ROYAL CANADIAN NAVY - FIGHTING THE INTERNAL BATTLE WITH A BATTLE DAMAGE CONTROL SYSTEM AND EMBEDDED KILL CARDS

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Synopsis

Naval ships are designed for deployment in extreme and dangerous environments. In order to meet their external battle requirements and achieve mission success naval ships must maintain their ability to Float, Move and Fight. All actions taken to contain and prosecute damage, and repair and restore the capability to support the External Battle are recoverability actions and form what is called the Internal Battle. Through the ongoing development of a Battle Damage Control System and embedded Kill Cards the Internal Battle is better prosecuted through improved picture compilation, system monitoring plus personnel accountability.

Keywords: Kill Cards, Battle Damage Control System (BDCS)

1. Introduction:

The past decade has witnessed a major shift in the Royal Canadian Navy's approach to warship Internal Battle. This shift has been largely due to a significant capability upgrade to the Halifax Class Integrated Machinery Control System (IMCS) and the Damage Control System (DCS) that has led to the development of a Battle Damage Control System (BDCS) and associated Kill Cards during and after the Halifax Class Modernization Project.

RCN Internal Battle Doctrine

The RCN's Internal Battle requirements are identified as:

> RCN warships are designed to globally project military force in the maritime environment either independently or when integrated into an RCN, coalition or NATO task group. RCN warships must be able to sustain offensive and defensive force in a multi-threat environment. This projection of force in the completion of assigned missions is called the External Battle and is only possible when the ship is able to simultaneously maintain Float, Move and Fight capabilities.
> All actions taken to contain and prosecute damage, and repair and restore the capability to the support the external Battle are recoverability actions and form what is called the Internal Battle.
> The elements of the Internal Battle include the provision of power and propulsion to the external battle, combat systems emergency repair, damage control, explosive ordinance identification and disposal, casualty clearing and treatment, and Chemical, Biological, Radiological and Nuclear (CBRN) defence. (RCN NFR/SSO SWIP, 2017)

Authors' Biographies

Marco Nottegar served with the RCN for 14 years as a Marine Engineer and currently is a Senior Engineer with NETE. He graduated from McMaster University with a degree in Chemical Engineering in 1986 and then from the University of Ottawa with a Masters in Applied Science, Chemical Engineering in 2000.
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Suthakar Pakianathan has been employed with DGMEPM for 10 years and is currently the Technical Authority for the RCN Integrated Platform Management System, which includes both BDCS and Kill Cards. Prior to joining DGMEPM he was employed in the High Technology sector, primarily with Nortel. He graduated from the University of Waterloo with a degree in Electrical Engineering in 2000.
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Timely detection and appropriate reaction to damage is essential. The BDCS, being a function of the Integrated Platform Management System (IPMS), reduces operator task loading, enables synergy, situational awareness, and rapid support for timely decision throughout the Internal Battle Organization. It is important that future classes of ships use a similar user interface to ensure commonality of damage detection and response across the RCN fleet. Due to the RCNs Internal Battle Organization and philosophy the BDCS is being designed and validated by an integrated project team of industry and RCN subject matter experts.

Battle Damage Control System (BDCS)

Picture compilation for the entire Internal Battle (not just damage control) is achieved through the BDCS. Prioritization and decision-making has the greatest chance of being effective when all the factors that impact picture compilation are automatically integrated in the system.

Common characteristic for a fleet-wide RCN BDCS should include the following:

- The human interface and symbology associated with this system must be consistent across all classes of RCN warships;
- All BDCSs must incorporate monitoring of the ventilation, fire suppression systems and fire main system;
- All BDCSs must provide an indication of power isolation for an affected area, combat systems battle damage assessment and repair priorities, HAZMAT and CBRN zone management, and casualty locations and clearing efforts;
- All BDCSs must enable monitoring of the citadel and sub-citadel as fitted and conduct liquid level management and stability assessments/calculations;
- All BDCSs must facilitate personnel accountability (aka team management) of all Internal Battle special teams based on the watch and station bill as a database;
- All BDCSs must be integrated across the entire Internal shipboard Battle space and be informed by the External Battle priorities so that all efforts and movements within the ship are simultaneous, and ship staff are aware of damaged areas, contaminated areas, casualties and essential spaces.

The commonality of the BDCS user-interface across all classes of RCN ships is considered essential to ensure familiarity and confidence for all RCN crew members, regardless of the platform they are serving in. (RCN NFR/SSO SWIP, 2017)

Kill Cards

The design and delivery of all RCN warships must include a BDCS/management with accurate and comprehensive Kill Cards. Kill Cards can significantly reduce operator task loading by fusing data into information to provide situational awareness and decision support. There are two types of Kill Cards:

- Static Kill Cards. These are used to display information that does not change such as power panel locations and compartment hazards; and
- Dynamic Kill Cards. Dynamic Kill Cards have links to live system status and provide systems monitoring appropriate to the damage situation and External Battle priority.

Kill Cards can clearly identify considerations that facilitate the safest and most effective manner of attacking fires and floods in a compartment. They also identify what will be damaged or potentially damaged by an incident in the area. They also detail the considerations for recovery, including smoke evacuation and surgical power isolation for equipment that could be damaged or destroyed. Kill Cards can group normal systems operations and maintenance actions together to facilitate rapid system isolation and reconfiguration taking into account sustained damage. (RCN NFR/SSO SWIP, 2017)

The only limitation to the types and numbers of Kill Cards that may be integrated into a BDCS is the number of field devices installed and the level of automation provided.

2. BDCS Overview / Capabilities - Original Halifax Class DCS

The original Halifax Class DCS was designed in 1989 as a stand-alone control system that provided for the automation, remote operation and monitoring for the following systems (CFTO C-77-231-000/MS-001, 1994):

- Fire Detection and Suppression (FDS)
- Heating, Ventilation and Air Conditioning (HVAC)

- Liquid Level Management (LLM)
- Firemain fire suppression system

There were hundreds of input/output (I/O) sensors associated with the original HFX class DCS. Since having integrated all the DCS signals into the IPMS, the total number of signals related to DCS that are managed by the IPMS is close to 2000.

