Human Systems Roadmap Review

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

Approved for Public Release: DCN# 43-1322-16

Human Systems Community of Interest Vision and Goals

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

Personalized Assessment, Education, and Training

Right Person, Right Job, Right Skills

- First Principles for Training Design
- Personnel Selection and Assignment

System Interfaces and Cognitive Processes

Effective, Natural Human-Machine Teaming

- Human-Machine Teaming
- Intelligent, Adaptive Aiding

Protection, Sustainment, and Warfighter Performance

Ensuring Warfighter Safety and Survivability

- Understanding and Quantifying the Effects of Critical Stressors
- Critical Stressor Mitigation Strategies

Human Aspects of Operations in Military Environments

Our Forces Prepared for Global Challenges

- Exploiting Social Data, Dominating Human Terrain, Effective Engagement

Personalized Assessment, Education, and Training

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

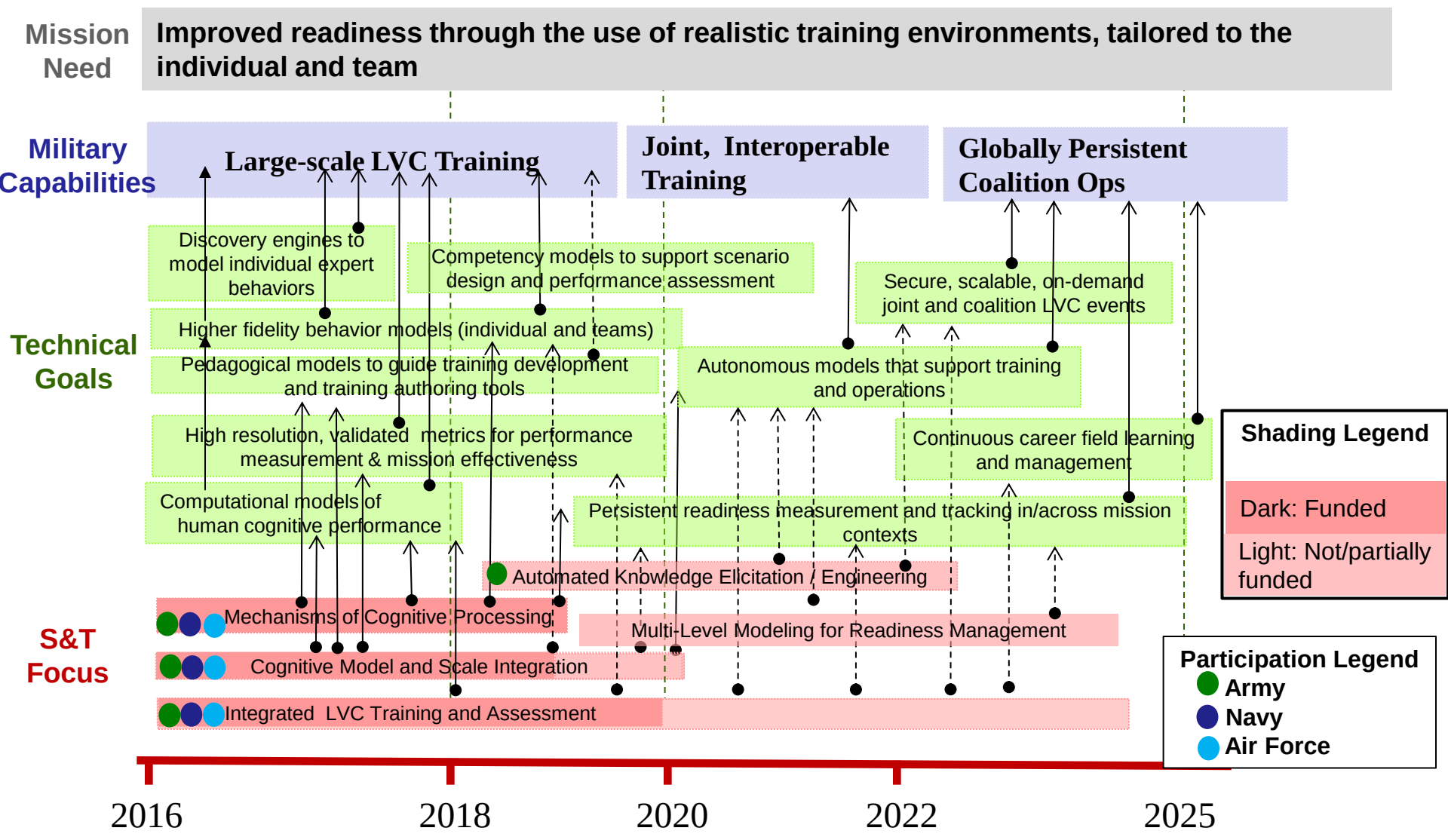
Develop ability to model individual expert behaviors

