AFRL

PANEL DISCUSSION ON TRAINING SCIENCE AND TECHNOLOGY AT AFRL

16 APRIL 2025

DAYTON CONVENTION CENTER





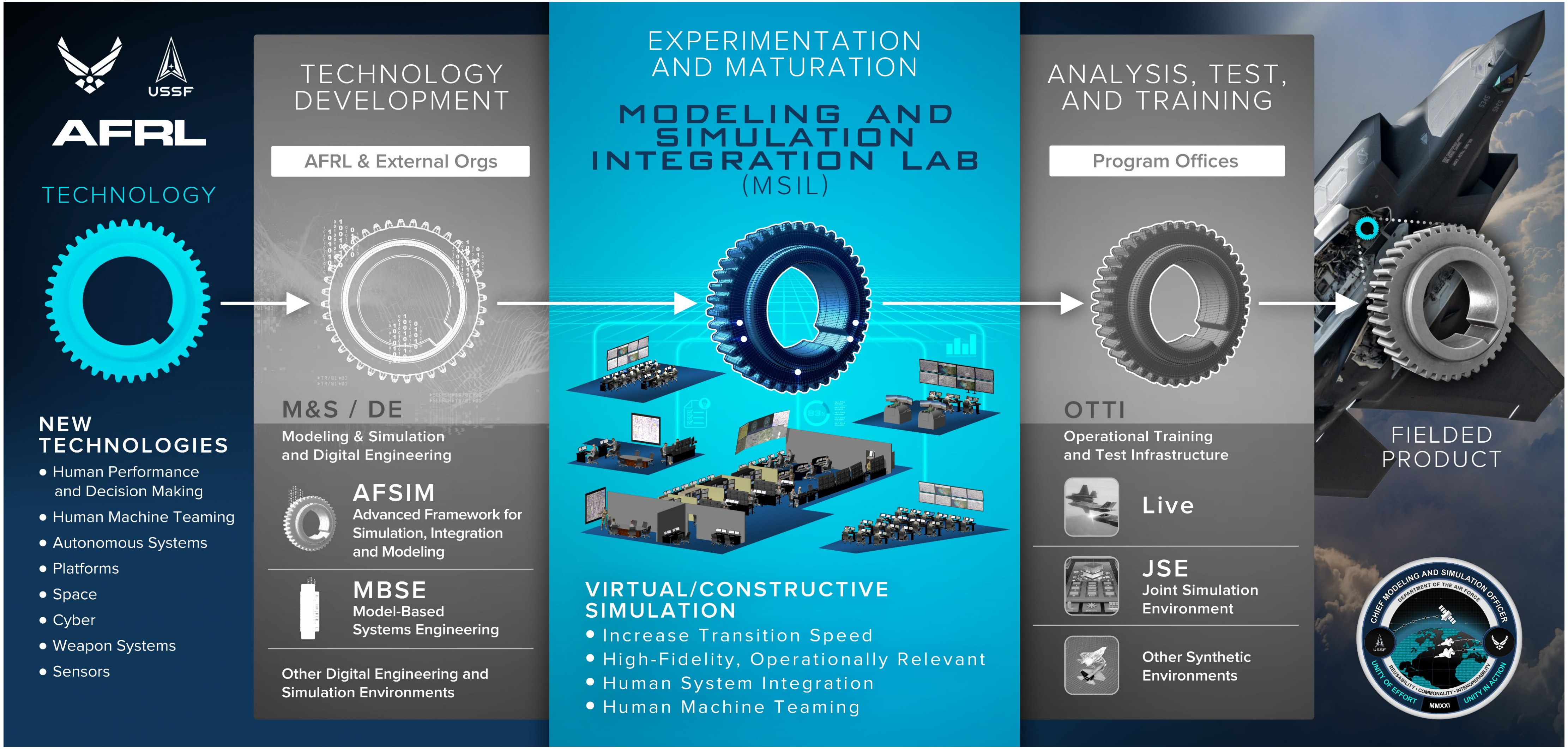
Panelists

- Moderator: Dr. Glenn Gunzelmann
- Presenters:
  - Dr. Dave Malek
  - Dr. Christopher Stevens
  - Dr. Lorraine Borghetti
  - Dr. Tiffany Jastrzembski

AFRL Human Effectiveness Directorate Applied Research Areas

Modeling & Simulation Integration Lab (MSIL)

IOC: December 2024
FOC: December 2026 (Planned)



Continuing Human Enabling, Enhancing, Restoring, and Sustaining (CHEERS)

Multiple Authority Announcement (MAA)

https://www.afrl.af.mil/711HPW/711HPW-Opportunities/

- The 711th Human Performance Wing's (711 HPW) Multiple-Authority Announcement (MAA) is intended to provide a comprehensive strategy for 711 HPW's range of Science and Technology and Studies and Analysis, creating an announcement that allows for progression from basic research to technology maturation and transition. This approach will accomplish the following:
  - Foster collaborative environment between the systems program office and research lab by allowing for transition from applied research to system specific requirements.
  - Enable faster development and rapid transition of emerging technologies into fielded systems for testing and evaluation.
- A single contract/instrument cannot be awarded for 6.1-6.8, but it allows for solicitation under a single announcement as the technology matures. An entire research effort may span multiple CHEERS solicitations.
- Please direct any questions you have regarding CHEERS to: AFRL.711HPW.MAA@us.af.mil

READINESS PRODUCT LINE REVIEW

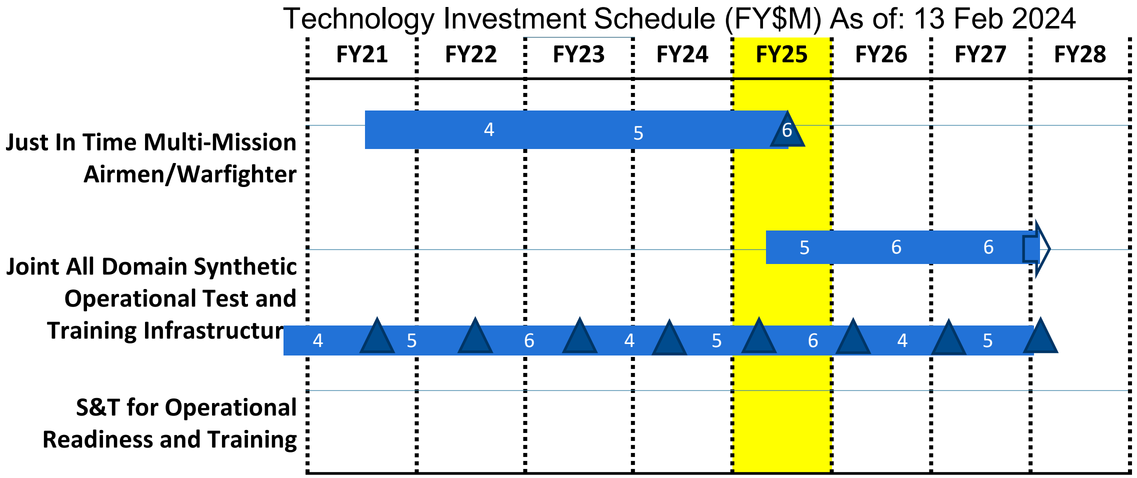
DAVID MALEK, READINESS PRODUCT LINE LEAD

711 HPW/RHW

16 APRIL 2025

S&T Funding (FY21--FY28):
Current TRL / TAD: TRL 4/7 / FY21-28
Transition: AFLCMC/WN; ACC/A3/5/4/589; AETC/ Det 23/24
Lead TD/POC: RH / David Malek
Contributing TDs: RH/RX//RI

READINESS



Description

The Readiness product line leverages maturing technology and tools and develops and extends capabilities for improving the cognitive effectiveness, decision making, and the performance and proficiency of airmen and guardians in current and potential training, rehearsal and operational mission contexts

Delivers

- Ops integration: Stds, data lake/feedback tools transition for CAF Future Training Concept FY22
- HRDE twin maintenance and logistics models FY23
- Just in time personalized content delivery, assessment, and monitoring FY25
- Field evals of just in time components in ACE events FY23, FY24, FY25
- C3BM Synthetic Operational Test and Training proof-of-concept FY27
- JADOPS OTTI Validated models and environment FY28

Technology/Technical Challenges

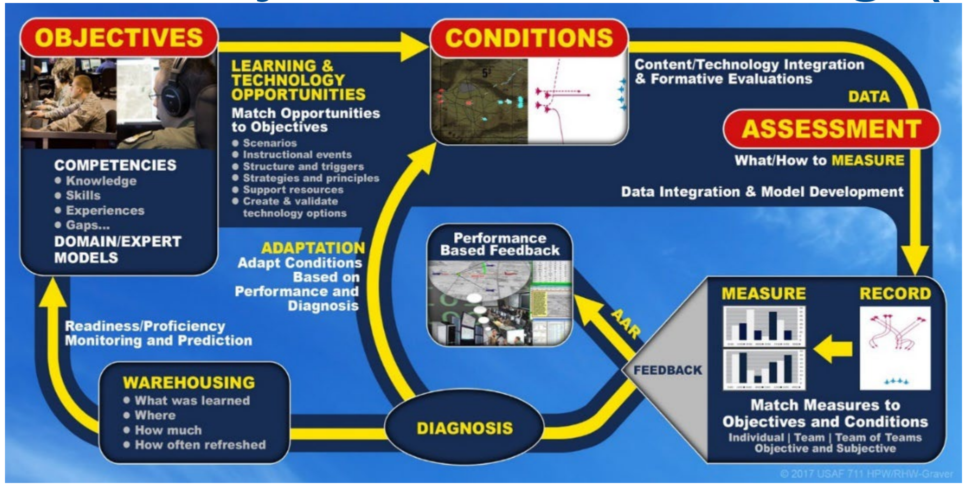
- Operationally relevant, unobtrusive, integrated metrics, software, hardware, & devices to assess proficiency & readiness in real-time
- Models & algorithms for performance prediction, training support, & automated instruction
- Operational educational, training, & rehearsal content management & analysis methods
- Standards for sharable scenario content, data, & metrics (DMO and JSE)
- Operational data standards for agent development & validation (DMO and JSE)

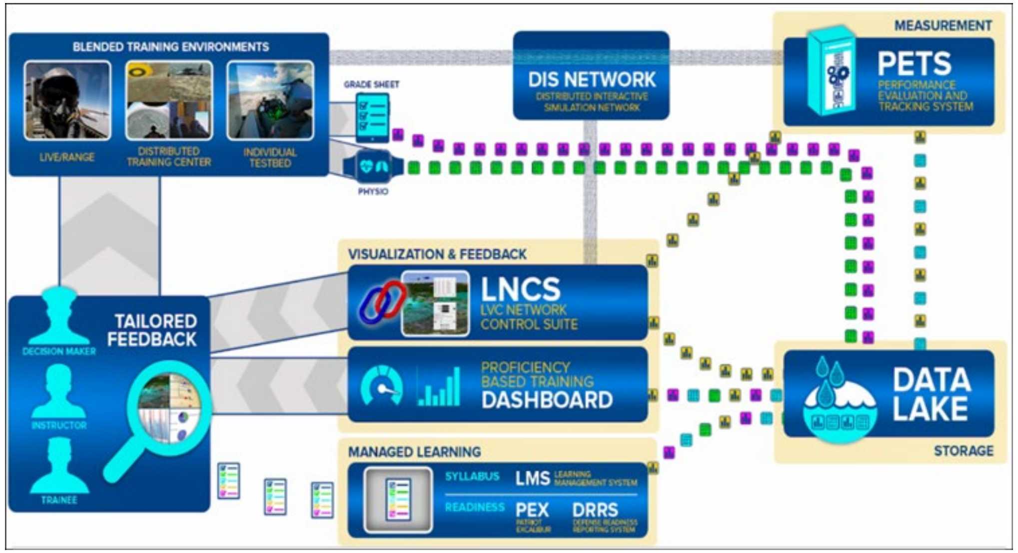
Benefits to the Warfighter

- Persistent and real-time readiness prediction & tracking
- Unobtrusive individual state & task tracking for readiness
- Just-in-time proficiency assessment
- Tailored ops contexts based on actual performance diagnosis
- Operational data-driven feedback/debriefing capability
- Digital twin operational test and training infrastructure for Joint/Coalition All Domain Ops

Sample Individual Projects

Proficiency-Based Training (PBT)





Description

Enables Proficiency-Based Training (PBT) by defining training, readiness requirements, and gaps. Identifies and demonstrates training and education technology options, Mission Essential Competency (MEC) workshops, and automated methodology to permit routine assessments of the complexity of the events and experiences.

