



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

TARDEC Ground Vehicle Robotics

Overview Briefing for OESA

10 May 2012

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**Requirement
s**

Concepts

Analysis

**Component
Development**

**Component
Testing**

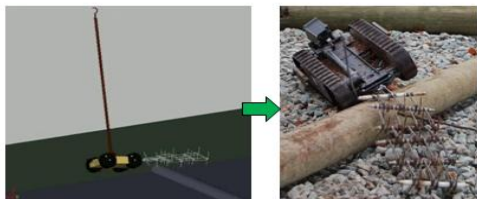
**System
Integration**

**Virtual Proving
Ground**

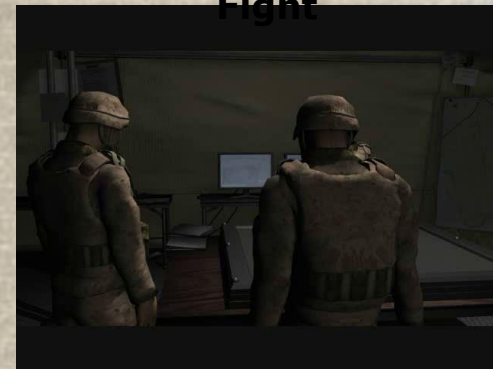
**Vehicle
Testing/Demo**

Supporting the Current

Concepts → M&S → OEF/OIF



Enabling the Future Fight



Pointman-Alpha



Mini Ripsaw

Pointman-Bravo

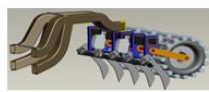


HDT Platform with Flail

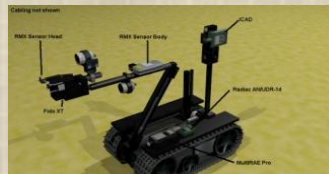
Pointman-Charlie



Seaway RMP



TARDEC Countermine Roller



2004

162 systems

- No single vendor could produce 162
- 5 vendors, multiple configurations
- Joint effort, EOD focused

2005

1800 systems

- Robot's proven ability to save lives
- Expansion beyond EOD mission (Countermine, Security)
- Agreements with Rapid Equipping force (REF) and Army material Command (AMC)

2006

4000 systems

- Engineers and Infantry
- Route clearance, Explosive detection & development of robotic weapons payloads

2007

5000 systems

- Special Forces robot applications assessed
- Route clearance, Explosive detection & development of robotic weapons payloads (lethal and non-lethal)

2008

6000 systems

- Maneuver elements
- Range extension
- CBRNE detection
- Persistent surveillance
- More capable payloads

2009-12

Max 10,000 Systems (Current 4,000)

- Batteries – longer life, standardized
- OEF – Mobility
- Limited autonomy
- Weaponization
- Increased agility & dexterity
- Interoperability
- Collaboration

Sustain:

- + Trust and Confidence
- + Reduced Operator Workload
- + Expanded Missions

Improve:

- Modularity
- Reliability
- Interoperability
- Collaboration
- Autonomy

*beyond
tele-op*

Man-Transportable

Micro UGV



Packbot
FIDO



Mini EOD



SUGV



Vehicle-Transportable



MDARS



MTRS



MK3



Self-Transportable & Appliqué

M160 Light Flail



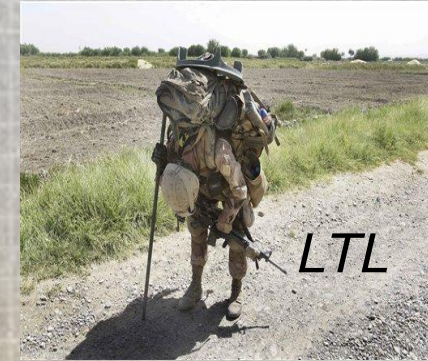
HMDS



SANDI



- Robotics benefits...
 - Robots can extend the reach of the soldier
 - Robots can reduce the load of the soldier
 - Robots can go into some dangerous places
 - Robots are better at doing some tasks
- The current realities of **'fielded'** mobile ground robotics...
 - Robots are mostly remotely controlled or tele-operated
 - Robots are difficult to control
 - Robots work best in benign, structured environments
 - Robots are slow and can't keep up with the operation tempo
 - Robots are expensive
 - Robots break down frequently
 - Robots that are 'intelligent' aren't fielded because we can't guarantee their behavior under all conditions
 - Some soldiers think robots will take their jobs**





Safe Ops
*'Rules of the Road', structured
environments*

APD
*Off-road mobility, unstructured
environments*



Increased Mobility and Operational Performance through Autonomous Technologies (IMOPAT)



Provide visual local situational awareness (LSA) thru electro-optic indirect vision (EOIV) technologies during manned and unmanned platform operations



Safe Ops of Unmanned Systems for Reconnaissance in Complex Environments (SOURCE)



Autonomous Mobility Appliqué System (AMAS) - JCTD

Problem Statement:

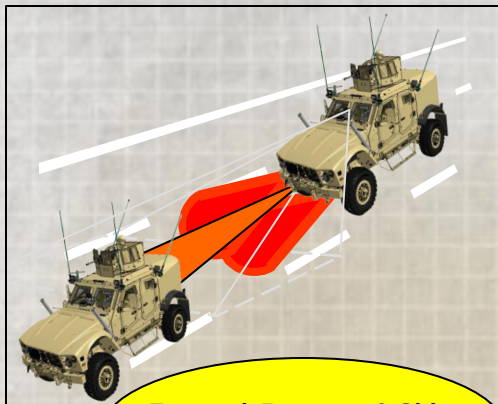
Soldiers in Small Units (squads/fire teams/crews) are physically overburdened, often carrying up to 130lbs; this degrades performance and may result in immediate, as well as, long term consequences.

