TOTAL SHIP SURVIVABILITY SYSTEM (TS^3)
INTEGRATING MOTISS AND BDCS TO PROVIDE PREDICTIVE AWARENESS CAPABILITIES

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ABSTRACT

Ship Survivability is a measure of vessel’s ability to withstand unplanned incidents, such as structural damage, fire and flooding induced by accident or man-made hostilities, with minimum impact on ship system operations. The process of survivability improvement starts with considerations during ship’s design phases and continues during shipbuilding and post-delivery. Based on the class of ship and its purpose, the above requires detailed consideration of three factors: Susceptibility (ability to avoid being hit or likelihood to be affected by harm or failure), Vulnerability (level of damage or inability to withstand the effects of a hostile environment) and Recoverability (ability to recover from an incident or a given damage). Within this paper the authors take into consideration the above factors for all the desired ship systems: from early stage design phases (1) - where through various simulations and analysis the optimum configurations are developed; to the detailed design and construction phase (2) - where static killcards are created, modified and optimized; to the operational phase (3) – where advanced Battle Damage Control and Engineering Control Systems utilize available sensor and operator data to provide Real-Time Situation Awareness for the crew; and present a new generation of Warship Survivability – a TS^3 solution - integrating Alion’s Measure Of Total Integrated Ship Survivability (MOTISS) design survivability enhancement and analysis suite within the BDCS by L-3 MAPPS to generate a Predictive Awareness solution to support total decisions involving ship automation, resource management, damage and casualty control, susceptibility, vulnerability, recoverability, threat assessment, advisories and actions to minimise undesired impacts on operational survivability under damaged conditions.

KEY WORDS

Engineering Control System (ECS), Integrated Platform Management system (IPMS), Battle Damage Control System (BDCS), Measure Of Total Integrated Ship Survivability (MOTISS), Total Ship Survivability System (TS^3), Ship Safety Assessment System (SAS), Casualty Control Management System (CCMS), Damage Control Isolation Information (DCII)

1. INTRODUCTION

Ship Survivability assessment and improvement strategies are critical for the safe and effective operation of both naval combatants and mission critical commercial ships. For naval combatants, cruise ships and LNGs special considerations related with survivability must be given throughout design – from concept to detailed design. However, the approach considered by most shipyard designers is generally limited to conventional applications that, on the one hand, do not include due consideration for Susceptibility, Vulnerability and Recoverability (SV&R), and on the other, do not continue through construction or even through the post ship delivery phase when SV&R factors become of paramount importance for ship crew.

Ship Survivability is a measure of vessel's ability to withstand unplanned incidents, such as structural damage, fire and flooding induced by accident or man-made hostilities, with minimum impact on ship system operations. The process of survivability improvement should start with considerations during ship's earliest design phases and shall continue during shipbuilding and post-delivery. Based on the class of ship and its mission, the above requires detailed consideration of three factors: Susceptibility (ability to avoid being hit or likelihood to be affected by harm or failure), Vulnerability (level of damage or inability to withstand the effects of a hostile environment) and Recoverability (ability to recover from an incident or a given damage).

Furthermore, conventional Battle Damage Control System (BDCS) on naval vessels, and Ship Safety Monitoring Systems on commercial vessels, are generally deployed with limited dynamic killcards that could be executed in manual, semi automatic or automatic modes in the event of incidents. These killcards are developed during shipbuilding phase with various challenges for the shipyard and the Engineering Control System provider. Above all, they do not include the required consideration for the critical SV&R factors.

In this paper the authors present an effective approach that takes the above factors into consideration from early design phase, where through various simulations and analysis, optimal configurations are developed for all the desired ship subsystems; to the detailed design and construction phase, where static killcards for all the desired ship subsystems are created, modified and optimized; to the operational phase, where an advanced BDCS and Engineering Control Systems (ECS) utilize available sensor and operator data to provide Real-Time Situation Awareness for the crew. As a result, a new generation, highly advanced BDCS, enabled with Total Ship Survivability System (TS^3) assessment capability is presented.

The ECS and BDCS application functions shall be fully integrated in order to best achieve the objectives of TS^3. This is achieved through an Integrated Platform Management System (IPMS) that interfaces with ship machinery, damage control system, Aux/Anc subsystems as well as combat, communication and navigation systems.

The proposed approach integrates Alion's Measure Of Total Integrated Ship Survivability (MOTISS) design survivability enhancement and analysis suite with the L-3 MAPPS enhanced IPMS incorporating survivability improvement and Situational Awareness capabilities, to generate a Predictive Awareness solution to support total decisions involving ship automation, resource management, damage and casualty control, susceptibility, vulnerability, recoverability, threat assessment, advisories and actions to minimise undesired impacts on operational survivability under damaged conditions.