Delivers

- PETS, LNCS, and Data Lake software supporting human performance data collection, storage, analysis, visualization, and feedback
- SimMD software supporting simulator capabilities assessments
- Competency-based measurements, learning and training frameworks, and documentation; includes advancing standards and collaborations enabling proficiency-based training
- Demonstration and validation of operationally-relevant science and technology within AFRL training research and operational mission training environments

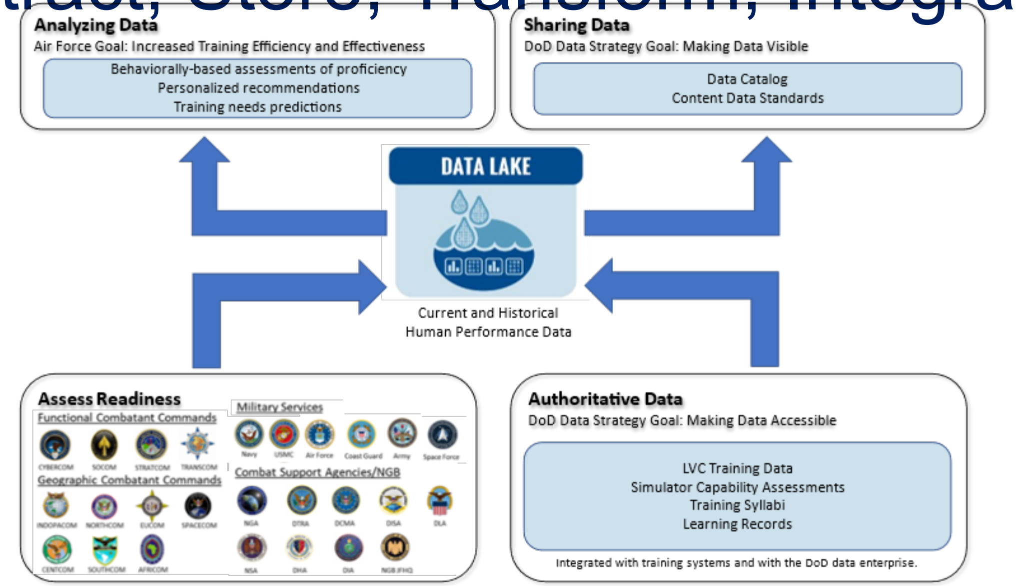
Technology/Technical Challenges

- Unobtrusive human performance measurements, including software and hardware, for assessing proficiency and readiness
- Models, algorithms, and competency frameworks for performance prediction, training support, and automated instruction
- Data and content standards enabling proficiency-based training implementation and adoption

Benefits to the Warfighter

- Persistent and real-time readiness prediction and tracking supporting individuals, instructors, and decision makers
- Tailored training based on current and anticipated performance gaps
- Data-driven distributed debrief

Extract, Store, Transform, Integrate, Analyze & Visualize Data



Technical Area

- Mature the data management and processing infrastructure to support the growing variety and volume of data present in emerging LVC training environments
- Enable the Warfighter-driven repeatable measurements, assessments, predictions, and reports identified in other task areas
- Implement and validate emerging data specifications and standards
- Develop training optimization and adaptation to capture, analyze, visualize, and remediate gaps or deficiencies in proficiency
- Develop methods for applying metadata tags to data and standardize the fields and format of data across sources

Value to the Air Force

- Provide a data foundation for proficiency-based training to extend DoD and service-level data, training, and readiness initiatives
- Enhance and expedite ACC's ability to deliver CMR pilots through data science, big data, and AI/ML methods
- Improve debrief through real-time behaviorally-based assessments of proficiency
- Increase efficiency of training through personalized recommendations for individuals and teams for knowledge and skill acquisition opportunities

XR Technologies for High End Tactical Training

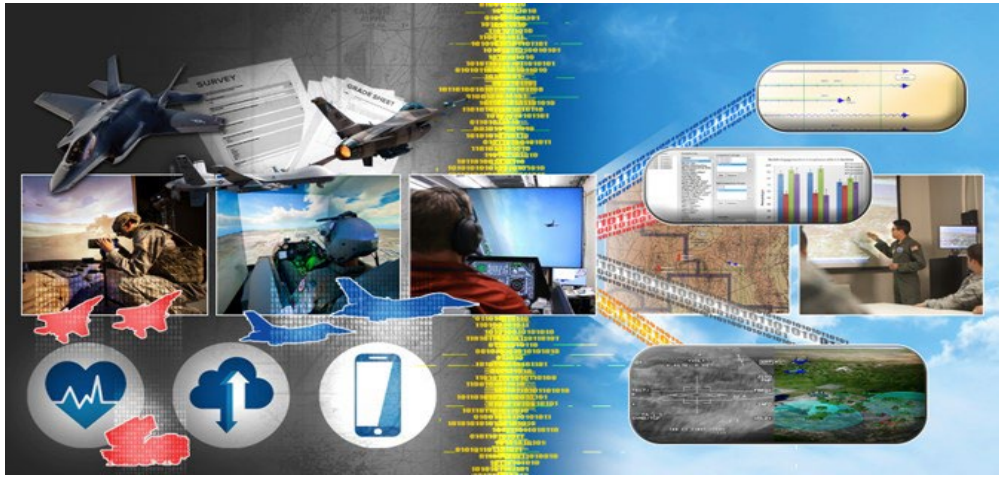
Technical Area

- Provide expertise to support assessment of proposed XR capabilities
- Support evaluations of current joint service XR development efforts to identify needed improvements
- Integrate Super Goggle solutions into training squadron simulation training capabilities
- Conduct research studies to evaluate add-on capabilities that can improve capabilities and reduce human performance issues (e.g., cybersickness)

Value to the Air Force

- Advance XR technology to enable high end tactical training in the simulation environment
- Address human factors challenges associated with XR usage
- Provide guidance to the Air Force on implementation of XR implementation
- Improve fidelity and realism of M&S test and training center capabilities
- Utilize sensor data from XR headsets to better inform readiness

SCARS



Description

SCARS (Simulator Common Architecture Reference Standards), aligns existing representative tactical training testbeds for initial test architecture. Supports maintenance, and alignment of the testbed with open mission systems and service-oriented architecture requirements. Uses MBSE to define and detail an Enterprise/Reference Architecture to successfully compare multiple technologies.

Delivers

Item	Description
10	Scientific and Technical Reports
11	Technical and Management Work Plan
12	System/Subsystem Specification
13	Computer Software Product Source Code
14	Computer Software Product End Items
15	DoD Risk Management Framework (RMF) package
16	MBSE System/Subsystem Models
17	Training Application Reports
18	Data Distribution Service (DDS) and Interface Definition Languages (IDLs) for potential establishment as SCARS Standards technical report
19	Virtualization and Containerization technical report & briefings
20	SCARS CGF technical report
21	SCARS 5th Gen Testbed Report(s)

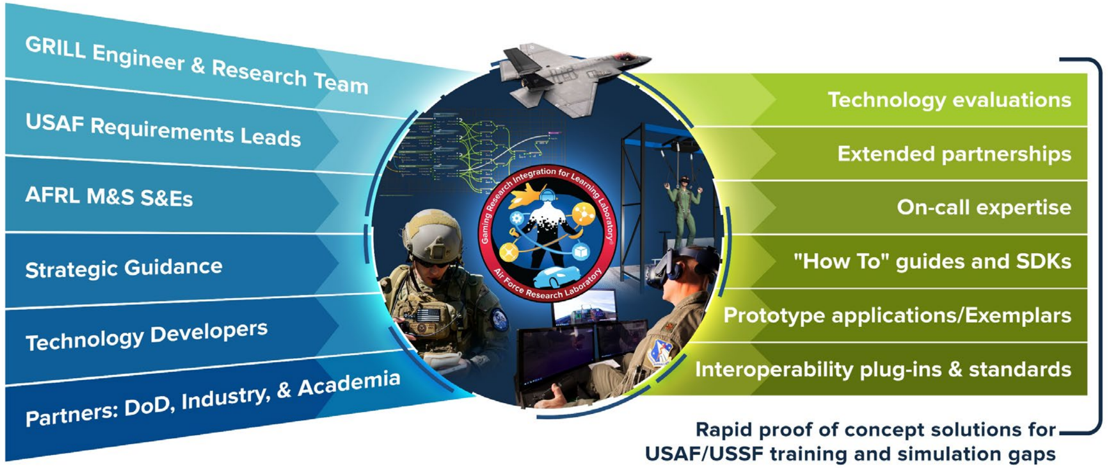
Technology/Technical Challenges

- Model Based Systems Engineering (MBSE) modeling of SCARS infrastructure, simulator and simulation components
- Multiple near Program of Record (PoR) testbeds for evaluation and experimentation environments (Unclass and Secret)
- Cybersecurity testing, analysis and reporting using best-of-breed Industry capabilities
- Alignment of AFRL training systems to SCARS testbed architecture

Benefits to the Warfighter

- Cybersecurity and RMF compliance of SCARS assets
- Common M&S assets across SCARS testbeds, e.g., terrain databases
- Modular Open Systems Architecture approach increases interoperability, enables cost savings, facilitates rapid technology refresh cycles
- Centralized management of SCARS training centers via SCARS Ops Center

GRILL



Description

GRILL: Support GRILL through evaluating AR/VR tech, enhancing performance augmentation technologies describe methods for determining the effect of training on long-term readiness

Delivers

- MVPs and task part trainers to the AF in XR technology
- Technology evaluations of the latest tech
- Research on novel approaches for training using XR tech
- Workforce development for USAFA cadets, teachers and local STEM communities in which 25% chose to support the DoD for later careers.

Technology/Technical Challenges

- Understand how to use the latest commercial tech to train the Air Force
- Integrating modern technology with existing training systems
- Extracting data that can inform readiness

Benefits to the Warfighter

- More immersive and deployable training
- Resources for understanding optimal technology for training use cases
- Plugins and projects to expedite other simulated training development

Fighter Integration Training

Description

Create/apply learning and performance science and technology to enhance the efficiency of fighter aircrew readiness training across the United States Combat Air Forces (CAF) while providing realistic training events that decrease training costs without sacrificing readiness or mission performance. Evolved from F-16 DMO study.

Delivers

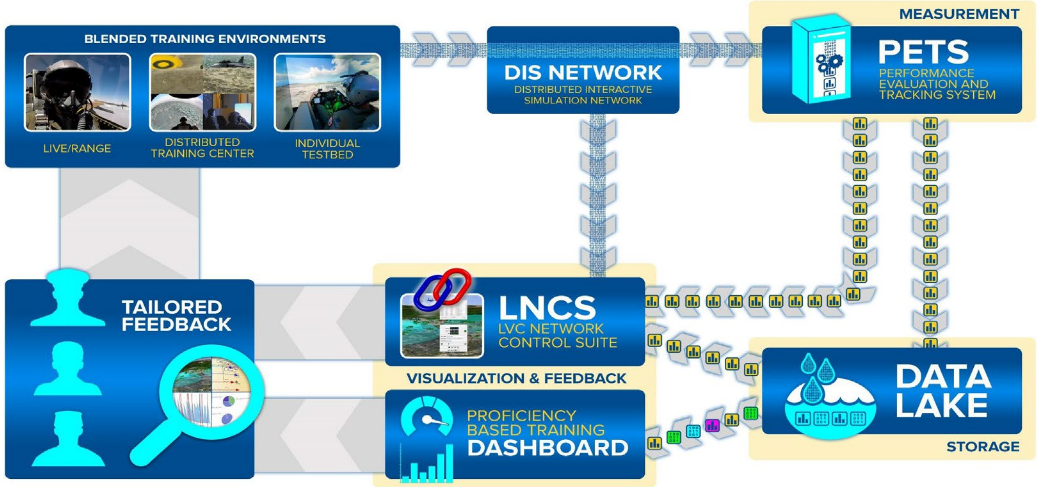
- Fighter Integration-Training Research (FITR)
- 4th & 5th gen virtual sim devices in an environment that allows for integrated mission planning, execution and debrief to the warfighter which many operators may not receive until LFE exercises or deployments
- Objective and survey human subjects research to the lab

Technology/Technical Challenges

Benefits to the Warfighter

- No other 4th / 5th gen FI sim training like it with multiple reps-n-sets.
- Away from home station allows for min external distractions.
- Adaptive portion allows warfighters to modify & manage scenarios.
- Formal / informal upgrade capability (i.e. FLUG, IPUG)
- AFRL pays travel expenses for TRWs

FI MTC PETS/LNCS Integration Support



Description

Integrate the Performance Evaluation Tracking System (PETS) and LVC Networked Control Suite (LNCS) into the F-15, F-16, and AWACS Mission Training Centers (MTC) in order to provide the Simulator Program Office (SPO) with a de-risked procedure for incorporation into fielded devices. Add F-22 and F-35 to the list of platforms (FI-TRW has demonstrated that PBT works with F-22s, F-35s not yet)

Delivers

- Valuable operator and Warfighter feedback on the PETS/LNCS debrief system
- LNCS recordings and PETS data for performance analysis

Technology/Technical Challenges

- Engineering manpower is minimal adding time to new software and measurement updates
- Security approval timelines can be long adding time to bringing new software into the room

Benefits to the Warfighter

- PETS/LNCS debrief system allows the Warfighter to review Debrief Focal Points for reaching learning objectives faster

Mission Adaptive Tactical Training (MATTIE)

Description

Create a government-owned virtual cockpit simulation with a modular design that can be used for any aircraft. Used to bridge the gap between OFP upgrades and field delivery. Provide manned virtual cockpit to assist with the development of various AI agents by providing human-in-the-loop pilot tactical interactions.
Provides man-in-the-loop training using red aircraft models in a blue (F-16) cockpit providing experienced pilots using a virtual simulation to provide tactical interact assisting in training current pilots against near peer threats.

Delivers

- AFOTI certified Dail-A-Platform (Platform Executive; Touch Screen GUI; LNCS Plug-in)
- AFOTI certified Public Release F-16
- AFOTI certified CUI F-16 / LANTIRN
- AFOTI certified CUI F-16 / Sniper

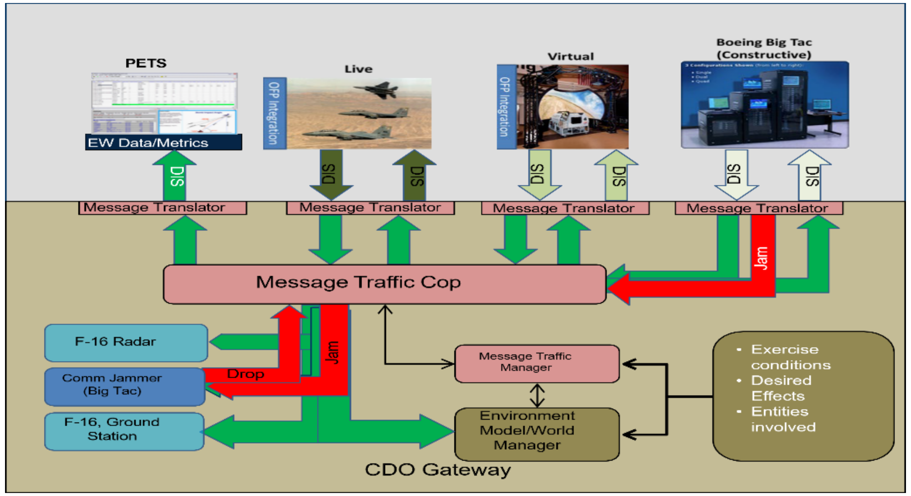
Technology/Technical Challenges

- Common simulation framework capable of creating and running simulations from public through SAP/SAR environments
- Fast jet capable terrain display with adaptable details using real world images and locations
- Modular structure to support varying levels of simulation fidelity and classification levels
- Realistic radio, cockpit, and environmental sound integration providing the pilot the same expectation as actual flight

Benefits to the Warfighter

- Support for utilizing current and previous F-16 pilots in various research roles.
- Test bed for assisting the development of various AI agents and systems in a simulation environment
- Tactical evaluation for current and future capabilities for multiple aircraft, trusted systems, and development of tactics, techniques, and procedures

EW Server (Contested Degraded Operations Gateway)



Description

Provide programmable jamming capability that communicates via industry standards (DIS, CIGI, HLA, etc.) to existing simulations without having to modify them.

