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DEFENSE SYSTEMS MANAGEMENT COLLEGE

PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

THE IMPACT OF STANDARD ELECTRONIC
MODULES ON FUTURE NAVY
ELECTRONIC SYSTEMS DEVELOPMENT

STUDY PROJECT REPORT
PMC 77-2

James W. Hugo
CDR USN

FORT BELVOIR, VIRGINIA 22060

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DEFENSE SYSTEMS MANAGEMENT COLLEGE

STUDY TITLE: THE IMPACT OF STANDARD ELECTRONIC MODULES ON FUTURE NAVY ELECTRONIC SYSTEMS DEVELOPMENT

STUDY PROJECT GOALS:

- Analyse past attempts, successes, and failures.
- Analyse present efforts.
- Arrive at a conclusion and recommendation.

STUDY REPORT ABSTRACT:

The purpose of this study report was to investigate the potential benefits which might be brought about by a more wide-spread use of Standard Electronic Modules (SEM) in the production of present and future electronic systems.

The method of reporting paralleled the method of research. First, the physical and environmental description of SEM was discussed along with a description of the SEM program organization and documentation. Next, a data search and personal interviews were conducted to ascertain the success or failure of some typical operational systems. The present situation was then examined and several different types of SEM implemented systems were examined. In order to investigate the widest possible applications, typical landbased, airborne and shipborne SEM implemented equipments were compared with similar equipments built using conventional designs and custom modules. Comparisons were then made as to life-cycle-cost (LCC), Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), changes in weight and volume, ease of maintenance, skill levels required for maintenance, logistic support requirements, and initial acquisition cost.

The findings were then summarized, conclusions were drawn, and recommendations made. The readers of this report may find the observations and conclusions useful in further pursuit of the subject.

SUBJECT DESCRIPTORS

Design-to-Cost (10.02.07)
Standard Module Subsystem (10.02.03.03)
Reliability, Availability, Maintainability (10.05.02)

NAME, RANK, SERVICE	CLASS	DATE
James W. Hugo, CDR, USN	PMC 77-2	November 1977

THE IMPACT OF STANDARD ELECTRONIC MODULES ON FUTURE NAVY ELECTRONIC SYSTEMS DEVELOPMENT

Individual Study Program
Study Project Report
Prepared as a Formal Report

Defense Systems Management College
Program Management Course
Class 77-2

by

James W. Hugo
CDR USN

November 1977

Study Project Advisor
Mr. Wayne Schmidt

EXECUTIVE SUMMARY

The purpose of this study project was to investigate and illuminate the role of the United States Navy's Standard Electronic Module (SEM) program in the electronic systems acquisition process. The report examines past efforts as well as present and future applications.

The report examines landbased, shipborne, airborne and submarine applications ranging from operational SEM based equipment to systems presently in development.

An overview of several current studies is presented to demonstrate the potential for wider application of the SEM concept. These studies include the use of SEM in the design of shipborne radar, TACAN, airborne radar, and general purpose transmitters.

Based on the data researched and the interview responses, the author concludes that the wide-spread use of SEM based electronic systems could result in significant life-cycle cost savings and greatly improved system availability. These potential benefits are based on proven improvements in system reliability and ease of maintenance, and a reduction of the maintenance skill level requirements.

Additional savings could be realized due to shorter development times and less expensive operations and support costs due to modular commonality (both intersystem and intra-system).

TABLE OF CONTENTS

Section

SECTION I

INTRODUCTION

In the past, military electronic systems were developed in a manner that encouraged proliferation of electronic hardware. New systems were designed with little if any thought given to commonality with either existing systems or other systems being developed at the same time. As a result, we find ourselves faced with long lead times and high technical risks in fielding new equipments, high maintenance skill level requirements, and poor logistic support. The resulting high life-cycles costs are becoming increasingly unacceptable in the light of dwindling defense budgets. In an attempt to halt the continuing proliferation of packaging technologies being used in military electronic systems (and at the same time improve reliability and life-cycle cost) the U.S. Navy is actively pursuing a design standardization program. The Standard Electronic Module (SEM) program "provides the hardware acquisition manager and design engineer alike with a practical electronics hardware methodology that is consistent with the goals and objectives of the Navy and industry." (1-21)

Purpose and Scope

In a study report written in November 1974, while attending the Defense Systems Management School, Mr. John A. Wyatt examined the main features of the Navy Standard Hardware Program (subsequently renamed the Standard Electronic Module Program). In his report, he speculated about the likely impact on its effectiveness "in terms of its ability to bring about significant life-cycle cost reductions in electronic systems." (5-1) Additional goals were "to show how the use of Standard Electronic Modules affects the cost of systems in which they are used", and "to demonstrate the results in quantifiable terms" by comparing "two distinctly separate modular systems .....i.e., the AN/BQQ-5 and the Trident (AN/BQQ-6) sonar systems." (5-2)

The purpose of this paper will be to understand, from a systems acquisition viewpoint, what Reliability and Maintainability (RAM) and Life-Cycle Cost (LCC) advantages might be realized through wide-spread use of SEM in future Navy electronic systems.

Specific goals will be to:

- Investigate the progress in implementing the SEM program in the Navy during the ensuing time period between Mr. Wyatt's November 1974 report and the present.
- Analyse past attempts, successes and failures.
- Analyse present efforts.
- Arrive at conclusions and recommendations.

The scope of this paper will be to:

- Describe the goals of the SEM program, and the mechanical and environmental requirements for the modules on which the program is based.
- Compile a representative list of electronic systems presently employing SEM concepts, examine two such systems in detail, and report on the conclusions of

several other SEM application studies.

- Examine the political climate (concerning SEM) which exists in OSD, in Industry, and with the Navy.
- Examine the possible impact of widespread utilization of SEM based systems on:
    - Design to Cost (DTC)
    - Life-Cycle Cost (LCC)
    - Logistic Support
    - Reliability and Maintainability (RAM)
    - Product Improvement
    - Training and Maintenance Skill Levels

Limitations

A complete examination of the entire Standard Electronic Module program is beyond the scope of this paper, and although Tri-Service implications will be touched upon, lack of time precludes an in-depth examination of efforts outside the Navy. For the same reason, no attempt is made to present complete, life-cycle costing models.

Data Base

The sources of data used in preparing this paper are listed in the bibliography. All conclusions and recommendations are based on these sources as well as the author's personal observations while assigned to air and sea units of the operational fleet, and tours of duty on both OPNAV and NAVMAT staffs.

SECTION II

THE NAVY STANDARD ELECTRONIC MODULE PROGRAM

"The Navy's Standard Electronic Module (SEM) program is a highly successful design standardization program that is commanding considerable attention within the Department of Defense as a result of its achieving significant cost and reliability improvements. This program establishes a rational discipline for the development process for military electronics systems by providing families of functional electronic modules which are already developed, documented, qualified, and for which a wide industrial base exists." (6-132A)

Concept

The SEM concept is based on the principle of limiting redundant design through the use of standard functions, thus achieving cost benefits through consequent large production volumes and wide competitive availability. Equally important are the expected increases in reliability and maintainability, coupled with decreased logistic support requirements.

Definitions

The following terms may appear several times throughout this paper. The definitions of the terms will have the same meaning that they would in any document controlled by the SEM program.

- Standard Modules - those modules having potential for multisystem applications which have been documented and qualified in accordance with the requirements of MIL-STD-1378.

- Special Modules - those module having little or no potential for multisystem applications. Documentation and qualification is the responsibility of the applicable Program Manager.
- Key Codes - three letter symbols for marking and identification of both special and standard modules. The first and last letters of each symbol indicate the combination of keying pin configuration and rotational orientation used to safeguard against incorrect insertion of modules into receptacles.

Organization

The Navy SEM program organization is made up of three main functional areas: the Technical Management Activity, the Design Review Activity, and the Quality Assurance Activity.