- 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



First Principles for Training Design
Program Detail

S&T Focus Areas	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Integrated LVC Training and Assessment *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)*	Adaptive LVC Training for Enhanced Warfighter Readiness						Seamless integration of live, virtual, & constructive training environments; personalized training grounded in operationally relevant proficiency assessments; Range infrastructure to support LVC integration for 4th/5th gen aircraft; scalable, adaptive constructive agents that think and act like people to support training & ops
	Adaptive Training for C4ISR						
		Secure LVC Advance Training Environment.					
	Autonomous Models and Agents for Training & Operations						
	Live Virtual Constructive Simulation & Training						
	Live, Virtual, Constructive Training Fidelity						
Cognitive Model and Scale Integration *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*	Autonomous Models and Agents for Training & Operations						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
	Adaptive LVC Training for Enhanced Warfighter Readiness						
	Adaptive Training Research						
	Computational/Cognitive Models for ITS						
Mechanisms of Cognitive Processing *More robust, valid, & Integrated mechanisms that enable constructive agents that truly think and act like people*	Autonomous Models and Agents for Training & Operations						Increased adaptivity in constructive forces for training; Enhanced validity; increased cognitive & behavioral fidelity; agents that are language enabled & situationally aware
	Virtual Human Research						
	Biorobotic Computational/Cognitive Modeling						

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.

