Director of INNOVATION

Innovation Beyond Imagination™

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Navy Center for Applied Research in Artificial Intelligence

The Navy Center for Applied Research in Artificial Intelligence (NCARAI) has been involved in basic and applied research in artificial intelligence, autonomous systems, and human-centered computing since its inception in 1981. NCARAI, part of the Information Technology Division within the Naval Research Laboratory (NRL), is engaged in research and development efforts designed to address the application of artificial intelligence technology and techniques to critical Navy and national problems, with a strong emphasis on autonomous systems.

NCARAI's research in autonomous systems addresses multiple, critical capabilities for future naval autonomous systems: human interaction with autonomous systems; adaptation in dynamic environments; coordination of multiple vehicles; and architectures that allow integration of high-level reasoning, planning and decision making with low-level vehicle control. The emphasis at NCARAI is the linkage of theory and application in demonstration projects that use a full spectrum of artificial intelligence techniques.

Dr. Alan Schultz, the Director of NCARAI, has been emphasizing the need for intelligent autonomy in unmanned systems as an enabling naval capability that cuts across specific vehicle platforms since 2002 when he worked with the Office of Naval Research (ONR) as a Deputy Program Manager for Intelligence Autonomy for the Autonomous Operations Future Naval Capabilities (FNC).

Adaptation is a critical capability for autonomous systems, and NCARAI's research includes the development of techniques that allow systems to change their level of autonomy dynamically. Additionally autonomous systems must adapt to changes in the environment and to changes in their own and team capabilities as well as learn new behaviors when appropriate. Research projects are addressing the autonomous control of heterogeneous teams of vehicles. Using a technique known as *physicomimetics*, NCARAI researchers have demonstrated a team of ground robots that can perform a force protection task autonomously, and can adapt to changes of team make up (e.g. being robust to attrition). The technique is now being applied to the control of autonomous air vehicles.

Since introducing autonomy means that the warfighter is now freed from constant direct control of a vehicle and is able to attend to other tasks, the issue of interruption and resumption of tasks becomes critical. NCARAI research addresses this issue by understanding, modeling, and improving the resumption process following interruptions. Computational cognitive models are built, based on experiments (e.g. eye-tracking data), and then systems are created that help people resume a task after an interruption.

In exciting, new research, NCARAI researchers have developed a general theory and specific models that can predict when people will make specific types of procedural errors (e.g. a post-completion error is forgetting to attach a document to an email before sending). They have demonstrated models that can predict with high accuracy when someone will make these errors, and consequently can prevent these errors before they occur by using a combination of our prediction algorithm, knowledge of the task, and a just-in-time environmental cue to the warfighter. The basic research has

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led to an applied research project that examines how to improve an operator's performance in monitoring and directing the actions of multiple autonomous air vehicles.

Other research addresses the intersection of autonomy, perception and reasoning. Researchers at NCARAI have developed an algorithm that allows a small air vehicle to autonomously follow a coastline using passive (and inexpensive) optical sensors. Extensions to this research should allow autonomous navigation along rivers, roads and even crude paths, such as those found in mountainous terrain in Afghanistan. In another project, novel structured light sensors and algorithms are being developed that allow for rapid and autonomous identification of relevant objects such as munitions and emitters.

How warfighters will interact with autonomous systems is a critical research area. One key component of this work is the development of computational cognitive architectures that allow the researchers to model how people reason and how they work in groups. These computational models then become the basis for reasoning and interaction on the autonomous system. The hypothesis is that enabling the autonomous system to reason and interact in a manner that is compatible with people will allow for more natural and thus efficient interactions, allow for systems that are more transparent in their decision making, and ultimately, allow greater trust and acceptance of autonomous systems by the warfighter.

Other work in human-robot interaction includes multimodal interfaces that allow warfighters and autonomous systems to interact using a variety of natural modes of communication including speech, gestures and other novel interfaces. This research is based on the hypothesis that natural interfaces will permit the warfighter to concentrate more on the task at hand, rather than on the details of the interface.

Reflecting the multidisciplinary nature of autonomous systems, support for NCARAI's autonomy research comes from ONR codes 31, 32, 34 and 35, as well as from NRL base funding and external sources such as Defense Advanced Research Projects Agency (DARPA).

