TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Army Robotics

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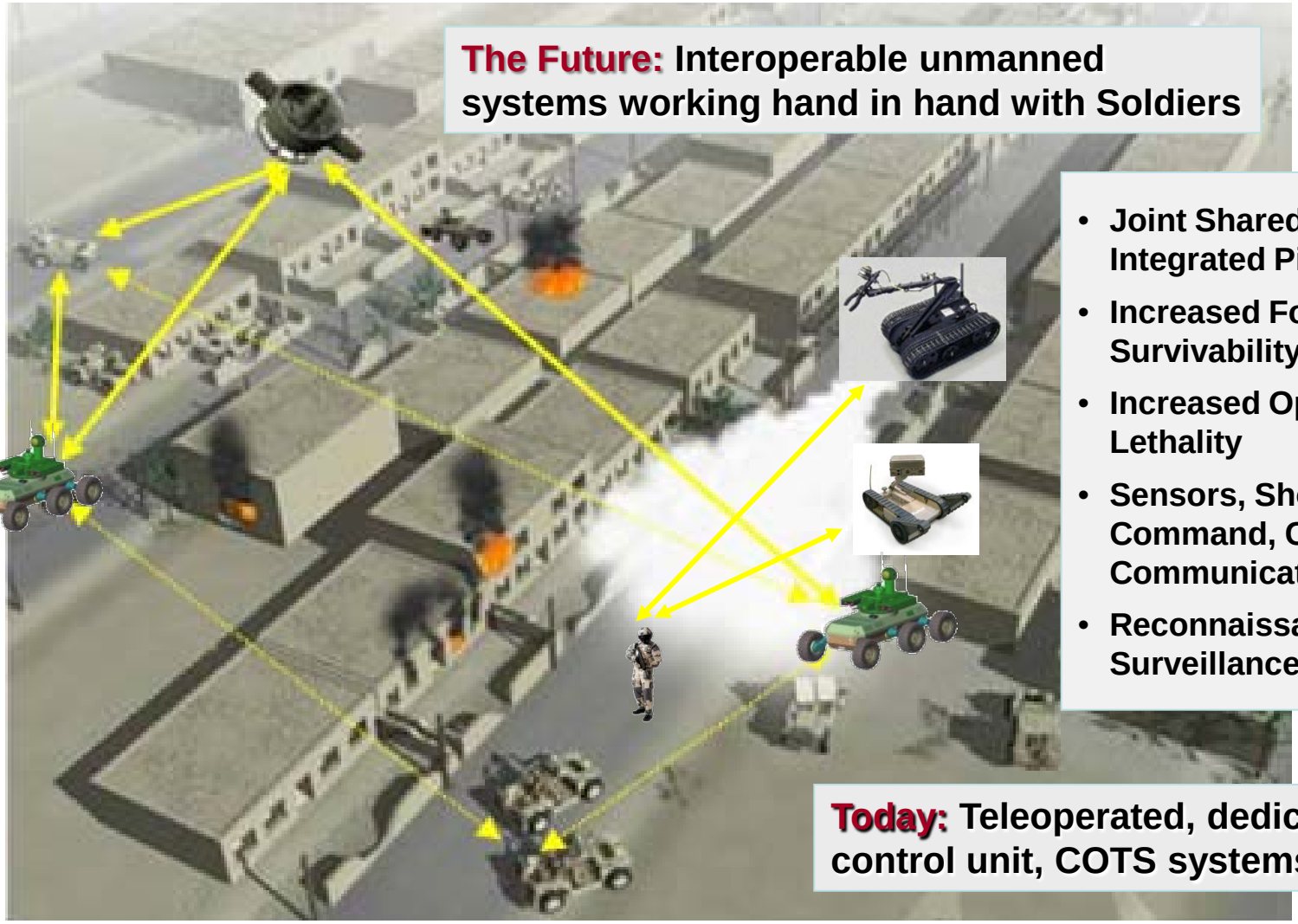
Interoperability

