Military Unmanned Ground Vehicles

International Development Activities

Nicholas S.J. Karvonides
Institute for Defense Analyses (IDA)
Alexandria, VA

NDIA Ground Robotics Capabilities Conference & Exhibition
San Antonio, TX

March 2008
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- NATO-US & International UGV Technology Standards
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Introduction
NATO & International UGV R&D Activities
NATO RTO R&D Activities

Unmanned systems are prevalent in numerous NATO R&D activities as both the focus of R&D topics (platforms) or as a subset of other topics (ISR)
-- However, attention to UAVs far outpace attention to UGVs

Nonetheless, R&D efforts in both areas above provide insights into foreign military UGV capabilities & R&D activities while identifying key participants

Background: NATO's Research & Technology Organization (RTO) promotes cooperative R&D & S&T exchanges among 26 nations & 38 partner countries
-- Largest international collaborative body, 3,000 subject matter experts (SMEs)

RTO operates by “organizing studies, workshops, symposia & other forums” through Working Groups (WGs) from RTO’s 6 Technology Panels (TPs):

- Applied Vehicles
- Human Factors & Medicine
- System Analysis
- Systems Concepts & Integration
- Information Systems
- Sensors - Electronics

RTO generally does not fund R&D (e.g. grants, contracts) nor does RTO typically initiate cooperative R&D ventures (e.g. CRADAs)
-- RTO mostly supports (NATO-only) symposiums (50 - 100 SMEs) & joint analytic projects of small (~12 SMEs) study groups (SGs) -- (~45 SGs total)
A initial review of 6 NATO RTO TPs & quick scan of related TP SGs, show UxVs & related technologies were popular subjects & many aspects are addressed by numerous TPs

Surprisingly, there does not exist an individual NATO RTO TP on UxVs in general or UGVs specifically

UxVs & UGV TP activities seem more focused on new technology developments vs. expanded application of existing technology to broader warfighter capability needs (e.g. CONOPS, TTPs, DOTMLPF)

Numerous UxVs & UGV R&D activities are currently underway or recently concluded among NATO’s 6 TPs & various WGs
One (multi-phase) WG of particular note (2001 through December 2007) was the Information Systems TP’s (IST) Research Task Groups (RTGs) on:

[1] “Multi-Robot Systems in Military Domains” (IST-032 / RTG-014) &

-- Maintained a long-term focus & emphasis on UGVs (vs. other UxVs)
-- Undertook unique efforts (2004 - 2005) to forecast military UGV capability needs, warfighter requirements & UGV technology-industrial base capacity
-- Related results where used to identifying near-term military capability “gaps” & “gaps” in future technology-industrial base capacity (2004 - 2008)
-- Outcomes included the development of requirements analyses & notional technology roadmap as well as identification of UGV R&D investment priorities

RTG activities concluded in December 2007 & a final report is due in 2008
### NATO RTG UGV 2004-2008 Roadmap Exercise Needs, Requirements & Technology Gaps