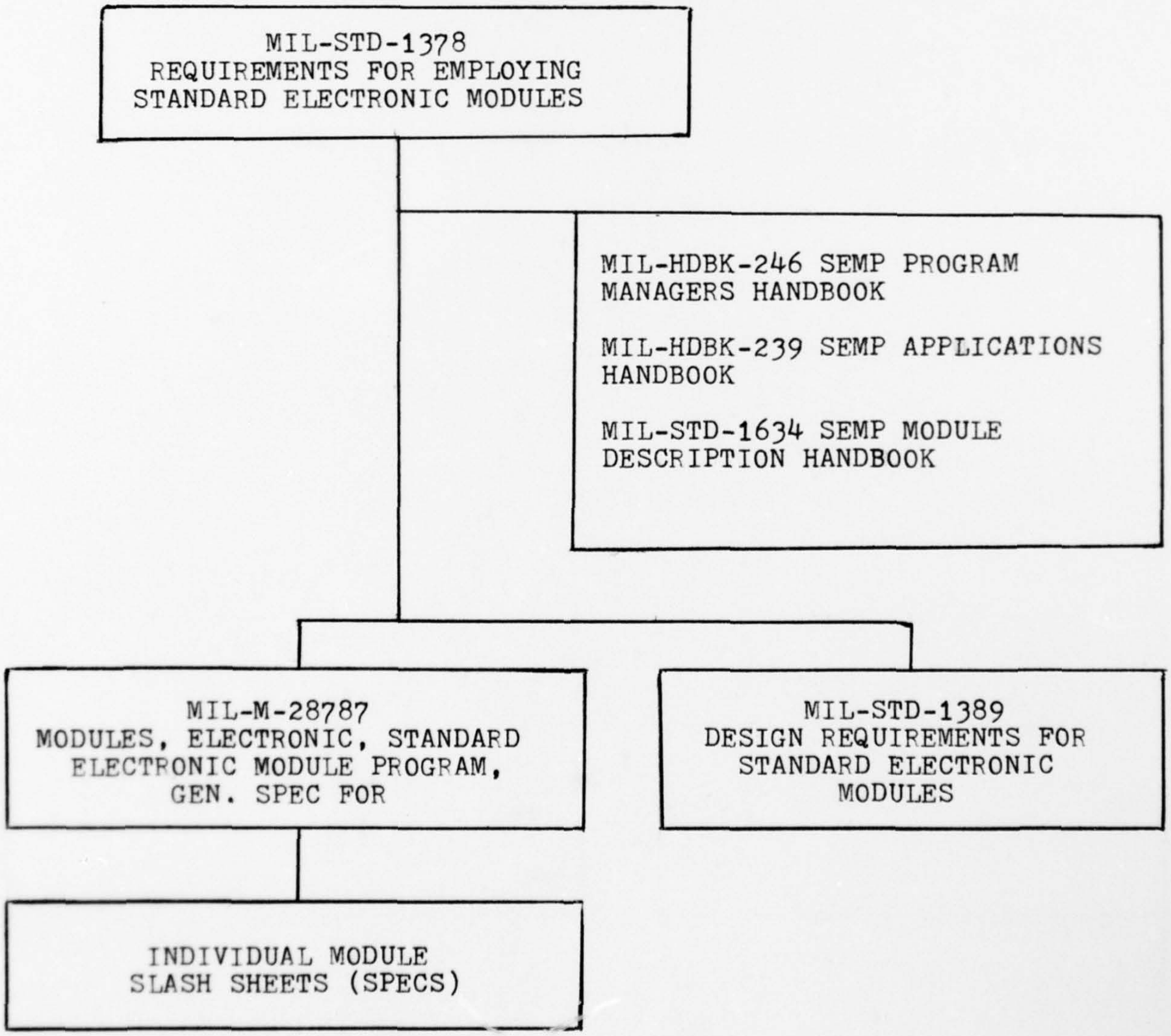
The first of these is the responsibility of the Naval Electronic Systems Command (NAVELEX), whose functions include the establishment of SEM objectives, organization and direction of Navy Laboratory efforts, promotion of the program within the Navy, and sponsorship of module development activities.

The Naval Avionic Facility, Indianapolis (NAFI) serves as the Design Review Activity and is responsible for the review and classification of each SEM module. Additionally, NAFI is tasked to assign SEM module key codes and specification numbers, perform advanced exploratory development studies relative to SEM module designs, provide technical coordination and assistance as required, and maintain the

SEM data bank and information retrieval system.

Documentation

The mechanical and environmental requirements for SEM modules are specified in the following documents which also describe the electrical functions and reliability requirements for each module type:



Configuration

The basic SEM module (1A size) configuration is depicted in Figure 1. The principle rationale for this physical form factor was based on a size and configuration which would enable rapid replacement and yet be able to accommodate reasonably high functional complexity. At the same time it was important that the modules be in a cost range which would justify throw-away upon failure and in a size and configuration compatatible with existing electronic technologies (flat packs, dips, LSI, etc.).

Provisions for module growth increments for use in the expansion of module size allow increases in span by increments of 3.00 inches and in thickness by increments of .300 inches.

The SEM program has evolved to where it consists of approximately 280 different module types. These modules are made up of the following general families:

- Digital logic: from basic gates to memories, microprocessors etc.
- Interface circuits: drivers, receivers, logic level shifters etc.
- Converter: analog to digital, synchro to digital etc.
- Analog: operational amplifiers, filters, switches etc.
- Power supplies
- Miscellaneous: resistors, capacitors, terminators, inductors, transformers, relays etc.

Figure 2 is a representative list of 42 SEM types.

