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UxV Data to the Cloud via Widgets - 051

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Abstract

This paper proposes a new paradigm for distributing tactical control of unmanned vehicles using widgets in a web browser leveraging the Ozone Widget Framework (OWF). In order to accomplish this objective, the infrastructure, storage, and display of the data being retrieved from unmanned systems must migrate from existing closed systems to a Modular Open Systems Approach (MOSA). A locally available ship-based Accumulo/Hadoop Cloud Infrastructure enables the large amounts of data to be retrieved, appended and stored by multiple operators (both local and remote) via widgets in a web browser. Traditionally, this data is only available to the warfighter with line of sight to the unmanned system; however, our approach is to exploit this data operationally and strategically which will enable increased Situational Awareness and support long-term planning, emergency response and evolving threat requirements. The proposed architecture stipulates that the Cloud infrastructure and Services will be locally available to accommodate Disconnected, Intermittent, Limited (DIL) environments where reach-back is not possible. Another component of the architecture would be a federated, shore-based Cloud that would allow the ship-based Cloud to push and pull data when communications and bandwidth are available.

Introduction

"Information dominance enables end-to-end defense and management of Navy networks and the information and knowledge that is transported by those networks. The Navy's information capabilities and info-centric communities place the Navy in a better position to meet the challenges and threats of the Information Age. Success in the Information Age will require unmatched mastery of the capabilities, tools and techniques that enable us to collect, process, analyze and apply information."

U.S. Navy Program Guide 2012[1]

As the quotation from the *U.S. Navy Program Guide 2012* illustrates, today's Navy must prepare for a battlefield that extends not only to the traditional physical warfare domains of land, sea, air and space, but to the information warfare domain as well. The Navy's recent focus on the information domain signals a paradigm shift in the way the Navy views and utilizes information from a supporting role to that of a core tenet. As Vice Admirals Kendall L. Card and Michael S. Rogers[2] noted in their recent Proceedings article, "Just as the United States dominates the maritime domain, we must do the same in the information realm, which includes cyberspace and the electromagnetic spectrum, if we are to preserve our Navy's superiority and primacy. From our perspective, this is a new center of gravity for maritime warfare."[3]

While the U.S. Navy currently enjoys "superiority on land, air and sea, as well as in the space and cyberspace domains" this "asymmetric advantage is due in large part to our assured C2 capabilities." Of particular concern is an adversary's potential for contest our information dominance by "employing the full range of emerging technologies in warfare to include cyber and advanced electronic warfare, and utilizing information warfare as a key weapons system."[4] Furthermore, the Joint Operations Access Concept (JOAC) notes:

> Due to three major trends - the growth of antiaccess and area-denial capabilities around the globe, the changing U.S. overseas defense posture, and the emergence of space and cyberspace as contested domains - future enemies, both states and nonstates, see the adoption of anti-access/ area-denial strategies against the United States as a favorable course of action for them.[5]

[1] U.S. Navy Program Guide 2012

[2] Vice Admiral Kendall Card is the Deputy Chief of Naval Operations For Information Dominance. Vice Admiral Michael S. Rogers is the Commander of Fleet Cyber Command/ Commander Tenth Fleet. Together they authored the U.S. Navy's Strategy for Information Dominance.

[3] Card, Kendal and Michael Rogers, "The Navy's Newest Warfighting Imperative". *Proceedings*, U.S. Naval Institute (Annapolis, Maryland: 2012).

[4] Department of Navy (DoN) *Information Dominance Roadmap* (Washington D.C.: Department of Navy 2013).

[5] Department of Defense (DoD), *Joint Operational Access Concept* (Washington D.C.: Department of Defense, 2012), 3.

Thus the U.S. Navy is facing increasing challenges to the information domain it has come to rely upon so heavily.

