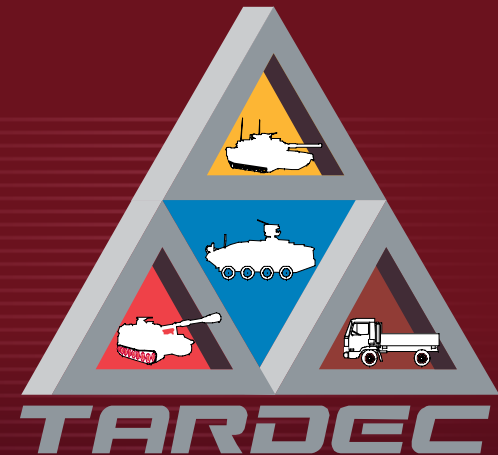




## TARDEC Intelligent Ground Systems

UNCLAS: Dist A. Approved for public release



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

AUVSI Unmanned Systems Interoperability Conference  
San Diego, CA  
31 Oct 07  
Bill Smuda, Ph.D.

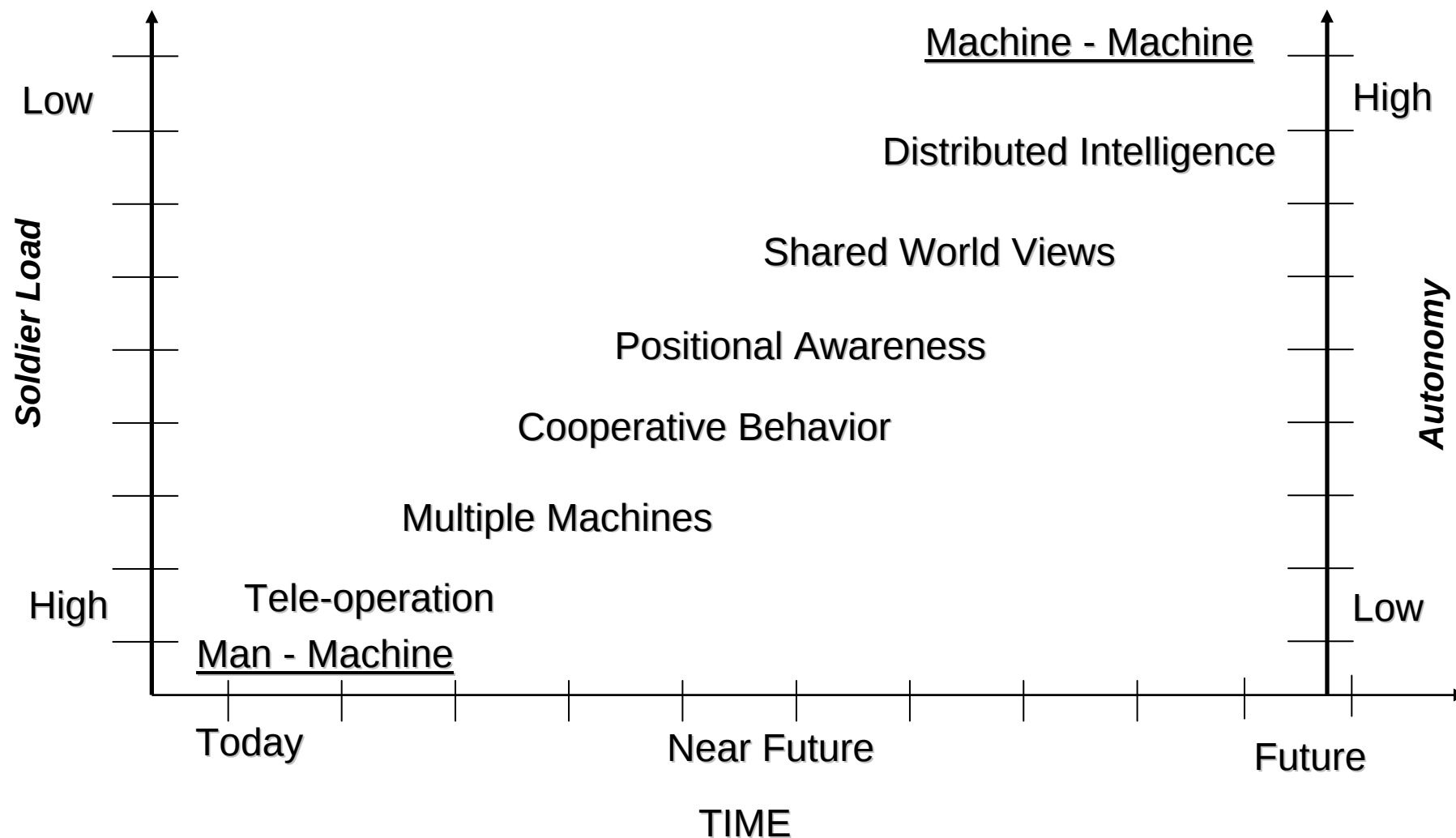
| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                          | Form Approved<br>OMB No. 0704-0188                          |                                 |
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| 1. REPORT DATE<br><b>31 OCT 2007</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                    | 2. REPORT TYPE<br><b>N/A</b>        |                                          | 3. DATES COVERED<br><b>-</b>                                |                                 |
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| 13. SUPPLEMENTARY NOTES<br><b>The original document contains color images.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                    |                                     |                                          |                                                             |                                 |
| 14. ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                          |                                                             |                                 |
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| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     | 17. LIMITATION OF ABSTRACT<br><b>SAR</b> | 18. NUMBER OF PAGES<br><b>22</b>                            | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT<br><b>unclassified</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b> |                                          |                                                             |                                 |



