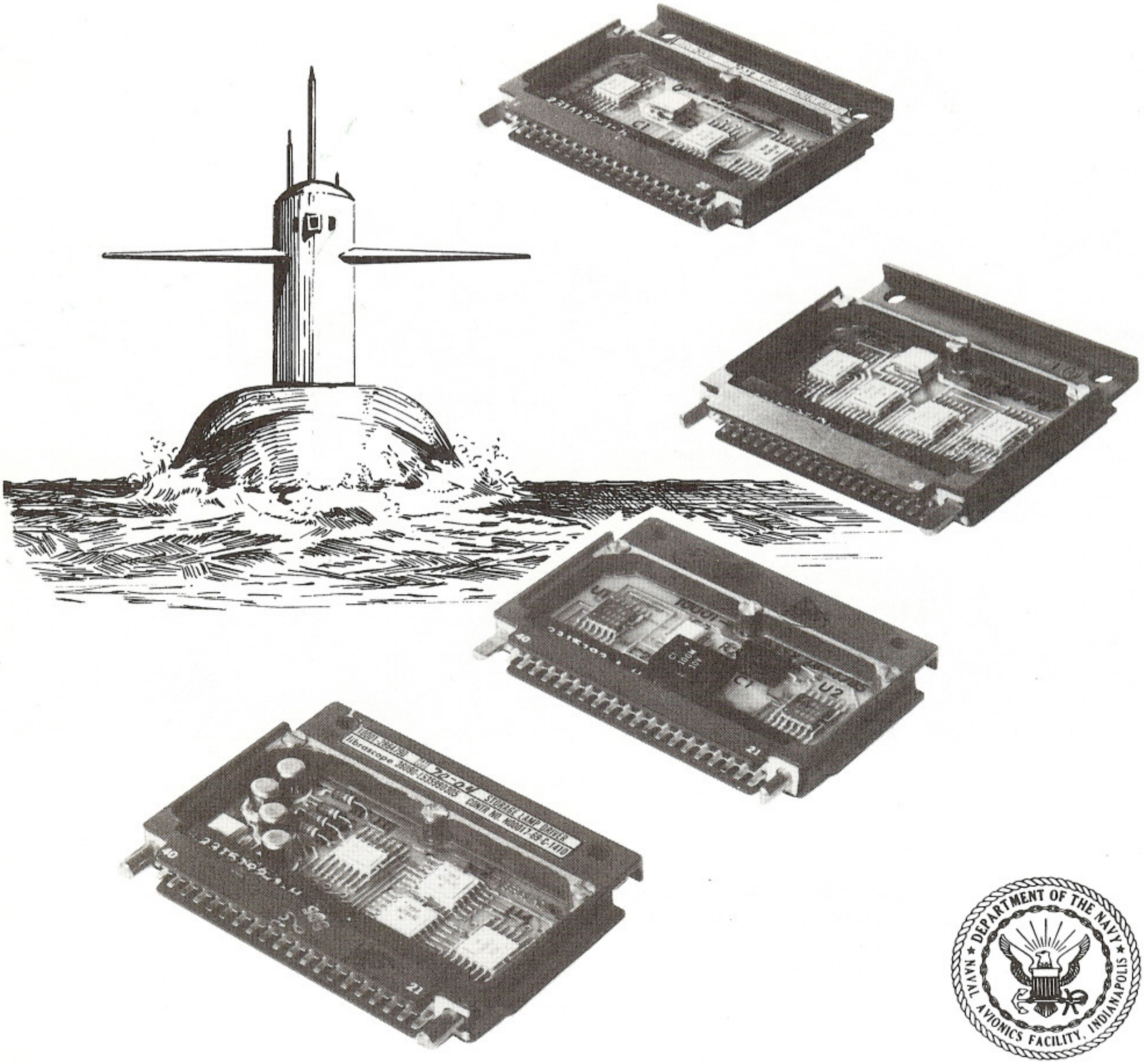
SEM Design Consideration in Advanced Submarine Fire Control Systems



BUILDING BLOCK

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Figure 1

Standard Electronic Modules (SEM's) are the basic building blocks for the fire control system of the Oberon Submarine.

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I am here to report on a highly successful application of the SEM concept: An advanced fire control system designed and built by Singer's Librascope Division for the Royal Australian Navy's submarine fleet. This system, four of which have already been successfully tested and delivered to the RAN, has received the Australian designation SFCS Mark 1 Mod 0.

The purpose of the SFCS Mk 1 Mod 0 is to integrate submarine sensors and weapons in the most efficient and automated manner possible, in order to improve submarine operational effectiveness. The SFCS is the command focal point for sensor/fire control integration, threat assessment and weapon firing and control. Figure 2 shows the functions and features of the SFCS.

Development of the systems was initiated in the spring of 1974 by the RAN after careful review of their OBERON modernization objectives. The Australian government issued an international tender for a contract definition study, to which companies from Norway, Holland and England, as well as the United States, responded. Librascope was selected in September 1974, and prepared a comprehensive system performance specification. Concurrently, the RAN was procuring the BQG MicroPUFFS sonar, and soliciting proposals for an improved BQS sonar and a new torpedo. Finally, in September 1975, Librascope was awarded a $14 million contract to develop and deliver eight Mk 1Mod 0 systems and associated support items.

The decision to implement the design with Standard Electronic Modules was a decisive factor in the award of the contract to Librascope. Librascope had a background of successful applications of SEM's in the U.S. Navy systems going back to 1968, and had recently completed delivery of the Mark 116 Fire Control System based on SEM's to NOSC in San Diego. The RAN foresaw the same advantages of modularity, repairability and logistics supportability that have made SEM's attractive to the U.S.N.

Each SFCS as now configured contains 1231 SEM modules of 50 types, or a population of 24.6 modules of each type on the average. Later slides will show the distribution of this population.

Two new families of size 1A SEM's were developed for the program. The first is a microcomputer set consisting of five module types: DRH – the M6800 microprocessor, DRN – a peripheral interface adapter, DRM – a 512 byte erasable read only memory, EYA – a 512 byte random access memory, and DRJ – microprocessor clock. These are all size 1A modules. In fact, all SEM's used within the SFCS are size 1, and over 96 percent are size 1A.

We also developed a family of seven size 1A low power Schottky logic modules. At the request of NAC, these were given the same pin-outs as the existing standard family of high speed Schottky modules, and are interchangeable with them for many applications although they have different key codes.

