Robotics Roadmap 2013 Highlights

William Finn
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Recently, the 2013 Robotics Roadmap was presented to the Congressional Robotics Caucus. This is an updated version of the 2009 report, which helped established the National Robotics Initiative (NRI), a federal multi- agency joint effort.

Members of the unmanned system community are barraged with roadmaps all the time, so it would be tempting to ignore this one. However, key influencers are involved in this roadmap, so it should be considered seriously. You can slog through all 129 pages of the report or examine the highlights described below.

The following summary is not even-handed. Because of AMREL's involvement in the Defense sector, especially Unmanned Ground Vehicles (UGVs), I placed greater emphasis on these areas (In fact, photographs of our Operator Control Units appear several times in the section on UGVs). However, after reading these highlights, you should have an overall idea of what's in the Roadmap.

Who wrote this roadmap?

Over 160 people were involved in this document's creation. The list of contributors reads like who's who of heavy hitters for unmanned systems. Participants came from a variety of important institutions, including:

- Georgia Institute of Technology
- Carnegie Mellon University
- Robotics Technology Consortium
- University of Pennsylvania
- University of Southern California
- Stanford University
- University of California–Berkeley
- University of Washington
- Massachusetts Institute of Technology

What are the Roadmap goals?

The Roadmap had three areas in which it was tasked to identify:

1) Business/application drivers
2) Current set of gaps to provide solutions to end-users
3) R&D priorities to enable delivery on the business drivers.

What were the key findings?

Summary of major findings include:

"• Robotics technology holds the potential to transform the future of the country and is expected to become as ubiquitous over the next decades as computer technology is today.

- Through adoption of robots in flexible manufacturing, it is possible to generate production systems that are economically competitive to outsourcing to other countries with lower wages.
- A key driver in adopting robotics technology is the aging population that results in an aging workforce but it also poses a number of challenges to the healthcare system.
- Robotics technology has advanced sufficiently to allow for 'human augmented' labor that enables acting on the vision of co-workers who assist people with dirty, dull, and dangerous tasks, and it facilitates a new generation of systems for domestic support to improve quality of life for the broader population. In addition, robots have already proven their value in removing first-responders and soldiers from immediate danger.
- Robotics technology offers a unique opportunity to invest in an area that has a real potential for new jobs, increased productivity, and to add to worker safety in the short-term. It will allow an acceleration of inshoring of jobs, and longer-term, will offer improved quality of life in a society that is expected to experience significant aging.
- Each of the areas covered by the roadmap identifies both near- and long-term applications of robotics technology, establishing 5-, 10-, and 15-year goals for critical capabilities required to provide such applications, and identifies the underlying technologies needed to enable these critical capabilities.
- While some critical capabilities and underlying technologies are domain-specific, the systems effort identified a number of critical capabilities that are common across the board, including robust 3-D perception, planning and navigation, human-like dexterous manipulation, intuitive human-robot interaction, and safe robot behavior."

None of these findings should come as a surprise to anyone who has been closely observing robotics. Still, two findings caught my eye:

1) The aging of the population was repeatedly mentioned throughout the Roadmap. Bear in mind, lower birthrates and shrinking workforces is a global phenomenon affecting countries as diverse as Japan, US, China, Mexico, and even the Middle East.
2) Robotics, which has a history of displacing human workers, is playing a role in bringing manufacturing back to American shores. Recently, I had a conversation with an American manufacturer who was relocating a Chinese factory to the United States. Automation had largely made the wage difference irrelevant. However, the America's superior infrastructure for goods and services, as well as decreased transportation costs, made his supply chain problems much easier to deal with in the US.

Another key finding was in regard to autonomy. "After much discussion, there was general agreement among those present at the meeting that we are still 10 to 15 years away from a wide variety of applications and solutions incorporating full-scale, general autonomous functionality."

What applications did the Roadmap discuss?

The Roadmap included sections on manufacturing, medical, services, space, and Defense. Below are selected quotes from each area.

Manufacturing selected quote

"The sale of robotics for manufacturing grew 44% during 2011, which is a clear indictor of the revitalization of the production system in the U.S. Robots have been used as a facilitator to inshore manufacturing for companies such as Apple, Lenovo, Samsung, and Foxconn. The use of robots is shifting from big companies such as GM, Ford, Boeing, and Lockheed Martin to small- and medium-sized enterprises to enable burst manufacturing for one-off products."

