



Technologies for Human-Robot Interactions (HRI) in Soldier-Robot Teaming ATO-D, III.C4.2004.04 SPIE Conference, Unmanned Systems Session



Terrance M. Tierney

HRI ATO Manager

Intelligent Systems Business Area

Email: terrance.m.tierney@us.army.mil

(586) 574-8678 / DSN 786-8678

Orlando, Florida

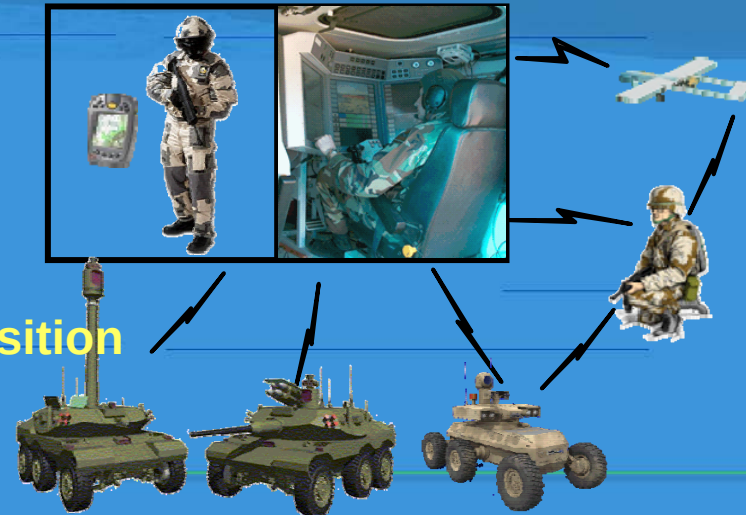
28 March – 1 April 2005

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 14 MAR 2005		2. REPORT TYPE Briefing Charts		3. DATES COVERED 12-12-2004 to 16-02-2005	
4. TITLE AND SUBTITLE Technologies for Human-Robot Interactions (HRI) in Soldier-Robot Teaming			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Terrance Tierney			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000			8. PERFORMING ORGANIZATION REPORT NUMBER #14747		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000			10. SPONSOR/MONITOR'S ACRONYM(S) TARDEC		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S) #14747		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES ATO-D, IILC4.2004.04 SPIE Conference, Unmanned Systems Session					
14. ABSTRACT Briefing Charts					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Public Release	18. NUMBER OF PAGES 27	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Agenda

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

- Background
 - Why HRI is necessary
 - Previous programs, how they feed
- TARDEC's HRI Approach
 - Program Methodology
 - Requirements analysis/Task decomposition
 - Ontology/Behaviors development
 - Modeling Environment
 - End-to-end modeling environment
 - Constructive modeling/simulation
 - Component/system/vehicle modeling
 - Virtual and HWITL simulation
 - Technology Exploration
 - Multi-model devices
 - Interfaces



Problem Definition

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

The soldier has an ever increasing task load...

- **Interact with:**
 - Other soldiers
 - Manned systems
 - Unmanned systems
 - Ground vehicles
 - Air vehicles
 - Ground sensors
- **Operating with varying**
 - Mobility
 - Payloads
 - Missions
 - Levels of autonomy
- **While operating**
 - Mounted
 - Dismounted



...and still must perform his primary mission!



Problem Definition (cont)

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

- Many different unmanned systems in existence
- Each system has developed unique Interface
 - Integrator specific – unique solution to unique problem
 - Typically engineering solutions – not soldier-centric
- Lack of standardization for WMI's
- Increased complexity and diversity of systems and interfaces requires:
 - specialized training
 - Retraining/familiarization when moving between systems
- Under time critical life/death situations, this is unacceptable to the soldier





September 2002 ASB Study Findings

III.BC.2004.04
HRI ATO-D

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

- No existing program is systematically addressing the challenges of humans and complex unmanned systems interactions.
- **Lack of human-robot design rigor can lead to catastrophic results**
- Catastrophic problems would result in severe setbacks to the fielding of robotic systems
- **No “user-pull” for semi/autonomous systems to couple user needs with research**
- Robotics communities are fragmented, no advocate or manager for robotics technology
- **Unfocused efforts will restrict development and deployment into force**



ASB Study Recommendation

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

- Create a new “systems-oriented program for analysis, understanding, development and improvement of human-robot interactions” with ARL as program steward (with other agency cooperation), stimulating spiral development
- Requirements Community should:
 - establish operational architecture for autonomous robots
 - validate with available field testing
- FCS Increment I should have as a minimum:
 - follower robots w/ significant level of autonomy
 - surveillance and reconnaissance robots operating in limited environment

HRI STO
creation

TARDEC Program Progress

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

Robotic Technology
Development

FY93

FY96

FY98

FY06

FY08

Crewman's
Associate
Baseline SMI

System Integration
(Lab)

Demo
Semi-Autonomous
Development

IVES STO
Field Experiment

Crew integration and Automation (CAT)
Robotic Follower (RF) ATDs
Warfighter Experiment Fort Bliss

