THE NAVAL INFORMATION SYSTEMS ARCHITECTURE STUDY

BY

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ABSTRACT

The aim of the Naval Information Systems Architecture Study (NISAS) is to devise an integrated, interoperable maritime Communication and Information System by evolution, not by a totally new design. Requirements, architectures and standards are considered.

Introduction

The increasing speed, scale and overall complexity of warfare has led to the need to disseminate ever-increasing quantities of information to geographically dispersed maritime platforms and command centres ashore, and for operational instructions to be promulgated with great rapidity. This has resulted in the development of a category of automatic data processing systems known as 'communication and information systems' (CIS). CIS incorporates not only communications systems but also systems which permit the tactical and wide area pictures to be presented to appropriate decision-makers ashore or afloat. Unfortunately, although the need for CIS has become universally understood, individual systems, developed to meet specific requirements, often tend to lack compatibility with other systems. Frequently, the result has been the development of a fragmented (i.e. not integrated) set of primarily dedicated systems offering limited scope for flexible and efficient use. This has led to the following consequences:

- The overall system lacks robustness; for example loss of a particular capability, through whatever cause, cannot be compensated for.
- Many communication systems are heavily over-subscribed because of the ever-increasing demand being placed on military maritime CIS, while others are consistently under-utilized because there is little scope for dynamically reassigning resources according to need.
- Transfer of data between individual information systems is often undertaken manually with a consequent impact on 'picture' quality and timeliness.

Evidence had been accumulating for many years but it took the Falklands conflict really to bring home the difficulties in meeting the Royal Navy's information and information exchange requirements, and the consequences of a lack of interoperability. Several initiatives were put in place in the aftermath of the conflict. One of these led, in April 1984, to the setting up of the 'Naval Information Systems Architecture Study' (NISAS) whose remit is to devise an integrated CIS architecture (known as the 'goal' CIS architecture) which will meet the requirements of UK maritime forces, and to provide advice and support to the operational staff and procurement branches to ensure that the goal architecture is achieved in an evolutionary (rather than revolutionary) manner.

The scope of NISAS interest extends from the geographically large scale (e.g. dissemination of information from headquarters to every unit of the fleet) down to the small scale (e.g. distribution of information within an individual ship). This article is intended to provide a background to the NISAS study and to outline the concepts it has generated to date, its current and planned research activities, and the characteristics of two computer-based simulation facilities which were developed specifically to support its research.

NISAS Background

NISAS exists within the communications division of ARE Portsdown, but policy direction is established by the NISAS steering committee, whose members represent most of the operational staff and procurement branches under the chairmanship of the Chief Naval Signal Officer. Its interest covers all maritime systems, from the political interface down to those within individual platforms, that process, manage or provide for the communication of information, i.e. all CIS. Primary emphasis is placed on operational CIS (including logistics systems), though account is taken of non-operational requirements where these must share resources or interact with operational systems.

In order to ensure that the goal architecture is implemented in practice, NISAS provides guidance and assistance to the operational staff in deciding what future systems are required and in drafting staff targets and staff requirements so that these promote evolution towards the 'goal'. Of equal importance, NISAS provides guidance and support to individual procurement projects. This is essential in order to ensure that, in the short term, remedies to deficiencies in current maritime CIS align with a longer-term, system-wide approach and, also in the longer term, that individual CIS are designed at the outset to be fully integrated components of the overall system.

The Royal Navy, as the prime UK user of maritime CIS, will be the focal point for NISAS research. However, as the Royal Navy does not operate in isolation, NISAS must ensure that the goal architecture encompasses not only the RN's needs, but also the needs of other UK forces co-operating in the maritime environment (RAF and Royal Marines) and those of other NATO nations. Interoperability between CIS of all co-operating maritime forces is essential and to this end NISAS is extensively involved in national and international committees in order to influence the setting of standards for a comprehensive allied CIS architecture.

NISAS Concepts

The aim of devising an integrated, interoperable, overall maritime CIS and of guiding its implementation through all stages of procurement has one main constraint placed upon it, namely that the transition to the final architecture must be evolutionary, with current in-service equipment (both UK and NATO) as the point from which to evolve. While this constraint is essential from both financial (no expensive equipment will be made prematurely redundant) and operational (no essential capability will be lost) viewpoints, it has precluded the option of devising a revolutionary CIS architecture. It has also dictated that NISAS must take an evolutionary approach in which it examines current architectures, defines the 'goal' architecture, and co-ordinates the procurement of individual CIS in order to realize the goal.

