INTEGRATED DAMAGE SURVEILLANCE AND DAMAGE CONTROL

BY

D. J. CLEMENTS, B.ENG.(TECH.), C.ENG., M.I.E.E., R.C.N.C.
(*formerly of Sea Systems Controllerate*)

AND

G. P. KNEEBONE, B.SC.
(*YARD, Ltd.*)

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INTRODUCTION

Scope

This article describes both the present and possible future forms of integrated Damage Surveillance and Control (DSC) applicable to surface warships of the Royal Navy, in the light of lessons learned during the current decade.

Although prevention of initial damage is implicit within many of the systems to be described, this article concentrates upon the functions and actions that follow an incident, with the object of assessing, containing and recovering from that incident as quickly and efficiently as possible. The intention has been to set out the sequence of events that follow an incident, whether caused by peacetime or action damage, and to relate these activities to existing and future DSC techniques.

Pressure for change exists not only as a result of recent experiences and the advent of new technologies but also as a result of reduced manning levels with each new generation of warship.

Background

Before considering the trends that have taken place in R.N. warships over the years, it is necessary to review the more important priorities and terms now established.

Although the priorities of a warship have always been to float, move, and fight, in that order, under certain circumstances the Command may have to modify the sequence for a limited period of time, such as by the diversion of electrical power from fire pumps to weapon systems.

The R.N. has evolved various 'states' and 'conditions' to express ships' readiness to deal with the most likely situations.

The 'states' refer to the disposition of manning and the readiness of machinery for action. As higher states are assumed, more stand-by machinery is started and more damage control teams 'stood to'.

The ship's 'condition' refers to the state of the watertight integrity of the vessel. As higher conditions are assumed, so more watertight doors and hatches are shut. The condition assumed has to be a compromise between risk to the ship and the restriction of movement of the ship's personnel and equipment.

It is also important to distinguish between the two types of damage likely to occur in an incident: primary damage caused by the incident itself and secondary damage produced as a direct result of efforts made to contain the incident. An example of the latter would be loss of stability caused by the extensive use of water when fighting a fire.

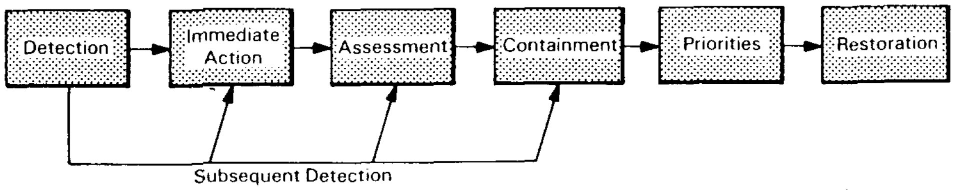

FIG. 1—SEQUENCE OF EVENTS AFTER AN INCIDENT

Aims of DSC

The sequence of events taking place after a typical incident are shown in FIG. 1 and described briefly below.

Detection

Whether by manual or automatic methods, detection is here considered to mean the initial notification of an event to the co-ordinating centre, although a trend will sometimes be indicated by subsequent further detection taking place.

Immediate action

'Alarm' category detection necessitates immediate action, in most cases in the form of pre-planned procedures that have been practised as drills during exercises. The 'standing to' of a fire and repair party or the initiation of particular fire-quench equipment in a magazine may already form part of a check-list which was previously agreed to take place under circumstances where time is of the essence.

Assessment

Collation of information received by both automatic and manual surveillance and recorded (at present) by a manual incident board will begin to enable the co-ordinating centre to build up a picture of the primary events and, by prediction, the secondary effects likely to occur.

Containment

To contain an extreme incident may involve the limiting of the spread of smoke, fire, and flood throughout the vessel at the same time. The sealing off of a compartment can only be considered to have been successful when transmission of all three has ceased. The traditional methods of shoring and of bulkhead cooling form the main techniques for stemming flood and fire, whilst the selective control of ventilation is essential to suppress the spread of smoke.

Priorities

Overall assessment of vessel damage and the spread likely to occur will focus on one officer at the central co-ordinating position. This post forms the single, formal link with the Captain who, in judging the regular assessment against that of the vessel's external priorities, will decide the overall allocation of resources.

Restoration

Following containment of the incident it will be necessary to restore the ship to the maximum state of availability compatible with the damage. This may require the re-opening of compartments and restoration of services together with whatever counterflooding may be necessary.

History

Before the advent of nuclear weapons, cruisers and above possessed a compartment nominated the Damage Control Headquarters (DCHQ). This compartment was generally sited above the primary flooding area, on a communication deck away from the ship's side and within the armoured protective box.

In small ships the Engineer Officer's cabin or engineers' office was utilized as DCHQ and the ship's staff were charged with overall responsibility for producing their own display/information boards. Communications consisted of sound-powered telephones with associated cabling being duplicated along both sides of the ship.

In the 1950s it was recommended that the electrical and marine engineering offices be combined and that the compartment should also function as the equivalent of DCHQ. The recommendation was implemented in the Type 81 and Leander Class frigates but was later rescinded.

With the advent of nuclear weapons and the development of nerve gases and biological agents as potential forms of warfare, the requirements arose for an overall ship protection organization. DCHQ was redefined NBCDHQ (Nuclear, Biological, Chemical and Damage Control Headquarters) and additional control facilities were superimposed on the existing arrangements.