Supports internal and external jamming models. Provides unique data tailored for each connected simulation

Delivers

- Classified surrogate DRFM radar jammer with MATTIE translators
- Classified NASIC provided TMAP DRFM radar jamming with MATTIE Translator
- Notional radio/datalink/GPS jamming
- LNCS integrated programming and status visualization

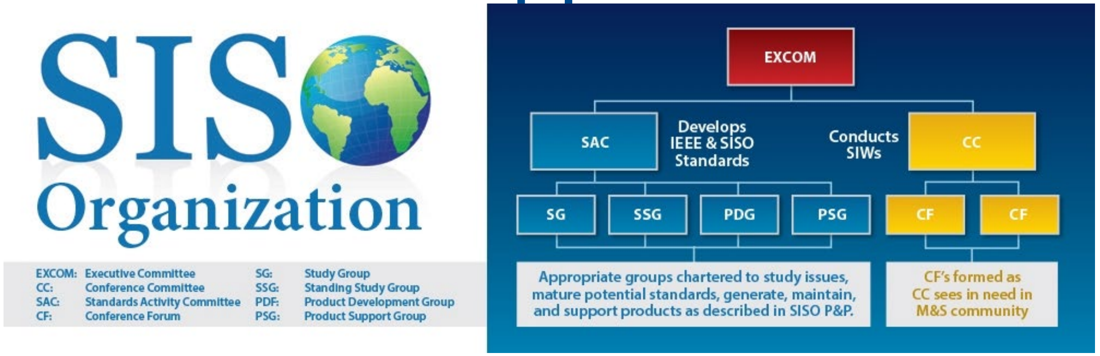
Technology/Technical Challenges

- Segregating all the simulations to control the information sent and received by eash
- Maintaining real time simulation tempo so pilots are being exposed to similar situations that occur in the real world
- Accurate recreation of jamming effects both active and passive
- Determining the realistic spoofing if any jamming systems provide
- Extending EW Servers through long haul networks

Benefits to the Warfighter

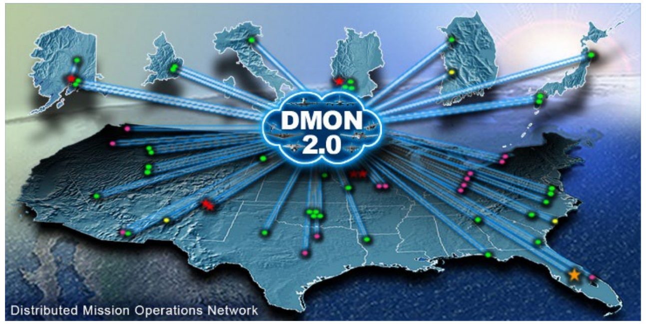
- Training in a simulated environment of jamming effects and countermeasures
- Simulating and training in a near peer combat environment with multiple engagements across long distances
- Create simulated jamming for AI agent and system testing

Standards Support



IEEE
Advancing Technology for Humanity

CAF DMO Standards



- IEEE 1278.1™2026 Completed 2026
- SISO-REF-030 Version 1 Completed Q4 2025

Description

The Distributed Interactive Simulation (DIS) standard has been the basis of Air Force simulation since the 1990's. It also informs the Navy's HLA systems. The DIS standard is currently being overhauled in a major way that will provide new capabilities and the ability to extend DIS in ways that were not previously supported. In addition to DIS AFRL has also created the Compressed DIS Standard (C-DIS – SISO-STD-023.2024) and will support a new C-DIS standard for DIS V8. AFRL also support the Hight Level Architecture (HLA) and Real-Time Platform Reference (RPR) Federation Object Model and Distributed Debrief Control Architecture (DDCA), and Simulation Interoperability Standards Organization (SISO) reference documents SISO-REF-010 and SISO-REF-030. NATO Distributed Simulation Training (DST) and FVEY Operational Training Infrastructure (OTI) support.

Delivers

- Draft 4 of DIS (IEEE1278.1) January 2025
- Draft 5 of DIS (IEEE1278.1) August 2025
- SISO-REF-030 for DIS V8 Dec 2025
- Attendance at DST monthly telecons and semi-annual face to face meetings
- Attendance at OTI monthly telcons and semi-annual face to face meetings
- Final IEEE1278.1 DIS Standard expected Q2 2026
- C-DIS for V8 late 2026

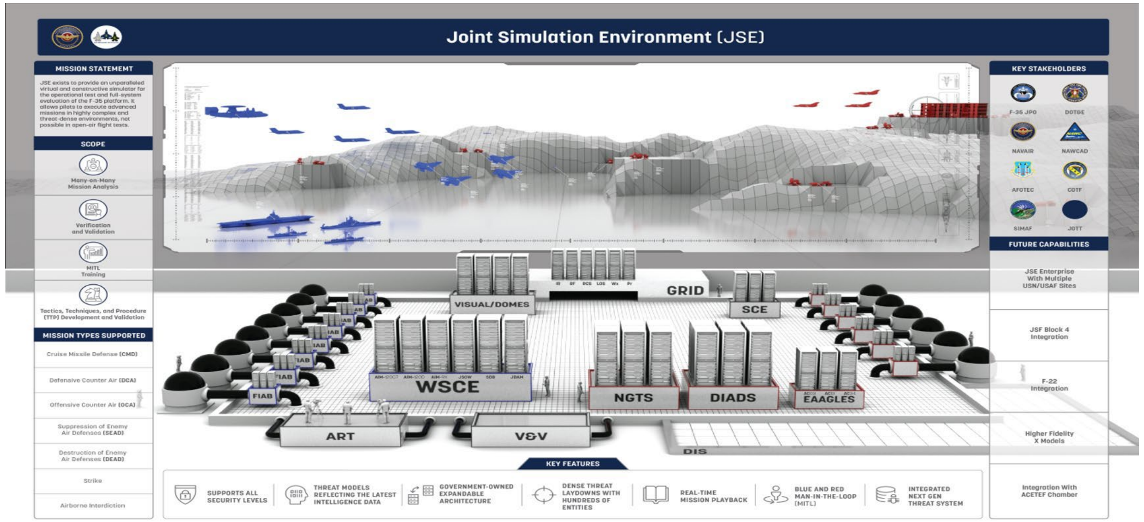
Technology/Technical Challenges

- Due to the volunteer aspect of standards development it takes a long time, while the need is high and imminent.

Benefits to the Warfighter

- Ability to implement high fidelity AESA Radars, more efficient bandwidth usage leading to the ability to support larger and more complex training scenarios.
- Ability to integrate Live Training with Virtual and Constructive systems in non-proprietary ways.
- Common standards for US and Coalition systems supports interoperability

JSE



- AFRL JIAB equivalent engineering functional Q4 2025

Description

The Joint Simulation Environment (JSE) is a government owned architecture to do high end night one simulation to support tactics and training primarily for the F-35 currently. AFRL has purchased two instances of JSE equipment (JSE in a box - JIAB's or equivalent) to support basic JSE development and integration activities at two locations. AFRL is researching ways for JSE to be able to connect multiple JSE devices over a WAN in order to support distributed training. DIS V8 is one possible way to adapt JSE to be distributable among other possibly solutions. The JSE devices are running at a basic level. Development of non OFP base F-35 (FENIX).

Delivers

- JSE (JIAB) or similar hardware purchased for AFRL
- Research platforms to test JSE distributed operations and CDS concept

Technology/Technical Challenges

- Making JSE distributable
- Making JSE releasable to ACGU/FVEY countries and or having a CDS solution to support ACGU/FVEY connectivity
- Reduce bandwidth and latency requirements
- Cost of equipment and WAN networks

Benefits to the Warfighter

- Ability to create distributed training networks using high fidelity government owned systems
- FENIX delivers low cost training and ability for FVEY participation

AFRL

PREDICTIVE ANALYTICS FOR OPTIMIZED SKILL ACQUISITION AND SUSTAINMENT

16 April 2025

TIFFANY JASTRZEMBSKI MYERS, PHD/ SENIOR COGNITIVE SCIENTIST
AIRMAN SYSTEMS DIRECTORATE
TIFFANY.MYERS.1@US.AF.MIL

Predictive Analytics for Learning

Strategic Alignment

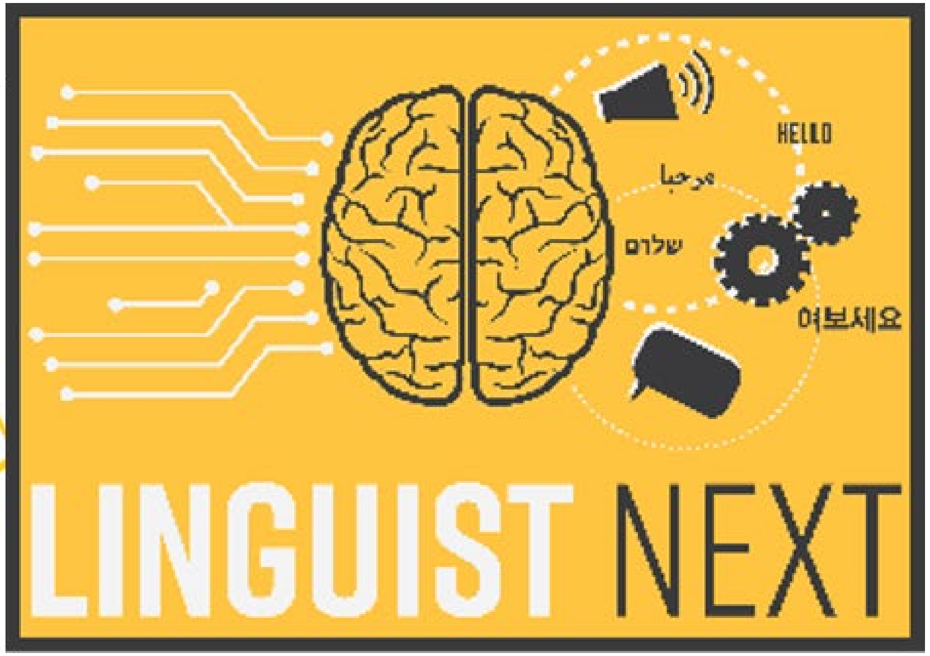
- Warfighter learning technologies required to optimize mission effectiveness
  - Proficiency-based tracking of individual skills/readiness required
  - Validated predictive analytics must guide training personalization

Core Research Questions

- How can hybrid models best be implemented in adaptive instructional systems to improve learning outcomes and tailor training pipelines?
- Can actionable student and instructor-facing dashboards enhance learner motivation and enable more targeted learning interventions?
- Can hybrid models integrate with complementary technologies to deliver optimized content recommendations and interactive, generative learning experiences?
- Can integration of change detection statistical models enable real-time model switching and model application across continuous data streams?