The Internal Battle picture compilation (aka situational awareness) was provided through the following stand-alone DCS Human Machine Interface (HMI) and a manual compilation of the overall Internal Battle overview through ship-level incident boards and DCS verbal communications:

- Damage Control Console (DCC) HQ1
- Firemain HQ2 Console
- Bridge Alarm Panel
- Quartermasters Panel
- Hangar Gas Monitor
- Operations Room Alarm panel
- Landing Safety Officer Compartment Panel
- Helo Fuel Compartment Panel
- Warning Buzzer Assembly
- (23) Local Control Units

Figures 1 and 2 identify this original Internal Battle communication suite.

Figure 1: HQ1 DCC

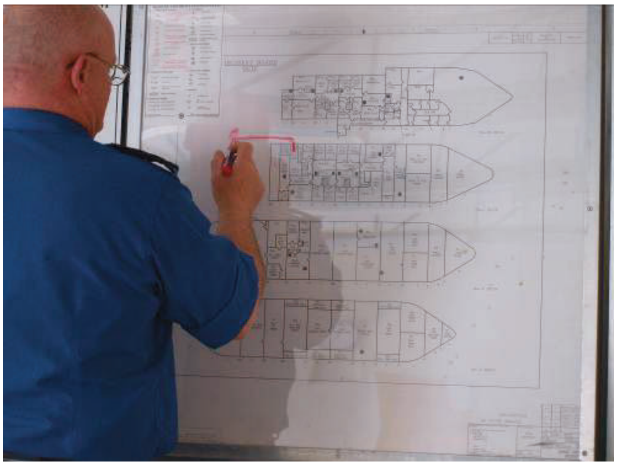

Figure 2: DC Plotting

The original Halifax Class DCS system achieved the BDCS Picture Compilation goal albeit with some significant limitations. The following is a summary of how the original Halifax Class BDCS goals fulfilled the Internal Battle requirements.

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2.1 Original Halifax Class DCS Picture Compilation

The internal battle picture compilation was accomplished through monitoring of ship's internal communications, including verbal communications provided at key internal battle locations (e.g. HQ1, Section Bases), manual tracked through Damage Control (DC) Plotting and the HMIs which were repeater panels informing personnel in the immediate vicinity of the internal battle condition. The DCS captured all I/O sensor information and disseminated it to these HMIs for the internal battle picture compilation. While the HMIs disseminated DC fitted system information the overall internal battle picture compilation was still heavily dependent on internal (e.g. verbal, Main Broadcast, sound powered telephone, ship telephone) communications and manual plotting requiring significant personnel training to ensure accurate internal battle picture compilation at the various internal battle organization locations.

2.2 Original Halifax Class DCS System Monitoring

As identified above, the original Halifax Class DCS provided monitoring of ventilation, fire suppression and firemain systems. CBRN zone management was conducted through a monitoring of the ventilation system within the various Citadel and sub-Citadel zones including barometric pressure differential for each zone. Additionally, visual and audible Citadel pressure alarms were provided when the ship was in condition Alpha. However, the requirement to provide an indication of power isolation, combat system battle damage assessment and repair priorities, HAZMAT and casualty clearing efforts was provided through verbal communications and manual recording of these requirements; similar to the picture compilation.

2.3 Original Halifax Class DCS Personnel Accountability

Personnel Accountability was tracked through the use of 'Accountability Boards' at the key internal battle locations – e.g. HQ1, Section Bases. These 'Accountability Boards' were manually maintained in a similar method as the DC Plotting using the Incident Boards. The section bases and HQ1 maintained the 'Accountability Boards' to monitor personnel, with the primary function to track personnel assigned to DC (flood and/or fire attack) teams with a specific need to track Breathing Apparatus usage.

Again, this meets the Internal Battle requirements but as it is completely manual and due to the multi-functional requirements associated with the Internal Battle, it was prone to error.

3. <u>Current Halifax Class BDCS</u>

The current Halifax Class BDCS replaces the original DCS and is fully incorporated into the IPMS; which also replaced the Integrated Machinery Control System (IMCS). Only marginal new capability upgrades were provided, such as increased Closed-Circuit Television (CCTV) capability, therefore the number of I/O sensors remained approximately the same. Thus, the associated improvements for the current Halifax Class BDCS are primarily associated with improved integration and picture compilation. Figure 3 provides an example of the current Halifax Class BDCS.

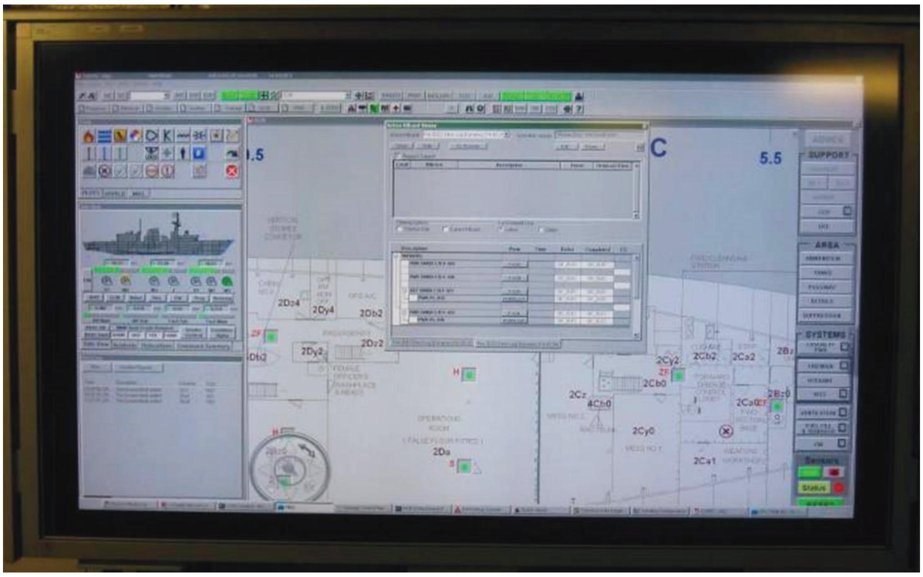

Figure 1: Current Halifax Class BDCS

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3.1. *Current Halifax Class BDCS Picture Compilation*

This feature is undoubtedly the greatest area of improvement for addressing internal battle requirements since DC plotting is now completed by the lead DC team through the HMIs and provided in real time to the entire internal battle organization. Challenges associated with manual picture compilation by way of internal communications have been eliminated plus each key internal battle location only has to plot their unique DC actions. Figure 4 displays the BDCS communication network, which highlights the integration of all BDCS HMIs, thereby ensuring the same situational awareness / picture compilation to the entire Internal Battle Organization. This improved picture compilation allows for improved briefings throughout the internal battle organization – e.g. at section bases to DC teams, at HQ1 to the internal battle organization – and as well from the internal to the external battle organization allowing the Command Team to have an enhanced picture of the Internal Battle.