ARV Robotic
Technologies STO

CAT and RF ATDs
Final Warfighter Experiment

Human Robot
Interaction STO

FCS & FFW

Soldier Machine Interface
Development

TARDEC

U.S. ARMY TANK-AUTOMOTIVE RESEARCH DEVELOPMENT AND ENGINEERING CENTER

Background

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



- Focus is Integration
- VTI Program
 - Crew integration and Automation Testbed (CAT) ATD
 - Robotic Follower ATD



Crew integration & Automation Testbed (CAT) ATD

Technologies

- Crew Driving and Decision Aids
- Advanced Warfighter Interfaces (AWI)
- UGV, small UGV, and UAV Control
- Multi-mission Crew stations
- Autonomous Navigation for MGV
- Embedded Simulation System



Warfighter Payoff

- Enhance performance and minimize workload to support reduced crew size
- Control various unmanned systems from a common crew station interface
- Mission planning and rehearsal while deployed with embedded simulation
- Develop TTPs for unmanned systems through continual field experiments

Demonstrating the crew interfaces, automation, and integration technologies for Current and Future Systems

Crewstation Display Hardware

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

- **COTS Sharp 20.1" TFT-LCD display was selected due to video requirements**
 - Resolution: 1600 X 1200
 - Optical Response: 5 ms ON, 20 ms OFF
- **Portrait Orientation**
 - Allows up to 2 "SMI displays" per display
- **3 displays per crewstation**
 - Combined 135° HFOV (45° each)
- **Two side displays were angled for equal viewing distance to each panel**
- **Goal: Seamless gap between displays for indirect vision imagery**
 - Display and touchscreen hardware resulted in 2" gap between displays (1" around each display)

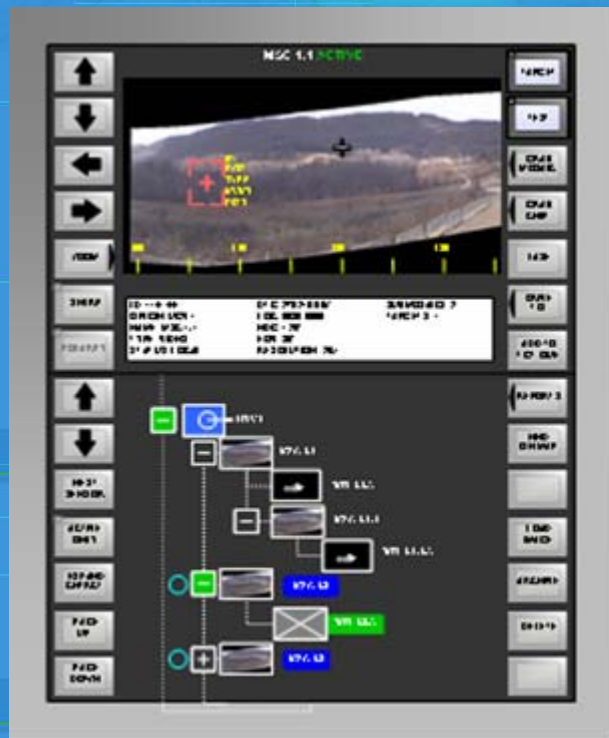




Crew Station Features - Screen Functionality

III.BC.2004.04
HRI ATO-D

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



RSTA Viewer
& Browser



ARV Drive
Tactical Map



Target Acq Sensor
& Unmanned Asset Control





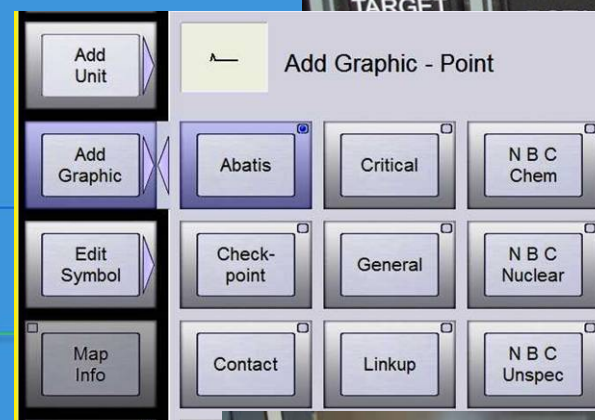
Crew Station Features - Multi-modal Inputs

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

Multi-modal Interface

Redundant Inputs

- **Hard (bezel) buttons**
- **Touch buttons**
 - Button type indicators can be used to anticipate button behavior.
- **Yoke**
- **Voice commands**
- **Keyboard/Trackball**



12. 4. 2002

Embedded Simulation System

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

Crew Stations



Vehicle
and crew
interaction
data

Embedded
Simulation
System



FCS Class Vehicle



Virtual Battlefield



MISSION APPLICATIONS

- Embedded Training
- Mission Rehearsal
- Mission Planning

SIMULATION CAPABILITIES

- Simulated Turret
- Virtual Lethality
- Virtual Sensors
- Simulated ATR
- Simulated ATT
- Simulated C2

VEHICLE SIMULATIONS

- Mobility
- Survivability
- Virtual OPFOR
- Virtual Friendlies

OPERATIONAL APPLICATIONS

- Battlefield Visualization
- Terrain Registration
- Virtual Sensor Coverage
- Virtual Lethality Coverage



