An Automated UAV Mission System

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ABSTRACT

In March of last year, engineers from SPAWAR Systems Center, San Diego (SSC San Diego) and Allied Aerospace (formerly Micro Craft, Inc.) conducted the first known launch of a Vertical Takeoff and Landing Unmanned Air Vehicle (UAV) from an Unmanned Ground Vehicle (UGV) in Holtville, California (2002). The launch concluded a week-long demonstration to the Defense Advanced Research Projects Agency as part of the U.S. Army's Future Combat Systems Organic Air Vehicle Phase I effort. The launch involved Allied Aerospace's 29-inch Lift Augmented Ducted Fan iSTAR UAV and SSC San Diego's Mobile Detection Assessment Response System-Exterior UGV.

SSC San Diego is now pursuing integration efforts in order to increase base security and defense missions by decreasing time and personnel required to maintain a UAV during operations. The main project goal is to develop a system that allows a UAV to be launched, recovered, and refueled in order to provide force extension through autonomous aerial response. This paper presents an overview of near term mission areas, benefits, and target recipients of the integrated system. It also provides a description of the project plan, including challenges faced and lessons learned, in order to inspire further integration ideas and efforts with existing unmanned systems.

BACKGROUND

Unmanned aerial systems can provide significant reductions in manpower and risk to humans for critical security and defense roles. UAVs can carry payloads to areas where it would be dangerous for a human to go, and they can transit between operating stations at high speeds, allowing for quick response to changing situations. Unlike ground vehicles, UAVs are highly mobile in rough terrain and urban environments.

The use of UAVs in defense and security applications has increased significantly in recent years. Traditional applications for UAV systems include Intelligence, Surveillance, and Reconnaissance (ISR), target acquisition, and communications relaying. Emerging uses include medical resupply, border patrol, maritime security, crowd control, search and rescue, and environmental monitoring. UAVs in these roles provide reductions in manpower, as well as increased safety for personnel [1]. Unmanned aerial systems will continue to increase in importance as government agencies and military services find new methods of providing security with increasing effectiveness, while keeping financial costs and human risks low.

The focus in surveillance and security applications emphasizes the development of Vertical Takeoff and Landing (VTOL) UAVs. VTOL UAVs have advantages over fixed-wing UAVs in that they require no runway for takeoff or landing, can hover, and can maneuver in three dimensions. The ability to take off and land vertically means that these UAVs can be more easily deployed and recovered, eliminating the need for large takeoff and landing areas. This allows VTOL UAVs to be easily integrated into existing systems such as boats or trucks, whereas fixed-wing UAVs require catapults or rockets for takeoff and nets or parachutes for landing.

The ability to maneuver freely in three dimensions makes VTOL UAVs well suited for flying through cluttered spaces such as forests or urban environments, whereas conventional UAVs have difficulty maneuvering. The ability to hover and land in small areas also makes VTOL UAVs valuable for their "Perch and Stare" capability, landing in an area of interest and shut down their engines, becoming a stationary sensor platform until they need to move again [2]. Their hover and three-dimensional maneuvering capabilities are also essential for successful operation in windy conditions when providing low-altitude coverage.

The primary downside to VTOL UAVs is that they have a significantly smaller payload-range ratio than similar-sized fixed-wing UAVs. For a given payload weight, a fixed-wing UAV is able to fly for a longer time than a VTOL UAV. As a result, VTOL UAVs must remain closer to their refueling station and/or spend less time in operation areas. This also means that human ground crews must spend more time landing and refueling a VTOL UAV, usually close to the operations area putting them at greater risk.

BENEFITS OF AN AUTOMATED UAV MISSION SYSTEM

The use of an automated UAV mission system for the launch, landing and refueling of a UAV provides the potential for significant manpower savings in comparison to existing UAV systems requiring human ground crews to perform recovery and refueling of the UAV. Reducing the number of support personnel required to operate a UAV will free up personnel and financial assets for other tasks. Savings are realized from the ability to have a forward-based refueling station. With a more also accessible refueling station, the efficiency of the UAV is increased since less time is spent in transit to and from the manned refueling station. As a result, more time is spent in mission execution. This allows for fewer UAVs to perform a given task, reducing the overall cost of the UAV mission system.

