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

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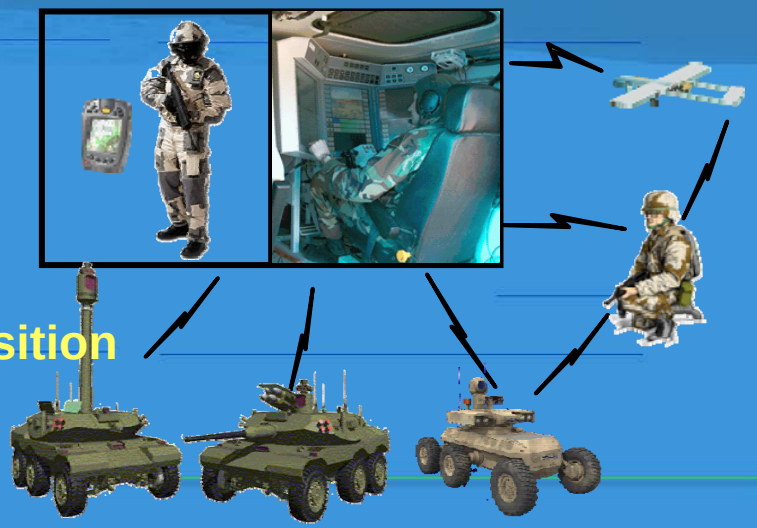
Agenda

- 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

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)

- 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

- 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

- 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

HRI STO creation

- 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

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

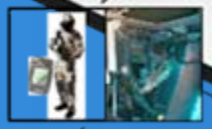
ARV Robotic Technologies STO

CAT and RF ATDs Final Warfighter Experiment

Human Robot Interaction STO

FCS & FFW

Soldier Machine Interface Development



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

Background

- **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

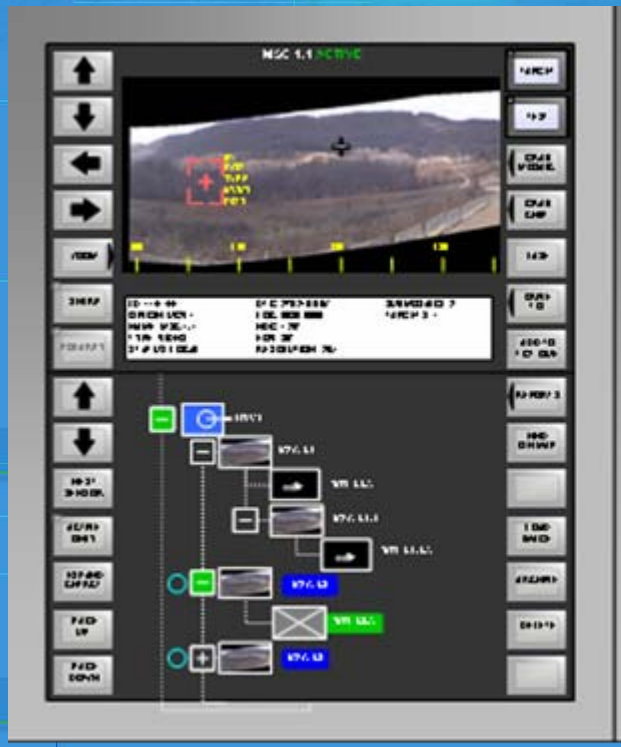
Crewstation Display Hardware

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

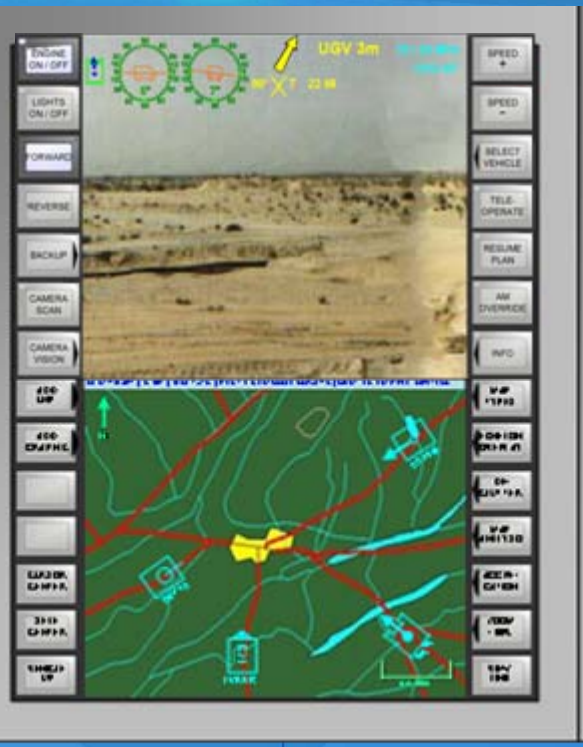
- **COTS Sharp 20.1” TFT-LCD display was selected due to video requirements**
  - Resolution: 1600 X 1200
  - Optical Response: 5 ms ON, 20 ms OFF
- **Portrait Orientation**
  - Allows up to 2 “SMI displays” per display
- **3 displays per crewstation**
  - Combined 135° HFOV (45° each)
- **Two side displays 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

