Office of Coast Survey
Executive Summary of Autonomous Systems Strategy

Background:
Autonomous systems are capable of executing pre-programmed missions without operator interaction, and are operated on continuum from attended to fully autonomous. Autonomous Underwater Vehicles (AUVs) refer to unmanned, untethered, systems capable of autonomous submerged operation. Unmanned Surface Vehicles (USVs) refer to untethered, self-propelled surface craft ranging in size from man-portable systems to small boat-size vessels that are capable of autonomous, semi-autonomous, or remote-controlled operations.

Autonomous Systems at Coast Survey and Collaborative Efforts:
Coast Survey has the broadest operational portfolio and expertise with unmanned maritime systems in NOAA. Coast Survey intends to employ that experience to the broader development of other autonomous systems, including USVs and automated hydrographic data acquisition and processing. Coast Survey achieves this expertise through operational experience with both small and large AUVs, as well as collaborative work with other NOAA offices, government agencies, academia, and private industry.

Coast Survey has operated small, man-portable AUVs in support of its navigation safety mission and projects supporting other NOAA offices, including National Marine Sanctuaries, NOAA Fisheries, and the Office of Response and Restoration. Additionally, Coast Survey has operated a large, bathymetric mapping AUV for evaluation in support of nautical charting and continues to operate the system in support high-resolution seafloor mapping requirements for other NOAA offices.

Coast Survey is supporting several activities currently underway in the evaluation of USVs, including the development of autonomous control systems for USVs with the University of New Hampshire and coordination with the Integrated Ocean Observing System (IOOS), National Centers for Coastal and Ocean Science (NCCOS), and Alliance for Coastal Technologies (ACT) to hold workshops and demonstrations on USVs for shallow water observations. Coast Survey is also supporting an OMAO effort to demonstrate small, remote-controlled USVs for hydrographic surveying aboard the NOAA ship *Thomas Jefferson*, and has tested a large, long endurance USV aboard a NOAA survey vessel to define shipboard support requirements and evaluate operational procedures.

Drivers for Developing Autonomous Systems:
- Innovation, i.e. pursuit to pioneer and be the nation's experts
- Efficiency, i.e. reduced operational cost, manpower requirements, or time to produce products
- Enhanced Capabilities, i.e. improved responsiveness; ability to collect data previously inaccessible; ability to improve the quality of data collected
- Personnel Management, i.e. with automation, workforce can focus on tasks that require their expertise, rather than on repetitive, laborious tasks

Lessons Learned:
1. The adoption of unmanned systems requires the development of key enabling technologies, such as automated data acquisition and processing and data telemetry, to support the operational use of platforms with autonomous navigation capabilities.
2. Unmanned systems must provide new capabilities or open new mission profiles; one-for-one replacement of manned platforms in existing mission profiles is not effective.

3. Unmanned systems require skilled personnel to operate and maintain, and do not necessarily reduce staffing requirements. However, the use of unmanned systems can allow for the more effective use of personnel.
4. Unmanned systems do not diminish the need for ships, which are necessary to deliver the systems to remote locations and provide operational control and logistical support.
5. Unmanned systems require unique shipboard infrastructure, including Launch and Recovery Systems (LARS), maintenance facilities, and communications, for their safe and effective operation.
6. The current state of autonomous navigation is rudimentary and unmanned systems require supervision. Unmanned systems can operate on a continuum of control ranging from remote-controlled to fully autonomous depending on the operating environment and the capabilities of the system.

Coast Survey's Autonomous Systems Strategy:

1. Develop enabling technologies and procedures, including automated data acquisition and processing tools, new data acquisition procedures, and data telemetry to support unmanned operations and benefit conventional manned survey platforms.
2. Establish a dedicated Coast Survey team specializing in the operational use of unmanned systems, including AUVs and USVs.
3. Convert existing hydrographic survey launches to operate in either manned or unmanned modes to take advantage of existing shipboard infrastructure and expertise, while incrementally adopting enabling technology and procedures.
4. Continue to support the development and transfer-to-operations of unmanned systems, including AUVs, USVs, and UAVs, that provide benefit to Coast Survey's missions.
5. Continue to collaborate with government, academic, and industrial partners to share expertise and resources and direct and expedite development.