Despite the challenges, achieving information dominance is, and will remain, key to the U.S. Navy's ability to maintain maritime superiority. The Navy's proposition to enter into this new domain follows the Information Dominance principle, which the *Strategy for Achieving Information Dominance* defines as, "the operational advantage gained from fully integrating the Navy's information functions, capabilities and resources to optimize decision making and maximize warfighting effects.[6]" Instead of standing by to see its information dominance eroded, the U.S. Navy has been proactively moving forward with the creating of both the *Information Dominance Strategy* and it's recently released follow-on implementation plan the *Information Dominance Roadmap*. In simplistic terms, the Information Dominance principle can be distilled into three main components in order to achieve the desired effect of gaining the operational advantage: Assured C2, Battlespace Awareness, and Integrated Fires

In each of these areas the Navy has recognized that its ability to collect and disseminate information will be challenged by a potentially Disconnected, Intermittent, Limited (DIL) information environment.

This paper contends that the architecture and technologies explored in the *UxV Data to the Cloud via Widgets* effort can help address some of the goals and objectives stipulated by the *Navy's Strategy for Achieving Information Dominance*. In particular, the architecture and capabilities discussed have the potential to allow even forward deployed battle groups to maximize the efficiency of even intermittent information environments to collect and disseminate information, information that can be quickly mirrored throughout all the crucial nodes of the information grid. Utilizing multiple local, ship-based Cloud infrastructures will enable a common repository to ingest, tag, store and retrieve data from disparate sources in one centralized, forward-deployed location. The envisioned architecture would also feature a singular shore-based Cloud infrastructure that could push data to the forward-deployed clouds and pull data from them. This will allow a forward deployed unit to enter a DIL environment and take with it the most current information it can. After achieving connectivity, it could quickly sync with the ashore cloud and pass just the new information quickly. Two forward-deployed units could also push and pull data from and to one another given that an IP-based network could be provisioned between them and sufficient bandwidth was available. Thus, the cloud architecture enables all the forward deployed information gatherers to both have a copy of up to date information and also to share it among other units in a DIL environment. This architecture addresses DIL considerations by localizing the storage, analysis and information to forward-deployed assets and decouples the dependence on external data, employing the concept of opportune reach-back. Most importantly, even though the Cloud could potentially contain a vast amount of data, all of the data from the cloud would be searchable and visualized via widgets in a web browser running on a local, ship-based instance of the Ozone Widget Framework.

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[6] Department of Navy (DoN) *Navy's Strategy for Achieving Information Dominance* (Washington D.C.: Department of Navy, 2012); Available at http://www.public.navy.mil/fcc-c10f/Strategies/Navy_Strategy_for_Achieving_Information_Dominance.pdf

Background on the Ozone Widget Framework (OWF)

The Ozone Widget Framework (OWF) is a framework that allows users to easily access all their online tools from one location. Not only can users access websites and applications with widgets, they can group them and configure selected applications to interact with each other via inter-widget communication. Widgets are defined as portable, lightweight, single-purpose applications that can be installed and executed within an HTML-based Web page. Widgets are often used to provide summary views of dynamic information content as components of information dashboards[7]. OWF and other components of the Ozone platform are governed, managed and made available via the Government Open-Source Software (GOSS) model.