## IGS Has a Dual Role:

- **Furthering Unmanned Systems Autonomy**
  - Unmanned Ground Vehicle Platforms
  - Vehicle Intelligence and Control
  - Mission Payload Integration
  - Embedded Simulation
- **Increasing Soldier-Robot Interaction**
  - Human-Robot Interaction
  - Soldier Machine Interface
  - Embedded Simulation





## •Intelligent Systems Overview

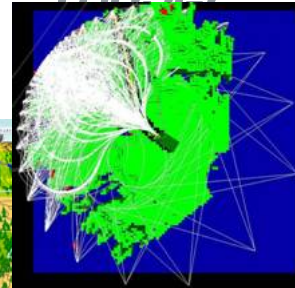
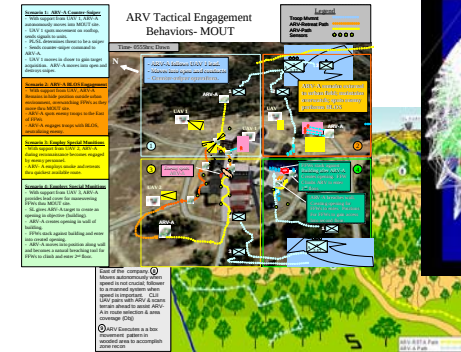
## •Highlight

- Multi Robot Control – Sentinel SBIR
- Convoy
- Near Autonomous Unmanned System



## Primary Efforts:

- Unmanned Ground Systems Integration
- Robotic Vehicle Control Architectures
- Safe Operations in Dynamic Environments
- Near Autonomous Unmanned Systems
- Autonomous Maneuver
- Tactical Behaviors/Reactive Formation Control
- System Self Security
- Convoy Active Safety Technologies
- Robotic Decontamination
- Manned-Unmanned Collaboration
- Small Robot Mobility, Perception and Payloads



**Customers:** PM-FCS (BCT), PEO-GCS/Robotic System JPO, Joint Ground Robotics Enterprise, PEO-CS/CSS, PM-TWV

## Existing Actions/Contracts for FY08:

- Safe Operations
- ARV Tactical Behaviors
- Convoy Safety
- Small Robot Technologies
- Warfighter Experiments



## Potential Competitive Solicitations for FY08/09:

- Complex Urban Operations
- IGS Research and Support

## Maturing UGV Safe Operations Technology through Integration and Test



*Detect, track, and avoid humans*



*Dismounted forces safety*



*Maintain lane among civilian traffic*



**Integrating FCS  
representative  
technologies**

### Integration:

- Gen 5 Autonomous Navigation System (ANS)
- Tactical Autonomous Combat – Chassis (TAC-C)
- ARL R-CTA developed algorithms

### Test & Experimentation:

- Address FCS Risk UGV0213
- MULE & ARV relevant scenarios

- Directly address risks associated with employing UGVs in dynamic environments.
- Identify additional risk areas of operating UGVs around moving traffic, pedestrians, and dismounted forces.