STUDENT ONE
User data
Personalized training and adaptive prescribed study regimens
STUDENT TWO
User data
Instructor Manual Interventions
PREDICTIVE ANALYTICS
Tracks and predicts student performance
COGNITIVE MODELS
Trace individual learning & forgetting processes; provide targeted, personalized interventions & content recommendations
LARGE LANGUAGE MODELS (LLM)
Deliver optimally tailored, interactive, multimodal learning experiences to bolster independent practice
MACHINE LEARNING
Augment the predictive capabilities of the cognitive model & generatively deliver targeted content
COLLABORATORS
AETC > Linguist Training Next
Air Force Research Laboratory
Jedburgh Technology
INSTRUCTOR
Continuous, quantitative tracking of individual & learner(s)/class readiness
Performance data and training recommendations
STUDENT ONE
83%
STUDENT TWO
67%

Case Study



Linguist Next at the Defense Language Institute

- Goal is to *empower* students and instructors to make effective decisions in their learning trajectory and enhance student proficiencies via adaptive instructional systems

- A mix of technological & analytical approaches are being brought to bear

  - *Cognitive models* trace individual learning & forgetting processes; provide targeted, personalized interventions & content recommendations

  - Performance data are compiled for actionable presentation via *student and instructor-facing dashboards*

  - *AI/ML tools* augment predictive capabilities of the cognitive model & *generatively* deliver targeted content

Initial Flight Training Applications

- Netherlands Aerospace Centre (NLR)
  - Data Exchange Agreement (DEA) in place
  - Follow-On Project Agreement (PA) moving through approval process
  - Collaborative research goals:

Validate enhanced subjective instructor evaluations

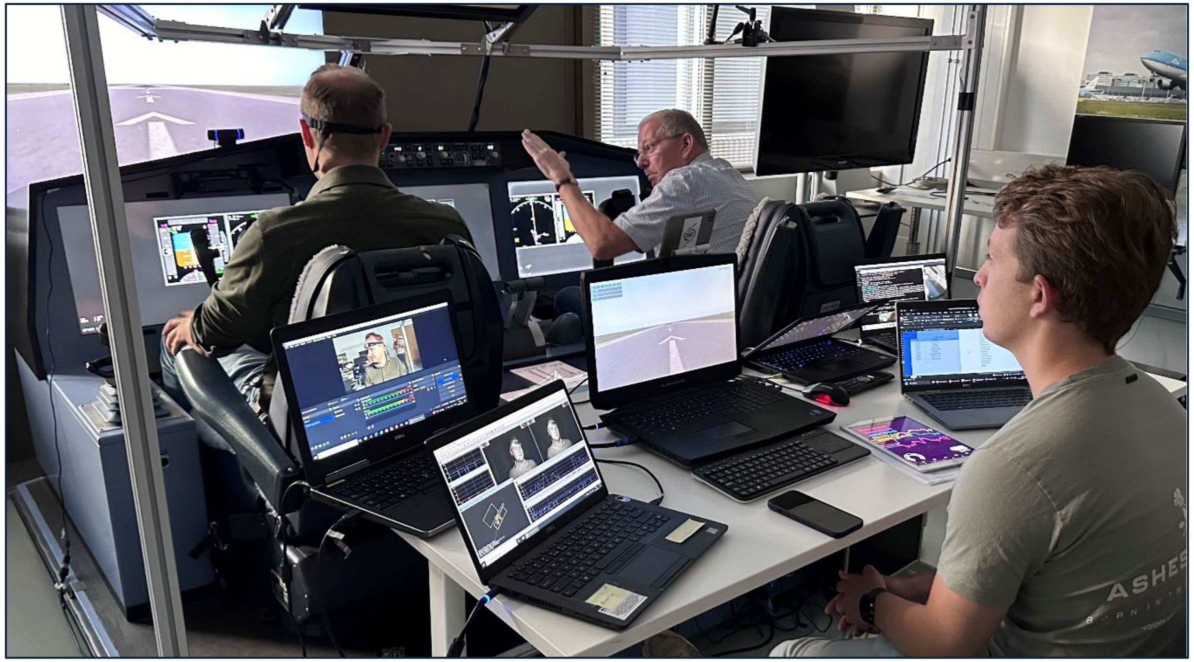
Predict learning & skill decay

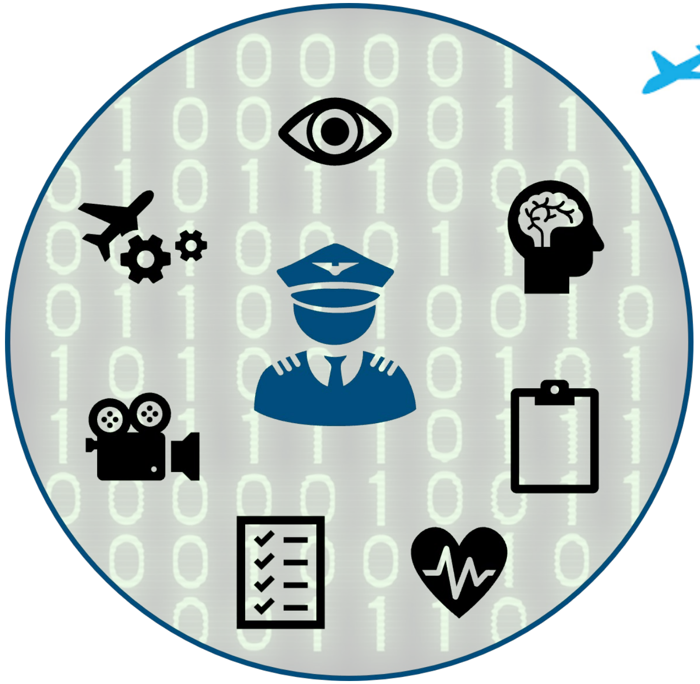
Deliver learning analytics dashboards for trainees & instructors

Deliver prescribed recommendations

Initial Flight Training (737) Experimental Design

STUDENT INSTRUCTOR EXP. LEADER



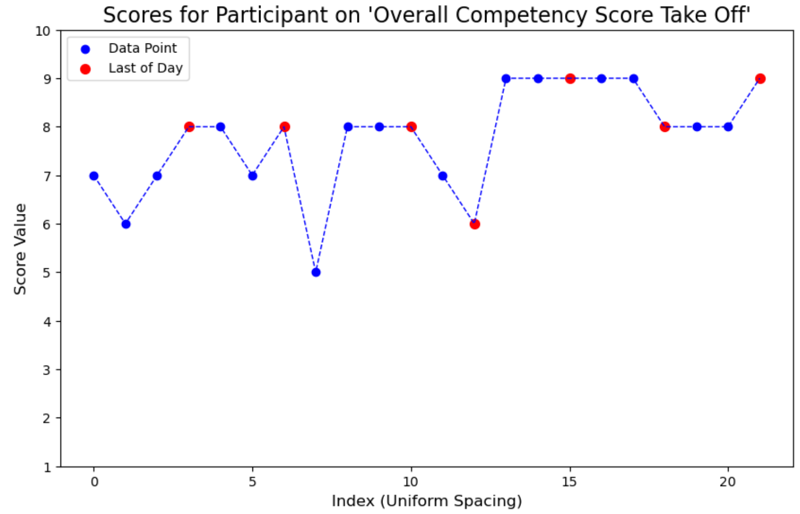


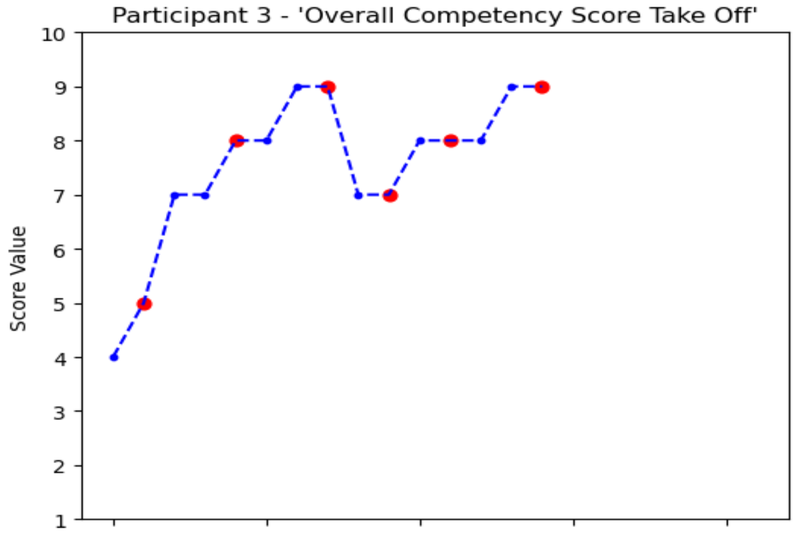
- Multimodal measure collection:
  - Objective simulator data, enhanced subjective instructor ratings, eye tracking, EEG, heartrate, cognitive workload

Initial Flight Training Data & Analytics

Enhanced instructor evaluations

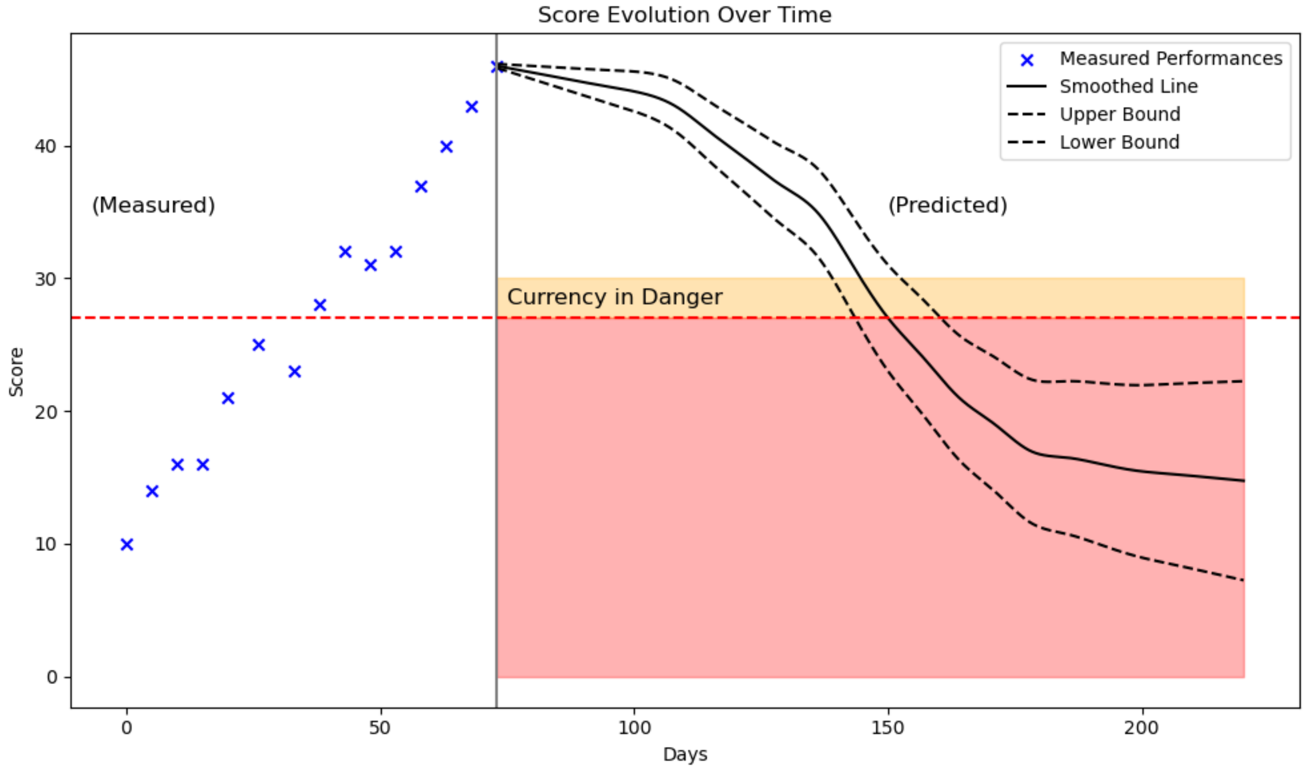
- Instructor data collected
  - Frequently, consistently and in a standardized fashion
- Learning profiles broken down by flight phases
  - Competency-driven
  - Mapping to objective simulator data underway





Prediction of learning curve & skill decay

- Apply hybrid models to multimodal learning profiles to predict:
  - Initial performance on trial 1 of the next session
  - Speed of relearning within sessions
  - Durability of trained skills (When will proficiency be lost without additional refreshers?)
  - Personalized and adaptive instructional content & scheduling to optimize acquisition & sustainment

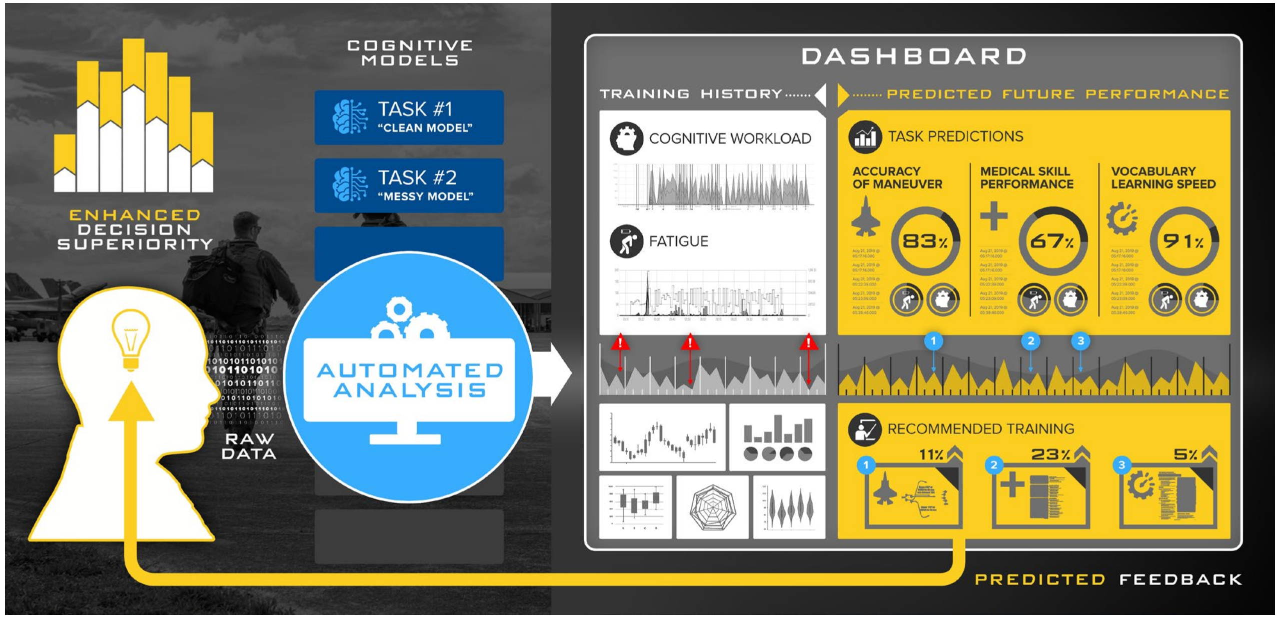


Comprehensive Readiness for Aircrew Flying Training (CRAFT, 19th AF)

- Standing up a simulation system to achieve key CRAFT goals:
  - Deliver personalized, proficiency-driven baseline training to all UPT students
  - Target and tailor undergraduate and graduate educational syllabi based on identified learning needs
  - Achieve better learning outcomes and produce better pilots
  - NLR data analytics and planned collaborative research will speed opportunities to meet CRAFT needs

Tailored Regimens for Adaptive Instructional Needs (TRAIN) – FY26 Readiness Product

- Domain-agnostic, generalizable next-generation training architecture/framework for personalized readiness
- Proficiency-based architecture/framework that trains skills/knowledge needed through adaptive, optimized task selection, scheduling, & intelligent tutoring using human language technology and content libraries
- Automated performance assessments and robust, interactive training capabilities delivered through novel integrations of Large Language Models (LLMs)
- Ability to understand/visualize the impact of cognitive moderators (fatigue, workload, noise & pharmaceuticals) on acquisition and execution



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MODELING AND SIMULATION FOR TRAINING: CHALLENGES AND USE CASES

CHRISTOPHER STEVENS, PHD, CORE RESEARCH AREA LEAD
AIRMAN SYSTEMS DIRECTORATE, 16 APRIL 2025

Team

- Dr. Lorraine Borghetti
- Dr. Ryan Wohleber
- Dr. Tiffany Myers
- Dr. Megan Morris
- Dr. Kent Etherton
- Ms. Katelyn Kay
- Lt. Seth Bohn
- Dr. Daniel Sahzin
- Mr. Tyler Gandee
- Dr. Bella Veksler

Learning and Operational Training

Mission: Enhance learning and understanding in the context of *rapidly evolving technology*. Develop novel methods, metrics, and ecosystems for human learning and co-learning with AI to ***maximize effectiveness and minimize training costs***.

