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ROBOTIC SYSTEMS JOINT PROJECT OFFICE TECHNOLOGY NEEDS ANALYSIS

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ABSTRACT

This paper addresses the Program Management Office's perspective of the robotic technology needs required to meet the capability gaps identified by the Warfighter. The objective is to relay these needs to the Science and Technology (S&T) community and industry in order to guide their investment dollars in the right direction. The Robotic Systems Joint Project Office (RS JPO) has been working closely with the Tank Automotive Research, Development, and Engineering Center (TARDEC) to establish near, mid and far term needs for robotic technologies. The hope is to communicate those needs to successfully steer the robotic research and development efforts to meet the capabilities most needed by our Warfighters.

INTRODUCTION

In the past five years, robotic technology has seen a dramatic increase in priority within the Department of Defense. There has been a tremendous push to focus both time and money in certain areas of robotic technologies. Use of robots by the United States Army (USA) and the United States Marine Corps (USMC) has greatly increased during the current conflicts in Iraq and Afghanistan. The Warfighter is continuously evaluating new potential requirements against changes to doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) to ensure the best national security capability is available. For the purposes of this paper, only the materiel solutions will be discussed.

Once the Warfighter determines a materiel solution is needed to meet the new requirement, Program Management Offices (PMO), with support from the Science and Technology (S&T) community, start to determine the best solution to meet the new requirement. One of the most difficult parts of this process is creating the linkages between current requirements and work done in the S&T community. These linkages are vital in order to prioritize the technology needs of the PMOs and focus the necessary Research and Engineering dollars of the S&T community to achieve the desired capability to appropriately support the Warfighter.

The USA and USMC have assigned the responsibility for the life cycle management of all ground robotic platforms and robotic appliqué kits to the Robotic Systems Joint Project Office (RS JPO), headquartered in Warren, Michigan. RS JPOs mission is to take Warfighter requirements and then lead the development, systems engineering, integration, acquisition, testing, fielding, and sustainment of unmanned ground systems for the Warfighter to ensure safe, effective and supportable capabilities are provided while meeting cost, schedule and performance.

RS JPO has three system types: Commercial Off-The-Shelf (COTS), military unique built robotic platforms, and robotic appliqué kits. COTS robotic platforms have been in the fight for many years and are mainly small vehicles used by Explosive Ordnance Disposal (EOD) and Combat Engineers to investigate and neutralize explosive hazards, new robotic platforms are platforms built specifically for military use and are considered new systems. These systems

have unique requirements that are not readily available in the COTS robotic configurations. Robotic appliqué kits are not new systems, rather a suite of technologies that enhance the capability of an existing vehicle platform. At a simple platform level, the difference between a small man transportability robot designed for reconnaissance (Figure 1) and a robotic mine field clearing system is stark (Figure 2). However, when viewed beyond the physical platform, robotic systems share common core technologies and have very similar capability gaps. This underlining commonality will allow the S&T community to focus on agnostic technology priorities, and then as the technologies mature, allow the RS JPO to integrate technology breakthroughs across the spectrum of robotic systems.

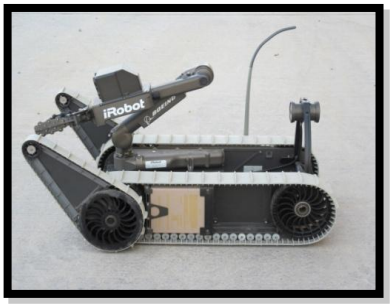

Figure 1: SUGV 310 (manufactured by Boeing/iRobot)

Figure 2: M160 (manufactured by Dok-Ing)

TECHNOLOGY NEEDS

RS JPO conducted a review of all known Warfighter requirements found within Operational Needs Statements, Initial Capabilities Documents, Capability Development Documents, and Capability Production Documents. From that review, the RS JPO identified agnostic technology needs across all domains, and ranked seventeen need areas based on priorities outlined in the requirements documents. For the intended audience of this paper, only the top three need areas will be covered in depth. The remaining needs are listed at the end of this paper.

Priority 1: Autonomy

The highest priority technology need for robotic systems is autonomy. Increased autonomous capabilities will enable the next generation of robotic platforms to operate, with the reliability required for military missions, with a decreased need for constant operator interaction. This will enable platforms to detect and avoid obstacles, autonomously navigate terrain, and ultimately plan routes and missions with minimum operator input and intervention. Given these challenges, it should not be a surprise that the Department of Defense has identified autonomy as one of its top S&T priorities.

Various levels of autonomy have already been demonstrated through the Defense Advanced Research Projects Agency's (DARPA) Grand Challenge [2]; and through the independent research and development efforts of multiple agencies and companies [3]. However, to date, these systems lack the robustness required for Warfighter operations.

There are three major technology deficiencies that must be overcome in order to achieve the higher level autonomy features for the Warfighter. Advances must be made in computing power, algorithms (software), and sensors. These deficiencies are well known within the robotic systems community and already have many organizations and companies researching these areas.

Computing power is the easiest deficiency to solve, a rare case where time will solve the problem. As Moore's Law [1] progresses, computer power will continue to double every two years, allowing more and more robust computers to be placed into robotic systems. Moore's Law may slow in the next ten years based on physical limitations, but advances in nanotechnology, synthetic biology, and quantum computing may open up avenues for Moore's Law to continue to progress.

The biggest technology deficiency within autonomy, and a common thread within all the technology needs identified, is software. Unique military investments are required in this area, along with a robust effort to leverage commercial Independent Research & Development (IR&D). The development of algorithms that allow for higher autonomous behaviors and capabilities must also include major development efforts in the realm of software reliability and safety. These areas are of critical importance, since any new developmental materiel solution fielded by RS JPO will have significant reliability and safety requirements.

