DAMAGE COMMAND AND CONTROL

REQUIREMENTS AND FUTURE TRENDS

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ABSTRACT

Damage command and control is a complex activity requiring the co-ordination of a large number of men and systems. The aids given to damage control personnel in current ships are very basic, with little use being made of Information Technology. Future ships will have fewer men to undertake the tasks. There is therefore a need to provide systems which give the operators a fuller, more consistent picture of the situation, which allow them to communicate effectively with each other and which give them advice on possible actions and consequences. This article discusses the requirements in each of these areas and relates them to the state of the necessary technology.

Introduction

The evolution of damage control and surveillance systems over the past thirty years has lagged far behind that for weapon and machinery control systems. In both these latter areas successive generations of systems can be identified, with each generation using more sophisticated and automated means of controlling their respective equipments and with each generation adding extra functionality. In the field of damage control, however, there have been far fewer advances. Whilst modern electronics have been used in the latest systems, the capabilities of current systems are not much greater than those provided in the early 1960s. For example, the use of manually marked up stateboards, and heavy reliance on verbal reporting is still a feature of our present ships.

During the 1980s there have been a number of instances in which the need for more effective damage control has been made painfully apparent. The command, control and surveillance systems are among those in which improvements have been recognized to be necessary. Added to this are the extra capabilities required by the call for reduced manning in future ships. Since damage control is a manpower-intensive activity there is great pressure to use modern techniques to automate wherever possible.

Damage Control and Surveillance, a Historical Summary

Damage command and control in World War II ships largely consisted of the Executive Officer rushing to the scene of the damage, co-ordinating action and reporting back to the captain on the bridge. Repair and containment of damage to machinery was the direct responsibility of the ship's engineer with little or no requirement to worry about incidents and consequences outside the engine room. Whilst the Executive Officer has retained his role of assessing the damage 'on the spot' and keeping the Damage Control Officer briefed on the extent of the damage, the increasing complexity and interdependence of systems has demanded a more co-ordinated approach to damage control. A damage control headquarters (DCHQ) has therefore become necessary. In the early 1960s this was in a convenient office and equipped only with stateboards and limited voice communications. The task of running DCHQ has since, however, been given to the ship's Marine Engineer Officer, and DCHQ and the machinery control room (MCR) have been combined into a ship control centre (SCC).

Alongside this evolution of the organizational aspects there has been a real but slow evolution in the facilities. Alarms and warnings for fire and flood have been provided since the 1960s but the presentation of the information has been less than ideal. Voice communication has been improved with primary and secondary links to fire and repair party posts (FRPPs), secondary damage control headquarters (HQ2) and the command positions. However, the compilation of a picture of the damage sustained is still reliant on men with chinagraph pencils marking up perspex display boards from verbal reports.

The Type 23 frigate has provided for the first time a single damage surveillance system which senses fire and flood and monitors the status of important doors and hatches and gaseous firefighting systems. The information is presented on a large ship mimic which can also be used for the traditional marking-up of incident reports. Also provided to the supervisors in the SCC is a computer-based library of ship, compartment and system data which enables the operator to access information, previously available only in BRs, on compartment firefighting check-off cards ('kill cards') and on drawings.

Despite these advances, current technology would enable much more to be done to assist operators, so the time is right for future systems to be made more capable.

Current Requirement

The successful application of damage command and control requires the sequence of events and activities shown in Fig. 1 to occur in an efficient and co-ordinated manner. This sequence is discussed in more detail in a previous article[1]. When damage occurs it must first be sensed and the information transmitted to a person (or system) who has to decide on and take the appropriate action. Assuming the sensor is still undamaged, it will then provide some feedback. The 'inform' box at the centre of the diagram

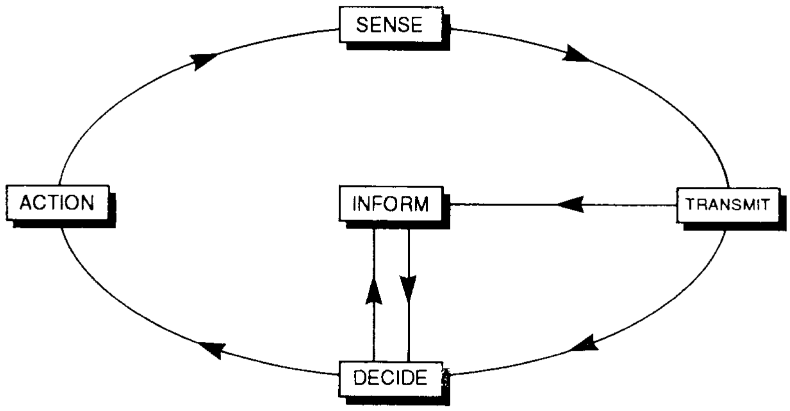

FIG. 1—DAMAGE CONTROL SEQUENCE

indicates the need to report the current status to others who have a need to know. Any or all of these activities can be carried out automatically or manually.