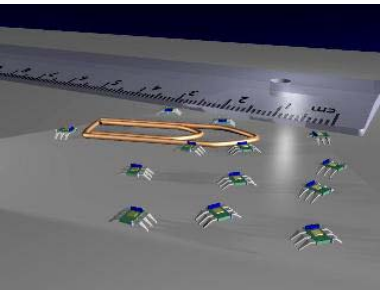


- Joint Shared Integrated Picture
- Increased Force Survivability
- Increased Operational Lethality
- Sensors, Shooters, Command, Control & Communications
- Reconnaissance / Surveillance

Payload Integration

Common payload interface across platforms by mission or class

Family of unmanned ground systems






Payload Interface Standard Architecture

Payload A | Payload B | Payload C | Payload D | Payload E

Mission equipment payloads

JPO Robotic Systems (Non FCS)

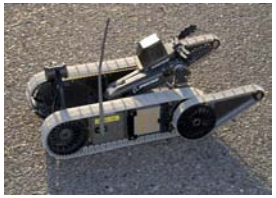
Maneuver

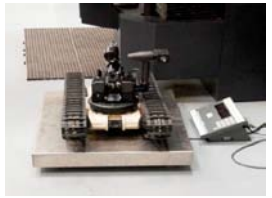
- IED Defeat Systems
- Disarm / Disrupt
- Reconnaissance
- Investigation
- Explosive Sniffer