SYSTEM FUNCTIONS AND FEATURES

The SFCS Mk 1 Mod 0 performs five functions critically important to submarine attack operations:

1. *Multiple Sensor Coordination:* There are direct transmission lines from all sensor stations to the SFCS. While these data are received automatically, provision is made for operator overrides and manual entries. A time history of data from these sensors is maintained, both in a digital tape recorder and on a large format paper chart recorder. The SFCS is used to designate bearings for search and to direct another sonar for a contact/target already detected. Note that periscope, ESM/ECM and radar contacts can also be recorded and used.

2. *Assessment of Multiple Threats:* Threat assessment starts when a contact is so nominated and the SFCS begins the computations to estimate the contact state vector (location, course and speed). This analysis and the automated TMA process depends on the kind of sensor data available: bearings only, bearings and estimated ranges, or active (sonar, radar), visual or intercept data. Three modes of operator interactive TMA are provided, in addition

SFCS MK 1 FUNCTIONS AND FEATURES

- SENSOR INTEGRATION
  - GYROCOMPASS
  - SPEED LOG
  - DATE/TIME CLOCK
  - PERISCOPES
  - ESM/ECM SYSTEMS
  - RADAR
  - SONARS: 2007 (SEARCHER)
AN/BQG (RANGER)
AN/BQS (ATTACKER)
- THREAT ASSESSMENT
  - MULTIPLE MODES
  - AUTO + INTERACTIVE TMA
  - SOLUTION QUALITY
- WEAPONS
  - MK 8 – 4 (SALVO)
  - MK 23 – 3 (W/G)
  - MK 48 – 3 (W/G)
  - AIRFLIGHT MISSILE
- WEAPON CONTROL MODES
  - CORRECTED INTERCEPT
  - BEARING RIDER
  - PURSUIT
  - SWEEP INTERCEPT
- ACOUSTIC ENVIRONMENT ASSESSMENT
- MULTIPLE TARGET ATTACK CAPABILITY

Figure 2

to an automatic Kalman filter TMA estimator program. Results of the analyses for all threats are summarized in both tabular and graphical forms for evaluation. The quality of TMA solution is indicated.

3. *Weapon Assignment and Control:* The weapon order generation (WOG) process starts when a threat is chosen as a target. A weapon is selected based on the type of target, tactical situation and command decision criteria. An attacking approach may be selected based upon the quality of the TMA solution. All prelaunch weapon orders can be computed automatically – or with operator/Command overrides as desired – for both salvo fire and wire-guided torpedoes. The SFCS computes the proper solution for the weapon control mode selected and gives the operator a clear choice of the necessity for postlaunch guidance and control of the wire-guided torpedoes. Capacity for handling an airflight submarine-launched missile is also incorporated in the SFCS.

4. *Acoustic Environment Assessment:* Using bathythermograph or similar sensor data, the sound velocity profiles and ray traces are computed and displayed to the SFCS operator. With this information, the acoustic environment may be evaluated in order to (a) decide on own ship search depth, and (b) make optimum settings for acoustic homing torpedoes.

5. *Multiple Target Attack Capability:* The SFCS Mk 1 Mod 0 is a "TRACK 4, FIRE 2" system. "TRACK 4" means that it can simultaneously compute complete TMA solutions for four different targets. "FIRE 2" means that two different targets can be attacked simultaneously – for example: one W/G torpedo and one salvo of up to five Mk 8 torpedoes.

SFCS OPERATION OVERVIEW

Figure 3 shows the eight different hardware elements of the system, and the primary data flow between them.

SUBMARINE FIRE CONTROL SYSTEM MK 1 MOD 0

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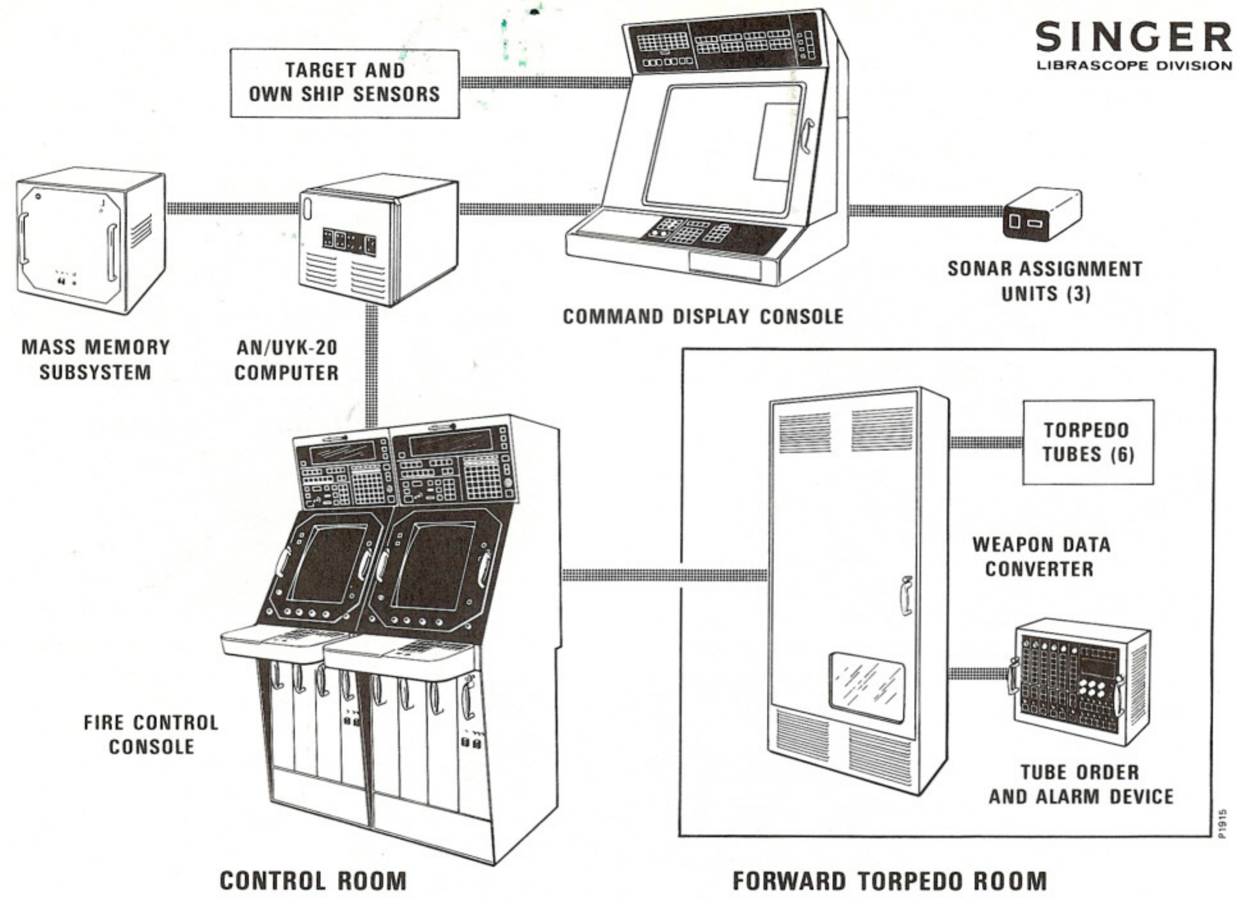