- Lines of Effort
  - **Co-Learning for Adaptive Human Machine Teams: Establish the foundation for interactive learning and collaborative training of humans and AI-enabled technology to enable uniquely effective human-machine teams.**
  - **Warfighter Learning Technologies: Develop analytic framework and M&S tools enabling personalized, proficiency-based readiness in AF training ecosystems.**

Graphic by Mr. Will Graver (BAE Systems Inc.)

Modeling and Simulation Training Challenges

- Motivation
  - Achieving the advantage over adversaries requires robust, reliable, and innovative training capabilities.
  - Training ecosystems should be *validated*, *theory-driven*, and *responsive* to warfighter needs.

- Challenges for Training Ecosystems
  - **Anticipating training needs** and approaches for emerging capabilities and missions
  - **Objective measurement** of learner proficiency from vast, multimodal training datasets
  - **Personalizing** and **adapting** training to suit Warfighter needs
  - **Optimizing M&S design** for simulators

Reuters

China Unveils 'Loyal Wingman' Armed Drone Concept (9/2021)

GT

PLA is Deploying the Latest Intelligent Simulation Technologies in Its Daily Training (5/2023)

FDD

"Having altered its training and personnel management systems… the PLA has… increasingly emphasized its combat readiness" (12/2024)

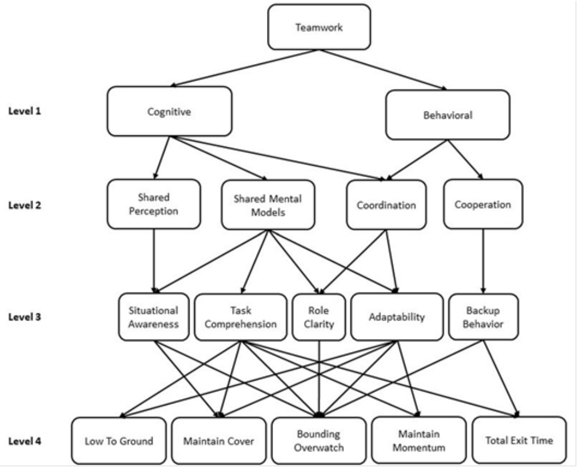
Methods/Theoretical Approaches

Modeling the learner and competencies

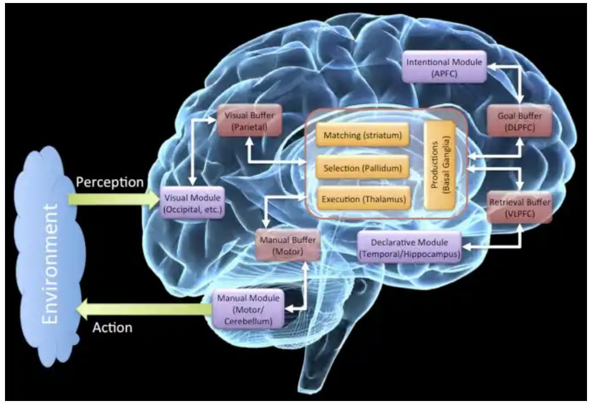
- Hierarchical Learner Models (HLM)
- Cognitive Models
- Dynamical Systems
- Machine Learning

Achieving Adaptation and Optimal fidelity

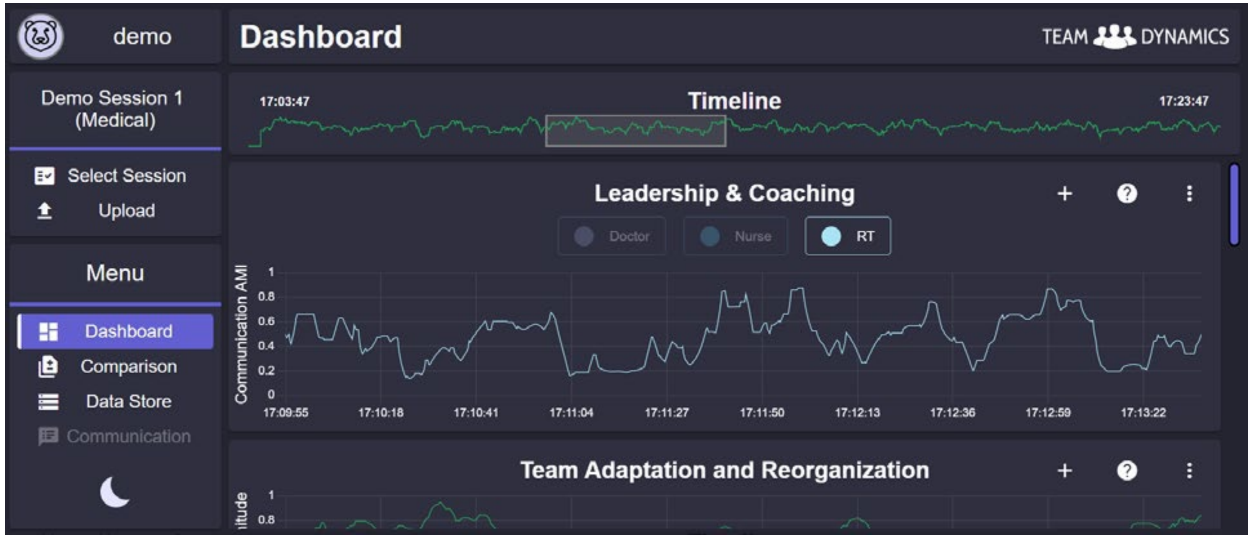
- Fidelity Decomposition (Mathematical) Models
- Large Language Models



(Vatral, Biswas, Goldberg, 2023)



(Romero & Lebiere, 2019)



Screen capture by 711HPW/RHWOW

Fidelity of Training Simulations

Proficiency-based Requirements for Optimizing Fidelity Impact in Learning Environments PROFILE

- Fidelity – faithfulness of representation to real world task
    - Physical
    - Cognitive/Psychological
- Problem
    - Tools exist for post hoc evaluation of training simulator fidelity
    - How to prospectively generate fidelity requirements before making investments in training platforms?

Proficiency-based Requirements for Optimizing Fidelity Impact in Learning Environments (PROFILE)

Training and Simulation Fidelity

- Mapping Fidelity Parameters to Competency Models
  - Mission Essential Competencies (MECs)
  - Mission Essential Task Lists (METLs)
  - Hierarchical competency models (Vatral et al., 2020)
- Applying Fidelity Decomposition Models
  - Hays & Singer (1989)
  - Paige & Morin (2013)
  - Rehmann et al (1995; adapted by Beaubein & Baker, 2017)
  - Meyer (1998)
  - Roza (2004)
- Data collection
  - SME knowledge elicitation (Self-report with referent prompts, self-report without referent prompts)
  - Behavioral data collection

Modeling and Simulation in Wargaming

Wargaming

- “Wargames are representations of conflict or competition in a synthetic environment, in which people make decisions and respond to the consequences of those decisions.” (Joint Planning, 2017)

- Critical tool to aid in training and planning wartime strategy and maneuvers

- Digital simulation capabilities have enhanced effectiveness of games (Applegate, 2021; Caffrey, 2000)


Photo by Cpl. Yvonna Guyette

AFRL Wargaming Mission

- Evaluate AFRL's technology portfolio through analytical wargaming—both internal & Title 10 wargames
- Provide (S&T) concept development and SME support for: internal, Air Force, and Joint wargaming

Human Factors in Wargames

- Fatigue/Alertness
- Injury
  - Directed Energy Impacts
  - Kinetic impacts
- Training
- Morale
- Public opinion
- How can we represent the effects of human factors in Wargames?

COMBAT

- **C**ombat **O**perations **M**ission and **B**asing **A**nalysis **T**ool
- Rapid simulation framework developed by Booz Allen to ‘digitize’ Title 10 wargames (campaign level conflict to mission-focused engagements)
- Software is based on the open-source software environment R
- Available at multi-level security as a stand-alone application or accessed via DAF cloud services
- Blue laydown and Red threat data based on Title 10 Wargames (e.g., Futures Game and Global Engagement)

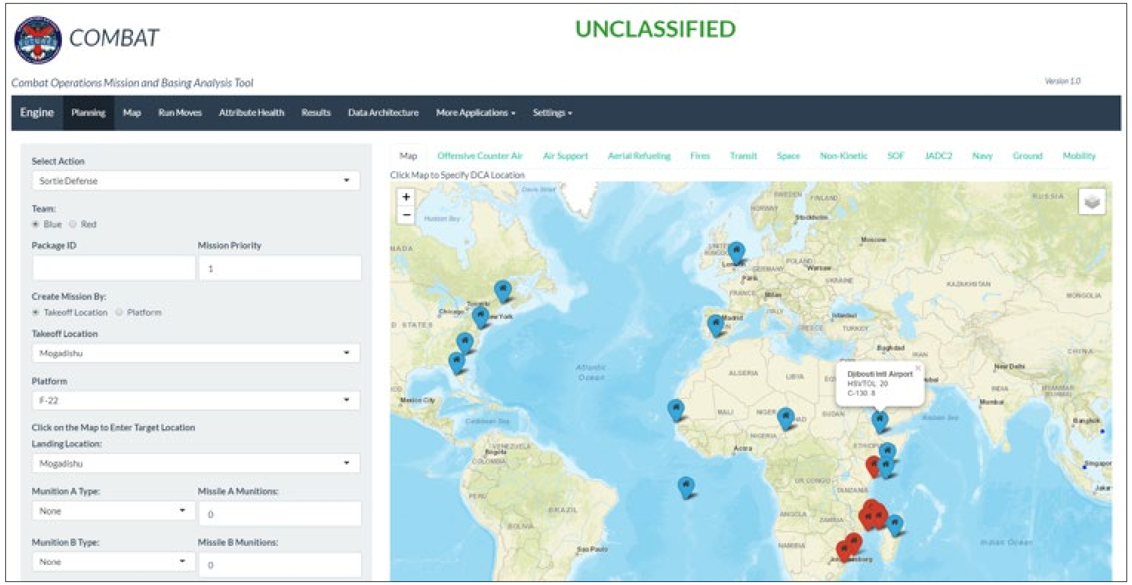
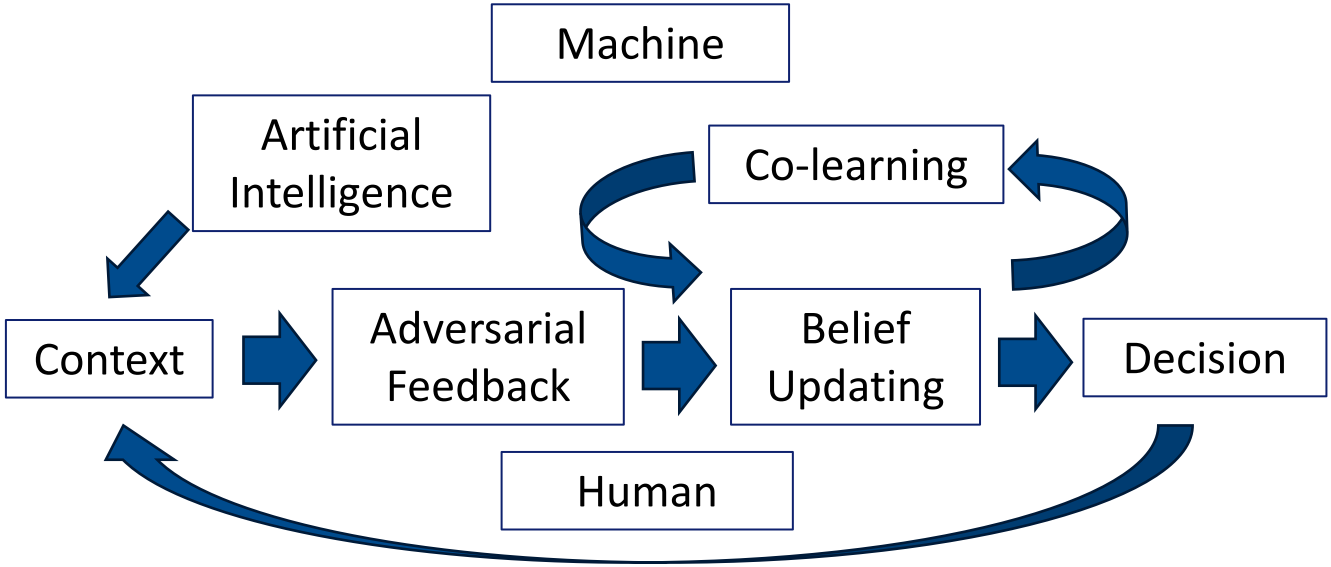


Image provided by Booz Allen

Deterrence theory

- Deterrence decisions happen in a **changing, uncertain and complex environment.**
  - What is the context?
  - What is my adversary thinking? Are they bluffing?
  - Can AI and co-learning decision aids help?
- What are the connections with **deterrence**, **theory of mind** and how people perceive **context** when updating their **beliefs**.
- Our goals are to develop new **wargaming strategies**, investigate **vulnerabilities**, and develop **new technologies** implementing **AI** and **Co-learning** in deterrence scenarios.