**Safe Robotic Operations**

**Increased  
OPTEMPO**

**Enhanced human/robot  
interaction & teaming**

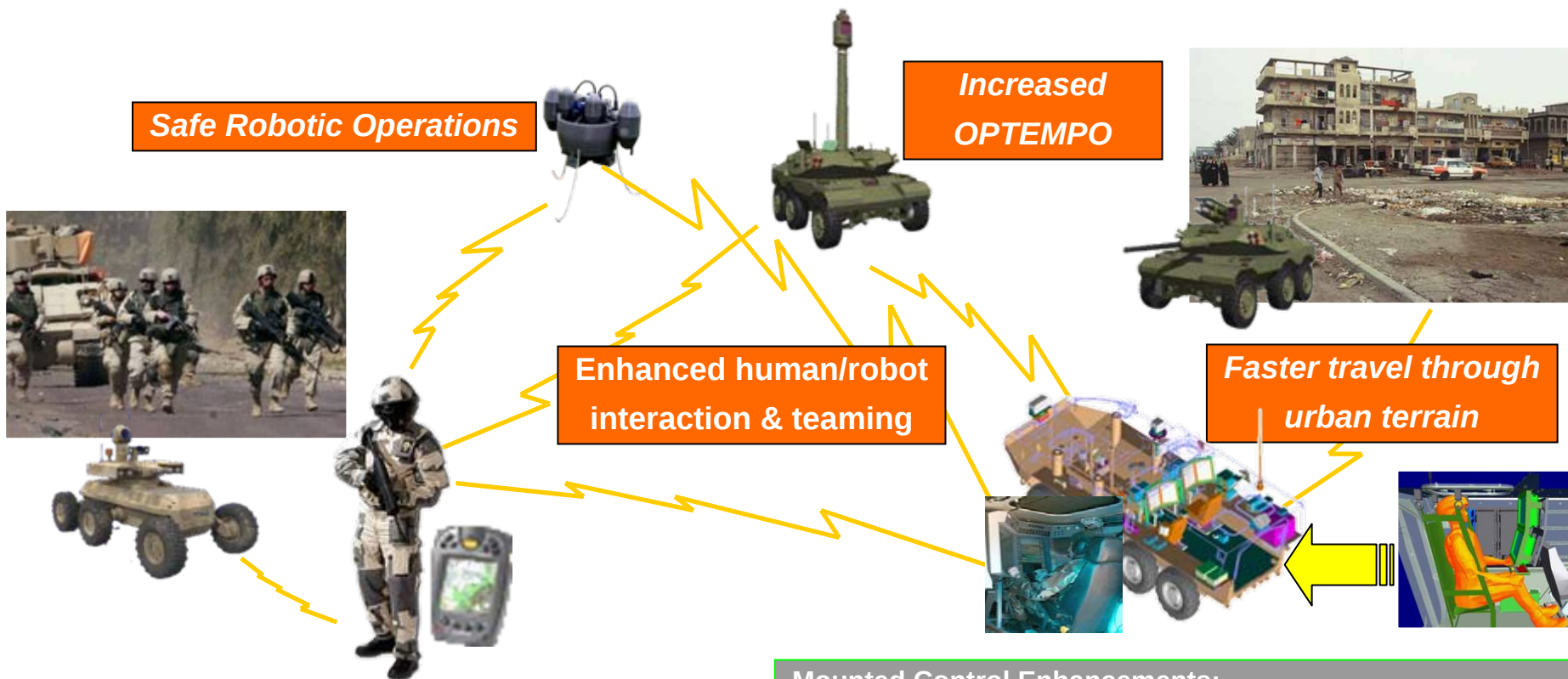
**Faster travel through  
urban terrain**

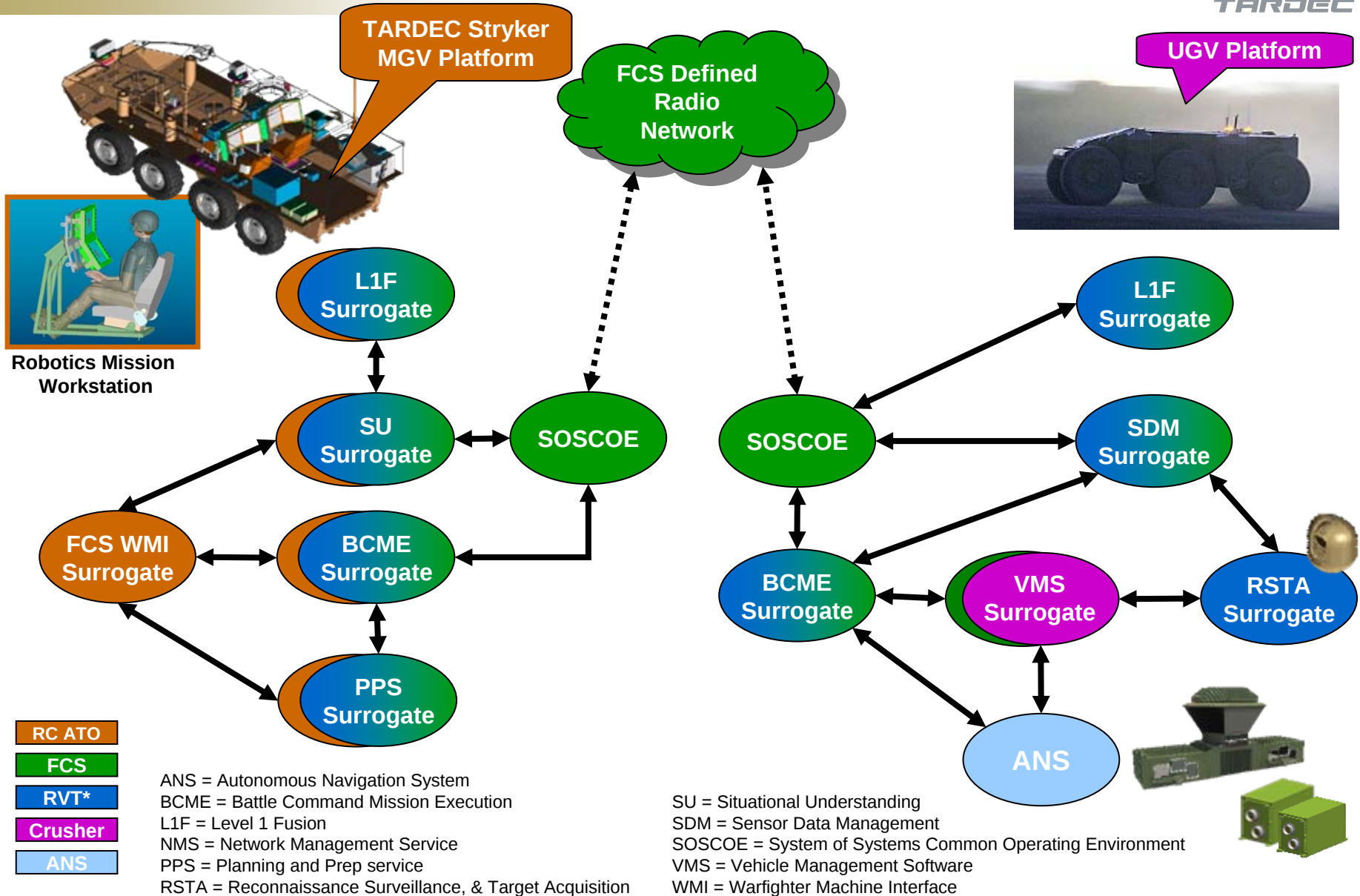
## Dismount Development and Integration:

- Dismounted UGV following
- Increased planning capability
- Enhanced robotic understanding through non-visual cues (tactile)

## Mounted Control Enhancements:

- Increased planning capability (replan and formations)
- Coordinated UAV/UGV operations for increased SA
- Soldier assists to autonomous capability during slow-downs and stoppages
- Better UV understanding for enhanced tele-operations

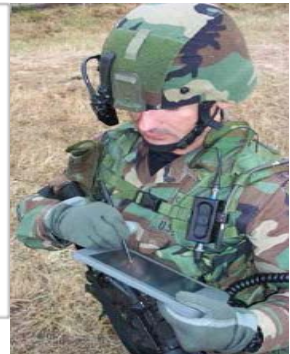
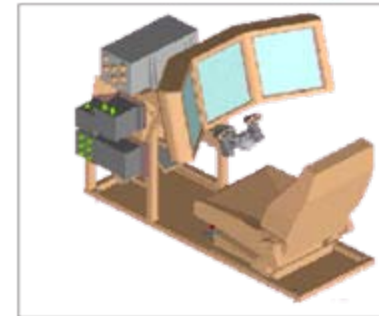






## Primary Efforts:

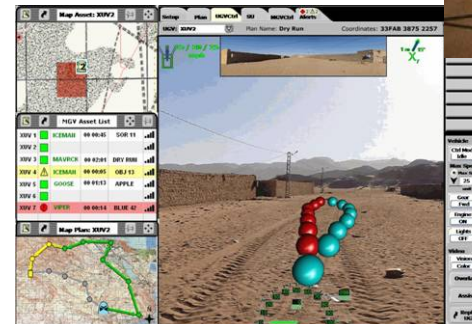
- Manned and Unmanned System Control
- Scalable Mounted and Dismounted
- Soldier-Machine Interfaces
- Intelligent Agents and Adaptive Automation
- Improved Local Situational Awareness and
- Mobility/Navigation
- 3D Map Visualization
- Indirect Vision Driving



**Customers: PM FCS (BCT), PEO GCS, PM MSI**

## Existing Actions/Contracts for FY08:

- Human Robot Control
- Intelligent Systems Simulation & Technology
- Colorized Ranging