Manuever Support

- Area/Route Clearance
- Mine Neutralization
- Counter IED
- CBRNE

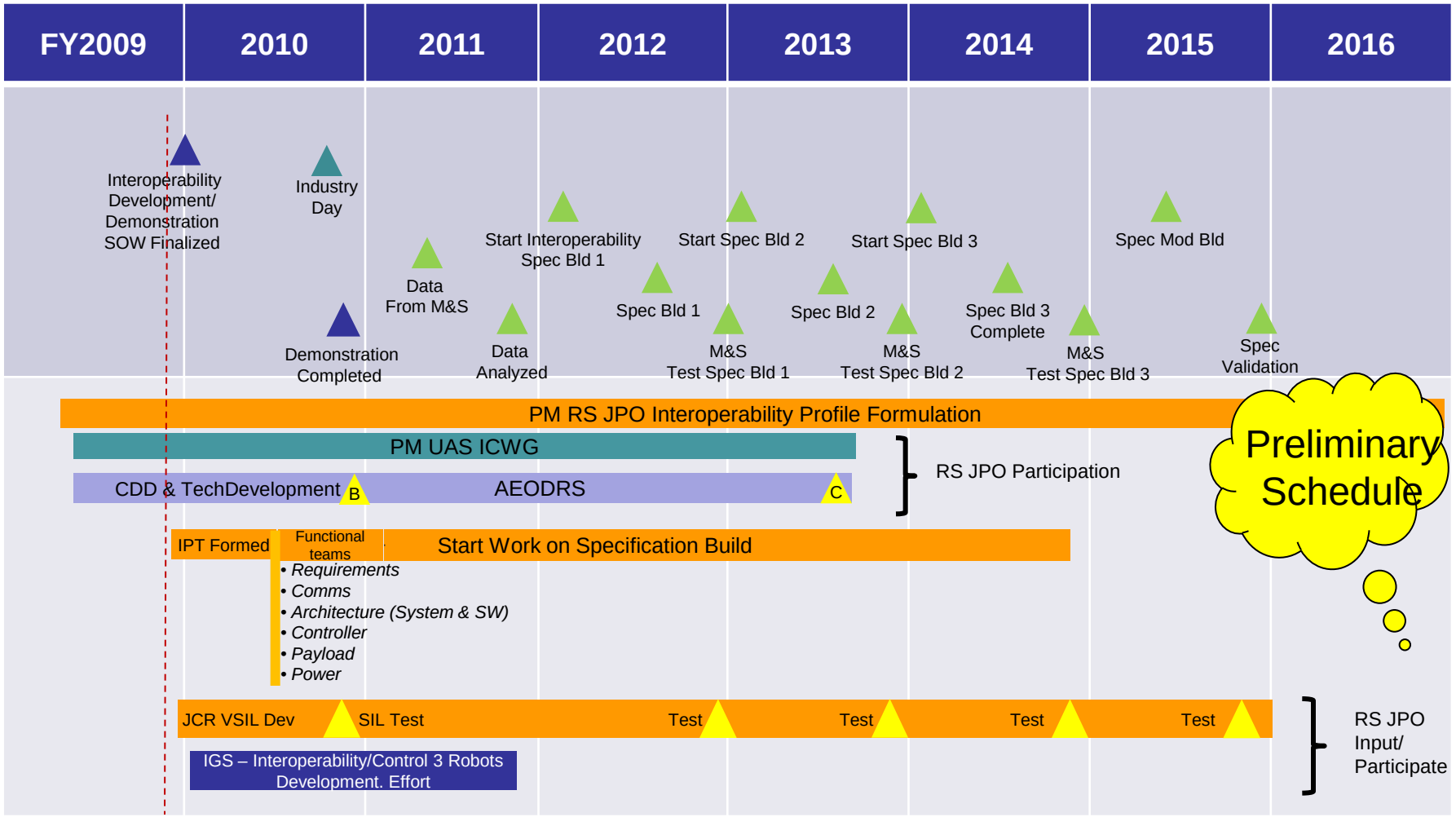
Sustainment





- Common Robotic Kit
- EOD
- Convoy
- Log/Resupply

Interoperability Top Level Schedule



TARDEC Joint Center for Robotics

- S&T Support to the RS-JPO
- Develops and Fosters external Relationships
- Matures technology for Insertion into ATO programs
- Robotics Outreach
- RS JPO Collaboration Cell Lead
- Support to IGS Capability Cells
- Robotics Academic Programs (Including Curriculum Development)

Government Partnerships	Industry Partnerships	Academia Partnerships	Community Outreach
TRADOC	ABB BAE Delphi Ford General Dynamics General Motors Google iRobot JADI John Deere Lockheed Martin Oshkosh Polaris QinetiQ Quantum Signal Raytheon SoarTechnology Think-A-Move Toyota	Auburn University Carnegie Mellon Lawrence Technological University Massachusetts Institute of Technology Michigan State University Michigan Technological University Oakland University University of Detroit Mercy University of Michigan – Ann Arbor University of Michigan - Dearborn US Military Academy at West Point Virginia Tech Wayne State University	IGVC FIRST Robofest Robotics, Engineering and Technology Days TARDEC Robotics Quarterlies

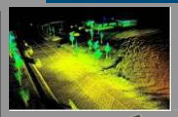
TARDEC Intelligent Ground Systems

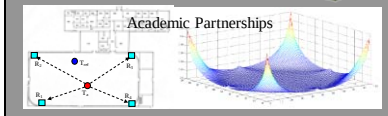
Mission

Integrate, Explore, and Develop Robotics, Network and Control Components with a Focus on Customer Driven Requirements to Provide Full System Solutions to the War Fighter

Technology Components





Integration

Demonstrators





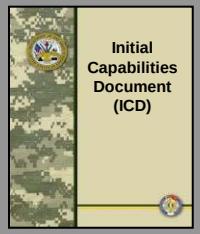
SME Defined Scenarios

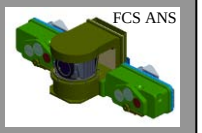
Military Relevant Test & Experimentation



Tech Transfer

Transition and Requirements Development



Integration Technology Development Lessons Learned to Enable Early Technology Insertion

TARDEC Robotics

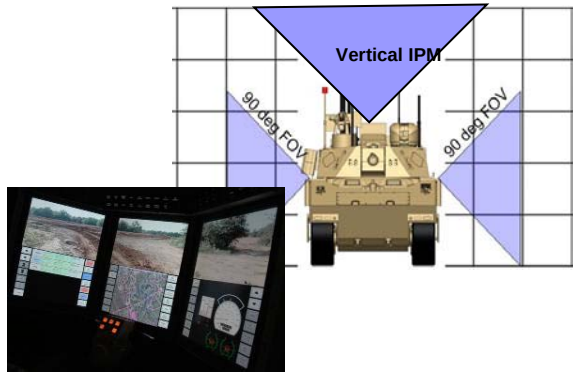
Autonomous Behaviors

Warfighter Support

III Corps
THE PHANTOM CORPS
AMERICA'S ARMORED CORPS

ROBOTIC SYSTEMS
JOINT PROJECT OFFICE

360° Situational Awareness



UGV Safe Operations

Architecture Development & Demonstration

Human – Robot Interface

Recent Warfighter Experiments

Near Autonomous Unmanned Systems
ATO Capstone

Robotic Vehicle Control Architecture
In collaboration with PM-FCS (BCT)