The automated UAV mission system also allows the UAV to operate at a greater distance from operational personnel. This moves the ground crew out of harm's way. An automated UAV mission system allows the UAV the capability to be forward-deployed, allowing for rapid response. Having automated UAV mission systems pre-placed in strategic locations can significantly reduce the time required to respond to dynamic situations. Pre-placed automated UAV mission systems can also act as range extenders for UAVs, allowing a UAV to refuel itself repeatedly while traversing a long distance. This allows for fewer UAVs to be used as resources for large areas, adding the capability to move to different locations to meet current needs.

The physical combination of a UAV with a UGV or Unmanned Surface Vehicle (USV) creates a robotic mission system that allows the operation of the UGV or USV alone (while transporting the UAV), the UAV alone (with the UGV or USV acting as a stationary base), or both in cooperation to perform complex tasks, such as mine clearing. In such an arrangement, effectiveness is increased by utilizing the benefits of the UAV (fast transit, overhead view, long communications range, ability to travel over poor terrain) and the UGV or USV (large payload, large power supply, long range).

The UAV's ability to hop from one automated system to another will also allow for UAV resources to be more easily shared. For instance, a UAV could be launched from a UGV and landed on a USV. In a large network of multiple unmanned vehicles, the need for an aerial communications relay, an extensive view of local coverage area, or deployment of a defense for immediate response. This eliminates geographic constraints associated with single unmanned vehicles, allowing the dispersed platforms to work cooperatively to achieve increased shared situational awareness and synergistic effects, and provides dynamic adaptation to the situation by providing a way to exchange roles and/or responsibilities.

TARGET RECIPIENTS AND APPLICATIONS

Several users in the security and offensive military community have been identified that would potentially benefit from the automated UAV mission system. They include the Program Manager-Physical Security Equipment (PM-PSE) Mobile Detection Assessment Response System (MDARS) program, the Cooperative Unmanned Ground Attack Robot (COUGAR) program, the U.S. Army's Future Combat System (FCS), the Defense Advance Research Projects Agency (DARPA) Perception for Off-Road Robotics (PerceptOR) program, and the U.S. Navy SPARTAN Advanced Concept Technology Demonstration (ACTD).

MDARS Program

The MDARS program sponsored by the PM-PSE is a joint development effort between the U.S. Army and U.S. Navy to field mobile robots for physical security. The

MDARS-Exterior (MDARS-E) provides intruder detection and assessment, barrier assessment, and inventory accountability. Expanded force-protection and force-multiplication capabilities have facilitated investigations into aiming and firing less-than-lethal weapons on the MDARS-E platform. A Marsupial Delivery System has been integrated to carry and transport smaller deployable assets, such as a Man-Portable Robotic System (MPRS) Urban Robot (Figure 1) [3].

Figure 1. MDARS-E with Marsupial Delivery System

The MDARS-E platform is being used during the development of the automated UAV mission system. The benefits of an automated UAV mission system would extend the MDARS mission areas. For example, an MDARS-E platform could autonomously patrol a weapons storage facility performing intruder detection. If an intruder was detected and attempted to elude the MDARS-E platform, the automated UAV mission system could launch the UAV in order to maintain pursuit of the intruder. The automated mission system also allows the UAV to spend more time in the air for continuous aerial coverage. This would expand the physical security system's mission of intruder detection by extending its zone of security.

In the Project Leap Ahead demonstration held December 2002 in Florida (USA), the MDARS-E platform was part of the "Flightline or Alert Area" scenario. The 29-inch iSTAR was used to further illustrate the MDARS system's capability to detect, identify, track, assess, report, and respond to adversary personnel and vehicles.