2. ALION MOTISS

Effort has been made to develop advanced methodologies to better assess performance based total ship survivability. In the United States, these efforts led to the development of modeling and simulation methodologies to accurately reflect the effect of the initial weapon event as well as the through time impacts to systems and overall mission capability.

The development of these modeling and simulation tools were born of the realization that traditional methodologies of assessing ship survivability via prescriptive assessment had been outpaced by the significant increase of system complexity and interdependencies present in modern warships. Simply put, static rule based damage assessments were no longer able to accurately predict mission capability after damage occurred nor was there any effective way to assess the through time consequences of that damage as systems and crew responded to, and were affected by, the initial hit and follow-on events. What developed became known as Integrated Survivability Assessments (ISAs).

ISA software for naval combatant survivability are designed to simulate ships susceptibility (realistic battle engagements including the tracking and prediction of missile and torpedo seekers against the ships signatures and the targeting of the ships combat systems to counter the threat), vulnerability (physics based prediction of battle damage inclusive of ballistic impact, blast, shaped-jetting, structural failure, equipment failure, system damage and crew injury), and recoverability (assessing cascading system failures, fire and smoke spread, and flooding). With more advanced ISA programs like MOTISS it is possible to assess Man-In-The-Loop Operations (MITLO) and human systems interactions such as fire-fighting, system isolation, jumpering and damage control repair, which allows navies to better understand combat capability and performance characteristics.

The MOTISS ISA software is a physics-based, integrated survivability modeling and simulation package that permits integrated assessment of hazard and accident events together with response actions. MOTISS was originally developed as a commercially available modeling and simulation technology to evaluate complex naval ship survivability weapons effects incidents. In its original application, MOTISS provided a single survivability measure enabling direct vessel to vessel comparisons of survivability requirement achievement and allowed for the inclusion of optimization and "best buy" evaluation of design changes and survivability features, within a balanced and mathematically accurate integration of susceptibility, vulnerability, and recoverability in order to guide resource allocations. Like risk, survivability is a statistical measure of performance, requiring many (~1000's) analyses in order to provide high statistical confidence. In order to maintain manageable computation times, MOTISS takes advantage of simplified "Empirical" and "First Order Physics" routines in order to reduce the computational time while maintaining statistical confidence thus mitigating the potential for higher error through the use of experimental method error corrective routines, producing sufficient statistical data to magnify the signal (or accuracy of the result) while mitigating the error through random error noise reduction. MOTISS is a supra-simulation tool designed to precede (supra) Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) assessments in order to identify those specific events needing consideration of High Accuracy and High Precision – i.e. the "Critical Consequence" survivability events (Figure 1).

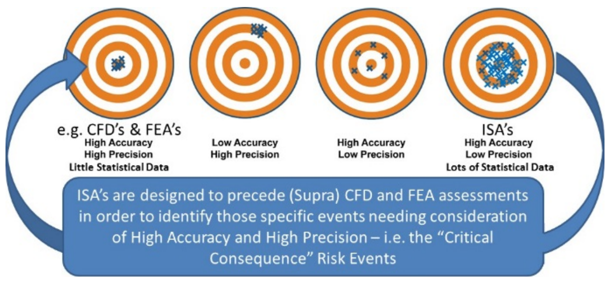

Figure 1: ISA Supra-Simulation Statistical Explanation

Following an intense verification and validation effort to over 800 tests, MOTISS ISA software was accredited by the United States Navy and has been used to support both U.S. and international naval combatant and noncombatant ship designs, ISAs and survivability assessment reports (SARs).

ISAs are built as a federation of software subroutines or modules linked by a common physical model and controlled by a single master routine (Figure 2). The MOTISS ISA utilizes a 3D meta-model representation of the system coupled with detailed logic models of selected subsystems. This "one model and one tool" approach enables through-time integrated failure effect and consequence classification analyses across all barriers (technical, operational, and procedural). The benefits of this approach include reduced costs to perform the analysis through the use of less software and the development of fewer separate system models, reduced time to conduct analysis by requiring fewer models to be built and less total run-time to generate results, and enhanced capability and understanding of the total system through significantly enhanced integration of efforts and a greater understanding of system complexities.

