- Individual variability influences the extent to which physical augmentation can mitigate physical loads.

Program Overview
- Lower Extremity motor adaptations to actuation
- Effects of physical augmentation on walking efficiency
- Enhanced Technologies for Optimization of Warfighter Load

Wiggin et al. (2014)

Photo property of MIT Prof. Hugh Herr 75 Amherst St., Rm. E14-374L, Cambridge, MA, 02139. (I) 617-258-6574, hherr@media.mit.edu
Critical Stressor Mitigation Strategies

Mission Need

Military Capabilities

Technical Goals

S&T Focus

Improved operational performance through load mitigation technologies

Physical Augmentation Devices / Exoskeletons

Warfighter off-loading technology

Develop tools and technology to lessen effect of load, environment, and terrain on physical stress

Develop an understanding of the effects of load mitigation on performance and how to optimize it

Develop better control algorithms for physical augmentation devices

M&S tools (Biomechanical and others) capable of predicting effects of physical load on individuals

Development of Physical Augmentation Devices

Modeling Effects of Mitigation Strategies

Reducing Effects of High G Environments

Reducing Physical Load

Shading Legend
Dark: Funded
Light: Not/partially funded

Participation Legend
- Army
- Navy
- Air Force

Distribution Statement A: Approved for Public Release
## Critical Stressor Mitigation Strategies

### Program Details

<table>
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<th>Development of physical augmentation</th>
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<tbody>
<tr>
<td>Devices designed to lessen the effects of physical load on the Warfighter</td>
<td>warrior web [DARPA]</td>
<td>Increased endurance, decreased physical fatigue, improved performance.</td>
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<td>Tactical Assault Light Operator Suit (TALOS) [ ]</td>
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<td>Lower Extremity Adaptations to Joint Actuation [ ]</td>
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<td>Human Body adaptations to physical augmentation [ ]</td>
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<td>The Effects of Training on the Efficacy of a Physical Augmentation Device [ ]</td>
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<td>Advanced control algorithms for enhanced augmentation [ ]</td>
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<td>Ankle Exoskeletons to assist Load Carriage [ ]</td>
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<tr>
<td>Modeling effects of mitigation</td>
<td>Joint Biomechanical Modeling and Simulation Initiative [ ]</td>
<td>Augmentation devices that are better suited to the user, resulting in increased physical performance, and less cognitive decrement resulting from physical fatigue.</td>
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<tr>
<td>M&amp;S aimed at improving augmentation devices and better understanding their effects</td>
<td>Enhanced Technologies for Optimization of Warfighter Load [ ]</td>
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<td>3-D Modeling &amp; Spinal Injury Assessment [ ]</td>
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<td>Advanced Human Whole-Body Response Model [ ]</td>
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<tr>
<td>Reducing Effects of High G Environment</td>
<td>Hypersonic Escape [ ]</td>
<td>Increased pilot performance in high G environments, decreased injury.</td>
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<td>Efforts aimed at reducing the effects of high G environments for pilots</td>
<td>Next Gen Escape Systems Concepts for Pilots [ ]</td>
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<td>Repetitive G-Loading mitigation for Pilots [ ]</td>
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<td>Reducing Physical Load</td>
<td>NSRDEC Route Planning Tool [ ]</td>
<td>The ability to reduce Warfighter physical load while maintaining capability and performance.</td>
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<tr>
<td>Technology aimed at reducing the physical load (actual weight, ‘easier’ terrain, etc.) a warfighter needs to traverse.</td>
<td>Energy Harvesting BackPack [ ]</td>
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<td></td>
<td>Load Carriage / Novel Load Mitigation studies [ ]</td>
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</table>
Operational Challenge

Hearing loss in high noise areas produce life long disability

Problem: The combination of jet fuel and high noise environment can exacerbate hearing loss

Objective: Expose rats to simulated flight line noise and aerosol exposure to jet fuel and evaluate auditory nerve damage and hearing loss

Outcome: Noise and fuel – increased hearing loss

Retrospective human hear loss in flight line workers – increased hearing loss in fuel handlers on the flight line

S&T Accomplishments

• New finding of auditory nerve damage with fuel exposure
• Transitioned to USAFSAM - hearing database assessment of flight line workers fuel and non-fuel handlers
• Found enhanced hearing loss in fuel handlers
• Transitioned information to flight line workers and assessed personal protection equipment usage reemphasized the importance of proper use of protection equipment

Customers Agile Combat Support. ACC/SG

Return on Investment

Affordability

Hearing loss is the number one occupational health issue in the DoD. The cost of treating hearing loss is incurred by both the DoD and VA – more than $1.4 billion in veterans disability payments annually

Readiness

Hearing loss can medically disqualify a military member disqualifying them from both occupations in the DoD or from military service
Human Aspects of Operations in Military Environments
Vision:
Using effective engagement with the dynamic human terrain to make better courses of action and predict human responses to our actions.

