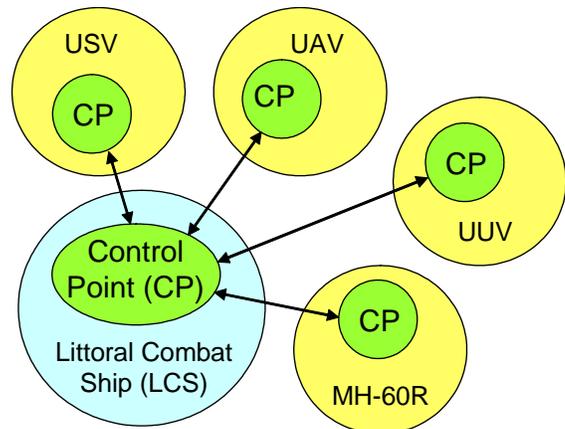


Network Monitoring and Management System (NMMS)

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PROBLEM STATEMENT

The Littoral Combat Ship (LCS) combat system will include a network of multiple acoustic and non-acoustic sensor modules deployed on airborne, surface, and sub-surface unmanned vehicles. Sensor data will be communicated from offboard vehicles to host platform(s) through a variety of communications paths that could include line-of-sight, satellite, and acoustic data paths. Naval communications technologies and data networking protocols have improved the bandwidth and range of remote sensor connections, nevertheless, the demands placed on these communications links continue to increase rapidly due to: (1) higher bandwidth sensors, (2) the increasing complexity of remote sensor packages with active sonar, passive sonar, video/infrared, radar, and electronic surveillance components, and (3) the increasing number and types of remote vehicles. With limited manpower available to manage the multi-vehicle sensor system, operators will not have sufficient time to continuously monitor and adjust communications assets in response to rapidly changing conditions.

A system is needed for optimizing Littoral Combat Ship (LCS) information flow and generating an accurate and operationally relevant Situational Awareness (SA) picture. The Network Management and Monitoring System (NMMS) is an intelligent architecture for automated monitoring and control of federated sensors that optimizes information flow, generates an accurate and operationally relevant TOTAL SA picture, generates Prioritization/Classification recommendations and Alerts, and supports the development of optimal mission plans. NMMS can monitor multiple communication links and automatically reroute data or reconfigure remote sensor operating modes when necessary. Operational benefits of this technology include reduced operator workload and improved remote sensor effectiveness.

WHO CAN BENEFIT?

NMMS components have been tested in a laboratory environment using simulated and real-world data fusion and optimal information flow scenarios. The primary transition targets are:

- Littoral Combat Ship (LCS) ASW Mission Package
- Other LCS Mission Packages
- Netted Sensors
- Undersea Warfare Decision Support System (USW-DSS)
- SQQ-89 Sonar Situational Awareness Functional Segment (SSAFS)
- Anti-Torpedo Torpedo Defensive System (ATTDS)

NMMS components are designed for rapid and cost-effective integration into any distributed system that needs an accurate SA picture and/or the capability to optimize information flow.

BASELINE TECHNOLOGY

The baseline technology currently available in the Navy (and to the rest of the government) is manual control of the Unmanned Surface Vehicle (USV) or Unmanned Air Vehicle (UAV) using a data (e.g., video, radar) feed from the vehicle (newer Unmanned Underwater Vehicles (UUVs) usually operate autonomously). This requires one or more operators per UV, and also a high bandwidth communications network, often line-of-sight (see Figure 1).