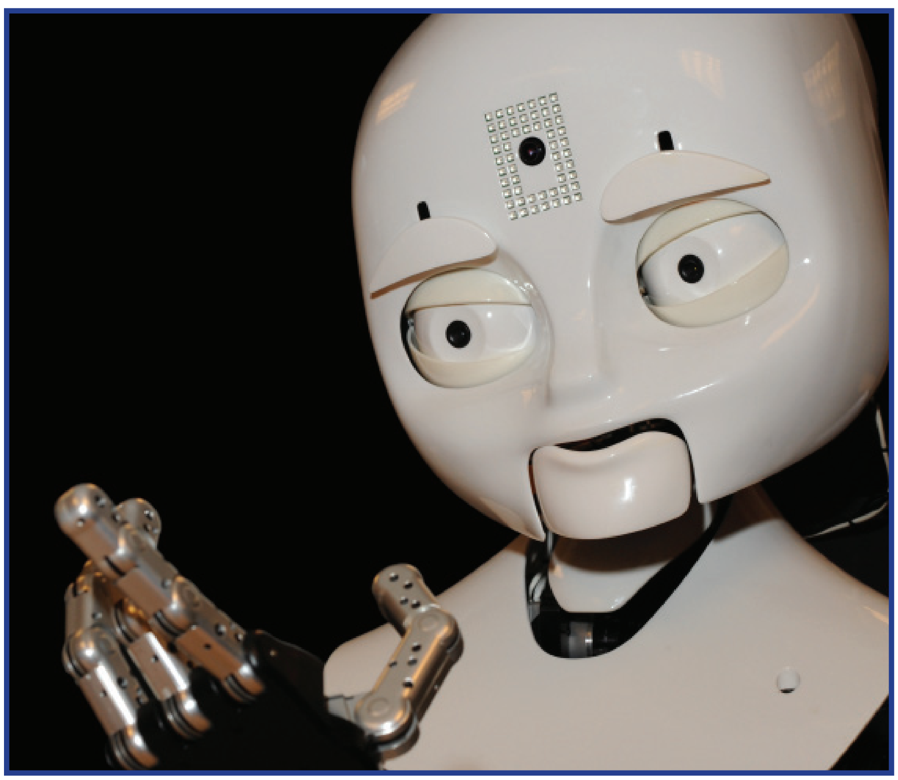
The overall emphasis at NCARAI is best captured in this quote from the former Chief of Naval Operations (CNO), RADM Mullen: "We can't have networks or platforms be the center of the universe. I want networks and platforms that put Sailors at the center of the universe." NCARAI's human-centered approach to autonomy emphasizes the warfighter, and the development of tools that allow them to get the job done.

For more information about NCARAI visit: http://www.nrl.navy.mil/aic. ■

This picture shows Octavia, one of the NCARAI robots. To see more about Octavia, link to the video short:

An Intelligent Systems film short: "Robotics Secrets Revealed"

http://glue.ccs.nrl.navy.mil/aic/rsr_001/final-grain-auto.swf



Underwater Unmanned Vehicle Featuring Gliders

In Spring 2009, the Navy announced that it will acquire underwater gliders to increase and improve oceanographic research efforts and operations. The Space and Naval Warfare Command (SPAWAR) awarded a $6.2 million contract to Teledyne Webb Brown Engineering, Inc., of Huntsville, AL, to design, engineer, build, test and deliver ocean Littoral Battlespace Sensing-Gliders (LBS-G), and associated support equipment. The design for the LBS-Gs will be based on the Slocum Glider, an unmanned, underwater vehicle funded by ONR in collaboration with Webb Research. It is one of four underwater glider efforts sponsored by ONR; the other three are the Spray from The University of California San Diego's Scripps Institute of Oceanography (UCSD-SIO); the Seaglider from the University of Washington's Applied Physics Lab (APL-UW); and Liberdade, the flying wing jointly developed at UCSD-SIO and APL-UW. The LBS-G will be designed to weigh about 118 pounds and measure nearly five feet in length. Alkaline and ion batteries will power the device, and it will have a GPS installed for navigation purposes. It will also be equipped with oceanographic and optical sensors to communicate the data through a satellite based system.

Unmanned underwater vehicles are where they are today after years of basic research and technological developments. These devices evolved from profiling floats, which were developed in the 1980s. More recent developments have vastly improved unmanned underwater vehicle capabilities. Notably, the modification of adding a wing which provides lift and allows the gliders to move horizontally, vertically, or remain stationary, instead of drifting with the current. What makes gliders innovative compared to other UUVs is their low power propulsion system, which allows them to operate for months at a time. Gliders propel themselves by changing buoyancy and shifting internal mass to turn and produce forward motion. The conversion of vertical motion to horizontal motion uses very little power and allows for an increase in range and duration. It also makes them inexpensive and efficient resources for ocean research.

According to CAPT Douglas Marble of ONR Code 32 which focuses their investments and research on Ocean Battlespace Sensing, "we have autonomous, affordable and persistent ocean gliders today because almost 20 years ago, visionary ONR program officers recognized the need and took on the challenge of growing our ocean observing capacity in the face of rising costs of sea-going research, which is core to our business."

The Navy recognizes the utility of ocean gliders and the positive impact they have operationally on ocean prediction systems, making this technology an essential resource to naval research and development.

Assistant program manager for the Navy's littoral battlespace sensing, fusion and integration project, Randall Case, spoke with National Defense magazine in May and said that the Navy will use the LBS-Gs to collect data on water temperature and salinity in order to better understand the properties that affect underwater sounds picked up by sensors. To date, gliders have also been used by scientists to create better models for weather forecasting, conducting sustained, multi-vehicle collaborative monitoring of oceanographic variables, and to investigate the distribution and habitat of marine mammals over time.