**Potential Competitive Solicitations for FY08/09:**  
Secure Mobility

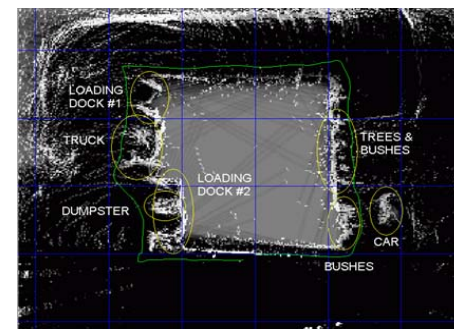
## Intrinsic Mobility



## Intelligent Mobility



Autonomous street following

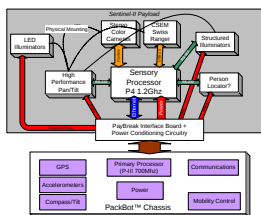


Autonomous perimeter following demonstration

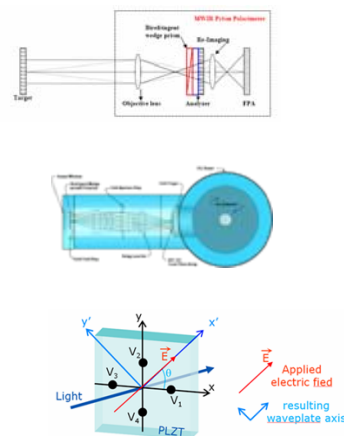
## Innovative Control



Sensor positioning for sub-vocal speech detection



## Advanced Sensors

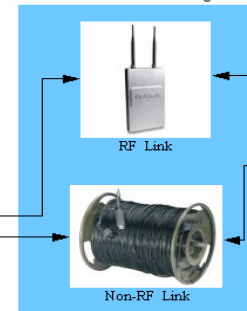


## Adaptive Payloads

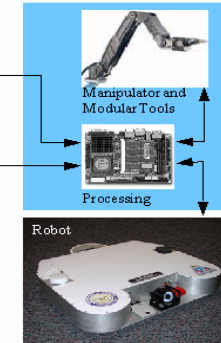
### Adaptive OCU and Controller



### Dual Communications Package



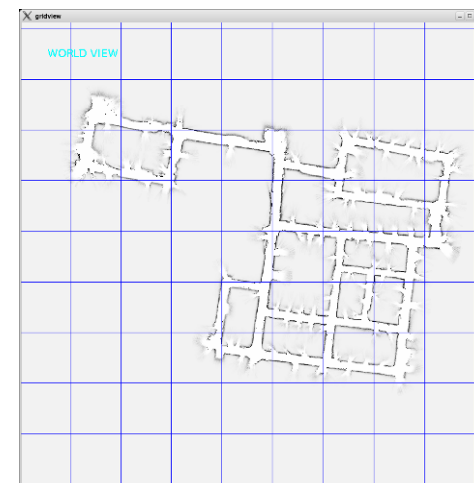
### Manipulator and Modular Tool Attachments



## Sentinel: A System for Command and Control of Small Tele-operated Robots

iRobot

POC: Robert Karlsen

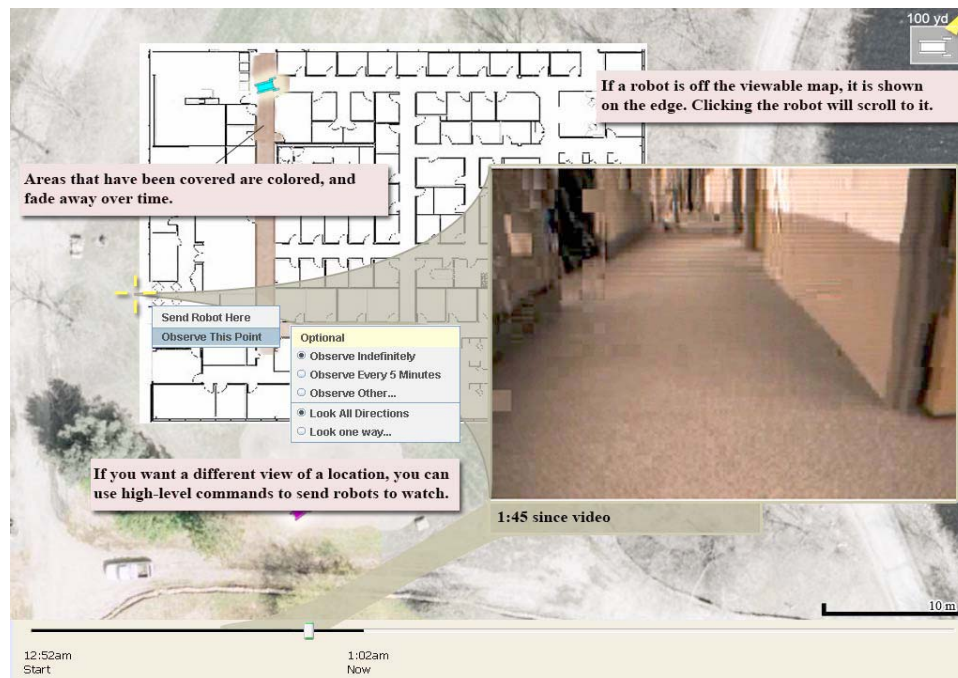


- Dynamic camera selection
- Tele-operated control of robot teams
- Semi-autonomous control of robot teams including local waypoints and leader-follower behaviors
- Fully-autonomous control of robot teams including navigate to waypoint

- Variable autonomy levels based on current situational demands
- Mobile robot self-localization and mapping in indoor environments
- Path planning
- Obstacle avoidance and understanding



- Building breaching operation
- One operator & team of robots
  - Two or three robots scout corridors, around corners and in rooms
  - One follows to guard the area behind
- Autonomy allows control via a high-level map interface.
- Tele-operate any of the vehicles when necessary.



- Sentinel builds on the Wayfarer program
  - Autonomous travel down communications-denied urban streets
  - Gather video and map data and return to the operator
- Sentinel project is expanding to allow control of an R-Gator



Sentinel applied to control a USN 7-meter RHIB

- Joint ground/water operations
  - Remote transport of ground platforms via water
  - Landing on a beach
  - Deploying the ground systems for reconnaissance
- Harbor patrol with multiple USV platforms
  - Harbor mapping
  - Change detection
  - Ship security radius