Office of Coast Survey
Automation and Autonomous Systems Strategy

April 2017

"Impressive as they are, most robots today are either limited to pristine and precisely controlled settings like factories and research labs, employed in simple, repetitive tasks, or used as mechanical stand-ins for humans who must direct their every move." – *DARPA Robots Challenge 2015, http://www.theroboticschallenge.org/overview, accessed 8/27/15*

GOAL

Utilize autonomy for more efficient and effective extraction of environmental information into valuable navigational products.

SUMMARY

NOAA's Office of Coast Survey has been investigating the use of autonomous systems to support hydrographic survey operations since 2004. Through collaborative work with other NOAA offices, other government agencies, academia, and industry, Coast Survey has the broadest operational portfolio and expertise with Autonomous Underwater Vehicles (AUVs) in NOAA. Coast Survey intends to employ that experience, both in success and failure, to the broader development of automation and autonomous systems, including Unmanned Surface Vehicles (USVs) and automated hydrographic data acquisition and processing.

What we have learned and intend to apply to future development:

1. The adoption of unmanned systems requires the development enabling technologies, such as automated data acquisition and processing and data telemetry, to support the operational use of platforms with autonomous navigation capabilities.
2. Unmanned systems must provide new capabilities or open new mission profiles; one-for-one replacement of manned platforms in existing mission profiles is not effective.
3. Unmanned systems require skilled personnel to operate and maintain, and do not necessarily reduce staffing requirements. However, the use of unmanned systems can allow for the more effective use of personnel.
4. Unmanned systems do not diminish need for ships, which are necessary to deliver the systems to remote locations and provide operational control and logistical support.
5. Unmanned systems require unique shipboard infrastructure, including Launch and Recovery Systems (LARS), maintenance facilities, and communications, for their safe and effective operation.
6. The current state of autonomous navigation is rudimentary and unmanned systems require supervision. Unmanned systems can operate on a continuum of control ranging

from remote-controlled to fully autonomous depending on the operating environment and the capabilities of the system

Coast Survey's Autonomous Systems Strategy

1. Develop enabling technologies and procedures, including automated data acquisition and processing tools, new data acquisition procedures, and data telemetry to support unmanned operations and benefit conventional manned survey.
2. Establish a Coast Survey team specializing in the operational use of unmanned systems, including AUVs and USVs.
3. Convert existing hydrographic survey launches to operate either manned or unmanned modes to take advantage of existing shipboard infrastructure and expertise, while incrementally adopting enabling technology and procedures.
4. Continue to support the development and transfer-to-operations of unmanned systems, including AUVs, USVs, and UAVs, that provide benefits to Coast Survey's missions.
5. Continue to collaborate with government, academic, and industrial partners to share expertise and resources and direct and expedite development.

Coast Survey has formally approved man-portable AUVs equipped with side scan sonar as tools to enhance its emergency response and navigation safety survey capabilities. Standard operating procedures, training and proficiency requirements, and risk management procedures have been approved for the use of those systems specifically for object detection and seafloor imaging side scan sonar surveys. Operation of the Coast Survey's REMUS-100 sidescan sonar AUV will be managed by the Navigation Services Division as part of the suite of tools comprising the Mobile Integrated Survey Team (MIST) utilized by the Navigation Response Teams.

Additionally, Coast Survey completed a project to evaluate mid-sized AUVs equipped with multibeam bathymetric sonars for routine hydrographic surveys. The findings demonstrate that large AUVs provide only limited benefits for routine hydrographic surveys in shallow coastal waterways and ports, but can provide high resolution data in deep water that may not be obtainable by other means. Several NOAA programs, including Coast Survey, can benefit from the deep water, high resolution seafloor mapping capability that large AUVs can provide and Coast Survey will maintain its Hydroid REMUS-600 AUV equipped with a multibeam bathymetric echosounder to meet those needs on a cost-reimbursable and cooperative basis.

Coast Survey has supported several activities in the evaluation of USVs, including supporting the development of autonomous control systems for USVs in collaboration with the University of New Hampshire, coordinating with the Integrated Ocean Observing System (IOOS), National Centers for Coastal and Ocean Science (NCCOS), and Alliance for Coastal Technologies (ACT) to hold a workshop and demonstration focused on ASVs for shallow water observations, and chartering a large, long-endurance USV for an operational demonstration aboard the NOAA Ship *Nancy Foster* in September 2016. Additionally, Coast Survey is supporting an OMAO effort to operate small, remote-controlled USVs (Teledyne Marine Z-Boats) for hydrographic surveying aboard the NOAA Ship *Thomas Jefferson*.