FCS Demonstration Program

The U.S. Army's FCS demonstration program plans to develop a network-centric concept for a multi-mission combat system. Its purpose is to be overwhelmingly lethal, strategically deployable, self-sustaining, and highly survivable in combat through the use of a Family of Systems. The goal of the program is to develop an ensemble of manned and unmanned ground and air vehicles that maximizes the following critical performance factors: ground platform strategy; operational and tactical mobility; lethality; survivability; and sustainability. The program will be adaptable to a changing set of missions ranging from warfighting to peacekeeping [4].

An automated UAV mission system will address FCS requirements for UAVs deployed at the platoon, company, battalion, and brigade levels. By incorporating UAVs with other manned and unmanned vehicles, coverage area and mission flexibility are expanded. Since the UAV can be launched from one type of platform and recovered by another, the strengths of each type of platform offers are leveraged to accomplish a specific task or set of tasks.

An automated UAV mission system benefits the key FCS mission areas by providing better situational understanding and awareness, beyond line-of-sight targeting, and a wider surveillance and communications coverage area. One key mission area is the use of UAVs for ISR missions. The ability to operate from different unmanned vehicles extends these capabilities and extends UAV time-in-mission execution by having the automated UAV mission systems closer to the mission area.

The second key mission area is the use of UAVs for Military Operations in Urban Terrain (MOUT) involving ground units, operators, and UGVs. Buildings and other large structures limit the communications and transmission of image data between ground troops. An automated UAV mission system would allow rapid deployment of a UAV communications repeater vehicle to maintain communications between ground units, operators, and UGVs.

PerceptOR Program

The FCS PerceptOR program focuses on off-road robotic navigation, and, therefore, conducts unrehearsed field experiments in a variety of terrains and weather conditions. The developed technology will be used for various combat roles and will help to identify the weather and terrain conditions under which unmanned off-road vehicles can be used effectively.

The PerceptOR program is also examining the use and significance of a-priori overhead data and multiple cooperative ground and air vehicle perspectives for off-road robotic operations [4]. The automated UAV mission system would be mounted on a UGV and used to launch a UAV to fly ahead of the UGV in order to aid its navigation.

The ability to launch the UAV directly from the platform instead of a separate base station will improve response time and decrease the manpower needed for coordination and logistics.

COUGAR Technology

COUGAR is a technology effort to integrate multiple unmanned systems to demonstrate detection, designation, and engagement of threat systems. As such, COUGAR is a lethal capability that could transition into other unmanned system programs, including the U.S. Army's FCS and the U.S. Marine Corps Gladiator Program. Gladiator is an initiative to support the dismounted infantry with unmanned scout/surveillance capabilities.

Phase II of COUGAR consists of a command vehicle that hosts the Operator Control Unit, a "killer" Hybrid HMMVW robot that carries long range weapons, and a "hunter" robot with a day/night reconnaissance payload, a laser designation system, and a UAV. The "hunter" robot will use an onboard launch/recovery system for quick response to potential targets. The human operator programs the UAV's flight path before launch and monitors its aerial imagery. The "killer" robot will be slightly autonomous with waypoint navigation and convoying modes. It will follow the "hunter" robot to a firing point, and the hunter robot will go to a reconnaissance position. The human operator sends a command to launch the UAV from the "hunter" robot using an automated UAV mission system for aerial reconnaissance and survey of targets. The UAV will then confirm a positive or negative hit by the missile launched (Figure 2) [5].