Each of the elements in FIG. 1 is now discussed separately, to identify the requirements.

Sensing

Clearly there is a requirement for remote detection of incidents so that their type, severity and location can all be reported as early and as accurately as possible. The traditional requirement to sense fire and flood will obviously continue but it is also necessary to ensure that all important systems have adequate instrumentation of their own so that any damage they sustain can be reported. It will also be necessary to monitor the closed down integrity of the ship. The degree of monitoring required for systems is to a level sufficient to enable system re-configuration to take place or so that the loss of capability can be assessed. If no re-configuration is possible or the system is not important then the damage control personnel should not be burdened with excess data.

Transmission

Raw data from sensors needs to be transmitted as reliably as possible to those people or systems who have to act on that data.

Since damage control and surveillance is a shipwide system and DCHQ will need to initiate many actions, a dual redundant means of transmission is necessary. Moreover, since DCHQ is itself liable to become untenable, there is a need to provide the most important data directly to HQ2. The advent of independent zones within ships means it would also be desirable to provide the relevant data directly to a position within each zone. However, cost considerations may preclude this.

The transmission of manually sensed information is also important. Traditionally this has been achieved using voice communications. These are notorious for allowing misinterpretation and confusion when a number of reports are being received against a background of high noise and stress. It is therefore essential to provide a means of making manual reports via data links. This will be discussed further below.

Decision

The decision process is the most difficult to define and solve. Local automatic initiation of systems will not be considered here but rather the process which occurs in DCHQ and to a lesser extent at fire and repair party posts.

The decision on what action to take, whether it be in response to battle damage at sea or to a harbour fire incident, requires knowledge of a number of factors. The most important of these are:

- Number, location and type of incidents.
- Severity of incidents and hazards involved.
- Availability of defensive systems (e.g. halon, firemain).
- Availability of electrical power.
- Availability, position and skill of manpower.
- Command priorities.
- Watertight integrity of ship.
- Possible consequences/dependencies of actions.

The man in charge (the DCO) has a very difficult task and if the incident is in harbour or is unexpected he may not be highly trained or experienced. It is therefore necessary to provide accurate, easily read and understood displays of all the factors listed above. The DCO will also need access to a database of information concerning compartments, systems and the ship so that the likely effects of incidents and containment actions can be assessed.

There is risk of swamping the operators with so much data that they cannot 'see the wood for the trees'. The display formats and content therefore need to be carefully designed and the operator given the option to select the detail and information he wants. Since the chinagraph incident board enables the DCO to see the whole picture it should not be abandoned without a suitable replacement. There remains, therefore, the requirement for a picture of the known confirmed status of damage to be compiled and presented electronically. In this way the picture is then available for transmission to other locations.

Given the complexity of the problem there is significant potential for the use of the emerging artificial intelligence (AI) technology to make the damage control task easier. This could be used to take action automatically or merely to advise. Such a system would need to be given both sensor data and an encyclopaedic database and, since to a large extent both these should already be provided in the SCC, the basic building blocks are available. The degree to which AI techniques are likely to be used is debated later.

Action

Damage control is traditionally a manpower-intensive activity in which the adaptability, mobility and muscle power of men are used to combat the damage. However, given the continuing pressure to reduce manpower, there is a need to automate as many activities as possible. For firefighting the further application of gaseous fixed suppression systems and fixed water spray/fog systems will be necessary. In high risk compartments these may be automatically initiated but in others simple local and remote actuation is all that is required. The use of built-in systems for boundary cooling of high value and/or high risk compartments is under investigation as is the potential value of increased thermal insulation using either conventional or intumescent materials or one of the new temperature-resistant compounds coming on the market. For flood removal a more extensive fit of fixed equipment will be necessary but portable manually controlled pumps will remain essential.

The requirement manually to close a number of ventilation flaps and valves and manually to re-align the firemain and chilled water systems on receipt of alarm or on going to the action state will need to be largely automated or remotely controlled. Similar consideration will have to be given to the remote actuation of some door and hatch openings.