Coast Survey believes an incremental approach toward the implementation of USVs is the most effective. This approach begins with continuing the work with small USVs aboard the *Thomas Jefferson* and potentially expanding their use to other hydrographic survey platforms and Navigation Response Teams (NRTs). The next planned step is the conversion of one or more existing hydrographic survey launches to operate as optionally manned vessels. This step has the potential to reduce the staffing requirements aboard the survey launches which would allow for a more effective use of personnel.

Importantly, Coast Survey believes that the greatest benefits to efficiency and personnel management may be found in the automation of the data acquisition and processing pipeline and the development of technology, such as data telemetry, that enables the adoption of unmanned platforms while immediately benefiting current manned operations.

DRIVERS FOR DEVELOPMENT OF AUTONOMOUS SYSTEMS

Innovation

The Office of Coast Survey must be willing to invest resources and accept the risks associated with evaluation of new technology in its pursuit to innovate hydrography and be the nation's experts. The evaluation of emerging autonomous technologies should be undertaken with informed consideration of the potential benefits and acknowledgement of the potential failure.

Efficiency

Automation and autonomous systems have the potential to improve the efficiency of Coast Survey's hydrographic surveying and nautical charting operations. This efficiency may be realized in reduced operational cost, manpower requirements, or time to produce products.

Enhanced Capabilities

Automation and autonomous system have the potential to enhance Coast Survey's ability to meet its customer's needs. This includes improved responsiveness, the ability collect data previously inaccessible, or the ability to improve the quality of the data collected.

Personnel Management

While manpower requirements are an element of efficiency, other aspects of personnel management may also be affected by automation and autonomous systems. This may allow Coast Survey's workforce to focus on tasks that require their education and skills, rather than on repetitive, laborious, or unpleasant tasks. The adoption of autonomous systems may also require new skills or training for the workforce.

COAST SURVEY'S AUTONOMOUS SYSTEMS EXPERIENCE

The Office of Coast Survey has been investigating the use of autonomous systems as tools to support hydrography since 2004, beginning the acquisition of a man-portable AUV (Hydroid REMUS-100) to serve as a test and evaluation with the primary purpose to provide Coast Survey personnel with experience operating AUVs to develop expertise and explore possible operational concepts.

Coast Survey collaborated with other NOAA offices to deploy the AUV on projects that would allow Coast Survey to explore its benefits to hydrographic survey operations, while demonstrating the system capabilities for other NOAA missions and collecting data that would satisfy other NOAA observation requirements. During the test and evaluation period, Coast Survey's AUV team conducted operations in collaboration with the Office of Response and Restoration, Florida Keys and Thunder Bay National Marine Sanctuaries, Fisheries Restoration Center, and Southeast Fisheries Science Center, among others.

Additionally, Coast Survey has actively participated in internal and external forums to inform and promote the wise use of autonomous systems to meet NOAA's mission needs. In 2004, Coast Survey coordinated and hosted the first NOAA AUV Workshop, where the first NOAA AUV Working group, which has since evolved into the Ocean Observations Innovation Forum, was chartered.

In 2011, Coast Survey formally accepted man-portable, side scan sonar equipped AUVs as operational tools in support of its navigation safety mission, and currently owns a Hydroid REMUS-100 AUV which can be rapidly deployed as part of the Mobile Integrated Survey Team (MIST) in response to significant storm or maritime incident, or could be used in support of a routine hydrographic survey. In 2016, Navigation Services Division accepted the system as part of the suite of tools comprising the Mobile Integrated Survey Team (MIST) utilized by the Navigation Response Teams.

In 2012, Coast Survey began its evaluation of a mid-sized AUV (Hydroid REMUS-600) equipped with multibeam bathymetric sonar as tool to collect depth sounding data to update nautical charts. Coast Survey collaborated with NOAA's Office of Marine and Aviation Operations (OMAO) for two successful deployments of the AUV aboard the NOAA Ship

Ferdinand R. Hassler. Those deployments demonstrated that large AUVs provide only limited benefits and significant challenges for routine hydrographic surveys in shallow coastal waterways and ports, but can provide high resolution data in deep water that may not be obtainable by other means. Several NOAA programs can benefit from the deep water, high resolution seafloor mapping capability that mid-sized AUVs can provide and Coast Survey will maintain its Hydroid REMUS-600 AUV equipped with a multibeam bathymetric echosounder to meet those needs on a cost-reimbursable basis.