Medical selected quote

"More than 11 million people live with severe disabilities and need personal assistance. The cost of assistance from a certified nurse is $24K annually and a service dog typically costs $15K plus there is a significant wait. In addition, more than 5.4 million people live with dementia and are in need of cognitive support for their daily lives."

Service selected quote

"The annual growth in professional service robots is 30%, and in domestic service applications, the growth is 20+%. U.S. companies have dominated this area, and it is considered important to maintain the momentum."

Space highlight selected quote

"Going forward, there is no doubt that unmanned space exploration, will, in many ways, benefit from the use of robotics technologies to go where no man has gone."

Defense

The strongest impression that I had of this section is the obsession with the civilian sector that characterizes the whole report persisted even in discussions on military applications. No matter what platforms they were describing, UGVs or Unmanned Aerial Vehicles (UAVs), the authors insisted on mentioning "dual-use" technology and the military-to-civilian transition of unmanned technology. For example, in the section concerning the military's use of UAVs, they rhapsodize about the possibilities of unmanned deliveries of domestic air freight.

This section draws heavily from Department of Defense's (DoD) biannual *Unmanned Systems Integrated Roadmap*. It is supplemented by input from a defense robotics workshop held on December 4, 2012.

Defense selected quotes

"With significant budget and force structure reductions in all four services and across the law enforcement agencies, the U.S. no longer has the resources or manpower to physically cover the scope and the geographic separation that this future landscape portends. Unmanned systems can help fill gaps in presence and capability in order to address these future threats in a timely and efficient manner."

"The Department of Defense's vision for unmanned systems is the seamless integration of diverse unmanned capabilities that provide flexible capabilities for joint warfighters. The intent is to exploit the inherent advantages of unmanned systems including their persistence, size, speed, maneuverability, and better sensing capabilities. As the technology continues to advance, the DoD envisions unmanned systems seamlessly operating with manned systems as 'Co-Defenders' able to aid in human decision making and reduce the degree of required human control."

"Unmanned systems must:

- Provide capabilities more efficiently through modularity, commonality and interoperability.
- Be more effective through greater autonomy and greater performance.
- Be more survivable with improved and resilient communications, development for antipermissive environments, and more security from tampering.
- Be trustworthy and reliable.
- Take the 'man' out of unmanned. Unmanned systems must strive to reduce the number of personnel required to operate and maintain the systems."

UGV selected quote

"The rapid fielding and proliferation of UGVs have helped with many missions, but resulted in many challenges, not the least of which are configuration, sustainment and maintenance costs. UGVs continue to provide tremendous benefit to the ground commander. In order to meet the challenges anticipated in future conflicts, however, there will need to be improvements in user interfaces, and UGV mobility, reliability, endurance and survivability. These improvements need to keep pace with advances in 360° sensing, recording fidelity, and CBRN and explosive detection."

Joint Capability Areas

The Roadmap identifies Joint Capability Areas (JCAs), capabilities gaps, and capabilities goals. Note the word *joint*. The Pentagon hasn't given up on the idea of establishing standards that transcend services and internal departments. Below is a table that summarizes the goals, and timetables for the JCAs.