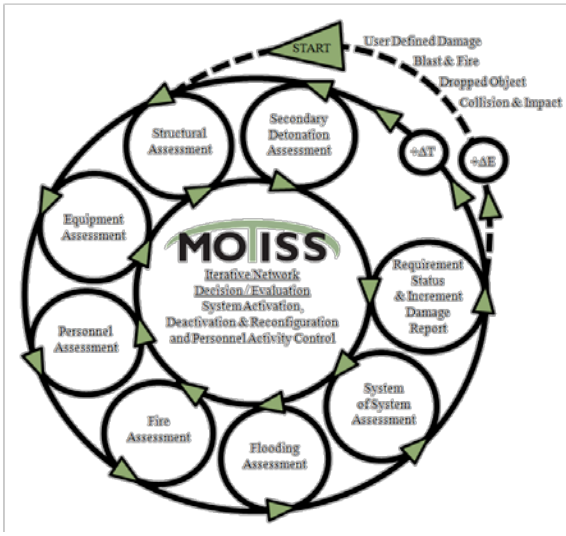

Figure 2: MOTISS Federated Architecture

The MOTISS ISA methodology enables a better understanding of the system's response to causality events by incorporating effective Hardware Software Integration (HSI) as well as Human Systems Integration (HSI). This understanding in turn offers the opportunity to modify the design in the most optimal fashion to achieve the specified requirements or to incorporate operational or procedural changes (with or without associated design changes) that will enhance survivability effectiveness. The MOTISS ISA therefore can be used significantly through design to assess the evolving safety and survivability of a vessel.

As described later in this paper, survivability improvement is also an integral part of modern BDCS and ECS applications that aim at reducing risks from major accidents that can be hazardous to the health and safety of crew as well as to optimum and safe operations of mission critical machinery. As an example, the BDCS image processing analytics and the BDCS advanced advisories, or the ECS Autonomic Control System (ACS) application to Chilled Water System, provide superior survivability improvement capabilities. The proposed TS^3 takes advantage of such capabilities of L-3 MAPPS modern IPMS and Alion's MOTIS ISA by incorporating their methodology and objectives for use during basic and detailed design phases of target vessels such that appropriate static killcards and design improvements will be fully considered by shipyard designers and their consultants before vessel construction phase begins. Hence, TS3 ensures that risks are kept 'As Low As Reasonably Practical (ALARP) through extension of the MOTIS ISA construct.

MOTISS further supports commanding officers and emergency response leadership (ERL) in developing, conducting and assessing emergency response team (ERT) emergency preparedness trials and training – i.e. enabling the effect of crew competence to be quantified specifically.

In this context, during a casualty condition, the ships commanding officer (CO) is interested in four pieces of information so that he may make effective command decisions to minimize the damage effects, to reduce the probability of lives lost and possibility of retaining operations. These are:

1) What equipment, systems and capabilities has the ship lost?

2) What equipment, systems and capabilities does the ship still have?

3) What equipment, systems and capabilities will the ship lose and when will they be lost?

4) Can the ship regain the capabilities that were lost and if so, when will they be regained?

To answer these questions, the CO relies upon his knowledge of the vessel as well as the capability of his damage control officer (DCO) or ERL. The DCO/ERL must therefore fully understand the ship system dependencies and be able to convey the state of the vessel in order to answer the CO's questions. More importantly however, the DCO/ERL must know:

1) How to isolate the damage in order to minimize the cascading damage,

2) What equipment, systems and capabilities are impacted by the isolation, and

3) How to restore or reconfigure systems in order to regain lost capabilities as they are needed.

To assist CO's and ERL/DCO's in answering these questions, L-3 MAPPS Ship Safety Assessment System (SAS) or L3 MAPPS enhanced Battle Damage Control System (BDCS) that is integrated with MOTIS predefined static and dynamic killcards is required. These systems assist the DCO/ERL by:

1) Tracking equipment and system damage based on sensors or human-machine interface (HMI) inputs,

2) Tracking fire, flooding, casualty damage based on sensors and HMI inputs, and

3) Calculating and / or predicting stability.

In order to effectively perform the above, Damage Control Isolation Instructions (DCIIs) or Emergency Response Plans (ERPs) are established in the form of appropriate killcards so as to provide methodical instruction for the mitigation of cascading damage and maintenance of operational capabilities.

The primary objective of an ERP/DCII killcard is to provide information and procedures which are of critical importance to quickly contain and suppress fires (isolate flammable fluids piping), as well as contain and stop flooding (isolate ruptured fluid piping) within a compartment or space within the primary damage zone (PDZ). ERP/DCIIs static killcards are developed for each accessible compartment on the ship, and on notification of damage, fire or flooding, the DCII killcard for the space is accessed through the BDCS HMI by the DCO/ERL. If damage conditions extend beyond a single space, the DCII/ERP static killcards for all the affected spaces are accessed. The DCII/ERP provides information on primary and secondary fire, flood and smoke boundaries for a given compartment. Additionally, the DCII/ERP static killcards list distributive piping systems passing through the compartment, detailed information about what components require action in order to facilitate electrical isolation, mechanical isolation, piping systems isolation, and ventilation control to minimize the effects of smoke and reduce combustion air; etc.