Sensor technologies have been identified by RS JPO as its own technology need area. Sensor technologies will continue to develop for the automotive, smart phone, and

gaming industries. This type of robust commercial development helps to drive down costs of sensors, and will allow high quality "perception" to be enabled on robotic platforms. Additional research must be pursued in the area of specialty sensor technologies that are unique to military applications; however, these will not be discussed within this paper.

Priority 2: Interoperability and Commonality

When thinking of big picture technology needs for robotic systems, interoperability and commonality do not usually come to mind. However, given emerging Warfighter's requirements, the anticipated continued progression of Moore's Law[1], reduced budgets and the standard ground system life cycle of 20 years, some key points become very clear. First, the military will likely have to upgrade hardware several times within a given robotic system's lifecycle in order to leverage rapidly advancing technology and rapid component level obsolescence rates. In addition,, components used across systems need to be as common as possible to leverage economic order quantities and reduce the logistics footprint.

RS JPO has been supporting operations in Iraq and Afghanistan with COTS systems. COTS systems allow the military to forgo the standard military development cycle and quickly respond to Warfighter needs. However, the ability to procure and field quickly does have several drawbacks. Most of these COTS systems have their own architectures unique to each platform and manufacturer, with unique support hardware and software interfaces. Combine propriety components with multiple configurations of the same platforms, and the logistical footprint required to sustain these systems increases exponentially.

To avoid this issue in the future, RS JPO (with support from TARDEC and industry partners) has been developing the first RS JPO interoperability profile, to be published in the fall of 2011. This effort is aimed at developing accepted software and hardware interfaces that will be used to procure future systems and sustainment components by RS JPO. The development of hardware and software interfaces in accordance with RS JPO's interoperability profiles will allow RS JPO, as the life cycle manager for robotic systems, to replace obsolete hardware systems and to update software with minimum system redesign, therefore saving both time and money. It will also enable the rapid upgrade of systems in order to provide new capabilities, such as mesh networks and connectivity with other manned and unmanned systems in the ground and air domains. This is a critical issue for RS JPO, as any changes to a given system's hardware or software requires independent testing and safety confirmations prior to fielding. The less software changes that are required, the quicker RS JPO can respond to Warfighter needs.

Priority 3: Communications

Robotic systems, even at the most basic level, require robust and secure radio communications in order to ensure Warfighters are able to successfully accomplish their assigned missions. In today's battlefield, almost all robotic systems have an operator controlling the system from some other position (i.e.,tele-operated). Tele-operation requires large streams of video, audio, and controls data to be transmitted near real-time in complex and urban terrains. In addition to the large data stream, Warfighter's require greater distance/range in Line of Sight (LOS) and Non-Line of Sight (NLOS) communication scenarios. The large data stream, near real-time controls, increased LOS and NLOS range, encryption, and frequency adaptability requirements, are complex but technologically manageable obstacles, as individual requirements. However, as a whole, these challenges require careful technical management and requirements trades.

Increased LOS and NLOS communication capabilities come at a price of increased power consumption. Power availability in the battlefield is at a premium on all classes of vehicles. Man transportable robotic systems are powered by batteries and any increase in radio power draw reduces the robotics mission endurance. Power availability is also an issue on appliqué systems. Most vehicle platforms have limited power availability due to the size of alternators or on-board power levels.

Additionally, robotic systems that are controlled by units above the immediate squad, store data, broadcast, or contain Critical Program Information are required to have advanced encryptions on the radio signals to prevent the enemy from intercepting the data stream, and/or taking over control of the system. Also, the robot operator control units (OCUs) are required to pass the same Information Assurance requirements as other DoD information systems.

The present challenge is that current radios do not have the ability to adapt to different frequency ranges based on location or interference issues. Having this capability provides the Warfighter with robots that are more compatible with Counter Radio Electronic Warfare (CREW) systems used to protect Warfighters from radio controlled Improvised Explosive Devices. CREW systems can use an advanced architecture that supports rapid reconfiguration which allows it to adapt to the continually evolving threat in an operational environment. The next generation of robotic radios needs to have this versatility.

Additional Priorities

Though unable to provide a more detailed account of all the priorities identified during the technology needs analysis, it is important to highlight some of the remaining current and long-term technology needs of the RS JPO.

Warfighters continue to express the need for extended mission duration capability on self or vehicle transportable robots. This technology need, taken in conjunction with the needs listed above, give evidence to the derived requirement for additional power.

Current robotic platforms each have a unique OCU with different control methodologies. A common controller or OCU for both the man and vehicle transportable ground robots would help reduce the logistics footprint, training time, and would support the development of much needed plug and play capabilities.

Additional needs include: improved optics, health management systems, render useless mechanisms, non-lethal self defense capabilities, directional audio detection, explosive detection payloads, advanced location reporting, and integrated tool kits for manipulator arms.

CONCLUSIONS

Almost all of the needs identified during the technology analysis involve hardware and software components. If Moore's law[1] continues unabated, some of the electronic hardware issues identified above will become easier to solve. Unfortunately, software complexity required to meet identified needs are going to require increased emphasis on software design methodology, architecture, and software development and safety planning.

As the Warfighter continues to require increased battlefield capabilities without manpower increases, robotic platforms and appliqué kits will be chosen to fill these capability gaps. The RS JPO, the S&T community, and industry will continue to work closely together in order to ensure there are affordable and integrated robotic systems available to meet current and future Warfighter requirements.

ADDITIONAL INFORMATION

For additional information please contact the Robotic Systems Joint Project Office at 586-282-7264.

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