The first design for the LBS-G is scheduled to come out in July 2010. If all options are exercised, the Navy could buy up to 150 gliders by 2014. ■

The Crimson Viper Experiment

From 20-31 July, 2009 fourteen Naval Reserve officers from the ONR Reserve Program (Program 38) tested and evaluated five ONR and NRL technologies as part of the first-ever Crimson Viper Experiment. Under sponsorship from Thailand's Defence Science and Technology Department and US Pacific Command, Crimson Viper was organized by the Marine Corps Forces Pacific Experimentation Center and held at the Royal Thai Navy and Marine Corps Base in Sattahip, Chonburi Province, Thailand. ONR Program 38 participation in Crimson Viper 2009 follows four years of involvement in the Cooperative Operations and Applied Science & Technology Studies international field experimentation program run in Thailand by the US Naval Postgraduate School.

Crimson Viper is a US-Thai Technology Collaboration Test Bed designed to engage domestic and international partners at the Research and Development (R&D) level through cooperative Science and Technology (S&T) field experimentation, focusing primarily on integrated Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) solutions for domestic, bi-lateral and multi-national military and homeland security missions. Because it is not an operational exercise, it provides a highly flexible and adaptive exploratory S&T environment, unconstrained by the traditional military exercise framework, that can be tailored to fit an individual project's requirements.

The Program 38 Reservists are experienced, technically-oriented officers with real world military warfighting experience, typically coupled with post-graduate education, as well as a wide breadth of technical and programmatic expertise from their civilian experience. They follow an established, documented Military Utility Assessment (MUA) process resulting in formal written final reports for each of the technologies evaluated. These MUAs and reports are valuable tools that can help identify technical shortfalls and areas requiring improvement, provide information to support program decisions regarding funding and future development direction, etc.

Technologies evaluated at Crimson Viper 2009 included the Portable Acoustic Contraband Detector (PACD) and the Fluxgate Magnetometer, two projects from SPAWAR Systems Center Pacific funded by 03I's TechSolutions program. PACD uses ultrasonic technology to rapidly, reliably, and safely identify or classify the contents of sealed, liquid-filled containers and non-porous solids; it can also determine fill levels, and detect compartments or objects concealed within the containers. The Fluxgate Magnetometer is a hockey puck-sized sensor head that can detect vehicles and weapons by measuring changes in the magnetic field caused by movements of ferro-magnetic material in the vicinity of the sensor. Both of these systems are of interest to the Royal Thai Armed Forces for potential application to their security missions.

One of the more innovative technologies demonstrated at Crimson Viper 2009 was NRL's Zero Power Ballast Control (ZPBC) for Distributed Autonomous Sensor Networks, which uses microbial gas generation to surface and re-submerge a small buoy several times per day. It requires no batteries or external power source, and works in both salt and fresh water.

Crimson Viper provides an excellent opportunity for emerging government technology prototypes to be tested and evaluated outside the laboratory by experienced and technically skilled military personnel. The challenging environment – high heat and humidity, rain and wind, limited logistic support and infrastructure – helps identify potential issues that might arise when systems are deployed to operational settings. Technologies showing sufficient maturity and potential for military utility can transition to further experimentation during operational exercises such as Cobra Gold or Talisman Sabre.

More information on ONR Program 38's participation in Crimson Viper and other field experimentation venues can be obtained from CAPT(RC) Paul Marshall at pmarshall@techflow.com or 858-412-8216. ■

Program Officer Question & Answer Section

Interview with Dr. Marc Steinberg

What do you do here at ONR; what projects/programs do you typically work on?

I manage basic and applied research in autonomy. At the basic research level, I focus on highly multi-disciplinary autonomy research that cuts across different technical areas and mission domains. Some of the types of fields that are involved include control theory, computational intelligence, human factors engineering, and related fields such as biology/animal behavior/cognition, economics/game theory, cognitive science/psychology, and neuroscience. At the applied research level, I focus on autonomous air systems and on multi-vehicle collaborative systems that may include air, sea, undersea, and ground systems.

How long have you worked at ONR? During that time, have you been in the same position? If not, what other areas/codes have you worked in?

I've actually been working with ONR in one way or another for most of my career, starting as a PI funded by ONR in the early 1990's. In 2001, I came up to ONR as a part-time detailee to manage the Intelligent Autonomy part of the Autonomous Operations Future Naval Capability program. This part of the FNC developed and demonstrated technologies that were common or overarching across air, sea surface, undersea, and ground vehicles. That gave me a great excuse to poke around in everything that was going on in the field of autonomy within ONR and elsewhere. In 2007, I accepted a permanent position at ONR, and have since shifted back primarily to basic and applied research, which is what I particularly love to do.