Near term (FY17):

Reduce physical burden of Soldier and Small Unit, including the grenadier, SAW gunner and attached combat medic, so that load reduction of the carried weight equates to a percentage not exceeding 50% of individual's body weight across the central 90% of the male Soldier population.



OCP Active Safety Demonstrators (AMAS-Based Component Set)



Forward, Reverse, & Side
Pre-Crash Warning and
Collision Avoidance

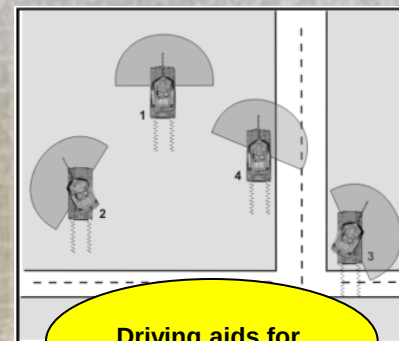


OCP Phase1

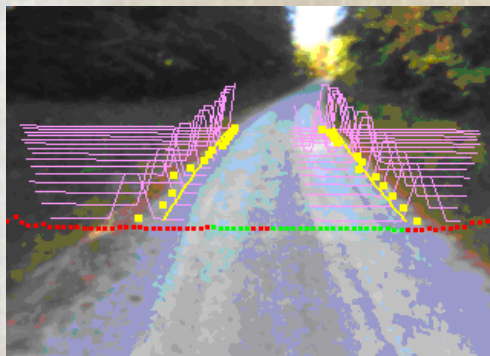


OCP Phase 2

360° Situational Awareness, Decreased Fatigue,
Decreased Collisions and Rollovers, and Improved
Vision under all Visibility Conditions.



Driving aids for
Improved Mobility



Unintended Roadway
Departure
Warning/Prevention



Improved SA and
operator workload
reduction



Motion Based Cueing for
Pop Up/Close-In
Target Detection



Provides SA to
Soldiers immediately
prior to dismount.



X-by-wire kit

Autonomy kit

Electronic
Architecture

Driving functions
only

2 modalities

Human in vehicle

(i.e. shared driving)

Human NOT in vehicle

(i.e. remotely operated)

invariant across all missions for OMV

Mission
Payloads

OMV can be driven by a soldier;
OMV can drive a soldier;
OMV can be remotely operated;
OMV can be autonomous