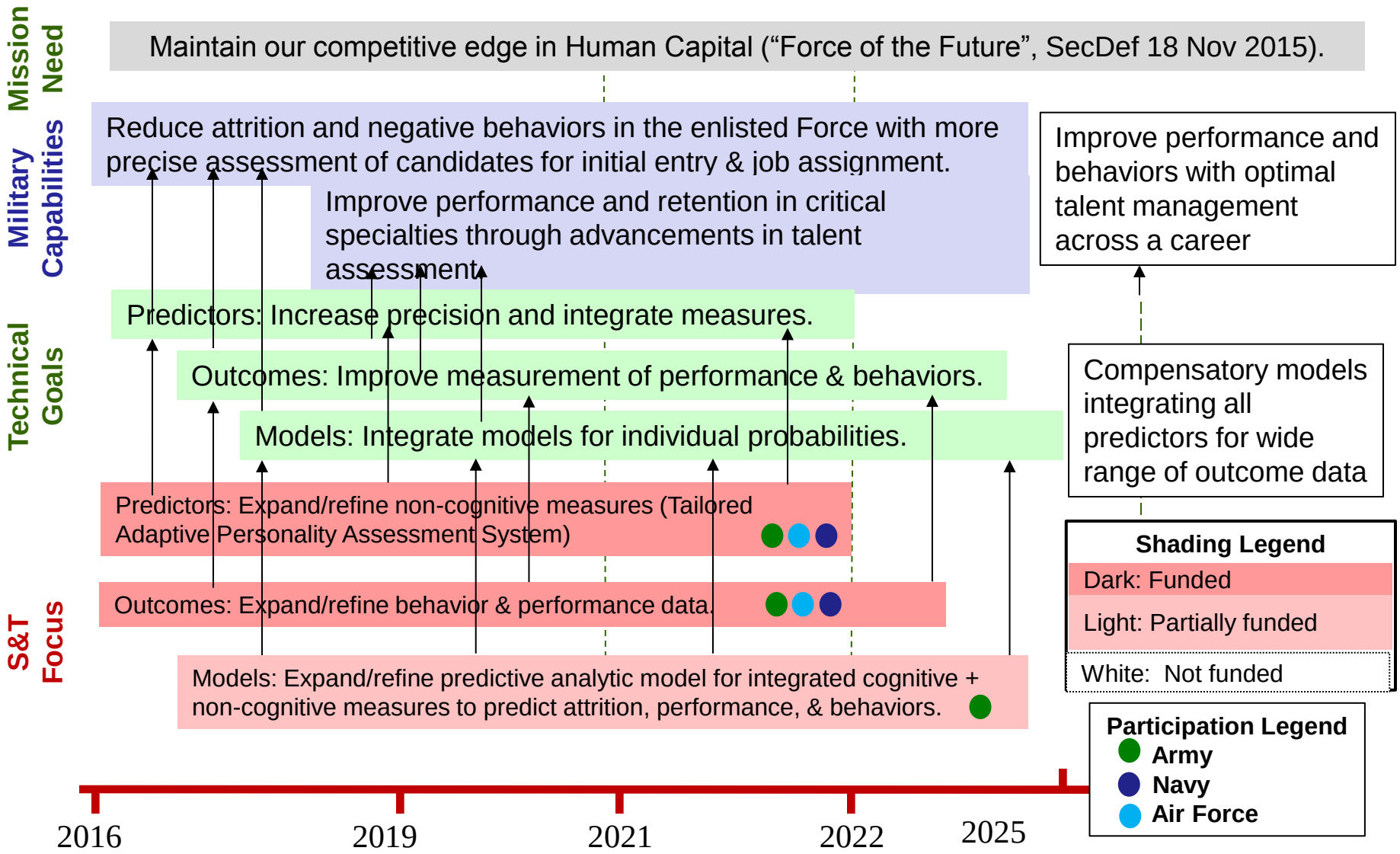
Key Technical Challenges

- 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



Personnel Selection and Assignment
Program Detail

S&T Focus Areas	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Predictors *Expand and refine non-cognitive measures (temperament, interests) and specialized cognitive assessments.*	Expand and increase precision of Tailored Adaptive Personality Assessment Develop, refine, and validate Vocational Interest Inventories Develop and refine specialized cognitive tests (e.g., Cyber, Strategic Thinking)						More precisely and fully assess individual potential and risk.
Outcomes *Integrate the behavioral and competency data that define criterion job performance.*	*Leverage Training S&T competency assessments in realistic mission scenarios.* *Develop, refine, and validate behavioral outcome measures*						More accurately assess performance and behaviors.
Models *Expand and refine predictive analytic models for integrated personnel measures to predict attrition, performance, & behaviors.*	Predictive analytical models based on predictors and longitudinal outcomes.						With enhanced Talent Management, improve performance, reduce attrition and negative behaviors.

System Interfaces and Cognitive Processes

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

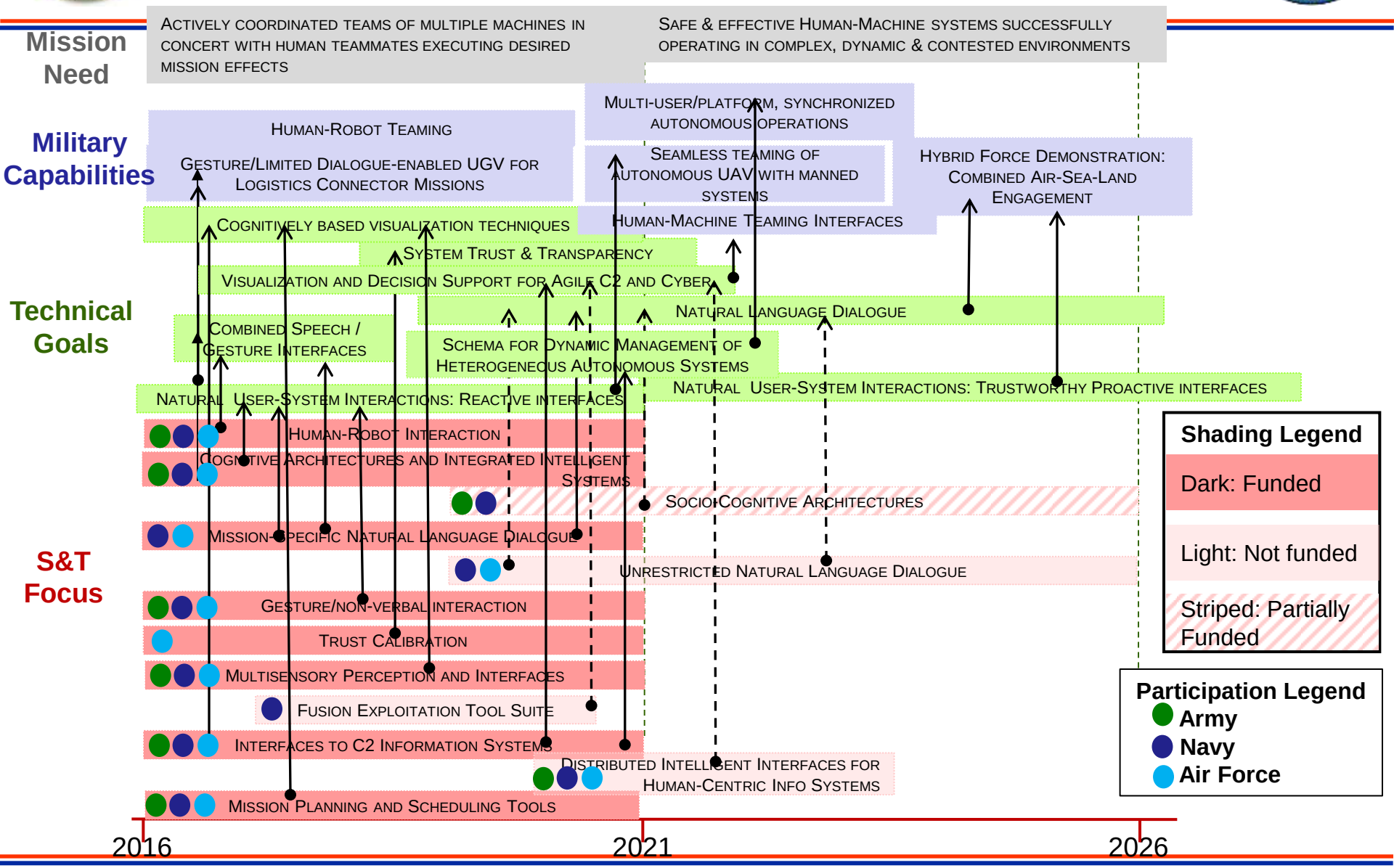
- Immature intuitive, multisensory, adaptive interfaces
- Lack of robust and reliable natural language interfaces
- Absence of effective gesture control interfaces
- Fragile cognitive models and architectures for autonomous agents and synthetic teammates
- Insufficient degree of trust calibration and 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