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



RSTA Viewer & Browser



ARV Drive Tactical Map

Target Acq Sensor & Unmanned Asset Control

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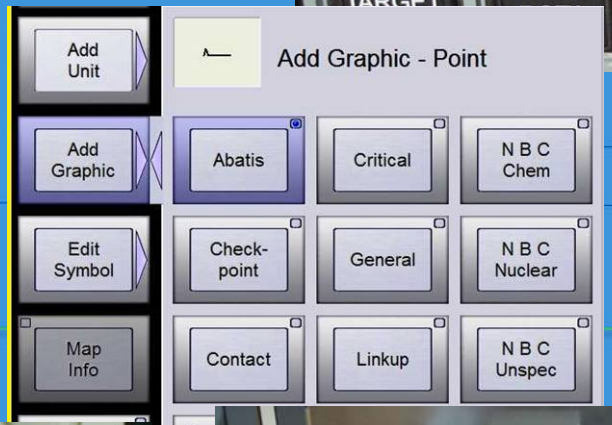
Crew Station Features - Multi-modal Inputs

Multi-modal Interface

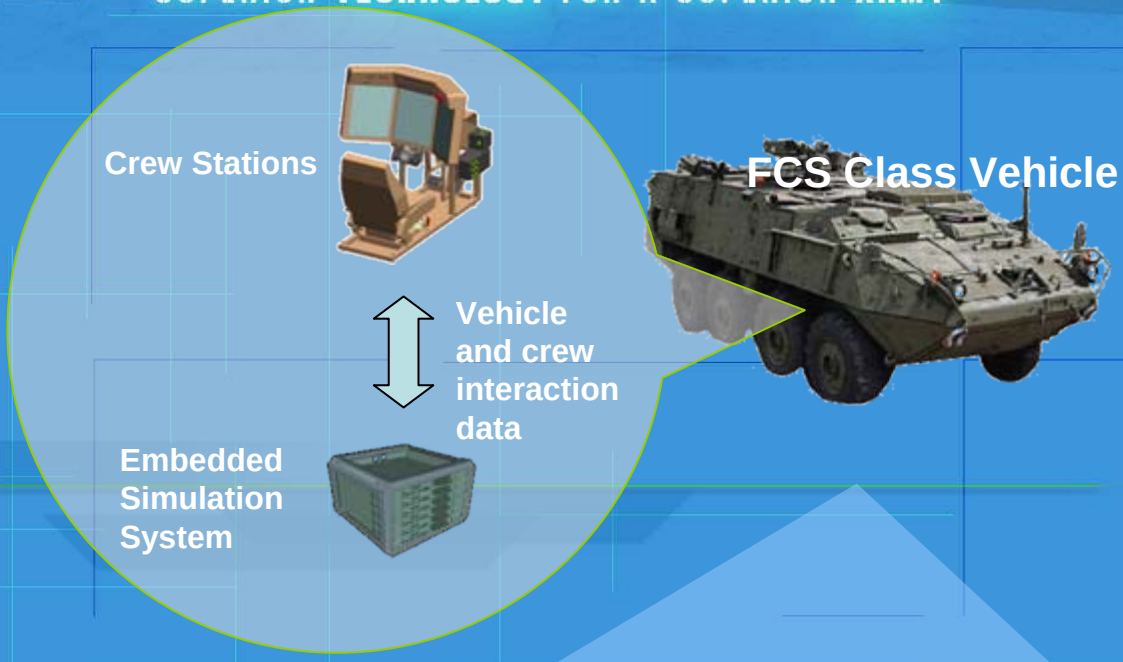
Redundant Inputs

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



Embedded Simulation System

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY



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

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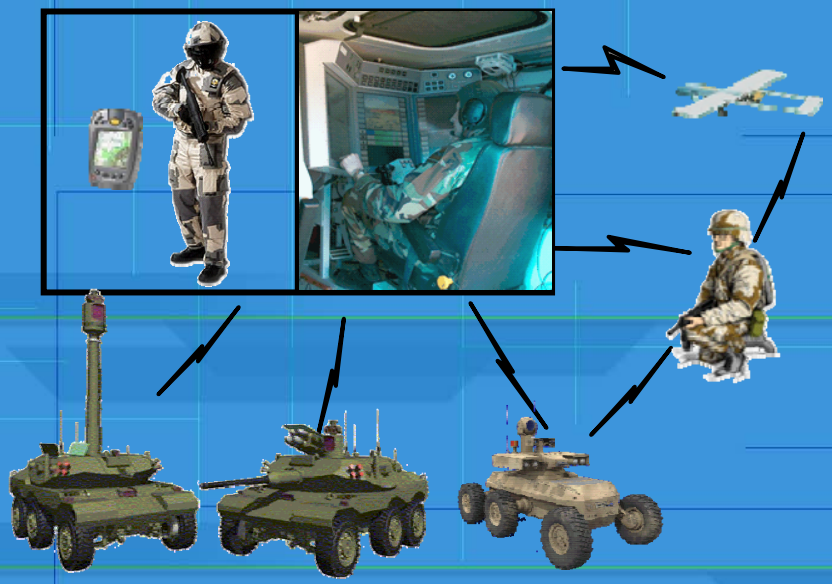
