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of the
Special Projects Office
Steering Task Group

Task II - Monitor the Fleet Ballistic
Missile Development Program
45th Meeting - 30 September 1964
1 October 1964

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INTRODUCTION

"Good morning, gentlemen," Rear Admiral Galantin began. "Let me tell you briefly what has transpired since the last STG. Admiral Smith and I are still trying to get the B3 Program Change Proposal from Navy to DDR&E. We want to get a recommendation forward that will give the Navy and DDR&E the greatest assurance of being able to cover all eventualities, such as a cruise ABM. Phase I, the Program Definition Phase, is going ahead now and will get into high gear this winter. The question now is at what rate we should enter Phase II.

"Since the last STG we have fired five fully successful A3 DASO shots, bringing our DASO successes to 12 out of 13. Two A3X experimental shots were fired very similarly to DASOs, bringing the total of succesful fully submerged shots to 14 out of 15, a phenomenal record. The real proof, however, will be in the operational tests, which begin in April, or later if delays arise.

"A very major milestone was reached last Monday, when the A3 was deployed and went to sea. The USS DANIEL WEBSTER and all succeeding ships will go out with the A3, except the 620, which was delayed in the yards and will go out with A2's.

"The follow-on tests for the A2 begin in October. These are the validation firings. Initially, there was to be one missile per ship per year which a DASO or operational test would fire. Now, as an economy measure not to take ships off the line too much, the Fleet has proposed that each go out with four missiles. The early ones will have five, because the operational training was finished with less than the predicted number. Or extras may be added to the follow-on testing. A2 follow-on tests, which were run to establish a .75 confidence level that true reliability is within one-tenth of apparent reliability, were completed with less than the expected number, 24 instead of 30.

"Last week was our latest JSTG meeting with the British. They reported no major technical difficulties, only routine management problems. Other recent happenings were dedication of Raborn Hall, which is the POLARIS training facility at Dam Neck, and commissioning of the U.S. POLARIS Missile Facility, Pacific.

"The Deep Submergence Program, which is not strictly POLARIS but concerns all of you, is still in the administrative organizational level. An all-day industry briefing will be held on 24 November. The Sea-Based Deterrrent follow-on program is causing some problems. Very heavy funding and exploratory research and development are needed just to enable system development. We have, under Project SEABED, a number of key SBD developmental items for which we hope to get support. Our Program Change Proposal for the Submarine Integrated Defensive System is not yet approved. Here we have to point out how our ASW problem differs from the Navy's overall ASW problem in order to get support.

"As a general statement, watching our program week by week as I do, we have no major technical problems at present. Our problems lie in the management and administrative areas, having to fulfill our reliability requirements while being hard headed businessmen. We have to keep 55 percent of our ships on station for an indefinite period, which raises a serious problem. We deliver about 13 ships in one year and they use up their cores at about the same pace. Putting all 13 ships in the yard at once would take nearly 33 percent off the line, so they will have to be overhauled before reaching 99 percent core depletion. This will mean some extra expense.

"These are the things we have to bring to the fore, and we are. And those are the only notes I have for you today.

NAVIGATION COMMITTEE REPORT DISCUSSION

"Good afternoon, gentlemen," Commander Peyton began. "I would like to begin my report with the findings of the USS COMPASS ISLAND survey program of July and August of this year.

"During this operation, three AMR sites were surveyed, C-9B C-8A and a new site designated 'C7-3.' Fixes were taken of each of these three sites by BRN-3, the Nortronics azimuth monitor, and the Farrand star-tracker. The azimuth monitor had been adapted to provide fixes as well as azimuth.

"Both C-9B and C-8A had been surveyed in 1963 with a fix site established by the EAG-154 using BRN-3 and the Series 4 satellites which were available at that time. In each case, the 1963 datum is given in the following figures.

"Figure 1 gives the C-9B location as determined by the BRN-3. Thirteen fixes were taken. The squares represent half-miles. The evident center is displaced from the 1963 datum.

"Figure 2 adds the two star fixes from the azimuth monitor. They seem to track quite closely to the BRN-3 fixes.

"On figure 3 the Farrand star-tracker fixes are also shown. There is a great deal more scatter. The data from the star-tracker are called 'Quick Look' because of a number of possible constraints or corrections. One of these is a recheck of calculations relating the fix to the datum point. The technique used here was to establish a

COSAR buoy to serve as a datum, and there have to be refinements of these data to relate them to the datum point. In addition, there were checks in New York and in San Juan on the star-tracker calibration, for constant biases in these various systems. There are additional points for the star-tracker which were not included in these data due to lack of computer time. Calculations took longer because there are 64 star-tracker fixes, which is more than the sum of the other two together.

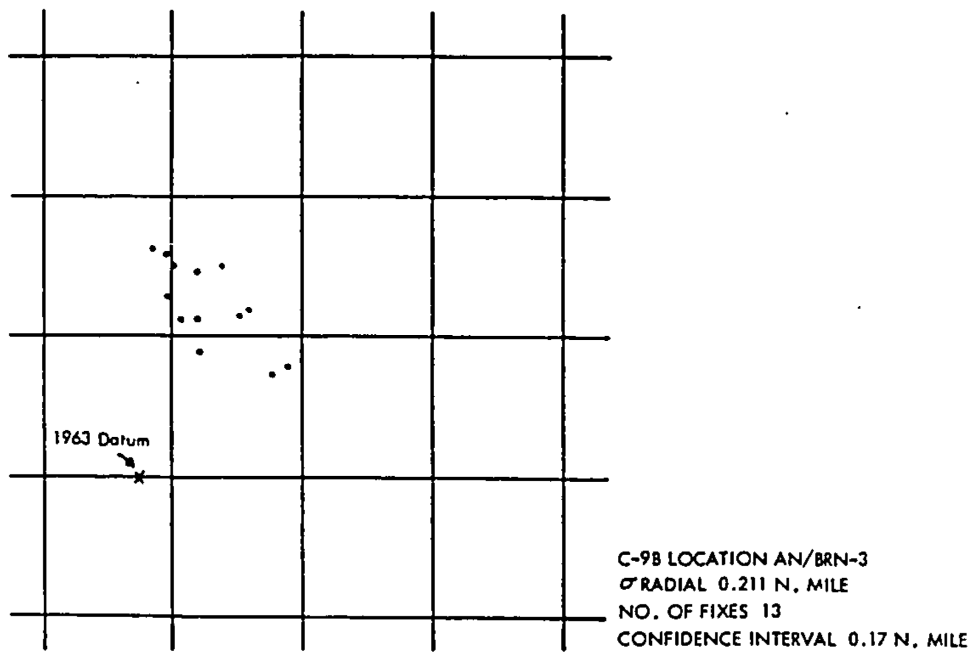


Figure 1

"Gravity data will also have to be checked. There is an indication of anomalies in this one. Sound velocity corrections need to be checked. Corrections are needed to relate the sonar beacon hydrophones and the location of the COSAR buoy. This does indicate that the datum is not correct as we now see it. The azimuth monitor and the BRN-3 fixes are in quite close agreement. The Farrand star-tracker fixes may come in better after they have been massaged by virtue of all these other corrections that have to be made."

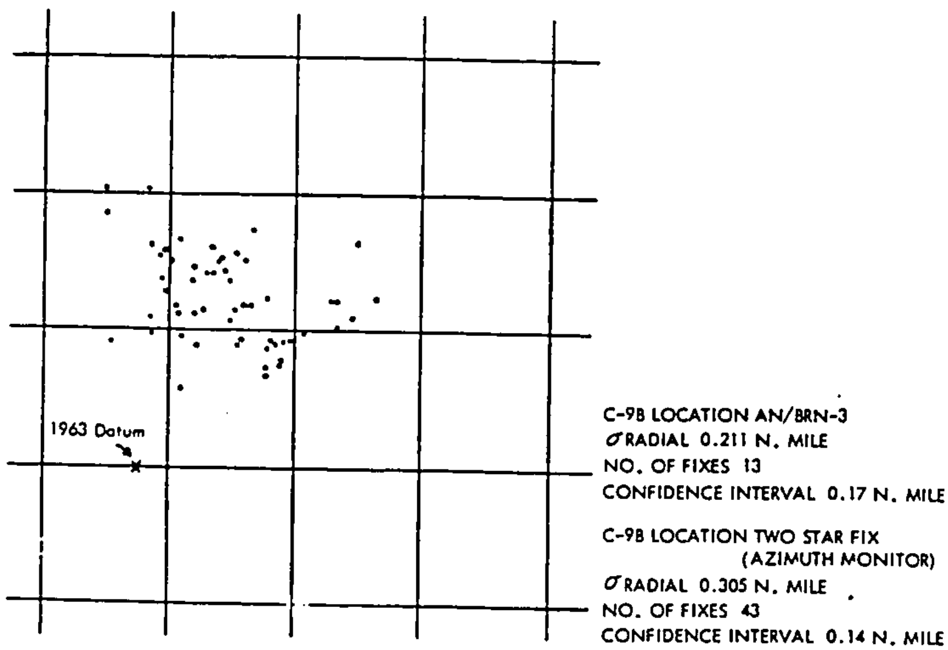


Figure 2

Mr. Forter noted that the displacement of a fairly consistent set of observations from the 1963 datum are east and north, like the missile impacts are, which raises doubts about the datum.

"The 1963 datum was taken using BRN-3 fixes with the old series of satellites," Commander Peyton replied. "They should be as good as fixes taken with the new series of satellites, except that the newer satellites presumably have the benefit of better tracking and injection information. However, if you plotted the positions of all of the fixes which resulted in establishing the 1963 datum, you would probably find a somewhat greater dispersion than you do for the fixes with the current one.

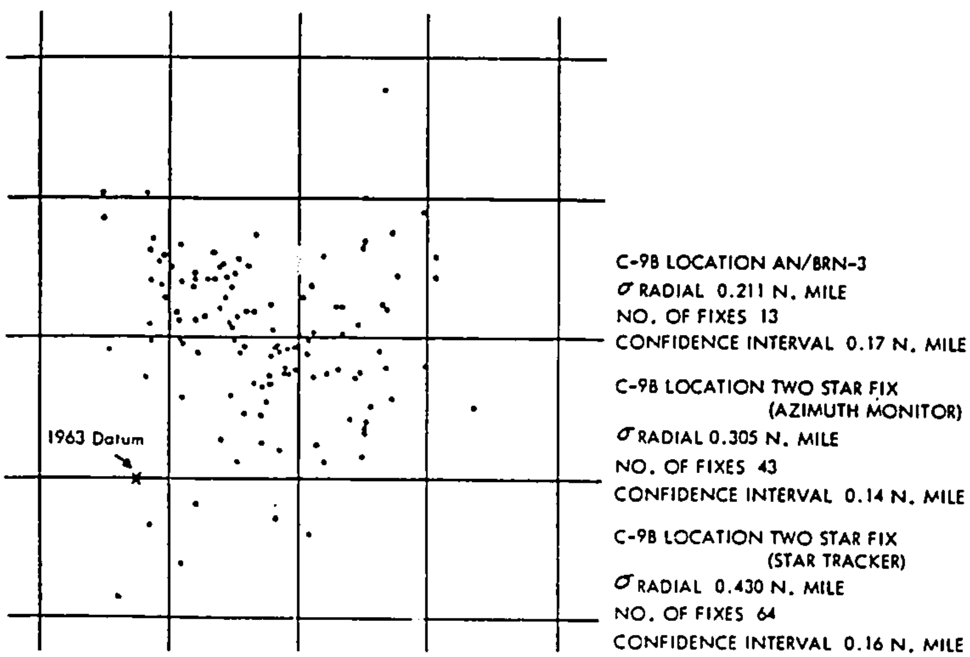


Figure 3

"'Confidence Interval' is the three-sigma number. It is three sigma with the square root of the number of fixes, three times the standard deviation. In essence, it is a confidence level that the point is where the datum is."

"The confidence interval gives you 99.7 percent confidence that the fix is within 0.17 n.m. of where it says it is," Captain Gooding added.

Rear Admiral Smith asked how it can be determined that the buoy is still in the same location as it was in 1963.

"The site has been profiled so you know what the bottom looks like," Mr. Cestone replied. "In addition to that, you have three beacons which are 120 degrees apart, forming a triangle to give the reference points that the impact point will come from when the depth charge is dropped. So the point of reference is the three beacons. The datum point in 1963 was a point with reference to where the beacons were on the bottom. The old beacons in this particular location were still operating when the 1964 operation began. They tried to make a correction where these beacons were located with respect to the previous shots. The points we are showing here are only in relation to the old beacons, not the new beacons. They seated new beacons because the battery life on the others was gone.

"These data have reference points to the old and to the new beacon array. The data shown here is just a correction to the old beacon array. The way this was done was to use a reference, which was the buoy, with respect to the old beacon setup to relocate it. The point that Commander Peyton is making is that the figures as we have them now might have computational errors in figuring relative positions. There is a possibility that some of the points may change or they may be correct."

"In other words," Admiral Smith observed, "a recheck of the computations may change some of your points because all these calculations were done on the ship. But the actual observation adjusted from the position of the ship to the position of this imaginary point is set by the beacons and going via the buoy as a means of accomplishing this correction."

"For each fix, we have a reference to where the ship is with respect to the bottom, and can go back to make double checks with respect to the bottom and to the buoy," Mr. Cestone added. "It is not necessary to drop SOFAR bombs each time. The reading is taken from the PDR."

"The 1963 datum may be in the wrong latitude and longitude but it is defined with respect to the bottom," Commander Peyton summarized. "The beacons relate to the bottom."

"But you may not know where the bottom is with respect to latitude and longitude," Mr. Parran remarked, "so each time the dots went on the chart, it says that the ship thought it was there when it took its fix."

"Now, we will double-check with the bottom to make sure that the relative displacement is correct," Mr. Cestone said.

"The ship is there with respect to the bottom, with respect to the beacons in 1963;" noted Mr. Forter, "and it said that the latitude and longitude were there. If the 1963 latitude and longitude is wrong, the X might be right in the middle of the smudge."

"Is this then subject to the precision of the PDR recovery of position with relation to the bottom?" Admiral Smith inquired.

"No," replied Mr. Cestone, "it is just another means of checking it. You can get a double check by knowing where the ship is with respect to the brochure of the bottom for this particular area. We know where the beacons are with respect to that. And the level of precision of the relative number with respect to the bottom is within one to three seconds."

"I agree with regard to the relative number," stated Captain Gooding. "If you have a brochure, you can fix yourself in that brochure.

But where is your brochure? That is where the imprecision comes about. What is the real longitude and latitude of the topographical map of the bottom? The patrol analyses do not give this."

"The problem in a patrol analysis is not its relocation within a particular brochure with respect to the latitude and longitude. It is with respect to its original position in that brochure," answered Mr. Cestone. "But let me modify my statement concerning precision. It will depend upon how good a bottom you have. If we have some points where the confidence levels are such because of the slopes, there are some areas they had to take because they could not find anything else, and that particular area was not a good area to run profiles on. But if the area is good, you can do it to three seconds. But this is just another method for checking the old beacon array with the relative point. Incidentally, LORAN-C was the original yardstick in making the brochure."

"The problem is really comparatively simple," Captain Gooding observed. "The ship takes a fix by some means, such as the star-tracker, latitude and longitude fix -- or position fix. At the same time he knows where these buoys are by ranging techniques. Therefore, he says, 'I am here. The buoys are so far away in that direction. Therefore, the position of the buoys is such and such.' The position of the buoys resulted in this 1963 datum, so what he is doing in effect is saying that the 1963 datum is in the lower left-hand corner, by the same method. That represents the scatter where he thinks the buoy is, referenced back to his position-taking mechanism and the method of ranging on the beacons."

"If you say that the error in determining your position relative to the buoy is three seconds -- which is 300 feet or one-tenth of one of the squares on the figure," observed Mr. Eyestone, "then this scatter is primarily scatter to the absolute determination of latitude and longitude."

"The error in the position of the ship from the buoys has not been discussed yet," said Commander Peyton, "and it is one of the things that does have to be massaged."

"Yes, but all these dots are saying is that, on the basis of some information, that is where the 1963 datum should have been," added Captain Gooding. "The buoys determine the 1963 datum."

"Figure 4 is the C-8A location with the BRN-3 fixes," Commander Peyton continued. "The C-9B had a similar kind of bias there.

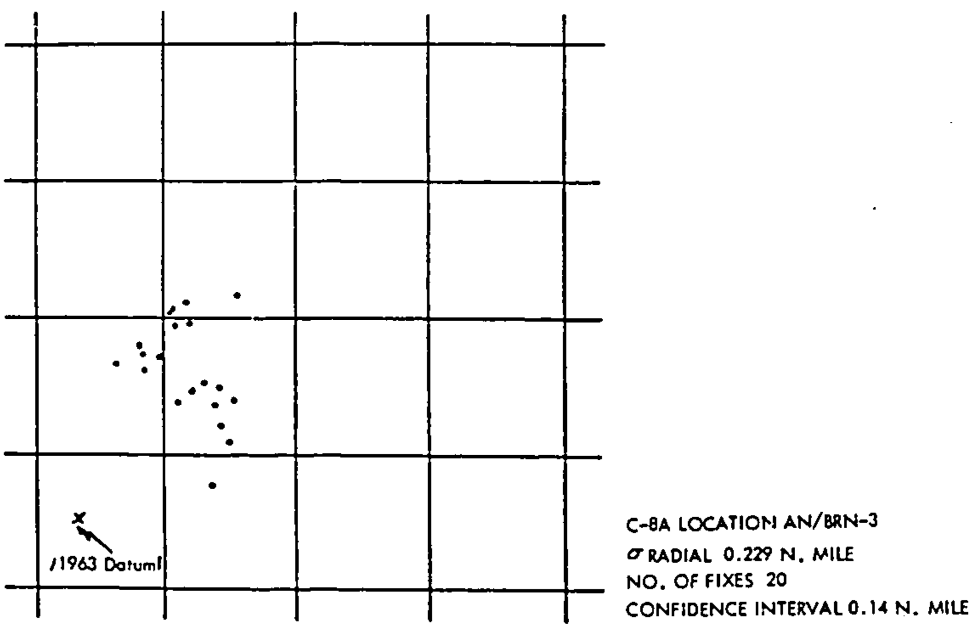


Figure 4

"On figure 5, the azimuth monitor fixes are also shown. The azimuth monitor and the BRN-3 fixes for C-8A seem to agree better than for C-9B. Figure 6 adds the Farrand star-tracker scattering all over the plot. This, among other things, has a residual elevation index error which must be corrected. Hopefully then the scatter will not be as great."

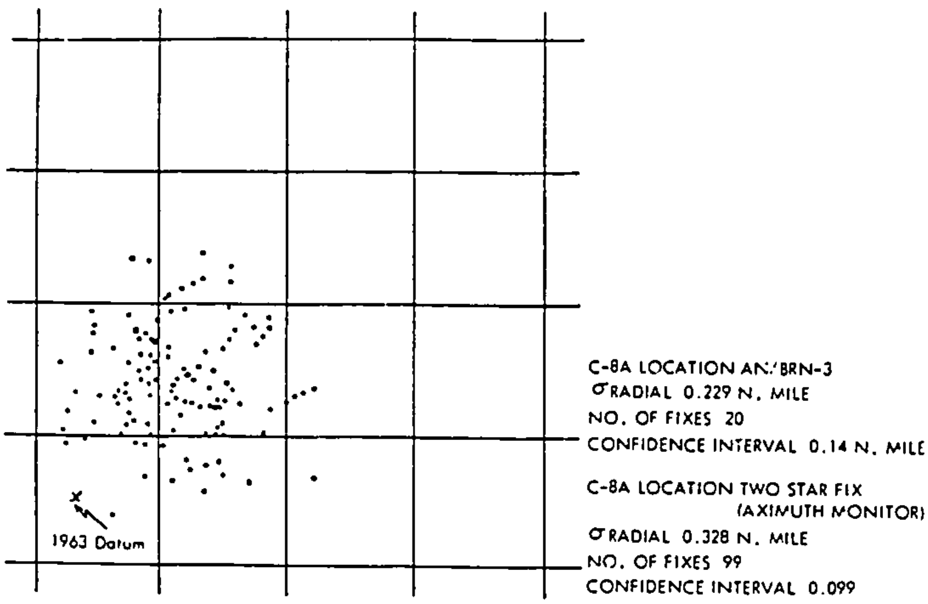
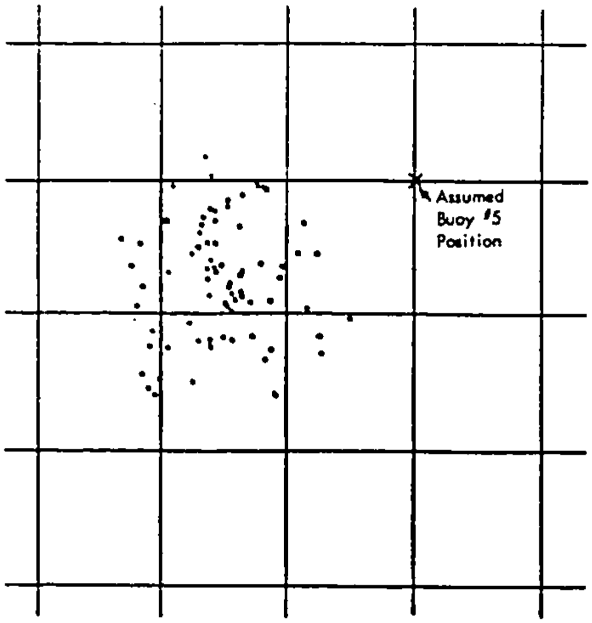


Figure 5

"The reason for the Farrand tracker dispersal is that it has its own vertical," noted Mr. Cestone. "It is an open-loop vertical. It does not get its vertical from SINS like the other tracker does. When it has been corrected, it may come in a lot closer."

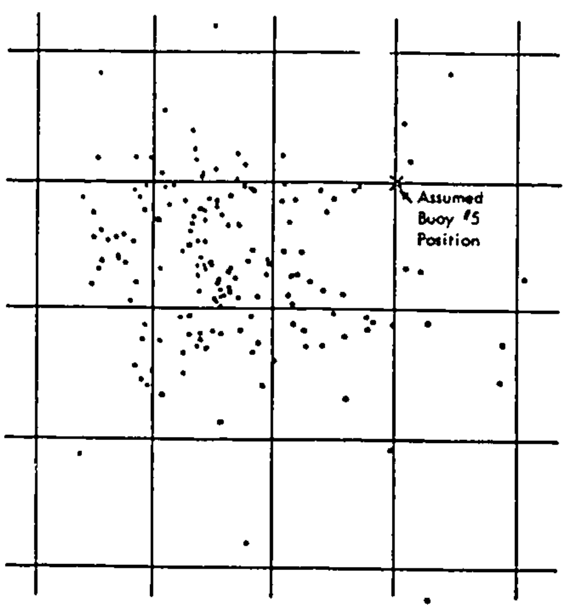
"Figures 7, 8, and 9 are of the C7-3 site, which is the new area surveyed and has no 1963 datum," resumed Commander Peyton. "A COSAR buoy was planted to serve as a position reference. Figure 7 gives only the BRN-3 fixes, figure 8 adds the azimuth monitor fixes, and figure 9 adds the Farrand star-tracker fixes. This again requires the same corrections as on the two previous sites.



C7-3 LOCATION AN/BRN-3
σ RADIAL 0.219 N. MILE
NO. OF FIXES 24
CONFIDENCE INTERVAL 0.12 N. MILE

C7-3 LOCATION TWO STAR FIX
(AZIMUTH MONITOR)
σ RADIAL 0.273 N. MILE
NO. OF FIXES 51
CONFIDENCE INTERVAL 0.11 N. MILE

Figure 8



C7-3 LOCATION AN/BRN-3
σ RADIAL 0.219 N. MILE
NO. OF FIXES 24
CONFIDENCE INTERVAL 0.12 N. MILE

C7-3 LOCATION TWO STAR FIX
(AZIMUTH MONITOR)
σ RADIAL 0.273 N. MILE
NO. OF FIXES 51
CONFIDENCE INTERVAL 0.11 N. MILE

C7-3 LOCATION TWO STAR FIX
(STAR TRACKER)
σ RADIAL 0.589 N. MILE
NO. OF FIXES 96
CONFIDENCE INTERVAL 0. 17 N. MILE

Figure 9

"Figure 10 is a five-day-long run, from 27 August to 1 September, of the Mark 2 Mod 3 SINS on the USS COMPASS ISLAND, without resets. Errors are expressed in nautical miles.

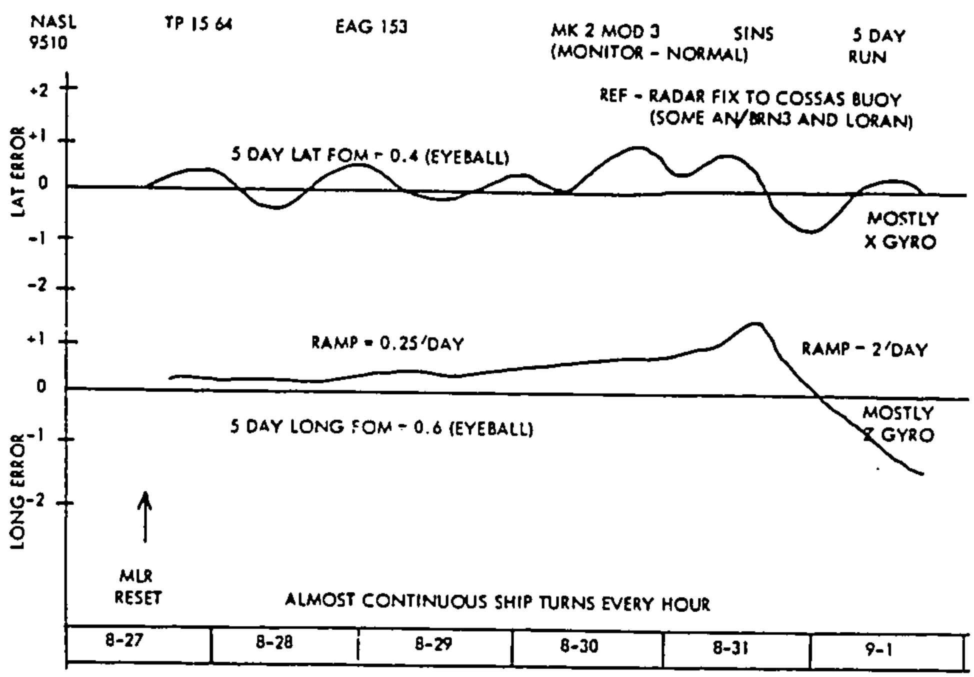


Figure 10

"The interesting thing about this is that there were ship turns almost every hour, implying that the SINS is not very upset by that kind of treatment. It started out with a maximum likelihood reset, and this looks like pretty good information. If the submarines had these data, they would probably start talking in terms of demanding a five-day reset interval."

"The USS COMPASS ISLAND results in the past six months showed that the 24 hr. number for SINS Mk 3 is almost identical to the 8 hr. for the Mk 2 Mod 2," Mr. Cestone said. "This particular information is really amazing. The data were taken during the survey operations of the C7-3 site and all they did for five days was go back and forth. This could be the worst condition possible for SINS because changing speed, ship turns and all the influences that would cause SINS to go off were there; but we obtained these data without resets."

"There is one thing to watch here," observed Commander Peyton. "The prime reference used in determining error was the radar fix to a COSAR buoy with some BRN-3 and LORAN-C fixes. There is probably some slight possiblity of an introduction of error there; but one would be inclined to suspect that the errors would tend in the same direction, particularly the error of the buoy in movement in a current, for example, which should be fairly constant in this area."

"This also shows the effect of your azimuth monitor on the Mark 2 Mod 3," Mr. Cestone noted. "The latitude was kept well within our specs. And it also justifies our position now in looking at the Z gyro monitor."

"Radar fixes were almost continuous because they were in constant sight of the buoy, which would mean in effect a fix every sweep," continued Commander Peyton. "So there is, in effect, a continuous plot by radar and from SINS. However, the continuous plot from radar is not absolute; it is a relative one.

"Figure 11 contains information on USS MICHELSON's late results. In July 1964, Captain Gooding made a presentation to the STG in California, in which he showed various overlays of bathymetric maps made in different directions during the 2 June to 11 June at-sea period. The performance of the array was expressed as a figure of merit defined as the standard deviation of the amount in latitude and longitude that the upper overlay of a pair had to be moved with respect to a lower overlay to get the best correlation of individual contours.

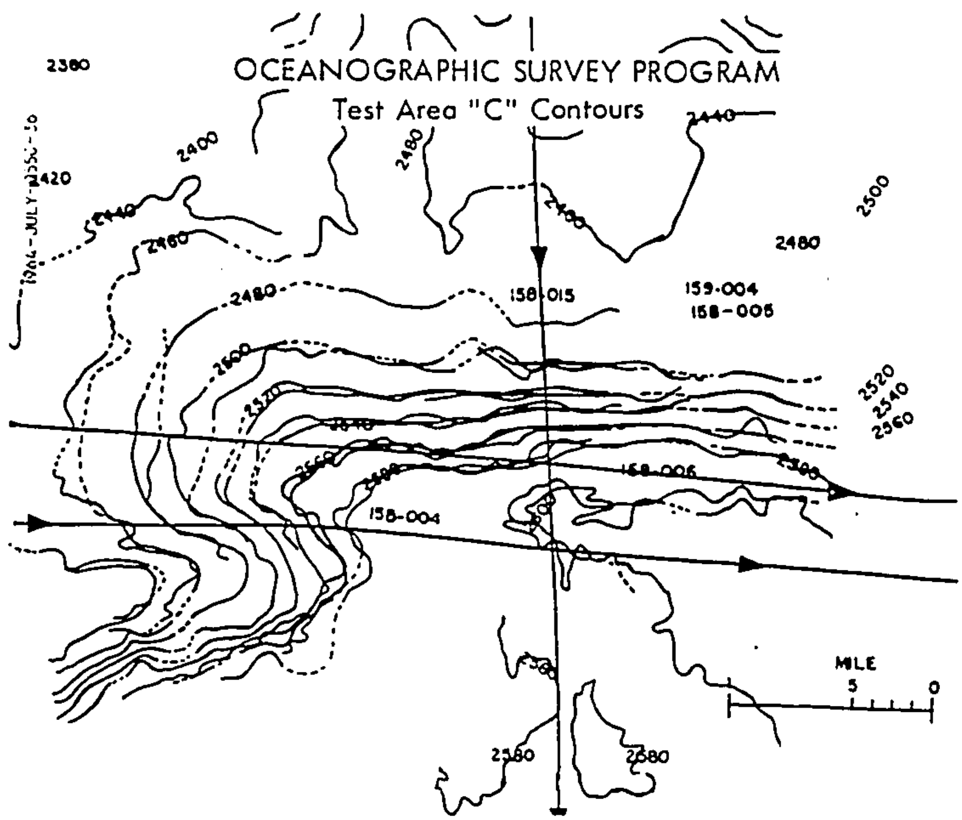


Figure 11

"On figure 11 are two pairs that were shown at that time. One pair is comparing the 158-004 with the -006 run. You can see, among other things, considerable amounts of dotted lines indicating that the oceanographer was not sure how to connect the dots. The other pair was -015 and -004. They match up reasonably well. The figures of merit were 0.02 miles in latitude and 0.06 in longitude for one pair, 0.04 in latitude and 0.02 miles in longitude for the other, so there is a 0.01 figure between the two.