Human-Machine Teaming
Program Detail

S&T Focus Area	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Mission Planning and Scheduling Tools	Visual Interactive Exploratory Data Analysis						Mission planning and scheduling tools that simplify COA generation and enhance mission efficiency.
	Soldier-centered Design Tools						
	Mission Planning and Scheduling Tools						
Interfaces to C2 Information Systems	Supervisory Control Technology Integration and Demonstration						Operator-centered interfaces to C2 Information Systems that enhance/multiply mission effectiveness.
	Soldier-centered Design Tools						
	Interfaces to C2 Information Systems						
Multisensory Perception and Interfaces	Multisensory Perception and Data Presentation Interfaces						Novel multi-modal human-system interfaces that enhance operator performance.
	Soldier Sensory Performance						
	Advanced Technologies for Battlefield Airmen						
Cognitive Architectures and Integrated Intelligent Systems	Cognitive Architectures and Integrated Intelligent Systems						Cognitive architectures that maximize human-machine team performance.
	Perceptional and Cognitive Foundations of Soldier Performance						
	Brain-Computer Interaction						
	Human Insight and Trust						
Human-Robot Interaction	Human-Robot Interaction						Human-machine teams that can successfully operate in an agile fashion in an operational environment.
	Human-agent Teaming, & Shared Cognition						
	Human Interaction with Adaptive Automation						