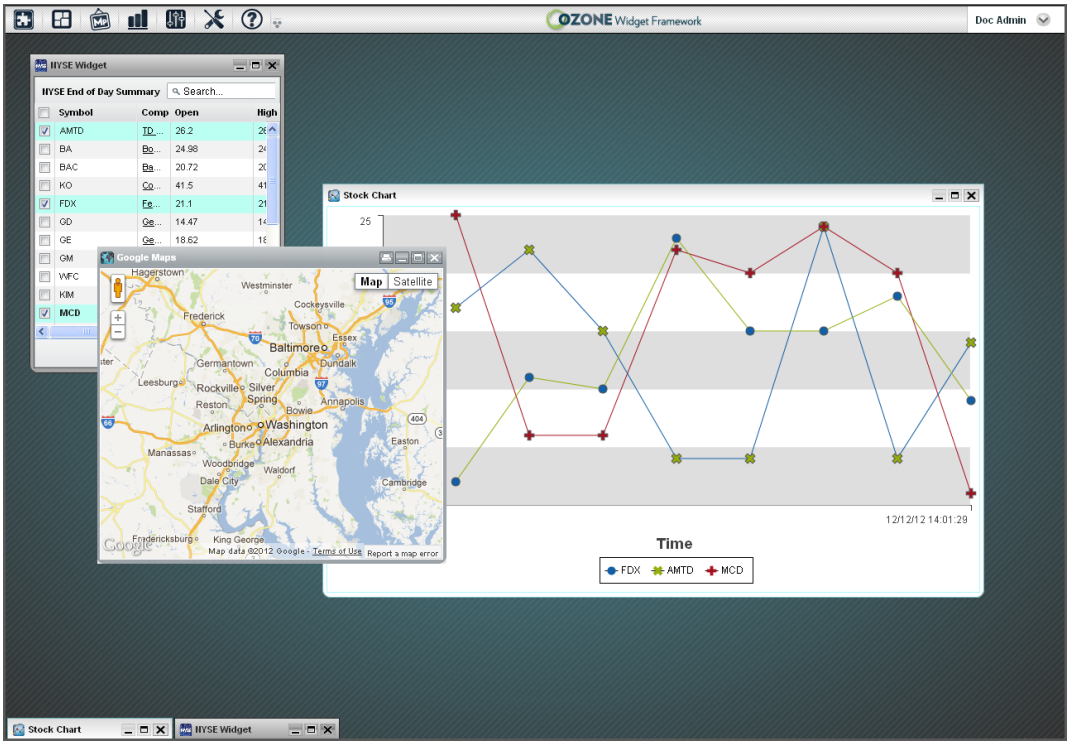

Figure 1 – Example widgets running in OWF

Leveraging OWF as a common computing environment provides a uniform look and feel and standard user experience for applications across disparate functional areas. OWF provides an intuitive web-based desktop view, a webtop if you will, that allows users to open, close, resize and position applications as they like. The widgets are technology agnostic so they can be developed in myriad of programming languages. On the client-side, the only requirements are a compatible web browser and an internet connection, rather than installing a thick client application or plug-in.

[7] Ozone Platform - https://www.owfgoss.org/

Background on the Cloud: Accumulo/Hadoop

Accumulo and Hadoop are both Free and Open Source (FOSS) Apache projects that constitute the underlying Cloud infrastructure that this paper supposes. Accumulo was originally developed by the National Security Agency (NSA) starting in 2008 and subsequently joined the Apache project in 2011. Accumulo can be thought of less as a traditional SQL database and more of a sorted, distributed key/value store based on Google's BigTable design with some notable enhancements, namely the implementation of cell-level security[8]. The main design drivers of Accumulo were to design a generic platform with a baked in performant, cheap, simple, scalable, secure and adaptable feature set. Accumulo's basic key/value data type features a 5-tuple key, including:

- Row: controls *Atomicity*
- Column Family: controls *Locality*
- Column Qualifier: controls *Uniqueness*
- Visibility: controls *Access* (Cell-level security)
- Timestamp: controls *Versioning*[9]

Row	Column Family	Column Qualifier	Visibility	Timestamp	Value
Adam	Favorites	Food	(Public)	20090801	Pizza
Adam	Favorites	Color	(Public)	20090785	Blue
Adam	Favorites	Color	(Private)	17545712	Pink

Figure 2 - Accumulo Data Model

Accumulo is built on top of Apache Hadoop, another FOSS product, which provides a reliable, scalable and distributed computing framework. Hadoop is designed to run on thousands of machines facilitating computation and storage. Hadoop can detect and handle failures at the application layer, delivering high-availability on top of the hardware itself that is prone to failure. Accumulo leverages two main components of Hadoop; the Hadoop Distributed File System (HDFS) which provides high-throughput read/write to data and MapReduce which promotes parallel processing by splitting larger jobs across multiple compute units[10]. A Cloud infrastructure built upon Accumulo/Hadoop provides a fault tolerant, highly-available infrastructure that can quickly store and access big data sets.

[8] http://accumulo.apache.org/
[9] http://people.apache.org/~afuchs/slides/morgan_state_talk.pdf
[10] http://hadoop.apache.org/

Background on UxV Data to the Cloud via Widgets

UxV Data to the Cloud via Widgets is a leadership-driven, cross-competency Naval Innovative Science and Engineering (NISE) project being worked out of SPAWAR Systems Center (SSC) Pacific. It is a Technology Transition S&T project in its second year of funding. The main objectives of the project are to tactically control unmanned systems (UxV) via control widgets running in OWF and also to store the telemetry data and imagery coming of the UxV in a local, ship-based Accumulo/Hadoop Cloud. Analysis widgets could then be employed to search and exploit this data from Accumulo via a RESTful API.