As a first step towards providing a framework within which any naval CIS architecture could be described, NISAS set about devising a 'reference model' to identify and show the relationships between the various component functions in CIS, and therefore to help identify where interoperability standards are needed. A suitable starting point was the commercially orientated International Standards Organisation Open Systems Interconnection

(ISO/OSI) seven-layer reference model, proposed by the ISO as a framework for the development of commonly defined ('open') standards for communications systems.

The basis of a layered reference model is that discrete functions within a system are arranged in a hierarchical structure with interfaces between functions made explicit (FIG. 1). The idea is that when functions are found to be common between systems, then protocols can be defined to control the interactions between them. If these standards are adhered to, a manufacturer may use proprietary technology to implement a particular function yet be

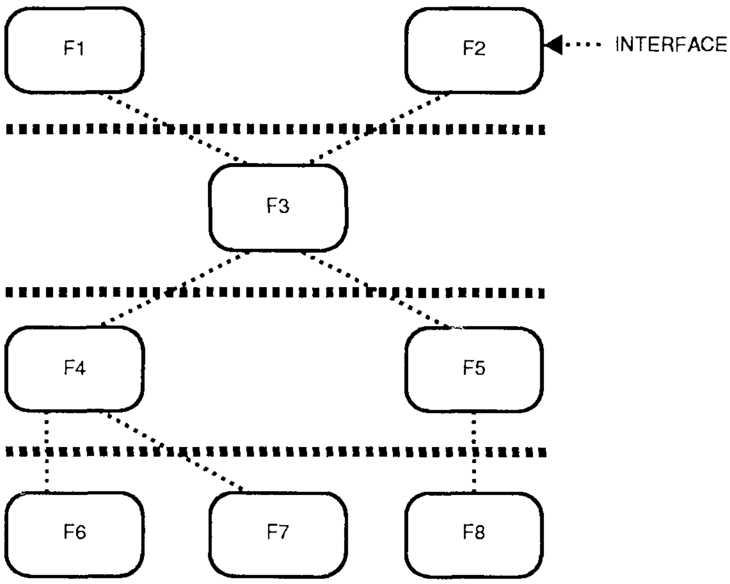

FIG. 1—RELATIONSHIP BETWEEN FUNCTIONS IN A LAYERED REFERENCE MODEL

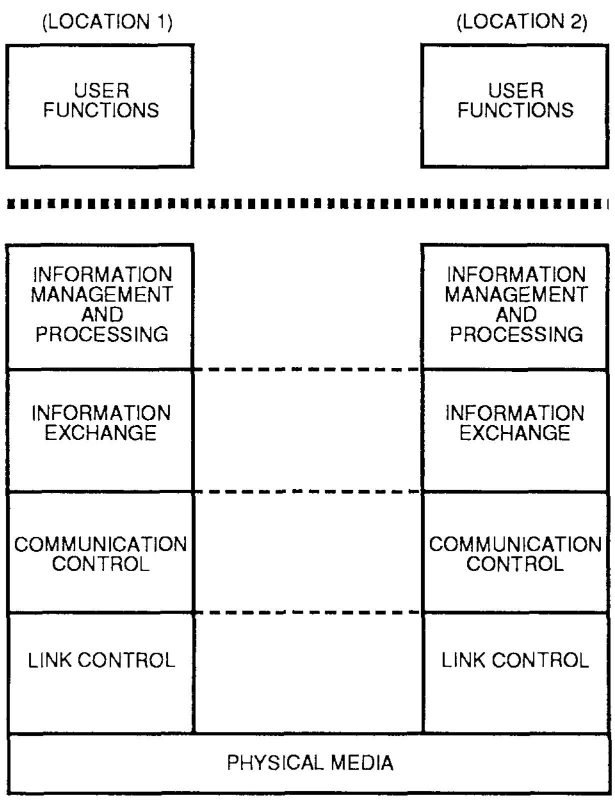

FIG. 2—THE NISAS REFERENCE MODEL

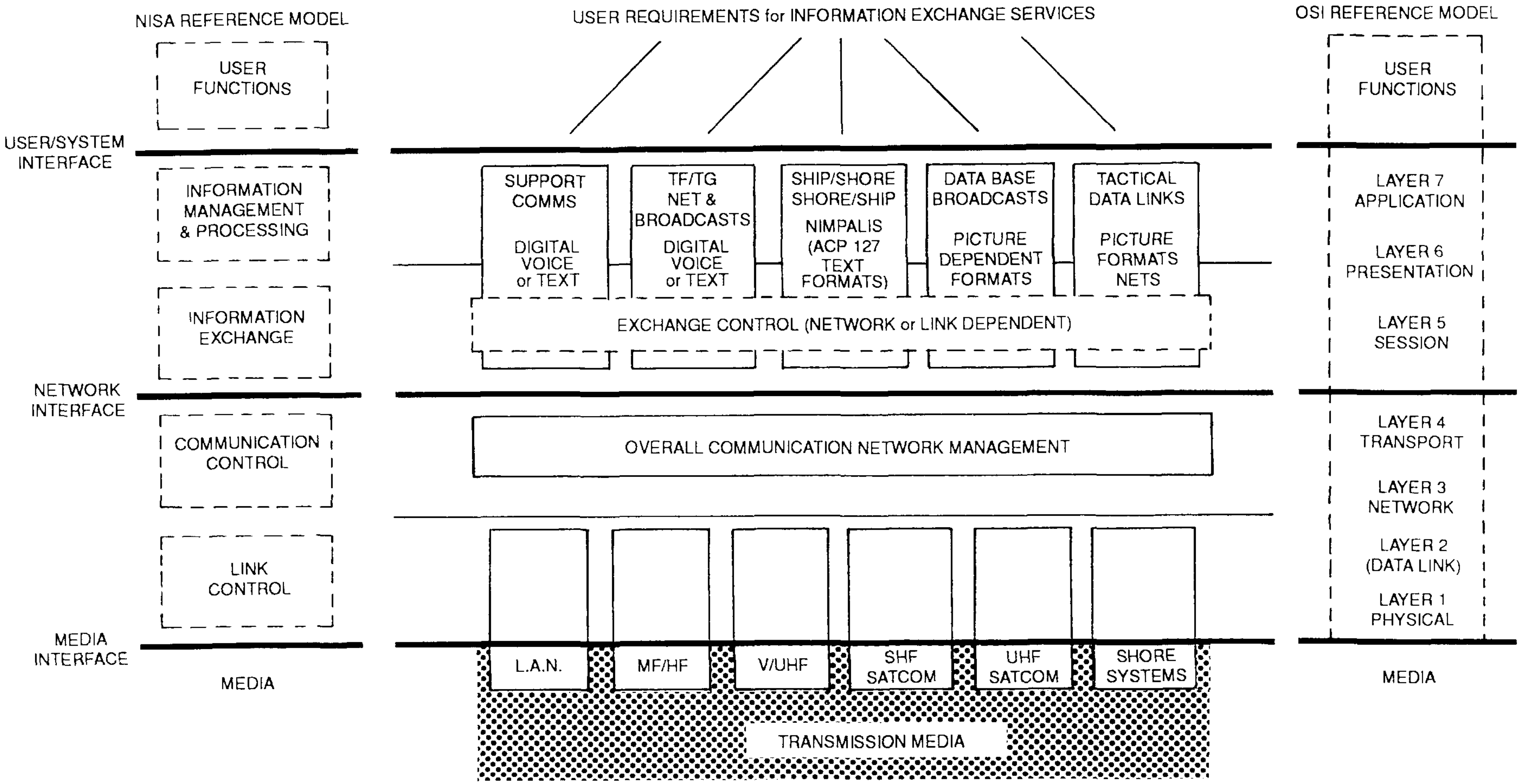

FIG. 3—TYPICAL NAVAL COMMUNICATION SYSTEMS FUNCTIONS COMPARED WITH THE NISAS AND ISO/OSI ARCHITECTURAL MODELS

TABLE I—*Functional breakdown within the NISAS reference model*

Layer	*Function*	*Sub-Function*
Information Management and Processing	Information System Management	Monitor QoS
		Reconfigure
	Prediction	Future Projection
		Threat Warning
	Picture compilation	Classification
		Identification