University of Colorado **Boulder**

Additional Issues and Challenges

- Data and sensemaking
- Knowledge bottlenecks
- Infrastructure and Networks
- Content Adaptation

AFRL

M&S FOR CO-LEARNING FOR ADAPTIVE HUMAN-MACHINE TEAMS

LORRAINE BORGHETTI, PHD, TECHNICAL LEAD

711 HPW/RHWOH

16 APRIL 2025

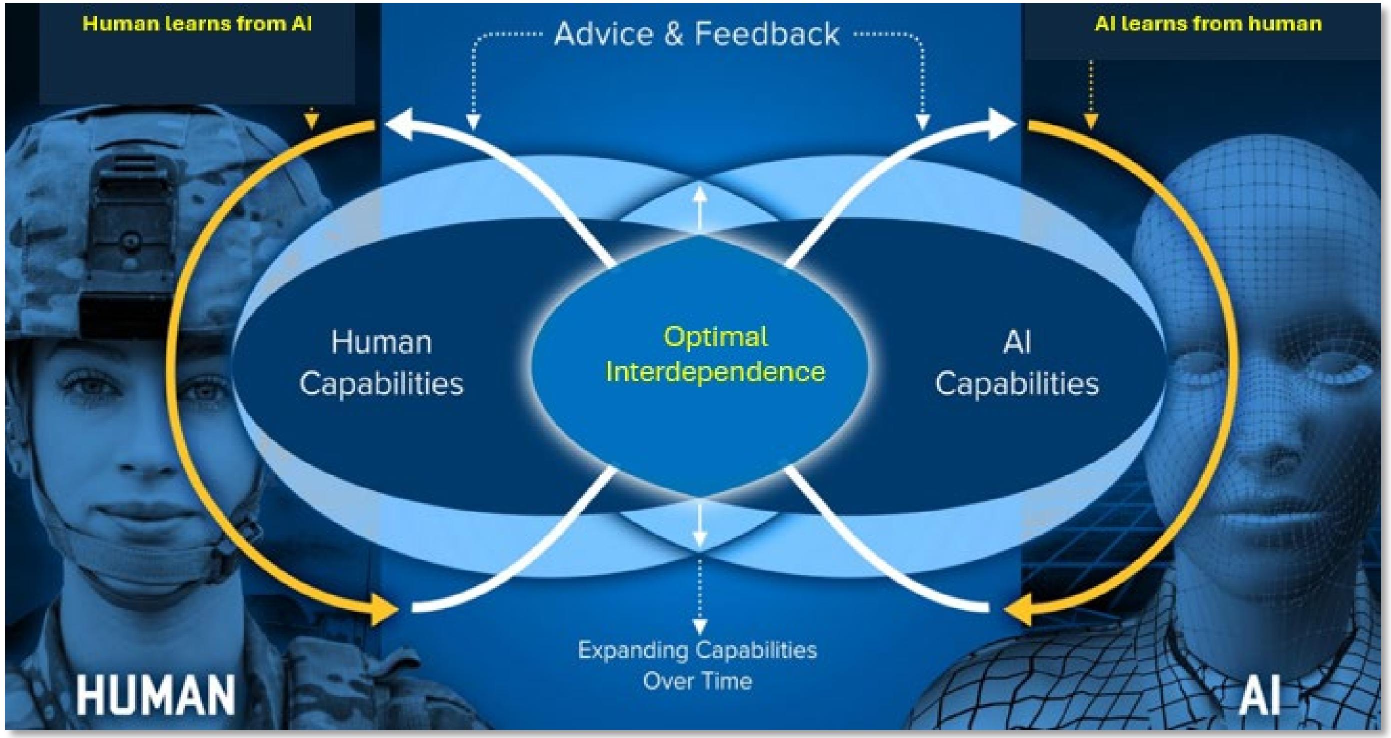
Why Co-learning HMTs for the Warfighter?

- Time, change and uncertainty only constants in war
  - Strategy used last encounter may be woefully inadequate for next one
- Operational space -- Air or Space – is too vast, complex, and consequential for merely "competent" human-machine teams
  - Must evolve interdependently with (and ahead of) the environment and the adversary
- Resulting HMT interdependence is the essence of co-learning and poised to be a promising technology for decision superiority

What is Co-learning?

- **Co-learning** refers to the ability of human and machine teammates to learn *with* as well as *from* each other over time to achieve superior results beyond what can be achieved independently.
  - Learning is bi-directional
- **Co-learning** is a novel concept and technology
  - Lack of foundational principles – we are part of defining it

The Co-learning Cycle

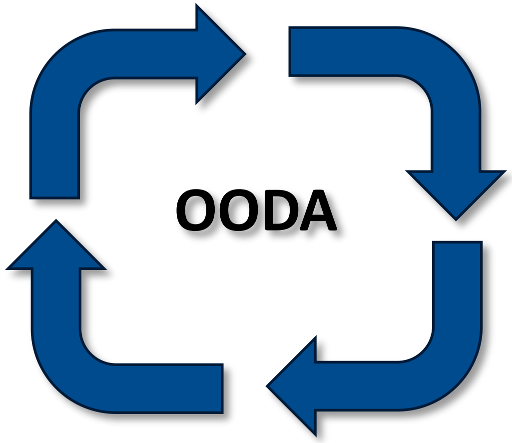


Learning here refers to *skill & knowledge acquisition* and/or *belief updating*

About the Human Teammates

Learners

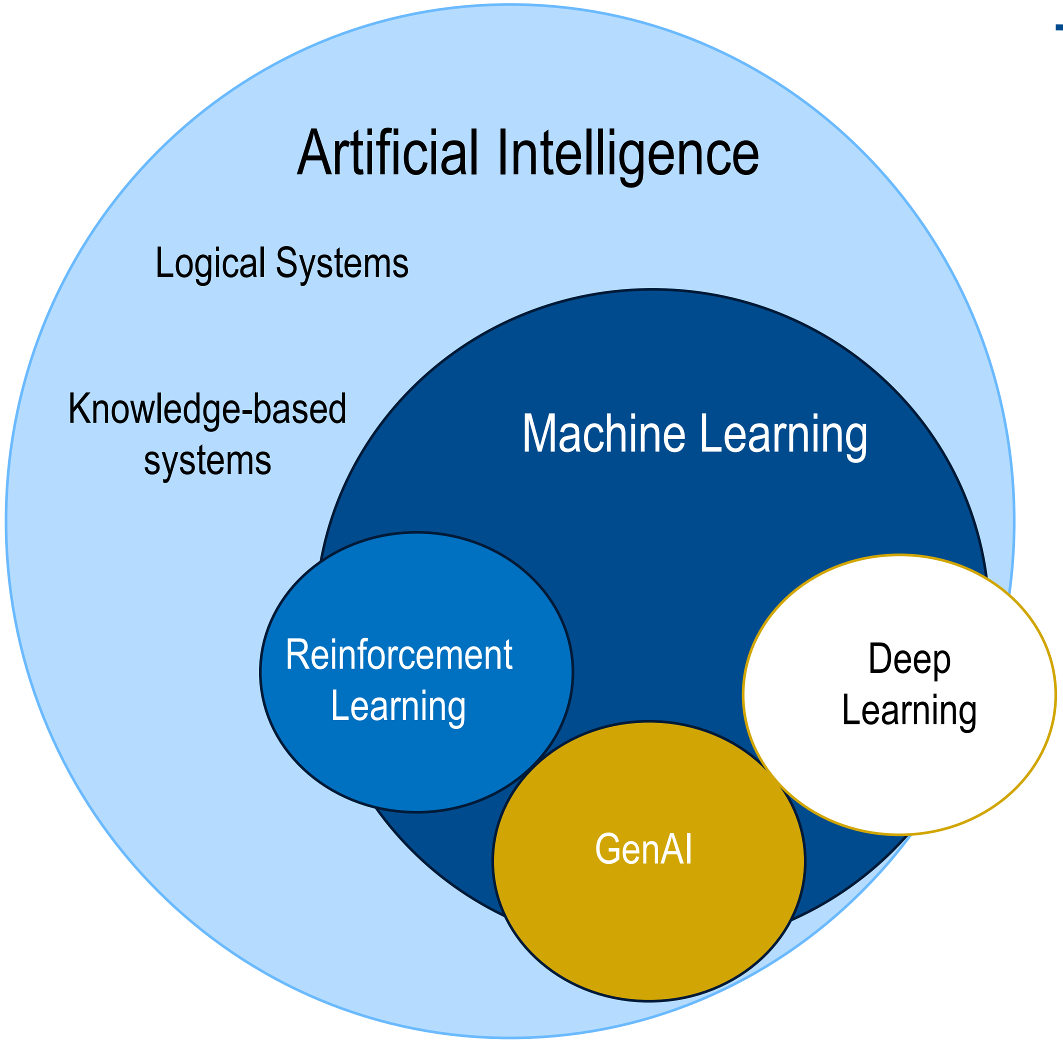
- Tactical, operational, strategic audiences
- Individuals and teams
- Interact during knowledge acquisition, feedback



Decision-makers

- Tactical, operational levels
- Operators, planners, mission leads
- Interact at one or more points in OODA Loop

About the machine teammates



Hybrid Systems

From the AI and co-learning perspective, a machine teammate is a computational-based intelligent agent that perceives its environment and processes the information to accomplish a task (e.g., making predictions, generating knowledge, or depending level of autonomy, taking actions).

Pipelines

Architectures

Hallmarks of Adaptive Co-learning HMTs (C-HMT)

Mirror high-functioning human teams

Contribute unique capabilities

Dynamic interactions, Adaptive behavior

Converge on shared representational space

Mental models, theory of mind, spatial reasoning

Exhibit fluent, resilient team performance

To be clear, we are not proposing to create machines that are human like in their mutual understanding complementariness.
Rather, we seek to methods of mutual understanding native to each system and optimize team behavior from there.

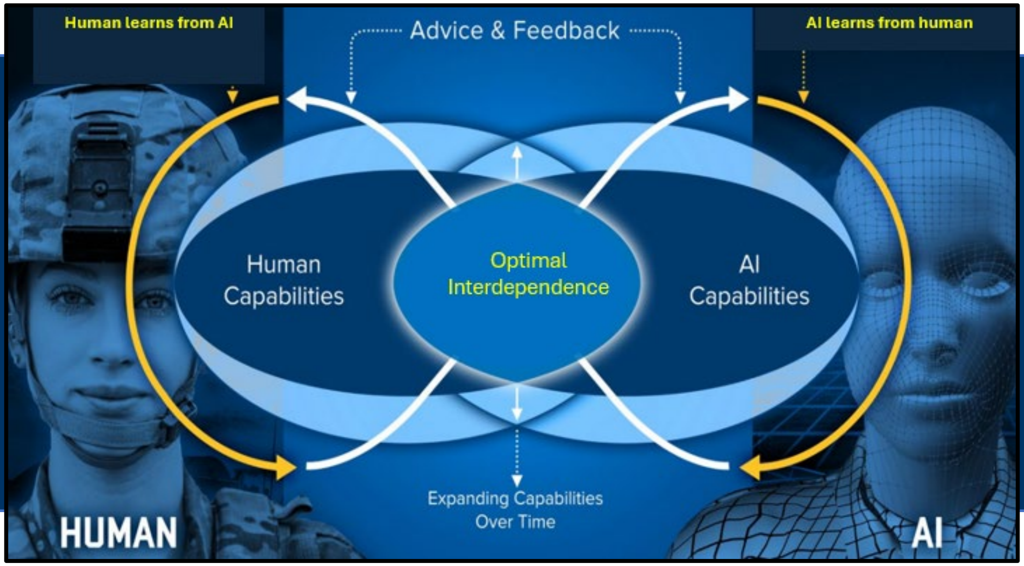
Unique Human and Machine Teammates

Human	Attribute	Machine (summarizing across AI/ML)
Reason for meaning (context, norms, ethics, consequences)	Sensemaking	Reason for statistical relations
Limited cognitive capacity to reason over big data	Approach to big data	Easily finds complex patterns in big data; precise values
Milliseconds to seconds (or more depending on scale)	Reasoning speed	Microseconds to nanoseconds per operation
Limited ability to estimate uncertainty; use heuristics	Quantifying uncertainty	Produce precise probability distributions or likelihoods
Only provide a few at a time; contextual but subject to bias	Recommendations	Can provide millions simultaneously; consistent
Can create deeply original works by making intuitive “leaps” or combining ideas in unprecedented ways.	Scenario generation	LLMs produce large volumes of scenario by recombining training data
Learn experientially, socially across a lifetime	Learning over time	Data driven learning and/or rule-based learning
Easily integrate single event into mental models	Single shot learning	Poor at learning from single event; rely upon prior training
Continuously adapt to changes in everyday life	Real-time learning	Very uncommon; nascent research field
Mental models; Heuristic, simplified systems, fuzzy boundaries, updates with experience	Representational structure	Statistical and/or symbolic structures; develop during training
Innate; use varied human and non-human cues; can recognize hidden intents and false beliefs	Theory of mind / intent inference	Learns from data; limited use of human cues; struggles to recognize deception, intent
Capable of deep multi-level reasoning (k-4 plus) in complex strategic scenarios	k-level reasoning (Recursive reasoning)	Can handle k-2 level but struggle at deeper levels of recursive reasoning

Co-learning Synergizes Across Teammate Advantages

Human Advantages

Learn fast (and on sparse data)
Apply meaning to events
Theory of mind in context
Uncertainty interpretation