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<tr>
<th>Military Capability Needs</th>
<th>Military Requirements</th>
<th>Technology Gaps</th>
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<tr>
<td>Reconnaissance and surveillance for tactical support for forces on the ground including NBC</td>
<td>Communications (COMS): mobile, wireless ad-hoc, high ranges / rates, multipoint, QoS compliant, prioritize data, secure, network availability adjustable</td>
<td>COMS system should meet requirements but current tech does not support all requirements at same time</td>
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<td>De-mining (tactical-post-conflict) clearing roads, fields (anti-tank/anti-personnel).</td>
<td>Platform mobility, ruggedness, EMP shielded, low manning burden, modular concepts, greater standardization (power, connectors)</td>
<td>Platform SOA power cells, efficient motor drive / power train, refined transition / suspension, lower mass / armored, lower workload, EMC hardening</td>
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<td>Convoying, transport of goods</td>
<td>Sensing &amp; World Modeling (S&amp;WM): World modeling for navigation &amp; mission execution, high on-board processing capacity &amp; information</td>
<td>S&amp;WM: multi-sensor suite fusion - more robust world view, obstacle avoidance, terrain modeling, UXO/OED &amp; NBC sensors, environmental mapping, sensor fusion, object detect-recognition</td>
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<td>Inspect vehicles and people for explosives and weapons at checkpoints.</td>
<td>Navigation &amp; Mission Planning (N&amp;MS): Mission planning, path planning and navigation; sensor information distribution and distributed behavior communication and coordination (e.g. JAUS)</td>
<td>MRS: multi robot interaction different-same tasks, collaborative tasks, autonomously divide a task, cooperative perception, autonomously manage-prioritize</td>
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<td>Carry equipment for dismounted soldier</td>
<td>Multi-Robot Systems (MRS): workload sharing, distributed sensing, cooperative-collaborative behavior, fully distributive / hierarchical control</td>
<td>N&amp;MS: autonomous road following, mixed traffic, moving in tactical behavior, follow the leader</td>
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<td>Human Robot Interaction (HRI): Upgrade from continuous manual remote controlled to supervised autonomous</td>
<td>HRI: &lt;50% workload simple terrain / &lt;75% difficult terrain, execution plan in advance of maneuver, wearable interface, evaluate performance measures, improved ergonomics, common interface</td>
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NATO RTG Roadmap Exercise Observations

- Said to be the first effort of its kinds (likely regarding a multi-national military UGV “requirements development & technology roadmapping” initiative)

- Interesting note about importance of standards & reference to JAUS

- Nevertheless, self-assessed need for broader involvement of NATO military & warfighter inputs concerning UGV CONOPS, TTPs & DOTMLPHF issues

- No apparent references found about counter-IED needs (vs. possibly more conventional de-mining applications) or counter-sniper / counter-mortar

- No needs identified specific to the weaponization of UGVs (possible ethical concern) & limited reference to target acquisition for precision weapons

- No reference found concerning application of lessons-learned relative to UGVs & OEF / OIF or those specific to urban reconnaissance-surveillance needs

- Finally, detailed mention was observed concerning opportunities for UGV experimentation & simulation of future military UGV CONOPS & TTPs

- Overall, this RTG exercise seems to be an impressive & novel effort between NATO militaries, defense firms & research organizations
Recommendation for multi-nation military UGV R&D investment campaign & increased warfighter customer & requirements community participation

“A problem is that military users are interested in UGVs but have to consolidate funding” & “current research is ad hoc & no real user pull”

Recommendation for a “European version of DARPA” & “lobbying for funding & defense research demands”
-- cooperation should come from military users (war fighters) from various countries” (2005)

Recently revealed (late 2007) the European Defense Agency (EDA), is taking on role to advance EU military UGV R&D & investment (next section)
- However, US-firms & DOD are generally restricted from EDA participation

Other RTG activities include close collaboration w/ European Robotics Network (EURON) illustrating value of commercial & academic innovation

RTG instrumental in the creation of the newly established (2006) European Robotic Trails (ELROB) to assess EU’s UGV state-of-the-art (next section)

NATO said to be forming new RTG to address deconflicting & harmonization of interoperability standards (e.g. JAUS vs. NATO STANAG) (next section)
Additional NATO RTO UGV-UxV R&D Activities

Information on additional NATO RTO UGV-UxV activities are listed below which provide useful insights into other international military UGV-UxV current capabilities, near-term R&D activities & key participants:


**SCI-144: Integration of Systems with Varying Levels of Autonomy** (2004 – 2007)
NATO-US & International UGV Technology Standards
International Standards & Harmonizing UxV Interoperability

Further UGV technology development & greater utilization face challenges:
- International barriers to accelerating innovation & faster technology transition
- Impediments to broader systems integration & increased interoperability