"Figure 12 was taken on the most recent trip, 9 to 22 September. A number of improvements have been made in the program in the adjustment of the hardware. The results of these improvements are that the sea recorder should exhibit less noise and, in general, the individual contours should be a little more accurate. The figure shows one of the results obtained with a figure of merit of 0.01 miles in latitude and 0.01 miles in longitude. The depth lines represent fathoms.

OCEANOGRAPHY SURVEY PROGRAM

C2M-18 SE C2M--8 Sept-64 Contour Comparison

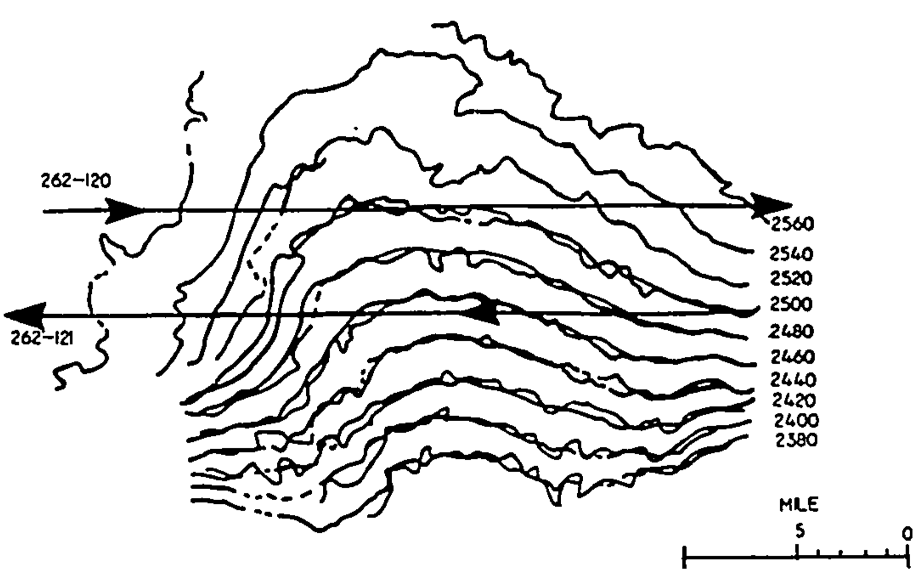


Figure 12

"These are the only data that have been processed at this time. We really have to wait for NAVOCEANO to finish processing the rest of it before we can say this is typical.

"In the previous set of data, figure 11, there also was one which had a 0.01 figure of merit in each direction, but we hope that this is more typical of the recent results than the other one was.

"The most significant point to be mentioned here is the relative absence or the smaller amount of dotted lines. This implies that the oceanographer is better able to fill the contours in."

"You have quite a hill there," observed Mr. Parran. "You have a difference of 200 fathoms over a period of two miles. This is a rather good condition for this kind of effort, is it not?"

"Yes," Captain Gooding repl. , "but these numbers have nothing to do with the excellence of the fix you get from this kind of terrain. This is simply repeatability between two successive passes. It does not say you will get a fix to 0.01 or a fix to 0.05 or anything of the sort."

"There are relatively fewer of the wild lines than we had in past efforts," Commander Peyton continued. "It would seem that the matches are quite good. In those places where the passes do not seem to match too well, the oceanographer was not too sure how to connect up his dots. The reference point for these two successive passes was again LORAN-C.

"This was done with the SINS. Some of the runs were adjacent and there was not any genuine attempt to make the new line pass over the previous line. They wanted to have some displacement. The idea here was to see how well you could line up with the previously charted contours, and see how far you had to move one overlay with respect to the other in order to obtain the best match. This is where these 0.01 latitude and longitude figures of merit arise."

"The azimuth error is the thing that would be detrimental if you are off, if you were trying to repeat this," Mr. Cestone added. "Loran-C would tell you where you were on earth. You would depend on it to give you the abosolute reference. And if you use LORAN-C to steer the ship it will also tell you that those tracks were where they were with relation to each other. That is, it will tell you if you know where the previous track was when you go back over it, and you try to position yourself with respect to it."

"The runs indicated a useable width of about one mile and three-quarters at the depth of two-and-a-half miles," Commander Peyton resumed. "This is about 70 percent of the maximum possible width; and it would appear that a coverage of, roughly, 50 percent would be usable for survey purposes, although this does not satisfy the contract specs.

"As you know, the USS MICHELSON left on 25 September for San Francisco prior to deployment in the Pacific and the USS DUTTON went on its first sea trials in August and also left on 25 September and headed for New York. It is scheduled to leave New York on 8 October for Europe and survey operations.

"USS BOWDITCH will start a six-month yard period on 1 December and in the interim, the only ship available for long-range analysis of this system is the USS COMPASS ISLAND. There are several product improvement programs underway and under consideration. Of particular importance is the isolation of noise sources and development of hardware and software to reduce their effect.

"With this system, large blasts of noise are rejected by the computer program but noise whose amplitude approximates the signal amplitude can result in depth errors which cannot be eliminated. This situation requires further work. This is a very novel system. It is probably at about the same state as the first SINS was when it had been installed this long.

"The sonar array is presently usable. Considerable room for improvement exists. It will be followed up on the USS COMPASS ISLAND.

"For exploratory runs, the amount of detail shown in its present form is far superior to the old method of searching with a broad beam sonar. For survey operations it would appear that both sonar array and SQN-6 should be operated. Depending on the status of equipment at any particular time, one or the other can be used as the master.

"The technique of manually joining the dots on the sea recorder is tedious and time-consuming, and we are considering replacement of this with an automatic contouring device. NAVOCEANO has such a device programed for their shore operation which they are anxious to get us to put on the ships. We would like to see more data before we jump on this particular one.

"That completes my report. Are there any questions?"

Admiral Smith asked for an amplification of possible improvements in the survey system.

"The amount of time to sweep a given area can be reduced," Captain Gooding stated.

"The contract specs call for a certain sweep width, which is a function of the depth of water;" Commander Peyton added, "we are not getting quite that. It was 45. We are getting 30. It is now between 7 and 10 to 1 better than what we had with the original surveys.

We do not know how much better with respect to the original one it would be if the additional improvements were made.

"The situation is a bit more complicated than that, however. If you make your outermost beams more reliable and, therefore, less susceptible to noise in rolling this ship, this would increase the number of inner beams which you could count on in severe sea conditions. So it makes more weather available for good surveying operations.

"It also makes the sweep operation possible for a preliminary survey. You can cover a great deal more ground. You would be able to if we could get these outer beams into a usable state, a state in which we had confidence."

"There is some given amount of surveying that needs to be done for the FBM system," Admiral Smith noted. "How much sooner could we get that all done?"

"If you had a couple years of surveying laid out, you would probably save a few months, maybe as much as five, maybe as little as two," Captain Gooding stated.

"Out of our experience on patrols, has there been a number drawn that you would say is our RMS bottom fixing accuracy that we currently plow into our forecast of target accuracy?" Mr. Eyestone inquired. "Is it two-tenths or something of that nature?"

"Going back over all the data of patrols and so forth and comparing them with LORAN-C, we are getting three-tenths of a mile for sure, and possibly a quarter of a mile," Admiral Smith replied. "There are some ambiguities in the data relative to LORAN-C. There has been no agreement to take out the probable error of

LORAN-C. You could get somewhat closer than these, but this is in relation to the essentially raw LORAN-C data. There is a large enough number of measurements though that I do not believe this would improve it very much."

"This means looking at the bottom and matching to those brochures the position of the submarine itself relative to the bottom so he knows where he is with a three-tenths of a mile uncertainty, as far as the bottom setting was supposed to be," Mr. Peterson stated. "The bottom may be off relative to the pure latitudes and longitudes, but that is another problem."

"This is with relation to LORAN-C," added Commander Peyton. "The LORAN-C is a device by which the absolute position of the bottom point was established in the first place, however. And it is also in reference to what you are doing in the patrol."

"LORAN-C is positioned with reference to the geodetic location of the stations," Admiral Smith observed. "So if you took some of those earlier charts where you had all these data, you would have the same dispersion there. I mean there is another set of data, there is another bit of dispersion at the inboard end, too.

"Of course, then you have to bring azimuth into it for that range," Mr. Eyestone noted.

Rear.Admiral Smith then introduced Commander Skinner, to present the report on Submarine Design.

SUBMARINE DESIGN COMMITTEE
REPORT DISCUSSION

"Good afternoon," said Commander Skinner, "the Design Committee report this afternoon is going to be fairly brief. We have two topics, both associated with the submarine safety program.

"At the last meeting in Sunnyvale, we reported on a study to be conducted that would determine the feasibility of constructing a full-scale submarine test facility. At this point it appears that it would be feasible to build either a free-standing steel cylinder type facility similar to that shown in Figure 1 or a steel-lined tunnel that would be built into rock in the side of a cliff and would be as shown in Figure 2.

"Thus far the study shows that there is only one really feasible location for a tunnel of this type, and that is up the Hudson River -- ten miles above West Point. We found that we can build either type for about the same total cost. So we abandoned the tunnel concept in favor of the other one, and we will continue the rest of the study based on the free-standing steel cylinder type. We had a rough estimate of cost. For the free-standing type it is about 50 million dollars. So the study is now expected to be completed sometime during October."

"Do I remember correctly that it was about a year ago that this was estimated to be about a hundred million?" inquired Rear Admiral Smith.

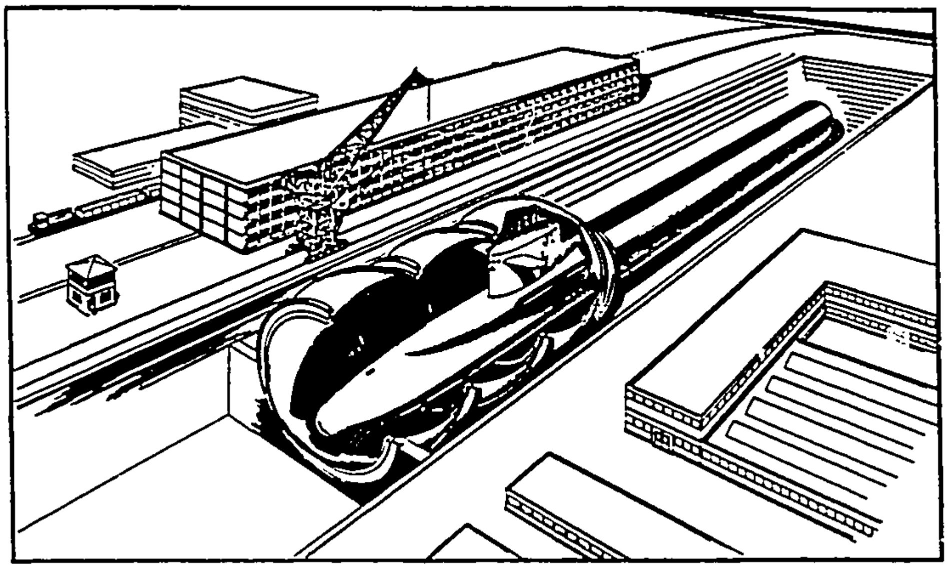


Figure 1

"Yes, sir, that is correct," Captain Kern replied. "That was our first rough cut, an in-house kind of estimate, without benefit of calculations as to thickness of steel and the like."

"What do you do with the door? When you slam a door behind a submarine, do you weld it shut?" asked Rear Admiral Galantin.

"No," replied Captain Kern. "There are several means of locking the door that are being studied. One involves a number of large tapered pins and a sliding-type fit. Another involves a locking bar, heavy cast forging, that would lock around similar to a torpedo tube to hold the door shut. This has not been worked out in detail; all this is still in the study.

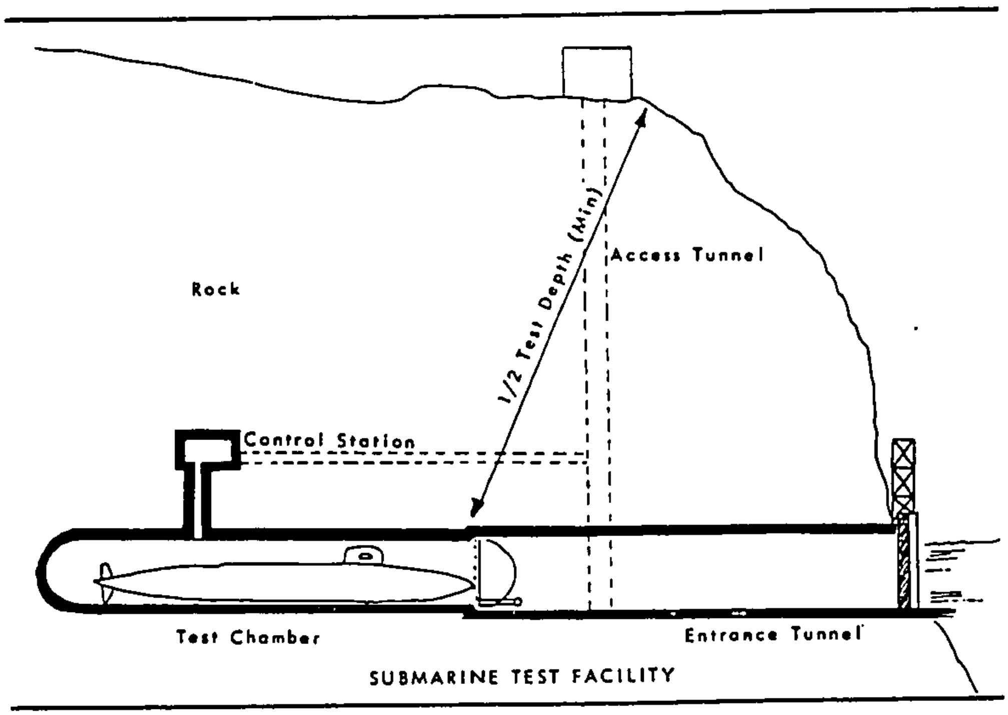


Figure 2

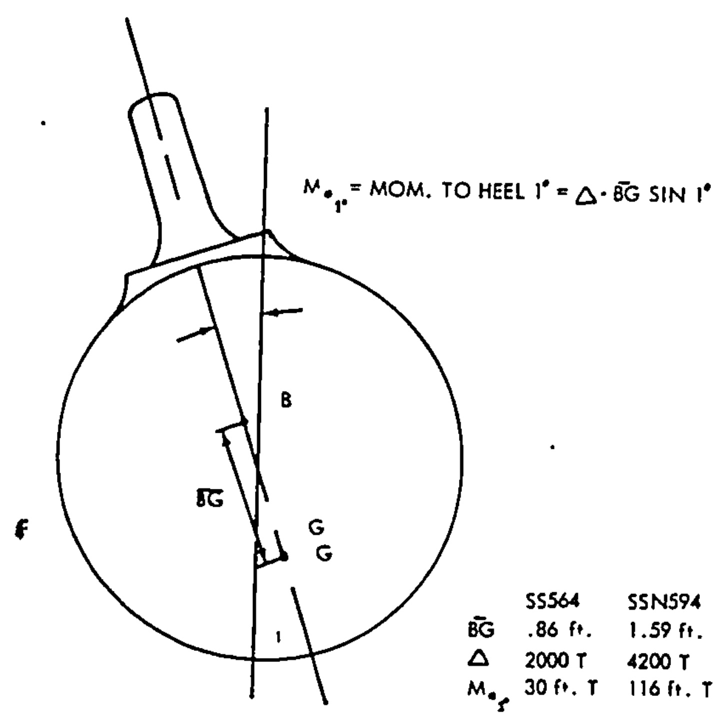
"Our second topic is related to the emergency main ballast blow system. We reported this several months ago in the progress with regard to installing and testing these on board submarines. With a few exceptions, all of these have been tested. We are now installing them on attack submarines.

"Early this month we ran a test on the USS TRIGGER,which was one of the 563-Class boats to get the new system. During the blow test, the ship took a heavy roll angle as it was coming up. We did not conduct any more tests on the USS TRIGGER, but we ran some more model tests on the USS TRIGGER model out at the David Taylor Model Basin and we found that the model had a tendency to roll quite violently as it was surfacing. In surfacing, the main ballast tanks were blown at using the emergency blowing system. As the ship came up it actually rolled about 25° to port and then 50° to starboard and then surfaced. The USS TRIGGER has a $\overline{BG}$ (distance from center of buoyancy to center of gravity) of 0.86 feet submerged. She can go to 90° before things fall loose and the power goes. We had another test last week that was run on the USS ALBACORE. There was a 60° roll on this test.

"Yesterday we ran some free-ascent tests with a model of the 616-Class out at the Model Basin; and with this model surfacing from the ship rolls about 45 degrees from port to starboard, but it oscillates about zero. The model that we are using is simulating a buoyancy equivalent to two-thirds the main ballast blown and starting from rest at The vertical velocity was about 13 feet per second, which was quite high for that type of test; and the model had a metracentric height of 11.5 inches, which was lower than the actual ships. They all are in the order of 1.25 feet. We used this model because it was available; it was the only one we had at the time and that was the most stability we could get in the model.

"During the actual blow test on the SSB(N)616 class, the ships have shown a slight tendency to roll but in every case it has been a small, 3 or 4 degree, type thing. It has been less than 10 degrees in every case. These were starting at There were some tests at There was no tendency to roll violently with the SSB(N)s. It appears that submarines surfacing in this type of situation have a hydrodynamic force acting on them that overcomes the inherent stability of the ship. The magnitude of a reaction to this force depends on the stability that is built into the ship.

"In figure 3, in the case of USS TRIGGER and USS ALBACORE, the moment to heel one degree is given by the displacement times this righting arm times the sine of the angle, one degree, which is in the order of 32 tons for these small ships. Now, they roll fairly violently. Thus, you can see if you have a small force, it will give you a bigger roll angle on a ship of this size. The SSB(N)594 class has a larger $\overline{BG}$, a larger righting arm, a higher displacement, and the moment to roll one degree is 116 foot-tons. In the case of the SSB(N)616 class this is up in the neighborhood of 180 foot-tons. So we feel that the large displacement in the SSB(N)s prevents any serious roll effect as we have now on the small ships. For example the USS DOLPHIN, our worst case, has very small displacement and 0.5 $\overline{BG}$. We



	SS564	SSN594	SSBN616
$\overline{BG}$	.86 ft.	1.59 ft.	1.23 ft.
Δ	2000 T	4200 T	8200 T
$M_{\phi_{1°}}$	30 ft. T	116 ft. T	176 ft. T

Figure 3

have a problem, but it is not as serious in the SSB(N)s as in some of the other ships that we are coming to now."

"Concerning this large roll that you said you get on the USS TRIGGER when you conduct these tests" said Admiral Galantin, "do you start from absolute zero-level with no fore and aft angle?"

"You start at level trim and a speed of about five knots, and try to limit trim angle on the way up. You then blow, say, a 30-second emergency blow, and make a free ascent, holding the speed at five knots. The blow started at 400 feet; roll was started at 100 feet," said Captain Kern.

"This is an air system, of course, and they are centrally controlled from one place," said Admiral Galantin. "I think that maybe someday you will have to go to generators in individual ballast tanks, although the time for getting those things ignited may introduce a more severe problem."

"We would be introducing an exciting force if we have any unevenness in our gas generation," responded Commander Skinner.

"You may have to take that into account and maybe use a smaller one or some other method," suggested Admiral Galantin.

"The problem apparently is in the ship's vertical velocity and stability," said Commander Skinner. "We either have to control the velocity so as to keep it slow or provide more stability. In an existing ship, we cannot do a great deal to add to the existing stability, and probably would not want to because of the surface effects on the ship.

"Is this heeling moment simply due to the fact that your sail is sticking up in the water?" inquired Captain Gooding.

We really do not understand it, Captain," said Commander Skinner, "but that certainly is part of it. There have been other cases of this type. Cousteau reported on the vortex-shedding problem in servicing the bathyscaphes. We have a similar problem on the periscopes. It could be part of the problem.

"We have an intensive study going on at the Model Basin now to better understand the problem and to try to find out what to do about it. In the first stages, we are trying to develop coefficients to predict roll angle on a computer. We have already predicted in two planes; we predict pitch/depth, vertical velocity. We have a computer program so that we can get six degrees of freedom, but we have never been interested in ships moving in this direction before, so we did not have coefficients for that type of motion. They are towing a model of USS TRIGGER broadside to try to develop the coefficients to predict roll angle."

"Isn't it your strong suspicion that the primary cause is the torque caused by the unbalanced hydrodynamic load on the sail?" questioned Mr. Parran. "That would be quite a torque."

"Well, analytically, the force on the sail is not of enough magnitude to cause the ship to roll," replied Commander Skinner.

"As long as the ship remains in a vertical position," added Captain Kern, "nothing happens. It is like trying to throw a dart backwards -- the tail feathers are on the wrong side of the arrow and the body is inherently instable. Proceeding through that direction, then, if it tends to trip one way or another, there is no question that the lift force generated by the sail going through the water at that velocity would tend to trip it more. Also, this vortex shedding can introduce very large unbalanced shed-offs which cause it to go from one side to the other. This is a change in drag. You can shake a periscope or any cylindrical body violently dragging it through the water.

"If the shedding frequency is in phase with the natural period of the ship, you get a tremendous shake out of it."

At this point, Commander Skinner showed a movie of the USS TRIGGER model tests, where models with 13- and 7-inch $\overline{BG}$ were tested; The USS TRIGGER itself has about a 10-inch $\overline{BG}$. They were tested at zero way at an equivalent depth of 350 feet. The 13-inch BG showed good stability.

"What cumulative effect do you have for five knots, for instance, on the thing -- any significant effect at all?" asked Mr. Stevenson.

"We think that with a pitch angle on the ship you get a little more stability, but just speed in itself does not necessarily give you any more stability. It gives you the ability to retain a pitch angle," resumed Commander Skinner.

"I think we have to remember a number of things here," said Captain Kern. "This is a test to simulate blowing, and unfortunately there is no way to simulate a flooding casualty for which you are blowing it. Flooding would do two things: it would decrease the rate of ascent, which is part of the thing that is giving you the problem along with how fast you are going through the water sideways; and also the water flooding in would tend to lower the center of gravity.

"On the other hand, we still want to be able to test these systems down to test depth, and we want to be able to do it safely. This phenomenon we see here, of course, is not safe. It is a matter of getting a safe way to test a new system, and I think this is something we can do."

"I think the simultaneity of igniting the gas generators could be handled; you would have to worry about the possibility of one of them not going off, but smaller generators and redundancy would help in this problem."

As there was no further discussion Admiral Smith introduced Dr. Craven with the Systems Appraisal Committee Report.

SYSTEMS APPRAISAL COMMITTEE REPORT DISCUSSION

"I have a very brief report today," began Dr. Craven. "Due to the fact that the Chairman of the Systems Appraisal Committee got involved in the results of both Project SEABED and the Deep Submergence Program--occupying all his waking hours and a few of his sleeping hours--we did not have a formal Committee meeting. However, during this period I have been able to step back and, with a different perspective, observe the system as a system. As a result, there are two points I would like to make.

"First, coming back to this program after two months absence, there is the impression that from a system standpoint it is in very good shape. And that, although viewgraphs have been showing the same status, or slightly improved status, one is able to observe in these statuses an ever-increasing progress that is relevant to our goals.

"The second point concerns the question of whether or not this system is now moving with such force or with such inertia that management at this juncture can do anything about it. The impression is that there is tremendous human resource committed and dedicated with a tremendous amount of built-in inertia. Looking forward from this, two problems seem to arise that are generic to all aspects of the program.

"The first problem is illustrated in figure 1, an on-line/off-line summary, for which I am indebted to Captain Lacy. It shows a projection of the number of SSB(N)s that will be on the line or off the line as a function of time if we run out the core life on the SSB(N)s -- assuming this summary is the approximate basis for bringing them back to overhaul.

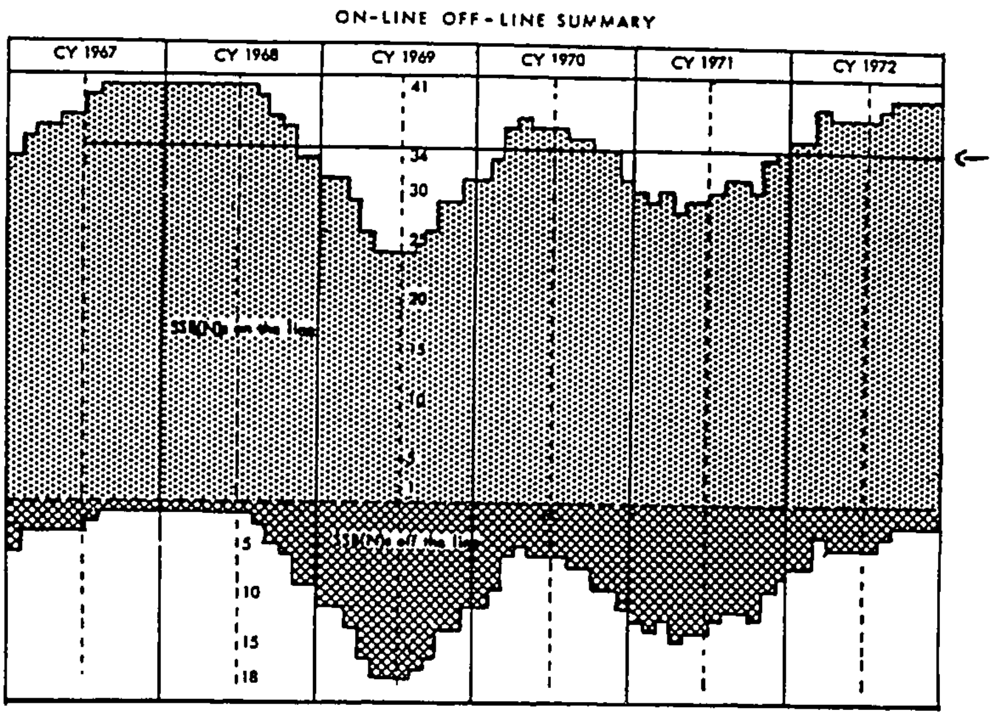


Figure 1

"The program requirement is that we maintain the percentage indicated by the solid horizontal line in figure 1. We meet this average in 1967 and 1968 because we have had an extensive period of intensive building; a period when the ships will have depleted their core life and the cycle swings downward; then it is built back up and the cycle continues on in this fashion. If we want to damp this cycle, we would probably have to bring in SSB(N)s off the line for core replacement before the core is fully used.

"I have reason to believe, from talking with Captain Christman, that we are going to run into cycling problems because of missile replacements as we move down the line. I have not looked into this yet, but he indicated that start-up and slowdown of missile lines will be a problem we face in the future. I suspect that this cyclic problem will be so not only in the area of submarines, but also with other portions of the weapon system. This cyclic problem may become serious because it has to do with the application of resources and with the justification for doing things earlier than we should on a semi-optimized basis. I propose that the Systems Appraisal Committee look into this problem in the near future.

"The second problem I see facing us that results from this inertia, as well as other things, are those programs that we have not yet done, that must be done because they are either required now or will be, and that have gotten off the ground before but are having more trouble getting off the ground and moving in SP style now. I note the progress of Project SECT. I think it is moving well in terms of the present environment, but it will probably be 36 months before we have a SECT buoy deployed on the submarines. This is very long in terms of our previous experience for developments of comparable technical magnitude.

"I note the defensive weapons suit that is recommended but which we may find difficult to implement either totally as a system or in the time scale concerned.

"I noticed from last Monday's presentation, for example, that there is a definite need for some sort of hydrophone in the Mediterranean patrols in order to penetrate the very heavy summer layer as the ship comes up for TRANSIT fixes or for other near surface conditions where the Skipper is required to move up. I wonder whether we could easily implement the development of such a hydrophone with this capability.

"So the second generic problem that I have identified is that this inertia may prevent us from starting these new programs which are required for contingency and which are certain to arise, and although they have not yet hindered the POLARIS program they will be a bar to development of a successful program.

"Those are my two points."

Concerning Dr. Craven's reference to the need for a satisfactory hydrophone on the submarines, Admiral Galantin suggested that possibly a hydrophone could be put in the PY system which has been provided in the rudder of some boats but not yet committed to going operational. Admiral Smith replied that it was too late for this and asked about the VLF buoy.

"It has been tried and had a very high noise level. We just have no acceptable solution," replied Dr. Craven.

"If it is operationally successful," added Captain Gooding, "the answer would be for the submarine to stop dead in the water, hover, say, at 200 feet, raise a tethered hydrophone, whose ascent he can measure, until it gets above the layer, and then listen. According to Captain Hannifin, they can judge reasonably well by the noise how far away the target is; crudely, maybe, but enough for their purposes. Whether this can be done under operational conditions, I do not know, but that may be a way to lick it.

"Another way would be to pull this hydrophone up with a balloon; the balloon when it broaches will stop pulling and the hydrophone will be at the appropriate depth. There is a problem here, however, of how to get the balloon back on board. You can get the hydrophone set back, but the balloon will still be loose."

"Most of you are familiar with the so-called Sims buoy," noted Captain Kern, "which we put in place in the forward escape trunk hatch; and it is possible, by using the floating wire antenna hull penetration, to push a buoy up towards the surface and control its height by controlling a wire inside the submarine. And it is similar to the floating wire station that we use every day on patrol, so it is a question of coming pretty close to stop and hovering. But the problem with hydrophones in dealing with small patrol vehicles is that self-noise is so high that you do not hear anything."

"This is quite operationally unacceptable at the present time," commented Dr. Craven.

Captain Christman with the Missile Committee Report was introduced by Admiral Smith.

MISSILE COMMITTEE REPORT DISCUSSION

"Since the last meeting," said Captain Christman, "no A1Ps or A2Ps have been fired. We have fired seven more A3 DASO missiles, to give a total of thirteen; we have had just one failure and twelve successes.

"Figure 1 lists the A3E DASO problems and the attendant failure rates predicted last January. Our score on the second-stage nozzle is one failure out of 13 shots. We have had one STAS failure and were asked to examine the data to find out how many times we could have seen STAS. Of course, on the later missiles, we can now actually get a STAS indication on all three bodies, so the total times we could have seen STAS on these 13 flights is 24 times, and we have had only the one failure. Other than that, there are no new problems. In fact, these missiles are in good shape in missile checkout, getting ready to fire, and firing on time. The missile test and readiness equipment is working perfectly.

"Figure 2 summarizes in detail all the flights except the last two. One nozzle stuck on the third missile. This is a first-stage nozzle but it stuck for about three seconds and then became unstuck. We have not had nozzles sticking on any of the other first-stage nozzles of the 13 fired. The STAS failure is shown in the fourth slot. A3P-3 failure was the loss of the bird here where the second-stage nozzle was ejected. We have had some trouble on SOFAR bombs A3P-7 and A3P-33.

"On A3P-13 there seemed to be some interference between the flow meter and the telemetering equipment. As far as we can tell, it appears to be a test problem and not a tactical problem.