HRI Program Methodology

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

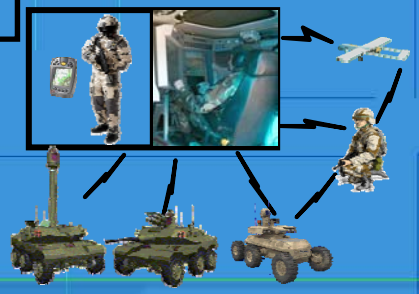
HRI ATO and ART ATO Focus

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

CAT ATD

FFW

HRI



Robotics CTA

RF ATD

ART

Soldier Focused

- Reduce Controlling Workload
- Optimize Teaming w/ vehicle
- Scale SMI for Mounted & Dismounted Ops
- Provide like control for UGV's & UAV's

Scalable Interface

Intelligent Agents

Adaptive Automation

Vehicle Focused

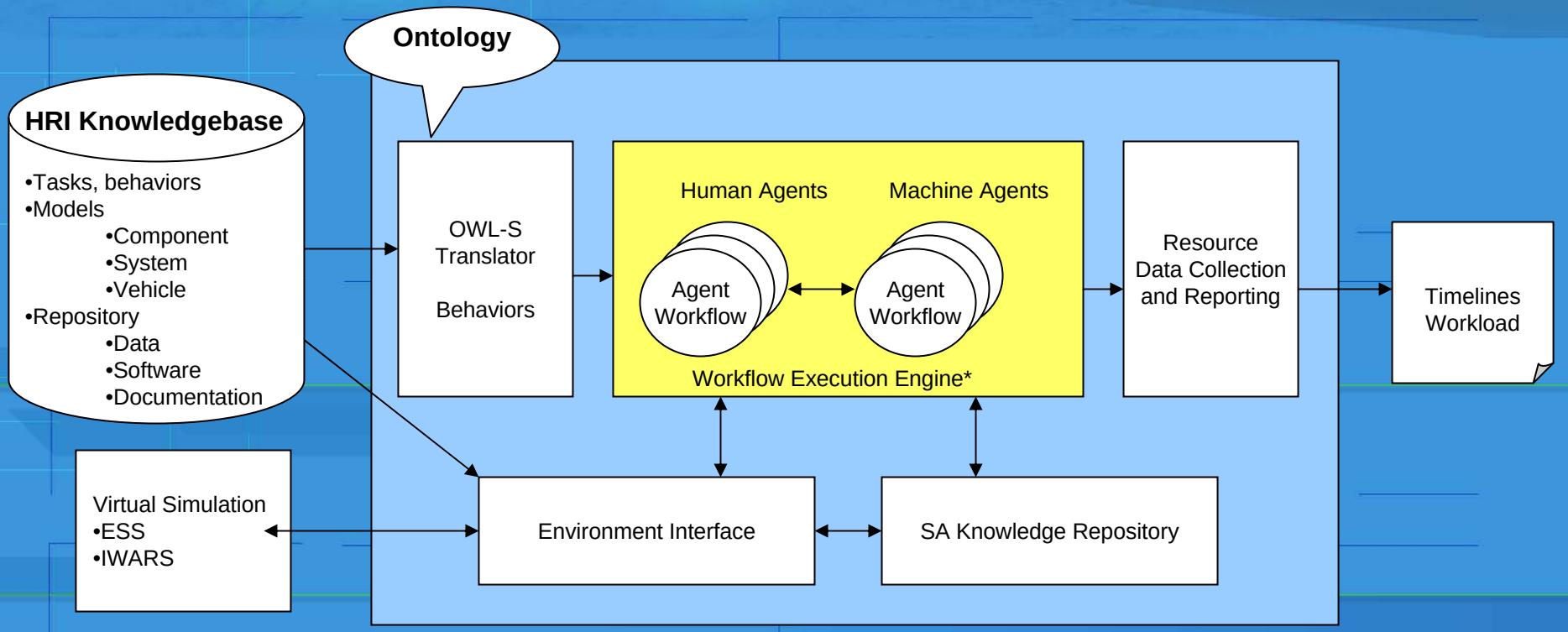
- Increase current perception capabilities
- Make vehicle more survivable
- Address anti-tampering issues
- Provide tactical behaviors

