NAVAL SHIP SYSTEMS ENGINEERING STATION PHILADELPHIA

BY

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Introduction

The regular reader may be forgiven for questioning the validity of publishing an article on a United States Naval Establishment in this *Journal*. Nevertheless, based on the volume of exchange information which flows between the two nations and the significant role that the Naval Ship Systems Engineering Station (NAVSSES) fulfils in establishing much of that information, the article should prove relevant and of value to a wide audience.

The aim of this article is to outline the organization and tasks of NAVSSES and to discuss some of the work that is in progress or is planned for the immediate future. As part of the agreement between the two governments to exchange personnel in areas of common interest and also in recognition of the engineering role of NAVSSES, an exchange post for a Royal Navy officer was established at NAVSSES in 1984 and the nature of this job will be discussed in detail later in the article.

U.S.N. Administrative Organization

To understand fully the function of NAVSSES it is first necessary to appreciate where the establishment fits into the overall naval structure. Any organization which exists to support a 600 ship fleet is necessarily large and complex, and the numerous authorities and agencies involved in the warship and equipment procurement process is at first sight bewildering. For this reason the organizational details which follow have been simplified. The administrative organization of the Navy begins with the Secretary of Defense and then goes through the Secretary of the Navy and the Chief of Naval Operations (CNO), a four star post. The primary task of the CNO is to support his operational commanders but amongst other things he is responsible for the procurement of warships, their systems and equipments, and research and development (FIG. 1).

One of his subordinate Commands is the Naval Sea Systems Command (NAVSEA) which is headed by a three star admiral, some of whose responsibilities are illustrated in FIG. 2. The headquarters for the Ship Design and Engineering Directorate is located in Washington and broadly fulfils the same role as the Royal Navy's DGME and CNA organizations. NAVSSES, one of its agencies, is located in Philadelphia and can best be likened to a number of Admiralty Research and Test Establishments combined under one roof, although NAVSSES does play a more significant fleet support role. Direct fleet engineering support is provided principally by the Naval Sea Centres based in Norfolk and San Diego and they have similar responsibilities to those of the Royal Navy's Fleet CSO(E) organization.

NAVSSES Tasks

The primary tasks of the establishment are to serve as the Navy's principal centre for the test and evaluation (T&E) of hull, mechanical and electrical (HM&E) ship systems and to provide in-service engineering (ISE) support