A3E DASO PROBLEMS

	Failure Rates JAN 64	PRESENT
1. Electrical Failure (A3X-44)	1/33	
2. Stuck Nozzle A3X-46	1/33	
3. S/S Nozzle (A3X-58)	1/33	1/13
4. Front End Rework	1/33	
5. Miscellaneous	1/33	
a. STAS (A3X-60)		1/24
b. Umbilical		
c. AFD Unlock		
d. Aft Skirt Corrosion F/S		

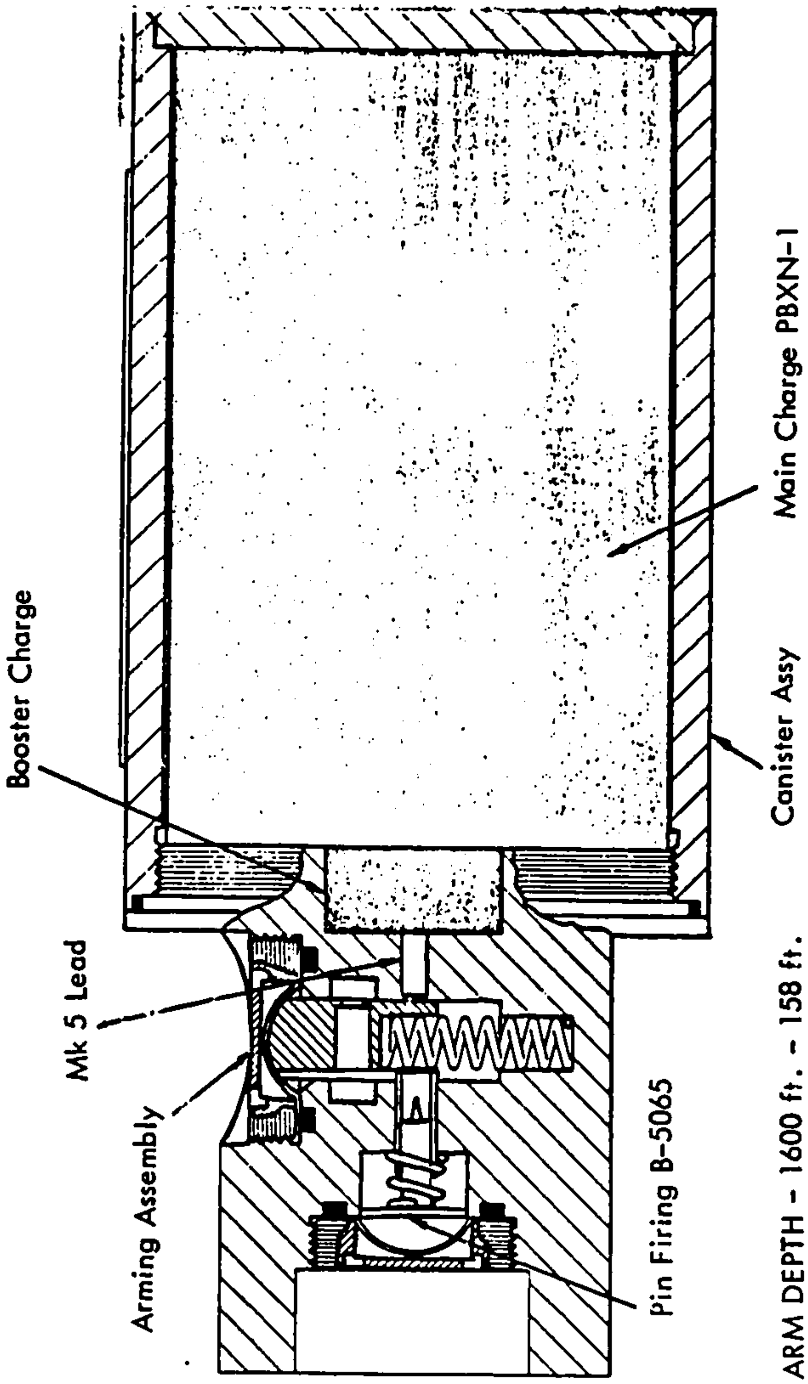
Figure 1

"Figure 3 is a cut away view of the SOFAR bomb. We have been having some trouble with these bombs. The bomb arms at about 1600 feet by having the disc force the slider across. This puts the channel in line with the firing pin. At the fire depth, the cap presses inward, stabbing a firing charge, igniting the booster charge, and finally the main charge. There is some evidence that the booster charge is firing properly, but we are having trouble transmitting the flame to the main charge.

A3P FLIGHT TEST SUMMARY

Vehicle	Date	Malfunctions (Anomalies)	Corrective Action for Malfunction (Corrective Action for Anomalies)
A3P-6	5-25-64	None	
		(Erroneous third level dump command issued due to narrow countdown pulse width and second source transistors.)	(Change specification limiting transistor base charge)
A3P-1	5-25-64	None	
A3P-2	6-8-64	None	
		Nozzle 3 stuck from 18.08-21.89 seconds.)	(None)
		(Erroneous third level dump command issued due to narrow countdown pulse width and second source transistors.)	(Change specification limiting transistor base change)
A3P-4	6-8-64	None	
		(STAS not received due to short of +30V)	(Isolation resistors added to STAS and F/U 30V lines.)
A3-19	7-16-64	None	
		(Noisy Waugh Flowmeter prevented dumping between 84.68 and 95.8 seconds)	(None)
		(800 cycle power lost at second separation)	(None)
A3P-3	7-16-64	Nozzle 2 throat ejected --69.68 seconds.	None
A3P-8	7-30-64	None	None
		(Link 5_D inoperative throughout flight)	(None)
A3P-32	7-30-64	None	None
		(Link 9 intermittent from 2nd sep. through re-entry	(None)
A3P-7	8-6-64	None	None
		(No return from SOFAR bomb	(Under investigation)
A3P-33	8-20-64	None	None
		(No return from SOFAR bomb)	(Under investigation)
		(3 erroneous third level dump commands)	Change specification limiting transistor base charge)
A3P-13	9-5-64	None	None
		(Noisy Waugh Flowmeter prevented dumping between 85.78 and 89 seconds)	(None)
			(None)

Figure 2



ARM DEPTH - 1600 ft. - 158 ft.
FIRE DEPTH - 2700 ft. - 78 ft.
BOMB WEIGHTS - 1 lb
2 lb
4 lb

SOFAR BOMB

Figure 3

"The history to date of the ground and flight tests is summarized in figure 4. On ground tests we have actually attempted to operate 198 of them, and had a malfunction in 7. The failure rate is 3.5 percent.

"The lower group of flight tests in figure 4 actually includes all the tests to date except some re-entry body tests which we believe were not a true test of deployment of the re-entry vehicle; on some of those tests, the SOFAR bomb did not operate. In fact, the re-entry vehicles did not separate from the second stage. So, if we look at those where the re-entry vehicles did separate, we have 97 tests and four failures.

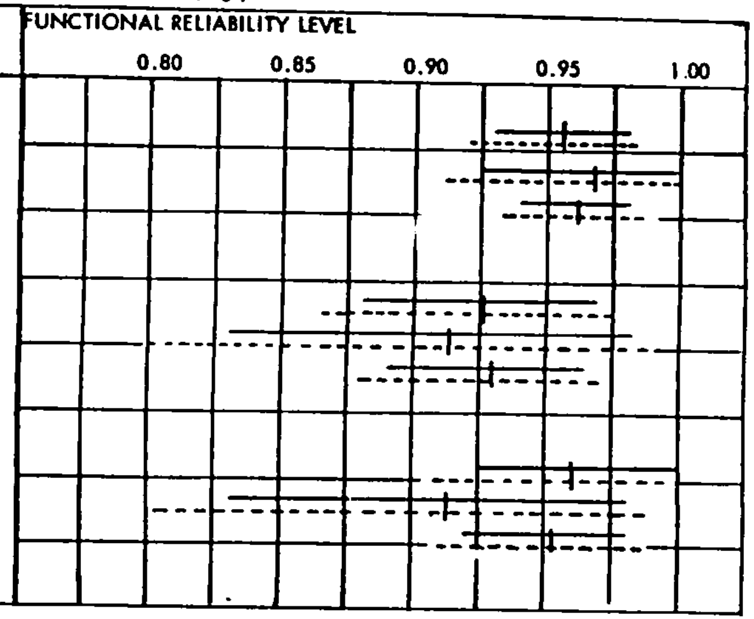
"We have also looked at the history of SOFAR bombs which are used at the range, i.e., dropped over from ships for range calibration. The general experience was been about four to five percent failures. It appears that the failure rate we are getting here is typical of all the bombs of various types that have been used to date. We feel now that the percentage is so small we do not plan any changes.

"In the report this period, we included about a four page write-up on motor ignition safety precautions. I do not have any particular comments on it. I think the write-up is self-explanatory. NASA has not actually come out with a final report on how their X-248 rocket motor at AMR was ignited, but we are using their corrective measures at POMFLANT, POMFPAC, and on the tenders.

"Perhaps the problem which has had the most interest since the last meeting has been the question of A3 first stage aft-skirt corrosion. The next four figures will show the history of the problem and what we are planning to do about it.

A3 SOFAR BOMB
GROUND AND FLIGHT FUNCTIONAL TEST SUMMARY
THRU 9-4-64

TEST	Quantity	Function	% Function
GROUND			
DEVELOPMENT	147	141	.959
ATP-OD	51	50	.980
TOTAL	198	191	.965
FLIGHT*			
A3X(26 VEH)	76***	71	.934
DASO	30	28	.933
TOTAL	106	99	.934
FLIGHT**			
A3X(23 VEH)	67***	65	.970
DASO	30	28	.933
TOTAL	97	93	.959



NOTE: —— 80% CONFIDENCE INTERVAL
---- 90% CONFIDENCE INTERVAL
I 50% LOWER LEVEL
*INCLUDING 3 FLIGHTS WITH IMPROPER REB SEPARATION
**EXCLUDING 3 FLIGHTS WITH IMPROPER REB SEPARATION
***EXCLUDING 2 SDI SOFAR BOMBS USED TO MEET FLIGHT SCHEDULE

Figure 4

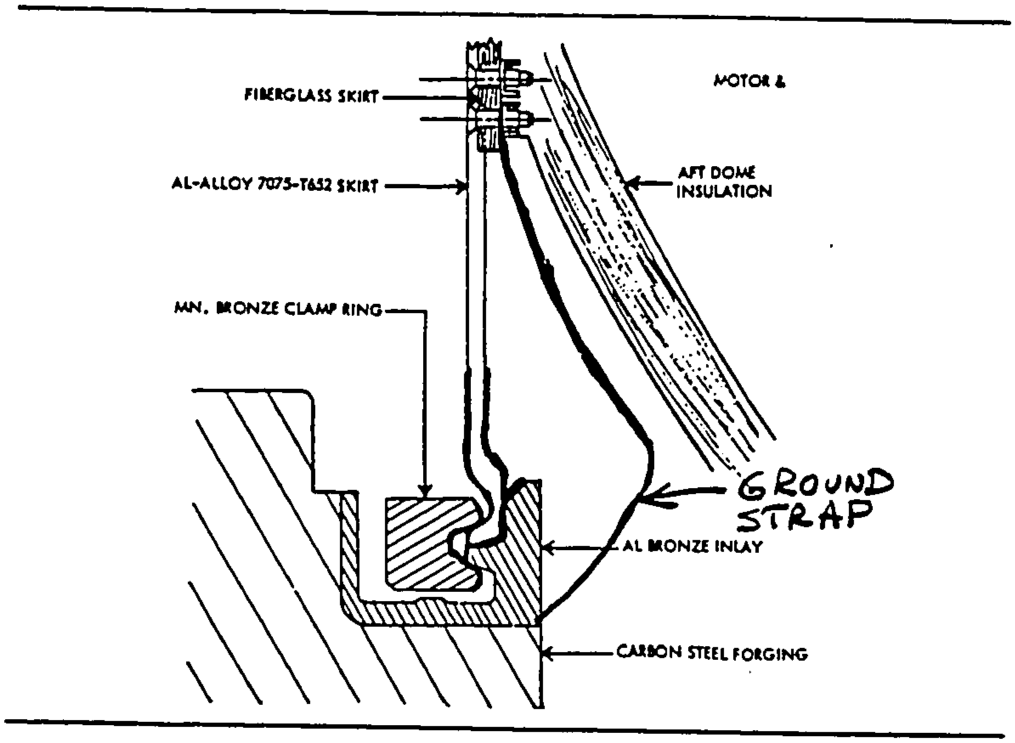


Figure 5

"As seen in figure 5 the missile sits on an aluminum bronze ring which is provided by Sp 22. It is held in position for depth charge attack by a magnesium bronze clamp ring; the missile skirt is aluminum.

"The corrosion problem was recognized about 2-1/2 years ago and various recommendations were made to change the skirt ring.

At the time, however, we believed that the dehumidification alone would be adequate to protect the ring.

"The problem occurs either during accidental flooding or perhaps during loadings of missiles when the tube doors are open. Salt spray gets down into the region between the aluminum skirt and the bronze ring. This sets up a very nice battery with galvanic action. The grounding path is shown by the line marked ground strap.

"Figure 6 shows the electromotive series. Bronze (tin and copper) is near the bottom. We actually have been using two materials and have been studying the steel used on the A1/A2, and copper and titanium which are very close in the electromotive series. We feel that there would be no problem in adapting any of these materials to the skirt.

A3 FIRST STAGE MOTOR AFT SKIRT CORROSION

ELECTROMOTIVE SERIES

Potassium (Less Noble)
Calcium
Sodium
Magnesium
Aluminum (Skirt)
Zinc
Iron (A1/A2) (A3?)
Cadmium
Nickel
Tin
Lead
Copper (Tube Ring)
Titanium Alternate for A3? (More Noble)

Figure 6

"A final decision has not been made. We just received a 12-page TWX from Lockheed, and it appears that steel can be phased in more quickly than the other two. The advantage of using steel is that we have had three or four years' experience with it, and have demonstrated it can live in this evnironment. There seems to be no particular technical reason why titanium is not usable. Lockheed has recommended using steel.

"We would not rivet or bolt an iron skirt on to the aluminum; we would replace the entire skirt. Aerojet has looked at this problem and we feel confident that we can remove the corroded skirt from a loaded motor, manufacture a new skirt, and replace it on the loaded motor. Presumably, this would be done at the factory.

"Our first thought is to phase the different skirt material into new production and then wait to see whether we have been too pessimistic as far as Fleet operation is concerned."

"Outside the area of the clamping ring the dehumidification should indeed be of great assistance," remarked Captain Gooding.

"Figure 7," resumed Captain Christman, "is a summary of the reported instances of corrosion. As Captain Gooding pointed out, none of these missiles has been used under Fleet conditions. None of them have had the dehumidifiers in operation. We feel that they have seen a worse environment than they will under tactical use.

"The action that has been taken on this problem is shown in figure 8; there are four major actions. First, we are painting the missile skirts and using a moly-disulfide lubricant on the skirt after we apply the paint. Next, we are applying a thin vinyl coating on the launch clamp and the base rings.

A3 FIRST STAGE MOTOR AFT SKIRT CORROSION

MISSILE	REPORTED INSTANCES SUB	TIME	CORROSION
A3E-10	SSB(N)628	24 DAYS	HEAVY
A3E-13	SSB(N)628	1 DAY	STARTING
A3E-05	SSB(N)626	30 DAYS	HEAVY
A3E-03	SSB(N)626	30 DAYS	MEDIUM
AIM-03	ELECTRIC BOAT	UNKNOWN	SEVERE
AIM-08	ELECTRIC BOAT	UNKNOWN	SEVERE
OTHER AIM'S	OTHER YARDS	UNKNOWN	MILD TO HEAVY

Figure 7

"Third, we have sent a letter to the Fleet requesting extreme care in removing any salt from the launcher. We have asked POMFPAC, POMFLANT and the tenders to clean out the launcher area carefully before they load the missiles. We also are planning to retract the clamp except for depth charge attack. It will be disengaged to eliminate any bruising from the clamp mating with the missile skirt.

"Finally, we are attacking the basic problem by planning to change the skirt material for the third and fourth buys. We are also going to study the problem of replacement on loaded tactical motors in the event that we do get a heavy return or get any return, for that matter.

"The range penalty for using steel in the skirt is about 6 n.m., and for the titanium, about 2. From a production standpoint, it really does not make much difference other than a little lead-time problem on getting the titanium.

A3 FIRST STAGE AFT SKIRT CORROSION

ACTION TAKEN

1. SPALT to paint and lubricate missile skirts.
2. SPALT to paint launch clamp and base rings.
3. NWA has painted and lubricated first outload for SSB(N)626 and is continuing to paint.
4. SSB(N)626 launch clamp and base rings have been painted.
5. Determined that TDP 2500 schock requirements are met with painted and lubricated surfaces.
6. All DASO missile skirts will be painted.
7. Paint launcher parts prior to DASO if yard availability permits. SSB(N)631, 627, 633, and 634 will not be painted prior to DASO.
8. AIM missile skirts will be painted and lubricated.
9. LMSC and WEC to test other paints and lubricants as backup.
10. Action being taken to replace skirts on AIM-03 and -08.
11. Investigating changing skirt material in production plus replacement of skirt on loaded tactical motors.
12. LTR to Fleet requesting removal of salt deposits from launcher, retracting clamp except for depth charge attack, care in maintaining dry environment, plus checking and touchup of coatings if needed any time missile removed.

Figure 8

"Figure 9 concerns the low-density problem. We have been accumulating more information and the chart shows the cumulative percentage of motors that have low density up to a given tactical production point. You can see that 43 percent of the motors up to No. 80 have evidenced low density.

A3P INCIDENCE OF LOW DENSITY

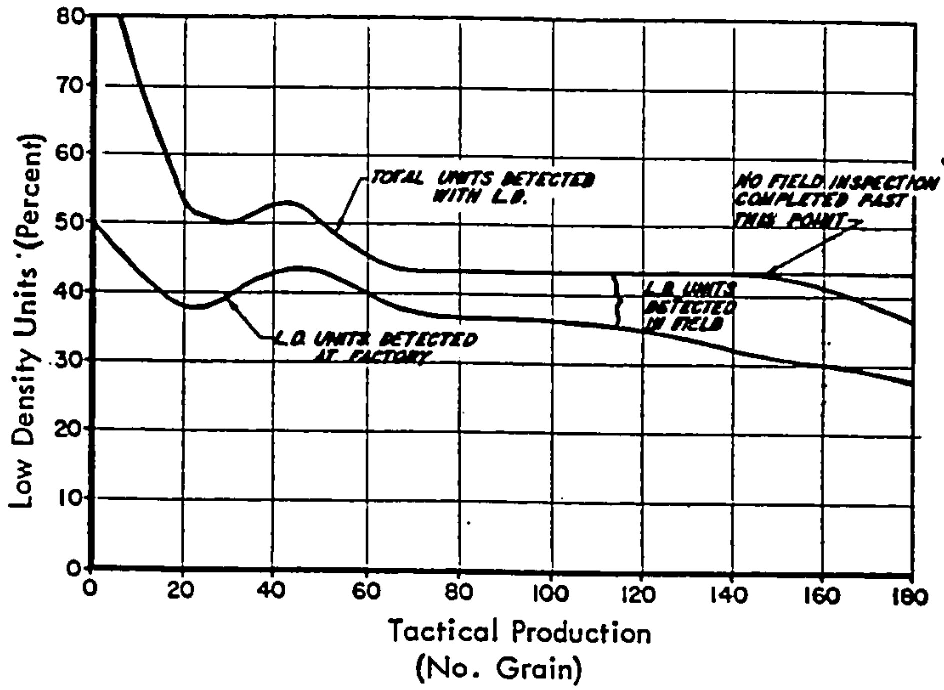


Figure 9

"This whole question of analyzing the low density numbers gets very confusing because you must be sure of the age of the motor. We have found that the number of low density units detected at the factory is decreasing. This means that we are making them at the factory so they do not show an indication of low density. The occurrence of low density has leveled at 43 percent. Instead of low density occurring at the factory and being detected, it is occurring slightly later in time. We are detecting it in about a hundred days at the Naval Weapons Annex.

"We have three major programs in this area. The first has to do with delivery. We require two X-rays at the factory and one at NWA.

We are accumulating experience on the tactical missiles. The SSB(N) 626 has just put out to sea with the first tactical outload; in two months, we will examine two or three of these units to see what the experience has been after a patrol.

"Secondly, we have a mock missile program. One of the problems has been that although we get DASO missiles back with second-stage motors that have not been fired, we are reluctant to break them down because there is such a long processing time at NWA. We are, therefore, making four mock missiles. These are simply missiles with second stages that can be broken down without all the electrical continuity tests. We are planning to use these missiles as riders on various DASO trips, and perhaps let some of them ride until the submarine is to outload at NWA to see what happens under a Fleet environment.

"The third major program is at NAD Concord. We have stored 12 or 14 motors with varying amounts of low-density and case-bond separation. We are X-raying them once a month to obtain growth rates to predict when the low density will transform into case-bond separation.

"Low density without case-bond separation has no perceptible effect on the firing trace. We cannot see anything in a pressure trace, neither shock nor vibration. We do not even see low density by itself. We do see pressure rises where there is an actual separation between an insulator and the propellant.

"All the case-bond motors that we have fired have been successful. We have had no failures. We will fire in about a month one motor which has almost double the case-bond separation of those we have fired to date. However, we think that even that one will not fail because of the location of the case-bond separation.

"Based on fragmentary data on some of the older motors with low density, there does seem to be a tendency for all motors with low density to develop case-bond separations, even in very small amounts. It seems that within a year we can expect every motor with low-density to develop case-bond separation."

In response to a question from Mr. Stevenson, Captain Christman said, "If we have no evidence of low density after 100 or 150 days, we do not see any growth. In other words, they stay clean. Essentially the problem is the one we stated about four months ago. Case-bond separation in small amounts is not a problem. The problem is discovering the upper limit where we know the motor will overpressurize itself.

"We still do not know what causes low density. Movement of motors has been suspected as a cause, as have various arrangements of loading the base grain into the motor, and resins which are in the bond in the insulator area. All we can say is that we have adjusted the process so that we are not making quite so many at the factory that would show low density. The low density that is occurring in the field is, over-all, in smaller amounts.

"The second problem is the nozzle problem that caused our single failure to date in DASO. As you remember, when we got into the program, we were very concerned because Kaiser had shown up with five failures and we only had about 20 tests where they had been successful. We wondered if the population in DASO was going to show a proportionate failure rate. Kaiser appeared to be able to make nozzles better than anybody else, so that,out of the first 50 missiles delivered to POMFLANT,I suspect that Kaiser provided the nozzles for 40 of them; There was a strong possibility that because of the incidence of failures -- if this number on figure 10 were a true indication of the failure rate -- we could be in serious trouble. Fortunately, the flight test results have been very successful.

TACTICAL 14P NOZZLE SUMMARY BY VENDOR

Vendor	Successful	Incipient Failure	Failure
Valley Machine Company	152	2	0
Kaiser Aircraft & Electronics	65	22	5
Thompson-Ramo-Wooldridge	22	1	1
TOTALS	239	25	6
Exit Cone Insert Material			
CS-312	211	25	6
ATJ Graphite	18	0	0
MHLM-85 Graphite	2	0	0
TOTALS	231	25	6

Figure 10

"I have added here the last two flights which have flown since the date of this report, which is the first part of September. We picked up four more Valley and four Thompson-Ramo-Wooldridge.

"These numbers are confusing and I will explain them. The incipient failures are the ones in static tests where we disassemble a motor after firing and section the nozzle to see where the cracks are beginning, although the nozzle itself did not fail. The successful tests include static tests and all the flight tests, so it is very possible that more of these could have been incipient failures.

"The program now is that we were not going to introduce any change into the tactical missile but that we would substitute some ATJ graphite retaining rings for the CS-312 on nozzles manufactured by Valley and Thompson-Ramo-Wooldridge. We are trying to obtain statistics here to support the ATJ graphite as a substitute if we should decide to replace the CS-312.

"Figure 11 depicts the forward nozzle section load path. There are two major forces working on this action. There is the pressure from the motor itself, and a thermal expansion load. The combination of these two puts a net axial load on the exit cone insert.

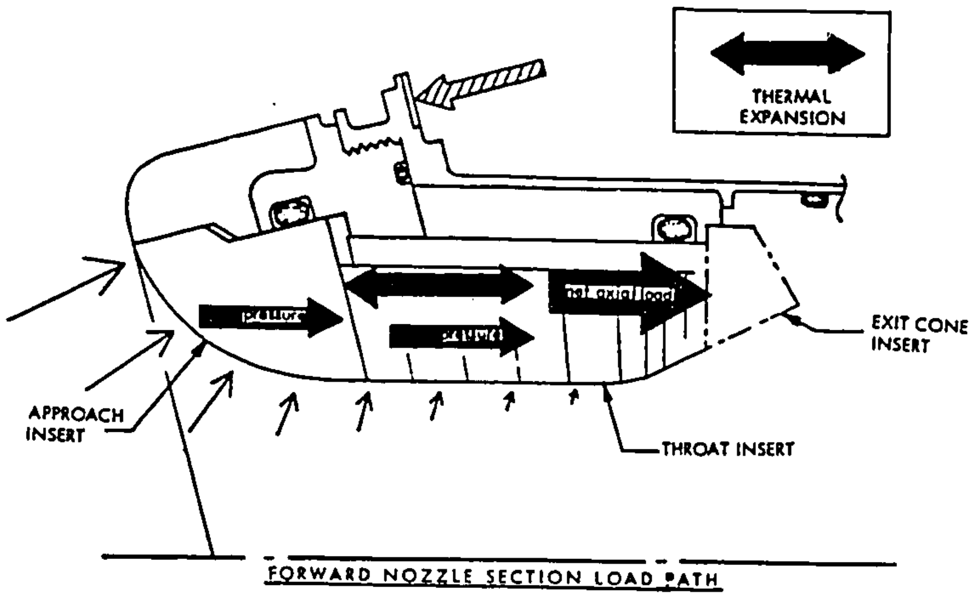
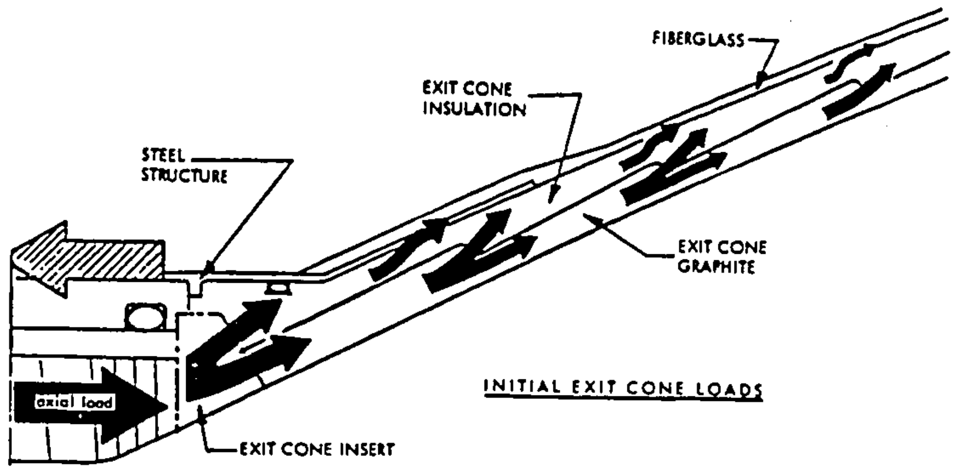


Figure 11

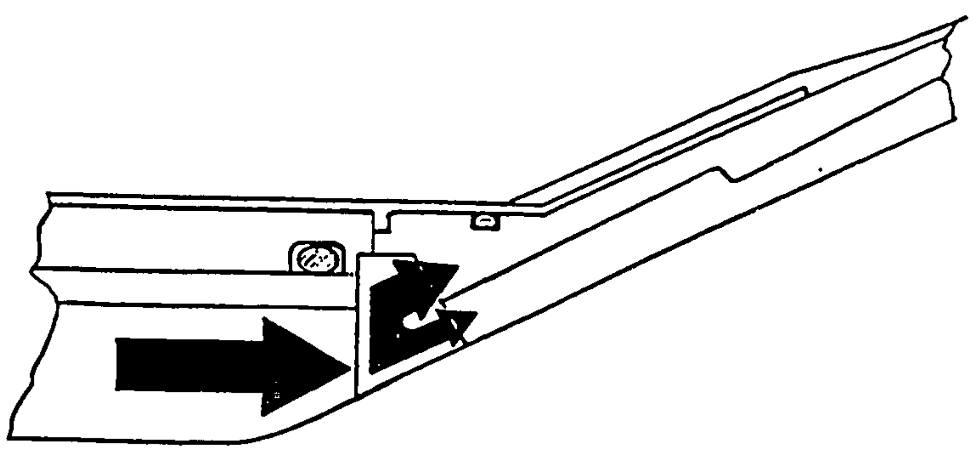
"This axial load goes into the exit cone insert as shown in figure 12. The load is supported by the exit cone graphite and the backup insulation.

"Figure 13 simply illustrates the exit cone load path as the liner deteriorates, and the redistribution of the full load.



INITIAL EXIT CONE LOADS

Figure 12



EXIT CONE LOAD PATH AS LINER DETERIORATES

Figure 13

"The method of failure is shown in three stages in figure 14. An incipient failure occurs when we find cracks in the exit cone insert. In the nozzles that fail, apparently the net axial load working on the locking ring cracks the insert which, in turn, deteriorates the liner depending on how far the failure propagates. This illustrates from a theoretical standpoint and from test data--why we predicted the Kaiser nozzles would have failed, but this does not explain why there have been so many successes. If we analyze the load on the insert, our calculations show that if the insert head can withstand 17,000 pounds, it should be able to carry the load.

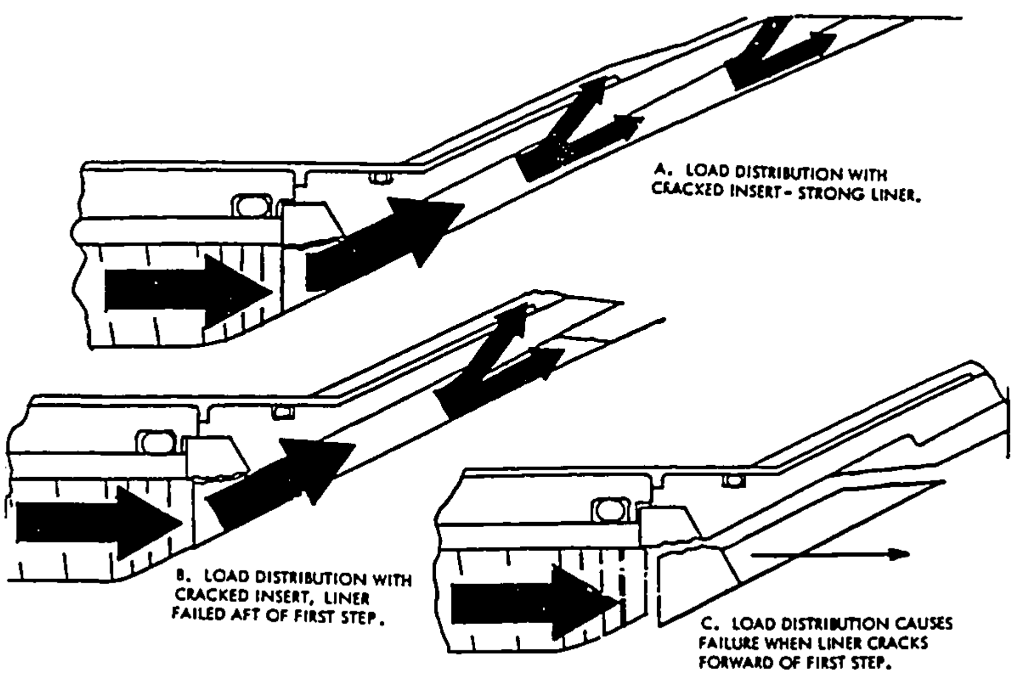


Figure 14

"Figure 15 shows a histogram of shear tests on Kaiser and Valley Machine materials wherein the Kaiser material is theoretically below the so-called safe limit.