Throughout design and planning of operations, the MOTISS ISA is employed to develop and optimize DCII and ERP static killcards through analyses by subjecting the 3D Meta-model including all technical, operational, and procedural barriers to situations of hazard. Within MOTISS these hazard situations include weapons effects such as missile impact, detonation, fragmentation, fire, flooding etc. for combatants, and include loss of well control, gas explosion, dropped objects, collision, fire, etc. for commercial vessels.

During the vessel's basic design phase, based on potential damage incidents, within the MOTISS construct each planned crewmember is assigned to one or more capability skill sets (e.g. fire-fighter, electrician, damage control, etc.), a speed of movement, an initial start location and an assigned task priority for operational effectiveness assessment. With the MITLO capability embedded within the MOTISS package, the effectiveness of shipboard operations in reconfiguration, personnel task loading, data and communication connectivity, as well as passive and active damage control can be measured to ensure graceful degradation and enhanced operational risk reduction *DURING DESIGN*. Furthermore, the MOTISS computational resource enables full evaluation of the crew damage control procedures and training; allowing full predictive simulations of total ship safety survivability trials prior to construction.

3. MOTISS LINK TO IPMS

Within MOTISS, the various weapon effect and hazard simulations are used to determine optimal time to correct, most critical paths, and cascading damage expectations (what systems, equipment and capabilities are lost when other equipment or system components are lost or isolated).

After analysis, the identified pertinent information, such as critical paths, downstream effects and ALARP operational responses are condensed within the DCII/ERPs. Based on the developed response doctrine, it generates a Predictive Awareness solution to support total decisions involving ship automation, resource management, damage and casualty control, susceptibility, vulnerability, recoverability, threat assessment, as well as advisories and killcard actions to minimise undesired impacts on operational survivability under damaged conditions (see Figure 3). In the proposed TS^3 solution, these are integrated with the BDCS and ECS to achieve an Integrated Platform Management System (IPMS) that through interfaces with ship machinery, damage control system, Aux/Anc subsystems as well as combat, communication and navigation systems will deploy improved dynamic killcards and operator decision support advisories.

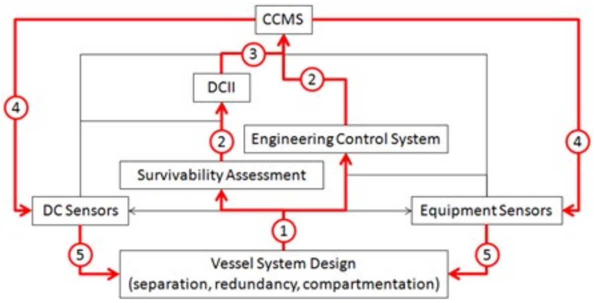

Figure 3: Integration of Design, Survivability Analyses, DCII and CCMS

Because MOTISS utilizes a detailed model of the system that can be modified to reflect system changes as well as different procedures or updated emergency response plans, it offers a holistic assessment capability to assess barriers and doctrinal DC processes in order to determine the probabilistic risk of major or minor damage events, supports the identification of exposure to individuals or groups, and identifies potential impacts to the capability and effectiveness of the ship.

4. L-3 MAPPS IPMS

The IPMS for combatant ships has become increasingly complex, in part due to extended hardware and systems integrations, and in part due to the application of intelligent/smart technologies that are required for improved survivability, improved equipment health monitoring, lower maintenance and operational costs, and in order to meet the ever increasing demand for reduced manning.

Most conventional IPMS solutions simply cater for remote machinery control and monitoring with limited Damage Control capabilities. However, the L-3 MAPPS Integrated Platform Management Systems (IPMS) provides a number of advanced capabilities, such as:

1. Engineering Control System (ECS)
2. Battle Damage Control System (BDCS)
3. Decision Support Advisories
4. Survivability Improvement applications
5. Situation Awareness capability
6. Advanced Dynamic Stability Assessment
7. Ship Readiness Status
8. Casualty Power Reconfiguration Assistance
9. Smart Condition Based Maintenance
10. On Board Simulation System (OBTS)

The inclusion of applicable technologies for each item in the above list for a given naval vessel is a function of the Navy's Technical Specification/Shipyard's Specification. Therefore, familiarity of the end-user's technical team with such advanced technologies is essential.