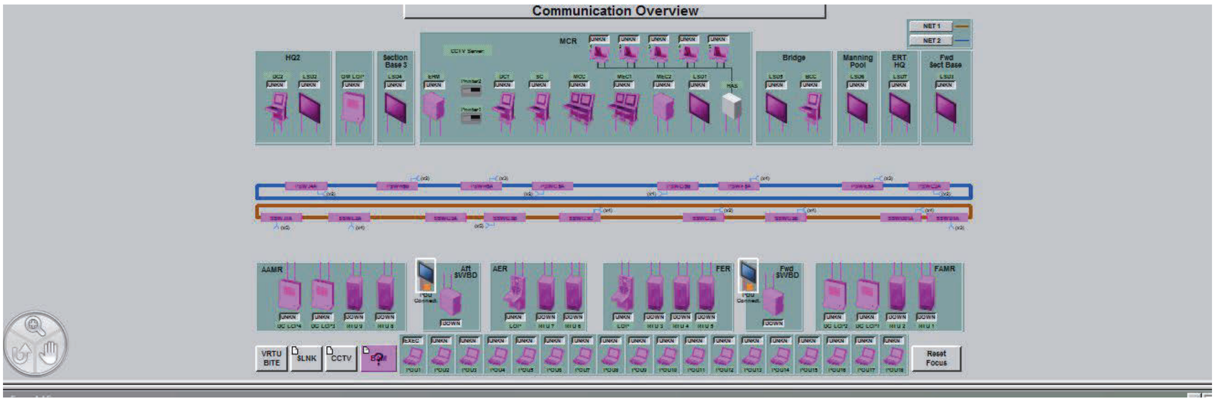

Figure 4: Halifax Class BDCS Communication Network

3.2. *Current Halifax Class BDCS System Monitoring*

While no additional system functionality was added to the BDCS from the original DCS, a significant improvement is the ability to monitor various marine systems. Improved system monitoring visualization and functionality also occurred, since the BDCS advanced from a circa 1980s design system to one of circa 2010. The original DCS design preceded the current Internal Battle requirements and associated technological advances which can improve picture compilation. One example of these improvements is:

- Dedicated Citadel monitoring capability: While Citadel parameters are available through the various IPMS pages it can be improved by consolidating all the information onto one dedicated Citadel page.

3.3. *Current Halifax Class BDCS Personnel Accountability*

Figures 5 and 6 provide an example of the Team and Team Member Management functionality now available, which has addressed all the original requirements including breathing apparatus status. Similar to the picture compilation improvements it provides a uniform presentation of Team Management available to the entire Internal Battle Organization.

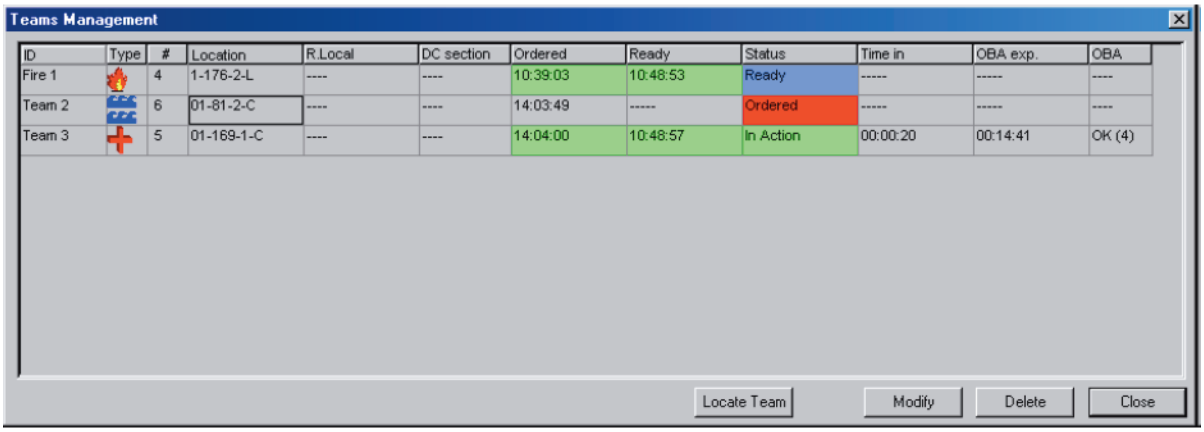

Figure 5: Team Management Window

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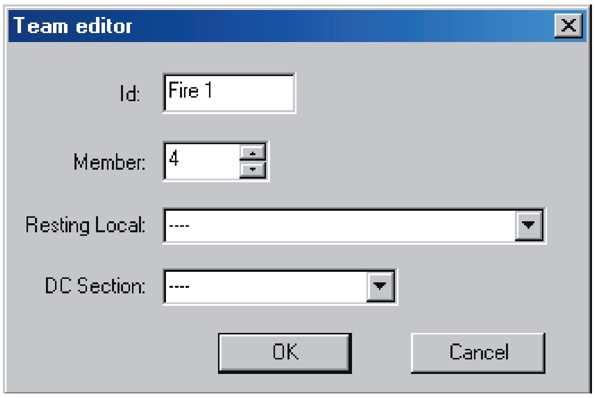


Figure 6: Team Editor Window

4. Next Generation RCN BDCS

The next generation of BDCS will be installed on the Halifax Class and it will likely be installed on new builds of RCN ships. Additional Halifax class BDCS I/O sensors will require engineering changes to install new sensors; whereas new builds will likely have more I/O sensors than currently on board Halifax Class ships. However, even without considering additional automation, the next generation of BDCS will be improved through an increased picture compilation. Figures 7 and 8 provide examples of the next generation BDCS, highlighting the increase picture compilation through enhanced technology and BDCS software development.