HRI Program Methodology

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

Program Methodology

- **Requirements analysis/Task decomposition**
- **Ontology/Behaviors development**
- **Modeling Environment**
 - End-to-end modeling environment
 - Constructive modeling and simulation
 - WMI decomposition
 - Component/system/vehicle modeling
 - Virtual and HWITL simulation
- **Technology Exploration**
 - Multi-model devices
 - Scalable interfaces

Technology for Human-Robot Interaction (HRI) in Soldier-Robot Teaming

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



Goal:

Provide intelligent, scalable mounted and dismounted control for unmanned ground and air systems and optimize human-robot teams

Pacing Technologies:

- Human-robot teams
- Intelligent scalable interface
- Intelligent agents and adaptive automation
- Recursive end to end modeling environment

What HRI provides for the Warfighter

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

- Reduces training/retraining burden between mounted and dismounted controlling missions
- Reduces task timelines
- Eases cognitive burden on soldier
- Provides human-centered design
- Standardizes air and ground unmanned systems interfaces
- Provides scalability for varying screen sizes
- Sheds tasks when soldier is overloaded, adds tasks to keep soldier alert
- Consolidates Army interface programs
- Optimizes soldier-robot teaming



HRI ATO and ART ATO Focus

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

CAT ATD

FFW

HRI



Robotics
CTA

RF ATD

ART



Vehicle Focused

- Increase current perception capabilities
- Make vehicle more survivable
- Address anti-tampering issues
- Provide tactical behaviors