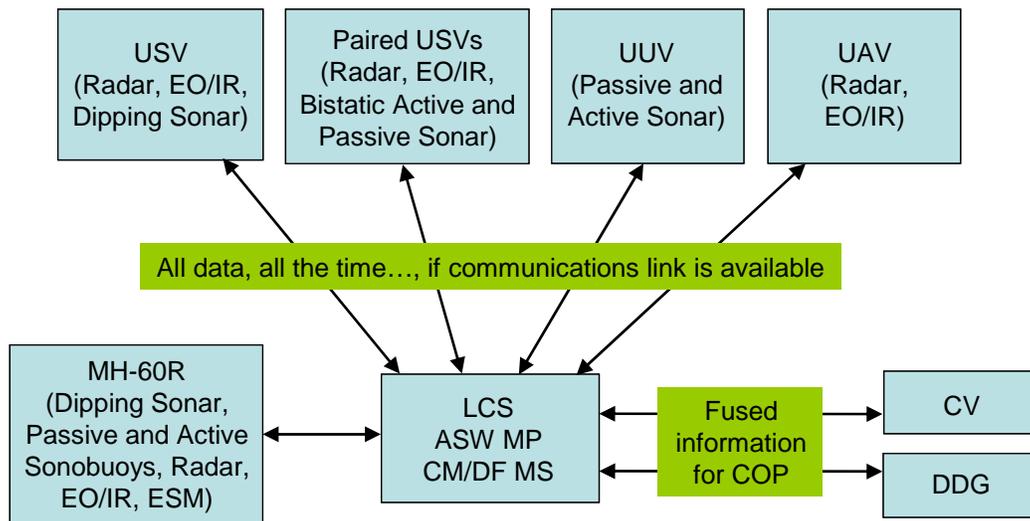


Figure 1. Information Flow to Off-Board Vehicles Today - LCS Monitoring/Control; LCS-Centric Communications with battle group; all raw data coming back to LCS; fused information to battle group to form the Common Operational Picture (COP)

Operationally, this means that most of the available personnel are performing low-level tasks such as watching screens for objects of interest, as opposed to analyzing information and planning more effective operations. Also, it means that UV operations need to be conducted within or not far beyond line-of-sight (in order to provide constant high-bandwidth communications paths), leaving the control platform much more vulnerable to threat attacks.

In addition, there are typically no automated tools available for optimizing the use of UV (and other distributed) platform, sensor, and operator resources.

In comparison, the Network Monitoring and Management System (NMMS):

- Better utilizes scarce resources (context-sensitive recommendations/cueing for control of network devices and optimal use of available bandwidth)
 - communications bandwidth (including, if necessary, indirect approaches to estimate available bandwidth)
 - operators
 - processing
 - sensors
 - platforms
- Produces a more accurate Situational Awareness (SA) Picture
 - leads to more accurate decisions
 - supports development of optimal mission plans
 - » including obtaining *in-situ* environmental data using minimal bandwidth
- Provides automated real-time monitoring of network performance
 - communications plans easily implemented
 - reduce operator workload
 - bring less experienced communications operators up to automated level and assist experienced operators
- Allows for quantitative evaluation of communications options

TECHNOLOGY DESCRIPTION

Goal: Develop Intelligent Architecture for Automated Monitoring and Control of Federated Sensors

Our technical approach is to leverage recent technology improvements in signal processing, data fusion, peer-to-peer (P2P) networking, software agent technologies, and computing hardware, in order to make optimal use of the communications bandwidth available to the LCS and its off-board platforms while requiring minimal operator involvement. There are two key areas to optimizing information flow: sending only the information necessary to support the LCS mission across the available bandwidth, and automated optimized use of the available bandwidth.

We implement these two classes of optimization algorithms in a system node that we refer to as a Control Point. A deployment of NMMS is a set of Control Points, with each Control Point (running on a UV or control platform) acting as an intelligent peer responsible for the following tasks (in increasing order of UV autonomy).

- optimizing communications (i.e., use of available bandwidth) to and from the asset(s) it represents; optimizing communications from the asset(s) may include employment of data fusion and information optimization techniques; optimizing communications to the asset(s) may include smart subscription to other peer(s) (e.g., don't alert me until this threshold is met);
- representing asset(s) to control mechanism(s) (e.g., human operator); this may include making proactive requests (e.g., for guidance, maneuver, additional resources), as well as monitoring control commands to alert other peers of changes in status (e.g., maneuvering out of this patrol box);
- locating and maintaining awareness of other peers; this includes understanding the paths to other peers (e.g., topological distance) and their capabilities (i.e., service descriptions); and
- representing asset(s) (e.g., remote sensor; UV with multiple sensors) to other assets; this includes describing the asset's capabilities (i.e., service description) and performing actions on its behalf, such as sharing information and resources (e.g., through negotiation) and requesting peer action (e.g., teaming assets, such as complementary sensor types); along with (c) this enables the formation of cooperative/collaborative *ad hoc* peer groups.