		Registration
	Fusion	Fusion Rules
		Data Ownership
		Correlation
	User interfaces	MMI
		Displays
		Presentation
		Query/Response
	Storage	Data Representation
		DBMS
		Static/Dynamic
Information Exchange	Information formatting	Data Representation
		Message Formats
		Parity Checks
	Addressing and control	Destinations
		Source
		Precedence
		Routing instructions
Communication Control	Scheduling and routing	Buffering
		Rules
		Addressing
	Internet control Network control	Gateways
		EMCON
		End to End Connections
		Message Flow Control
		Error Detection and Correction
Link Control	Link control	Data Flow Control
		Multiple Access
		Link Management
	Modulation	Analogue
		Digital
		ECCM
	Bearer control	Frequency
		Power
		Aerials

confident that it will correctly interface with other functions in higher or lower levels, and work harmoniously with 'peer' functions in different systems.

The NISAS attempt to describe maritime CIS using the ISO/OSI reference model was only partially successful for, although the general concept of a layered architecture retained its desirability, it was discovered that many functions present in naval systems were not neatly encapsulated within the ISO/OSI reference model's seven layers. In order to provide useful and applicable layering NISAS adopted a simplified four-layer reference model (FIG. 2). TABLE I shows examples of the type of functions contained within the layers of the NISAS reference model and how these functions may themselves be broken down into sub-functions. Although not shown, the breakdown can be taken further until individual systems are described in detail. The 'user functions' layer in FIG. 2 is not part of the NISAS reference model since it lies outside the scope of NISAS, but it is included to illustrate that functions within the NISAS model ultimately provide services to users. Functions encapsulated within the user functions layer include: command assessment, resource control, logistics and administration.

FIG. 3 illustrates how the NISAS reference model can be applied across a range of naval CIS. It also shows where three interface layers of the NISAS reference model and the ISO/OSI reference model coincide. Despite the coincidence of these layers and the fact that functions in the OSI model may be equated to functions in current maritime systems, interfaces in current maritime systems do not conform to recognized OSI standards. For the future, however, adherence to commercial and international standards, where possible, is desirable since this will open the way for UK forces to exploit commercially developed technology, thus saving on the costs and risks associated with bespoke developments.

As mentioned earlier, NISAS interest extends from the geographically large scale to the small. The two examples below are intended to illustrate the conditions of present-day architectures at the two extremes, and possible future architectures that may be developed as a result ot the NISAS research programme.

(*a*) The nature of the current ship/shore/ship communications architecture is shown in FIG. 4. What is apparent from the diagram is that the architecture is very much compartmentalized according to user requirements. Should the channel dedicated to a particular user fail, for any reason, the possibility of meeting that user's requirement