The benefits of these technological advancements and familiarity include:

- ➢ Higher automation levels that provide superior situational awareness and effective remote control and monitoring capabilities, thereby enabling reduced manning under normal operations.

- ➢ Increased survivability and reduced manning during casualty incidents.

- ➢ The IPMS distributed control system approach, with greater hardware redundancy at the levels of the Data Acquisition Units (DAUs), Data Communication Network Configuration, Human-Machine Interface (HMI), etc. have further resulted in improved overall ship survivability compared to Client-Server Architecture.

- ➢ For high-value vessels such as mission critical surface ships, submarines, LNGs and cruise ships, smart technology such as Smart Valves ensure high level of overall Survivability during severe damage incidents. Advanced IPMS ECS incorporating Smart Valves can be applied to critical ship subsystems; such as the Fuel system, Fire Main System (FMS), Chilled Water System (CWS), and other relevant fluid systems where damage to the fluid system piping, or damage to the IPMS main hardware (data network, consoles, DAUs) impacts a ship subsystem operational capability.

4.1 Engineering Control System (ECS)

The L-3 MAPPS IPMS is based on Distributed Control System architecture utilizing single integrated LAN, widely used on navies of the world and utilizes world renowned ECS and BDCS that includes various survivability enabling technologies. A typical IPMS configuration is shown in Figure 4.

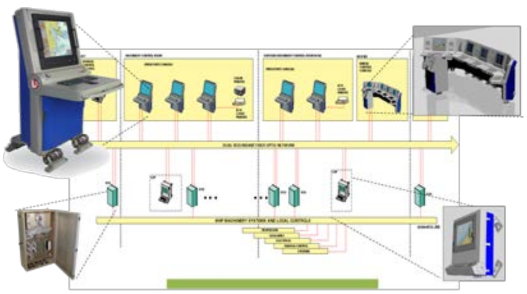

Figure 4: IPMS typical Architecture

In conventional IPMS, the ECS component provides remote control and monitoring of shipboard machinery. The above is not sufficient in Real-Time operations however. Consideration must be given for provision of advanced advisories for mission critical equipment such as the propulsion system engines or electrical generation system, or smart condition assessment of vital shipboard equipment related to Combat, Communication, Navigation and ECS, including due consideration for fuel saving features and oil debris monitoring, or Agent Based Autonomic Control System (ACS) utilizing smart valve/actuator units, for application to CWS and other fluid systems. All such features are an integral part of the L-3 MAPPS ECS.

4.2 Battle Damage Control System (BDCS)

In recent years, there has been greater emphasis on strategies to improve situational awareness, survivability under damage conditions, crew reduction initiatives, Damage Assessment, Ship Readiness Status and Damage Action Management. Optimum deployment of some of these features require consideration during conceptual and basic ship design phases in order to ensure availability of the required sensors, data acquisition, and definition of appropriate static killcards before the BDCS detailed design phase.

The L-3 MAPPS enhanced BDCS is an integral part of the IPMS. Therefore, within BDCS capability is provided for full integration with all ECS application functions. As such, authorized ship crew can communicate with ship machinery for control and monitoring and for sending instructions during normal operations and during incidents.

The following is a list of major features integrated with the L-3 MAPPS BDCS, above and beyond conventional BDCS capabilities (such as Damage Control, incident management or ship view & overlays):

- Compartment based and system wide Layered graphics
- Incident Record and Replay
- Dynamic stability assessment including information on time to capsizing
- Dynamic Killcards
- Operator Decision Support
- Ship Readiness Status during normal operations and incidents
- Casualty Power Reconfiguration Assistance
- Interface with desired ship subsystems and ability to issue commands to related equipment based on Station In Control (SIC) assignment
- Casualty Team Management
- Enhanced “Advisories” including automatic plotting of attack routes, smoke and cooling boundaries, smoke removal plans, electrical isolation, machinery safeguarding, hazardous material/combustibles location, etc.
- Propulsion system malfunction detection and associated operator decision support advisory

Figure 5 provides sample BDCS HMI.

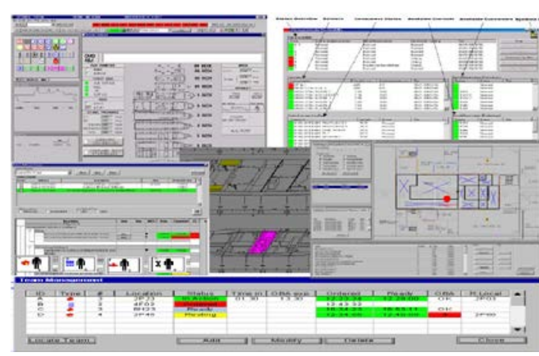

Figure 5: BDCS sample Human Machine Interface (HMI)

4.3 Survivability Improvement Technologies

The level of integration across and between shipboard systems has increased in recent decade. There has also been greater emphasis on strategies to improve situational awareness, survivability under damage conditions, crew reduction initiatives, Damage Assessment, and Damage Action Management System (DAMS).

