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of the
Special Projects Office

Task II - Monitor and Sponsor the Fleet Ballistic Missile Development Program

37th Meeting - 23, 24 May 1963

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INTRODUCTION

The 37th meeting of the Steering Task Group was convened at 0910 on 23 May 1963 by Rear Admiral Levering Smith.

"First, I should like to welcome Dr. Kirchner of Aerojet-General back into our membership," said Admiral Smith. "Dr. Kirchner sat on the STG during the early days of our program; he was reassigned to the TITAN project for a time but happily he is now back with us. He replaces Dick Geckler, who is another of our original members that has been promoted off our Committee.

"Since our last STG meeting, we have had one special meeting concerned with developing a Program Change Proposal, or PCP, for over-all system improvements that would lead directly to a definite improvement in the CEP. We have put together the PCP from the reports and discussion of that meeting and forwarded it to the Navy Department. It has already been received there, but I have not asked what they are going to do with it. We will find out soon enough."

Admiral Smith then asked for changes or corrections in the minutes of the previous meeting. There were none, so the first speaker, Captain Dudley, was introduced for his presentation of the Command Communications Committee Report.

COMMAND COMMUNICATIONS COMMITTEE REPORT DISCUSSION

"The actual coverage," began Captain Dudley, "will be a quick runthrough of the entire communications area with many illustrations. If you do have technical questions, I will be very willing to answer them but, if I tried to cover the technical aspects of the program, I am afraid we would be here all day.

"In figure 1 we have a simple statement of exactly what we have to do in command communications. Figure 2 indicates the relative span of conditions under which we are expected to carry out the communication mission, ranging from the present non-jam conditions to the physical destruction of shore facilities. In all this, we are expected to get the message through under prevailing conditions.

OPERATIONAL REQUIREMENTS
PROVIDE POSITIVE AND IRREFUTABLE COMMUNICATIONS TO SSB(N)'s UNDER A SPECTRUM OF COMMAND-CONTROL COMMUNICATIONS THREATS VARYING FROM NON-JAM (EXISTING) TO THE JAM AND SURVIVABLE ENVIRONMENT.

Figure 1

"Figure 3 indicates the various postures in which our submarines are operating, working from periscope depths with an exposed antenna to the acoustic systems which may be the only method when the submarine is deeply submerged. The trailing wire and towed buoy represent the gradual restriction of the communication freedom enjoyed at periscope depth. Note that ELF is not presented on this illustration; under ideal conditions, I think ELF could be received in all four of those submarine postures.

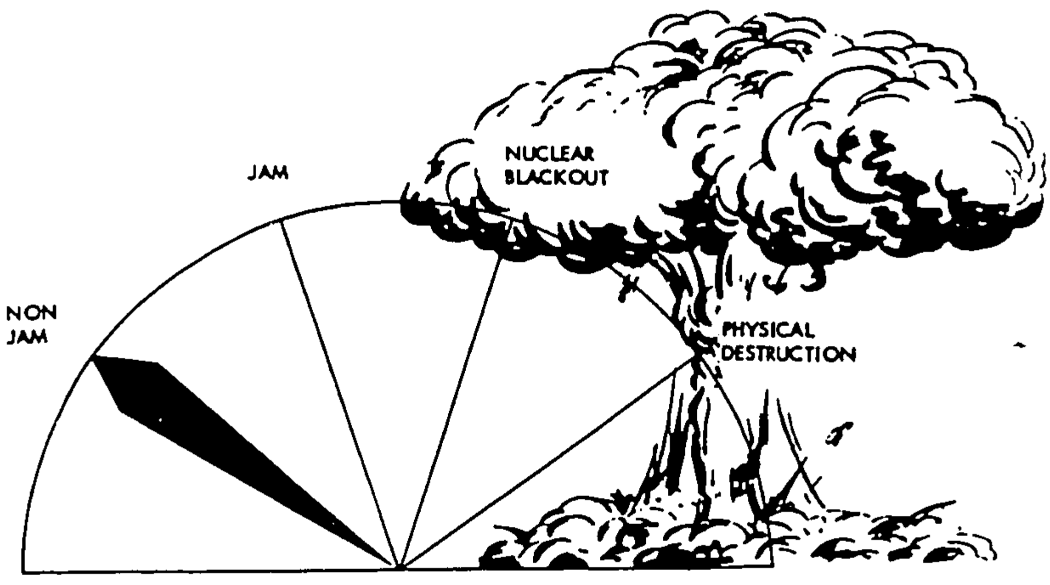


Figure 2

"Figure 4 indicates both the structure of our office and the breadth of our activities in these communication areas. The various blocks SP2042 to 2048, indicate the six general areas of research and development. Under SP2042, we have a number of programs that I cannot discuss, unfortunately, as well as some programs which represent improvements on our present systems. Under SP2043, there is a buoy-improvement program and the development of the BRA-15 and BRA-16. SP2044 covers the EXTREMIS or SECT program for equipment to be used by submarines to signal their destruction or sinking.

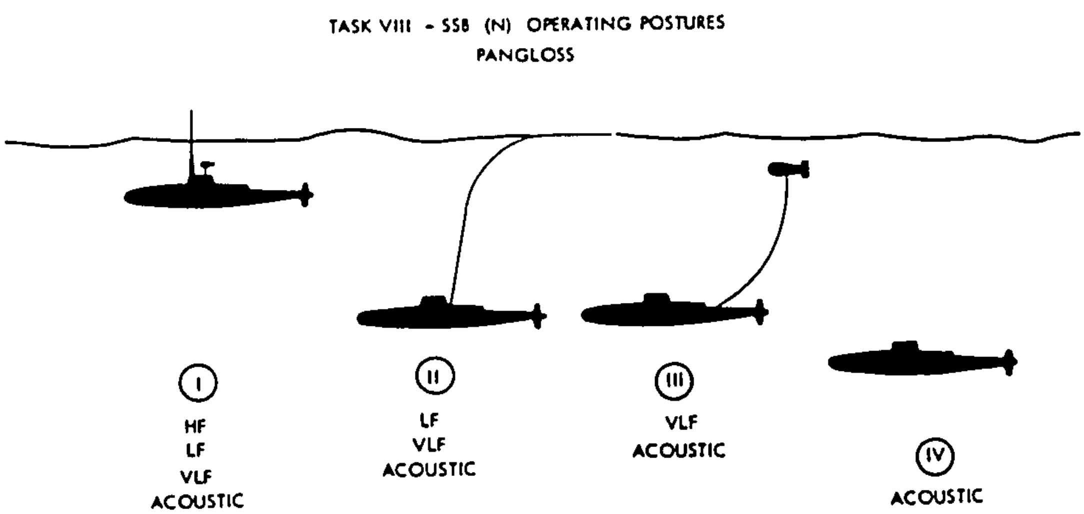


Figure 3

"The Shore-Ship efforts under SP2045 cover survivable shore systems, anti-jam efforts and ELF or Task IX work."

Admiral Smith asked how the SECT program would fit with the statement of figure 1, and Captain Dudley explained that the communications with the submarine carried the implication of two-way communications rather than simply getting messages to the submarine.

COMMAND COMMUNICATIONS

PLAN STRUCTURE 204

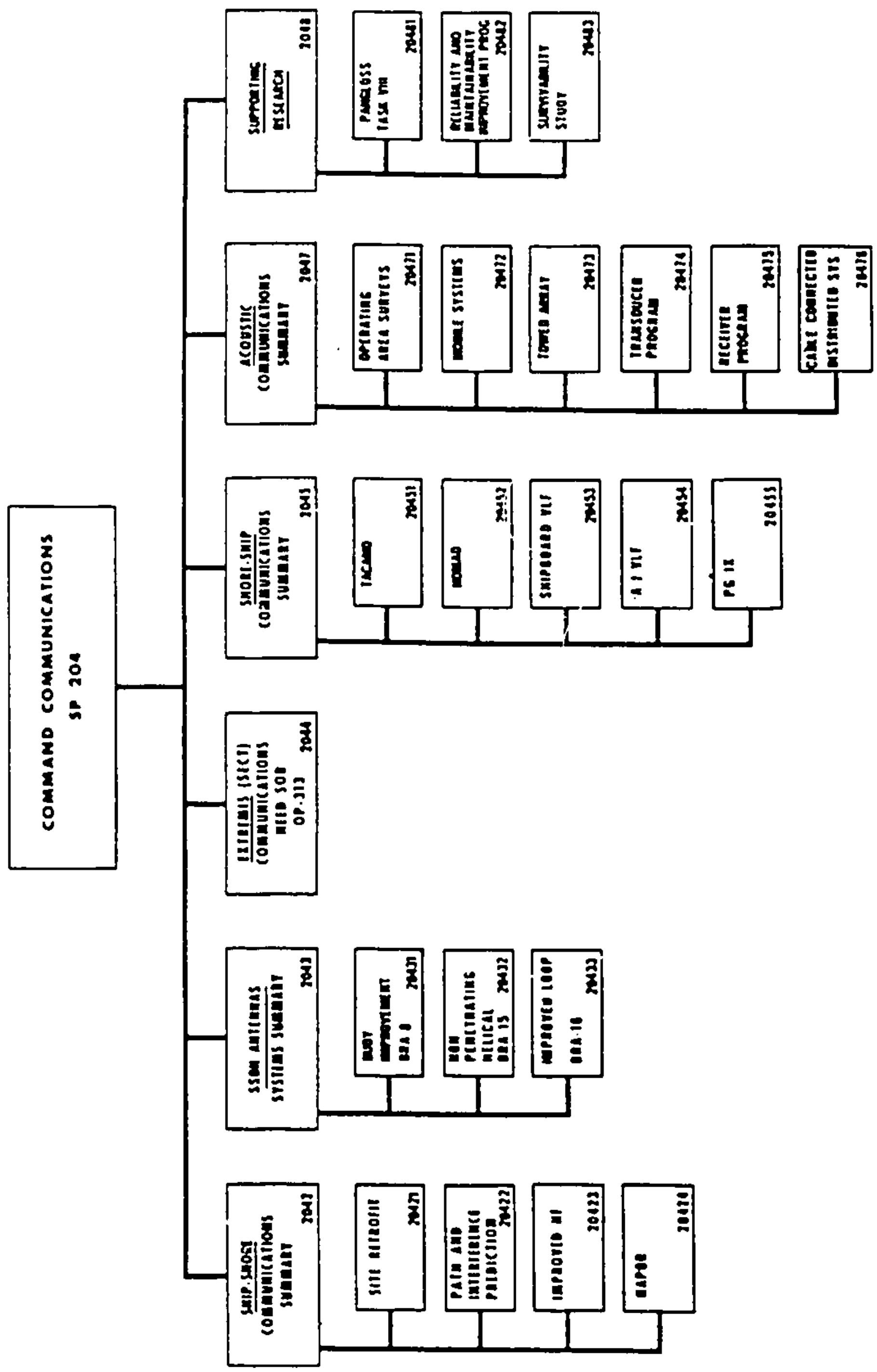


Figure 4

"The final column," continued Captain Dudley, "covers the acoustic projects. We do have an acoustic system which we are testing right now in some long range efforts, and we have research and development going on in many areas.

"Figure 5 suggests that Ship-to-Shore communications is in great part a security problem. It goes without saying that we cannot let the enemy fix a submarine's position by DF or radio intercept. Much of this program is classified on a strict Need-to-Know basis for just those people who are actually involved in it.

SHIP - TO - SHORE

GOAL: TO PROVIDE SSB(N)'s WITH A RELIABLE RETURN COMMUNICATION LINK.

OPTIMIZE FREQUENCY SELECTIONS.
PREVENT LOCALIZATION OF THE SUBMARINE.
MAINTAIN CRYPTO SECURITY.

Figure 5

"We recently received a proposed technical approach from BuShips which relates to this entire area, and we tried through CNO to get permission for our Ship-to-Shore panel to make a study of it. Permission was granted, but just as we were ready to meet with them to give a presentation, the permission was rescinded. They felt we were letting out too much information about the entire area of Ship-Shore communications.

"Our present efforts include up-grading existing facilities, like HARE. We are working on better frequency prediction ability, and an improved high frequency system which may be several years off. We are also working on satellite systems and we are hoping to have a satellite system feasibility demonstration within a year.

"Figure 6 defines our goals in the antenna area where we have committed ourselves to increasing the strength, efficiency, and sensitivity of the antennas while developing some steerable null antenna systems. The four major areas of our concern with antennas are illustrated in figure 7 which shows the various types, either presently in service or in development. Figure 8 shows how and where the basic antenna systems would be installed on the submarine. The helical antennas, while they are not shown, would be similar to the basic whip antenna in terms of their appearance and installation.

ANTENNAS

GOAL: TO PROVIDE SSB(N)'s WITH AN APPROPRIATE SYSTEM OF ANTENNAS THAT WILL OPERATE RELIABLY UNDER ALL WEATHER CONDITIONS.

INCREASE PHYSICAL STRENGTH.
INCREASE POWER CAPACITY.
INCREASE SENSITIVITY.
PROVIDE STEERABLE NULLS.

Figure 6

"A detailed summary of our work with VLF buoys, given in terms of the buoy characteristics, is shown in figure 9. We are currently working working on an electronic package to add to the present BRA-8. In general, these systems represent the best we can do with deep-submergance operation.

ANTENNAS

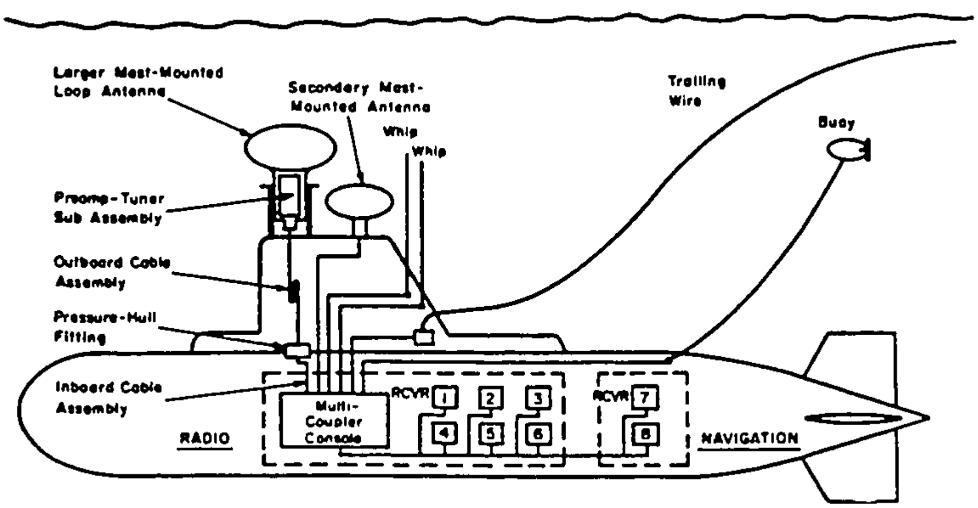
INTRODUCTION

SPECIAL PROJECTS OFFICE IS PRESENTLY CONCERNED WITH FOUR SEPARATE TYPES OF "ON-BOARD" SSB(N) ANTENNAS. THESE ARE GROUPED AS FOLLOWS:

1. TRAILING UNDERWATER BUOY
   *BRA-7, BRA-8, BRA-8 MODIFIED
2. TRAILING FLOATING WIRE
   *BRA-18, BRA-18A
3. SAIL MOUNTED LOOP
   *AT-317-B, BRA-16
4. SAIL MOUNTED HELICAL
   *BRA-9, BRA-15

*DENOTES MODEL ALREADY IN OPERATION

Figure 7



PICTORIAL REPRESENTATION OF VLF ANTENNA SYSTEM NETWORK

Figure 8

VLF BUOY CHARACTERISTICS						
BUOY SYSTEM	Used on SSB(N)	Maximum Usable Depth	Frequency Range	Sensitivity Ref. to AT-317 B/BRR	Max. Buoy Depth for Good Reception	REMARKS
BRA-7	598 Class	700' at 3 Knots	14-35 Kcps	+ 15 db Avg.	30-35' Max.	Buoyant Lift Vehicle with Little Dynamic Lift Characteristics, Circular Fin on Buoy. Telephone Type Switching Provides Antenna Tuning in Buoy
BRA-8	608 Class 616 Class	C 3 Knots C	14-35 Kcps	+ 15 db Avg.	30-35' Max.	Buoyant Lift Vehicle with Little Dynamic Lift Characteristics, Crossed Fins on Buoy. Larger Than BRA-7 with Increased Lift and Deep Dive Capabilities. Improved, Redundant Antenna Tuning Switching Matrix
BRA-8 (IMP.)	SSBN 632 Backfit 608 616 Classes	3 Knots	4-150 Kcps Usuable to 600 Kcps	+ 20-22 db Avg.	30-40' Max.	Includes L. F. and LORAN Capability. Remote Pre-Amplifiers in Buoy-Redundant Channels with Fail-safe Provisions.

Figure 9

"One of the original problems with the VLF buoy was concerned with an exploder device for sinking the buoy should it become inoperative, loose from its cable, or if the buoy should suffer an antenna short. We had troubles with this -- the exploder device would operate when the submarine surfaced and it could have blown when the submarine was dockside. The major problems have been solved.

"The performance of the VLF buoys in terms of depth versus speed can be seen in figure 10. The predicted performance curve relates to material and mechanical limitations and cable fatigue. We have seen some trouble with the nesting arrangements where the doors fail to open to allow the buoy to be ejected from the submarine or where the doors close upon the cable when the buoy is being streamed. We have had problems with weakened cables due to shock loading, kinks, flooding out and shorts. We have had problems with the winch in controlling tension on the cable and the destruct problem I mentioned earlier.

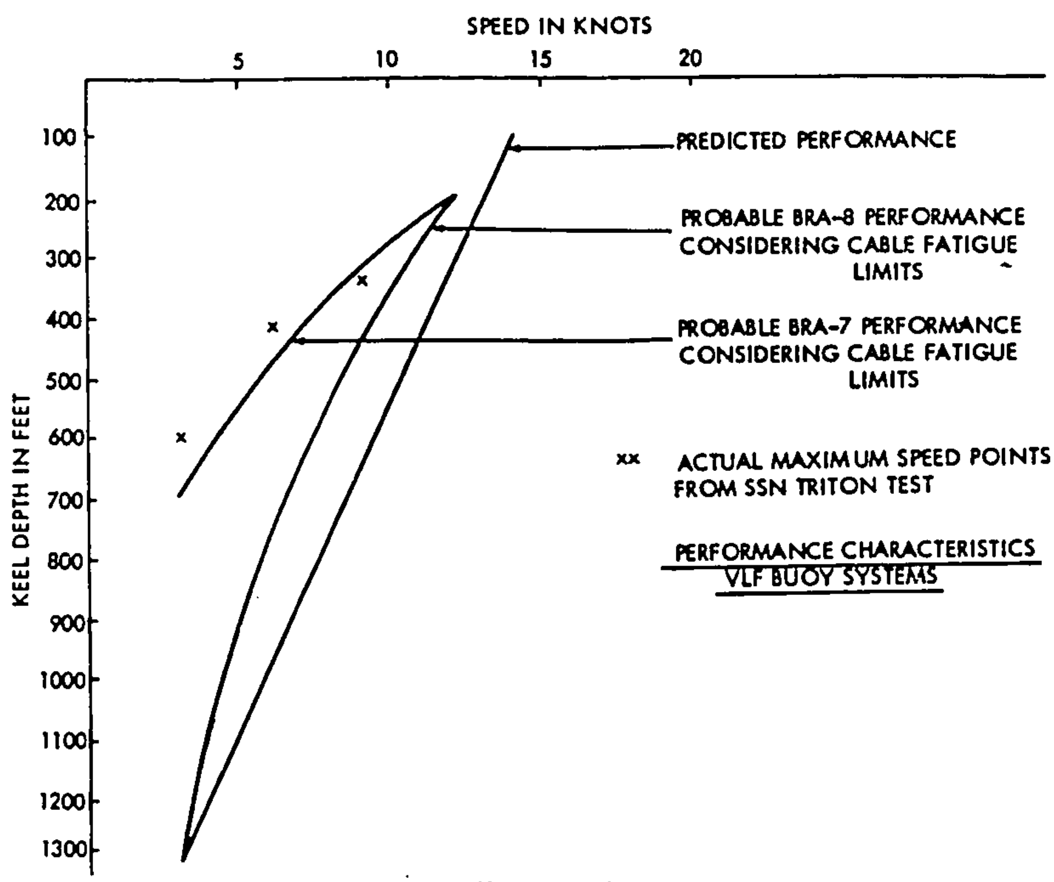


Figure 10

"These problems have been about 99 per cent solved, but the biggest problem remaining is that the submarines do not use the buoy nearly as much as they did previously. This may well be due to the very unsatisfactory early history with the buoys, but I am also sure that the excellent performance now being obtained with the trailing wire explains the disuse of the trailing buoy.

"In figure 11, we have comparable information for the floating wire VLF antenna. According to the reports, it is our most popular antenna, being used about 60 per cent of the time. It is effective at the lower speeds, two to three knots, and works well in an area of ice caps and bergs. It has an inherently low reliability which is offset by its high repairability and the availability of spares, of which the SSB(N)'s carry at least two or three. Such problems as it has seen have been mechanical rather than electrical.

FLOATING WIRE VLF

	RECEPTION	SPEED - DEPTH
SUBTASK I		
TIP GROUNDING AERIAL VISIBILITY INSTRUCTION MANUALS	10-300 KC VLF, LF, LORAN C RECEIVE ONLY	120 FT. AT 9 KTS 300 FT. AT 2.3 KTS FOR 1800 FT. OF WIRE
SUBTASK II		
DOUBLE WIRE STRENGTH FOR SUBSTANTIAL INCREASE IN MEAN TIME BETWEEN FAILURES PROTOTYPE IN EARLY 1964	10-300 KC VLF, LF, LORAN C RECEIVE ONLY	120 FT. AT 13 KTS 300 FT. AT 2.3 KTS
SUBTASK III		
BROADBANDING PROCUREMENT MID 1964	10 KC - 30 MC VLF, LF, LORAN C, MF, HF RECEIVE ONLY	SAME
SUBTASK IV		
BUSHIPS FUNDED TRANSMIT MF/HF PRODUCTION MID 1965	VLF,LF, LORAN C, MF, HF TRANSMIT AND RECEIVE	SAME
SUBTASK V		
LIFT DEVICE TO INCREASE KEEL DEPTH FOR GIVEN LENGTH OF WIRE PROGRAM START LATE 1963	SAME	?

Figure 11

"The submarine cannot go below 300 feet even when it is streaming 1500 feet of wire, and this is a limitation that we hope to modify by changes in the buoy which will allow a little deeper keel depth. Another problem is the tendency of the long wire to limit maneuverability, to be susceptible to drift, and to be very difficult to recover rapidly should the submarine have to move out in a hurry for any reason. When the submarines are forced to maneuver, they must must make turns that will avoid cutting the wire. This happens often enough to warrant carrying spare wires.

"The sub-tasks of figure 11 cover the improvements being made in the whole area. Improving the tensile strength of the wire from 400 to 900 pounds will reduce the breakage and loss of wire. We are extending reception range and working on a system for MF and HF transmissions from the antenna. We found most of the breakage to occur in the 50 or 75 feet area and we think that we have corrected that.

"In figure 12, the dotted line shows the strength of the wire. I think this chart also shows the problems involved in speed and that longer wires will increase depth, but the speed at any maximum depth remains at about two knots.

"Incidentally, we have observed one problem with the trailing wires that was not anticipated. When the wires are recovered, we have been finding that they are very slimey and that the slime needs to be removed with scouring powder to prevent interference when wire is streamed out or taken in.

"The loop antennas are covered in figure 13. At present, the AT-317B is the only one used and installed on all our submarines, but it has only limited usefulness. Sharp tuning is essential for good signal sensitivity, and the antenna patterns are fixed relative to the axis of the submarine. The BRA-16 allows us to go a little deeper. The new antenna is larger in both length and diameter, and it increases the drag almost twofold. It needs a 20-foot retractable mast which has certain bending moment limitations where we mistakenly thought we would have trouble.

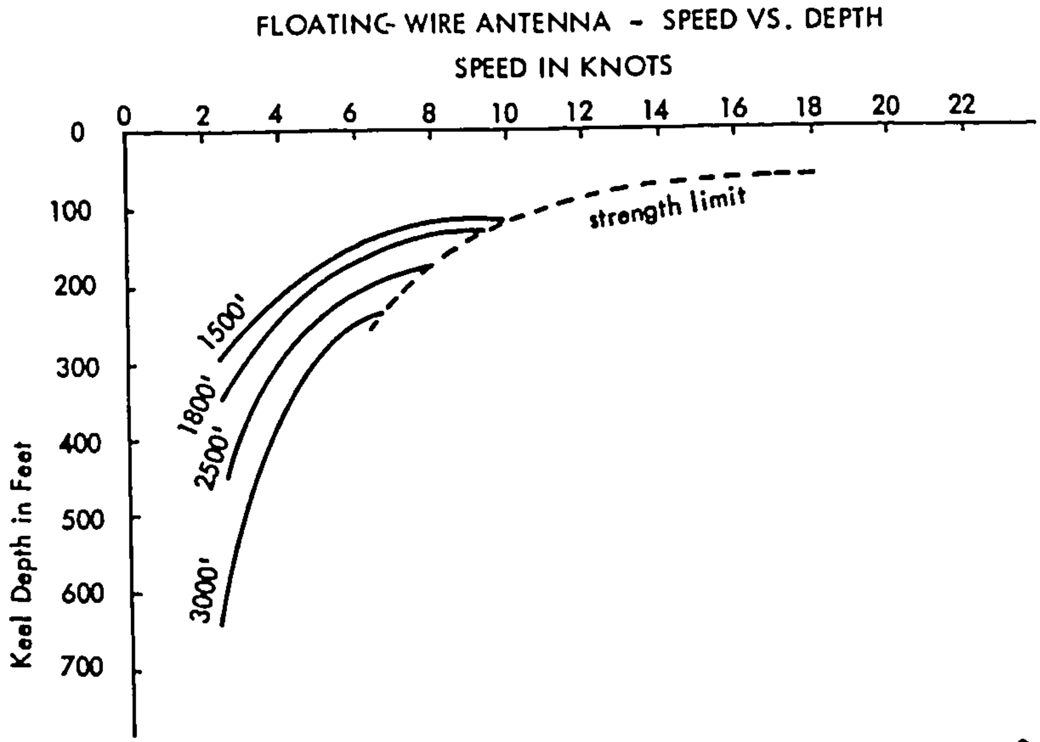


Figure 12

SAIL MOUNTED LOOP VLF

	RECEPTION	SPEED - DEPTH
AT-317B/BRR PRESENTLY ON ALL SSB(N)'S LATER AS BACK-UP FOR BRA-16	14-35 KC TUNED	110 FT. ALL SPS. NORWEGIAN SEA
BRA-16 AVAILABLE IN LATE 1963	14-35 KC TUNED 8-135 KC BROAD IMPROVED, FLEXIBLE MULTI-COUPLER LIMITED ANTI-JAM 5 TO 1 CONDENSATION OF EQUIPMENT SIZE	120 FT. ALL SPS. NORWEGIAN SEA

Figure 13

"But this new antenna has 15 db greater signal sensitivity than the old one. The electronic package at the antenna cuts down cable losses and greatly increases sensitivity.

"We do feel that there is little possibility of maintaining this level of VLF reception with this type of antenna at depths much greater than those presently used. We would like to have at least 150 feet, but this will probably require another type of antenna system.

"Among the other improvements in the BRA-16 is the ability to change antennas and to shift frequencies rapidly, which will be a great aid to the operators.

"The sail-mounted helical HF antennas are shown in figure 14. We are now using the BRA-9 on the submarines and we will be using the BRA-15 once it comes into production. The original helical antennas were disappointing both in their failure rates and in their performance. The BRA-9, which replaced the original WRA-2, has done much better even though it is plagued with hardware problems largely due to corrosion. The on-station reliability has been quite good.

SAIL MOUNT HELICAL HF

	RECEPTION	SPEED - DEPTH
BRA-9 PRESENTLY ON ALL SSB(N)'S LATER AS BACK-UP FOR BRA-15 "NON-PENETRATING" TYPE (UNPROTECTED LEADS)	2-30 MC 4 TO 1 STANDING WAVE TRANSMIT & RECEIVE	EXTENDED ABOVE SURFACE FOR OPERATION.
BRA-15 1 UNDER TEST ON SSB(N) 617 PRODUCTION EARLY 1963 "NON-PENETRATING" TYPE	2-30 MC 2 TO 1 STANDING WAVE TRANSMIT & RECEIVE	EXTENDED ABOVE SURFACE FOR OPERATION

Figure 14

"The BRA-15 is a non-penetrating antenna. We developed a penetrating version of it which we discarded, but lately the British have evinced some interest in that one and have asked to borrow the one built so they can run their tests with it. The penetrating type has certain advantages in that it can be repaired during patrol, if needed, because you have access to it. In performance, the two types are almost identical. We feel that the penetrating type may bring with it more problems than can be repaired easily at sea -- mechanical difficulties more than anything else. Possibly the British tests will be more revealing about the value of the penetrating type.

"The summary in figure 15 needs very little explanation save to note that from the data it would appear that one of these days we may not need a VLF buoy. I think the mean-time between failure figure is particularly interesting.

RELIABILITY OF SSB(N) INSTALLED ANTENNAS

Antenna System	Number of Patrols Analyzed	Number of Hours in Usable Condition	Number of Failures	MTBF HR	MTTR HR.	Per cent of Time Used on Patrols	
Recoverable Floating Wire	29	27,600	26	1060	9.2	66.3	Average of 3 Wires Carried on Each Patrol
BRA-7 or BRA-8 VLF Buoy			24	2040*	Not Repairable	21	Data is very Sparse *Based on an Extrapolated Data Curve
AT-317 B/BRR Retractable Mast	25	33,000	3	11,000	Not Repairable	12.1 (Both Loops)	
Manual (Emergency) AT-317 B/BRR	25	36,000	3	12,000	Not Repairable	12.1 (Both Loops)	
BRA-9	13	17,000	1	17,000	Not Repairable	0.6 (For VLF Reception)	Normally Used for H. F. Transmission

Figure 15

"Figure 16 covers the actual availability of the floating wire on a 60-day patrol. Again, the slide is self-explanatory.

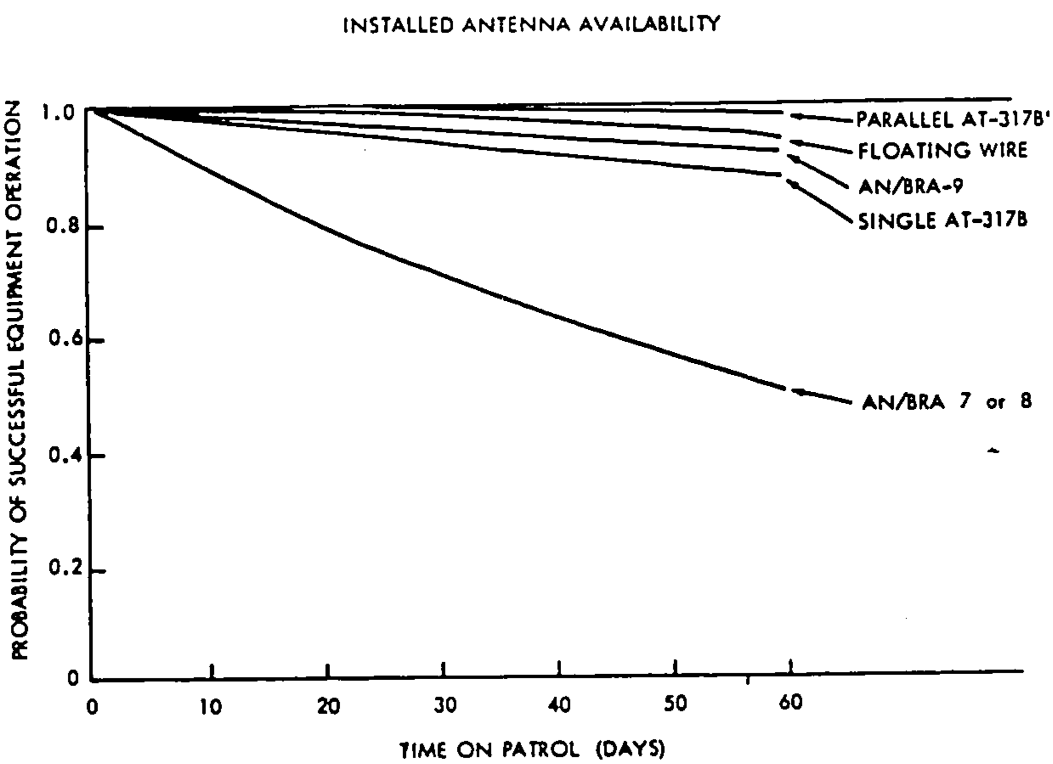


Figure 16

"Figure 17 gives the speed versus depth figures for the VLF antennas. The VLF loop is straight across the board at 120 feet. We feel we can improve the trailing wire by adding a buoy with a 100-foot stream of trailing wire behind it.

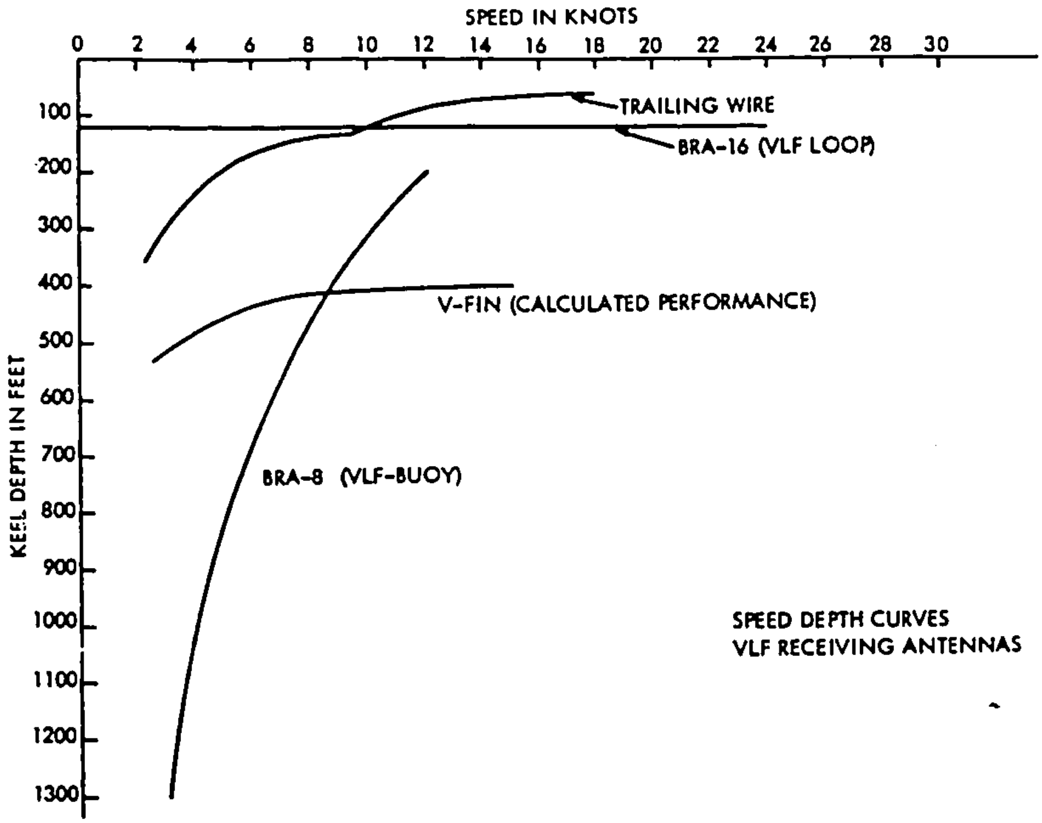


Figure 17

"We are not completely satisfied with all the antennas and we have been looking ahead to figure out new ones. We had one interesting idea that we thought might prove to be successful; this was called our electron spin resonant antenna. It was a rather new development involving flux concentrators and signal levels down in the order of 20 gausses. It required a reliable system involving the need for stable oscillators which are not presently available and are not within the present state of the art. It involved having temperature control capability which was quite beyond what we have now.

"We looked into this, and our best experts told us that this might be something that might be working ten or twenty years from now; but it was completely beyond our capability at the present time.

"The claims for depth indicated that we could have gone down something in the order of another 50 or 100 feet. We looked into it, and actually found that what was being proposed was nothing new. It was something that had been known for some 10 or 15 years but still remains completely beyond our capability. It was actually working down where the noise level of the submarine itself would have been a considerable hazard. A man passing with a screwdriver in his pocket could have upset the whole system just from the change in the magnetic field that he would have caused.

"Our EXTREMIS program, figure 18, would provide the operational commander with a reliable and prompt notification of the loss of a submarine on station. This program would include automatic initiation and would insure message delivery, minimize false alarm probability and include automatic sequencing capability.

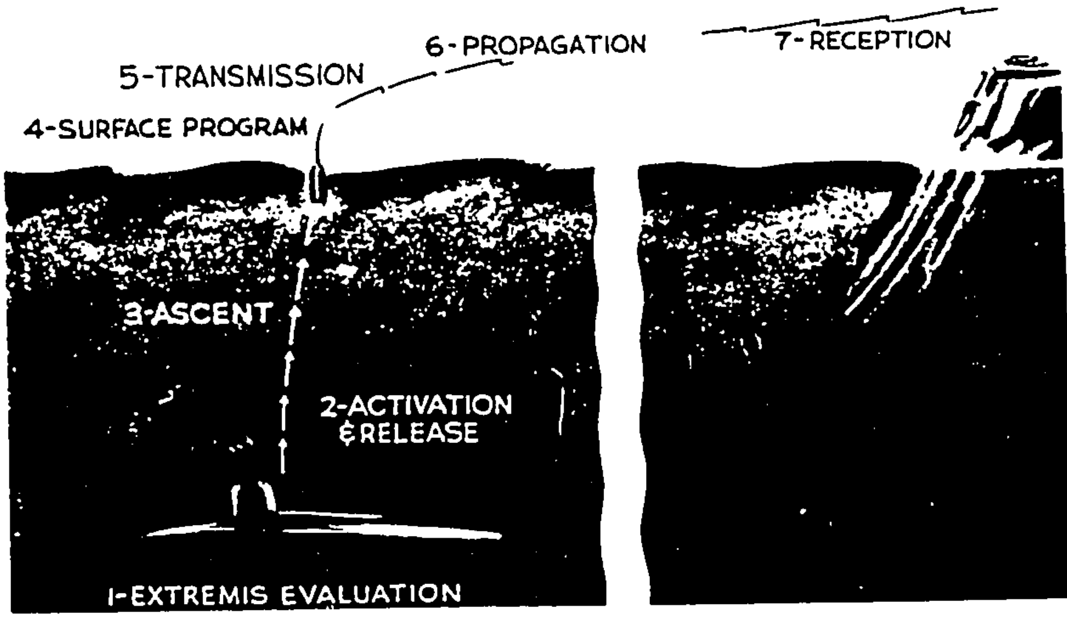
EXTREMIS

GOAL: TO PROVIDE THE OPERATIONAL COMMAND WITH RELIABLE, PROMPT NOTIFICATION OF LOSS OF A SUBMARINE ON STATION.

PROVIDE AUTOMATIC INITIATION.
INSURE MESSAGE DELIVERY.
MINIMIZE FALSE ALARM PROBABILITY.
INCLUDE AUTOMATIC SEQUENCING.

Figure 18

"In figure 19, we have pictured a situation of the EXTREMIS nature involving a submarine which has had trouble and goes to the bottom or is for some reason unable to come to the surface. He releases a buoy which then transmits a message which is then received by the operational commander and advises him that he no longer has the capability of that particular SSB(N).



SUBMARINE EMERGENCY COMMUNICATION TRANSMISSION SYSTEM
Figure 19

"This system basically consists of two buoys with the release mechanism contained in nests external to the pressure hull but within the superstructure envelope. An additional buoy is stowed in the torpedo tube. In each buoy there are three high frequency radio transmitters, each having keying, tuning, coding and power supplies. We have an independent releasing activating device with the control panel which can be worked either manually or automatically to release the buoys. There is a pressure sensing device which supports the automatic release mechanism. The release of the two external buoys is accomplished by the functions of a control panel located at a central point in the submarine. In the event of a casualty, the senior person remaining may activate the system by depressing the push button systems in a prescribed sequence. If the internal buoy were to be used, it would be manually ejected through a torpedo tube. When there are no survivors, the external buoys are released automatically; an indicator timer must be reset periodically by ship personnel to prevent this automatic release of the buoys. This automatic buoy release will also occur if the submarine exceeds its test depth by some predetermined amount. This depth release is activated by a highly damped pressure sensing device which responds to excessive static pressures, and not to short pulse pressures. In other words, depth charges or something of that nature will not release the device.

"Actual activation takes place at the cradle of the external buoys through the use of an explosive bolt fastening mechanism and spring booster which permits ejection with the assurance of clearing the ship's structure. The ejected buoy surfaces, erects the antenna, and transmits an _in extremis_ message. This short code SECT message imposes radio silence. It will identify the submarine, the message, and the addressee, and establish priority; it can include a one-letter-inserted-message, and is transmitted in 35 seconds. This message is repeated five times at the rate of 20 words per minute on each of six frequencies. This makes a total of 30 transmissions during each transmission period. After completion of this 18-minute 6-frequency sending cycle, this buoy remains silent for about 54 minutes before it starts transmitting again, and this program repeats for about 72 hours until the batteries are exhausted.

"The physical configuration of this buoy is about 84 inches long, 15.5 inches in diameter, and weighs about 500 pounds. It is constructed of high strength steel reinforced to resist the static and shock pressures that might be anticipated.

"The present program has been speeded up recently and we now plan on actually starting on the SSB(N)627 installation in late 1963. Our major problem is the actual manufacture and installation of the cradle on the submarine. The electronics are pretty well along. We are going to have the actual test of the buoy with electronics this summer being conducted by OPTEVFOR. Our backfit program we hope to start on the 598-Class by backfitting in mid 1964. Our first operational use will be actually on the SSB(N)627 in about October 1964.

"The external installations on the submarine are positioned well forward and aft so that both of them would not be damaged by a close depth charge explosion. Because the buoys are faired into the hull to reduce the noise possibility, it is a shipyard job to install them. The earlier ships could accommodate the torpedo tube buoy without any major change, as this device is designed to fit a standard tube and needs only manual insertion into the tube. The wiring and controls for the automatic release could be done during overhaul. The devices are being designed by Aerojet and the electronics by Collins Radio.

"Figure 20 covers our Shore-to-Ship where we are trying to extend the coverage of our shore based capabilities. We are trying to combat jamming, provide survivable transmitter facilities, and minimize the depth-speed constraints that we have on our submarines.

"Figure 21 illustrates the efforts under development at the present time. We have our three transportable VLF mobile systems -- TACAMO, NOMAD, and shipboard VLF -- which were developed under an SOR directing us to provide survivable VLF stations. The airborne TACAMO is basically a long wire coming out of an aircraft with transmission from 14 to 30 kc using a 25-kw transmitter. NOMAD and shipboard transmitters are 100-kw transmitters, operating at 15-30 kc. The Task IX, or ELF, program transmits at frequencies of 50 to 100 cycles per second Finally, the anti-jam program that we are promoting is BEDROCK II.

SHORE - TO - SHIP

GOAL: TO PROVIDE POSITIVE COMMAND COMMUNICATIONS FROM CONUS TO SUBMERGED FBM SUBMARINES IN ALL OPERATING AREAS, WITH A MINIMUM CONSTRAINT ON THE SUBMARINE.

EXTEND COVERAGE.
COMBAT JAMMING.
PROVIDE SURVIVABLE TRANSMITTER FACILITIES.
MINIMIZE DEPTH SPEED CONSTRAINTS.

Figure 20

SHORE - TO - SHIP

UNDER DEVELOPMENT

A. TRANSPORTABLE/MOBILE VLF AIRBORNE (TACAMO) TRANSPORTABLE (NOMAD) SHIPBOARD	SOR: PROVIDE SURVIVABLE VLF STATIONS
B. TASK IX ELF	ADO: PROVIDE SURVIVABLE GLOBAL COMM. SYS. CAPABLE OF BEING RECEIVED WITH HULL-MOUNTED SENSORS AT DEPTHS OF 1,000' AND AT A RANGE OF 10,000 MILES.
C. A/J BEDROCK II	

Figure 21

"Shipboard and airborne survivable communications, shown in figure 22, are systems which can be moved about and still transmit at the same time. Our transportable is a shore based system which must be moved to a location, set up and then put in operation. This work requires about four hours to complete. Our airborne TACAMO operational date was met with an R&D unit which has been successfully tried out. We are going into production and hope to have one unit operational in December of this year and three more in 1964. Regarding the transportable NOMAD, we hope to have one unit in 1964 and two in 1965. For the shipboard VLF, we hope to have one unit in 1964 on the CC-3 and a second one in 1965 on the CC-2.

THE VARIOUS ELEMENTS OF THE SURVIVABLE COMMUNICATIONS CURRENTLY DELINEATED BY OPNAV ARE AS FOLLOWS:

1. MOBILE. (A VLF COMMUNICATION SYSTEM WHICH CAN BE MOVED FROM ONE LOCATION TO ANOTHER WITHOUT INTERRUPTING ITS TRANSMITTING CAPABILITY.) THESE INCLUDE:
   A. SHIPBOARD
   B. AIRBORNE
2. TRANSPORTABLE. (A VLF COMMUNICATION SYSTEM WHICH CAN BE MOVED FROM ONE LOCATION TO ANOTHER BUT CANNOT TRANSMIT IN TRANSIT.)

OPERATION DATES

	1962	1963	1964	1965
AIRBORNE	1 UNIT (R & D)	1 UNIT	3 UNITS	
TRANSPORTABLE			1 UNIT	2 UNITS
SHIPBOARD			1 UNIT (CC-3)	1 UNIT (CC-2)

Figure 22

"Figure 23 shows the TACAMO. We realize much better transmission efficiency by utilizing the vertical mode. The operational concept requires that the aircraft take off when directed, proceed to the designated area which may be directly overhead, and start transmitting while flying a tight circle. We realize about 50 per cent efficiency when the wire is vertical and get about 12 to 15 kw output. In the horizontal mode, we only get about 4 kw output. For both flight patterns, the length of wire used is about 25,000 feet. This program is proceeding with no particular problems at the present time.

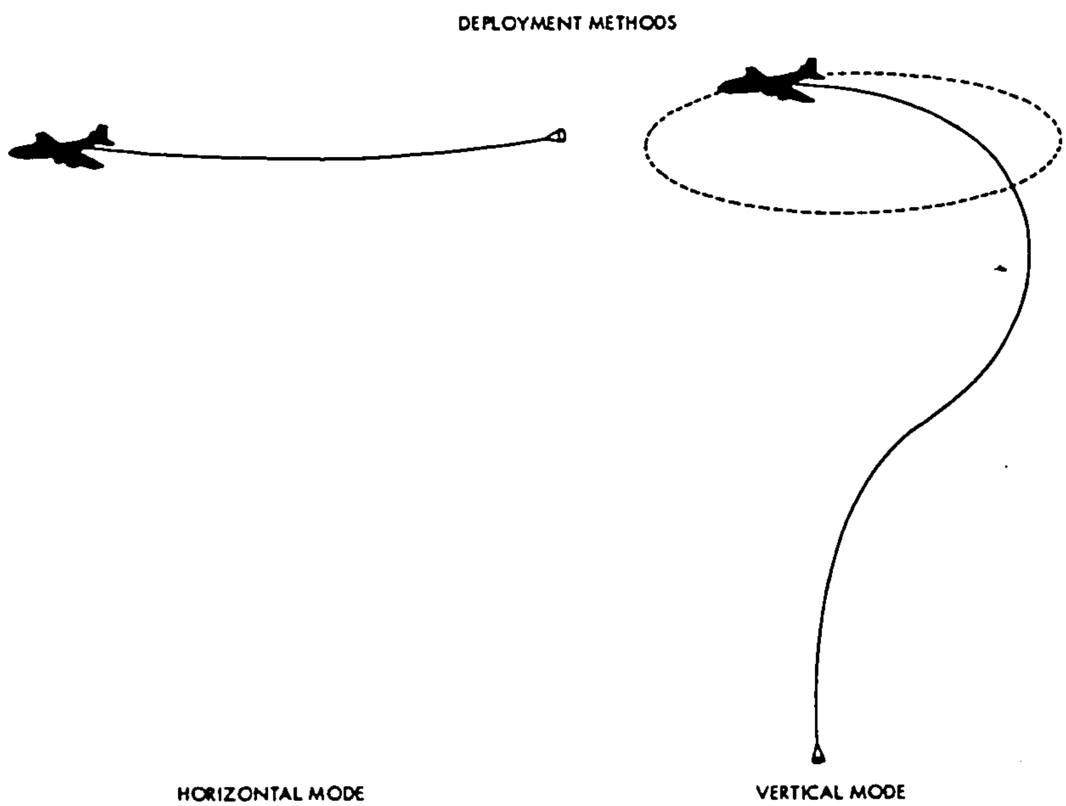


Figure 23

"Figures 24 and 25 show the equipment used in the NOMAD system. The unusual V-shaped balloon was developed for us by Goodyear Rubber and will be undergoing tests this summer. The length of each balloon section is about 100 feet and the design permits the best use of aerodynamics in launching and handling. Supporting the equipment in the balloon are about 12 vans fully loaded with transmitting equipment, helium gear, balloon handling gear, and the components of the wind-screen which is placed around the launch site to provide ease in handling.

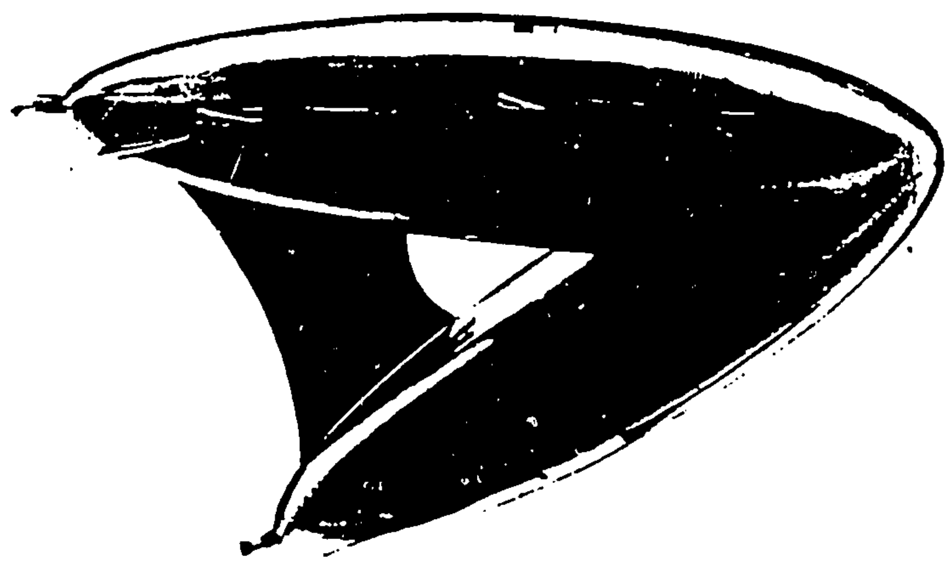


Figure 24

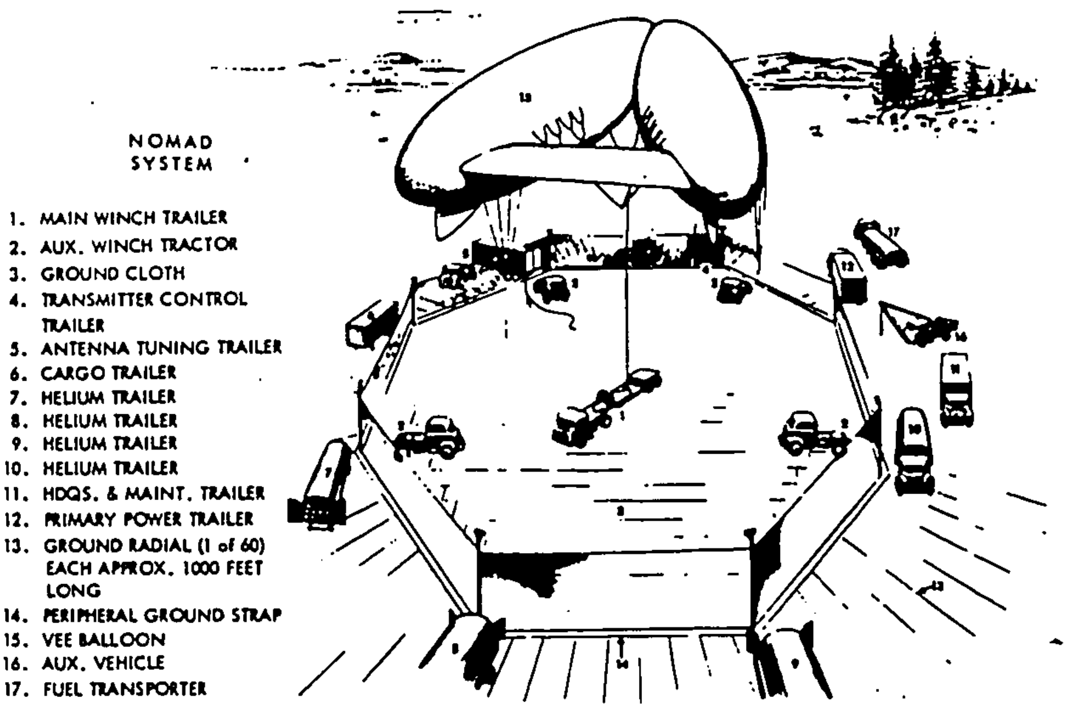


Figure 25

"We have already flown the balloon at 3000- to 4000-foot altitudes. Operationally, there will be about 10,000 feet of wire connecting the balloon to the ground and this wire will be the transmitting antenna. There is no problem anticipated in its actual operation; the wire is strong enough to handle winds of 50 miles per hour once the balloon is airborne. The tensile strength of the wire might be exceeded unless care is taken in the actual launching operations.

"We do not expect to have a perfectly vertical wire with the balloon, nor with the shipboard version of NOMAD, shown in figure 26, which employs a drone helicopter with a flight time of about four hours. We have plans, though they may never materialize, for an electric-powered drone helicopter which gets its current from the wire holding it down. Right now, we have no other progress than the investigative studies.

"The helicopter is unmanned because we felt that the presence of a man would then entail the presence of considerable equipment to ensure the man's safety. We would actually be trading fuel capacity and lift capability to include this additional weight. I suspect that the pilots might have reservations about flying with a wire hanging down."

Mr. Morton mentioned that APL had done some work with helicopters carrying a drag-type radar antenna; the particular interest was with the electric powered helicopter operating at a relatively low altitude.

"Figure 27 shows the expected area of coverage for a shipboard NOMAD VLF system operating from Annapolis and we feel certain that we would have the same area of coverage from the land-based NOMAD," continued Captain Dudley. "The shaded area is the area where we feel we would get coverage from either type system, transmitting from the same general area.

"Figure 28, giving a block diagram for HTA systems, shows the commonality of components between shipboard VLF and NOMAD. The cross-hatched items are being used in both systems with a resultant reduction in the costs involved.

"Figure 29 is the first of a set concerning the ELF program of Shore-to Ship communications. This ELF transmission involves frequencies below 500 cycles, which is exceedingly low on the electromagnetic spectrum. In testing this idea out, we have been using a 110-mile antenna line down in the mountains of Virginia. The transmission uses the duct existing between the ionosphere and the earth as its medium.