Figure 3

Data from 15 separate channels enters the SFCS via a sensor data converter (SDC) located in the Command Display Console. The SDC has nine passive sonar tracking channels, as well as capacity for active sonar data, periscope data, intercept receiver data, and own ship course and speed inputs. Analog-to-digital conversions are performed as required, and all available data is formatted for transmission to the central computer.

The sensor data is stored in the computer memory for analysis. It is also formatted for plotting and output to the Record/Reproduce unit. The Command Display is a large 20-by 24-inch paper plotter which produces a permanent time-versus-bearing record of all desired sensor bearings. Additionally, other pertinent information may be annotated. These data are plotted at one of three selectable rates, as appropriate to the tactical situation. The Command Display Console controls allow the operator to direct sonar search and track actions – by designating contact bearings via Sonar Assignment Units installed at each sonar console. Additionally, the operator may designate track I.D. numbers for the nine sonar data channels. Designating a track number initiates the storing of all data from the selected channel in the computer memory for the most recent 30-minute time period. Finally, he may nominate any four of the nine tracking channels as threats – which initiates threat motion analysis.

The movement and processing of data within the SFCS is controlled by a central AN/UYK-20 computer and its associated programs, augmented by a Mass Memory Subsystem. This militarized memory is a CL-107MA fixed head disc, which contains 409,600 16-bit memory locations and has an average access time of 18.4 milliseconds. Communication between the computer and other elements of the SFCS is via microprocessors contained within each element. There are six microcomputers within each SFCS: one in the Weapon Data Converter, one in each of the two Fire Control Consoles, and three in the Command Display Console.

These latter three perform the functions of sensor data conversion, control of a cartridge tape unit used for program storage and data recording, and control of the large paper plotter.

Architecturally, the microcomputers act as smart peripheral controllers connected to the AN/UYK-20 via NTDS fast interfaces. They are smart because the UYK-20 External Function Commands which they can interpret and execute are much more complex and sophisticated than those normally associated with peripheral devices. In addition, the microcomputer programs contain self-test diagnostic programs which continuously check the status of the associated subsystems and report back to the UYK-20. The built-in test and diagnostic capabilities made possible by the use of microprocessors have enabled us to demonstrate a mean time to repair of 14 minutes.

Tactical and off-line computer programs are stored and safeguarded on a sealed magnetic tape in the Record/Reproduce unit. Normally, at the start of each sea patrol, the programs are moved from the tape to the disc under computer control. From then on, the programs are loaded from the disc to the computer memory for execution. The tactical program supports all normal fire control functioning. It also provides for both hardware fault monitoring and the recording of sensor input and fire control output data for post mission analysis.

The combination of a general purpose computer, mass memory and microprocessors distributed within the SFCS results in a digital control system which provides: computational redundancy, flexibility and reliability, and emergency operating modes, should something happen to the computer.

The dual Fire Control Consoles are hardware identical. Each contains a CRT, alphanumeric "toteboard" displays, and associated controls. Primary interactive controls are: a light pen, special function keyboards, four shaft angle encoders, a joystick and various pushbuttons. The nomination of a contact as a threat initiates action at each of the consoles. Threat assessment is normally performed by a tactical analyst at the right hand console using CRT displays. These displays are a combination of numerical and graphical data, and include a time bearing plot, a threat motion analysis display, and a tactical plan display. A summary of the data on all four threats also appears in numerical form on a tactical tote at the top of the console.

Two of the four threats may be chosen as targets by the tactical analyst and passed to the weapon controller at the left console. In his operations, the weapon controller uses the dedicated function buttons and interactive CRT displays, which include a sound velocity profile display, a ray trace display, and a weapon control display. Weapon options include straight running torpedoes, which may be fired in salvos, and two different types of wireguided torpedoes. Two different targets may be attacked simultaneously. Communication both ways between the Fire Control Console and the forward torpedo compartment is via dedicated function buttons on the Fire Control Console and on the Tube Order and Alarm Device in the torpedo compartment. Orders to torpedoes are initiated at the console and are output to the six torpedo tubes via the Weapon Data Converter. The orders include prelaunch settings, the fire order, and postlaunch wireguide control. Postlaunch wireguide maneuver commands are automatically generated and sent to the weapons, but they may be overridden manually with the joystick.

The SFCS Mk 1 has a computationally redundant EMERGENCY mode for torpedo firing. Should the central computer malfunction, microprocessors within each Fire Control Console will automatically make appropriate presets to the weapon, including display indications for firing and postlaunch control. Additionally, the more critical preset parameters can be modified by the weapon controller. During an emergency, each console retains the display existing at the instant of computer malfunction, thereby allowing the operator to review the existing tactical situation before changing any presets.

Figure 4 shows three of the new module types designed for the SFCS program. In the upper left is the NFE low power Schottky Schmidt trigger module which contains 12 independent circuits. The upper right is the DRM ultraviolet erasable read-only memory containing 512 bytes of memory. The lower module is the DRN microprocessor interface module, a 40-pin DIP with each pin simply brought out to the module connector allowing all interconnects to made by back panel wire-wrap.

Figure 5 shows three modules implemented using thick film hybrid techniques. These are the CMC plasma panel display driver and the NTDS interface drivers and receivers.