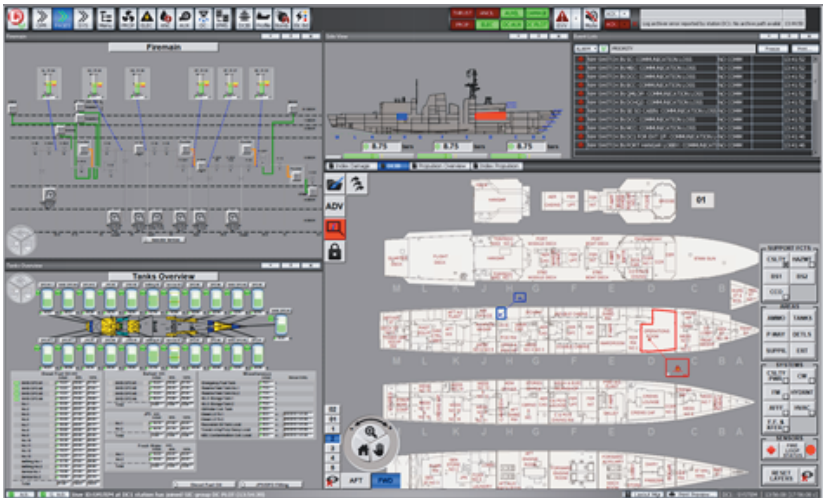


Figure 7: Next Generation of BDCS

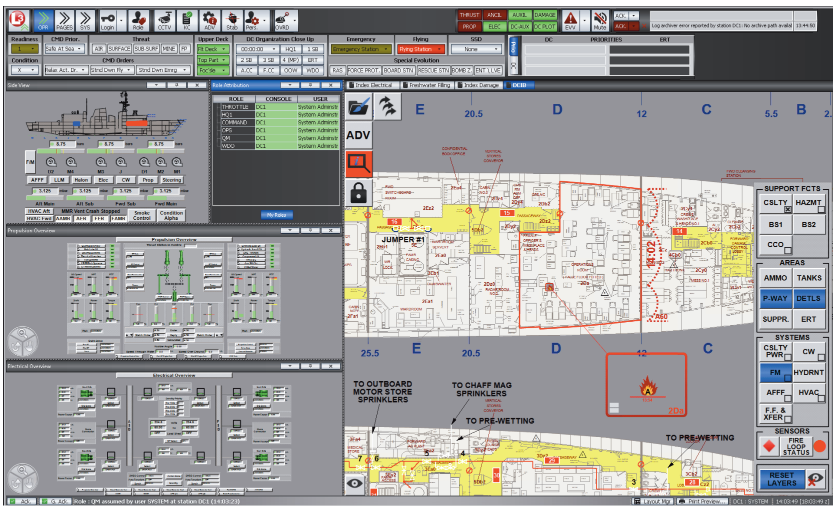


Figure 8: Next Generation of BDCS

4.1. Next generation RCN BDCS Picture Compilation

In this next generation BDCS, the picture compilation is further improved through the ability to more easily / automatically have multiple screens displayed at once and its capability to take full advantage of 4K multi-touch displays. This provides maximum flexibility and freedom for the operator to configure the views to better support operation – see Figure 9.

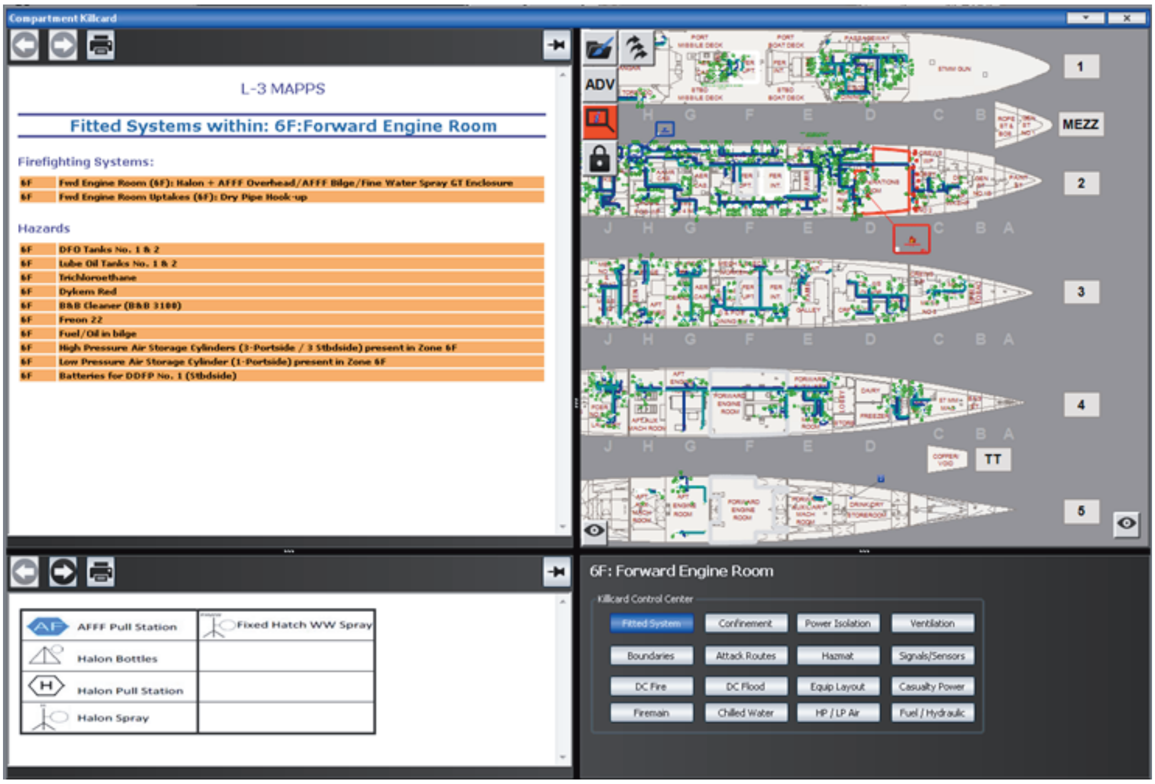


Figure 9: Next Generation of BDCS

4.2. Next generation of System Monitoring for the Halifax Class

The BDCS must be integrated across the entire Internal Battle and be informed by the External Battle priorities such that all efforts and movements within the ship are simultaneously aware of damage areas, contaminated areas, casualties, and essential spaces, etc. As the BDCS is now fully incorporated within IPMS, it is no longer limited to the functionality of the original DCS systems. In order to combat the Internal Battle, the BDCS is able to monitor IPMS controlled systems required to combat the Internal or External Battle; e.g. Electrical Distribution / Isolation or Compressed Air.