In the late 1950s it was recommended that the marine engineering, electrical and NBCDHQ elements and emergency steering arrangements be combined into a compartment known as the Ship Control Centre (SCC).

The concept of the SCC has continued through to current classes of ship, although the extent of automatic surveillance and control has increased considerably in recent years.

Organization

The central point from which total monitoring and control can be exercised has become known as Headquarters One or HQ1. A secondary or fall-back position, known as HQ2, is maintained at a physically separate location in case HQ1 becomes inoperative.

Owing to the interaction that is necessary between damage control and machinery control functions, their location within the same compartment permits better communication to take place and allows the use of common monitoring and control facilities.

According to the 'state' in which the vessel has been placed, one or more fire and repair parties (FRP) may be closed up at mustering points in direct communication with HQ1.

Information detailing the cause, subsequent state, and action being taken by a FRP is recorded in the SCC with respect to compartments and important systems within the vessel.

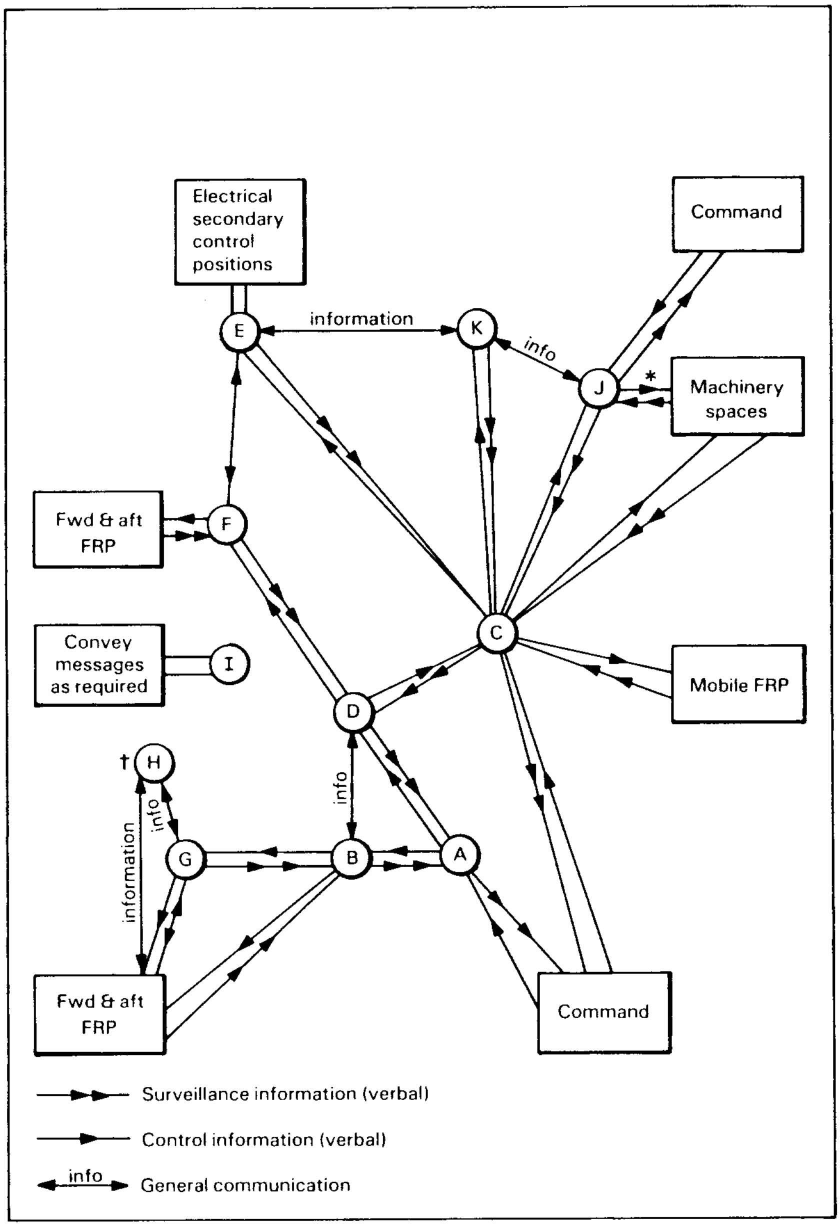

FIG. 2—SHIP CONTROL CENTRE MANNING FOR THE TYPE 22, WITH FLOW OF ORDERS, INFORMATION, AND FEEDBACK

*the propulsion operator also 'communicates' by remote control and surveillance with the main propulsion machinery.
†HQ1 watchkeeping monitors installed auto alarm systems.
For key to letters see TABLE I.

The primary communication paths are shown in FIG. 2 and described in more detail below.

CURRENT DAMAGE CONTROL ARRANGEMENTS

The damage control arrangements of current in-service R.N. warships employ techniques and philosophies based on experience gained in World War II. Achieving and maintaining an accurate picture of damage incidents and coordinating damage control activity is dependent on reliable voice communications. Alarm systems are installed for fire and flood detection, but they are very limited in the extent of ship coverage they provide, being primarily intended for peacetime or low manning harbour incidents.