What is the current major project you are working? (Brief explanation)

One of the most interesting projects I am working on at the moment is the Science of Autonomy basic research program. This program is designed to be very multi-disciplinary and address research challenges that cut across different ONR departments and warfighting areas/domains. I think it's fairly unique for a basic research program in that we not only have a very multi-disciplinary group of performers, but are also managing it internally via a multi-disciplinary team of program officers here at ONR. The research is focused on making progress on a set of "tough problems" that were identified at two ONR/NRL Innovation Summits. These are in the four interrelated areas of Human Collaboration with Autonomous Systems, Perception and Intelligent Decision-Making, Scalable and Robust Distributed Collaboration, and Intelligent Architectures. The long-term vision is to enable systems of heterogeneous unmanned systems to robustly perform complex naval missions with greatly reduced need for human intervention, while promoting effective collaboration with the warfighter.

Who are you collaborating with on that project?

Quite a few people here at ONR, but particularly Dr. Behzad Kamgar-Parsi in Code 31, Dr. Jason Stack, Mr. Dan Deitz, and Dr. Terri Paluszkiewicz in Code 32, Dr. Bob Brizzolara in Code 33, and Dr. Tom McKenna and Dr. Paul Bello in Code 34. We also work with NRL, other naval labs, and the other services.

What do you like most about work at ONR?

One of my favorite things about working at ONR is the ability to explore radical new research directions within a very multi-disciplinary framework. I particularly enjoy this when it gives me the opportunity to work with program officers and researchers that have significantly different areas of expertise from me. In my past jobs, I often felt a little constrained by how the different technical department responsibilities were stove-piped within the lab organizations. As someone who is very interested in the history of science, I believe that in the twentieth century we solved many problems that lend themselves to a reductionist type of approach in which you can break the problem up into specialized pieces and solve them separately. For the twenty-first century, I think that many of the problems that remain to be solved may require a much more cross-disciplinary and holistic approach to make progress, even at the fundamental level.

What do you think qualifies something for being considered as "innovative"?

I tend to think of innovation as applied creativity. Taking novel ideas and using them to do something in a new and better way. This requires both a new discovery of sufficient significance to overcome barriers and the right type of organization and societal context to allow that innovation to be used effectively. The most exciting type of innovation for me is when it changes entire systems, what is sometimes now referred to as disruptive innovation. Historically, this is somewhat less common, and I have always been fascinated by those historical periods, like the late 17th-18th century, where you see so much innovation in fundamental systems (e.g., scientific, economic, government, political, etc) in ways that still impact us today.

In what ways do you think the Navy is innovative?

Certainly, one way that I am personally very grateful for is the Navy's support of fundamental research. Having seen how other services and government agencies treat basic research, I think there is a lot to be said for the role ONR has within the Department of the Navy. In a more general sense, I think the Navy often does a good job at moving component technologies forward that can do things better, cheaper, or faster within existing frameworks. However, implementing the more disruptive type of innovation has often been more challenging. A classic example of this is the development of the role of aircraft carriers in naval warfare. Initially, carriers were seen by many naval leaders as a support capability for battleships, mainly to provide stand-off sensing. I think a similar situation exists today with autonomous systems. So far, we use them mainly for stand-off sensors for existing systems and for other types of telepresence needs, such as manipulating IEDs without requiring a warfighter to get close to them. The more radical changes in how wars might be fought with autonomous systems are, for good or ill, still to come.

If you could have unlimited resources, what project/program would you invest in, why?

One of the areas I am most interested in is in better understanding animal and human intelligence within a rigorous mathematical framework, and using that understanding to enable engineered systems with greater ability to survive and thrive and the real world. I am particularly interested in how to develop large, distributed, complex systems that are locally resilient to any type of disruption. This is a much broader issue than just autonomous vehicles, given, for example, all the networks that our society has increasingly come to rely upon.

Where do you see the future of your area of expertise heading?

I think much of the last decade has focused on solving lower level mobility and safety-related problems in guidance, navigation, and control. The future will be focused on systems that have the intelligence to carry out tasks with much more limited guidance and oversight from humans. The potential opportunities are exciting, and there are also all kinds of new social and cultural issues that will need to be dealt with as this technical area evolves. ■

Dr. Marc Steinberg

Autonomous Technology Progressing for UUVs

by Vice Admiral Joseph W. Dyer (U.S. Navy, Ret.) and Dr. Larry Schuette, ONR Director of Innovation

Unmanned Ground Vehicles (UGVs) have been recognized in the current fight in Afghanistan and Iraq as deterrents against Improvised Explosive Devices (IEDs). Autonomous vehicles – ground, aerial, surface and underwater – are being used and developed to meet the current and future needs of warfighters. In response to the critical role unmanned systems are playing as they protect and assist our warfighters, several Navy organizations have held studies and summits focused on enhancing the Navy and other armed forces capabilities in unmanned systems. For example, just over a year ago, ONR hosted summits focusing on autonomous behavior and autonomous systems. This past summer, the Chief of Naval Operations Strategic Studies Group, released a report titled "The Unmanned Imperative," after a year long study dedicated to integration of unmanned systems into Navy force structure.