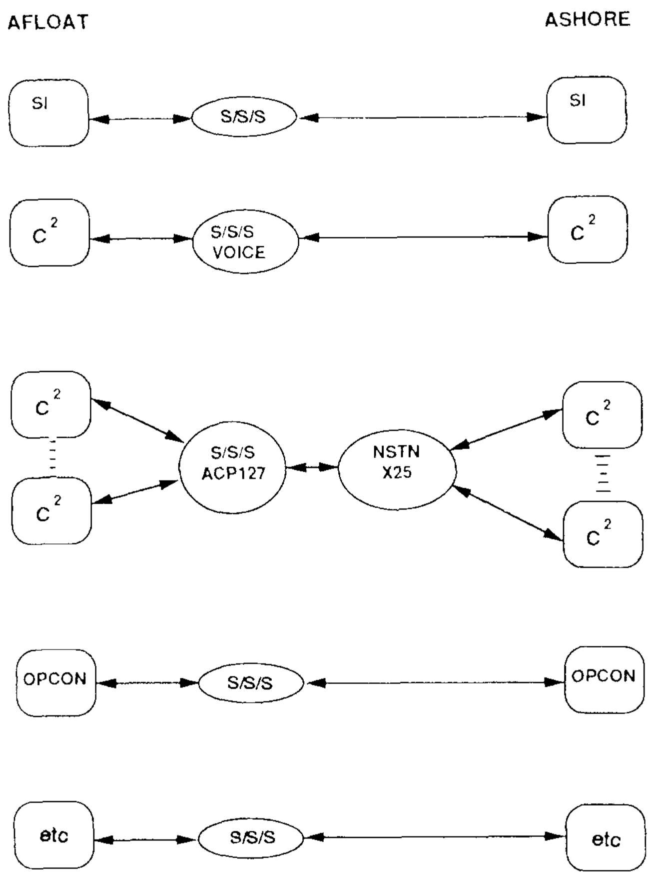

FIG. 4—CURRENT SHIP/SHORE/SHIP ARCHITECTURE

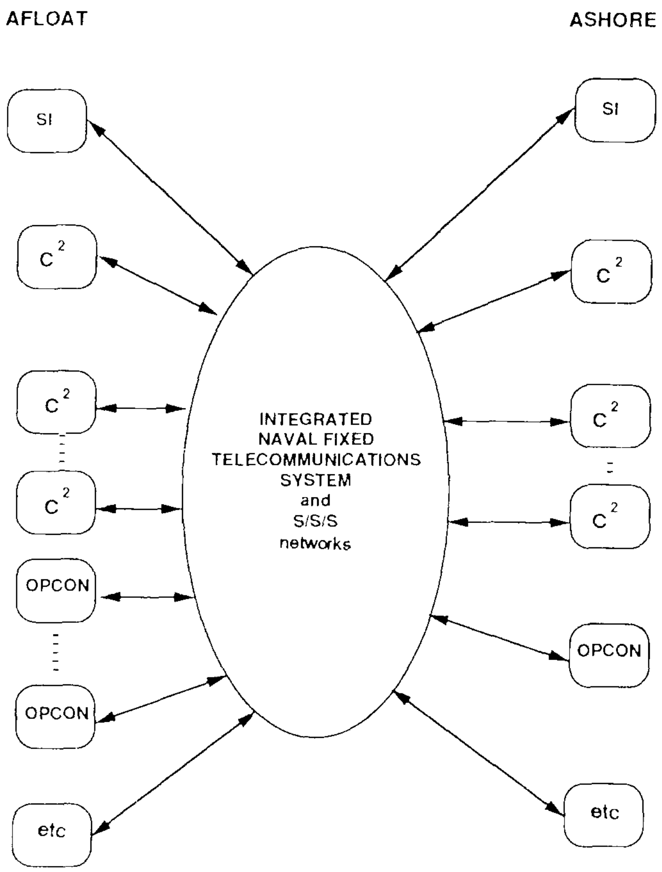

FIG. 5—CANDIDATE SHIP/SHORE/SHIP ARCHITECTURE

by re-routing is unlikely. FIG. 5 depicts a candidate ship/shore/ship communications architecture. No longer is the architecture compartmentalized according to user requirements, which are now met by dynamically allocating resources, from a common pool, according to need. Furthermore, should a particular resource be disabled the overall system will be automatically reconfigured to permit traffic to go by another route. The overall aim is for graceful (as opposed to catastrophic) degradation of the system, wherein the least operationally important requirement is the first to be lost and the most important the last.

(*b*) The second example illustrates the way NISAS might influence information exchange in a ship. FIG. 6 represents the current arrangement. As can be seen all the important user facilities are stand-alone, with little, if any, means of transferring data between them. FIG. 7 shows a candidate shipborne information management architecture. Information from external communications networks is transferred directly onto an on-board local area network (LAN) to be distributed to the appropriate user. Also, it may be routed to multiple automatic data processing (ADP) and database nodes for processing and storage. Although individual ADP and database nodes may have dedicated roles it should be possible to duplicate their functions at other locations within the ship in order to allow a degree of redundancy. User functions will be able to access the ADP and database nodes to obtain processed and historical data respectively, and will also be able to exchange appropriate data with each other. With this architecture it is the LAN which most effectively promotes the expansion in platform capability.