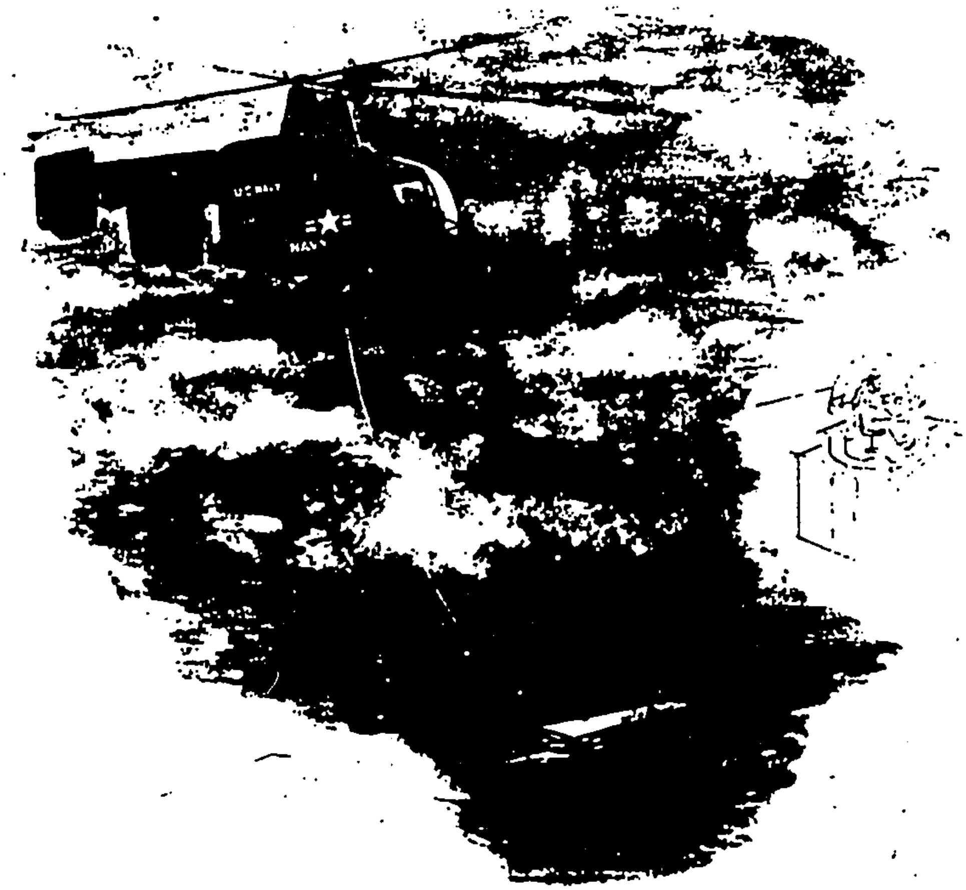


Figure 26

NOMAD AT ANNAPOLIS

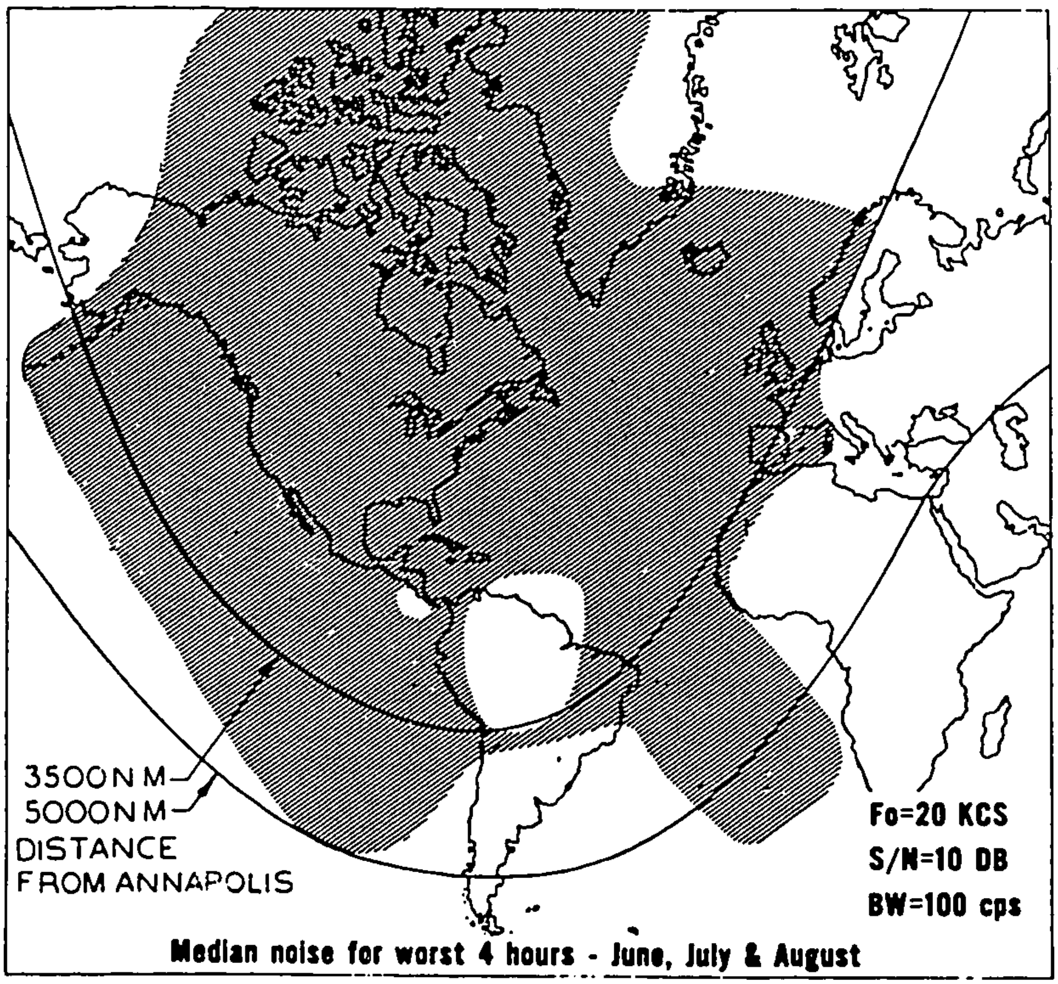


Figure 27

Figure 2 HTA SYSTEM BLOCK DIAGRAM.

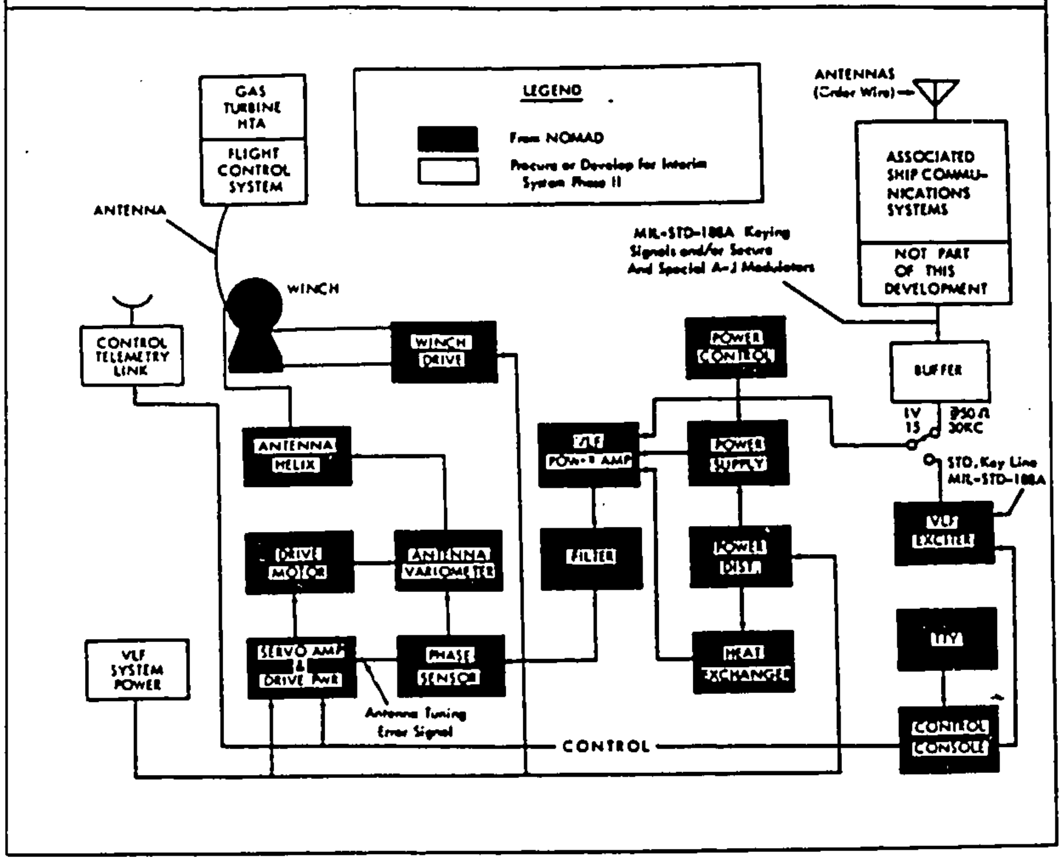


Figure 28

"In practice, we found that the actual equipment could be fitted into three or four vans. Once set up, we ran something that could be regarded as a decisive experiment and figure 30 indicates the results at 520 miles with the submarine moving at 6 knots at a 150-foot depth. Again, we received a 156-cycle signal at 2500 miles with the submarine moving at 18 knots at a 150-foot depth. The submarine tests were conducted last spring; we are still testing, but without a submarine at present.

S/ELF PROPAGATION

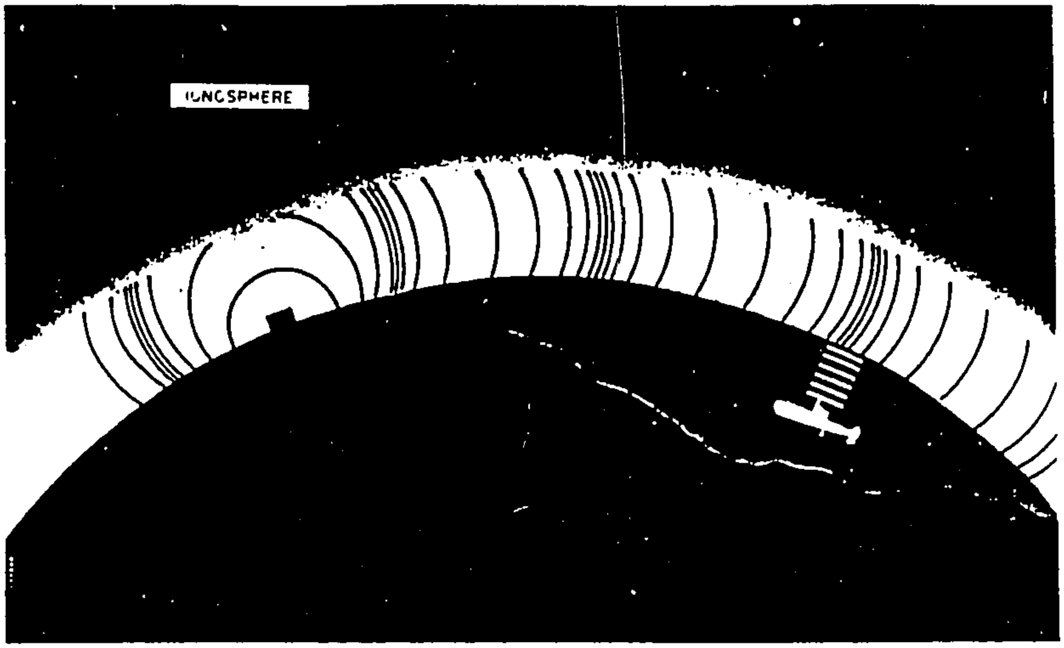


Figure 29

ELF DECISIVE EXPERIMENT RESULTS

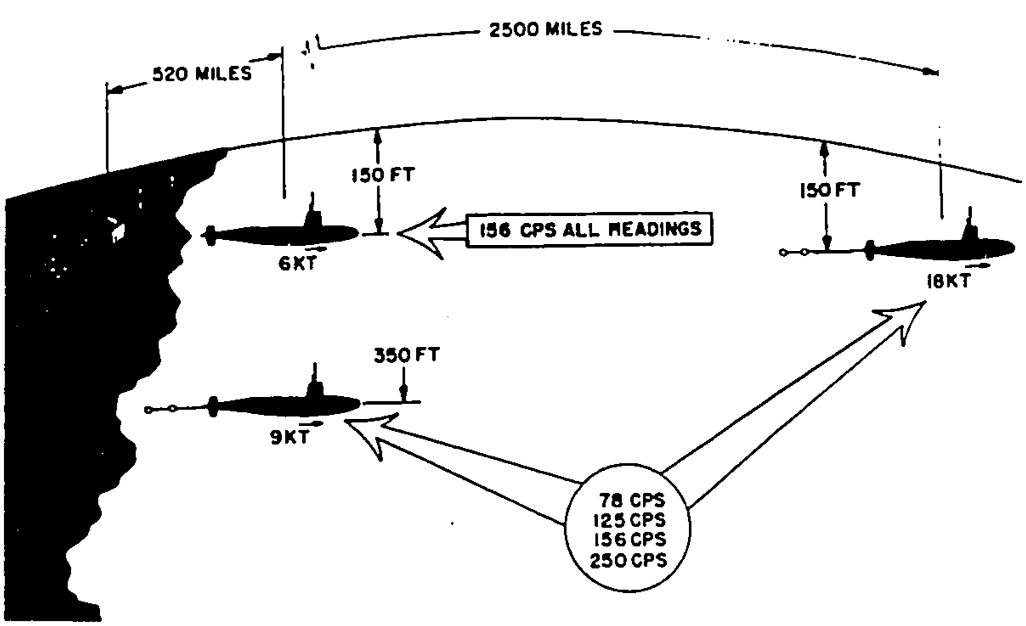


Figure 30

"A proposed site for ELF transmission would possibly look like figure 31 which shows the crossed elements and the straight elements of transmission lines. The elements themselves can be anywhere from 100 to 300 miles long, which presents us with a major real estate problem. The configuration of the lines is generally similar to that which the power companies have been using for several years.

ELF SYSTEM

SITE PERSPECTIVE ABOVE GROUND QUADRATURE ELEMENT

Figure 31

"The station shown in figure 31 is somewhat far removed from the four or five vans we used in the tests. Ultimately we would want power on the order of 6000 kilowatts per station, which itself creates a sizeable installation. Our experts on this agree that it is almost impossible to have ELF mobile and still get the data rates we would like.

"In figure 32 we have defined an ELF installation in another sense, with a number of crossed antennas located at various places throughout the country. I think the cost -- 138 million dollars -- is the biggest stumbling block in this program, but I think this is the price we will have to pay for this capability. That money will buy us the ability to communicate with an unrestricted submarine at deeper operating depths than we use at present. There is no impediment to submarine speed, and the ranges are exceptionally attractive. The submarine further is not required to operate and maintain the gear for trailing wires and streaming buoys.

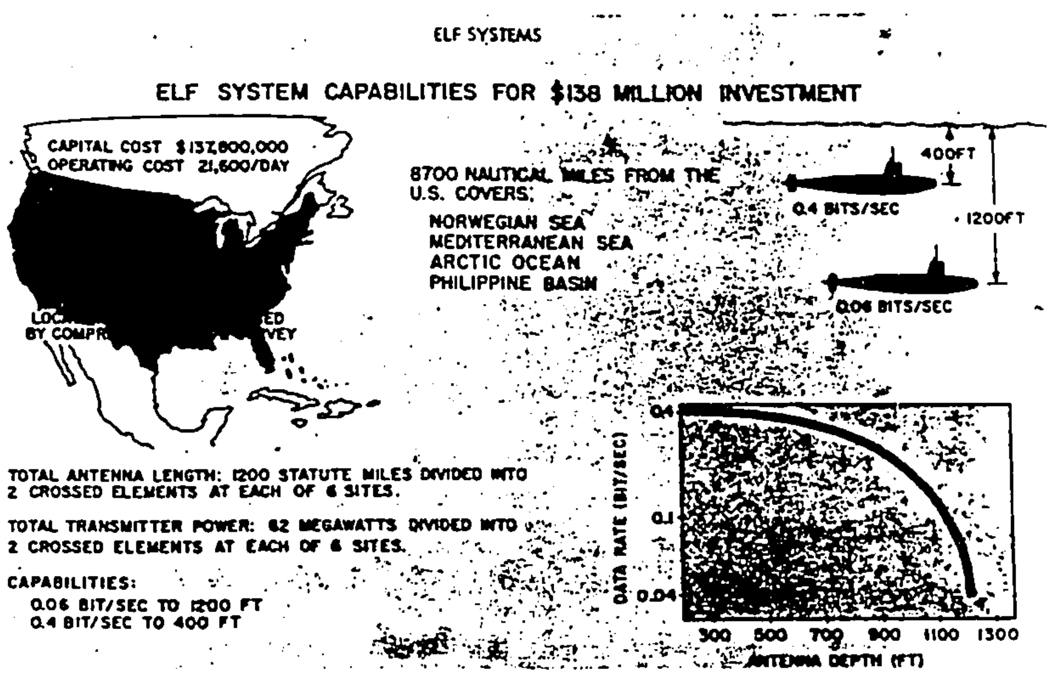


Figure 32

"In figure 33, we are dealing with the trade-off between depth and data rate, showing that greater depths mean reduction in data rate. At greater depths, we need either more power in transmission for the same data rate, or more time for integrating the signal received, which slows the data rate. In the near surface areas the data rate is fairly constant. The two curves also indicate the relationship between submarine speed and data rates.

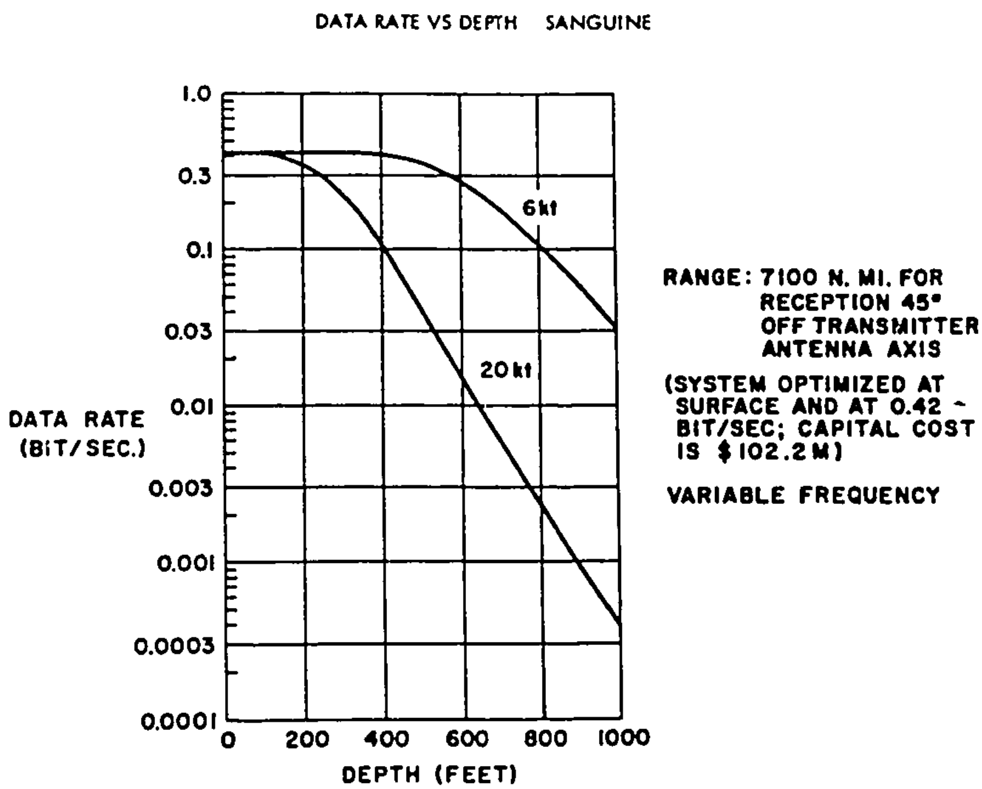


Figure 33

"Once we are above the basic noise level, additional power buys us additional decibels in terms of penetration. Water attenuates at the rate of 8 db per 100 feet, so greater depths mean greater power.

"The previous illustration, figure 32, dealt with a particular system at a given price figure with the results as defined. In figure 33, using a slightly different system, we come up with slightly different results; the process is the same. In all the ELF approaches, one basic problem area is the noise created by the submarine, for these systems inherently find their effectiveness in a signal-to-noise ratio existing at the submarine. Attempts at noise reduction are important then in the wider success of ELF systems. We got one improvement recently with the installation of a new slip ring on the turbine which reduced the noise level considerably. The tests were run on the USS SEA WOLF.

"We compared cost versus data rate in figure 34, and the right hand graph shows what we can do with an unhardened system, while the left hand graph covers the costs of hardening the system. These are very large, somewhere between three and four times the cost of the unhardened system, because everything has to be underground.

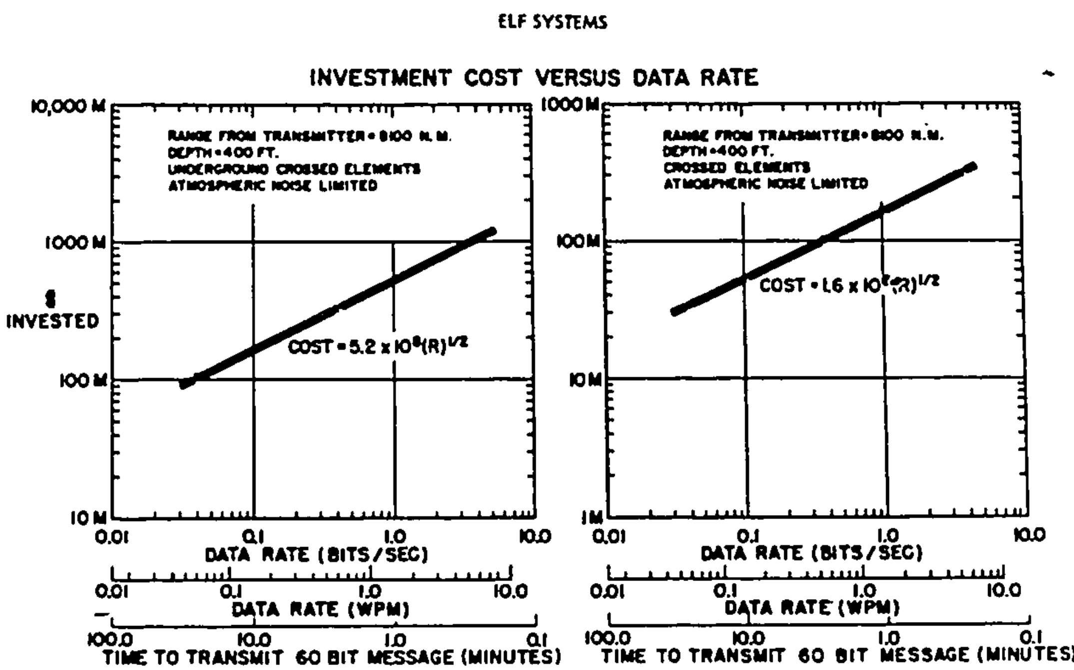


Figure 34.

"The major part of the cost of the unhardened system is spent in real estate, the antenna wire, and the antenna installation. Remember that we are considering 1800 miles of 1.5-inch copper wire, the towers to string it from, and the transmitter installation. We looked for, and found no existing transmission lines that we can use, largely due to the grounding problems.

"You can reduce cost by cutting down the data rate, because less power is required for the transmission. There are many trade-offs possible, and some suggestion of them is shown in figure 35 where we have related speed to reception depth. The white bar across the top covers the hull mounted antennas which require periscope depth or better for their operation. For example, fragmentary or low data rate reception at the more extreme depths can be construed as a signal to the submarine to move up into the better reception areas.

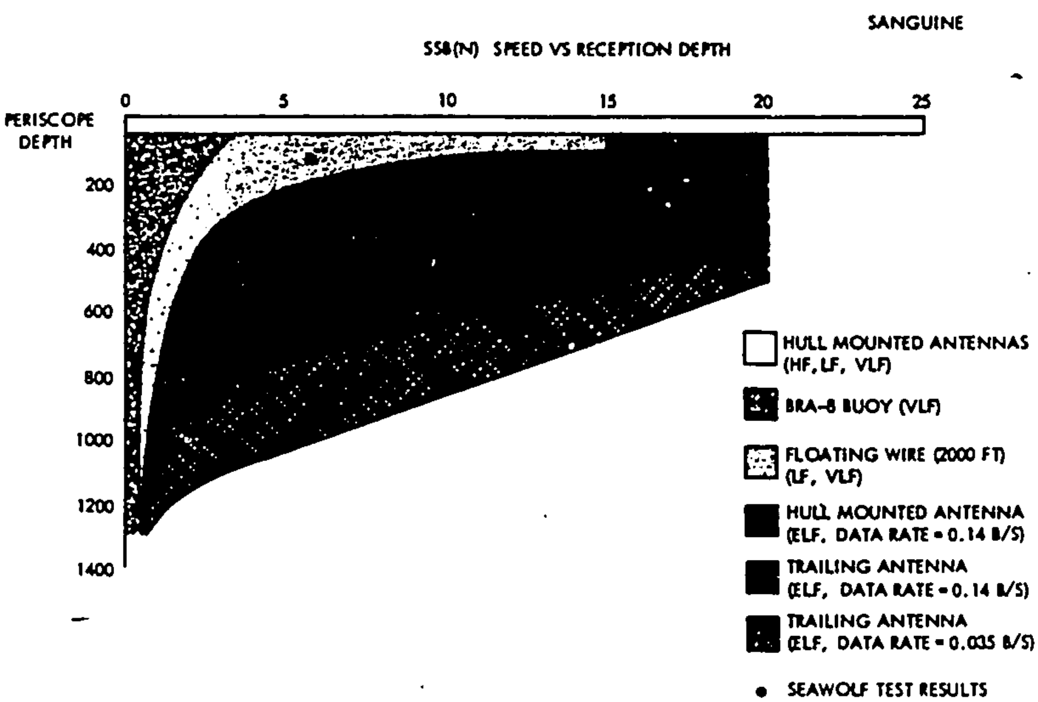


Figure 35

"Figure 36 covers the anti-jam capabilities. BEDROCK I is the system we have at present, a working facsimile technique. PANGLOSS - TASK II, or what we sometimes call the IIE system, was developed by RCA and has many attractive features, although it was by-passed in procurement in favor of the BAGATELLE which seemed to offer more for the money. BAGATELLE was mighty expensive and the purchase was not approved at CNO levels, so we are left still with the BEDROCK I plus the studies for PANGLOSS and BAGATELLE.

BEDROCK I: VLF FACSIMILE SYSTEM -- SLOW DATA RATE -- HIGHLY RESISTANT TO IMPULSE TYPE ATMOSPHERIC NOISE. RECEIVER INSTALLED ON ALL SSB(N)'s. EFFECTIVELY EXTENDS VLF COVERAGE.

PANGLOSS -- TASK II: VLF ANTI-JAM COMMUNICATION SYSTEM DEVELOPED BY RCA UNDER PANGLOSS CONTRACT. UTILIZES SPREAD-SPECTRUM TECHNIQUES TO PROVIDE A/J AND CONTINUOUSLY SAMPLES AND INTEGRATES THE LAST 10 MINUTES OF TIME TO DETERMINE IF A MESSAGE HAS BEEN SENT. NOT IMPLEMENTED BY BUSHIPS BECAUSE OF BAGATELLE AND BEDROCK II.

BAGATELLE: VLF COMMUNICATION CONCEIVED UNDER "SOUTH LINCOLN STUDY" TO PROVIDE BOTH ANTI-JAMMING AND PHYSICAL SURVIVABILITY. SYSTEM NOT BOUGHT BY CNO BECAUSE OF COST. SURVIVABILITY NOW PROVIDED BY MOBILE VLF SYSTEMS.

BEDROCK II: BUSHIPS PROPOSED MODIFICATION TO BEDROCK I TO ADD ANTI-JAM CAPABILITY. PROTOTYPE MODEL UNDER CONSTRUCTION, AVAILABLE IN 1964. INSTALLATION SCHEDULED IN 1965.

Figure 36

"BEDROCK II is under development to replace the present equipment. A great advantage is that it can be installed by a tender and does not require shipyard time. It is admittedly a quick and dirty system, but it is cheaper than the others and will provide some increase in capability over BEDROCK I.

"In figure 37, we have given the basic premises in our efforts in acoustical systems, while figure 38 gives the organization of our activity towards accomplishing the basic demands on us in the acoustic area.

ACOUSTICS
GOAL: TO PROVIDE SSB(N)'s WITH A SONIC COMMUNICATION SYSTEM.
REMOVE DEPTH-SPEED CONSTRAINTS.
IMPROVE CURRENT SYSTEMS.
DETERMINE OPTIMUM LONG-RANGE APPROACH.

Figure 37

"In the 1963 time frame, we are spending a good part of our effort in operating area selection surveys where we have been actually determining the acoustic characteristics of various ocean areas to learn how far we can transmit and whether the sea mountains and valleys give us problems. We have done this already for a considerable portion of the Atlantic area. We are now also working in the Pacific and our Project LOLA is a survey of this area. We hope to get a considerable amount of information on it this summer.

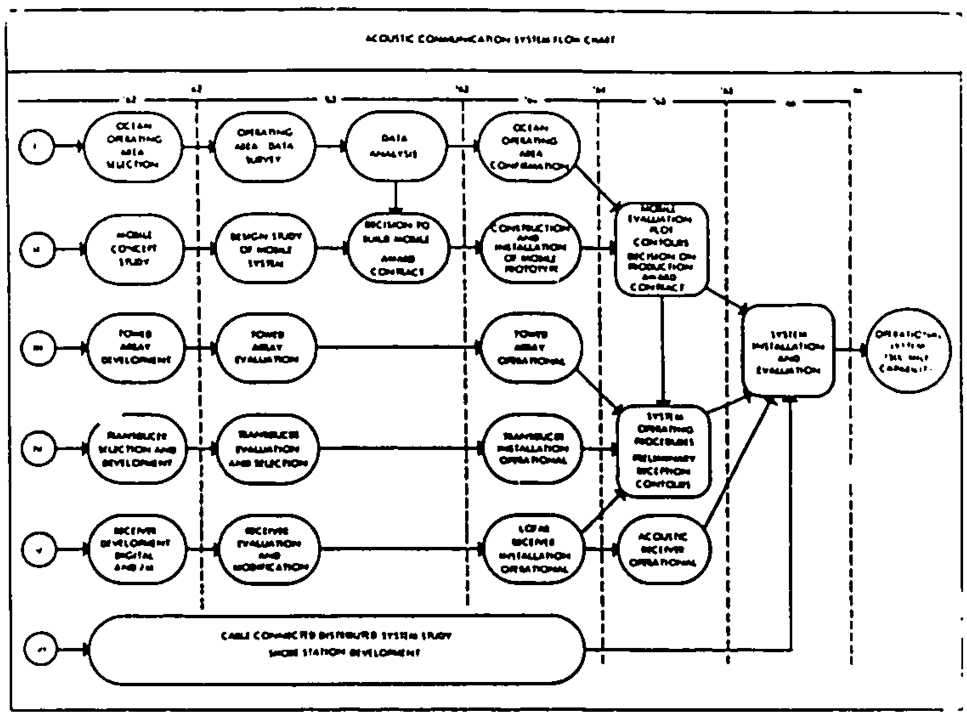


Figure 38

"We are also studying a mobile system where we would put a transducer on the command ship in order to communicate with the submarines. We have, in-house, a towed array system which is really a towed hydrophone strung behind the submarine. We actually have evaluated this before and it looked quite good. BuShips now wants a part of the development and perhaps use it for sonar work. We now will have a minor combined effort in this area to see what we can do on it.

"We have a considerable problem in our transducer evaluation and selection. We need high power, low frequency transducers in order to have an adequate acoustic communications system, but these are not available to date. We have some that afford some promise, but we do not have the answers.

"We are hoping to have answers by December of this year which may lead us to some idea of what a definitive acoustic system might be and what form it should have so that we can sell it as a feasible system. We are not sure that the operators will buy an acoustic system although we have an advanced development objective to investigate and see what sort of an acoustic system you can develop.

"For example, the POSAC-SUCCESS system in figure 39 employs an explosive charge that would be dropped which could either tell the submarine to come up to the surface and listen, or to come partly up and stream his buoy so he could listen on VLF; by appropriate timing of the explosive signals, a certain message could be sent to the submarine. This system is on the shelf now because the operators would not buy it.

"Another similar system which represents a smaller effort was the radio acoustic buoy of figure 40. Here again, the submarine would hear the POSAC-SUCCESS explosive package and would put up this radio acoustic buoy which would surface, receive the VLF/CW Morse, convert it to an acoustic signal, and then transmit it out down to the submarine.

The submarine receives it on an acoustic receiver. We have some 24 of these units on the shelf and, again, it is a system which has not been bought by the operators, who did not feel that they wanted acoustic buoys floating all over the ocean which might identify the position of the submarine.

"POSAC"

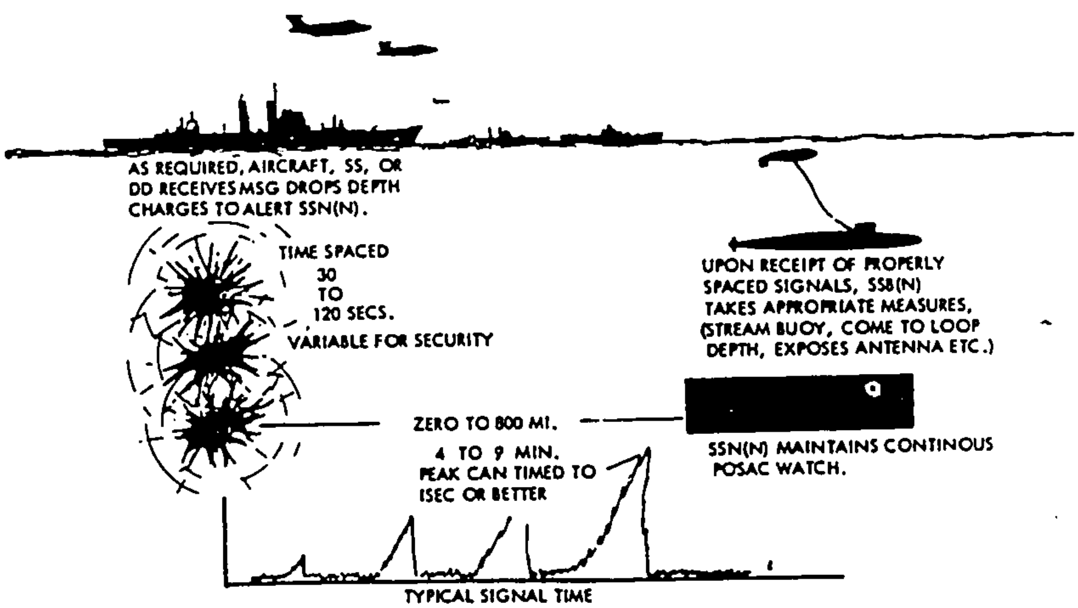


Figure 39

"This completes the overall area of command communications. Basically, we are in good shape on communications. We can communicate with our submarines even though we do have several problems which have to be faced in the future. One I just mentioned is, where do we go on acoustics? Another one is, where do we go on ELF? Do we buy it and continue R&D on ELF? Does it cost too much money?

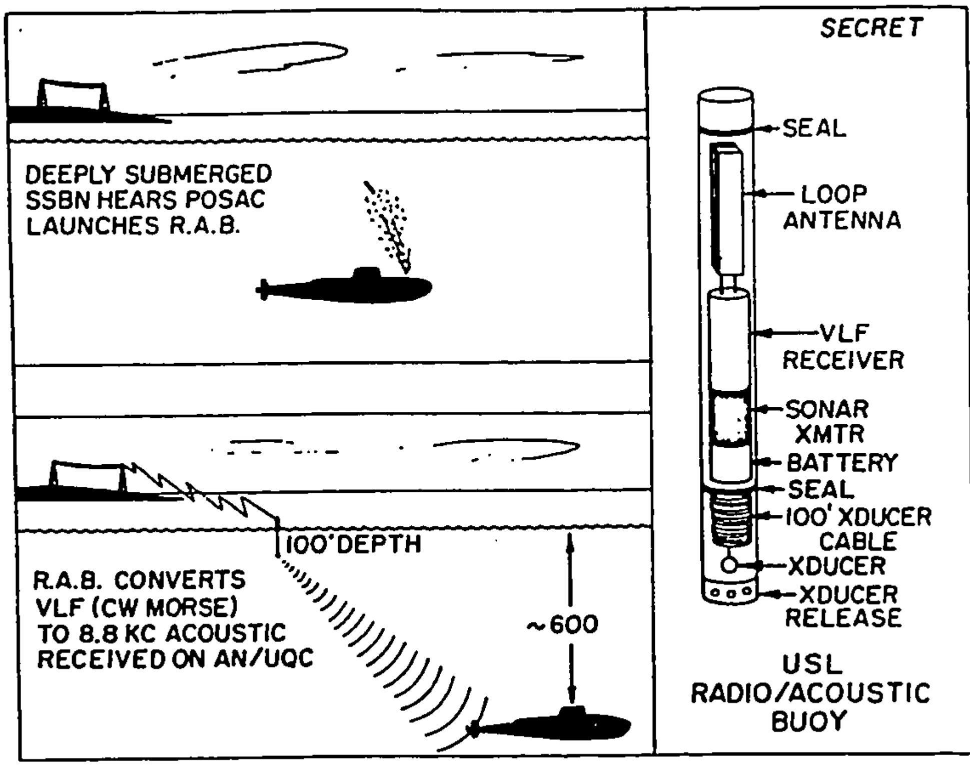


Figure 40

"Antennas are in reasonably good shape. I cannot say too much about our Ship-to Shore system, but we have some in-house programs which promise feasibility. Here again, they are expensive."

"In your presentation," commented Admiral Smith, "it seemed to me that you greatly simplified the operational requirement as you went along. For example, I think you reduced the operational requirements on Shore-to-Ship communication to the level where almost anything might have met the requirement."

"We have the general requirement to communicate with the submarine," replied Captain Dudley, "but in terms of the many specific aspects of how this communication is done, we do not even have an operational requirement."

Admiral Smith itemized qualities of Shore-to-Ship communication on the blackboard, including: Jamming, survival, range coverage, data rate, total message transmission time, depth, speed, maneuverability, detection, and message security. Other members added weather, data rate per address, and the number of addresses. Captain Dudley observed that traffic load had been overlooked.

Admiral Smith asked, "Do you have specific requirements for each of these?"

"No, we do not," replied Captain Dudley. "On some, yes. The SOR's we have specified a 14-db signal-to-noise jamming and OPNAV gave a verbal indication for 500 bits per hour, but even there we have nothing firm and the 500-bit per hour requirement raised a few eyebrows.

"We do have an operational requirement for developing an acoustic system with a 1500-mile range and the ability to reach submarines 1000 feet deep, and that requirement is all we have to define our effort. On other requirements, a survivable system is specified, but with no indication of the degree of survivability. They require non-jammable communications, but the only figure cited is the 14 decibels. Range coverage frequently, tacitly, means world-wide coverage.

"They require that the submarine be non-detectable in these communications but the detection ranges among systems can span from 400 to 3000 miles."

As the discussion of this subject proceeded, it became apparent that that there were not many specific operational requirements covering the efforts in command communications, and those which did exist were not generally known to the STG members to the degree that would permit useful group discussion. Admiral Smith and Captain Dudley concurred that that a second presentation of the Command Communications Committee -- this one entirely concerned with the nature and shortage of SOR's -- was eminently desirable if the discussion were to continue. This presentation was arranged for the afternoon of the second day. The report of this presentation has been included as the final section of the Communications Discussion in this report of the STG proceedings.

"Before you leave the subject," said Dr. Barrow, "I should like to ask what 'detection' means in Admiral Smith's listing." Admiral Smith explained that the term included disclosure of the submarine through some act in either radio transmission or reception.

"There is a definite requirement concerned with transmission from the submarine to the shore," added Captain Dudley, "but I cannot go into the details of these systems because of security. I am sure you will grant that there are times when transmission from the submarine would be needed to answer questions, to count noses, to find out who fired missiles and who did not."

"To change the subject," said Captain Eubanks, "in our concern with towed sonar, although many things were discarded from that effort, we did learn enough so that we could answer a real requirement. Further, we plan to press ahead in this effort. But my impression is that we would like to keep any statement of operational requirements as broad as possible.

"For example, the submarine has the requirement for two-way communication which has not yet been successfully met. We need this ability in the SSN's every bit as much as in the SSB(N)'s and I think, for example, that a major limitation in the THRESHER-Class is the lack of reliable two-way communications. Until the requirement is met, I think the requirement itself should be a broad statement."

"We do have such ability," replied Admiral Smith.

"But from the ability itself, everything then is a trade-off," said Captain Eubanks. "Reliability may be the first requirement but when you throw in security, detectability and similar items, then you are trading off the reliability to some degree."

"But there is the ability to communicate, even though you cannot do it and be secure from detection and such things," replied Admiral Smith. "You will never be able to communicate with 100 per cent reliability."

"We would like to strive for it," said Captain Eubanks.

In subsequent discussion, Captain Eubanks expressed concern that the mechanism of the Communications Subcommittee was not working as it should or that it was not supplying sufficient guidance.

"I think the problem is that they do not have the criteria to judge by," stated Admiral Smith. "All they seem to have as criteria for judgement is whether something looks interesting from a research angle, or looks like something nice to develop. The guidance from the committee is not enough to support a reasonable recommendation about the profitable areas for us to explore."

"There is some duplication here," said Captain Eubanks," but one path that we have for stating our normal requirements is going through Op07 and back onto Op94. This is the circuit which we must of necessity keep more rigid than possibly we would like. This is properly so because we are competing with every other naval program in that search.

"If you feel that we are not giving you the proper guidance, we possibly need to take a hard look at it. I think the recent submission of the PCP may have brought that out. For myself, I feel that we have not, in communications, communicated with each other as clearly as we should. We are not only taking a hard look at each of these things, but we are looking at the procedures that we have gone through. There is some obvious duplication in there that should not have occurred. There is some development work that we, like you, question. These things I am going to look into."

"From my experience," said Mr. Eyestone, "I think it is a great deal easier to write a requirement when you know the things you want are extremely difficult to attain. When you write a requirement for something you know can easily be accomplished, you become rather concerned that you might cut off some worthwhile idea or shut down on some very useful approach, just in the wording of the requirement. I think that possibly requirements should be developed so that a greater latitude exists in the early stages of a program, during which the data can be collected and evaluated and at some point in time used for a judgement about the possibilities and a decision as to the next step. In the communications programs, I think the point where judgement is exercised and decisions made is too far along the line. I think it could be made sooner and at a greater economy."

With no further discussion forthcoming, Admiral Smith called a coffee break, after which Admiral Galantin addressed the members off the record.

Second Presentation

After the conclusion of the other business of the meeting on Friday afternoon, Admiral Smith invited Captain Dudley to return and continue the discussion of the Communications Development Characteristics which had been begun on Thursday morning.

"Today, I would like to take up the background information relating to the efforts in communications," resumed Captain Dudley, "and to discuss the SOR's, ADO's, and TSOR's which specify some of the parameters of our systems. Most of the information will be evident in the forthcoming illustrations which generally do not require very much further comment.

"First to bring our information to a common point, figure 41 shows the general RDT&E procedures and defines some of the terms we use in this discussion. You can see the relationship between the need or requirement, as seen by CNO, and the eventual Technical Development Plan and work program resulting from this need.

"Similarly, the quotation in figure 42 which is drawn from an OPNAV Instruction points out the recognition by CNO of responsibility for developing prototype material and the need for co-ordinating the operational requirements with CNO. Figure 43, taken from the recent OPNAV Instruction, covers the exploratory development area for communications. The underlined material is pertinent and important to our efforts, and the 'et cetera' at the end of the first paragraph does, as you may suspect, cover a very broad field of activity. Another extract from the same document is given in figure 44 and this has special pertinency because of the entry concerning direct acoustic communications through air or water.

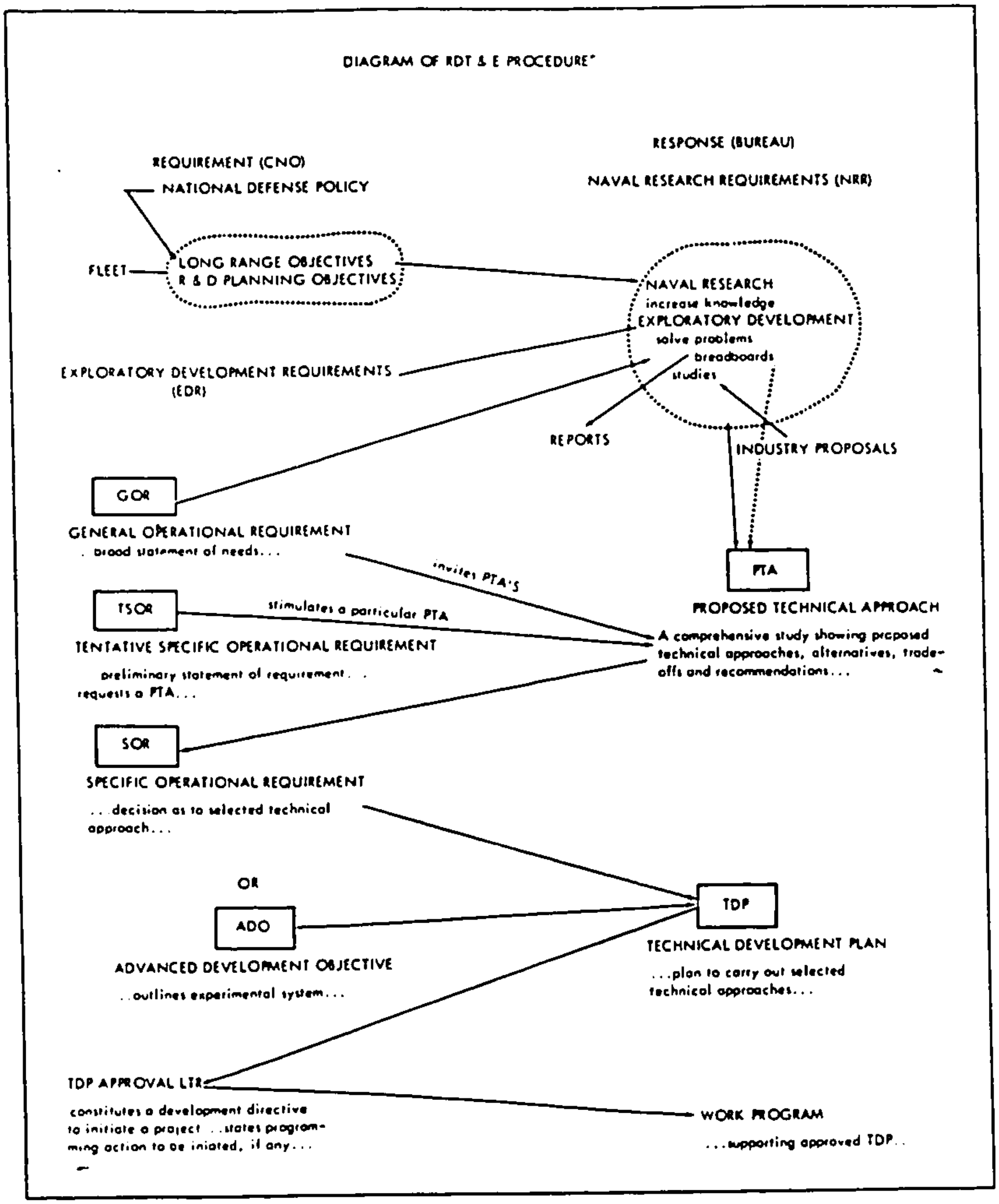


DIAGRAM OF RDT & E PROCEDURE*
RESPONSE (BUREAU)
REQUIREMENT (CNO)
NATIONAL DEFENSE POLICY
NAVAL RESEARCH REQUIREMENTS (NRR)
FLEET
LONG RANGE OBJECTIVES
R & D PLANNING OBJECTIVES
NAVAL RESEARCH
increase knowledge
EXPLORATORY DEVELOPMENT
solve problems
breadboards
studies
EXPLORATORY DEVELOPMENT REQUIREMENTS (EDR)
REPORTS
INDUSTRY PROPOSALS
GOR
GENERAL OPERATIONAL REQUIREMENT
. broad statement of needs...
invites PTA'S
PTA
TSOR
stimulates a particular PTA
PROPOSED TECHNICAL APPROACH
TENTATIVE SPECIFIC OPERATIONAL REQUIREMENT
A comprehensive study showing proposed technical approaches, alternatives, trade-offs and recommendations...
preliminary statement of requirement. . requests a PTA...
SOR
SPECIFIC OPERATIONAL REQUIREMENT
...decision as to selected technical approach...
OR
TDP
ADO
ADVANCED DEVELOPMENT OBJECTIVE
..outlines experimental system...
TECHNICAL DEVELOPMENT PLAN
...plan to carry out selected technical approaches...
TDP APPROVAL LTR
constitutes a development directive to initiate a project ..states programming action to be iniated, if any...
WORK PROGRAM
...supporting approved TDP..

Figure 41

"DEVELOPMENT" - THE DEVELOPMENT OF PROTOTYPE MATERIAL AND EQUIPMENT SHALL BE DONE UNDER THE DIRECTION OF THE NAVY TECHNICAL ASSISTANTS. THE DEVELOPMENT OF MATERIAL TO FULFILL OPERATIONAL REQUIREMENTS SHALL BE COORDINATED WITH THE CHIEF OF NAVAL OPERATIONS."

FROM OPNAVINST 4720.9 B OF 13 FEB 1963

Figure 42

EXPLORATORY DEVELOPMENT AREA F 006

COMMUNICATIONS

"APPLIED RESEARCH AND DEVELOPMENT ARE REQUIRED TO ATTAIN IMPROVED CAPABILITIES FOR COMMUNICATIONS FOR NAVAL AND MARINE CORPS OPERATIONS INVOLVING THE USE OF AIRCRAFT, SHIPS, SUBMARINES, SHORE INSTALLATIONS AND LANDING FORCES. THESE INVESTIGATIONS SHOULD INCLUDE THE STUDY, DESIGN (INCORPORATING SEMI-AUTOMATIC FAILURE DETECTION). CONSTRUCTION AND TEST OF EXPERIMENTAL EQUIPMENT, AND ALSO THE CONSIDERATION OF NEW TECHNIQUES AND METHODS, INCLUDING EARTH SATELLITES, WHICH MAY BE USED IN FUTURE COMMUNICATION SYSTEMS OR WHICH WILL IMPROVE PRESENT OPERATING SYSTEMS. NEW MODES OF PROPAGATION SHOULD BE EXPLORED FOR POSSIBLE APPLICATION TO NAVAL COMMUNICATIONS. EMPHASIS SHOULD BE PLACED ON EXTENDING COMMUNICATION RANGE, IMPROVING RELIABILITY, ENHANCING SECURITY, INCREASING DATA (OR INFORMATION) RATES, ETC."

"EACH DEVELOPING AGENCY SHOULD INITIATE ONE PROJECT UNDER EACH EXPLORATORY DEVELOPMENT REQUIREMENT THAT IS PERTINENT TO ITS AREA OR RESPONSIBILITY."

FROM OPNAV INST 3910. 3A OF 21 AUG. 1962

Figure 43

EXPLORATORY DEVELOPMENT REQUIREMENT COMMUNICATIONS AREA INCLUDES:

"DESIGNED TO DEFINE THE CHARACTERISTICS OF ADVANCED SYSTEMS COMPONENTS."

"RESEARCH AND DEVELOPMENT ON, AND THE USE OF, RADIO TRANSMITTERS, RECEIVERS, AND TRANSCEIVERS."

"RESEARCH AND DEVELOPMENT ON ANTENNAS AND RADIATING SYSTEMS, AND THEIR USE ON AIRCRAFT, SHIPS, SUBMARINES, SHORE INSTALLATIONS, ETC."

"ENCOMPASSES ALL ASPECTS OF THE USE OF DIRECT ACOUSTIC SIGNAL THROUGH AIR OR WATER FOR COMMUNICATIONS."

"EMBRACES PROBLEMS PERTINENT TO THE SECURITY OF COMMUNICATIONS, I.E., FREEDOM FROM DETECTION, INTERCEPT, INTERPRETATION, ETC."

from OPNAV INST 3910. 3A of 21 Aug 1962

Figure 44

"Getting into the specifics of our program now, the basic Development Characteristics upon which we rely in communications were issued in 1957 as a portion of the Development Characteristics for the Fleet Ballistic Missile Submarine in document SC-16702-2; figure 45 gives the sections pertinent to the communication program and item (4) covers the direction of many of our major efforts. Figure 46, taken from the same document, states how the efforts shall be administered, with BuShips as the cognizant bureau, responsive to the direction of the Director, Special Projects.

"Continuing with extracts from SC-16702-2, the Major Features are summarized in figure 47. A number of efforts we are now working on and have been working on steadily in the past go back to this document for guidance in terms of basic requirements, because this document is the only guideline we have in many areas. The initial concern was with reliability, speed, and security. There was a specific minimum data rate and maximum transmission time for the fire order.

DEVELOPMENT CHARACTERISTIC SC 16702-2

COMMUNICATIONS SUPPORT FOR FLEET BALLISTIC MISSILE SUBMARINE/WEAPON SYSTEM

PURPOSE

THE FEATURES, CHARACTERISTICS, AND CAPABILITIES HEREIN ARE ESTABLISHED AS GUIDES FOR THE DEVELOPMENT OF AN FBM COMMUNICATIONS SUPPORT SYSTEM INCLUDING:

(1) THE DEVELOPMENT OF A SUBMARINE INTEGRATED COMMUNICATIONS SYSTEM FOR ASSURING WITHIN THE SUBMARINE ADEQUATE MEANS FOR EFFECTING OPERATIONAL CONTROL OF FBM SUBMARINES BY THE FLEET COMMANDER, OR THE CHIEF OF NAVAL OPERATIONS AT THE SEAT OF GOVERNMENT.

(2) THE DEVELOPMENT OF AN ADEQUATE COMMUNICATIONS RELAY CAPABILITY WITHIN A MOBILE TENDER.

(3) THE IMPROVEMENT OF THE COMMUNICATION CAPABILITIES OF SHORE-BASED FACILITIES, AND FINALLY,

(4) ADDITIONAL RESEARCH AND DEVELOPMENT EFFORT TO IMPROVE THE CAPABILITIES AND REDUCE THE LIMITATIONS OF CONVENTIONAL RADIO AND/OR SONAR SYSTEMS AND TO DEVELOP TECHNIQUES FOR ALTERNATIVE METHODS OF ASSURING A COMMAND COMMUNICATIONS LINK FOR THE FBM SUBMARINE/WEAPON SYSTEM.

Figure 45

SC 16702-2 (IMPLEMENTATION)

"BUREAU OF SHIPS IS DESIGNATED AS THE COGNIZANT BUREAU FOR IMPLEMENTATION OF THIS DEVELOPMENT CHARACTERISTIC."

"SPECIAL PROJECTS OFFICE DESIGNATED COORDINATION AND MANAGEMENT CONTROL (BUSHIPS TO BE "RESPONSIVE" TO THE DIRECTION OF DIRECTOR, SPECIAL PROJECTS)."

Figure 46

SC 16702-2 MAJOR FEATURES

1. SYSTEMS "MUST BE DESIGNED TO INSURE MAXIMUM PRACTICAL DEGREE THE RELIABILITY, SPEED AND SECURITY."

2. "RELIABILITY OF THE COMMAND CONTROL MESSAGE TRANSMISSION AND ITS INVULNERABILITY TO ENEMY COUNTERMEASURES WILL DETERMINE THE MINIMUM ACCEPTABLE DATA RATE AND REDUNDANCY THAT CAN BE TOLERATED."
"DATA RATE AS LOW AS 5 WORDS PERMINUTE COULD BE ACCEPTABLE AS AN INTERIM MEASURE IF THE SYSTEM EMPLOYED ASSURED IRREFUTABLE DELIVERY OF THE 'ORDER TO FIRE.' "
"MINIMUM ACCEPTABLE TIME FOR THE TRANSMISSION OF THE ORDER TO FIRE FROM THE SHORE COMMANDER TO THE SUBMARINE IS 30 MINUTES."

3. DEVELOPMENT IN 2 PHASES

a. INTERIM SYSTEMS - TO PROVIDE ACCEPTABLE COMMUNICATIONS BY OPERATIONAL DATE OF FIRST FBM.

b. FINAL SYSTEMS - DEVELOPED THRU R&D - PROVIDE "ULTIMATE" COMMUNICATION LINK TAILORED TO THE REQUIREMENTS OF A SUBMARINE (SSB(N) WEAPONS SYSTEM CONTROLLING OBJECTIVE).

Figure 47

"Note that the document presumes the development of both an interim and a final system, which presented us with a two-fold problem of setting up an acceptable system for the first FBM submarines while working on the system that ultimately would be employed on all of them. Some of the items suggested for the interim system are shown in figure 48. You can see that the greater effort here was directed towards improvement of the reception, and that the HARE transmission was regarded as acceptable, although there was a statement regarding transmission that the submarines would transmit through Sea State 5 conditions with less than one minute antenna exposure at any depth or speed, with transmission security that is better than is offered by the HARE system. Additionally, we were asked to look into the possibilities of a communication relay ship with VLF/LF capabilities, HARE reception, and the possible use of a drone helicopter.

SC 16702-2

INTERIM SYSTEMS - RECEPTION

1. CONCURRENT DEVELOPMENT ALONG BUT NOT NECESSARILY LIMITED TO:
   A. INVESTIGATE IMPROVED LOOP ANTENNAS.
   B. DEVELOP VLF FLOATING BUOY, SUBMERGED ANY SPEED/DEPTH, NOT DETECTABLE (VISUAL), UNATTENDED OPERATION 90 DAY PERIODS.
   C. DEVELOP FLOATING WIRE ANTENNA.
2. R&D TO EXTEND RANGE AND RELIABILITY OF VLF COMMUNICATIONS
   A. RECEIVER DEVELOPMENT
   B. VLF NOISE MODULATION COMMUNICATION TECHNIQUES
   C. VLF ERROR CORRECTION TECHNIQUES
   D. SHORE BASED DIRECTIONAL TRANSMITTING ANTENNA

TRANSMISSION

1. ACCEPTABLE - HARE
2. DESIRED - TRANSMITTER/ANTENNA SYSTEM - SEA STATE 5 - LESS ONE MIN EXPOSURE - ANY DEPTH/SPEED - WITH TRANSMISSION SECURITY BETTER THAN HARE.
3. R&D TO IMPROVE HARE

COMM RELAY SHIP - VLF/LF CAPABILITY, HARE RECEPTION, R&D ON DRONE HELO ANTENNA.

Figure 48

"Figure 49 covers the R&D suggested for the final system. You may possibly recognize some of the studies from past reports, for we have looked into many of them quite thoroughly and discarded quite a number already. With others, the work is still going on.

"Up to now, I have shown you only the 1957 advice and guidelines that we have received. In some areas, we have more up-to-date guidance than 1957, and these areas are shown in figure 50 for the three Specific Operational Requirements that we have received covering TACAMO, NOMAD, and Shipboard VLF -- all survivable systems. There are not many definitive statements given in these SOR's, largely because they cover antenna systems and some of the cited parameters do not apply. For each of these programs we have forwarded a Technical Development Plan to CNO. As yet, we have received no approvals, but we have been proceeding with the development of the systems while waiting out the approval. We feel that we are in good shape for the three programs.

SC 16702-2

FINAL SYSTEMS: R&D ON FOLLOWING:

1. EXTENDED RANGE SECURE SONAR COMMUNICATIONS
2. MINIATURIZED SUBMARINE CABLE SYSTEM
3. FEASIBILITY OF USING:
   METEOR BURST, ROCKET LAUNCHED TRANSMITTERS, BALLOON TRANSMITTERS, MOON RELAY, SATELLITE, SUBMARINE RF INDUCTION CABLE
4. BASIC RESEARCH AND DEVELOPMENT IN FOLLOWING AREAS:
   VLF PROPAGATION AND NOISE STUDY
   PREDICTION OF COMMUNICATION PROBABILITY
   UPPER AIR RESEARCH
   CENTRAL TIME AND FREQUENCY CONTROL
   ARCTIC ENVIRONMENT COMMUNICATION STUDIES
   EARTH PROPAGATIONS MODES
   ULF COMMUNICATIONS
   CONJUGATE COMMUNICATIONS

Figure 49

"I also mentioned that we had received three Advanced Development Objectives; figure 51, the first of these, applies to Survivable Dispersed VLF Communications. This ADO has a particular concern with the strike message and will accept a data rate as low as one five-character word each 15 minutes under jamming if we are unable to do any better in transmission of the strike message. The notes on this ADO specify the size of the equipment, instruct us to proceed only until a decisive experiment can be made to establish the basic worth of the project, and acknowledge that BAGATELLE may be the approach to survivability while the PANGLOSS provides the needed data rate capability. This ADO has not as yet been satisfied as far as CNO is concerned. BAGATELLE is the closest thing we have to meeting the characteristics and it does not meet the unspoken requirements about the complexity and size of the equipment aboard ship.