Increased Perception

Survivability & Anti-tampering

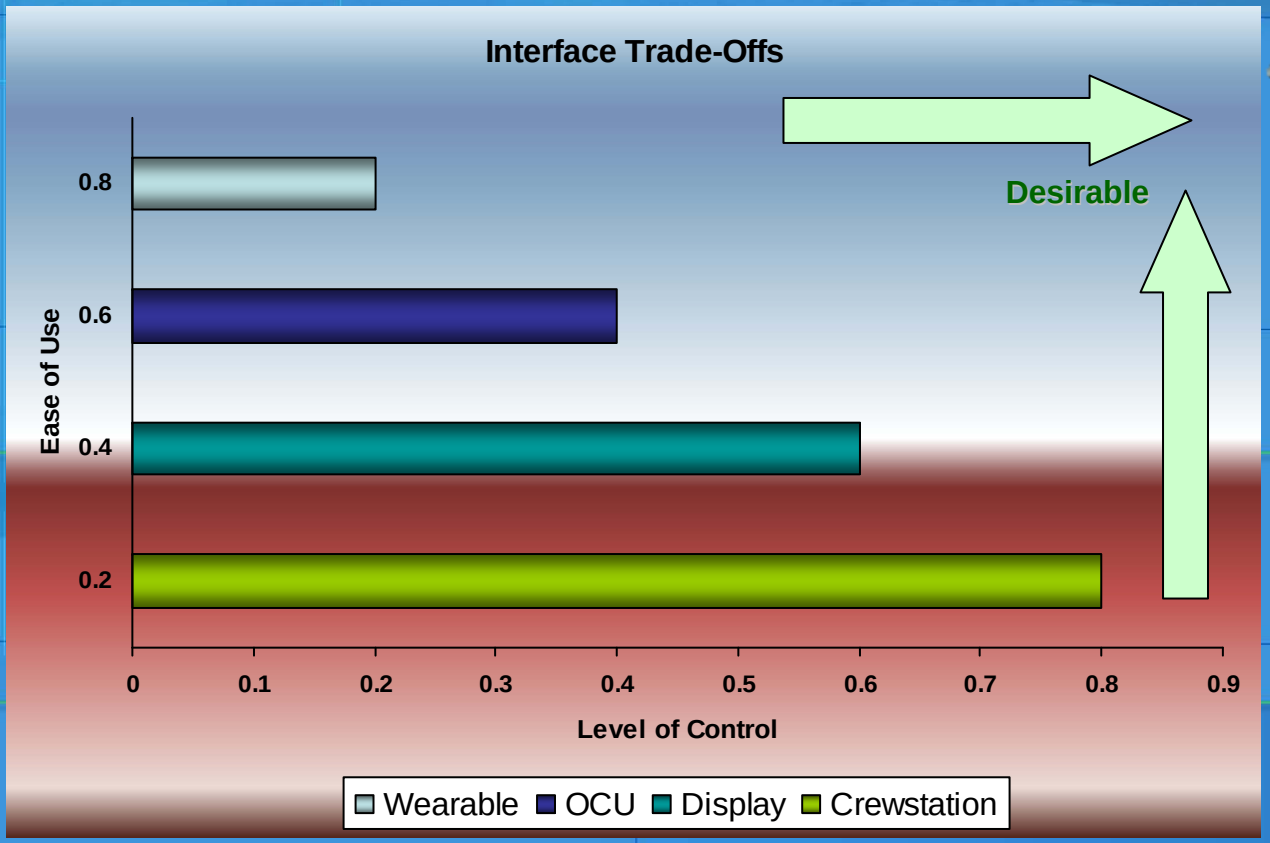
Tactical Behaviors

Intelligent Systems Behavior Simulator



Candidate Workflow Execution Engines*
- Microsaint (IMPRINT)
- Cougar
- JESS
- FCS TIN Services
- VTI DSS

Scalability Issue for Interface



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

Scalable Interface Configuration Approach

ICV

RSV

MCS mission and tasks

Environment
•Temperature
•Time of day
•Terrain
•Constraints (ex MOPP gloves)

Intelligent Scalable Interface Builder

WMI Intelligent Agent

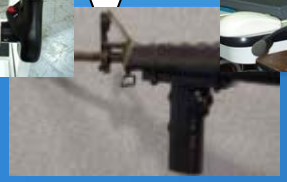
WMI repository
Intelligent Agents
Widgets
• behaviors
•representations

Interrogate HW

HW Results
Display surface size, devices, etc

Configure WMI