With rapidly changing technology, increasing globalization of manufacturing supply chains & internationally distributive product development
...internationally adopted standards are crucial to commercial, defense &
dual-use industrial base integration & increased competitiveness

Dynamic & unpredictable national security & homeland defense scenarios
...require fast-forming coalitions (locally & abroad), responsive net-centric
enabled systems & transformational military capabilities
...all are dependant on interoperability to communicate, coordinate & collaborate

Interoperability standards also support key UGV acquisition goals:
- Lower life cycle costs, faster development time & quicker product integration
- Open standards further support common interface for technology insertion
- Enable expansion of existing systems w/ additional (spiral-on) capabilities
DOD / SAE AS-4 “JAUS” Standard

- To facilitate greater interoperability of future US unmanned systems
  ...new standards were developed by DOD & industry

- DOD developed the Joint Architecture for Unmanned Systems (JAUS) as the interoperability standard for UGVs (Army in 1994, OSD in 2002)
  - Primarily for communications & data handling for UGV command & control
  - Applicable at the system level as well as subsystem & component level
  - Consistent with US Government (USG) policy DOD transitioned JAUS to the private sector & the international Society of Automotive Engineers (SAE AS-4)
  - DOD UGVs utilize JAUS as do Army UAVs & Unattended Ground Systems (UGS) for Future Combat System (FCS)
  - As UxVs proliferate with state-local authorities, so will the use of JAUS standard
  - For example, National Bomb Squad Commanders Advisory Board (NBSCAB) requires EOD robots to be JAUS-compliant when purchased w/ USG funds
NATO “STANAG 4586” Standard

- NATO established Standardization Agreement (STANAG) 4586 in 1996

- Following a NATO Industrial Advisory Group (NIAG) study on tactical UAV system interoperability

- 4586 supports a standard interface of the Unmanned Control Systems (UCS) for NATO UAV interoperability (established 2002)

- The goal is to support NATO “multinational UAV interoperability”

- Specific objective is “to provide a standard for three key interfaces”
  - Data Link Interface (DLI)
  - Command and Control Interface (CCI)
  - Human Control Interface (HCI)

- Applicable at the system level vs. the subsystem & component level
JAUS & STANAG evolved to the most common standards for unmanned systems

However, JAUS & STANAG are not fully interoperable:

- Among full UxV spectrum (all domains) as well as unmanned-manned systems

- Across DOD Services, NATO & coalition allies as well as state-local authorities

  - Example: NATO, US NAVY & AF UAVs use STANAG (plus Navy USVs & UUVs) which raises question of interoperability of UGVs in littoral & riverine environs

- In addition, DOD-NATO interoperability challenges exist w/ UAVs & STANAG

- Another twist: USG policy support of open industry standards & the goal of USG standards to “promote efficiency & economic competition”

  - Example, STANAG 4586 is NATO “UNCLASSIFIED” (but NATO-only) restricting access to many global suppliers & non-traditional innovators from non-NATO countries such as robotics industry leaders in Japan & South Korea

  - Could similarly conflict with civilian state-local authorities & their supplier base relative to USG technology transfer authorities & impeded interoperability of related commercial dual-use systems with military systems
Future J AUS VS. STANAG Questions-I ssues

- Unknown extent of the future use of J AUS vs. STANAG by foreign military UGVs vs. foreign law enforcement UGVs given they often share common equipment

- Foreign UGV manufacturers may often use proprietary standards
  - Example, U.K.-based, QinetiQ’s use of Common Interface Protocol (CIP)

- Foreign “home grown” standards possibly common as UGVs traditionally used locally in stand alone scenarios vs. systems-of-systems of international coalitions

- This will change as future teams of UxVs (& manned systems) evolve globally

- It may be likely that foreign UGV companies will develop future UGVs around J AUS in order to compete for export opportunities within the world’s largest J AUS-compliant defense & homeland security market

- Will US firms selling J AUS systems to DOD proliferate J AUS internationally through exports given US lead in military UGVs & defense exports overall

- With the flood of US & foreign STANAG-compliant UAVs (& quarter century lead & growing integration w/ other systems) …..is STANAG positioned for growth
According to DOD’s new Unmanned Systems Roadmap: US is engaged in working with nearly a dozen NATO countries on improving STANAG UAV interoperability.