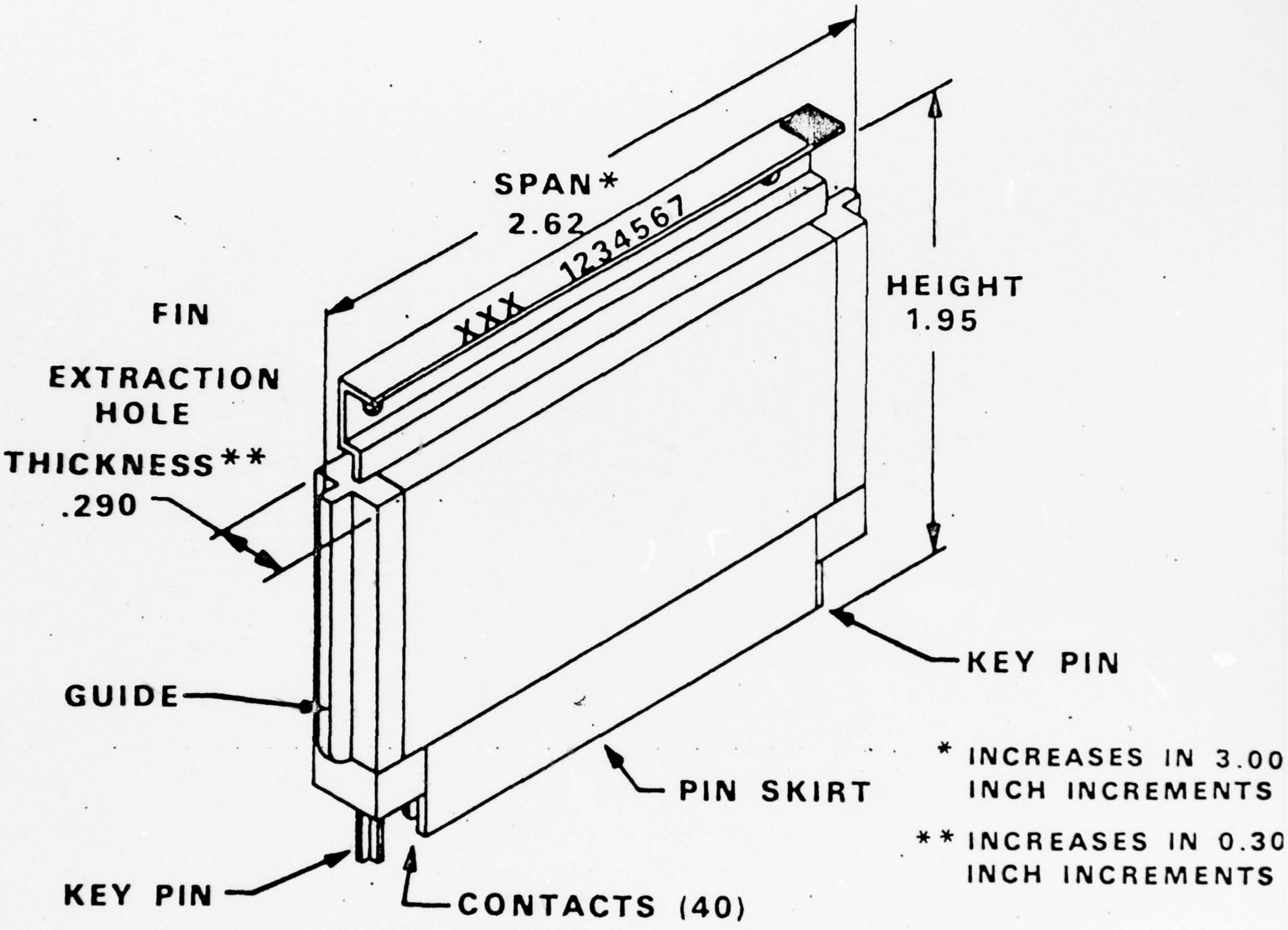

SPAN*
2.62
XXX 1234567
FIN
EXTRACTION
HOLE
THICKNESS**
.290
HEIGHT
1.95
GUIDE
KEY PIN
PIN SKIRT
KEY PIN
CONTACTS (40)
* INCREASES IN 3.00
INCH INCREMENTS
** INCREASES IN 0.30
INCH INCREMENTS

Figure 1.

DEPARTMENT OF THE NAVY ELECTRONIC SYSTEMS COMMAND

1 SEPTEMBER 1977

STANDARD ELECTRONIC MODULES PROGRAM

MODULE LISTING

Formerly **NAVELEX 0101-053B**

SLASH SHEET NO. M28787/	KEY[4] CODE	MODULE NAME	SIZE	MODULE DESCRIPTION	REV	STATUS
1	GDJ	Latch	1A	Four 4-bit latches, TTL (QBA[3])	A	AP
2	GDE	Flip-Flop, J-K	1A	Six J-K flip-flops, HSTTL	(2)	AP
3	GDA	Gate, NAND	1A	Twelve 2-input strobable, NAND gates, HSTTL	(1)	AP
4	GDK	Gate, OR, Exclusive	1A	Multiple exclusive OR/NOR gates, TTL (QDB[3])	(1)	AP
5	BDL	Multiplexer	1A	Three 8-input digital multiplexers, TTL (KHC[3])	A	AP
6	FDA	Counter, Binary, Synchronous	1A	Three 4-bit synchronous binary counters, TTL	A	AP
7	GDN	Decoder, Binary	1A	One of sixteen binary decoder, TTL (QBE[3])	A	AP
8	GDC	Gate, NAND	1A	Six 4-input and two 3-input power NAND gates, HSTTL	A*	AP
9	LDP	Gate, NAND	1A	Four 8-input NAND gates, TTL	(3)	AP
10	GDB	Gate, NAND	1A	Six 4-input and two 3-input NAND gates, HSTTL	(1)	AP
11	KDL	Adder, Digital	1A	Two 4-bit and one 2-bit adders, TTL	(1)	AP
12	KDJ	Arithmetic Logic Unit	1A	Two 4-bit arithmetic logic units, TTL	(2)	AP
13	FPQ	Network, Resistor, Independent	1C	Two 2.37Ω and two 332Ω, 4W, resistors (PPQ[1])		AP
14	JBD	Terminator, Resistor-Capacitor	1A	Single ended terminator (ADD[1])		AP
15	PMN	Fuse	1B	Eight fuses (FMN[1])		AP
16	JDK	Receiver, Interface	1A	Eighteen logic level receivers, TTL (AHB[3])	(1)	AP
17	LDJ	Gate, AND-OR-INVERT	1A	Six AND-OR-INVERT gates, TTL (CBJ[3])	(1)	AP
18	LDQ	Gate, NAND	1A	Twelve 2-input NAND gates, TTL (CHG[3])	(3)	AP
19	LDN	Gate, NAND	1A	Six 4-input and two 3-input NAND gates, TTL (CHE[3])	(1)	AP
20	LDC	Inverter	1A	Eighteen inverter gates, TTL (CBL[3])	(3)	AP
21	WDU	Gate, NAND	1A	Four 8-input NAND gates, HSTTL	(1)	AP
22	ABE	Diode, Programmable	1A	Twenty independent high speed diodes (ADE[1])	A*	AP
23	SBT	Receiver, Interface	1A	Receiver, SEM interface, 28V to 5V (SDT[1]) (SQT[3])		AP
24	GPR	Rectifier, Low Current	1A	Twelve 1.75-amp rectifiers (QPR[1])		AP
25	HPJ	Rectifier, High Current	1C	Three 8-amp diodes (RPJ[1])		AP
26	GPN	Fuse	1B	One 20-amp fuse (QPN[1])		AP
27	GDM	Counter, Up and Down, Binary	1A	Four 4-bit synchronous binary up/down counters, TTL	(1)	AP
28	PDM	Shift Register	1A	Two 32-bit shift registers, TTL		AP
29	FDH	Inverter	1A	Eighteen inverter gates, HSTTL	(1)	AP
30	BBA	Counter, Up-Down, Binary	1A	Three binary up/down counters, TTL	A(1)	AP
31	JDD	Counter, Up-Down, BCD, Presettable	1A	Three BCD, presettable up/down counters, TTL	A	AP
32	KBR	Flip-Flop, D-Type	1A	Six D-type flip-flops, LPTTL	A	AP
33	JDJ	Shift Register	1A	Four 4-bit serial/parallel shift registers, TTL	A	AP
34	JBN	Multivibrator, Monostable	1A	Two monostable multivibrators (JDN[1])	A(1)	AP
35	EPL	Resistor, Power	1C	3.84Ω power resistor, 12 watt (NPL[1])		AP
36	YKT	Fuse	1B	One 3-amp slow blow fuse (YMT[1])		AP
37	YKW	Fuse	1B	Eight fuses, 1 ea, 4/10, 3/4, 2, 5 amp; 2 ea, 1/4 and 1 amp (YMW[1])		AP
38	NPM	Relay, DPDT	1B	Four undervoltage DPDT relays (EPM[1])	A(2)	AP
39	KBC	Adder	1A	Two 4-bit and one 2-bit adder, LSTTL	A	AP
40	KBL	Multiplexer, Digital	1A	Three 8-input digital multiplexers, LPTTL	A	AP
41	EBL	Flip-Flop, J-K	1A	Six J-K flip-flops, TTL	(2)	AP
42	JBK	Comparator, Magnitude	1A	One 4-bit and one 8-bit expandable magnitude comparators, LPTTL	A(1)	AP

Figure 2.

SECTION III

PAST SEM BASED EFFORTS

One of the earliest large scale uses of SEMs in an operational system was the redesign of the AN/BQG-2B Signal Comparator. The first installation of this equipment was aboard the USS BARB (SSN 596) in March of 1970. The Signal Comparator cabinet contains 256 SEMs which perform virtually all its electronic functions. Demonstrated Mean Time Between Failure (MTBF) is over 1,200 hours, compared with 150 hours for the unit it replaced. Equally impressive is the Mean Time To Repair (MTTR) figure of .25 hours.