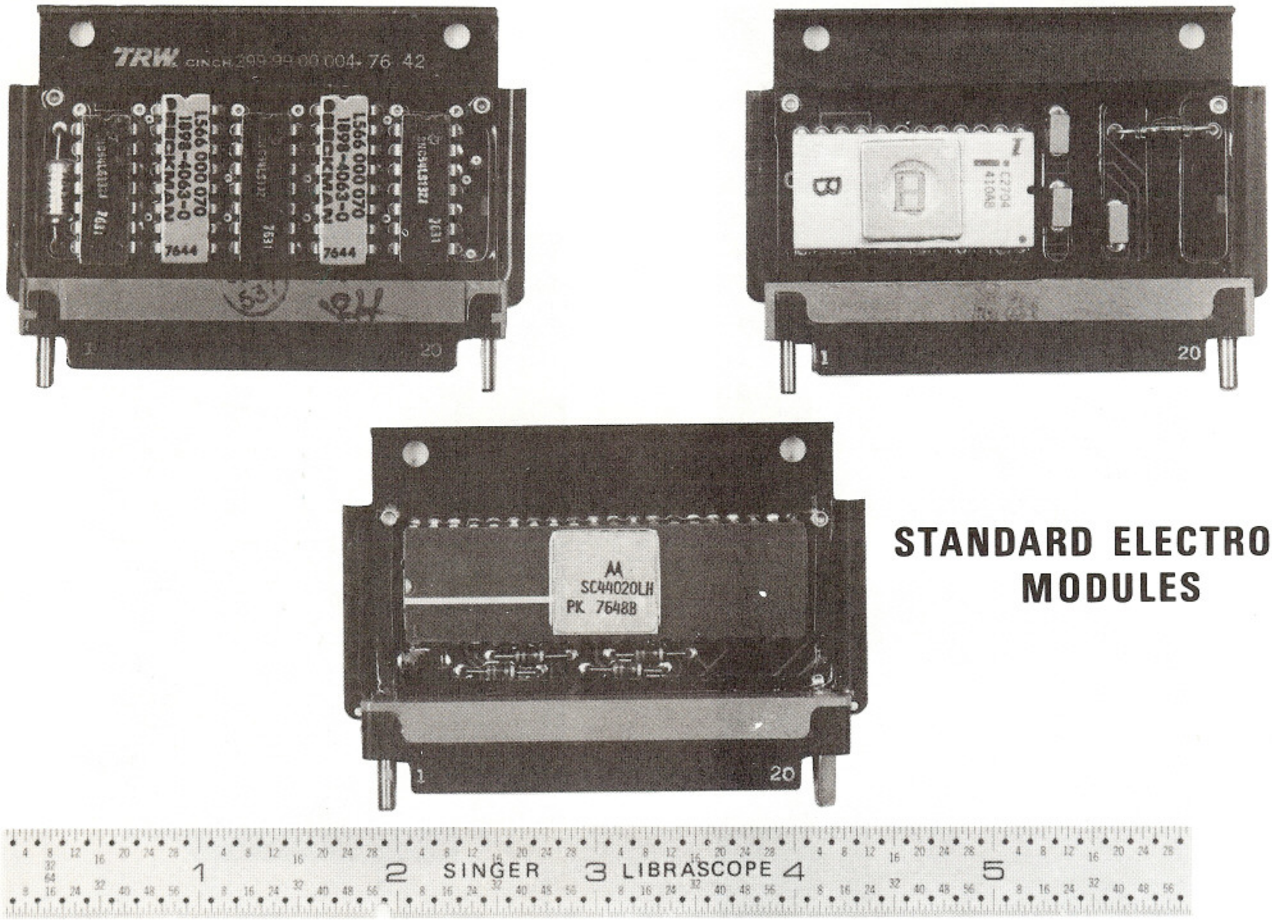
The number of modules of each of the 50 types is shown in Figure 6. The most populous module, which is the DRM read only memory, has 110 per system. Note that four types contribute 25% of the total and nine types 50%.

Figure 7 illustrates several facts. The graph shows the number of modules in each of the major units. It also shows the fraction that is low power Schottky (LPS), the fraction that is standard types, and the fraction that is size 1A. The table includes statistics on the number of modules we built in-house (844 per system) versus the number purchased outside (407).

Figure 8 shows a typical SEM drawer. Note in particular the size 1R and 1W SEM power supplies in the lower two rows.

Figure 9 shows the back plane wiring in a typical drawer. It was designed by an automated system (Librascope Design Automation System) and wire wrapped on semi-automatic machinery. In the SFCS, this wiring is covered by a panel shown in Figure 10 which is marked with each connector pin number and has an access hole to each pin for access as test points.

The SFCS Mk 1 is now in full production with deliveries being made every month to the RAN. As an all digital system incorporating the modularity and adaptability of the SEM concept, the SFCS is designed to be easily adaptable to other applications well into the 1980's.