Manned Vehicles

Optionally Manned Vehicles

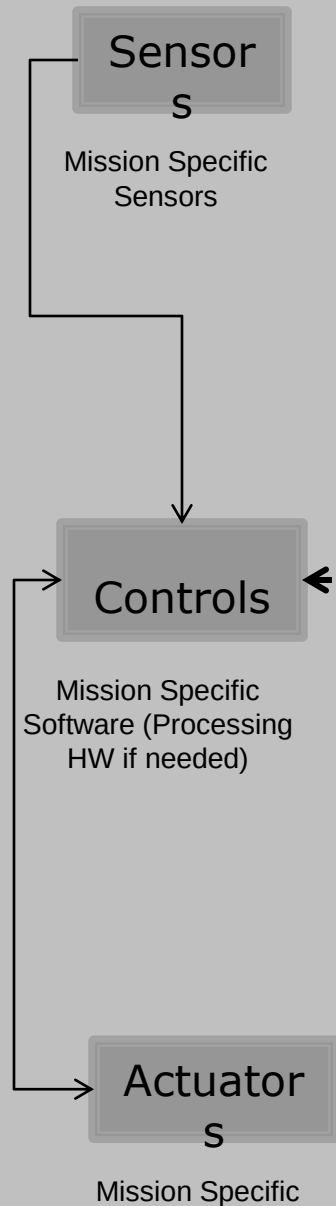


Unmanned Vehicles

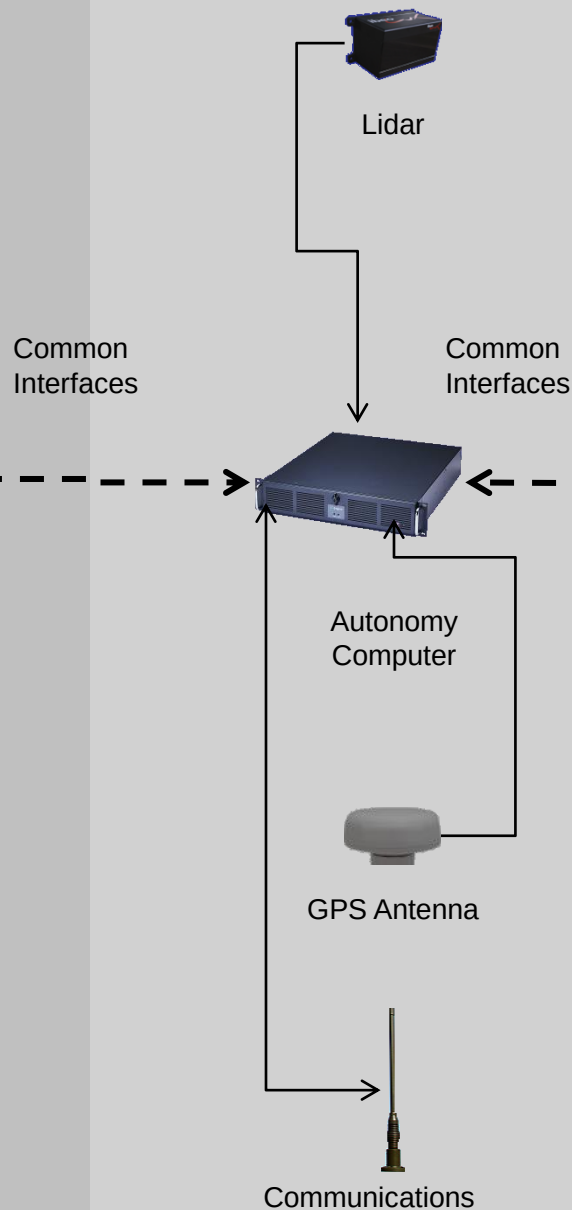
- Major accidents due to driver error
 - Very long convoy missions—10 to 14 hours
 - Difficult, unpaved, rugged terrain
 - Inexperienced drivers—age 18 & 19 years
 - Collision(Front & Rear), Rollover, Roadway Departure, etc.
- Susceptibility to attack by adversary
 - Asymmetric warfare
 - Improvised explosive devices (IEDs)
 - Coordinated threat attack



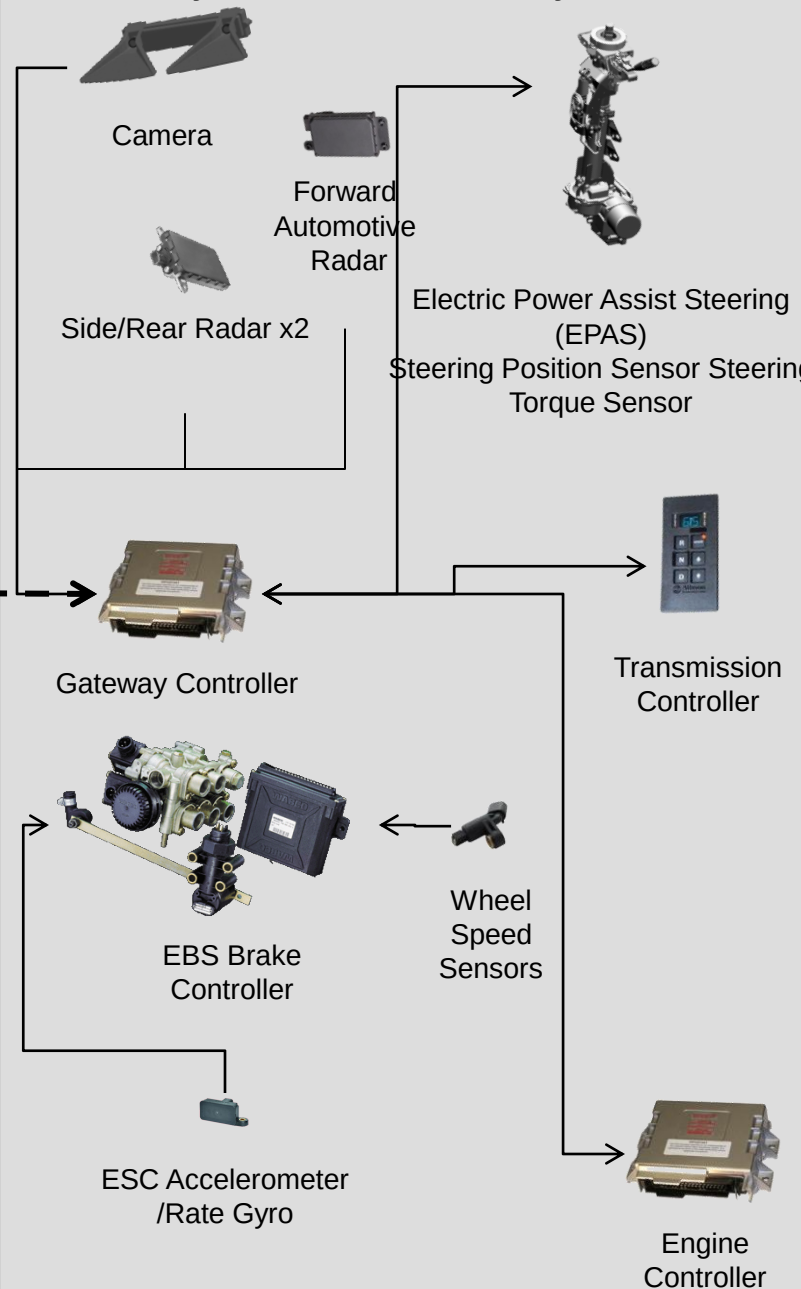
Mission Payload Kit



General Autonomy/Leader-Follower Kit



By-Wire/Active Safety Kit



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Mobility Disruptive Technology?

Increasing
Capabilities

State of the Art
Military Sensors (*i.e.* Lidars)

Technology can meet
requirements but
not business case

Technology can meet
requirements and
business case is positive

e.g. Google

Automotive Sensors
(CMOS Stereo Camera,
Single Chip Radar,
Low Cost Lidar)

Drive-By-Wire
(Electronically Controlled
Throttle, Trans, & Brakes,
Electric Steering Column)

Disruption?