Organization

The damage-control organization centres around the Damage Control Headquarters. This position is, in ships designed since the 1960s, co-located with the Machinery Control Room (MCR) to form an overall Ship Control Centre. Typical SCC manning is shown in TABLE I. HQ1 is responsible for maintaining an up-to-date picture of the overall state of the ship, damage incidents, availability and use of resources, effectiveness of containment and restoration action, etc., and co-ordinating damage control activities to achieve the priorities set by the Command.

TABLE I—*Current SCC Manning in a Frigate*

Damage control team position		*Normal rank*	*Responsibility*
A	Action NBCDO	MEO	All damage and machinery control operations
B	Action NCBDO's assistant	Deputy MEO or Senior Rate	Damage control co-ordinator
C	Marine Engineer Officer of the Watch	Senior Rate	Machinery
D	Damage Control Engineer Officer	Senior Rate	Machinery/damage co-ordinator
E	Main Electrical Control Panel Operator	Senior Rate	Main electrical switchboard
F	Electrical Damage Control Officer	Senior Rate	Electrical generation and distribution
G	Incident Board Operator	Junior Rate	—
H	HQ1 Watchkeeper	Junior Rate	Shipwide warnings and alarms; fire-pump control
I	Messenger	Senior or Junior Rate	—
J	Propulsion Operator	Senior or Junior Rate	—
K	Leading Hand of the Watch	—	Auxiliary machinery

Detailed investigation of incidents and the execution of damage control activities not possible automatically by the installed systems or remotely from HQ1 are the responsibility of fire and repair parties (FRPs). The number of FRPs is dependent on the size and complexity of the ship, but in general there would be two, one forward and one aft, in a frigate size vessel. They operate from FRP posts, are responsible for their respective zone of the ship as dictated by defined watertight and smoke boundaries, and carry out their tasks either in accordance with pre-defined procedures or as directed by HQ1.

In addition to these essentially 'fixed' FRPs there is also usually a mobile FRP. This unit is responsible to the HQ1 Damage Control Engineer Officer and/or Marine Engineer Officer of the Watch (MEOOW) and undertakes tasks to maintain the availability of the ship's machinery and services such as electrical power, chilled water for weapons systems, etc.

Overall damage control responsibility and authority rests with the ship's Command, located in the Operation Room and/or on the Bridge. The Command is kept informed by HQ1 of the ship's and the systems' status, damage incidents and containment/restoration action and dictates to HQ1 the priority between floating, moving and fighting. The Command is kept informed of the availability of the weapons systems themselves by the Weapons Electrical Officer (WEO), located in the Operations Room.

In addition to HQ1 there is a fall-back co-ordinating position, Secondary HQ1 or HQ2. This position has minimal manning and is kept up-to-date with the status information in HQ1 and damage control activities. This is achieved by a combination of limited repetition of the automatic HQ1 alarms, information passed by HQ1, and the HQ2 team listening-in to the damage control voice communication exchanges. Should HQ1 become untenable HQ2 would take over damage control co-ordination.

To maximize survivability of the organization in action damage situations, the main positions are geographically separated by as much as is practical, particularly HQ1 and HQ2. However, as with most aspects of ship design, this aim has to be a compromise with other factors such as available space, communication availability, etc.

The organization is shown in FIG. 3 and the intercommunication (voice and data) in FIG. 2. As can be seen, the 'hub' of damage control activity is HQ1, with the consequence that the information flow in and out is extensive. Owing to the manning structure of HQ1 the internal information flow is also complex and considerable.

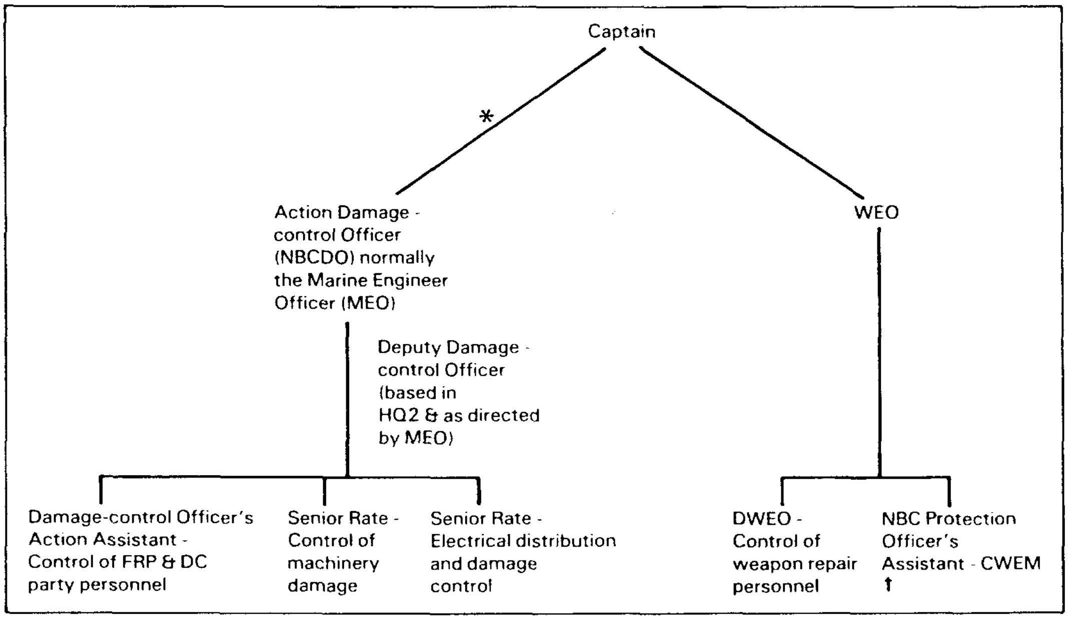

FIG. 3—NBCD RESPONSIBILITIES IN CURRENT SHIPS

*the MEO normally communicates with the Command via the WEO.