STANDARD ELECTRONIC MODULES

Figure 4

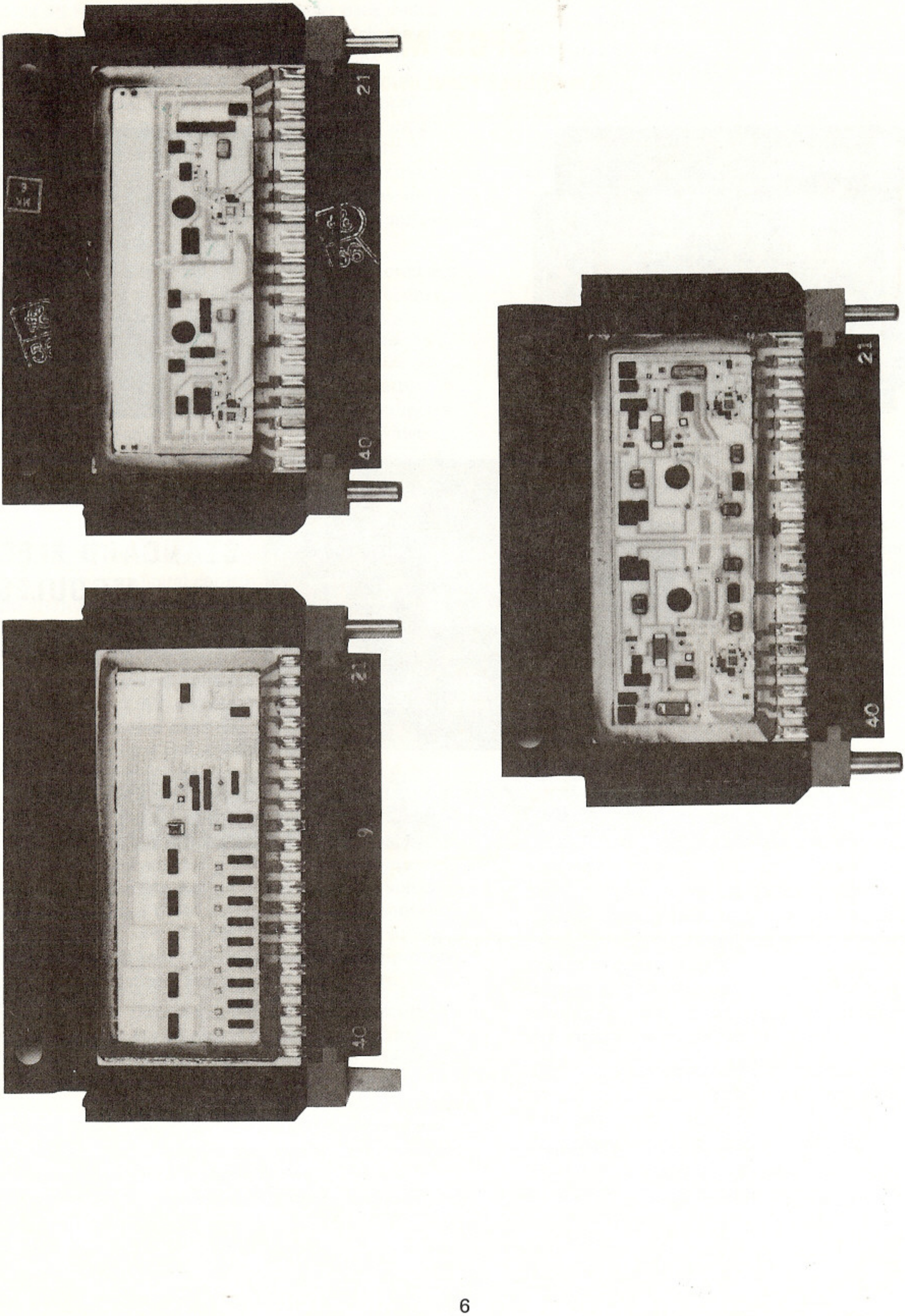


Figure 5

SFCS MK 1