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

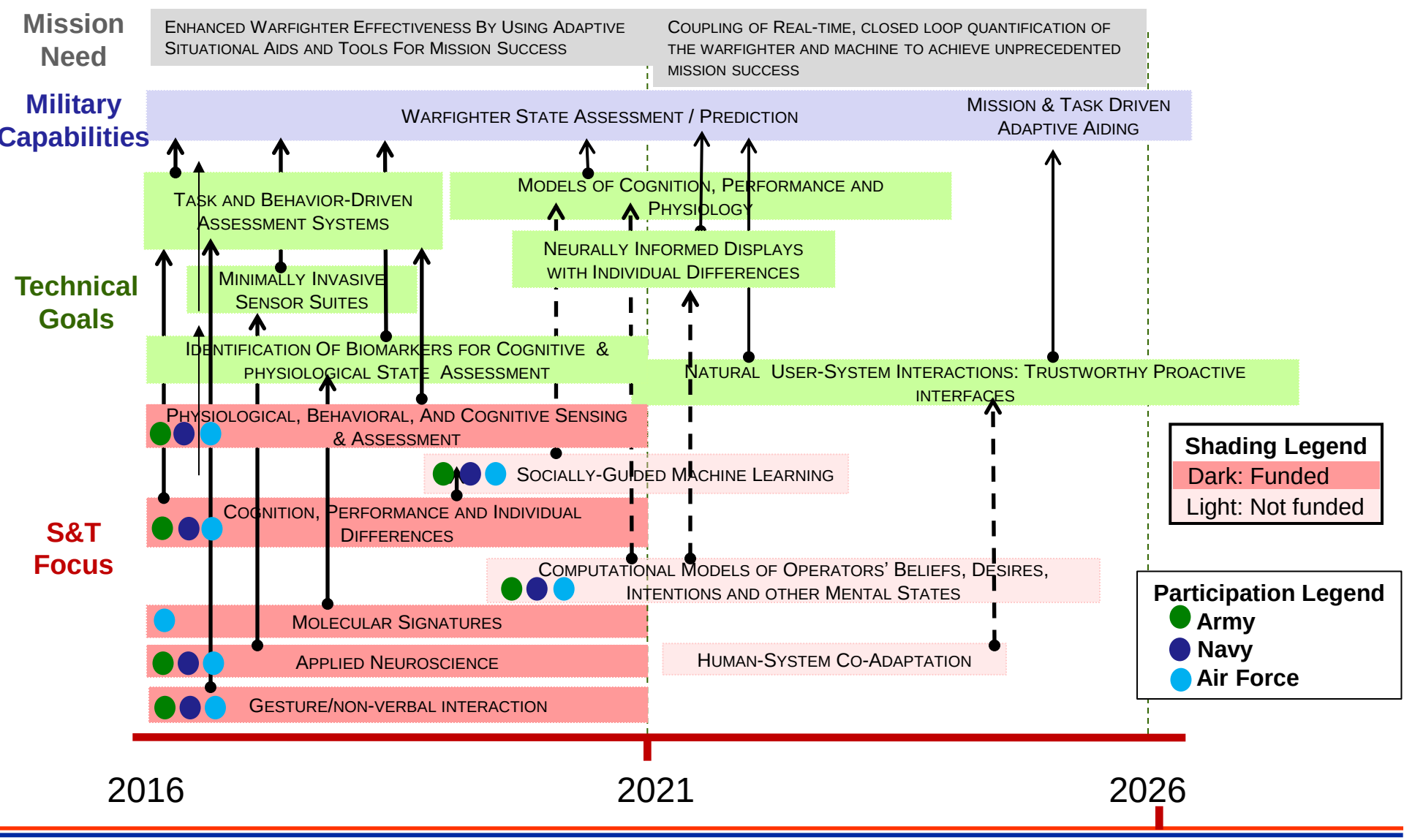
Key Technical Challenges

- 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
- Perceptional & Cognitive Foundations of Soldier Performance
- Cognition, Performance, and Individual Differences

Intelligent, Adaptive Aiding



Intelligent, Adaptive Aiding
Program Detail

S&T Focus Area	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Gesture/Non-Verbal Interaction	Gesture and Non-verbal Interaction Brain-Computer Interaction Applied Adaptive Aiding						Human-machine interaction using gestures and/or other non-verbal means to communicate/execute mission intent.
Applied Neuroscience	Applied Computational Neuroscience Translational Neuroscience Molecular Signatures Soldier-focused Neuro-technologies						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.

Intelligent, Adaptive Aiding
Program Detail

S&T Focus Area	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Cognition, Performance, and Individual Differences	Cognition, Performance and Individual Differences						Advanced technology to sense, measure and quantify individual warfighter cognition and performance parameters to predict and augment warfighter performance.
	Cognitive Performance Optimization						
	Perceptional and Cognitive Foundations of Soldier Performance						
Physiological, Behavioral, and Cognitive Sensing and Assessment	Applied Computational Neuroscience						On-line operator monitoring and assessment technology, integrating multiple and concurrent data streams to predict and augment warfighter performance.
	Perceptional and Cognitive Foundations of Soldier Performance						
	Soldier-focused Neuro-technologies						
	Molecular Signatures						
	Cognitive Performance Optimization						
	Applied Adaptive Aiding						

Protection, Sustainment, and Warfighter Performance

HUMAN SYSTEMS COI SUB-AREA:
Protection, Sustainment, and Warfighter Performance

VISION

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

DARPA Warrior Web early prototype

Wearable sensor technology

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.