†With a low NBC threat, the Protection Officer's Assistant may assist with electrical tasks.

Facilities

The primary damage control and surveillance facility is the ship's installed internal voice communication system, with back-up communications facilities being provided by sound-powered telephones and/or stornophones enhanced by emergency run leaky feeders (magnetic loop) for in-harbour incidents.

The installed DSC facilities are a combination of those provided solely for damage control purposes and those installed as part of the ship's normal machinery control and surveillance functions. The former comprise:

(*a*) Automatic fire and flood alarm systems in HQ1.

(*b*) Sprinkler systems for magazines supplied by the ship's high pressure sea water system (HPSW).

(*c*) Gas drenching systems for machinery spaces.

The latter comprise remote control and surveillance from the MCR of:

(*a*) The HPSW system pumps and essential valves:

(*b*) The electrical generation and distribution system.

(*c*) The chilled water, LP and HP air systems plant.

Operation of the fire-suppression sprinkler and gas drench systems is either local or remote manual from HQ1 as a result of a confirmed fire alarm.

An overall picture of the state of the ship, its systems and the availability/utilization of damage control measures is established and maintained in HQ1. This picture is updated from the verbal reports received from the FRPs. An identical picture is updated at HQ2 and to a lesser extent at the FRP posts.

Relationship to achievement of aims

Achievement of the aims outlined above relies on communication between the Command, HQ1 and the FRP posts, co-ordination within the SCC of the damage and machinery control and surveillance functions and facilities, and use of the installed alarm and machinery system. These are combined to achieve each aim as described below.

Detection

This is either by an automatic alarm annunciating in HQ1 or by verbal reports from the FRPs. In the event of the former, confirmation by FRP investigation is normally required; not only does this validate the automatic indication but also serves to provide additional information such as cause, exact location and extent. FRPs must also act as a local information filter ensuring that only accurate information is passed to HQ1.

Immediate action

This is normally in accordance with pre-defined drills involving either operation of installed systems (e.g. gas drenching, crash stop ventilation) and/or direct action by FRPs.

Assessment

This, and the effect of the incident on the ship and systems' status, is done by the NBCDO in HQ1. He considers verbal reports from the FRPs, displayed DSC information, active alarms and information displayed on the machinery control and surveillance panels regarding status and availability of ship's services. To a large extent the interpretation of this information and hence accuracy of assessment is dependent on the NBCDO's experience.

Containment

This is achieved by the use of the installed systems, co-ordination by HQ1 of the FRPs and a close liaison in the SCC between the HQ1 and MCR functions. Whilst the FRPs do maintain a degree of autonomy, the effectiveness of containment action relies on efficient and reliable communications between HQ1, FRP section bases, and the ship's staff at the scene of the incident(s).

Priorities

These are determined by the Command, considering the overall position of the ship, the availability of the weapons systems as advised by the WEO, and the overall status of the ship and its systems as advised by the NBCDO in HQ1.

Restoration

This is gradually achieved in the same manner as containment by using installed systems with HQ1 co-ordinating the activities of FRPs. It covers both direct damage control activities and control of the machinery systems.

Summary

Although changes have occurred since World War II with improvements in internal voice communications systems and automatic alarm system technology, the emphasis is still on the use of traditional manual damage control and surveillance techniques. This is primarily due to a lack of confidence in the installed alarm systems, which have developed a reputation for unreliability (e.g. fire detection, where the presence of combustion products can lead to false alarms), and the restricted alarm system coverage provided.

The co-location of the HQ1 and MCR functions in a SCC in ships designed since the 1960s has assisted their integration and therefore the overall co-ordination task. However the layout of current in-service SCCs reflects a consideration of the space constraints rather than a compartment integrated for ship control (damage and machinery). The consequence is a tendency to overmanning of the SCC. The Type 22 SCC layout is shown in FIG. 4, with location of the State I manning.