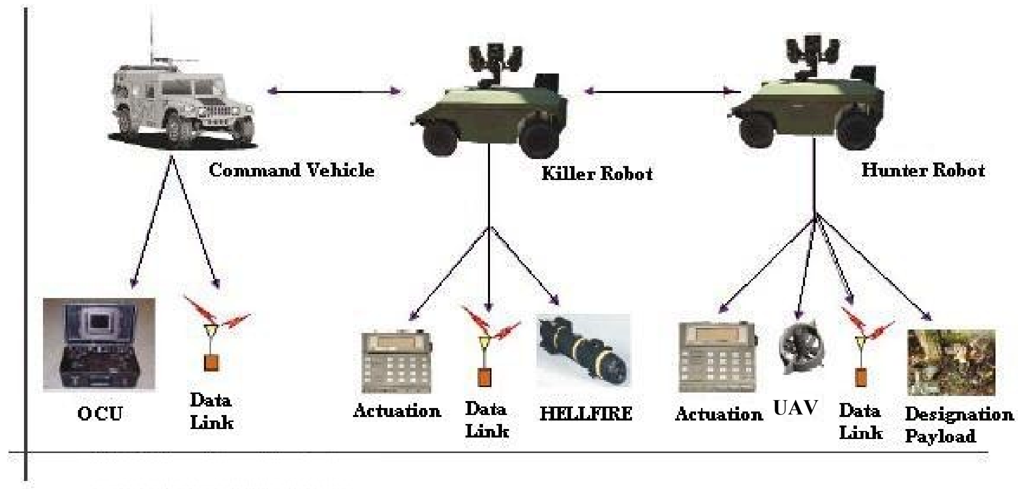

Figure 2. COUGAR Phase II Demonstration System

SPARTAN ACTD

SPARTAN ACTD is a joint U.S. Army and U.S. Navy effort, in coalition with the Republic of Singapore, aimed at demonstrating the utility of multi-mission unmanned surface vehicles as sensor and weapons platforms. The mission areas to be demonstrated include ISR, Reconnaissance, Surveillance, and Target Acquisition (RSTA), Precision Strike (PS), Anti-Surface Warfare (ASuW), Force Protection (FP), and littoral Mine Warfare (MIW).

The automated UAV mission system can be mounted on the SPARTAN test bed (Figure 3) and used to support FP and ISR activities by providing stand-off capabilities and overhead visual imagery. The UAV can be deployed from SPARTAN and used to investigate suspect vessels or objects before an interdiction team.

Figure 3: SPARTAN Test Bed, NUWC, Newport, RI

AUTOMATED UAV MISSION SYSTEM DEVELOPMENT

SSC San Diego has been in the business of developing robotic technology for over 25 years and posses a strong background in security robots and Command and Control (C^2) for unmanned systems. SSC San Diego has also developed a series of research prototypes for the development of component technologies needed for security missions including mobility, camera, sensors, and weapon functions [6].

Development of the automated UAV mission system at SSC San Diego began in Spring 2002. In March 2002, an Allied Aerospace 29" iSTAR UAV was launched from an MDARS UGV in Holtville, CA using a simple fiberglass launch fixture as a milestone of the DARPA FCS program (Figure 4). Since then, SSC San Diego has developed a second generation fixture that will be able to launch, land, and refuel the 29" iSTAR UAV under the control of the Multi-Robot Operator Control Unit (MOCU), also developed at SSC San Diego. MOCU provides for control of multiple robots and displays the robots and their paths to be overlaid on an aerial photograph of the mission area. [7]

Figure 4. MDARS-E with Allied Aerospace's 29" iSTAR UAV and First Generation Launch Fixture

The second generation automated UAV mission system fixture consists of a round base where the UAV sits and four large arms which are raised to enclose the vehicle and lowered to provide a large landing area. When lowered the arms form a funnel which guides the UAV into the center of the fixture (Figure 5). When raised the arms provide protection for the UAV while it is carried by the UGV (Figure 6). Experiments are planned to determine the best configuration of the arms for takeoff. Expectations are that the arms should be closed fully for takeoff, providing a launch tube effect.

Figure 5. Launch Fixture Opened

Figure 6. Launch Fixture Closed

In the center of the launch fixture is a capture and release mechanism (Figure 7). This mechanism attaches to the bottom of the UAV and is used at launch to hold the UAV down until the engine spins up to full throttle, and at which time the capture mechanism is released to launch the UAV. This mechanism also incorporates a fuel pump and nozzle so that the UAV can be refueled. Engineering students at the University of California, San Diego performed initial design and testing of this mechanism during their senior design course [8].