The above objectives necessitate consideration of smart agent based situational awareness technologies, such as Autonomic Control System (ACS) utilizing Smart Valve/Actuator units with improved intelligence that includes autonomous decision making by smart hardware and embedded software intelligence. Furthermore, to increase survivability, consideration is given to continued operation of the intelligent agents independent of the IPMS hardware/software and its related data communication network so that in the event of damage to the IPMS main hardware and/or the IPMS data communication network, there will be no undesired operational impact on mission critical ship systems.

An example of the above, that is critical to the survivability of combat and communication systems in the event of rupture(s) in the Chilled Water System as a result of a direct missile hit, is the application of ACS incorporating Smart valves to the CWS as shown in Figure 6.

The above requires simulation studies to identify optimum number of smart valves, location of these valves and evaluation of the designed CWS. When such consideration is not included in the ship basic design or in survivability improvement analysis that shall be part of the vessel's basic design, the effectiveness of the ACS is impacted by lack of design considerations.

The L-3 MAPPS IPMS includes capability for both simulations as well as Real-Time ACS implementation. Various configurations can be selected by the design authority, tested and optimized.

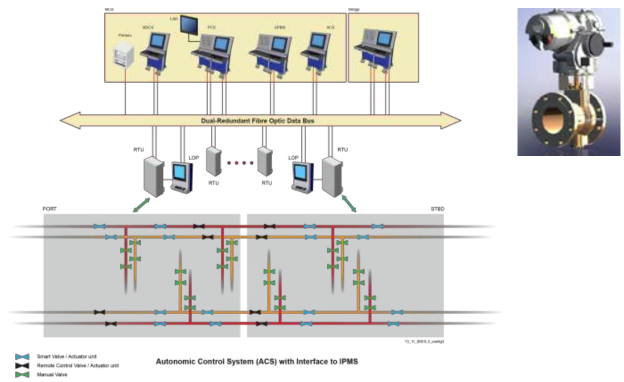

Figure 6: Autonomic Control with Smart Valves

Smart Vales can be applied to other fluid systems, such as fuel system or fire main system. The above agent based technology increases vessel's survivability under damaged conditions.

The L-3 MAPPS BDCS includes other survivability improvement capabilities. The BDCS Asset Management subsystem's digital image processing capability detects fire, smoke, motion in areas monitored by CCTVs and also identifies major leakages due to burst pipes. As a result, in the event of sensor failure (e.g. due to aging), the BDCS Damage Action Management subsystem executes predefined dynamic Killcards to initiate automatic actions and procedures that are pre-programmed. These features improve ship survivability even with reduced manning.

Other L-3 MAPPS BDCS survivability improvement related functions include considerations for Propulsion, Electrical and Fuel systems. Various dynamic killcards, as well as situational awareness information such as subsystem overview, sensor data, equipment status, and available controls assist the crew during incidents to increase survivability. All the above, together with base BDCS capabilities addressed in section 4.2, need consideration during the vessel's design phases. It is critical that appropriate sensors are identified during the basic design phase. Above all, survivability assessment shall be an integral part of the vessel's design phases in order to establish the desired survivability level, define detailed static killcards and in collaboration with the IPMS supplier to specify the requirements for appropriate ECS and BDCS capabilities. In the next section, Alion and L-3 MAPPS present an optimum strategy for the above that best serves the intent of Total Ship Survivability System (TS^3).

5. TS3 SOLUTION INCLUDING SITUATIONAL AWARENESS

By the time an IPMS supplier gets involved (usually during the shipbuilding phase), the vessel's Basic Design and Detailed Design phases are already complete. Making changes to the design can prove costly but at the same time some of the specified ECS or BDCS capabilities may not be deployable in an optimum way due to lack of considerations during the design phases. Typical example is the deployment of Smart Valves for CWS.

In addition, when a detailed survivability assessment is not performed during the design phases, less than optimum dynamic killcards become available in Real-Time operations, and in some cases due to lack of consideration for the required sensors/automation, it is not possible to execute dynamic killcards. This naturally can affect the vessel's survivability under damaged incidents.