	SOR'S		
	AIRBORNE VLF (TACAMO)	TRANSPORTABLE VLF (NOMAD)	SHIPBOARD VLF
JAM	NOT PART OF THIS DEVELOPMENT		
SURVIVABILITY	MOBILE	TRANSPORTABLE	MOBILE
RANGE COVERAGE	(100 v/meter) 2500 - 3000 mi	(100 v/meter) 3500 - 5000 mi	(100 v/meter) 3500 - 5000 mi
DATA RATE (MODULATION)	20 WPM (CW)	20 WPM (CW)	20 WPM (CW)
DEPTH	—	—	—
SPEED/MANEUVERABILITY	—	—	—
DETECTION	—	—	—
MESSAGE SECURITY	—	—	—
RELIABILITY	—	—	—
TDP	FWD 1962 NO APPROVAL YET	FWD 1962 NO APPROVAL YET	FWD 1962 NO APPROVAL YET

Figure 50

ADO - SURVIVABLE DISPERSED VLF COMMUNICATIONS

JAM	IMPROVED ANTI-JAM COMM. FOR STRIKE MSG TO SUBMARINE (ONE 5 CHARACTER WORD AT INTERVALS NOT TO EXCEED 15 MINUTES UNDER JAMMING)
SURVIVABILITY	PHYSICAL SURVIVABILITY (THROUGH DISPERSION) OF A HIGHER CALCULABLE PROBABILITY THAN EXISTING VLF STATIONS HAVE.
RANGE COVERAGE	3,000 MILES
DATA RATE (MODULATION)	20 WORDS/MINUTE NORMAL, ONE 5 CHARACTER WORD/15 MINUTES UNDER JAMMING.
DEPTH	PRESENT VLF RECEPTION DEPTH AS A MINIMUM.
SPEED MANEUVERABILITY	OPERABLE WHEN SHIP IS "UNDERWAY OR MANEUVERING"
DETECTION	---------------
MESSAGE SECURITY	---------------
RELIABILITY	.1% CHARACTER ERROR. 95% PROBABILITY MTBF 500 HRS.

NOTE: (1) "PROCEED ONLY THROUGH A DECISIVE EXPERIMENT WHICH WILL PERMIT A DECISION TO BE MADE REGARDING MILITARY USEFULNESS, TECHNICAL FEASIBILITY AND FINANCIAL RESPONSIBILITY."
(2) SHIPBOARD SIZE NOT MORE THAN ONE STANDARD 6FT RACK.
(3) ACKNOWLEDGES BAGATELLE IS THE BEGINNING OF AN APPROACH TO SURVIVAL PROBLEM, AND IIE PROVIDES LOW DATA RATE A/J CAPABILITY BUT DOES NOT ATTEMPT TO SOLVE SURVIVABILITY PROBLEM.

Figure 51

"In figure 52 we have the ADO pertaining to ELF Survivable Command Communications which specifies an improvement in the Anti-Jam Capability for the strike message through use of special modulation techniques. They say it is to be 'survivable' but make no further mention or definition of what they mean by it. This ADO only contains a limited amount of information, but they are the important guidelines.

ELF SURVIVABLE COMMAND COMMUNICATIONS ADO

JAM	"IMPROVED ANTI-JAM CAPABILITY FOR STRIKE MSG THROUGH SPECIAL MODULATION TECHNIQUES"
SURVIVABILITY	(ONLY MENTIONED IN TITLE - NO OTHER REFERENCE MADE)
RANGE COVERAGE	10,000 MILES
DATA RATE (MODULATION)	INHERENT DATA RATE RECOGNIZABLY SLOW" - "SIGNAL CHARACTERISTICS READILY INTEGRATED INTO AN INFORMATION THEORY SYSTEM"
DEPTH	
SPEED/ MANEUVERABILITY	20 KNOTS (HULL MOUNTED ANTENNA)
DETECTION	---------------
MESSAGE SECURITY	---------------
RELIABILITY	.1% CHARACTER ERROR 95% PROBABILITY MTBF 500 HRS. 99.90 PROBABILITY STRIKE MSG RECEIVED THROUGH MAJOR JAMMING EFFORT

Figure 52

"The ELF system that we have been working on will generally meet the characteristics spelled out in the ADO, but not completely. If we want to put more money into the effort, I think that we can meet all the characteristics of the directive.

"The third ADO, figure 53, covers Low Frequency High Power Acoustic Communications and gives no information on jamming and no information about survivability other than it is required. The read-out on the submarine will employ LOFAR principles and the transmission must be effective at any depth compatible with the submarine's mission. The ADO also cites a definite need to improve transducer reliability. Again, note that we are empowered only to carry this effort along until the point when a decisive experiment can be run to determine the value of the system.

LOW FREQUENCY HIGH POWER ACOUSTIC COMMUNICATIONS ADO

JAM	----------------
SURVIVABILITY	REQUIRED - BUT NOT DEFINED
RANGE COVERAGE	1500 MILES (MINIMUM)
DATA RATE (MODULATION)	LOFAR TYPE READOUT
DEPTH	ANY DEPTH. COMPATIBLE WITH FBM MISSION
SPEED/ MANEUVERABILITY	6 KNOTS
DETECTION	----------------
MESSAGE SECURITY	----------------
RELIABILITY	"IMPROVE TRANSDUCER RELIABILITY". 95% PROBABILITY MTBF 500 HRS.

NOTE: (1) "PROCEED ONLY THROUGH A DECISIVE EXPERIMENT WHICH WILL PERMIT A DECISION TO BE MADE REGARDING MILITARY USEFULNESS, TECHNICAL FEASIBILITY AND FINANCIAL RESPONSIBILITY."

(2) "TO TRANSMIT ACOUSTIC SIGNALS VIA REMOTE CONTROLLED TRANSDUCERS FROM COMMAND COMMUNICATIONS RELAY INSTALLATIONS TO SUBMERGED SUBMARINES."

Figure 53

"There are many problems in the field of acoustic communications in terms of reliability and effectiveness. Special Projects has become, I feel, the lead Bureau in the Navy for this field.

"Figure 54 covers an effort which is directed at BuShips and CNO rather than SP -- the development of a VLF-MUX system. It most definitely relates to our efforts because it is being proposed as an all-around communications system to be compatible with both the FBM submarines and the surface fleet. Basically, this effort is not our responsibility, and the project is momentarily sitting on the shelf as far as factory work is concerned. You can, I am sure, see where such an effort is of-primary interest to us, even though we are not basically concerned with it.

VLF RADIO TELETYPE TERMINAL EQUIPMENT TSOR-532-54T
DATED 28 DECEMBER 1962

1. ADDRESSED TO BUSHIPS.
2. REQUIRES DEVELOPMENT OF (A) INCREASE CAPABITY OF FLEET VLF BROADCAST IN THE NORMAL MODE (B) A SPECIAL MODE OF OPERATION TO INSURE RECEPTION OF HIGH-PRECEDENCE OPERATIONAL MESSAGES UNDER CONDITIONS OF SEVERE JAMMING.
3. REQUESTED OPERATIONAL TIME FRAME 1966-67.
4. SYSTEMS TO OPERATE COMPATIBLY WITH PLANNED MOBILE VLF TRANSMITTERS.
5. SPO ON 31 OCTOBER 1962 REQUESTED BUSHIPS TO ADVISE OF THE EFFECTS OF THIS TSOR UPON THE BAGATELLE CONCEPT OF FLF ANTI-JAM MODULATION BEING IMPLEMENTED.
6. BUSHIPS REPLY OF 4 APRIL 1963 RECOMMENDED:
   (A) A DEFERAL OF FURTHER COMMITMENT TO ANY PHASE SHIFT SYSTEMS PENDING FURTHER ANALYSIS. FURTHER RECOMMENDATIONS TO BE MADE BY THE BUREAU WITHIN 60 DAYS
   (B) PURSUE DEVELOPMENT OF A BEDROCK A/J CAPABILITY AS AN INTERIM SYSTEM.

Figure 54

"Figure 55 covers our concern with Project SECT which is one of those developments that seems a little on the oddball side but may pay off handsomely if it works out. The quotation is from an OPNAV letter agreeing to a proposal submitted on SECT, and advising us that they were preparing a Development Characteristic for the effort. As yet, we have not received this document, but we are proceeding with the development and feel that it is in good shape.

"Figure 56 is a general summary of all our efforts as related to whatever basic requirement we have to back us up. A good many of the efforts go back to the basic SC-17602-2 document from 1957 and have no other guidelines at all. Some of the projects have no guidelines at all. In the Ship-to-Shore systems, we do have a TSOR on a new system which we are not able to say much about as yet, except that it has a

400- to 4000-mile range and a fairly low data rate working with 60-character messages. We do not have an SOR for NAPOR, but we have a CNO letter with good guidelines in it, but no indication as to whether they will support the ground station program needed for NAPOR in the future.

SPEED LETTER Op-90L3/11h   Ser 00500P90

12 SEP 1961

1. "REFERENCE (o) DESCRIBES THE STATUS OF PROJECT SECT. THE DIRECTOR, SPECIAL PROJECTS, IN HIS ENDORSEMENT OF REFERENCE (o), REQUESTS THAT THE CHIEF, BUREAU OF SHIPS INITIATE PROCUREMENT ACTION FOR THE SERVICE TEST MODELS OF SECT.

2. THE ACTION OF THE DIRECTOR, SPECIAL PROJECTS IS CONCURRED IN, AND THE NEED TO PROVIDE AN EMERGENCY COMMUNICATION CAPABILITY FOR SSB(N)'s AT THE EARLIEST PRACTICABLE DATE IS REITERATED.

3. OPNAV IS PREPARING A DEVELOPMENT CHARACTERISTIC FOR PROJECT SECT IN ORDER TO DEFINE THE REQUIREMENT IN MORE SPECIFIC TERMS."

Figure 55

"The acoustic systems are generally covered by the previously mentioned ADO, where guidelines exist do exist. The SECT project, or EXTREMIS as it has been known, was defined somewhat in a memo from Admiral Burke. We have requested an SOR on this effort, but none has yet been received.

"What we have covered to this point has been the general guidelines relating to the specific things we have been working on. Next, I should like to cover some specifics about the various programs underway, and in figure 57 we have some definite comparative material about the various systems. In some, the mobile systems, TACAMO, NOMAD, and shipboard VLF, the antennas limitations make it difficult to apply any data to any columns save data rate and cost. The entries for the BRA-8 are clear -- there is a low probability of detection and a low reliability in comparison to the floating wire. The BRA-16 system, which is sail-mounted, has a very high reliability in comparison to the whip antenna.

	PROGRAMS	OPERATIONAL REQUIREMENTS ADO/SOR
A.	ANTENNA IMPROVEMENT	
	AN/BRA-8 - AN/BRA-16 - AN/BRA-15	SC-16702.2
	FLOATING WIRE	
	"V" FIN BUOY	
B.	SHORE - TO - SHIP	
	TACAMO	SOR - AIRBORNE VLF
	NOMAD	SOR - TRANSPORTABLE VLF BORADCAST
	SHIPBOARD VLF	SOR - SHIPBOARD VLF BROADCAST
	TASK IX (ELF)	ADO - ELF SURVIVABLE COMMAND COMMUNICATIONS
	BAGATELLE	ADO - SURVIVABLE DISPERSED VLF COMMUNICATIONS
	TASK IIE A/J MODE	SC-16702.2
	BEDROCK II A/J MODE	SC-16702.2
C.	SHIP - TO - SHORE	
	SITE RETROFIT. IMPROVEMENT	SC-16702.2
	TO HARE	
	IMPROVED HF SYSTEM	SC-16702.2
	NEW SYSTEM	TSOR
	NAPOR	SC-16702.2 AND CNO LETTER
D.	ACOUSTICS	
	OPERATING AREA SURVEYS	ADO - LOW FREQUENCY, HIGH POWER ACOUSTIC COMMUNICATIONS
	MOBILE SYSTEMS	
	TRANSDUCER DEVELOPMENT	
	RECEIVER DEVELOPMENT	
	CABLE CONNECTED DISTRIBUTED SYSTEMS	
E.	EXTREMIS (SECT)	INFORMAL REQUEST. SOR REQUESTED - NOT REC'D.

Figure 56

"Figure 58 continues this comparative statement for the other systems -- BAGATELLE, BEDROCK, ELF and Acoustical -- but leaves out the reliability column. The detectability of these systems is not applicable either.

COMMAND COMMUNICATIONS COMMITTEE DISCUSSION

SYSTEMS	DATA RATE	DEPTH	SPEED MANEUVERABILITY	DETECTION	COST
BAGATELLE	LOW STANDARD CW 2 BITS/MIN.	BUOY SUBMERGED 20 FT.	LIMITATIONS IMPOSED BY FLOATING WIRE AND BUOYS	N/A	100 MILLION
BEDROCK II	LOW 2 BITS/MIN.	SAME AS ABOVE	SAME AS ABOVE	N/A	5 MILLION
ELF	LOW 0.4 BITS/SEC	PRESENTLY - 6 KNOTS AT 300 FT. WITH HULL MOUNTED SENSORS GREATER DEPTH WITH TRAILING SENSORS AT LOWER SPEED. IMPROVEMENT IN SENSORS WILL INCREASE DEPTH/SPEED CAPABILITY.		N/A	120 MILLION NON-HARDENED COST INCREASES APPROXIMATELY BY FACTOR OF 3 TO HARDENED SITE.
ACOUSTICS	LOW PRESENTLY 2.5 BITS/MIN BY 1966 0.38 BITS/SEC.	UNLIMITED	PRESENTLY 6 KNOTS AT ANY DEPTH BY 1966 10 KNOTS AT ANY DEPTH.	N/A	6-10 MILLION PER AREA

Figure 57

SYSTEMS	DATA RATE	DEPTH	SPEED MANEUVERABILITY	DETECTION	RELIABILITY	COST
MOBILE SYSTEMS TACAMO NOMAD SHIPBOARD	LOW	LIMITATIONS IMPOSED BY RECEIVING ANTENNAS				ESTIMATED 2.5 MILLION PER SHIP-BOARD SYSTEM 1.5 MILLION PER MOBILE SYSTEM
BRA-8	N/A	MAXIMUM USABLE DEPTH/SPEED OR 3 KNOTS BUOY DEPTH FOR GOOD RECEPTION 30'		LOW	LOW AS COMPARED TO FLOAT-ING WIRE	250 K EACH
BRA-8 (IMPROVED)	INCLUDES L.F AND LORAN CAPABILITY	MAXIMUM USABLE DEPTH/ SPEED .OR 3 KNOTS BUOY DEPTH FOR GOOD RECEPTION 40'		LOW	LOW AS COMPARED TO FLOAT-ING WIRE	260 K EACH
BRA-16 SYSTEM		120 FT. AT ALL SPEEDS. SYSTEM HAS A MULTICOUPLER WHICH LINKS 5 MAJOR ANTENNA INPUTS IN VLF/MF/ HF TO ELIMINATE PATCH PANELING		LOW	NO DATA AVAILABLE	100 K EACH
BRA-15		SAIL MOUNTED		LOW	HIGH AS COMPARED TO WHIP	60 K EACH

Figure 58

"In figures 59 and 60, we have another set of comparative figures for the grouped programs, these covering the anti-jam capability, the physical posture of the equipment and the range coverage. The mobile systems will require the same anti-jam as would be given a fixed station those systems, incidentally, are not designed with any special anti-jam con considerations because they are, basically, antenna systems for use with the available VLF transmitters. Here the advantage lies in the number of systems and the difficulty in locating, identifying, and determining them.

"BAGATELLE has a very high resistance to jamming, while BEDROCK has only a moderate resistance -- a lower resistance in fixed stations and a higher resistance in the mobile stations. ELF is good against jamming, assuming that the multiple elements are properly spread out across the country. The system can be hardened but at a great increase in cost.

"The acoustic systems can be blotted out by megaton explosions in the ocean at 15-minute intervals and might well be obscured during periods of time in a shooting war for similar reasons. Present ranges with acoustic gear are only about 500 miles, although this may be raised to 1500 miles by 1966. We are doing a survey of the oceans to determine locations where we are not impeded by mountains or valleys, as these will cause shadow areas and restrict the acoustic ranges sharply. We do feel that we will soon know the areas where we can get these ranges."

Captain Sanger asked about the megaton explosion effect. Captain Dudley explained that the detonation would create a tremendous sonic energy content in the ocean which would follow the reverberancy paths to the bottom, back to the surface, and continue to do so until the noise subsided, which would take about 15 minutes. Captain Gooding asked if a nuclear blackout would occur with the VLF, and Captain Dudley replied that the interference would probably be less than with any other band of frequencies.

SYSTEMS	RESISTENCE TO JAMMING	PHYSICAL COVERT	OVERT	RANGE COVERAGE
MOBILE SYSTEMS TACAMO NOMAD SHIPBOARD VLF	ANTI-JAM TECHNIQUES OF FIXED STATIONS	HIGH -	ADVANTAGES ARE DIFFICULT TO LOCATE, IDENTIFY AND DETERMINE NUMBER OF TRANSPORTABLE/MOBILE PACKAGES	DEPENDS ON NUMBER OF SYSTEMS
BRA-8	NONE	SUBMERGED		N/A
BRA-8 IMPROVED	NONE	SUBMERGED		N/A
BRA-16 SYSTEM	PROVIDES A DEGREE OF RESISTANCE TO JAMMING (10-15 DB)	SUBMERGED		N/A
BRA-15	NONE	EXTEND OUT OF THE WATER		USED FOR HF TRANSMISSION AND RECEPTION CAN HANDLE 5 KW RADIATED POWER.

Figure 59

SYSTEMS	RESISTANCE TO JAMMING	VULNERABILITY PHYSICAL COVERT	OVERT	RANGE COVERAGE
BAGATELLE	HIGH 30 DB	MEDIUM MULTIPLEXITY OF ELEMENTS	MEDIUM ESTIMATED (20 TIMED COST OF ELIMINATING NAA) 20 ANTENNAS SEPARATED BY AT LEAST 10 N. MI. OVER-PRESSURE OF 5 PSI.	USE AS ALTERNATE TO NAA
BEDROCK II	MEDIUM 12 DB.	SAME AS ANTENNA SITES LOW FOR FIXED SITES HIGH FOR MOBILE SITES	SAME AS ANTENNA SITES	SAME AS PRESENT VLF STATIONS
ELF	HIGH	MEDIUM MULTIPLEXITY OF ELEMENTS	MEDIUM CAN BE HARDENED AT INCREASED COST. DOES NOT APPEAR FEASIBLE TO HAVE MOBILE TRANSMITTER COMPLEX	WORLD WIDE
ACOUSTICS	MEDIUM 1 MEGATON BOMBS DROPPED AT 15 MIN. INTERVALS COULD JAM SYSTEM	MEDIUM MULTIPLE SHORE STATIONS TRANSDUCERS AND CABLES PER AREA	MEDIUM SHORE STATIONS WOULD BE HARDENED. MOBILE RELAYS REDUCE VULNERABILITY	PRESENTLY 500 NM. RADIUS. WITH FAVORABLE MEDIUM 1500 NM. BY 1966.

Figure 60

Dr. Hartmann asked about the acoustic system and whether it required wiring up the ocean with transducers. Captain Dudley answered that there were several acoustic systems, of which this was one.

"The 1500-mile capability for acoustic systems," continued Captain Dudley, "comes originally from the OpNav requirement, but we also have considered it a realizable goal. Depending on what we learn in the ocean studies, we may be able to set up a system with one transducer, or one with a series of transducers connected by hard wire to a shore station. We have already developed a transducer with a 500-mile range; this has a few bugs in it but it has already demonstrated the range."

MISSILE COMMITTEE REPORT DISCUSSION

"I would like to bring the group up to date with our standard opening feature," began Captain Dubyk. "This is, of course, the POLARIS A3 status, as shown in figure 1. We are getting to the point where our oscillations are fewer and our introduction of new design features have been programmed long in advance, except those that might be occasioned by flight testing.

"What I have tried to do is to refer to the basic figures presented at the meeting we had in June 1962. The plusses and minuses on the figure refer to the numbers as of that date. For example, the first stage inerts were 99 pounds greater in March than those we spoke of last June. The number has now gone up to 117 pounds. All but one pound of the additional 18 pounds are the result of first stage changes. The one pound has to do with the introduction of the standard firing unit that is present in the first stage, second stage, and re-entry system. You may recall that we are putting in a firing unit that is uniform throughout the entire missile. The 18 pounds seem to be a bookkeeping problem between Lockheed and Aerojet; it was not previously reported and amounts to 13 pounds of actual weight that we are seeing in the nozzles and 5 pounds in the base end brackets of the first stage.

"The numbers you see in this chart are actual weights that apply through A3X-25, but it is interesting to note that if we extend these numbers to A3P-1, the Aerojet and the Lockheed predictions of A3P-1 weight are within two pounds of each other.

"Getting back to the figure, we are introducing a decrease from 72 to 70 inches in throat diameter on the A3X-22. This was programmed some time ago and represents the last nozzle change that we have in our first stage nozzle. This nozzle, by the way, has performed much better than we had anticipated.

POLARIS A3 - STG STATUS

ITEM	JUNE 1962	SEPT. 1962	DEC. 1962	MAR. 1963	MAY 1963
1ST STAGE	24242	141	108	113	132
PROPULSION	23840	52	125	115	133
PROPELLANT	20800	0	21	16	16
INERT	3040	52	104	99	117
I_T X 10^6	5.406	.002	.007	.027	.016
BALLISTIC SHELL	116	2	1	10	10
FLIGHT CONTROL	172	-12	-16	-9	-9
ELECTRICAL	114	-2	-2	-3	-2
2ND STAGE	10305	-15	-1	2	21
PROPULSION	9536	9	-1	-36	-41
PROPELLANT	8876	4	-11	-32	-32
INERT	610	7	10	11	6
POTTING COMPOUND	50	0	0	-15	-15
I_T X 10^6	2.436	-.014	.004	.012	.012
BALLISTIC SHELL	260	9	0	6	8
NOSE FAIRING	137	8	3	3	3
EQUIPMENT SECTION	123	1	-3	-3	-5
FLIGHT CONTROLS	323	4	22	24	37
ELECTRICAL	88	-3	-5	-7	6
GUIDANCE	80	1	1	1	6
CONT. & TRIM	18	-6	-18	14	5
RE-ENTRY SYSTEM	----	23	34	30	49
BASIC R/S		20	25	19	33
HEAT SHIELD		3	9	11	16
PX-2/PY-2	246	20	14	22	20
R/S	228	14	4	17	12
ELECTRICAL	18	0	4	-1	-1
PY-2	0	6	6	6	9
MISSILE GROSS					
WITH PX/PY	35843	98	155	167	222
WITHOUT PX/PY	35597	78	155	127	195
RANGE*					
WITH PX/PY	2160	-14	-10	-10	-10
WITHOUT PX/PY	2500	-75	-50	-32	-34

*RANGE INCLUDES 250 POUNDS FIRST STAGE AND 130 POUNDS SECOND STAGE INERT WEIGHT LOSS DURING FLIGHT. FIRST AND SECOND STAGE WEIGHT LOSS FIRST ADDED IN MAY 1963.

"On the A3X-27 we will be flying the standard firing unit and a new firing unit mounting bracket on the motor. There will also be cable bosses that will accommodate the type four cable which comes in with the Mod 6B actuator. These are all of the various changes that have yet to be flown on the first stage."

In answer to a question from Captain Sanger, Captain Dubyk said that the last column in the figure represented the A3X-27 and that the weights were very close to what they should be ultimately.

"There are three areas in which we need good definition, the greatest of which is the re-entry system," continued Captain Dubyk. "We have made estimates of the 45 pounds and we will have to continue making estimates until we get some actual weights. Throughout the rest of the system we are very close to what we think we will have on the A3P-1.

"We show a decrease of 5 pounds -- from 11 to 6 -- in the second-stage inerts. In the inert area our nozzles weigh 3 pounds less than we estimated previously. We are getting more actual weights in this area, and the other 2 pounds of the 5 is scattered all across the board.

"Regarding the over-all second stage, we are in good shape; we have no fixes ahead. At A3X-27 we bring in the standard firing unit bracketry on the second stage. Also at A3X-27 we will be using the epoxylite 810 bonding system that we use in bonding our insulator to the chamber adapter. This was developed by U.S. Rubber and takes care of some of the separation we had at this point. Goodyear and Goodrich now have it also."

Admiral Smith asked about the 13 pounds increase in flight controls on the second stage. Captain Dubyk replied that as a result of the A3X-20 and A3X-9 flights the nozzle design was changed. "The AGR graphite, shown in figure 2," continued Captain Dubyk, "showed up with circumferential cracks after the static firing. A3X-20 flew very well until about 74 seconds when we began to lose the throat of number four nozzle. The whole nozzle came out at about 79 seconds. Therefore, we went to a CS-1312 graphite which is basically stronger and more consistent; it increased our strength 50 per cent. Further, we thickened this to give another 40 per cent strength. This is not a new product; just new to the program. Generally, we static fire these things a number of times, but in this case events overtook us. We had one static firing in BC 24 in which no cracking was observed, and then we had two flight tests of A3X-12 and A3X-15. Fortunately all worked well and we seem to have this fixed nicely."

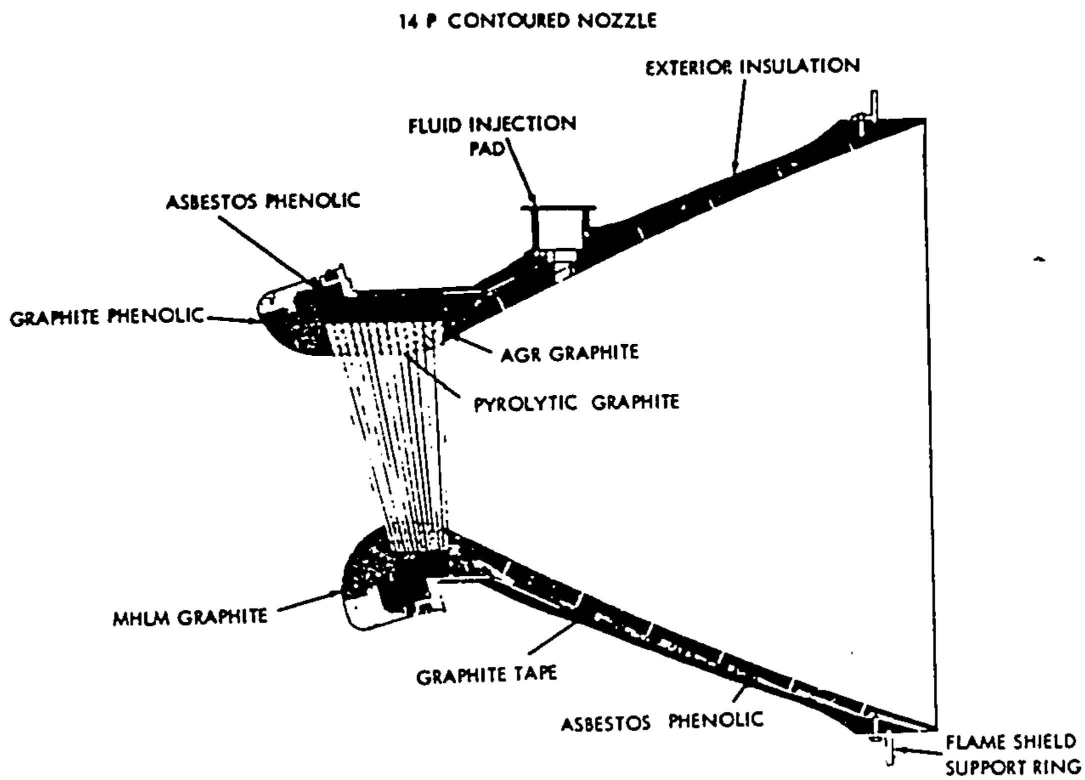


Figure 2

Dr. Craven wanted to know why AGR graphite was selected initially and Captain Dubyk replied that at that time pyrolytic graphite did expand and a material was needed that would crush in a controlled fashion and would be more absorptive of this expansion. "However, this did not work out too well because it crushed and cracked in some cases. The quality of the AGR graphite was too hard to control. Along with the pattern of circumferential cracking on almost every one we had in static firing, we then had cases in flight where added loads were imposed and the thing did not come out completely.

"Another innovation we are making," continued Captain Dubyk referring to figure 2, "is thickening the local area in the back end of the second stage. In some of our static firings we have noted that the areas between the nozzles and the base end eroded; in at least one case right down to the bare metal of the case. To remedy this we are thickening the insulation which is done very easily by removing some metal that we have in our molds when they make the insulator for us. This will be introduced in A3X-44. This will mean a decrease in range of about three miles.

"I want to mention something this Group may not be entirely aware of before I leave the second stage discussion, and that has to do with the explosion that we had at Alleghany Ballistics Laboratory about a month ago. This occurred during the processing of our A3X motors. It appears to be associated with the handling of nitroglycerin which we use as a solvent. The material is 90 per cent nitroglycerin and it wiped us out as far as A3X work is concerned at ABL.

"We were able to transfer operations -- what tooling remained -- and some selected personnel out to the Bacchus Plant where we do our A2P production fabrication of the second stage motor. We are in a difficult spot now because our casting work for both the A2P and the A3X is done in one building at Bacchus and should we have a detonation there, the program would be very seriously damaged. The Hercules Powder Company hopes to have another single building available by the middle of June where we could do our A3X casting."

In answer to a question from Dr. Mechlin, Captain Dubyk replied that the production of the A3X motors required the use of 90 per cent nitroglycerin, and that going to a lesser concentration of perhaps 75 per cent it would take from six to eight months to determine what the processing would be. Admiral Smith noted that this would cost 60 miles in range.

A discussion followed about the dangers of using 90 per cent nitroglycerin. Captain Dubyk pointed out that Hercules Powder Company had substantial experience in handling nitroglycerin -- they process great quantities of 100 per cent nitroglycerin -- but the handling of 100 per cent nitroglycerin is done by gravity only. "Our processing," he continued, "requires the use of pressure for proper solution of the casting powder; it requires pressure for transfer, for example. Besides the pressure, you have to use clamps to regulate pressures of 35 psi which are used as a head over the solvent solutions. You have the casting powder which is rather like gelatin grains. Then you put in water but you also put a head on to make sure you have enough solvent, and you also use pressure. When you do these things you are using the pinch clamps or screw clamps and you are running a risk, as has been shown in the ABL explosion, of having contact. The nitroglycerin may get into threads and the screwing action in the confined area may have been the reason for the detonation. Physical handling of the nitroglycerin is also another possible cause of the explosion. They are investigating other ways of handling the nitroglycerin, trying to eliminate the use of excess solvent and pressure and relying more on gravity for the transfer of the solvent."

"How about eliminating the screws and screw threads in the seals?" asked Dr. Mechlin. "Is it not possible to use some gravity technique with a very heavy weight for sealing purposes? Are there other ways of sealing besides putting pressure on by screwing bolts?"

Captain Dubyk replied that those ways had not yet been found. He also stated that the final propellant was not dangerous but the plan at present for propellant beyond the A3 was to use 75 per cent desensitized nitroglycerin. It was pointed out in the subsequent discussion that use of the 75 per cent nitroglycerin was certainly less sensitive, but what it did to the performance of the motors was still unknown.

Dr. Kirchner asked about the increase in total impulse from December to March shown in figure 1. Captain Dubyk said that the I_{sp} of the first stage was running at 260.5. On the second stage the I_{sp} value was agreed by both Lockheed and Hercules to be 276.8. "Encouragingly enough, the last two flights had values in excess of 276.8 -- much closer to 279. This may be on the statistical high side, and further tests may come back to the average of 276.8. There have been no changes in the composition of the propellant or in the thrust coefficient in the nozzle. If the 279 figure is valid we might have another 50 miles in range."

In answer to a question from Admiral Galantin, Captain Dubyk stated that although the missile gross weight increased from plus 98 in December to plus 222 in May, the range was off very little because of the increased I_{sp}.

"The reason the flight control weight has gone up by 13 pounds," continued Captain Dubyk, "is that we are putting 8 pounds additional heat protection on our Freon tank and 5 pounds in the tank supports. We are going to use silicone tape heat protection instead of the lighter cork. Silicone tape is heavier, but gives more uniform protection. We feel this is warranted because the tanks are near the nozzles and we have radiated heat. We are measuring all the data and feel that this change is necessary.

"We had two successful flights, the A3X-12 and A3X-15, with the 8 pounds of base protection removed. The maximum temperatures ran to about 225 degrees.

"Regarding changes in flight control besides the silicone tape which we will fly on A3X-22, we are going to fly for the first time the Mod 6B hydraulics package. On the A3X-39 we are going to fly the so-called over-and-under Freon hoses in order to accommodate second stage dome expansion which might move the nozzles. If you have a length of Freon hose that is at its extreme as short as it can be, it can put undue stress on the nozzles. To accommodate this we are making the line lengths a bit longer and, to ensure they do not butt against each other, we are putting them over and under each other. This is going to be statically fired in one of the two static firings planned in the second stage static firing program in the next two months. We are making certain that the line lengths are not on the low side, and we are using shims to tell us what happens -- if we have some movement, what would the length have been and how much pull would there have been on the nozzle.

"This is a fiberglass motor which has more movement than steel does, so when the chamber pressure reaches 400 psi, the chamber tends to go outward and the nozzles are also turned outward. This is in the second stage; when the motor is ignited, it is put under pressure. The back end is more flexible than it would be with a metal back end. As it expands, it turns the nozzles outward so these Freon lines, if they are relatively inflexible, are shortened, putting strain on the nozzles.

"At A3X-38 we put in the kluge velocity sensors and firing unit that we have for the partial PX-2 kit. This adds 16 pounds and loses 21 n.m. in range. The tactical version of this goes on at A3X-48."

"The kluge velocity sensor sits in the middle of the re-entry system delta frame," said Commander Julian, "and senses velocity from 271 feet to go at increments to provide the three salvo eject signals for the PX package. It is an integrating accelerometer with three outputs. We are now using timers which sense time but not integrated velocity. We eject the PX package now after separation. With PX-2, all packages will be completely separated prior to re-entry body separation."

"The difficulty," commented Mr Stevenson, "is that you have thrust-termination now and it is still burning so you are gaining velocity which you use to kick off these PX elements." Captain Sanger remarked that Commander Julian had just said that the PX elements were kicked off before the re-entry body, and Dr. Kirchner felt this could not be done on an absolute time basis.

"We are talking about time after 270 feet per second which will vary with the range you are firing at. The acceleration can vary considerably between a short range shot and a long range shot," said Captain Sanger. Commander Julian added that it could be as short as 0.8 second.

"SP23 may want to comment on this," resumed Captain Dubyk, "but the actual weights in guidance are about 86 pounds which is 6 over the 80 pounds we spoke of at the STG meeting last year. About 4 or 5 pounds of this is in the computer area and about 1 pound in inertial.

"We have changed the contingency and trim by 9 pounds -- we have reduced it by 9 pounds. This is a way of partially offsetting some of the added weight we have been putting on."

Dr. Kirchner asked what the contingency on Freon in the second-stage vector control system was and where such a figure would be shown.

"What we have," replied Captain Dubyk, "is 200 pounds of Freon and a dump system so that if we do not use it at the rate we expect to, then the flight control package signals it to dump.

"The last item I want to mention is the 19-pound increase in the re-entry system. Five pounds of this is being assigned to a heavier heat shield. The estimate now of what we are going to be flying at A3X-27 is about 43 pounds; when we start getting actual weights it may even go up to 45 pounds. It is a substantial heat shield, although it is lighter than those we have been flying in the last several flights. These were temporary heat shields whose weight has been given to me as high as 70 pounds."

"Before we flew the last missile," said Mr. Stevenson, "I felt the heat shield we had was strong enough, but apparently from the data that is coming back, it collapsed, so I do not really know how easy it is going to be in cutting that weight down."

"It is hard for me to see how it collapsed," said Captain Dubyk, "but according to the telemetry it did. All our functions on the last flight of the A3X-15 except for second stage pressure were lost at the time of the initial blastoff. The second stage pressure kept going for about eight or ten seconds.

"Unless we can invent some other things that knocked out all these functions and still allowed the heat shield to remain intact, we have to assume that the heat shield let go," said Mr. Stevenson. "It might have been a cable some place that knocked out everything but the second stage transmitter, but the cables are all on the other side. If the heat shield goes, then anything can happen, but we do not know how it failed."

"It seems a very slim chance to knock out everything else and leave the transmitter going," said Admiral Smith.

"That is true," said Mr. Stevenson, "but the point is that this is a random situation which might next time fail in another fashion and leave some other things going and kick out the transmitter. It depends on where the wires were and how they were broken.

"First, we are trying to say that the heat shield was solid, but there is no other possible way of doing this. We cannot find any one thing that could fail and do all this damage. We cannot blame it on g forces or vibration, so we come back to the conclusion that the heat shield failed."

"Continuing my remarks about the re-entry system and the increase of 19 pounds," said Captain Dubyk, "we are also beefing up our heat protection for the re-entry bodies themselves and consequently have put on 14 additional pounds."

Commander Julian stated that he thought the re-entry system weight was not accurately reflected in the June 1962 column. "I would like to recount a little history," he said. "In December 1961 at the MCM we got a change in the Data Book number for re-entry systems to At the time it was I requested the 25-pound increase to account specifically for 3 pounds for each body for vulnerability protection and 5 or 4.9 pounds for each body for additional modulators. Through some bookkeeping inaccuracy the basic re-entry system weight of stated in the June 1962 column should be I think the increases shown are through mishandling of the basic system weight which was and not ."

- CFRD

Admiral Smith pointed out that it was all bookkeeping and that the weight of the re-entry system had not changed.

"Our additional weight," resumed Captain Dubyk, "has its effects against our target. As you can see from figure 1, our range is 2150 n.m. with PX and 2466 without PX-PY. Thanks to the I_{sp} situation, our range is better than I had expected six months ago.

"One other thing I want to touch on in connection with this range figure is the retention of the nose fairing. If we keep the nose fairing on longer, we are going to take a range penalty. If it stays on ten seconds longer, we will lose 40 miles. I meant to talk about this in connection with the A3X-15 flight and with our next shot, the A3X-25. After lunch I will comment on the last two shots of our flight test program."

Admiral Smith then called for a luncheon recess at 12:15 p.m.

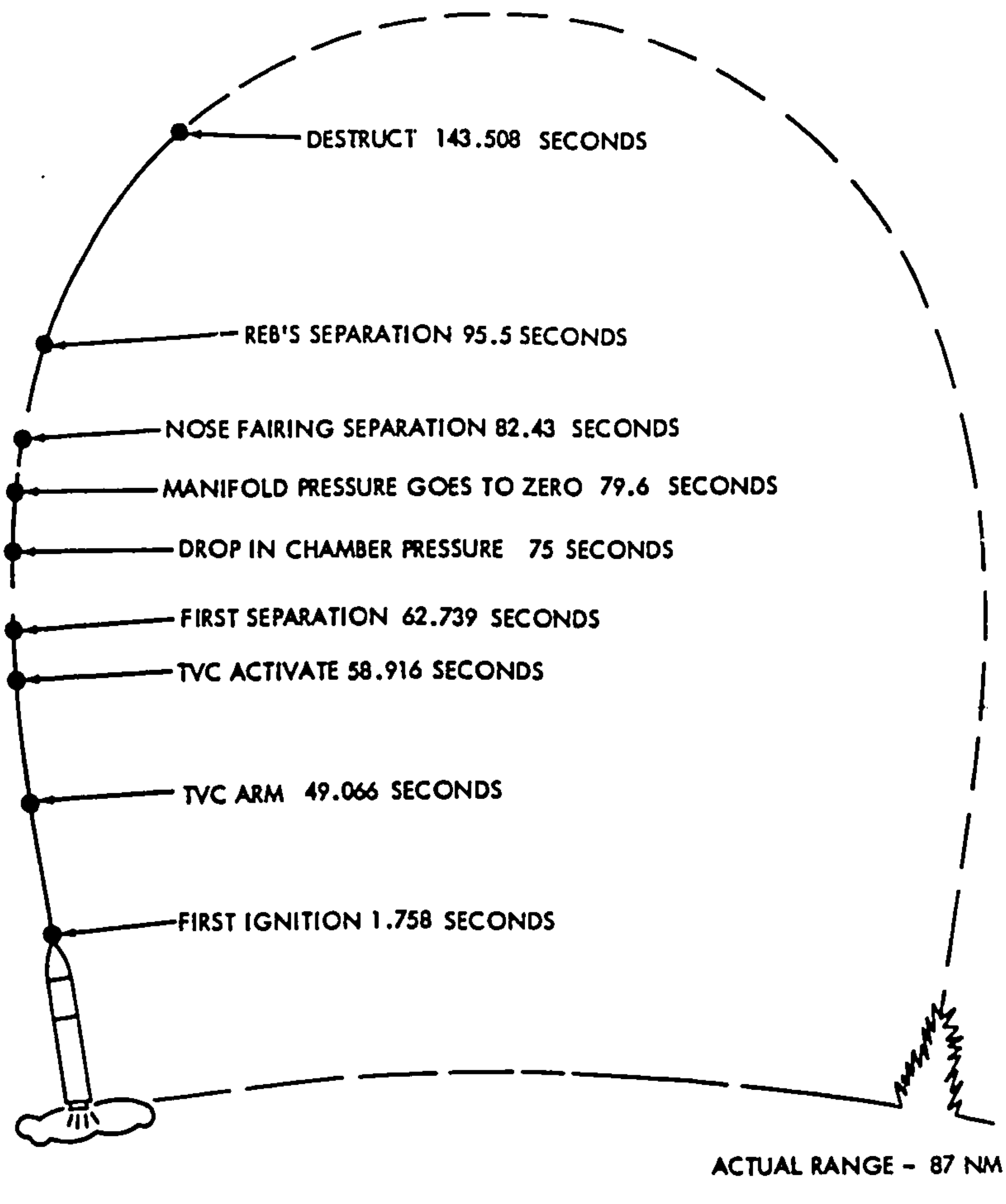
The meeting reconvened at 1:14 p.m., 23 May 1963.

"The A3X-20, -12, and -15 are the last three flights we have had," resumed Captain Dubyk. "All three of these had some similarities; they all carried the Mark 2 guidance and all had the same nose fairing configuration. They had the Mod 6A hydraulics system on the first stage and they all had the Mod 2 TVC. We do not intend to fly any more Mod 1 TVC's. The A3X-20 had the earlier version first stage nozzles -- the soft graphite. From the A3X-12 on, they will have the improved graphite.

"A3X-20, shown in figure 3, was a fully guided flight, launched from the USS OBSERVATION ISLAND. The primary objectives were re-entry body and Mark 2 guidance; the first stage was completely satisfactory

"Interlocks I worked as it should. We had trouble in an earlier shot (A3X-14) regarding the fire control inputs, but on the A3X-20 we had a good flight as far as navigation inputs and fire control operation were concerned. Guidance was properly erected and aligned; proper velocities were established; and there was no trouble with the guidance and umbilical disconnect.

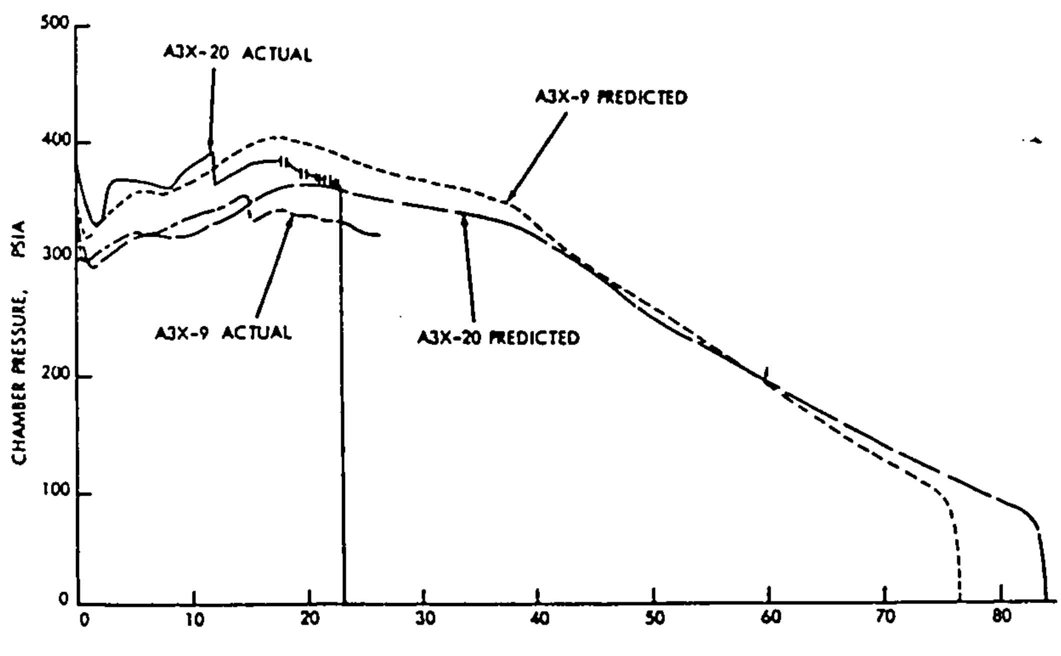
"The problem we had was second stage chamber pressure, which was normal up to 75 seconds, or about 12.24 seconds after second ignition. At that point we saw disturbance in longitudinal acceleration and film data showed pieces being ejected. After our analyses, these events are seen to be associated with the loss of the throat in nozzle No. 4. Losing the throat would give us an increase of about two square inches, and this is about the opening you would have to have to get a 30 psi drop. This was the second missile to fly with the 14P configuration.



FLIGHT EVENTS, A3X-20

Figure 3

"Figure 4 is a comparison of second stage chamber pressure histories between the A3X-9 and the A3X-20. Our A3X-9 flight had a malfunction in its TVC regarding a blockage of our Freon manifold. Also on that flight we noted an apparent loss of a throat at the same time. The A3X-9 had the 12P configuration but it also had the same kind of throat and the behavior was quite similar. The missile flew long enough to show a pressure drop in the second stage and we checked our data and found the same failure was also ascribed to the throat, so we have not one but two flights in which we have had this type of failure. We do not, however, know which nozzle was lost on this flight. On the A3X-20 flight we were able to identify Nozzle No. 4 because, looking at the attempted correction, other nozzles moved, in a fashion. The fluid flow was such that we found they tried to compensate for having this loss."



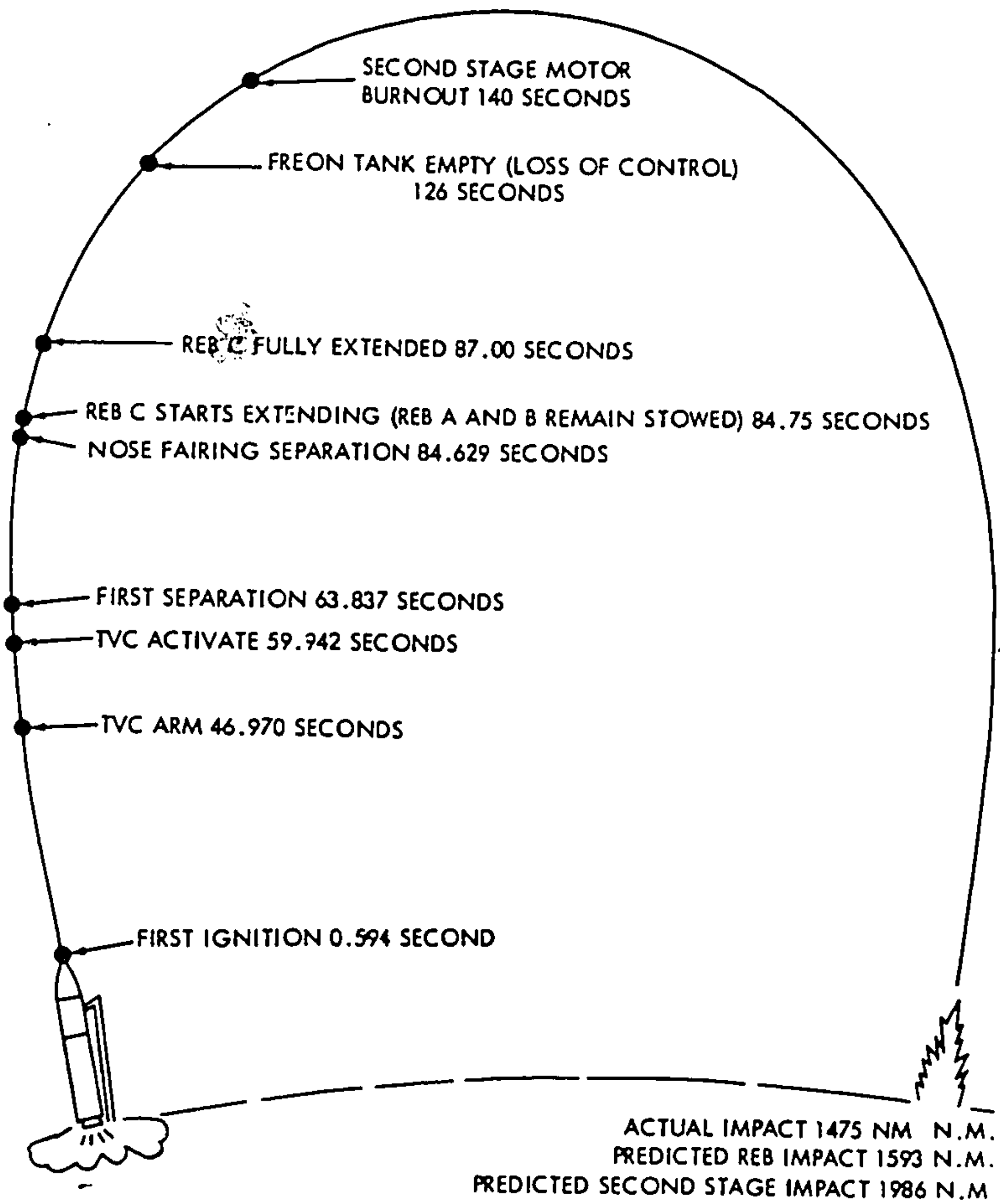
COMPARISON OF SECOND MOTOR CHAMBER PRESSURE HISTORIES, A3X-9 AND A3X-20

Figure 4

Dr. Kirchner pointed out that the same reasoning could be applied to the A3X-9 flight because of the unbalanced thrust caused by the larger throat. "The important thing is," he said, "if you can identify with the same nozzle, then possibly you can translate this back to the asymmetry of the entire system and vector control and on the basis of that see what the strain is actually doing to the nozzles."

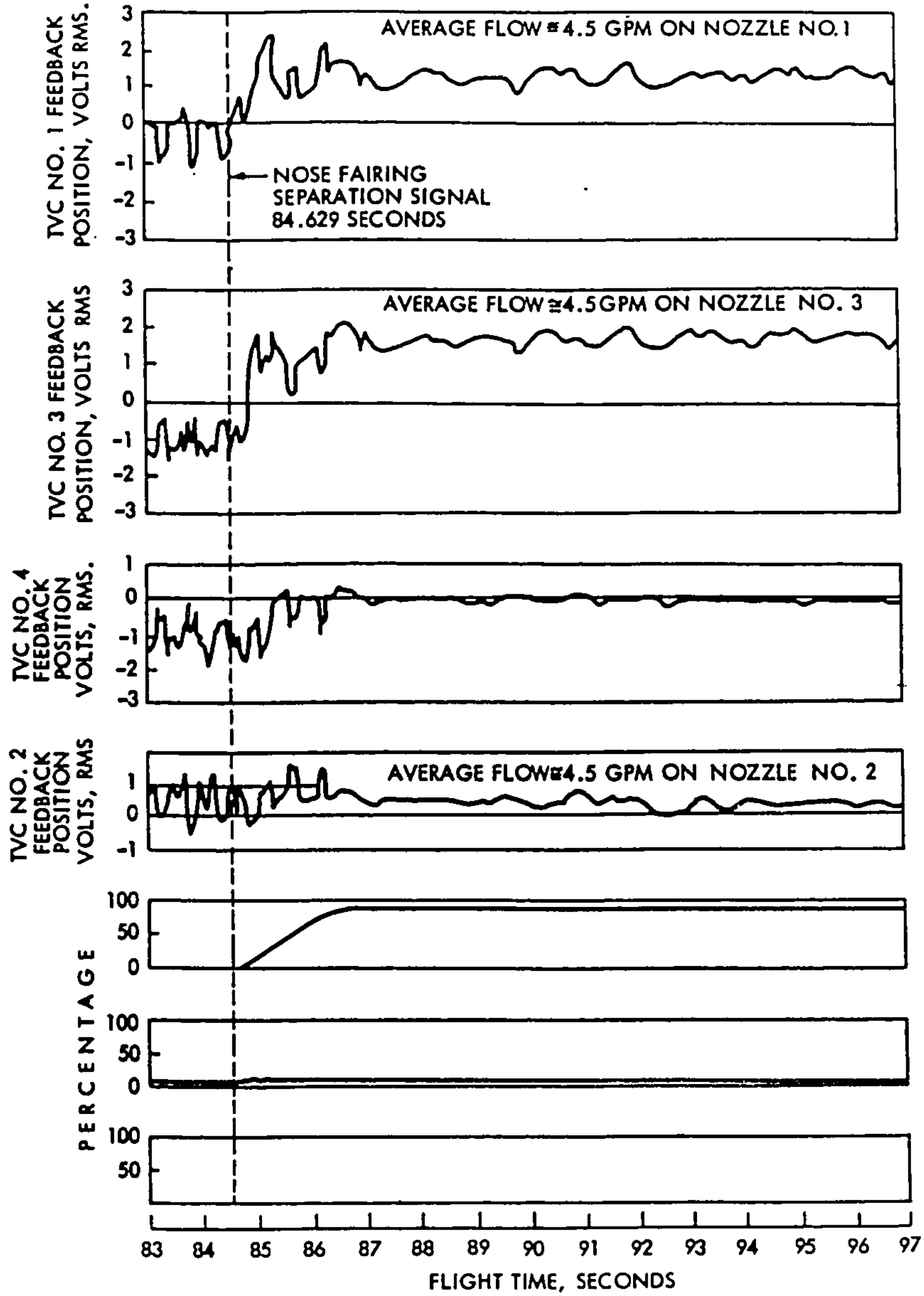
"As a result of losing the throat on Nozzle 4," continued Captain Dubyk, "we burned through the Freon manifold and the manifold pressure dropped down to 20 psi in less than 90 milliseconds.

"Going on to the A3X-12, this was launched on 10 May and it was planned to be a 1600 nautical mile fully-guided flight with basic vehicle and re-entry body objectives. In this particular one we put on the improved nozzle, and we also flew the A3X-15 with this same nozzle, so we have two successful shots, plus one static firing with the new graphite. The problem we had on the A3X-12 was that everything was successful up through the nose fairing separation, but then re-entry bodies A and B failed to eject. The re-entry bodies are restrained by the nose fairings, but when a nose fairing flies off, the mechanism which secures the bodies is released. The bodies are permitted to deploy outward and there is a snubber mechanism in there which ensures that we do not swing out too rapidly and that we deploy to the exact angular position. This is important with regard to the impact pattern of our re-entry bodies. What happened in A3X-12 was that one of the bodies, C, did extend at 87 seconds, but re-entry bodies A and B did not drop down. The missile was then, in effect, in asymmetrical flight and we had to have a high Freon injection rate to keep the vehicle in trim condition. The amount of Freon was substantially higher than we would normally use -- four to five gallons flow -- and at 126 seconds we ran out of Freon, as shown in figure 5. Freon flow during this flight is shown in figure 6.



FLIGHT EVENTS, A3X-12

Figure 5



FLIGHT DATA, A3X-12

Figure 6

"In order to take care of this pitchdown that we were getting by having one body drag, two nozzles had to work to give us a pitchup movement. As a result of this we investigated very carefully the mechanism that is used to do those functions, namely, to keep all re-entry bodies tucked in in order to make use of the volume that we have there before the nose fairing eject. In other words, the piston-like snubbers act to have the re-entry bodies properly extend. We found that in some circumstances there could be an alignment of our various pivot points which would permit getting behind the dead center; looking at our tolerances and making changes at some of our springs or some of our dimensions, we proved on the ground that we could correct the problem and we did.

"Figure 7 depicts the flight test of the A3X-15. The first stage flight was satisfactory. TVC Freon got up to 920 psi pressure as it should. Freon flow rates were good. The second stage performance was also satisfactory; nose fairing eject was good. Just to refresh your memory before continuing, each re-entry body has two actions which occur almost simultaneously. One is to break the primacord at its base to separate it; and the other is to ignite the rocket motor to kick it off. This rocket motor burns for only 0.25 second and the re-entry body is leaving at about 125 feet per second. Our telemetry reports that the three re-entry body units on the A3X-15 did charge up as they should at the time of nose fairing separation.

"We have two bits of information about the firing units for the rocket in each of the three re-entry bodies. We monitor the inverter current which is the one that sends out the charge to the firing unit. The inverter current, sent out at the in-flight signal safety time, indicated that the three firing units were all charged. We also monitor capacitor voltages, and these indicated that one firing unit was not charged. In spite of the conflicting information, we feel that all six of the firing units were charged.

FP25A	17 MAY 1963	SUCCESSFUL

RANGE — PROGRAMMED 1598 NM; IMPACT PREDICTION ______ NM

TIME ______ SEC; QUALITY ______

MAJOR OBJECTIVES
MK 2 GUIDANCE PERFORMANCE EVALUATION AND R/S DEVELOPMENT INFORMATION

FLIGHT (● INDICATES NORMAL)

● IGNITION	0.918 SEC	● 2ND STAGE FLIGHT	
● 1ST STAGE FLIGHT		● NOSE FAIRING SEPARATION	81.05 SEC
● 1ST SEPARATION		● REB EJECTION	124.63 SEC
● 2ND STAGE IGNITION	61.35 SEC	O RE-ENTRY BODY SPIN	______ RPM

SIGNIFICANT HARDWARE
ONE EACH 1H, DH--13 AND DW--5

REMARKS

Figure 7

"With regard to re-entry break wires, the A body break wires went off as they should, but our best estimate is that the break wires on B body did not. The reason we say this is that the instrumentation we had on that particular head did not stop spin-up as it should have with the rate gyro that we had and acceleration is not as is should have been had it cleared off. On the C body there was indication that it went off 8 seconds later. The reason we say this is that the RF signal strength went up at about 132 seconds, which happens if the body clears and if it deploys its monopole antenna.

"According to our SOFAR data, the A body landed where it should have landed; the B body was out about 7 miles; and the C body was 21 miles out.

"Apparently we saw 11 psi pressure at separation in the equipment section. This seems to indicate that for some reason we have a very unusual buildup of pressure in the equipment section. This was a second pressure that we continued receiving from the telemetry until 121 seconds."