In 2013, Coast Survey transferred ownership of its OceanServer Iver-2 AUV to the Southeast Fisheries Science Center. Coast Survey had been evaluating the capabilities of the system to conduct continuous sound speed profile observations in support of manned hydrographic survey vessels, but the system was found to be inadequate for that purpose. However, discussions held during Coast Survey's participation in Fisheries Advanced Sampling Technology Working Group's (ASTWG) 2012 AUV identified the potential benefits of the system to Fisheries.

In 2015, Coast Survey supported development of autonomous control systems for an USV in collaboration with its partnership with the University of New Hampshire as a graduate research project, and coordinated with the Integrated Ocean Observing System (IOOS), National Centers for Coastal and Ocean Science (NCCOS), and Alliance for Coastal Technologies (ACT) to hold a workshop and demonstration focused on ASVs for shallow water observations. At the same time, the NOAA Ship *Thomas Jefferson* began the operational use of small, man-portable USVs (Teledyne Marine Z-Boats) to meet very shallow water hydrographic survey requirements and bridge the gap between conventional manned launch and airborne LIDAR surveys. These experiences informed Coast Survey's next step, which was to charter a larger, long endurance USV for an operational demonstration on a seafloor mapping cruise in September 2016.

The objective of the USV charter was to deploy a USV with full technical and operational support for one underway leg aboard a NOAA survey vessel to perform multibeam sonar surveys in coordination with the ship to evaluate shipboard infrastructure requirements, staffing and manpower requirements, technical capabilities of the USV, and operational concepts. The operational demonstration was in partnership with NOAA's National Centers for Coastal Ocean Science (NCCOS) during a habitat mapping cruise aboard the NOAA Ship *Nancy Foster*.

VISION & STRATEGY

Enabling Technologies and Procedures

Discussion

Coast Survey recognizes that the full potential of unmanned platforms, including AUVs and USVs, will not be realized without development, maturation, and adoption of enabling technologies and procedures, such as autonomous sensor operation, automated data acquisition and processing, and high-bandwidth data telemetry. In addition to supporting the operational transition of unmanned platforms, those technologies and procedures can also improve the effectiveness of manned operations.

A significant portion of a Coast Survey hydrographer's time is spent analyzing visual representations of acoustic and digital data to detect identify contacts of interest, remove or correct data artifacts or anomalies, and evaluate data quality. This type of data analysis and processing is particularly well suited for automation, and automation of these tasks is necessary to the effective use of autonomous systems, such as AUVs and USVs.. Without automating data acquisition and processing tasks any efficiency gained during hydrographic surveys will be quickly consumed by an increased workload in data analysis and product generation, effectively moving bottlenecks further down the data pipeline. Automation of these routine data tasks frees personnel to potentially manage a greater number of surveys, focus on challenging data analysis and unique product generation requirements, or oversee additional autonomous systems.

Coast Survey is interested in automating aspects of hydrographic survey operations to improve real-time coverage and reduce resurvey requirements. Additionally, commercial data acquisition and processing software providers and academic are working towards automation of sonar tuning and control, computer-aided contact detection and classification, and real-time data processing. Coast Survey believes that the greatest benefits to efficiency and personnel management may be found in the automation of the data acquisition and processing pipeline.

Vision

Coast Survey will invest in commercial, academic, and internal development and testing of data acquisition, processing, and management automation tools with the following five year goals:

- Evaluation and Implementation of Improved Data Telemetry Systems
- Automation of Data Acquisition and Coverage
- Automation of Initial Data Processing and Cleaning
- Automation of Sonar Contact Identification
- Automation of Routine Product Generation

Small Autonomous Underwater Vehicles

Discussion

The Office of Coast Survey has demonstrated that small, man-portable AUVs, such as its REMUS-100 AUV, can enhance its capabilities to respond to navigation safety survey requirements. These systems can be quickly delivered to a survey location by commercial or government character and operated from a wide variety of platforms or shore by small team of trained personnel. When operated in a fully-autonomous manner, the AUVs can allow the host platform to perform other necessary work, such as additional survey coverage or repair to damaged navigational aids.