Additionally, better automation can be provided to other critical requirements. For example, the development of a dedicated Citadel monitoring page highlights the ongoing review of BDCS requirements through the following:

- Citadel improvements have been identified and existing citadel-related functions, equipment and sensors are being collated into a unique Citadel page. These include Citadel and sub-Citadel pressures and most Condition Alpha (doors, hatches, etc.) opening, already have I/O sensors.
- Additional Citadel page improvements, including additional I/O sensors, are being identified.

The incorporation of these features in the Halifax Class Citadel page can provide the details for an improved Citadel monitoring requirements for new builds of ships.

4.3. Personnel Accountability in the next generation of RCN BDCS

With the past four years use of BDCS Team Management and the associated lessons learned on the Halifax Class, Team Management functionality is being upgraded to more fully meet RCN requirements. The next generation of RCN BDCS will have the capability to import crew lists, the Watch & Station bill, and monitor the gangway and all mustering activities using Radio Frequency Identification (RFID) cards as a means to simplify, speed up and automate reporting. RFID is also being investigated to determine if it will allow for automatic personnel tracking throughout ship compartments. Figure 10 displays the next generation of Personnel Accountability.

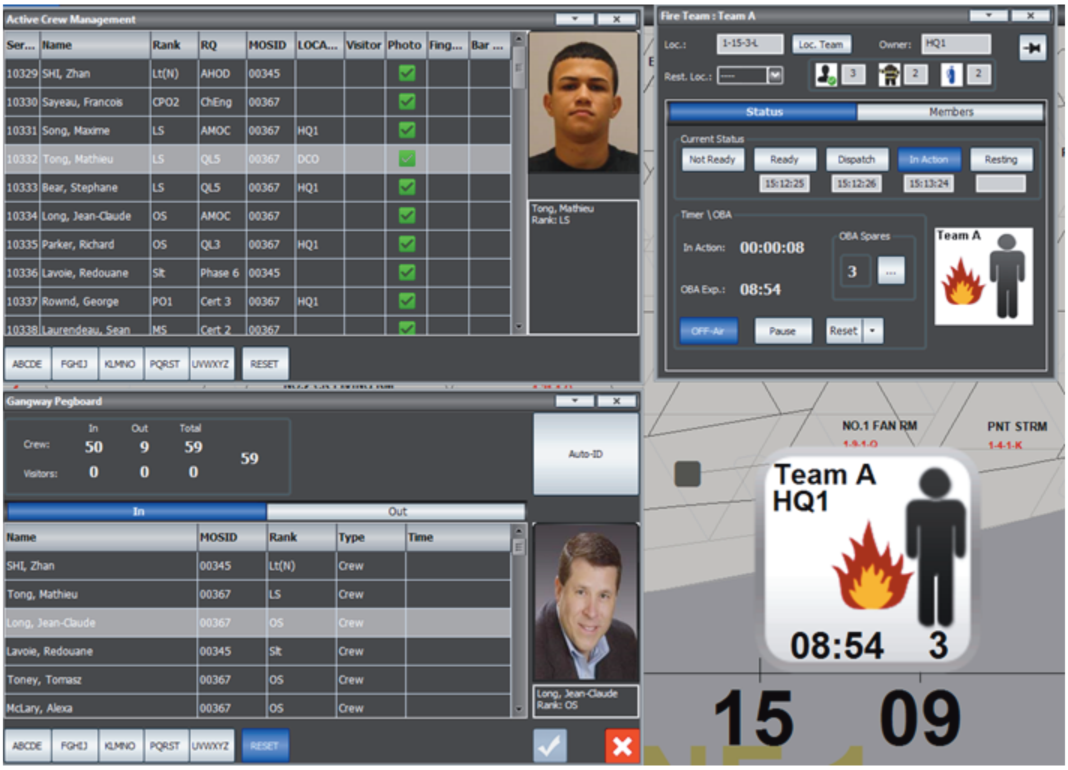


Figure 10: Next Generation BDCS – Team Management

5. Kill Cards

The original Kill Cards were an official RCN manual – Damage Control Risk Folio - that each ship retained and utilized for Damage Control events. This manual nominally provided the following Damage Control information in a graphical format (see Figure 11):

- Fire Suppression Equipment, fitted and portable
- Ventilation requirements
- Hazards
- Pumping Out Arrangements
- Electrical Considerations
- Fuel Considerations