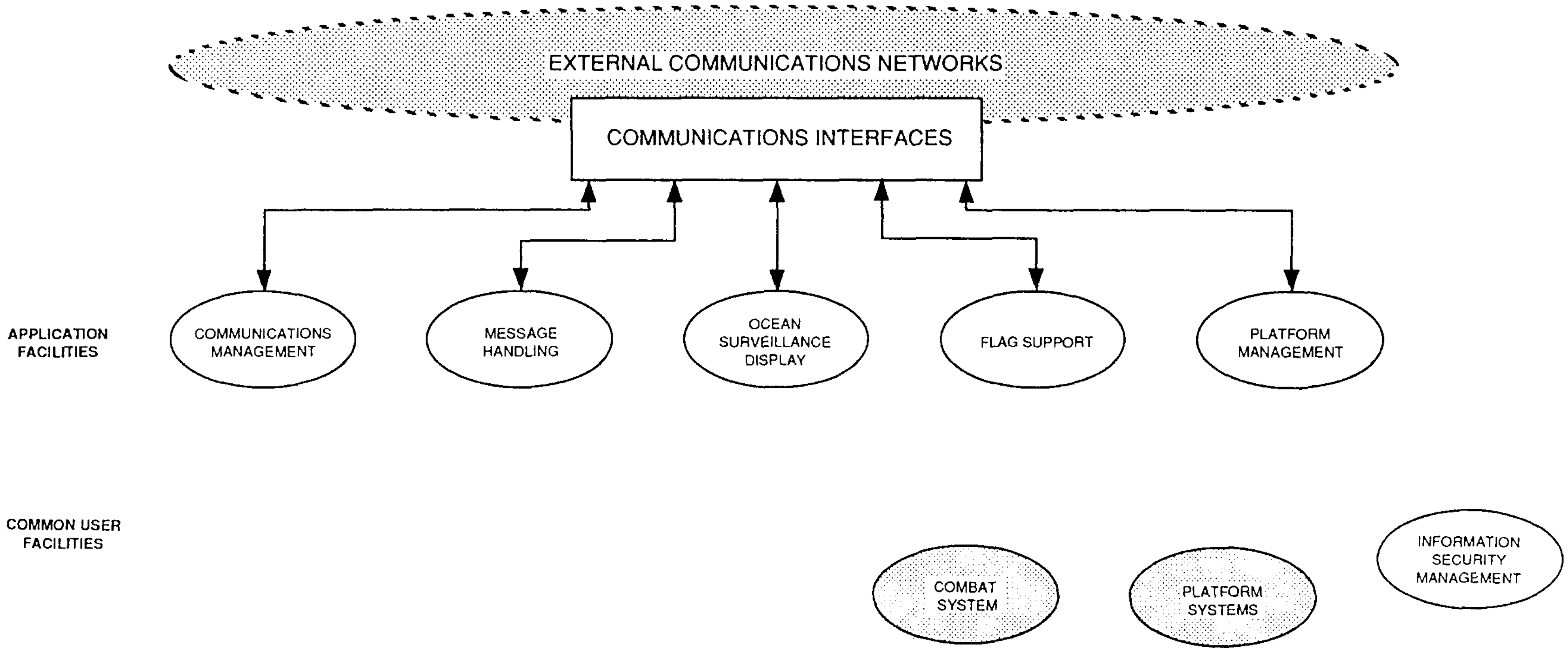

FIG. 6—SHIPBOARD INFORMATION MANAGEMENT—CURRENT ARCHITECTURE

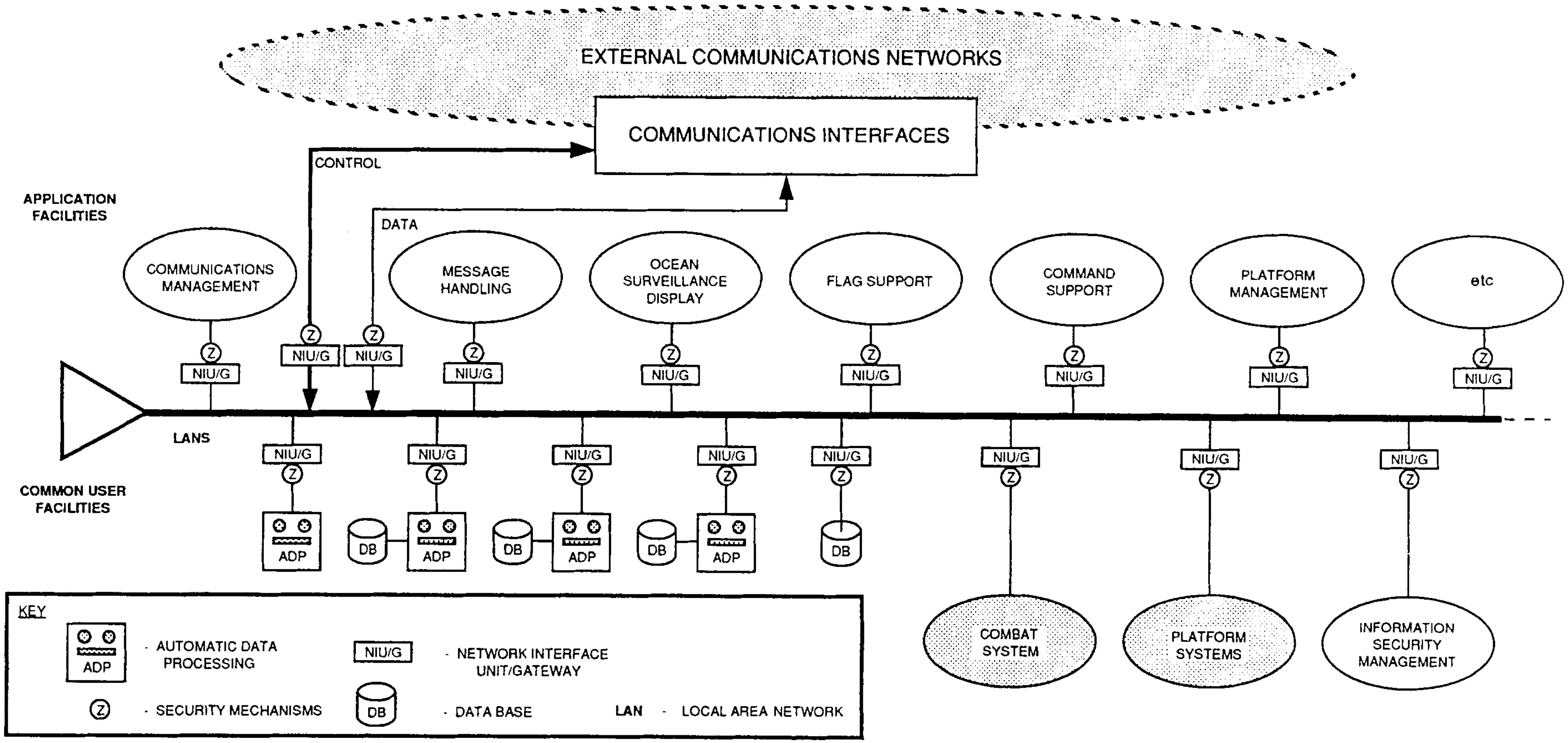

FIG. 7—SHIPBOARD INFORMATION MANAGEMENT—CANDIDATE ARCHITECTURE

NISAS Research Tasks

In order to realize the objectives described earlier, the following research tasks are under way within NISAS:

- C^3I (Command Control, Communications and Intelligence) information exchange requirements;
- naval communications architecture;
- naval C^3 information management standards;
- data link architecture;
- overall communication and information system architecture.

Although these tasks are segregated according to the needs of specific research objectives, there is still a high level of interdependence between them, often to the extent that one task can only progress when another has attained particular objectives.

C^3I Information Exchange Requirements

The C^3I information exchange requirements task is intended to determine the overall requirements for information exchanges between ships, aircraft, amphibious forces and maritime headquarters. The requirements are stated quantitatively, and performance attributes (often termed quality of service or QoS), such as timeliness, integrity and security are also captured.

Two methods are being applied in order to achieve the objective:

(*a*) Simulation of information exchanges in operational settings regarded as likely to put a high degree of stress on a naval communications architecture.

(*b*) Examination of information exchanges during live and paper RN and NATO exercises.

A range of scripts for operational settings has been compiled and the computer-based 'Command and Control Information Requirements' (C^2IR) system, which can generate, quantify and categorize information exchanges from a given script, is being used to process them. Since the value of this task is highly dependent on the validity of the scripted settings, each setting will be scrutinized, by the serving Royal Navy officers of the NISAS operational review group (NORG), before it is processed.