# Robotic Convoy Concept

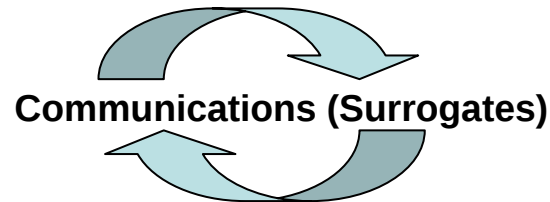


## Armored-C2 Leader Vehicle



- Manned or Unmanned Vehicle
- Single Crew Station (ANS Operator Can Teleop Follower; Initiate, Monitor, Terminate Ops)
- Leader or Follower Capability
- ANS Components
  - Perception Sensors
  - Computer System
  - GPS / INS

25m – 2000m  
Vehicle Spacing



- Leader Follower behavior
  - Lead Vehicle Provides GPS / INS Waypoints for Follower
  - Captures Sensor Data
  - Records vehicle status
- Teleoperation
  - Operator Provides Velocity / Steering Commands
  - Uses Compressed Video
- Surrogate Communication Network to Address Initial Bandwidth and Latency Considerations

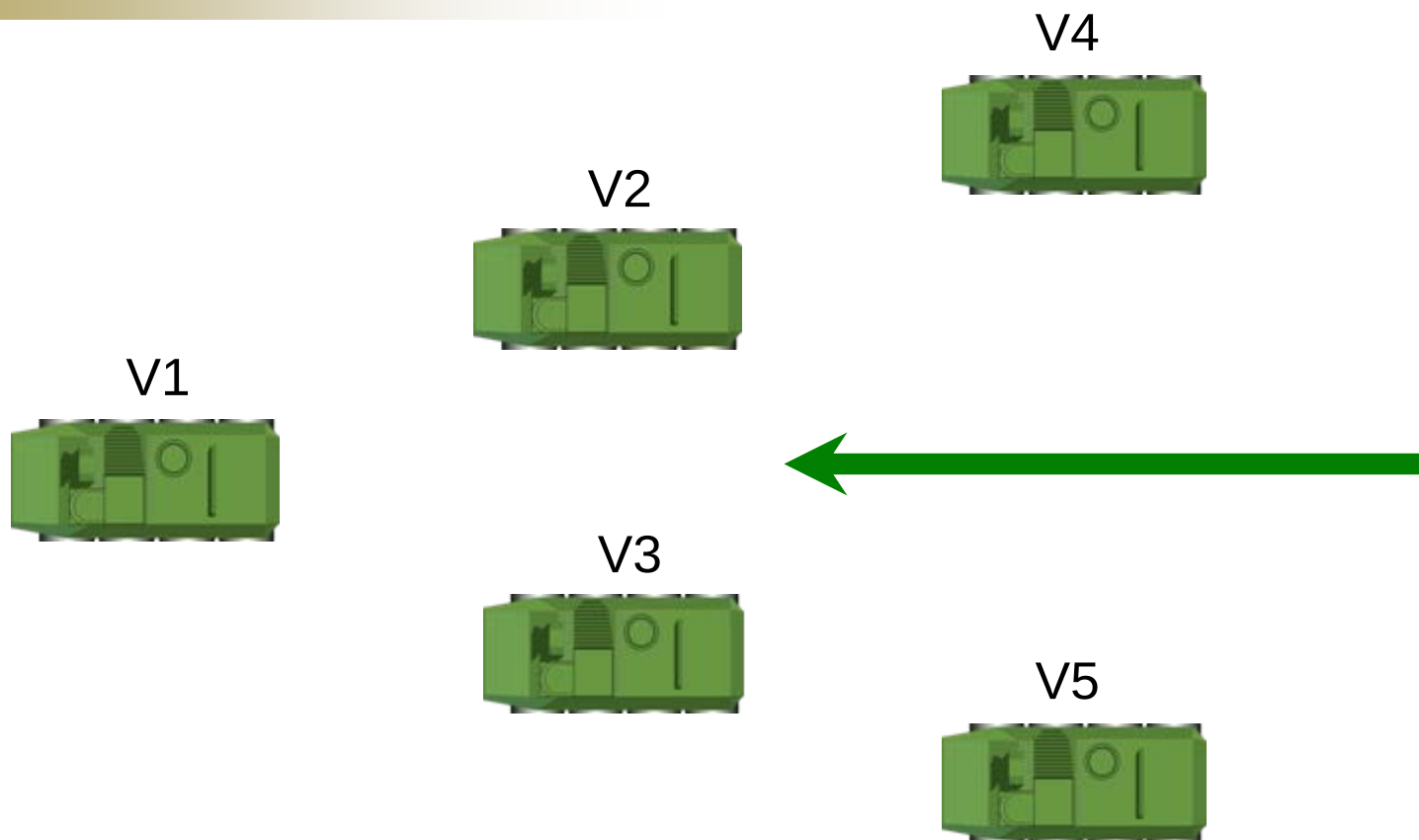
## Military Tactical Vehicles – Followers (FMTV 5.0 & 2.5 Ton)



- Autonomous Navigation
  - Safety Operator in Each Vehicle
  - 2 to 4 Vehicles Follow the Lead Vehicle in Various “Formations”
- ANS System Navigates
- Communication System
- Leader Follower Capability
- ANS Components
  - Perception sensors
  - Computer system
  - GPS / INS