Rapidly identify human behavior threat signals

Innovative planning for new mission demands

Predictive analytics for multi-source data
Delivering the Mission
Effectively evaluate/engage social influence groups in the op-environment to understand and exploit support, threats, and vulnerabilities throughout the conflict space. Master the new information environment with capability to exploit new data sources rapidly
- Defeating novel adversaries in every kind of conflict
- Extend capabilities for forecast, rapid planning and real-time situation awareness of human activities / behaviors and intent to operators
  - Forecast models for novel threats and critical events with 48-72 hour timeframes

Key Technical Challenges
- Lack advanced modeling and complex algorithms to process new social data streams for actionable information in real-time
- Poorly understand new social dynamics including cyber-social behavior, global reach and new social innovations
- Few well developed counter-measures, TTPs and resources to guide military engagement in the human domain to impact rapidly changing crises
- Goals to drive military capabilities are reliant upon programs that are not fully funded and not structurally aligned/accountable to long-term military objectives

Delivering Capability
Predictive, autonomous analytics to forecast and mitigate human threats and events
- Provide real-time situation awareness
  - Engage and defeat new adversaries and tactics
  - Anticipate human crises & mission problems
- Develop data theory and algorithms
  - Develop behavioral models that reveal sociocultural uncertainty and mission risk
- Improve contextual translation & interpretation
  - Discriminating among seized documents

Program Overview
- Crisis and Disaster Informatics and Models
- Social Network Research on New Threats (Daesh, Novorossiya)
- Text Analytics for Context and Event Prediction
- Foreign Language Machine Translation for Threat Warnings
- COI-coordinated SBIR projects for full spectrum social media analysis
Human Aspects of Operations In Military Environments

**EFFECTIVE ENGAGEMENT IN THE HUMAN TERRAIN**
Planners, analysts and decision makers can create effective approaches to missions to managing human security needs and mission concerns using kinetic and non-kinetic means achieve desired end-states.

**MISSION NEED**

**Military Capabilities**

**Technical Goals**

**S&T Focus**

**Participation Legend**
- Army
- Navy
- Air Force

**Shading Legend**
- Dark: Funded
- Light: Not/partially funded

**Mission Need**

**Military Capabilities**

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<td>Data to Decision</td>
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<td>Foreign Language Translation &amp; Narrative Analysis</td>
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<td>Social Media Exploitation for Intel</td>
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<td>Weak Signal Analysis &amp; Social Network Analysis for</td>
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<td>Threat Forecasting</td>
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<td><strong>Augmented Reality Tactical Displays and Novel Sensors</strong></td>
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<td>Social Media Fusion to alert tactical edge Soldiers</td>
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<td>Person of Interest recognition and associated relations</td>
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<td>Document Exploitation on foreign printed material in field</td>
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<td>Smart Glass field use for facial recognition</td>
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<td>Transition to Army labs and Joint Operational Customers (TBD) to include NPS-Maritime Interdiction Ops</td>
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**Success Story: Trident Juncture 2015: Social Media Analysis Demonstration for NATO**

**Operational Challenge**

**Real-Time Support of Strategic Communication During a Live Exercise**

**Problem:** Social media information campaigns during live, massive exercise are brand new to NATO

**Objective:** Provide real-time understanding of the social media information environment for strategic communication situation awareness

**Outcome:** Recognition and invitation to assist NATO to develop a Digital Working Group in 2016, future engagements to be discussed for 2017

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**S&T Accomplishments**

- Rapid training (>3 hours) of personnel accomplished
- Curated over 2M relevant tweets, including information attacks (trolling) and other conflicts in the information space, including 6 months of baseline analysis
- Curated and analyzed over 20K tweets and 700 Instagrams during the exercise.

Customers included NATO HQ personnel, the NATO Military Information Center staffers, JFC Brunnsum public affairs, EUCOM, and other VIPs from SHAPE HQ, DSTL and HQ ARRC.

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**Return on Investment**

**Affordability**

Capabilities demonstrated are 1/4th the cost of COTS tools, with 50% less manning required than COTS to achieve equivalent situation awareness. According to Department of State users.

NATO funded the travel and accommodations for USG participants (Thank to JFC Brunnsum HQ)

**Readiness**

**Army and Navy have several technologies** that are ready for such technical demonstrations (shown at TJ15 as a joint effort)

NATO, NATO Allied Command Transformation and constituent NATO partner nations are very interested in closer cooperation in this kind of research and development.
Success Story: SCRAAWL: Joint Army/Navy Social Media Analysis and Models

**Operational Challenge**

*Provide real-time situation awareness and automated analytics of social media sources with low manning, at affordable cost*

**Problem:** Military and USG responders to crisis need the rapid SA that social media can provide, but must be able to rapidly see whole patterns of data flow and critical pieces of data that actionable.

**Objective:** Rapid SA from social media with low manning, with ability to discern actionable information readily,

**Outcome:** Control of strategic narratives, capability to discern and counter competitive and hostile messaging, “know what the crowd knows” about changing situations on the ground in real time.

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**S&T Accomplishments**

- Real-time monitoring and 30-day backlist of breaking news and topics
- Automatic identification of viral information and rumor
- Automatic identification of suspected false accounts.
- Automatic identification of viral photos and videos
- Transitioned to SOCOM Open Source Environment and Combat Zone Tool Kit for multiple commands

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**Return on Investment**

**Affordability**

- 1/4<sup>th</sup> the price of comparable systems
- Low training requirements

**Readiness**

- New capabilities are being added to existing commercial system, in daily operational use. Joint funded by Army and Navy.
Thank You