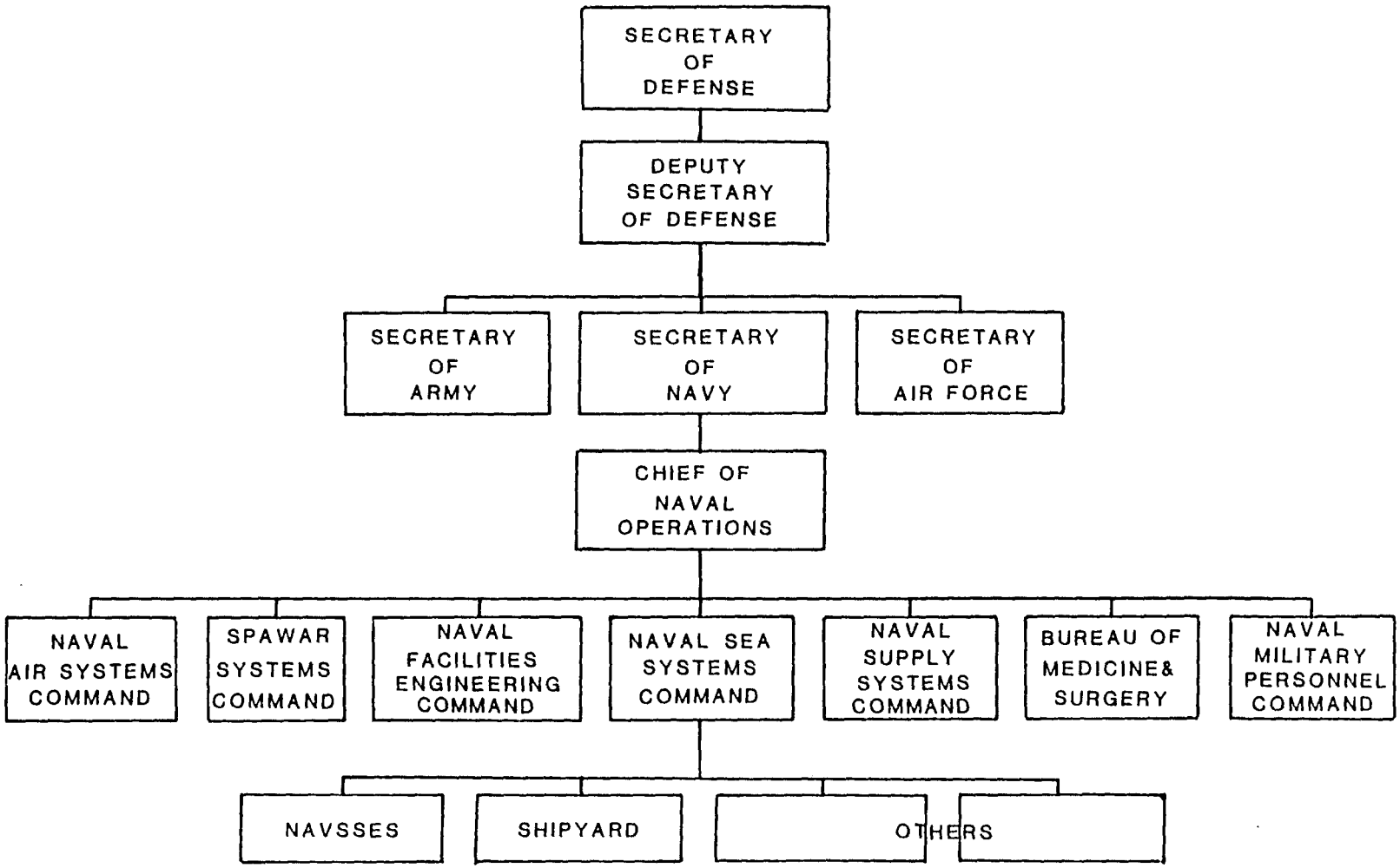

FIG. 1—CHIEF OF NAVAL OPERATIONS ADMINISTRATIVE ORGANIZATION

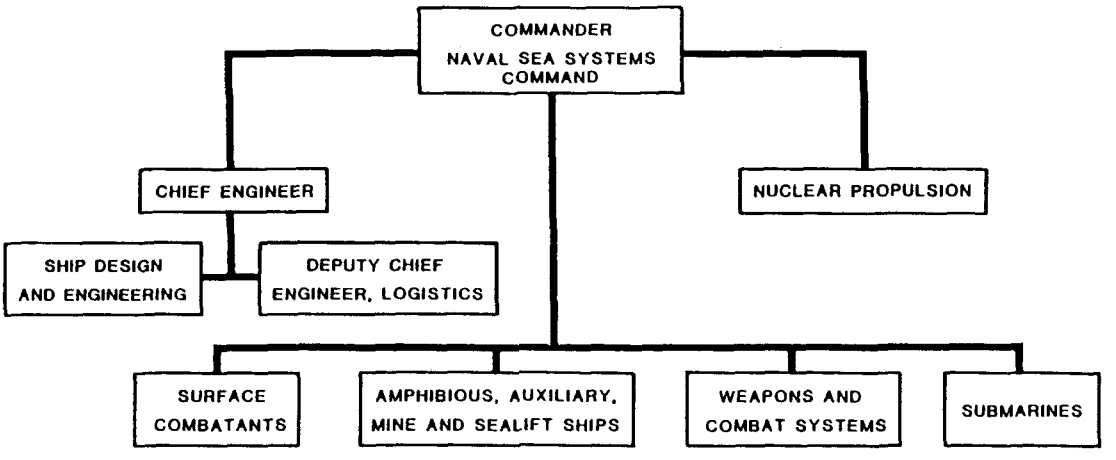

FIG. 2—NAVAL SEA SYSTEMS COMMAND ORGANIZATION

for these systems and other equipments. The majority of this work is performed for NAVSSES's primary customers, the Naval Sea Systems Command (NAVSEA), the Space and Naval Warfare Systems Command (SPAWARS), and the various Fleet Commands. The Life Cycle Reference Chart (FIG. 3) puts these tasks in better perspective and clarifies the responsibilities that the Commands have for ship systems.

NAVSSES's tasks can be grouped under three headings.

Ship Systems Test and Evaluation Centre

The tasks of the Ship Systems Test and Evaluation Centre are to:

(*a*) Conduct test and evaluation programmes required to demonstrate and determine the acceptance, suitability and approval of ship systems, equipments and components for naval service.

(*b*) Provide for the test and evaluation of ship systems in the research and development process.

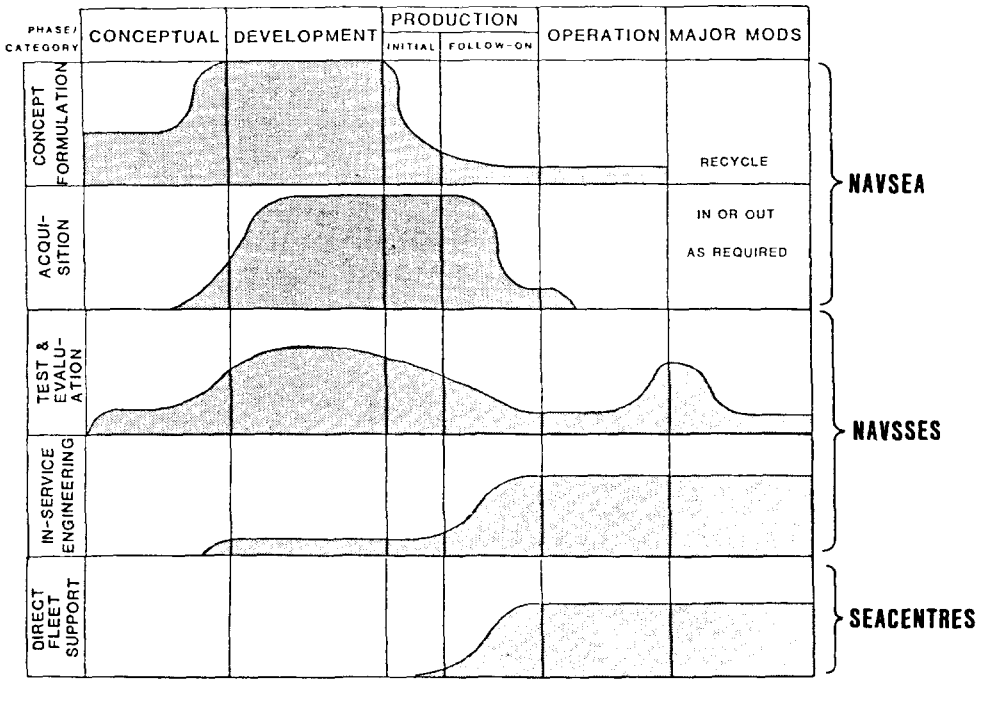

FIG. 3—LIFE CYCLE REFERENCE CHART

(*c*) Participate in the Total Ship Test Programme as the Ship Systems Test Director.

