Unmanned Common Control Station Paper

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ABSTRACT

Common Control Station for Multiple, Heterogeneous Unmanned Vehicles using STANAG 4586 and JAUS standards is being requested by Military Operators. The objective is to allow a single operator to easily control and maintain situational awareness of many dissimilar unmanned systems. To date the concept has been tested with multiple UAVs, Unmanned Surface Vehicles (USVs), Unmanned Underwater Vehicles (UUVs) and Unmanned Ground Vehicles (UGVs) in simulation and real world exercises. The common control station provides the advantage of decentralized cooperation/coordination for situation awareness of unmanned vehicles and sensors to a distributed force. The reduced logistic costs of one control station and savings for crew training are an added benefit. The goal is to make common control station software with an open and functional architecture that one can easily plug-in new operator interfaces without breaking the essential core capabilities. Presentation will focus on lessons learned during development/demonstration of DTI's Open Unmanned Mission Interface (OpenUMI) with a summary of the path ahead.

INTRODUCTION

While Unmanned Aerial Vehicles (UAVs) have been known around the world since the early twentieth century, technology hindered application to present day situations. Over the past ten years with technology advances in materials and microprocessors, these UAVs have exponential applications important to agriculture, law enforcement, air carriers, military, homeland security, and private use. However, issues associated with Unmanned Control Station design and aircrew training is impacting which unmanned vehicles are used. As the interest in using unmanned vehicles grows both for military and commercial use, so does the interest in controlling multiple unmanned vehicles simultaneously. This includes the desire to operate multiple types of unmanned vehicles (UAVs, USVs, UUVs or UGVs) know as Heterogeneous Unmanned Vehicles. An example of a commercial application would be to use both UAVs and UGVs for broadcasting and security during a NASCAR event. One or more UAVs could give you low cost aerial views of the track and the crowd, while UGVs could collect video on the track's edge and the pit. Other examples would include monitoring and policing boating events using UAVs, USVs and/or UUVs. This use would also cross over to military operations in rivers or littoral waters. The military has a strong desire for operation of unmanned vehicles as a distributed force.

PROBLEM DEFINITION

Today's problem is that the control stations for unmanned vehicles control only a single unmanned vehicle at a time, using proprietary software, datalinks or interfaces. As a result, any operation of multiple types of unmanned vehicles, or vehicles from different vendors, requires multiple control stations. The multiple control stations, or software, can leave the operator with no data fusion and thus poor understanding of how the operation is going. Increased costs are incurred with the need to purchase unique software, datalinks and interfaces from each vendor.

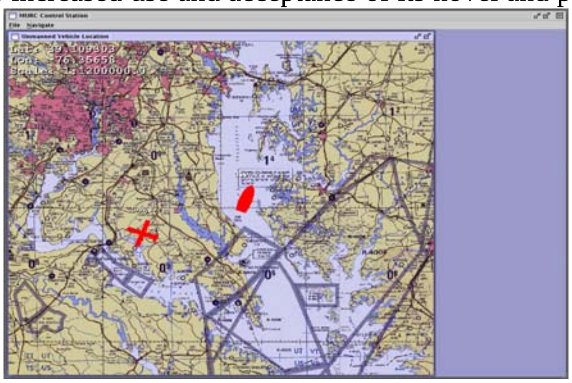
DISCUSSION

A common control station is a critical part of operation involving unmanned vehicles carrying a variety of sensors. To create a common control station, a communications and control station architecture must be in place that allows the control station to interface with all the unmanned vehicles and sensors. This architecture must allow an operator to control multiple vehicles, or payloads of vehicles, as well as allowing other operators to view or accept control of these vehicles or payloads. For communications, a networked environment using industry standards is required. This allows any control station to recognize all control stations, vehicles and payloads on the network. IP is an obvious choice with the large about of commercial equipment available but other options could be considered.

The key to creating this common control station architecture is not to try and create a single monolithic interface that covers all of the unique aspects of different unmanned systems, which we feel is impossible, but to create a system that provides the user a simple intuitive user interface for control and monitoring the common aspects of unmanned systems with the ability for the system to present to the user the vehicle specific operator interfaces. This concept focuses on the 80/20% rule of life. You can never get to the 100% optimized solution within a realistic time and budget, in fact probably not even with an unrealistic one. What you can do is rapidly get to the 20% solution and then find a unique and usable technique to handle 80% of the problem. The 'common' for controlling unmanned systems is about 20%, but these are the commands and messages that are used 80% of the time. The 'uncommon' that are left normally are only used at discrete mission segments, like startup, and require vehicle specific knowledge and training. This is also the current philosophy for the new NATO UAV controls and monitoring protocol STANAG 4586. All that are not common must be handled by vehicle specific module (VSM), normally created by the vehicle manufacturer. The goal of the common control station is to create a user interface that embraces the 'common' and accommodates the 'uncommon'. To do this, architecture has been designed that allows the uncommon user interfaces to be seamlessly integrated without modifying the core. The result is a common control station that does not need to know anything about a specific vehicle until it comes into contact with it, at which point it will be able to acquire all the necessary controls and information to allow the user to interact with it. Among other things, a control station built under this architecture resists obsolescence and the need to retest (for every vehicle previously controlled) each time a new vehicle is added.