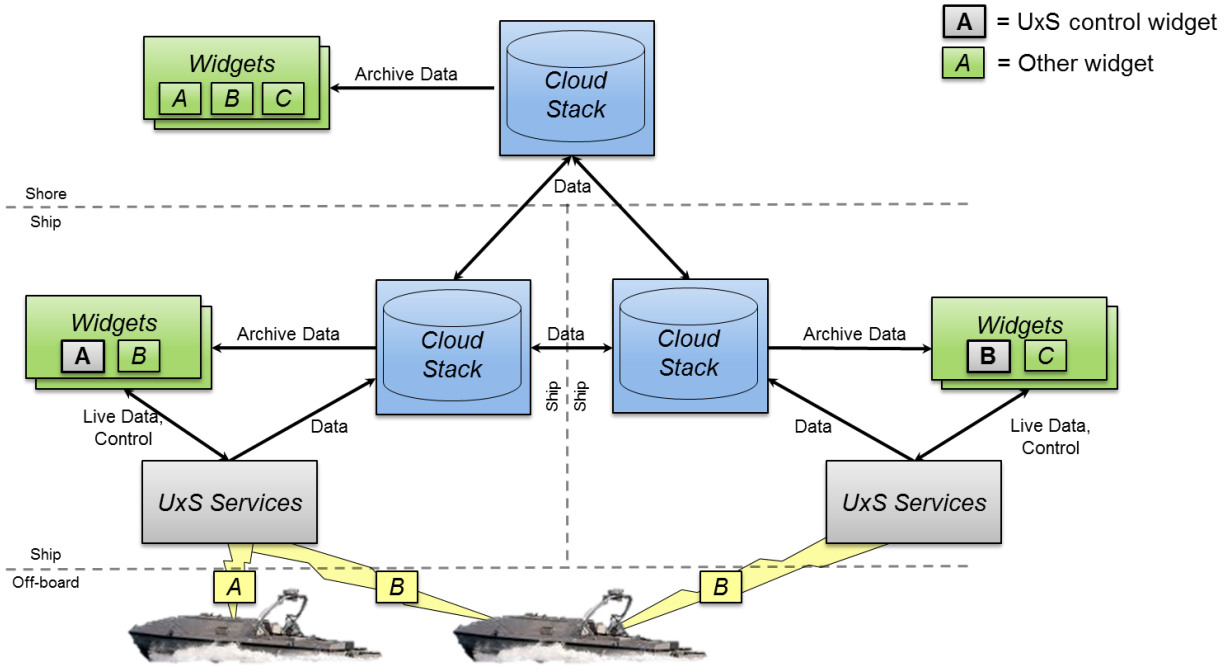

Figure 3 - UxV Data to the Cloud via Widgets System Architecture

UxV Data to the Cloud via Widgets directly aligns with strategic guidance and initiatives coming from the highest echelon of the Navy. Chief of Naval Operations, Admiral Jonathan Greenert, in his Sailing Directions advocates the, "u*se* [of] new technologies and operating concepts to sharpen our warfighting advantage against evolving threats," and predicts, "unmanned systems in the air and water will employ greater autonomy and be fully integrated with their manned counterparts.[11]" The data that these unmanned systems is vital, but can be difficult to integrate into the battlespace common operating picture. It is additionally important that local users can use their forward deployed cloud to store the information when they are in a DIL environment; without the appropriate data tool the data would be unusable without connecting to the larger ashore data environment.