(*d*) Provide engineering and facilities assistance to vendors for the testing and evaluation of ship systems intended for naval shipyard installation.

Ship Systems In-Service Engineering Support

Comprehensive in-service engineering support is provided for HM&E ship systems and related fuels, materials and instrumentation in operational ships and repair and maintenance facilities. These responsibilities include development of design changes and, upon approval, implementing follow-on actions, safety reviews, test support, technical documentation, performance and maintenance data analysis, maintenance and installation engineering, training support, logistic support, repair standards and procedures. This is a very broad statement which clearly represents an enormous task and therefore of the three functional areas of ISE in which NAVSSES is involved—data management, integrated logistic support and equipment engineering—the key is effective data management so that system and equipment problems in the fleet can be identified in the first place. Management by exception then becomes the method of execution.

Submarine Antenna and Periscope Systems Support

This consists of:

(*a*) Similar in-service engineering support of submarine antenna and periscope systems.

(*b*) R&D and T&E programmes for submarine antenna and periscope systems.

Examples of current and future work in some of these catagories will be discussed later.

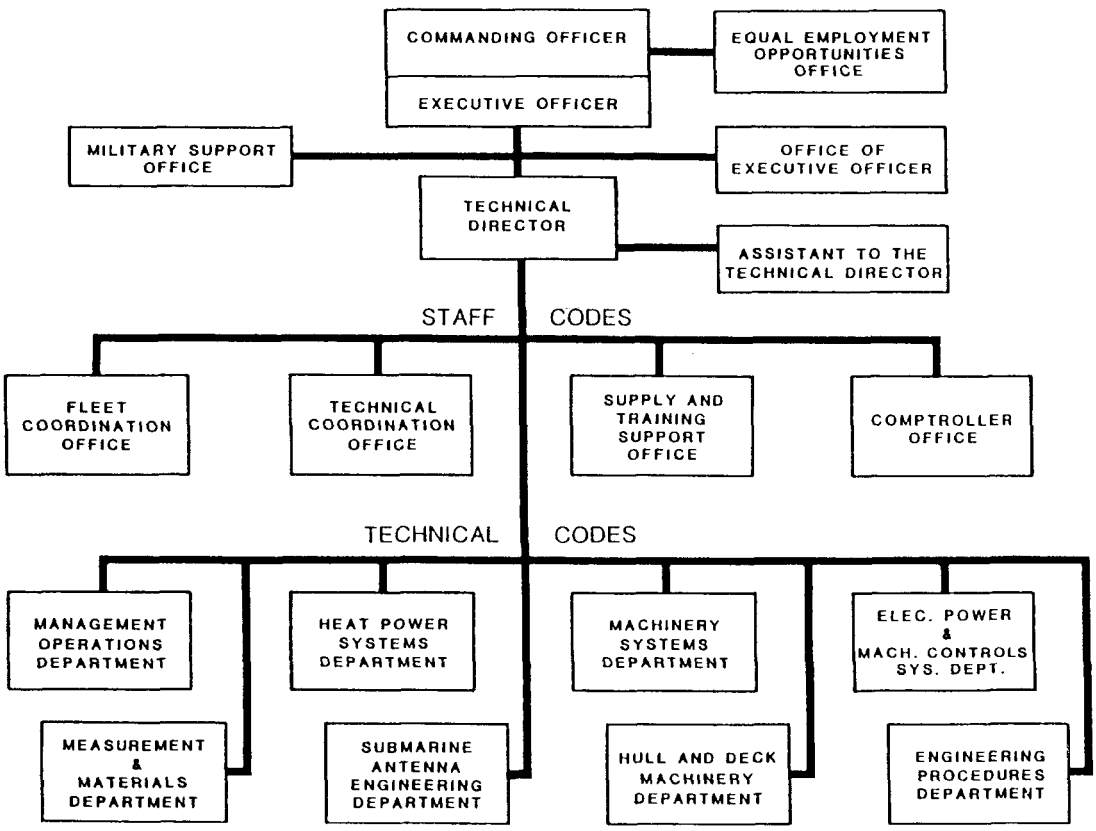

FIG. 4—NAVSSES ORGANIZATION

NAVSSES Organization

NAVSSES is located in the U.S. Naval Base at Philadelphia and adjacent to the naval shipyard. The station is designated a major Command in the U.S.N. and the staff of 1550 personnel is headed by a senior captain. The various tasks of NAVSSES are accomplished by the staff and technical departments (FIG. 4) who are directly responsible to the Technical Director, a senior civilian government service officer, with the R.N. exchange officer acting as his assistant. The technical departments at NAVSSES are organized along system lines to reflect this approach to the work and a matrix management *modus operandi* has been adopted which allows the expertise of the various departments to be utilized by one another without being hampered by traditional chains of command. In essence this avoids micro-management and encourages delegation.

The majority of people employed at NAVSSES are civilian, although there is a strong corps of uniformed personnel of various ranks and rates. Current proportions of staff are shown in FIG. 5.

Whilst most of the staff are employed at Headquarters in Philadelphia, field representatives are stationed at locations around the United States and abroad to provide more immediate ISE support. In many areas the establishment is self-sufficient but where in-house expertise, facilities, services and capacity are not sufficient then work is contracted out. The legal aspects of seeking competitive tenders, sole source procurement and the general contracting business are involved and, whilst a separate authority exists to deal with the procurement process, the detailed preparation of contract documents is entirely in the hands of the cognizant technical departments within NAVSSES. All activities are run on a commercial basis and strict financial accountability and control are exercised. All funding is provided from the charges made to 'customers'. In fiscal year (FY) 1986 it amounted to $178M, and the projected figure for FY 87 is $200M of which about $84M will be for work contracted out.