Vehicle Drives

Human Drives

Fully
Autonomous
(Auto Pilot)

Highly
Automated
(Co-pilot)

Active Safety
Vehicle Controls

Safety
Warning
Systems

Driver Training;
Passive Safety
(e.g. Air Bags)

2000

Today

Future

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'Roboticizing' Manned Vehicles

Capability	Description	Man-Vehicle Tasks				Comments
System Off	Current fleet, no intelligence or additional external sensors		Info	Cntr	Rsp	All manned vehicles
		M	x	x	x	
		V				
Driver Warning	Additional sensors being added to monitor activity immediately around Vehicle. Info Task is shared		Info	Cntr	Rsp	Blind-side detectors, collision warning, roll-over warning, V2I and V2V
		M	x	x	x	
		V	x			
Driver Safety	By-wire hardware being added w/ additional sensing. Info task shared and Control task occasionally taken by Vehicle for safety reasons		Info	Cntr	Rsp	At this point, by-wire kit (brake, throttle, gear and steer) is integrated into the vehicle
		M	x	x	x	
		V	x	x		
Optionally Operated (Auto-Pilot)	Human still in vehicle but can 'willingly' give up control so that he/she can perform other tasks (autonomy kit first needed)		Info	Cntr	Rsp	Under certain conditions, 'distracted driving' is the preferred mode of operation
		M	x	x	x	
		V	x	x		
Optionally Manned	All of the previous capabilities plus the additional feature of the vehicle being operated w/o a driver present and a OCU (e.g. convoying, perimeter security)... AMAS-JCTD		Info	Cntr	Rsp	Includes emergency modes; Chaufer and Ambulance where I, C and R are Vehicle tasks
		M	x	x	x	
		V	x	x	x	