This flexibility enhances, but cannot replace, the capabilities of Navigation Response Teams or portable manned survey systems which can be temporarily installed on vessels of opportunity. The primary limitations of these AUVs are survey speed and coverage, lack of real-time data analysis, and risk of damage or loss.

Vision

Coast Survey will stand up a operational unmanned systems team with a focus on the operational use of its unmanned systems, including the REMUS-100 AUV, as tools to support both Coast Survey's navigation safety mission and support NOAA's seafloor mapping requirements.

Mid-Sized Autonomous Underwater Vehicles

Discussion

The Office of Coast Survey owns a Hydroid REMUS-600 AUV equipped with a hydrographic survey grade multibeam bathymetric echosounder. This system was acquired to keep pace with innovations in hydrographic surveying as other government and commercial survey organizations are pursuing the technology. The potential existed for AUVs to increase the data acquisition capabilities of manned survey platforms, and therefore provide increased efficiency in hydrographic surveying. The ideal goal was to increase the annual Linear Nautical Miles (LNM) surveyed by a hydrographic survey vessel with a minimal investment in infrastructure, no additional shipboard personnel, and no interruption to current shipboard productivity.

During initial underway testing aboard the NOAA Ship *Ferdinand R. Hassler*, the REMUS-600 AUV demonstrated the potential to increase the ship's data acquisition by 20% while requiring 3.25 man hours dedicated to AUV operations, in addition to shipboard personnel necessary for launch, recovery, and monitoring. Additionally, the *Hassler*'s shipboard infrastructure was adequate for AUV testing, but would require significant alterations to improve efficiency and safety for permanent AUV operations. The other hydrographic survey vessels in NOAA's fleet are less suited to host a large AUV due to limited working deck space suitable for Launch and Recovery Systems (LARS) and accessible interior lab space.

The most significant limitation to AUV's potential is Coast Survey's typical operating environment of shallow, coastal waterways with substantial vessel traffic. Multibeam echosounders provide the most efficient mapping coverage when the can be operated the maximum height off the seafloor for the desire resolution. In shallow water the swath width of the coverage is narrower because of the low height of the echosounder's tranducer above the seafloor. An AUV must be operated deep enough to be safe from vessels passing overhead, which further reduces the achievable swath width. In shallow water, an AUV will typically achieve less than 75% of the swath width of a surface vehicle and typically surveys at less than half the speed, resulting in a very inefficient use system.

Mid-sized and large AUVs have been used by other organizations with greater benefits in much deeper water. In some cases, the AUV can provide a significant efficiency gain over a deeply towed sonar because speed and maneuverability limitations a ship experiences with a deep tow. In other cases, an AUV can provide dramatically enhanced capabilities over a shipboard system because it can dive deep enough to collect much higher resolution data than is possible from the surface.

Another limitation is the complexity of the data analysis. Bathymetric data collected for nautical charting must conform to strict NOAA and international standards. Submerged systems are significantly more complex and challenging to qualify and quantify due to the lack of full-time, precise three-dimensional positioning possible with the GPS positioning systems used by NOAA surface vessels.

Because of these limitations, Coast Survey has determined that mid-sized and large AUVs are not ideally suited to use for routine shallow-water hydrographic surveys for nautical charting. However, the systems have a unique capability to provide high-resolution seafloor mapping data in water depths greater than possible with shipboard sensors. Several NOAA programs can benefit from the deep water, high resolution seafloor mapping capability that large AUVs can provide and Coast Survey will maintain its Hydroid REMUS-600 AUV equipped with a multibeam bathymetric echosounder to meet those needs on a cost-reimbursable basis.

Vision

Coast Survey will stand up an operational unmanned systems team with a focus on the use of its unmanned systems, including the REMUS-600 AUV, as tools to support both Coast Survey's navigation safety mission and support NOAA's seafloor mapping requirements.