Follow-ons to the successful AN/BQG-2B effort have included the following major system applications:

PROGRAM OFFICE	SYSTEM	DEVELOPER
PM-1	MK 88 MOD 0 POSEIDON FCS	GE
NSEA	AN/BQR-21 "DIMUS" SONAR	HONEYWELL
NSEA	AN/BQQ-5 SONAR	IBM
NSEA	AN/DKT UHF TELEMETRY	NAFI/ECI
NSEA	SUBMARINE ACOUSTIC WARFARE SYSTEM	SPERRY GYROSCOPE
PM-1	MISSILE MONITOR SIGNAL CONDITIONER	LOCKHEED
PM-1	MK 98 MOD 0 TRIDENT FCS	GE, HUGHES
NSEA	AN/BQQ-6 TRIDENT SONAR SYSTEM	IBM
NELEX	AN/BQH-6 SONAR	RAYTHEON
NAIR	HARPOON GSE	McDONNELL DOUGLAS

PROGRAM OFFICE	SYSTEM	DEVELOPER
NAIR	AN/AWG-21 WEAPON CONTROL SYSTEM	NAFI
AIR FORCE	TACTICAL WEATHER RADAR	NAFI
ARMY	TOW MISSILE GUIDANCE SYSTEM	NWSC

It is worthy of note that the major user of SEM design concepts has been the developers of submarine systems. Based on the successes achieved in this warfare area, the Naval Material Command is presently investigating additional areas which would be feasible for SEM implementation. Several possible applications will be discussed in the next section.

SECTION IV
PRESENT SITUATION

Over 5000 SEMs are presently in use in electronic systems throughout the Navy. Approximately 20 of these systems are operational, with another 50 in various stages of development or production. In complexity they vary from a relatively small Test Set (AN/BQG-28/4A), which uses 27 SEMs per unit, to a Trident Fire Control System (MK98) using 13420 per unit. It is interesting to note that the very large SEMs count making up the MK 98 is actually comprised of only 88 different Standard Electronic Module types.

The majority of the SEM based systems in use, as well as most of the systems under development, are associated with submarine systems. Several studies and/or development efforts have been completed however which appear to demonstrate the feasibility for much wider applications of the concept. The remainder of this section is devoted to examining an extensive development effort aimed at demonstrating the feasibility of a family of Modular Radars, as well as a cost tradeoff analysis between Alternative AN/ARN-84 TACAN Systems. Additionally, the conclusions of several other SEM application studies will be briefly noted.

2175 Modular Radar Project

The U.S. Navy presently has over a hundred different radars in its current inventory of supportable systems. Included are over twenty-nine different radars in the surface-search category alone, with many of these performing basically the same functions.

Of prime concern in the operation of these equipments is a figure of merit, called Operational Availability, which is defined as the percentage of time the radar is functioning properly given that the radar operation is required. Not included in this calculation is the time when radar operation is not required, such as when the ship is in port.

Typically, radar systems exhibit Operational Availabilities on the order of 30 to 40 percent. The availabilities are influenced by factors such as mean-time-between-failure (MTBF), mean-time-to-repair (MTTR), availability and qualifications of repair personnel, availability of repair parts, and the ease by which technical manuals can be used for fault isolation. In addition to attempting to improve the availability figure, the problem of logistic support for such a large number of unique radar designs adds to the complexity of the problem.

In an effort to demonstrate a plausible solution to the problem areas identified,the Naval Electronics Laboratory Center (NELC), San Diego, California, undertook to design a family of modular radars which could meet the operational requirements of the 29 different types of surface-search radars in the active inventory. Additionally it was decided to approach the problem in such a way as to demonstrate a two-for-one improvement over the existing systems. This two-for-one improvement, it was found, was very difficult to put into words. Would doubling the output power be a two-for-one improvement even if it required tripling prime input power? Would cutting repair time in half be an improvement if the repair part cost four times the cost of the other part? It was decided that in order to choose a goal that could be quantified, the system would be developed to show a two-for-one improvement in life-cycle cost (over a 15 year period), while meeting or exceeding all of the operational requirements. The program was started in 1973 using funds provided from the Naval Material Command, with plans for completion in 1975. The program title, 2175, then stands for "two-for-one in seventy-five".

A survey was conducted of all the surface search radars in the Navy's current inventory. As was stated earlier, it was found that 29 different types are presently in the active status. Further, if all of the modifications of these 29 types are taken into account, there are actually 53 different designs. They cover two frequency bands, produce peak output powers from 10 to 270 kilowatts, and can be grouped into four categorical areas:

- Type I - Major Combatant
- Type II - Precision Navigation
- Type III - Major Auxiliary
- Type IV - Small Boat

Figure 3 lists the basic parameters for these four radar types.

The simplest approach would have been to design one radar

BASIC PARAMETERS FOR SURFACE-SEARCH RADARS.

TYPICAL RADAR	TYPE I AN/SPS-10	TYPE I AN/SPS-55	TYPE III AN/SPS-60	TYPE II & IV LN 66
Freq. Band	C	X	X	X
Peak Power (kW) (Minimum)	190	130	35 – 75	10
Pulse Rate	625-650 pps	750-2250 pps	750-1500 pps	1250-2500 pps
Pulse Width	0.25-2.5 μsec	0.12-1.0 μsec	0.1-0.5 μsec	0.05-0.5 μsec
Power Tube Type	Magnetron	Magnetron	Magnetron	Magnetron
I-F Freq.	30 MHz	60 MHz	60 MHz	45 MHz
Bandwidth	1-5 MHz	1.2-10 MHz	2-12 MHz	14 MHz
Noise Figure	14 dB	10.1 dB	7 dB	11 dB
Input Power	115V 60 Hz 3 Phase	115V 60 Hz 1 Phase	115V 60 Hz 1 Phase	115V 60 Hz 1 Phase, or 12-36 Vdc

Figure 3.

to meet all requirements, however, it would obviously not be possible to meet the long range requirement for major combatants while satisfying the small size and minimum power-drain requirements for the small boat. It was decided, therefore, to design a family of radars which would demonstrate a high degree of commonality of functional sub-systems while at the same time meeting the four type requirements.

It was next decided that the 2175 Modular Radar Program would be designed using a modular concept. After an investigation of the various modular formats, the SEM concept was chosen. The reason for this choice was that these modules were already in the Navy logistic supply system, were of proven high reliability, and the plug-in feature would lead to more rapid repairs. Additionally, these modules were available in a wide variety of digital circuits such as multiple-input AND gates, flip-flops, multivibrators, shift registers, and the like, as well as analog circuits such as OP-AMPS, oscillators, buffers, and voltage regulators. These circuit modules have a range of application which encompasses not only a family of radar sets, but all types of electronic systems. The advantage in logistic support is obvious.

A large problem area in present systems is that of repair of failed systems. Problems of component storage and shipping and training of repair personnel has caused attention to be given to a throw-away-on-failure concept. The average cost for a SEM is about $60, well under the $150 to $200 figure usually stated as the maximum for the throw-away concept.

Another important feature of the 2175 Modular Radar design is its commonality, not only within itself, but across system lines. It can be envisioned that all Navy electronic systems such as communications systems, command and control systems, radar systems, sonar systems, and electronic warfare systems could eventually have a high degree of common parts. This would result in lower cost due to increased production runs of modules, easier logistic support, and better availability of parts (one module might, for example, support ten different systems aboard a ship).

Flexibility of design is another by-product of this approach. The SEM program specifies form, fit and function, but does not dictate the circuitry to achieve these. The manufacturer is allowed to use any fabrication technique and circuit to achieve the function, the only requirement being that NAD Crane approve the design as meeting the form, fit and function requirements. Should the manufacturer desire a design that does not exist in the SEM inventory, he can submit his design to NAFI for approval and inclusion in the SEM listings. It would also be possible to redesign selected modules to improve performance of an existing SEM based radar without requiring a whole new radar design.