Nominal RG31



	I	C	R
M	x	x	x
V			

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RG31 with Driver Warning

Stereo Camera

Automotive Radar

Side Blind Zone Radar

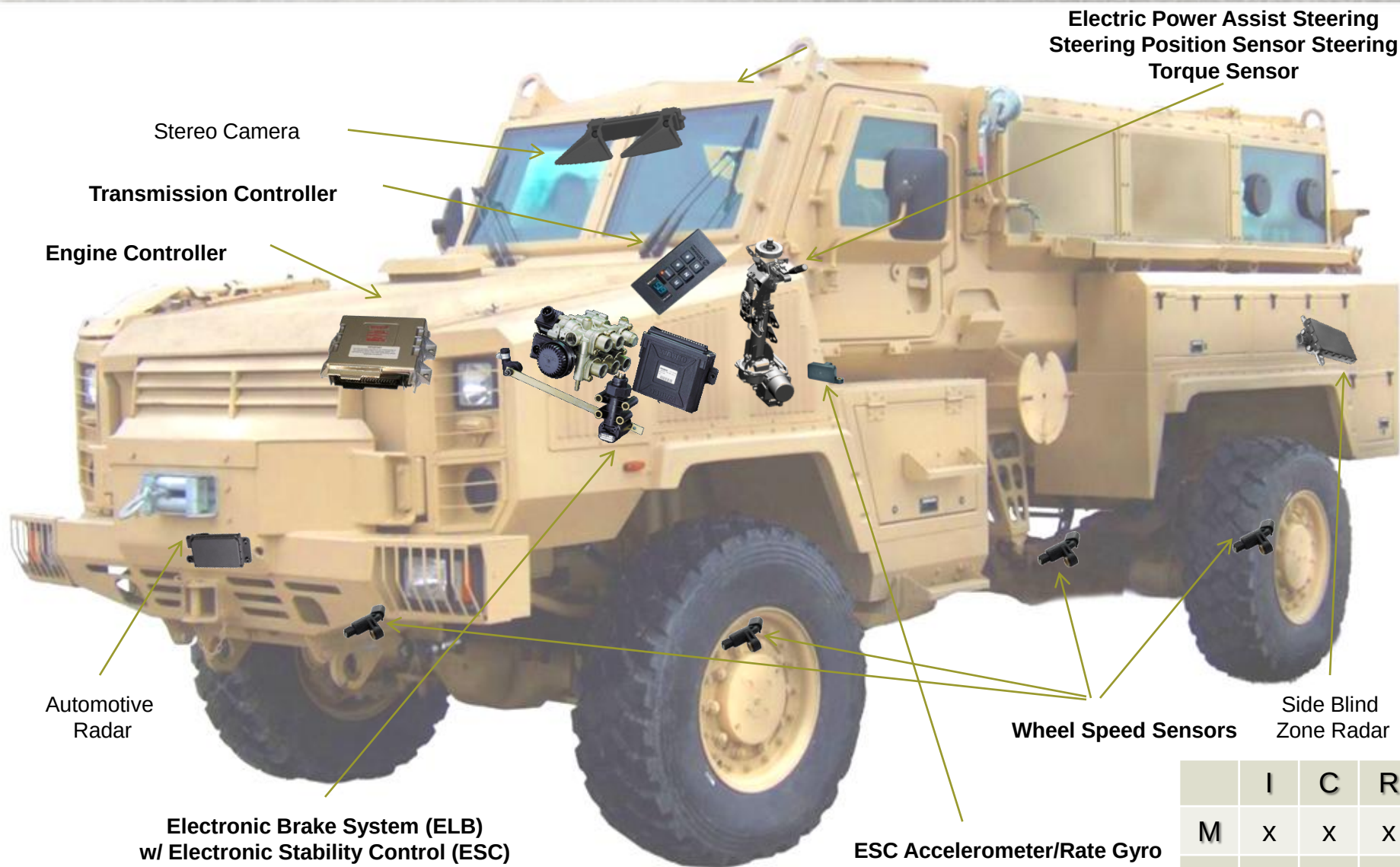


	I	C	R
M	x	x	x
V	x		

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RG31 with Active Safety

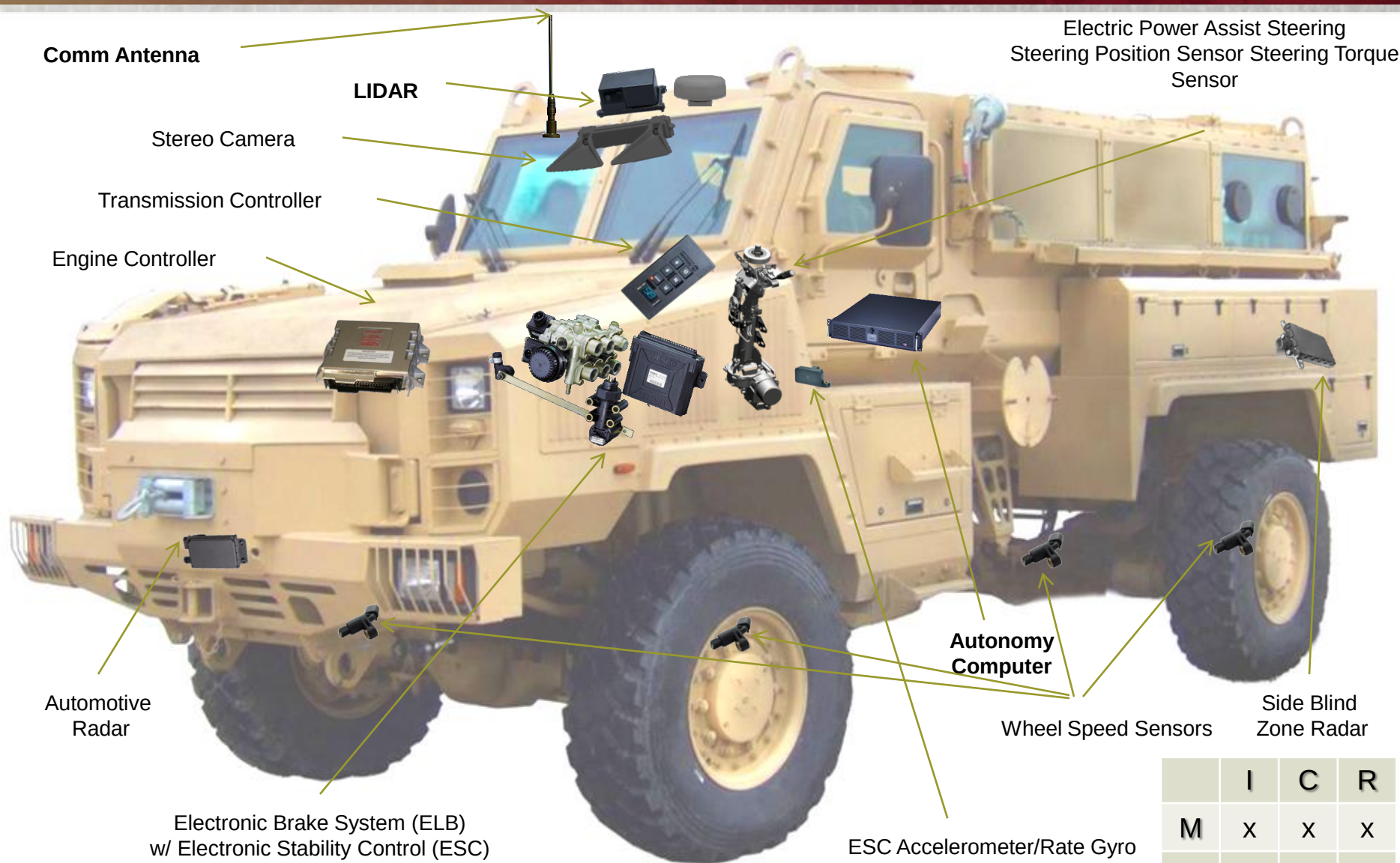


	I	C	R
M	x	x	x
V	x	x	

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RG31 – Optionally Operated

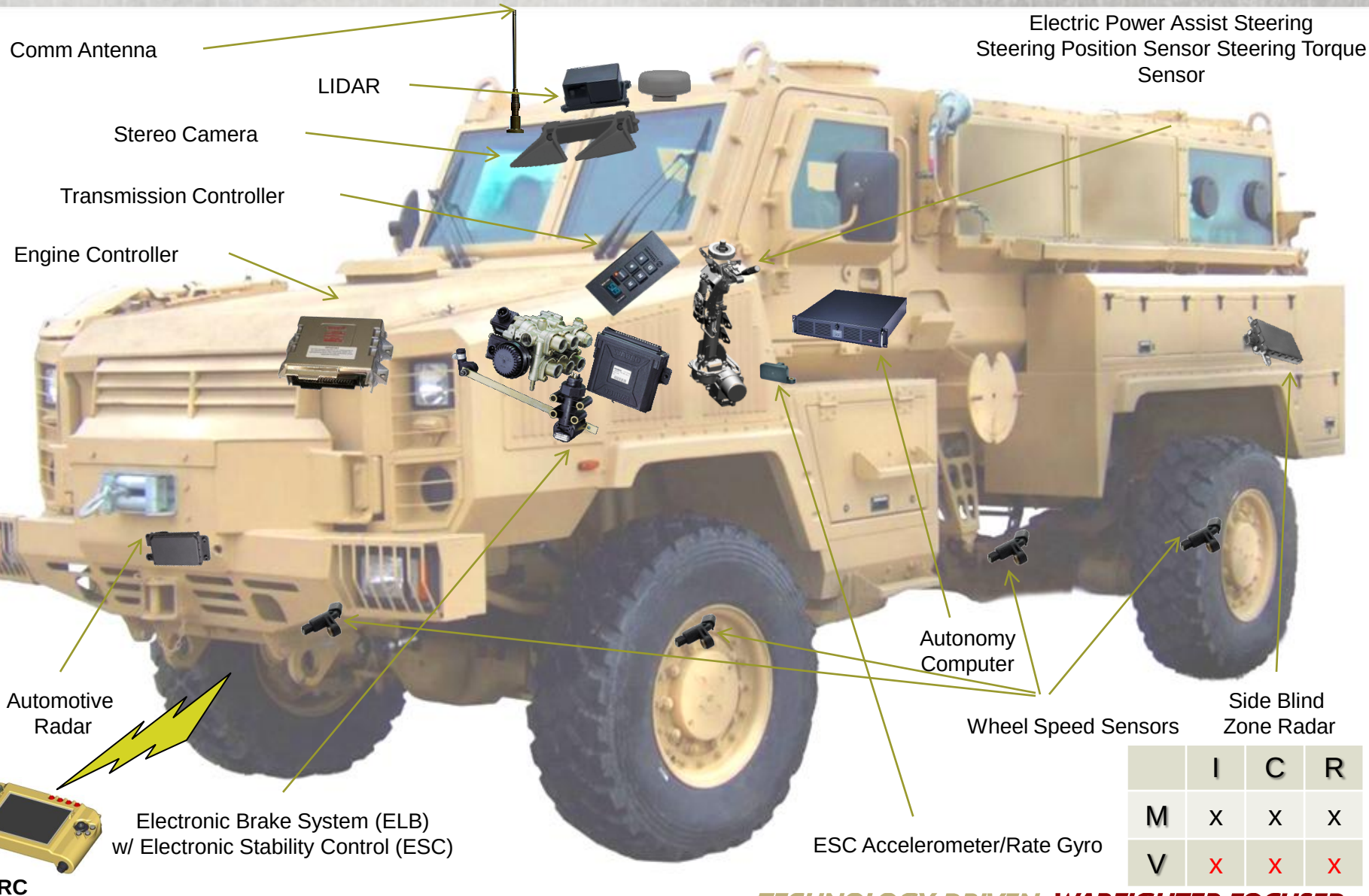


	I	C	R
M	X	X	X
V	X	X	

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RG31 – Optionally Manned



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UGV Risk Matrix



RISK Acceptance Levels per DODI 5000.02, 8 Dec 08 Risk Assessment Levels & Definitions per Tables A-I thru A-IV of MIL-STD 882D, 10 Feb 00				HAZARD SEVERITY				
		Specific Individual Item	Fleet or Inventory	Catastrophic	Critical	Marginal	Negligible	
				1	2	3	4	
HAZARD PROBABILITY	Frequent	Likely to occur often in the life of an item, with a probability of occurrence greater than 10 ⁻¹ in that life.	Continuously experienced	A	1-A HIGH AAE	2-A HIGH AAE	3-A SERIOUS PEO	4-A MEDIUM PM
	Probable	Will occur several times in the life of an item, with a probability of occurrence less than 10 ⁻¹ but greater than 10 ⁻² in that life	Will occur frequently	B	1-B HIGH AAE	2-B HIGH AAE	3-B SERIOUS PEO	4-B MEDIUM PM