Although no formal mechanism is in place between DOD and NATO on working through like kinds of interoperability challenges with JAUS -- current efforts between DOD and NATO on improving UAV interoperability with could serve as an effective entrée to harmonize JAUS & STANAG.

Recent news of a new effort getting underway in Europe with the possible creation of a NATO RTO Working Group on harmonizing standards across multiple UxV domains as well as between unmanned & manned systems.

Growing momentum exist for DOD & NATO to collaborate on harmonizing interoperability standards for UGVs as well as the full spectrum of UxVs across all domains.
NATO-EURON & European Robotic Trails (ELROB)
European Land-Robot Trial (ELROB)

- Annual field robotic demonstration of state-of-the-art (SOA) UGV capabilities for military & related civilian applications (est. 2006 & 2007)
  - sponsored by NATO RTG & European Robotics Network (EURON) & hosted by German MOD
  - goal is to stimulate European UGV innovation & expand industrial base
    .... by encouraging UGV cluster development & multi-country collaboration as well as leveraging R&D investment & increasing market awareness & demand

ELROB first hosted 20 European teams from 5 countries in Germany (2006)
- 600 spectators from 19 countries
- military scenarios in both urban & non-urban environments
- focused on vehicle mobility & reconnaissance-surveillance applications

ELROB is considered a one-of-kind window into Europe’s SOA UGV capabilities

ELROB excludes direct US firm participation although EU-based US subsidiaries (or potential EU teaming possibilities) may possibly enable US involvement
-- non-EU observers are welcomed to attend
EU-EDA & International UGV R&D Activities
European Defense Agency (EDA) Multi-Government Military UGV R&D Initiatives

EDA created in mid-2004 as an agency of the European Union (EU) & governed by Ministries of Defense (MODs) of 26 participating EU states

Objective: Increase shared-use of military equipment between EU member nations & support of multi-country defense industrial base collaboration & R&D partnerships

Goal: Increase cost-effectiveness & affordability of equipping EU armed forces while strengthening the international competitiveness of EU’s defense technology-industrial base

First of 4 EDA initiatives in 2005 included development of an Armored Fighting Vehicle (AFV) Roadmap & 2 associated feasibility studies (Networked Enabled AFVs & Unmanned Ground Tactical Vehicles)

Feasibility studies resulted in recent launch of 3 military UGV R&D programs in late 2007 & subsequent start of a 4th UGV program in December 2007

Combined level-of-effort (LOE) of 4 UGV R&D programs initially ~$30M USD

Non-European country MODs & companies are generally excluded from directly participating in EDA R&D programs
EDA Military UGV R&D Program 1: “Semi Autonomous UGV” (SAM)

Scope to included identification of:
- Existing, state-of-the-art (SOA) UGV systems & subsystem technology & industrial base capabilities of EDA countries
- UGV military capability gaps (primarily reconnaissance missions)
- Corresponding UGV & subsystem R&D development projects
- Latter will be used to formulate follow on UGV integrated development teams

Applications aimed at UGV missions for patrolling, counter-IED & CBRN

EDA German MOD Leads Program
Industry Participation: Germany (Rheinmetall and Diehl BGT), Spain, France (Thales and Canberra Eurisys), Italy (Galileo Avionica) & UK (BAE Air Systems)

Level of Effort (LOE): 4 years with 10M - 12M Euros (up to ~$17.5M USD)
EDA Military UGV R&D Program 2: “Use Robotics” (UGV)