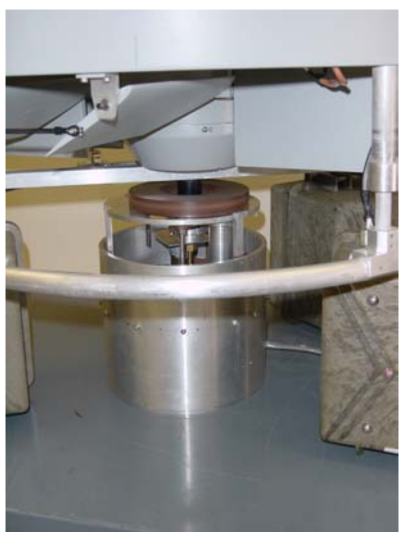

Figure 7. Center Latch

When the UAV lands on the launch fixture, a set of rotating fingers grab the UAV landing ring and pull the UAV into the center of the fixture (Figure 8). The center latch mechanism is then raised to mate with the refueling nozzle in preparation for refueling and re-launch.

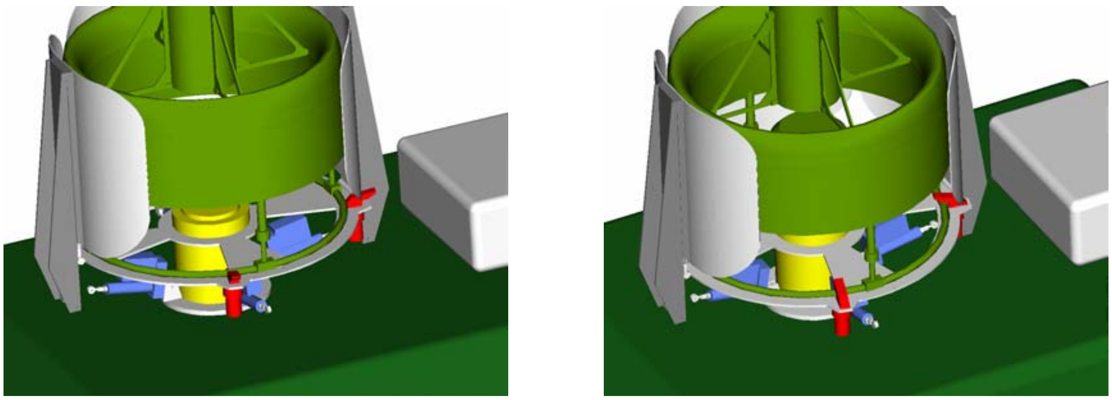

Figure 8. Rotating Finger Latches

Presently, the second-generation fixture has been fabricated, and initial launch and landing tests are scheduled for September 2003. These initial tests will use a remotely piloted UAV. Further development will then lead to use of the fixture with a fully autonomous UAV.

SSC San Diego and Allied Aerospace have partnered with Geodetics, Inc., Carnegie Mellon University (CMU) and NASA's Jet Propulsion Laboratory (JPL) to apply existing technologies to the challenging problem of landing the UAV on the fixture autonomously. Geodetics provides a Global Positioning System (GPS) solution that allows for high relative accuracy between the GPS receivers on the UGV and the UAV without use of a Differential GPS base station. This system also benefits from epoch-by-epoch dwell time, greatly reducing the amount of time required to achieve an initial GPS position fix. CMU and JPL are providing vision-based landing systems to augment the

GPS solution. Experiments are planned to determine the relative effectiveness of these systems used alone and together and to determine the range of conditions under which the system can be expected to operate effectively in fully autonomous mode. These positioning technologies are also being leveraged by other projects at SSC San Diego to provide docking and refueling for small UGVs.

CONCLUSION

SSC San Diego is working with other developmental partners to increase security and defense applications through the development of an automated launch, recover, refuel, and re-launch mechanism for a VTOL UAV. The automated UAV system augments the UAV's functionalities and benefits, such as minimizing the personnel required for mission operation, range extension, and increased operational awareness. Its wide range of benefits results in a wider range of security and defense applications in the civil, commercial, and military sectors including fire-fighting and relaying communications on the battlefield and opens the door for new mission areas in scientific research, law enforcement, and network-centric defense tactics. Being the first to develop such a robust system presents a number of challenges, which hope to inspire other efforts for continued integration and development of UAVs into existing robotic systems and supporting robotic technologies.

ACKNOWLEDGEMENTS

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