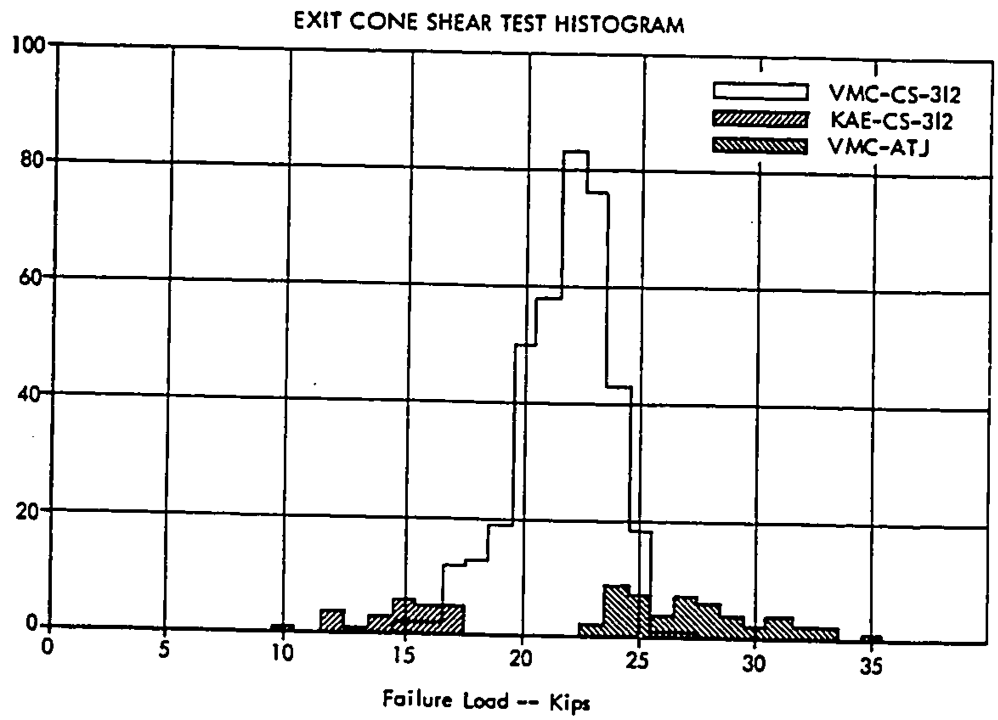


Figure 15

"We have been attempting to devise a test which would determine whether every graphite insert could withstand a load of 17,000 pounds. If it could, we would use it for loading into the nozzle. However, we destroy so many of these that the test seems more destructive than helpful in sorting out the good ones from the bad ones."

Mr. Peterson asked why Valley Machine makes nozzles better than anybody else.

Captain Christman said, "There have been several minor differences in processing noted. We have tried to make Valley nozzles using the Kaiser process to induce a failure. We are also trying to make the Kaiser process as similar to the Valley process as we can.

"Our latest effort has been to fire Kaiser nozzles with ATJ just to demonstrate the backup capability. Fortunately, the statistics are building up fairly well for them. We cannot pinpoint at this time any specific reason why the Kaiser nozzles should have a higher failure rate. Incidentally, they have had only five failures, so it is possible that this could be a learning curve."

"Perhaps the graphite is substandard," remarked Mr. Wetmore. "Since the graphite properties vary appreciably, Kaiser may have been using bad graphite."

"As a matter of fact," said Captain Christman, "two of their nozzle failures came from the same billet. There was some evidence that Valley received their material from one plant and Kaiser got theirs from the other one. So it is quite possible that the problem lies with the material, not the fabricator. We do not know.

"Much of the material we put into the writeup for you is about our test methods. The real difficulty seems to be that with our specifications, based on our current knowledge, we are just not able to test any given ring in advance and tell whether it is good or bad.

"The process used to make the graphite is quite complicated. The material is in and out of kilns, furnaces, screens, and coolers. You can see why it would be a very difficult process to control. The unhappy part is that there is no test that we can make when we get these large billets to pick out which ones might make a uniform product.

"The last two figures deal with some management problems. As 12 out of 13 of the DASOs are successful, and the flights are going off within 10 or 15 seconds of the scheduled time, technical problems are very difficult to find. However, DOD, the Bureau of the Budget, and the General Accounting Office are generating other problems and the program itself is moving into a different phase.

"Figure 16 lists some of the problems that we are working with. We are trying to develop the ability to meet quality and delivery targets concurrent with the advanced-type contracts and value engineering. The problem is setting up a scheme readily understandable to all of us. In value engineering, for example, we see some very attractive cost savings that might be achieved. We have already flown 37 A3X and 13 A3P missiles. Nevertheless, we can see savings of as much as ten dollars' payoff for each dollar that we invest in developing a new component. The problem here is setting up a realistic program to demonstrate the suitability of engineering ideas before we phase them into tactical production, and have time to phase them in."

"It is more than that," commented Mr. Stevenson. "If you have to flight-test them, you have to write off the cost of the flight-testing which reduces the savings of the value engineering."

"Another of the problems we are worrying about is verifying, perhaps on an annual basis, our existing sources. During the first production run, we have done an extensive amount of testing. We have had engineering evaluation tests; we have had qualification tests; we have been flying parts in the various experimental missiles; and, of course, we have had a very heavy DASO firing. The question is whether we should be doing additional ground testing for some possible deterioration in the existing sources.

"I think qualifying major changes and current or new sources is perhaps more illustrative of the problem. However, we are afraid that perhaps unknown to us, insidious changes might be introduced that could lower the reliability we are now demonstrating."

MANAGEMENT PROBLEMS

A. Ability to meet quality and delivery targets concurrent with advanced type contracts and value ENG.

B. Requal annually of existing sources.

C. Qual major changes current or new sources.

D. Ability to restart production lines and recapture demonstrated reliability.

E. Establish tooling plan
 Active: Repair and replenishment
 Inactive: Emergency.

F. Budgeting contractor technical support with more mathematical approach.

G. Establish longrange in-house vs. out-house policy in areas of:
 Logistics
 Contractor technical support
 Repair.

Figure 16.

Mr. Peterson noted that the cumulative effect of very minor changes such as wire sizes, or coating on the pins could be one of reduced reliability, and discovering what went wrong was exceedingly complicated and time consuming.

"The next problem in figure 16," continued Captain Christman. "is one that faces us from day to day. This may be a case where a man has two plants, or his company is reorganizing, or he wants to change the work to a new location. Presumably he wants to make the product as he has always made it. You may remember in the AFDs we had a problem in casting the little housing that held one of the sensitive elements in the fuze because the manufacturer changed his plant location from the East Coast back into the Central States. Our problem then is requalifying a current source, when he has made a change significant enough to warrant a more extensive qualification.

"The problem is qualifying, if at all, second source suppliers, and paying for this qualification. One of the ground rules in the missile program is that we do not consider an item completely qualified unless it has flown in at least five different missiles. When the qualification for a new sources is that his product has to fly in five missiles, we effectively bar him as a supplier."

"Then you have answered your own question," said Dr. Bandtel, "which is that you cannot do it. Is there a great deal of pressure for second sources?"

"Quite a bit," replied Captain Christman. "For example, a procurement review was made by an audit team for the Chief of Naval Material, who audited our field establishments. One of the recommendations was that SP abolish the 'No Change' policy because it was felt significant cost savings could be achieved through value engineering if SP would let these alternate sources be phased in. The General Accounting Office gets involved in some of the recommendations, but the specific one, I believe, is from the Chief of Naval Material Audit Group."

"Let them guarantee Fleet readiness!" exclaimed Dr. Bandtel.

"Item D in figure 16 poses the greatest challenge," resumed Captain Christman. "This has to do with A2s, and ultimately with A3s. We are now closing down our A2 production lines and eventually we will probably close down the A3 production line. From time to time we will have to restart these lines under the current plan and build enough missiles and parts to replace those being fired in operational tests, follow-on tests, and post-overhaul DASOs. How do we restart a complete production line and recapture the demonstrated reliability that we had before?"

"What is the problem with a two-a-month or one-a-month production?" asked Captain Sadler. "Can you sustain this, or do you have to build, for example, 10 missiles a year?"

"I think you maintain a certain reliability," said Dr. Wetmore. "We have had two outside suppliers for our chambers and nozzles on a third buy. We are dropping one of each for the nozzle and chamber and keeping only one. When the fourth buy comes up how do we deal with these qualified suppliers who did not get the third buy? There are two different levels in answer to your question about a one- or two-a-month production. It would be expensive because you would have to schedule DASOs, OTs, and FOTs."

"The reason I asked the question is in running out the program base lines, it is pretty obvious we are going to be building one A2 a month through 1972 in order to meet requirements. As you know, we procure on an annual basis. We only buy those that we need during that current year. Now the need is one a month in A3s, but with more ships, it will go up to two or three a month. I can foresee considerable trouble. There are two ways of solving this -- by building 12 a year or building 12 in one month and then shutting down for 11 months," explained Captain Sadler.

Mr. Stevenson remarked, "The components that start aging the minute they are made, can cause a problem. You do not want to make those until you are going to need them. On the whole, however, I think making components in batches is sensible and reliable. We assume that the technical skills are still available. These are not complex skills we are talking about, but mechanical skills. The production facilities must be maintained, but I do not think this will affect reliability.

"There is no argument about reliability whether these components are made one a month or in batches of 12 once a year. As for economy, making them in batches is cheaper."

"What is the breaking point where you have to work at a level of effort?" asked Captain Sadler.

"In some elements it is two a month; in some cases, much more," replied Mr. Stevenson.

"The problem becomes more complex when it concerns the spares or some type of R&R material where there is not a full year's backlog," said Mr. Peterson.

"Assuming there are other motors, for example, in the system, of a similar type," said Mr. Wetmore, "it would not make any difference in quality if they were made 12 in a month or one a month or in three months if the skill is maintained.

"One problem we have, for example, is in the A2 chamber where special welding skills were developed. We are not now making many steel chambers-- they are all glass. The skillful welders have gone and it will be difficult to get them all back, with their skills intact.

"The best thing we can do on chambers is buy two years worth at a time. It would be better to set them aside because there is no deterioration."

"We in Sp 27 do have to come up with a tooling and facilities plan, as listed in figure 16," resumed Captain Christman. "We must work out with our contractors how much active capability we are going to keep at all of the plants. This includes all the feeder plants and all the suppliers, the chamber manufacturers. Do we dry up to one source? Do we pull all of this tooling back into Stockton, preserve it there, and then draw it out later?

"We also need, first of all, a repair capability; secondly, we have to be able to replenish those parts which are being damaged or which cannot be repaired. Finally, presumably, there will be some sort of inactive or emergency capability if, for some reason, we have to increase our numbers.

"A couple of other problems that we are working on are also shown in figure 16. There has been pressure on all of us to establish a better method of budgeting and estimating our contractor technical support. The budgeteers are not satisfied in general with the approach we have used. We have projected from our negotiated contracts in the past, using increase in number of missiles and complexity to adjust the contract. They now question the amount of money given the contractor in the first place. At the moment, we are trying to come up with a mathematical approach which will enable us to project return and repair and engineering support, SPALT proposals and the like over the seven- or eight-year forecasts that we have to make into the 1970's.

"This becomes even more important in trying to project the cost of programs like B3 and a variety of alternates. Each time a new alternate comes in for B3, the budget people want to know what would be dropped from the current base line for A3 if that substitution were used. So we are almost forced into some sort of logical approach.

"Finally, we are working to establish long range policies on certain problems. There are various pressures, depending on which part of the Government you talk to, to put more work in-house in Government laboratories. There are others fighting to give more work to contractors. This is a problem in logistics, contractor technical services, and repair.

"Our major effort in this area is a study by Booz, Allen and Hamilton. They have been visiting Lockheed, Aerojet, Hercules Powder Company, and an assortment of eight or ten Government activities, to establish the pros and cons of making shifts, and what constitutes a reasonable shift.

"Figure 17 has to do with a new requirement at the Branch level for fixed-price contracts, presumably those primarily let from SP. We will bring all waivers and deviations back to SP for approval, including Category C waivers and deviations. The C waiver is a category of defect, generally of workmanship. Most of our contractors, the local government inspector, and the inspectors on the floor, grant this type of waiver. it deals with minor variations in process or authorized repairs where, say, a scratch is found on a metal piece and there is some way of honing it out or replating it. It is now proposed that these types of waivers come back to SP if the contract is fixed price.

"There is mention of a Category D, but so far I cannot define Category D other than corrections which do not result in cost benefits to the contractor. So it looks as though the use of that category will be limited."

"This is classification of what kind of document? Where is this classification referenced? Where are the definitions?" asked Mr. Eyestone.

WAIVER AND DEVIATIONS APPROVAL
UNDER FIXED-PRICE CONTRACTS

"Each cognizance branch must be the reviewing technical group for all Class A, B, and C waivers and deviations, certifying the acceptability and specifying to the contracting officer the effect on cost."

"This category "D" will be limited to insignificant variations from contract requirements which in no way will have any effect on the usability of the product. It is clearly in the interest of the government to grant the waivers of deviation, and does not result in cost benifits to the contractor."

Figure 17

"The definitions are in a SP letter, dated 1 July 1959," replied Captain Christman. "They are pretty well understoond throughout the industry. The best reference point is the drawings. Generally, the A and B categories are all contained in an Ordnance Classification of Defects. You have, therefore, a very specific list defining an A category discrepancy or a B category discrepancy. By inference, any other requirement on a drawing or specification falls into a C category. The A category is the most severe. It includes items which have to do with safety or interchangeability."

"The C category pertains to what we call 'cosmetic' defects," remarked Mr. Eyestone, "a scratch on paint or a finish. The B category is a performance defect, and A is safety of flight."

Mr. Buescher noted that the new requirement on category C waivers concerned firm fixed-price contracts, not fixed-price incentive contracts.

"There are two reasons for this," remarked Captain Gooding. "One is the obvious one of the cost implication. It would be possible to have to pay a lot of money for correcting a minor defect. The other reason is that in the long run we are probably going to lose the very large inspecting force we have in the field with their deep knowledge of what is going on. We may be forced to have inspectors on your floors who really do not know the POLARIS system and, therefore, whose competence to decide between a C and a B category is far less than that we now have."

"If that is the intent," commented Mr. Stevenson, "then we can work this out ourselves because you can determine those things to which the special learning of the inspectors is sensitive."

Captain Gooding remarked that there was no intent to be completely unreasonable about this matter.

As there was no further discussion, Admiral Smith called upon Commander Julian to present the Re-entry Committee Report.

RE-ENTRY BODY COMMITTEE
REPORT DISCUSSION

"Good afternoon," said Commander Julian. "Dr. Mechlin, as you have noted, is not here today. He is participating in the deliberations of a new DOD study panel called PENEX. PENEX is a six-month study to begin within a week. It will involve large segments of the non-profit, DOD-oriented community in the country, and will be led by Ben Alexander of the Defense Research Corporation, who also led the INTERCEPT-X studies. The INTERCEPT-X studies were instrumental in setting up the NIKE-X program and the Bell-SRI-AMC work now being done to define a new SPRINT-MAR defense system.

"The study panel is headed by a three-man steering group. Dr. Fink, Assistant Director (Defensive Systems), DDR&E, is the chairman. Mr. Geckler and one other person complete the steering panel; these three coordinate and run the study.

"One of the two groups that will act as their staff is a service liaison committee. We have nominated two people from the Navy; JCS, DIA, and AEC have members as well. They will advise the steering panel and, I suppose, the chairman of the study. On the civilian side is the technical review panel of which Dr. Mechlin and Dr. Lobb are members. This panel and the service liaison committee advise the study chairman.

"Under the chairman are three working groups, headed respectively by Dr. Pierce of Aerospace, Dr. Earl Crisler -- temporarily, until Dr. Bruechner is available and Professor O'Neill, on loan from Columbia University. Mr. Leete (LMSC) will be working in these

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groups. They have had some difficulty with the agenda the first two days of this week. However, I think the groups will see their task divided into three areas. One is an evaluation of the present U.S. strategic force capability. The second is the future of these systems--how they should perform against any postulated threat. The third area is that of the threat. In other words, what is a workable defense system and when will it be mounted?

"To recapitulate in perhaps a better order, the first group would evaluate present force capabilities and with the other two groups, decide which system can do the job best.

"The second group is concerned with the threat definition.

"The third group then deals with a postulation of various defense models, and examines all the techniques available for penetration. It trades these against each of the basic systems available to see which has the greatest potential.

"We have decided that the results of this study panel will greatly affect the future of all strategic missile program plans, including our own. Therefore, before the study is too far underway, we have asked to give the entire group a thorough and technically competent briefing on the content of our current and projected FBM programs. We have asked that this briefing be scheduled for 19, 20 and 21 October. Lockheed will lead the briefing and may require the participation of the other sub-system contractors.

"The Admiral would like the briefing to be in SP, or at least in Washington. Since there are so many people involved -- 50 or 60 in the study group alone -- it seems logical to have it here rather than California. There are, however, some advantages to having the briefing at Lockheed in terms of viewing the mockups and the like.

"I do not know the agenda in detail at the moment, but I think we will be called on from time to time during the next six or seven months to provide study inputs for the panel. The study may be funded by foundation research funds from each of the contractors.

"As you know, we have added one more missile to the inventory of the A3X flights so now there are three rather than two remaining. The new missile is A3X-61. We did this deliberately for several reasons. We were criticized by the DDR&E review group directly and implicitly because our multiple objectives on the last two flights did not satisfy their objectives for testing the instrumentation complex at Kwajalein.

"As a consequence, we have changed the configuration on the three final missiles to fulfill rather specialized sub-system objectives, as well as the FBM system development objectives.

"On A3X-13, scheduled to be fired about 20 November, we have basic missile, re-entry system, and some wake investigations objectives. We have changed the material on the cover of two of the bodies--one to teflon; the other to beryllium.

"The next missile will carry only our PX-2, and will have a PX-2 system objective. The people at Kwajalein are most interested in this missile because they have objected to our combining wake and penetration aids objectives besides all the other system objectives. If we are looking for one ohiective, we may get some results; if we are looking for all of them, we may get none. While we do not really think this is true, the overriding importance of getting the system performance objectives accomplished has led us to accept this attitude.

"The result of the briefing given to DDR&E about a month ago on this subject is that they expect something else as a response. The something else was a full-fledged proposal from us to mount a program for IRBM-observables testing in Kwajalein. This would be specifically directed at the data objectives for defensive system development of the Army, Lincoln Laboratory, and DDR&E.

"I think we should pursue with PMR discussions already begun on the configuration of a range ship to perform the launch-safety functions. We have been firing from Johnstone Island and using the radars based on Johnstone Island. The range safety officer has required PMR safety criteria there, which are somewhat more stringent than AMR safety criteria. The A1, for example, was evaluated because of the over-all interest in the Mark 2 and Mark 12. The preliminary range investigations indicate we cannot go the necessary 1423 miles; we would be 100 to 150 miles short. This means we could not use Johnstone Island for the same range safety purposes that we did before. It will mean moving in to accommodate the range safety requirement. This is where the range ship comes in. The proposal for A1s would not require our money; it would be funded by ARPA or DDR&E and managed by SP.

"We have plans, but not money yet for flying six A1s with Mark 12s specifically for verification of the Mark 12 fuzing system in POLARIS trajectories. It may be possible to divert a batch of these A1s into Kwajalein rather than AMR as we now tentatively plan.

"The Air Force interest in the IRBM-observables proposal would be quite limited per se. I think this proposal might be oriented more towards the Army objectives."

"There could have been other ways that DDR&E could seek to stimulate management of this program," remarked Dr. Bandtel. "They could have had the Army run it or have done a number of other things. Am I to understand that they are really soliciting this proposal from you? If this is true, the only conclusion I can draw is that there seemed to be no other effective program manager that would satisfy the requirements from their view."

"You can look at this two ways," explained Captain Christman. "One way would be that the U.S. ought to know what the POLARIS looks like so we can see whether an enemy would knock it out of the sky. If you think of it this way, you would be establishing the vulnerability of the POLARIS system. It appears this is primarily the way the program will be oriented.

"The other side of the story is what the Army can see from the ground. If you were primarily interested in that, it would be an Army project which is the way Commander Julian describes it."

"Mr. Eyestone asked if the proposal were for A1s or A3s. Commander Julian replied that SP would probably respond with an A1 program. "I do think closer examination of the interface hardware requirements may show that an A1 could get there with a single Mark 12 or a single Mark 2," Commander Julian said.

"The primary interest at Lincoln Laboratory is with sharp-pointed vehicles," continued Commander Julian, "because the Bell, AMC, and Stanford Research Institute discrimination studies show that there is an intermediate class of sharp bodies which may be indistinguishable. The blunt bodies are fairly easily identified because there appears to be quieting of the cross section at a certain altitude where the normal shock becomes very intense. The opacity of the shock wave results in backscatter from it rather than the re-entry vehicle. The shock wave has about the same nose radius of curvature as the body. At about 200,000 feet, the cross section which has been jiggling all over quiets and becomes very close to the value that is measured in static range of that body.

"The blunt bodies seem to be discriminable. Heavy cones seem to be discriminable because they dump so much energy into the atmosphere that the wake velocity and temperature can be measured. Techniques for sampling wake temperature and velocity are well advanced."

Captain Sadler asked why A1s were selected with their poor reliability factor, and Commander Julian answered that the A1s will be available and are relatively cheap. "They have poor reliability compared to A2 and A3," said Commander Julian, "but are still much better than some systems which have been flying this kind of experimental program. The ATHENA program, for example, has had one success in five firings. The A2s are quite expensive. The people who are funding this program may be able to buy an expensive vehicle, but if not, one alternative would be an A1-based program.

"Recently, as a result of CNO Advisory Board action, the PX procurement plan was revised slightly. For PX-1, we will have bought, in effect, 4-1/2 systems per boat for 13 boats, the number needed to cover our DASO expenditures, plus a few that went into special tests, and one quarter of the total OT's and FOT's through Procurement Year 1966. This turns out to be a total of 85; we have in fact more than that in inventory. Our present plan is to procure no more PX-1s.

"For PX-2, our plan is to purchase 4-1/2 systems per boat for 28 boats, six for DASOs, plus one quarter of the total OT's and FOT's through Procurement Year 1966. This turns out to be about 134 systems. We are tooling the PX procurement line to a rate capability of 21 per month although we will not need that rate to produce 134 PX-2s.

"We have prepared a schedule of costs showing the lead time and number of dollars required to start from the interim inventory which has been accumulated according to the present plan and fill a heavy demand. In the case of the PX-1, since we are not buying any additional tooling, we would have to continue at the rate of roughly nine systems per month, and it would be approximately 22 months from the time of the initial demand to the time we reach the rate of nine a month. In the case of the PX-2 systems, it would take about 24 months from initial demand until full-rate production, and it is expensive. Administration, procurement, fabrication, and lead time and reaching full-rate capability are appreciable periods and are costly. We made this revision in PX plans to ensure against buying something that would become obsolete before we needed it or could find a requirement for it.

"Today was the date the UK re-entry system people needed the first increment of their R&D order, and all the parts to be sold under the POLARIS Sales Agreement are available for shipment. All the parts to be sold under the 1958 agreement are awaiting air shipment to the UK, so we have satisfied the first increment of the R&D order. This hardware and the other parts of the R&D order will be used to educate the people at the Royal Ordnance Factory in assembly techniques, to assist them in sizing and fitting the warhead and help them plan their capability and confidence test program.

"Because we had a favorable schedule position at this time, we were able to satisfy this first increment. The order was filled partly with tactical hardware and partly with production sampling and test and trainer hardware which were diverted. Satisfying the other increments of this order will in turn depend on our schedule position at that time. We have not given the UK any assurances that we can do this and we guarantee delivery in about 12 months from receipt of the purchase order. I think we will be able to do it.

"Right now we are evaluating their tactical procurement order. A UK production survey team left yesterday to visit Lockheed. From there they will go to the Cape and AEC installations and then to AVCO and back here. While at Lockheed, they have a very important job to do; they must go through what they consider to be their operational requirements to get the required capability in five boats. They must ensure that their lists are correct in segregating the AEC from DOD parts according to the 1958 agreement, and in differentiating between parts under the Sales Agreement and parts for which an AEC procurement document must be developed. Pricing will have to be handled here at SP because the material is in three different categories and different pricing schedules will apply. They will have to define at each point in their stockpile-to-target sequence their handling, processing, assembly and dismantling requirements so we can advise them on the surface support requirements.

"Because of the administrative and contractual lead times, they must give us a firm production order by 15 December 1964 in order to start their hardware program in the middle of 1966. It is also quite apparent at the present time that although they would like to extend their buy through several years, fitting it in with the rate at which their ships will be deployed may require the pre-buy of a large inventory and then storing of these components for their ships.

"This, of course, raises problems of packing for storage, storage inspection, whether the storage need be environmentally controlled, what re-acceptance is necessary, what inspection they must do out of storage, what refurbishing must be done, and so on. So they have to decide back home among these alternatives based on what we suggest to them as the best course of action. It would be totally uneconomical, for example, for them to insist on our producing AFDs for three years after our line is done. They just could not afford it; it would be foolish. There may be a way at the end of our production line to produce at a rate not quite as high as ours but still somewhat greater than their need. This would save them money and still not give them too much of an inventory problem.

"The statutory determination, which is an agreement between the AEC and the Department of Defense, that the UK may buy certain parts and have access to certain information, was passed through the Military Liaison Committee yesterday and is on Mr. Vance's desk today for signing.

"In Article VII of the POLARIS Sales Agreement, is a commitment by the U.S. that the UK can participate in the inspection process. This means that their inspectors can walk down our lines and review what is going on at each point for over-the-shoulder fabrication techniques. This license does not extend to DOD plants for parts destined to be sold under the 1958 agreement. A part sold under the 1958 agreement is designated as a non-nuclear part of an atomic weapon and, therefore, inspection of our lines will disclose stockpile information. Since the British are already privy to most of this information because of their own program, they are going to be allowed into DOD plants making parts to be sold under the 1958 agreement, under the terms of the statutory determination.

"DOD has requested that this agreement not be implemented until the President has signed the sales program. This is troublesome, because on 11 November, the UK people had planned a visit through our plants, with their electrical inspection personnel and representatives of the Chief Inspector of Naval Ordnance. And administrative delay is inevitable in getting this agreement to the President after Mr. Vance signs it, so we have asked that the visit be postponed for about two weeks."

"We do have a problem on handling equipment for the re-entry system hardware," remarked Captain Christman. "They had not originally asked for it and we thought they did not want it. Recently they have changed their minds. We can furnish it to them, but unfortunately we need it back in about four months. We have a procurement problem."

"We cannot give them the production drawings for the SSE," commented Commander Julian. "We can give them production drawings for any part of the atomic weapon only. The Sales Agreement states that we will not give them a production capability. It is very involved. They have a lot of money committed in the program, over a $100 million to date. They are buying from AEC, complete flare assemblies, bond shell assemblies, AFDs, and the thermal battery. They are buying some honeycomb and various connectors and cables. They are going to put their own back coverplate on and the inside has to be of their design.

"We have discovered a number of minor problems during the few weeks that we have been assembling the Mark 2 re-entry body at POMFLANT. None of these is caused by design deficiencies, but there are problems. For example, we carry extra missiles on the DASOs which are completely assembled as though they were going to be fired. During the disassembly of two of these re-entry systems, we found the monoballs were completely stuck. The monoball is like a universal joint through which is a bolt that the flare and separation ring are attached to. It took an awful lot of work and torque to free it.

"The monoball is not a functional part to the system; its position dictates the alignment, but not too critically, when the system is assembled and it does not stop the tilt-out. Nevertheless, we would like to know what made it stick in the bearing. The bearing race is made of teflon. It may be that in the assembly operations, which are horizontal, the teflon is loaded and deformed. Subsequent vibration may set it so it cannot be moved.

"Another minor problem is a number of instances where we have discovered minor nicks and cracks and surface defects in the ablative shell. As a matter of fact, we had initially set up a repair or reject critieria which I thought was pretty generous, but we got a lot of defects which did not fall within the criteria, so we further relaxed the criteria. Of approximately 100 assembled warheads which have been delivered to NWA, there are about 11 that arrived with cracks and nicks in the shell. And after an examination we still have just three out of a hundred that we have not yet resolved. We are trying to determine if these can be repaired.

"The defects are all in tactical shells. We have agreed with the AEC that they must inspect these shells at each point in their assembly sequence. Our ablative shell goes to Bendix; it is bonded there by AEC to the magnesium sub-structure. The bonded structure goes from Bendix, Kansas City to Oak Ridge where the secondary nuclear system is put in, and from there to Pantex, the final assembly point. We and the AEC have agreed that at each point where a defect that is repairable is discovered, it will be fixed at their facility. This includes Pantex as well. In fact, we decided earlier that any defects discovered at Pantex would be noted and sent on to Charleston for repair, but the AEC has decided it can repair at Pantex as well as we can at Charleston.

"It is important to note that the two A3X underwater firings and all the DASO shots to date were successful; we have had no system deficiencies disclosed in the re-entry system. All of the AFDs performed satisfactorily.

"The Mark 12 program is the joint Navy-Air Force development of a re-entry body, and is on schedule.

"We, the Air Force BSD, and Aerospace have been studying a set of weight reduction proposals. We hope to reduce the weight of the bare vehicle from 365 to 350 pounds. We have been told, as a matter of fact, that anything over 350 pounds will not be acceptable.

"The weight reduction program indicates that we can cut the weight to 350 pounds without prejudice to our vulnerability criteria. I admit that it was our insistence on the vulnerability criteria that added some of the weight to this vehicle. A weight of 350 pounds can be reached by taking advantage of other weight-saving features possible.

"I think that our criteria are realistic, and I think the Air Force agrees with us, although they find it difficult to admit."

"Do the vulnerability criteria have to do with the radar cross section?" asked Mr. Eyestone.

"No," replied Commander Julian. "This concerns neutron vulnerability basically. The system that was in has been shown in a brief experimental test at Livermore to have very poor resistance to high-energy neutrons, whereas the system that is now in has much better resistance."

"Did they ever open up the definition of the warhead classification?" queried Captain Christman.

"That is still being argued," explained Commander Julian. "The AEC would like the entire re-entry vehicle to be classified SRD or RD in some way. The Air Force strenuously objects to this because the vehicle is in three sections: the forward cone, the middle section containing the warhead, and the aft section containing more of the fuzing device. If it is classified RD, they will have nothing but problems in their logistics sequence. This is not resolved. The AEC is certain they will win. The Air Force is certain they will. I do not know what is going to become of it.

"In the last few weeks, we have undertaken several studies which might interest you. The studies are made generally in response to requests from CNO. The most recent one is a study of providing the Mark 1 and the Mark 2 re-entry body or warhead with the ability to be fuzed at a very high altitude, as a percursor bursts at 200,000 or 225,000 feet. We have been asked to try to devise a very quick method to use for both systems, and then to study a sophisticated approach which would preserve all the fuzing options we now have.

"We have preliminary answers on the quick, unsophisticated fix and it was not as quick as I had hoped. The preservation of nuclear safety imposes some criteria which state that there must be sampling of two different kinds of environment unique to flight. We have considered, therefore, using a very low level G integrating device, or a vacuum sensor. These do not operate until you are well up in the exosphere. They have not been developed yet and will take an appreciable amount of time and money. As a matter of fact, it is thought that those two safety devices would be the pacing items in a quick fix and would take about 18 months. I think it can be done a little more quickly.