Machine Advantages

Advanced pattern recognition at scale
Precise output values
Voluminous recommendations
Uncertainty quantification

Optimal Interdependence

Exploits unique reasoning advantages
Manages uncertainty holistically
Increases team coherency
Well-scoped recommendations
Well-scoped estimates of intention
Advances capabilities for strategic decisions

Co-learning Challenges

Issues with Human Learning from Machine

- Filtering due existing expectations, emotional states, motivations, trust, explainability
- Novel info may be over- or under-weighted in mental models
- Limited working memory capacity
- Numerous situations (distractions, overload, fatigue) can interfere with machine info integration into long-term memory

Issues with Bi-directional Learning

- Controlling, capturing, and communicating the evolving and convergent interactions of both humans and machines
- Quantifying ingestion of data by both humans and machines
- Estimating team "cognitive" state

Issues with Machine Learning from Human

- Complexity of domain-specific human beliefs not-well approximated by LLMs
- Finding a proper task that would benefit from human input challenging
- Co-learning instances may not always generalize as desired
- Human data tends to be sparse and variable in quality
- Model convergence not guaranteed
- Implementing human input may introduce noise to the weightings
- RL models struggle to learn in complex environments
- Catastrophic forgetting can occur without proper prevention techniques

M&S Requirements for Co-learning

- Dynamic environment which produces novel events over time
- Task requiring:
  - Unique human-machine capabilities
  - Adaption to new events
- Human-machine team that is interdependent
  - Machine that can co-learn in real-time
  - Data to train machine (a priori)
- Interface allowing for interactions
  - Approximates use-case
  - Machine and human readable inputs/outputs
- Co-learning and performance metrics

Example Co-learning Scenario

Dynamic Environment	A disaster occurs and the rescue team causing severe damage to the landscape, property, people, and animals.
Team Task	A rescue team (rescue workers and a drone) are tasked with finding and rescuing survivors
Machine Task	The drone teammate surveys the affected zone to identify survivors.
Human Task	The rescue team provides real-time corrections to the drone's imagery data by distinguishing heat signatures for humans versus animals.
Team Co-learning	Across the duration of the operations, the drone learns how to discriminate between similar heat signatures, while the rescue team learns from the drone's broader aerial perspective to improve situational awareness of the disaster area.

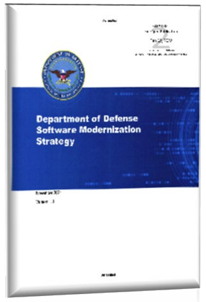
Oko: M&S For Co-learning

Driving Factors

- Developed for research purposes to model the uncertainty, complexity, and dynamics inherent in the underlying Co-learning processes.
- Available Synthetic Task Environments (STEs) provide limited functionality for integrating Co-learning processes
  - AFRL/RQ: AFSIM / UC Boulder: Vizard
- DoD Directives motivate modernization

2018

2019



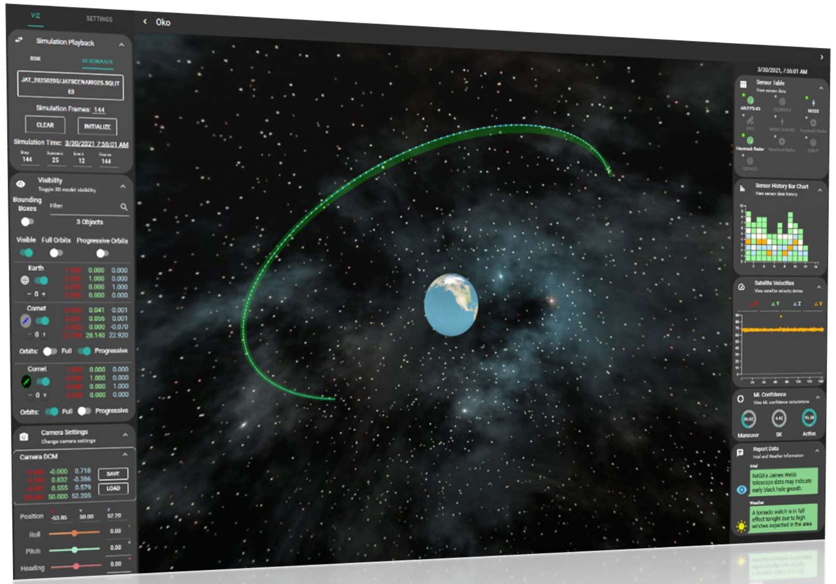
2020

Technical Challenges when Learning Bi-directionally

- Controlling, capturing, and communicating the evolving and convergent interactions of both humans and machines
- Integration of AI/ML concepts and enabling interaction with humans
- Ingestion of data by both humans and machines

Objectives

- Enable developing an AI/ML-driven Co-learning framework
- Support testing methods for 0/1-shot learning
- Simulate Real-world Scenarios
- Understand optimal interdependence between humans and machines



Oko UI

Oko: Front-end Overview

AFRL

'Admin' Controls

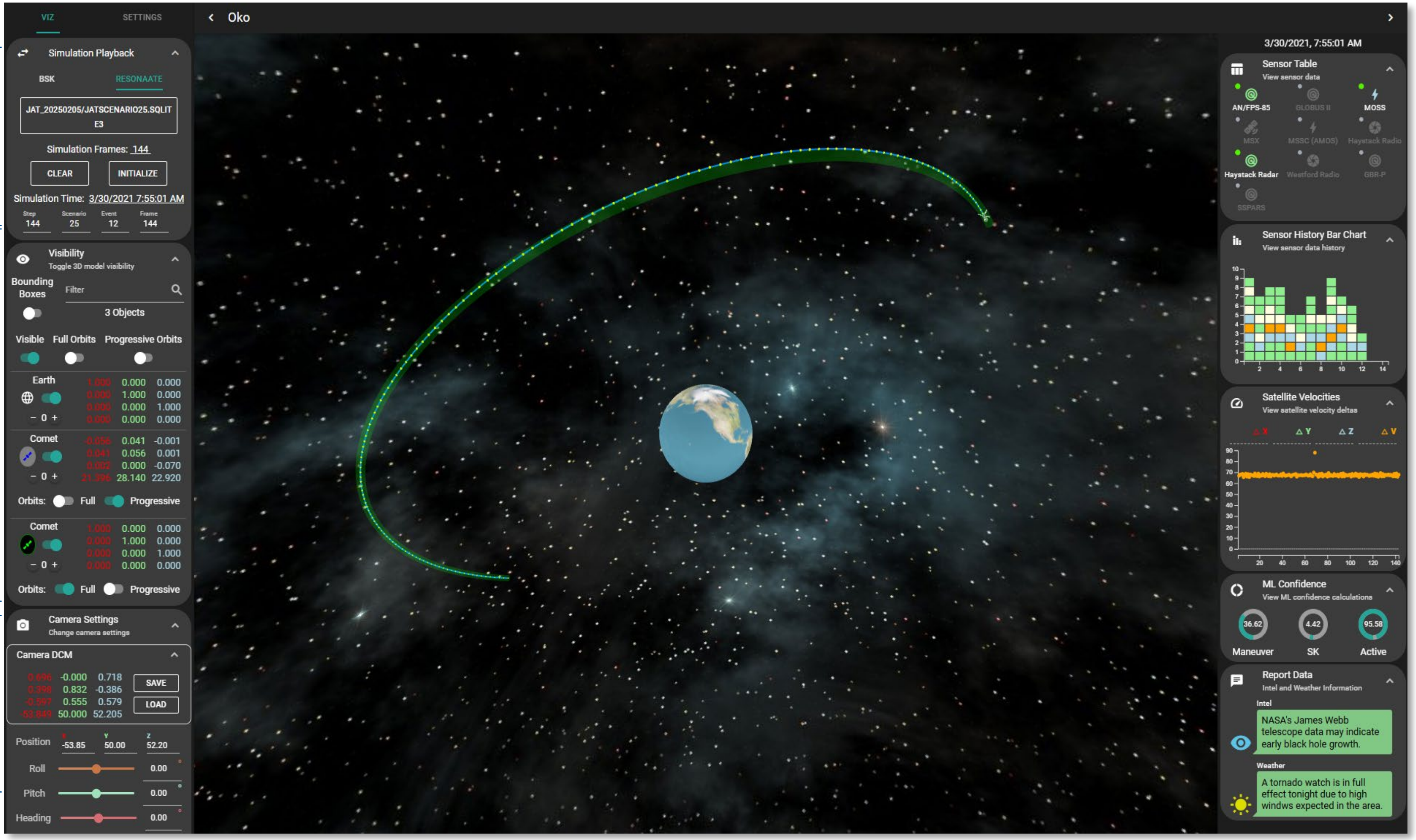
3D Display

Information Displays

Simulation Data Control

3D Object Control

Camera Manipulation



Latest Sensor Data

Historical Sensor Data Bar Chart

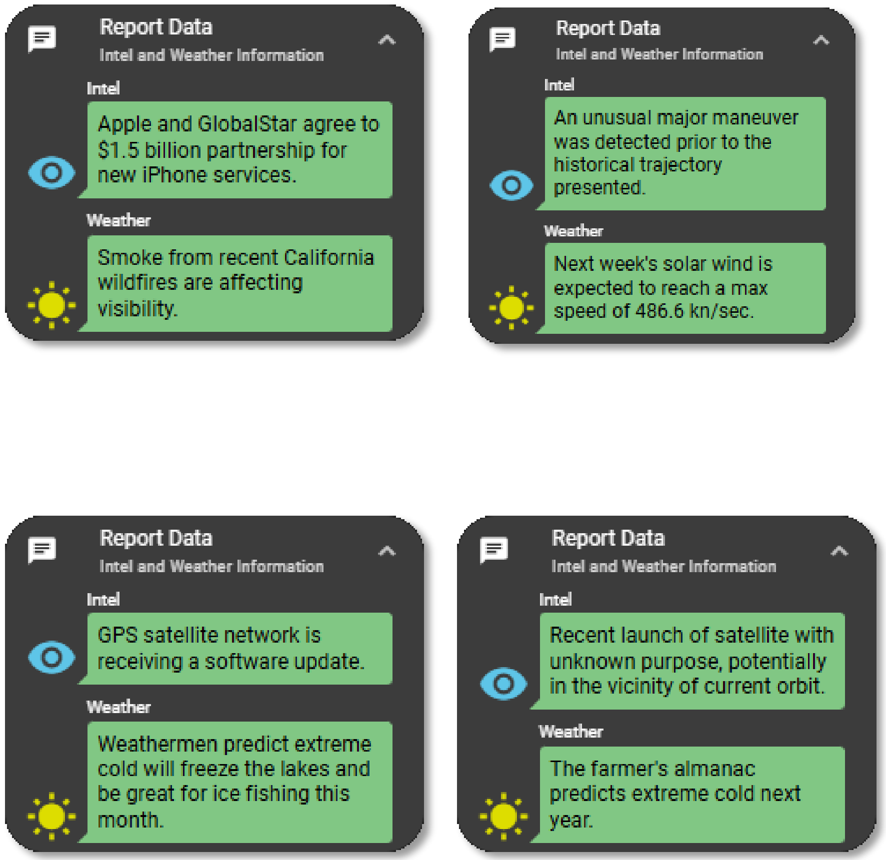
Recent Delta-V

ML Confidence

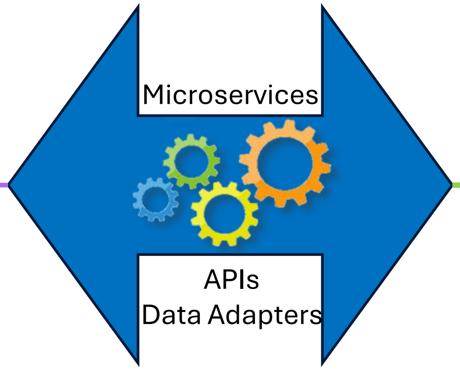
Intel/Weather Reports

Oko: Reports

Front-End



Back-End

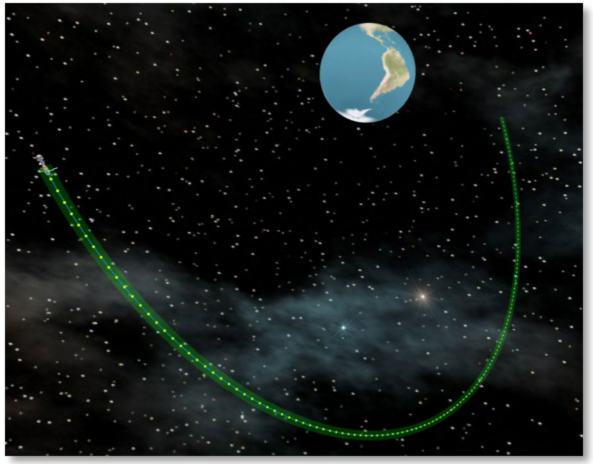


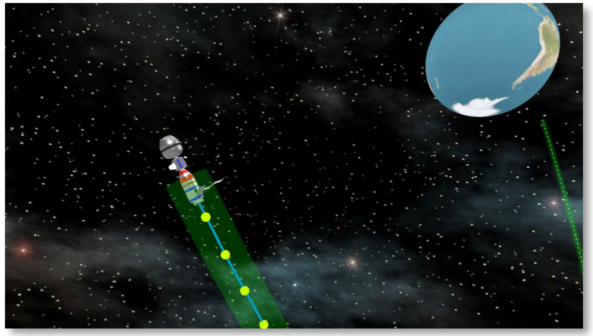
Co-learning

- Humans ingest sparse data differently based on experience
- We hypothesize the human will better integrate these data into their decision