Unmanned systems change combat dynamics and provide significant and measurable operational value. On the ground, in the air, on the water and under water, robots can be used to establish faster, better and safer situational awareness and increase the tactical speed of a mission. ONR has a number of funded efforts in autonomy and unmanned systems and works closely with industry, academia, the acquisition community and the warfighter to champion the diverse levels of S&T that are a necessary to develop these complex systems.

Military robots are going to be even more valuable as they become more autonomous. Right now, all the deployed military robots are tele-operated, requiring a one-to-one relationship between an operator and the robot. It's early, but we're starting to build the autonomy. Some simple but important incremental changes, such as autonomous assistance and workload reducers for the robot operator, have already begun to be fielded in unmanned ground vehicles to support the warfighters in Iraq and Afghanistan. This includes the ability for the robot to right itself if it flips over and to climb stairs at the touch of a button, for example. Those kinds of technical builds will continue to evolve.

Over time, autonomy is going to reduce bandwidth and personnel requirements. It's also going to break the nexus of one operator and one robot; one operator will control many robots, providing force multiplication.

There isn't going to be a giant step of autonomous capability in the field. Rather, autonomy will be applied to unmanned vehicles in increments. Aviation provides a typical example of how autonomous capabilities are implemented gradually. In aircraft, augmentation systems were followed by auto-pilots, automatic landings and automatic take-offs. At that point, it was possible to fly an aircraft without a man in the system. But the changes came in increments, not all at once.

The same progression of autonomy is true with commercial technology. Autonomy has slowly been appearing in our cars over the last couple of decades. Autonomous capabilities, such as park assist, blind spot sensing and lane departure warnings, were developed and implemented in increments, not simultaneously.

There's not going to be a sudden explosion of autonomous technology in the field in the short-term; this journey is going to be more like a marathon than a sprint.

Right now, the development of advanced sensors and the integration of them are two of the main technical challenges for military robots. In addition, UUVs operating autonomously in the maritime environment face even greater challenges than their ground and aerial counterparts. Cut off from communications while operating submerged, UUVs must conduct at least portions of their missions unguided by an operator or navigational aids.

The ONR sponsored Seaglider (featured on page 8) is an early, simple example of an autonomous UUV. Originally designed by the University of Washington through funding and guidance from ONR, and being further developed by iRobot, Seaglider makes oceanographic measurements, performs persistent surveillance and accomplishes other missions for a fraction of the costs of traditional vessels and instruments. Seaglider UUVs have been delivered worldwide, collecting ocean physical properties and performing various other missions for oceanographers, in-

cluding the Navy, government agencies and research organizations.

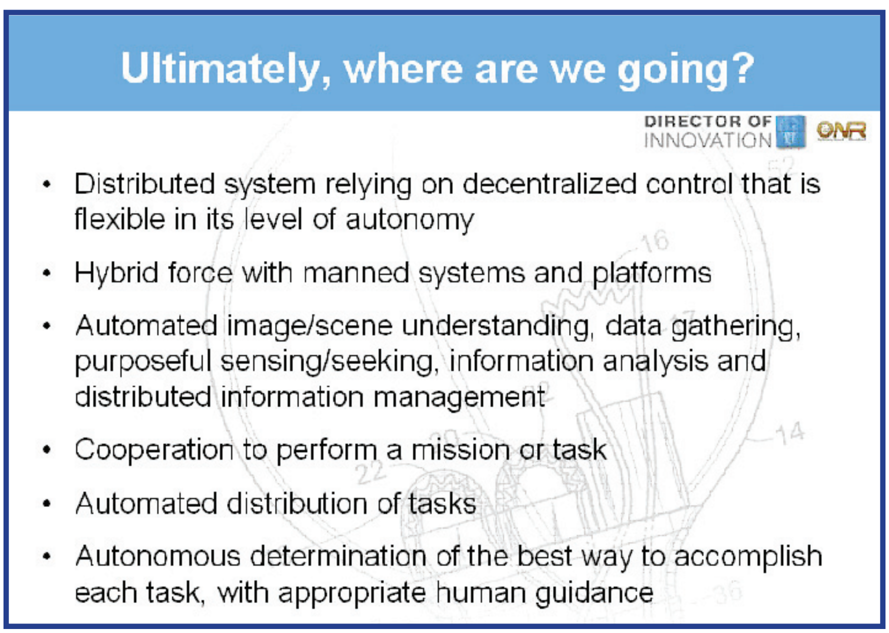
To help provide some additional near-term solutions, iRobot is developing two high speed autonomous UUVs for ONR under the Future Naval Capability (FNC) program.