"Aerojet (Dr. Kirchner and Dr. Wetmore) have studied the comparative features of a hydrazine fuel and a solid power fuel power unit for our advanced PX program requirements.

"Another study is one that examines the sensitivity of POLARIS against advanced defense models -- rather unique ones. This study is called Project HIGHBOY. We have conceived a defense model that uses a radar frequency quite unlike those that are normally projected. It does not, in fact, include the characteristics of a terminal defense system but rather those of a multistatic area defense system where there is one transmitter and a number of receivers which are passive, and the receivers receive the reflected signal from the transmitted beam. It is possible to speculate that such a system used in certain ways would have a capability for tracking a re-entry cloud in mid-course well enough to send up an interceptor."

Captain Christman asked Commander Julian to speak about the FOOTPRINT program.

"Single re-entry body ejection from the B3 re-entry platform and the ability to direct the platform and fly it to a new velocity vector each time also gives you, depending on total fuel and energy capacity in the platform, the potential ability to attack widely separated targets -- one vector for each of the re-entry vehicles on the platform.

"Our preliminary studies show that it may be possible indeed to interdict with a single missile a very large area in which there could be half a dozen or more targets and put one re-entry vehicle/warhead on each of these targets. This means in effect if you go after undefended targets and you have five or six re-entry vehicles, you can fly one missile and attack five or six targets. It is a way of increasing very substantially the total number of targets attacked with a limited missile force. The size of the area depends on the geometry that you really want. The shape is quite sensitive to where the targets are.

"The Air Force is quite interested in this as well. Their program is called MIRV -- Multiple Impact Re-entry Vehicle. In the MAILMAN program, we have a somewhat limited capability without putting more fuel on the platform, but there are ways of putting more fuel on a platform, in fact, on a trade-off basis. If you look ahead a bit, using a smaller warhead like PEBBLES, you might be able to put 12 warheads on 12 individual targets in that manner. DDR&E is making an intensive study of this same capability.

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SATELLITE-BASED GLOBAL NAVIGATION SYSTEM REPORT

Presentation Given by Dr. R. B. Kershner

The Steering Task Group was called to order on its second day of meeting by its Chairman, Rear Admiral Smith. Admiral Smith called on Dr. R. B. Kershner of the Applied Physics Laboratory of Johns Hopkins University for a presentation on the current status of the satellite-based global navigation system.

"This Steering Task Group," began Dr. Kershner, "was one of the pioneer motivating forces in our development of a satellite navigation system, and it has been some time since I last brought the STG up to date on progress and developments in this program. Since we now have reached a point where the initial goals have been met and the ultimate goals are in sight, it might be appropriate for me to discuss how the program has gone, where it now stands, and what it can achieve in the very immediate future.

"One happy indication of the way the program has gone is that I can use figures, such as figure 1, that are as much as five years old and are still valid; it does not ordinarily work out that way. The basic concept is exactly as it was when initially proposed six years ago and it has been implemented in exactly that form. Figure 1 is about five years old and is almost completely valid for the system that has been implemented in the past two years.

"The concept was to establish a series of satellites in polar orbits. Then, for a brief time, they considered other orbits but they reverted to the polar orbit and have stayed that way ever since. These satellites would be placed in about 600-mile altitude orbits which would be fixed in inertial space. Since the earth turns within that fixed circle in inertial space twice a day, any spot on earth passes under the orbit; during the time it is doing that, you can usually get two or three opportunities to navigate within the range of acceptable angles.

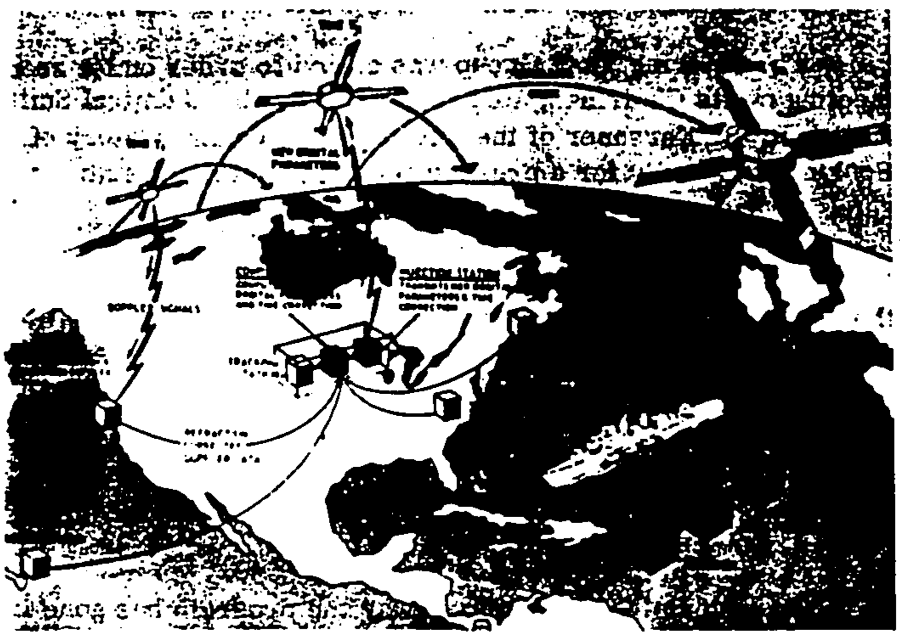


Figure 1

"Thus, from a single satellite in orbit, we can get four to six opportunities per day grouped in 12-hour intervals to obtain a navigation fix. To obtain a navigation fix from the satellite, we determine our position relative to the satellite by an analysis of the Doppler shift generated on any stable oscillator. With a stable frequency transmitted from the satellite, the Doppler shift is due to the relative motions of the satellite moving in orbit and of our point on the rotating would be fixed in inertial space. Since the earth turns within that fixed circle in inertial space twice a day, any spot on earth passes under the orbit; during the time it is doing that, you can usually get two or three opportunities to navigate within the range of acceptable angles.

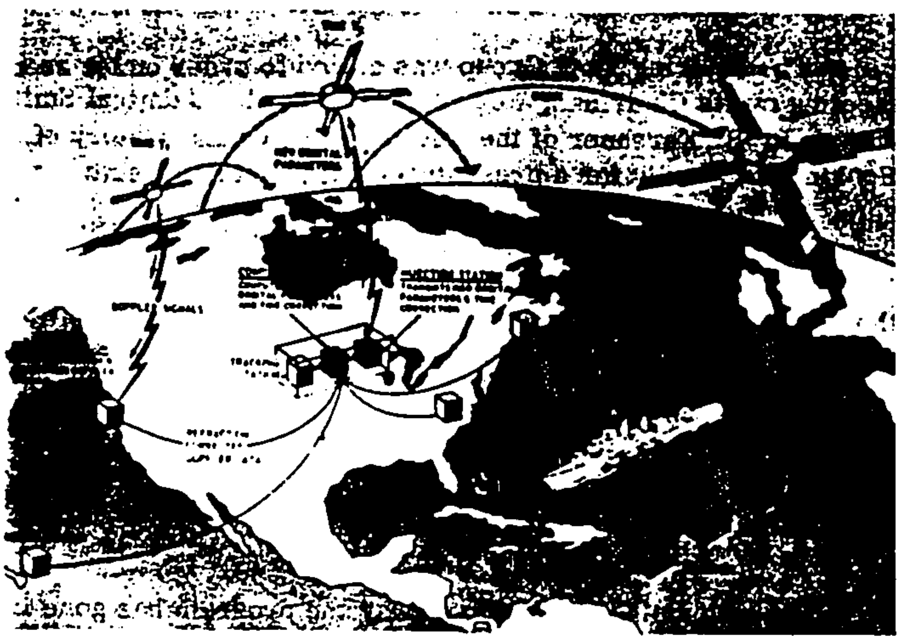


Figure 1

"Thus, from a single satellite in orbit, we can get four to six opportunities per day grouped in 12-hour intervals to obtain a navigation fix. To obtain a navigation fix from the satellite, we determine our position relative to the satellite by an analysis of the Doppler shift generated on any stable oscillator. With a stable frequency transmitted from the satellite, the Doppler shift is due to the relative motions of the satellite moving in orbit and of our point on the rotating earth moving under it. With a sufficiently stabilized oscillator, we are able to make an analysis of this Doppler shift to get the relative geometry of our position and the satellite position with exceedingly high accuracy. The problem of determining a position on earth comes down to knowing the satellite's exact orbit during the time it passes you. To determine the satellite's orbit, we use the same technique and analyze the Doppler shift generated as the satellite passes over a fixed observing station on the ground. While these are called tracking stations, the word tracking is misleading; they only have to measure frequency and a Doppler curve. The computations can be done at the station and the results sent to a center where all the analysis is done.

"Four of the proposed stations have been established and operating for well over a year--at Winter Harbor, Maine; Minneapolis; Point Mugu; and Hawaii. Figure 1 is in error in suggesting that the computer center would be at Minneapolis; it is located at Point Mugu. The data is sent to Mugu where the orbit of the satellite is computed for the time in which the tracking data were accumulated, and then extrapolated for about 12 hours into the future. In other words, we obtain a collection of numbers from which the orbit can be generated; these numbers are sent by an injection station to the satellite where they are recorded and automatically re-transmitted on a two-minute interval for the benefit of any user. The user obtains the orbit position of the satellite from the satellite itself as it was determined within the past day on the ground. This orbit is valid for the time of the observation because it is based on an extrapolation from the ground.

"The computer center is operating, the injection station at Point Mugu is operating and we have two satellites which function fully in accordance with this intention. One of them has been in orbit and functioning perfectly since December, the other since April. Their orbits are 90 degrees apart and permit a series of observations approximately every six hours. In any day from any location we can get 12 to 18 fixes.

"The initial plan was as in figure 2 to have four polar orbits 45 degrees apart which gives a fix capability roughly every 110 minutes. We plan to launch a third satellite within a very few days, but we have not yet decided about placement of a fourth satellite in orbit. The three satellites will operate for quite a while, and we have no current users who need more frequent fix information than can be obtained from just two satellites. The point of the third satellite lies only in the possibility of one failing; we need to have two functioning satellites up there.

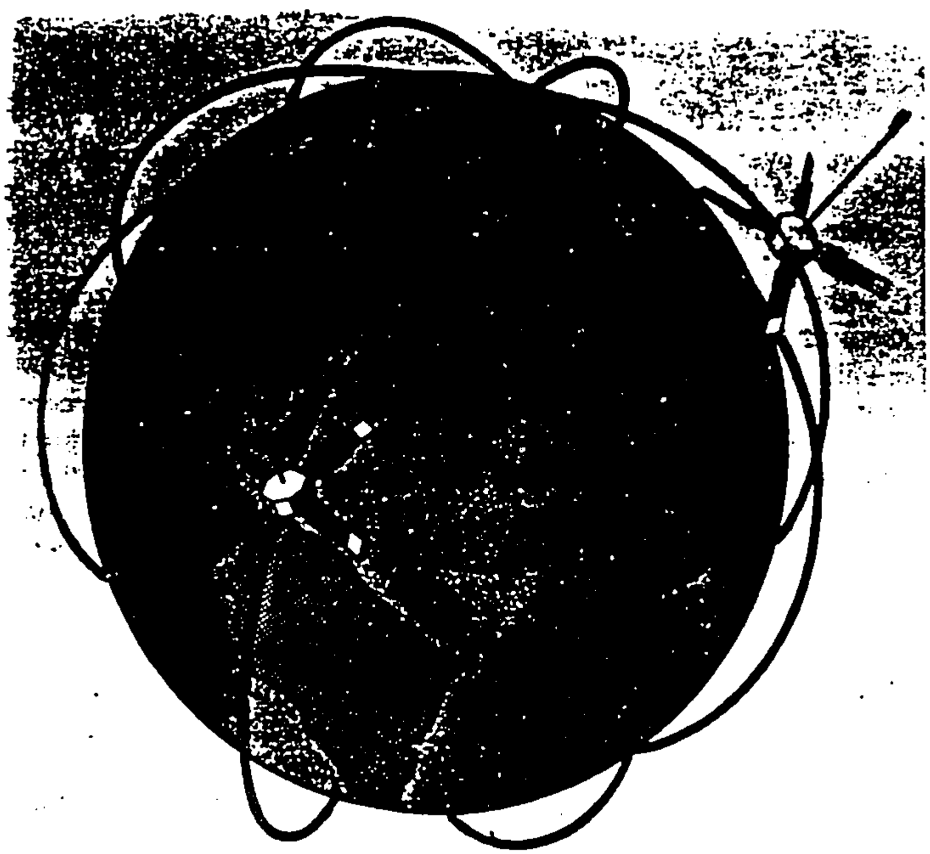


Figure 2

"The present orientation of the orbits is 90 degrees and the third satellite will come in between at 45 degrees. If our original plans had called for only three orbits, we would have placed them at 60 degrees and 120 degrees instead. Incidentally, one of the present orbits is not quite polar. This satellite was put up by a SCOUT vehicle and it is continually precessing to a slight degree so as to open up the 90 degree slot. The new satellite will be placed into this widening slot and should give us a better orbit for fixes than does the precessing satellite.

"The injection station, figure 3, is based on a 60-foot antenna with an XY mount. The first of these was established at APL and has been functioning there for some time as a prototype to prove our capability of injecting a message into the satellite; this was accomplished. The second station differs only in the local terrain; it is identical as far as mount and dish are concerned. It has been functioning from Point Mugu in regular daily service since February.

"A third injection station with a slightly different antenna is being constructed at Minneapolis. It will soon be operating to give us two operational injection stations.

"The two satellites now orbiting are not identical. Each is a prototype of a potential operational configuration particularly with respect to the power supply. One of them is the first operational satellite system designed; at the time, we did not know whether the solar cells would meet a five year life and we did not have enough experience with satellites. We had two potential power supply systems developed and we could not choose between them on the basis of ground tests. So we installed them, one in each of the first two satellites, to prove their reliability and service life. Figure 4 is the power supply using the radioactive isotope of plutonium as its active element; the isotope simply generates heat and is surrounded by a series of thermoelectric generators which convert heat to electricity. Cooling is effected by the radiating fins shown on the figure. The thermal gradient is maintained by decay of the isotope in the center of the generator. The system works quite well and should continue working for about five years unless some unanticipated trouble occurs. In theory, the generator should work for 30 to 40 years, but we have discovered that we have a slight gas leakage from the pressurized generator which is cutting down the life span of the unit.

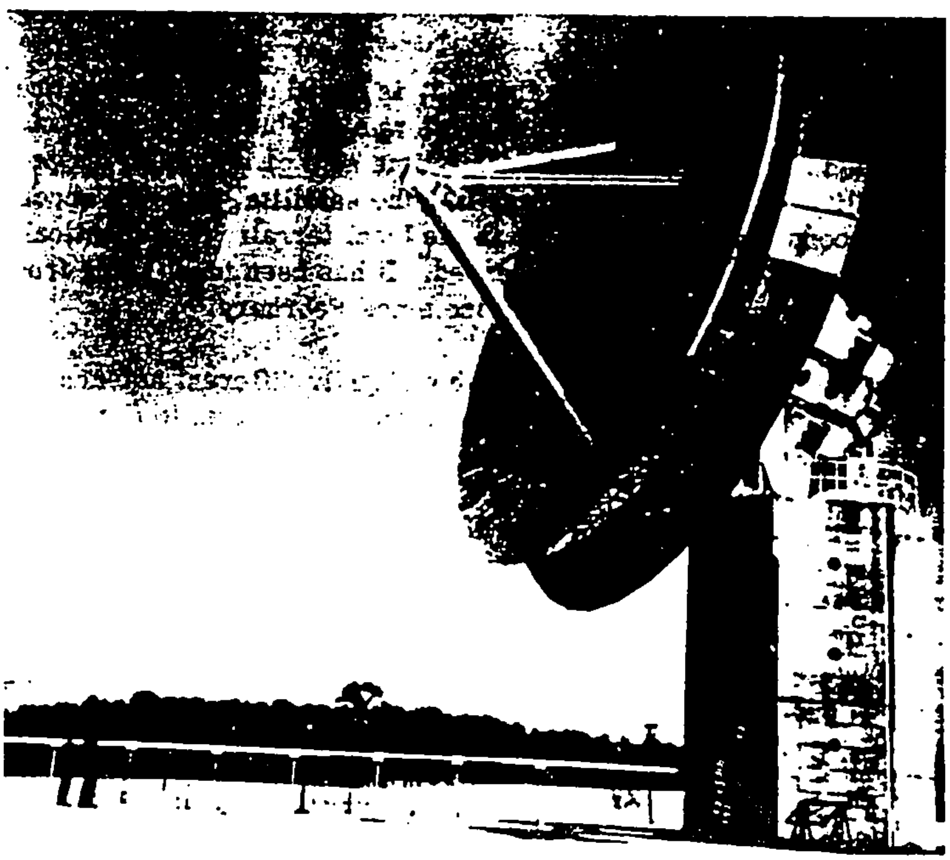


Figure 3

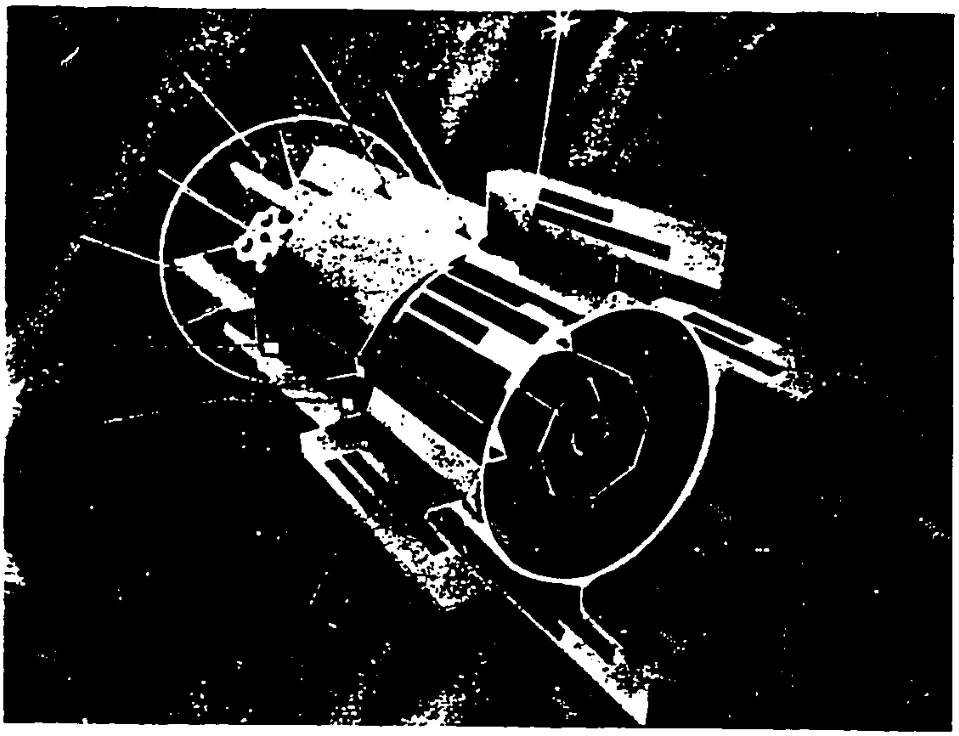


Figure 4

"The configuration of this satellite is dictated by the necessities present when dealing with radioactive materials. The unusual looking fins will ensure that the unit will assume a proper re-entry angle for destruction should there be a bad launch. The design will ensure that the radioactive materials are dispersed at high altitudes, should the attempt to orbit fail. The safety requirements in launching radioactive materials gave us many aerodynamic problems that are not usually associated with a satellite. Figure 4 shows the satellite as launched, and figure 5 shows the changes that occur after it has been in orbit a few days.

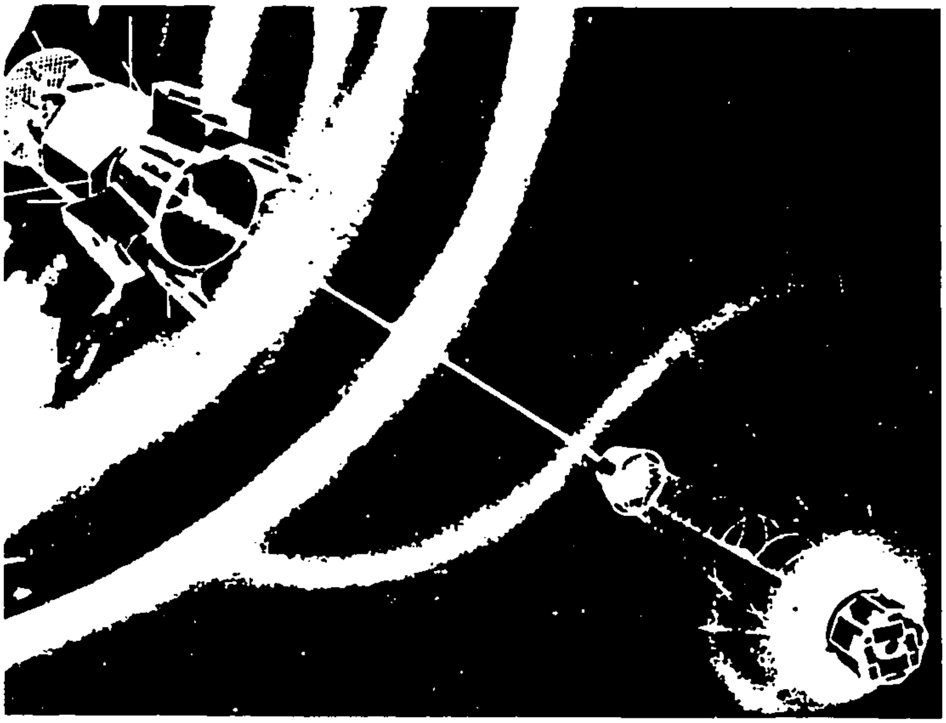


Figure 5

"In connection with this program, we have developed the concept of gravity gradient stabilization. We stabilize the attitude of the satellite by use of the fact that the force of gravity falls off according to distance from the earth. Given a satellite with enough dimension or distance across itself, the difference in the force of gravity across the dimensions of the satellite can actually provide a torque which will align the satellite toward the earth.

"This technique has been positioning the moon successfully for millions of years; we simply borrowed it from nature. The satellite is initially stabilized in a magnetic field at a time when the magnetic field forces it to point toward the earth. Then you turn off the magnet and shove out a 100-foot long boom. (My figure is an artist's conception that should be considered as very foreshortened.) This boom is a piece of beryllium copper tape 100 feet long that unrolls and forms itself in a pre-formed tube. There is also a spring in the satellite which extends within the boom to place additional weight out at the end. This spring acts to dampen any oscillation with respect to the vertical that might occur from variations in centrifugal force. The type of service imposed some unusual requirements on this spring -- so many that we had to build it ourselves. For example, it is cadmium plated, has hysteresis of about 40 percent per cycle, and has a force constant to a millionth of a pound per foot. It is probably the world's worst spring.

"The other satellite that is in orbit, figure 6, was launched in April, is powered by solar cells and looks somewhat different. The box in the center containing all the electronics is essentially identical in the two units; there is some difference in the nature of the power supply. For example, in the very early stages of the power conversion unit, a difference required in the electronics itself led to a DC-to-DC converter problem. We do not have this problem in the other. All of the rest of the electronics is identical in both units, and we could use the boxes built for one as spares for the other.

"The satellite of figure 6 has long blades on which the solar cells are mounted; that is the primary physical difference between the two. Obviously, the main advantage of using gravity gradient stabilization is to point the bottom face of the satellite down toward the earth. With the boom and spring system radially outward from the earth, it becomes possible to put the antenna on the other end and get reasonable directionality with considerably better power levels and better signals on the ground.

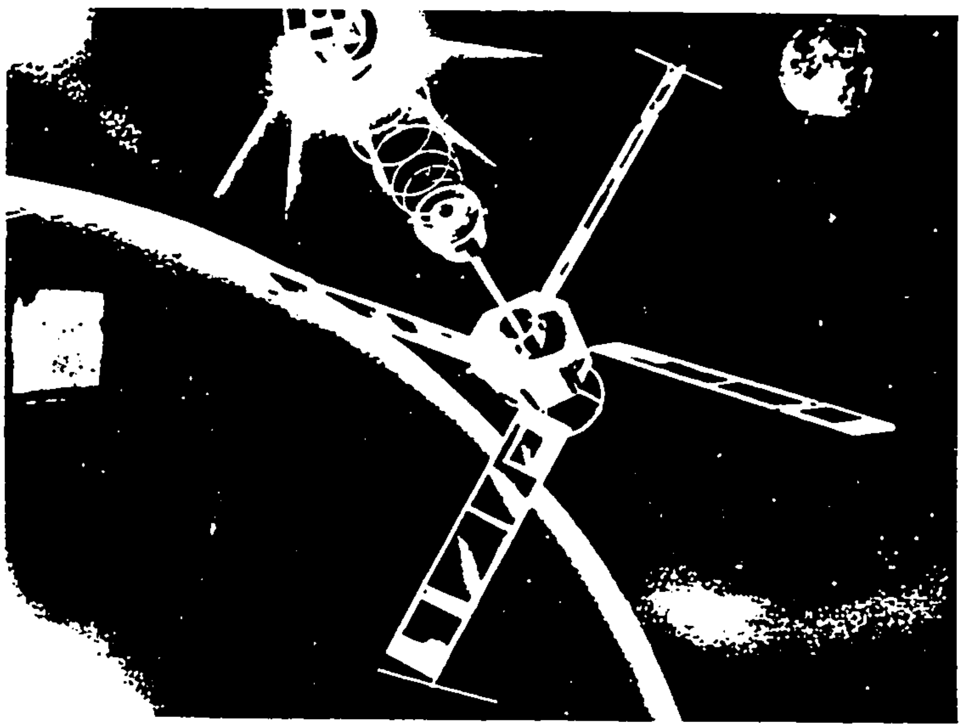


Figure 6

"The primary and certainly most crucial element in the satellite is the stable oscillator, shown in the block diagram in figure 7. If you are going to determine your position relative to the satellite on the basis of an analysis of the Doppler, it is mandatory that any frequency change must be properly and only ascribable to the Doppler effect, and not arise from a frequency change within an unstable oscillator. This stable oscillator was the first really crucial development required for this program; it is so essential and so crucial that we have a pair of oscillators, one of which is essentially a spare, in orbit. We also have the ability of switching either one in to control the system.

TRANSIT 5A
BLOCK DIAGRAM

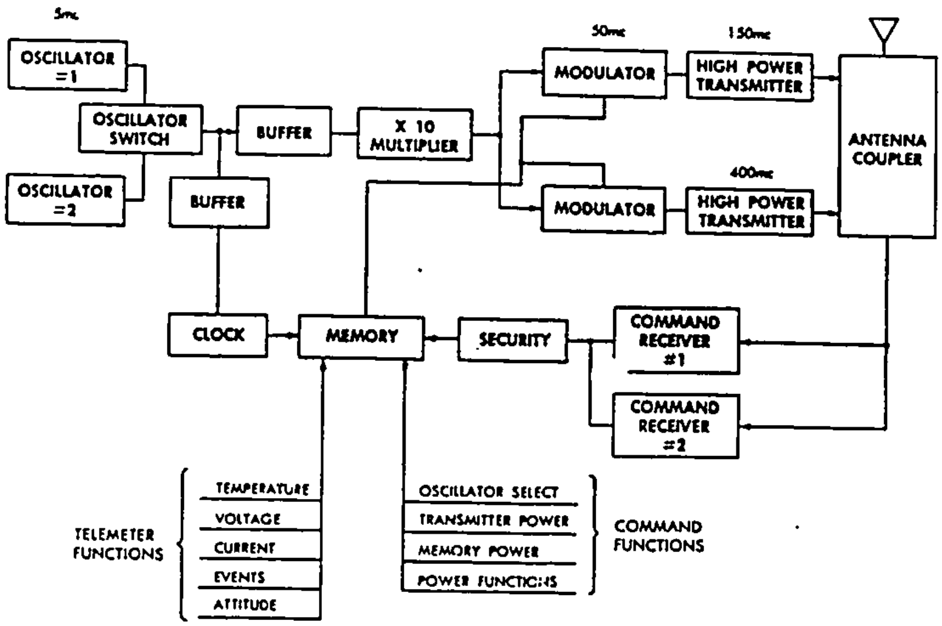


Figure 7

"The oscillator output is multiplied in frequency from the basic five megacycles to fifty megacycles after which we supply the modulation required to carry the message down announcing the orbit parameters. The modulated signal is multiplied by 3 up to 150 megacycles for the transmitter.

"The next major problem, after oscillator stability, that can lead to accuracy difficulties, was the matter of refraction of the signal through the ionosphere. These signals are not high enough that one can totally neglect the existence of ionosphere refraction. To solve this problem we built another multiplier stage and modulator that went up to 400 megacycles so we could transmit two coherent frequencies at the same time.

"If there were no refraction, the Doppler received at 150 and at 400, when scaled back to the same frequency, would be identical. But there is refraction and it is frequency dependent; thus, we receive a different amount of refraction at 150 mc. than at 400 mc. When the two signals are received and scaled back to the same frequency on the ground, they are not identical and the deviation between them is an accurate measure of the amount of refraction that has occurred to the signal through the ionosphere. We can measure this refraction and correct for it, thereby generating on the ground a pure Doppler curve such as would have occurred in the absence of ionospheric refraction. This two-frequency system has eliminated or reduced refraction to an extremely low level in terms of its effect on the accuracy of navigation fixes.

"In addition to transmitting these two frequencies, we have one further requirement which will be used to analyze the Doppler. We must transmit the information describing the orbit of the satellite, and we must have a receiver on the ground which can receive this information. We also must define the orbital parameters on the ground and store them in a memory system in the satellite. So, we require a memory and we require a transmission to carry this information back. To simplify the satellite we use the same frequencies that we use for the Doppler as carrier frequencies for this information. A modulation is imposed on these transmitted frequencies controlled by the memory system which conveys this information.

"We use both frequencies so that we can have frequency reception on the ground and cover phase very neatly to get the extra assurance of a valid message provided by a two-frequency as compared to a one-frequency transmission. This also takes care of problems like multipath if you have an antenna near the water and things of that nature.

"We thought we would have a severe problem in developing a sufficiently stable oscillator, but that proved to be disappointingly easy. There were no breakthroughs required whatsoever; one simply did a reasonable engineering job, and it came out. The secret was nothing but a well-selected crystal. You start with the best crystals you can get. You buy many of them, and put them on standby test for six months. Then the very best -- the top ten percent -- of these crystals are put through something like a curing process within a carefully controlled thermal environment. The crystal is embedded in a fairly large thermal mass with excellent insulation around it and temperatures controlled to within a ±0.1 degree. The result is shown in the graph of figure 8, a recent reading from a satellite in orbit, and even here I think there is more indication of noise or instability in our measuring equipment than in the satellite oscillator. We are measuring such small increments here that the measuring instruments cannot be sufficiently better than the oscillator to do a decent job of measuring.