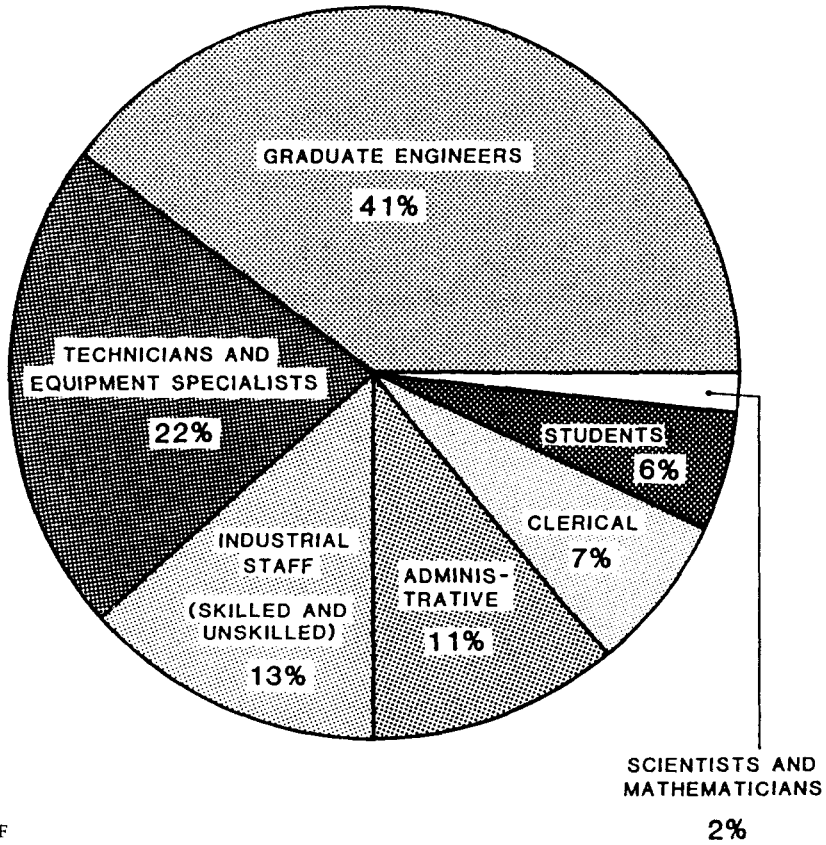

FIG. 5—NAVSSES STAFF

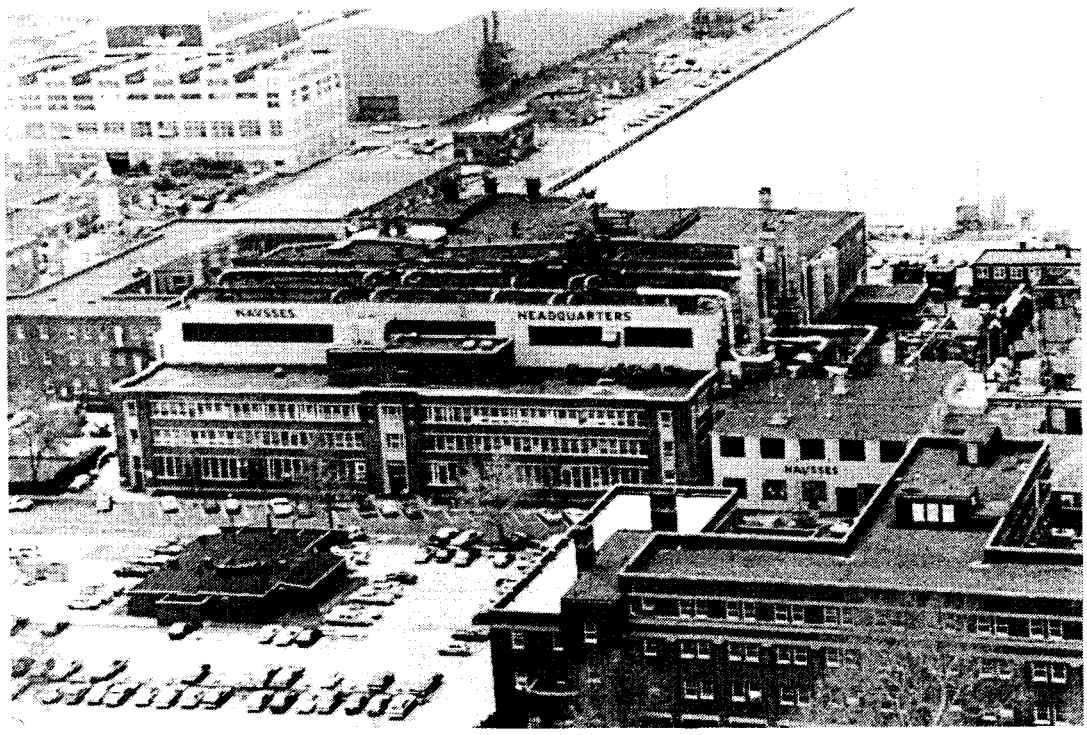

FIG. 6—NAVSSES HEADQUARTERS COMPLEX

Facilities

NAVSSES occupies some fifty sites on the base and most of this space is devoted to test facilities, FIG. 6 shows the headquarters building.