- Program scope to include:
  - Develop generic “demonstration system” for UGV convoy applications
  - Likely intended platform(s) will be an existing “manned” vehicles
  - R&D program aim is to develop a UGV “modular conversion kit”
  - Various vehicles targeted in “several tons” class & upto 10 to 12 tons
  - Vehicles to operate in different environments & road conditions
  - Allow remote operator to supervise mission & take control when needed

EDA Italian MOD Leads Program

Industry Participation: Italy (CIO Consorzio Iveco - Oto Melara), Germany (Rheinmetall and Diehl), Greece (Hellenic Aerospace Industry), Spain (Espelsa), Finland (Patria Group), France (Thales), Poland (Edisoft), Portugal & (possibly), Cyprus

LOE: 4 year, phase one 9 mo., 1.2M Euros - 1.4M Euros (~$2.07M USD)

Subsequent R&D funding phase(s) to be determined after UGV MOD phase one requirements identified, industrial base capabilities assessed & gaps determine
EDA Military UGV R&D Program 3: “Networked Multi Robot System”

- Focus: “open architecture”, software tool development effort

- Goal: Simulating (i.e. “test bed”) networked, multi-robot (“collaboration”) UxV systems in ground, air & sea domains

- Application area: C4I

EDA German MOD Leads Program

Industry Participation: Germany (Diehl BGT Defense and FGAN research center), Belgium (Royal Military Academy), Italy (Oto Melara of Finmeccanica), and Spain (Sener)

- LOE: 36 month, with $4.5M Euro (≈$6.57M USD)
EDA Military UGV R&D Program 4: “Generic Urban Area Robotized Detection CBRNE Devices” (GUARDED)

- Demonstrating (presumably developing) remote controlled, mobile platform for detecting / sensing CBRNE devices (materials)

- Key aspects: High detection confidence & at a safe (stand-off) distance

- Sensor technologies of interest: Ground Penetrating Radar, Proton Transfer Reaction & Mass Spectrometry (through-wall & buried target detection)

- GUARDED is 1 of 3 new R&D Joint Investment Programs for EDA’s Force Protection (JIP-FP) initiative

- JIP-FP is a new EDA initiative funded with 55M Euros (~$80.3M USD)

- EDA MOD Program Lead Unknown
  - Industry participation: France (ECA & DDSC), Austria (Ion), Slovenia (IPS) & Finland (ENV)

- LOE: 3 years with 3.5M Euros (~$5.1M USD)
International Participation in DARPA Urban Challenge
Foreign Country Participation in DARPA’s 2007 Urban Challenge

Significant international involvement from foreign universities, industry & associated technology organizations:
- 3 to 4 countries registered 6 to 7 teams including:
  - 1 team from Canada, 1 from France & 4 teams from Germany
  - 1 US team, AvantGaurd, (Israeli Elbit subsidiary) -- semi-finalist

2 German teams selected as semi-finalists:
- Team Berlin (led by Frey University Berlin)
- Team-LUX (industry led by Ibeo & STICK)

2 German teams selected as finalists:
- Team AnnieWAY (Collaborative Research Center Cognitive Automobiles)
- Team CarOLO (five institute collaboration of the Braunschweig University)
Foreign Technology Contributors to DARPA’s 2007 Urban Challenge

- Germany S&T & industrial base also a major contributor to other teams:
  - Volkswagen of America’s Electronics Research Laboratory (Palo Alto) partnered with Stanford University’s Racing Team
  - Ibeo & SICK laser scanner navigation devices outfitted 53 out of 89 teams

- Italy plays key role in equipping US Team Oshkosh (formerly TerraMax):
  - Leading edge, stereo visioning system technology developed by Italy’s University of Parma’s VisLab
  - VisLab has a history of R&D collaborations with US industry on a number of DOD military UGV projects

- Additional international participation including:
  Australia, Austria, China, New Zealand & Mexico
Conclusions