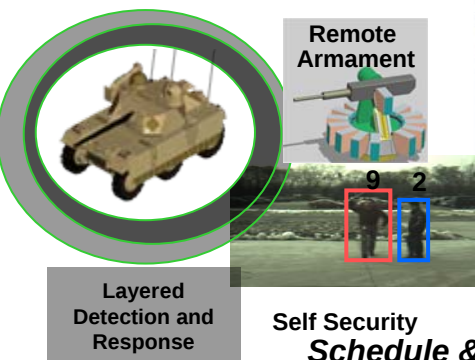
- Automate two 5 ton FMTV trucks to perform autonomous vehicle following
- Joint Project with PM CS/CSS
- Goal is low cost robotic convoy capability
- Supports manned driver automation for manned convoys
- On- and off- road operations
- Field Testing in November 06



- Echelon Formation Used in Open Terrain
- Operator Control Unit Located in Any Vehicle or on the Ground
- Formations Will Vary With Terrain and Experimentation Needs
- A Formation is Defined by Following Distance, Lateral Offset, and Speed

# Near Autonomous Unmanned Systems (NAUS)

## Autonomous Mobility



Tactical Behaviors

Self Security  
Schedule & Cost

## Purpose:

*Develop and demonstrate key robotics technologies to reduce risk for PM FCS (BCT) and increase the utility of future unmanned systems.*

## Product:

- *Near-autonomous maneuver in environments relevant to FCS*
- *Validated tactical behavior methodology and integrated tactical behaviors*
- *System self security – fundamental technology for detection & tracking, and integration of weapon station*

## Payoff:

- *Unmanned systems able to meet FCS threshold operational requirements*
- *Reduced burden on soldier & network*
- *Unmanned systems with greater survivability*

| <div>Layered Detection and Response</div> <div>MILESTONE</div> | FY06 | FY07 | FY08 | FY09 |
|----------------------------------------------------------------|------|------|------|------|
| Longer range, higher resolution perception (ARL)               |      |      |      |      |
| Personnel & vehicle detection & avoidance (ARL)                |      |      |      |      |
| Tactical Behaviors (ARL/TARDEC)                                |      |      |      |      |
| System self security (TARDEC)                                  |      |      |      |      |
| Remote weapon station (ARDEC)                                  |      |      |      |      |
| Integrated reduced workload human interface (ARL)              |      |      |      |      |
| Autonomous unmanned vehicle field exercises (ARL)              | ▲    | ▲    | ▲    | ▲    |
| Conduct development trials (TARDEC)                            |      |      | 5    | 6    |
|                                                                |      |      |      |      |

- \* Vehicle
- \*\* Squad
- \*\*\* Platoon

## Past

Leveraged Core Behaviors \*  
from CAT ATD

Fixed Formations \*\*

System Self Security \*

- Detect / Classify threat tracks
- Recommend Response
- User executes the response

## Current

Dynamic Formations \*\*

- Enter/Exit Formation
- Contact Drills
- GPS based localization

System Self Security \*

- Autonomous Response
- Rules of Engagement
- Threat Pre-emption
- Response Resource Mgmt.
- Threat Track Consolidation

## Future

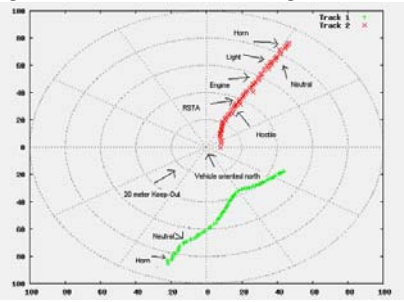
Reactive Formations \*\*\*

- "Beyond GPS" based localization
- Action Drills (Action left/right)
- Manage COM Loss

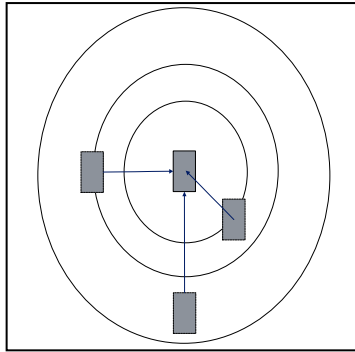
System Self Security \*

- Vision based Intent Classification
- Threat cluster detection
- Multi-system tracks consolidation
- Intrusion detection on-the-move
- On-the-move detection and response

## System Self Security

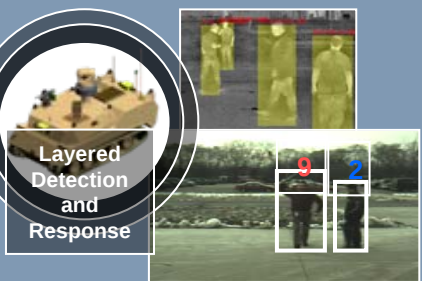
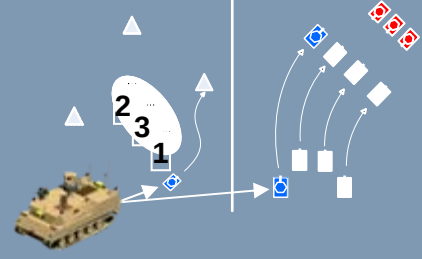