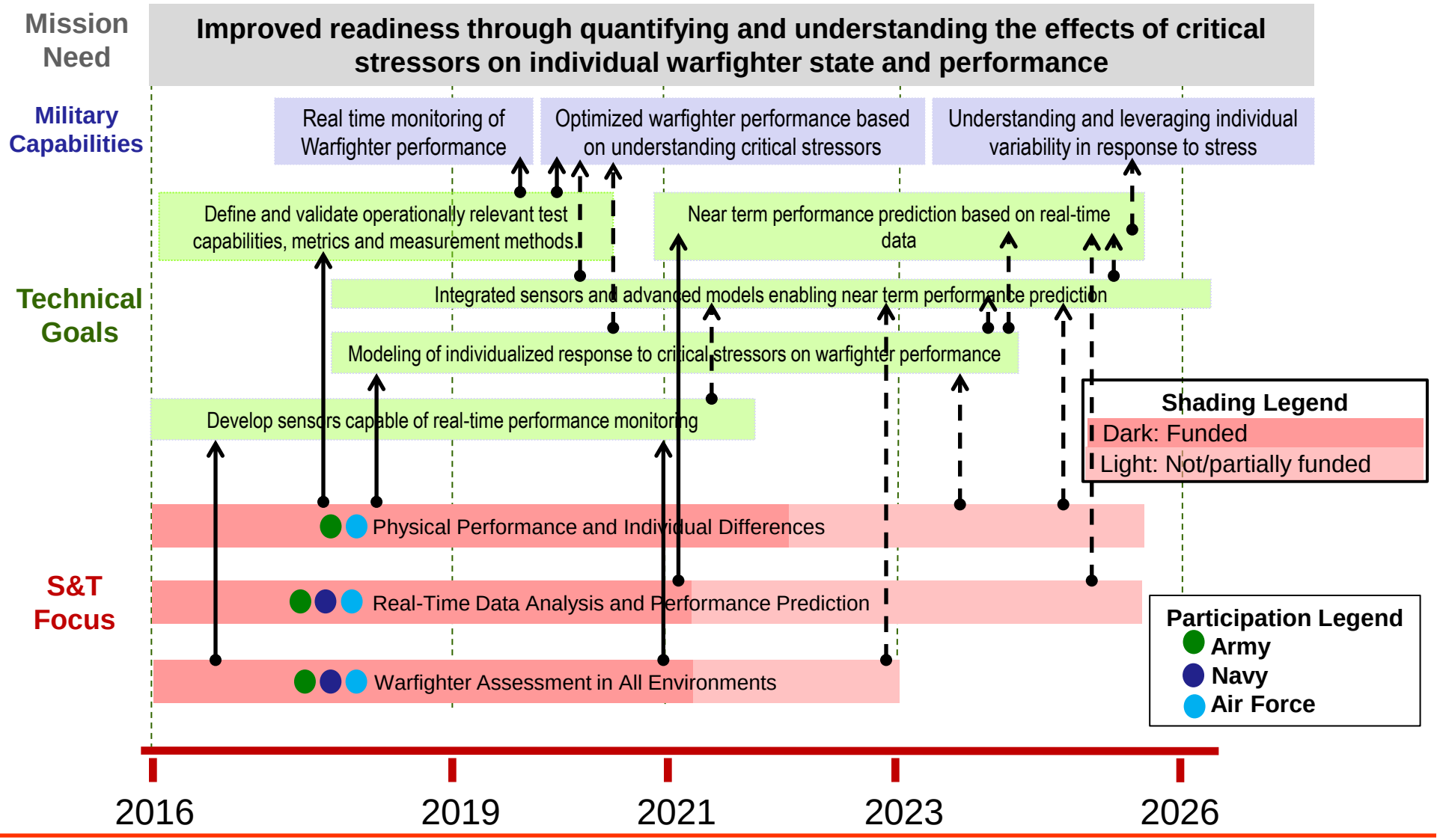
Key Technical Challenges

- 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



Understanding and Quantifying the Effects of Critical Stressors
Program Details

	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Physical Performance and Individual Differences *Understanding the effects of physical stress and of individual variability on the effects of that stress on performance.*	Determinants of hazardous biomechanics						*An understanding the individualized effects of critical stressors on physical performance will enable greater warfighter resilience.*
	Bioeffects:toxic particles, nanomaterials, directed energy exposures						
	Effects of operational environment on pilot toxicology						
	Human Integrated Performance Optimizer						
			Advanced Research focusing on Individual Differences				
Real-Time Data Analysis and Performance Prediction *Developing the ability to predict near and far term performance decrements before they happen.*	High resolution, wearable kinematic sensor and real-time algorithms development →						*Real-Time information on Soldier state and impending performance decrements will provide critical information on Soldier readiness.*
			Real-time IMU feedback to improve Warfighter Performance →				
	Sustainment Technologies for Enhanced Performance of Soldiers (STEPS)						
				Real-Time Bioeffects analysis			
Warfighter Assessment in All Environments *The development of metrics and tools for quantifying Warfighter states in any environment.*	IMU Arrays for Warfighter Kinematic Measurement						*The ability to collect information on Warfighter state in the operational environment. This information can be used to prevent performance decrements.*
			Omnipresent Real-World Soldier Assessment				
				Aerospace Toxicology Human on a Chip →			
				Integrated Sensor Suite Development →			

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.