Informing

At present the passing of DC information and orders around the ship is achieved almost entirely by voice communications. These are recognized as being unreliable, and investigations are in hand to identify how technology can best be employed to assist. The requirement for this function is described here. Alongside the detailed displays at the SCC, HQ2 and the FRPPs, derived from sensors throughout the ship, there is a requirement to display a large-scale picture of the recognized damage state. This picture should be compiled in a single location, probably the SCC, and electrically transmitted to HQ2, the FRPPs, the Operations Room, the Weapon Section base, and the Bridge. Displays at these positions, however, could be VDUs with an easily operated page selection system. This system could also provide status information on important service systems (generation, HPSW, etc.). This information could come directly from the machinery control system or could be manually inputted by the relevant system operator. The data links necessary between these stations would also provide a means for the operators to make and receive manual reports to and from other locations. The data could be 'broadcast' in a similar manner to the open line voice links currently used but avoid many of the drawbacks of using a verbal system. In this way it would be possible for the command to pass messages concerning priorities and weapon system requirements, to those co-ordinating the damage control activities. It would also be feasible to provide a number of connection points at strategic positions around the ship at which portable terminals could be used by action teams to report on the situation and seek information or instructions. Finally each operational terminal would need to have its own uninterruptable power supply with at least a four hour battery back-up.

Technology Considerations

Having considered in fairly general terms the requirements for fulfilling the functions identified in FIG. 1, it is now relevant to discuss the technological trends/availability in each area and the cost considerations which might dominate the decisions on what is actually employed in future ships.

Sensors

The development of new sensors is being driven largely by the requirements of the process industry. Happily these are numerous and the range and capability of sensors are growing fairly fast. Happily, too there is a growing trend to standardize both the mechanical and electrical interfaces.

In the areas of fire and flood detection, reduced manpower means that there is a need for each individual sensor to be addressed, for sensors to be capable of reporting analogue values (i.e. to be not just on/off sensors) and for sensors to be able to give a malfunction warning. Micro-electronics are now making it possible to put the necessary 'intelligence' inside the sensor, thus making it more affordable and simplifying controller design. It also means that data collection from a number of transducers can be achieved on a data transmission system without having to use complex units solely for data collection. Justifying the use of these more capable but nevertheless more costly sensors will have to be done on a through-life cost basis. They will therefore need to live up to the claims of high reliability and/or lower preventive maintenance that are being made for them.

Transmission

Data from a large number of sub-systems concerned with machinery, weapon and damage control will be generated and require transmission to a number of locations. Data transmission networks will therefore exist in the ship to provide for these requirements. There are numerous debates on whether a single (albeit dual, triple or more redundant) highway should be provided to cater for all needs.

The problems of managing the data flow requirements from a large number of diverse users in a real time control environment are probably too great for our current procurement processes to handle. Moreover, since the various machinery and weapon systems have different requirements, the 'ideal' of a single ship-wide data transmission system is unlikely to come to fruition in the near to medium future. However, an Integrated Platform Management System (IPMS) is likely to be implemented in future ships[2] and this should contain a 'platform' data transmission system which will have characteristics suitable for the damage surveillance systems. The overall data rates, time delays, and other communications requirements of all the platform data will be within the capacity of copper or optical fibre network systems that are already available. The system architecture required to give the necessary degree of invulnerability will therefore dominate the choice of transmission system to be used.

Within this overall architecture it is probable that the fire detection will be undertaken by a system or systems based on commercial developments. Analogue addressable fire detectors and controllers are being developed with their own transmission networks and it is possible that use of one or more of these (perhaps one per zone) will provide a more cost-effective solution than a completely new development. FIG. 2 shows a possible damage control and surveillance system based on this architecture.