Oko: 3D Visualization

Front-End

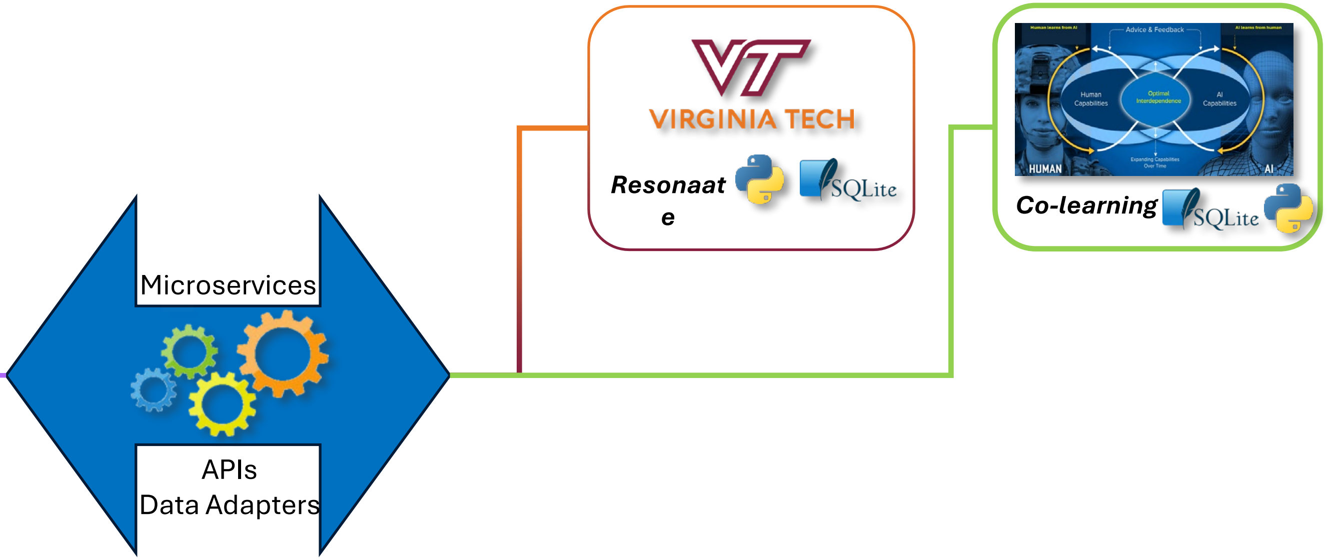




Sensed Orbit Points

Green Outline – Boundary of Station-Keeping
Yellow Dots – Locations Depicting when the Satellite was sensed.
Blue Curve – Estimated Traject
Points

Back-End

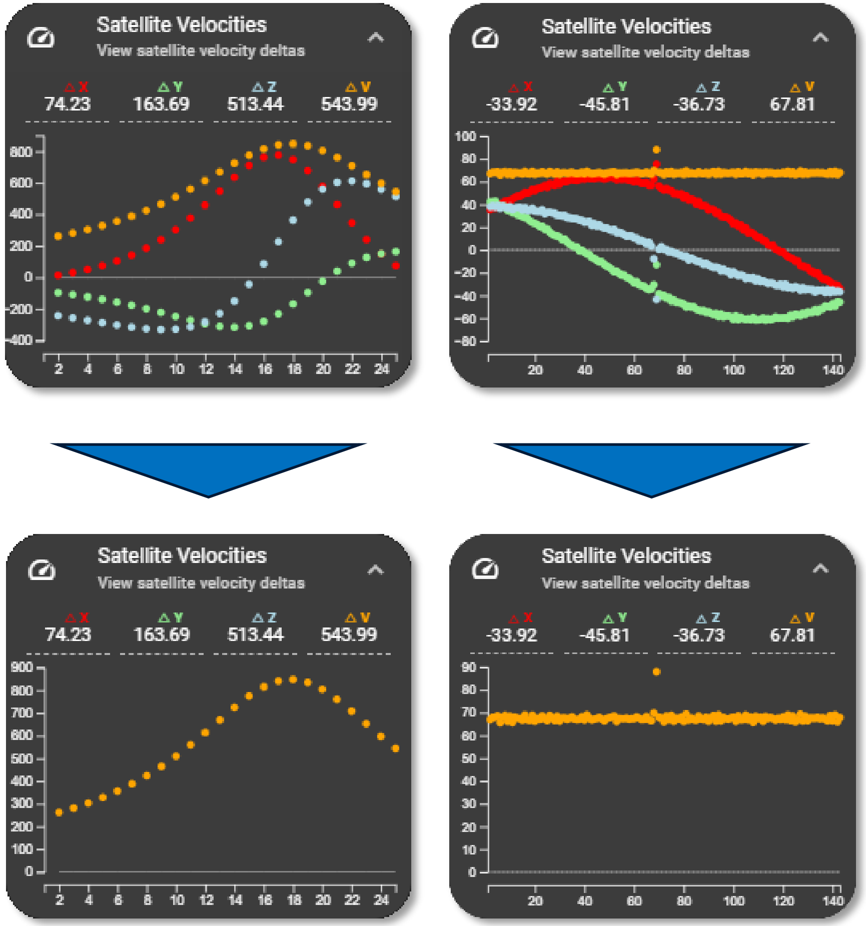


Co-learning

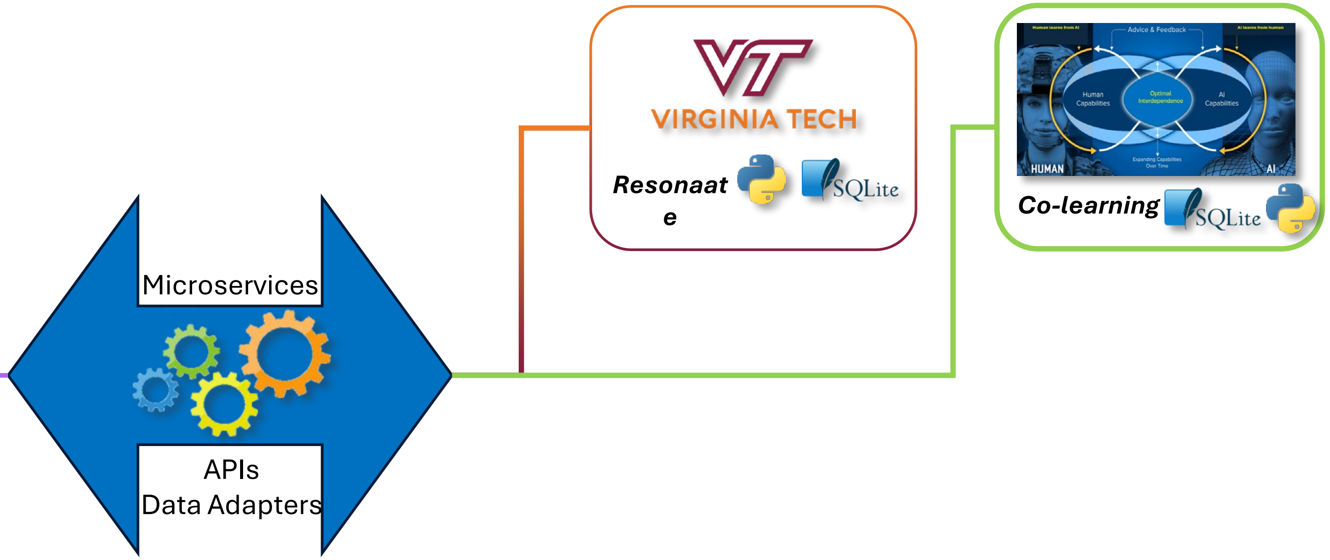
- The machine can calculate and compare distances to make recommendations based purely on numbers.
- The machine provides the human with a visual to create a shared mental model of those distances.

Oko: Satellite Velocities

Front-End



Back-End



Co-learning

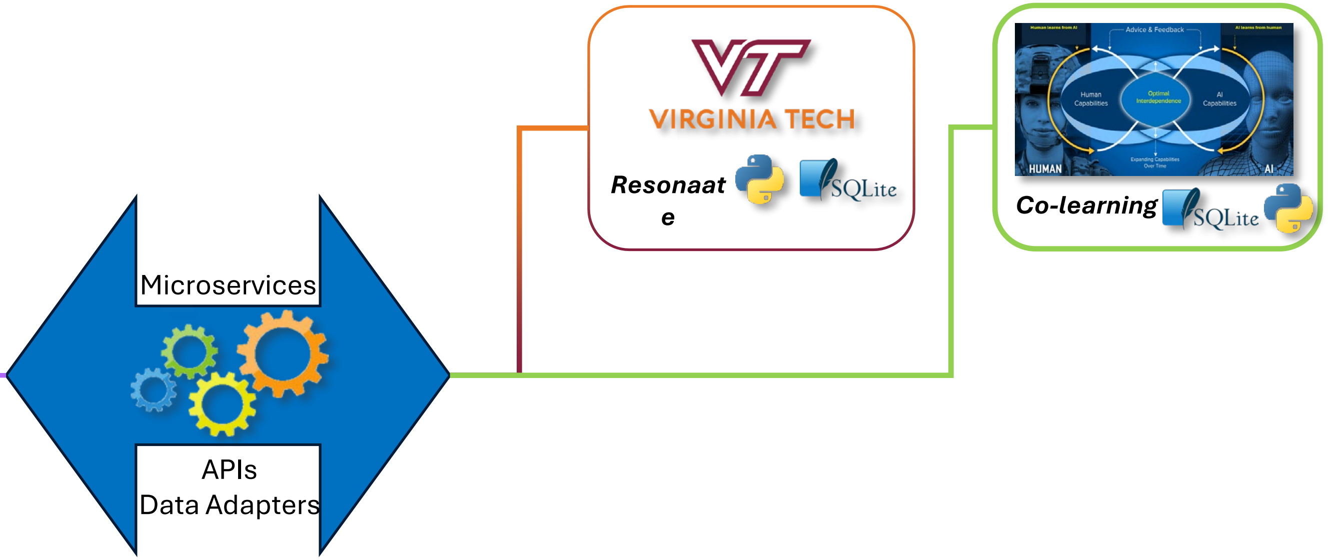
- The human receives velocity graphs at each time step
- ΔV is the magnitude of the x, y, and z deltas:

$$\Delta V = \sqrt{\Delta x * \Delta x + \Delta y * \Delta y + \Delta z * \Delta z}$$

Oko: Sensor Availability

Front-End

Back-End



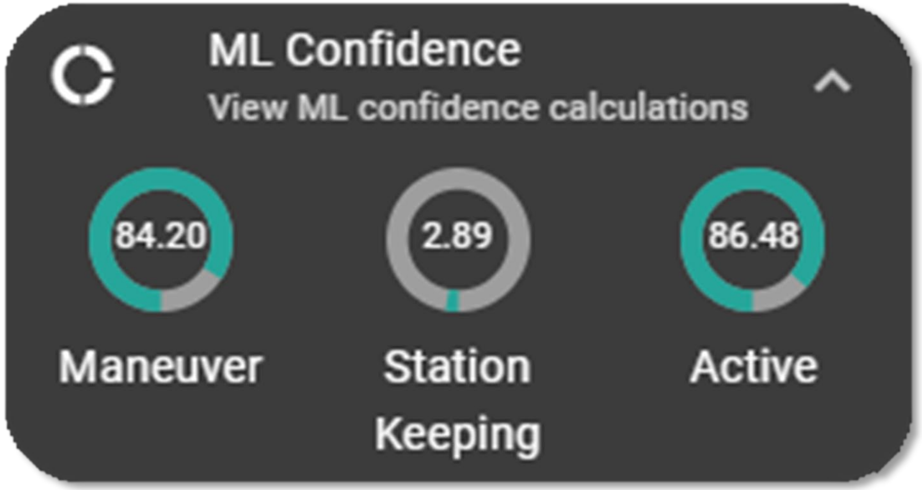
Co-learning

- The availability of sensors can cause lapses in data availability
- Humans and machines have different methods of weighing historical data

AIR

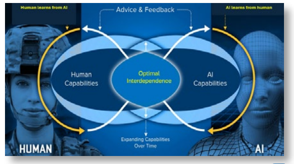
Oko: ML Confidences

Front-End

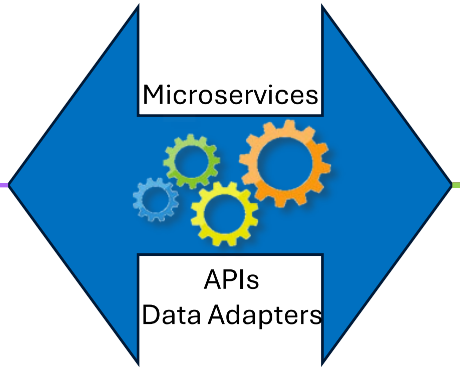


Back-End

VIRGINIA TECH
Resonaate
SQLite



Co-learning
SQLite



Co-learning

- The ML Model has access to a history of velocity trends
  - Computes Confidence values for various metrics.
- The human receives the same history data to support their decision

Oko: Video Demonstration

Q&A

Continuing Human Enabling, Enhancing, Restoring, and Sustaining (CHEERS)

Multiple Authority Announcement (MAA)

https://www.afrl.af.mil/711HPW/711HPW-Opportunities/

- The 711th Human Performance Wing's (711 HPW) Multiple-Authority Announcement (MAA) is intended to provide a comprehensive strategy for 711 HPW's range of Science and Technology and Studies and Analysis, creating an announcement that allows for progression from basic research to technology maturation and transition. This approach will accomplish the following:
  - Foster collaborative environment between the systems program office and research lab by allowing for transition from applied research to system specific requirements.
  - Enable faster development and rapid transition of emerging technologies into fielded systems for testing and evaluation.
- A single contract/instrument cannot be awarded for 6.1-6.8, but it allows for solicitation under a single announcement as the technology matures. An entire research effort may span multiple CHEERS solicitations.
- Please direct any questions you have regarding CHEERS to: AFRL.711HPW.MAA@us.af.mil