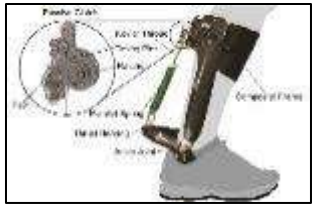
Key Technical Challenges

- 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

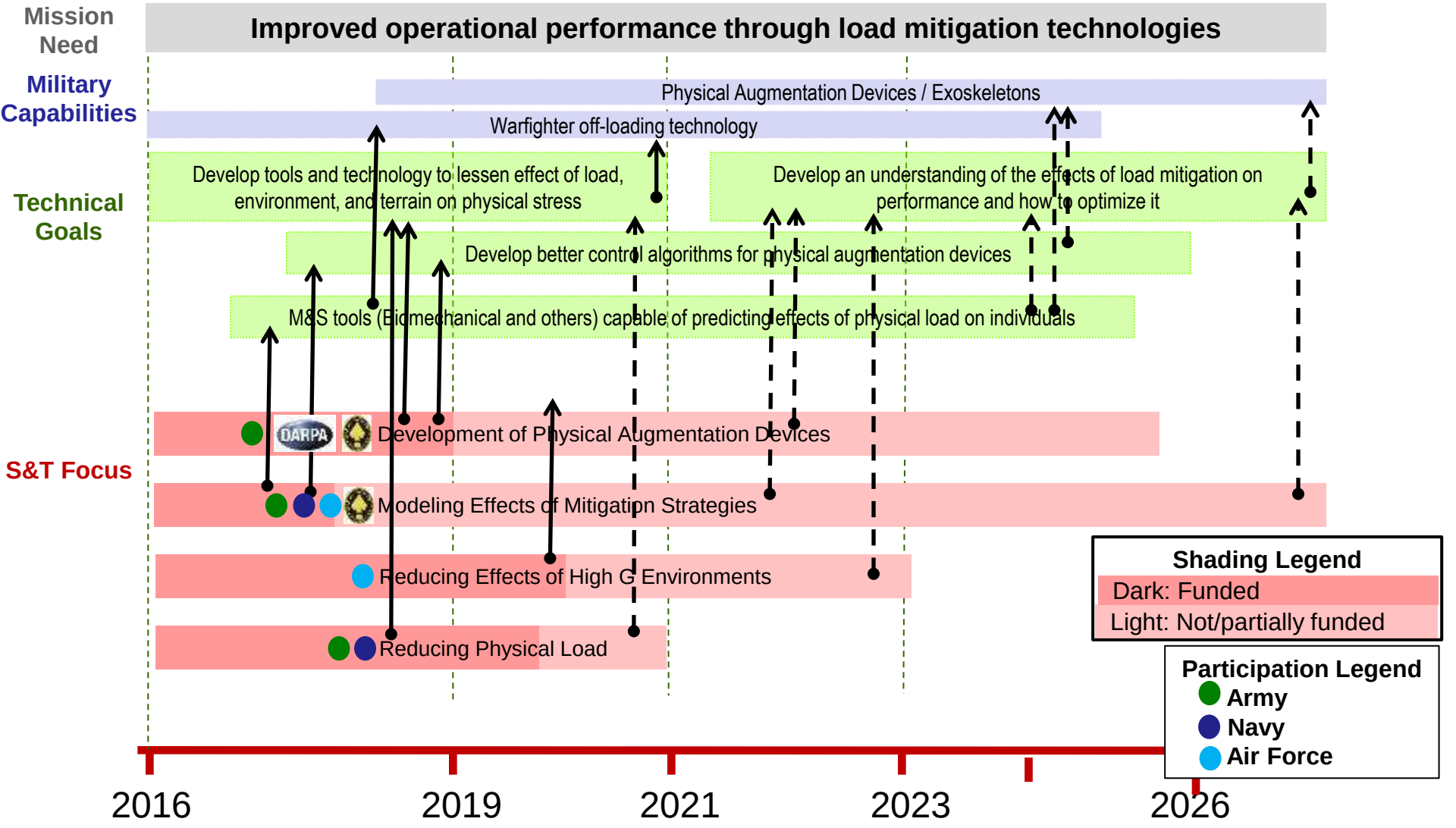
- Lower Extremity motor adaptations to actuation
- Effects of physical augmentation on walking efficiency
- Enhanced Technologies for Optimization of Warfighter Load

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



Wiggin et al. (2014)

Critical Stressor Mitigation Strategies



Critical Stressor Mitigation Strategies
Program Details

	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Development of physical augmentation *Devices designed to lessen the effects of physical load on the Warfighter*	Warrior Web (DARPA)						*Increased endurance, decreased physical fatigue, improved performance.*
	Tactical Assault Light Operator Suit (TALOS)						
	Lower Extremity Adaptations to Joint Actuation						
	Human Body adaptations to physical augmentation						
	The Effects of Training on the Efficacy of a Physical Augmentation Device						
			Advanced control algorithms for enhanced augmentation				
	Ankle Exoskeletons to assist Load Carriage						
Modeling effects of mitigation *M&S aimed at improving augmentation devices and better understanding their effects*	Joint Biomechanical Modeling and Simulation Initiative						*Augmentation devices that are better suited to the user, resulting in increased physical performance, and less cognitive decrement resulting from physical fatigue*
	Enhanced Technologies for Optimization of Warfighter Load						
				3-D Modeling & Spinal Injury Assessment			
	Advanced Human Whole-Body Response Model						
Reducing Effects of High G Environment *Efforts aimed at reducing the effects of high G environments for pilots*					Hypersonic Escape		*Increased pilot performance in high G environments, decreased injury*
					Next Gen Escape Systems Concepts for Pilots		
	Repetitive G-Loading mitigation for Pilots						
Reducing Physical Load *Technology aimed at reducing the physical load (actual weight, 'easier' terrain, etc.) a warfighter needs to traverse.*	NSRDEC Route Planning Tool						*The ability to reduce Warfighter physical load while maintaining capability and performance.*
	Energy Harvesting BackPack						
	Load Carriage / Novel Load Mitigation studies						