Increased
Perception

Survivability &
Anti-tampering

Tactical
Behaviors

Scalable
Interface

Intelligent
Agents

Adaptive
Automation

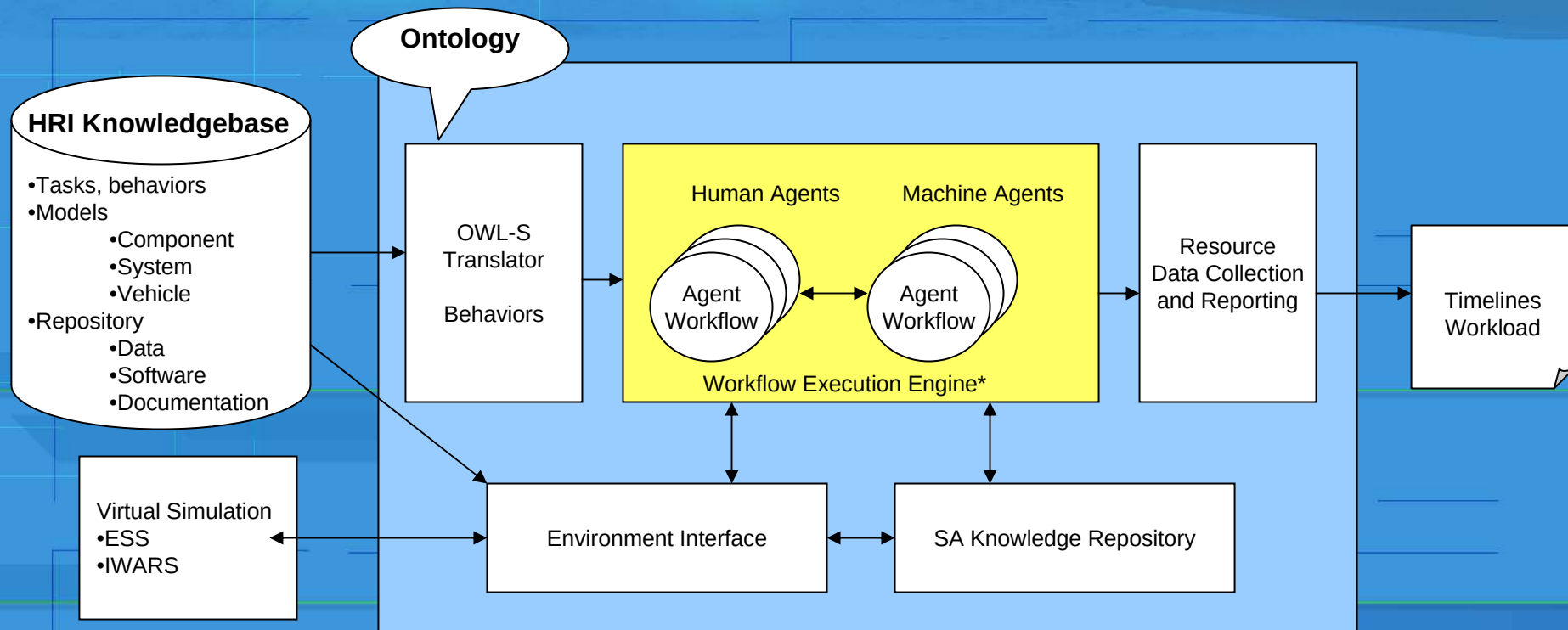


Intelligent Systems Behavior Simulator

III.BC.2004.04

HRI ATO-D

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



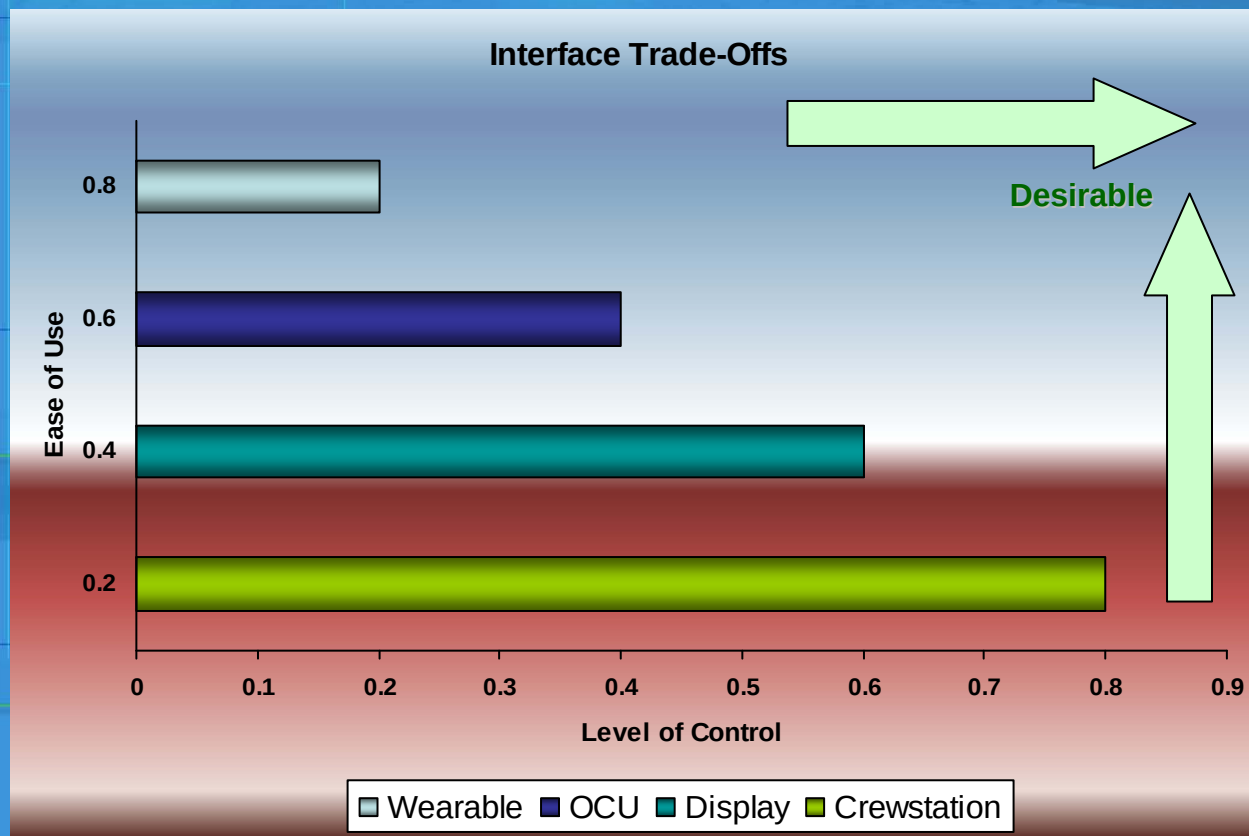
Candidate Workflow Execution Engines*

- Microsaint (IMPRINT)
- Cougar
- JESS
- FCS TIN Services
- VTI DSS



Scalability Issue for Interface

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



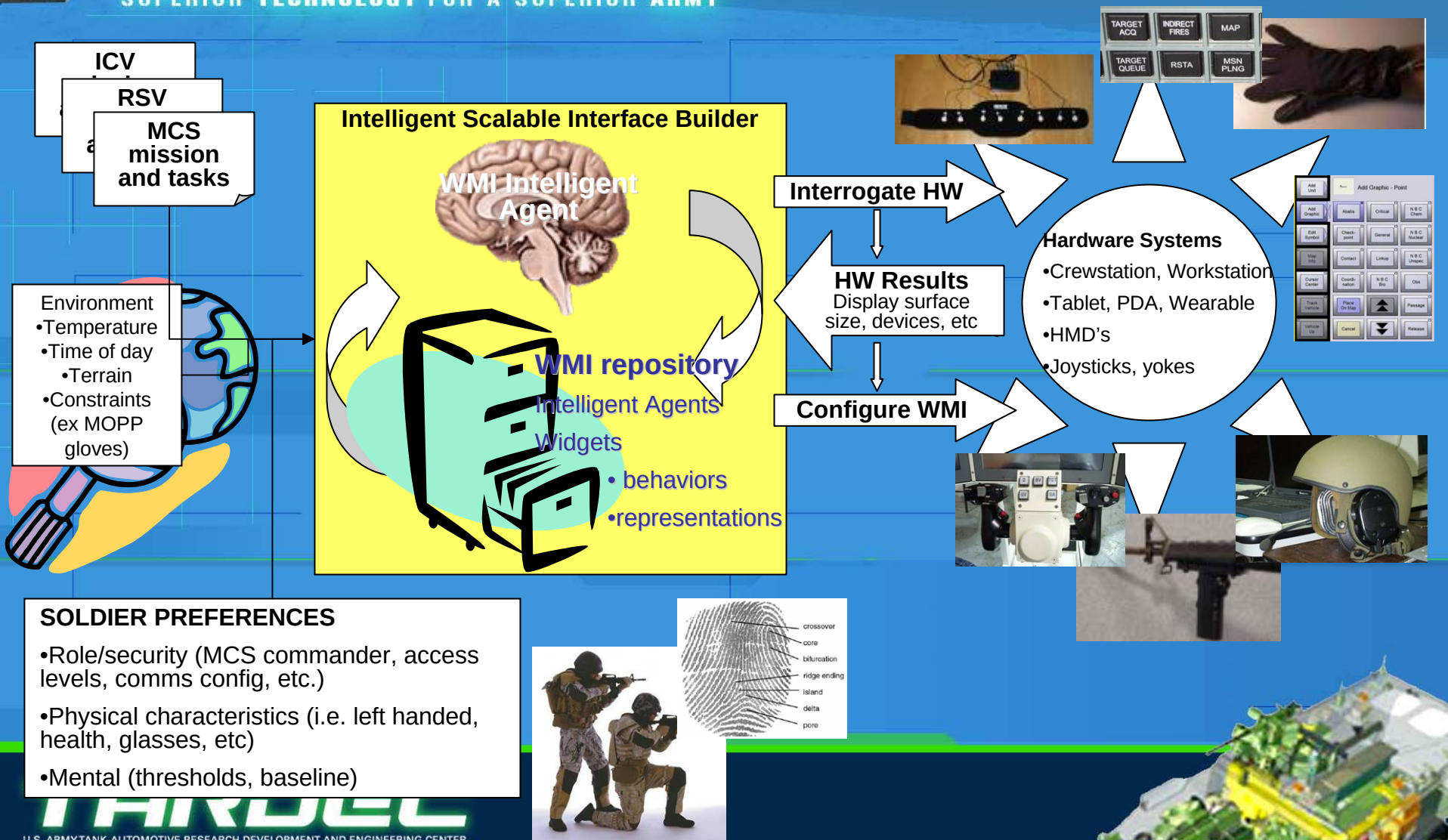
Objective: Desire easy to use (intuitive) device with highest level of control



Scalable Interface Configuration Approach

III.BC.2004.04
HRI ATO-D

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



Warfighter Machine Interface Goals

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

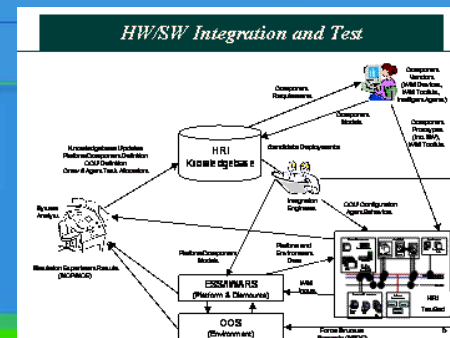
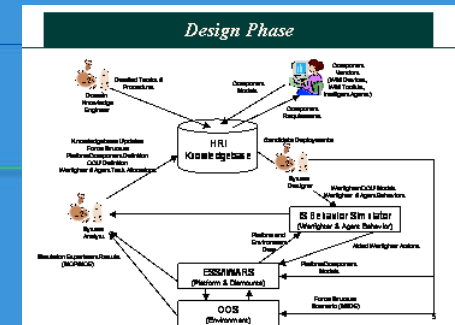
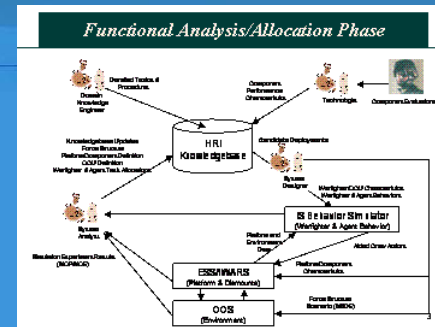
- Reduce training between systems
- Standardize interface
 - Inputs are consistent (i.e.: CTRL-C is copy)
 - Behavior is consistent ((ex: button highlights when touched)
 - Intuitive to user – in his/her mission language
 - Steps to do task match TTP's
- Present information consistently
 - Look and feel (same font, color scheme, etc)
 - Menu system layering
 - Acronyms are identical
- Establish common unmanned system tasks (ground and air)
 - Mobility, navigation
 - RSTA
 - Fire Control
 - Communication link
 - Other
- Target processes to automate
- Reduce/eliminate controlling aspect of mission to allow soldier to focus on primary mission

HRI Program Methodology

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

Systems Engineering Approach

- Technology exploration
 - Multi-model devices
 - interfaces
- Modeling environment
 - Task decomposition
 - Behaviors
 - Constructive, virtual HWITL simulation
 - Logical integration points
- Laboratory facility
 - Recursive simulation
 - Hardware trades