"During the course of a pass, the frequency variation is something in the order of one part in 10^{11} so it is totally negligible. The stability of the oscillator is well below significance as far as influencing the accuracy of your determination is concerned. For a time, we considered the possibility of using some kind of two-way Doppler for our geodetic work, though not for navigation, for we never wished an active system for navigation. We abandoned the idea for geodetic work because we found we could get such excellent frequency stability that nothing could be gained by going to a two-way Doppler. The refraction correction technique that I mentioned is exceedingly simple; the block circuit diagram is shown in figure 9. On the ground, you simply receive both of the two frequencies. Then the V_{co} is multiplied in each reception channel, which will nominally make the channels identical. By mixing them appropriately, we automatically create a vacuum Doppler signal without even the effort of a computation. It is a very straightforward technique at the analog level to derive the refraction correction.

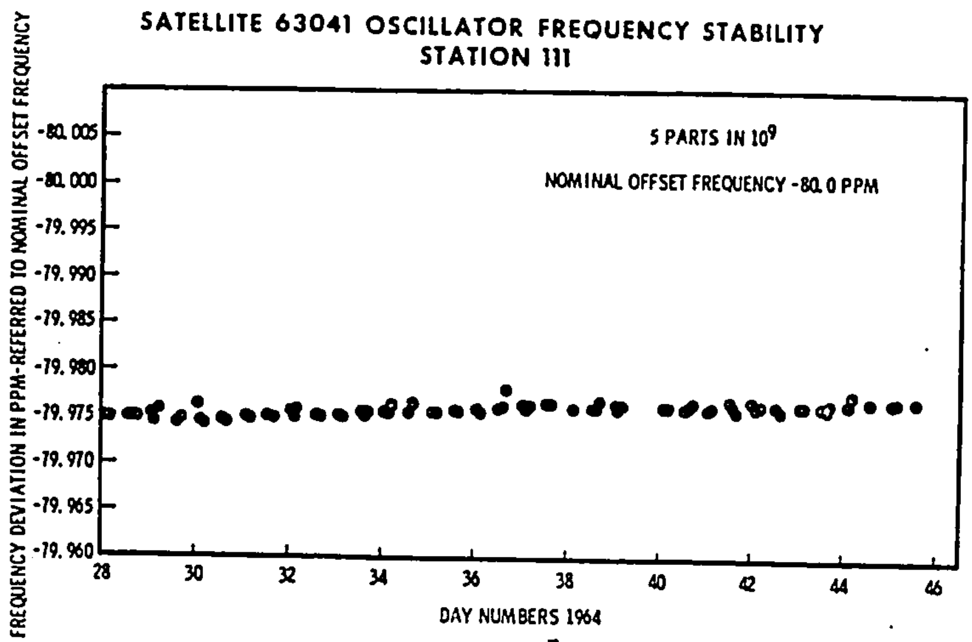


Figure 8

"One of the problems in transmitting the memory information on the same frequency that we use for the Doppler is the necessity of a modulation pattern that does not degrade the accuracy with which you measure the Doppler. The pattern chosen has turned out to do this very well indeed. It is a phase advance-phase retard system and in fact you make a rather balanced pattern in which a bit, which is intended to be interpreted as one, is a phase advance followed by a retard, another retard and another advance; and a bit, that is intended to be interpreted as zero, is just the opposite, i.e., phase retard, advance, advance and retard, as shown in figure 10. These patterns are sufficiently symmetrical that one can read the Doppler with no degradation in accuracy while this modulation is present.

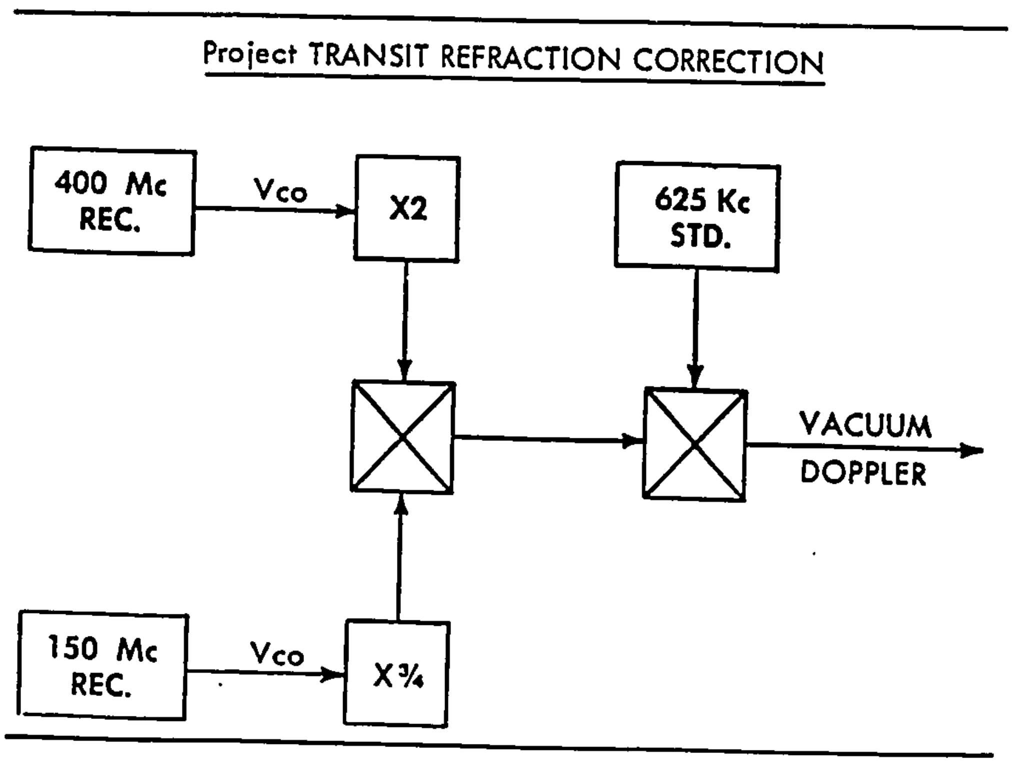


Figure 9

"Another highly difficult problem was choosing the format in which the satellite position would be announced. Obviously, the most convenient from the standpoint of the user would have been simply to announce the absolute position of the satellite in space in XYZ coordinates every two minutes. This technique, however, took a tremendous memory and we simply could not afford the total memory that would be required to give this amount of information every two minutes for a full 12 hours. Instead, we chose a technique to give a good approximate description of the orbit which was a sufficiently simple analytical formula that it could be computed on the ground. The satellite then supplies, on a two minute basis, the correction terms. The difference between the true position of the satellite and the approximate position would be calculated by this analytic formula, with the correction as supplied.

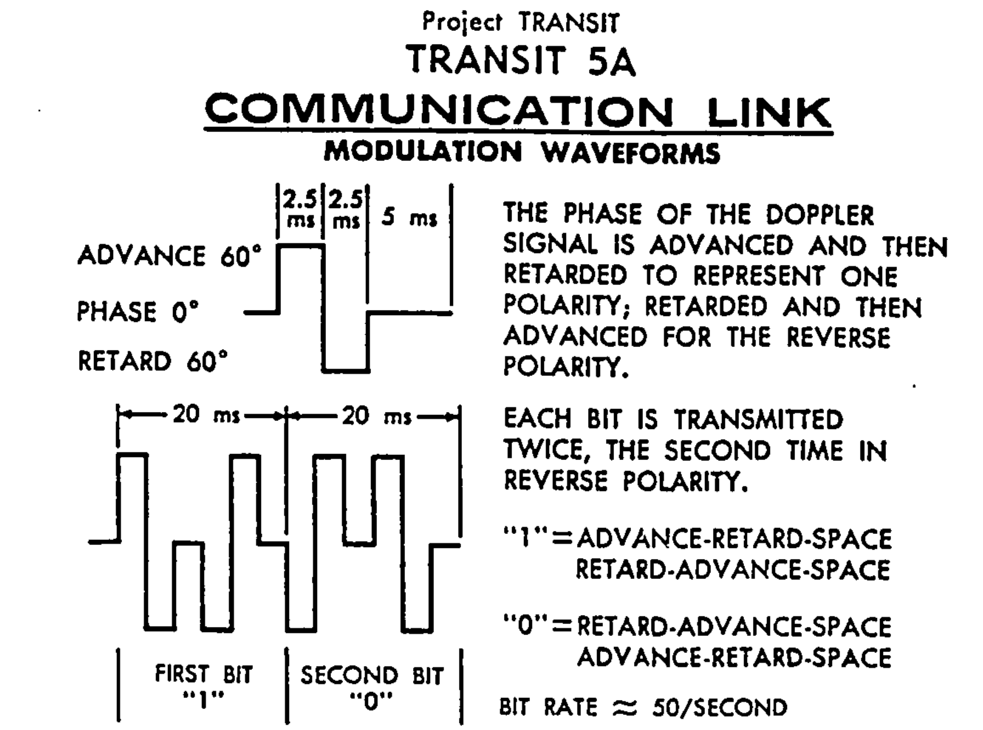


Figure 10

"For the analytic formula, we took a precessing Koeppler ellipse so we could transmit the normal parameter anomoly eccentricity which describes a Koeppler ellipse. Then we say no Koeppler ellipse is accurate enough, and to calculate the true position, we must add certain correction terms. Instead of actually calculating the approximate position by the analytic formula and then adding the corrections, we first add the corrections to the paramters, themselves. If you add the correction terms to the anomoly and to the semi-major axis, then by using the analytic formula you get the right position. The correction term supplied to each will be different for each two-minute interval.

"The various terms of the orbit computations are shown in figure 11 and the equations themselves are given in figure 12. I think you can see why everyone has favored development of a special small computer for solving these problems. They can, of course, be done by hand but it takes about an hour to complete the job. If you recall that the XYZ coordinate data comes in every two minutes, the computer seems essential if one is to take advantage of more than one reading.

"In the format that we have chosen, we transmit the Koeppler element parameters that are valid for the whole 12 hours, and then define and send the little correction terms that are valid every two minutes. The memory correspondingly must have a permanent component to contain these numbers that will be valid for the whole 12 hour period, together with the ephemeral memory to handle the set of numbers that are valid for each two minute period. The ephemeral memory must contain an entry every two minutes during the entire injection period of something over 12 hours.

"Every two minutes, the permanent memory is read out completely; at the end of each readout a single word is brought over from the ephemeral memory and entered into the permanent memory. On the next readout, that particular ephemeral word is actually moved up one slot in the memory and is read out again; at the same time a new word is brought over. There are eight slots in the permanent memory, which is blocked out in figure 13, that are filled from the ephemeral memory. After you have moved a word in the ephemeral memory up eight times, which means you have read it out eight times at two minute intervals for a total of 16 minutes, it gets to the top slot and is thrown away. These eight slots are continually being refilled as a new entry is added and an old entry is thrown away with each two-minute interval. Thus, the ephemeral memory contributes its contents at a rate of one entry per two minute interval. If the system should ever run through the entire contents of the ephemeral memory, the last word that comes over is a warning that the ephemeral memory has not been refilled and that something has indeed gone awry. This indication also removes the system from the secure mode until the trouble is corrected.

Project TRANSIT

t_o : TIME FIRST PERIGEE AFTER 0^H OR 12^H U.T.

ω_o : MEAN MOTION: 2π/PERIOD

$\phi_o^{(o)}$: ARGUMENT OF PERIGEE AT t_o

ω_p : PRECESSION RATE OF PERIGEE

ε : ECCENTRICITY

A_o : MEAN SEMI-MAJOR AXIS

$\Lambda_N^{(o)}$: RIGHT ASCENSION ASCENDING NODE AT t_o

ω_N : PRECESSION RATE OF NODE

C_i : $\sin(\frac{\pi}{2} - i)$; i : INCLINATION ORBITAL PLANE

S_i : $\cos(\frac{\pi}{2} - i)$

ΔM : CHANGE OF MEAN ANOMALY FOR 1 HOUR

δM : CHANGE OF MEAN ANOMALY FOR 2 MINUTES

VARIABLE:

t_k : TIME AFTER INTEGRAL HALF HOUR δE_k, δA_k

δE_k : CORRECTION TO TRUE ANOMALY AT t_k

δA_k : CORRECTION TO SEMI-MAJOR AXIS AT t_k

Figure 11

Project TRANSIT

$$\Delta t_m = t_m - t_p = 1 \cdot 60 + \delta t_m$$

$$\phi_p = \phi_p^{(0)} + \omega_p \Delta t_m$$

$$\Lambda_N = \Lambda_N^{(0)} + \omega_N \Delta t_m$$

$$C_p = \cos \phi_p;\ S_p = \sin \phi_p$$

$$M_m = \underset{360^\circ}{\mathrm{Mod}} \left[1 \cdot \Delta M + \omega_0 \delta t_m \right]$$

$$M_K = M_m + (k - m)\, \delta M$$

$$\sigma_K = \varepsilon \sin M_K$$

$$E_K = M_K + \sigma_K + \delta E_K$$

$$C_K = \cos E_K;\ \delta_K = \sin E_K$$

$$A_K = A_0 + \delta A_K$$

$$\xi_K = A_K (C_K - \varepsilon)$$

$$\zeta_K = A_K S_K$$

$$\begin{cases} x_K^{(K)} = \xi_K \cdot C_p - \zeta_K \cdot S_p \\ y_K^{(K)} = \xi_K \cdot S_p - \zeta_K \cdot C_p \\ \eta_K = y_K^{(K)} S_i \end{cases}$$

$$\lambda_K = \Lambda_N - \Lambda_K^{(0)}$$

$$C_\lambda^{(K)} = \cos \lambda_K;\ S_\lambda^{(K)} = \sin \lambda_K$$

$$\begin{cases} X_K = X_K^{(K)} \cdot C_\lambda^{(K)} - \eta_K \cdot S_\lambda^{(K)} \\ Y_K = X_K^{(K)} \cdot S_\lambda^{(K)} + \eta_K \cdot C_\lambda^{(K)} \\ Z_K = Y_K^{(K)} \cdot C_i \end{cases}$$

TOTAL OPERATIONS:
- 43 ADDITIONS
- 57 MULTIPLICATIONS
- 18 TABLE LOOK-UP

Figure 12

"One rather nice refinement is a byproduct of the way this memory operates -- a particular bit in each of the words in this memory has a special interpretation, namely, it tells you whether or not to suppress a count in the process of counting down from your basic oscillator to the clock rates that control the readout of your memory. In other words, the readout of memory is controlled at a rate which is obtained by counting down from the oscillator, but in this countdown, a single count can be suppressed. If the corresponding bit in each word of the memory is a one, it is not suppressed. If the corresponding bit is a zero, then by injecting a message from the ground that contains the appropriate number of ones in this column you can control and adjust the clock rate independently of frequency variations in your oscillator. For a long term frequency drift, you can still keep your clock rate to a two minute readout with great accuracy. Further, there is enough adjustment capability in this device to cover the full aging characteristics for the lifetime of the satellite oscillator.

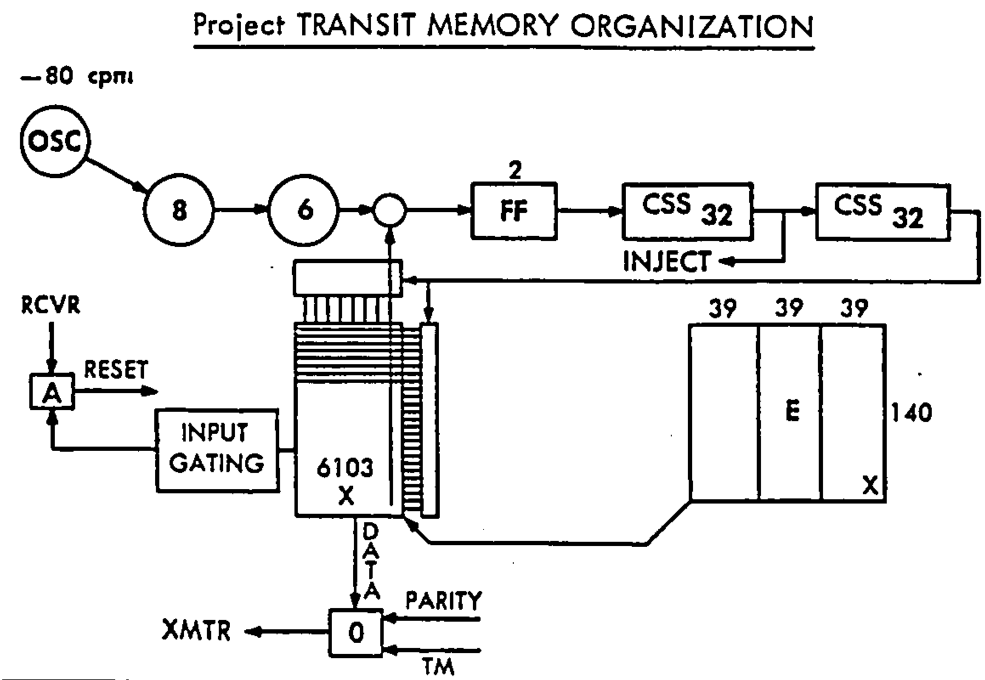


Figure 13

"That leads to the point of the byproduct. The satellite provides time signals that are accurate to better than a hundred microseconds, which is a considerable advance over any time standard available. We have not yet found any enthusiastic users for time signals accurate to 100 microseconds, but we keep looking because somebody must surely want such accuracy in time signals.

"Now, as soon as we started tracking satellites with reasonable precision, using a satellite with good oscillators aboard and having the appropriate Doppler tracking station on the ground, we found, as we had suspected, that the most serious accuracy problem was neither instrumentation nor timing but the basic lack of knowledge about the force field in which the satellite was operating, in other words, ignorance about the actual gravitational field and correspondingly the form of the differential equations that controlled the motion of the satellite. This lack became quite obvious once we had a satellite that could be tracked with accuracy and started tracking it. For a period of a few weeks, we thought we were losing our minds because, with the accuracy we had which was rather good, it became quite clear that the apogee of the satellite was increasing, as in the May-June period of figure 14.

"At that particular time in our history, all we knew was that we had a satellite that was falling uphill, presumably due to drag. None of the simple theories of orbit motion can explain why drag should cause a satellite apogee to increase. The satellite finally took pity on us and decided to plunge downhill; as a result, John O'Keefe came out with the so-called pear-shaped term describing the first major departure from traditional thinking about the gravitational field of the earth. He obtained his data from the satellite tracking and indeed the pear-shaped term did explain very neatly what was happening here.

"Overall, the satellite was going downhill, as you know it has to, as a result of drag. There is a slope through the uphill area and a perceptible oscillation around it. The oscillation is in phase with the rotation of the principal axis of the satellite orbit North/South; the difference in behavior depends on whether the perigee is over the southern or northern hemisphere. The difference is a reflection of the fact that the northern and southern hemispheres of the earth are not alike gravitationally. This difference is the so-called pear-shaped term which is the primary deviation; as soon as we added that term, the problem was completely explained.

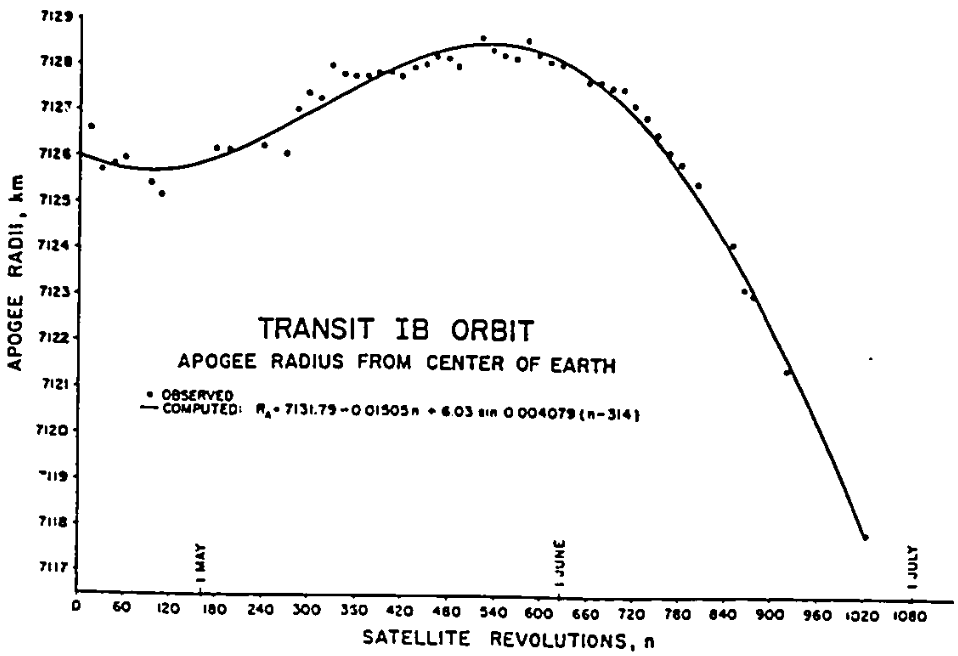


Figure 14

"Looking at it the other way around, we can get a good determination of the pear-shape term by the data obtained on any two or three days from this satellite.

"Throughout the past five years, we have always had a history of deciding that our data were a little noiser than they ought to be.

Then we would discover that it was not noise but was indeed perfectly valid information. The perigee was behaving as in figure 15 at the same time that the apogee was acting up in the fashion shown on figure 14. If you put the two together you find that the semi-major axis, which represents the energy, is continually decreasing in terms of the energy. The semi-major axis for this period is shown in figure 16, where the decrease of the radius is obvious. It was also noisier than we would have liked and it did not follow a smooth curve quite as neatly as we would have liked. The points deviate more from the computed line here than they do later. It almost appears that there is a sharp break near the 310 revolution point in which the behavior changes abruptly. I would say the drag was far different here during this period than later.

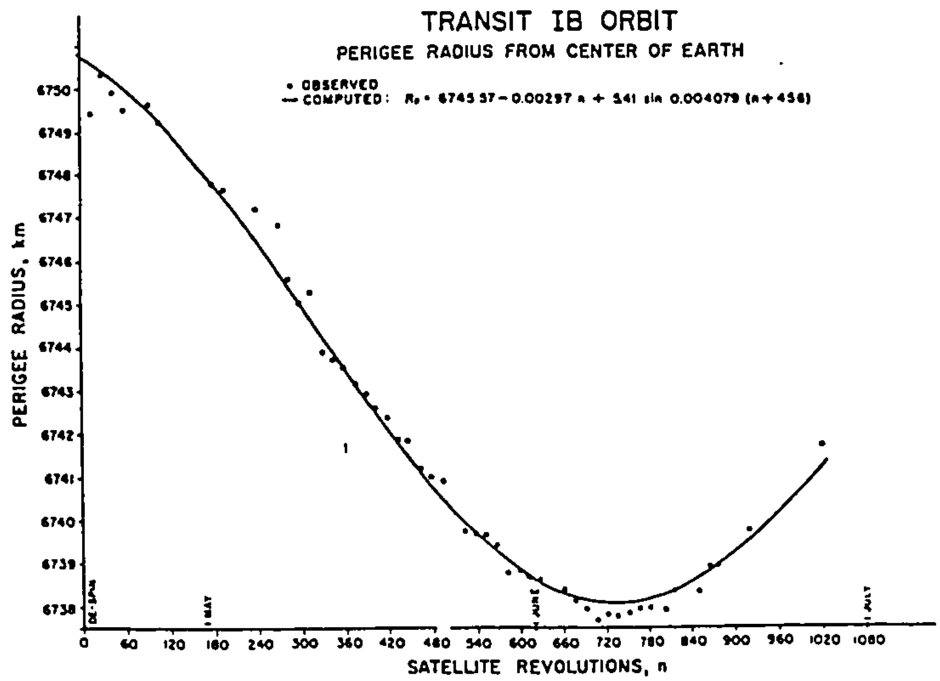


Figure 15

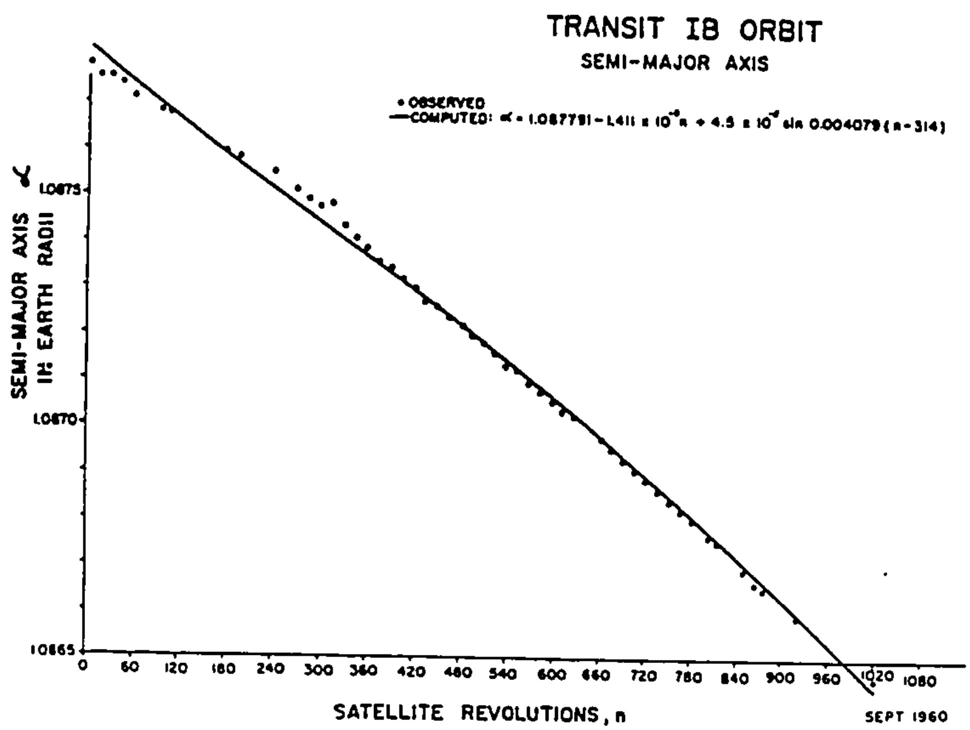


Figure 16

"When we drew this graph, we did not have nerve enough to draw the change in because we could not find any reason why drag should suddenly change its value. One year later we realized that the change point was exactly the point at which the perigee stopped occurring in darkness and started to occur in daylight. During the entire period up until revolution 300, the perigee always occurred at night behind the sun; as the orbit precessed, it finally came out into the daylight and from then on the perigee occurred in sunshine. This graph is an absolute reflection of the fact that drag is considerably higher even at very high altitudes when the sun is shining on the atmosphere than it is when the atmosphere is in darkness. We had buoyed up in the atmosphere due to the solar radiation and a corresponding gross change in drag at very high altitude at night.

"With the pear-shaped term, and other geodesy information, we made good progress but we were still getting errors. Figure 17 defines the inability to match theoretical calculations of the orbit against actual observations to better than half a mile or thereabouts. The plot was made in 1961 and we are still at about the half mile level. Figure 17 is a typical collection of tracking data throughout a 24-hour period taken at a number of stations around the world. The points just seem to scatter with something close to 0.5-mile amplitude. We, however, found as we gathered data over many months that this was not scatter but a precise pattern accurately reproduced day in and day out as a sine wave with a 12-hour period. Over a period of several months, the location on earth where the peaks and valleys were occurring would change but the curve looked about the same.

"As soon as we gathered enough data from enough stations around the world to fill in the details, we discovered that this was a curve. It then became quite clear that not only was there a North/South dissymmetry, there was also an East/West dissymmetry of the earth. In other words, the earth is not a body of equal rotation; we had to start looking at things like elliptical equators. At that time the Smithsonian had come to the same conclusion that we had, i.e., to accept the existence of an elliptical equator. They calculated and published a value for this ellipticity. We applied their value to our problem but it only brought us down to about 0.4 miles, as shown in figure 18. Still, we knew that we were on the right track. We kept the same ellipticity, a difference of 100 meters between the long radius and the short radius of the equator. The Smithsonian had rotated the direction in which the long axis points 33 degrees west, but we moved it to 10 degrees west. This cut our errors to under 0.2-mile, as indicated in figure 19. This indicates the impact this technique of tracking has had on assumptions about the earth's gravitational field. Placing the long axis at 10 degrees rather than 30 degrees West gives us a much closer agreement between theory and reality.

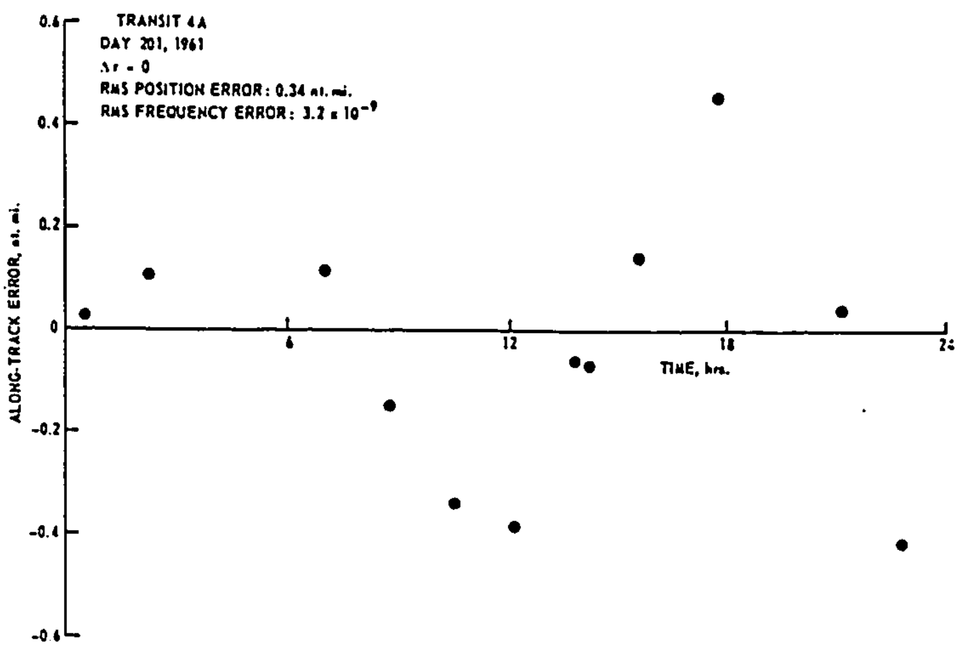


Figure 17

"We simply had to accept the fact that the gravitation field of the earth was totally unknown. None of the simplifying assumptions, such as that the earth is a body of revolution, were correct. We had to start with the gravitational field of the earth, expand it in spherical harmonics, consider all the coefficients as unknowns no matter what their index, and then proceed to program a mechanism for determining all these unknowns.