SEM MODULE POPULATION BY TYPE

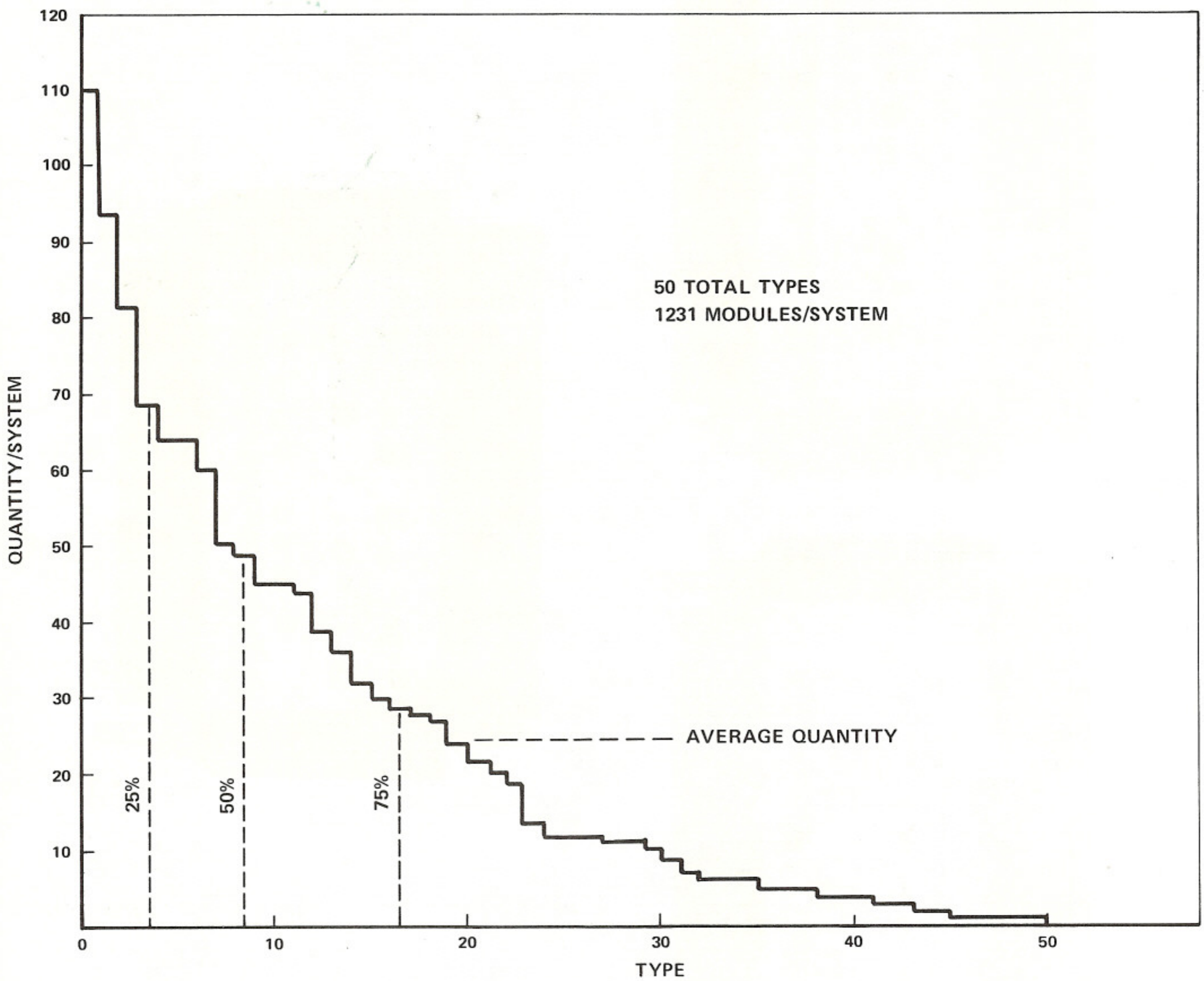
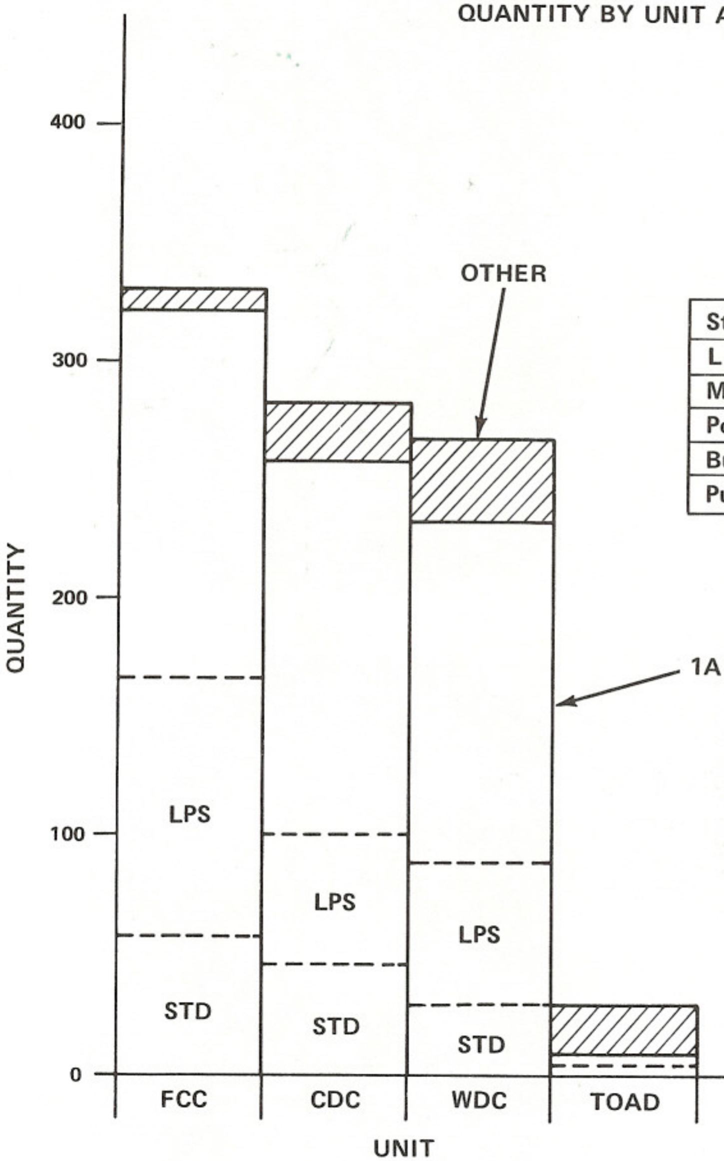