Convoy Active Safety Technologies (CAST)

Robotics Collaboration ATO Capstone

Robotics for Current Operations

Under Vehicle Inspections

Remote Mine Detection System

Construction Engineering Robotic Kit

Robotic Decontamination

RDECOM Robotics Rodeo

Autonomous Detection Vehicle

- Autonomous route investigation and hazard marking
- Fundamentally an appliqué kit for Husky
- Funding exists for developmental phase (JIEDDO to NVL)
- Leverage previous work by GDRS for NVL

Convoy Logistics

- Kit-based system for TWV automated leader-follower
- User assessment at Fort Hood in the September – October timeframe
- Funding exists for developmental phase
  - Potential to leverage JCTD for cycle development

Robotics Rodeo

- Input from Army needs (ONS)
- Demonstration of related state of the art technologies
- Provide user and SME feedback to industry

Manned/Unmanned Teaming (MUT)

- Large armed robotic platform assumes role as a member of squad / formation
- Leverage existing ARDEC, AMREC, CERDEC technologies and Fort Hood rodeo for target acquisition and engagement capability

Persistent Stare

- Small robot with autonomous navigation to perform recon and surveillance
- Utilize robotic rodeo to demonstrate vendor capabilities

VOIED Defeat

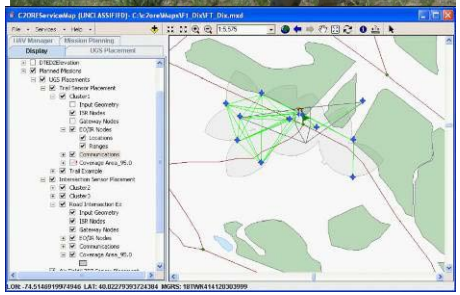
- Capability for autonomous VOIED defeat
- Utilize robotic rodeo to demonstrate vendor capabilities

Future Force Technologies

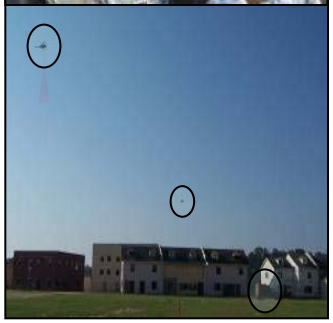
Robotics CTA – Technology for Near Autonomous Systems

Robotic Platform for Engineer Missions

MAST CTA - Small “Creatures for Urban Terrain”



Command & Control of Robotic Entities



Air-Ground Collaboration

Following, Awareness, SafeOps, and Tracking through IGS (fastIGS)

Crewstation Interface and Control Advancements

PAST

- Workload reduction
- Embedded crewstation

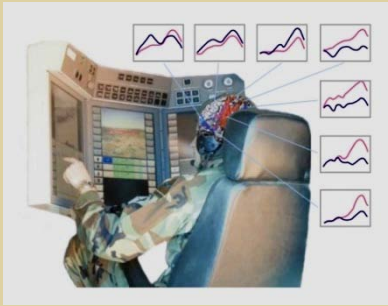
PRESENT

- Robotic control (mounted, dismounted)
- Driving aids (Soldier assist)
- Scalable, portable Interface

Dismounted Controller

FUTURE

- Soldier monitoring and task assist
- Intelligent agents
- 360 degree situational awareness



Manned And Unmanned Vehicle Systems Integration Lab

Purpose: Incorporate actual hardware both fielded and prototypes using simulation, stimulation and emulation to test concepts and validate capabilities.