The family of surface-search radars would have to include systems sufficient to fill the four type requirements noted in Figure 3. The 2175 approach was to design in such a manner as to achieve maximum commonality. Five levels of commonality were defined and are shown in Figure 4. The intention here was to

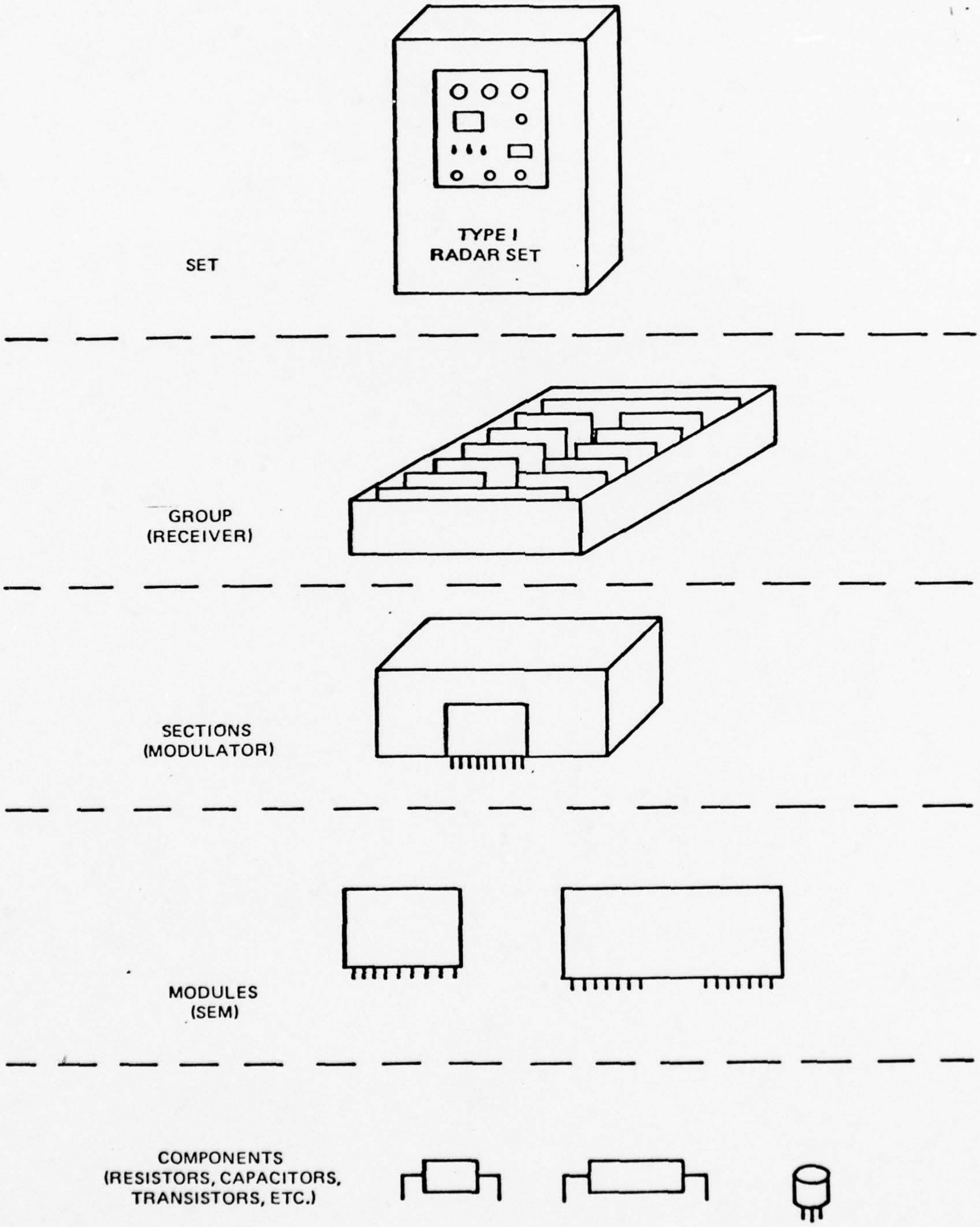

TYPE I
RADAR SET
SET
GROUP
(RECEIVER)
SECTIONS
(MODULATOR)
MODULES
(SEM)
COMPONENTS
(RESISTORS, CAPACITORS,
TRANSISTORS, ETC.)

Figure 4.

use common components on different SEMs, to use common SEMs in different sections, to use various sections to build different groups, and to use common groups to construct different sets.

The performance requirements for the four types led to defining the following groups which would be needed for the construction of the four types:

- One receiver (used in all types).
- Three transmitters (C-and X- band high power, and X- band low power).
- One signal processor.
- Two power supplies (one 115V ac and one 28V dc).
- One built-in test equipment (BITE).
- One timing and control.
- Three microwave units (C-band high power, X-band high power, X- band low power).

These group-level modules or building blocks are shown in Figure 5. It should be pointed out that the three transmitters and two power supplies are not really unique sections since they have a high degree of commonality at the SEM level. A comparison of the degree of commonality between the four types can be shown by using the Type I system as a baseline and expressing the percentage of SEMs and components in the other sets that also exist in the Type I. Doing this leads to the following figures:

- Type II- 90 percent common with Type I
- Type III - 100 percent common with Type I
- Type IV - 81 percent common with Type I

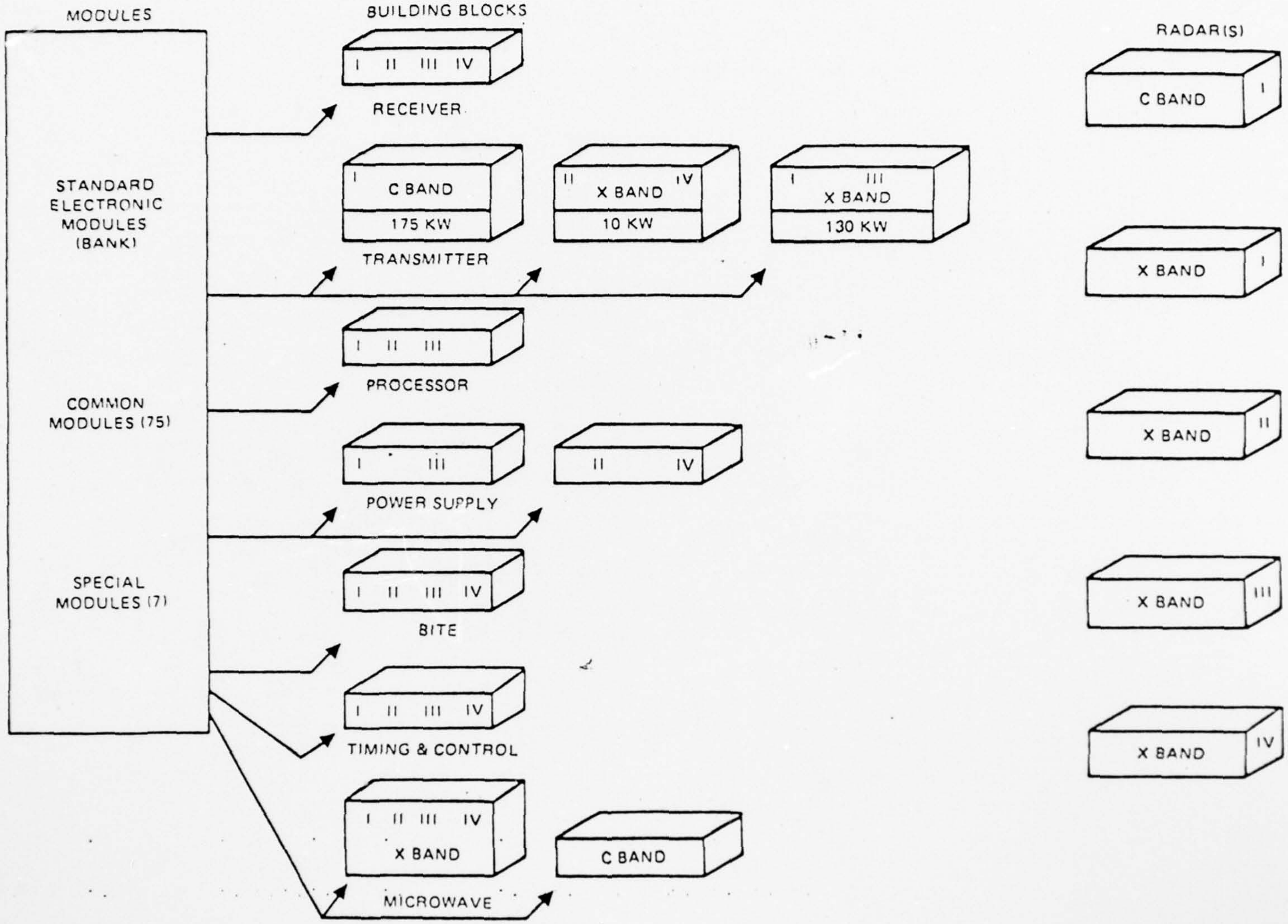

MODULES
STANDARD ELECTRONIC MODULES (BANK)
COMMON MODULES (75)
SPECIAL MODULES (7)
BUILDING BLOCKS
I II III IV
RECEIVER
I C BAND 175 KW
II X BAND IV 10 KW
I III X BAND 130 KW
TRANSMITTER
I II III
PROCESSOR
I III
II IV
POWER SUPPLY
I II III IV
BITE
I II III IV
TIMING & CONTROL
I II III IV X BAND
C BAND
MICROWAVE
RADAR(S)
C BAND I
X BAND I
X BAND II
X BAND III
X BAND IV

Figure 5.