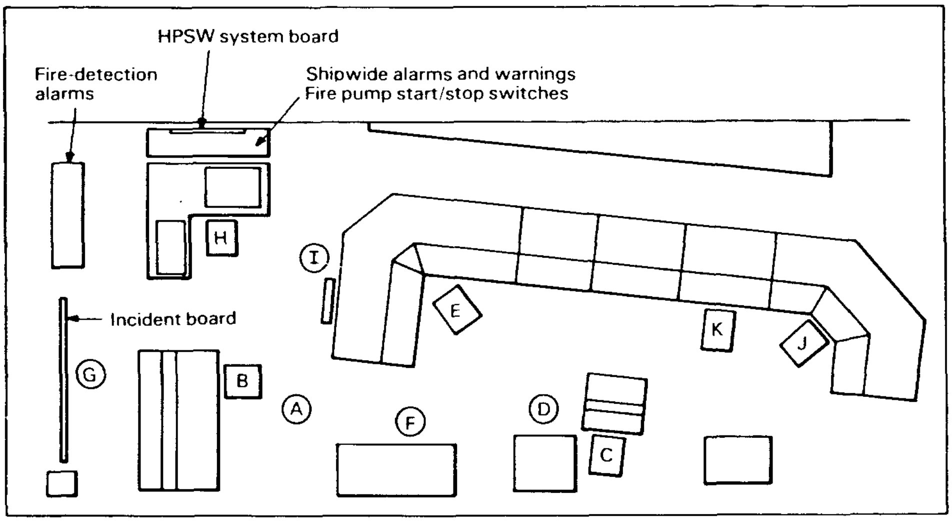

FIG. 4—TYPE 22 SCC LAYOUT AND MANNING
For key see TABLE I

LESSONS FROM THE FALKLANDS WAR

The Falklands campaign was the first major naval conflict since World War II and the Korean War. Relatively modern warship designs were subjected to the effects of both modern and traditional weapons and the in-service damage surveillance and control arrangements were used to combat the resulting damage.

Subsequent analysis of the various incidents has questioned the effectiveness of these arrangements. Of the damage surveillance and control aims outlined it seems that detection, assessment and containment proved most difficult to achieve both reliably and effectively. The reason is attributable to a mixture of shortcomings in the areas of information flow, detection coverage, and organization.

Information flow

The effectiveness of the damage control organization and activities is primarily dependent on the flow of information between the scene of an incident and HQ1 (and/or HQ2). In this context information flow encompasses verbal communication, remote automatic monitoring of both ship and equipment status, and remote control of damage control related equipment/systems. Shortcomings identified from analysis of Falklands incidents included:

(*a*) In the absence of adequate installed automatic detection facility, damage to the installed voice communications system, in one incident, resulted in a considerable time lapse before HQ1 obtained an adequate 'picture' of the damage.

(*b*) In a number of other incidents lack of adequate and reliable information on the status of the ship and installed systems (e.g. extent and volume of flooding, status of compartments) significantly hampered HQ1's assessment and containment activities.

Overall it was concluded that the flow of information, in what was a confused situation, was inadequate for satisfactory damage surveillance and control.

Organization

In general, analysis of Falklands incidents concluded that the high-level damage control organization centred around HQ1 appeared to function satisfactorily. In particular, the requirement for a central position to monitor overall ship status, etc., and coordinate damage control activities seems to have been sustained. The necessity to maintain an up-to-date and effective HQ2 was also demonstrated.

It was this latter aspect which was found to be deficient. In at least one incident, when HQ1 had to be evacuated, further damage surveillance and control activities were handicapped by lack of up-to-date information at HQ2.

Information processing

In association with the identified deficiencies in information flow and detection coverage, the arrangement and display of damage- and machinery-related information in HQ1, together with the manual updating methods, did not provide for easy assessment of damage effects.

In the absence of any decision-making aids, damage assessment is dependent on the Damage Control Officer's expertise and his ability to analyse the displayed information and that transmitted from the scene of the incident. Consequently the ergonomics of information displays and the general HQ1 environment can influence damage assessment. In particular, it is essential that the Damage Control Officer is easily able to relate damage and machinery information.

In general the ability of personnel to tackle the various incidents was not in question. What has been a subject for scrutiny is the extent of automation, decision-making aids and information displays that should be provided to assist the HQ1 team in controlling and dealing with damage incidents.

POST FALKLANDS

Following the analysis of the Falklands incidents, the MOD, in addition to reviewing the design of damage surveillance and control arrangements in both existing and new warships, instigated investigations into possible improvements that might be gained from employing modern technology and/or new damage surveillance and control techniques.

Current ship design activities

Before the Falklands war, the layout of the SCC in warships being designed was already based on compartment functions rather than the fitting of equipment into an available space[1]. A tiered console layout has been adopted with better integration of the damage and machinery control and monitoring facilities. This arrangement provides for more efficient manning of the SCC and enables the Damage Control Officer to obtain an overall picture of ship and system status more easily and ascertain the effectiveness of damage control activities.

The Type 23 layout is given in FIG. 5 and the respective action-state manning is listed in Table II; the expected information flow is shown in FIG. 6. Damage surveillance and control facilities have been integrated with those for related auxiliary machinery systems on the left-hand side of the