Hardware Systems
•Crewstation, Workstation
•Tablet, PDA, Wearable
•HMD's
•Joysticks, yokes



SOLDIER PREFERENCES

•Role/security (MCS commander, access levels, comms config, etc.)

•Physical characteristics (i.e. left handed, health, glasses, etc)

•Mental (thresholds, baseline)

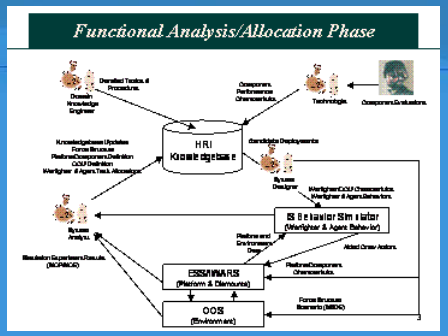
Warfighter Machine Interface Goals

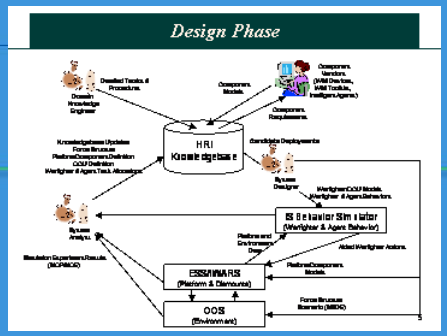
- Reduce training between systems
- Standardize interface
  - Inputs are consistent (i.e.: CTRL-C is copy)
  - Behavior is consistent ((ex: button highlights when touched)
  - Intuitive to user – in his/her mission language
  - Steps to do task match TTP's
- Present information consistently
  - Look 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