Furthermore, for a modern mission critical naval vessel or cruise ship, it is highly desired to include comprehensive ship wide survivability related simulations and assessments during the design phase in order to include appropriate static killcards that shall become an integral part of the IPMS ECS and BDCS.

The proposed TS^3 solution not only overcomes all the above challenges but as explained in this section, will improve vessel's situational awareness post vessel delivery to the ship owner.

The vessel's stability is considered during the vessel's design phase. Various simulations and analysis performed during the vessel's basic design phase by TS^3's MOTISS component can further establish survivability improvement strategies and define static killcards. In the Real-Time operations, the BDCS Dynamic Stability calculation takes advantage of the design phase computed information and provides meaningful information on time and predictive time to capsizing in the event of major structural damage and equipment loss.

Ensuring increased survivability based on improved recoverability from major incidents is of paramount importance and must be addressed during vessel's basic design phase. Equally so, safety and security of vessels at port, in littoral waters and at sea against external threats that has also become an ever increasing concern requires due consideration during the initial designs. The above gives rise to the deployment of technologies that collectively cater for improved survivability and Situational Awareness (SA). However, effective operations require the integration of reliable technologies into a seamless system in order to fully support the operational missions. To best detect and react to potential external threats and onboard incidents, requires the integration of suitable technologies that can cover a wider range of operations, from offshore platform protection, to forced protection at port, to amphibious, sovereignty, law enforcement, fishery protection, search & rescue operations, normal operations, operation in dangerous waters and in combat.

The above is a complex challenge given that threats at Port, as an example, or threats in littoral waters, are different from the threats at sea. None of the conventional OEM solutions deployed on existing naval ships provides Modular Integrated Situational Awareness System (MISAS) that can manage combined onboard & external threats as well as provide for optimal management of unplanned incidents in an efficient way.

Conventional approach is based on solutions that are standalone with limited systems integration, some requiring standalone hardware and software, and excessive embedded data communication networks that have less commonality with other systems deployed onboard a target vessel. Furthermore, none of the existing platforms take into consideration the static killcards, advisories and simulation results that the proposed TS^3 solution caters for.

The proposed TS^3 solution fully integrates MOTISS with L-3 MAPPS Situational Awareness enabled IPMS and ensures inclusion of mission critical static Killcards for various ship subsystems, including combat and communications systems. In Real-Time operations, when threats are identified, or in the event of incidents, the IPMS dynamic killcards will ensure improved survivability. Through Real-Time snapshots of desired ship subsystems and sensor data by the IPMS software, Real-Time simulation of various threats could be accomplished by utilizing some of Alion's advanced software analytics. These can include advisory on potential damage that could be caused as a result of a direct hit by missiles. Figure 7 illustrates the TS^3 concept and architecture.

6. CONCLUSION

The proposed TS^3 integrates Alion's MOTISS design survivability enhancement and analysis suite with the L-3 MAPPS enhanced IPMS incorporating survivability improvement and Situational Awareness capabilities, to generate a Predictive Awareness solution to support total decisions involving ship automation, resource management, damage and casualty control, susceptibility, vulnerability, recoverability, threat assessment, advisories and actions to minimise undesired impacts on operational survivability under damaged conditions.

The TS^3 offers an advancement of IPMS, BDCS and ECS systems by integrating survivability analysis results, taking and developing control logic DCIIs which prompt the damage control team automatically based on shipboard and equipment sensor signals. In simplified terms, the thousands of battle damage scenarios calculated by MOTISS are placed within probabilistic response surfaces (i.e. calculated damage, expected future damage and expected damage progression verses sensor signal or HMI input) and then associated with specific DCII or dynamic Killcards for the vessel which are displayed by the TS^3 when the calculated or expected probability of occurrence is greater than the defined threshold.

The future benefit of being able to anticipate emergent damage and provide the correct response, offers obvious survivability enhancements to the system effectiveness, situational awareness and safety of naval combatants and commercial assets.

BIOGRAPHY

Dr. Reza Shafiepour obtained BSc in Electrical Engineering from Newcastle Polytechnic (University of Northumbria; UK) in 1980, MSc in Power Transmission and Distribution from UMIST (Manchester University; UK) in 1982 and PhD in Power Systems Control & Monitoring from Durham University in the UK in 1986. His expertise in Control Systems is as a result of working at larger scale Industrial Companies in the UK and Canada; including Westinghouse Systems Ltd (Schneider), National Grid Company (UK), CAE Inc (Canada). He is currently a Regional Director of Marketing at L-3 Communications MAPPS Inc. in Canada. In his capacity he contributes to product and business development. He continues contributing to the IPMS and BDCS product evolution and the application of smart technologies to L-3 MAPPS IPMS.