	Occasional	Likely to occur some time in the life of an item, with a probability of occurrence less than 10 ⁻² but greater than 10 ⁻³ in that life	Will occur several times	C	1-C HIGH AAE	2-C SERIOUS PEO	3-C MEDIUM PM	4-C LOW PM
	Remote	Unlikely but possible to occur in the life of an item, with a probability of occurrence less than 10 ⁻³ but greater than 10 ⁻⁶ in that life	Unlikely, but can reasonably be expected to occur	D	1-D SERIOUS PEO	2-D MEDIUM PM	3-D MEDIUM PM	4-D LOW PM
	Improbable	So unlikely, it can be assumed occurrence may not be experienced, with a probability of occurrence less than 10 ⁻⁶ in that life	Unlikely to occur, but possible	E	1-E MEDIUM PM	2-E MEDIUM PM	3-E MEDIUM PM	4-E LOW PM

► Hazard Analysis and Risk Assignment

- ASIL (Automotive Safety Integrity Level)*

Severity		Exposure		Controllability	
S0	No injuries	E1	Very low probability	C0	Controllable in general
S1	Light and moderate injuries	E2	Low probability (<1%)	C1	Simply controllable (>99% of drivers)
S2	Severe injuries (survival probable)	E3	Medium probability (1%~10%)	C2	Normally controllable (>90% of drivers)
S3	Life-threatening injuries	E4	High probability (>10%)	C3	Difficult to control (<90% of drivers)