The *UxV* project demonstrates a mechanism in which data is collected by unmanned vehicles to be analyzed for post-mission analysis which feeds operational and strategic decision making. This signals a new concept in the way unmanned systems are utilized by operators. As opposed to the telemetry and imagery data coming off the vehicle for a single operator to view before falling onto the floor, this data

[11] CNO Sailing Directions http://www.navy.mil/cno/cno_sailing_direction_final-lowres.pdf

is archived, aggregated and stored for later retrieval. Multiple operators now have access to this data, through a web browser, in a highly distributed manner; rather than a single operator sitting at a specialized terminal. Furthermore, this data is being stored in a Hadoop cluster which features High-Availability (HA) and Fault Tolerance (FT) at the software layer. Relying on clusters of hardware does provide a level of HA and FT, however leveraging a technology like Hadoop provides another layer of protection abstracted from the bare metal machines. In the event of a hardware failure, the Hadoop cluster will continue to function, allowing for the bad hardware to be swapped out and replaced. All of this appears seamless to the operator, allowing the warfighter to continue uninterrupted operations.

The proposed architecture addresses many of the considerations of performing C2 in denied and contested environments. By standing up a local cloud on the ship, a forward deployed asset could continue to operate and perform its missions without having to rely on reach-back or even Line-of-Sight communication. Once connectivity was established and bandwidth available, the ship could reach-back to the shore-based cloud to pull new data down or push data from its cloud to the shore or to another ship.

Realizing Information Dominance

In addition to enabling multiple users to access the data in a limited information environment, the UxV project can give the operator the ability to tactically control, maneuver and task unmanned systems in order to conform to up-to-the minute and emerging collection requirements. The control widgets give a real-time view into what the Unmanned Surface Vehicle (USV) is seeing through its camera and also where it is on the map.