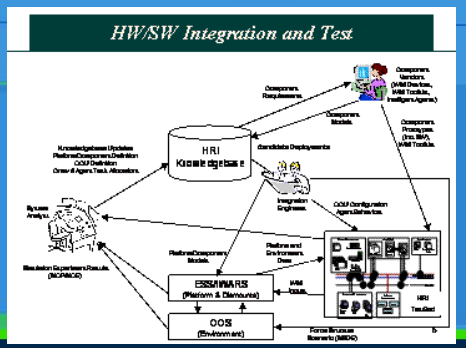
HRI Program Methodology

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

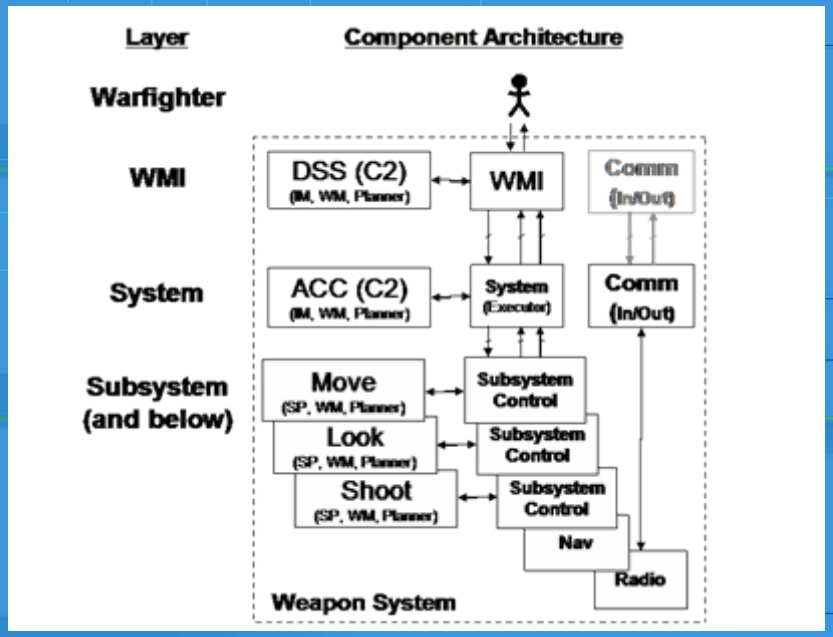


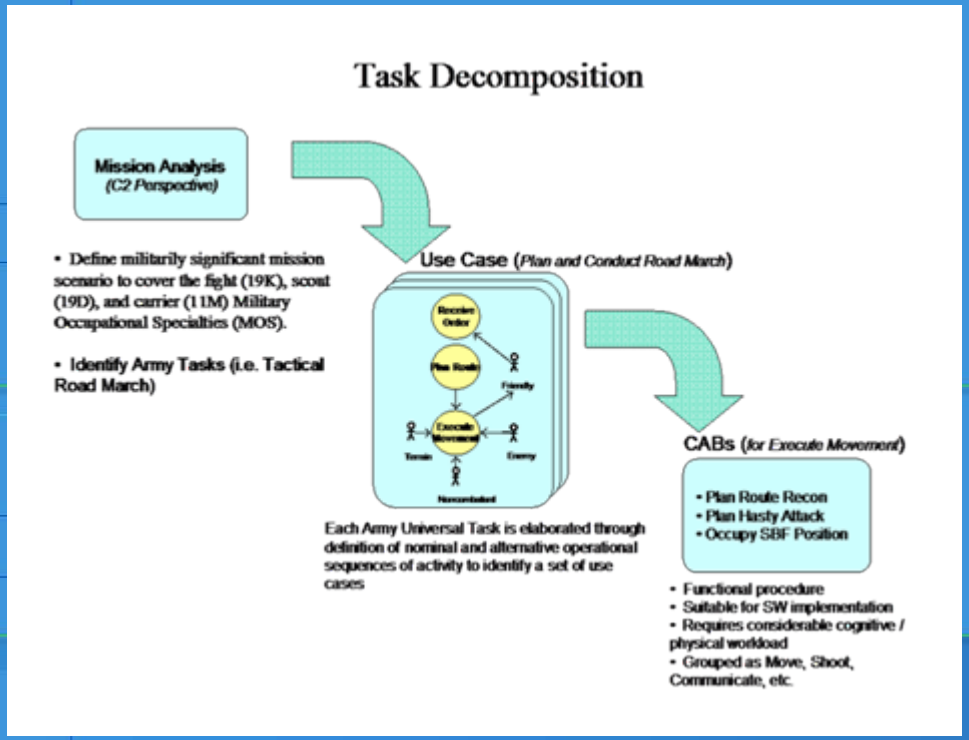




Agent Development

- CAT & FFW
  - Architecture development
  - Workload analysis
  - Intelligent agent development

