Overview: Robotics Alliance to National Defense Industrial Association-Robotics Panel

13 December 07
### Robotics CTA Members and Objectives

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<th>Consortium Members</th>
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<td>General Dynamics</td>
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<td>Robotic Systems</td>
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<tr>
<td>(Lead Industrial Partner)</td>
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<tr>
<td>Carnegie Mellon University</td>
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<td>Applied Systems</td>
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<td>Intelligence</td>
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<td>Jet Propulsion Laboratory</td>
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<td>Alion Science &amp; Technology</td>
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<td>Skeyes Unlimited</td>
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<th>Objectives</th>
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<td>Make the research investments that support the Army’s robotic system development goals:</td>
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<td>• Develop perception technologies that allow robotic vehicles to sense and understand their environment;</td>
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<td>• Develop intelligent control technologies and architectures enabling robotic systems to autonomously plan, execute, and monitor operational tasks undertaken in complex, tactical environments;</td>
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<td>• Develop human-machine interfaces that allow soldiers to effectively task robotic systems and minimize operator workload.</td>
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<th>Technical Areas</th>
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<td>Advanced Perception</td>
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<tr>
<td>Intelligent Control &amp; Behavior Development</td>
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<tr>
<td>Human / Machine Interfaces</td>
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**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
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- University of Pennsylvania
- Skeyes Unlimited
Robotics CTA Task Areas

Requires advancing the state of the art in three critical areas:

- **Perception**
- **Intelligent Control**
- **Human Machine Interface**

Requires integrating research advances from all three areas using a system-level approach to provide a mechanism for:

- Field experimentation and research validation
- User input
Advances in Sensors and Perception

LADAR Development & Processing Algorithms

Terrain Classification

Moving Agent Understanding

Air / Ground & Mid-Range Sensing
Advances in Human Machine Interface

Scalable Human Machine Interfaces

Multi-Modal Input

Workload / Trust in Automation

HMI Interface Extensions
# Evaluation and Experimentation

## Overview

### Stages of Experimentation and Integration

<table>
<thead>
<tr>
<th>Proof of Concept Testing with COTS Hardware</th>
<th><img src="image1.png" alt="Image" /></th>
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<tbody>
<tr>
<td>Researchers test proof of concept in their own labs with commercial off-the-shelf (COTS) hardware. The image at right is from the Carnegie Mellon Robotics Institute Laboratory.</td>
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<tr>
<th>Perception and Autonomous Navigation Testing with GDRS Standardized Test Facilities</th>
<th><img src="image2.png" alt="Image" /></th>
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<tr>
<td>GDRS facilities are used to test perception and autonomous navigation tasks. Data is analyzed against the ground truth of known obstacles. ARL and NIST design quantitative experiments.</td>
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<tr>
<th>Simulation Testing with RCTA SIL</th>
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<tr>
<td>The RCTA Systems Integration Lab (SIL) at GDRS provides a hardware-in-the-loop simulation testbed for Advanced Perception, Intelligent Control Architecture (ICA) and Human Machine Interface (HMI) technologies.</td>
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<th>Integration and Testing in Realistic Environments</th>
<th><img src="image4.png" alt="Image" /></th>
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<td>New technology is integrated and tested on the Demo III XUV and commercial vehicles in various terrains including rolling and forested terrain, as well as a MOUT environment at Fort Indiantown Gap.</td>
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Fort Indiantown Gap, Pennsylvania
Robotics Lab and Test Facility

- State-of-the-art Robotics Facility located at Ft. Indiantown Gap, PA.
- Realistic environment for Field Experimentation currently used as a training facility
  - 10th Mtn. Division Exercises
  - 20th ID Training prior to deployment in Iraq
  - Stryker Brigade
- Facility Statistics
  - 5,000 sq. ft. Office / Lab Space
  - 3,500 sq. ft. High Bay
  - Floor capable of supporting large vehicles such as Stryker
  - TVMA-B Range 4km x 1.5 km
Hardware-in-the-Loop Simulation

- Capability Developed in FY 2007
- Leverages Visualization Technology from COTS Gaming Technology
- Exploits Graphics Technology to Emulate Vehicle Sensors
Hardware-in-the-Loop Simulation: Benefits and Uses

• Benefits
  – Engineers: Closed-Loop Desktop Test Environment
  – Soldiers: Scalable, Coherent Evaluation Environment

• Uses
  – Exercise Perception Algorithms
  – Exercise ICA & Tactical Behavior Algorithms
  – HRI Development
  – Workload Theory Data Collection
  – Soldier Training
Robotics CTA Technology Transfer

**DEVELOP** technologies to meet current and anticipated military needs……..

**ASSESS** applicability of developed technologies to new applications as they arise through interaction, analysis and integrated field experimentation……..

**TRANSFER** technologies to maximize investment and advance the state-of-the-art!!!
RCTA Transitions to FCS ANS

- Provided the technical foundation for FCS-ANS and the demonstration in 2003 that was instrumental in funding FCS unmanned ground systems
  - Field-tested LADAR hardware
  - LADAR processing algorithms for obstacle detection, classification algorithms for obstacle detection, and terrain classification
  - Engineering visualization tools for LADAR and vehicle planner development
  - Field-tested robotic testbed platforms (with interfaces to navigation sensors), capable of data collection and archiving in realistic tactical environments
  - LADAR optics, TX/RX electronics and processing firmware (FFT, multi-pulse, ranging, etc.)
  - Passive perception system algorithms; stereo correlator, rectification and pyramid algorithms
RCTA Transitions to TARDEC’s VTI RF and CAT STO