It is beyond the scope of this article to describe every facility but suffice it to say that they range in terms of size from destroyer and submarine main propulsion plants to instrument calibration rigs, and in terms of diverse technology from fibre optics to boiler water treatment. In addition to the many test sites the establishment also boasts sophisticated laboratories and equipment to support work in such fields as materials technology, fire detection, gear metrology, electronic equipment calibration, shock and vibration, marine coatings, emission and X ray spectroscopy and radar absorbent materials. Before discussing particular test programmes, a distinction needs to be drawn between the three fundamental types of test site used at NAVSSES:

(*a*) Test Site (TS)—a facility which is designed and built to test system components or equipments.

(*b*) Land Based Test Site (LBTS)—a facility which serves as a multi-purpose test and evaluation platform where a total system is tested but shipboard space, maintainability and configuration constraints are not fully reproduced.

(*c*) Land Based Enginering Site (LBES)—as (*b*) above but the facility fully replicates shipboard operation, space, maintainability and configuration restrictions.

Additionally NAVSSES administers a FORREST SHERMAN Class destroyer as a floating test platform. These test facilities are used not only for traditional test and evaluation purposes but also for crew training, validation of maintenance practices, evaluation of future system changes and alterations, and validation and verification of technical documentation.

FIGS. 7 and 8 show the test sites housed in two NAVSSES buildings.