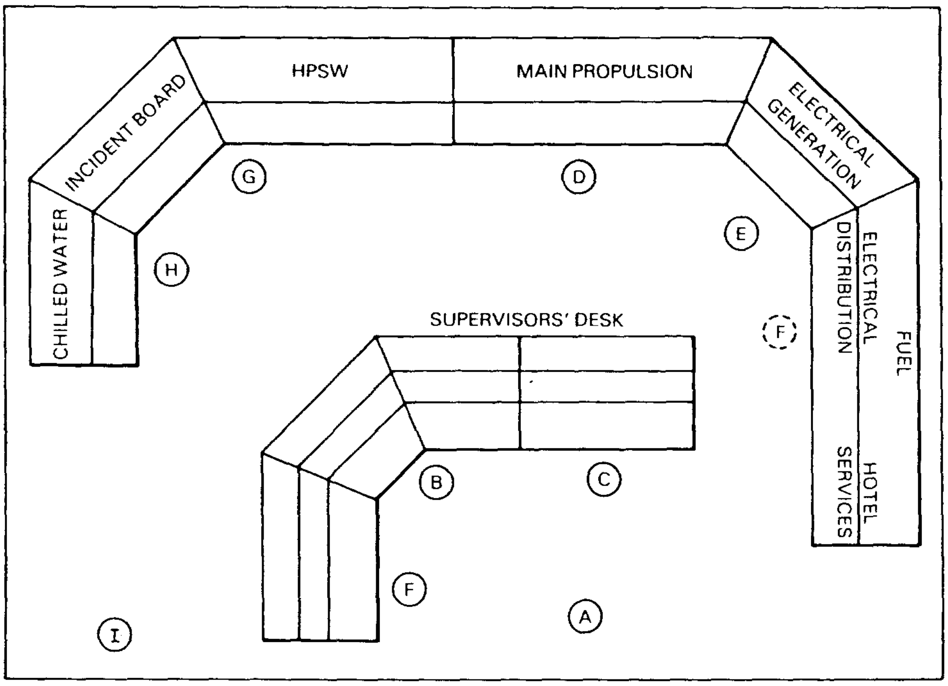

FIG. 5—TYPE 23 SCC LAYOUT WITH PROPOSED MANNING
For key see TABLE II

TABLE II—*Proposed SCC Manning for a new design Frigate*

	Damage control team position	*Normal rank*	*Responsibility*
A	Action NBCDO	MEO	All damage control and machinery operations
B	Action NCBDO's assistant	Officer or Senior Rate	Damage control co-ordinator
C	Marine Engineer Officer of the Watch	Senior Rate	Machinery co-ordinator
D	1st Panel Operator	Senior or Junior Rate	Propulsion and machinery operation
E	2nd Panel Operator	Senior Rate	Electrical co-ordinator
F	NBC Protection Officer's assistant	WE Senior Rate	Specialist NBCD functions and assist 2nd Panel Operator
G	Incident Board Operator 1	Junior Rate	—
H	Incident Board Operator 2	Junior Rate	—
I	Messengers	2 Junior Rates	—

main console, next to the machinery control and surveillance facilities. The second tier provides a supervisory level for both machinery and damage control.

In response to the lessons from the Falklands war, more installed automatic detection with greater ship coverage is being considered in new design ships together with semi-active mimic displays in HQ1, to improve detection performance and presentation of damage-control information. Design innovations will include:

(*a*) Automatic surveillance of the status of selected doors and hatches displayed, together with automatic fire and flood alarms, on a semi-active mimic of the ship general arrangement in HQ1.