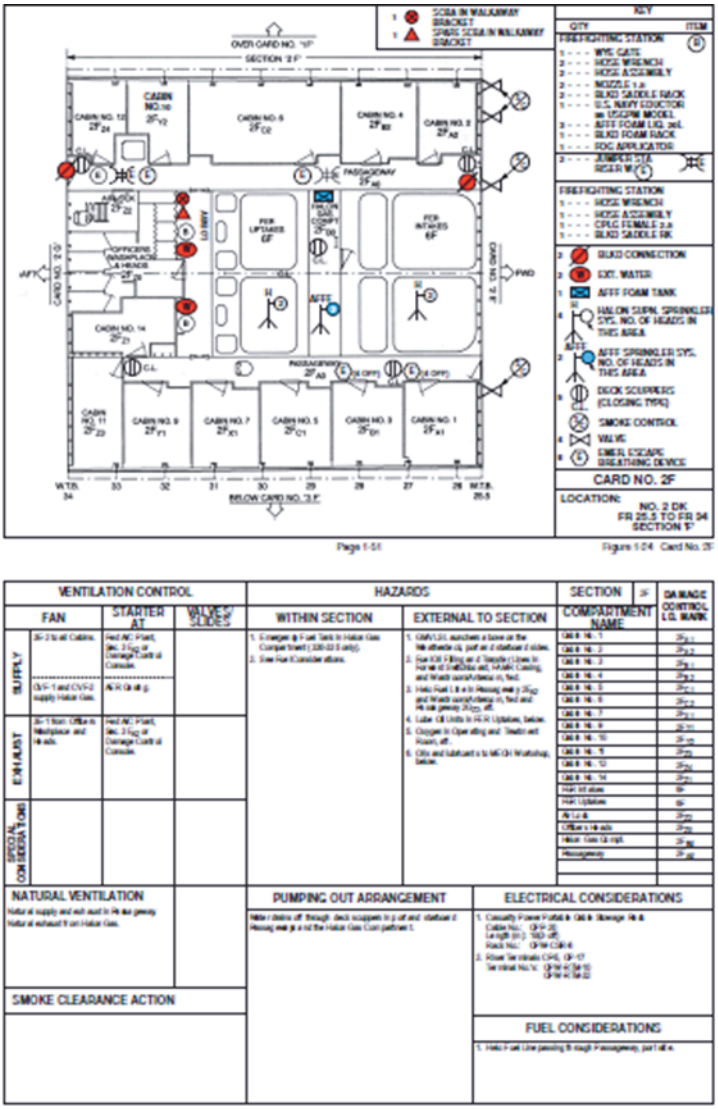


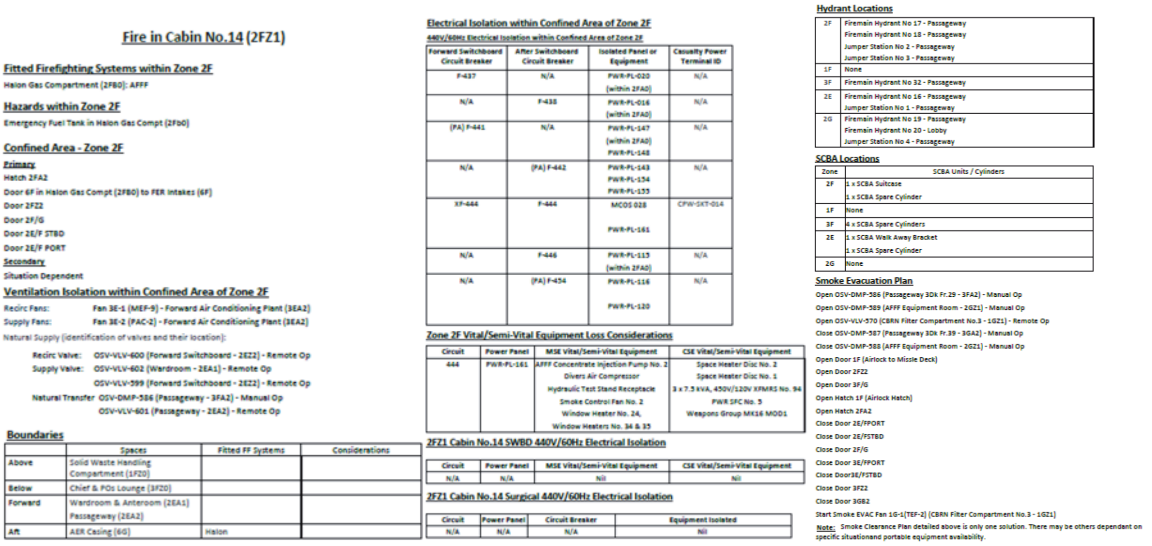
Figure 11: Example of an Original Halifax Class Compartment Risk Folio

This original Risk Folio detailed the considerations for recovery but was used in isolation from the DCS. The Risk Folio achieved the requirements of a Static Kill Card, but was only available to personnel who had a hard copy of the manual. The Risk Folio did not address or include Dynamic Kill Cards.

5.1. Current Halifax Class Kill Cards

The initial BDCS Kill Cards addressed both Static and Dynamic Kill Cards addressing some Internal Battle requirements. These Kill Cards are retrievable directly from the BDCS General Arrangement Plan (GAP), allowing for better damage control information availability as compared to the original Risk Folio since the Kill Cards were more accessible to the entire Internal Battle Organization.

The initial Static Kill Cards, Figure 12, were texted based stand-alone read-only (Adobe Acrobat) documents based upon the Halifax Class Compartment Risk Folio addressing all of the Risk Folio elements plus some additional requirements, such as compartment confinement. Additionally, all compartments are provided with a minimum of Fire Kill Cards and for those compartments below the waterline, i.e. Red Risk Zone, a Flood Kill Card was also created.



Fire in Cabin No.14 (2FZ1)

Fitted Firefighting Systems within Zone 2F

Halon Gas Compartment (2FB0): AFFF

Hazards within Zone 2F

Emergency Fuel Tank in Halon Gas Compt (2Fb0)

Confined Area - Zone 2F

Primary
Hatch 2FA2
Door 6F in Halon Gas Compt (2FB0) to FER intakes (6F)
Door 2FZ2
Door 2F/G
Door 2E/F STBD
Door 2E/F PORT
Secondary
Situation Dependent

Ventilation Isolation within Confined Area of Zone 2F

Recirc Fans: Fan 3E-1 (MEF-9) - Forward Air Conditioning Plant (3EA2)
Supply Fans: Fan 3E-2 (PAC-2) - Forward Air Conditioning Plant (3EA2)
Natural Supply (identification of valves and their location):
Recirc Valve: OSV-VLV-600 (Forward Switchboard - 2EZ2) - Remote Op
Supply Valve: OSV-VLV-602 (Wardroom - 2EA1) - Remote Op
OSV-VLV-599 (Forward Switchboard - 2EZ2) - Remote Op
Natural Transfer OSV-DMP-586 (Passageway - 3FA2) - Manual Op
OSV-VLV-601 (Passageway - 2EA2) - Remote Op

Boundaries

	Spaces	Fitted FF Systems	Considerations
Above	Solid Waste Handling Compartment (1FZ0)		
Below	Chief & POs Lounge (3FZ0)		
Forward	Wardroom & Anteroom (2EA1) Passageway (2EA2)		
Aft	AER Casing (6G)	Halon	

Electrical Isolation within Confined Area of Zone 2F

440V/60Hz Electrical Isolation within Confined Area of Zone 2F

Forward Switchboard Circuit Breaker	After Switchboard Circuit Breaker	Isolated Panel or Equipment	Casualty Power Terminal ID
F-437	N/A	PWR-PL-020 (within 2FA0)	N/A
N/A	F-438	PWR-PL-016 (within 2FA0)	N/A
(PA) F-441	N/A	PWR-PL-147 (within 2FA0) PWR-PL-148	N/A
N/A	(PA) F-442	PWR-PL-143 PWR-PL-154 PWR-PL-155	N/A
XF-444	F-444	MCOS 028 PWR-PL-161	CPW-SKT-014
N/A	F-446	PWR-PL-115 (within 2FA0)	N/A
N/A	(PA) F-454	PWR-PL-116 PWR-PL-120	N/A