Just five inches in diameter, RILS (Reacquire, Identify and Localize Swimmers) is an UUV being developed for defense against swimmers threatening ships in port. When a potential threat is detected, RILS travels to the location, deploys a gateway buoy and activates its imaging sonar. This allows a remote operator to conduct the mission in real time. RILS trails a threat that swims out of detection system range and sends GPS updates until help arrives. Funded to protect our strategic submarine bases, RILS will also help protect our commercial ports and Navy ships in foreign ports.

MATC (Mobile Acoustic Torpedo Countermeasure) is another example of an ONR-sponsored UUV that protects submarines from torpedoes in littoral combat. Designed to close with the inbound threat, MATC emits signals that confuse and draw away torpedoes.

To remain ahead of threats to Navy personnel and assets, these UUVs are being developed as modular devices with COTS components and open source operating systems, meeting requirements for affordability, interoperability and the rapid evolution of new capabilities. By tackling urgent needs and integrating platforms for spiral development of advanced autonomy, the Navy will continue to advance its capabilities while fighting today's battles and preparing for tomorrow's. ■

– Dr. Larry Schuette is co-author and an ONR partner in autonomy innovation. Joe Dyer is president of iRobot's Government and Industrial Robots Division. His career in the U.S. Navy included positions as the commander of the Naval Air Systems Command, naval aviation's chief engineer, commander of the Naval Air Warfare Center, Aircraft Division and F/A-18 program manager. He chairs NASA's Aerospace Safety Advisory Panel.



This slide developed by Larry Schuette from research collected from SMEs at the ONR autonomous systems summits.

TechSolutions

NUWCDIVNPT Addresses Autonomy in Man-Portable AUVs under the ONR TechSolutions Program

by Dr. Michael L. Incze, Naval Undersea Warfare Center Division, Newport

NAVSEA NEWPORT
Undersea Warfare Center Division

The sophistication of Autonomous Underwater Vehicle (AUV) technology is advancing rapidly as investment in research and development expands to meet the interest of commercial and military customers. With this increased sophistication comes an expanded set of expectations from the user group, so that missions and applications are continuously pushing the limits of technology development and implementation. Additionally, the growing confidence in vehicle performance has promoted the adoption of multi-vehicle operations, and this is escalated by the availability of economical, man-portable vehicles in commercial markets.

Both mission complexity and multi-vehicle operations underscore the need for cultivating autonomy in undersea vehicles. In the first case, a reliable autonomous capability is required by the increasing web of potentially competing decision factors associated with multiple missions and platform safety and capabilities. In the second case, management of fleets of vehicles can easily overwhelm the decision making and communication networks required to maintain a human operator in the Command and Control process for mission execution. Autonomy development has focused on both areas to provide increased reliability and performance with a variety of vehicles. This development has initially taken the most elementary approach to provide an increased sophistication in onboard decision making for ownship safety, but more robust approaches have also been implemented to allow for a broad and forward-looking solution that supports complex missions.

The elementary solution is most often adopted because of the initial ease and familiarity with the tenets of such an approach. Autonomy in this sense consists of a single behavior, or set of behaviors, tied to a triggering event(s). The IF-THEN approach satisfies the most basic response mechanisms required for many mission and safety requirements. Avoidance of shallow depths, response to subsystem failures, and other simple behaviors associated with sensor inputs are characteristic of this level of autonomy. More complex behaviors can be established by arranging stimuli in a hierarchy, so that concurrent, and even competing, drivers can be managed to select a single, or coupled, but non-competing set of responses.

While this elementary solution can provide an effective extension of behaviors for specific missions and ownship safety, the limitations are obvious. The correct tactical solution in many scenarios with competing factors is not the selection of a single pre-planned behavior or set of behaviors, but the adaptation of multiple options to reach a compromise that most effectively addresses a weighted set of objectives without violating any absolutes. The Mission Oriented Operating Suite (MOOS) architecture and IvP Helm application have been effectively coupled to allow an implementation of this approach to autonomy in a platform-independent way. Initial experimentation with Bluefin Robotics Corp., OceanServer Technology, Inc., and REMUS AUVs has illustrated this platform independence and allowed for evaluation of the effectiveness of this approach.

The Office of Naval Research TechSolutions program office has responded to a request from military operational commands to expand the capabilities of the Iver 2 Autonomous Underwater Vehicles purchased for operational evaluation in 2007 and put in-theater for tactical service. The Lightweight UUV project was funded to address requirements for both sensors and Command and Control, including more robust autonomy. The Naval Undersea Warfare Center Division Newport (NUWCDIVNPT) is providing oversight to the integration and interfacing of sensors by OceanServer Technology, Inc., the Naval Oceanographic Office, U. of Massachusetts at Dartmouth, and YSI. NUWCDIVNPT is taking the lead in the development and implementation of software for increased autonomy. The autonomy focus areas for this task are ownship safety during mission execution and survey optimization.