Unmanned Surface Vehicles

Discussion

Coast Survey's initial investigation into autonomous systems focused on underwater vehicles because, at the time, the available Unmanned Surface Vehicles (USVs) were large and somewhat unsophisticated. Their size presented significant challenges in equipment, vessels, and facilities necessary to undertake an evaluation of the systems, while the size and lack of sophistication presented significant risk of the USV to do harm to another vessel in a port or harbor environment. In the last few years, the variety of USVs available has increased to include systems of a manageable size that still maintain adequate survey capabilities. Also, while the systems have improved and become more sophisticated, the common approach towards the operation has become more realistic. Rather than pushing unsophisticated systems towards unachievable, or dangerous, levels of autonomy, most of the new systems are making incremental steps towards full autonomy, beginning with remote controlled and semi-autonomous systems. These systems acknowledge that the seemingly simple task of navigating a small boat actually requires a great deal of intelligent and adaptive decision making to safely deal with other vessel traffic, so it is left to a human operator. While simpler functions, such as survey line steering, coverage control, sensor control can potentially be automated. As these systems are developed they present a strong potential for both improved efficiency and more effective personnel management. Additionally, very small USVs can enhance capabilities to survey in very shallow water, which can be important to emergency responders, coastal resource managers, and recreational boaters.

The most promising application of USV technology is in dual-capability hydrographic survey launches. These systems can be operated as traditional manned survey launches or on a continuum of autonomous control. At the beginning of the continuum the USV is manned, but employs advanced auto-pilot systems to manage survey line control and coverage, while high-bandwidth radio communications can allow data acquisition to be managed remotely . Continuing along the continuum, prior to fully-autonomous operations, the launch may be unmanned, but operating within visual range of the host ship, which would provide situational awareness, command and control, and remote data acquisition management.

This approach allows Coast Survey to incrementally adopt enabling technologies and unmanned operations as the technology improves and expertise grows. Additionally, Coast Survey is able to leverage the existing shipboard infrastructure and knowledge for survey launch operations.

Vision

Coast Survey supports the incremental development and adoption of USV technology, which includes continued integration of small ASVs for shallow water, near shore survey operations to realize data acquisition benefits not otherwise achievable and develop expertise.

Coast Survey is pursuing the conversion of one or more hydrographic survey launches to operate in either manned or unmanned modes.

Unmanned Aerial Vehicles

The Office of Coast Survey does not have an observation or mission requirement that can be readily addressed with current UAV technology. However, Coast Survey maintains an active role as stakeholder in the development and use of UAS technology and is collaborating with the

National Centers for Coastal Ocean Science (NCCOS) and National Geodetic Survey (NGS) on UAS development projects.

DEFINITIONS

Automation

Automation refers to hardware, software, and procedural tools used to remove or reduce the need for operator interaction to complete a task.

Autonomous Systems

Autonomous systems are capable of executing pre-programmed instructions without operator interaction. At their simplest, autonomous systems follow the pre-programmed instructions with very little awareness, response, or adaptability to external input. More complex systems can incorporate sensors and artificial intelligence to modify pre-programmed instructions based on external input.

Even though user interaction is not necessary, autonomous systems are operated on continuum from attended to fully autonomous. In attended operations, continuous communications are maintained to monitor status, aid navigational positioning, or receive data, and the host platform may remain nearby. In fully autonomous operations the system may operate at a significant distance from the host platform and only periodic or fault communications may be monitored.

Semi-Autonomous Systems

Semi-autonomous systems are capable of executing pre-programmed instructions under operator supervision and periodic interaction. These systems included those capable of both manned and unmanned operation. The complexity and capabilities of these systems may be very similar to autonomous systems, with the distinguishing difference being reliance on operator interaction for routine operations, safety, or fault response.

Remote Controlled Systems

Remote controlled systems require constant operator command and control.

Autonomous Underwater Vehicles (AUVs)

AUVs refer to unmanned, untethered, propeller driven, cylindrically shaped systems, such as the Hydroid REMUS-100 and REMUS-600 AUVs, capable of autonomous operation. Excluded are buoyancy-driven systems, such as Teledyne Webb Research Glider.

Unmanned Aerial Vehicles (UAVs)

UAVs refer to unmanned fixed or rotary wing aircraft capable of autonomous or remote controlled operation.

Unmanned Surface Vehicles (USVs)

For the purpose of the document, ASVs refer to untethered, self-propelled surface craft ranging that can range in size from man-portable systems to small boat size vessels, that are capable of autonomous, semi-autonomous, or remote controlled operations. These systems are typically unmanned, by some may be capable of dual manned and unmanned operations.