This percentage includes SEMs, microwave components, magnetrons, cabinets , control box, cabling, cooling system, mounting plates, cable connectors, delay lines, and card cages.

As pointed out earlier, the attempt of this program was to demonstrate a two-for-one reduction in LCC while maintaining at least equivalent performance. Comparisons of the operating performance were calculated using a computer program and can be found in Figure 6. The figures shown compare each of the Modular designs with a similar radar currently in use throughout the fleet, and are useful for mathematical comparisons.

An independent LCC study was developed by EG&G Washington Analytical Services Inc. to estimate the LCC of the 2175 radar. As stated in NELC's final report on the 2175 Modular Radar Project:

> The report examined all cost areas except manning. This cost item was excluded because it was felt that it would be the same regardless of the design of a particular radar. The report shows that if the Type I C - band, the Type II, and Type IV X-band systems only were used (these represent current requirements), the average cost-per-year, based on a 15-year useful life, would amount to $5,300. A separate calculation of only the Types II and IV yielded the same LCC ($5,300 per set per year). This means that the Type I, C-band set, when included in the family, has a life cycle cost in the family of $5,300.
>
> The only surface-search radar found with complete data was the AN/SPS -10 and its Mods. A report prepared by ARINC Research Corporation gave a complete break-down of the life-cycle costs for 987 AN/SPS -10 radars. The data, as calculated, were for a 10-year expected life. Since the LCC estimate for the modular radar was based on a more realistic 15-year expected life, a correction was needed in order to compare the LCC estimate with the AN/SPS-10

COMPARISONS OF OPERATING PERFORMANCE.

	AN/SPS-10	I-C	AN/SPS-55	I-X	AN/SPS-53	IV-X_1	LN-66	IV-X_2	AN/BPS-15	IV-X_{sub}
P(Kw)	285	170	130	130	35	10	10	10	35	10
Horiz Beam	1.5°	1.5°	1.5°	1.5°	1.6°	1.5°	1.56°	1.56°	3°	3 °
Ant RPM	16	16	16	16	15	15	22	22	15	15
Bandwidth	1 & 5	1.2 & 12	1.2 & 10	1.2 & 12	4 & 12	1.2 & 12	14	1.2 & 12	4 & 12	1.2 & 12
PRF	650	4K & 1K	750 & 2.5K	4K & 1K	750 & 1.5K	4K & 1K	800 & 2.5K	4K & 1K	750 & 1.5K	4K & 1K
Pulse Width	0.25 & 1.3	0.1 & 1.0	0.12 & 1.0	0.1 & 1.0	0.1 & 1.0	0.1 & 1.0	0.05 & 0.5	0.1 & 1.0	0.1 & 0.5	0.1 & 1.0
Ant Gain	32	32	31	31	29	31	28	28	29.5	29.5
T_x Freq	5.5	5.5	9.5	9.5	9.4	9.4	9.4	9.4	8.8	9.0
NF	14	10	10	10	11	10	11	10	10	10
P_{avg}(w)	240	170	97	130	26.3	10	4	10	13.1	10
Range (nm)	15.72	17.51	10.71	11.11	4.81	5.93	2.56	4.09	5.37	5.43
Change (nm)	—	1.79	—	0.4	—	1.12	—	1.53	—	0.06

Figure 6.

> figures. To do this, development, production, installation, and disposal costs were kept constant as one-time costs while maintenance, technical and management, and modification costs were multiplied by 1.5 to reflect the 15-year period. This calculation is shown in Figure 7. The estimate for the modular radar was made using 1975 dollars. By multiplying the AN/APS-10 costs by 1.66, generally taken to be the escalation in costs from 1965 to 1975, we arrive at a comparative 1975 figure. The result of the calculation shows that the AN/SPS-10, if designed and used today, would cost $10,747 per year per set. When this is compared to the estimated cost per year of the Modular Type I C-band set of $5,300 per year per set, an improvement of 2.03 to 1 is shown in favor of the modular set. (2-47)

The same NELC report states the following conclusions:

> The 2175 Modular Radar Program has successfully completed its original objective of showing the feasibility of building surface-search radar systems in a modular format having a high degree of commonality leading to reductions in life-cycle costs. (2-51)
>
> The full potential of cost savings using SEMs, while shown to be worthwhile in just the surface-search radar alone, will be even greater as more and more electronic systems are designed using Standard Electronic Modules. (2-53)

ALTERNATIVE AN/ARN - 84 TACAN SYSTEMS

One of the most often stated reasons for not using the SEM concept is that the resulting systems tend to be heavier and bulkier than conventionally designed systems of equal performance. By and large this tends to be true. Designers of submarine, shipboard, and landbased electronic systems are inclined to trade off these limitations in order to reap the benefits inherent in SEM designs in the areas of LCC, MTBF, MTTR, and commonality. Those responsible for the design of airborne systems, however, are much more

LIFE-CYCLE COSTS (CORRECTED).

AN/SPS-10 DATA	$ Per Yr	$ Per 10 Yrs	$ per 15 Yrs
Development	37.43	374.30	374.30
Procurement	1523.50	15235.00	15235.00
Installation	1532.00	15320.00	15320.00
Maintenance	3682.34	36823.40	55235.10
Mgmt & Tech Service	150.28	1502.80	2254.20
Modifications	24.44	244.40	366.60
Disposal	832.78	8327.80	8327.80
			97113.00

Cost per yr per set = $6474.2 (1966 Dollars)

Cost Today = $6474.2 X 1.66 = $10747 (1975 $)

$$\text{LCC Saving} = \frac{\$10{,}747}{\$5300} = 2.03/1.0$$

These are actual reported costs. The ARINC report shows an average cost of $3,682 per year per set (based on 1975 dollars). It should be noted that the ARINC data on the AN/SPS-10 represent low estimates. This can also be seen by noting that ARINC lists the acquisition cost of each AN/SPS-10 as $15,235. A check, made with the Federal Stock Number Book, revealed that the purchase prices for the AN/SPS-10 series varied from $17,530 to $52,000. These costs are shown in table 5.

PROCUREMENT COSTS FOR AN/SPS-10 RADARS.

Set	Price	Quantity in Use (1972)
AN/SPS-10	$47,500	42
AN/SPS-10B	47,500	215
AN/SPS-10C	27,750	50
AN/SPS-10D	17,530	83
AN/SPS-10E	52,000	33
AN/SPS-10F	29,000	85
AN/SPS-10G	44,900	(not available)

The reason for the wide spread of costs has not been determined. However, a look over the list would lead to a conservative estimate of cost of $30,000, at least, if these sets were to be procured today. The ARINC figure, when multiplied by the 1.66 escalation factor, yields a figure of $25,290. Again, this figure can be observed to be on the low side.

Figure 7.

constrained, especially in the area of increased weight.