- All hardware and software perception sensors
- Sensor processing algorithms
- Vehicle planners
- Planning algorithms via Terrain Reasoner
- Selected tactical and cooperative behavior algorithms
- Perception technologies from the 3500-pound XUV testbed to the 18-ton Stryker vehicle
- SMI related components
RCTA Transitions to PM-FPS MDARS

- Perception Sensors (LADAR and EO/IR)
- Sensor processing algorithms
- Vehicle planners and OA Planning algorithms
- LADAR optics and TX/RX electronics
- LADAR processing firmware (FFT, multi-pulse, ranging, etc.)
- Acadia Vision Processor
RCTA Transitions to DARPA OAV-II

- LADAR Core Sensor Technology
- Sensor Processing and Obstacle Avoidance/Path Planning Algorithms
- Human-Robotic Interface and Command and Control Technologies
RCTA Transitions to AATD UACO

- UGV Perception Sensors and Demonstration Platforms
- UGV and LADAR Sensor Processing Algorithms
- Vehicle planners and OA planning algorithms
- Market-Based Collaborative Tasking Algorithms
- SMI Interface, Decision Support System, and Terrain Reasoner
- Air / Ground Cooperative C2
- Test and Demo Facilities
Transitions to Other Government Programs

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<th>Summary of RCTA Transitions to Other Government Programs</th>
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| **DARPA Robotic Vision 2020 (RV2020) Program** | • Real-time optical flow algorithm that runs in parallel with stereo ranging to develop a moving obstacle detection on-the-move capability  
  • Run-time stereo algorithms on a compact smart camera board |
| **DARPA Perception for Off-road Robotics (PerceptOR) Program, and Unmanned Ground Combat Vehicle (UGCV)** | • Visual pose estimation capability to provide accurate autonomous vehicle position estimation during extended GPS-denied operation  
  • Stereo bilateral pre-filter |
| **DARPA Multi-Spectral Adaptive Networked Tactical Imaging System (MANTIS) Program** | • Pose and 3D estimation capabilities to provide accurate position and orientation estimation based on visual inputs from helmet mounted VNIR and SWIR sensors |
| **DARPA Learning Applied to Ground Robots (LAGR) Program** | • Large-baseline stereo analysis |
| **USMC Self Mobile Trailer (SMT) Program** | • Perception Sensors and Processing Algorithms  
  • Vehicle Path Planning & Control |
| **Robotic Systems JPO – Ground Standoff Mine Detection System (GSTAMIDS) Program** | • Actuation and low-level vehicle control |
| **TARDEC Safe Operations Program** | • Perception, Planning & Tactical Behaviors |
| **TARDEC Near-Autonomous Unmanned System STO (formerly ARV Robotics Technology STO)** | • Perception, Planning & Tactical Behaviors |
| **NASA Mars Technology Program** | • Run-time stereo algorithms and 3D stereo range visualization and diagnostic tools for integration into future Mars Rovers |

- TARDEC
- DARPA
- Robotic Systems JPO
- NASA
FCS Risk Mitigation Accomplishments

- FCS Risk 213 – Safe Operations
- 11 Research Tasks, 4 Sensor Modalities
  - Assessments Designed by ARL & NIST
  - Approval for Live Human Experimentation
  - Common Evaluation Platform
  - 3 Quantitative Assessments in 2007
  - Additional Assessments in 2008
RCTA Focus Going Forward
Advanced Perception

• Continued Emphasis on Safe Operations
  – Focus future research on detecting and tracking of **humans** to meet FCS criteria for safe operations
  – In any and all terrain types
  – Upright, crouched, prone
  – Occluded, emerging from occlusions
  – Fast detection, accurate tracking
  – Long ranges (100 m), varying speeds (up to 40 mph)
  – Anytime, anyplace, anywhere
RCTA Focus Going Forward
Advanced Perception

- Develop better/faster **obstacle detection and classification** algorithms to improve speed in open/rolling terrain and urban environments.

- Emphasize **local situational awareness and scene understanding** to address the development and maintenance of an operational picture.

- Advance **perception algorithms for mid-range planning** in order to enhance planning for safe operations, effective reconnaissance and tactical behaviors.

- Advance **cooperative perception and planning** among heterogeneous assets including airborne perception for use as a planning aid.
RCTA Focus Going Forward
Intelligent Control Architectures

- Develop technologies to support FCS Requirements for **Deliberative Planning** in support of safe operations in dynamic environments
  - GPP planner, multi-resolution planning, planning with uncertainty
  - Collaborative planning for heterogeneous robots
- Enable **Local Planning for Autonomous Safe Operations**
  - Incorporate vehicle dynamics
  - (x,y,t) planning, etc.
- **Combining Global and Local Planners**
  - Field Interface at the cost level
  - AM data used by the global planner
RCTA Focus Going Forward
Intelligent Control Architectures

• Develop **Supporting Tools** to enhance Algorithm Development
  – Visualization for planning algorithms
  – Hardware-in-the-loop sensor simulation
  – Simulated data to test new approaches

• Integrate **Perception-Based Feedback** into Tactical Behaviors
  – Bowls, tree lines, urban sight lines, intervisibility, etc.

• Enable **Best-Information Planning** for robotic command and control
  – Ingest real-time data from aerial sensors, a-priori maps, AM sensors
RCTA Focus Going Forward

Human Machine Interface

- Develop **HMI Extensions** to support increased situational awareness and operator control in cluttered environments
  - Support human detection for safe operations
  - Enhance visualization for situational awareness
  - Enhance simulation tools
  - Improve Spoken Language Interface

- Quantify **Human Performance and Cognitive Capability** during control of multiple heterogeneous robots
  - Data collection with UAMBL to support FCS concept development
  - ARL data collection to support AM / Reconnaissance workload