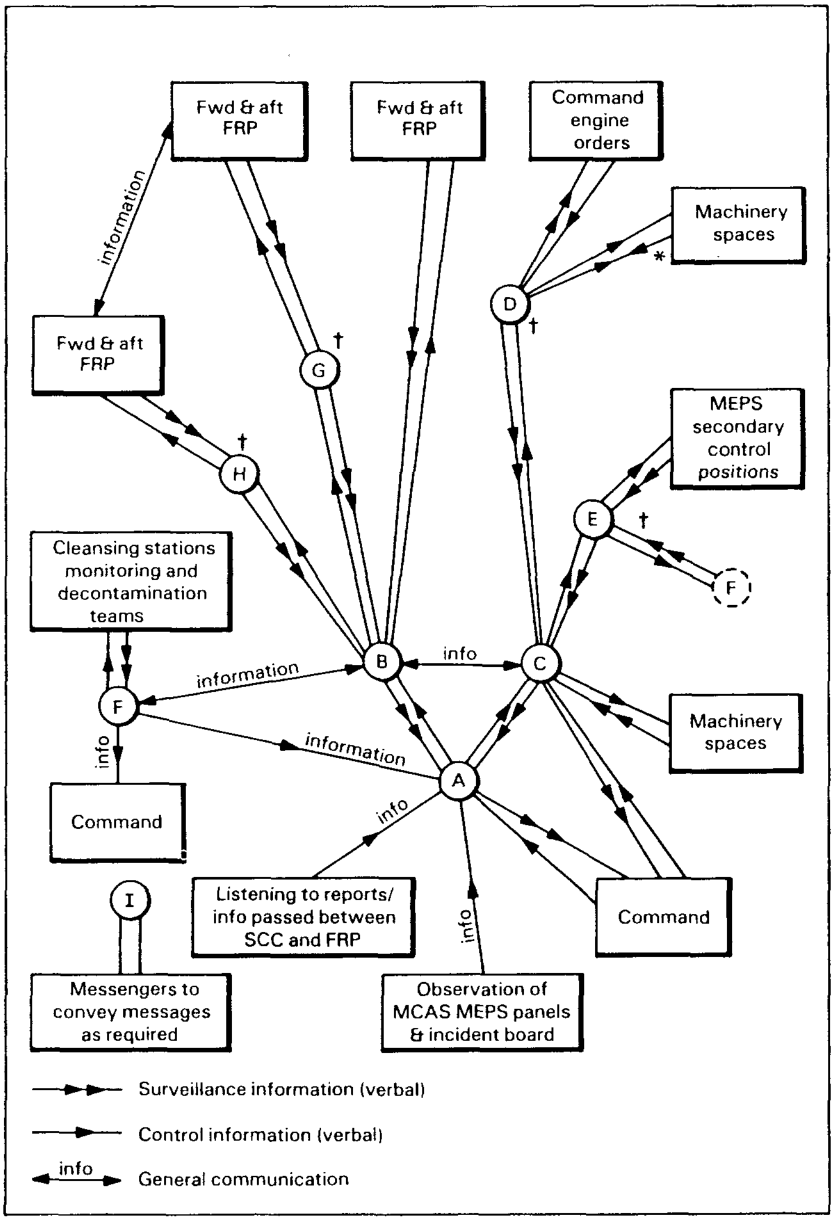

FIG. 6—SCC MANNING FOR THE TYPE 23, WITH FLOW OF ORDERS, INFORMATION, AND FEEDBACK

*the propulsion operator also 'communicates' by remote control and surveillance with the main propulsion machinery

†HQ1 watchkeeper monitors installed auto alarm systems

MCAS: machinery control and surveillance.

MEPS: marine electrical propulsion system.

For key to circled letters see TABLE II.

(*b*) Increased coverage of fire and flood detection.

(*c*) Remote control and surveillance from HQ1 of selected HPSW (fire-main) valves and ventilation fans, with display via semi-active mimics.

(*d*) Use of semi-active mimics for displaying the status of damage control related auxiliary machinery systems.

(*e*) Use of an integrated surveillance system, employing microprocessors and digital multiplexing techniques, to interconnect fire, flood, door and hatch status and ventilation and HPSW valve status detectors with the HQ1 semi-active mimic displays.

Although the aim is to reduce the dependence on voice communication for transferring information, constraints imposed by the ship design programmes have limited the degree of automation and detection coverage that could be implemented retrospectively.

Consequently, although significant improvements have been achieved, the damage control arrangements in ship designs currently in progress will still have a large dependence on voice communication and manual display techniques to supplement the installed facilities.

FUTURE DAMAGE CONTROL ARRANGEMENTS

Study of future arrangements

As a direct result of the analysis of Falklands incidents, the MOD has instigated investigations into the possible use of modern technology and/or new techniques for future damage surveillance and control, with particular emphasis on continued operation in post-damage environments. These investigations will cover detection, data distribution, damage assessment and man/machine interfaces. Technologies which are likely to be considered are:

(*a*) Visual display units (VDUs, monochrome and colour).

(*b*) Active mimic display panels.

(*c*) Microprocessors.

(*d*) Digital data transmission and multiplexing techniques.

The areas where the application of modern technology appears to promise the most potential are those of the man/machine interface and, ultimately, damage assessment. Because of the rate of technological advance and the need to ensure that the technology of today does not dictate trends and solutions, a study is taking place to define the future requirements for damage surveillance and control at man/machine interfaces.

Once these requirements have been definitely specified, a market survey and investigation of technology and techniques, both those available and those in the course of research and development, will be carried out to determine possible methods of meeting the requirements. In support of these investigations prototype facilities may be constructed and evaluated. If necessary the requirements may have to be modified to reflect possible constraints imposed by the state of technological development or cost.

Some possible benefits that might be gained from employing modern technology in damage surveillance and control applications are outlined below.

Future requirements

The overall future requirement is to reduce the dependence of damage surveillance and control on manual techniques and voice communication whilst maintaining personnel and ship safety standards and improving the effectiveness of damage control activities. As is always the case when designing any system, the eventual solution is inevitably a compromise between the ideal aims and prevailing design technology and financial constraints.

Considering each of the aims outlined above, the general future damage surveillance and control requirements as currently foreseen could include the following.

Detection

The extent and scope of automatic surveillance of the status of the ship and damage control related systems should be increased as much as is practicable. In addition to detection of the change of a state, the extent of detection discrimination should also be increased, e.g. rise of temperatures to give early warning of fires, extent of flooding such as level and volume, extent to which doors and hatches are closed, and distinction between heat and smoke detection. There is also a requirement for more reliable and accurate detection to ensure that the damage control team have confidence in the information with which they are presented.

Immediate action

As already stated, 'immediate action' is usually implemented in accordance with pre-defined manual drills. This could be reduced by the provision of more automatic reaction by installed systems, e.g. operation of water- or gas-drench systems and crash stopping of selected ventilation fans on valid detection of a fire. Again this would require high-responsibility detection, which would only be placed on-line during periods of high risk.

Assessment

Increased automatic displays of damage control information, maximising the use of mimics, should be provided in both HQ1 and HQ2. This includes display of information which is currently updated totally manually, such as time of incident, boundary cooling action, commitment of damage-control resources, etc.

In addition quick access to related damage control information (e.g. ship compartment layouts) should be provided together with decision-making aids and automatic information filtering, i.e. not all damage control information is required to be displayed all of the time or to maximum detail; it could be argued that whilst fire alarms should be available continuously this need only be on a group basis, exact identification being achieved by interrogation. Additionally, door and hatch status information is only required when assuming a new ship's state or after detection of an incident.