Cross-reference will be made between the results obtained from computer simulations and those from exercise analysis in order to ensure that no important information exchanges are overlooked and that trivial information exchanges are not endowed with unjustified significance.

Information exchange requirements determined in this research task are being used, in other NISAS tasks, to determine the effectiveness of candidate communications architectures.

Naval Communications Architecture

A modular communications architecture for data, voice and message traffic is being developed, and its results will form one part of the NISAS architecture recommendation.

The scope of the work covers all ship/ship, ship/shore/ship, ship/air, shore/shore and intra-ship communications supporting both operational and non-operational information exchange. Initially, however, primary emphasis is being placed on the ship/shore/ship communications architecture since this will attend to the Royal Navy's current perception of its most pressing needs for communications architecture research.

Candidate architectures and standards are being evaluated to identify those most suited to specialized maritime communications. The starting point is with civilian and NATO standards, although modifications to these appear to be necessary in many areas. Key issues include networking, network management, security, modularity of design (hence ease of enhancement), survivability, robustness, redundancy, and the trade-off between flexibility and efficiency.

This research task is founded upon the use of the NISAS information systems architecture tool (ISAT) which provides computer simulation of the capability of candidate architecture.

Naval C^3 Information Management Standards

Procedures and standards needed to ensure consistent and effective information management within and between distributed information systems used by the Royal Navy are being investigated. Generic concepts for management of information have been established; key military functions (for example, wide area picture compilation) are being examined in detail, and the use of various information management concepts is being evaluated in the specialized military environment. In particular, due consideration is being given to issues of security, integrity, communications constraints and the technology expected to be state-of-the-art at the turn of the century.

Data link Architecture

A modular data link architecture is being developed for the compilation and dissemination of tactical picture and situation information. The initial work is evolving a framework in the form of a reference model to be used in future designs of strategic and tactical picture compilation 'networks'. Standards, which are suitable for the different types of picture compilation process, are being outlined and the extent to which these are applicable across different areas is being determined. The starting point of this work is the ISO/OSI seven-layer model and associated standards.

Overall Command Information System Architecture

The overall architecture for future Royal Navy CIS will be defined and an outline strategy developed for evolution from current architectures to the goal. The NISAS reference model will be used to describe architecture functionality standards, and the NISAS computerized analysis facilities (the C^2IR system and ISAT) to evaluate architecture effectiveness. This work will also effectively draw together and take account of the work in the naval communications architecture task and other areas of NISAS, as well as the result of that carried out elsewhere, (for example: NATO, AUSCANNZUKUS and Director General Information Technology Systems (DGITS)) in deriving the goal overall Royal Navy CIS architecture. Thus, while Naval Communications Architecture will initially focus on ship/shore/ship communications issues Overall Command Information System Architecture will take a total system view.

NISAS Simulation Facilities

Two computer-based modelling facilities have been mentioned as being used in support of NISAS research objectives. Both were developed by NISAS. The C^2IR system is intended to model 'nodes' (source/sinks of information exchange) and, by means of a driving script of events (representative of those that might occur operationally), cause them to generate information exchanges. Each node has associated rules which determine the types of messages it transmits in response to an event, and each message type has associated operationally relevant attributes such as timeliness, priority and security. As well as determining the chronology of events, scripts permit control over the geographical location and movement of nodes and also the policies which determine communications linkage. Output from the C^2IR, in the form of a chronological log of information exchanges plus node location and movement, may be sent to the second NISAS modelling facility, the ISAT.

The ISAT is designed to model the flow of information (generated by the C^2IR system) through a candidate CIS architecture, and express the capability of that architecture by a set of 'measures of performance' (MoP) which include error rates, lost messages, end-to-end delays, throughput and overall resource utilization. The ISAT takes account of 'external' parameters such as variable propagation conditions, and system degradation through natural or hostile means, in order more closely to simulate real operating conditions.

Conclusions

The NISAS research programme is now in full swing but it will take many years to identify and define fully the goal CIS architecture. However, even without a full definition, certain aspects of its nature are already apparent—in particular that its embedded functions should be both modular and layered—and NISAS will seek to ensure that individual CIS systems, procured before final definition of the goal architecture, accord with known aspects of it.