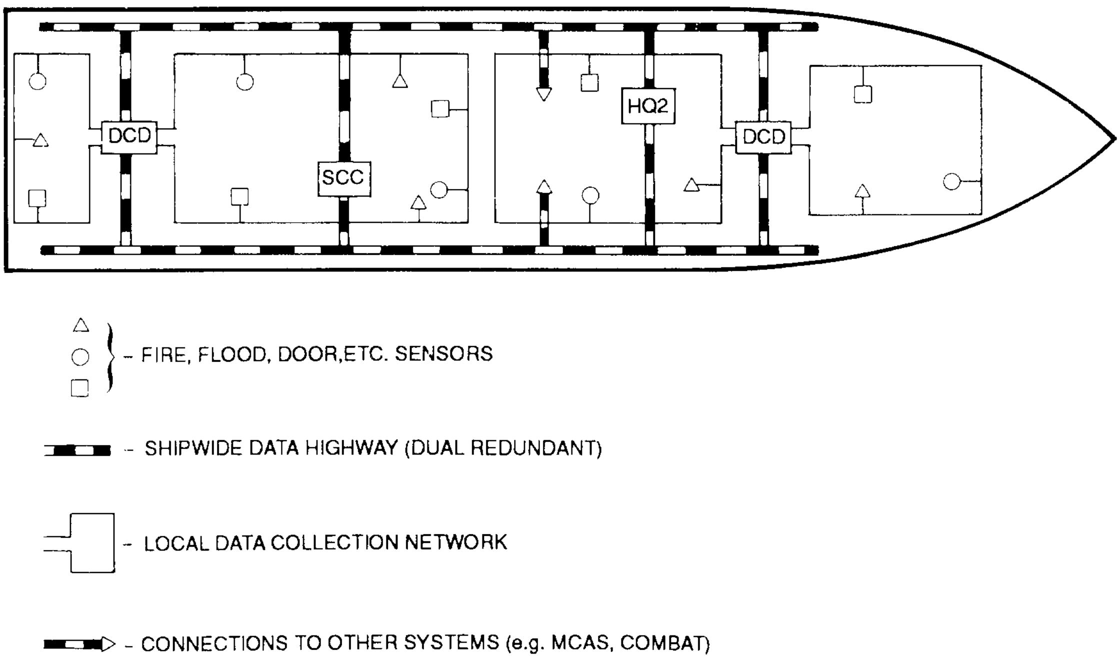

FIG. 2—POSSIBLE DAMAGE SURVEILLANCE AND CONTROL SYSTEM ARCHITECTURE
DCD: Data Collection and Display unit (at fire and repair party posts)
HQ2: Secondary Damage Control HQ display
SCC: Ship Control Centre damage control display

Decision

It is in this area that most development is required to provide the operator with the assistance he needs. The provision of easily read displays, ergonomically designed controls and a co-ordinated approach to providing the correct data to each team member will require considerable investment in system engineering, human factors investigations and prototype designs.

The techniques for achieving a good SCC design and user-friendly operator displays and controls are now available and will need to be used to the full if our future ships are to be easy to operate. This will require considerable customer input over a prolonged period and will need a shared MOD/ Industry approach to responsibility for the design.

Extensive use will need to be made of visual display units which will use windowing techniques, menu-driven pages and panning and zooming capabilities to move around mimic diagrams. The information and controls available at the various positions will need to allow for both the peacetime and action conditions which will inevitably have very different manning levels. The control consoles in the SCC are therefore likely to be multi-functional and the IPMS approach to platform system design will be essential if optimum performance is to be achieved.

The potential for use of artificial intelligence to assist the damage control officer is great and indeed some early studies into the firefighting application have been carried out[3]. The technology, however, is still young and the cost overheads in procuring a very capable system are potentially high. It is therefore likely that a step-by-step approach to the use of AI languages in damage control systems will be employed.

This leads on to the provision in the SCC, in HQ2 and to a lesser extent in the weapon section base of an encyclopaedic knowledge-based system. The technique and usefulness of this has already been demonstrated in ships and the only difficulty in expanding the system is the cost of data capture and data 'upkeep'. The integration of some elements of AI into this system is seen as the most useful means of introducing it. The operator can then be presented with data relevant to the situation and be given prompts and advice rather than have to hunt for information or not realise it was available. The system provided should allow even largely untrained personnel easy access to the data and should have battery-backed supplies. The database at each location should be independent and there should be at least one portable system on board.

A further requirement in the SCC is the provision of a stability monitoring or assessment system. Computer technology and flood level sensing equipment have now reached the state whereby the DC supervisor can be given a facility which will perform calculations on the current stability situation. This may well require the supervisor to enter some data manually—or at least confirm what has been automatically sensed—and it may give only a first order approximation. However, when stability is a real concern, reliable access to some guidance on its state is almost essential.

Action

The relative merits of automatic and remote firefighting systems will not be discussed here but again the technology required is largely available and is already starting to be introduced more widely. The cost of such systems is therefore likely to dominate decisions on the extent of coverage.