## Tactical Formations



September 2008

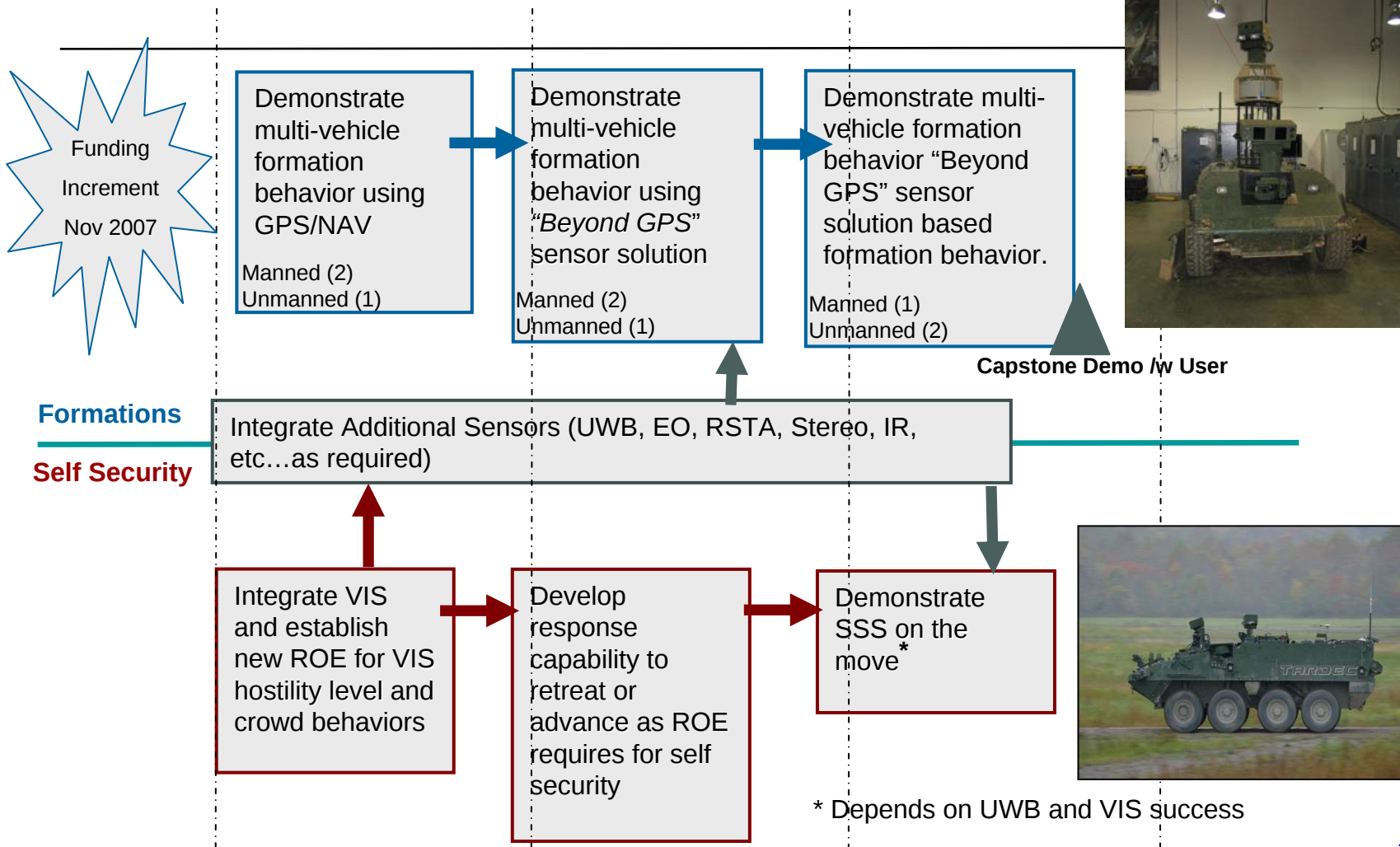
## CAPSTONE DEMO w/ USERS



# Program Exit Criteria Elements



|                                                                                 |
|---------------------------------------------------------------------------------|
| \                                                                               |
| <u>Move in Formation (<i>Flat terrain</i>)</u>                                  |
| <b>Max Deviation Separation Distance (<i>heading rate is +/- 3 deg/sec</i>)</b> |
| <b>Average Speed (<i>Meters/Seconds</i>)</b>                                    |
| <b>Interventions (<i>Qty.</i>)</b>                                              |
| <u>System Self Security (<i>sTarget/mTarget</i>)</u>                            |
| <b>Probability of true positive detection (<i>% of time</i>)</b>                |
| <b>Probability of false positive detection (<i>% of time</i>)</b>               |
| <b>Avg ID Time (<i>Seconds</i>)</b>                                             |
| <b>Range (<i>Meters</i>)</b>                                                    |



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