S	E	C		
		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	ASIL A
	E4	QM	ASIL A	ASIL B
S2	E1	QM	QM	QM
	E2	QM	QM	ASIL A
	E3	QM	ASIL A	ASIL B
	E4	ASIL A	ASIL B	ASIL C
S3	E1	QM	QM	ASIL A
	E2	QM	ASIL A	ASIL B
	E3	ASIL A	ASIL B	ASIL C
	E4	ASIL B	ASIL C	ASIL D

SAE International™

* From ISO 26262

PAPER #2011-01-2357

• ENVIRONMENT...

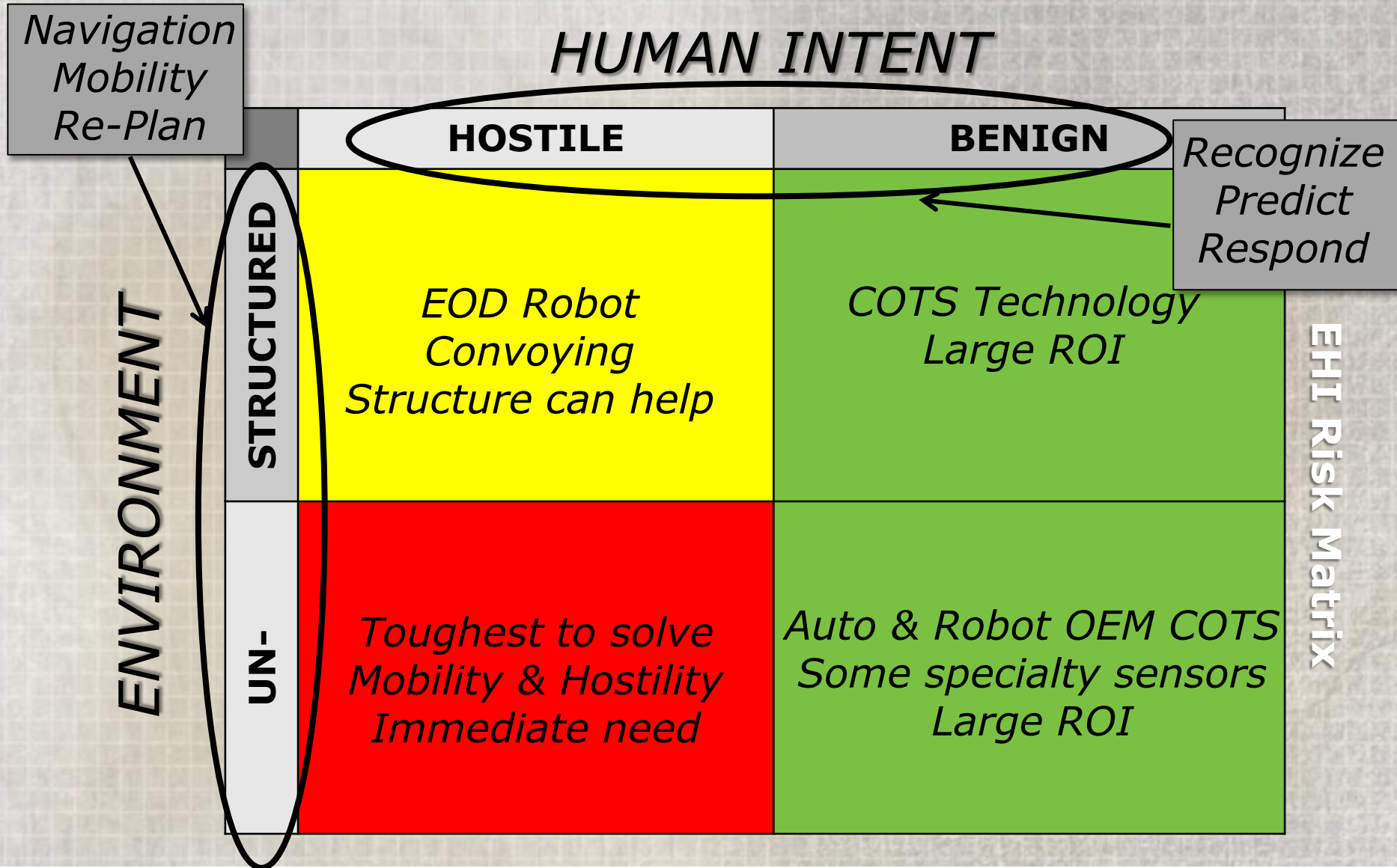
- **Structured** vs. **Un-Structured**
- Structured includes road-ways, upright buildings, military bases
- Un-structured includes x-country, rubble, dense forest/jungle, snow, rain, fog,...
- In general, no roads/hallways = un-structured
- Radiation, deep ocean, deep space, etc...



• HUMAN INTENT...