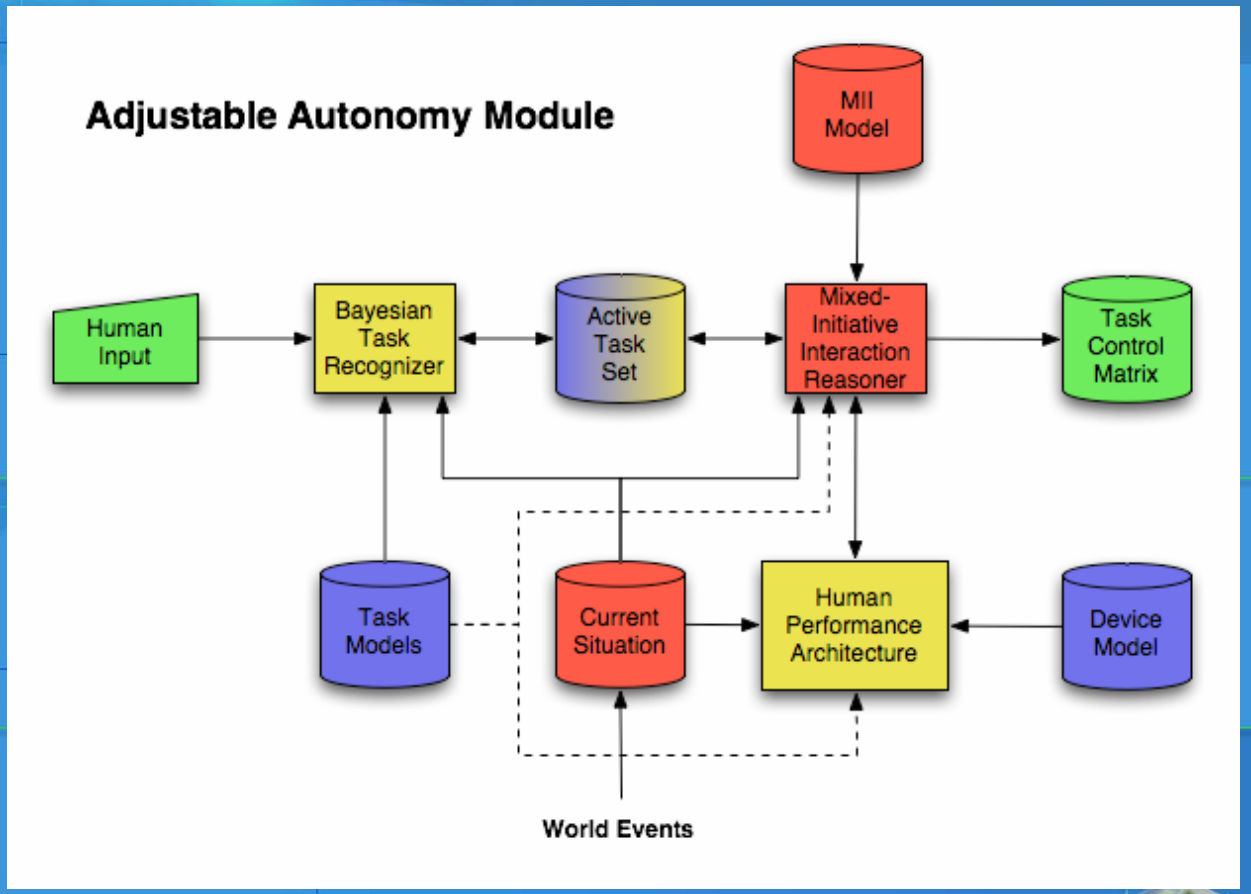




Alternate Approach

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

Stress
Crew members
Environment
Outside communications
Fatigue
Soldier
Monitor/Assimilate/Understand

INTERACTIONS

Automate/Adjust

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

Ownship
Other soldiers
Unmanned assets
Other battlefield entities
WMI/System
Control Methods and automation levels

Modeling Environment

End to End Collaborative Modeling Environment
/ Constructive / Virtual / Live Distributed

Modeling Environment

Payload Modeling
- ATR
- Miles
- Sensors
- Comms
- Survivability
- Etc.

Unmanned Systems Modeling

Teaming & Adaptive Automation

VSIL, WMI, Motion Sim

Human Performance Modeling

Repository
- Models
- Documents
- Data

Inputs:
- Requirements
- AUTL's, TTP's, FOC's
- Task analysis
- Framework
- Architecture
- Cognitive
- CAT & RF
- FCS/FFW
- Other joint programs

TARDEC, ARL & AMRDEC

Manned & Unmanned Systems

Optimize:
- Task, platform, payload automation mix
- Soldier workload
- Rapid WMI prototyping
- Architecture, components, processing, modularity
- Technology readiness levels

DEVELOPMENT AND ENGINEERING CENTER

Technology Exploration

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