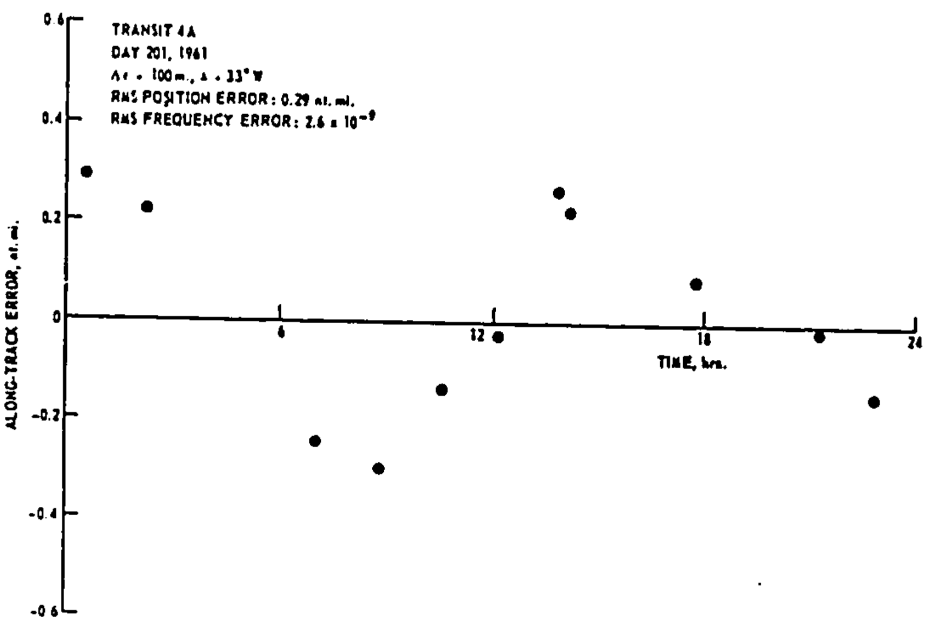


Figure 18

"Fortunately, we had known for a long time that geodesy was going to be the most challenging problem, and had established a terrain net, a global network, of tracking stations. We have 17 that have been functioning for a number of years, located in Alaska, Hawaii, Japan, Philippines, Australia, South America, South Africa, England and so on. These could give us sufficient density of data to determine the assumptions that would have to be made about these coeffecients in order to get the closest agreement between observation and theoretical calculations.

"The job was complicated by the fact that the position of the tracking stations was unknown. This included all three coordinates, latitude, longitude, but most particularly altitude. We knew their relation to sea level but sea level, being simply the equi-potential surface in an unknown gravitational field.was also unknown. Because these coordinates were unknown, the problem took about two years to program. It filled the core of the 7094 about seventeen times, and a single interpretation took fifty hours of computer running time.

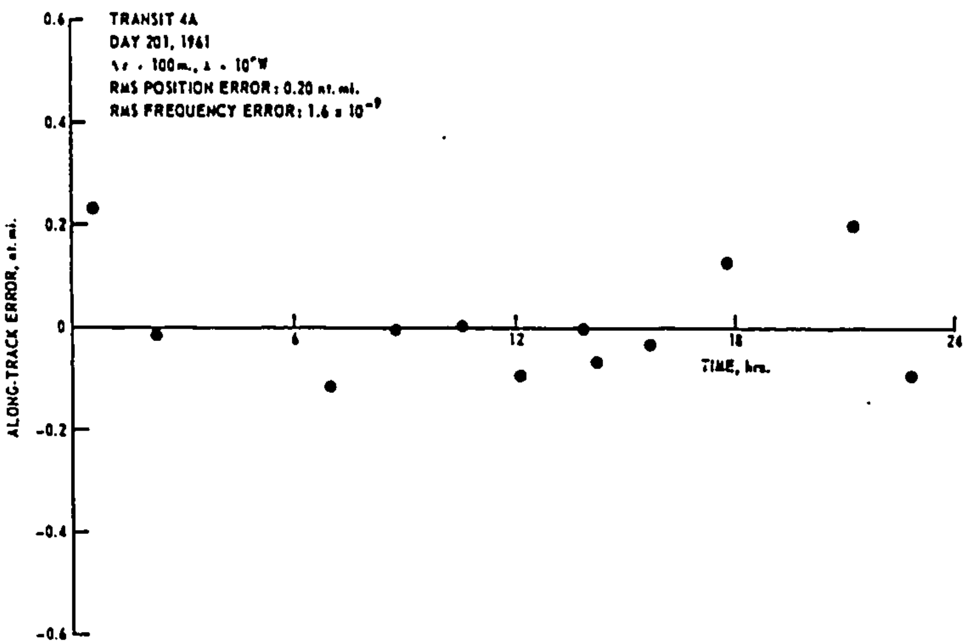


Figure 19

"About a year ago, we were able to calculate the position of our tracking stations and the coefficient of the graviational field through the fourth order. The basic equation is given in figure 20. This brought our ability to track down into within 0.15 n.m. At first it seemed to bring it down to under a tenth, but this determination was based on three non-polar satellites. When we began working with a polar satellite we found that this gravitational field.which with the other satellites had given results with errors of less than 0.1 n.m., began developing errors of up to 0.15 n.m. This was not as good as we had hoped for.

PRINCIPAL GRAVITATIONAL FORCE PARAMETERS

$$V(r, \varphi, \lambda) = -\frac{K}{r}\left[1 + \sum_{\ell=2}^{\infty} \sum_{m=-\ell}^{\ell} \frac{J_{\ell m}}{r^{\ell}} Y_{\ell}^{m}(\varphi, \lambda)\right]$$

$J_{2,0}$ = 1st oblateness term

$J_{4,0}$ = 2nd oblateness term

$J_{3,0}$ = Pear shape term

$J_{5,0}; J_{7,0}$ = Higher order odd-harmonics

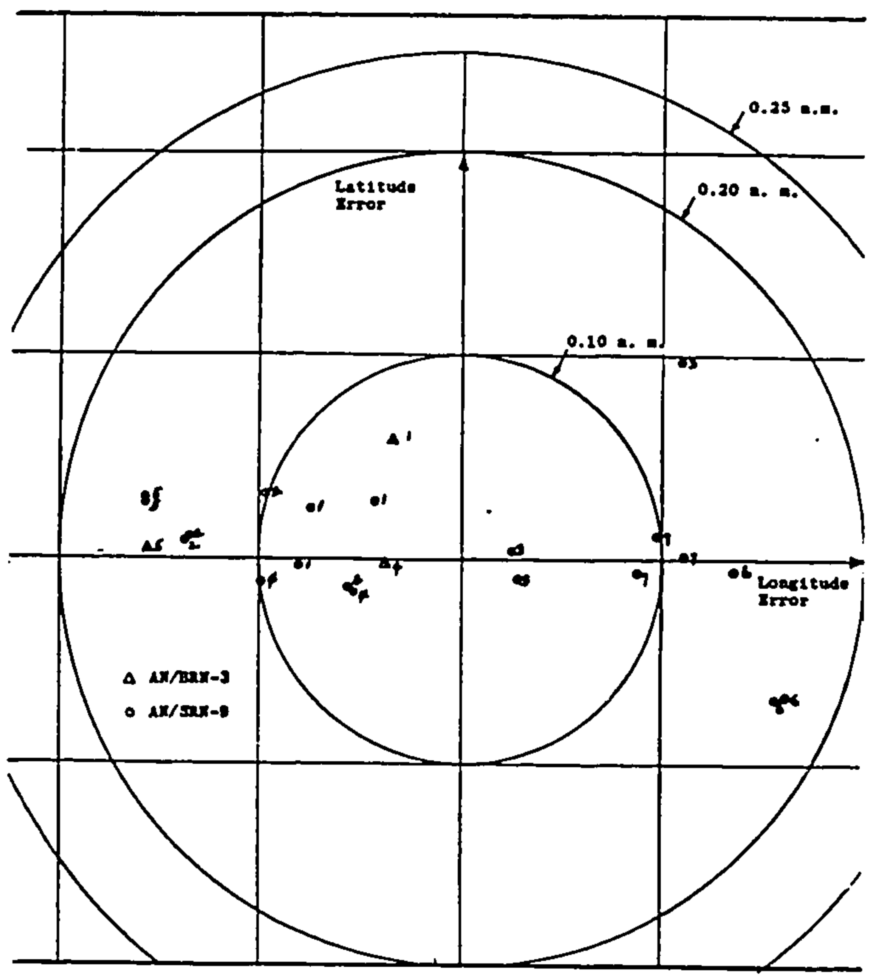
J_{6} = Higher order even harmonics

$J_{2,2}\,J_{2,-2}$ = 1st elliptic equator term

Figure 20

"We suspected that in determining a gravitational field from non-polar satellites we had developed many errors around the poles which would only affect results from actual polar satellites. With better knowledge of the poles we hoped to correct these errors. We continued collecting data from the polar satellite and about five months ago were able to compute the gravitational coefficient through eighth order terms. This required many more interratios and all the variables could not be computed simultaneously. We had to cheat a little, holding one group of terms constant while working out another and then working out the first; but the results were valid. However, the error problem did not disappear.

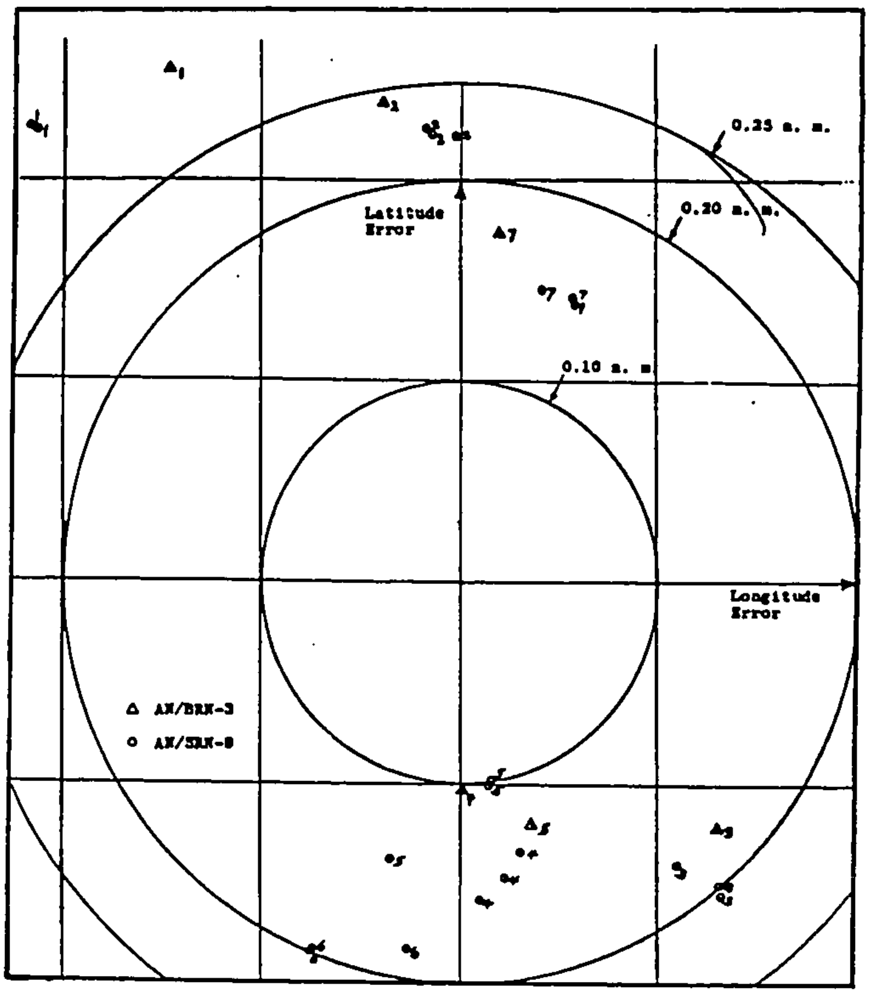
"By this time the two polar navigational satellites described earlier were in orbit and functioning properly. Their first navigation runs, which used our latest gravitational coefficient, revealed striking phenomena. Figure 21 records the results of the first exercise of the 03164, the solar cell satellite shown in figure 6, which was launched in April. Errors in along track in latitude are less than 0.1 n.m. but longitudinal errors in cross track are as great as 0.25 n.m.



EXERCISE 1 NAVIGATION RESULTS WITH SATELLITE 03164

Figure 21

"The radioactive isotope powered satellite launched in December gave opposite results, as shown in figure 22. Accuracy in longitude in cross track was well within 0.1 mile from R.M.S., but the satellites along track latitudinal errors splattered very badly out to a quarter of a mile and once even further.



EXERCISE 1 NAVIGATION RESULTS WITH SATELLITE 63041

Figure 22

"Both satellites were polar and both tracks were made with the same geodetic assumptions. The only difference we could see was in satellite altitude and power supply, and we rejected the power supply as a possible influence. We continued following the track of the radioactive isotope powered satellite. Use of the newest geodesy with all the terms through the eighth order cut down the noise level and the random splatter and revealed a hidden long term oscillation with a period of 60 hours. This is shown in figure 23. At first we thought the 60 hour period could not be related to physics but had to do with the way we grouped our data for the computer program. But, as we finally discovered, the period is the result of the influence of the thirteenth order geodetic terms of the earth on the orbit of the radioactive isotope powered satellite.

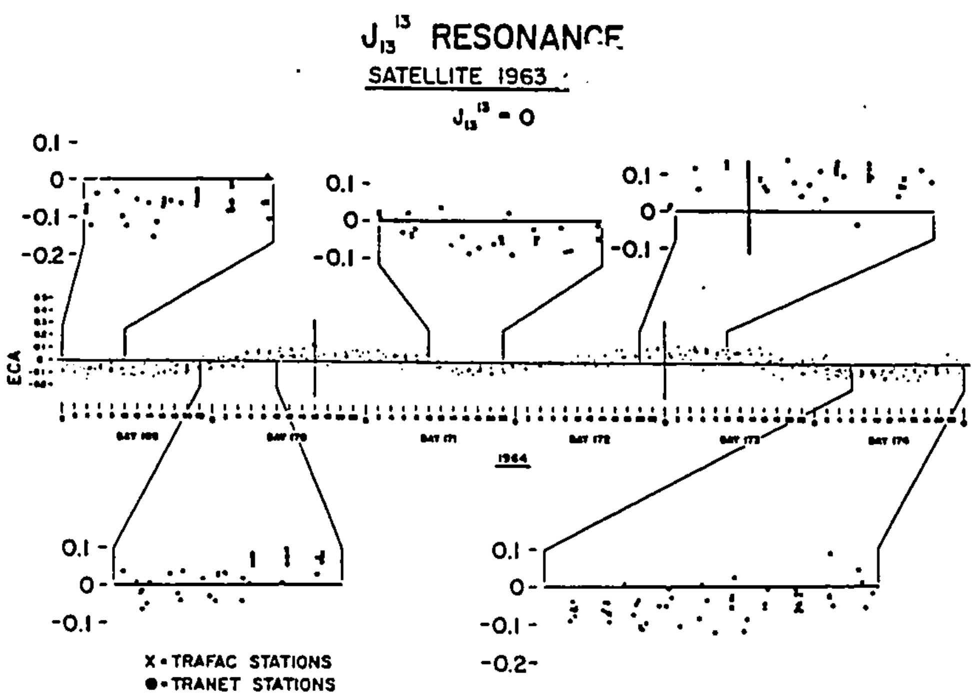


Figure 23

"This satellite has an orbit very close to 1/13 a revolution of the earth; it responds to the thirteenth order geodetic term of the earth by seeing the equator as a series of peaks and valleys, 13 each, arranged in cogwheel fashion. Because 13 is an odd number a valley is directly opposite each peak on the wheel. Assume the satellite starting a half-orbit from a point -- we will call it point A -- over one of the equator peaks. By the time it reaches the equator again, that is, completes the half-orbit, the earth will have gone through half of 1/13 revolution. Thus, the satellite will not cross the valley opposite point A, but the hill which has rotated into its position. When the satellite crosses this peak there is a valley opposite it on the other side of the wheel. But after the satellite completes another half-orbit a peak will have rotated into the valley's place. If the satellite's orbit were exactly 1/13 a revolution of the earth it would always cross peaks at the equator.

"But the orbit is not exactly 1/13 a revolution. After 30 hours the satellite stops crossing peaks and during the next 30 hours it crosses the valleys. The satellite sees the earth slightly heavy for 30 hours and slightly light for the next 30; it speeds up for 30 hours and slows down for the next 30. This is a perfectly real physical response of the satellite to very high order structure in the gravitational field of the earth.

"Adding to the track a value for the thirteenth order harmonic, which can be determined from figure 23, results in a smooth plot. We tracked the middle two-day period shown in figure 24 extrapolated two days forward and backward. The data show errors of less than 0.03 n.m. over the entire period. This was the last breakthrough in geodesy we needed to reach our goal of 0.05 n.m. tracking accuracy.

"The cross track splatter in longitude received by the solar cell powered satellite was a similar response of that satellite to a fourteenth order harmonic of the earth. Since 14 is an even number instead of odd, the response is short-term cross-track rather than long-term along track. The altitudes of the two satellites account for their different responses. The radioactive powered satellite at 600 miles has a period very close to 1/13 a revolution while the other satellite at 500 miles has a period nearer 1/14 a revolution.

"We are now in the process of injecting the thirteenth and fourteenth order terms into the appropriate computations. Unfortunately, this means we have to redo all the terms through the eighth order; the previous determination of these geodetic terms did not take into account the thirteenth and fourteenth order resonance.

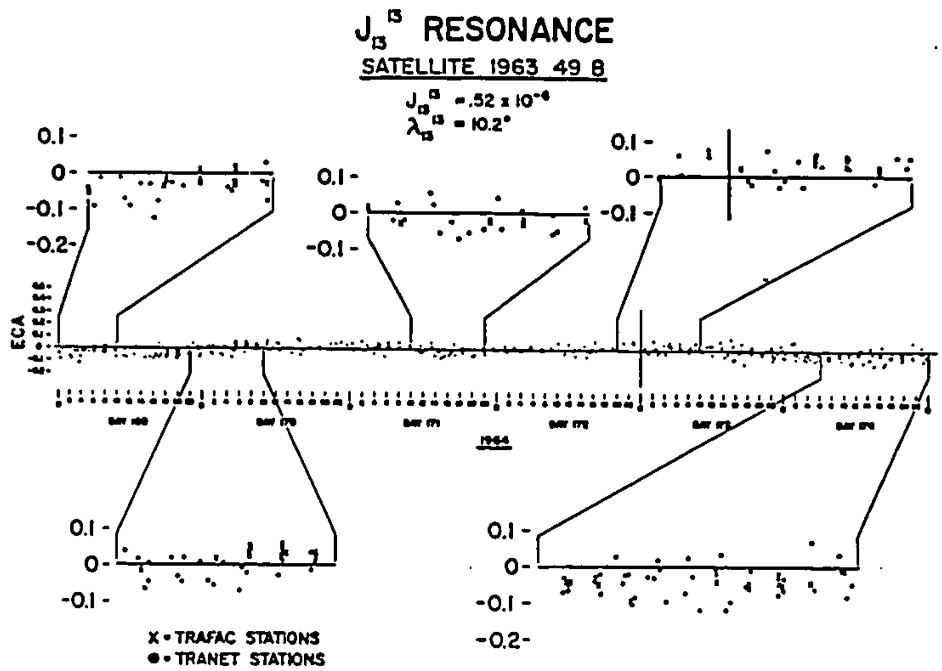


Figure 24

"In our current navigation program we have been using only the uncorrected fourth order geodesy, but our results have been pretty good. Navigation fixes taken over the entire Tranet system resulted in a radial sigma of 0.144 n.m., as shown in figure 25. With this level of geodesy the geographical bias is not a serious problem. We have no velocity problems because these are navigation runs made from fixed ground stations. Figures 26 and 27 record fixes over a longer period of time from two widely scattered stations. The tracking station in Japan showed a radial sigma of 0.187 n.m. and Lasham, England, station, after a very extensive collection of data, showed one of 0.213 n.m.

"In addition to the BRN-3 equipment on board POLARIS submarines, we have developed a greatly simplified piece of gear, the SRN-9. Under conditions where there is no wave wash over the antenna and lock-on can be maintained over a fairly long period, the accuracy of the tracking device is competitive with that of the BRN-3 equipment. Some results are shown in figure 28.

"There are two other areas I would like to discuss briefly. For some time we were unable to analyze accurately the effect of ship velocity on the Doppler shift used in making fixes. About nine months ago we tried vectoring the velocity into its cross track and along track components. We discovered that the along track velocity was the only component which had an important effect on measurement of the Doppler. By treating this component as one of the variables, in addition to latitude and longitude, to be determined from the Doppler curve, the BRN-3 can obtain valid fixes despite a substantial error in the ship's assumed velocity.

"This third variable has been programed and the new system, the Mark 2, has been checked out in the laboratory; at-sea trials are to start next week. It will soon be available as a modification for the BRN-3 equipment now in use on the submarines and should give results quite comparable to those of the fixed stations shown in figures 25, 26, and 27.

TRANET TRACKING STATIONS NAVIGATED WITH TRAFAC ORBITS ORBIT 1 (DAY 36)

STATION	PASS RISE TIME HR	MIN	ELEVATION DEGREES	NAVIGATION ERRORS (NM) LATITUDE	LONGITUDE
111	01	39	27	-.1012	-.0055
101	01	40	27	-.0974	-.0023
013	02	09	12	.0248	•.0576
011	02	15	42	.1209	.0159
092	03	23	36	-.1983	-.1116
003	03	25	18	-.1495	-.0294
101	03	25	48	-.1729	-.0304
111	03	25	48	-.1911	-.0118
018	03	36	61	-.0603	-.1387
003	05	10	59	-.1684	-.0988
014	05	24	21	-.2275	.0238
018	05	25	37	-.0032	-.2107
010	06	55	21	-.1406	.0412
014	07	07	64	-.2037	-.0978
018	07	14	28	-.0511	-.1373
006	07	28	12	.0506	-.1809
010	08	41	40	-.1088	.1045
018	09	03	27	-.0593	-.0664
006	09	13	60	.0259	-.1820
017	10	19	17	.0204	-.0617
013	10	38	17	.0201	.0747
014	10	45	13	-.1095	.1531
018	10	52	36	-.0411	-.1064
008	11	26	17	.0422	-.0017
012	12	05	59	-.1088	-.0604
011	12	17	14	-.0937	.0069
018	12	40	57	.1189	-.1153
018	13	11	52	.2102	-.1730

σ_ϕ = .1102 NM σ_λ = .0922 σ radial = .144 NM

Figure 25

NAVIGATION ERROR FOR STATION 013 JAPAN

DAY NUMBER	PASS RISE TIME HR	MIN	ELEVATION DEGREES	LATITUDE ERRORS (NM) $\Delta\phi$	LONGITUDE ERRORS (NM) $\Delta\lambda$
36	02	09	12	+.0248	+.0576
36	10	38	17	+.2013	+.0747
37	01	21	27	-.0858	-.0537
37	11	37	51	+.3189	+.0126
37	13	24	26	+.2324	+.1698

$\overline{\Delta\phi}$ = +.1021

$\overline{\Delta\lambda}$ = +.0522

σ_ϕ = .1673

σ_λ = .0823

σ_{radial} = .187

Figure 26

"At present, with velocity determined from SINS, navigation error is still under 0.25 n.m. This was our objective for the initial stage of the program. But with the incorporation of the Mark 2 modification we will be able to achieve our second goal -- accuracy within 0.10 n.m.

"The other area has to do with difficulties in using the latest geodesy. We assumed that for polar satellites, motion outside of the precessing plane would be negligible. This would certainly be true if non-rotational effects on the earth are negligible; but they are not. To take into account motion within the plane we use correction parameters for the anomoly and the major axis. We have now developed a method for incorporating a third correction term, for the out-of-plane motion, into the present satellite memory system. By winter the satellite computing program will include this third term and the latest geodesy with the thirteenth and fourteenth order corrections. The submarines will easily be able to make navigation fixes accurate within 0.10 n.m."

NAVIGATION ERROR FOR STATION 006 LASHAM, ENGLAND

DAY NUMBER	PASS RISE TIME HR	MIN	ELEVATION DEGREES	LATITUDE ERRORS (NM) $\Delta\phi$	LONGITUDE ERRORS (NM) $\Delta\lambda$
36	09	13	60	+.0259	-.1820
36	19	38	15	+.1656	-.0685
36	21	22	68	+.2606	-.0455
36	23	10	27	+.2057	+.1088
37	08	27	32	-.2365	-.0670
37	10	14	56	-.2939	-.1827
37	20	35	37	+.2685	-.0248
37	22	23	49	+.2584	+.1782
38	07	43	18	-.1206	-.1093
38	11	15	23	-.0062	-.2177
44	08	22	45	+.1184	-.1275
44	10	14	40	+.2136	-.0705
44	20	08	52	+.3364	-.0908
44	22	18	35	+.3272	+.1144
45	09	22	74	+.1312	-.1240
45	11	10	16	+.0977	-.1000
45	19	45	28	+.0161	-.0082
45	21	31	65	+.0447	+.0882

$\Delta\phi$ = +.1007 $\Delta\lambda$ = -.0516

σ_ϕ = .1815 σ_λ = .1109

σ_{radial} = .213

Figure 27

"Size is involved as well as shape in this computation of geodesy, is it not?" asked Mr. Eyestone.

AN/SRN–9 NAVIGATION
RESULTS WITH TRAFAC DATA

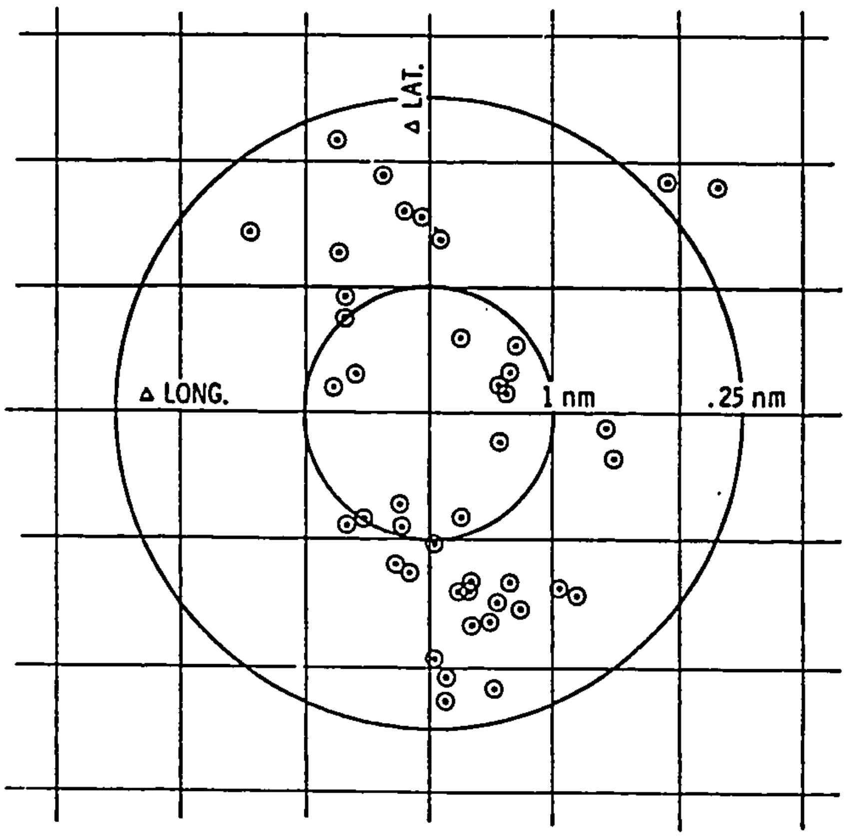


Figure 28

"Size is hard to deal with," replied Dr. Kershner. "It is really a function of the speed of light and thus cannot be separated from speed. First you arrive at a determination of the speed of light, which, of course, will be arbitrary. Then you establish a ratio between this speed and the size of the earth. From that ratio you define a unit of measure, such as the meter, which you can use as your size parameter."

"Is the modulation code available to the general public or is it militarily classified?" Dr. Mechlin inquired.

"At the moment, that is still being reviewed," Dr. Kershner answered. "It has not yet been made available. The initial intent was that the information would be available to the general public. DOD reversed this policy about four years ago and presently the program is classified. There is a rumor that the situation will change next week, but that is only a rumor as far as I know.

"The system as it now exists uses no coding, just a simple modulation, and this can be figured out pretty quickly from the parameters I described. But there is nothing to prevent you from lying about these parameters a little bit. In this case the satellite sends an additional encrypted message which reveals the degree to which you lied about the parameters. This will only be available to the ships who have the decrypting equipment.

"This could be done in the existing system. It is not being done currently, and I think the Navy must make a basic policy decision as to whether this is a wartime emergency measure or one that should be implemented at all times. If the latter course is chosen, a second decision is needed as to the accuracy you will hold for the general purpose use. Because of the structure of the satellite and the navigating equipment, you can chose any degree of accuracy and begin using it at any time. The magnitude of the built-in error can be changed at any time simply by changing the injection program. This is actually the way the system is now operating.

"The ships are receiving correction terms in the encoded messages and putting them into their computations; but the present correction terms read zero."

"One thing continues to bother me," Captain Gooding said. "After the tilt word rings up and the satellite goes insecure, anybody can get in. Is it possible for them to get in and slam the door and lock us out?"

"No, the door cannot be slammed," replied Dr. Kershner. "The security system, a black box, puts out a challenge word for which there is only one acceptable answer. We have the identical black box and so know the answer to every challenge. But no matter what the enemy tries to put in, the satellite will issue a challenge, to which they do not know the answer unless they have stolen the black boxes. With this type of security, the satellite cannot be stolen."

"Can we detect a major change in the satellite orbit that was caused by some external source?" Mr. Peterson asked.

"Yes, you can certainly detect it," replied Dr. Kershner, "but you will not know how to respond to it. Incidentally, that is what we thought was causing the 60 hour orbit irregularities. It looked like some sort of mereorite impact. We chased these meteorites for a while; we found that they came regularly every other direction at 30-hour intervals; we began looking for another solution."

"What is the maximum time that the two minute correction memory will last," Rear Admiral Smith asked.

"It is 16 hours," answered Dr. Kershner. "This just gives us enough margin to cover the 12 hours. If you lose injection capability, the satellite goes insecure 16 hours after the last injection and begins transmitting non-essentials or zeros. It is no longer a navigating satellite."

"We now have one currently operational injection station. A second, being built in Minneapolis, is almost finished and APL is always available as a backup.

"Do you now have a fairly good idea of the physical dimensions or shape of the earth?" queried Captain Sadler.

"We know the geoid, or absolute physical dimensions of the earth to ten meters, at least," Dr. Kershner replied. "We have covered all points; though we cannot yet read tidal effects, which are less than a meter. I would like to mention that we did a very careful survey across the U.S. and were quite impressed to discover that the current surveys are good to 17 meters. In navigation, as I mentioned, we are at the 0.10 n.m. level. But when this device is used as a surveying instrument accuracy is much greater because of the greater density of data that can be obtained over a number of readings."

"Knowledge of the geoid is very important for surface ships," Mr. Cestone pointed out. "It is the base from which you figure the height of the antenna."

"That is correct," agreed Dr. Kershner. "By antenna height we mean the distance of the antenna from the center of the earth. What we have determined is the shape of the earth relative to its center of mass; this shape is not based on measurements around the surface. The center of mass, not the geometrical center, is the point around which the satellite orbits. Because the earth has so many lumps and bumps, finding the geometrical center may take as long as ten years. But we can do it more accurately and much more inexpensively than a first order survey."

"WGS60 is now outdated, in fact," observed Captain Gooding.

"Yes," continued Dr. Kershner, "DOD plans to have WGS65 and it certainly would be a shame not to use this data extensively in any new WGS that comes up; but there are so many vested interests. One will insist that you must use gravity meters, another that you have to photograph flashing lights. If you are in the Army Map Service, you have to use SECOR.

"Both SECOR and the flashing lights system make very good measurements, quite comparable with ours, but we have the capability of obtaining vastly greater data density. The basic measurement accuracy is the same in the three systems. They are limited by the residual refraction error remaining after all frequency corrections have been made."

"Previously there was a question as to the relation between the Tokyo datum and the North American datum," Captain Gooding pointed out. "Can it now be resolved?"

"I am not certain," replied Dr. Kershner, "because we have only one Japanese station. I do not know where we have another good point on the same Tokyo datum. You need at least two, and preferably three points on each. Without these you can resolve East/West shifts, but tilts are still possible. We will get a final solution as soon as we have enough data."