Dr. Kirchner noted that the level of the pressure was as predicted on the second stage which made him wonder about the 11 psi. Captain Dubyk said that the level of pressure in the motor was as predicted but the equipment section pressure was 11 psi, which was higher than predicted.

Captain Sanger asked what might be happening during the sequence of events -- were the motor closures the same as those in the nose fairing? Would they be acting as projectiles? What had been seen in ground tests?

"We have had only one all-up test," replied Captain Dubyk. "The motor closures were Teflon, and in that particular instance there was little evidence of scorching and no evidence of a shrapnel effect."

In the following discussion Captain Dubyk pointed out that the equipment section pressure was high right after the rocket went off on re-entry body A. Admiral Smith wanted to know how this fit in with the statement that the only telemetry received after was second stage pressure. Mr. Parran noted that there was a buildup in pressure; the pressure was not only failing to decrease, it was increasing.

"Is the mounting or the construction of that heat shield such that it might be more apt to fail with one body gone than with all three gone?" asked Captain Sanger.

"It is actually located underneath the delta frame that holds the bodies," said Mr. Stevenson, pointing to a model on the table. "It is made up of quite a few pieces and the suspicion is that there was one piece, located in the middle between the three bodies, that let go." Mr. Stevenson noted also that the thrust of the re-entry rocket was taken into account in designing the shield, so that whatever the thrust was had been predicted. "Something may be wrong with the prediction," he continued, "but it was taken into account in the design of the baffle system."

"We went over the design of the baffle," said Dr. Kirchner, "especially the heating effect, and this was just aerodynamic heating." Mr. Stevenson noted that when the first re-entry rocket comes off there is a diffusion coming in creating the greatest amount of heat. "The baffle is composed of steel, plastic filler, aluminum and about an eighth of an inch of cork on top of that," added Mr. Stevenson, "which is more than sufficient for the heat from the rockets."

Captain Dubyk said that the equipment section then had to be designed to pressure loads criteria and that it was easy to stop the gas flow but it was necessary to withstand the pressure involved. Mr. Parran noted that these rockets burn for 0.25 second at 8000 pounds. Dr. Kirchner felt, however, that this sort of arrangement lent itself very well to bench tests so that there ought to be a lot of data on how the mechanical features and rockets themselves behave under these conditions. He said that taking the missile up to altitude and firing the rockets was not the same thing. Mr. Stevenson stated that altitude made a difference in the pattern and that was why the Rye Canyon test was more representative.

"You should have a restrained test program," said Dr. Kirchner "where you actually have thrust cells and methods to show the timing as far as the movement of it is concerned as related to the sequence of actuation of rockets."

"We have done that," said Mr. Stevenson, "and the tests showed no problems; the baffle design was good. We ran half a dozen tests, one rocket motor at a time."

In answer to a question from Dr. Craven, Mr. Stevenson said that there was a possibility of a progressive failure resulting from the initial damage caused; that the thing was weakened when the nose cone came off; the rocket blast was the final blow.

Mr. Parran asked what the range penalty was in keeping the nose fairing on until getting out of the heat flux area. "Holding onto the nose fairing," replied Mr. Stevenson, "for an additional ten seconds takes you out of the heat flux problem, but gives you a 40-mile range penalty."

"I think we have touched on some of the possible reasons for failure," resumed Captain Dubyk. "One of the other things we are looking at is the possibility of a primacord failure. The particular primacord that does the separating is a 7-grain flexed linear shaped charge and it breaks a flange to which the re-entry body is attached. The flange is attached to the re-entry body frame and to the underside of the re-entry body. When the primacord is broken you permit flyaway. It may be that in this particular case the firing unit did not operate properly, although we have tested this a great deal at altitude. It could also be that we had excessive heating because the primacord itself at temperatures of 400 degrees, say, would start malfunctioning. It was my understanding, though, that the base of the DH head was instrumented and on five to seven temperature readings we did not see temperatures above 130 degrees. I received this data yesterday which seems to preclude the possibility of thermal effects on the primacord."

"The suspicion," explained Mr. Stevenson, "was that if the primacord were heated, it would degrade and thus would not work correctly. We had some reason to suspect this was the case because this same method of separation is used for the satellites. The satellite people have a lot of this material in storage and periodically they take it out and test it; the specification calls for it to be tested at room temperature. Some of the primacord that had been in stock for six months was tested at elevated temperatures and was found to have different characteristics than it had earlier, which showed that time was having some effect on that particular batch. We took a look then and found that even at the temperature we had reached and with the condition that prevailed, we should have had plenty of power left in the primacord. Besides this is the same primacord we have had in the A1 and A2, but it is 7-grain instead of 9-grain."

"We are following several lines of investigation of this failure," resumed Captain Dubyk. "We are looking at the possibility of using a heavier flexed linear shaped charge and also shock vibrations and shock effects causing the failure. We are examining the possibility of igniting the primacord at both ends instead of just one end. Another area that is being looked at is the thermal effects on re-entry body cables. I do not think this is the case because thermal analyses indicated that the PR 1910 tape was at least twice what we need for anything we have seen to date, as far as temperature is concerned, but the possibility of using a metal shielded cabling in all the forward re-entry body area is being investigated."

"If all three primacords and rockets had fired as they should, and if all three re-entry bodies had gone off correctly," said Mr. Stevenson, "then the relative motion during the 0.25-second interval when the pressure builds up is of little importance. We went back over this, and one of the first things we came to was the need for a shorter period of time and the necessity of designing it so that the rockets cannot cause trouble, even if they should stay on.

"There is still the possibility that damage could be done to the
electrical system if the rocket fired and the nose cone stayed on. By
23 the time the bodies are signalled to leave, there could be some hard-
ware moving about, or gases blowing things around, that would damage
or clean off the PR 1910 tape and allow the heat to get to the wires.
The nose fairing eject rocket burns for only 0.5 second."

"If you restrained the nose cone and expended the rocket," asked Dr. Kirchner, "what would the anticipated pressure inside be if you considered this a closed system? Is the nose cone designed to take this sort of pressure? For example, the interstage ruptured at 105 psi. Anyway, I would like to know the pressure depth."

Mr Stevenson said he did not know, but could get the information for Dr. Kirchner.

"We would like to slip the next shot, the A3X-25, one week because of this failure," continued Captain Dubyk. "We want to put in all our instrumentation that was planned for the A3X-25 and distribute it throughout the rest of the missile. We want to put more pressure and some temperature instrumentation up front. We need information about our pressure buildups, vibration, and temperature."

"This comes about," said Mr. Stevenson, "as the analysis progresses in the A3X-15 flight. We are running a survey to learn as much as we can up there and take as much instrumentation as we can. In addition to that, we propose also to put a wiring and metal conduit up in order to prevent the heat protection from being knocked off. We may be going overboard a bit, but we are trying to overprotect, if you will."

"Additional tests are going on," said Captain Dubyk. "Lockheed recommends that we consider using a metal shielding for the next one, although we are not quite ready to do this. Tests are continuing on the flexed linear shaped charge, but I do not think we will be ready in time for the next flight to make any specific recommendations about changing our mode of attachment or ignition, or to increase from 7-grain to 9.

"I do not believe these tests will delay our next flights which are scheduled for the EAG on the 17th and 21st of the month. We plan to fly those right on time with one variation which we can readily accommodate. Recognizing that we may have some trouble with the nose fairing on our next shot, and assuming that we have some type of heat-aggravated phenomenon, we propose to keep the nose fairing on ten seconds longer. If we keep it on from 81 to 91 seconds, most of our heat will have passed. Our heavy heat input is over by that time. If we use more instrumentation on the next flight, we may be able to see if we had lowered heat inputs by retaining the nose fairing; if we have a successful flight, then it may be possible to infer that the heat alone or heat in combination with something else is one of the basic reasons for the failure.

"We could not retain the nose fairing ten seconds longer on the A3X-25, but it is a fairly simple Interlocks II change and we propose to use it on the A3X-22 and -24."

"We are getting temperatures up to 1000 degrees," explained Mr. Stevenson, "and the design analysis shows that the nose cone ought to be able to take it. However, with that high heat condition, things may be happening that we do not understand. Therefore, we want to hold the nose cone on and eliminate the environment."

Captain Dubyk noted that the range penalty for holding the nose fairing on 10 seconds longer was 40 miles, and that the weight of equivalent equipment for that 40 miles was 30 pounds. Dr. Craven asked if there were any ablative material that weighs 30 pounds that could be put in there to resolve the problem.

"We have got twice the thickness of the PR 1910 tape we thought necessary," replied Captain Dubyk. "This is an insulating material, silicon plastic, and it burns off. I think we put on 60 to 70 pounds plus a thicker heat shield. The heat shield weighs about 70 pounds. It foams and chars and forms a better insulation than before it is heated. Then the char corrodes and it progresses this way. It is better as an insulator than as an ablative material."

Captain Dubyk stated again that more and better instrumentation was necessary in order to determine what the environment is. He said that the failure might have been due to a combination of shock and ablation effects with temperature.

Mr. Stevenson explained further by saying that if some of the PR 1910 were knocked off and there were no heat, the wiring would survive. "So, if you keep the nose cone on, you would not have a high heat input at the end of an additional ten seconds."

Commander Julian noted that if the nose cone were kept on it would mean giving up minimum range and accepting a reduction in maximum range, but it also might mean eliminating the 70-pound diaphragm. Mr. Stevenson felt the diaphragm was still needed because of the pressure, noting that it could be redesigned in order to cut down the weight. The problem was whether to start a redesign this late in the program.

Mr. Parran remarked that they had gone through all of this discussion last year when Commander Julian wanted to keep the nose fairing on longer because he did not want to mess up the accesses by putting on the heat shield. "There must have been a good reason to continue the plan to get rid of the nose fairing early and put in the weight penalty," he concluded.

"The diaphragm was only going to weigh 27 pounds," said Commander Julian. "Now we see it getting heavier and heavier. The one in A3X-15 did not survive and it weighed 60 pounds."

"If keeping on the nose fairing bypasses some of our environmental effects," said Captain Dubyk, "we would be much better off doing that instead of continuing to add weight. It means accepting the 40-mile range degradation, and it increases our minimum range to 700 n.m."

Captain Sanger asked how long the nose fairing would have to be kept on in order to avoid the need for the diaphragm ablating. Captain Dubyk replied that it was about 105 seconds, but they were concerned about rocket pressure effects also. "I think we are now in the position of feeling we must keep our missile flying straight for two seconds after our rocket re-entry bodies eject," he said.

"The clearances between our re-entry bodies and our second-stage motor are so close -- around 12 inches -- that any kind of movement would probably cause a perturbation. With these clearances any maneuvering within a second or so would bring you dangerously close to the bodies."

In answer to a question from Mr. Parran about whether keeping the nose fairing on longer compromised the re-entry problem, Captain Dubyk said, "No, this is all on the ascending arc. It now comes off at 81 seconds."

"If you kept the nose cone on until the Q is completely gone," said Mr. Stevenson, "it would move in the same area although it would have an offset trajectory. It takes off over-the-shoulder and the only question would be how far away it would continue to be. It might even look like a decoy during mid-phase. Where we now jettison it, it drags far behind; it would still lag back, even with ten more seconds of flight."

"You said that you initiate the primacord and the rocket engine simultaneously," said Mr. Eyestone. "The question I have is, how sensitive does it have to be to have the rocket engine go off just a little before the primacord?"

"The signals are given simultaneously," replied Captain Dubyk, "but because of the pressure buildup that you have in any rocket, the primacord is always gone."

Mr. Stevenson noted that it would not be gone if something delayed the electrical firing of the primacord. "It would only have to go 100 milliseconds later." Captain Dubyk said that the instrumentation was not sensitive enough for such a delay to be detected.

Mr. Eyestone asked if there were any chance that if the primacord did not fire, the rocket engine firing would cause the primacord to fire. Mr. Stevenson thought not, because the primacord was well protected and in a special channel. Captain Dubyk said that they did not think this happened because the evidence was that the DH head fell off because of structural considerations.

Mr. Parran asked if there were any shrapnel effects from the firing of the rockets and Mr. Stevenson replied that it was a clean break.

"The re-entry body," commented Captain Dubyk, "is screwed to a flange which is screwed to the base ring. It ruptures in a ring all the way around; it flies away, and the flange stays bolted to the base ring.

"Anyway, to summarize, we are asking to slip a week on this flight in order to get better instrumentation in there. We want to put in primary pressure instrumentation. If we go in extensively for temperature-type instrumentation, we may have to wait another three days.

"We propose to put in pressure transducers, especially around the heat shield and around the re-entry body. We have to make our commitments for instrumentation about a month before the flight."

Dr. Kirchner wanted to know what they would do with the data received from the instrumentation, and Mr. Stevenson said that they would compare it with the design data to see if the design could take the effects that were reported. "There is a possibility," he said, "that we are predicting here less than what is actually happening. The heat shield is made up of various pieces, some thicker than others. It may be that the pressure is distributed differently and that in certain areas we do not have a strong enough condition. We hope the data will tell us this."

"If we had to do this data over again," said Captain Dubyk, "I would have liked to have had pressure transducers in there to tell me if there were any sudden rises at the time of nose fairing separation. I would also like to know if, in selected areas, we got the temperatures we had predicted."

"Can you predict that the pressure is not going to affect the cabling?" asked Dr. Kirchner.

"I cannot with the nose fairing eject," answered Captain Dubyk.

"You can say the flow pattern is different," remarked Mr. Stevenson. "It may be tearing up some cables."

In answer to a question from Dr. Barrow, Mr. Stevenson said it was not possible to test this on the ground because the heat you get at altitude cannot be duplicated in a tunnel. Dr. Mechlin said that if flow phenomena were to be examined, this could be done on the ground because it would not be necessary to duplicate exactly aerodynamic conditions. Mr. Stevenson remarked that building a full-scale tunnel would be such a large task that it would be quicker to fire the missile and get the information that way. Dr. Barrow disagreed, saying that it might not be quicker because of the limited amount of information that came back from altitude testing.

"We are going to do much more ground testing," said Captain Dubyk. "For example, we have done a great deal of ground testing on the 7-grain flexed linear charge. We do not have the full answer on that yet, however. We may have some shock effects on these charges if we have asymmetrical firing on two of the bodies, for example."

"My proposal," said Mr. Stevenson, "is to put metal conduits on the lines that actually do the firing. It takes a week to do this. If the instrumentation is going to be changed at all, this takes another week. To add more temperature instrumentation would make it even longer."

"The cables over which you are going to put the metal covering," said Captain Sanger, "contain both the firing signal lines that we suspect may have been carried away and the charging signal lines. Does the same cable that carries the charging line also carry the firing pulse?" Mr. Stevenson answered that it did, but in order to be on the safe side they were going to protect all the forward cables.

"How do you know that you do not have detonator problems instead of a primacord problem?" asked Commander Julian. "How do you know it is not the thing at the end of the high voltage wire -- the squib?"

"For one thing," replied Captain Dubyk, "every installation is X-rayed, so we know they are good. The other thing is that the general quality level of both squibs and detonators has been significantly improved; this is reflected in our lot testing for every lot we made."

"We found out that we did have a marginal condition that could break down," said Mr. Stevenson, "and would not deliver the full energy to where it should go. We have made design changes to eliminate this problem by building more margin in at the higher altitude and extra voltage. Every one of them gets an altitude test before it is launched."

"Is there any place in that cabling where a single break could disable bodies B and C and leave body A functioning?" asked Captain Sanger.

"Not that we can find," replied Mr. Stevenson. "You would have to go back into a J-box south of the heat shield and they are all independent of the heat shield. If you see the installation, we do have wires running around in the flanges of the delta frame, and those are the lines that I suspect."

Mr. Morton asked if the temperature could be predicted and Captain Dubyk said that Lockheed had done that. Mr. Stevenson said that it was Dr. Wilson who had predicted how bad things might be, and he was proven right by the results of the flight. "We did not believe at that altitude you could do enough damage to get that effect," said Mr. Stevenson. "We looked at quite a few designs to build a new nose cone so that the top of the nose cone would stay on, and act as a probe. There was a great deal of weight in doing this and you had to worry about the reliability of these banana peels."

"That was a new wrinkle," said Dr. Kirchner. "What we had actually was a spike."

"The spike," said Mr. Stevenson, "has to be out of the way of the rocket. It has to be pretty far up. We had lots of sketches on ways of of doing it, but they are either too heavy or unreliable because of the banana peel. The nose cone would not come off. We even tried to have it so these things could break away as an actual motion in some fashion, but that alone did not work because any tipping motion was devastating for the combination. Each one we tried fell apart for one reason or another."

Admiral Smith observed that the subject had already been quite generously discussed.

"Then I will talk about another major area," resumed Captain Dubyk, "the fire control and guidance problem. Figure 8 is a summary of data from Phase I testing of the digital information 'scramble.' The A3X-14 flight failed because of a shift in our guidance computer time base which occurred at about the time of the main umbilical retract. Just to refresh your memories, this missile had three umbilicals -- the base umbilical for the hydraulics, the main umbilical for the eleven other missile functions, and the instrumentation umbilical. What we saw occurring in the A3X-14 was a shift in the guidance computer time base at the time of launch. The missile never flew properly, and it was destructed at 17 seconds.

SUMMARY OF INFORMATION FROM PHASE I TESTING REGARDING DIGITAL INFORMATION SCRAMBLE

1. INDEPENDENT OF DISCONNECT SEQUENCE.
2. COINCIDENT WITH TACTICAL UMBILICAL DISCONNECT.
3. NOT RELATED TO RF SYSTEMS OR PUMPS OPERATING.
4. OCCURS WITH ONLY GUIDANCE/FIRE CONTROL INTERFACE WIRING CONNECTED.
5. PROBLEM AGGRAVATED BY ABSENCE OF LINE SHIELDING WITHIN MISSILE.
6. HIGH FREQUENCY TRANSIENTS ARE GENERATED ON UMBILICAL WIRING AT DISCONNECT.
7. UMBILICAL CHATTERS IN LAB TESTS.
8. BLOWER POWER EFFECTS FAILURE RATE.

Figure 8

"As a result of this failure there has been continuing, intensive, and still uncompleted effort to try to find out more about our problem, and as expediency, what to do in our next few flights. Our initial heavy review showed that apparently the failure was independent of which umbilical was pulled first; it seemed to be tied in with the tactical umbilical. In other words, the exercise umbilical and the base umbilical did not affect what was happening. It was not related to an RF system or pumps operating. It occurred only when the guidance/fire control interface wiring was connected. The problem was aggravated by absence of line shielding within the missile. The high frequency transients are generated on the umbilical wiring at the time of disconnect; the umbilical does chatter in laboratory tests; the guidance package blower power does affect the failure rate. If you have it on, you will get some failures. If it is off, you will have substantially fewer failures.

"So we had a problem of transients affecting the inputs into the guidance package; and this resulted in our running tests on the A3X-20. It was the next one fired on the EAG after the bad flight of the A3X-14. Further tests were run on the pad with the A3X-12, and more testing was done back at Sunnyvale.

"Figure 9 shows the test statistics on the A3X-22 and A3X-25, and the A3X-20. There are two approaches we could use to solve the problem. We could try to keep our transients out of the missile; one way to do this is to try to eliminate the noise we generated at the umbilical by using an umbilical switch. The other approach would be to modify the input circuitry to the computer itself to cut down on its susceptibility to noise. That is done with what is known as a T-zero switch added to the telemetry adapter in the guidance package."

"These tests, it should be clearly stated, are not the same failure that occurred in A3X-14," said Mr. Forter. "A3X-14 was a timing shift in the computer and this is simply a change in the read-in constants into the computer of the fire control, caused by transients in the read-in line."

"One point back on item 4 of figure 8," said Mr. Leech, "is the fact that the fire control is no longer terminating the fire control interface lines here, that the umbilical has been retracted, and that the lines are exposed with no termination. As long as the fire control is hanging on there, we have no problem."

"I said it only occurs with guidance control interface wiring connected," said Captain Dubyk. "When they are disconnected, there are time shifts, bit losses and pre-arm inhibit occurrences."

A3X-22 AND A3X-25 (MOD CENTER)				NUMBER	PAI	DIGITAL MALFUNCTION
T_0	T_0 SHORT	UMBILICAL SWITCH	UMBILICAL RETRACT			
	NO	YES		57	0	12
	YES	NO		200	76	4
	YES	YES		243	0	0
A3X-20 (AMR)						
BLOWER/HEATER AND FUSE SELECT DISCONNECTED				52	NA	0
TEST STATISTICS						

Figure 9

"Well, pre-arm inhibit is not related at all; it is merely an indication of flux at the 10-volt line," replied Mr. Forter.

"Before sending A3X-22 and A3X-25 down to the Cape," continued Captain Dubyk, "we ran them at the Mod Center at Lockheed and tried affecting what came into the missile through the umbilical and what came into the guidance computer. As you see on figure 9, we have had these combinations and we were quite successful when we used both, although we do not fully understand why yet.

"Before running A3X-20, we ran tests with the blower and the heater and fuze select disconnected, and had no failures."

Dr. Mechlin then referred to line 7 of figure 8, and asked what umbilical chatter was. Captain Dubyk answered by saying that when the umbilical is pulled it is possible for the break not to be clean which would cause arcing at the point of separation. This was the chattering that was referred to. Dr. Mechlin said it was actually a double or triple break with two dead faces and the connector itself.

"Figure 10," resumed Captain Dubyk, "shows the next step we went into which was to look at the A3X-10 digital information problem. That work is still going on; the Guidance Lab at Lockheed investigated the bit time shift. That is still very much under way. The A3X-0, our hangar queen, is being used in the screen room to investigate what happens to things like nose fairing ignition.

"Figure 11 summarizes the results of the Phase II test program. I will not read them, but one bit of information I want to add to this is that apparently we vary from missile to missile; that some missiles, like A3X-20, get the reputation of being clean, while others, like A3X-10, seem to be more susceptible, perhaps because of the way their grounds are located. This implies that in some of our missiles, like A3X-14, we did not have a precise knowledge of how we did our grounding.

"Figure 12 is some proposed solutions to the problem. Regarding our digital information malfunctions, we are investigating a redesign of the umbilical. Chatter was mentioned and also the question of what it is that is out of line when you are making your breaks. We would like to provide different lengths in our pins; if you have short pins for your power wiring and this is broken first, then you do the signal wires, and finally the functions that you have to keep to the bitter end, using the longest pins -- the T-zero erase pulse and the star computer. If these things are kept to the last, this sequence might give us an end to some of our problems. We are also looking at a fix to reduce the vibration of the pins on the missile side of the umbilical to eliminate pin chatter during the disconnect sequence.

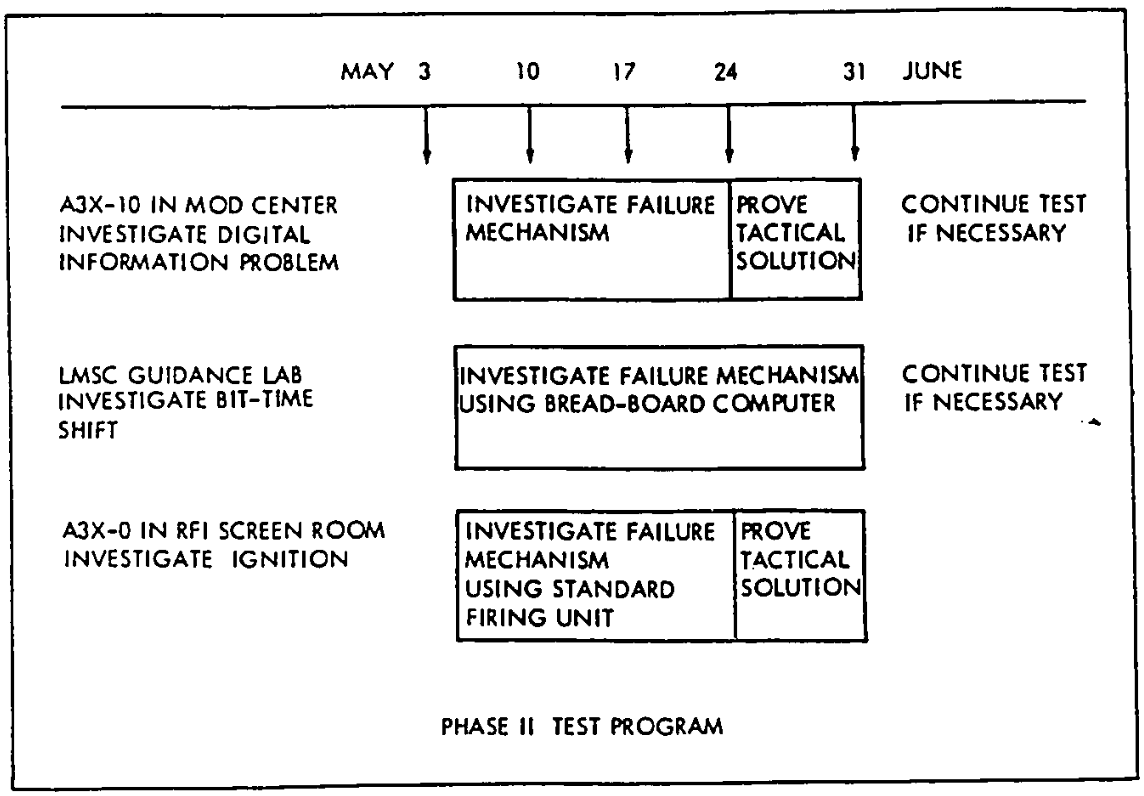


Figure 10

"The second item under Digital Information Malfunction is putting small capacitors to selected signal lines. This is something MIT is investigating.

SUMMARY OF PHASE II TEST RESULTS

1. RECONFIRMED RESULTS FROM PHASE I TESTING.
2. DIGITAL INFORMATION AND PAI FAILURE RATE IS AFFECTED BY FILTERING ON SIGNAL LINES.
3. UMBILICAL DISCONNECT NOISE CAN SET T_0.
4. TRANSIENTS BETWEEN 0 VOLTS (COMPUTER) AND COLD PLATE GENERATES BIT-TIME AND/OR DIGITAL INFORMATION MALFUNCTIONS.
5. NOSE FAIRING UNIT GENERATES BIT-TIME AND/OR DIGITAL INFORMATION MALFUNCTIONS.
6. IGNITION EFFECTS ARE GREATLY REDUCED BY FILTERING ON FIRING UNIT INPUT LINES.
7. BIT-TIME MALFUNCTIONS ARE PROBABLY RELATED TO EFFECTS OF NOISE TRANSIENTS ON "DIVIDE BY 3" COUNTER CIRCUITS.
8. DIGITAL INFORMATION MALFUNCTIONS ARE PROBABLY RELATED TO THE RISE TIME OF THE NOISE TRANSIENTS.
9. TRANSIENTS ON GUIDANCE INPUT POWER WIRING PROBABLY WILL NOT CAUSE COMPUTER MALFUNCTION.

Figure 11

"The third item, adding a T-zero and star computer null module, would be similar to what we are using in this T-zero switch. This might help on the digital information scramble problem by including other sensor circuits."

PROPOSED SOLUTIONS

DIGITAL INFORMATION MALFUNCTION

1. REDESIGN UMBILICAL.
2. ADD SMALL CAPACITORS TO SELECTED SIGNAL LINES.
3. ADD T_o AND S_c NULL MODULE.
4. ADD UMBILICAL RELAY.
5. CHANGE GROUNDING AND SHIELDING IN MISSILE WIRING.

BIT-TIME MALFUNCTION

1. ADD RF GROUND BETWEEN 0 VOLTS AND COLD PLATE.
2. ADD CAPACITOR BETWEEN 0 VOLTS AND COLD PLATE.
3. ADD FILTER TO NOSE FAIRING FIRING UNIT INPUT LINES.
4. CHANGE GROUNDING AND SHIELDING IN MISSILE WIRING.

PRE-ARM INHIBIT MALFUNCTION

1. PRESENT MIT REDESIGN
2. SOLUTION FOR DIGITAL INFORMATION MALFUNCTION WILL ALSO FIX PAI.

Figure 12

"The T-zero cures only one of the problems," said Mr. Forter. "It cures the problem of noise on the fire control read-in lines; it does not cure the clock shift."

"I will touch on that in a moment," said Captain Dubyk, "but now we are talking about the possibility of putting in a relay with the umbilical. I am not sure this will be needed. Incidentally, for the SSB(N)619, we do have a relay like this configured, and we will use it if we do not have any better information in time for our A3X-42 and A3X-43 flights in September.

"Changing the grounding and shielding in missile wiring is planned for every one of the ship's missiles. We are investigating this carefully at Sunnyvale because we think that possibly our vagaries in past grounding have given us some trouble and we need to look at the type of shielding we need and where it should best be grounded. I know people from SP23 and MIT are interested and have been partially opposed to using the 24 pins. We are eliminating the use of 24 pins until we find out more about what is happening with that type of grounding.

"With the bit-time information, tests are planned to investigate the effects of an RF ground between zero volts and the cold plate."

Captain Dubyk then referred to item 3 under bit-time malfunction adding a filter to the nose fairing firing unit input. Captain Sanger asked what was so special about the nose fairing, and Captain Dubyk said that they appeared to be tied in. "Isn't this a factor in our pre-arm inhibit now?" asked Mr. Forter.

"This is the one that causes the bit most frequently to shift," replied Mr. Forter, "because it is further away and the lead acts as a radiating antenna in inducing voltages in some of the other lines."

"This redesign will be phased in Systems 34 and 35, which are scheduled for flight test in about two months," noted Mr. Leech.

"Right now," said Mr. Forter, "the old pre-arm inhibit is a pretty good thing to have around because it is a good indicator of a shift in the 10-volt supply line."

"I would like," continued Captain Dubyk, "to mention several things at this point. With regard to the next series of flights, it is our plan to fly the T-zero switch until we get a better idea of what fixes are involved. There is some indication that the telemetry adapter without its T-zero switch might be giving us trouble. As a kind of complete stop in filter troubles we propose to keep the T-zero switch in. This is the way we do all our testing at Sunnyvale.

"I think if we pull the T-zero switch out at the Cape, we will have a different radiation and I do not know what is going to happen.

"The other suggestion I have is that it might be worthwhile to conduct full-scale tests with a Mark 2 guidance package with equipment section, nose fairing, and nose fairing eject to find out what happens as a result of these nose fairing firing units and actual physical ejection on the computer clock. I think we may be getting high g effects there."

"You were commenting on the vibration environment," remarked Mr. Leech, "which we confirmed on the centrifuge measurements. Our position on this is that we would like to see some of the in-flight data to confirm that we have this high g environment before we commit the guidance system."

"Well, it goes back to the ground versus air testing argument we had earlier," said Captain Dubyk. "I think you can instrument much more fully on the ground, but obviously you do not get the same environment. I think this is severe enough to warrant having a full-scale test.

"The trouble we had in our earlier re-entry body was that our mechanical programmer definitely saw high g's and definitely malfunctioned as a result of what we had on re-entry body actions. We are going to have our PX rockets in there, and some of these actions will occur rather late in the flight, but I am suggesting that one of the two guidance packages that dropped might be available for something like this."

Captain Dubyk explained that two guidance packages were being transported by airplane back to the East Coast. The airplane crashed, but the guidance units survived and still worked.

"Have we ever made measurements on guidance systems with these firecrackers going off all around as well as these perturbations of the electrical equipment?" asked Mr. Parran.

"We are preparing to do this now at Raytheon," answered Mr. Leech. "We would still like some confirmation of what the environment is. If it is 3000 g's, then we will just crack the cold plate at 3000 g's. It worries us that the in-flight environment is at that level because it could be compromising other equipment ultimately."

Mr. Eyestone stressed the need for getting all the equipment together and having a thoroughly planned test program along with an analytical program. This would mean searing out, to the point of tracing the wiring, where the grounding system goes. He noted that he was talking primarily about the electrical environment.

Captain Dubyk stated that the problem had not been solved after four weeks of very hard work by people from MIT, Lockheed, GE, and Raytheon.

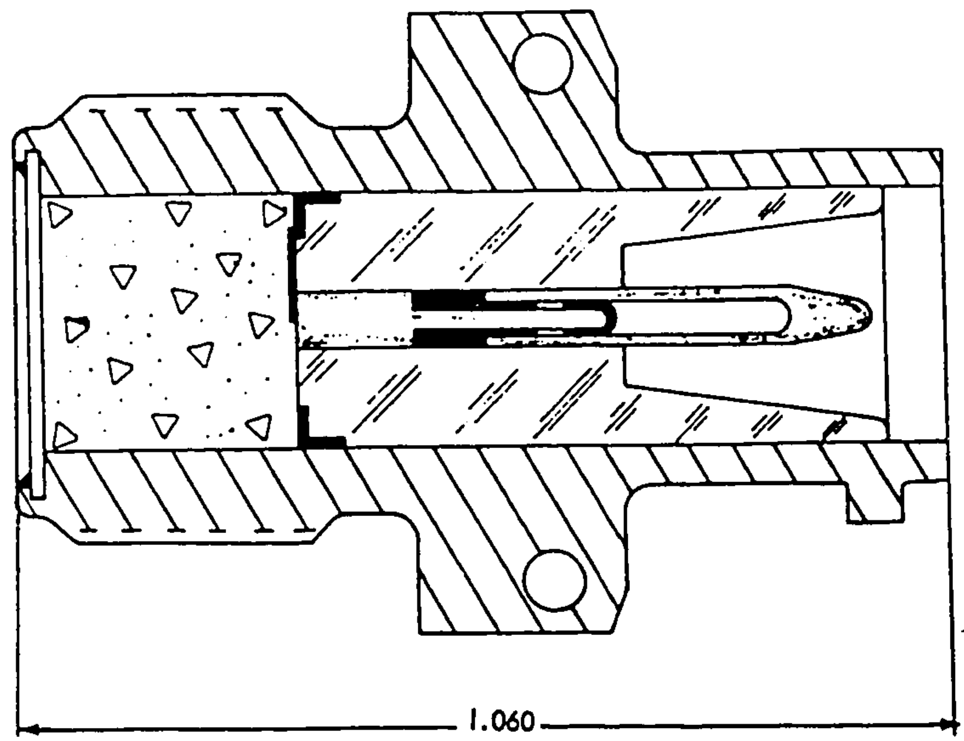
Mr. Leech said that the biggest problem was the low frequency of the malfunction which made it difficult to establish the mode of failure. "We know that 20 volts between zero volts and the cold plate will compromise our computer; I understand that 25 or 30 volts, which is being experienced on MINUTEMAN, will do the same thing."

"Speaking of MINUTEMAN," said Mr. Eyestone, "the crux of the matter was finally ferreted out and certain changes were made. They have since had a number of successes at the Cape. Then at Vandenberg, they ran into another problem which turned out to be that the connection between the re-entry vehicle which was made at the Cape had not been incorporated into the documentation and was not made when they started firing at Vandenberg. In that particular case it was something that comes from buildup of a static charge under some kinds of conditions that will allow a spark to go across if you do not have the connection in there. The connection, however, was made originally for an entirely different purpose."

Captain Dubyk then said he had one more comment on the subject that was basic. "As we know, we have had one flight fail because of the pre-arm inhibit not functioning properly. I wonder if the pre-arm inhibit signal is really needed. I know we want to use it as a delicate indicator of transients, but assuming our troubles are over, I wonder what the effect would be of eliminating this signal. We may be gilding the lily on safety considerations.

"The final topic to discuss is the status of the electric bridge wire coax. Figure 13 shows the single pin electric bridge wire system which is being introduced at A3X-27. Figure 14 shows the various components of the single pin EBW separately.

"Figure 15 depicts the detonator. The construction is the same type except that we have a larger charge. Figure 16 is an exploded view of this. They may seem alike, but they are different in that the detonator has a larger charge which provides more energy in connection with the primacord work. The squib and the detonator are electrically identical except for the larger charge in the detonator. Figure 17 shows an assembled arrangement of a detonator with the new connector and triax cable.



SQUIB, EBW P/N2339557

Figure 13

"With regard to our testing and qualification, we are in good shape as shown in figure 18. The tests for EIMAC have been good. We have had some leakage problems in some of our Physical Sciences detonators. We have various additional tests ahead of us and we aim to complete them by 28 May.

EBW SQUIB

PARTS NUMBER 2339557

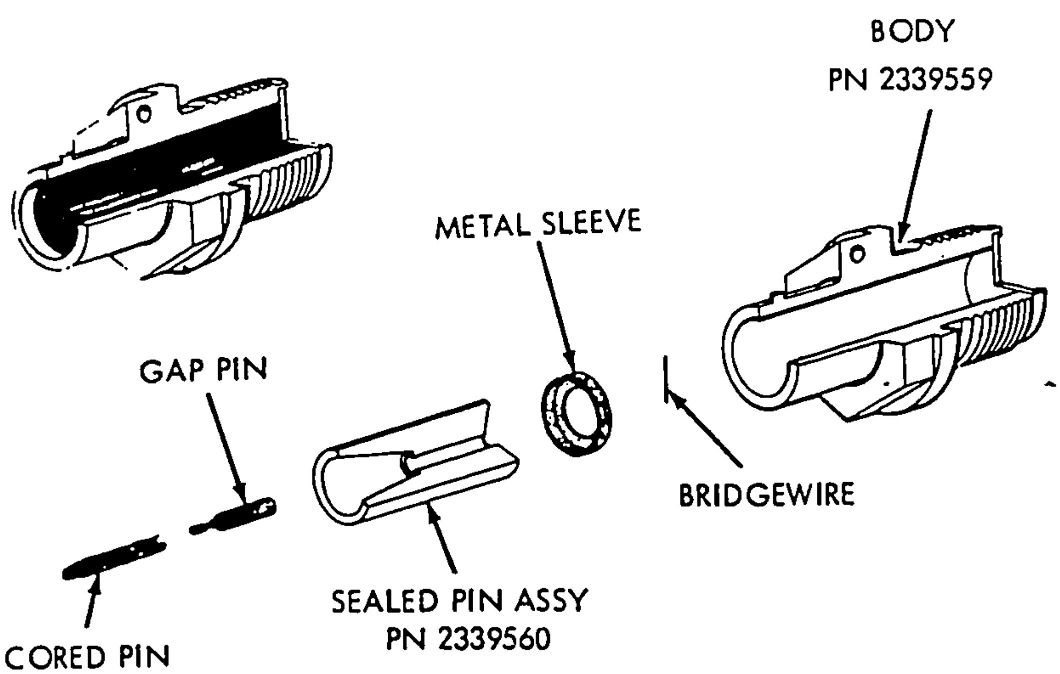
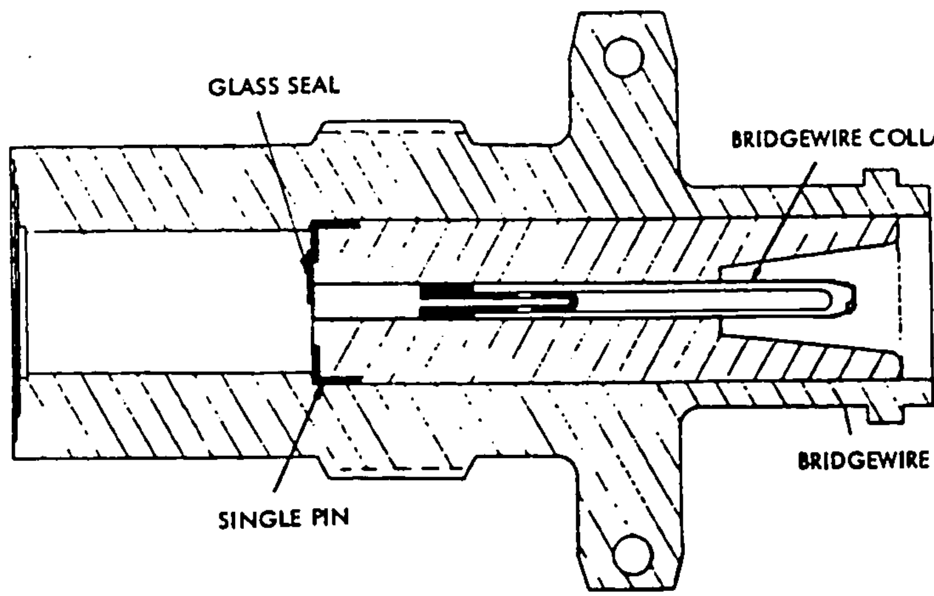


Figure 14

"Regarding A3X-27, it has been checked out at altitude with a two-pin type ordnance and we used headers and mockups at ambient conditions. We plan to run tests before 1 June if we can, with A3X-23, using this single connector ordnance at A3X altitude.



DETONATOR, EBW, 2339553

Figure 15

"We have a full set of two-pin ordnance, and if we cannot quite pack it for A3X-27, we will use it down at the Cape. We plan to run all our tests successfully and satisfy ourselves that this is no worse prior to flying A3X-27. The flight date at present is about 6 July."

Dr. Kirchner asked what the design of the leak test was, and Captain Dubyk said that they are sealing leaks. "There are points at which we assemble these things in a pretty tight fit; then either they weld or put in the potting material which seals the squibs."

EBW DETONATOR
PARTS NUMBER 2339553

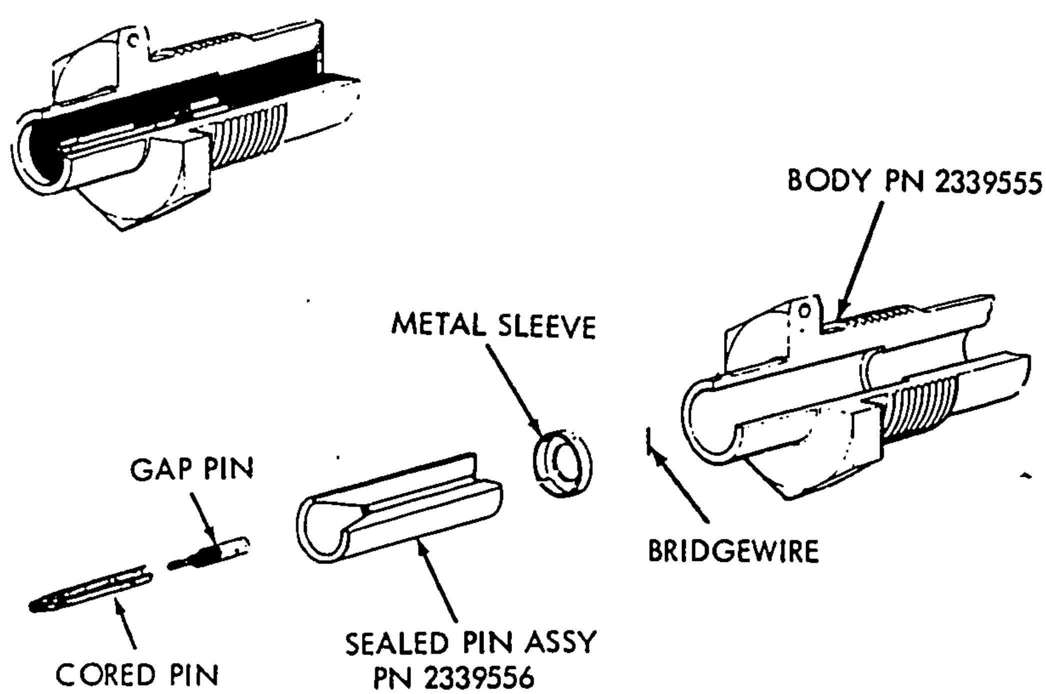


Figure 16

Dr. Kirchner wanted to know if each one had a leak test and Captain Dubyk replied that these are qualification tests not used as acceptance criteria. He said that they would probably have a leak test for all the squibs that were going to fly. Captain Sanger mentioned that there were some failures on part of it but Captain Dubyk said that these were not functional rejects; they were thread rejects.

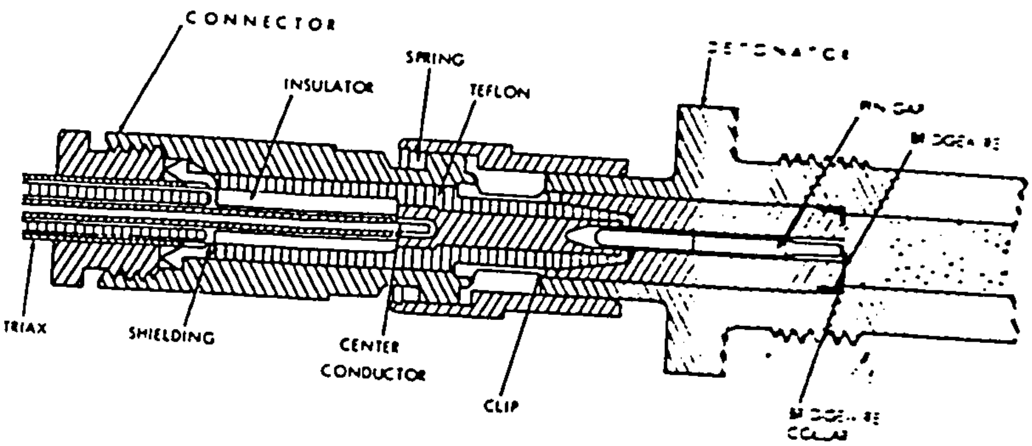


Figure 17

"In passing," continued Captain Dubyk, "I mentioned the squibs and detonators. The coax cable is obviously a very important part of the unit. There are three suppliers right now and one, Dage, is doing a good job. He has had to make major adjustments in sealing his items, too.

"The last model we got was pretty good. On the last units, we ran one at a 130,000-foot altitude for the voltage breakdown. One unit took 5 KV for 15 seconds at that altitude. Another took 5 KV for 30 seconds, and the third took 1 KV for 5 minutes -- no failures, so I think Dage is a good supplier. The other two suppliers, ABL and Verndee are slow in delivery.

"The other thing I might add is that Lockheed is confident enough to have committed themselves to 20 May for this design as the basis of procurement for the tactical missile. This is for the single pin although we still have the backup for the two-pin ordnance. We have 1447 SDI detonators at Santa Cruz and we have 633 of the Physical Sciences; we have two-pin squibs; we have 1090 of Special Devices and 460 of Reynolds; this is enough to take us through our A3X program."

COAX ORDNANCE TESTS

	Coaxial EBW Detonator		Coaxial EBW Squib	
	EIMAC	Physical Sciences	EIMAC	Network Electronic
Number Received	189	164	186	73
To Be Delivered	111	136	114	233
100% Inspection	188/189	162/164	183/186	73/73
Braceton	35	35	35	35
Safety Tests:				
Auto-Ignition	5/5	5/5	5/5	5/5
Jolt	5/5*	5/5*	5/5*	5/5*
500V Pulse	5/5*	5/5*	5/5*	5/5*
Leak Test-Function at Ambient	5/5	3/5[1]	5/5	5/5
Proof Pressure	NA	NA	5/5	0/5[2]
Environmental:				
Transp. Vib.	133/133	107/107	128/128	-
T&H	115	107	115	-
Pressure	To be completed by 28 May 1963			
Shock: 200 g's				
Shock: 65 g's				
Vibration				
Braceton				
Functional:				
Low Pressure and Ambient Temp.				
Ambient Pressure and Low Temp.				
Low Pressure and High Temp.				

The above figures shown with a slash mark (/) denote "Successes/Number Tested"

1 One unit leaked, and the second failed to function.

2 None leaked, all functioned, but all failed post functional proof pressure.

* Overtests - Functional tests after jolt and 500V pulse.
  a. Eimac Coax Detonators - All functioned properly after jolt and 500V pulse no-fire.
  b. PSC Coax Detonators - One unit failed to function after jolt and one unit failed to function after 500V pulse no-fire.
  c. Eimac EBW Squibs - All functioned properly and met proof pressure requirements.
  d. Networks Electronics Squibs - All functioned after jolt and 500V pulse no-fire, but 8 failed proof pressure; two were no test as threads or hex sheared.

Figure 18

Dr. Kirchner asked why the single-pin was chosen. "We looked at A1 and A2 and we were supposed to put four squibs in it to make sure we started to fire," he said.

"The problem is that they are not the easiest thing to make," said Captain Dubyk. "And even worse, they can be hooked up wrong. Another problem is the way the cabling and the way the detonators and squibs are rigged it is possible to have a gap between those two and have a voltage leakage path which means the voltage would leak out and we would not get a detonation. That is the reason for the single pin."

"When we first started to consider the single pin connector," said Mr. Stevenson, "it was reported that there was an ordnance requirement that said under no circumstances can the ground side be used as a current carrying element. We had to get special approval to do it, otherwise we could not have even started the single pin connector."

With no further comments forthcoming, Captain Dubyk concluded the Missile Committee Report Discussion.

RE-ENTRY BODY COMMITTEE REPORT DISCUSSION

"I have some pictures that may illustrate the problem we have been having with re-entry body tilt-out and the means by which we fixed it", began Commander Julian. "Figure 1 is a general view of the area of concern, and you can see the snubber cylinder with the linear potentiometer running alongside to measure snubber movement and position. The box visible is one of the firing units, and the larger connectors go on the eject motor and the separation ring.

"In figure 2, the foreground area shows the gunk we apply and the PR 1910 tape used for wrapping the cables. You can see the bottom of the re-entry body at the top of the picture, and the mating or connecting joint for the nose fairing on the missile. The surface upon which the plunger bears moves off with the nose fairing at separation. Once separation occurs, the plunger is free to move out and does. The bell crank is visible as is the connecting rod to the re-entry body.

"Figure 3 gives a different angle, as does figure 4, with the re-entry body tilted in. You cannot easily see the pin which bears on the circular shoulder of the upper link on the release mechanism, although the shoulder area is visible in figure 1. Now when the nose fairing separates, the release mechanism moves out; there is a break-joint between the upper and lower links of that release mechanism and the upper link and hardware are moved by the action of a Belleville washer located behind the plunger. Because the re-entry body is now on an axis slightly off center and because of acceleration, the re-entry body tends to flop out, carrying the bellcrank with it.

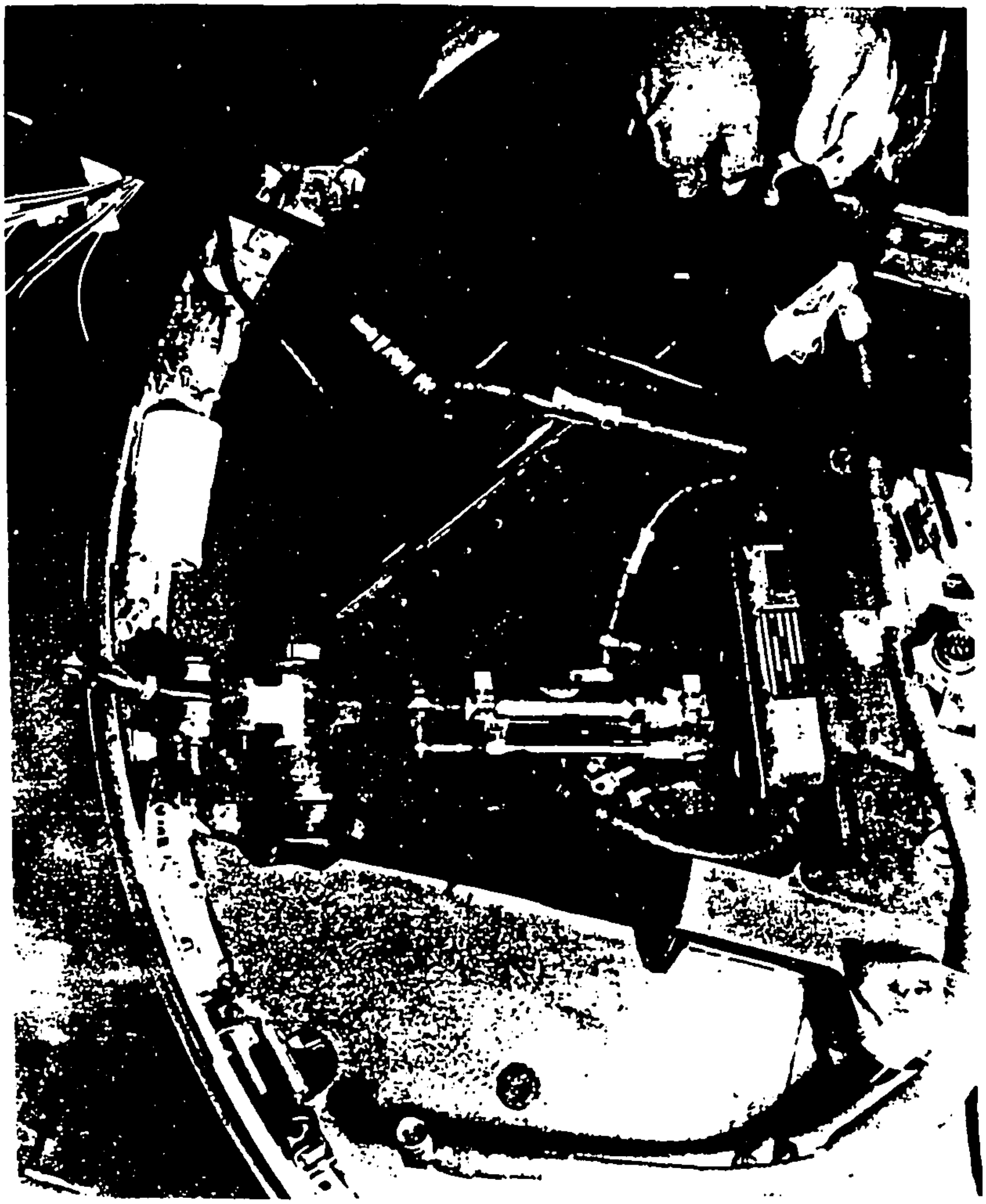


Figure 1

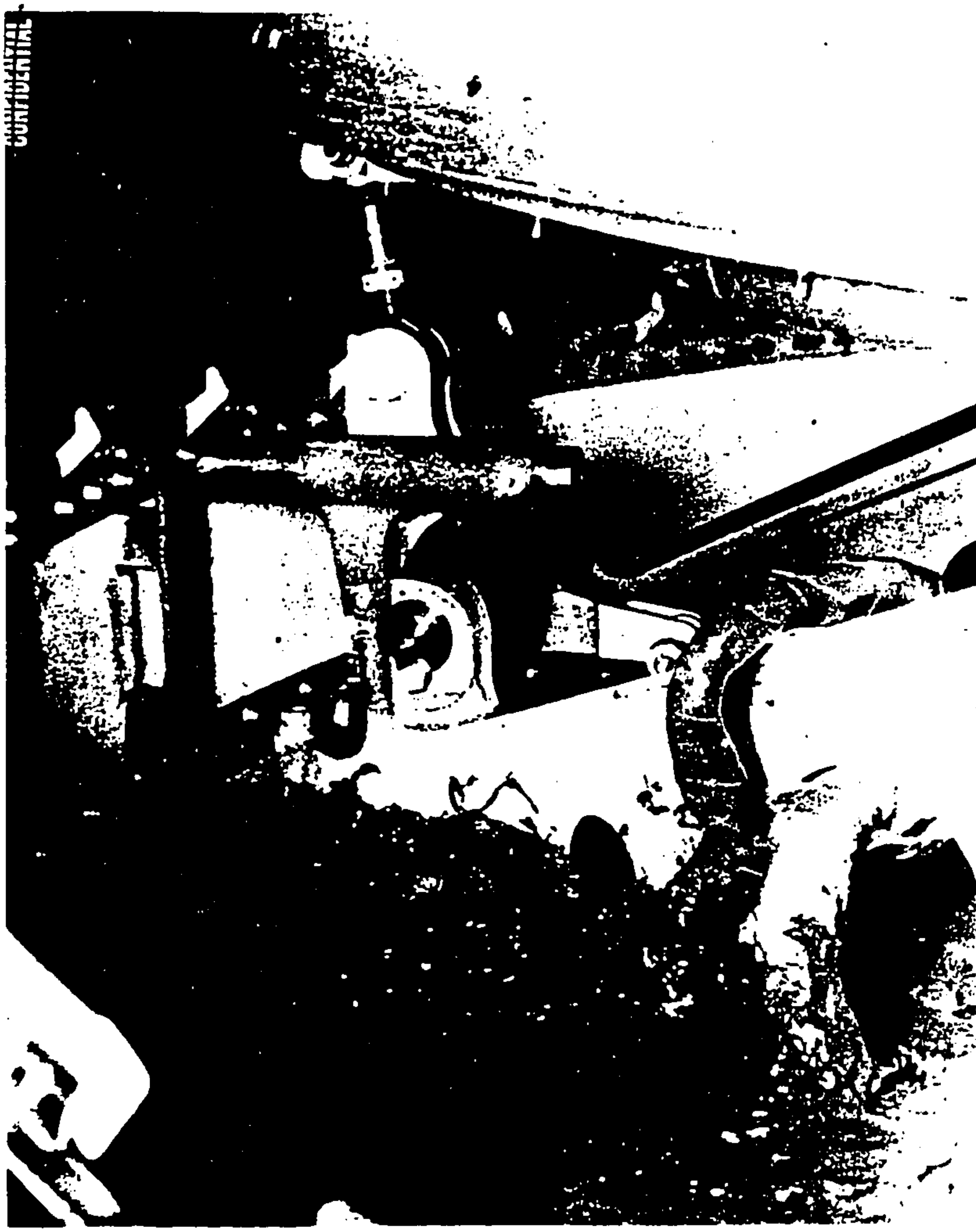


Figure 2

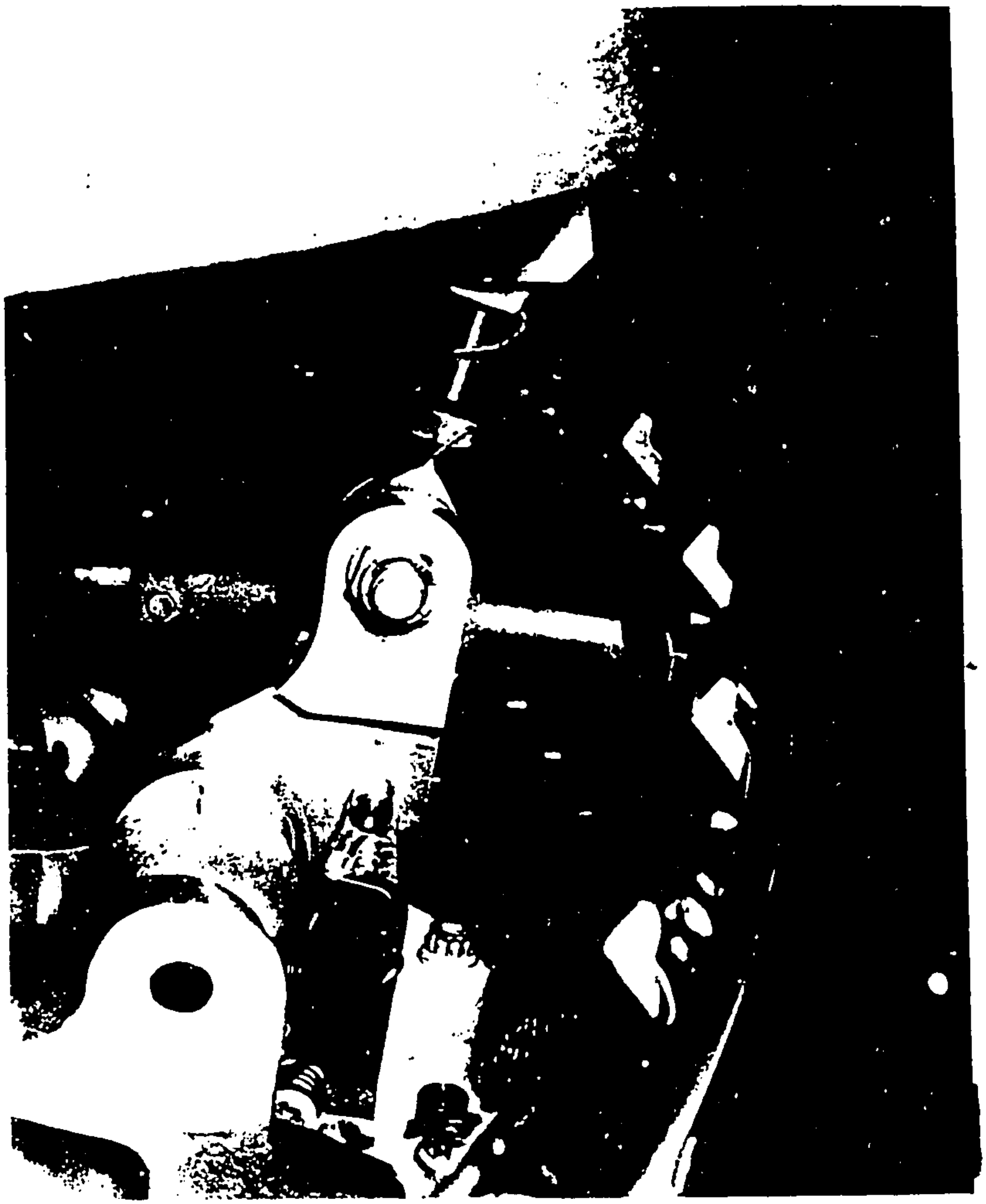


Figure 3

Figure 4

"In the A3X-12, when the release mechanism started to move outward, still having the pin bearing on the circular shoulder, the bellcrank moved as fast as the release mechanism did and the pin never left the shoulder. The system moved as far as it could, 22 degrees angular motion which put a 160-degree angle between the upper and lower link, and the motion between the links stopped. The pin was still not clear and the system jammed."