Our initial focus is on the Littoral Combat Ship (LCS) Anti-Submarine Warfare (ASW) Mission Package (MP), where we are:

- Developing the architecture and algorithms required for optimized communications to support operations by unmanned vehicles (UVs)
- Developing a modular and flexible architecture to allow for simple insertion of software/hardware into UVs
- Accounting for differing autonomy levels in UV control system (i.e., from manual control up to reactive autonomy)

Our primary research thrusts are:

- Optimal context-sensitive use of available bandwidth (guided by mission priorities/commander's intent)
 - identify types of information to be optimized in operational context
 - develop optimization algorithms/techniques
- Creation of *ad hoc* peer groups
 - operationally acceptable automatic (re)configuration of remote links
 - » (re)routing to another potential source
 - » (re)establishing connection with previously unreachable asset
 - dissemination of information, alerts
 - collaboration (context-sensitive recommendations/cueing)

Our primary accomplishments to date are:

- Demonstrated significant reduction in message traffic (by 96% without degrading SA picture) through information flow optimization
- Developed federated peers
- Designed and implemented prototype architecture (extensible to all LCS mission areas)
- Developed prototype scheduler

Our overall goal is illustrated in Figures 2 and 3. Our short term (end of Phase II) goal is illustrated in Figure 2. This would reduce LCS bandwidth requirements significantly and enable beyond line-of-sight operations. This prototype NMMS system allows us to demonstrate how powerful information flow optimization, Bayesian inferential reasoning, and data fusion techniques can significantly improve the ability of United States forces to conduct ASW missions.

The integration of these cutting-edge technologies into a single system that can process the data in real-time, and focus automated system/operator attention on high-interest contacts, will provide sufficient time to counter threats while keeping false alarms extremely low. Also, the use of these technologies, which automate much of the current work of the ASW planner/operator, will improve operator efficiency and potentially allow ASW related manning to be reduced without degrading ASW performance. In addition, these components are implemented as Open Architecture modules to allow them to be utilized within any Navy combat and command and control systems, and in particular within ASW systems designed to operate with reduced manning.

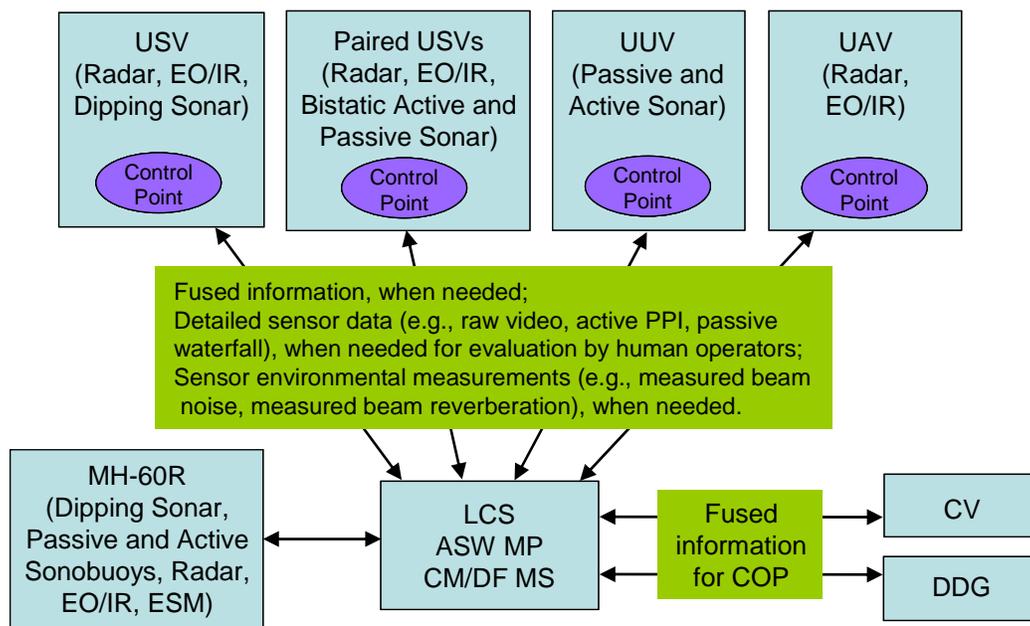


Figure 2. Optimized Information Flow to Off-Board Vehicles - Information coming back to LCS as needed from data fusion/information flow optimization systems on UVs

Our long term goal is illustrated in Figure 3. This would enable fully autonomous UV operation, in particular fully autonomous communications among heterogeneous vehicles.