Standards are a beginning to allow a common control station to be effective. To interface with USVs, UUVs or UGVs, the United States Army and Naval Sea System Command is endorsing the use of the JAUS Standard. Currently, DTI and several other companies have demonstrated the control of a USV using the STANAG 4586 Standard.

DTI has demonstrated these concepts with the Open Unmanned Mission Interface (OpenUMI) product. DTI's focus has been carefully directed at the OpenUMI architecture, Vehicle Tool Kit (VTK) and Vehicle Specific Modules (VSM) for easy integration of innovative technologies. The goal of DTI's OpenUMI investment is to make an open and functional architecture into one which can easily plug in new operator interfaces, innovative sensors and unmanned vehicles without breaking essential core capabilities. OpenUMI itself is freely distributed within the United States Government agencies to allow for increased use and acceptance of its novel and proven control interfaces and techniques. The power of OpenUMI is to allow a single operator to easily control and maintain situational awareness of many dissimilar unmanned systems. It has been tested to date with multiple unmanned vehicles in simulation and real world exercises.

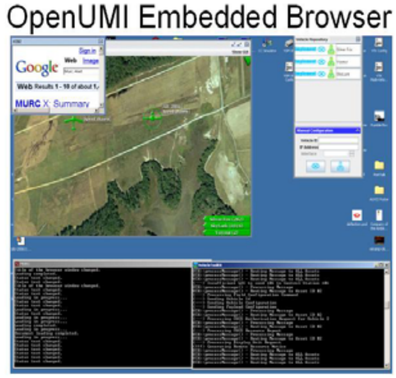


OpenUMI Command Display

As part of the ONR and NAVSEA Sea-based Heterogeneous Operations Uninhabited Teams (SHOUT) demonstration in July of 2004, this architecture was implemented in a very short time period by a diverse set of engineers. This distributed team of engineers from NAVAIR, NAVSEA, SPAWAR, and Industry where able to effectively pull together hardware and software for an operationally relevant demonstration that had several firsts. These firsts included the first time a USV and UAV were simultaneously controlled from a common control station, and the first time a UAV and USV were controlled using the Draft NATO Standard 4586.

Specific OpenUMI capabilities leverage the ability to superimpose real-time information over a moving map tool. This ability can support multiple National Geo-spatial Agency products such as charts and maps. The ability to provide weather overlays notifies users of changes in target area, and provides access to intelligence data. This icon passed system also provides single click access to additional information resources such as available assets, streaming video, still imagery, and mission information such as routes, ingress/egress points, and mission action points. Currently, OpenUMI has been tested to function over a standard wireless network (802.11) with functional tolerance to large variations to available bandwidth and dropouts. The output of the OpenUMI research is the OpenUMI system, which uses an IP-based embedded browser, which is used to access vehicles, payloads or processors over any IP-based network. This would allow any dismounted member of a small assault team or mounted team member to access or control any of the unmanned vehicles or payloads.

OpenUMI Embedded Browser



<u>The common control station interface and hardware must be flexible to the operator needs.</u> OpenUMI demonstrates this using JAVA based code which operates on a wide variety of operating systems and hardware, allowing the same control station to be used with either a human portable, unmanned air, or

ground system. OpenUMI has been tested in the Windows and Linux environments. This includes a current Small Business Innovative Research (SBIR) Phase II Contract with NAVAIR to develop a Common UAV Airborne Control Station for P-3 or Multi-Mission Maritime Aircraft (P-8).

In October 2007, DTI was awarded an SBIR Phase II contract to extend the OpenUMI concepts to a Disadvantaged User (DU). A DU is a soldier who needs unmanned vehicle or sensor data but is in a location where they do not have access to a full control station. Current solutions, such as the Rover III do not allow the soldier to be on the move. It allows the soldier to receive data, but not transmit data, and provides limited Situation Awareness. Hence, the current technology is used only on a limited basis prior to a mission.

The DU handheld computer will provide off-the-shelf technology in a package that provides moving map capability with identification of location, IP communications on the move, and display/integration of multiple sensor data by running OpenUMI.