"The motion applied by the Belleville is quite important here," said Mr. Stevenson. "Initially the Belleville is held in restraint by the crank arm sitting up against the side of the nose cone. When the cone separates, the constraint is released, and the Belleville then applies enough force to lift the re-entry body against three or four g's. The value of the Belleville here is that it has a tremendous amount of push, even though for only a relatively short distance. If we have a problem with the Belleville, I would suspect that it comes from our pushing the design almost to its limits; our inability at times to get enough push to carry us over the hump may exist in the tolerance limits of the Belleville."

"The failure situation," continued Commander Julian, "was something that did not turn up in testing. The fixture used in testing, to demonstrate that the bodies would tilt, would compress the Belleville so heavily that the re-entry load would always leave the bellcrank, even though the load might be as much as 1000 pounds. They did not ever hang up in test. We have now added a washer that further compresses the Belleville and moved the bellcrank so that it sits just about on center, relieving the over-the-center movement that was required. They should not hang up now."

Dr. Kirchner questioned the possibility of hysteresis and of getting a different response from an immediate spring compression to that from a spring that has been compressed for some time. Commander Julian replied the problem was more likely that the Belleville had not been compressed enough to allow the bellcrank to follow; the assurance of additional compression is part of the fix for the trouble.

"The redesign moves things very close to dead center, "resumed Commander Julian, "and does away with the need for breaking the joint. The change does not present any problems with exerting pressure against the shell. In the earlier design, motion carried only to 22 degrees and we have increased that up to nearly 60 degrees because we visualized the possibility of the upper base hitting the lower structure before the bellcrank was correctly seated. This would position re-entry body B at a wrong angle."

Mr. Eyestone noted that some tolerances must be very close and Commander Julian replied that while there are no close tolerances bearing against a fixed surface, some items ran as close as 0.001-to 0.0001-inch; the most critical tolerance may be in the little pin in the holddown spring mechanism.

"In our fix," explained Mr. Stevenson, "we felt that there were two possibilities that could have caused the kind of trouble seen on A3X-12; we took care of both of them. After the failure on A3X-12, they checked the subsequent missile and found that it also would hang up on us. With as much expansion as they could give it during test, they still found that the mechanism would not get the REB over the dead-center position."

"Getting into the other matters of my report," said Commander Julian, "Captain Dubyk mentioned earlier that we had compared the measured temperature histories on some flights with the predicted temperature responses; a pair of these measurement are shown in figure 5 for the A3X-7 flight. Both histories are surprisingly close to the predicted performance. The starting point for the measurements is 84 seconds -- the time of nose cone separation, -- and the temperature runs slightly higher than expected."

"From the look of things," observed Captain Sanger, "you could let the nose fairing go and forget about the diaphragm."

"We think so," replied Mr. Stevenson, "because the amount of heat flux you get by the time you integrate it out is not going to amount to a serious problem."

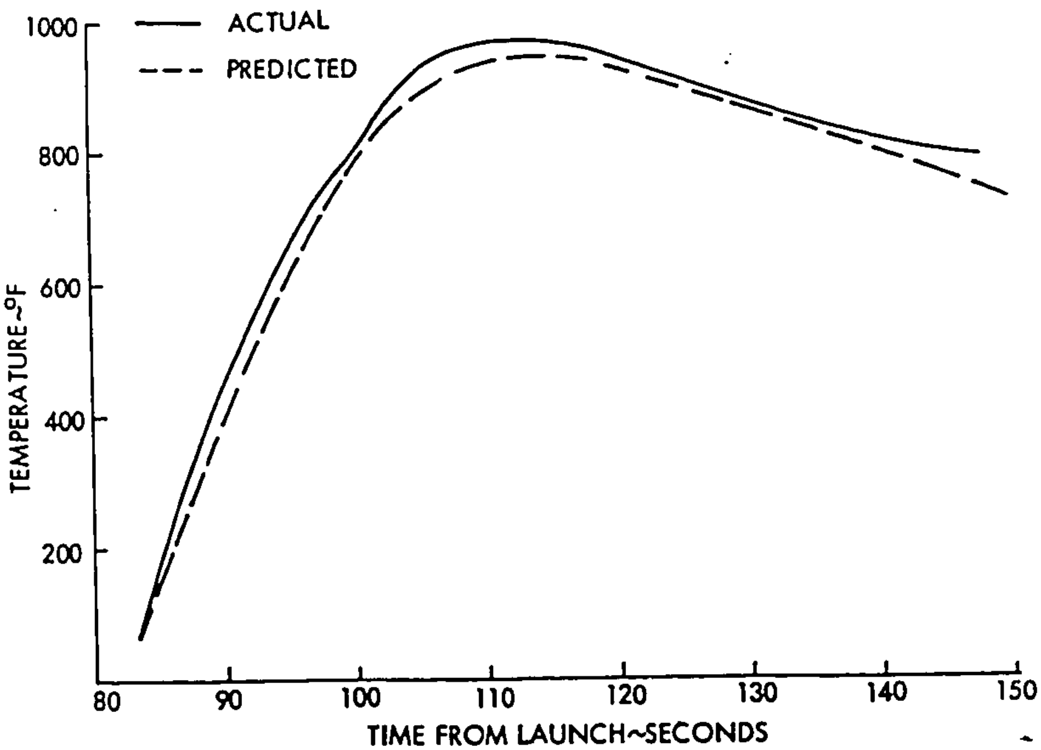
"Except for the rocket motors?" said Admiral Smith.

"Of course, they came along after the diaphragm was put there," said Captain Sanger, "but it has been figured that the equipment section would survive."

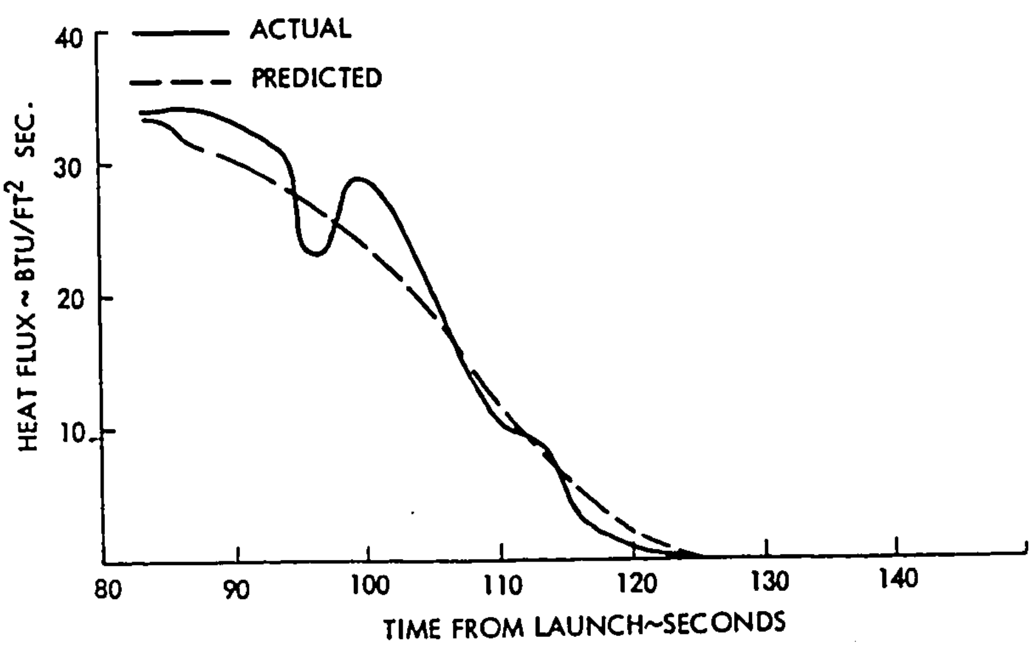
"I am not certain about that," replied Commander Julian. "We need to see some calculation of the effect of the burning of the eject rockets on the temperatures within the equipment section."

"I am not sure, but I think the aero-thermal people felt that no damage to the equipment section would occur," said Mr. Stevenson, "and I do not think they were worried about the missile itself. Once the re-entry bodies are kicked off, there is no need to worry about the missile going awry. Remember that the primary problem was the high heating at the time the nose cone came along."

CALORIMETER #31 PREDICTED AND ACTUAL TEMPERATURE RESPONSE



CALORIMETER #31 PREDICTED AND ACTUAL HEAT FLUX



Discussion then concerned the weight penalty that might be imposed by the diaphragm, and the suggestion was made that the entire problem might need to be re-examined; initially the diaphragm was to be 27 pounds, but it seems that additional pounds have been added at every meeting since then.

"In short," commented Mr. Stevenson, "we should run this problem through again completely."

"Practically speaking," observed Mr. Parran, "there is not much that can happen, is there? It may be that the delay in response time might take care of much of the problem of damage to the equipment section."

"I think we are forgetting how fast things can be ruined when rocket motor gas gets loose in there," cautioned Admiral Smith.

Mr. Stevenson explained that any disruption in the Freon flow, such as having all Freon flow through one or two nozzles, would effectively ruin the guidance. Mr. Parran suggested that some means be incorporated to prevent this shift of Freon flow, and Mr. Stevenson replied that the hot gas might just as easily wreck this device as the other components. Mr. Forter noted that after separation was commanded, there was an uncertainty in the second stage flight that warranted keeping the guidance control and vector control operative so that recovery could be made from any perturbation that might occur.

"The response time is still very short," said Mr. Leech. "Even though the steering commands are inhibited at the end of powered flight, all the signals needed to maintain vehicle attitude are still there."

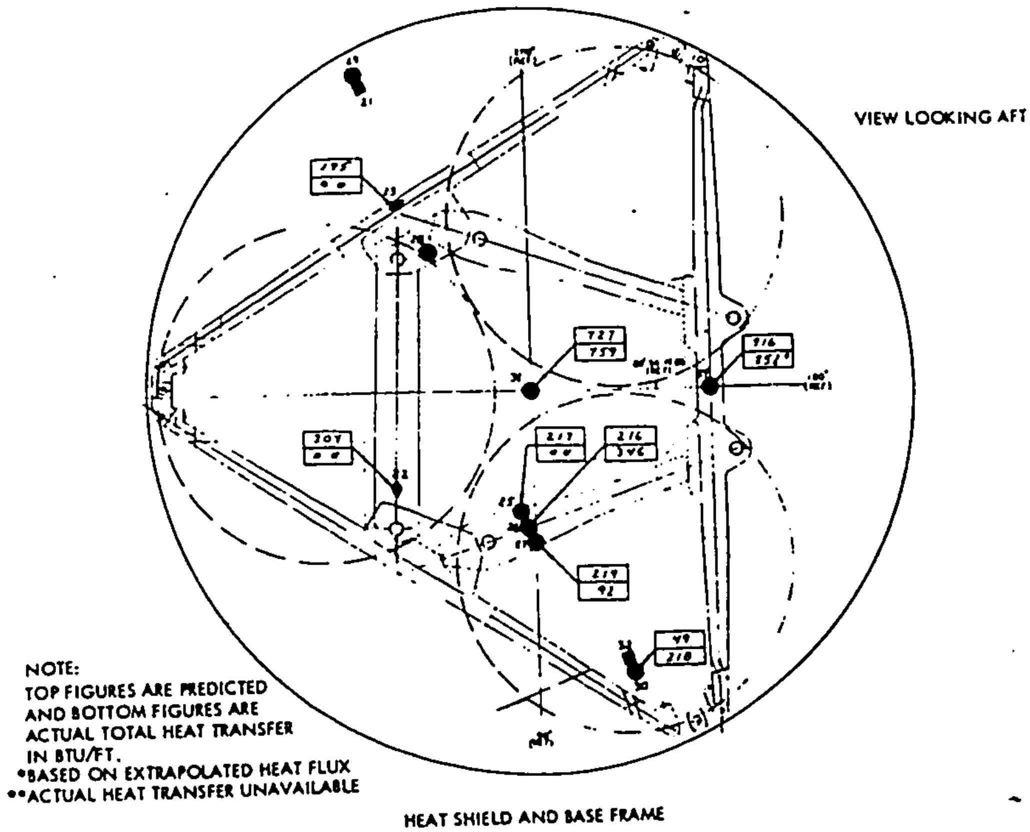


Figure 6

"The issue would be settled," said Mr. Parran, "if we had run a computer simulation and learned that we have to keep in control and running during that brief interval."

"Getting back to the subject," said Commander Julian, "figure 6 shows the location of the instrumentation in the heat shield and base frame. The numbers in the blocks indicate predicted and actual heat values.

"In figure 7 we have the observed and predicted heat values for the A3X-8 flight and again the values run rather closely together. I think the most appreciable value in these is the indication that we do know whàt is going on.

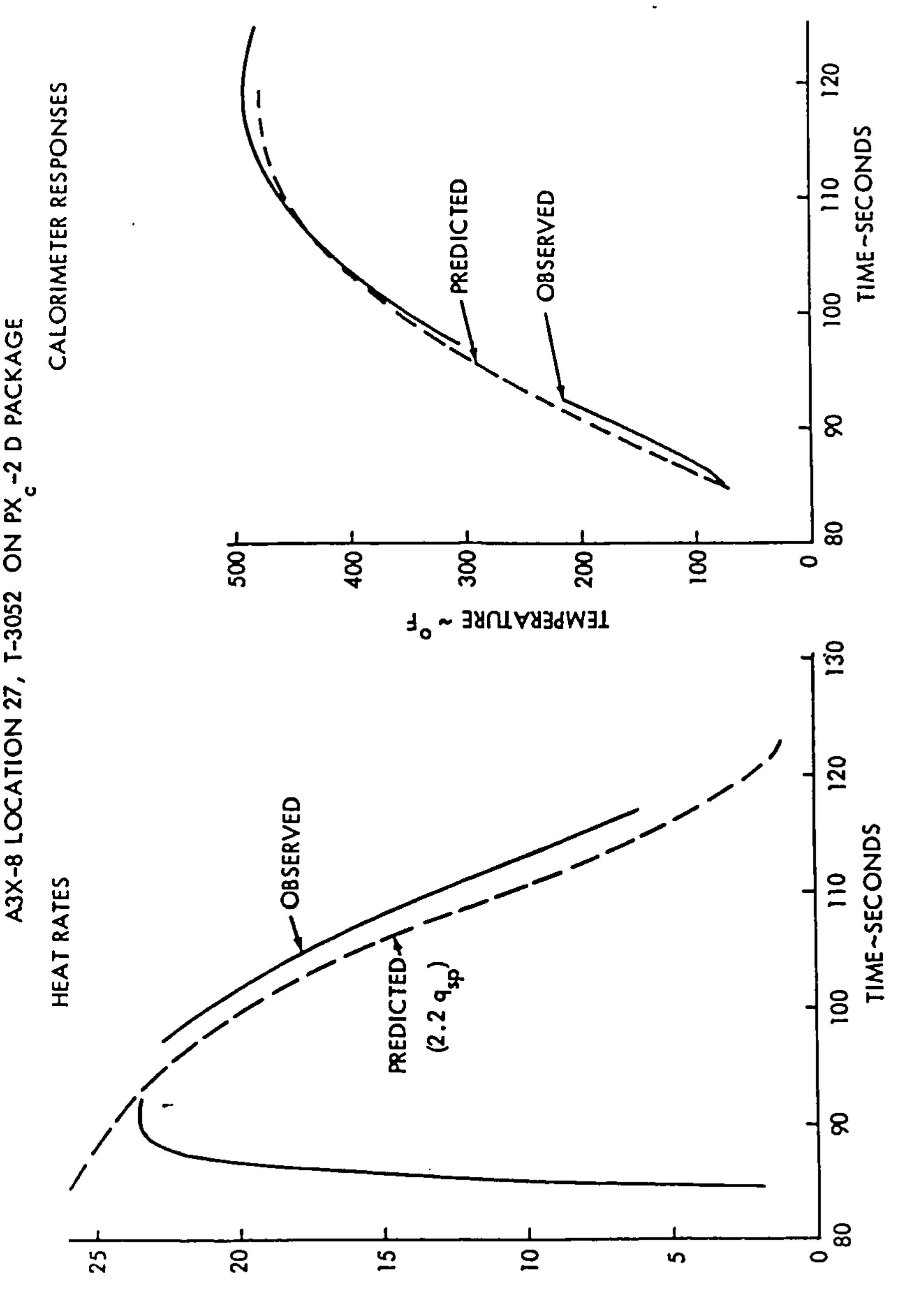

A3X-8 LOCATION 27, T-3052 ON PX$_c$ -2 D PACKAGE
HEAT RATES
CALORIMETER RESPONSES
OBSERVED
PREDICTED
(2.2 q_{sp})
TIME~SECONDS
TEMPERATURE ~ °F
PREDICTED
OBSERVED
TIME~SECONDS
0
5
10
15
20
25
80
90
100
110
120
130
0
100
200
300
400
500
80
90
100
110
120

Figure 7

"Figure 8 shows more of the same flight -- these figures taken from a different location than those of figure 7 -- and again there is a good correspondence between the predicted and the actual temperatures."

Both Dr. Williams and Dr. Craven wondered how it was possible to predict temperatures without also knowing the pressures, since they are closely correlated.

"The early missiles," continued Commander Julian, "did carry pressure transducers and their flights and the ensuing diaphragm failures convinced us that the diaphragms needed to be strengthened. We performed static tests to determine the kind of structure that would withstand the pressures which by design criteria were specified as 15, 30, 45 and 60 psi."

"As it stands," added Mr. Stevenson, "we seem to be measuring the right things correctly, and this has given us some confidence. We certainly do not have a complete survey of what is happening, and we may be able to increase our knowledge by putting these thermal sensors in other positions."

"Is it possible that this data might suggest that we have been overdoing some of the protection?" asked Admiral Smith.

"We have predictions indicating possible high temperatures," explained Commander Julian, "and in considering our protection techniques, we presumed the worst possible conditions."

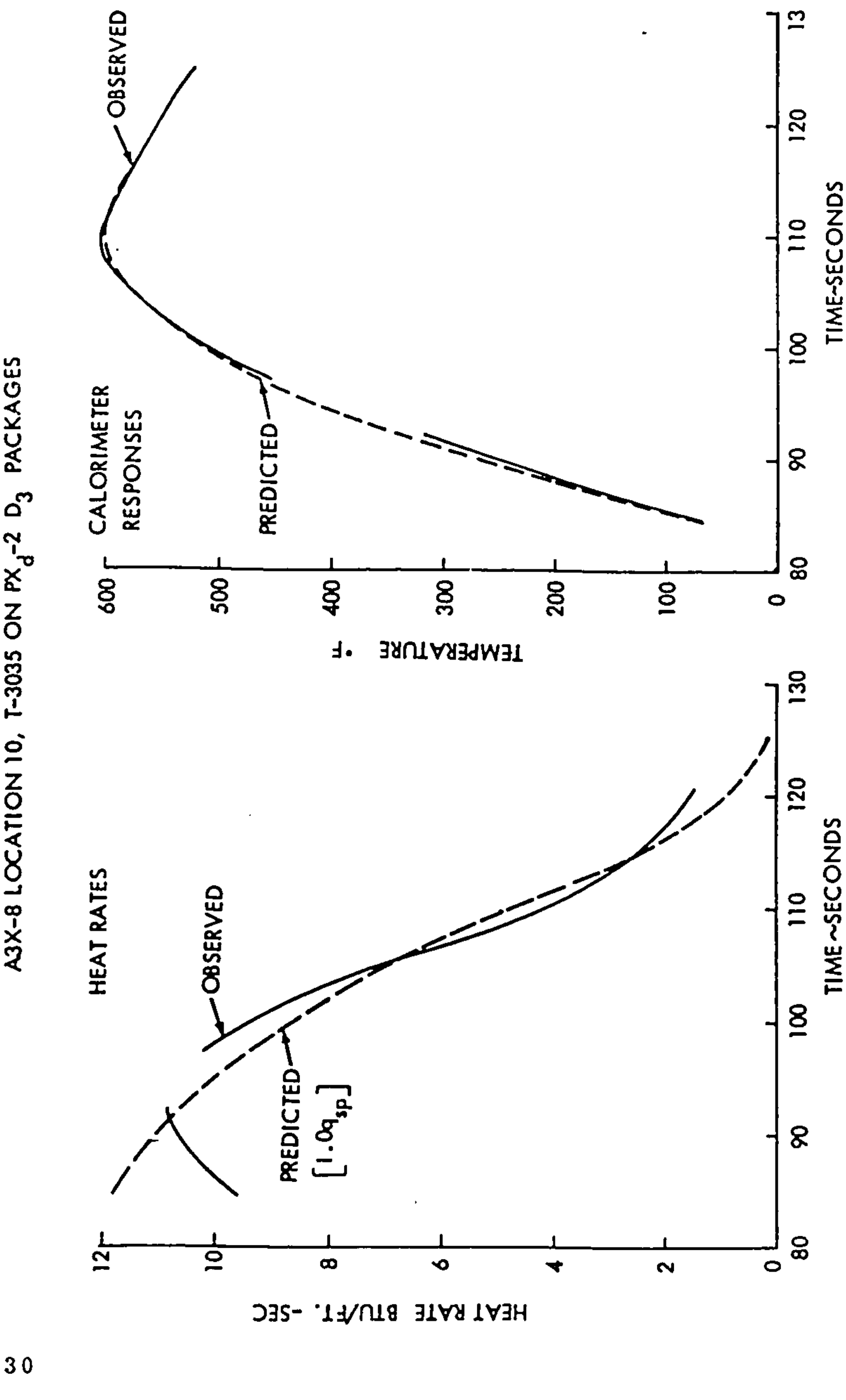

A3X-8 LOCATION 10, T-3035 ON PX_d-2 D_3 PACKAGES
HEAT RATES
OBSERVED
PREDICTED
[1.0q_{sp}]
HEAT RATE BTU/FT. -SEC
TIME ~SECONDS
CALORIMETER RESPONSES
OBSERVED
PREDICTED
TEMPERATURE °F
TIME-SECONDS

Figure 8

"Then we faced other problems, such as the effect of motion on the cables," explained Mr. Stevenson, "which also affected our decision about using the PR1910 tape on them. We need also to consider the possibility that the cable might not take the pressures present. However, we were told by the thermal people that if we could take care of the thermal problems we would be in a safe condition. I think that figure 8 indicates the kind of condition that we were protecting ourselves against -- we made everything safe in terms of that condition. We corrected for the pressures that we assumed would be present, and if anything went wrong we would suspect that things did not stay the way they were put together."

"How recently have pressures been measured in this?" asked Commander Julian. "It seems that we redesign after each failure, and then when we measure the pressures, they always seem higher than the fairing can take."

"We are checking to see when the heat enters the cluster," explained Mr. Stevenson, "and whether the structure becomes weakened in this so that it would collapse when the rockets fire. In that last failure, we have been checking to see if there was some other possible failure that might cause the rocket not to fire and also to see what had happened to the heat shield."

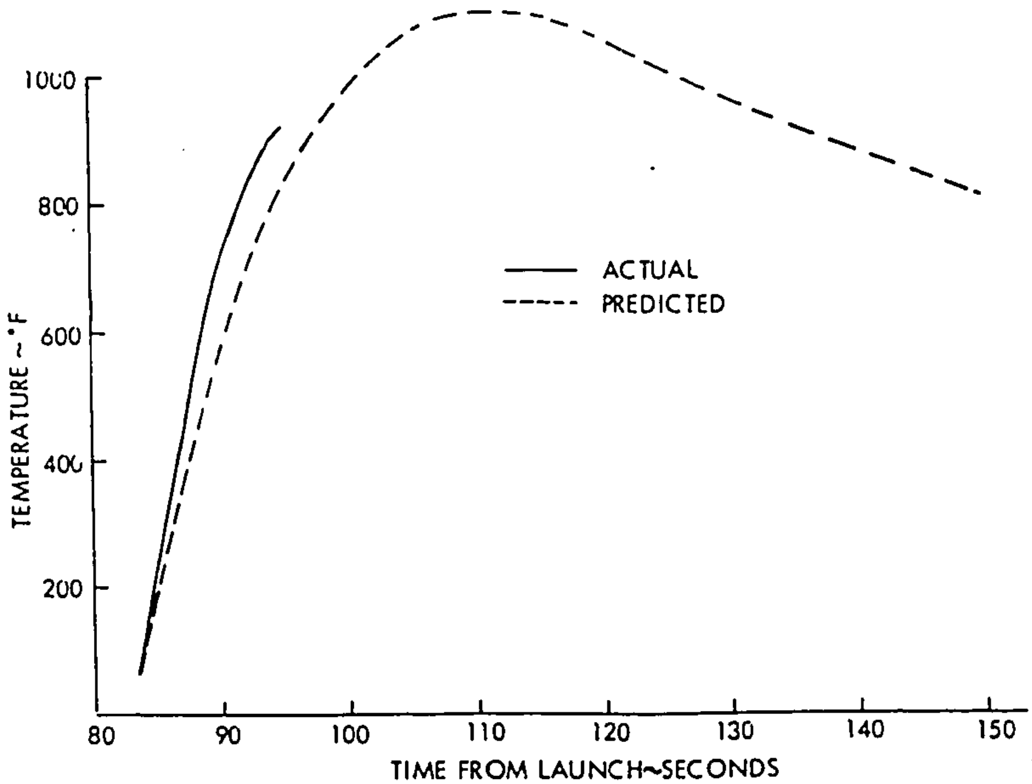
"The heat shield gave way and wiped out the telemetry, but only after something else took place," observed Admiral Smith.

"We would like to check if there might be one answer to explain both," replied Mr. Stevenson. "That would be the simplest approach, and it seems quite possible."

"Figure 9 shows another set of measurements from A3X-7," resumed Commander Julian, "again giving good agreement on temperature and flux for the duration of the time.

A3X-7 BASE FRAME INSTRUMENTATION

CALORIMETER #24 PREDICTED AND ACTUAL TEMPERATURE RESPONSE



CALORIMETER #24 PREDICTED AND ACTUAL HEAT FLUX

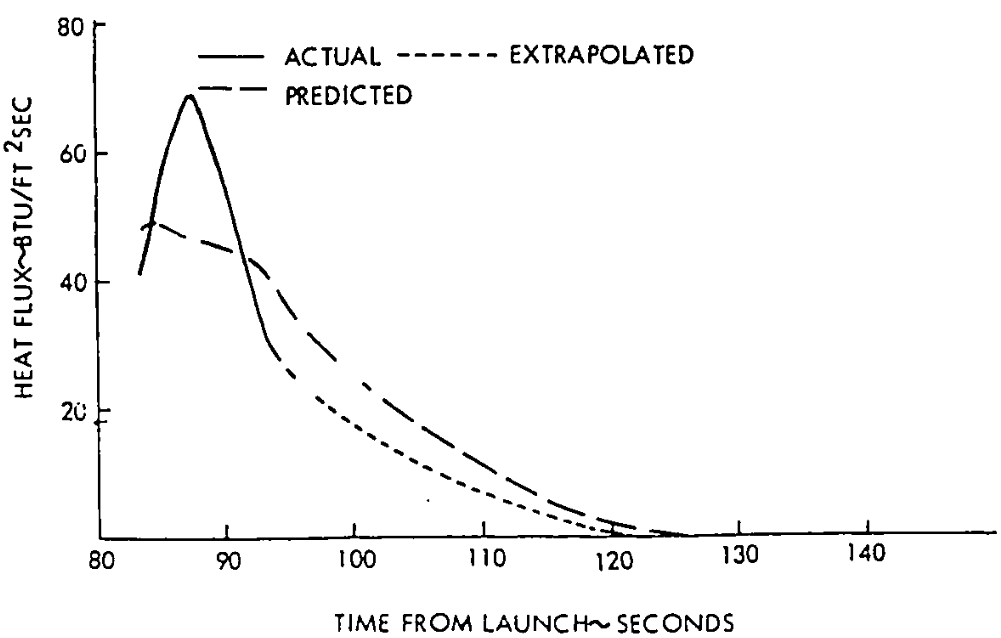
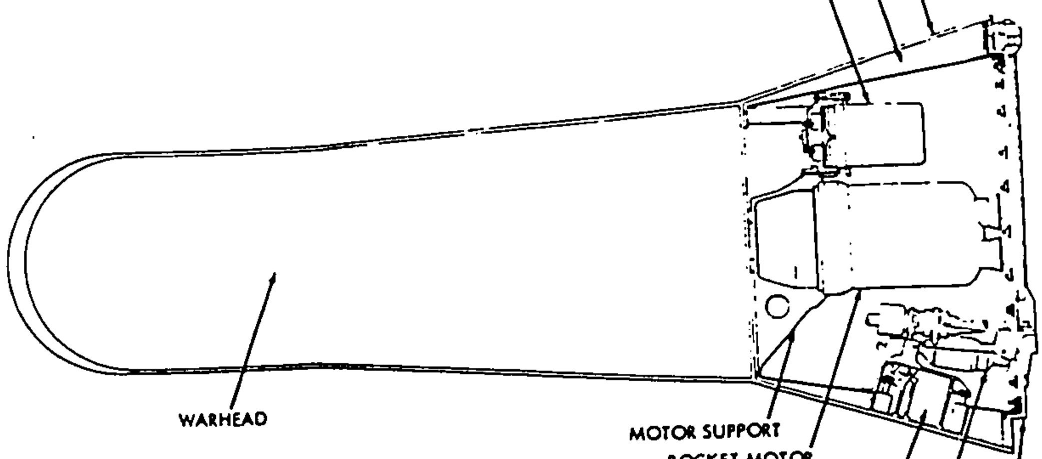


Figure 9



A3P RE-ENTRY BODY

Figure 10

"Figure 10 is one of the most recent A3P body designs. You may recall from recent remarks that the section to the flare is single-piece construction. We are no longer going to build it out of chopped nylon phenolic and then bond it. There have been no other significant changes in the flare, except that we are still looking at the potential usefulness of putting a local closure around the flare. This local closure would be a nylon phenolic and would provide access for the visual monitoring tool and for battery insertion. This closure seems to be a good idea because we can build it for four pounds and control its weight very closely. If we substitute it for the local protection that must be provided in the flare, we gain roughly two pounds, as well as precision in knowing exactly how much weight we have. We cannot control the weight of the cork and the PR 1910 to better than 6 pounds, plus or minus a pound or so.

"Another reason that needs identification is that the local protection in the closure of the flare area may assist in systematizing the impulses given to each of the bodies by the small plenum chamber when the three rockets go off. If the impact pattern is not good or is not systematic, this change may considerably improve it. We are carrying the design forward, but we need impact data to see whether or not we should attempt to fly. The basic idea is that the closure will not allow the gases from rocket motor burning into the flare; therefore, there will be fewer side forces into the flare.

"Speaking of impact patterns, figure 11 is the second SOFAR pattern for A3X-7. All I can say about this is it is not very satisfactory. The firing vector suggests that the system is completely out of order and position. At the present time I am not convinced that the SOFAR information is good."

"We were talking," said Dr. Kirchner, "about the effect of the distribution of pressure at the base of the payload upon dispersion. Have we first evaluated the variation of the interior ballistic characteristics of the little rockets, and the effect on the range from changes or variations in the ignition lock, total impulse delivered, thrust level, and duration misalignment in the mechanical orientation of the rocket itself ?"

"The rocket, as you know, has been designed to most precise specifications", replied Commander Julian, "so that the total reproducible impulse variation is down to about 0.25 of one percent. This is the claim from Atlantic Research, and it is supported by the qualification test data. However, I doubt that the internal ballistics here will be much of a problem; we have other sources of dispersion that will be much more serious."

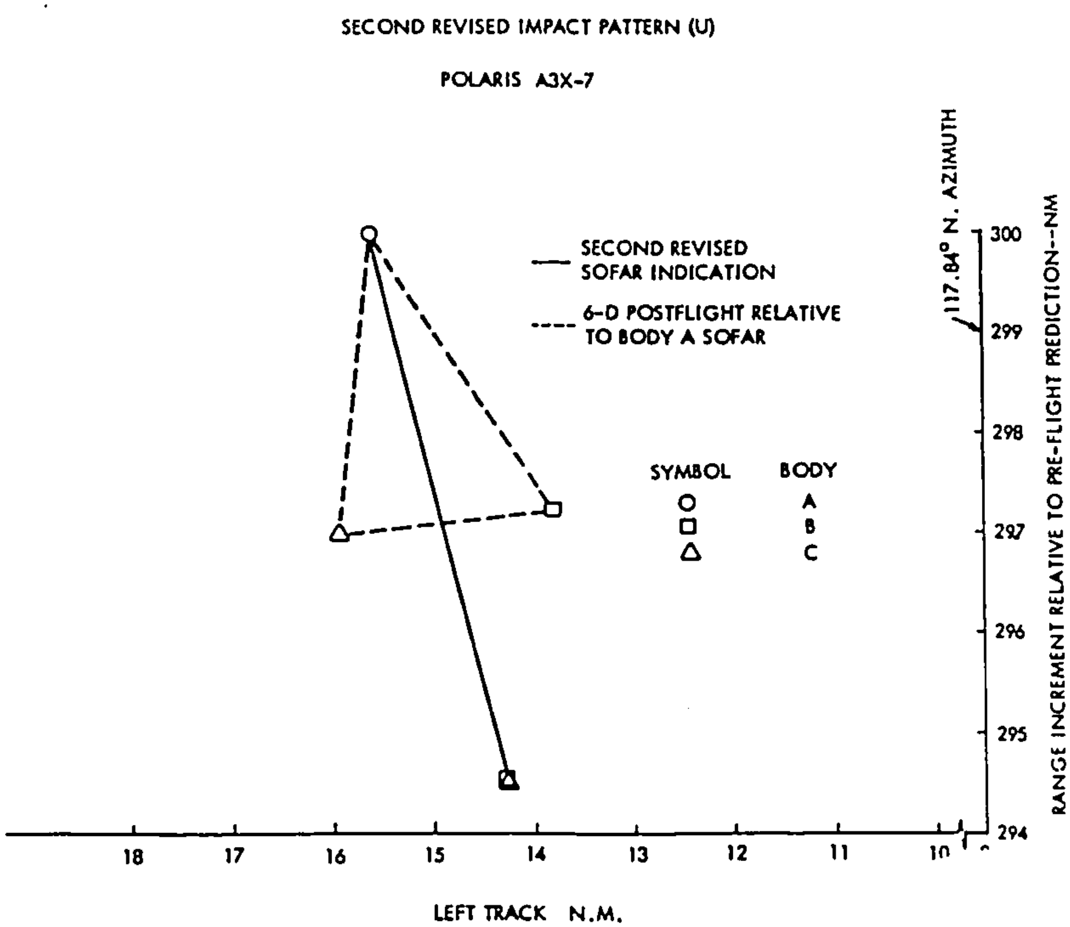

SECOND REVISED IMPACT PATTERN (U)
POLARIS A3X-7
117.84° N. AZIMUTH
SECOND REVISED SOFAR INDICATION
6-D POSTFLIGHT RELATIVE TO BODY A SOFAR
SYMBOL
BODY
A
B
C
300
299
298
297
296
295
294
RANGE INCREMENT RELATIVE TO PRE-FLIGHT PREDICTION--NM
18
17
16
15
14
13
12
11
10
LEFT TRACK N.M.

Figure 11

Dr. Kirchner asked about ignition lag, adding, "The ignition lag -- the interval to 90-per cent of thrust from the instant of firing current -- should be small. A large lag would of itself create large dispersions."

"To get onto to another subject," resumed Commander Julian, "our Pacific Flight Test Number 1 was not a very successful demonstration of the chaff package in our PX aids. As a result of that, we generated a supplementary program at White Sands Missile Range using SPEEDBALL rockets in a program which we call our PX-1 SPEEDBALL tests (figure 12). We flew ten rockets which were successful in the program, using both the Nortronics package and the Lesona Moos package. Our feeling generally is that the tests were successful in identifying the difficulties in both of the packages, but incompletely successful in proving a fix that will give us the dispersion velocities we need.

"The data is not complete, but it appears from the flight test data in general we have about a 50 to 65 foot per second average dispersal velocity. This compares to the 90 to 100 foot per second dispersal velocity we want. But when we got this requirement, we assumed that the asymmetry of the pattern would be in the ratio of about 2 to 1; the pattern would be greater radially than axially by a ratio of 2 to 1. It now appears that the pattern is less asymmetric than we thought, nearer to a ratio of 8 to 5."

Asked about the pattern, Commander Julian explained that the dispersion was determined by the way in which the packages left the cylinder; to a degree the cylinder is designed to shape this pattern as an ellipse with a 2 to 1 ratio but in actuality the shape appears to have an 8 to 5 ratio.

NO.	DATE LAUNCH	PACKAGE	RESULTS
1	14 MAR 1963	507	PROGRAMMED EVENTS DID NOT OCCUR
2	27 MAR 1963	507	SECOND STAGE FAILURE
3	3 APR 1963	507A	TEST SUCCESSFUL - FULL DATA
4	19 APR 1963	501	TEST SUCCESSFUL - FULL DATA
5	22 APR 1963	501	NO DATA - TEST PAK DIDN'T SEPARATE
6	24 APR 1963	507A	TEST SUCCESSFUL - FULL DATA
7	24 APR 1963	507B	TEST SUCCESSFUL - FULL DATA
8	3 MAY 1963	501	TEST SUCCESSFUL - FULL DATA
9	3 MAY 1963	507C	TEST SUCCESSFUL - FULL DATA
10	3 MAY 1963	507C	NO DATA - TEST PAK DIDN'T OPERATE

VELOCITIES OBTAINED WITH DESIGN CHANGE 50-60 FPS

Figure 12

"The packages themselves," continued Commander Julian, "are not stabilized but are flopping around, and it would be difficult to define orientation at any point during the flight, except that it will move relative to the trajectory. With the dispersal velocity at 50 to 65 feet per second, we will on the average get the needed overlapping or coverage at the center of the threat tube.

"The growth time, of course, depends upon the range but in general we will have 500 to 600 seconds of growth at that velocity and at maximum range about 1000 seconds in which to get about an eight nautical mile diameter to the tube.

"The measurement time at White Sands was very short -- from 150 to 200 seconds -- and the packages were not all ejected at the same velocity. The detection radar got different rates and velocities than did the acquisition radar, and the BR-16 got different rates than the others. The average results gave us velocities of around 60 to 65 feet per second.

"I am not making a recommendation now that we buy tactical units to replace the dummies. If the analysis now being conducted at Lockheed indicates that the ratio is indeed 8 to 5 and the average velocity is about 50 to 65, then I think we will have proper coverage and I will recommend that we replace the dummies with tacticals for the first 74 only.

"Figure 13 shows the mounting of one of the trays. We are mounting the chaff and the decoys on trays between the delta frame and the ballistic shell of the missile and in the interstices between the body so 'tray A B' means the tray between bodies A and B. There are three trays, one in each interstice, AB, BC, CA and they carry a mixed load of chaff and decoy units. The velocity sensor integrates acceleration, from the point at which the velocity to be gained is 270 feet. Then, at fixed increments of velocity from 270 feet to go, it ejects the packages - some from each tray - in three salvos. The design intent is to take the right weight from the trays so that the dynamic stability of the missile is not upset each time you have a salvo."

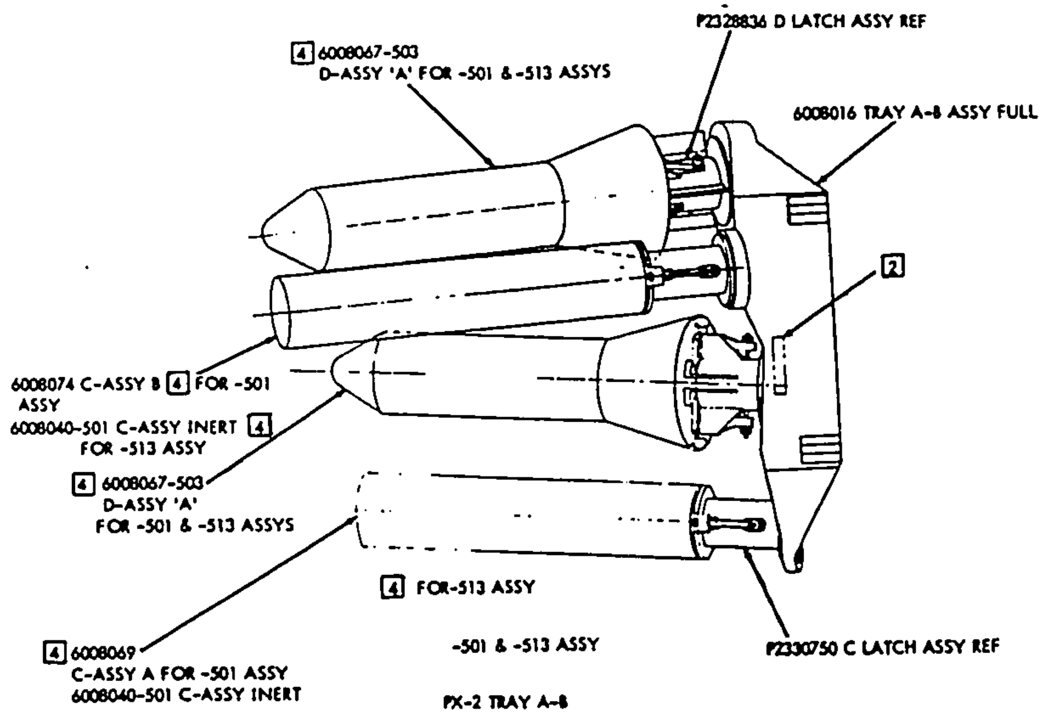


Figure 13

In response to questions, Commander Julian explained that the ejection of the PX material starts before the re-entry bodies are fired off, and the last salvo comes only 0.8 or 0.9 second before the firing of the re-entry body rockets.

"Then the velocity increment added to some of these is greater than that given the re-entry body?" asked Admiral Smith.

"Plus that velocity given by the second stage during this brief interval?" added Captain Sanger.

"For some this is true," said Commander Julian, "for we want them to come in ahead of the re-entry bodies and thus they must have a greater net absolute velocity. There is almost a second between the PX firing and the REB firing and velocity is being gained during that period. The velocity sensor starts integrating only when the in-flight safety signal is given."

Mr. Eyestone asked why this signal was not given from the guidance system. Admiral Smith replied that the guidance people had not been asked to provide it early enough in their program. Mr. Stevenson added that it was simpler to add the sensors than to go back and include this function into the guidance package. Admiral Smith noted that changes and additions would have to be made in either case.

"We recently have been informed," continued Commander Julian, "that Dr. Brown, DDR & E, told the Air Force that their Advanced Ballistics Re-entry System program is no longer an Air Force program but a national program instead. This ABRES effort is not directed toward any specific development objectives, nor to build or develop hardware for any specific missile system. It is a development directed toward proving concepts which may later be useful for a specific directed development. This year the ABRES program is budgeted at 113 million dollars; in 1964, it is proposed at 184 million and in FY 1965, it is proposed at a level of 284 million dollars.

That program encompasses a very wide range of sub-programs. The White Sands Missile Range is included with its small booster program, which involves about 20 sounding rockets and some 77 ATHENA vehicles to be launched from Utah into the range, plus full-scale tests of penetration-aid packages and basic new-concept re-entry systems. Signature information is part of it; a new re-entry system data sensor at Aerospace is part of it; a large contract with Sperry on electronic jamming is part of it; Giannini Controls on fuzing is part of it. There are at least 30 contractors doing various research projects in the field of advanced re-entry system developments.

"These efforts are advanced from the standpoint that the hardware being flown and studied is not associated with any particular missile system today. It could be in the future. The assumed threat is highly defended targets with defenses as stiff as any used in a model study. The Air Force model invented by Board of Technology of AF is the one in which the penetration work is being directed, and is quite similar to the one we generated.

In connection with this casting of ABRES into the national program, the Air Force Secretary is writing to the Navy to request that a naval officer be assigned to Aerospace BSD as deputy director for the program. We do not have a billet nor do we have anybody in mind, but it is interesting that apparently the Air Force feels the need for a Navy input. The reason is quite obvious, for unless they can assure DDR&E that the Navy program requirements are in, their budget will probably have rough sledding.

"There are a lot of problems to solve in this -- . rticularly, just how should the Navy and Air Force cooperate in this effort in the area of justifying the Air-Force-generated budgets. Should we jointly try to support them? How does the Air Force, when it takes a program forward through Air Force channels to get money, convince the Air Force that what DDR&E said to do is what they, the Air Force, should do? There are at least four important areas in the program where we can cooperate. The program contains several formal evaluation panels and we have requested Navy representation on one -- the Lees Panel -- of which you may have heard. At a meeting on the 3rd or 4th of next month, we are going to discuss reconstitution of the panel. We are looking forward with interest to joining with the Air Force in the ABRES program.

"We are now negotiating with the British to establish a Joint Re-entry System Working Group for the purpose of joint development of the UK warhead for the POLARIS Navy ballistic missile system. Admiral Galantin has agreed with the CPE (the Chief POLARIS Executive) that an early meeting is desirous. We have suggested a meeting here on 11 of June, to run from three to five days, as a joint organizational meeting and technical meeting. We have given them a suggested agenda which crossed in the mail with another joint directive of theirs suggesting how the group should be set up.

"On 4 and 5 June, the Re-entry Body Committee will meet to hear a Lockheed presentation on the six-months study of the B3 re-entry system. LMSC will make recommendations at that time to the Committee as to which system would best satisfy the job of penetrating a well defended target -- a very well defended target. There have been a few perturbations since the study was first generated, and the presentation will include the benefits of re-entry systems built around a hard single warhead or around hard cluster of smaller warheads, and that sort of thing. On 15 of June, Lockheed will then be prepared to submit a feasibility study."

With no further discussion, Admiral Smith called upon Captain O'Neil for the Fire Control and Guidance Report.

LAUNCHING COMMITTEE REPORT DISCUSSION

"We have had several problems crop up," began Captain Hammerstone, "during the last two months in the Launching System Mark 21. I think the most serious was a failure of a lower intertube seal on a Mark 21 Mod 1 launcher during factory test. Figure 1 shows this lower rubber seal; it is backed up by a ring of hard foam which distributes the loads evenly around the seal whenever the seal is under hydrostatic pressure. The seal failed at 200 psi during a pressure test.

"In figure 2, a cross section of a plan view, we have the proposed correction for this problem, together with a similar view of the present installation. The pressure is applied to the back-up which is not a continuous piece but rather is made up of eight segments. There is a gap in each of the areas around the flex rod housings, and we found that the gaps or discontinuities were the areas of the failure when hydrostatic pressure was placed on the launch tube.

"We fixed these gaps simply by placing a filler piece in between the gaps around the flex rod housing. On retesting, we had no more failures so we feel that the fix is quite satisfactory. The only hitch was that we had already sent out 32 tubes to the field, and we had to recall every one of them and apply the correction. Thus far, we have corrected and returned 11 of the recalled 32.

"We also met a problem at the Naval Propellant Plant, which is one of the facilities building our gas generator. A graphite nozzle insert failed during one of the lot acceptance tests. We ordered production stopped and sent a team to NPP immediately which included personnel from WEC and ABL. We learned that NPP was not inspecting in accordance with the philosophy and procedures defined in the quality assurance documentation. We also learned that an extruded insert, which was rather prone to defects, was being used.

INTERTUBE SEALS AND BELLOWS

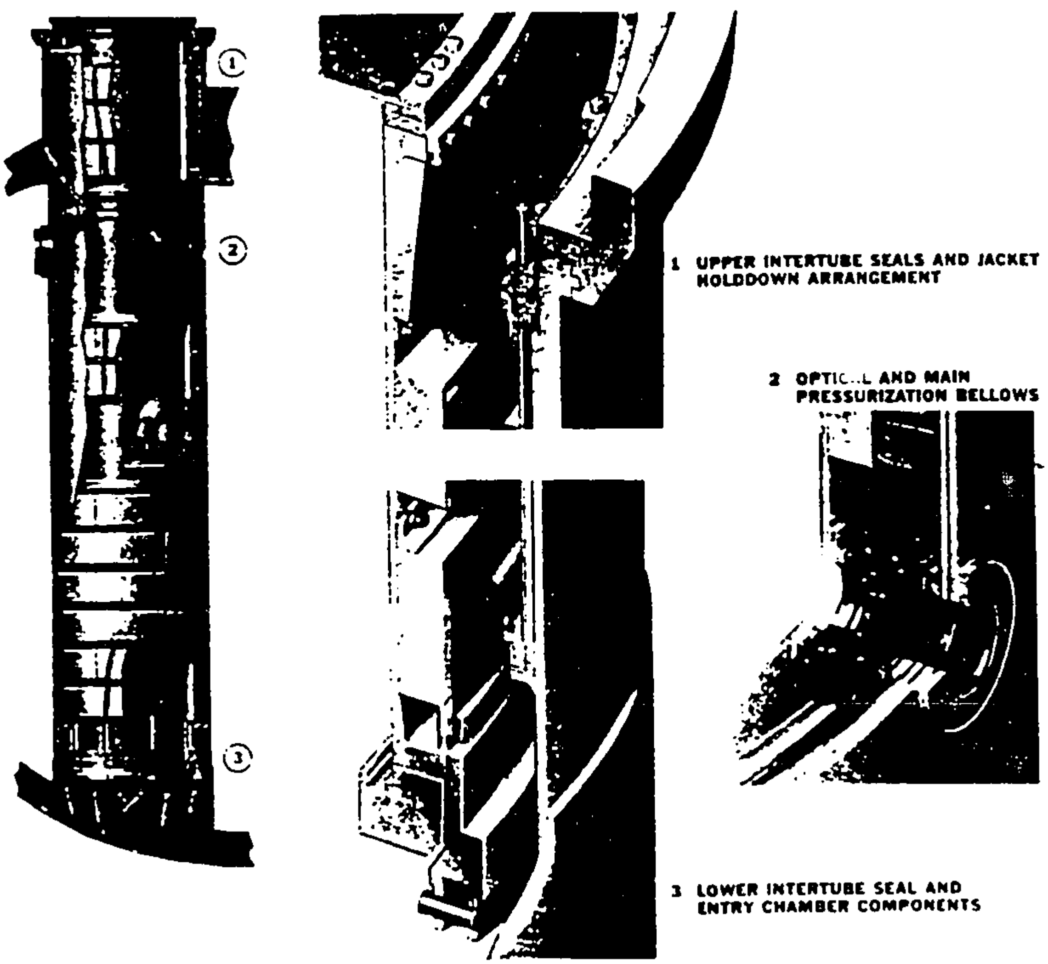


Figure 1

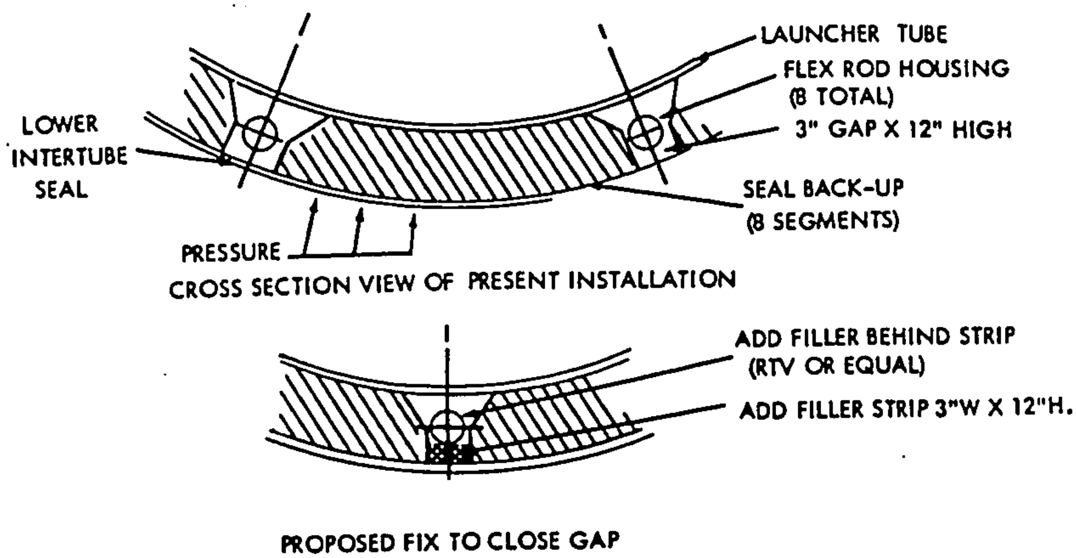


Figure 2

"Since these inserts were not being inspected prior to their installation and firing there was a failure. Although the failure did not cause the lot to fall below performance specifications, we do not wish to take any unnecessary chances; so we have restricted this lot to firings in tubes which do not contain a live missile. They are to be used only for firing water slugs and SABOTS during the builder's trials."

In response to a question from Admiral Smith, Captain Hammerston explained that the insert is a carbon nozzle insert which is part of the throat in the nozzle of the gas generator motor on the bottom plate of the motor. "It cracked and caused failure," concluded Captain Hammerstone.

Dr. Mechlin explained further, "The insert functions the same as the throat of a nozzle by inducing flow restriction which controls the internal pressure of the motor so that you get the burning rate desired."

"We could have gone back and disassembled the inserts, inspected every one of them, and put in new nozzle inserts," continued Captain Hammerstone. "However, since we do have many firings to make during the builder's trials, we accepted that lot for these trials. The method used to inspect the inserts was X-ray, black light inspection."

Dr. Mechlin said that a low grade graphite was used for the nozzle inserts. Dr. Kirchner felt low grade graphite was not suitable for nozzle parts. "In its pressed form," explained Dr. Mechlin, "low grade graphite is perfectly satisfactory in its present application."

Dr. Kirchner expressed the opinion that at least the density of the graphite should be inspected because a variation in density can have a fantastic effect on erosion. In response, Dr. Mechlin said, "There is really no problem in receiving satisfactory graphite nozzle inserts without any inspection. Using low grade graphite without any inspection at all, we have had only three insert failures out of about 60 firings. When quality control measures were added the problem completely disappeared. There is no need to upgrade the graphite."

"Since the cost is small," said Dr. Kirchner, "I believe it would be better to use a particular particle size graphite like A2J, check the density of the material and check the surface of the finished part with X-ray. If there are four nozzles on the gas generator, three failures out of 60 inserts could mean a failure with every firing!"

"Failure of a graphite insert," answered Dr. Mechlin, "will not cause catastrophic failure. Failure customarily causes a reduction in motor pressure of 200 psi when the motor is operating at 2000 psi, and this in turn changes launch velocity by about four feet per second. Dependable metal retaining plugs for the graphite inserts act as a secondary orifice and prevent more severe pressure loss. We are not saying that it is not important to get this graphite ring correct; but we are saying that good inspection standards produce satisfactory inserts of pressed material."

"Rather than the pressed material," said Captain Hammerstone, "NPP was using extruded material which is cheaper.