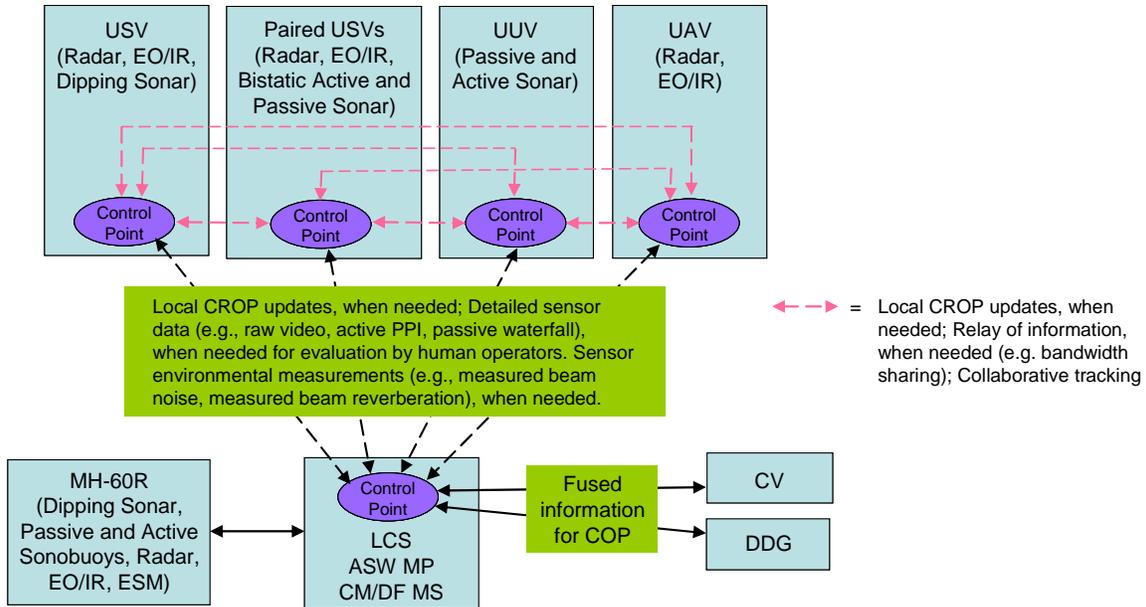


Figure 3. Autonomous Operations - Peer-based fusion across UVs to create local Common Relevant Operational Picture (CROP) and update LCS via SATCOM as needed; LCS monitoring/control becomes advisory; peers act as relays when needed; autonomous collaboration (e.g., request assistance from vehicle with complementary sensors) (Note that UUV comms go through the paired USVs or the LCS)

Table 1. NMMS Features, Advantages, and Benefits

Features	Advantages	Benefits
Accurate Situational Awareness (SA) picture using minimal bandwidth	Number of objects and priority/classification/ID of objects is more reliable	Improved ASW (and other mission) performance. Reduced bandwidth requirements. Reduced risk to friendly assets
High Degree of Automation (while still allowing operator value-added inputs)	Can create SA picture using all available data with minimal operator inputs	Improved ASW (and other mission) performance. Potential manpower reduction
Bayesian Inference Engine (BIE)	Accurate classification and prioritization of objects using all available kinematic and non-kinematic data	More accurate target classification estimate

Using real-world ASW data, we have shown that algorithms in NMMS can very effectively reduce clutter and prioritize contacts of interest. In a typical case, for example, these algorithms reduce the total number of tracks with which an operator would have to interact from 85 to 42 high-interest tracks, and tracks on submarines were always correctly identified as high-interest.