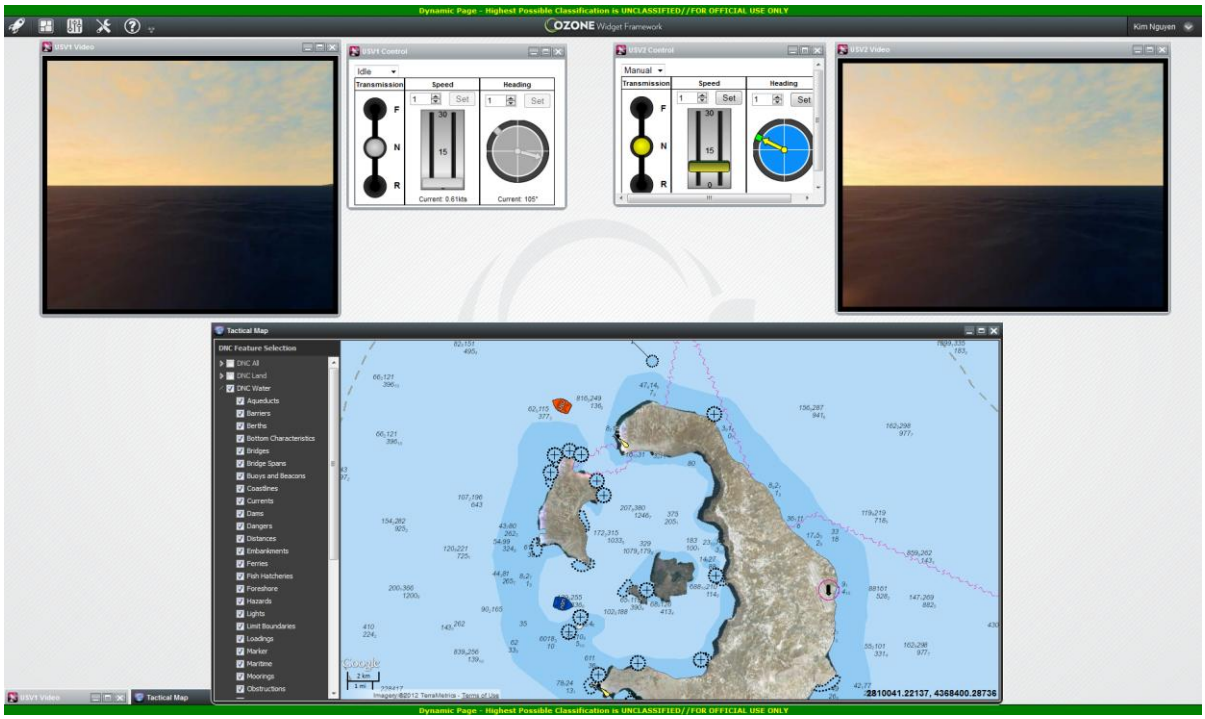

Figure 4 - USV Control Widgets

Often times, commanders do not have real-time cognizance of where their unmanned assets are located and certainly not what they are seeing. This information is only known to the operator controlling and viewing the UxV from a dedicated terminal. By exposing this information through widgets in a web-browser, the commander gains greater Situational Awareness of where all unmanned assets are at any given time. The agility to re-task unmanned assets in light on new intelligence is possible through the collaboration of exposing this data to a wider audience. This is particularly important because a deployed commander can gain this awareness even if the information environment does not permit the user to reach back to an ashore information cloud. The local, deployed Cloud using the UxV is sufficient for this capability.

Furthermore, the analysis widgets developed under this project can enable this process by synthesizing information from all sensor data that has been ingested into the cloud. An analysis widget exposes all of the data that any USV has ever seen via a multi-term query. This widget can search across date time ranges, a geographical bounding box and the name of a particular USV. There is also a map widget that

allows an operator to zoom into an AoR and then search across the entire Accumulo database for any USVs that have been in that area.

Figure 5 -Analysis Widgets

Finally, his paper contends that the work done on the *UxV* project at SSC Pacific has taken a crucial step in order to train the civilian arm of the Information Dominance Corps (IDC). Work down on cutting edge technologies like cloud computing, tactical control and analysis of unmanned systems data is critical to the Navy. The second year of this project has produced a Technology Transition Agreement (TTA) with the Distributed Common Ground System – Navy (DCGS-N) which will endeavor to transition the technology developed under this effort into the warfighter. The ultimate goal would be to deploy a system that would benefit the enlisted and officers of the IDC.

Conclusion

The use of cloud technologies combined with widgets to collect, synthesize and share the data make real progress towards achieving some of the planned milestones and even advanced capabilities laid out in the Information Dominance Roadmap. In fact, there are capabilities in this project that address each one of the three mission areas described in the Information Dominance Roadmap: Assured C2, Battlespace Awareness, and Integrated Fires.

With regards to Assured C2, this project has the potential to address the C2 problems that are inherent in a contested C2 environment. The establishment of a dynamic and flexible grid, as this cloud architecture proposes, is a key component of the U.S. Navy's future ability to ensure assured C2. The proposed architecture could fulfill one of the key components of a dynamic and flexible grid, namely "a network control capability at the tactical edge that reduces reliance on shore based network control." Additionally, the widgets ensure that the mission relevant data for shared awareness goal can be met. With the widgets any operator, at any platform, can access all the relevant data they need rather than wait for a data dump from the single operator who has contact with the external sensors (in this case UxVs).

As the Navy looks to expand its usage of unmanned vehicles and other sensors, the need to ingest, store, analyze and visualize the collected data becomes critical. The Battlespace Awareness goals in the Information Dominance Roadmap seek to directly combat this problem. Cloud technologies such as Accumulo/Hadoop have been demonstrated to support the large and varied data from unmanned systems where rigid traditional relational database tools will not suffice. Thus these technologies combined with widgets to organize the data will help address the goal to develop a shared, relevant real-time COP/CMP. Widget technologies such as Ozone have been shown to support rapid technology insertion by decoupling the presentation and data layers from one another.

Finally, the architecture and technology described in this paper will be invaluable for the third goal of integrating fires. As the Information Dominance Roadmap notes, "a comprehensive Integrated Fires capability would efficiently use all available sensor data, even from traditional ISR or combat systems." The flexibility of the widgets will enable this complete COP for integrated fires.

The architecture and technology developed under this project aligns directly with the Deputy Chief of Naval Operations (DCNO) for Information Dominance principles to reduce manning, transition to autonomous systems and to enable one operator to control multiple platforms. The Navy must look to technologies such as these in order to elevate Command and Control in forward deployed platforms that are cut off from the rest of the fleet and shore-based assets. Standing up a local, ship-based Cloud will enable the ship to continue to operate in denied and contested conditions. The Navy must invest in likewise S&T work in order to grow and mature a formidable Information Dominance Cops.