Containment

This could be improved by increasing the installed remote-control facilities and reducing the need to direct the activities of FRPs verbally (e.g. remote operation of firemain isolating valves and smoke clearance fans). Containment can also be improved by increasing the level of automation for achieving the required ship's state; ultimately, operation of a single input at HQ1 could result in automatic isolation of the respective installed systems and the starting of appropriate machinery in accordance with the selected state.

Future investigations

Although the damage control organization centred around HQ1 is unlikely to be changed in the foreseeable future, the mechanism for updating HQ2 and delegating control responsibility to the FRPs will require careful consideration and investigation. Ideally HQ2 should be a duplicate HQ1, automatically updated simultaneously and provided with duplicate remote control functions. It may not be necessary to have the same level of control and display facilities since, by its nature, activation of HQ2 implies a degraded situation, but identical functions and capabilities must be provided.

The extent of duplication and/or addition to HQ1 facilities that are required at FRP posts requires further investigation. However, as a minimum they should be provided with those facilities required to effect damage control activities within their respective ship zones.

Further investigation must also be carried out to define the extent of integration and interdependence of the damage and machinery control and surveillance functions. This will impact on the design of future SCCs.

DSC Techniques

FIG. 7 shows the key functions to be carried out in the collection, storage and presentation of data for damage surveillance. As already stated, the achievement of a large proportion of those functions is at present extensively dependent on manual methods. Employment of modern technology and new techniques could result in the following changes in future warship designs.

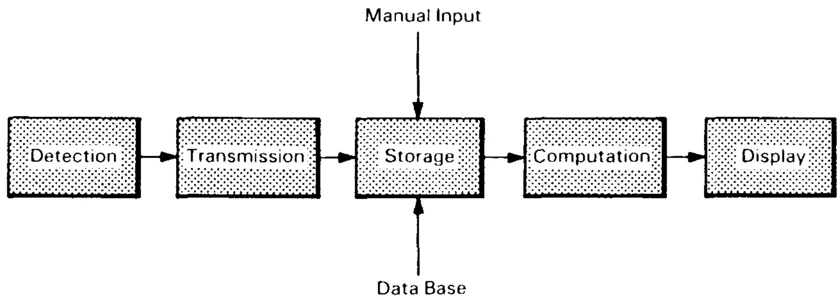

FIG. 7—DATA COLLECTION AND PROCESSING

Detection

To increase levels of responsibility, particularly with respect to fire detection, more extensive use of both comparison and trend-monitoring techniques could be employed in future surveillance systems to avoid the false-alarm situation, which can occur in current R.N. automatic surveillance/alarm systems. Additionally, the use of modern data transmission and distributed processing techniques could result in a cost-effective increase in the extent and depth of detection coverage.

Transmission

The use of modern data-transmission techniques, already being used in weapons applications, could permit the distribution of damage surveillance information on a shipwide basis. The use of such methods would allow multiple access to data and the input of control signals practicable with rapid connection to many points within the vessel. Hence duplication of facilities at HQ2 and FRP posts could be achieved cost-effectively.

The use of multiplexing techniques combined with sensible application of microprocessors could significantly improve surveillance and control system survivability against action damage, and also offers the possibility of being able to rig emergency data communication links to circumvent damage.

Storage

Retention of information is at present limited to chinagraph boards, peg boards, reference documents, and the memories of ship's staff. The efficient use of conventional electronic storage techniques to hold information relating to incidents, time, location, facilities available and action taken are being considered.

Computation

The ability to manipulate existing information, particularly related to stability on the recommended courses of action that should take place following an incident, is a powerful tool. The feasibility of developing the concepts currently applied to so called 'expert systems' is under study in the hope of optimizing complex processes presently dependent upon the experience of skilled personnel.

Retrieval

The existence of key information in digital form could allow fast and efficient retrieval to take place, provided that the access sequence is planned carefully. Key information is currently held in an abbreviated form whenever possible to minimize access time. The access process can be minimized even more by the introduction of electronic techniques.

Display

Visual display units using several forms of technology are already utilized for machinery control and surveillance functions. Where necessary and feasible, graphical presentation could be used in the future to indicate either physical location or trends following an incident.

Training

The central feature of all training is clear and precise communication, together with the ability to make decisions based upon often conflicting information under extreme pressure. The requirement will continue and can only be aided by new technology if a ship's staff can place as much confidence in its use as they do in existing techniques.

The present generation of school leavers entering naval service possess the familiarity necessary to operate such equipment efficiently provided that sufficiently high levels of integrity and survivability can be achieved for such an application.

CONCLUSIONS

In practically every area of automation, the advent of the microprocessor has now made possible fast and efficient information retrieval, storage, processing and display. The pressure to utilize such technology in R.N. damage surveillance and control is already significant and will increase, particularly as manpower is further decreased.

However, microprocessor introduction can also lead to dependency, and the nature of the applications makes it necessary to consider carefully where the technology just assists or becomes a critical link in the chain. Where the equipment is essential in the limitation of damage to a vessel, the level of confidence required by the command must be high but should be met by careful design, demonstration and controlled introduction into service.

Reference

1. Maclean, D. J.: Type 23 ship control centre; *Journal of Naval Engineering,* vol. 29, no. 2, Dec. 1985, pp. 337–344.