CURRENT STATE OF DEVELOPMENT

Table 2. NMMS Development Status

Milestone	TRL	Measure of Success	TRL Date
Generation of more accurate and operationally relevant total Situational Awareness (SA) picture	5 (simulated) Phase II Option: 7 (real-world)	Number of objects in generated total SA picture compared to ground truth: between 80% and 120% of ground truth (GT) (threshold); between 90% and 110% of GT (goal); number of GT objects contained in estimated 80% area of uncertainty (AOU): 60-100% (threshold); 70-90% (goal)	Aug 09 Phase II Option: Aug 10
Reduction in Bandwidth required to maintain accurate SA picture	5 (simulated) Phase II Option: 7 (real-world)	50% (threshold); 90% (goal)	Aug 09 Phase II Option: Aug 10
Generation of more accurate Prioritization/ Classification recommendations and Alerts in a limited bandwidth/manning environment	5 (simulated) Phase II Option: 7 (real-world)	Percent of time that automated target classification estimate is correct and that prioritization recommendation is correct: 80% (threshold); 90% (goal)	Dec 09 Phase II Option: Aug 10

NMMS is ready for rapid and cost-effective integration as a data fusion, classification, alerting, and information flow optimization module in a larger surveillance combat, or command and control system. We are also interested in discussing any other potential uses of NMMS.

Daniel H. Wagner Associates will provide services to integrate NMMS components into larger systems, to adapt/enhance NMMS components, to help develop Concepts of Operation for using NMMS components, and to train contractor and/or DoD personnel in the use of NMMS components. As part of our work to support DoD suppliers

transitioning these NMMS capabilities, Wagner will provide existing NMMS components under a royalty-free license.

Examples of our previous integration experience include:

- Acoustic Mission Planner (AMP) in MH-60R avionics system and shipboard Mission Planning System (MPS)
- Data Fusion Engine (DFEN) in SQQ-89 Data Fusion Functional Segment (DFFS) and Undersea Warfare-Decision Support System (USW-DSS)
- Mission Optimization Configuration Item (MOCI) Web Service in USW-DSS
- Anti-Torpedo Data Fusion and Optimization System (ATDOS) in ONR Counter Torpedo Detection, Classification and Localization (CTDCL) torpedo defense demonstration and the PMS-415 Anti-Torpedo Torpedo Defensive System (ATTDS)

REFERENCES

Our technical point of contact (TPOC) at Naval Undersea Warfare Center, Newport Division (NUWCDIVNPT) can be reached at 401-832-3355.

ABOUT THE COMPANY

Daniel H. Wagner Associates, Inc., founded in 1963, maintains a technical staff of the highest quality (25 personnel, 12 with PhDs in the mathematical sciences) that designs, develops, implements, and provides training for custom scientific software that provides highly effective and useful solutions to complex and technically challenging operational problems for defense and non-defense customers. We develop this software by working closely with our customers to ensure that their needs are satisfied and that they can effectively utilize the software in performing their mission and achieving their goals. These systems, which include data fusion, decision support, and resource optimization software, as well as software agents, assist their users to perform their tasks much more effectively through the use of sophisticated mathematical algorithms, programming techniques, and quantitative operations research tools.

Research by Wagner Associates has successfully transitioned into a number of key Navy systems. Recent military products developed by Wagner Associates that are currently fielded include: the Data Fusion Engine of the SQQ-89 Improved Performance Sonar (IPS) Data Fusion Functional Segment (DFFS) and the Undersea Warfare Decision Support System (USW-DSS); the Acoustic Mission Planner (AMP), which is embedded in the Navy's MH-60R Multi-Mission helicopter; the Environmental Data Fusion, Clearance Evaluation, Optimal Planning, and Risk Assessment Modules in the Mine Warfare and Environmental Decision Aids Library (MEDAL); the Mission Optimization Configuration Item (MOCI) Web Service in USW-DSS, which includes an Operational Route Planner (ORP) that is used to plan sonar searches for enemy submarines via a genetic algorithm; and the Surface Warfare Tactical Decision Aid (SUWTDA), a Windows based Tactical Decision Aid (TDA) for evaluating and optimizing non-acoustic

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searches for surface ships and submarines. Wagner Associates has offices in Hampton and Vienna, VA and its corporate office is located in Malvern, PA.