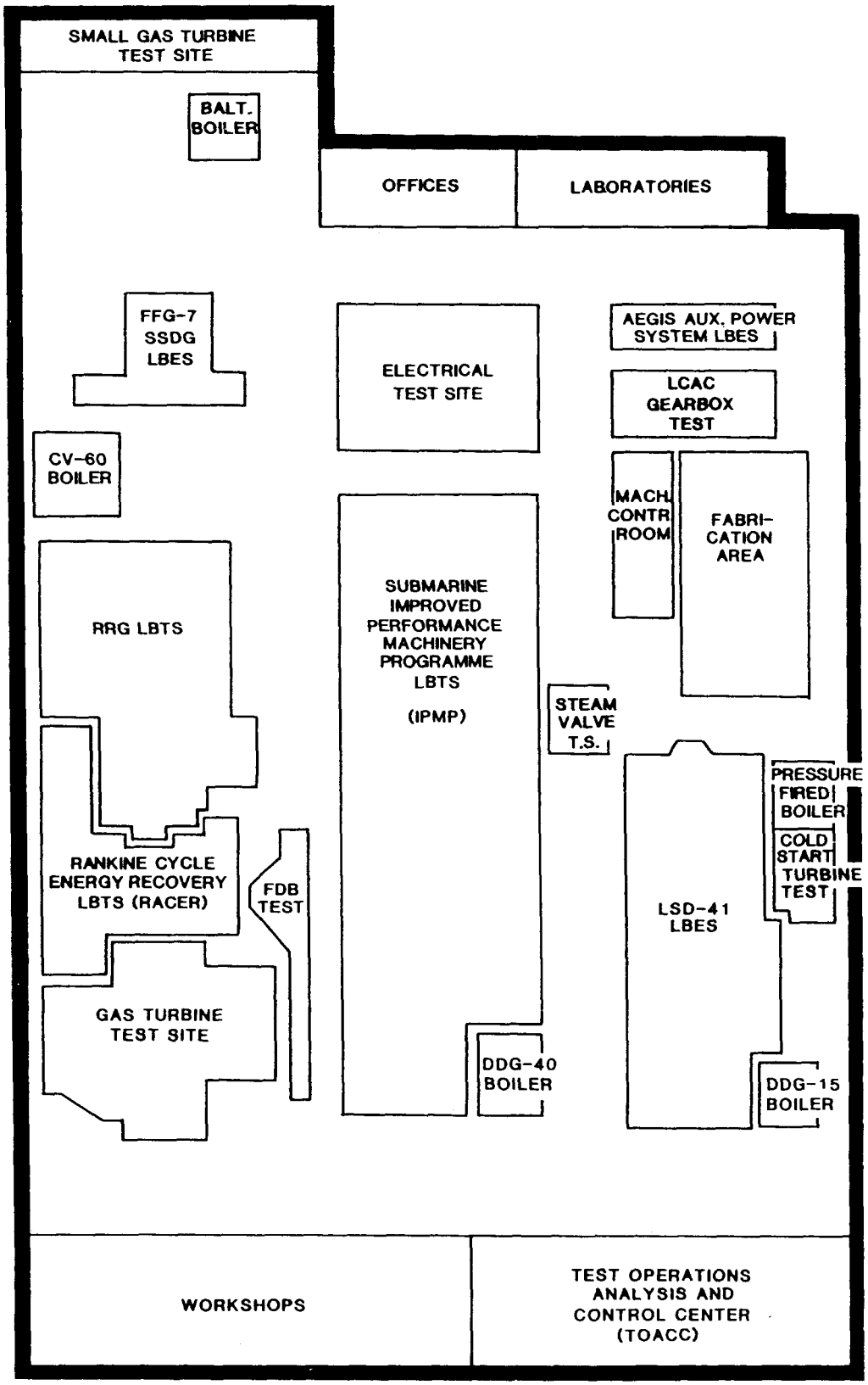

FIG. 7—TEST SITES IN BUILDING 633
for key see TABLE I

TABLE I—*Key to Major Test Facilities in Building 633 (FIG. 7)*

Small Gas Turbine Test Site	Two test cells and control room currently being used to test AGT 1500 gas turbine, the main engine of the M1 battle tank.
Various boilers	Used to provide steam for testing of steam plant propulsion systems and components.
FFG 7 Ship Service DG LBES	16 cylinder 1MW Stewart and Stevenson modified Detroit diesel generator fitted in FFG 7 Class ships, currently being used to evaluate engine and generator modifications.
Electrical Test Site	Site for testing motor starters, controllers, 60/400 Hz motor generators, switchboard breakers, etc.
AEGIS Auxiliary Power System-LBES	Allison K17 gas turbine and generator, waste heat boiler and associated domestic steam systems. As fitted on CG 47 (AEGIS) Class ships.
LCAC Gearbox Test Site	Facility for back-to-back testing of Landing Craft Air Cushion gearboxes.
RRG LBTS	Reverse Reduction Gear. Two LM 2500 gas turbines, reduction gearbox fitted with Franco Tosi coupling, auxiliary systems and propulsion controls.
IPMP LBTS	Submarine Improved Performance Machinery Programme. Security classification prevents further discussion.
RACER LBTS	Rankine Cycle Energy Recovery. LM 2500 gas turbine, water brake, waste heat boiler, steam turbine and condenser.
LSD 41 LBES	Two-Colt Pielstick 16 cylinder 500 bhp diesel engines, gearbox, water brake, associated systems and controls. Duplicates one half of LSD 41 Class propulsion system.

TABLE II—*Key to Major Test Facilities in Building 77 (FIG. 8)*

Electric Drive Propulsion System LBTS	Gas Turbine/Electric drive propulsion system.
Gas Turbine Propulsion System LBES	Propulsion System for the next generation DDG.
Electrical Test Site	Site for testing small to medium motor-driven hull and deck machinery and shipboard electrical power generation, distribution and control equipments.
Seawater Flow Test Site	Site to evaluate flow characteristics of SSN 21 seawater cooling systems.
Volumetric Flow Calibration Site	Flow facility consisting of volumetric provers and various diameter test pipe sections for the accurate calibration of flow measuring instrumentation used in the Fleet.
Standard Cargo and Weapons Elevator LBES	6 deck elevator machinery, hatch, door and associated components test facility.
Halon Drench Test Site	Enclosure containing oil fire trays and a BTM system.
Air Compressor Test Site	Facility consisting of a number of controlled environmental cells for testing HP and LP air compressor systems.
Acoustic Test Chamber	Evaluation of hydraulic pump airborne, fluid-borne and structure-borne noise.