A recent cost trade-off analysis funded by NAVAIR and developed by EG&G Washington Analytical Services Center Incorporated looks at a cost trade-off between the existing AN/ARN-84 TACAN and a SEM based TACAN system which meets the same specifications and performance. The analysis looks only at the LCC aspects, with one of the basic assumptions being that:

> The SEM hardware will plug-in and fit in the same space as the present AN/ARN-84 units. There are no significant space and weight differences between the two alternative systems. (3-5.1)

Airborne TACAN equipments can be grouped into three generations, with the present equipment, the AN/ARN-84, being in the third generation. It was procured by the Navy to obtain increased reliability, and in this regard it is considered a success. It is, therefore an excellent modern avionics system with which to compare a SEM based system.

> The analytical process used in performing the cost trade-off consisted of the following steps:
>
> . Hardware calculations compared the cost of the follow-on custom system (units 2001 through 4000) with a like number of SEM systems (units 3 through 2002). Both were placed on the same learning curve. Figure 8 conceptually depicts this comparison.
>
> . The two alternative systems were formatted into a Navy Work Breakdown Schedule (WBS) for electronic systems. This served as a check-off list of program activity. The list of WBS elements was carefully examined and only those areas where a variance between the two alternative systems existed were further developed in the trade-off analysis.

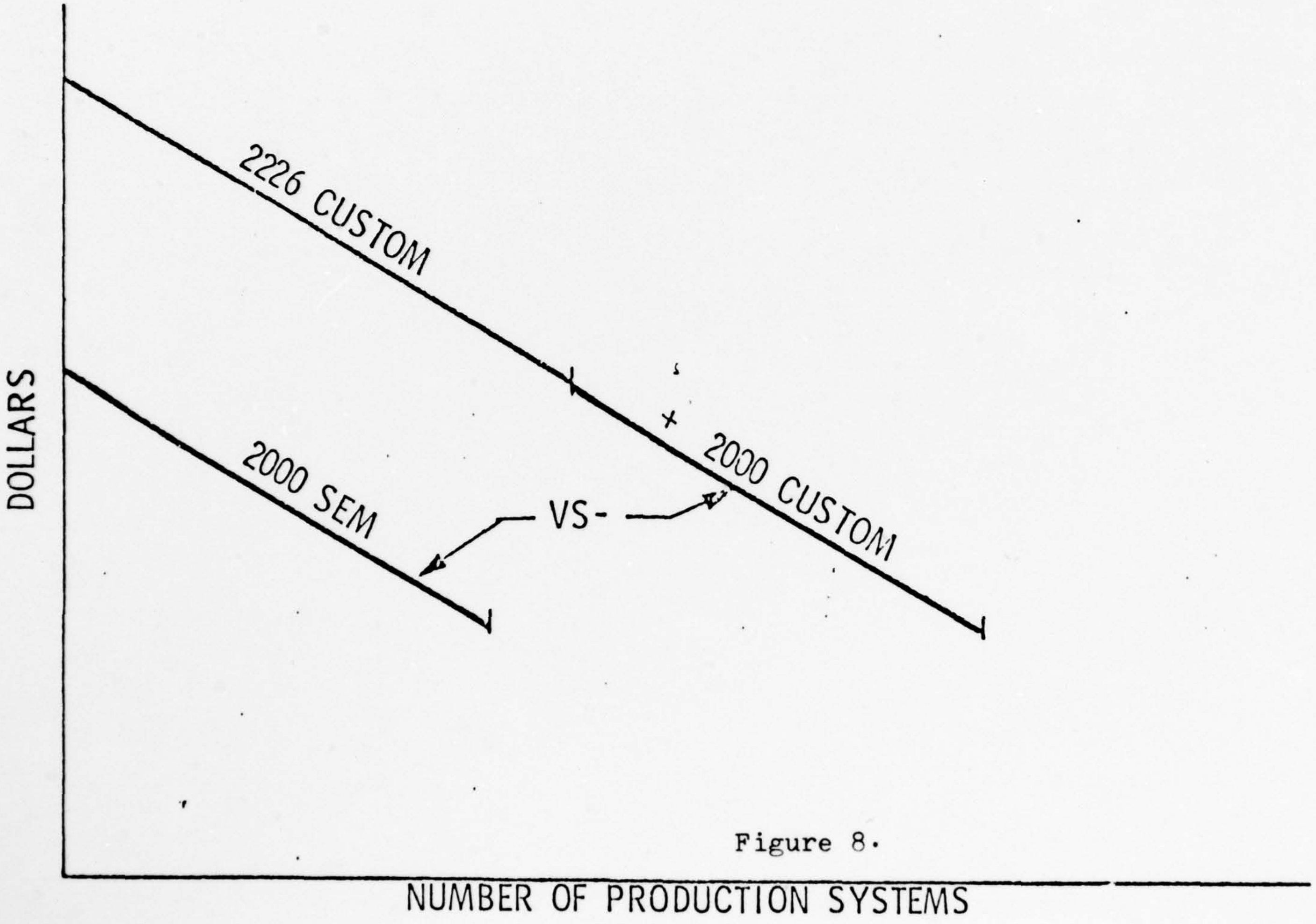

DOLLARS
2226 CUSTOM
+
2000 CUSTOM
2000 SEM
VS-
NUMBER OF PRODUCTION SYSTEMS

Figure 8.

- A detailed cost estimate for each area of variance was made for the two alternative systems.
- The calculations are then combined to give a cost summary .... (3-4.3)

The conclusion reached was that a $10.5 million savings (FY 76 dollars) could be realized through use of the SEM system over a 10 year life-cycle. Figure 9 is the complete cost summary. The possible cost savings to be realized as a result of commonality with other Naval systems was not considered.

While EG&G was developing the cost analysis just discussed, the Naval Weapons Support Center, Crane IN. was also conducting an alternative AN/ARN-84 study for the purpose of assessing the weight and cube impacts of the SEM system. The following presents pertinent technical comparisons for both the Existing TACAN (AN/ARN-84) and the SEM based TACAN:

	EXISTING TACAN	SEM
Size (in^3)	1211.39	1211.39
Weight (lbs)	46	52.09
Power (W)	302.5	303
Reliability (Hrs MTBF)	500	29,856

The study indicates that although the identical equipment cube was maintained and MTBF improved by a factor of 60, the weight can be expected to increase approximately 12%.

The Standard Modules Subpanel to the Electronics Panel, Defense Materiel Specifications and Standards Board was estab-

	FY-76 Dollars	
DOD Acquisition Cycle	Custom	SEM
• PROGRAM INITIATION:	Sunk	Sunk
• FULL SCALE DEVELOPMENT:	Sunk	
Systems Engineering		$ 150.0K
Module Development		$ 998.2K
Subtotal	Sunk	$ 1,148.2K
2 Hardware Systems for Test		$ 152.0K
Support & Services for Testing		$ 298.4K
Subtotal	Sunk	$ 450.4K
• PRODUCTION:		
Hardware	$43,520.0K ($21.76K ea)	$38,880.0K ($19.4K ea)
Support & Services		
• Module Spares	$ 1,092.3K	$ 41.3K
• Rotatable/Swing System	3,264.0K	$ 2,910.0K
• Other Support and Services	30,464.0K	$30,464.0K
Subtotal	$34,820.3K	$32,695.3K
• DEPLOYMENT OPERATIONS (only those costs where a variance exists)		
Replenishment Spares	$ 5,441.0K	$ 71.0K
Residual Value	-	($ 14.2K)
Subtotal	$ 5,441.0K	$ 56.8K
Total Program Cost 10 years	$83,781.3K	$73,230.7K
Savings (not escalated)	$10,550.6K	

Figure 9.

lished in February 1975 by the Assistant Secretary of Defense (Installations and Logistics). The purpose was to examine the merits, means and long range implications of more wide-spread use of SEM with emphasis on reducing production lead time, costs and proliferation of microelectronic devices. In their Final Report, the Subpanel listed thumbnail sketches of several studies which examined the technical and economic feasibility of implementing various electronic systems with SEM. In order to point out additional examples of areas being considered as possible SEM candidates the following are listed.