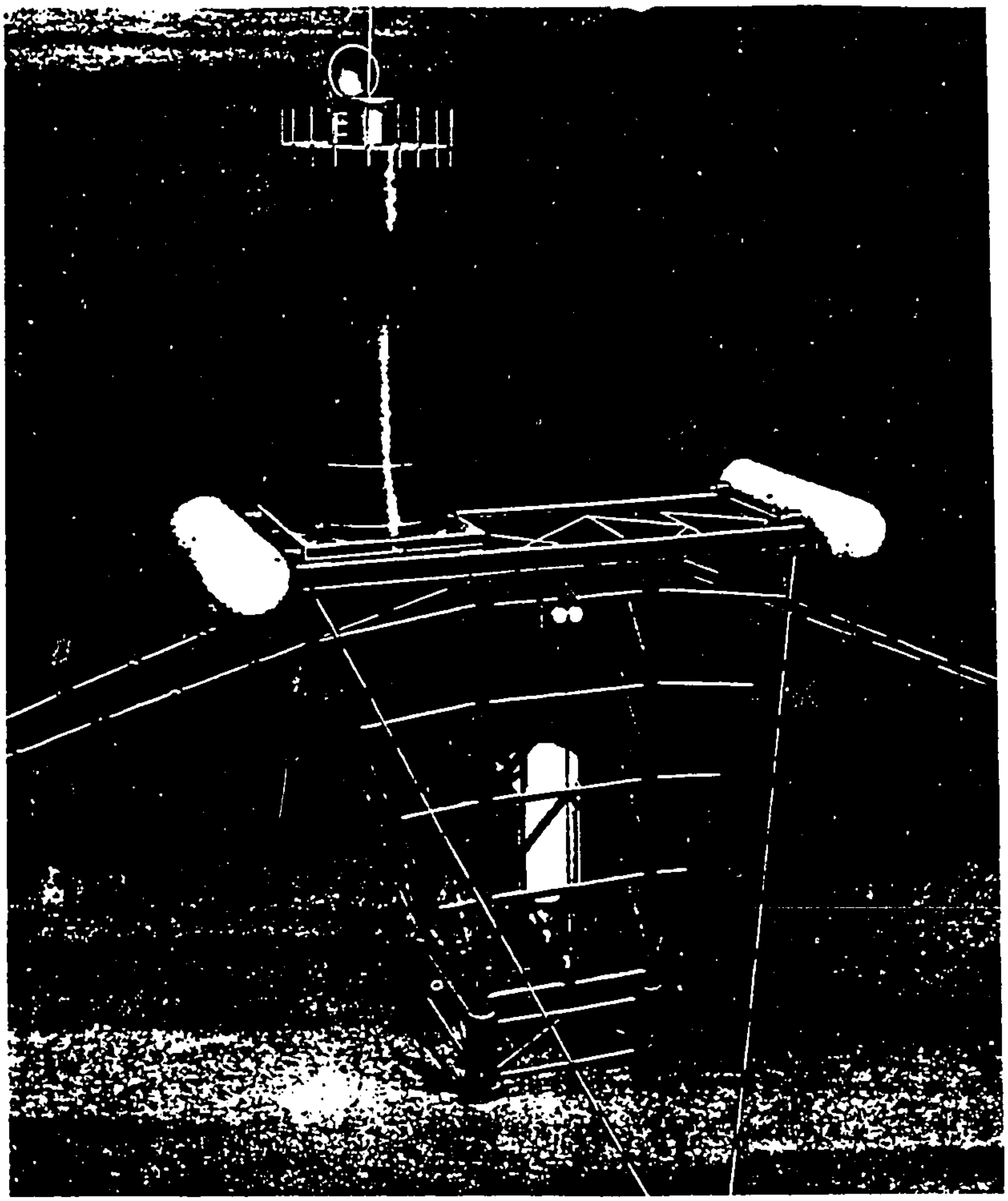
"A couple of months ago I mentioned some operational problems we had with the temperature monitoring system aboard one of the submarines," continued Captain Hammerstone. "Corrections were made in the system which proved satisfactory. However, when the system went into production, we had problems receiving good modules from Arno Corporation, and the module rejection rate was up to 40 per cent. This seemed to be a quality control problem, so more detailed documentation for inspection was implemented. Since then, the rejection rate has been reduced to 3 per cent, and it looks like we are out of the woods on that problem.

"Deliveries of the temperature monitoring systems are behind schedule. However, the shipyard has submitted dates when they need these systems, and it looks as if we can meet this schedule.

"I have a couple of other things I would like to discuss. First, a cross flow facility is being installed at POP-UP. This facility is being designed and installed in order to get a better insight on the underwater launch response of a missile to uniform cross flow.

"Figure 3 is an artist's conception of this cross flow facility. The objective of this concept is to come up with something which is simple, cheap, safe, and reliable for underwater test launchings. This facility will be built to translate the launcher in a horizontal direction; it will accelerate the launcher to a predetermined velocity up to five feet per second, and will maintain a constant velocity at the time of launch.

"The facility consists of a tower about 48 feet high. It has a horizontal structure, supporting rails, and launcher. It is mounted 166 feet below the surface of the water and is stayed by guides attached to sea anchors or piles. Two tanks on top of the supporting structure provide stability and flotation for towing, lowering and raising the structure in water.



POP-UP TRANSLATOR

Figure 3

"A sled carriage with four slippers and hold-downs which keep the launcher in place rides across the two supporting rails. The sled, rails, and slippers are designed to withstand all the forces involved at launch. The launcher is moved horizontally by vertical movement of a buoyancy tank connected by a series of sheaves and cables to the carriage. The initial position of the launcher is held by explosive bolts. When the explosive bolts are operated the tank rises and pulls the launcher across the rails. When the launcher passes the center line of the structure, the buoyancy tank operates in the opposite direction and decelerates the launcher to a stop.

"A typical velocity history of the POP-UP translator during an A3 launch is shown in figure 4. The center line of the stowed launcher is the left vertical axis; the center line of the tower is the right vertical axis. The velocity curve shows that after 5.2 seconds the velocity of the launcher becomes constant within 5 per cent. Launch command is given at 5.7 seconds and base exit occurs when the launcher is over the center line of the tower at 6.5 seconds.

"This entire facility was designed to be cheap. It will probably cost about $300,000 for design, fabrication and installation. This facility will be installed at POP-UP during the month of August, and we hope to be ready for operation by the early part of September. We expect to have enough information to determine the trend by the end of this year.'

In the ensuing discussion, Captain Hammerstone explained to Mr. Parran that there are essentially no currents in the testing area and therefore currents offer no problem to the translator apparatus. "Actually," said Captain Hammerstone, "the velocity of the translator can be predetermined to vary between zero and five feet per second by changing the buoyancy of the vertical tank."

"There are velocity measuring devices on the launcher which measure the relative water velocity," said Dr. Mechlin, "so a current can be measured for data analysis purposes if necessary."

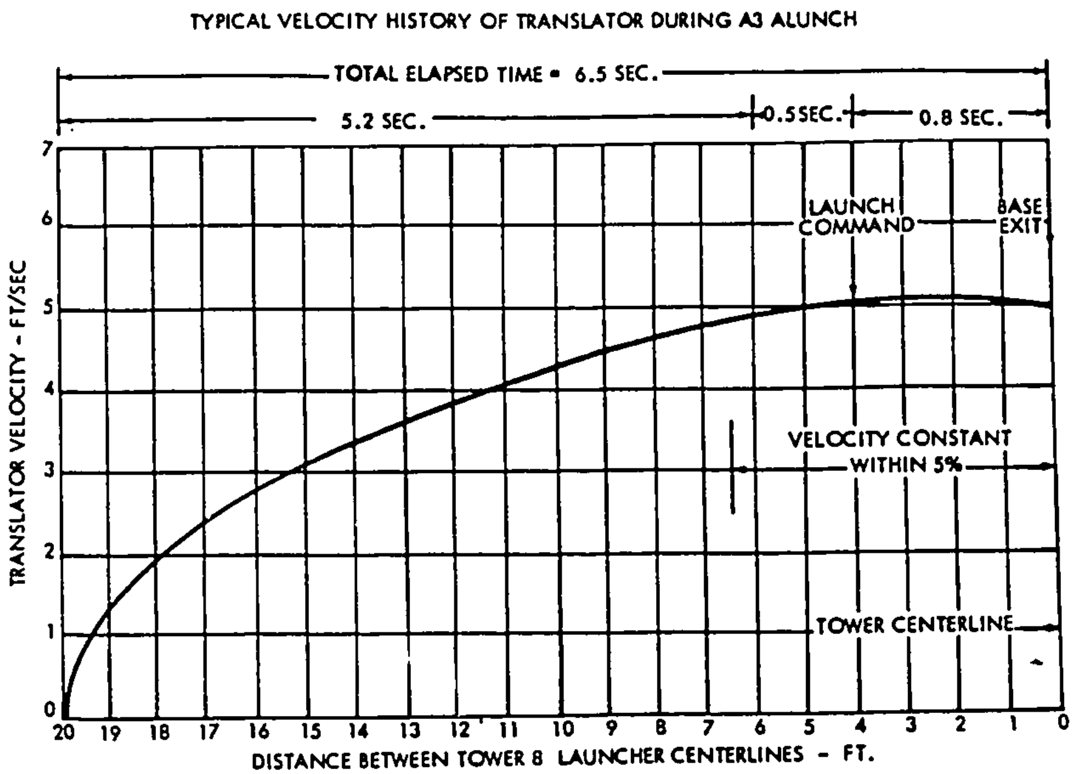


Figure 4

"The other item I would like to discuss is SABOT firings," said Captain Hammerstone. "Recently there has been a significant increase in the number of launchings to be made during the pre-deployed and post-deployed periods of a submarine. Our present plans are to fire disposable SABOT's.

"I said 'significant increase' because the boats using and firing gas generators raise the cost of SABOT firings appreciably. In four years our building program is going to run about 11 million dollars just for the pre-deployed firings. The total cost of the firings for the post-deployed ships after they reach their deployment area is going to run about 10 million dollars. This figure is the estimated cost for all post-deployed submarines to fire four shots apiece over a four year period.

"The number of firings, over the original specifications, have almost doubled during the building program period. About 40 per cent of these are for fleet training. Prior to ships being deployed, there will be 2 shots along side the dock, 14 shots for each weapons system first builder's trial, 16 shots for second builder's trial, 8 shots for INSURV, 15 shots from SDAP to PSA, and 15 shots from PSA to NWA; this adds up to 70 shots per ship and accounts for 11 million dollars."

"I wonder if it is time to raise the question as to whether four shots in the post-deployed period is a realistic planning figure," said Captain Sanger. "The most that we started off with was two shots. Are we over planning?"

Captain Pugh responded, "The Force Commanders have been insisting on four shots but so far there has not been time to get any results."

"How long does it take to get all the salt out of the tubes after firing?" inquired Admiral Smith.

Captain Pugh answered that it took the USS ROOSEVELT, using only deck personnel, 24 hours to clean the tubes from the four shots that they fired. Captain Hammerstone said that information from Holy Loch indicated that 19 hours was required for the ships force personnel to clean, dry and check out two tubes after firing.

"The reason I mentioned the costs involved in these SABOT firings," continued Captain Hammerstone, "was because we have been scouting around for another concept which would eliminate firing the gas generator but still serve the purpose for crew training. Figure 5 shows two methods of simulated firing launches. Scheme A is the SABOT method presently used. A SABOT is inserted and the launch tube is filled with water. A diaphragm is placed on top of the tube. After a complete countdown, the SABOT is fired out. This concept requires the use of the gas generator.

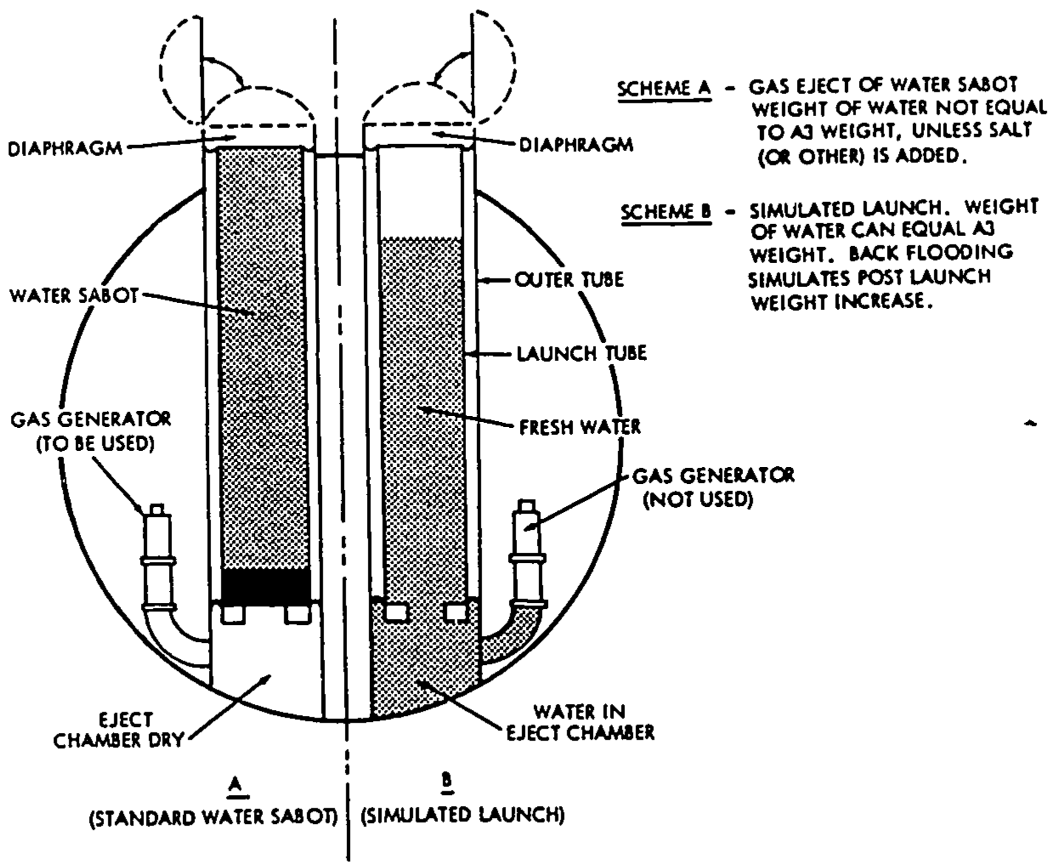


Figure 5

"Scheme B depicts a promising simulated launching method which does not require the use of either a SABOT or a gas generator. The launch tube, including the eject chamber, is filled with fresh water to a weight which simulates the weight of a missile. A diaphragm is placed on the tube. In order to run a simulated launch, the diaphragm is exploded and subsequent back flooding occurs causing an impulse which is similar to launching a regular missile.

"Figure 6 is a simulated launch pressure time history for the pressure in the eject chamber. The solid line curve is eject chamber pressure oscillations caused by the base end bubble. The dotted line is the time pressure trace of the back flooding subsequent to exploding the diaphragm. This simulated launch pressure curve shows that the impulse in a simulated launch is essentially the same as in the actual A3 launch. If the hatch is left open for its normal tactical time of 19 seconds, the compensation system will operate in normal fashion.

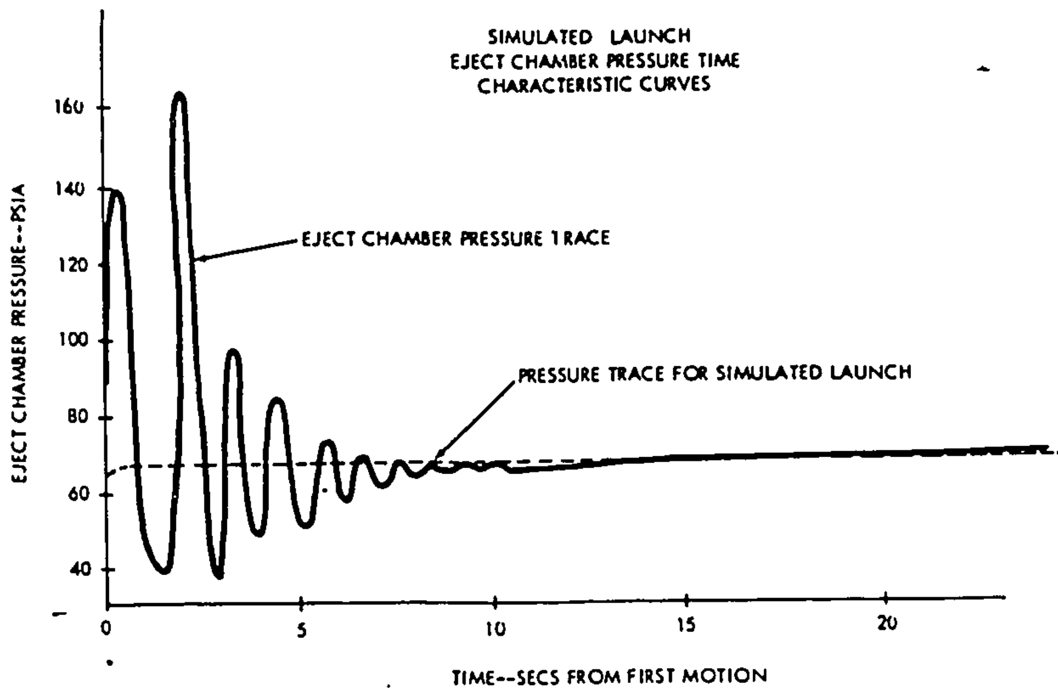
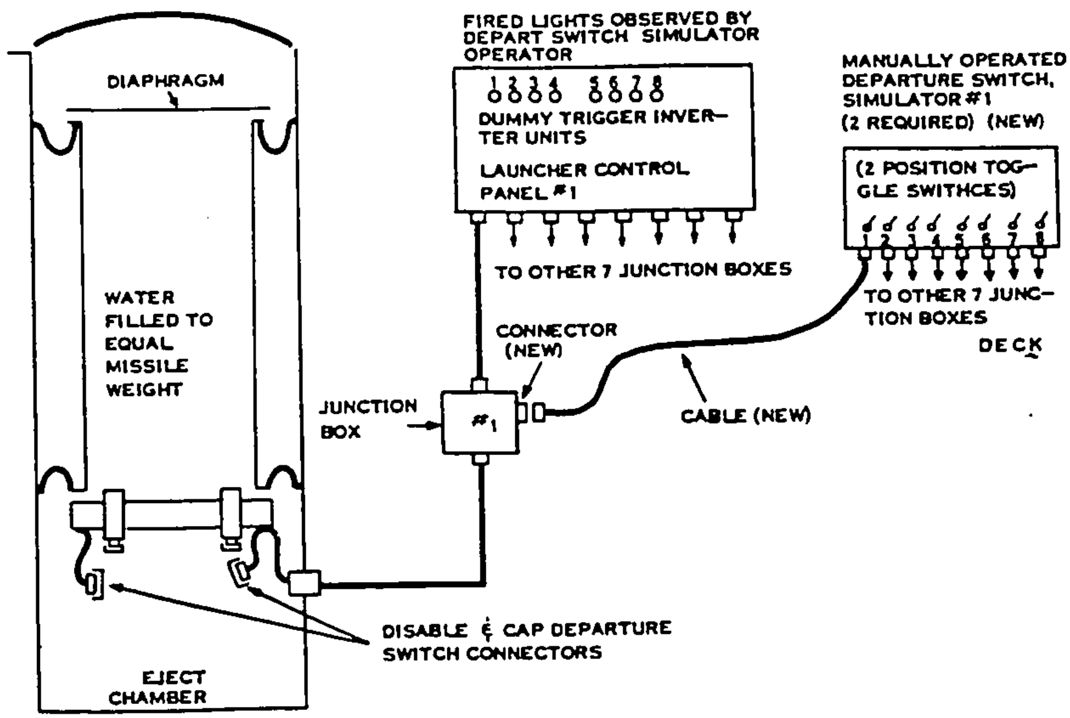


Figure 6

"A Scheme B control schematic is shown in figure 7. Although this simulated launch method is still in the concept stage and has not been fully engineered yet, this figure indicates the basic idea. First, the cables leading to the departure switches are disconnected and capped. A new cable from a manually operated departure switch simulator is connected to the tube junction box. The tube is filled with water equal to the weight of a missile and the diaphragm is set in place. A dummy trigger inverter unit with a light is installed in the tube.



SCHEME B CONTROL SCHEMATIC

Figure 7

"During normal countdown procedures, the toggle switch on the simulator is in the start off position. Fire Control fires and a light indication is received on the dummy trigger inverter unit. The man operating the simulator throws the switch which activates the 'missile away' signal and causes the diaphragm to detonate. Back flooding occurs and the tube operates as if an actual missile had been fired. The firing operation is carried out manually; however, it can be completed automatically if the system becomes more feasible.

"I would like to go ahead and engineer this system, and have it ready for checkout on the SSB(N)623. Although Scheme B cannot replace SABOT firings, this simulated launch system is all that seems necessary for crew training."

In response to questions from Captain Thompson, Captain Hammerstone said that by using Scheme B simulated launch system, firing of gas generators would not be necessary, and millions of dollars would be saved. "The amount of money saved," he explained, "depends upon the number of Scheme B simulated launchings substituted for SABOT firings, which require use of gas generators."

In further discussion, Dr. Craven asked what was accomplished by the firings. "The launchings test the compensation system," answered Captain Hammerstone, "and train the crew in procedures to take if compensation malfunctions." Dr. Mechlin said that 90 per cent of launch system equipment checkout was one of the major accomplishments of the firings. "We are not advocating that the simulated launch system replace SABOT firings," added Dr. Mechlin. "However, it does not seem necessary to fire four SABOT's to obtain equipment surveillance checkout. These two systems are complementary. As far as the compensation system is concerned, it is much harder to compensate the ship for four shots than it is for one or two shots. There are more human skills and interaction with the sea involved when four shots are made. Therefore, the best way to obtain optimum equipment checkout and crew training seems to be selection of a sample size of one shot per availibility for launcher checkout, and four equivalent shots using the Scheme B method per availability for compensation."

"What human skills are involved in the compensation cycle?" asked Admiral Smith.

"The compensation system is automated as far as transfer of water from the launch tubes to the sea is concerned," answered Dr. Mechlin. "However, after the first or second shot, the hovering system receives some very large signals and does not operate at maximum efficiency. At this point, depth control of the ship must be implemented manually."

"I do not completely agree with that," said Captain Kern, "because the hovering systems we have checked out had no real problem keeping the ship at launch depth during launchings. We have found that if the compensation system fails, the hovering system will not operate properly. What generates signals so large that the hovering system cannot adjust for them?"

"Large signals are generated," Dr. Mechlin responded, "due to conditions after launch such as the following: ten-ton weight changes on the ship during the first 15 seconds after launch; acceleration when the tube does not fill instantaneously; and compensating accelerations when the tube overfills with water."

"Vitro Laboratories have run some pretty thorough checks on the hovering system," said Commander Jackson. "They have found that the present hovering system is perfectly adequate to control the ship during ripple launch, even using the heavier B3 missile, as long as the compensation system is carefully programmed."

"This is true," said Dr. Mechlin, "but considerable crew experience is still necessary to properly control the ship after two launchings. The crew must have some experience periodically with the compensation system in order for it to be expected to work. For example, with a change in sea state, adjustments have to be made in the loop gain of the hovering system in order to continue reasonable performance; it is certainly desirable to check these adjustments from time to time during the launching evolution."

In further discussion, Captain Hammerstone told Mr. Stevenson that the modified junction box, shown in figure 7, would be modified permanently if the simulated launching method were adopted for extensive use. "However," Captain Hammerstone added, "this modification will be engineered so that the basic reliability of the present circuits will not be altered."

"I believe we should check to see how much of the system is being exercised automatically and how much manually," Admiral Smith recommended, "and then we ought to be able to estimate more accurately what sample size is needed for a complete exercise. After that, we can look further into the Scheme B simulated launch system as a method of primarily testing the compensation system under the demands of ripple fire.

"However, it seems to me that one problem involved is the interest in operating under heavy sea conditions while placing other heavy demands on the hovering and compensation systems. From an operational point of view, we will have to check to determine how much can be modified during the refit program."

"I have one more figure to show," said Captain Hammerstone. "Figure 8 is a comparison of the work and equipment used during a standard water SABOT and a Scheme B simulated launch system. The chart is self explanatory and it clearly shows how much more equipment, time and energy are necessary in a SABOT firing."

Dr. Hartmann inquired about cost and Captain Hammerstone said that each gas generator costs about $4,000.00 and the SABOT's $350.00 apiece.

With no further questions, Admiral Smith introduced Commander Jackson for his presentation of the Submarine Design Committee Report.

COMPARISON CHART

STANDARD WATER SABOT

A. HARDWARE SET CONSISTS OF

1. GAS GENERATOR
2. SABOT
3. DIAPHRAGM
4. COOLING CHAMBER DIAPHRAGM
5. COOLING CHAMBER BAFFLE ASSY CHANGE AFTER FIFTH SHOT AND POSSIBLY SOONER

B. POST LAUNCH WORK

1. CLEAN WATER FROM TUBE
2. CLEAN GAS GENERATOR
3. CLEAN COOLING CHAMBER AND BAFFLE ASSY
4. REPLACE COOLING CHAMBER DIAPHRAGM
5. POST LAUNCH CHECKOUT CABLES, ETC.

C. ADDED REQUIREMENTS

1. WORK OF UNLOADING FIRED GAS GENERATORS AND ON-LOADING NEW GAS GENERATORS
2. LOGISTICS OF SUPPORTING SABOTS AND GAS GENERATOR QUANTITIES FOR EXERCISE TRAINING PROGRAM

SIMULATED LAUNCH

A. HARDWARE USED UP CONSISTS OF

1. DIAPHRAGM

B. POST LAUNCH WORK

1. NORMAL WATER CLEAN OUT FROM LAUNCHER
2. POST LAUNCH CHECKOUT CABLES, ETC.

ESTIMATED GAS GENERATOR QUANTITIES REQUIRED FOR STANDARD SABOT SHOTS, NOT ASSOCIATED WITH A MISSILE LAUNCHINGS

2	DOCKSIDE
14	1ST BUILDERS TRIAL
16	2ND BUILDERS TRIAL
8	INSERV
15	SDAP BACK TO BUILDING YARD
15	PSA TO NWA
70	TOTAL PLUS 16 YEAR AT TENDER

SUBMARINE DESIGN COMMITTEE
REPORT DISCUSSION

"This morning I will cover three topics," began Commander Jackson, "the first of which is what the Bureau of Ships is doing to evaluate the capability of submarines to recover from a flooding casualty and to determine methods of improving this capability. Secondly, we are continuing with the measures intended to improve controllability of POLARIS submarines at shallow keel depth and high seas; and finally, we are proceeding with the design of the retrofit modifications in the 598-Class submarines.

"The Bureau of Ships has been studying the subject of emergency flooding casualties for the past year and a half. The submarines now at sea are designed on the criteria shown in figure 1, where the submarines can blow all their ballast tanks twice at surface pressures. For POLARIS submarines, we provide a third main ballast tank blow capability for surface missile launch.

PREVIOUS CRITERIA FOR SIZING AIR BANKS

TWO COMPLETE MBT BLOWS AT SURFACE PRESSURES.

AN ADDITIONAL MBT BLOW FOR SSB(N) SURFACE MISSILE LAUNCH.

FIRING ALL TORPEDOES.

RESIDUAL PRESSURE OF 1100 PSI IN AIR BANKS AFTER ABOVE EVOLUTIONS.

Figure 1

"These early criteria were established at the time when surface launch, which necessitated keeping the submarine relatively high in the water, was considered important. This accounts for the earlier POLARIS submarines having a third blow capability for surface launching in high sea states when they might take on water in the ballast tanks. I will speak later about the changes that have been made in this area.

"Figure 2 shows the time in seconds allowed the ship to secure the sea valves in an emergency. These curves assume that the submarine is at test depth and that it loses propulsion at the time flooding begins. The curve showing the submarine initially at zero knots may be somewhat unrealistic for a submarine at test depth, but nevertheless it is conceivable and we will use this as a criterion. If the submarine had a six-inch opening and was able to close it in 20 seconds, then the submarine could surface from test depth. This further assumes a 15-second delay in beginning to blow the ballast tanks. Of course, speed has a great effect on this; as you go up in speed, you are able to tolerate more flooding or longer delay before securing the sea valves because of the flooding. Under the old criteria it is possible to allow a 2.3-inch-I.P.S. system to flood continuously and still surface. If you will remember that 2.3 inches, it will come up in a later figure."

Dr. Hartmann inquired why you could wait longer before securing the sea valves if you have greater speed and Commander Jackson replied that there was a lift effect in the planes which increased proportionally with speed.

Mr. Hoag asked why, assuming loss of propulsion at the time of the casualty, all the curves would not approach the same asymptote. Commander Jackson explained that the submarine has a great deal of inertia and will continue to move through the water after loss of propulsion during the couple of minutes before the submarine surfaces; there is an effect of speed even though the submarine is slowing down.
Dr. Craven pointed out that the final asymptote is not out in infinity but at the time the submarine comes to the surface, and Commander Jackson concurred.

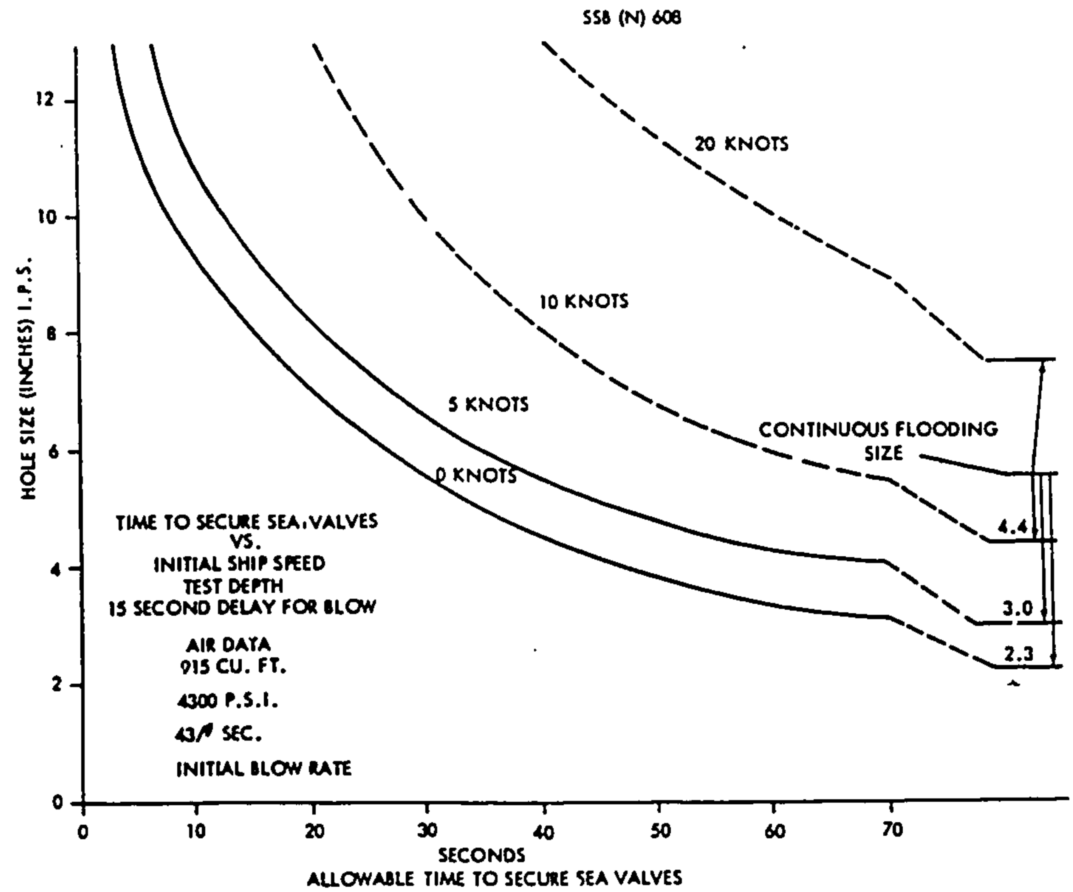


Figure 2

"In the past year and a half," continued Commander Jackson, "we have been generating new design criteria, and those we are now working towards are shown in figure 3. While it may be unrealistic to consider the ship at zero speed at test depth, it is a possible condition, which is why we regard it essential to use zero as a criterion for all ultimate designs. For backfit and correction of any designs that do not meet these specifications, we would assume a more realistic five-knot speed at test depth.

INTERIM DESIGN CRITERIA
TO PROVIDE A SHIP FLOODING RECOVERY CAPABILITY SUFFICIENT TO CAUSE THE SHIP TO SURFACE AFTER ANY SINGLE SEA WATER PIPING CASUALTY; ASSUMING FOLLOWING CONDITIONS:
1. SHIP AT TEST DEPTH.
2. SHIP AT ZERO SPEED.*
3. SHIP HAS ZERO TRIM.
4. SHIP HAS NEUTRAL BUOYANCY.
*FOR BACKFIT USE 5 KNOTS

Figure 3

"Figure 4 shows the effect of continuous flooding. Loss of propulsion incidental to a flooding casualty is one of the assumptions made in this chart. That is to say that the submarine is not dependent upon availability of propulsion power as a means of recovering since this is an emergency recovery operation."

In further discussion it was pointed out that, although it would be possible to lose the vital hydraulic power for plane operation because of flooding in the machinery space, emergency electrical power loss was not included in the assumptions for the current criteria.

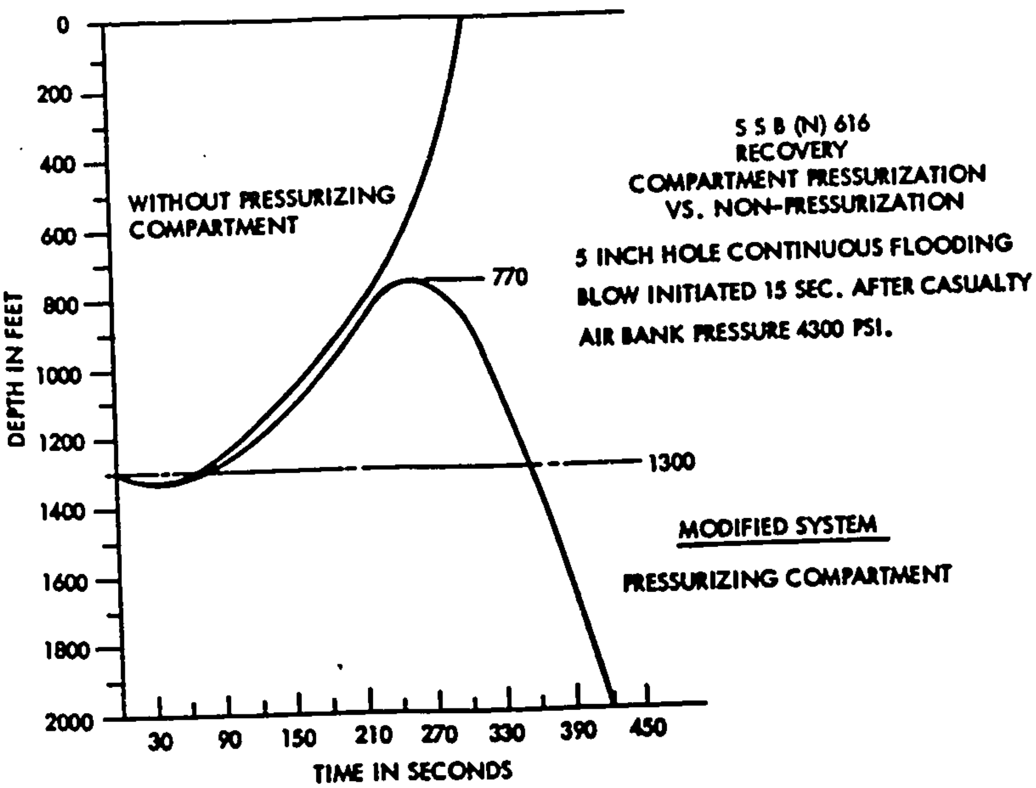


Figure 4

Responding to a request by Admiral Smith, Captain Sonenshein offered to enumerate the assumptions that were governing the BuShips study of flooding. "We first assume that the blow is initiated in 15 seconds," he began. "This is a very important assumption; it means that the commanding officer and his men cannot take a long time to decide to blow. We allow 30 seconds for decision on valve closure after the blow has started and then about 5 to 8 seconds for the actual valve closure. This, of course, could be by manual or automatic means.

"If we cannot recover in the 35-38 seconds, then we must assume automatic closure of valves. This also means devices have to be provided that would sense a change in pressure through a flow system and signal the need to close automatically.

"The matter of closure is subject to certain assumptions; we would not necessarily, for example, want to close the main propulsion valves because we might want to keep our main propulsion if it has not been affected. Therefore, we must be discriminating as to whether all valves should be provided with automatic closing devices or whether only the non-critical ones should be closed automatically and the others provided with partial closure devices.

"We also assumed that the ship's attitude would not reach an angle of more than 30 degrees so we would not lose our bubble. There are other less impelling assumptions such as the obvious one that you do not go below collapse depth. Then there are assumed recovery procedures that are associated with design criteria presented in figure 3: zero speed, test depth, no trim, and so forth. These conditions are much more severe than would probably be used at test depth. We know that a submarine at test depth, for instance, can be in a much more favorable position than we have assumed simply by being light. A submarine might be 20,000 to 30,000 pounds light, using his planes to keep him down, and proceeding at about ten knots; in this position he would be ready to go up immediately in case of difficulty."

"Are you assuming that you have both zero speed and zero power on the ship for the 15-second decision-making time?" asked Captain Brown. "Is that not a limiting condition?"

"That is as severe as we can go," replied Captain Sonenshein.

"That means that you have to design the system for manual operation in order to carry out the decision," observed Admiral Smith. "One of the things I was trying to get clear was whether you were imposing restrictions on yourself that would demand a fail safe kind of design."

"I am sure the decision to blow would have to be made by a human being, and it would have to be made very quickly," said Captain Sonenshein.

"Then it is a matter of what you assume is available to you in deciding to carry out that decision," added Admiral Smith.

Captain Sonenshein stated that the 15-second decision time was not really unreasonable if the crew was alert and the watches normal while at test depth. Serious flooding would be readily apparent and the command to blow should follow without delay.

"Going back to figure 4," resumed Commander Jackson, "this graph shows that, even with our modified design based upon our new criteria, the submarine's commanding officer can not remove the ballast from his ballast tanks in an attempt to surface if he diverts his air to blowing the compartment in an attempt to control flooding. In the 616-Class, this criteria gives us the capability of surfacing with a 5-inch hole, as contrasted with the 2.3-inch hole mentioned earlier, continuously flooding during the time required to come from test depth to the surface. You can see that this time is on the order of 300 seconds. However, the submarine must blow the ballast tanks and not attempt to pressurize the compartment in an effort to eliminate or reduce the rate of flooding.

"This figure applies to the 616-Class as it will be backfitted to meet the new criteria; it does not apply to today's capability. The blow rate here is on the order of 300 pounds of air per second with a modified ballast tank blow system. Material is now being procured which will allow us to achieve these capabilities."

"To clarify that," added Captain Sonenshein, "the 616-Class and subsequent ships do have blow rate requirements in their specifications that match the interim design criteria and the assumed recovery procedure that has just been posed."

"By interim design do you mean everything of the final design except moving the speed up to five knots?" asked Admiral Smith.

"The five-knot allowance does not apply here because this is new construction," replied Captain Sonenshein. "One portion of the assumed recovery procedure that is not yet provided for in any ship is the installation of automatic sensing and closure of valves. The 616-Class and subsequent ships have this requirement in their specifications but it has not yet been physically accomplished. We are in the process of developing the necessary closure devices at this time, however. The increased blow rates, recovery capabilities, air capacities, and so forth, have already been taken care of."

"Is this curve based on having the automatic closures?" asked Admiral Smith.

"It is based on continuous flooding through an opening as large as five inches and then blowing," stated Commander Jackson.

"Is this sensitive as to where the five-inch hole is and what compartment is affected?" asked Mr. Parran.

"It is assumed to be in the machinery compartment, and that is the most probable place," replied Commander Jackson. "This curve is intended to illustrate the effect of using, or diverting, air for pressurizing a compartment as compared with not pressurizing the compartment that is flooding. The point is that it is not a good idea to divert the air to pressurize a compartment."

In answer to a question from Captain Pugh, Commander Jackson said that this curve applied only to the 616-Class but that curves were available for some other types of sumarines. It was then pointed out that the new recovery procedure was exactly opposite to standard operating procedure which was therefore exactly wrong. Captain Kern noted that the new recovery procedure is just one of a number of things to be changed in the standard operating procedure.

"Do the same criteria apply regardless of where the flooding occurs or what the size of the opening is?" asked Captain Pugh.

"That is correct," replied Captain Kern. "At near test depth you practically expend all your air banks in an effort to pressurize the compartment. In the meantime, you are taking in water at a rapid rate as compared to the rate that you are able to pressurize the compartment. Therefore you will go down if you start at neutral buoyancy at zero speed. This works against you because the further you go down the faster the water comes in and the more difficult it becomes to pressurize the compartment. This is, of course, assuming a deep depth casualty."

"To make the point a little clearer," said Captain Sonenshein, "the criterion is that failure of any single pipe will probably be controlling, and we have 12-inch pipes in some systems. Another point I would like to make is that we do not rule out pressurization in shallow depths; at that time pressurization would do the best job."

"According to that curve, you must get the hole shut off within about 200 seconds if you elect to pressurize a compartment," observed Mr. Eyestone.

"Of course if you get the hole closed at any time, you ease the problem for the ship and it would come up," replied Commander Jackson. "If you get past about 250 seconds then you have started down. If you have expended all of your air, you have no capability to off-load ballast."

"If you elected to pressurize the compartment, then can you go back to blowing ballast?" asked Mr. Eyestone.

"There is a range of decision here," replied Commander Jackson, "but the point is that you will be at test depth at the time you elect to pressurize the compartment. No matter how small an opening you have, the pressure at test depth will be such that you cannot possibly do any good by trying to pressurize the compartment. By attempting to do so you will lose the air capacity needed to off-load the ballast."

Dr. Hartmann inquired what the ratio of the volume of the air bank to the compartment volume was and Dr. Mechlin answered that it would be many times the ratio between the sea pressure and the air in the banks which was about seven to one.

"If you have to put all of your air into the compartment to raise its pressure up to the 600 psi at depth, then obviously you are wasting time doing it," stated Dr. Hartmann.

"This becomes academic at this point," commented Captain Kern, "because the internal bulkheads will not take that pressure. If you attempt to match the external pressure at these depths, you will blow out your internal bulkheads. The internal bulkheads will only take about 400 psi and you are dealing with about 900 psi at collapse depth."

Mr. Parran asked what amount of pressure would be created in the flooding compartment by the sea water and Dr. Mechlin replied that it would not be great. Mr. Burg added that the pressure would be dropping off as the ship rises to the surface.

"Tons of water will still flood into the ship without a critical pressure and overcome the amount of positive buoyancy that can be generated by blowing the main ballast," noted Captain Kern.

"There must be another boundary condition that has nothing to do with where you put the air," stated Mr. Parran. "Are we safe in assuming that the resulting pressure buildup in the compartment will not exceed this 400 psi on the bulkhead before the ship surfaces?"

"The indications from our studies are that, if we carry out the criteria we have established here for this class of ship, the trajectory is up, and there is no failure of the bulkhead," replied Captain Sonenshein.

"Failure in the bulkhead would not change your trajectory," insisted Mr. Parran.

"If you have something approaching 3 or 4 thousand tons of water you are in serious buoyancy trouble by the time you take on 100 tons of water," observed Dr. Mechlin.

"It might help to clarify how much air we actually have available," interjected Captain Kern. "On the SSN593, using all of the air available in the airbanks, only 13 per cent of the total ballast tank volume, or 70 tons of water, would be expelled if the ship remained at test depth. On the 616-Class about 140 or 150 tons can be moved out."

"Will the bulkhead of the ballast tanks withstand the pressure when you blow the ballast tanks at test depth?" asked Commander Sadler.

"There is a maximum blow rate, of course," replied Commander Jackson, "but the structure will withstand the effect of the type of impulse that we are talking about here."

"Is this capacity for free blow that you mentioned at surface pressure only?" asked Mr. Hoag.

"Yes," replied Captain Sonenshein. "You must size the system and then look at what you have for moving the ballast out at test depth. This is quite difficult."

"Are you basing your criteria on a certain size hole, or is it the biggest hole that you have in the pipes?" inquired Mr. Eyestone.

"The criteria are any single pipe under conditions of continuous flooding," replied Captain Sonenshein.

"As the ship moves up, the bubble formed by the air being dumped into the tanks is continuously expanding," explained Captain Kern. "At the surface you can blow the tanks completely three times, but at test depth you can only blow 20 per cent of the capacity. As you go up, you are being helped by the expanding air bubble in the ballast tanks pushing more and more water out and decreasing the pressure of the water coming in. Everything is working for you. Conversely, everything works against you if you start down. This is why it is important to get started up, and why you only have 15 seconds for decision making."

"You mentioned a violent maneuver to blow," said Mr. Stevenson, "and I am talking about a quick decision situation again. Is it really an irrevocable move? In other words, once you make this decision to go, what would be wrong with not completely surfacing but rising to a much shallower depth?"

"It is a difficult problem," answered Captain Kern. "Once you start this process -- and I do not know of any submarine that has attempted to blow all ballast at any test depth -- you more or less lose control riding the expanding bubble. You are going to come out of the water without knowing who is sitting on top of you."

"If you maintain horizontal trim while carrying out this emergency procedure," said Dr. Mechlin, "you will come through the surface at about 20 feet per second."

"It is a very spectacular thing," agreed Captain Kern, "and not to be tried often. Obviously it is the lesser of two evils; regardless of who is up there you have no choice."

"Is this inevitable once you have started the process?" asked Dr. Hartmann.

"I think once you have gained control that the thing to do is to open your main ballast tank vents," replied Captain Kern. "These are very small, however, and would not peel off the air fast enough to prevent the uplift. The vents were originally sized by how fast you wanted to get the ship below the surface, and the small vents were adequate for a three-minute diving time."

"They could be sized again on the basis of stopping an emergency," commented Admiral Smith, "and this certainly is an emergency action. It seems to me that one of the things that is going to come out of this discussion is that any steps which would help make the operation less drastic will facilitate reaching a prompt decision to use it."

"This is an excellent point, Admiral," observed Commander Jackson. "In other words, if the commanding officer knows that he could take a certain emergency recovery action and discontinue it at will before getting into some other predicament that might be equally bad, it would make dependence on a quick decision more reasonable."

"For example," said Captain Sonenshein, "suppose the ship is operating at test depth and the commanding officer gets a report from aft of serious flooding and he immediately reacts according to the new doctrine and issues orders to blow. However, as he goes up, he discovers that he has not lost power, as we had assumed in our design criteria. He will not come bursting through the surface because he can use the power and level off; he can pressurize, investigate, or do whatever needs to be done. In other words, his decision is irrevocable only if he has actually lost power."

"The greater salvation is propulsive power," agreed Captain Kern. "If full power is there and available it can be used to recover. However, in flooding casualties, enough salt water gets in around the engine room or the auxiliary machinery space that almost inevitably vital gear is shorted out. This will affect the reactor and it will take 15 to 20 minutes to get it back into operation, which is just too long a period of time."

"Gentlemen, may we move on!" said Commander Jackson. Figure 5 shows some of the current efforts we have underway. Reduction of sea water piping, that is, piping inside the submarine that has to carry sea water at ambient pressure, has previously been accomplished on the SSB(N)640 design. Complete recovery capability analysis is underway; you have seen the results of some preliminary work. Silver brazed joints on the sea water pipe, as contrasted to the much more expensive welded joints, are being re-evaluated. These silver brazed joints, when good, are very good indeed, but they have been known to give trouble."

CURRENT EFFORT

1. REDUCE SEA WATER PIPING.
2. COMPLETE RECOVERY CAPABILITY ANALYSIS.
3. REEVALUATE WELDED VICE SIL BRAZE JOINTS.
4. REEVALUATE EB TYPE FLEX JOINTS VICE FLEX HOSE.
5. AUTOMATIC OPERATION OF HULL AND BACK UP VALVES.
6. INVESTIGATE INCREASED EMERGENCY PROPULSION.
7. PROVISION OF FLOODING ALARMS.
8. REEVALUATE INSURV'AND TEST DIVE PROCEDURES.

Figure 5

"What are the materials usually used for the sea water pipe?" asked Admiral Smith.

"Copper-nickel is used because of its anti-corrosive properties as well as strength and toughness," replied Commander Jackson. "For noise isolation we have to use a flexible connection from operating machinery to piping systems; for example, the hydraulic pump would be isolated from the hydraulic pump system by flexible connections."

"Have flexible connections been used whether or not there is another connection to the sea water?" inquired Mr. Parran.

"In the sea water system," Captain Kern answered, "there is a salt water pump that is sound isolated. Actually, to have sound isolation you need to break the metal connection through the pipe, and insert a flexible hose at that junction. The maximum diameter of flexible hoses installed in the deep diving submarine is two inches."

"Getting back to figure 5," continued Commander Jackson, partial or total automatic closure of the hull and backup valves was discussed previously. In some instances it is necessary to review the entire system to evaluate the precise functions of its parts. Regarding item 6, the present electric motor on the shaft is rated to give you a continuous speed of about four knots. It is possible to increase this rating to deliver more speed for a limited period of time. Flooding alarms should be provided in generally inaccessible parts of the ship. And finally, INSURV and test dive procedures are being re-evaluated. There are more programs and studies underway than I have mentioned specifically, but this is a sample.

Figure 6 is a summary of what we consider to be the most important factors in a submarine's capability for recovery from a flooding casualty."

SUMMARY

I. RECOVERY CAPABILITY IMPROVED IF:
   A. AIR BANK PRESSURE HIGH
   B. SHIP NOT AT DEEP DEPTH
   C. SHIP HAS SIGNIFICANT SPEED

II. IF A CASUALTY DOES OCCUR:
   A. QUICK ACTION IS REQUIRED
      1. TO SECURE FLOODING
      2. TO BLOW MAIN BALLAST TANKS
      3. TO APPLY PROPULSION POWER

III. FUTILITY OF PRESSURIZING COMPARTMENTS IS EMPHASIZED.

Figure 6

"I would like to add one point about the current efforts that are underway," interjected Captain Sonenshein. "One important effort is the development of a gas generator similar to the missile launch type that could be used to blow ballast tanks and which obviously would be independent of any power sources in the ship other than its own inherent energy. This effort is progressing now and we are sending out a request for proposals to many firms. We expect to go into the development program on this very shortly. This was not initiated just because of the USS THRESHER loss; it had been in progress before. However, it fits into this program now and is being accelerated."

"You did not say anything about the disadvantages of high speed at test depth; when you are at or near test depth, you want to be certain that you do not exceed your depth limitations," Admiral Smith pointed out.

"It is inadvisable for a submarine to operate at speeds high enough so that a minor error in the use of the controls could cause it to go below its limited depth," said Commander Jackson. "There are a number of very good reasons for this, not the least of which is the possibility of one of these systems giving way. Of course it is equally bad for a submarine to operate at such a slow speed that it is unable to maintain its depth in a reasonable fashion, and inadvertently sink. A submarine operating at test depth very close to the floor should elect a moderate speed which I consider to be between five and ten knots."

"Are you considering the type of casualty or error in ship control that would set some upper limit on this speed?" asked Admiral Smith.

"If you are operating above 50 per cent reactor power, you have more systems on the line in order to maintain that power," replied Commander Jackson. "If you are operating at such speed near the floor with all of the ship's machinery systems in operation and the piping systems in use for propulsion, then you are more susceptible to a casualty of this sort than if you were operating below 50 per cent reactor power."

"Are there control surface casualties that could put you in this sort of situation?" inquired Admiral Smith?

"Yes, sir," answered Commander Jackson. "That is a subject that is being pursued also, although not necessarily in connection with recovery from a flooding casualty. For example, if the submarine has a casualty on the stern planes at nominal operating depth, then the submarine should take certain recovery action. We call these emergency recovery tests."

"I am speaking in connection with test dives," explained Admiral Smith. "It seems to me that there is a time to recover from that sort of casualty. The effect of that casualty as associated with speed is the amount that you could go on down before you could recover."

"We have also made a study of the time needed to recover from a plane jammed at various angles and the number of feet that you could expect to transit before you could shift to emergency and get the planes off that particular jam," stated Captain Kern.

"Does that sort of study help to set a safe upper limit?" asked Admiral Smith.

"Yes, sir," replied Captain Kern. "It shows very clearly the effect of a plane casualty under circumstances of high speeds at test depth. This information is made available to the commanding officers for each new class of ship."

"I think it is fair to say that this is a well understood possible casualty; it has been thoroughly documented for each ship," said Commander Jackson. "Of course, if you have a redundancy of casualties that is another thing."

"What I am suggesting is that this information might well be incorporated into your present study with valuable results," stated Admiral Smith.

"We are going over the information that has been provided again, sir," said Captain Kern. "However, with plane jams, you are not normally confronted with power failure. Also, information is provided to the ships as to how to recover from a plane jam which is essentially back down full, stop, and use the rudder."

"There are three ways, in fact, of operating the planes in case one system fails," added Commander Jackson. "These are being re-examined for the possible effects of control surface failure."

"The USS ALBACORE has been used extensively to evaluate emergency recovery operations and has actually been run through tests in which the planes were purposely jammed, the dive brakes activated, and so forth," said Captain Kern.

"I would like to proceed now," said Commander Jackson, "to a subject which we have discussed previously in considerable detail, namely controllability of the POLARIS submarines at periscope depth under high sea states."

"Excuse me, Commander Jackson," interjected Dr. Barrow, "I wanted to ask several rather simple questions before we leave this thing. What is test depth in terms of the safest maximum depth to which the submarine can go?"

"It is generally defined as two-thirds of the design collapse depth of the hull and structure," replied Commander Jackson.

"Is the submarine supposed to be operated at test depth?" Dr. Barrow questioned further.

"The submarine is capable of operating at test depth, but it is up to the commanding officer of the submarine which depth would be best for his particular purposes at the time," replied Commander Jackson. "While nuclear submarines have been operated for extensive periods of time at high speeds at test depth, commanding officers now have very definite warnings not to do so. The high speed submarine is not designed to operate at high speeds at test depth for indefinite periods of time. The fact that they can do so is very interesting, but it is neither recommended nor endorsed."

"Is the submarine itself tested below test depth?" inquired Dr. Barrow.

"Not intentionally," answered Commander Jackson. "Occasionally a submarine has been known to go below test depth inadvertently, but for a number of reasons we require a detailed report of all the circumstances and all the effects observed. By the time the skipper finishes preparing all the required reports he knows he should not do it again!"

"What confidence do you have in design collapse depth?" asked Mr. Parran.

"Very good confidence indeed," answered Commander Jackson. "The correlation of confidence is easily within 5 per cent. To build our design criteria for a particular submarine, we study very large models at collapse depth. Every submarine design is tested on a model basis and the models themselves are tested with each other in order to establish correlation. We also include such variables as quality control in our 5 per cent degree of confidence figure."

"Are your tests for penetrations through the hull on a simple hull form or are they on a hull with realistic proportions?" inquired Dr. Barrow.

"We have studied full-scale submarine models at test depths, with penetrations in the model that are similar to the penetrations that we are using today," replied Captain Kern. "This was on the TANG Class submarine which was the first to go to . The full-scale model sections of that submarine were put in the test tank with penetrations such as hatches, plates, valves and wire, and those models were tested to collapse. The correlation was excellent in this case -- I think around 5 per cent also. Normally we come out with less than the design collapse depth. We then modify the design to get up to at least the design collapse depth with the 5 per cent correlation of confidence in all instances."

"Another aspect that gives us further confidence is that on every initial test dive of a new class of submarine we frequently instrument the ships with strain gages in critical spots and compare the full-scale strains with the model strains for further correlation," added Captain Sonenshein.

"With regard to the USS THRESHER, the thought has gone through my mind a number of times that, if it was at the maximum depth at which the submarine was supposed to be operated, that you would do this over a nice flat bottom of about a couple of hundred feet in excess of test depth," observed Dr. Barrow.

"You are beyond salvageable water at in any case," remarked Captain Kern. "The limit of rescue for personnel at the present time is roughly

"While we are still talking about recovery, may I ask if you are considering a gas generator as a possibility for augmenting your blowing capability?" asked Dr. Kirchner. "Let us suppose that a submarine is diving and exceeds test depth; have you considered water reactant materials which evolve large amounts of gases, even hydrogen, for increasing the blow capability?"

"We are investigating evolving gases by mixing lithium compounds with salt water," replied Captain Sonenshein. "We use this type of technique in surface ship salvage for blowing up pontoons, but we have not studied this completely other than considering blowing the ballast tanks by this technique of gas generation."

"I thought you were talking about a solid propellant gas generator like we are now using on the launcher," said Dr. Kirchner.

"We are considering both kinds," stated Captain Sonenshein. "We do have lithium peroxide which will give us large amounts of gas for ejecting water from the ballast tanks."

"Are you considering increasing compartmentation?" asked Commander Saddler.

"Compartmentation studies have not been done," replied Commander Jackson. "The problem of compartmentation resolves itself to the question of, 'why?', which is a large topic in itself. For example, in very deep diving submarines we are not building any compartmentation. The problem of trying to compartmentalize a submarine for the purpose of giving a limited number a haven from a flooding casualty is tied up with the question of how deep will the submarine be at the time you are attempting to rescue the crew. At depths exceeding 850 feet this question becomes academic because of the limited facility of the people inside to escape or for them to be rescued from the outside. If the submarine has sunk in water that is shallower than 850-feet, then compartments are important and you can save a large per cent of the crew. Below that depth there is not much chance of rescue, hence the limit on the strength of our internal compartment bulkheads. Incidentally, if you compartmentalize a submarine to withstand the test depth or the collapse depth of the submarine you add a tremendous amount of weight, thereby reducing the payload available for machinery, personnel, torpedoes, and so forth."

"In order to compartmentalize a submarine to the point where you can accept flooding in one compartment, you would need to increase the number of bulkheads by a tremendous amount," added Captain Sonenshein. "You must go back to our basic rescue philosophy and consider the per cent of the ocean that is within salvageable depth. With this in mind, [redacted] still seems to be the proper depth for possible rescue." C

"Are there not localized machinery areas around which we could have very small compartments for the purpose of allowing the incoming water to create its own inhibiting pressure?" asked Dr. Craven.

"It does not sound very feasible," observed Captain Sonenshein.

"We are doing some designs of a sea valve for hull penetration and then a backup valve in close association with the sea valve," said Captain Kern. "The backup valve would be checked periodically to give you the assurance that, in case your ourboard sea valve is not in the best condition, you can secure the pipe down stream if you have a flooding condition. In this manner you would be provided with double protection."

In answer to a question from Mr. Parran, Captain Kern replied that pipe ruptures are most apt to occur down stream in the joints. He added the comment that sea valves are designed to withstand as much as 200 g's of shock loading.

"The ultimate of this idea of comparmentation is included in a current study in which we propose to have a large heat exchanger and a compartment perhaps around the hull in which all the salt water is handled at sea pressure," said Captain Brown. "Only fresh water which is cooled by a tank inside the ship is used, thereby eliminating all salt water piping."

"We must appreciate the fact that additional compartments or a fresh water cooling system will inevitably add to the size and weight of the ship," emphasized Captain Sonenshein.

"I had intended to mention the retrofit program on the 598-Class," said Commander Jackson, "but in the interest of time I will bypass that subject and continue with the depth control problem in the 640-Class when operating at periscope depth under high sea states.

"Figure 7 shows the outline of the 640-Class as presently being designed. Under a simulated Sea State 5, the fairwater on the 640-Class is very close to the surface. In those frequent occasions when a Sea State 5 gives higher than nominal wave heights, the ship broaches. As you know, the fairwater planes are four feet lower on this design than on the 616-Class; the upper rudder has been lowered approximately 11 feet by removin g a fixed stool and putting the equivalent vertical surface on the outboard of the fixed part of the horizontal stabilizers.