Dr. Waltham-Sajdak obtained his Ph.D. from Virginia Tech in 2004 in Aerospace and Ocean Engineering with a concentration in collision and impact forensics. He holds the current position of Director of Ship Survivability at Alion Science and Technology where he is responsible for analysis, assessment and enhancement of naval survivability and commercial safety applications for domestic and international clientele. His previous experience includes the development of the MOTISS system as well as the design assessment and survivability enhancement of more than 15 naval combatants and auxiliaries and 3 offshore drilling units.

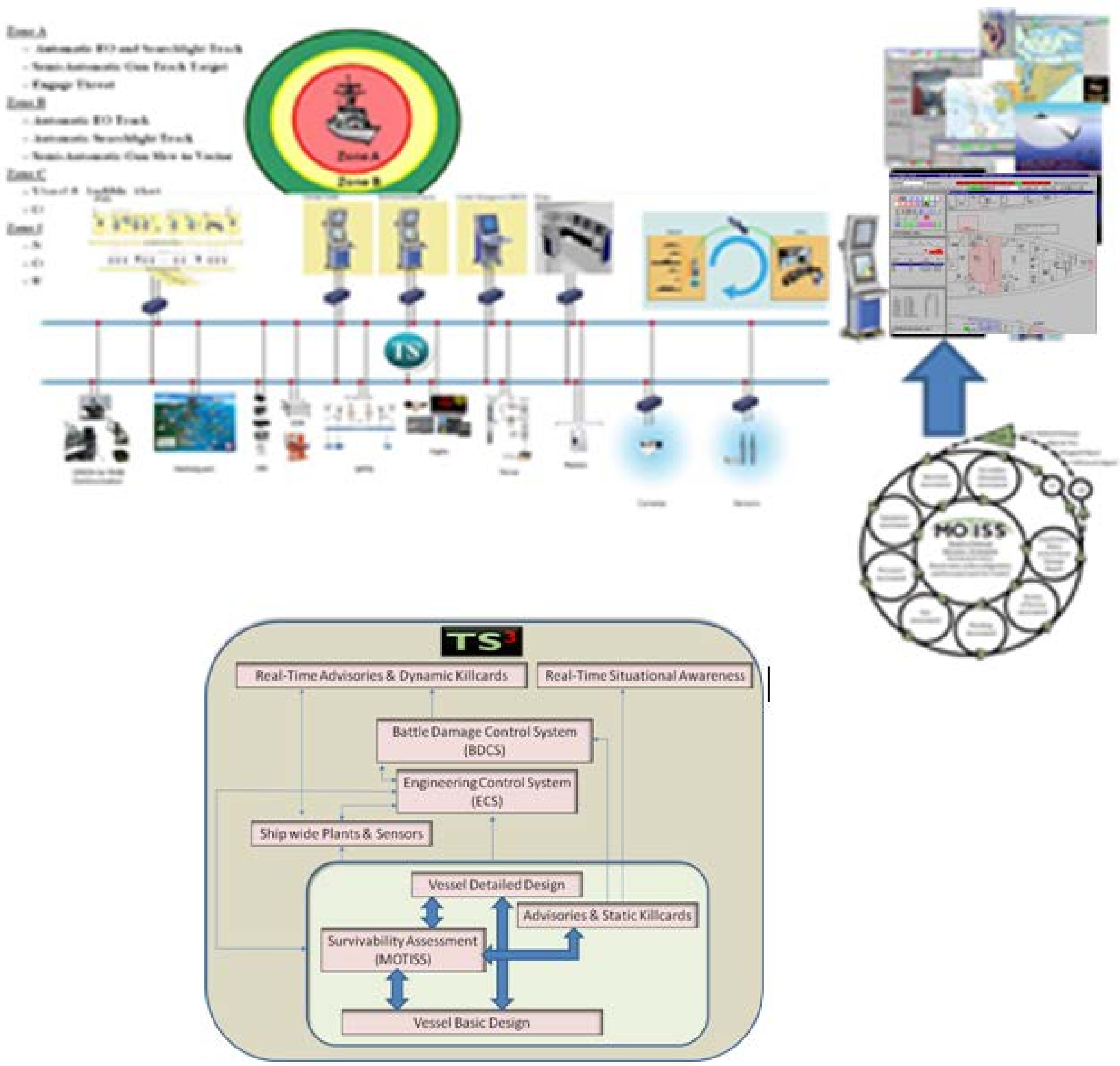

Figure 7: Enhanced Survivability & Situation Awareness concept and architecture