- **Benign** vs. **Hostile**
- Benign; Humans generally don't mean to do intentional harm
- Generally follow the 'rules of the road'
- Stupid behavior
- Hostile; Humans intend to inflict mayhem
- Humans don't generally follow the 'rules of the road'
- Legacy or Live engagements
- *Identify/Recognize/Response hierarchy*





Recognize
Predict
Respond

HUMAN INTENT

ENVIRONMENT

	HOSTILE	BENIGN
STRUCTURED	• Convoying (fuel/H₂O) • Convoying (maneuver) • Base security • Check point inspection • EOD • C-IED/Route Clearance • Persistent surveillance	• Convoying (e.g. CONUS) • Logistics warehousing • Sea-basing • Transportation • Base security
UN-	• Disaster Clean-Up • Engineering • EOD • C-IED • RSTA • Persistent surveillance • Wingman	• Range clearance • Soldier training • Decoys • Mining • Natural disasters (e.g. Hurricane Katrina) • Rescue robotics

COTS Technology
Large ROI

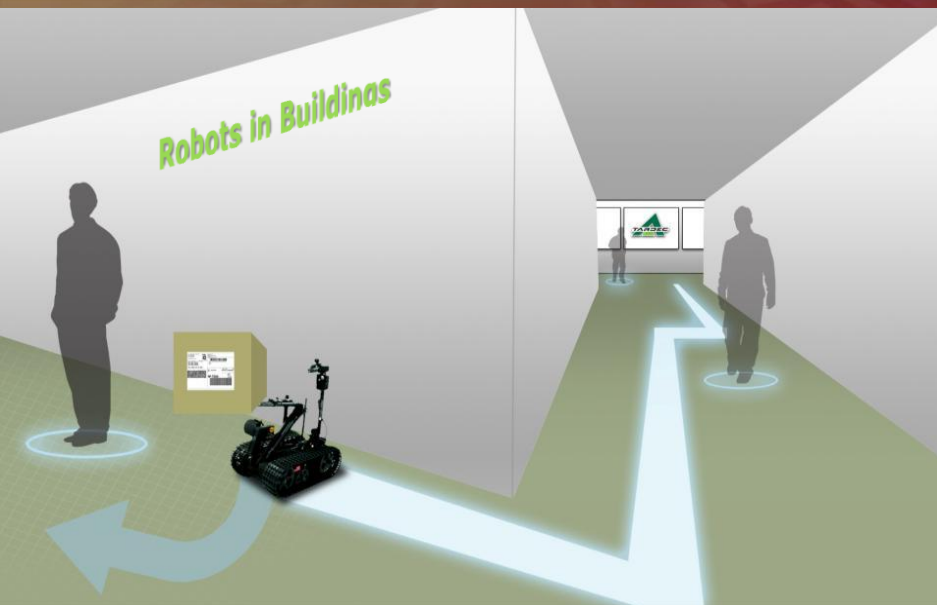
EHI Risk Matrix

Current Missions in **BOLD**

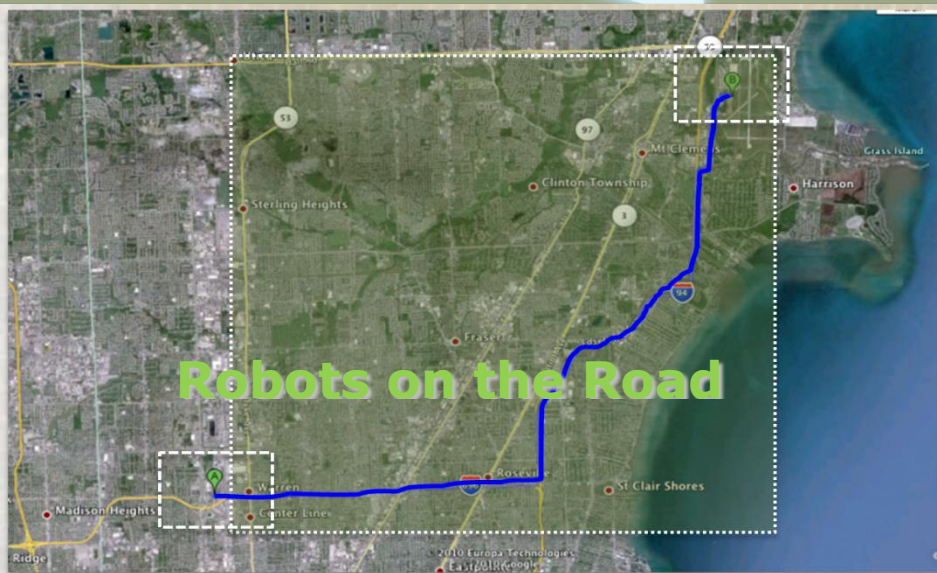
OCUSED.



Robots in Buildings



Robots on Post



Robots on the Road

ARIBO

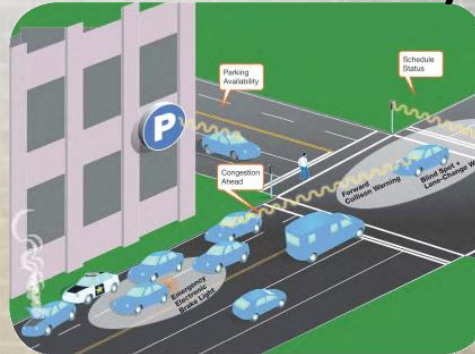
Autonomous Robotics for Installation & Base Operations

- Transportation
- Protection
- Logistics



Automotive Safety Sensors

Automotive Industry



Wireless V-to-X
communications



Automatic Platooning
Systems

Computer Industry



New Sensor Designs



High Performance GPUs



New Players in Autonomy



Questions?



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