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	5 Year	10 Year	15 Year
Unmanned Air Systems			
Battlespace Awareness	Maintain geospatial relationships with flight lead. Respond to orders to conduct and investigate ground POI. Greater ATR/AiTR. Improved battle damage assessment.	Perception of location and flight path intention of friendly air systems. Ability to search for specific threats. Improved target recognition and human presence change detection.	Ability to respond to standard ATC procedures in both military and civilian operations. Onboard ATR. Ability to detect and respond to threat UAS.
Force Application	Ground laser designation for an air engagement. Class II UAS with 2.75mm rockets or less for less collateral damage.	Limited air-air counter-UAS capability. Includes both the detection suite and support munitions.	Multiple target counter UAS capability. Cooperative engagement capability in a counter-UAS significant engagement.
Protection	Integrated MUM-T for the purpose of early warning.	Armed systems contributing to flank security to a dismounted force.	Collaborative engagement of UAVs against a standoff threat.
Logistics	Unmanned logistic resupply (Army ATUAS and USMC ACUS effort).	Unmanned medical evacuation with on board human assistance and intervention.	
Unmanned Ground Vehicles			
Battlespace Awareness	Self-positioning for optimal sector coverage.	Self-emplacement and self-recoverable small combat unit early-warning devices.	Self-aware of role within a group of sensors responsible for optimal sector coverage.
Force Application	Mount Infantry heavy weapons (mortar-50 cal-missiles) capability on UGV capable of following dismounted operation. Laser Designation capability.	Cooperative A-G; G-G and G-A engagements.	Cooperative engagement and ability to provide suppressive fires and maneuver against a fixed position.
Protection	Firefighting systems	Armed systems contributing to flank security to a dismounted force.	Collaborative engagement of UGVs against a standoff threat.
Logistics	Integrated manned-unmanned convoys in which multiple, large, optionally manned vehicles are able to autonomously traverse defined secondary roads as either a lead or follower vehicle under the supervision of a nearby operator.	Unmanned medical evacuation. Material-handling UGVs identify, unload, load and secure containerized or palletized cargo fully autonomously at CONUS and OCONUS distribution centers under all environmental conditions.	A fully automated logistics management system tracks in-country inventory and loads and routes UGVs with needed supplies over the horizon via ground lines of communication to units for just-in-time restocking without any human input.
	5 Year	**10 Year**	**15 Year**
Unmanned Maritime Systems			
Battlespace Awareness	Automated following COLREGs Remote sensor deployment Metal and plastic mine detection by UUVs.	Persistent automated surface and subsurface monitoring (user on the loop) Human detection by UUVs. UW Facility and infrastructure anomaly detection. Collaborative operations to operate as part of a wide area of detection.	Persistent automated surface and subsurface monitoring (user off the loop) with worldwide reach in all weather. Collaborative UUV operations to maintain detect and report on threat systems movement. Relocatable detection zones. Detection avoidance.
Force Application		Remote maritime threat interdiction response. Counter submarine capability.	Automated maritime threat interdiction response. SEAL team delivery.
Protection	Automated following COLREGs	Automated interdiction of manned and unmanned threats. Armed USVs and UUVs contributing to flank security.	Fully automated ship and shore installation security from maritime threats. Collaborative engagement of USVs and UUVs against a standoff threat.
Logistics UMV	• Automated refueling • Automated health monitoring • Automated hull cleaning • Continuous ship and shore installation inspection	• Automated UMV prognostics • Automated resurfacing and painting • Automated preventive ship and shore installation maintenance • Condition based UMV maintenance	Fully automated ship and shore based operations (no operator hands on interaction).

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Interoperability & Open Architecture

The Roadmap identifies several technical challenges, including propulsion, power, communications, and batteries.

What impressed me the most were the sections on interoperability and open architecture. The language was typically bureaucratic, but the underlying message was clear: We want interoperability and this time we mean it. We don't care about your revenue streams from proprietary technology. If you want to sell to us, your systems better work and play well with others.

Interoperability & open architecture selected quotes:

"The DoD's unmanned systems will need to demonstrate interoperability in a number of areas:

- Among similar components of the same or different systems—the plug-and-play use of different sensors on an unmanned vehicle.
- Among different systems of the same modality—an open common ground control station (GCS) architecture for multiple, heterogeneous unmanned vehicles.
- Among systems of different modalities—the ability of air, ground, and maritime vehicles to work cooperatively.
- Among systems operated by different Military Departments under various CONOPS and TTPs, i.e., in joint operations—joint service systems working in concert to execute a common task or mission.
- Among systems operated and employed by coalition and allied militaries under the governance of various concepts of employment, TTPs (e.g., in multinational combined operations or NATO STANAGs)—the ability of coalition and allied systems to work in concert to execute a common task or mission based on predefined roles and responsibilities.
- Among military systems and systems operated by other entities in a common environment—the ability of military UAS to share the NAS and international airspace with commercial airliners and general aviation aircraft.
- Among systems operated by non-DoD organizations, allies, and coalition partners (i.e. in combined operations)—the ability of assets from organizations such as Customs and Border Protection (CBP) and Department of Homeland Security (DHS) to coordinate, interoperate, and exchange information with DoD assets of the same modality and same model."