Zone 2F Vital/Semi-Vital Equipment Loss Considerations

Circuit	Power Panel	MSE Vital/Semi-Vital Equipment	CSE Vital/Semi-Vital Equipment
444	PWR-PL-161	AFFF Concentrate Injection Pump No. 2 Divers Air Compressor Hydraulic Test Stand Receptacle Smoke Control Fan No. 2 Window Heater No. 24, Window Heaters No. 34 & 35	Space Heater Disc No. 2 Space Heater Disc No. 1 3 x 7.5 kVA, 450V/120V XFMRS No. 94 PWR SFC No. 5 Weapons Group MK16 MOD1

2FZ1 Cabin No.14 SWBD 440V/60Hz Electrical Isolation

Circuit	Power Panel	MSE Vital/Semi-Vital Equipment	CSE Vital/Semi-Vital Equipment
N/A	N/A	Nil	Nil

2FZ1 Cabin No.14 Surgical 440V/60Hz Electrical Isolation

Circuit	Power Panel	Circuit Breaker	Equipment Isolated
N/A	N/A	N/A	Nil

Hydrant Locations

2F	Firemain Hydrant No 17 - Passageway Firemain Hydrant No 18 - Passageway Jumper Station No 2 - Passageway Jumper Station No 3 - Passageway
1F	None
3F	Firemain Hydrant No 32 - Passageway
2E	Firemain Hydrant No 16 - Passageway Jumper Station No 1 - Passageway
2G	Firemain Hydrant No 19 - Passageway Firemain Hydrant No 20 - Lobby Jumper Station No 4 - Passageway

SCBA Locations

Zone	SCBA Units / Cylinders
2F	1 x SCBA Suitcase 1 x SCBA Spare Cylinder
1F	None
3F	4 x SCBA Spare Cylinders
2E	1 x SCBA Walk Away Bracket 1 x SCBA Spare Cylinder
2G	None

Smoke Evacuation Plan

Open OSV-DMP-586 (Passageway 3Dk Fr.29 - 3FA2) - Manual Op
Open OSV-DMP-589 (AFFF Equipment Room - 2GZ1) - Manual Op
Open OSV-VLV-570 (CBRN Filter Compartment No.3 - 1GZ1) - Remote Op
Close OSV-DMP-587 (Passageway 3Dk Fr.39 - 3GA2) - Manual Op
Close OSV-DMP-588 (AFFF Equipment Room - 2GZ1) - Manual Op
Open Door 1F (Airlock to Missle Deck)
Open Door 2FZ2
Open Door 3F/G
Open Hatch 1F (Airlock Hatch)
Open Hatch 2FA2
Close Door 2E/FPORT
Close Door 2E/FSTBD
Close Door 2F/G
Close Door 3E/FPORT
Close Door3E/FSTBD
Close Door 3FZ2
Close Door 3GB2
Start Smoke EVAC Fan 1G-1(TEF-2) (CBRN Filter Compartment No.3 - 1GZ1)
Note: Smoke Clearance Plan detailed above is only one solution. There may be others dependant on specific situationand portable equipment availability.

Figure 12: Example of Initial Halifax Class Static Kill Card

One of the first major challenges associated with the creation of Kill Cards was associated with the Technical Data Package (TDP). Two key TDP issues were identified:

- The quantity of data associated with the Kill Card TDP requirements; and
- The acknowledgment that the Technical Data Package was not completely accurate. For certain Kill Card aspects this lack of accuracy was deemed to be critical for Internal Battle requirements, e.g. electrical isolation requirements.

These issues were resolved by:

- TDP Data Quantity: A stand-alone database was created to manage and create individual compartment Kill Cards based upon an agreed upon Kill Card template; and
- TDP Accuracy: Where accuracy for the information provided by the Kill Cards was deemed critical surveys were conducted to validate the actual configuration. This was specifically done for the electrical isolation, resulting in ship particularized Kill Cards.

Additional challenges which were identified and addressed during the initial Kill Card development were associated with:

- Kill Card Installation; and
- Kill Card configuration.

Notwithstanding these TDP challenges Kill Cards have provided easily accessible details allowing the Damage Control Organization to better fight the Internal Battle; addressing the Float, Move and Fight capabilities.

5.1.1 Kill Card Installation

Since the BDCS system was fitted for but not with Kill Cards, the Kill Card installation process was revamped in order to ensure proper and complete Kill Card installation throughout the entire BDCS system (i.e. consoles, displays, portable operating units, etc.). Additionally, as Kill Cards were installed independently of shipboard BDCS applications it was difficult to ensure the correct version of Kill Cards were installed. Ultimately this was resolved by directly linking Kill Card with BDCS installations, which are conducted by the same organization.

5.1.2 Kill Card Configuration

Kill Card development has resulted in significant discussion with key RCN stakeholders and the evolution of Kill Cards has therefore been rapid. The RCN created a Kill Card Working Group, co-chaired by the Technical Authority (to address BDCS and Kill Card technical capabilities) and the Senior Staff Officer for Surface Warship Internal Policy (to address Internal Battle Priorities). The Kill Card Working Group key stakeholders include Sea Training staffs plus BDCS and Kill Card Original Equipment Manufacturers (OEMs). This Kill Card Working Group confirms format, technical requirements, and roll-out/installation requirements. For the format and technical requirements, specific RCN standards have been developed, and continue to be reviewed and updated, to ensure commonality of Kill Cards throughout the entire RCN.

5.2. Next Generation of Halifax Class Kill Cards

The next generation of Halifax Class Kill Cards is being developed to address the following key requirements:

- Static Kill Cards:
  - More visual / graphical representation
  - Increased Kill Card content to address Internal Battle requirements, such as identification of chilled water and firemain isolation.
- TDP Data Management
- Development of dynamic Kill Cards

5.2.1 Static Kill Cards

Figure 13 provides an example of the next generation of Static Kill Cards, which contains all of the textual data from the initial Static Kill Cards but allows for an easier method of accessing the needed data. The four quadrants, in a clockwise direction starting from the top right-hand quadrant are the: GAP, Kill Card radio buttons, legend and Kill Card textual data. This upgraded format provides for an improved picture compilation since the GAP is always available and all Kill Card data is still available, but filtered, to allow for a more efficient retrieval of specific requirements.