DTI has also been working with the NAVAIR 4.6 Crew Systems department to develop a Control Station that can be operated on high speed boats. DTI successfully completed the initial water testing of the boat seat mounted Unmanned System Control Station. Shown in the photos is a triple display configuration (Think TacAir) and has the OpenUMI software loaded on the computers along with a few other programs to drive workload. Using the simulator, DTI was able to successfully control a simulated USSV and UAS while underway and used both the joystick and keyboard Operational Interface.

The OpenUMI Payload Operator Interface (POI) is based on connecting to IP-based devices, such as a 3D processor or imaging device. The operator receives an icon on the bottom left screen when data from a device is available. The operator simply clicks on it to view it.

Payload Operator Interface

The OpenUMI POI is also capable of bringing in other critical data, such as terrain, maps, GPS data to name just a few.

<u>OpenUMI has demonstrated how a common control station can be expanded to control unmanned vehicles with proprietary systems by developing additional VSMs using a standard VSM Tool Kit (VTK).</u> DTI has controlled or brought in sensor data from currently fielded UAVs, USVs and UUVs. Most of these unmanned vehicles use proprietary interfaces. To develop a VSM the proprietary interface data normally has to be provided by the developers of these vehicles to develop a STANAG 4586 or JAUS VSM. Another option would be for the control station developer or the vehicle developer to develop the VSM themselves using DTI's VTK. The VTK saves many months of work to develop a new VSM and does not require the developer to know the details of the Standards. These VSMs can then be used with any control station that meets the STANAG 4586 and JAUS Standards.

DTI further demonstrated these concepts in a successful "Unmanned Systems Demo" at Wallops Island on November 8, 2007 called Study 5, which involved personnel from ONR, NAVAIR, NAVSEA, Draper Labs, Lockheed Martin, OSD and NASA. The purpose was to determine the degree to which each of the mission planning tools and user interfaces allows a single mission manager to effectively carry out an ISR mission involving an unmanned Family of Systems (FOS). An additional goal was to highlight any system optimization opportunities associated with FOS mission planning and replanning.

Scenario: Intelligence reports that a ship is being loaded with contraband at a foreign port where U.S forces are denied access. Friendly forces will direct a (surrogate) Unmanned Underwater Vehicle (UUV) to proceed to an area near the port to monitor the departure of the suspected contraband ship. Once the suspect ship departs port, the UUV will report the ship's position and heading. A (surrogate) High Altitude Long Endurance (HALE) aircraft will then be re-tasked via dynamic planning systems and given a new route to attempt a high altitude over-flight at a slant range to get a RADAR signature of the target. Tactical Unmanned Aerial Systems (UAS) will then be launched to help identify and assure that the vessel being tracked is in fact the suspected contraband ship. Upon confirmation, an Unmanned Surface Vehicle (USV) will be directed to an intercept point and will stay on station, tracking the target, until a manned platform is in position.

What was unique about the Unmanned Systems Demonstration was that DTI used OpenUMI and VSMs to pull together a common display while some of the vehicles were controlled by the proprietary control stations of others. This includes the Draper Software which controlled the surrogate UUVs (really a USV) where a VSM was used on the front end with data provided to OpenUMI on the backend. As well as OpenUMI receiving data from the MicroPilot Vision UAV, after all this was an IP Device on the network. DTI also received data from two Kestrel UAVs with Piccolo Autopilots directly controlled by OpenUMI and interfaced with other software decision and planning tools.

The Unmanned Systems Demonstration brought together three UAVs, two USV's (one was a surrogate UUV) and three unmanned software planning tools into an integrated environment that shared data easily. This demonstrated an operation with multiple unmanned vehicles could reduce the number of operator needed, cost of training them, and other logistic costs. It is clearly not cost effective to do multi-vehicle operations with a control station for every vehicle.

Lessons learned and results from the Unmanned Systems Demonstration included the following:

1. Reducing the Need for Human Operator Intervention
   - Missions were successfully executed on the basis of high level mission objectives, priorities, risks, and constraints rather than lower-level vehicle control
     - Not necessary to modify low level route & payload plans if tasking correctly entered.
     - Lacked sufficient protections to prevent operators from making errors in specifying tasking
   - Fully autonomous dynamic replanning was successful when tasking was changed or when contingencies occurred (assuming it was possible to autonomously identify the contingency and the operator had allowed replanning in that case)
     - Solutions were often sub-optimal, though acceptable because of the way the problem was decomposed and constrained.
   - Users reported that the variable autonomy was very helpful and would provide considerable benefit in an operational environment
   - Problems occurred when
     - Tasking by the operator was not or became no longer feasible within the constraints.
       - Not always clear what constraints/tasking should be removed/adjusted to make a feasible plan
     - Replanning was done too rapidly with too little explanation to the user

        - Needed better way to determine when replanning is REALLY necessary and explain rationale
    - Plans were no longer effective by the time they were approved and sent out to all assets
        - Plans developed by autonomy need to be robust to what the situation may be by the time the plan is approved and communicated out to all assets.