- Hardware In The Loop includes:
  - Vehicle Warfighter Machine Interface
  - Dismounted Controllers
  - FBCB2 and other ABCS
  - SoSCOE
  - Autonomous Control Algorithms

Partners:

- Robotic Systems Joint Project Office (RS-JPO)
- Cross Command Collaboration Effort (3CE)
- Natick Soldier Center – Infantry Warrior Simulation (IWARS)
- Night Vision Labs – Comprehensive Munitions and Sensor Server (CMS2)
- Modeling Architecture for Technology, Research and EXperimentation (MATREX)

ARL Robotics Research

Robotics CTA

Micro-Autonomous Science & Technology CTA

Robotics CTA Members and Objectives
Current Consortium

Consortium Members

- General Dynamics Robotic Systems (Lead Industrial Partner)
- Carnegie Mellon University
- Applied Systems Intelligence
- Jet Propulsion Laboratory
- Alion Science & Technology
- BAE Systems
- Sarnoff Corporation
- SRI International
- Florida A&M University
- University of Maryland
- PercepTek
- Robotic Research
- Signal Systems Corp
- Howard University
- NC A&T University
- University of Pennsylvania
- Skeyes Unlimited
- Johns Hopkins University

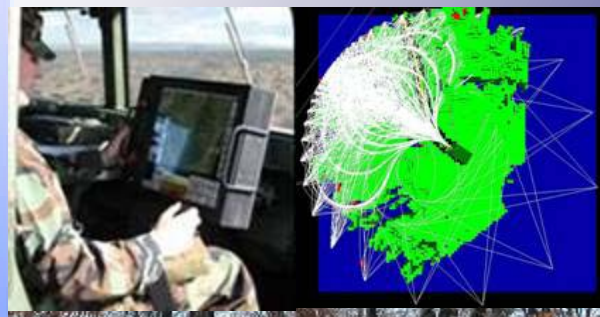
Objectives

Make the research investments that support the Army's robotic system development goals:

- *Develop perception technologies that allow robotic vehicles to sense and understand their environment;*
- *Develop intelligent control technologies and architectures enabling robotic systems to autonomously plan, execute, and monitor operational tasks undertaken in complex, tactical environments;*
- *Develop human-machine interfaces that allow soldiers to effectively task robotic systems and minimize operator workload.*

Technical Areas

- Advanced Perception
- Intelligent Control & Behavior Development
- Human / Machine Interfaces

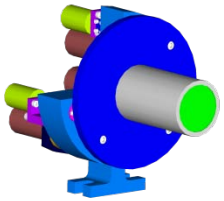


Sensors and Perception

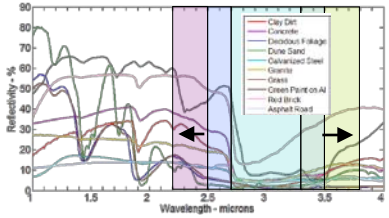
Improved environmental understanding, especially for dynamic environments