The Iver 2 AUVs commercially available from OceanServer Technology, Inc. are designed with a default hardware configuration of a single Central Processing Unit (CPU) for servicing all processing requirements. The vehicle controller, mission interfaces, and data and imagery logging are all managed in this single drive, which can be partitioned for specialized applications. The delivered Operating System is Windows XP to support the Iver 2 AUV Mission Planning tools. However, a second CPU is provided by request in roughly 50% of the delivered Iver 2 AUVs to provide for independence in software development and sensor interfaces. Because non-proprietary Application Program Interfaces (APIs) and documentation are provided with each delivery to support interaction with the primary CPU, non-vendor development of software to support vehicle behaviors is relatively straightforward. Hosting of the MOOS architecture and IvP Helm in this second CPU using the LINUX O/S is one example of software extension using the second CPU.

The autonomy behaviors for Iver 2 AUVs being provided to military operational commands under the ONR TechSolutions program will be implemented using a second CPU with MOOS architecture and IvP Helm. This represents a leap forward in the development and delivery to Navy tactical vehicles of vendor-independent software capabilities that interact with embedded vehicle controllers. Vendor-independent behaviors derived from an open library will interact with the Iver 2 vehicle sensors and vehicle controller through the primary CPU to modify vehicle actions for optimal performance in overall mission performance and vehicle safety. Specifically, onboard generation of optimal, non-hierarchical solutions will be supported in scenario-based Iridium communications, on-board re-planning of ladder surveys in shoaling water, mission aborts coupled with towfloat release and safety return paths, and feature following for thermocline and bathymetry contours. It is important to note that primary safety features and behaviors provided by the AUV manufacturer and embedded in the vehicle controller are not negated by the behaviors implemented in the secondary CPU unless specifically addressed.

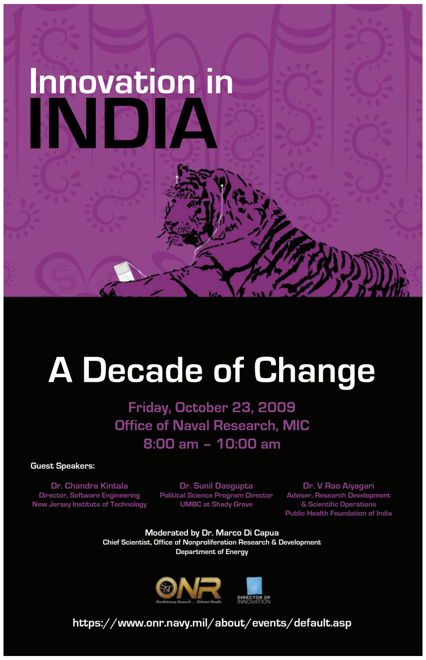
The Command and Control tasks for enhanced autonomy are being delivered in the Iver 2 in 4Q FY 10 in accordance with the ONR TechSolutions program schedule. Preliminary development began in SEP 09, and incremental in-water testing will occur in OCT-DEC 09 and in MAR 10. Final demonstration of capability is scheduled for JUN-JUL 10 in the NATO Recognized Environmental Picture (REP) 10 exercise. Note there are additional Command and Control autonomy demonstrations targeted for REP 10 using the MOOS IvP implementation and secondary CPU in the Iver 2 AUVs. These demonstrations will utilize NUWC Iver 2 AUV assets which have also been used in support of programs such as the ONR UC2I initiative. Survey optimization using on-board hosting of a NATO Undersea Research Centre (NURC) algorithm supporting Rapid Environmental Assessment (REA) will be demonstrated, and inter-vehicle collaboration employing both NUWC and Defence Research and Development Canada (DRDC) algorithms is targeted for demonstration. These algorithms will be integrated into scenarios utilizing low-powered AUVs in a hybrid fleet with common communication nodes in cooperation with the University of Oporto and Lightweight AUV (LAUV) platforms. ■

Events

International Lecture Series Featuring Innovation in India: A Decade of Change

A distinguished panel of experts hosted by the Office of Naval Research shared their perspectives on the key takeaways from the last decade in India with a focus on science and technology (S&T). This event was part of ONR's ongoing effort to increase understanding and awareness of global shifts and to foster the exchange of ideas within the S&T community.

The event brought to light many of the similarities shared by India and the United States and raised the question of opportunities for engagement and collaboration in the future between the two nations. Dr. Marco Di Capua, Chief Scientist at the Department of Energy's Office of Nonproliferation Research & Develop and the event's moderator remarked that "S&T is playing a strong role in improving relations between the two countries."



The lineup of experts consisted of three distinct perspectives: cultural and economic; industrial; and India's S&T. The first perspective was given by Dr. Sunil Dasgupta, a Nonresident Fellow at the Brookings Institute and the Political Science Program Director at UMBC at Shady Grove. Dr. Dasgupta began with a definition of innovation, which he stated as "the systematic and rapid production leading to new knowledge that enables societies to advance." He discussed the three major areas of innovation in India as being in agriculture and specifically the "green revolution," military technology, and scientific education.