Automatic or remote control of system valves, vent flaps, doors and hatches is an area where increased reliability and lower costs of actuators will be required if full use is to be made of control system potential. The reduced manpower requirement will undoubtedly drive the fitting of a number of such actuators but will also mean that maintenance labour will not be available to cope with an increased load. Closer attention will therefore need to be paid to system design to minimize the number of valves required whilst maintaining the ability to re-configure and partition systems. Key valves and flaps will then need to be automated.

Informing

There is a need for a data link between key positions to allow manually input data to be sent and to allow the recognized damage status to be available to all parties. Technology for achieving this is again available and indeed trials on a prototype system are being carried out. The means of entering data into the system needs full consideration as the use of a conventional keyboard would not be satisfactory. The choice would appear to lie between the use of a trackerball with a special purpose keypad and/or soft keys and a CAD digitizer tablet with a special overlay[4]. This system could be implemented using the same terminal hardware as that providing the encyclopaedic database at stations outside the SCC. A possible architecture for this is shown in FIG. 3.

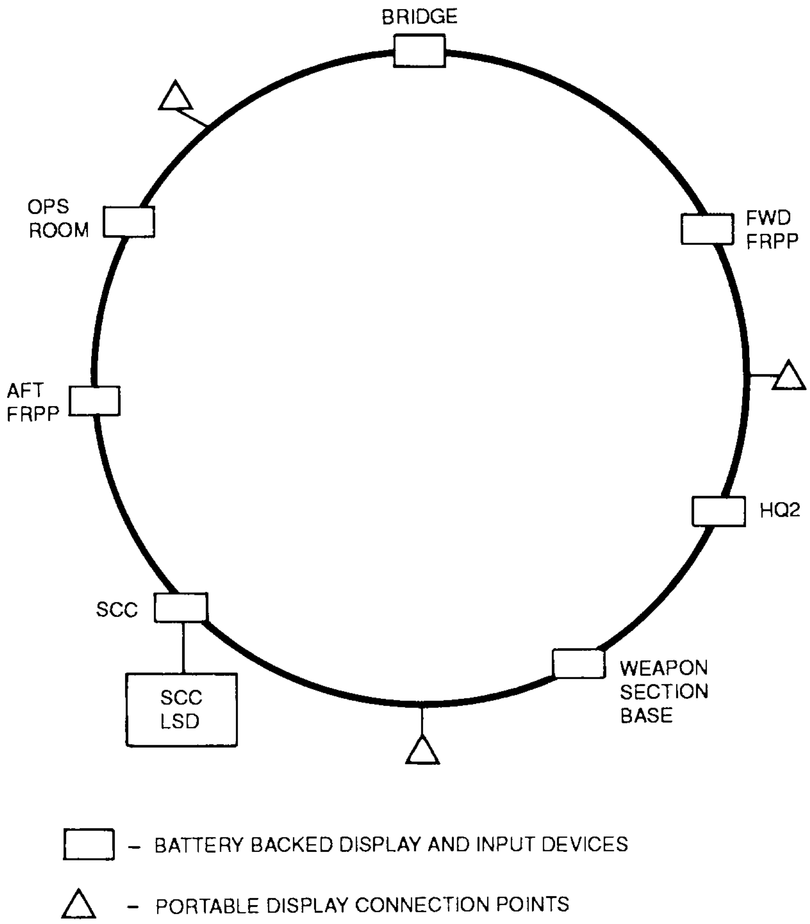

FIG. 3—Possible damage reporting/briefing links
HQ2: Secondary Damage Control HQ display
LSD: Large Scale Display
SCC: Ship Control Centre damage control display

The large-scale whole ship display required in the SCC is an area where further technological developments are necessary before it can be fully realized. The display needs to consume fairly low power, be readable in all light conditions from at least four metres and have a colour capability—as well as meet the usual naval environmental standards. It is not believed that this can be met as yet, but developments in colour liquid crystal display technology are promising.

Summary

Overall, the basic building blocks are already available for providing a more capable damage command and control system for the next generation of ships. The difficult job is to specify the requirements properly and then to integrate the DC requirements with those of other systems to ensure that the ship can be operated as a whole in both peacetime and action conditions. This will not be an easy task and will require a fuller analysis of the requirements than has been possible in this article. Developments already made and those envisaged for the next generation will extend the integration with weapon and machinery systems, will start to use AI techniques to assist the operators, and will increase the automation of a number of systems.

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