- *Application of learning techniques*

Exploration of novel sensor modes



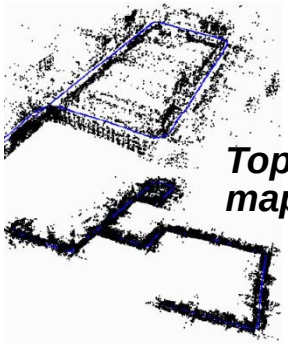
Novel LADAR for small systems



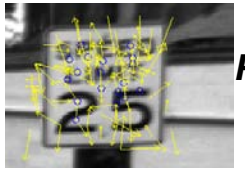
Spectral LADAR

…to expand applicability and enhance available information

Terrain Classification

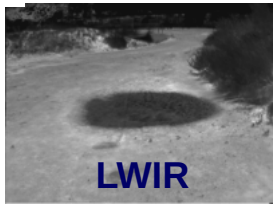


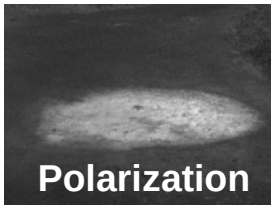
Topologic maps



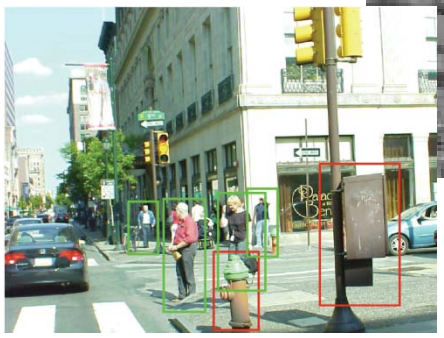
Road Features

Sensing Mud





Moving Agent Understanding



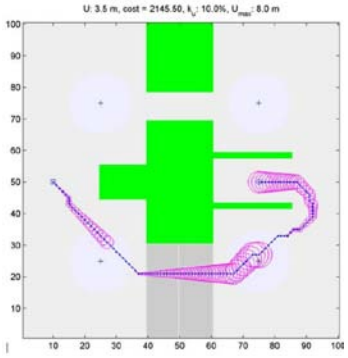
In clutter & complexity

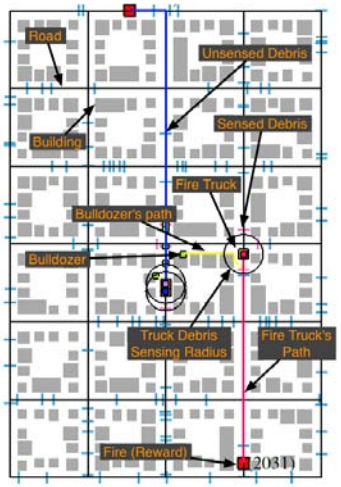
Goal is fusion of multiple techniques to improve accuracy and robustness

Intelligent Control

Examining methods for real-time planning and execution of complex missions

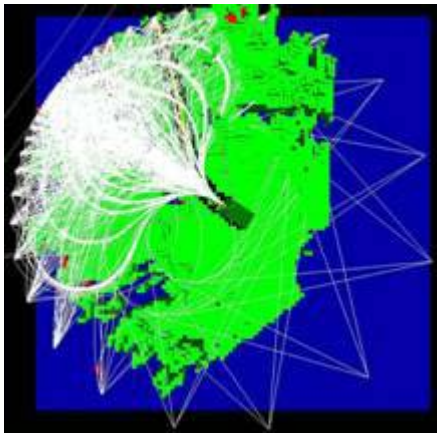
Planning with uncertainty





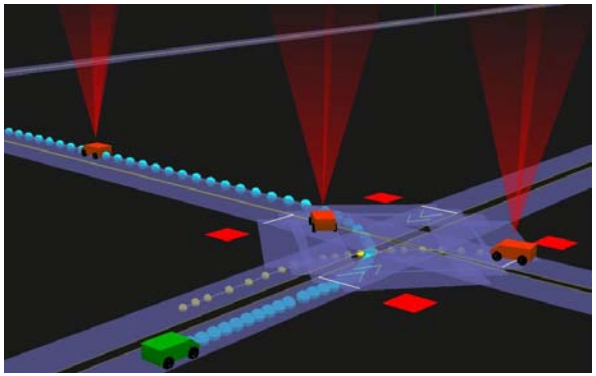
…and time constraints

Integration of multiple planners for real-time operation



Off-road

High Mobility



On-road

Full implementation of multi-layer planning

Dynamic Replanning Example

Advances in Human Machine Interface

Scalable Human Machine Interfaces

…and Multi-Modal Input

… to reduce soldier cognitive workload

A Vision of the Future
The new Robotics CTA

Unmanned Systems become another soldier in the unit:

highly capable with scalable attributes to meet mission requirements; requiring reduced communication and minimal soldier interaction; flexible, robust, and reliable; able to adapt fully to new & different tactical and environmental conditions; following commanders intent; effectively operating in mixed environments; able to "learn from experience; maneuvering unfettered in complex terrain; able to "live" in a world designed for humans, to grasp small objects, to open doors, or to carry the wounded.

- ***What missions will they conduct ?***
- ***What level of capability?***
- ***What degree of autonomy will they possess?***
- ***How will they work with soldiers ?***
- ***Or function in general society?***
- ***How will they be used in Urban operations?***
- ***In complex terrain?***
- ***How will they navigate in GPS denied environments ?***