ANALYSIS OF THE TIME DIVISION DIGITAL MULTIPLEXER TD1069 (XE-1) /G IMPLEMENTED WITH SEM

This study, conducted for the Army Electronics Command by EG&G Inc., concluded that the SEM configuration would:

- Be accommodated within the existing volume.
- Be compatible with the specified operating temperature range.
- Match the weight of the existing design.
- Result in reliability improvement of 56,000 hour MTBF vs. 7,500 hour MTBF.
- Result in a life-cycle cost of $13.0 million vs. $21.2 million.

" The study concluded that this equipment would be an excellent candidate for SEM implementation, and the Army should seriously consider its implimentation." (4-10)

ANALYSIS OF THE AN/UYK-15 DIGITAL COMPUTER IMPLEMENTED WITH SEM

This study, also conducted for the Army by EG&G Inc., generated two separate SEM configurations for comparison with the existing AN/UYK-15 design. The first of these designs used existing SEM, while the second used new higher functional complexity SEM, with both configurations maintaining functional interchangeability. The results of the study were:

	AN/UYK-15	SEM	NEW SEM
Power Dissipation (W)	120	119.7	65.4
Weight (lbs.)	146.6	155	142
Reliability (Hrs-MTBF)	2800	6300	7300
LCC (Million $)	30.8	31.5	24.4

> "As illustrated, SEM can be an attractive alternative for the ground-based computer system, provided that new higher functional complexity modules are made available." (4-11)

ANALYSIS OF THE COLLINS 651S-1/1A GENERAL PURPOSE HF RECEIVER IMPLEMENTED WITH SEM.

This study, conducted for the Air Force Avionics Laboratory by EG&G, Inc., concluded that "although significant increases in reliability could be expected (7,500 Hr MTBF vs. 3,400 Hr MTBF), with a corresponding reduction in LCC (40 million vs. 62 million), the SEM design resulted in an increase of 30% in size with a probable increase in weight as well." (4-15)

ANALYSIS OF THE PRECISION APPROACH CONTROL CONSOLE OJ-333/GRN IMPLEMENTED WITH SEM.

This study, conducted for the Naval Electronic Systems Command, concluded that the SEM design "would require less volume (275 in^3 vs. 734 in^3), less weight (6.18 lbs. vs. 10.96 lbs.), result in improved reliability (66,850 Hr. vs. 5,773 Hr. MTBF), and lower LCC ($3.1 million vs. $6.7 million)." (4-16)

STANDARD ELECTRONIC MODULE RADAR (SEMR)

This work was performed for the Air Force Avionics Laboratory by the Naval Avionics Facility (NAFI). The objectives of the program were:

- To use SEM in the development and fabrication of an Air Force X-band radar system.
- To provide Air Force Engineers with experience in system and SEM design and fabrication.
- To evaluate the suitability of existing SEMs for avionics applications.
- To provide data inputs to aid in the definition of a standard avionics module.

SEMR is similar in performance to the existing APN-59, a weather/navigation/beacon radar system in wide spread use on cargo aircraft. Characteristics are:

Frequency - 9375 MHZ
Power - 60-100 KW
Pulse Width - 4,2.34 ms
PRF - 250,1000,2000 HZ

Preliminary conclusions are:

- Implementation of power supplies using SEM is initially too costly.
- Standard SEMR Modules are not readily available.
- Weight/volume of SEMR is approximately double the APN-59.
- SEMR program did not demonstrate a reduction in design/development costs.

SECTION V

SUMMARY AND CONCLUSIONS

Summary

This report has presented the salient features of the Navy's Standard Electronic Module program. In this section, those SEM features which appear to have impact potential in the area of electronic systems acquisition will be grouped under one of three headings and briefly summarized. These groupings are: Development/Production, Operation/Maintenance, and Logistic Support.

Development/Production

Dwindling financial resources and a long history of cost over-runs and long development phases in the acquisition of military systems has resulted in ever increasing pressures on the services to develop and produce future systems based on Design-to-Cost (DTC) and Life-Cycle Cost goals.

Cost over-runs happen for a variety of reasons, some of which obviously cannot be affected by the use of SEM. Many over-runs, however, have been brought about due to poor initial cost estimates or contractor buy-ins. Specifying SEM in the design of future systems can go a long way in correcting these deficiencies. Since the cost and reliability of the majority of the modules to be used is known in advance, program cost estimates can be made much more accurately. For the same reasons, acquisition managers will find it easier to identify artificially low contractor estimates.

Decreasing a system's development time benefits the program both in cost savings and in the achievement of an early Initial Operational Capability (IOC). Improvements in this area can be realized through the use of proven hardware, existing module designs, documentation, and vendors, and shorter lead times while enabling the developer to concentrate on over-all system design. Additional savings in time can be realized due to minimizing the problems ordinarily encountered in transitioning from the breadboard phase to the production phase.

Operation/Maintenance

Studies have shown that the largest single expense associated with the life-cycle of a given system is devoted to Operations and Support (O&S). In the case of an electronic system, the associated O&S costs are greatly influenced by the availability of the system. Availability is, in turn, a function of the reliability and maintainability aspects of the equipment in question.

That the proven high reliability of a SEM implemented electronic system maximizes availability is readily seen. Less apparent, however, is the equally important impact of SEM on system maintainability. Documented MTTR times in the neighborhood of 15 minutes are not uncommon for systems employing Built In Test Equipment (BITE) in conjunction with SEM. For example, even systems as large as the TRIDENT BQQ-6, which employs over 13,000 SEMs per unit, can be fault isolated down to one of 15 modules. Once the fault has been thus narrowed by the BITE, further trouble-shooting can be achieved by simple substitution using modules known to be good. Further cost savings are possible based on the opportunities for common test equipment, the throw-away-upon-failure concept, and the reduction in maintenance skill levels required.

Logistic Support

The lack of commonality among electronic systems has led to serious logistic support problems and costly investments in parts inventories. The widespread use of SEM based equipment could greatly simplify these support problems in a cost effective way since fewer items would be required in the parts inventory. Additional savings could be realized through the use of modules in the federal supply system, as well as multiple source availability. The throw-away-upon-failure concept negates the requirement for costly repairs, and the large percentage of SEMs common to multiple systems gives the modules residual value even after the system for which they were originally stocked is no longer operational.

Conclusions

There are many conclusions that can be drawn from, and supported by the data presented in this report. Those conclusions which appear to have the greatest potential impact on future electronic systems are summarized in this section.

- It has been established that the use of Standard Electronic Modules can result in reduced life-cycle costs and a decrease in the maintenance skill levels required.

This is predicated on the assumption that the SEM program will continue to utilize functional specifications to promote intersystem commonality and stringent quality control to ensure requisite high reliability.

- Although SEM appears to be applicable to many classes of electronic systems, it is not necessary to implement all portions of a given system with SEM.
- Weight and volume savings have been noted when implementing existing systems with SEM, however, an estimated 10-15% weight penalty can be expected for a SEM based system vs. a system of equal performance which utilizes state-of-the-art microelectronics. For this reason, SEM may have limited applications in airborne electronics where the designers may not have the option of accepting the weight penalty in order to realize the positive attributes of SEM.
- The use of SEM simplifies product improvement since emerging technology can be incorporated into existing equipment by updating the applicable modules rather than the entire system.
- Using the same technique, system reliability can be increased by improving the reliability of selected modules instead of redesigning the entire system.
- A deterrent to broader acceptance of SEM is a general lack of knowledge concerning the program.
- Another deterrent is that potential contractors prefer

to use their own custom module designs. This assures them of 10-15 years of continued business in support of each new system they field, a benefit they may not realize if they are required to design the system making maximum use of SEM.

SECTION VI

RECOMMENDATIONS

Based on the conclusions stated in the preceding section, the following is recommended:

- Acquisition managers of electronic systems should become aware of the SEM program and understand what program benefits can be achieved by its implementation in future systems.
- The Naval Material Command should take positive action to insure that approval to acquire all future electronic systems be contingent on receiving written assurance either: that the system is being implemented with SEM, or that system constraints make it incompatible with the use of SEM.
- OSD should take positive steps to coordinate and encourage a Tri-Service SEM program.
- The Defense Systems Management College should make future Program Managers aware of the SEM program by structuring one or more lectures around the concept.

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