Human Aspects of Operations in Military Environments

Thrust: Exploiting Social Data, Dominating Human Terrain, Effective Engagement

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*

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

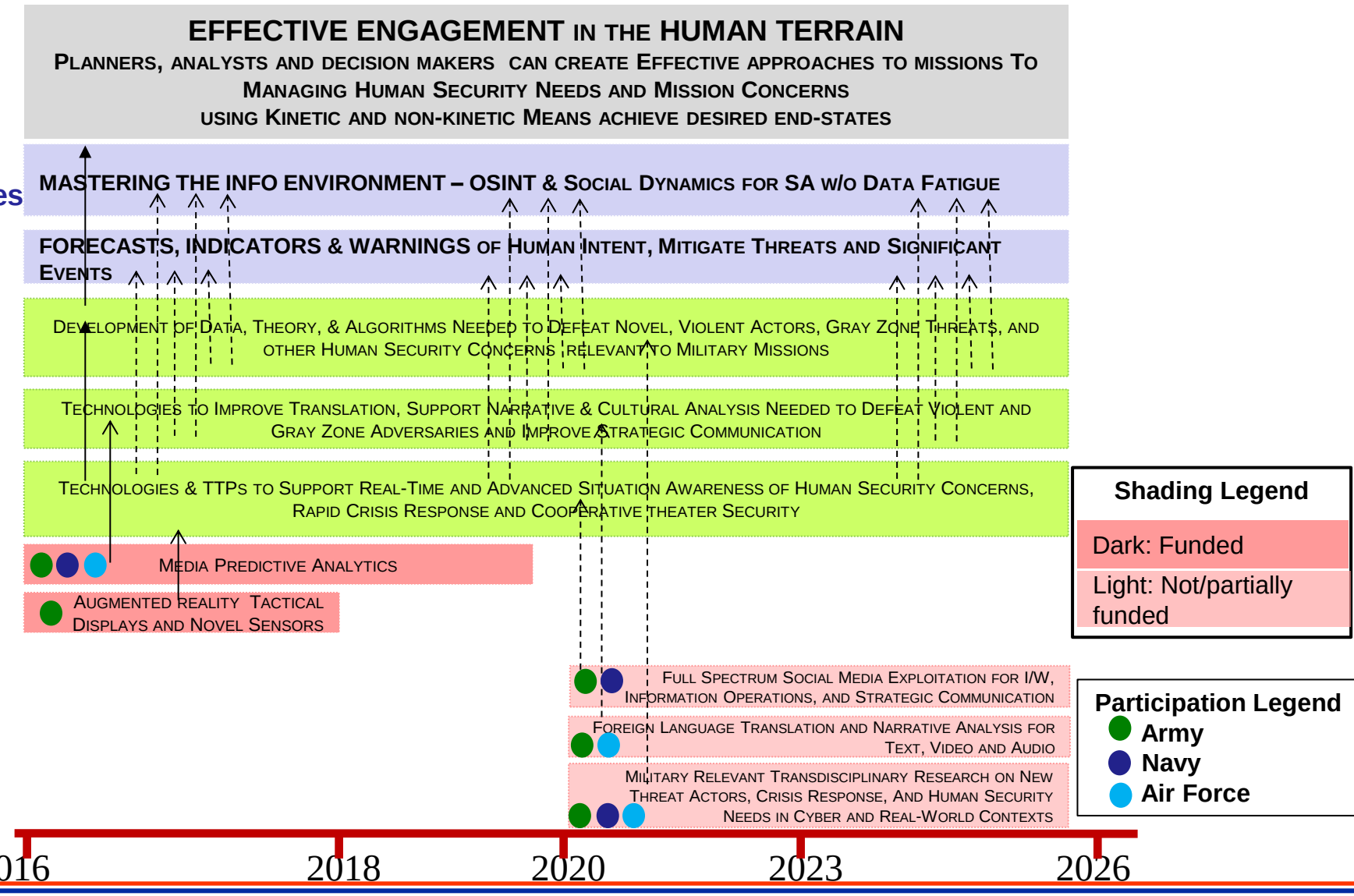
Key Technical Challenges

- 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

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



Exploiting Social Data, Dominating Human Terrain, Effective Engagement
Program Details

S&T Focus Areas	Near-term					Mid/ Far-term	Operational Opportunities
	FY 15	FY 16	FY 17	FY 18	FY 19		
Media Predictive Analytics	Content-Based Text & Video Retrieval Data to Decision Foreign Language Translation & Narrative Analysis Social Media Exploitation for Intel Social Media Exploitation for HADR Weak Signal Analysis & Social Network Analysis for Threat Forecasting						Develop real-time understanding of uncertain context with low-cost tools that are easy to train, reduce analyst workload, and inform COA selection/analysis.
Augmented Reality Tactical Displays and Novel Sensors	Social Media Fusion to alert tactical edge Soldiers Person of Interest recognition and associated relations Document Exploitation on foreign printed material in field Smart Glass field use for facial recognition					Transition to Army labs and Joint Operational Customers (TBD) to include NPS-Maritime Interdiction Ops	Development of devices and tactics to augment tactical edge soldiers with information analysis on-demand in dynamic environments.

Thank You