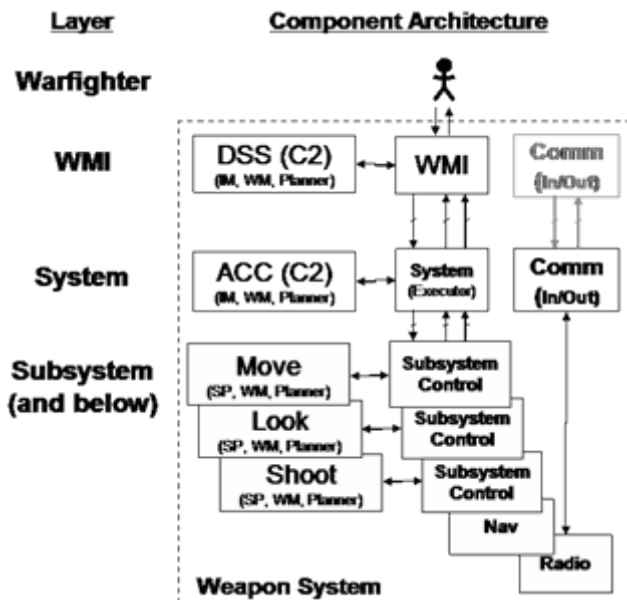


Agent Development

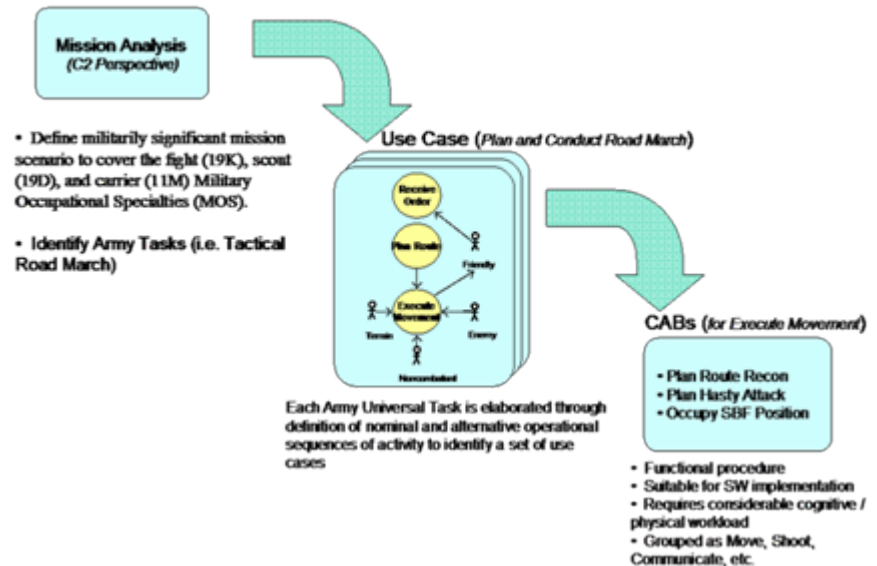
SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