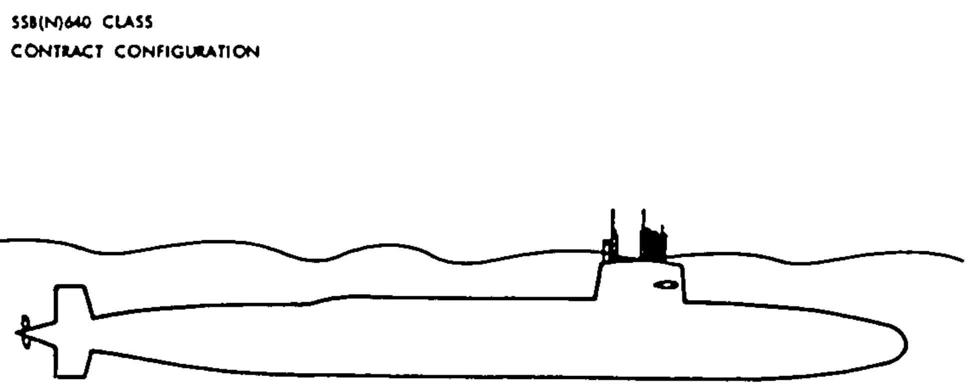


Figure 7

"As you know, a submarine is subjected to a surface suction force which is exponentially dependent upon its depth below the surface. This force causes the ship to broach when operating at shallow keel depths, which has been our major problem with the 608-Class. Improvements may be possible through auxiliary control devices or through the use of higher speeds which would make the control surfaces more effective. Through studies of various types of ships, BuShips has determined that the best way of improving the depth control of submarines at periscope depth is to put the submarine deeper in the water. We have underway a detailed design of a fairwater that will accomplish this. As shown in figure 8, the sail will be six feet higher than in the earlier design. We propose to lengthen the masts by ten feet of which six feet will be enclosed in the modified sail and the additional four feet will be stowed in the submarine itself. The effect of this design change will be to put the submarine deeper in the water.

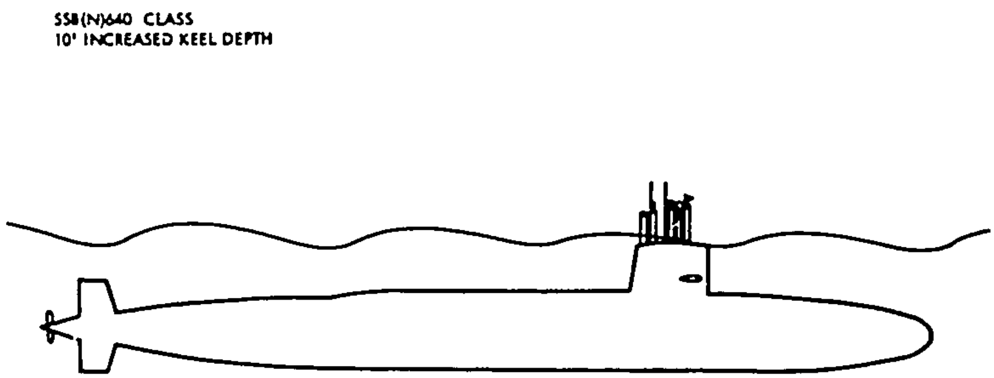


Figure 8

"Figure 9 shows the original configuration already shown in figure 7 superimposed upon the new design. The top of the fairwater is deeper in the water, hence is less likely to be exposed during high sea states. The whole submarine is ten feet deeper in the water with the result that there is less surface suction force on the submarine.

"Our design criteria on the 640-Class, as approved by the Type Commanders, are that the ship must be able to operate with an exposed mast in a Sea State 5 without broaching."

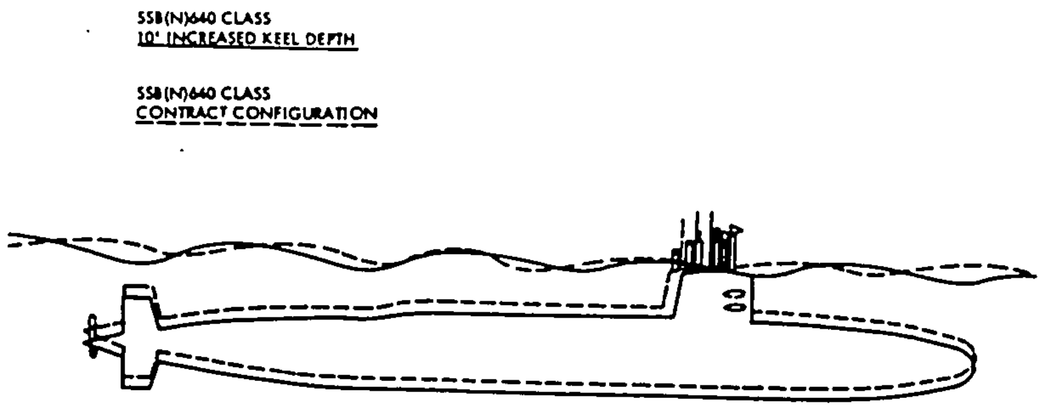


Figure 9

Admiral Smith observed that this would mean either broaching if the periscope was used in a higher sea state or accepting the limitation of not using it. Commander Jackson stated that, although patrol reports indicate that these submarines have been operating in sea states higher than 5, the Type Commander has accepted Sea State 5 as a design criterion.

In answer to further questions Commander Jackson explained that there would be no problem in increasing the length of penetrating masts to allow for the ten-foot addition in periscope depth, with the exception of the Type 11 periscope which could only be lengthened six feet. This would mean that two operating depths would be necessary, one for the Type 11 and one for the rest of the masts. When Type 11 was being used, the sail would be very close to the surface and the ship would tend to broach; although the situation would be improved, the stated operational requirements would not be met in this case.

Dr. Craven raised a question regarding the actual magnitude of improvement that would be gained by the design changes outlined by Commander Jackson. Captain Kern replied that the design changes were prompted by actual experience in the SSN593 where serious depth control problems had been solved simply by putting the submarine ten feet deeper in the water. Admiral Smith asked if other means were available for solving the problem and Captain Kern answered that they had considered other approaches and found this one to be the only positive solution available today.

"Would it be possible to put the existing Type 11 periscope into a ship that has a six-foot higher sail?" asked Dr. Mechlin.

"It is possible," replied Commander Jackson, "but it would actually make our problem of depth control worse. The Type 11 periscope now extends about 13 feet above the top of the existing sail, and would therefore extend seven feet above the top of a sail that had been heightened by six feet. The distance from the top of the periscope to the keel would be the same but the sail would be higher and would project out of the water on top of the waves."

"Next we should consider the relative difference in the use of the Type 11 periscope between our present experience and what we expect in the 640-Class," stated Dr. Mechlin. "Have the operational requirements been made up with the expected characteristics of the 640-Class in mind?"

"We understood that the Type Commander's approval of the criteria we are using applied both to the design of the 640-Class and to the corrections in the 608-Class," said Captain Kern. "It is possible that he only meant the 608-Class, and it seems worth checking."

"The Systems Appraisal Committee gives nine reasons for a submarine to come near the surface," said Dr. Craven, "with the conclusion that, unless we provide some other hardware, we have no right to constrain the operational behavior of the Commanding Officer in meeting these nine operational requirements. A portion of one of those reasons has to do with the Type 11 periscope."

"Our present position," stated Commander Jackson, "is that there is a fairwater now being constructed for installation on the 640-Class masts, including the Type 11 periscope, being procured for delivery. If we can decide prior to 5 June to install the higher sail and provide the longer masts, then the SSB(N)640 itself can be delivered without delay. Presently, the construction of the fairwater is considered to be the controlling factor in meeting the schedule, but being able to have the equipment delivered in time may present problems."

"Are you planning to keep the Type 11 periscope station in the same position that it is now?" asked Mr. Morton.

"We considered the possibility of providing a conning tower for the Type 11 within the fairwater," replied Commander Jackson, "but it is not feasible from the weight and moment considerations as well as construction."

"What is the frequency of broaching in a Sea State 5?" inquired Dr. Dunlap.

"In my opinion, a submarine operating continuously at periscope depth in a Sea State 5 could be expected to surface completely about twice an hour," replied Commander Jackson. "Once the ship broached, it would take two to five minutes to submerge again. If we accept the literal definition of broaching as any time any fixed portion of the submarine is exposed above the surface, then I would say that a ship operating at periscope depth in a Sea State 5 at a speed less than six knots would be broached about a third to a half of the time during a ten-minute operating period. During this period of time the submarine is exposed to detection, localization, and identification by radar contact."

"As far as radar detection is concerned, it would be extremely unlikely to detect the top part of a sail in a state 5 sea," observed Dr. Barrow. "You could not tell the sail from the waves that go squirting up much higher."

"That is largely a function of the type of radar being used and the proximity of the submarine to the installation," said Commander Jackson. "Perhaps the worst case would be if the ship were within 50 miles of a shore-based radar; in this situation the probability of detection would be rather high."

"Would you say that it is higher than the probability of detecting the Type 11 mast with that same radar?" asked Admiral Smith.

"That is a good question which I cannot answer," replied Commander Jackson. "We are requesting the Operations Evaluation Group at OPNAV to do an analysis of this subject for us."

Dr. Dunlap questioned how recently the entire problem of broaching had been studied thoroughly with respect to the frequency and duration of broaching, the probability of detection, and the costs involved in making the proposed design changes. Admiral Smith and Captain Kern agreed that more study was needed on the actual likelihood of detection by any means, including radar.

"There is a current speed limitation of six knots on the submarine when the periscope is in use," said Dr. Frank. "Will additional height in the periscope necessitate lowering the speed limitation? If so, this would entail a loss in controllability and thereby cancel what you have gained by lowering the keel depth."

"My understanding is that, if it is possible to increase the Type 11 by six feet, we will not degrade the speed at which it could be used," replied Commander Jackson.

"There will probably be an upper speed limitation of something like eight knots for use of the Type 11," added Captain Gooding. "The system manager and the manufacturer of the Type 11 have stated that it can be lenghtened six feet with the additional restriction that the allowable sea state for use be reduced from 5 to 4. However, I am inclined to doubt that the periscope can be lengthened without appreciable degradation of its performance."

"What we are considering, then," observed Admiral Smith, " is an 100 per cent limitation to Sea State 4 in exchange for an occasional limitation at Sea State 5; this is where we are not meeting all of our requirements. This does not appear to be much of a gain."

"It seems to us in BuShips that there is not much point in going into the expense of increasing the height of the sail by six feet and providing periscopes that are ten feet longer unless we also make some gains in the Type 11," stated Commander Jackson. "As I mentioned earlier, increasing the height of the sail without increasing the height of the Type 11 will actually make our situation worse. Accordingly, we need to know whether or not the Special Projects Office will provide a six-foot increase in length for the Type 11 and, furthermore, whether they can provide it in time to meet the schedule.

"Perhaps I should mention another method of improving the ship's controllability at periscope depth, and that is to increase the speed at which the submarine will operate at periscope depth in state 5 sea. We know from model studies and computer analyses that we are able to control the submarine, satisfactorily preventing it from broaching, by running at speeds as high as ten knots. However, there are objections to such high speeds at periscope depth, not the least of which is the increased probability of detection. For this reason alone it is not a desirable solution, but it does bring up the question of whether or not the Type 11 can be used at speeds above six knots."

"You may do so if you restrict the angle of movement of the rudder," replied Captain Gooding. "If you maintain an essentially straight course, restricting the rudder motion to 5 degrees, the Type 11 will take as much as 12 knots, irrespective of the direction of the sea."

Mr. Chadwick stressed that the strain of the ship's speed was taken by the fairwater rather than the Type 11 and, in response to a question from Admiral Smith, Captain Gooding stated that the angles of attack induced by traveling obliquely into the sea and by turning had been taken into account in his figures. Commander Jackson said that the rest of the masts could be fitted with a fairing that would permit them to be used at speeds over ten knots; the Type 8B periscope will already take over 12 knots, and the TRANSIT antenna, if mounted on a simple cylindrican mast, would be able to take over 10 knots.

"Our discussion has turned from the importance of the Type 11 to the performance of the 640-Class system," observed Captain Thompson. "May we hear from Captain Gooding about how important the Type 11 star sights will be in the 640-Class in comparison to their present importance in the 608-Class?"

"In the 640-Class navigation system, there will be nine gyros which will help to determine azimuth," stated Captain Gooding. "It is unreasonable to assume that all nine of the gyros would have a constant offset; therefore, by averaging techniques we expect to be able to do quite well in azimuth for long periods of time without using the Type 11 periscope. I would also like to state that we would accept immediately the limitation of using the Type 11 only in Sea State 4 or less; such a restriction would decrease its value to us only very slightly. I do question the idea of lengthening it by six feet; however, everything that is bad about a pericope is only made worse by lenghtening it and its performance would be degraded considerably."

"Could you raise the entire periscope without lengthening it?" asked Commander Saddler.

"It would require a large structure high in the ship," Commander Jackson pointed out, "and would therefore not be feasible without significant weight compensation. Speaking of weight compensation brings me to another point; we need a decision with regard to the radiometric sextant which is presently specified in the 640-Class design. The weight and space reserved for it is needed to accommodate the higher sail and if we delay past 5 June on giving the order to proceed, it will delay the delivery of the ship."

"We are preparing a message for the Admiral's signature that will withdraw the requirement for the radiometric sextant," replied Captain Gooding.

"Do we understand Captain Gooding to say that at Sea State 5 the cloud cover is sufficient that the stars are hardly ever visible?" asked Dr. Mechlin.

"My statement that the Type 11 was of little use to us in a state 5 sea was based on a study in which we assumed that cloud cover was not correlated with sea states," replied Captain Gooding. "This is not correct, but it is on the conservative side. We extrapolated how many sights were completed and in what sea states from patrol data of three areas; the Norwegian Sea, the North Sea and the Mediterranean. Our calculations showed that our miss distance would be decreased by 0.07 mile at the very most by using the additional sights we could take in Sea State 5, which does not seem like much in terms of A1 and A2 missiles. I do not think we should jeopardize our patrols by reducing our limit from Sea State 5 to 4, and putting the six-foot longer mast on the Type 11 would pose that limitation in any event."

"The idea of the study was to pinpoint how many fewer sights we get if we limit ourselves to Sea State 4 versus Sea State 5," Mr. Chadwick pointed out, "and then to propogate this through system performance and determine the results in terms of the entire patrol. We assumed that sea state and weather were uncorrelated, which is conservative because clouds tend to accompany heavier sea states."

"If there were never clouds, would there be any effect produced by the sea states alone on your ability to get sights?" asked Dr. Hartmann.

"If there were never any clouds, the sea states going from five to four would have the effect of removing fewer stars; if there were clouds, it would remove more stars," replied Mr. Chadwick. "In the presence of clouds, Sea State 5 removes more stars than it removes in the absence of clouds."

In the discussion which followed it was pointed out that a greater number of sights could be taken if the submarines were capable of remaining at periscope depth for longer periods of time. Dr. Craven pointed out that the amount of time it takes to get one shot is approximately the same as the time in which the ship will broach in a Sea State 5. Captain Pugh stated that it was not necessary to use the Type 11 periscope to look for stars; this can be done through any periscope.

"Our problem, as I understand it, is in reducing the probability of detection from broaching. In considering improving controllability at periscope depth by increasing speed, we must remember that increased speed will also increase the probability of being detected," said Dr. Dunlap.

"We have recognized this and have asked the Operations Evaluations Group to give us a curve as to the probability of detection because of speed," replied Commander Jackson. "We want to take this curve at the point it crosses a second curve based on the improvement in controllability with speed."

Dr. Craven pointed out that either acoustic or visual detection because of speed would be more probable in a higher sea state than in calm weather because of the coherent patterns created by the submarine in the otherwise incoherent turbulence of the waters. He emphasized that this would also apply to radar detection. In the discussion that followed it was brought out that there was a great deal of theoretical data available on this subject but that radar studies based upon actual experience were quite scarce.

At this point Admiral Smith adjourned the meeting for lunch.

NAVIGATION COMMITTEE REPORT DISCUSSION

"As I told you two meetings ago, we have been considering a second generation Type 11 periscope star tracker for the FBM submarine as a possible improvement to cost and accuracy," began Captain Gooding. "This effort has not stopped and we had a technical meeting this week with various vendors interested in providing the instruments. We should be able to make an evaluation of these proposals in a few weeks.

"Recent results of the performance of the Mark 2 Mod 2 SINS on the USS COMPASS ISLAND have been very good. The Mark 4 SINS performed well, but we had trouble with the appended gyro monitor on the Mark 3 Mod 3 SINS on the USS COMPASS ISLAND. This was because of basic design problems which are now being cleared up. The Mark 3 SINS itself did not do badly, although it was by no means the best SINS on board.

"I received this morning the results of a stationary run of a Mark 3 Mod 3 SINS. It was run in full automatic, with the X and Y gyro and X and Y accelerometer fed in automatically and no heading changes and SCORSBY motion. The RMS results of the 30-hour run were 13 seconds in azimuth, 12 seconds in latitude and 17.5 seconds in longitude which are very good results.

"Problem areas in Navigation are the Program 435 TRANSIT satellite which is due to fly next month, and the late deliveries to the SSB(N)627, notably the NAVDAC, navigational control console, and the SINS. The Mark 2 Mod 2 SINS has had its problems, although deliveries are beginning to come through now. I think the Steering Task Group will be interested in its problems and progress and I would like to turn the meeting over to Mr. Fred Eyestone, Executive Vice President of Autonetics, who will talk to you on that subject."

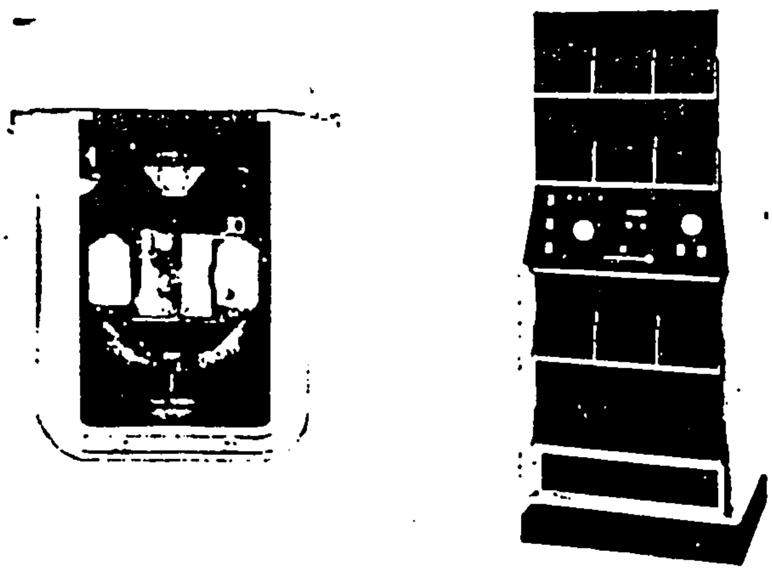
"We felt," began Mr. Eyestone, "that when the Mark 2 Mod 2 SINS reached the point where it had some test results on the USS COMPASS ISLAND, that it would be appropriate to have a brief and informal position report on the system since it is scheduled to take on the inertial responsibility on the SSB(N)627 submarine for the A3 missile.

"I would like to start by outlining the differences between the Mark 2 Mod 2 SINS and the Mark 2 Mod 0 SINS, which went on the SSB(N)598 and about 14 other earlier submarines, and then say a few words about the Mark 2 Mod 2 schedule status and problems it has encountered, and finally survey the test results that we have had so far on USS COMPASS ISLAND.

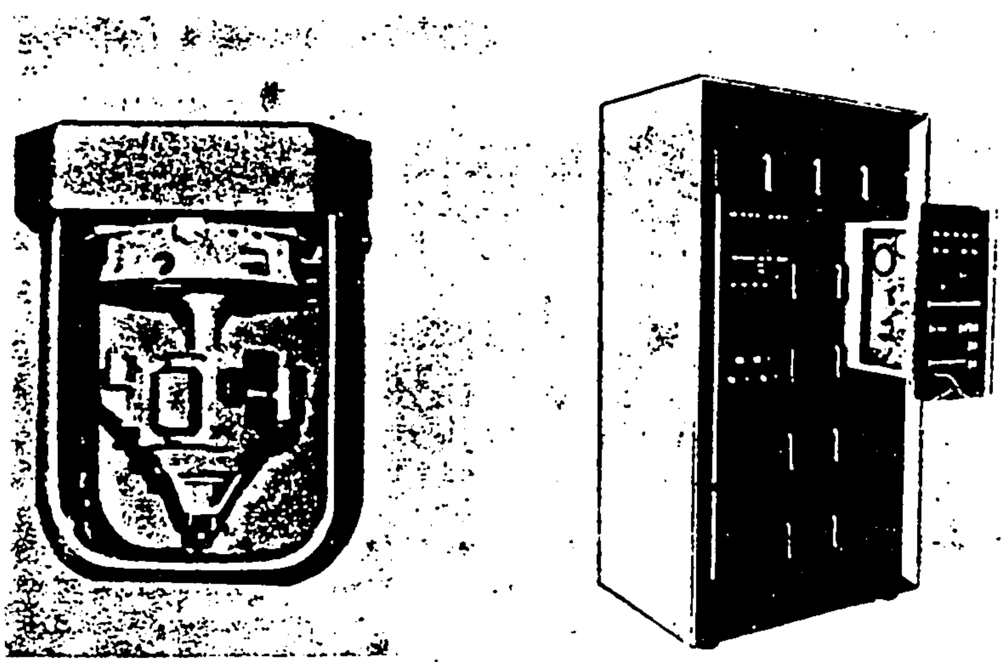
"Figure 1 compares the Mark 2 Mod 0 and the Mark 2 Mod SINS. Our objective in building the Mod 2 was to cut the position error and the azimuth error in half, and lengthen the time required between fixes by a factor of two. With the Mod 2 we have cut errors to 0.75 nautical miles in both latitude and longitude, and 70 seconds in azimuth up to 70 degrees latitude with fixes every 15 hours, as compared to the Mod 0 which has errors of 1.2 nautical miles longitude, 0.8 nautical miles latitude and 150 seconds azimuth to 70 degrees with fixes every 8 hours. We are hoping to lengthen the time between fixes to 30 hours as soon as possible.

"Concerning other changes, the shock mount in the Mod 2 has been moved inside the binnacle. The external shock mounts of the Mod 0 SINS caused the SINS to be very susceptible to the aggravating resonances from troublesome frequency areas the original ships were encountering, and two out of three of the SINS had to be rigidly blocked up to deter this. The shock mounts were also susceptible to banging and stresses which could disturb the alignment. Now these go to the bed plate through the shock mount, and can not get at the structure.

"There is a pedestal structure in the Mod 0 which comes down to a knuckle assembly containing pitch, roll and train axis bearings, pickoffs and so on, and a hat section that comes up on the base of the knuckle assembly and carries the gyros. We have stiffened this structure on the Mod 2 and use stainless steel. Also in the Mod 2 we refer to the acceleration measuring devices as velocity meters.



N7 MK II MOD 0 SINS



N7F MK II MOD 2 SINS

Figure 1

"We have attempted substantial correction in the influence of heading accuracy of the system by getting a better thermal situation inside the platform. There is a spherical baffle which comes down around the platform and the air circulates down through the chilled heat exchanger on the top, down through the platform and back up around the outside. The Mod 0 has an air-to-air heat exchanger which provides less thermal control of the platform or binnacle housing.

"The gyros and velocity meters have been improved. In addition, the Mod 2 velocity meters are all the same, whereas the Mod 0 has two different velocity meters, one each on the horizontal and vertical axes. The optical cube, which is involved in the bore-sighting on installation, is now permanently mounted in the hat section.

"The computer, which is housed in a console, is a combination of incremental computation and whole value computation -- a general purpose and digital differential analyzer type of computer which is programmable from a tape reader. The number of differential analyzer sections has been doubled to about 256 and the number of words in the general purpose memory has quadrupled to 4,023, giving the computer the capability of accomplishing on-line diagnostic routines such as periodic limit-checking of the servo air voltages, power supplies and so forth, and providing additional programs for off-line diagnostic purposes. It runs its own computer to self-check during operations. This computer contains the buffers within itself which allow operation with the NAVDAC, whereas previous buffers were in separate units outside the computers.

"Figure 2 shows the test results of 94 gyros of the Mark 2 Mod 0 system, with a sample mean of 0.0015 degree per hour, and for 89 G7B gyros which are going on the Mark 2 Mod 2 with their mean of about 0.00055 degree per hour. The results are commensurate with our attempt to increase by a factor of two the accuracy of the gyro which bears the large share of the performance accuracy. Improvement was achieved mainly by using beryllium in critical areas and by increasing the angular moment by about a factor of four, giving us a certain amount of aggravation and attention to detail through much of the gyro.

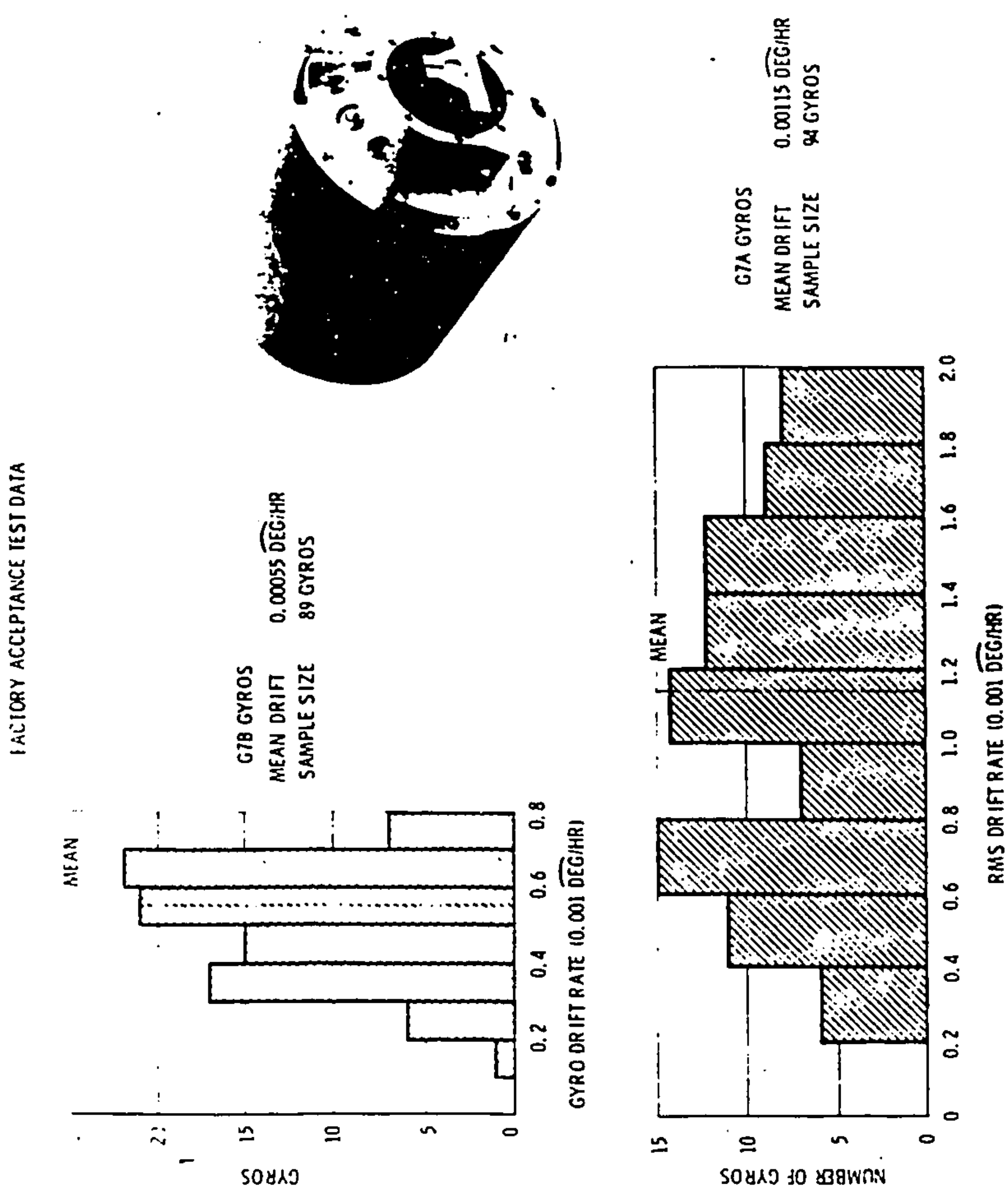
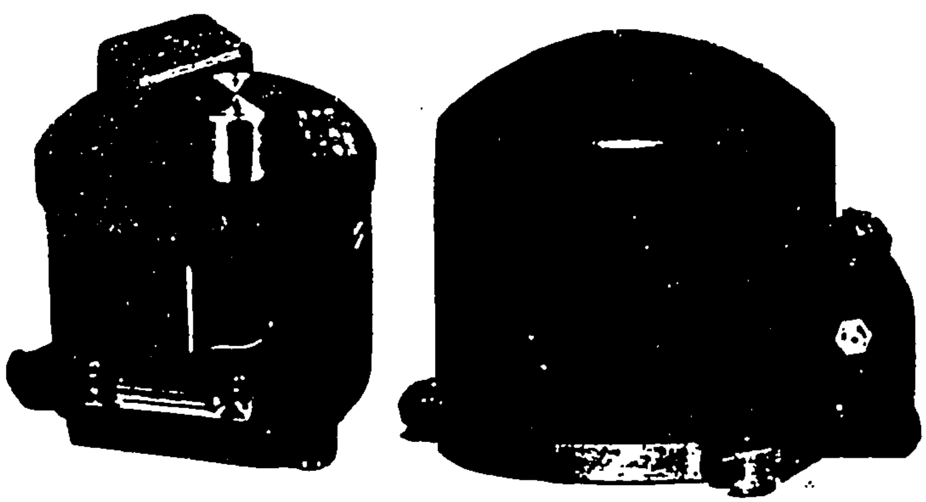

FACTORY ACCEPTANCE TEST DATA
G7B GYROS
MEAN DRIFT 0.00055 DEG/HR
SAMPLE SIZE 89 GYROS
MEAN
GYROS
GYRO DRIFT RATE (0.001 DEG/HR)
G7A GYROS
MEAN DRIFT 0.00115 DEG/HR
SAMPLE SIZE 94 GYROS
NUMBER OF GYROS
RMS DRIFT RATE (0.001 DEG/HR)

Figure 2

"Figure 3 is a comparison of the velocity meters. The Mark 2 Mod 2 velocity meter (VM7) is an adapted instrument which has increased pendulosity at low g environments and is a much more symmetrical instrument.

VELOCITY METER COMPARISON



	VM 2	VM 7
BIAS STABILITY	1 $\widehat{\text{SEC}}$	< 0.2 $\widehat{\text{SEC}}$
THRESHOLD SENSITIVITY	2 $\widehat{\text{SEC}}$	< 0.2 $\widehat{\text{SEC}}$
PENDULOSITY	1.79 GM CM	27.7 GM CM

Figure 3

"The test results in figure 4 give an indication of the bias stability, the most important parameter in the acceleration measuring device. The figure shows that over 80 percent of the instruments tested are below 0.2 second for a one-hour test, and almost 50 per cent are below 0.25 second for an eight-hour bias stability. It should be noted that we would like bias stability to be better than that of the gyros for fixing methods to recalibrate the gyros. We would like to have biases substantially more stable than the gyros for periods that are long compared to the fixing times. Getting drift rate is more of a problem than bias stability. We feel that the stability of the bias and the velocity meters is down to where the gyros are going to be carrying the burden and where if we can get good fixing accuracy in terms of position fixes used, we should be able to realize the benefit from the 0.0005 degree per hour.

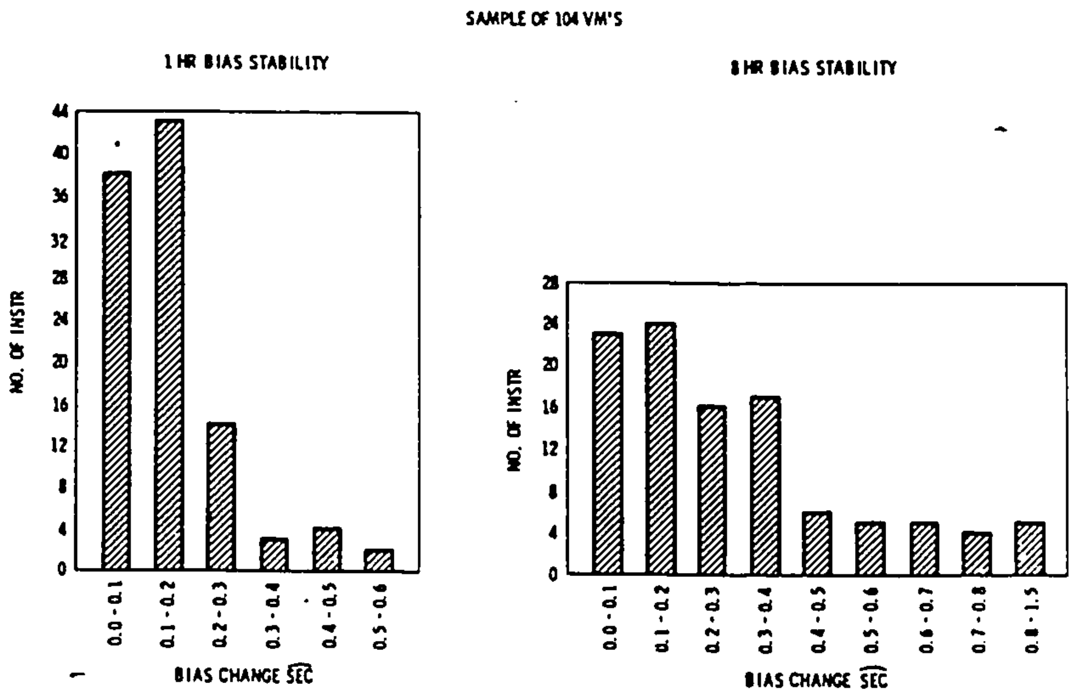


Figure 4

"Figure 5 shows ambient temperature and Velocity Meter bias versus time. An interesting sidelight of this study is that we observed that the temperature here was plotted over the same period of time that tilting had occurred in the building. As a result of this and other studies we took up the mounting slabs and repoured them in a different way.

AMBIENT TEMPERATURE AND VM BIAS VS TIME

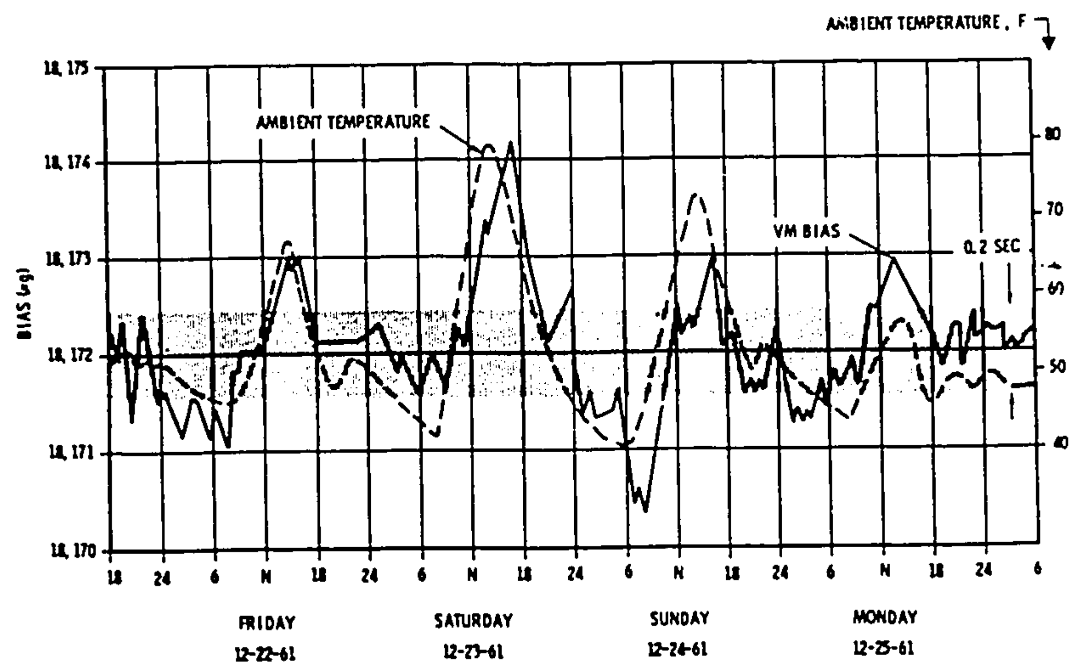


Figure 5

"The over-all redesign schedule of the Mark 2 Mod 2 SINS is shown in figure 6. About June 1961 we talked with SP-24 about possible redesign of SINS and various related work under SP sponsorship. Based on these conversations and a limited go-ahead, we began design studies on the long lead time items in the systems. November 1, 1961 on a contractual basis we began a design schedule to get the X model Mod 2 SINS out which we did by about the first of October 1962. We hoped to deliver in December 1962.

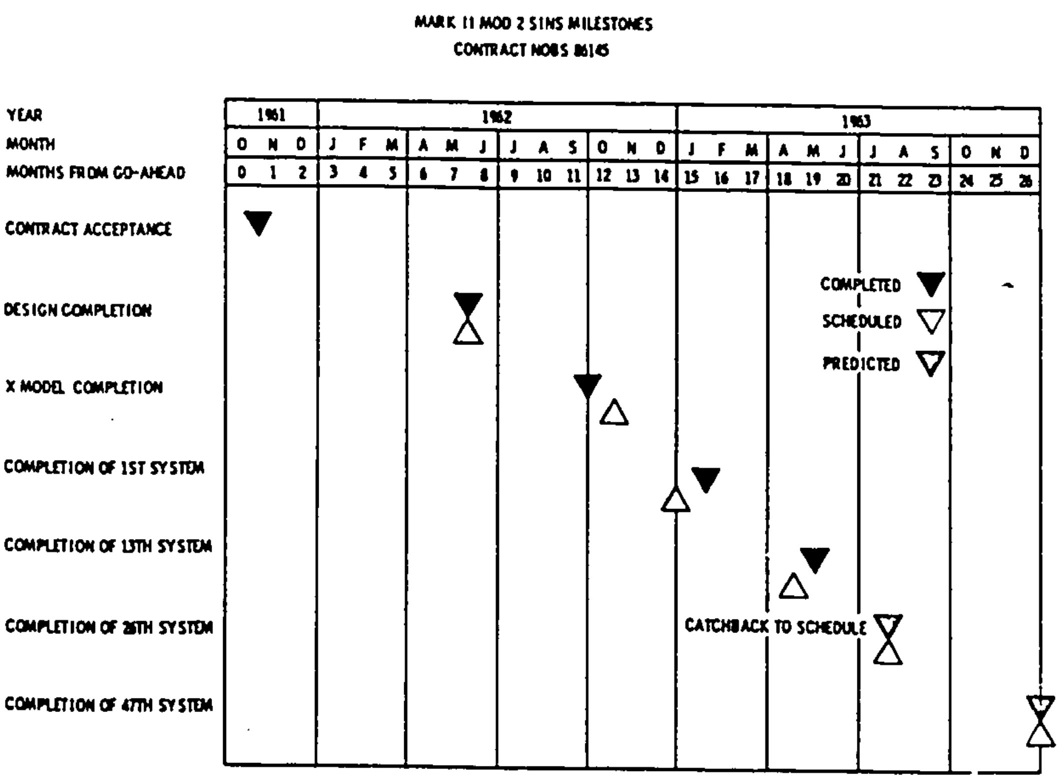


Figure 6

"Figure 7 shows the contracted schedule and actual completion schedule of the X model and subsequent units. The X's mean that the system has not been delivered yet. You can see there has been a five to six week lag on the completion of most units up to this time. After system 13, which is being shipped out now, we hope to be back on schedule and are on a tight schedule now to ship out three more by the end of May.

"We took two systems out of line, one for refurbishing the house model and the other which will become the first of the Mod 2's to have the fourth gyro monitor is scheduled for delivery in December for I believe the 640.

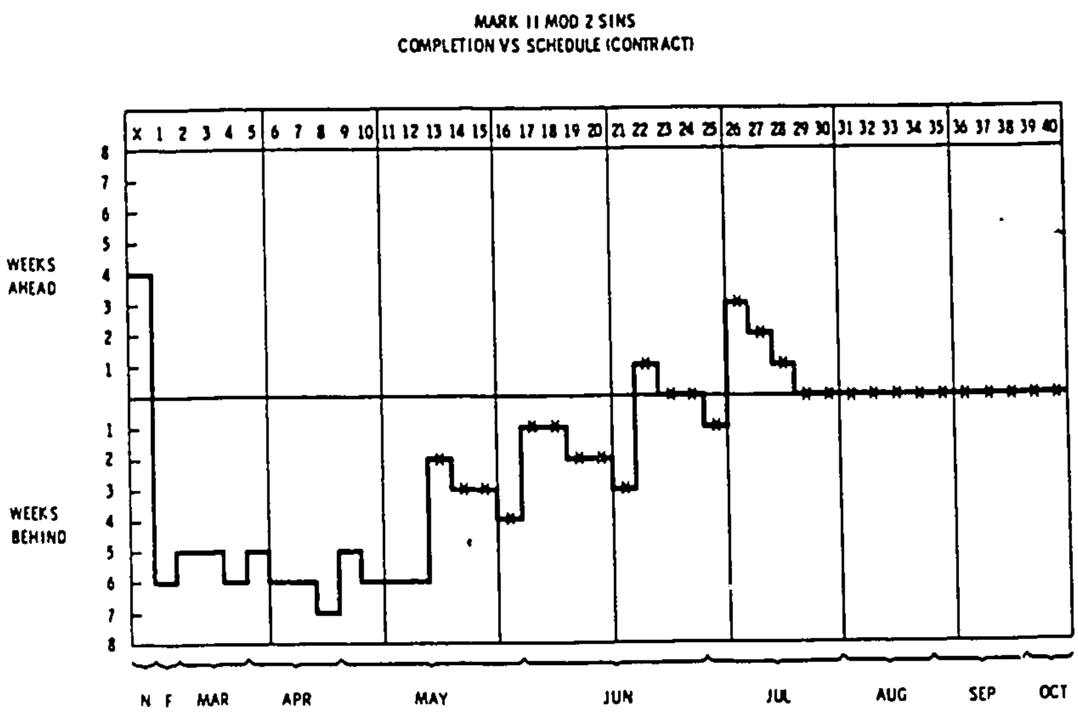


Figure 7

"About the first five Mod 2 systems were delivered with waivers on them and systems 5 to 12 were delivered under a modified FAT which SP agreed to if certain re-examination and research work would be done on problem areas. System 13 will be coming out under FAT procedure specifications which are some of the most stringent for inertial equipment.

"This system has a capability of continuous rotation about azimuth, and with proper programming in the computer, one can rotate about azimuth from the conventional angle we referred to as Alpha Angle and rotation around that axis we refer to as an Alpha Dot procedure. So you have capability in a single system to take on gimbal rotation to allow calibration of all the gyros at time of fix. The procedure in the FAT is to gyro-compass for an hour, run it for ten hours and then go through the fixing scheme, an Alpha Dot rotation, eight more hours of calibration and then a fix. The 30-hour performance run is begun, starting with a 2.5-hour Alpha Dot rotation; another Alpha Dot procedure occurs halfway through the run. When this procedure is used, it is necessary that the instruments be mounted with extreme accuracy.

"Figure 8 shows the first 15 hours of a 30-hour run that did not require the Alpha Dot rotation at the start. This took place in December. Requirements were 0.7 nautical mile RMS for the 30 hours in longitude, 0.63 in latitude and 27 seconds in azimuth.

"Figure 9 shows the delivery run. The system was delivered before the fix, and you can see the effect on it of the rotation and the fact that it had not been fixed. But the system had met specifications when it was delivered.

"Figure 10 shows test run results of System 3, with both the Alpha Dot and Alpha Angle. Then, following our agreement with SP to do further research on problem areas, we ran a test on System 13, as shown in figure 11. The system met specification except for a cockpit error at the end of the run which discontinued the test.

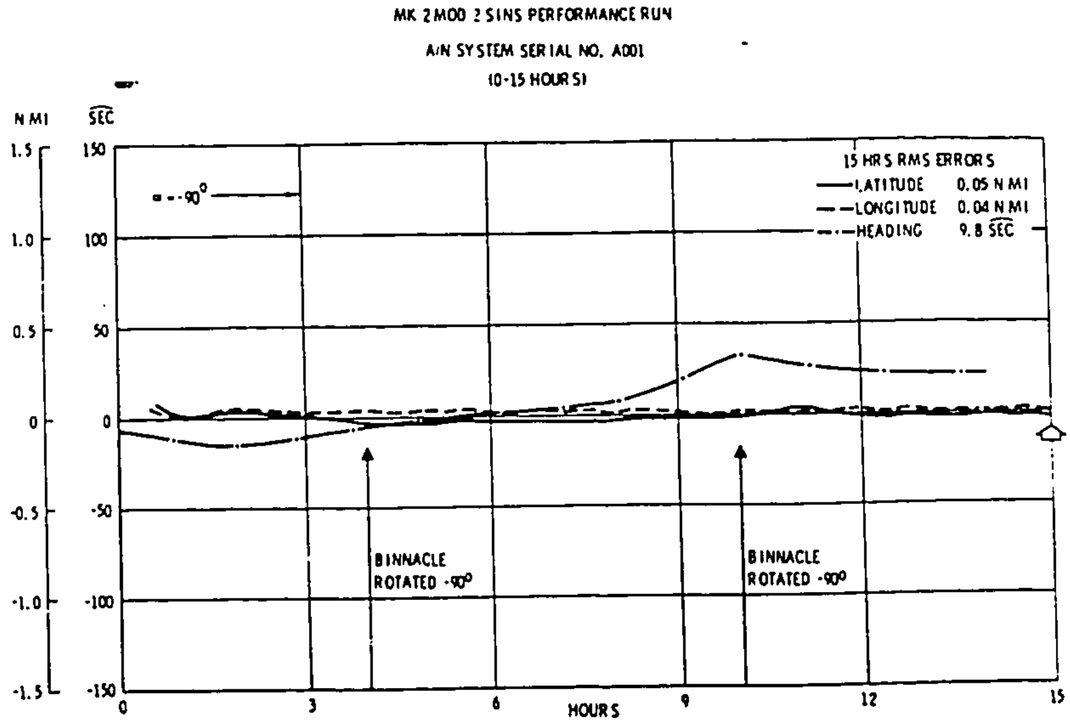


Figure 8

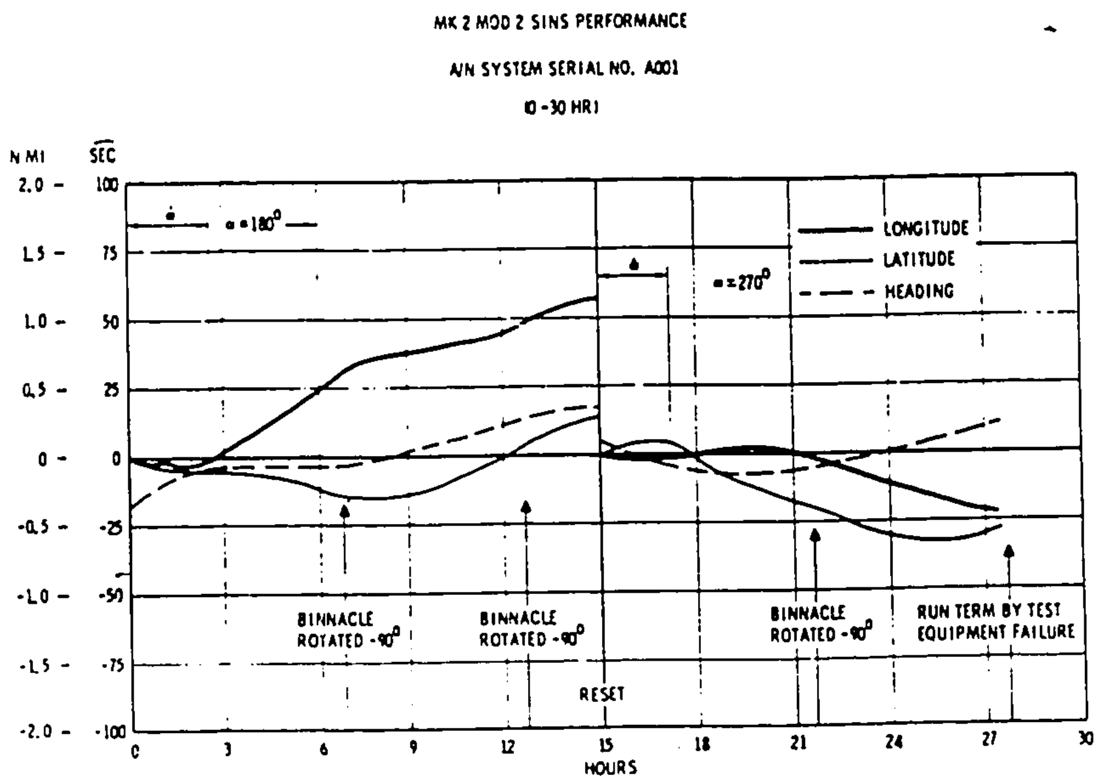


Figure 9

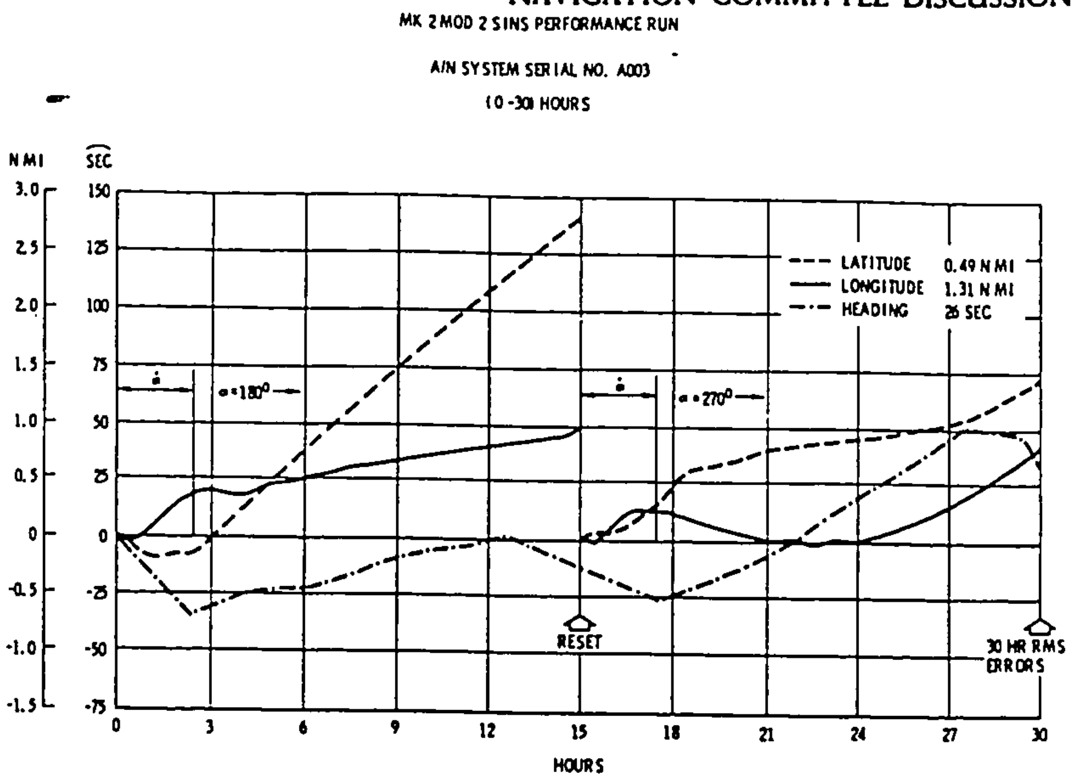


Figure 10

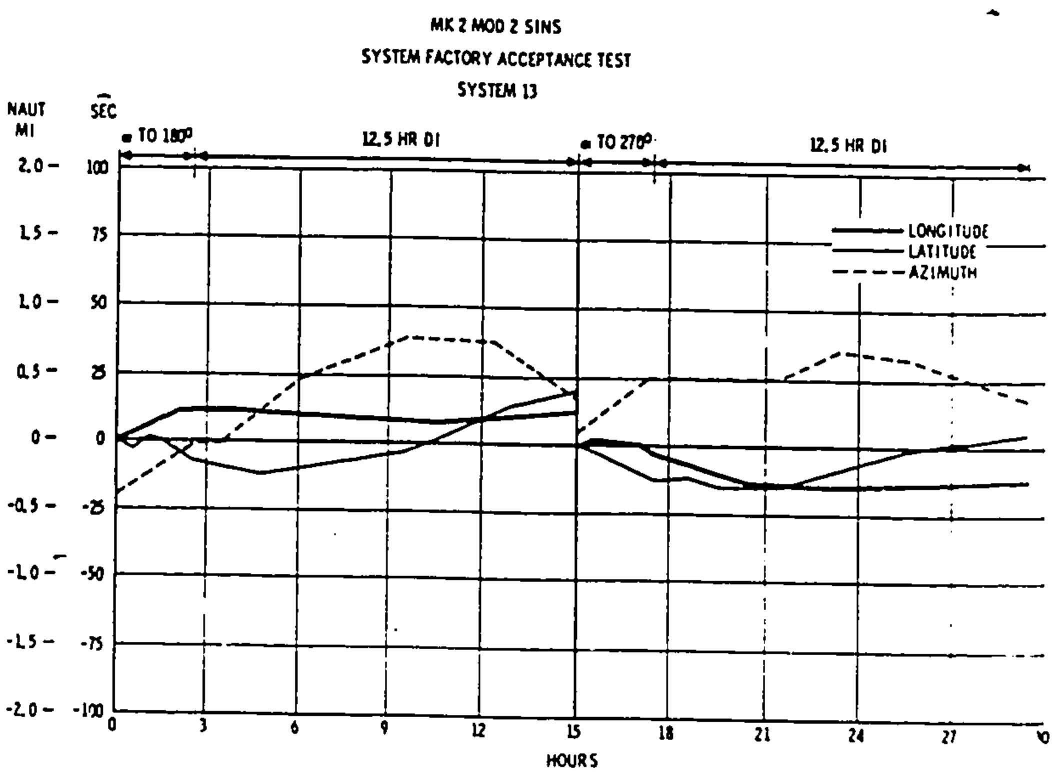


Figure 11

"On about March 11, System 1 was installed on the USS COMPASS ISLAND and our first sea run began on April 1. Figure 12 shows the first four days of the trip. During the first three days a computer programming problem was exposed, but this had been worked out by the fourth day. Figure 13 shows the subsequent days of the run, ending with the ship's arrival in New York indicated by the wiggling lines at the end of the graph. These always appear, since coming into port you are down to low incidence of the LORAN C beam and the accuracy is not good. There was an area off Bermuda where the systems were operated for a period of time in the vicinity of a substantial gravity anomaly which caused drift-off in one direction. Concerning the note on the figure indicating a LORAN C offset, I do not know if this is a known conclusion or a general conclusion. I believe that all systems showed movement off of about half a minute and I am told that the ship's log coming from LORAN data also showed the same kind of shift.

"Figure 14 shows, in plan form, our second trip, with heading on the various legs generally about eight hours, and figures 15, 16 and 17 chart the results of this trip. As you can see in figure 16, we experienced gyro bottom which is a condition where the gyro excursion within its pick-offs goes beyond a certain limit and we have to go back and realign. We realigned and reset from information taken during this period and during the cruise back to New York.

"When the gyro bottoms, realignment is accomplished by going through a gyro-compass operation against the ship's velocity information and then through a position reset which settles the system down to an accuracy that is commensurate with the gyro biases and the quality of information in the reset. There are a number of modes in which you can operate with this system -- standby, align, straight inertial, Doppler inertial, and so on. The computer automatically gets to the mode selected through a proper sequence.

"I would like to mention that the resets have been substantially longer than 15 hours and in many instances around the 30-hour objective

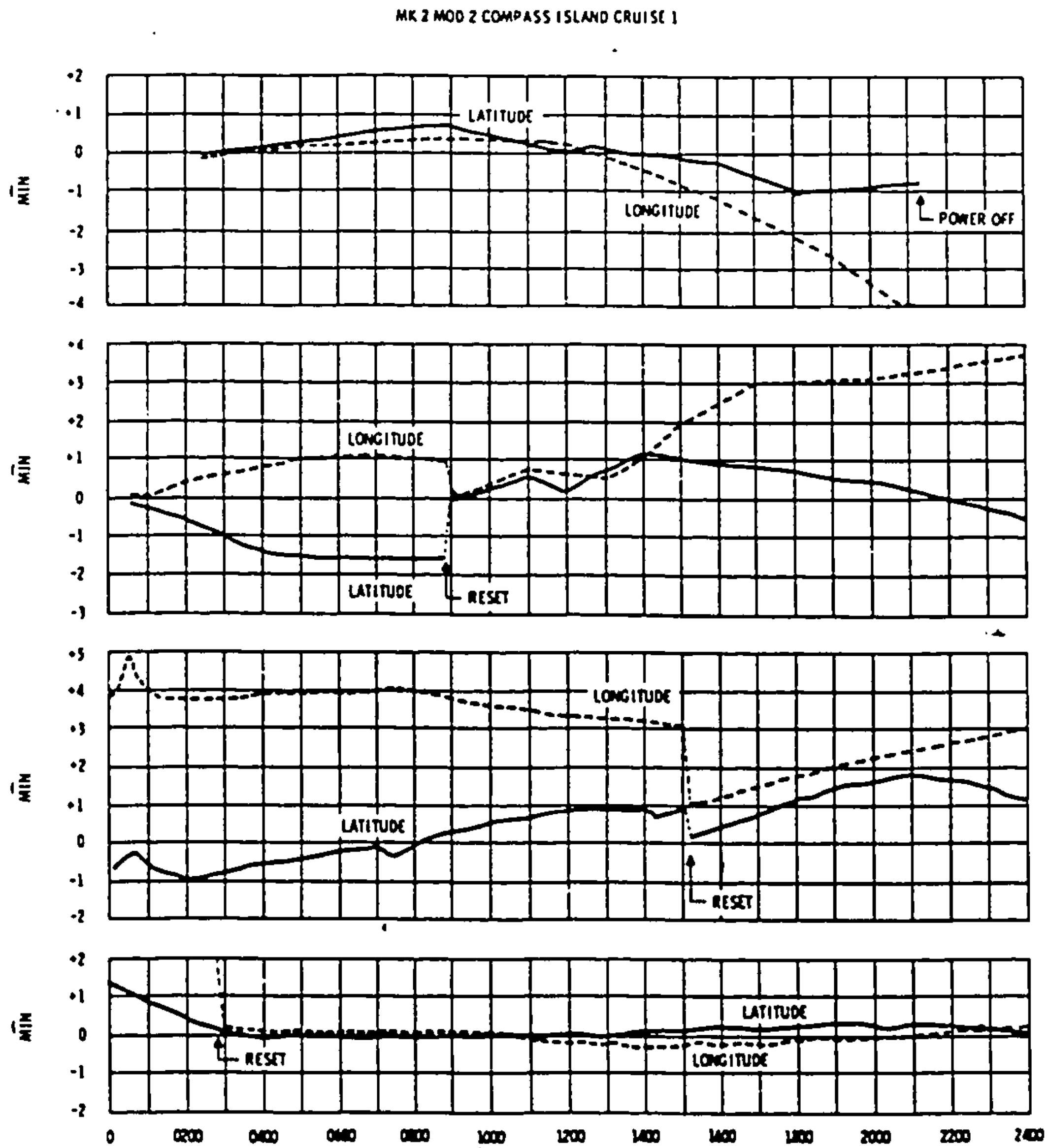

MK 2 MOD 2 COMPASS ISLAND CRUISE 1
MIN
LATITUDE
LONGITUDE
POWER OFF
RESET
0
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400

Figure 12

we want to see. The performance we are trying to achieve is around 0.75 nautical mile in each axis. Of course we do not have a direct measurement of azimuth in this instance.