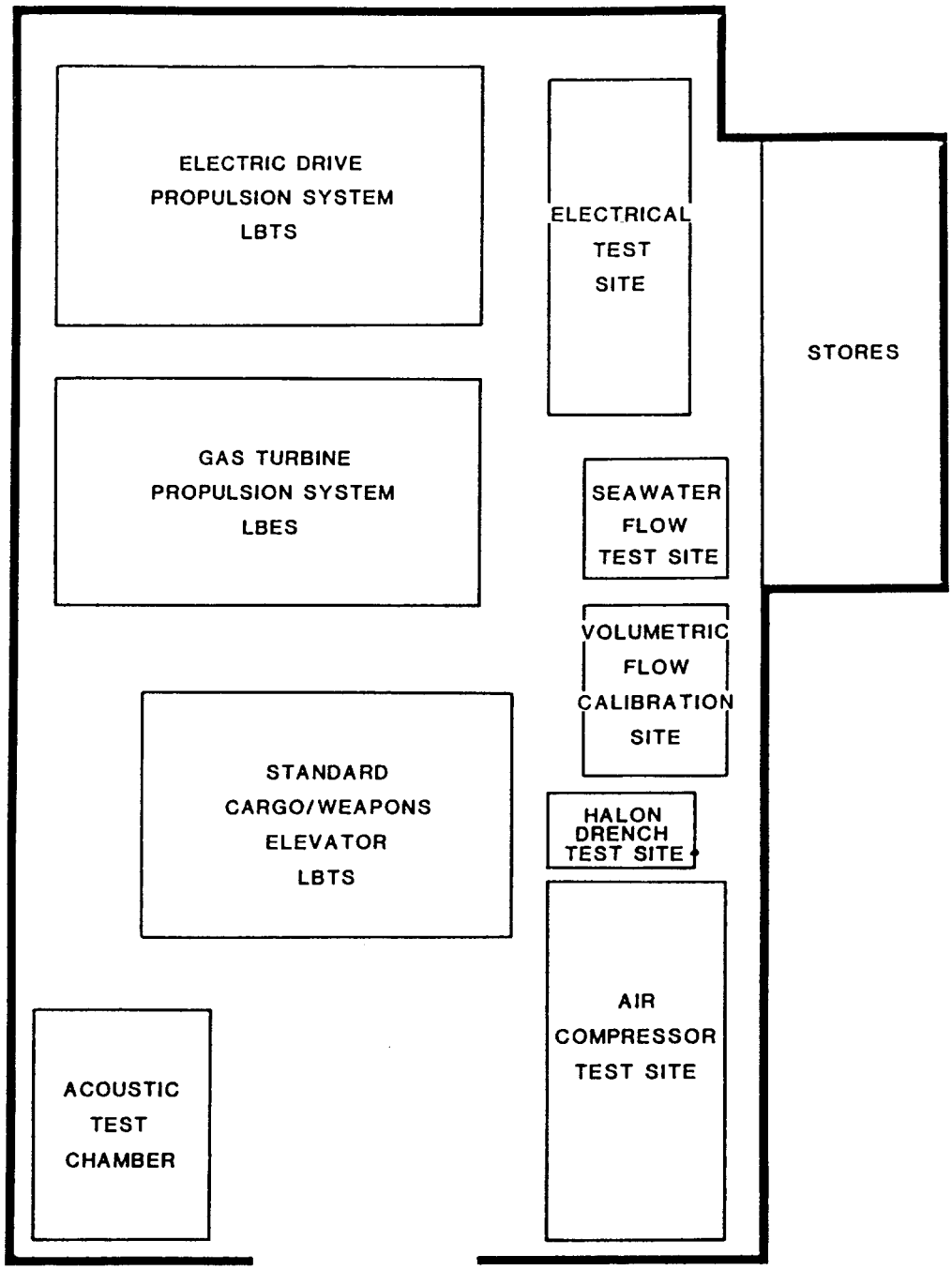

FIG. 8—TEST SITES IN BUILDING 77
for key see TABLE II

Test Programme Management

Test and evaluation activities are designated programmes or projects according to their degree of visibility, dollar value and complexity, and each has a designated manager. Managers of major test programmes have a team drawn from the various technical departments within NAVSSES—typically, a design, construction and test manager who are dedicated to the programme but have a dual technical reporting relationshp in that they also report to the director of their parent department. Management is kept up-to-date on programme and project progress through weekly status reports which are transmitted via the Management Information System. The latter is a computerized menu-driven system which provides easy access to a wide range of management and technical related information and reports. Test operations have been greatly enhanced recently by the addition of a centralized data acquisition and process facility, the Test Operations Analysis and Control Centre (TOACC). The TOACC is used to acquire, process, display, record and store test data from any selected test facility. Surveillance, operation and analysis of data are conducted by the test managers from four large consoles (FIG. 9) which are also equipped with visual and audio communications with the sites.

TOACC is linked to the establishment's central computer complex thus enabling vast amounts of data to be stored and recalled later, e.g. for trend analysis or comparison with ship operating profile data.

FIG. 9—PART OF TEST OPERATIONS ANALYSIS AND CONTROL CENTRE

Current Test Programmes

In the U.K., NAVSSES is probably most widely known for its recent work on Rankine Cycle Energy Recovery (RACER) and the Reverse Reduction Gear (RRG) which incorporates the Franco-Tosi coupling, and therefore these are appropriate subjects on which to start.

RACER

Detailed descriptions of the system have been published[1,2] and what follows is a summary of the present status of the programme. The system (FIG. 10) uses a heat recovery steam generator (HRSG) to recover waste exhaust heat from General Electric LM 2500 gas turbines. Superheated steam (900°F and 335 p.s.i.g) is produced by the generator, a once-through boiler, and is expanded in a turbine to produce additional propulsion power in the order of 8000 h.p. at 10 000 r.p.m.

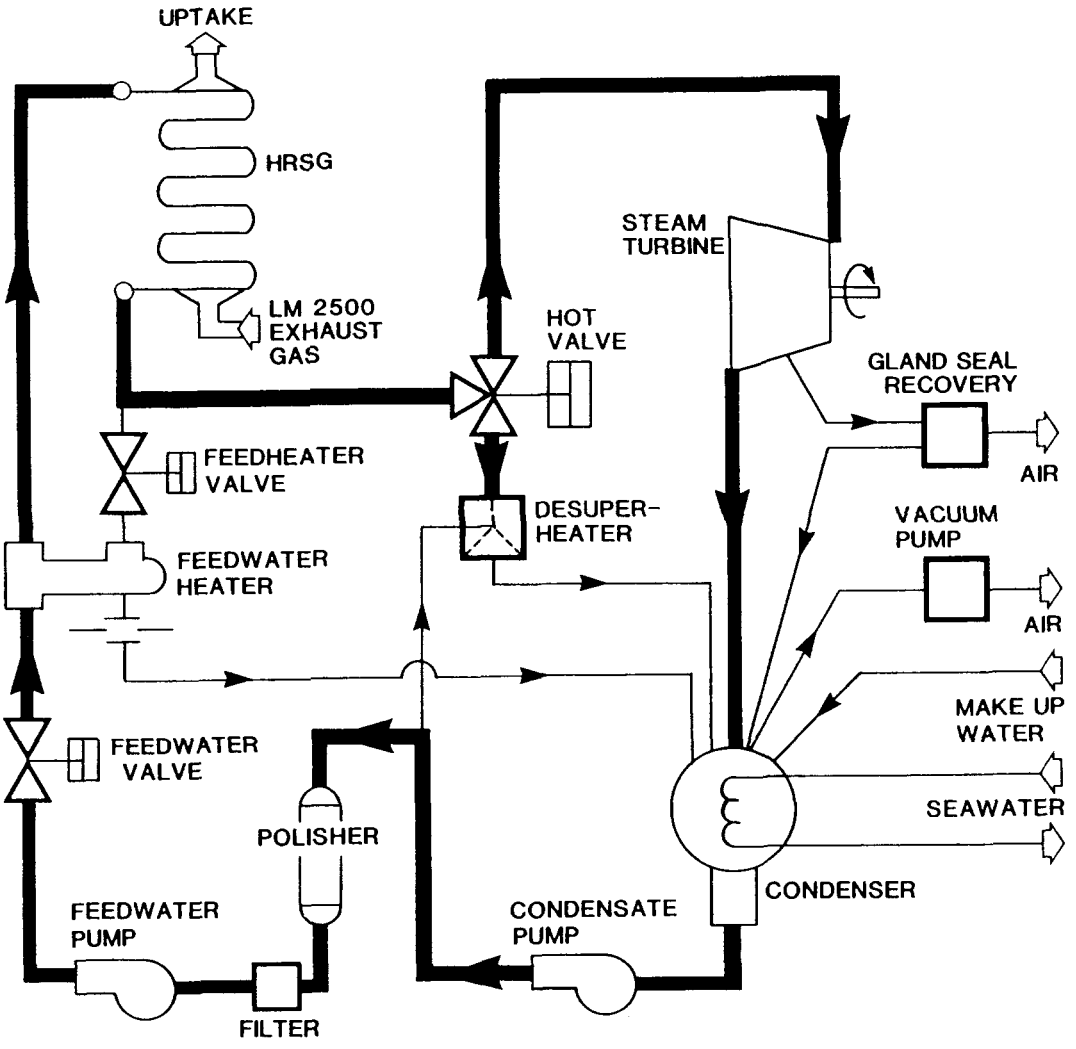

FIG. 10—RACER SYSTEM
HRSG: heat recovery steam generator

Extensive testing at NAVSSES' LBTS (FIG. 11) highlighted a number of design shortcomings, and although many of these have been resolved some key problems remain. In particular:

(*a*) *HRSG output.* In an effort to reduce HRSG noise when dry fired (boiler empty) some gas baffles were removed to allow exhaust gas to by-pass the generator and, whilst this proved successful, the removal of the baffles resulted in a reduced HRSG output.