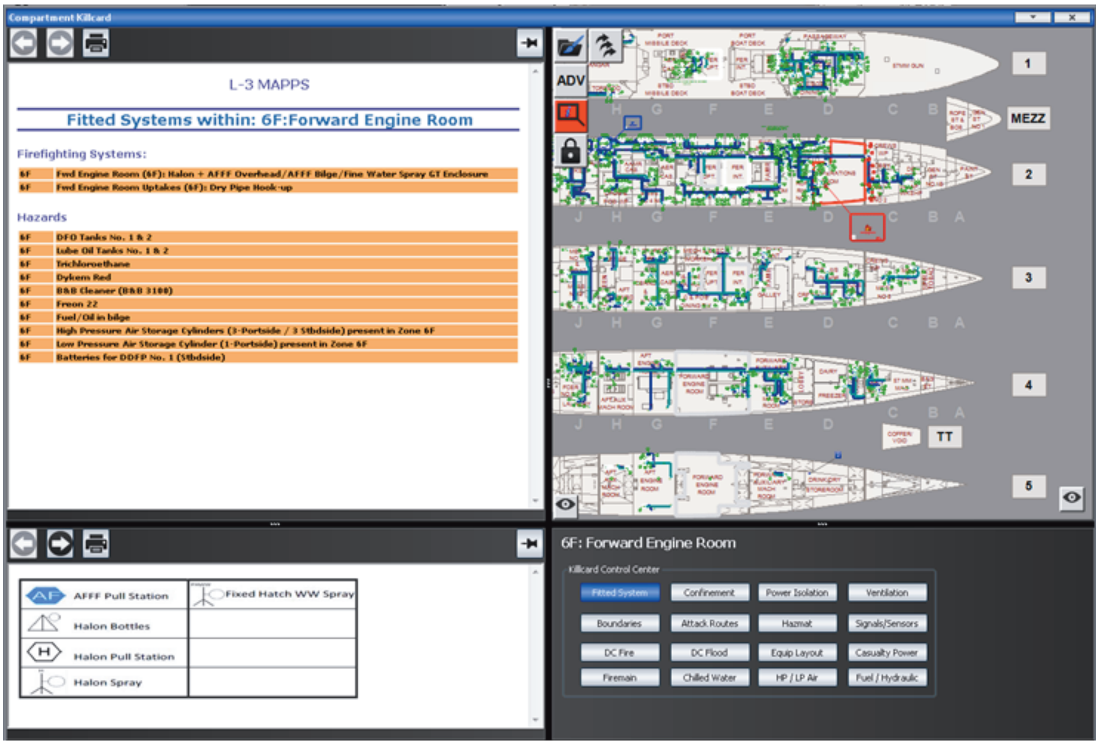


Figure 13: Next Generation of Static Kill Cards

One of the significant Kill Cards challenges, for both Static and Dynamic Kill Cards, has been to manage the volume of technical data and create the associated Kill Cards. The volume of data has created two key problems:

- Creation of Kill Cards from the data is a significant level of effort; and
- Ongoing data update the result of ongoing engineering / configuration changes.

To resolve these issues the RCN Technical Authority, BDCS and Kill Card OEMs have collaboratively worked on the development of a Kill Card database embedded within BDCS. The embedded database has eliminated the requirement to create stand-alone Static Kill Cards. Expanding the original stand-alone Kill Card database to link with BDCS requirements has allowed for a greater ability to track all TDP data requirements within the context of all BDCS requirements. As well, new BDCS functionality is being explored so that ship staff can record electronic notes that highlight discrepancies between Static Kill Card details and actual ship configuration.

5.2.1 Dynamic Kill Cards

Future Dynamic Kill Card developments will be made through the Kill Card Working Group, this allows the RCN to progressively review and define new monitoring requirements. The difficulty with increasing monitoring requirements is installing additional I/O sensors on an in-service ships. Whereas for new builds these additional requirements can be incorporated into the design. For example, one area of additional monitoring that the RCN is exploring is the addition of surgical and zonal ventilation isolation.

6. Conclusions

6.1. BDCS

Through the progression of the Halifax Class DCS to BDCS and the next generation of BDCS system it can be seen how the three main requirements of Picture Compilation, System Monitoring and Personnel Accountability have been progressively addressed through subsequent generations of BDCS. Table 1 provides a summary of the status and development through the BDCS lifecycle:

	Original DCS	Current BDCS	Future BDCS
Picture Compilation	• Manual DC plotting of Incident Boards • Relied on internal communications	• Automated + integrated plotting allows for real time and consistent picture compilation throughout entire DC organization	• Multiple views available. Ability to more easily access multiple DC information
System Monitoring	• DCS – monitored DC systems only • Stand-alone from IMCS	• BDCS fully integrated within IPMS • Able to monitor marine systems through BDCS.	• Additional system automation. Any system critical to the combat of the Internal or External Battle.
Personnel Accountability	• Manual update of Accountability Boards	• Accountability Boards integrated. Provides a real time and consistent picture	• Incorporation of crew lists within Accountability Boards • (Possible) automatic personnel tracking throughout ship

Table 1: BDCS Progression

While it is relatively easy to upgrade the BDCS system architecture, it is significantly more complex to upgrade to newer system monitoring requirements since the addition of field devices requires a significant degree of engineering / configuration change. The Citadel system monitoring requirements is a typical example.

6.2. KILL CARDS

Static Kill Cards are important since they provide an overall situational awareness of compartment Internal Battle requirements. Dynamic Kill Cards provide for particularized monitoring and can be the precursor for additional system monitoring requirements. Both of these types of Kill Cards facilitate information gathering and transfer so that miscommunication is reduced, resulting in a more efficient Internal Battle Organization and improved Picture Compilation.

The key challenges associated with Kill Cards are:

- Technical Data Management. As ships are constantly being upgraded it is important to have a robust data management system which can be quickly and efficiently maintained. Accordingly, the RCN is working towards an embedded database to create the Kill Cards.
- Automation Requirements. As highlighted by the Citadel monitoring improvements, while it is possible, it is difficult to retro-actively incorporate new system monitoring capabilities. Using Dynamic Kill Cards, possibly augmented with Static Kill Cards, could be an effective means in order to meet current and future RCN Kill Card requirements as well as identify and define new system monitoring capabilities. The true benefit of this approach could result in well-defined monitoring requirements for new builds.

7. Acknowledgements

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8. References

Canadian Forces Technical Order (CFTO) C-77-231-000/MS-001: "Operation, Installation and Maintenance: Damage Control System Model Number SYS-00501-00", May 16 1994.

Canadian Forces Technical Order (CFTO) C-97-007-000/DC-002: "Damage Control Risk Folio: Command Task Group Configuration", October 10 2013.