The industrial perspective was given by Dr. Chandra Kintala of the New Jersey Institute of Technology. Dr. Kintala discussed his experience in India with Motorola Labs and Yahoo Labs and provided insight from his experience as a software engineer. He commented on the importance of collaboration and interaction on a daily basis in software R&D and noted that additional international collaboration in this topic area would be beneficial. Dr. Kintala closed his talk with the suggestion to "nurture three-way partnerships" between the Indian government, the United States government, and industry in the two countries.

The third perspective, focused on India's S&T, was given by Dr. Rao Aiyagari, Adviser for the Research Development & Scientific Operations in the Public Health Foundation of India and previously Adviser to the Government of India's Department of S&T. Dr. Aiyagari discussed the role of S&T in India throughout the past half century and illustrated some of the efforts being taken by India's government to promote S&T development and international collaboration.

All three speakers seemed to agree that government investments, additional international collaboration, and more trust within India's S&T community are paramount to India's S&T growth. Partnerships within the global science and technology make sense, said Dr. Larry Schuette, ONR´s Director of Innovation, whose department has sponsored the fall and spring lecture series, which has focused on international issues. "There are many similarities between India and the United States. India´s challenges in attracting students to science and technology has led them to develop an outreach program similar to the "science, technology engineering and mathematics (STEM)" initiatives of the Department of the Navy. And of course, Asia is one of the fastest growing technology regions in the world," he said.

"In fact, ONR Global, our international presence, actively seeks opportunities to promote science and technology collaborations between the U.S. and researchers around the globe," Schuette continued. "Partnerships are a key tenet of the Department of the Navy´s Maritime strategy."

This spring, 2010, we will host the third session of the International Lecture Series shifting our attention to the Western side of the globe and focusing our conversation on the technology breakthroughs that have been occurring in Brazil. More details will be included in the next issue of our newsletter. To see the presentations from the India symposium, visit our ONR Innovation website's events page: http://www.onr.navy.mil/innovate/events.asp You may also request a video of the event by contacting Ms. Melody Mathews, melody.mathews.ctr@navy.mil. ■

Director's Corner

by Dr. Larry Schuette

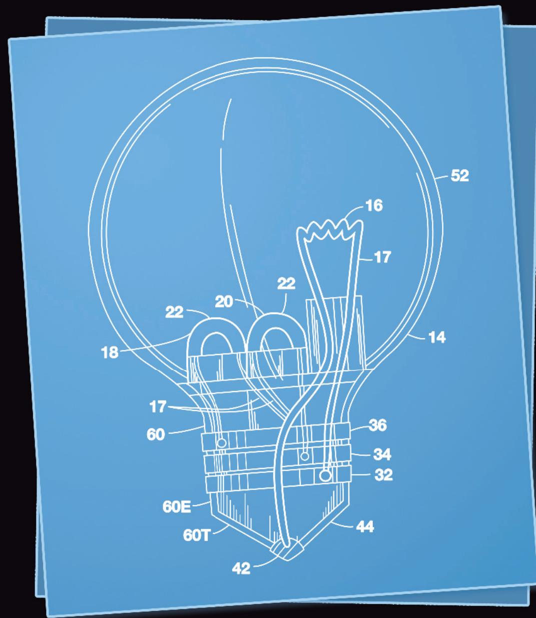
People often ask me what role ONR plays in the Concept Development process within the Navy. What I usually tell them is that ONR and the Navy Warfare Development Command (NWDC), the organization responsible for Concept Development, work very closely together to build future concepts. But more recently it has become clear to me that ONR plays a very specific role in Concept Development when you view it in a broader way than we traditionally have.

In general, we think of Concept Development as a process where by we articulate how we will operate within certain mission sets in the future. The goal is to be able to see out far enough that we can effectively predict what equipment, capabilities and personnel we will need. But, where do you start? How do you do that, without knowing the art of the possible? I have come to believe that ONR is the impetus for understanding that future. We provide the Concept Ideation. Let me give you an example.

In 2008, ONR held an Innovation Summit on Autonomy (detailed in our first edition of this newsletter). The summit included a very strong presence by NWDC, and without their help, the event would never have been as successful as it was. NWDC helped us understand how to look into the future and use current and planned S&T investments to understand how we might employ technologies and capabilities in future missions. We used a team of warfighters, technologists, and acquisition professionals to game potential technologies and capabilities in future warfare missions. The output of that effort was an understanding of where the critical roles for autonomy exist and what is preventing us from achieving those capabilities from an S&T standpoint.

This laid the groundwork for NWDC's Concept Development team to round out what the future will require in the area of autonomy to inform decisions today. Without the summit, I believe that the task would have been much harder for NWDC, and they may not have been able to predict with as much confidence. Concept Ideation informed Concept Development in a new and innovative way.

Following the summit, countless requests have come forward from within the Pentagon and from others of importance asking where we are going in Autonomy. The summit helped prepare us for those tough questions, because we now understand what is possible, and what is useful – two very different things. You can learn more about NWDC at their website http://www.nwdc.navy.mil/. ■



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