2. Common Interface for Management of a Family of Air & Sea, Systems

- Positive outcomes from measures of workload, situation awareness, usability, and user comments support the hypothesis that this type of system may allow a single user to plan and execute a mission involving multiple autonomous unmanned vehicles
    - Users reported that the automated features would be a great asset in an operational environment.
    - Users did suggest many potential improvements such as automated checklists
- Approaches considered basically user friendly with adequate situation awareness and acceptable workload across range of operators with the different skills/backgrounds used in the experiments
- Users reported that it was relatively easy to get started with the system even with limited training. Though, they also noted that they thought additional training would make it much easier to utilize the system.
- Users reported high levels of workload when adding in new tasks and assigning assets.
    - Users felt that this high workload might be reduced by adding automation to simplify the amount of work required to specify missions.

3. Situation Awareness

- Operator SA was measured in laboratory experiments only by stopping the simulation and administering SAGAT probes
- SA of current status sometimes lower than desirable when operators were busy with planning/re-planning
    - Users reported missing alerts and wanted more understanding of why the automation was making the decisions it was making
    - Users reported difficulty due to large amount of data on screens at one time
    - Favorable response to December evaluations that examined new display overlays for organizing the vast amount of data available into meaningful and useful groups based on a Cognitive Work Analysis
    - Still in process of analyzing data from .

4. Number of Vehicles Manageable by a Single Operator

- Up to 7-8 heterogeneous vehicles were looked at under different scenarios
    - We were trying to find the spot where things would break down, but we underestimated how many vehicles an operator could handle with the system in these scenarios
- Some reasons why managing this number of vehicles was feasible
    - Requiring major replans every 15 minutes seemed to be getting close to the limit of what was feasible for the operator/system. A faster rate of plan changes might have caused more serious problems.
    - The contingencies were fairly easy to diagnose. It might have caused problems if there were contingencies that required a lot of digging into details for the operator to make sense of while other things were going on.
    - Scenario complexity was considered by the operators as medium. Higher scenario complexity may have created problems for that number of vehicles
    - There was minimal workload involved with sensor data interpretation and real-time interaction with sensors in the scenarios. That can add a lot more manning requirements.

5. Human Factors Lessons Learned

- Cognitive Mission Task Analysis is critical
- Function allocation and levels of autonomy should be based on:
  - Complexity of task
  - Operator workload
  - Criticality of task success
  - Consistency of automation
  - Capability of autonomy
- Dynamic replanning requires collaboration between human and autonomy
- Situation awareness is based on quality of information presented and match with mental model
- Trust is dependent on consistency of automation (even more than accuracy)

6. Human Interaction Lessons Learned

- Standardization of symbology and color must be weighed against operational issues and legacy systems integration
- Alerting logic and presentation needs to be based on results of analysis
- Difficult to match operator mental model with autonomy algorithms
- Care must be used in developing evaluation training, scenarios and metrics to ensure fair assessment of autonomy software

DTI future recommendations:

- Recommendation: Set up a joint NAVAIR, ONR, NASA WFF live evaluation as a yearly event.
- What NAVAIR Common Systems would do:
  - Establishment of the Live Evaluation Testbed with WFF
  - Scenario Development for the common mission
  - Evaluation of mission planning tools
  - Human Factors Assessment of systems
  - Range Safety Plan
- What Unmanned System Programs would do:
  - Provide Systems and Operations
  - Provide Interface to the common systems architecture

DTI is currently expanding OpenUMI by working with multiple companies and government organizations. DTI has demonstrated OpenUMI with the Advanced Ceramics Research (ACR) Silver Fox, NAVAIR's Sonochute Launched (SLUAV) and Wing & Bombay Launched (WBBL) UAV Programs, NAVSEA's USSV Programs, ONR unmanned efforts, and the UUV efforts at OSD and Draper Labs. DTI is currently working with GT Aeronautics, Carolina Unmanned Vehicles, CONTROP, ACR, Lite Machines, Geneva Aerospace, Prioria, SAIC and several others.

CONCLUSION

In conclusion, a common control station can be developed to effectively control multiple heterogeneous unmanned vehicles for operations. This does require the unmanned vehicles to meet common standards such as STANAG 4586 and JAUS.