Topics for Future Perception Research

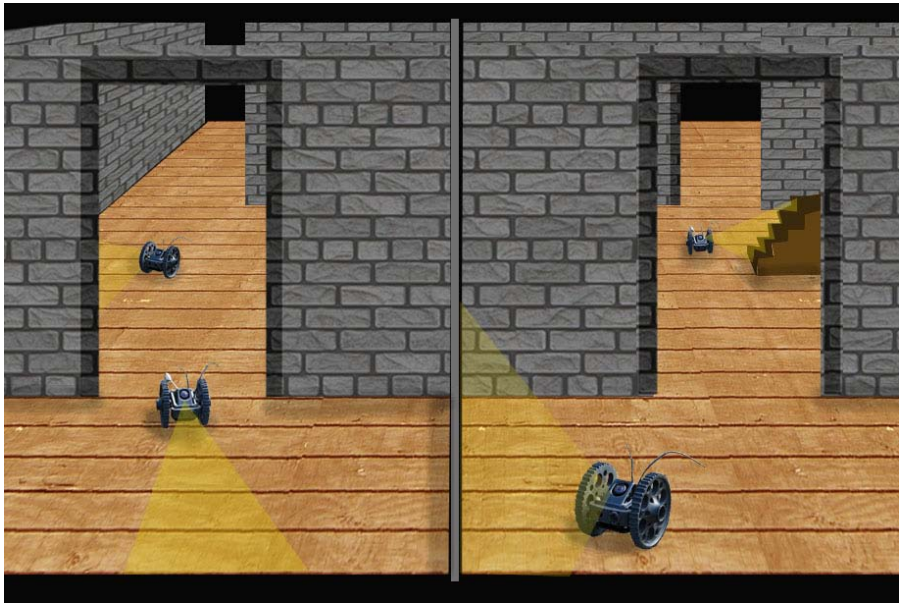
Perceive & understand a dynamic & unknown environment

- Sensors
- Information Fusion
- Perception Algorithms
- All environments
- All scales
- Relevant world model

- **Sensing**
  - Greater resolution & range, lower cost
  - Increased fields of view; focus of attention
  - Scale
  - All weather/environments
- **Terrain/Object Understanding**
  - Broader vocabulary
  - Recognition of cues/saliency of observations
  - Robust & adaptive
  - Reasoning
  - Fusion
- **Understanding activity**
  - Human activity/intent recognition
  - Saliency of observations/ context & cues
  - Learning
- **World model**
  - Managed & validated
  - Long-term & short-term memory
  - Collaborative or distributed
  - Common ground (HRI)
  - Navigation (Intelligence, mobility & manipulation)

Topics for Future Intelligence Research

Plan and execute military tasks & missions



- **Robust**
- **Adaptive**
- **Learns from Experience**
- **Transparent**

Some potential research topics

- **Learn & Adapt**
  - **Deductive reasoning**
  - **Inference**
  - **Generalization/Rules of engagement**
  - **Uncertainty of future conditions**
  - **Probabilistic reasoning**
  - **Spatial & temporal reasoning**
- **Self-awareness/introspection**
  - **Transparency**
  - **Providing non-verbal cues**
  - **Human-robot collaboration**
  - **Fault detection**
- **World model**
  - **Common ground**
  - **Mixed initiative**
- **Scale**
  - **Adapting to resource limitations**
- **Tactically intelligent behavior**
- **Collaboration between homogeneous & heterogeneous systems**

Human-Robot Interaction

Seamless integration of robots into military & civilian activity

- **Effective Control of multiple systems**
- **Human-robot Teaming**
- **Seamless integration of robots & society**

Some potential research topics

- **Shared situational awareness**
  - **Aware of cultural and behavioral norms.**
  - **Comprehend commander's intent & act upon it**
  - **Understand the intent of surrounding humans for consideration in planning**
  - **Possess common spatial & temporal frames of reference – a "common ground"**
- **Trust & Confidence**
  - **Transparency of action**
  - **Cues to activity**
  - **Tolerance to failure**
- **Intuitive Communication**
  - **Language – unconstrained dialogue**
  - **Non-verbal cues, gestures, context, & behavior**
- **Operating within society**
  - **Adaptable to varying social cues & context**
- **Span of control**

Summary

- ***Unmanned Systems will have a major impact on future military operations***
- ***The technology is still in its nascent stages – the Army has made a firm commitment to its development***
- ***The first systems, albeit teleoperated are already impacting current operations***
- ***The first systems with significant autonomy will be fielded over the next 5 – 10 years***
- ***How the Army employs the technology will, as much as the technology itself, determine its future impact***




Questions