CAT & FFW

- Architecture development
- Workload analysis
- Intelligent agent development



Task Decomposition

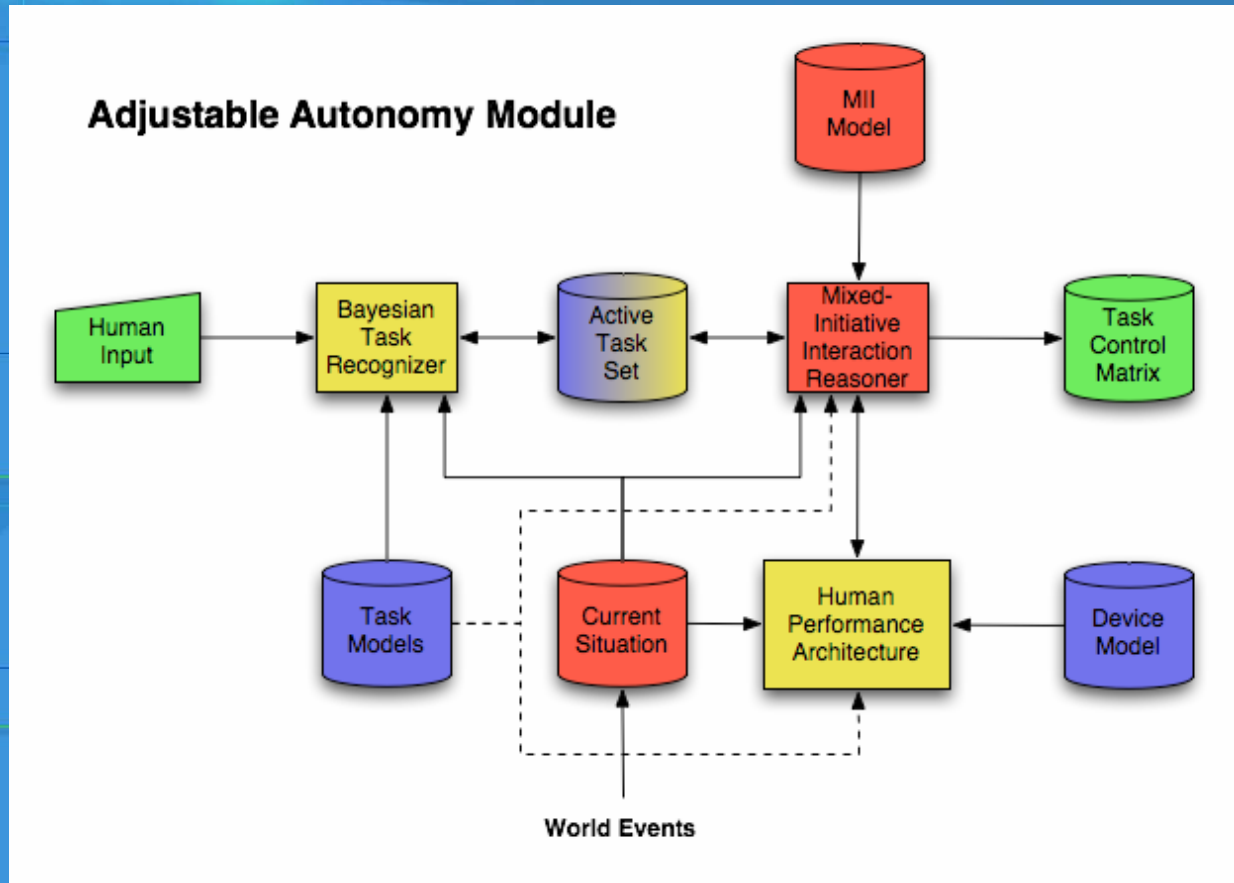


Alternate Approach

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

SOAR Tech Contract

- Adjustable Autonomy
- Extensive modeling
- Intelligent Agent development



Intelligent Agents/Adaptive Automation

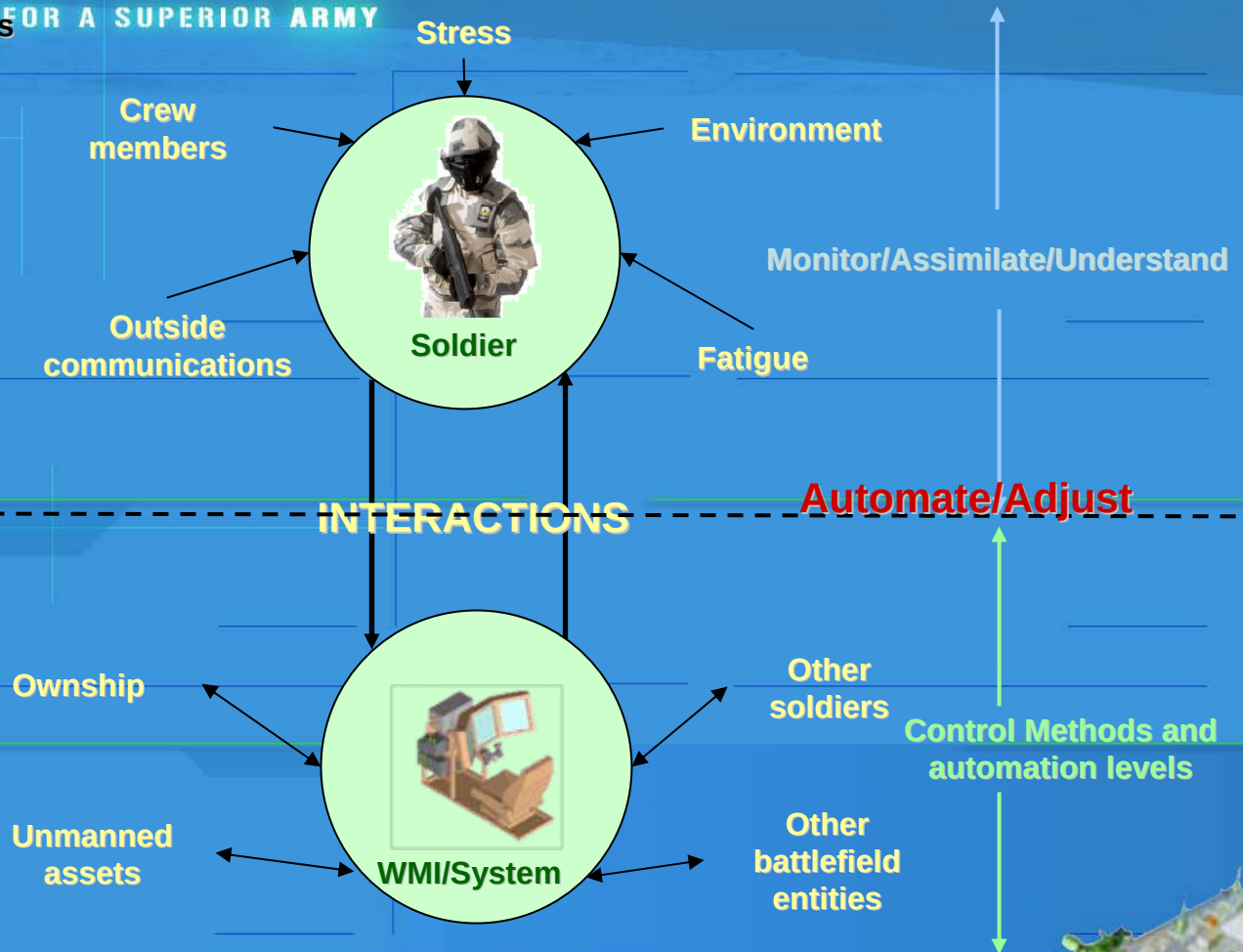
•Physiological Monitoring Methods

- Heart rate
- skin changes
- brain patterns
- Eye tracking

•Other Monitoring Methods

- Task execution times
- Error identification
- Observation

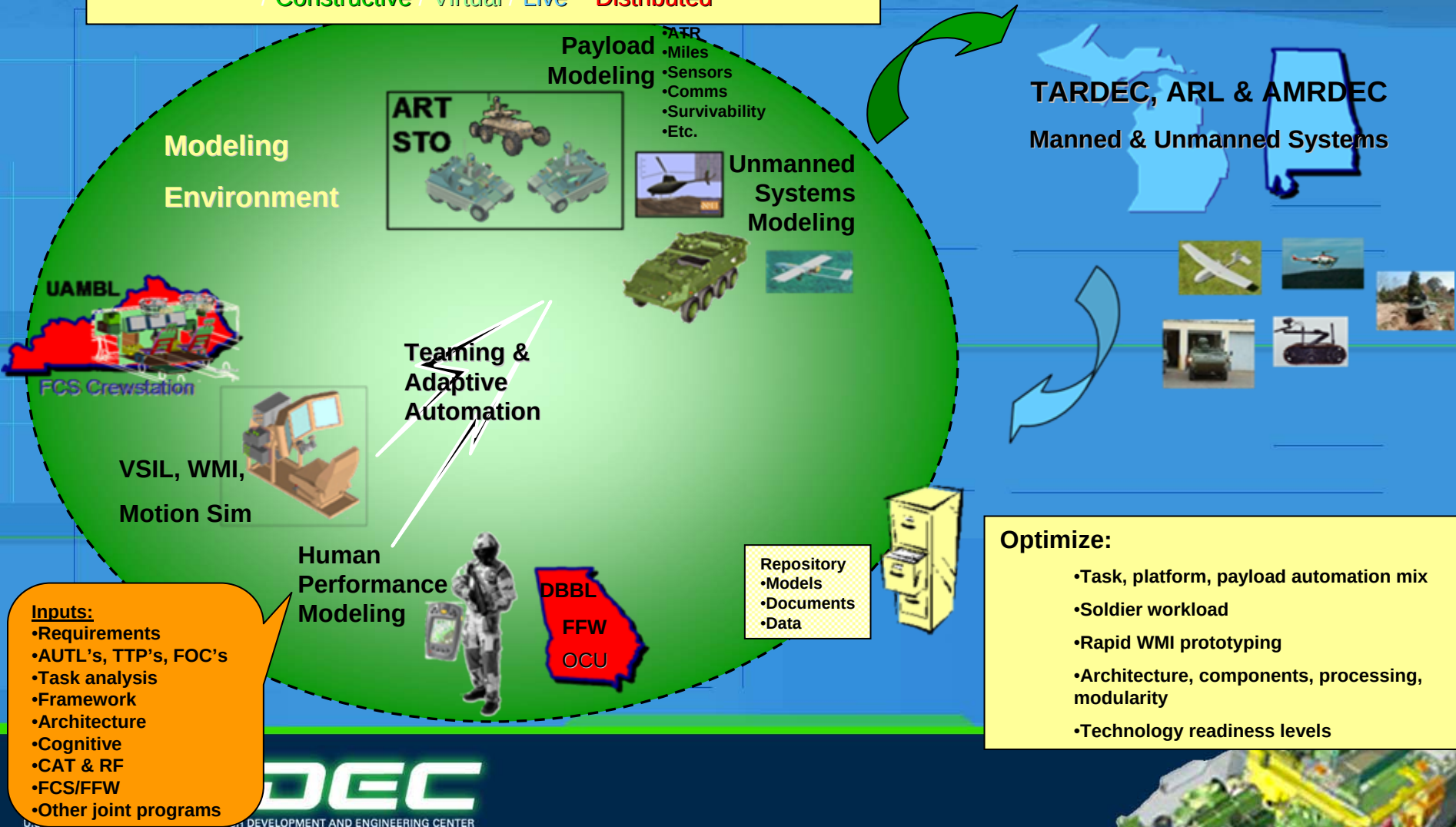
- Decision aids
- Task automation
- SMI design enhancements
- Vehicle tactical behaviors
- Sensor advancements



Modeling Environment

End to End Collaborative Modeling Environment

/ Constructive / Virtual / Live Distributed



Technology Exploration

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

Optimal Multi-modal input combinations

- **Mission (hardware) dependent**
 - Mounted (large display area)
 - Dismounted (limited display area)
- **Potential technologies**
 - Speech recognition
 - Haptic, vibro-tactile
 - HMD's, ocular, display size scalability
 - 3-D audio, head tracker (comms, alerts, etc.)
 - Biometrics (i.e card reader, user preferences)
 - Soldier monitoring systems (workload, stress)
 - Joystick, yoke, force feedback
 - Face recognition
 - Eye tracking
 - Gesturing