(*b*) *HRSG steam outlet temperature.* Control of steam outlet temperature has not been reliably achieved during certain upward and downward load transients with the result that the system shuts down when the steam temperature is outside the specified range.

(*c*) *Steam turbine performance/gland seal damage.* The turbine and condenser are an integral unit with the compact turbine designed for operation at various steam pressures. No throttle valve or nozzles are used; instead a valve (the hot steam valve) directs steam to the turbine during normal operations or by-passes it to the condenser via a desuperheater during start-ups and shut-downs. It would appear that some distortion is being caused either by heating during by-pass operations or rapid cooling by the condensate from the desuperheater following system shutdown. The net result is misalignment of bearing bracket, seal housing and turbine casing and this in turn has led to excessive rubbing of turbine gland and interstage seals and a degradation in turbine performance. During certain modes of operation excessive turbine exhaust temperatures have been experienced and turbine vibration has increased to the designated trip point.

The programme above all else has demonstrated the value to the Navy of thorough system testing. Much has been learned from the test process and the knowledge gained has been used to design better system components and, given the resources and time, there can be little doubt that a reliable integrated system could be developed for shipboard use.

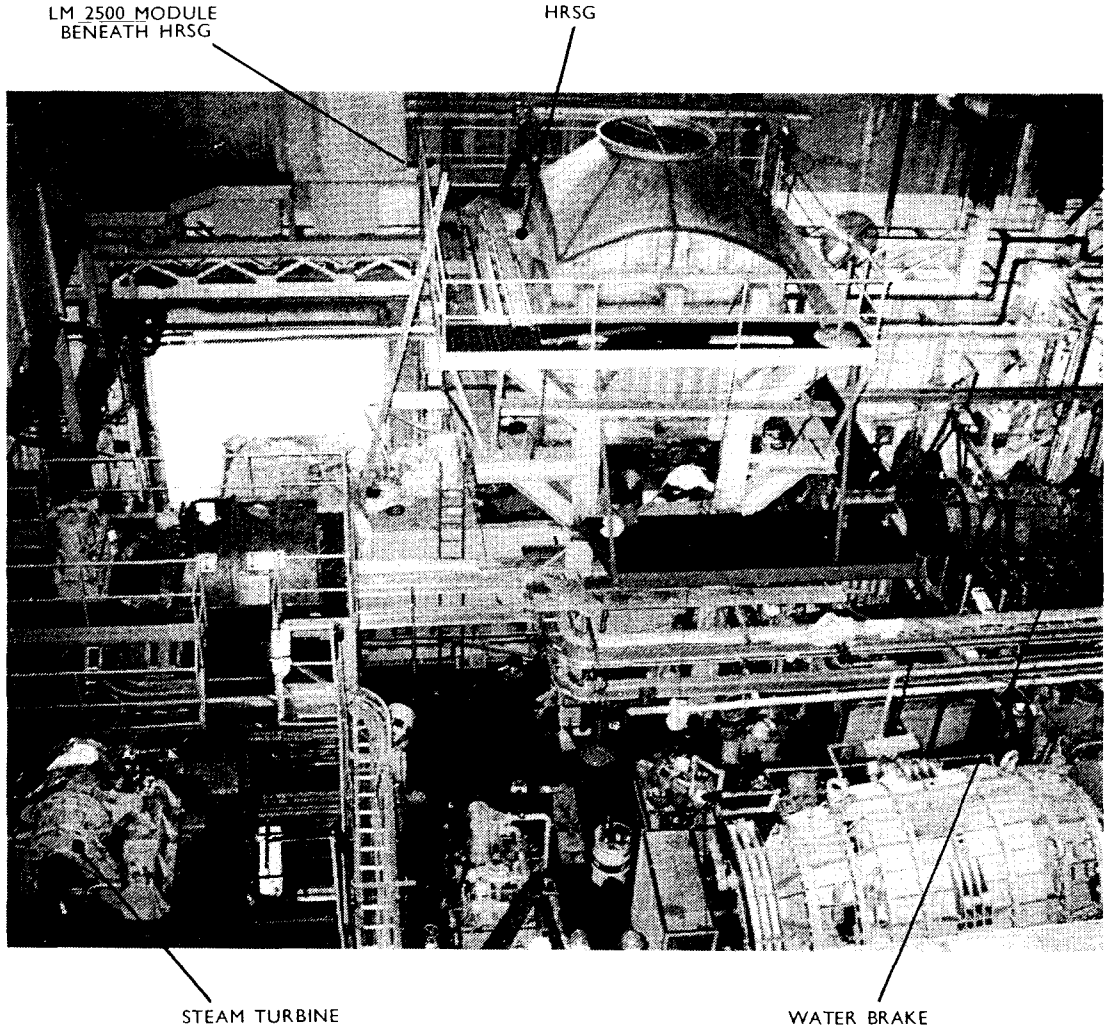

FIG. 11—RACER LAND BASED TEST SITE