"Open architectures (OAs) facilitate interoperability between systems by providing a framework for developing joint interoperable systems that adapt and exploit open-system design principles and architectures in order to:

- Provide more opportunities for competition and innovation
- Field affordable, interoperable systems
- Minimize total ownership cost
- Yield systems that are more rapidly developed and more easily upgraded
- Achieve component software reuse
- Facilitate development test and operational test evaluations"

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"At a minimum, a common set of interfaces and messaging standards is required for interoperability with respect to exchanging information. Without a common semantic understanding of what data represents, however, there is significant opportunity for lack of interoperability, even if messages are correctly parsed and interfaces are followed. Therefore, a key aspect is the recognition that data modeling is a separate, core aspect for defining interoperable systems. This aspect includes specifying definitions, taxonomies, and other semantic information to ensure there is a common understanding about what information a specific data item imparts. Service-oriented architectures (SOAs) provide a framework for facilitating the design of software in a standardized way to produce interchangeable and interoperable software components called *services*."

"In recognition of the rapidly changing technology, unmanned systems architectures would also benefit strongly from being defined at a platform-independent model (PIM) level, which is devoid of technology dependence."

Communications

AMREL deals a lot with communications, so I paid special attention to this area. I was especially curious about data congestion and RF de-confliction. UGV operators have told me that spectrum management was a huge problem in theater (see "Interoperability: Bandwidth is more precious than gold and platinum"). I was pleased to see that these issues were addressed directly.

Communications selected quotes

"As the number of fielded systems grows, planners face challenges such as communication link security, radio frequency spectrum availability, de-confliction of frequencies and bandwidth, network infrastructure, and link ranges.

"Specifically, the DoD must significantly improve communication transmission efficiencies; attain better bandwidth efficiencies; increase transmitter and receiver efficiencies; and acquire communications systems that are of less size and weight, require less power, and provide more efficient cooling to operate. Improved communication transmission technologies alone cannot achieve the necessary capacity, however. The DoD must also pursue a fundamental shift to a future state where the collected data is preprocessed to determine the critical data that must be rapidly passed on to the warfighters, with the rest stored for later retrieval as may be needed."

"There are numerous challenges to meeting these goals. First, operating a higher density of unmanned systems within relatively small areas creates increased local data rate demands. Second, size, weight, power, and cooling are limiting factors on many platforms, for both onboard systems and ground / surface control systems. Third, the fidelity of the communication links must be ensured. Fourth, latency associated with

digital systems must be reduced, especially for takeoff and landing of large UAS. These challenges will be exacerbated by an expected decrease in available spectrum available due to an increase in the civil uses of spectrum."

"Until recently, most unmanned systems utilized several radios: one for data, one for video, and sometimes one for voice. Because of congestion, frequency competition, and regulatory challenges in several theaters, many of these communication systems were redesigned to operate at higher frequencies. However, use of these higher frequencies reduced the operational effectiveness in dense foliage and urban areas."

Manned-Unmanned (MUM) Teaming

One whole section was devoted to manned -unmanned teaming, which was defined as, "…an overarching term used to describe platform interoperability and shared asset control to achieve a common operational mission objective."

Like most of this report, this is no surprise; Human Robotic Interface (HRI) has emerged as critical to the success of unmanned systems. What surprised me is that, according to the above definition, the term "interoperability" now includes human beings.

Another interesting point in this section was the continued effort to find a common controller for UGVs.

UGV (MUM) selected quotes

"The integration of one-system remote video terminal (OSRVT) technology and distributed UGV control into ground combat vehicles is leading to the adaptation of TTPs because all parties now receive the same picture at the same time, regardless of their location."

"These developments have also been the catalyst for the creation of the common robotic controller, a joint project between the Army and USMC to develop a universal, wearable controller to operate a wide variety of unmanned systems, including UGVs, UA, and unattended ground sensors. This effort is currently aimed at smaller platforms, but could be transitioned to include limited control (i.e., payload only) for larger platforms as the technology matures."

Overall impressions of the 2013 Robotic Roadmap

1) The unmanned systems community, as a whole, is determined to break into civilian markets.
2) Developers must sell unmanned systems that not only make them money, but also save the DoD money as well.
3) Developers, who ignore requirements for interoperability and open architecture, do so at their peril.

If you have any questions or comments, please write to editor@amrel.com.