Figure 6

SFCS MK 1

STANDARD ELECTRONICS MODULES

QUANTITY BY UNIT AND TYPE



	TYPES	QUANTITY	(Per System)
Standards	14	109	
L P Schottky	8	225	
Microcomputer	7	344	
Power Supplies	3	20	
Built In-House	28	844	(68.4%)
Purchased	22	407	(31.6%)

Figure 7

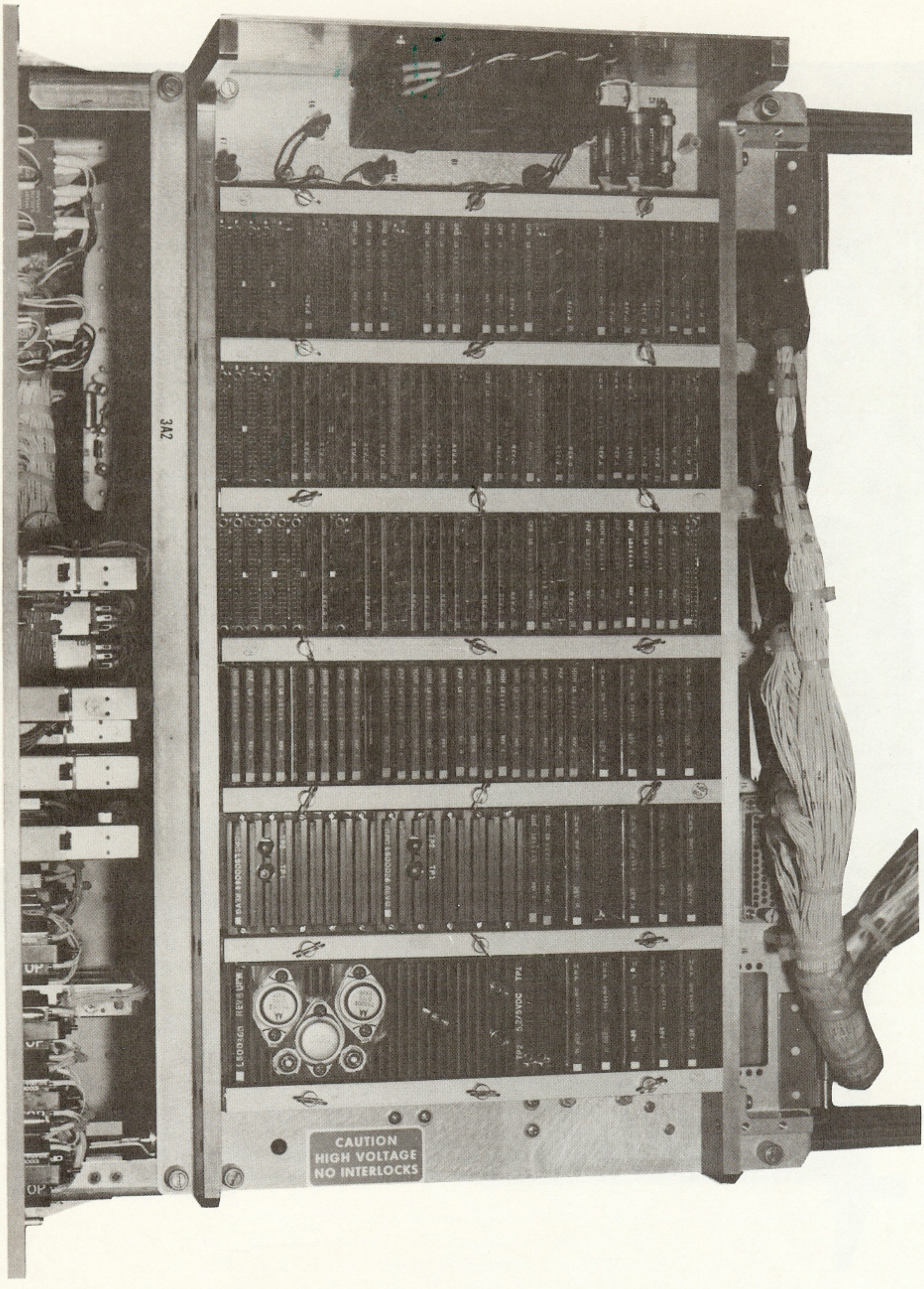


Figure 8

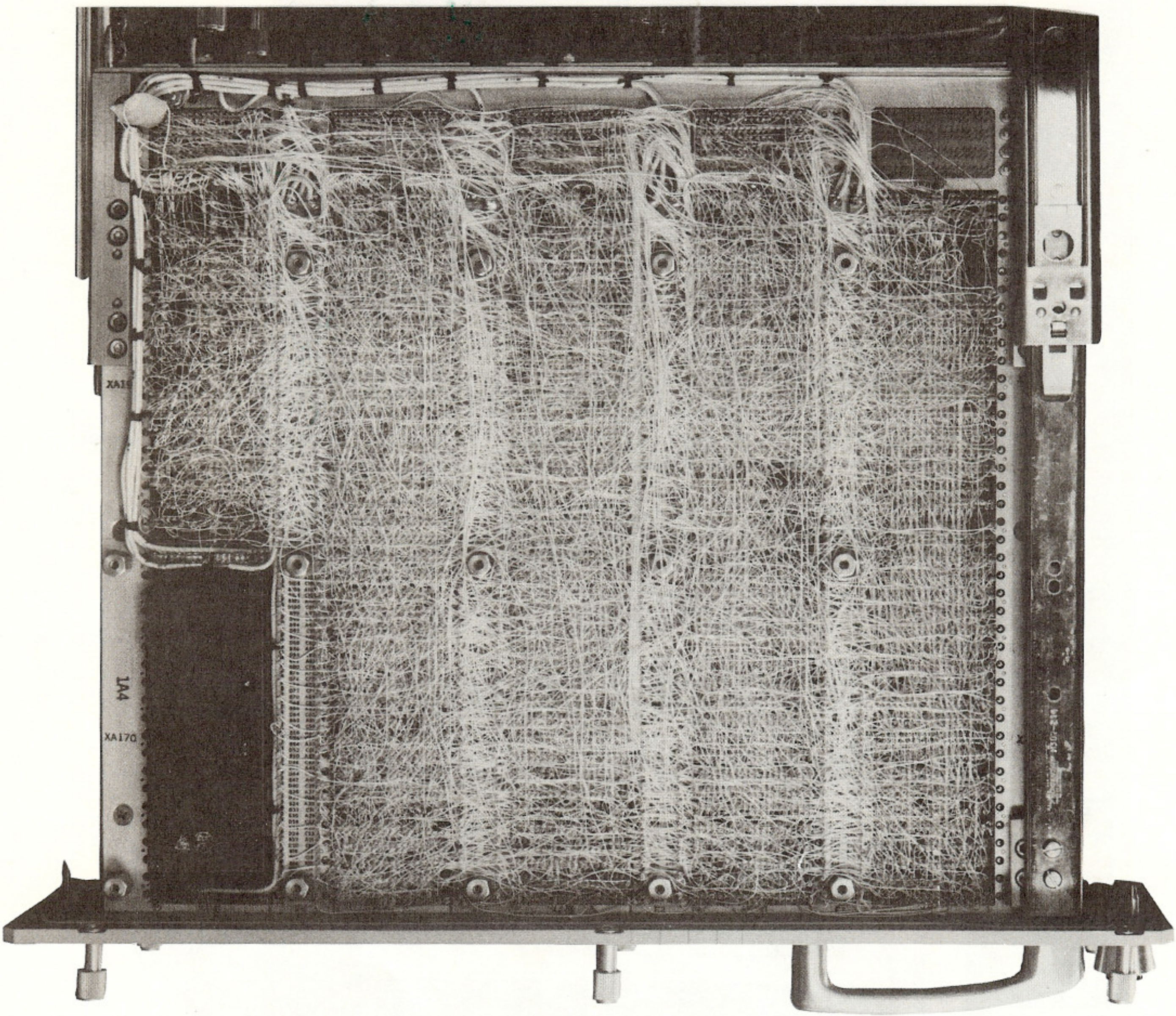


Figure 9

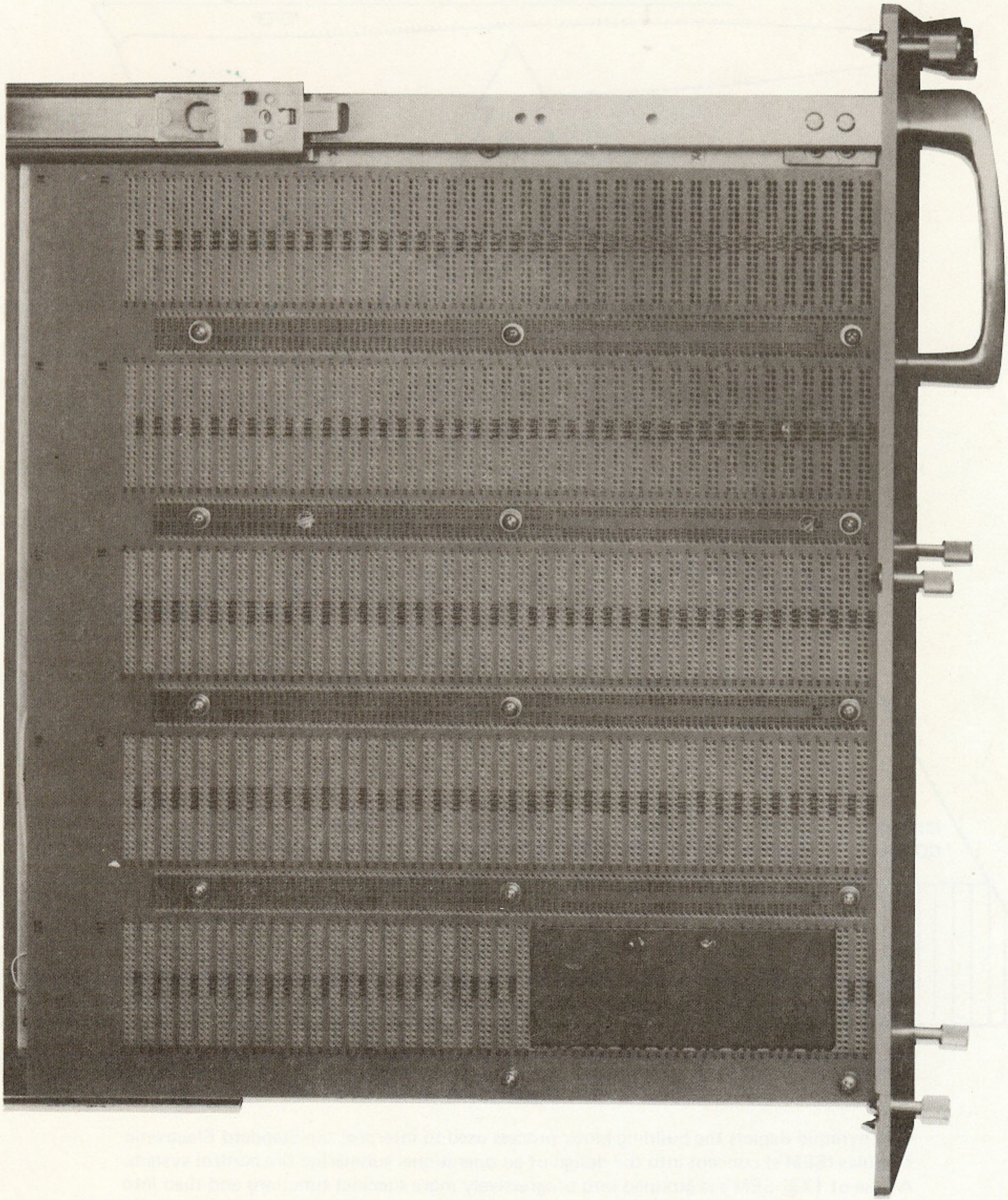


Figure 10

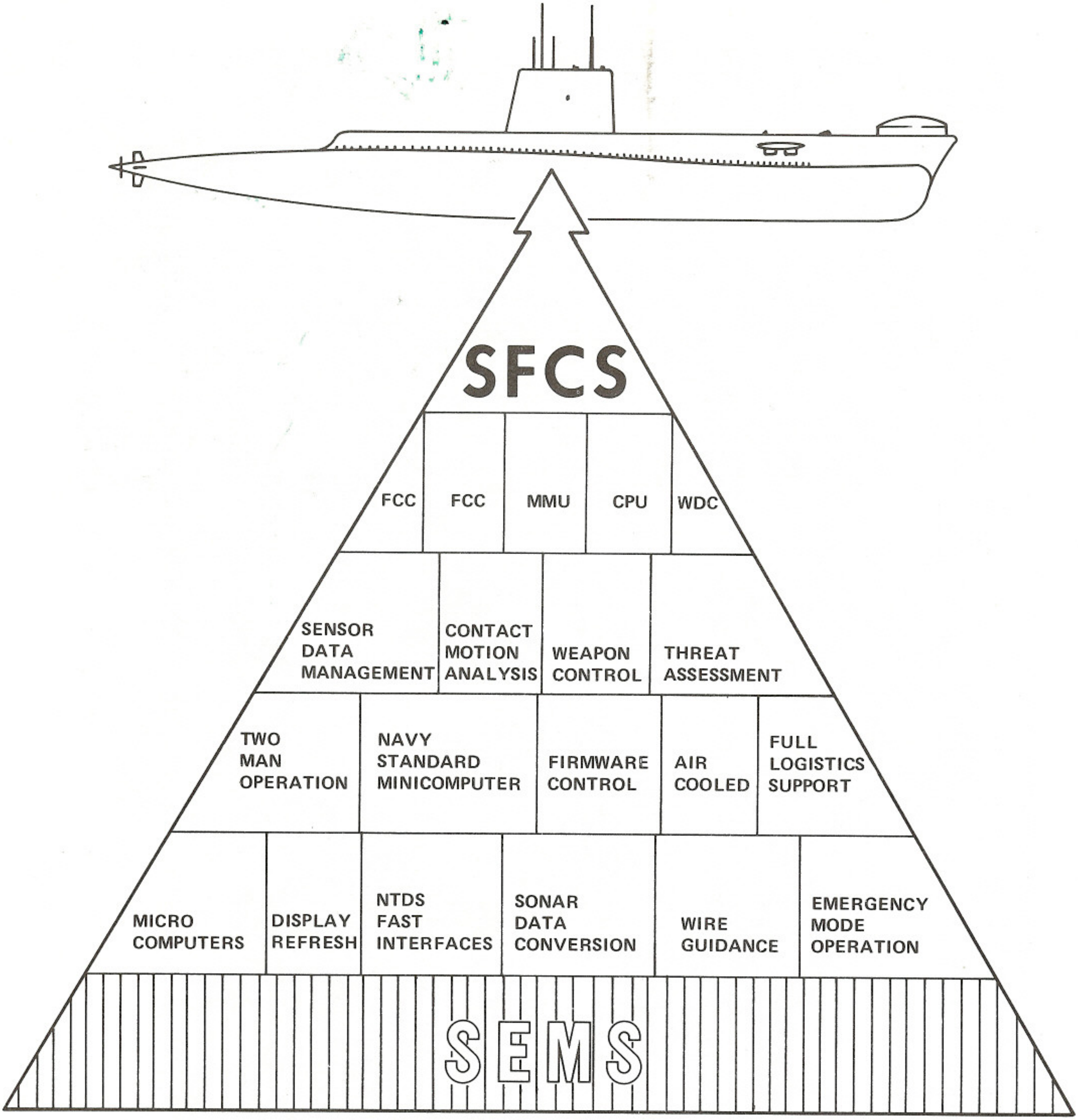


Figure 11

This pyramid depicts the building block process used to interpret the Standard Electronic Modules (SEM's) concept into the design of an operational submarine fire control system. A base of 1231 SEM's is grouped into progressively more succinct functions and then into successively more unitized packaging. The modules consist of only 50 types and provide the modularity, repairability, and logistics supportability necessary in the navies of today and tomorrow.

Librascope

a division of The SINGER Company