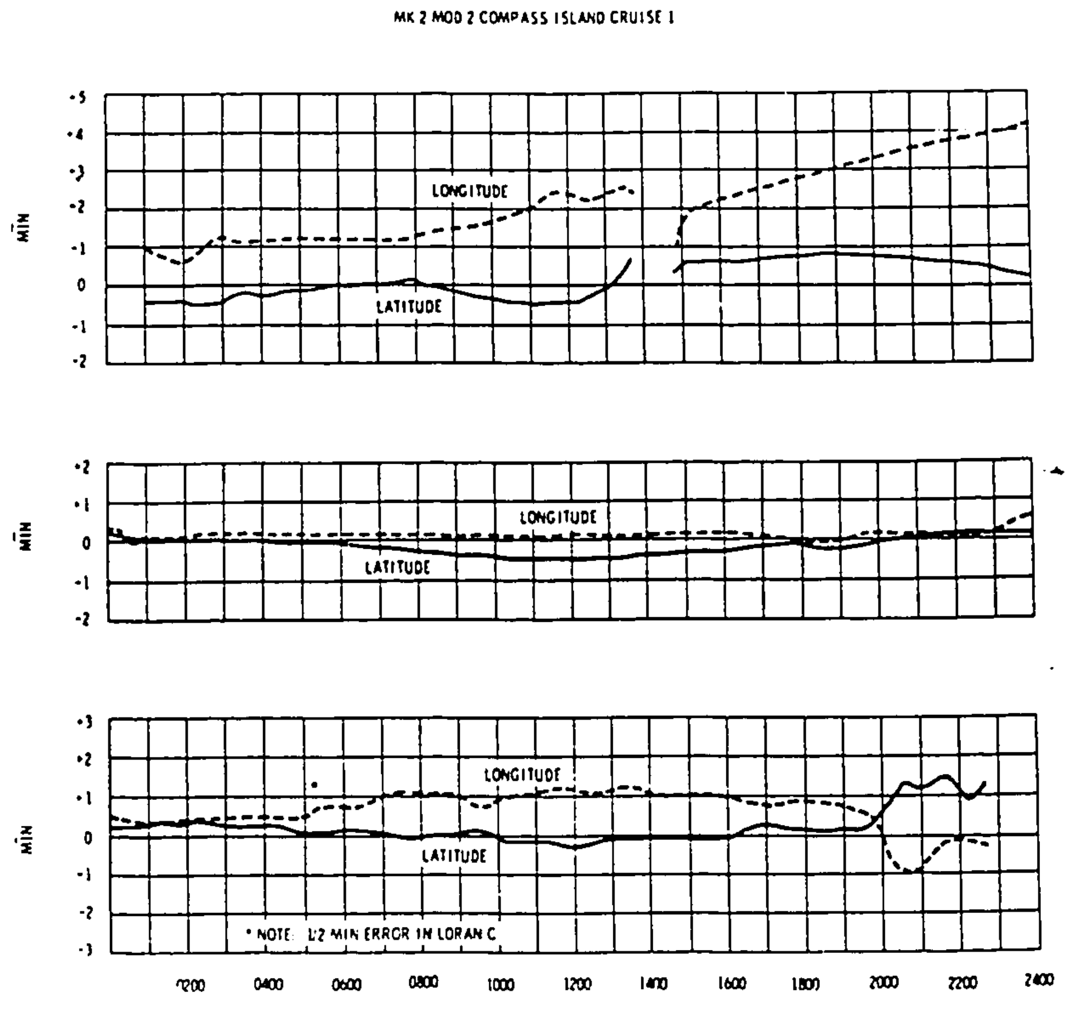


Figure 13

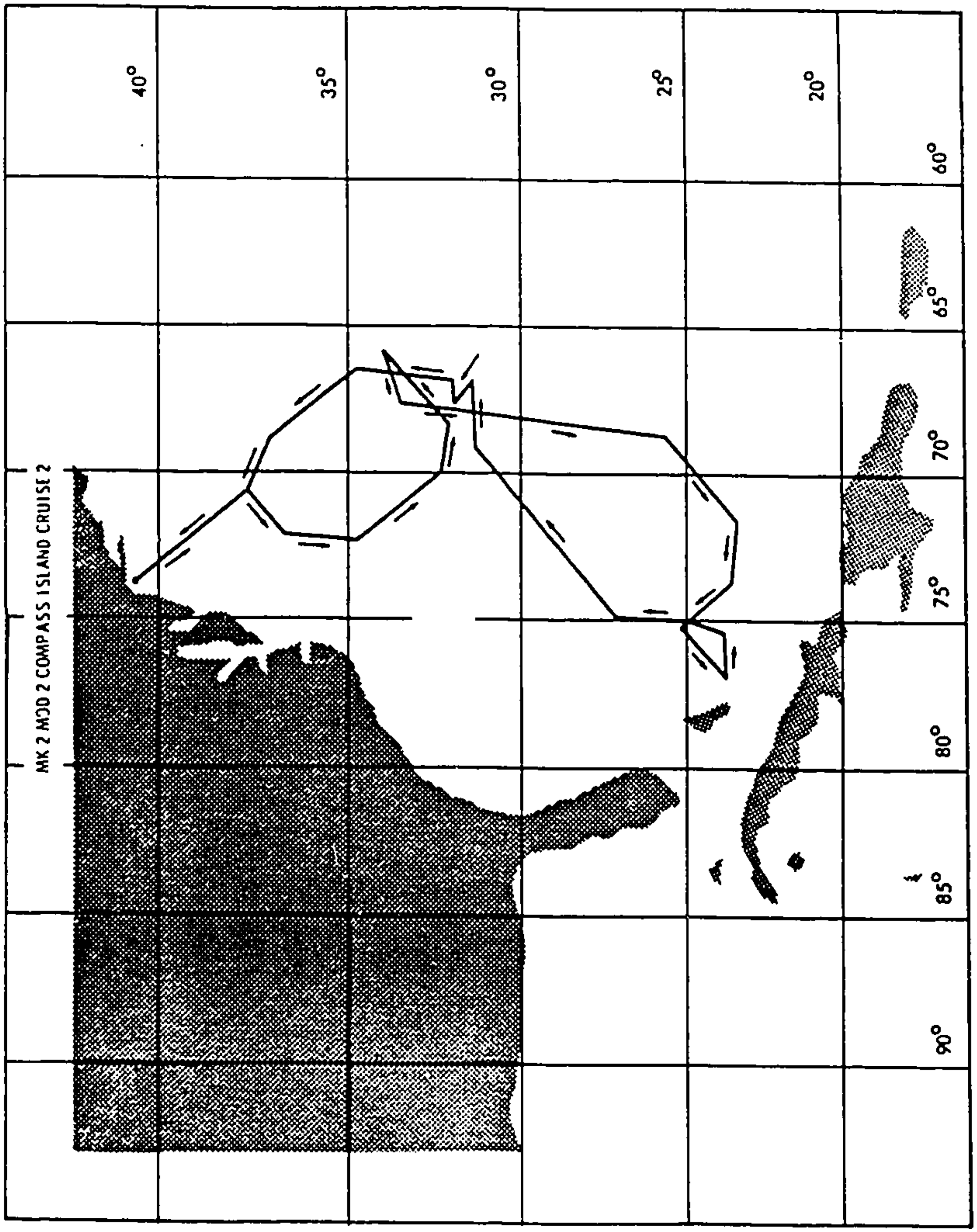

MK 2 MOD 2 COMPASS ISLAND CRUISE 2
40°
35°
30°
25°
20°
60°
65°
70°
75°
80°
85°
90°

Figure 14

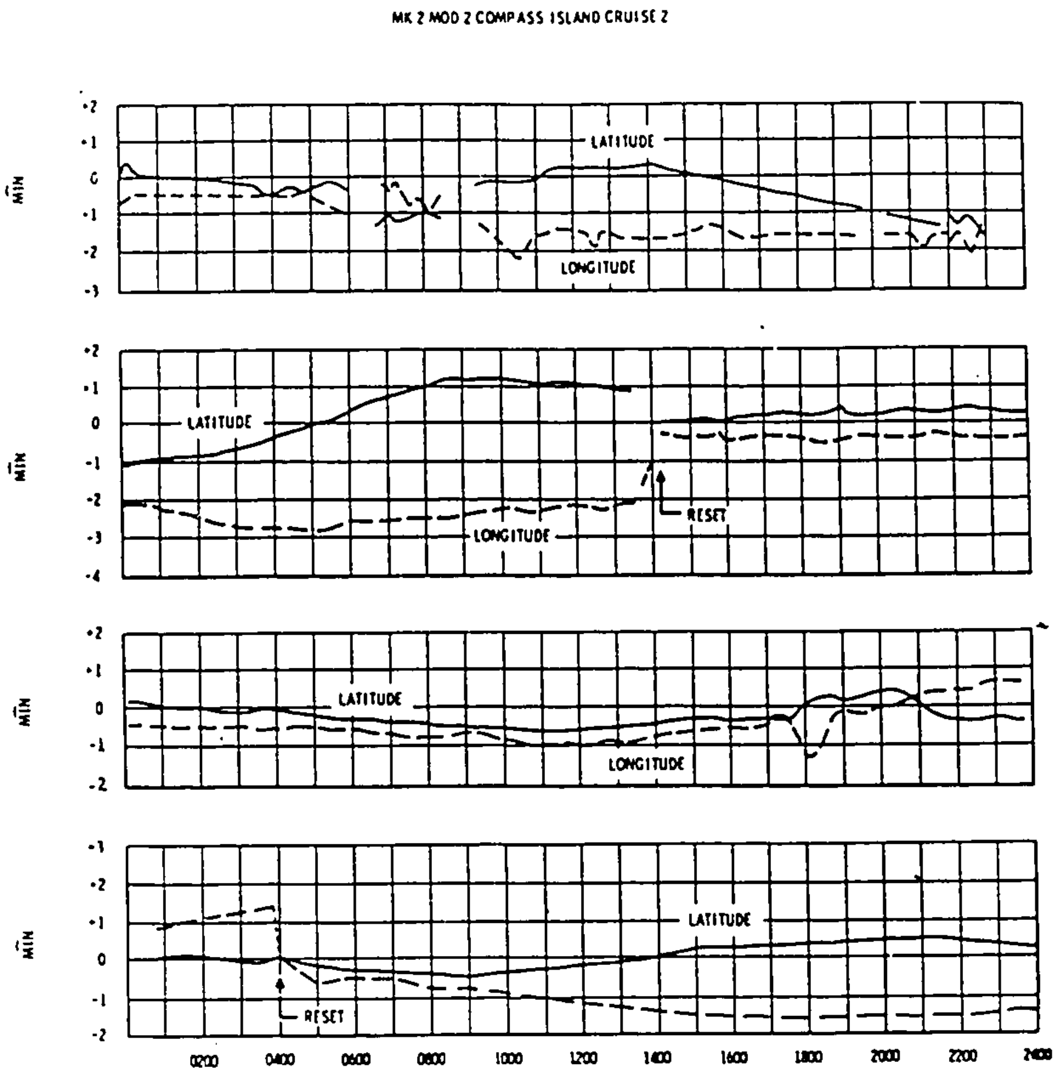

MK 2 MOD 2 COMPASS ISLAND CRUISE 2
MIN
LATITUDE
LONGITUDE
RESET
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400

Figure 15

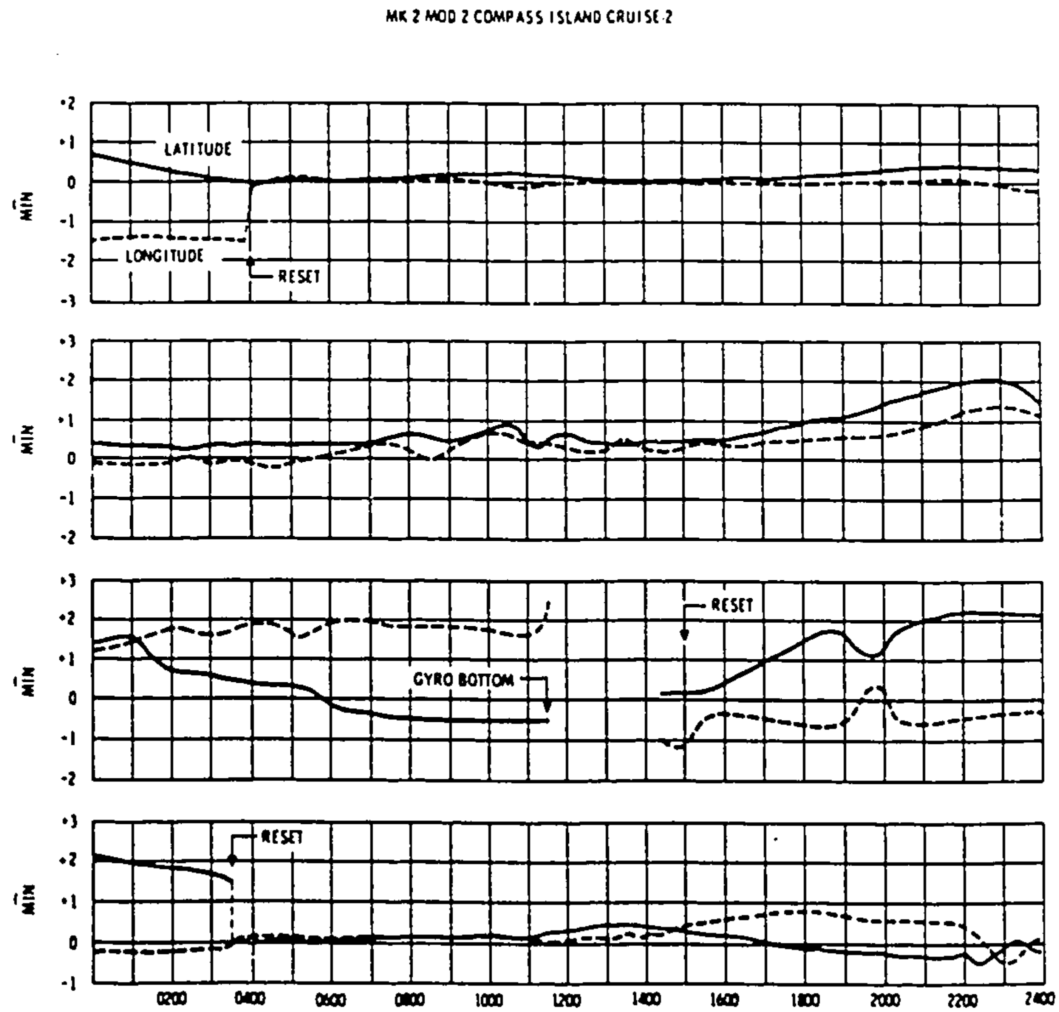


Figure 16

5050

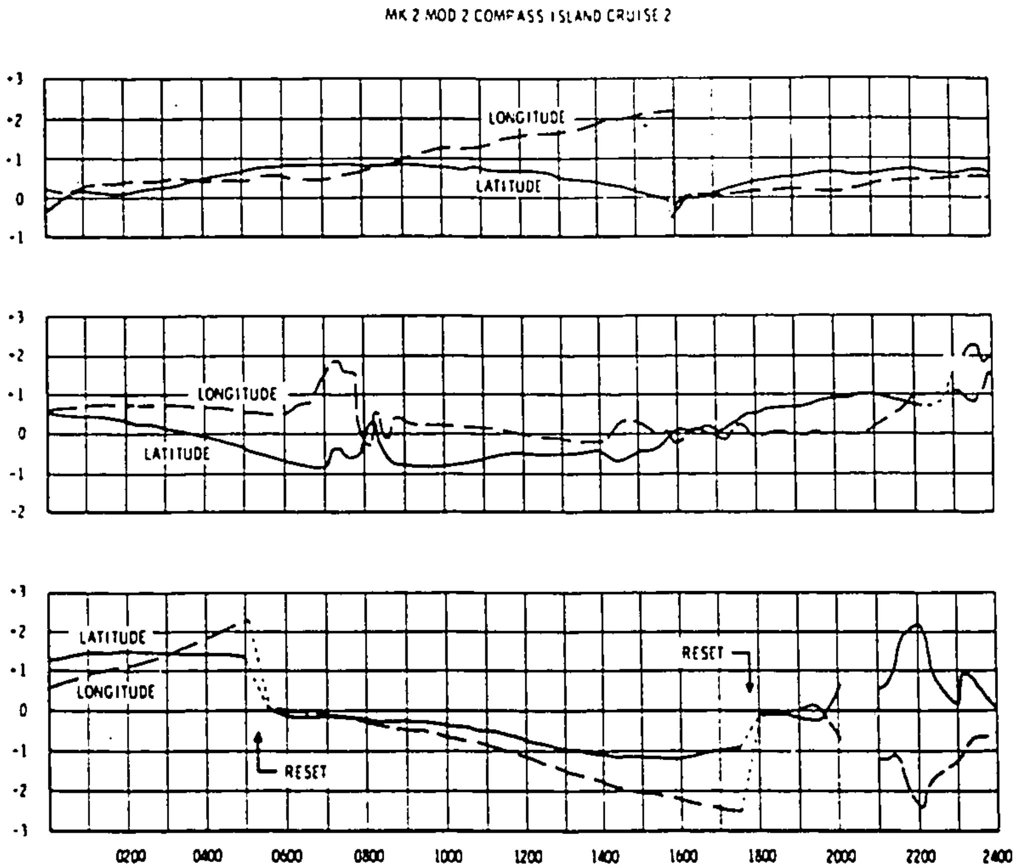


Figure 17

"The system operated continuously during these runs except for about three hours or so after that gyro bottoming. I believe I am correct in saying that since its debugging in the first trip, and it is now on its third, it has not had a failure. The house model is down for refurbishing now after a little under 2700 hours; the computer had operated about 2400 hours. Neither had failed during that period of in-plant testing.

NAVIGATION COMMITTEE DISCUSSION

Following Mr. Eyestone's presentation a five-minute film was shown on the production operation of the Mark 2 Mod 2. At the end of the film Mr. Chadwick asked whether the Alpha Dot procedure was to be used on the USS COMPASS ISLAND.

"On the present cruise, yes," replied Mr. Eyestone. "We did not have a program before. In addition to changing the orientation of the housing, the Alpha Dot of course changes the angle relative to the earth's rotation."

"In connection with the USS COMPASS ISLAND, you mentioned that at the end of the run there was a LORAN C error. Is this a significant part of the total error data?" asked Dr. Mechlin.

"With the inertial navigator," replied Mr. Cestone, "the accuracy for the LORAN C is well within 500 feet regardless of where we operate within the LORAN C net. We use the information from the three navigators in addition to the LORAN C to compile the smooth sea data, and any systematic error in the LORAN C would show up in the navigator's data."

"In other words," summed up Admiral Smith, "the end of the run error accounts for 10 to 20 per cent of the total error."

"When you are down there about a quarter of a minute, I think you may verge on getting a little LORAN C, but generally it is not much," said Mr. Chadwick.

"I think it is interesting to note," said Mr. Eyestone, "that we have a fix accuracy within a 0.10 nautical mile which is the same as introducing 0.00005 degree per hour error into the system over a 24-hour period. So, that accuracy is down scrapping with the accuracy already there which is 0.005 degree per hour. Of course here you are interested in whether it is over a long period of time and the fourth gyro on the system will allow periodic calibration of the instruments, assuming their stability is reasonably long relative to that calibration process."

"The difference in the USS COMPASS ISLAND," said Mr. Chadwick "is that having LORAN C all the time, you can do this calibration."

"Yes," replied Mr. Eyestone, "the LORAN C provides instrumentation too."

"You mentioned difficulty with operation in the vicinity of this gravity anomaly. I never heard this mentioned as an operational consideration. Should it be?" asked Dr. Mechlin.

"If you do not have any other fixing method," replied Mr. Eyestone, "and you move into an area where there is an anomaly, the system is going to adjust itself relative to local g vector. You will not be able to tell whether you moved the ship over a minute or whether the g vector moved over a minute."

"What about the Middle Atlantic Ridge, do you cross there?" asked Dr. Mechlin.

"The problem here is that we are not transiting. If you transit, the effect of the anomaly over the system is very small and you just go through it, but in the case we are talking about we stayed in the area for an hour or more and you can actually see the effect of the anomaly on the system," said Mr. Cestone.

"If you parallel the Atlantic Ridge," said Captain Gooding, "you could expect problems. If you crossed it, it would not bother you."

"Of course," said Mr. Eyestone, "if you are taking fixes at the same time, you could push it out. If you are in an area any length of time that has an anomaly in it, you will see it driven into the system and you will be able to reset the svstem."

"You can settle the system," added Mr. Chadwick, "but the anomaly in the vertical will remain."

"In terms of the longer range development possibilities," continued Dr. Barrow, "star fixes appear to be something that just might disappear from the system."

"This could be," said Captain Gooding. "The accuracy of the periscope for position reference is not good and it is not too widely used. It is principally used as an azimuth fix. We do not trust star fixes for more than 0.3 of a mile."

"It would be difficult to use the information from the present Type 11 to come up with the numbers Mr. Eyestone has presented today," said Mr. Cestone. "The radiometric star tracker would be more useful."

As discussion ended, Admiral Smith called on Dr. Craven for the Systems Appraisal Committee Report.

SYSTEMS APPRAISAL COMMITTEE DISCUSSION

"The Committee's report constitutes a different approach," began Dr. Craven, "to the old and much discussed problem of near-surface operations.

"I think the operators get our first attention, and for this context, we can consider the submarine commander somewhat as a machine and then consider what we have done as far as this machine is concerned. We have provided the submarine with equipment which interacts with this commanding officer-machine, and to the extent that we have provided equipment for this machine we may also have defined, in part, the way in which the machine will respond. Further, we have conditioned this machine quite intensively through the training that has been given to the commander. And, we have supplied this commander-machine with elaborate instructions about the way in which his equipment will operate, and we have given him a set of operating orders about what he shall do while on patrol.

"So, the way in which this machine is going to act is determined by the way it has been trained and conditioned, by limitations imposed by the nature of the equipment on all sides of him, and by the instructions and orders given. Then this commander-machine is told to act in such a way as to fit all this background together so that he will comply with these operating instructions in accordance with his best judgement.

"The point I want to make is that if we decide he is coming to periscope depth too frequently, we then have the choice of changing equipment, changing the training, changin g instructions about the equipment, or getting somebody else to change the operating instructions. But we are not in a position to question his good judgment. That is a condition that he has and that he is going to have, and there is nothing we can change about it.

"Next, I would like to make another caveat. We tend to think of the submarine as a submersible vehicle. This is not true -- it is a vehicle that operates a scant three ship-lengths below the surface. This is like flying a plane continuously under a bridge and we must think about it that way. To operate in this fashion, they must have highly reliable, rapidly movable control surfaces and the ability to move them five degrees a second to maintain the delicate altitude adjustments between broach and collapse depth. They must rely, at low speeds, on the ability to move large quantities of ballast water to maintain trim and depth control. The continuous availability of nuclear power extends this remarkable achievement into continuous submergence, but the submarine is still essentially a shallow-water vehicle and the constraints which will bring it to the surface are hard to avoid.

"There are nine operational situations identified for and accepted by the Committee in which conditions will bring the submarine near the surface. We need to consider what we can do about each of them.

1. Regardless of the type of operation or need that would call the submarine to the surface, the capabilities of sonar and listening equipment are sufficiently poor, and the possibility of collision is substantial enough, to necessitate a visual observation of the surface. I think we would consider this good judgement -- almost mandatory. This observation in turn requires a reduction of ship speed to six knots or less simply to reduce periscope vibration to an optically acceptable value -- this is a limitation built into the provided equipment that becomes a constraint upon the commander. He needs to operate near the surface; he ought to look around for safety's sake; hence he must slow down.

2. The submarine commander can be lured into near-surface operations for improvement of navigation data. First, he has been instructed to maintain the minimum CEP at all

times as long as this can be done without jeopardizing the security of the submarine. If he uses the Type 11 periscope to improve position data, then he will be drawn into near-surface operation. If he uses TRANSIT to improve position data, there may be antenna exposure coupled with a temptation to move nearer the surface. Now, here the commander has a set of operating instructions which places upon him the requirement to have his system not merely meet specifications but to do the best that he can at all times. The net effect of this requirement is to increase the number of his attempts to use all the references that are available to him. He has the Type 11. If he feels he can get a Type 11 shot and if he feels he can improve his CEP by doing so, his orders then tend to cause this commander machine to move up and take that star sight. Since he moves up, these other orders about maintaining invulnerability will cause him to make full use of his sensors. Thus, the tendency of the commander, in terms of all these operating instructions and equipments we have given him, will be to move up nearer the surface.

3. The submarine commander will need to move towards near-surface operation to verify his sonar contacts. The Committee regards this as one of the most difficult requirements. It is an unfortunate truth that current sonar and listening gear are not able to classify contacts readily and are often quite unable to differentiate between a snorkelling submarine and a trawler or small diesel-powered surface ship, as the sonic signatures of these vessels are quite similar. Because the submarine will make one evasive tactic in dealing with a surface ship and quite a different evasive tactic in dealing with a submarine, this differentiation is quite important. Visual observation is needed ultimately to determine what the contact is. Obviously, if nothing is visible on the surface, the contact is a submarine.

In some operating areas, the possibility of a surface contact is almost unity, and the importance of broaching in this case is not to be measured in terms of a probability that there is a ship operating in that area of the ocean. There is a ship somewhere close at hand. Here, we have the situation between the evader and the thing to be evaded where the interaction is such that the submarine may well make moves that he should not make, and breaking the surface for visual observation may be a bad move.

Admittedly the submarine should not break surface. But if we are going to relieve him of the need to do this then we must give him some means of classifying his sonar contacts so that he will not need to surface, or give him instructions for evasive maneuvers that will be effective whether the contact is a submarine or a trawler. We must resolve this problem for him or give him the means to resolve it with good judgement.

4. A submarine may need to operate near the surface in order to maintain communications radio reception. We have already seen failures in the towed buoy and floating wire antennas. If both these casualties occurred in one patrol, the submarine would have to surface to maintain communication reception. We feel that this is something with a certain probability of occurrence.

5. Also possible, although admittedly rare, would be the necessity of surfacing because of a failure in the atmosphere control system, a fire in the boat, ventilation failures, or a failure in the reactor.

6. The submarine would become a conventional diesel-operated submarine should the reactor fail. Here, the submarine would be faced with the frequent need to

snorkel and recharge the batteries because of the very high current requirement of the SSB(N). I think it is unlikely that a submarine would return from the patrol before the last day unless there was no chance at all that the casualty could be repaired.

7. Though we tend to overlook it, there is a definite possibility that a submarine would operate near the surface for radio transmission. In peacetime, we overlook any need to transmit and find no problems in keeping radio silence. However, as the deterrent is challenged, or as we enter into a crisis in which our deterrent is challenged, we can envision situations wherein radio transmission might be a vital action in maintaining our own security. If a submarine were late in returning from patrol, it is almost inconceivable that attempts would not be made to locate it or verify its existence. In this circumstance, transmission from the SSB(N) would be a mandatory part of verifying how much National Deterrent is on station. This may be a rare event, but its probability will be highest at those times when the National Deterrent is being challenged.

8. The submarine will find that operation near the surface or even on the surface may be necessary if a vigorous attempt to track and trail the submarine is being made by the enemy. The submarine, under these conditions, will take recourse to surveillance or evasion by utilizing every escape potential which the ocean has for him at that time -- and near-surface operation may be his safest way out if the thermal construction of the water favors it.

9. Finally, a submarine may surface or operate near the surface to make oceanographic observations. This may not seem an important reason for near-surface operations,

but we must admit that we have not as yet provided the submarines with adequate sensors of the ocean surface conditions. Submarine commanders, dissatisfied with the input from the sensors, may feel that it is necessary to approach the surface for a visual observation of the weather and of the state, magnitude and direction of the sea.

"These nine points then need, I feel, to be considered carefully in the light of three questions which pertain directly to them:

1. Is the need for conducting any of these nine operations in a high sea state sufficiently great to warrant substantial design changes?

2. Can an adequate solution to these problems be obtained by some modification which will permit higher speed operation in the near-surface areas?

3. Can these operations be performed on the surface in a high sea state without compromising the security of the submarine?

"In reference to the first question, we have noted that during the worst period of the year, sea states greater than 5 are encountered only during 10–15 per cent of the time. The ability of the present system to hover in such seas must be regarded as marginal.

"We should also note that there is a great difference among the conceptions of a Sea State 5 and accordingly a considerable difference in the force and energy of these conceptions. What can be called a Low Sea State 5 may have a suction force at 60 feet of 8000 pounds while a High Sea State 5 will have a suction force of 20000 pounds at the same depth. What we are really describing here is a spectrum and the swell components present in it. Thus, we could have two spectra with the same spectral energy in them and we will find that one is hard to hover in while the other is not. And it is my understanding that we do get markedly different spectral contents in the seas in our operational areas.

"We can conclude that there will be a certain number of days each year when hovering will be marginal at best in the Sea State 5. I think we also can conclude that there will be a certain number of days during which the submarine will be unable to operate at periscope depth without broaching. During these periods, the ability to meet the nine operational situations and to satisfy them will be beyond the ability of the submarine commander.

"Regarding the higher speed, the Committee's consideration here is more with detectability than with submergence. Increased speed means increased detectability under most conditions, and when we consider the interaction between the submarine and a surface, we must also consider that the ranges are short and that visual observation becomes more significant. As an aside here, I think we ought to consider that the deterrent effectiveness of our system will be substantially weakened if our submarines are photographed frequently, or if their presence or position can be announced by the Russians too frequently. While these events will not affect the military significance of the submarines, it will definitely tend to reduce public confidence in the system.

"Even when the submarine cannot itself be seen, it can be detected visually when it operates at high speeds in a near-surface condition by the disturbance visible on the water surface. This, of course, is a hydraulic phenomenon wherein the flow conditions produced by the fast moving submarine cause changes in the fluid flow situation that are intolerable in terms of the potential flow. This occasions a "hydraulic jump" with the creation of white water and other clearly visible changes in the ocean surface. Thus we must observe care, because the submarine could be detectable from the surface even though none of the metal is exposed.

"The third point is about the possibility of surface operations under conditions which would not compromise the submarine's security. In three of the nine situations, we would say that the submarine may well have to operate on the surface and that there will be times when he will be visible through surface disturbance if not through exposure.

"In conclusion, the Committee feels that as a result of the limitations existing in the hardware and equipment provided for surveillance, environmental sensing, communication, and navigation there will continue to be demands upon the submarine commander which will, in his best judgement, require operation at periscope depths during Sea State 5 and possibly 6."

Dr. Craven paused briefly and Mr. Morton asked if the variable span of the commander's decision can be reduced by different instructions. Dr. Craven replied that the best judgement to go to periscope depths relates directly to the equipment, training, and instructions given the commander, and that the presence of other equipment, such as the Type 11, would not materially change this.

Dr. Barrow observed that a navigation system that did not require external data would relieve this situation, but Dr. Craven argued that the submarine, while it might not surface for Type 11 operation, would still be going to the surface for other reasons. Captain Gooding noted that surfacing for Type 11 operation could be postponed for eight hours if surface conditions were rough.

"I think that the only thing more observable in a calm sea," said Dr. Craven in response to a question from Mr. Morton, "is the surface disturbance that can be created by a submarine operating near the surface at a good speed. The lift problem is, of course, more pronounced in a rough sea. The surface disturbance is observable in a rough sea where cresting and breaking of the waves will occur as a result of the shoaling effect of the submarine but these disturbances may not be more observable as they may be masked by the sea. Rough seas do not aid the submarine in near surface operation, particularly when the wave velocity becomes added to the ship's velocity."

"Considering your nine items," observed Dr. Kirchner, "It seems to me that numbers 1, 3 and 8 are quite similar in that they are all subjective and would have us tampering with the commander's judgement. I think that numbers 4, 5 and 6 are the strongest reasons."

"We do not concur," replied Dr. Craven, "for we felt that numbers 1, 3 and 8 were the strongest reasons. I think it is very important in the system that the submarine can make some estimate of its opposition and the extent to which the opposition is trying to disrupt operations. It is important to know whether there are Russian submarines in the area; unless we know about them, we certainly will not know with what intensity we should develop defensive techniques nor what the imminence of future dangers might be. These three belong in environmental surveillance, where the submarine studies its immediate environment to learn whether there are impending dangers, threats, or any concerted efforts being made to train or track the submarine. These things are important. If we were to try to convince him that he did not need to know exactly what the sonar contacts were, I would think it would require a mighty good operations study to prove the point."

"One thing I do not understand," said Dr. Barrow, "is our willingness to give a skipper completely free choice to do things that are manifestly not in his best interests."

"Who has demonstrated that they are not in his best interests?" asked Dr. Craven. Dr. Barrow replied that if the question could be settled, it could be turned into some limitation on the submarine's free choice.

Mr. Burg observed that the submarine, already in a state of 15-minute readiness, ought to have a continual curiosity about whatever might be on the surface above him.

Mr. Stevenson asked about evasive action, and Dr. Craven explained that evasive action took different forms, depending upon the type of possible attack. "You might wish to seek the thermal layer near the water surface where there is a heavy concentration of noise which would make detection more difficult," continued Dr. Craven, "but you would not want to try this tactic against trawlers or against a MAD sweep and trap operation.

"Presume we are in a submarine which has just made a sonar contact. It is a familiar type and we know that it is either a trawler or a submarine. We want to make evasive maneuvers because either way the contact may well be unfriendly. Against a submarine, we would evade by hitting the near-surface water where our sounds would be obscured, particularly if there is a good sea state working for us. There may be a good chance of broaching, but even so we would elect this evasion. If the contact is a trawler, we wish to stay as far from the surface as we can, so we would go deep and get out.

"Contacts are made by sonar, and by hearing the contact's machinery sounds we can make some attempts to classify him. Certainly we can hear him before he can see us; we cannot be sure about whether he hears us."

In a brief discussion, members settled the question of visible periscope range as being seven to eight thousand yards.

"The submarine is not looking for a fight, however?" said Dr. Kirchner.

"No, he definitely does not want a fight," replied Dr. Craven, "but the best way to avoid a fight may not always be turning tail and running. By hitting the deep water and bolting at high speed you may announce your presence loudly to an enemy submarine who would possibly not hear you at all if you chose to creep away slowly in a noisy thermal layer."

With questions about sonar range, Captain Pugh explained that the FBM submarines were almost totally deaf, as far as sonar acquisition went, within 20 degrees off the stern; the broadside ranges were in excess of periscope range. Dr. Craven added that this was still another reason for taking a look around visually, even though there were no contacts on sonar.

"Sometimes you may just want to shut down to silence," said Dr. Mechlin, "and spend your time listening. Sometimes so might the other ship. This is a favored mode of hunting in this business."

Mr. Chadwick asked about the planes and self-noise, and Dr. Craven replied that the quieting people were just now looking into transients, which have become known as the most reliable means of making an initial detection; the transients create some form of sharp spike relative to action from the submarine, such as plane movement, garbage eject, or similar items.

"Returning to the report," continued Dr. Craven. "two recommendations have resulted. One of them is presently leading to BuShip's preparation of a NavOp on the procedures for operating near the surface."

"This is not quite true," interrupted Commander Jackson. "I would like to make a proposal that someone write this NavOp. Right now it is sitting in the library. It needs to be done but BuShips has not as yet started on it. I want to recommend that it be done soon, and I think that Special Projects is in the position to sponsor this NavOp with BuShips' assistance."

"Well, let's just say that one of our recommendations is leading to BuShips' completion of the preparation of the NavOp," said Dr. Craven. "The other recommendation is that we pursue theoretical, experimental, and operational research to define the existing relationships between near-surface operations, ship speed, sea state and detectability. We need this kind of information badly. We think that the NavOp would be a useful compilation of everything that we presently know about near-surface operations.

"In any event, we need improvements in near-surface performance. The Bureau of Ships has suggested these seven possible improvements:

1. Extension of masts and sail to increase the depth of the hull below the free surface.

2. Stiffening and fairing of periscopes to increase the speed at which these devices are still effective.

3. Improved instrumentation for monitoring the depth-keeping process.

4. Relocation of control surfaces to minimize surface emergence, slamming, and other near-surface phenomena.

5. Improvement of automatic depth control systems.

6. Improvement of operating technique.

7. Development of a hover jet.

"The Committee felt that the most promising of these, with respect to improvement per dollar of investment, is in the sophistication of the control loop in the present system. At present, the 608-Class employs a relatively unsophisticated system with pneumatic computer which generates a control signal proportional to a weighted sum of the measured depth and its first and second time derivatives. The ordered changes in ballast are non-linear in that a two-inch or eight-inch valve is opened for flood or blow and that a limit on the magnitude of the acceleration term has been imposed in the computer so that when certain magnitudes appear, they are just levelled off in the equation. Modifications in coefficients and acceleration limits have already been made with demonstrable improvements in this system. However, there are two parallel, independent studies -- one by the Vitro Corporation and one by Oceanics -- which indicate that much greater gains can be achieved.

"The subject now is hovering, but the same technique can be used at slow speed for periscope depth operation. I will discuss the Vitro studies which look at the problem of hovering and then ask, 'Can we effectively hover at periscope depth?' They are the same problem but existing at different depths. When you hover you move with a certain forward velocity and when you operate at periscope depth, you move with a certain forward velocity large enough so that you can tie the control surfaces into your control loop. When the submarine is at hovering depth, it does have sufficient forward velocity to have the forward surfaces effective in a control loop. The Vitro simulation showed that use of the lead-lag control loop, unequal flood and blow rates and a filter on depth measurement with the appropriate time constant will result in a Neumann Sea State 5 performance for which the simulation indicated that the ship will maintain the requisite plus or minus 10 feet 99 per cent of the time, with average blowing and flooding rates of only 26 pounds per second. A similar simulation for the present system indicates that you can obtain the requisite performance for only 87 per cent of the time with average blowing and flood rates of 47 pounds per second.

"I think it's important to know whether we think the simulation is good or poor or meaningful in terms of actual full-scale results. In this simulation, they have taken a sea spectrum, computed the suction force, attenuated the sea spectrum down to the approximate depth, and finally used a linearization for various indications about that depth. It is an extremely difficult job to get the attenuated spectrum for each depth because each component of the spectrum attenuates differently. They generate random seas from these spectra which are put in the simulator to meet these random forces. They simulate the control loop in this system and they run it for a long period of time to observe what happens; i.e., for what per cent of the time various depths are exceeded or not exceeded. The results are in the ballpark of our observable experience and we feel that the variations are significant even though the absolute figures may not be too meaningful; if they show an improvement in their system, we feel that it will show an improvement in the actual system.

"The Oceanics study is a more sophisticated study in that the spectrum is properly attenuated with depth. Their conclusions are the same: there are substantial gains that can be achieved by utilizing a more sophisticated control loop.

"Adding to the sophisticated control loop are the possible gains that might be achieved by the incorporation of a sensing system which estimates the suction force from the local velocity over the ship -- and this is a study which is also under way.

"Regarding Admiral Smith's question, we feel that extension of hovering techniques to the periscope depth has not yet been extensively studied but preliminary studies indicate that similar improvements can be made. Relative to this, the Navy has very successful experience with incidence control hydrofoil craft operating with a control loop which senses the height of the free surface at the bow of the ship -- which is only a short distance from the control surfaces — and adjusts the angle of attack of the hydrofoils accordingly. These craft have been made to operate in rather heavy seas and have been quite successful in following long period waves which is what you really want to do. You do not want to stand still with respect to the inertial reference, but to follow long period waves with a remarkable degree of success. As a matter of fact these things have been able to follow short period waves, giving a very exciting and rough ride. The point here is that with a sophisticated control loop with the control surfaces tied into it, the Navy has demonstrated that you can indeed operate quite close to the skin of the surface with substantial forces involved and still resolve this problem. We feel that these techniques have merit -- and by 'these techniques', we really include four -- improving the control loop, (1) as Vitro might recommend, (2) as Oceanics might recommend, (3) as might be recommended with utilization of the ULCER equipment, or (4) as might be recommended for tying the planes into the control loop. We recommend these be pursued vigorously and that a milestone plan also be established which would result in early implementation of the most successful solution. Once the solution is established, the cost of implementation will be relatively small.

"The second group of measures proposed by the Bureau of Ships center around modifications of hydrodynamic hull form and appendages to move the ship down in the water -- for example, control surface location, sail height, periscope height, stern configuration. The Committee feels these techniques promise a low ratio of improvement to dollar expended. This does not mean a low improvement by any means. For example, an increase in 10 feet in submergence would result in an improvement of approximately one half of a sea state. In particular, there is one particular proposal which we understand will probably be implemented for installation of fixed bow fins on an FBM submarine. We feel this should be very carefully reviewed for we had an unhappy experience with similar fins on the USS COMPASS ISLAND and we know that in many sea conditions the fixed planes generate forces which are destabilizing insofar as broaching is concerned."

Commander Jackson pointed out that the bow fins would be able to change the angle of attack and were not fixed as Dr. Craven's remark seemed to imply.

"So I withdraw part of my criticism," said Dr. Craven, "but, unless they tie into a sensing and control loop, you don't know how to adjust the angle of attack."

"Unless you use the manual control," said Commander Jackson, "we will continue to do so here. This, as Dr. Craven has mentioned, is an improvement for several reasons over the existing situation on the 608- and 616-Classes. First and most significantly, it puts the forward control surfaces deeper in the water than they are presently. This will get us away from the sail-plane banging effect. Second, their forward location will control the ship better in pitch than is now possible with the fairwater planes with a definitely longer moment arm. For these two reasons, BuShips is proceding with an evaluation. We do not expect to see a tremendous improvement in the ship controllability, but we are proceeding now with installation of the fixed bow planes on the SSB(N)626 during construction. We will evaluate these planes in the period between delivery and post-shakedown availability, then re-install these planes on the fairwater. After PSA, we will re-evaluate the change in controllability of the submarine but we will not proceed with the general installation of fixed bow planes until we have completed this full-scale evaluation of these forward planes.

"The change is relatively inexpensive, costing on the order of $250,000.00, plus or minus 15 per cent. That's only to make this evaluation -- make the prototype, evaluate and relocate the planes back to the fairwater. We will use the same planes that would eventually wind up on the fairwater. The design will provide for the PSA relocation of the fairwater planes to the fairwater at minimum cost."

In response to question from Dr. Barrow and Mr. Parran, Commander Jackson explained that the planes would be removed from the sail and installed on the forward pedestal. "Based on our experience with the hindsight sonar dome," continued Commander Jackson, "we feel that cavitation is an unlikely problem and that the installation should eliminate the plane banging problem."

Dr. Craven, while apologizing for his reference to unhappy experiences on the USS COMPASS ISLAND, observed that the bow planes may still produce destabilizing forces. "At the control of the submarine," continued Dr. Craven, "they may think they are applying forces in the right direction when the opposite is true. There is a very complex relationship between the forces, particularly the wave phase, upward force and moment. To control this, one will have to do it almost by the seat of the pants, but only after much experience. The sail planes presented a smaller problem because there is very little moment effect because they are rather close to the center of moment."

"There are disadvantages to the forward location," replied Commander Jackson, "and we are doing this to determine where the advantages in the plan will outweigh the disadvantages. We do not have confidence that the benefits will win out, and we are waiting any decision to include this modification on submarines now under construction until after we learn the results of the evaluation."

"We suggest, sir, that the game is not worth the candle," observed Dr. Craven, "and the efforts would be better spent on control loop studies."

"I had intended to await my discussion of control loops," replied Commander Jackson, "but this appears as good a time as any.

"We had a similar problem of moving depth control which we studied extensively in connection with the need for the fast-attack submarines to operate near the surface in surveillance missions. We decided, after a good deal of study at the Model Basin and among ourselves at the Bureau of Ships, that the gains expected from improvement of automatic control systems would not be nearly as large as the gains to be expected from operating at higher speeds or from placing the submarine deeper in the water. This problem was studied independently at DTMB for about six years and they have generated a good deal of know-knowledge in the area. The problem was also studied by Electric Boat Division at our request and has been re-evaluated by them in connection with this POLARIS submarine depth control problem. Sperry has done some very good work in this particular area, as have some other companies whose names I do not recall right now -- possibly Kearfott and perhaps Westinghouse. "In short, we have evaluated the potential to be expected from an automatic control system using control surfaces only and have come to the conclusion that we cannot expect much gain from this approach. We will get some gain. I can agree with you that this particular approach should be followed and that improvements should be made in the automatic control systems installed; but I can not agree that this is the best answer or that it will give the greatest measure of improve ent in control for the lease expenditure of funds."

"I am glad that Commander Jackson and myself have been able to define the area of our disagreement," said Dr. Craven after a short recess for coffee. "To start with, we are not aware of the details of those various Bureau studies that were mentioned. I think it would certainly be a fair characterization of these studies to say that they represent progressive levels of sophistication. There are relatively few in which one takes the deep plunge, saying, 'I am going to apply the full resources of ballasting, control surfaces, independent action between the control surfaces, and all my knowledge of hydrodynamics, and tie these all into control.' I cited the hydrofoil case because this was one in which a very extensive study was made of the control of the hydrofoil contact where the hydrodynamics were thrown in as well as they are known. The hydrodynamics of hydrofoil are not simple, particularly in a following sea. In addition to this, one of the most sophisticated groups -- the MIT Flight Controls Group did the control study for it and the net result was a highly successful operation. There have also been highly successful studies on roll fins which have gone into the problem with the equal sophistication leading to, as we again note, such happy experiences as with the USS COMPASS ISLAND, and other vehicles. I would suggest that each study within its scope might be directly classified as something of limited value for the cost of investment. I also suggest that we are making a value judgement ourselves when we propose a study which says, 'We are going to apply the best that we know about hydrodynamics and control theory and all the available techniques for putting force on the ship. We feel this will result in a surprising gain.' "

"I do not disagree with that statement," replied Commander Jackson. "It is just the order of importance of the things that can be done in a short time frame. The SUBIC project is a good example here, as it is a sophisticated effort to provide a highly sophisticated arrangement of ship control and not merely depth-keeping. I recognize that the advent of hovering tanks, the control methods available for hovering, and the studies on the hover jet have all been quite promising. The two features, peculiar, to SSB(N) submarines as far as their present application is concerned, make me think that our present pessimism about automatic control systems ought to be reconsidered and I agree a hundred per cent with you along the line that you have also suggested."

"To emphasize Dr. Craven's remark here," said Dr. Mechlin, "on the control problem, one approach that can be taken of these control signals would be an ability to discriminate control signals from the noise fields of present control systems. The noise-signal ratio goes from 200 to a 1000 parts of noise to one part of control signal. The fact that studies in filtering techniques can succeed in getting an improvement is an indication of what can be done. If we find another set of control signals without this large noise content, then the gains available would be far greater than any of these studies indicate."

Dr. Barrow observed that the performance of modern aircraft, especially 'hot' planes, exceeds the ability of pilots and that automatic control must be employed; the technologies developed for this purpose can be redefined for use on a submarine where the problems are not basically too different.

"Automatic control fins are nothing new," added Commander Jackson. "The British Navy has been using them for roll stabilization for so long that they have almost forgotten why they originally installed them. We recognize that a lot can be done with control surfaces and that we have already done a good bit with them; they will do a good job about 90 per cent of the time that they are needed.

"The problems of using control fins at periscope depth are greatly simplified when the presently installed control surfaces are used at higher speeds. Their effectiveness varies with the square of the velocity. However kindly we may feel about the value of control surfaces and the ability to use them automatically, we do not feel that the efforts spent on them would compare in the value of the return with efforts spent on providing the ability to operate at higher speeds with the existing control systems. Moving the submarine down ten feet further from the surface seems to be a better method of improving control to our way of thinking.

"The Westinghouse study mentioned by Dr. Craven proposes to do a great deal more than we have thought feasible for the present time. We agree with their efforts here, and within BuShips there are two studies at least that are proceeding along parallel, if not the same, lines. What they intend to do toward improving ship control will take a very long time to accomplish. However, the Westinghouse group has something else of value to offer -- the potential capability of measuring the surface suction force and developing a signal that can be used in an automatic control system. We are definitely in favor of the continuance of this study for that reason alone. Nonetheless, as a result of meetings with Westinghouse I feel that their proposal is somewhat naive, particularly with respect to the time scale and the ultimate capabilities. I wish to caution about being too dependent on this single effort.

"The Vitro proposal I cannot comment on, for I have not seen it."

"The question of the time scale," replied Dr. Craven, "is indeed debatable and we all know the danger of prematurely pushing something. Nonetheless, I think this program has good experience with the concurrency of R&D and production. I think, insofar as these control systems are concerned that we have not seen any program which proposes concurrency. Most programs propose a sequential approach -- first, developing the theory, then checking out with the model, constructing an experimental or prototype installation on a non-FBM and, finally, installation on a FBM."

"Well, evidently there is something missing in this whole thing," said Captain Satterford, "because people have been trying for 18 years to do this control loop and automatic control business. These efforts as far as I know started with the end of the War but no one has achieved what I would call a great deal of success with it. I would like to back up Commander Jackson with my experience with the submarines. The first step, in my opinion, is to move the control surfaces deeper into the water and as far out toward the ends as you can, thus taking advantage of every benefit of the ordinary engineering of the thing. Then we can go into a sophisticated study of the potentialities in this automatic control business."

"I think your experience," answered Dr. Craven, "is in accordance with what has taken place in reality. I do think we can cite several breakthroughs that have occurred in the last year or so, not the least of which is the recognition of the hydrodynamic problems and the recognition of the forces that we are facing. I think this has been one prime difference. Secondly, greater strides have been made in control systems in the past few years than any one particular discipline could be expected to fully tap. I think that they are now more fully available."

"Do not misunderstand me," said Captain Satterford. "I am in favor of anything that will work -- automatic or elsewise. I detected a tendency here earlier not to consider getting the hull down deeper and the planes farther apart. These should be considered as a very important part of any program to improve this periscope depth performance which right now in some of our ships is very poor.

"During World War II, submarine commanders had occasions when they might wish to fire six torpedos from the bow tubes while moving at 2.5 to 2.8 knots in a heavy sea. This is no easy control problem, yet we had considerable confidence that we could do it, and did do it several times. We had the advantage of a long periscope and moment arm in doing it.

"Also, I think the comparative experiences of the SKIPJACK and THRESHER Class submarines attest pretty firmly to the superiority of the SKIPJACK during slow speed, rough sea operation at periscope depth. These two submarine classes are quite similar except for the keel depth when the periscope is exposed."

"I will agree that there is plenty of room for debate," said Dr. Craven, "until the time when studies on the problem are completed. My committee feels that the same degree of improvement will cost much more, particularly in the backfit area, if we follow the lines you suggest."

Captain Satterford asked about the ship control and water transfer. "Basically, what occurs in this," explained Dr. Craven, "is that once you have ballasted out against the average Cummings Force, you are then concerned with the fluctuation. You are particularly concerned with catching the fluctuation early enough so that you are not hauled up by this negative spring. The negative spring means you have a displacement and instead of having a restoring force in this displacement, you have a destabilizing force which is proportional to the displacement.

"The amount of force which you have to generate to overcome a negative spring is a function of the rate at which you can respond. If you respond too rapidly, then you force some displacements artificially which the negative spring picks up and carries away. But if you can spot at the time when you are getting displacements of this kind or changes in this spring force, and you can respond very rapidly in the proper phase and at the proper time, then you can do this.

"Now, the point I tried to make was that we regard the Vitro simulation as real because in the Vitro simulation the water rates used are the same as we use now -- on the order of 60 or 70 pounds per second. In the 608-Class, we can, if needed, move 250 pounds a second. And with that we can, certainly, as everyone will agree, hover sucessfully in that state 4 sea in the 608-Class. The Vitro model concurs on this point. People will agree or disagree depending upon their own estimate of the Sea State 5 as to whether she can or cannot hover in that condition, and so does the Vitro model, as well as predicting the right sort of water that is being used. When you consider the Vitro model and you understand that it is based upon a theoretical study which we regard as quite valid and that it does indeed produce a spectrum and a random distribution; from this, we have a great deal of confidence that the results of this order of magnitude in this direction will be achieved by utilizing some of these controls."

Mr. Parran observed that Dr. Craven was not really disagreeing about the bow planes, but rather about the money they would cost. Dr. Craven disagreed, noting that he was afraid the bow planes would exist in lieu of the automatic controls.

"If you install these bow planes and leave them under manual control," continued Dr. Craven, "the man will not be able to handle the submarine, to keep it from broaching. This is a very complex situation to handle with manual controls when the man cannot really sense the complexities."

"Use of an automatic control system in conjunction with bow planes," observed Dr. Barrow, "to reduce the forces required and make things mechanically easier would result in a fine system."

"Someone has already proposed," continued Dr. Craven, "a shape we could design to make the Bernoulli effect in the bottom of the submarine balance out the Cummings force. If you design a hull that has a banana shape on the bottom, then as the flow goes by in a uniform flow field, you get a higher velocity at the bottom than you do at the top, so you would have the Cummings force pulling you up and the Bernoulli effect pushing you down. In a non-uniform flow field, which is what you have then, you balance out. However, no one is recommending this shape."

"I have an intuitive feeling," said Dr. Barrow, "that if you get a good automatic control system working which will do things much faster than any operator or any captain can do them, you may find that this suction force may become of much less importance. You may find yourself broaching not because you are sucked up but because you force yourself up with vertical moments working about the boat from the wave motion."

"This has been argued," replied Commander Jackson, "in fact, some people with knowledge on the subject say that the depth control of a POLARIS submarine would be enhanced by removing the forward planes. At first this sounds like a terrible idea but if it is true that near the surface these planes are often being operated in the wrong direction, then one might be better off without them. I think you would still be better off to have them and make them operate correctly. While we are becoming very sophisticated in handling hydrofoil craft operating on the surface, I would like to point out that these skills are not always transferable. For example, the aircraft carrier design people made a rather extensive study of the possibility of anticipating what sea condition in the immediate future would affect the ship. They learned that they could not, even with all of the observations possible for an aircraft carrier, judge within a wavelength and a half what would be the effect of succeeding waves on the aircraft carrier."

"I can agree with that," said Dr. Craven, "and similar studies. You cannot do that for a wavelength and a half with the hydrofoil craft either, but the point is that with sufficiently rapid response and rapid control, the hydrofoil craft need only measure for less than a wavelength -- just enough to say, 'Hey, fellows; move it!' Those foils follow fast enough that by the time the crest of a wave has gone from the bow to the foil, the foil is there waiting for it. That is what can be done with a very fast reaction time.

"Finally, then, the next suggestion for development is the hover jet system. The Vitro studies support the DTMB studies as to the efficacy of this system, particularly when combined in a control loop with the existing ballast capabilities. For example, at a keel depth of 72 feet, the shallowest depth Vitro has studied, with 6000 pounds of hover force, an average depth error of one to two feet was maintained in a state 5 sea with a maximum excursion of six feet.

"An additional benefit which may accrue from the use of hover jets is in the control which must be afforded during the transition from the underway condition to the hovering or slow speed condition. This is a problem that we glossed over today, but it is an important one.

"At present, trim and ballast of the submarine are difficult to estimate during moderate speed operation because of the masking effect of forces produced by control surfaces and the hull. As a result, a great deal of time may be consumed in adjusting ballast during a period of gradual deceleration when you plan for hovering or for slow speed periscope operation. The existence of a positive means of control not dependent upon forward speed should alleviate this transition problem. To do this, you have got to balance out the unbalance in the ballast at the same time you are finding out what the unbalance is. On the other hand, the hover jet becomes fairly inefficient for even modest forward submarine speeds because you do not know what the unbalance is at the present time. So it may prevent its effective utilization during this transition period. It may not be effective soon enough to take over control from the surfaces. In any event there is a need to have the control surface tied into the loop and the means of transferring from the control surfaces to some other positive control means during the time you are slowing down, the period when control surfaces become less and less useful as the circulation around the hull becomes less and less effective upon them and the response speed in shifting ballast remains slow."

"I would like to add," said Commander Jackson, "that recognizing the limitations of the automatic hovering system at present which are caused primarily by error in pitch angle, we have also requested installation on the SSB(N)626 of a system to compensate for pitch angle while the submarine is hovering by moving ballast water in response to a rather elementary computer system that will sense pitch angle and indicate corrective action required. This will be evaluated on the SSB(N)626 during the same trial period I referred to earlier. We have so much confidence that it will improve the automatic hovering system that we are proceeding to this rather simple and inexpensive method of control on all of the submarines now under construction.

"The installation of this particular pitch control system will permit the use of the automatic hovering system at speeds over five knots, during which time the control surfaces are fully effective in maintaining the attitude of the submarine at launch depth. The particular approach of this control ought to resolve this problem of transiting from a speed of five knots down to a speed of zero knots at launch depth. It will use the trim pump and it will not be a noisy design. This will be one of the limitations. We are also thinking about another set of hover tanks as the ultimate installation and there are four designs now being developed. The one on the SSB(N)626 where we use the trim pumps will be very simple, very elementary, but will allow us to evaluate the effectiveness of this particular approach."

With no further business to discuss, Admiral Smith set the dates for the next STG meeting on the 25th and 26th of July and adjourned the present meeting at 1650 on 24 May 1963.