At this point, Rear Admiral Smith called upon Captain Lieber to present the Launching Committee Report.

LAUNCHING COMMITTEE REPORT DISCUSSION

"Yesterday Captain Christman gave you a rundown on the problem we are having with the interface between the missile skirt and launcher and presented some solutions from the missile standpoint," Captain Lieber began. "Today I would like to discuss some possible modifications to the launcher. Figure 1 was also presented by Captain Christman. As you remember, the aluminum missile skirt corrodes between the bronze surfaces of the mount ring and the clamp ring. A possible solution would be to machine off the face of the clamp ring and put on a glass epoxy compound, thus eliminating the area of metal-to-metal contact. These clamp rings can be removed fairly easily by bringing them up vertically through the tube. They can be made in sufficient quantities to replace the rings now in existence that are uncoated. Changeover should take about two hours per tube.

"The mount ring presents more of a problem in that the clearance involved is about 0.005 inch. Right now we are painting this with a two-mil epoxy paint, but this is a rather tight clearance and the ring would be subject to chipping. We might possibly manufacture a tool that could be mounted within the tube and machine off about 0.050 inch of the face of the mount ring and then manufacture a pre-formed, pre-impregnated insert that would go in after the machining and be heated and cured in place.

"Westinghouse has only taken a quick look at this up to now, but it is estimated that study and design work on this could be completed within 90 days. Westinghouse is now doing liaison work on this with

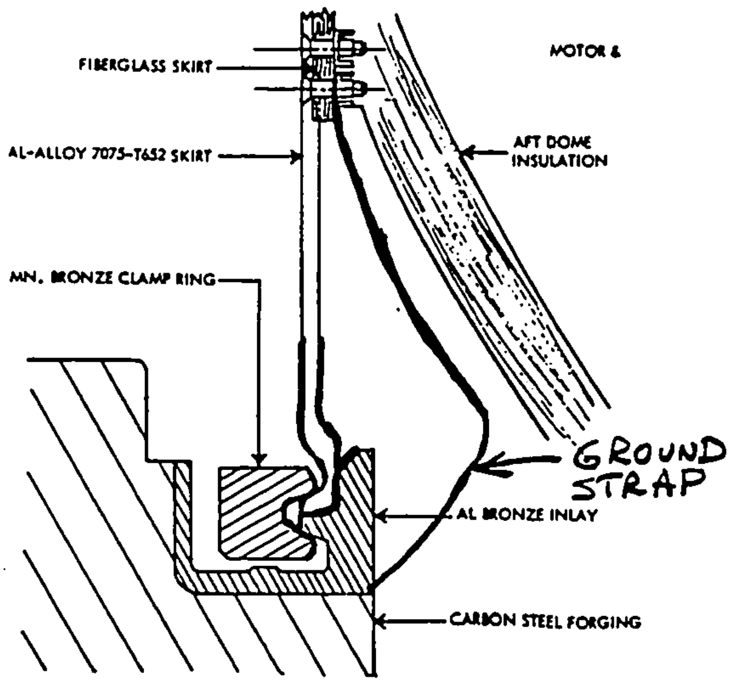


Figure 1

Lockheed. This would probably be considerably cheaper and easier than changing the skirts on the missiles.

"How well could you hold your tolerance after you machine off the 50 mils and put in the insert?" Captain Gooding asked.

"The existing tolerance is on the diameter," replied Dr. Mechlin, "plus 0, minus 0.020 of an inch, and we would be peeling off about 0.050 of an inch. We feel there would be little or no problem in maintaining the existing 0.020 tolerance. We would have to make it 0.010 or perhaps 0.015 thicker than the finished thickness, but it does not seem as though shrinkage or variation in the pre-impregnated densities would add serious trouble with respect to the existing 0.020 inch."

"Would you do it with a form cutter or make it in several passes," inquired Captain Gooding.

"We would use a form cutter, and air-motor driven tool, with a vacuum cleaner to pick up the chips," replied Dr. Mechlin. "It could be clipped into place and moved around by hand. I am not sure whether we would make one cut or two."

"Would you face off the bottom surface that the skirt sits on," questioned Mr. Wetmore, "or just on the diameter?"

"We would face off the bottom surface to roughen it up," Dr. Mechlin answered. "It has a pretty good surface finish."

"My next topic," continued Captain Lieber, "concerns our gas generator. Figure 2 shows the gas generator with the propellant above the water pot. This is a solid propellant generator for the steam eject system and uses a double-base propellant grain cast in the form of a cylinder with 37 internally burning longitudinal perforations.

"This grain is somewhat unconventional in two respects. First, it is operated at high pressure, in the range of 4,000 psi, and then it has a critical requirement for control of mass flow as a function of time making it necessary that the control of the burning rate be within the range of three percent.

"As previously reported to the STG, we have evidence that accumulated during the summer from quality control and acceptance tests and later was confirmed by PEASHOOTER and POPUP firings, that aging results in a slow decrease in the burning rate which subsequently causes a loss in the exit velocity of the missile. Extrapolation of staging data which considered the time from manufacture to stockpile to deployment, had indicated that many of the gas generators would have a useful life in a deployed submarine of less than a year.

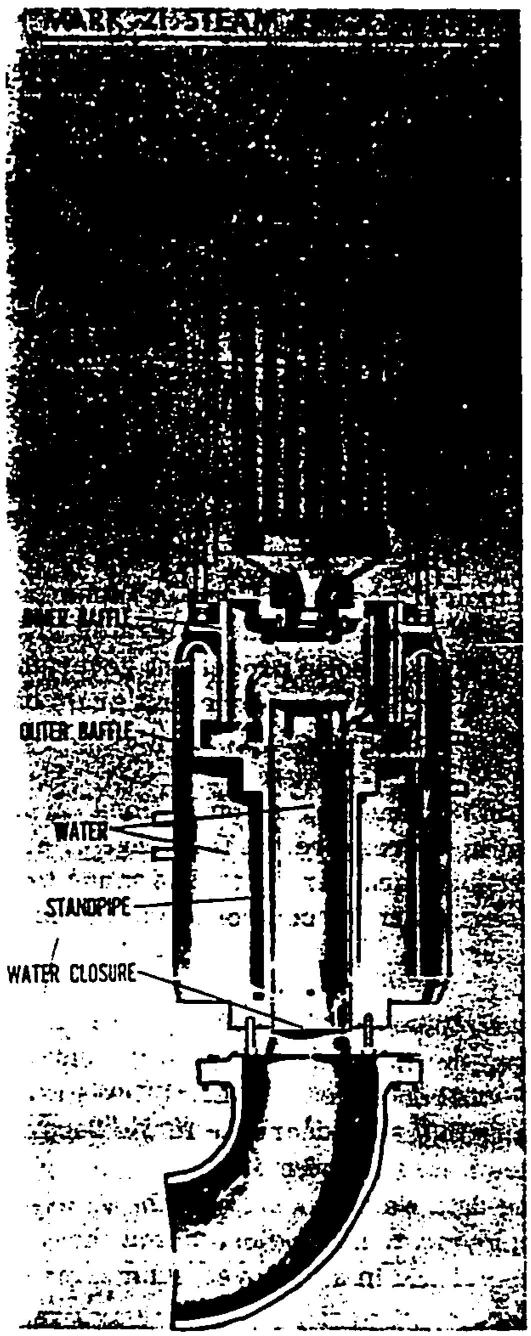


Figure 2

A program was established to discover the basic cause of the aging phenomena and the rate of aging of the existing stockpile of generators at that time. The items of this program are seen in figure 3.

AGING RATE INVESTIGATION

Lot-by-Lot Firing Tests
Nozzle Size SPALT Firings
Artificial Aging
Subscale Tests
- Chemical Analysis for Composition Changes
- Partial Burner Cube Tests
- Photomicrography
- Combustion Kinetics Samples

Process Change Tests

Figure 3

"It was the aim of this program to determine a short range fix that could be used to extend the life of the existing generators and a permanent long range solution for future production when our existing stockpile would be expended. The results of this program are the basis of the next part of my presentation.

"We had our lot-by-lot tests, which were quality control, PEASHOOTER, and POPUP, at-the-building program shots, and we SPALTed these generators and had five shots to prove out the SPALTed generators. We had artificial aging tests, about eleven of them, to prove out this aging phenomenon. This was done by subjecting the old generators to a high temperature to accelerate the aging. We had a whole series of subscale tests using ten pound charges, chemical analysis, partial burning, microphotography, combustion kinetics. And we did some process changing tests to arrive at a new gas generator process which I will cover a bit later. First, I want to consider the nature of the problem.

"Figure 4 shows the life performance for two production lots of 100 generators each. It is based upon the pessimistic assumption that aging occurs linearly with time rather than logarithmically. The linear aging rate is based upon composite data from earlier lots. The change in the burning rate represented by a year's aging is about six percent. It can be seen that the groups involved would be below the minimum acceptable velocity in a very short time. Considering the upper limit of acceptance, and the lower limit, this group would run out approximately at the end of 1964."

"What is the basis of establishing that lower limit?" Rear Admiral Smith asked.

"You get the maximum missile loading at the shallow depth, and you get the minimum missile velocity at the maximum launch depth," Dr. Mechlin replied. "Minimum missile velocity is sensitive primarily through providing an adequate margin for the interlock package operation . You have to sense a minimum velocity before arming and missile ignition can occur, so that the 82 foot-per-second number is selected and you have some reasonable tolerance at the maximum operating depth."

"As can be seen," Captain Lieber resumed, "the groups involved would have been below minimum by the end of this year. Change in the burning rate can be accomplished by a change in the nozzle size so that the generator, because of nozzle size, increases the pressure. The positive coefficient of burning rate with pressure responds to the higher generator pressure to give increased burning rate and increased mass flow rate.

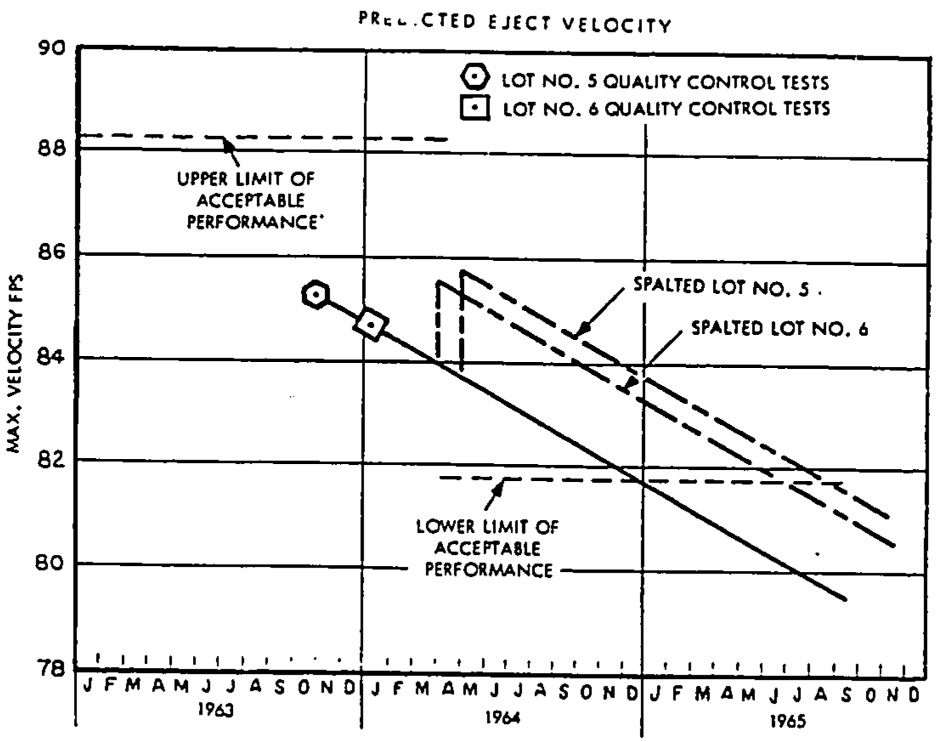


Figure 4

"Two lots of generators were so SPALTed by replacing these nozzles and the effect is shown by the dotted lines in figure 4. The first ship that is deployed and the other ships which will be initially deployed will carry these SPALTed generators. These generators, even on a pessimistic curve, will be good until mid-1965.

"We are currently in our second production run of gas generators; delivery is starting on these now. The same cure process has been used as in the first production run, but we have revised the specification with the risk of limits of maximum and minimum performance unsymmetrically biased to allow a maximum possible useful life. The quality control point in figure 4 is about 85 feet per second for the current production; it lies nearer the upper limit of the maximum velocity. We are now pushing to put the quality control point up to 88. This procedure, we feel, has added a minimum increment of six months to the life of these units.

"The current rapid consumption of gas generators in the shipbuilding trials and weapon system testing, the pre-deployment at tender training, and the DASO firings, makes it possible to consume our present generators of marginal age without prejudice to tactical readiness. This will require, and does require, a good inventory management program carefully coordinated with the actual day-to-day existing situations in the fleet to make sure that we use up our oldest generators. The nature of the problem in the fleet is critically dependent upon the aging rate. Rapid aging generators would have to be changed out, and perhaps eventually discarded after we get out of our heavy building program consumption.

"The discussion thus far has been based on a most pessimistic premise, which is linear extrapolation of short term data. A change factor of four or five in this rate over a several year period makes the whole problem disappear.

"For this reason, a critical statistical analysis of data generated from quality control, PEASHOOTER, POPUP, and submarine firings of old and new generators was undertaken as well as a program on accelerated aging to determine whether a logarithmic aging characteristic might exist. The accelerated aging program assumed that the aging had a diffusion or chemical reaction characteristic, so that an exchange relationship existed for time and temperature, or if we could apply a high temperature and artificially age for short periods it would be the same effect as long period aging at normal ambient temperatures. Two series of tests were established in connection with this effect. One was to determine the maximum extent of aging degradation, and the other one was to ascertain whether the accelerated aging was equivalent to natural aging. Results are shown in figure 5.

RESULTS OF ACCELERATED AGING

"Natural" Age Days	Accelerated Aging	Velocity FPS	Comments
35	None	84.6	Manufacturer's Quality Control Tests
205	None	82.8	
210	6 Days at 140°F	82.2	
220	12 Days at 140°F	82.1	

Figure 5

"To find the maximum limit of degradation, a group of gas generators was subjected to six days of aging at 140° F and was fired when 210 days old. A similar group was subjected to 12 days at 140° F and fired when 220 days old.

"There was essentially no change in the velocity between the six days and 12 days at 140° F. The aging was considered to have been completed by six days of accelerated aging. The total degradation due to natural aging and accelerated aging was approximately two-and-a-half feet per second. This is the difference between the 84.6 and 82.2. I believe there were three in each of the aging samples.

"In another series of tests, we took a group of nine gas generators and subjected them to 140° for six days when they were 95 days old. Of these, we fired three immediately and we received a control point down around 81.5. The balance was placed in storage. After 300 days, in August 1964, a sample of three was withdrawn and fired. The remaining three were aged at 95 days and placed back in storage and then fired. Results are given in figure 6. The solid line indicates the natural aging curve as estimated for this production lot. The × is the quality control point, and the ⊗ gave us the established line for natural aging."

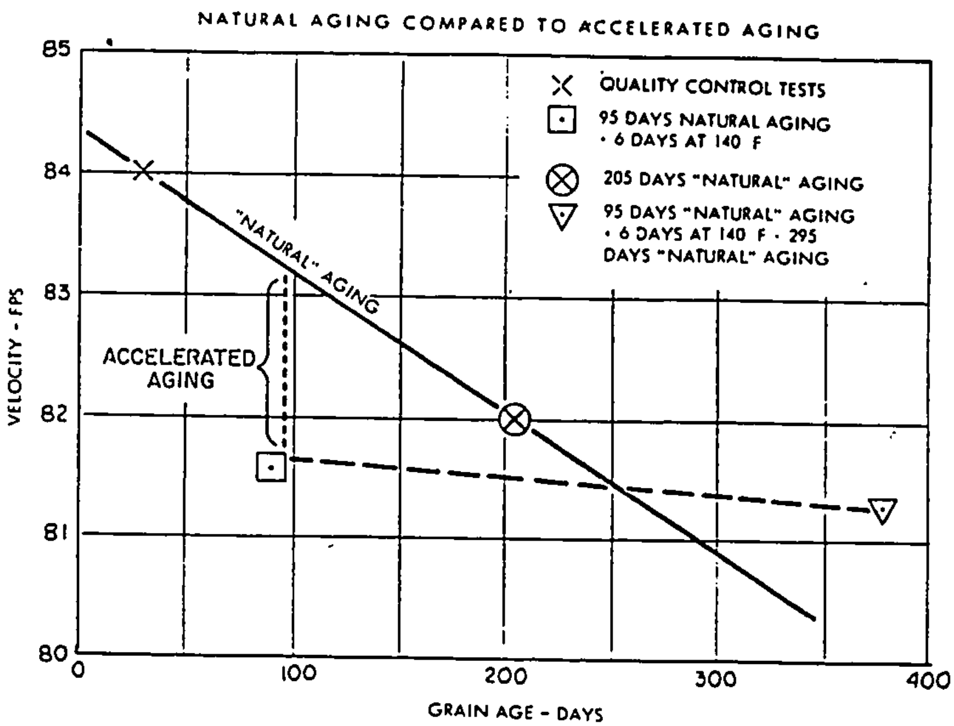


Figure 6

"If accelerated aging bottoms out or is saturated at that point, why would you not assume that natural aging would, too, if you extrapolate that?" asked Dr. Kershner.

"We will come to the point where we will make this assumption," replied Captain Lieber, "but at that time we did not have enough data to establish this. The accelerated aging was conducted when these were 95 days old. The 395 days is a sample which had been artificially aged and stored for 300 days. The small change in performance due to 300 days extra of natural aging is not considered significant.

"The conclusion may be made, then, that the six days at 140° accelerated the natural aging to completion, or at least was effective in arresting the natural aging rate, although it is recognized that the validity of each of these results is dependent on the assumption that the accelerated aging is equivalent to natural aging, and strong indications are that the aging degradation has an asymptotic lower level of approximately two and a half feet per second.

"With the asymptotic limit, the generators now being manufactured to the revised specification should have an unlimited tactical life; that is, if we start with the quality control toward the higher limit of 88.2 feet per second, then the two and a half foot degradation puts us above the approximately 82 foot per second lower limit.

"Sufficient data have been acquired from PEASHOOTER and other sites to permit an analysis of the aging characteristics. However, there is no model which the data is known to fit. If the aging mechanism is a diffusion process, or a chemical reaction, one would expect the rate of aging degradation to decrease as the age is increased. One would then expect that the mathematical model of the aging process would be a logarithmic curve. However, if the aging mechanism is a combination of different mechanisms proceeding at different rates, the logarithmic curve may indicate a leveling off which is not realistic. A useful alternative to the logarithmic characteristic is to assume a linear model, and both models have been applied to the existing data.

"The results are shown in figures 7 and 8. Figure 7 shows two lots manufactured by the Naval Propellant Plant with an interval of seven months between the manufacture of the lot shown on the top and that shown on the bottom. As can be seen from these curves, and borne out statistically, the difference in the quality of the fit of the logarithmic and linear curve is not significant over the range of the available data. The difference is pronounced in the extrapolation of the curves, but it is recognized that such extrapolations are without a sound physical foundation in this case. The implications for future performance are considerably more severe, however, for the linear curve than for the logarithmic curve. The logarithmic curve shows good agreement as a result of accelerated aging tests.

"An item of further interest in this figure is the close agreement between the coefficient of the linear and logarithmic curve for the respective plots. There is no apparent change in the characteristics, although dates of manufacture do differ by seven months.

"Figure 8 shows the results obtained for two lots manufactured by Hercules Powder Company. These two lots differ not only in the seven months lag in the time of manufacture, but also each lot was manufactured from a separate production lot of casting powders. As with figure 7, the quality of the fit is not significantly different in the logarithmic or linear curves from the data available. However, there is a marked difference from one lot to another. The lot shown at the bottom does not appear to be undergoing any aging degradation, and, in addition, the lot shown at the top is aging at approximately one-half of the rate shown on the lot for NPP in the previous figure. The observed differences among these lots were subsequently found to be due to differences in the solvation characteristics of the powder combined with a minor processing change in the cure cycle.

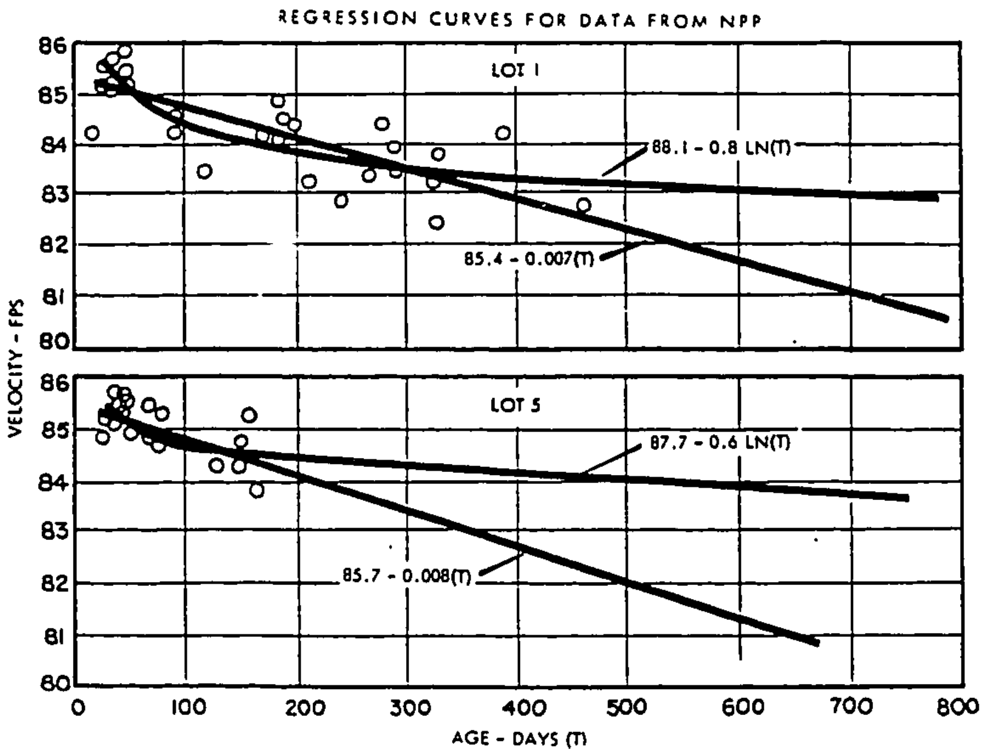


Figure 7

Hercules Powder exhibited superior nitroglycerine absorption characteristics. In addition, some of the units tested were allowed to have an ambient rest period of twelve to twenty-four hours prior to beginning the cure.

"The program to develop a permanent solution quickly established incomplete solvation of the casting powder granules during manufacture as a primary mechanism for aging.

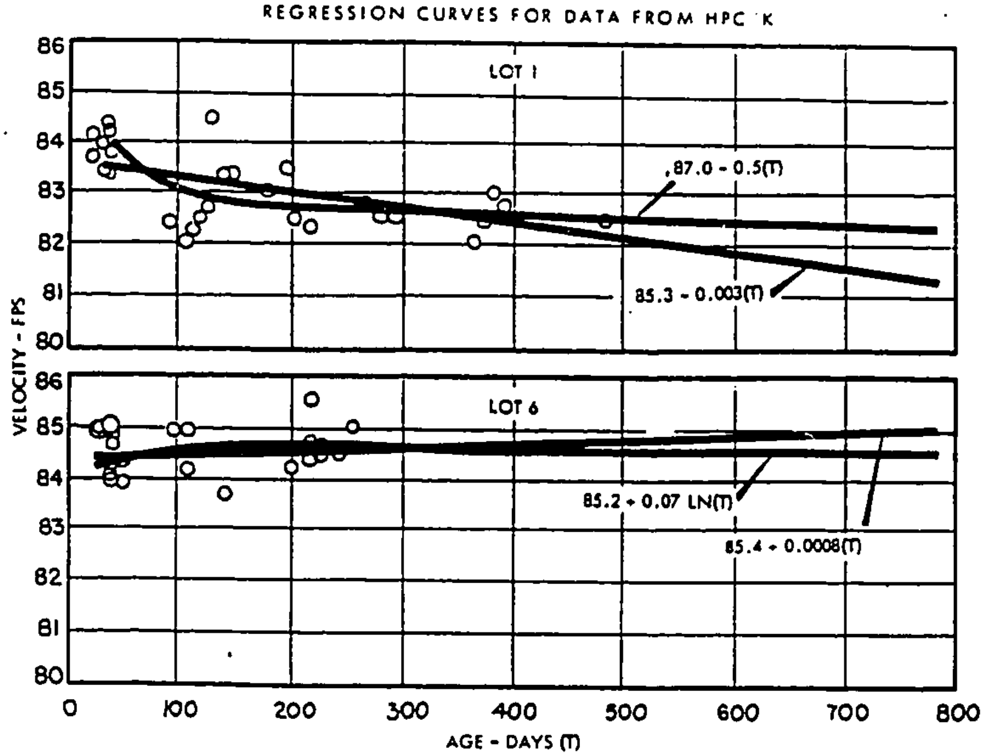


Figure 8

"Figure 9 shows typical micrographs of uniformly and non-uniformly solvated grains. The one at the top is non-uniformly solvated and the bottom made by the revised cure cycle is uniformly solvated. We can see dark areas which are areas of grains in the upper view which have not absorbed a sufficient quantity of nitroglycerine. The aging effect arises from the slow approach to complete solvation of the non-uniformly solvated material. Incompletely solvated material has a higher effective burning rate than uniformly solvated material, because the solvent rich areas, which are higher in nitroglycerine, that is, the whiter areas, have a high burning rate, and the propellant burns so as to give a pebbled surface which has a greater net surface area in

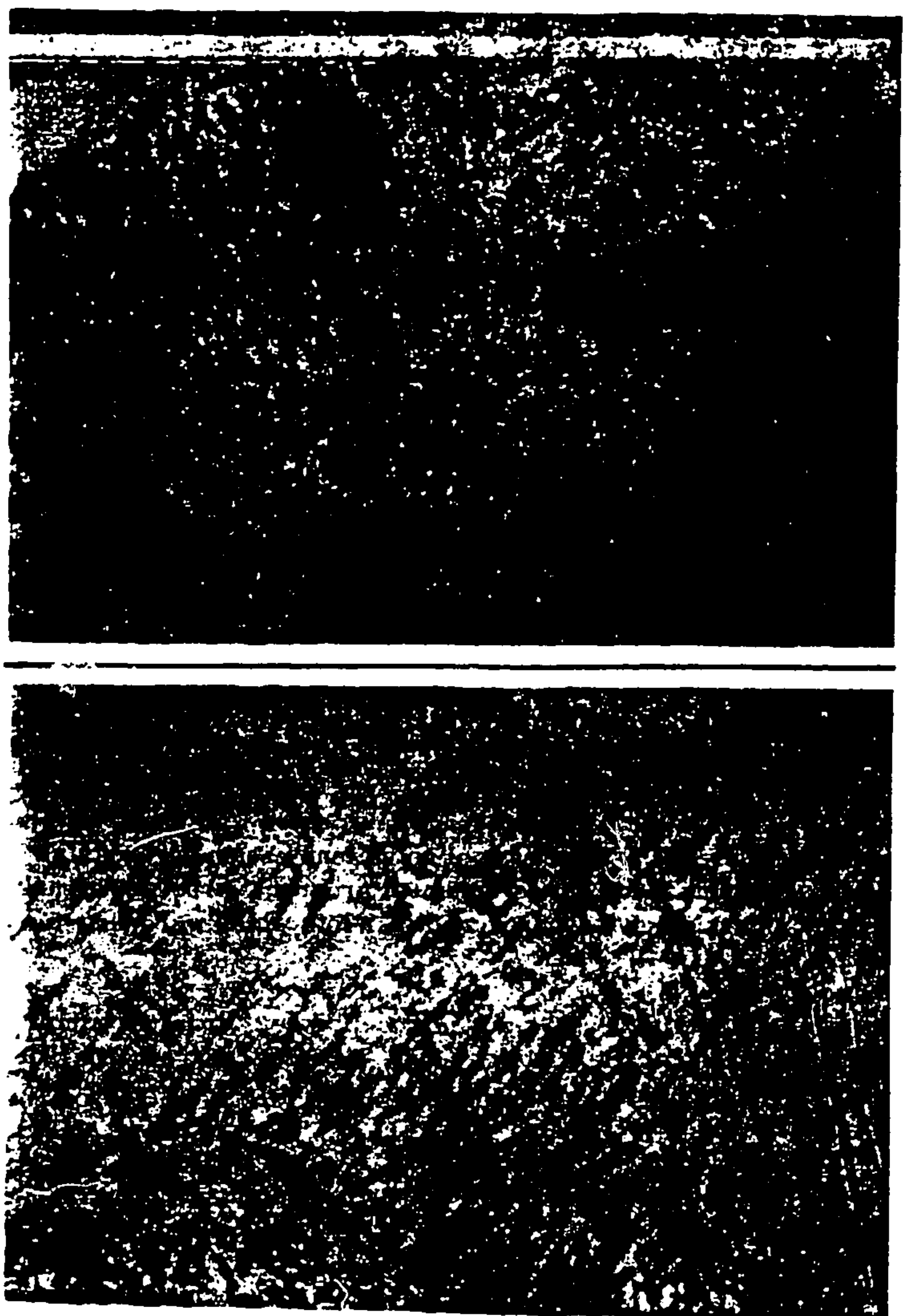


Figure 9

average burning rate than the uniformly solvated propellant which burns on a smoother surface.

"This correlation has been positively established through quenching tests of partially burned cubes and through the correlation of static firing data and propellant photomicrographs. This means that as the non-uniformly solvated grain ages, the nitroglycerine migrates from the nitroglycerine rich areas into the grains and completes solvation. Then it burns more smoothly or with a smooth surface, but more slowly with less pressure and less velocity."

"What are we looking at here?" asked Admiral Smith. "Is this reflected light?"

"This is transmitted light through a microfilm section about 50 power," explained Dr. Mechlin. "You can see in there the granule which, fullscale, is on the order of a sixteenth of an inch in diameter. I believe the light is white."

"The difficulty was traced to an unexpected wide variability among casting powder lots and the ease of solvation," resumed Captain Lieber. "During the grain development program, processing qualification was unfortunately based upon powder lots which were easy to solvate."

"What nitration level is this nitrocellulose?" inquired Admiral Smith. Neither Captain Lieber nor Dr. Mechlin knew exactly, but Dr. Mechlin suggested that it was in the moderate range, not extremely high or extremely low.

"When we went into production," said Captain Lieber, "production grains used powder lots which were relatively difficult to solvate. An extensive program was conducted at ABL using four different cure techniques in order to improve this solvation process. The standard control technique was five and a half days cure at 120°.

"Another one tried was two days at 120° followed by five days at 140°. The third one was three days at 70°, which is ambient, but with 30 to 35 psi on the mold head to force the nitroglycerine into the powder, followed by six days at 140°. The fourth one tried was two days at 70° ambient, rest (with the 30 to 35 psi pressure), followed by six days at 140°. It was the last one which was chosen, and we have now revised our processing techniques to include this pressure solvation, the holding step, and elevated temperature cure.

"A careful exploration was made of other possible factors in aging, including consideration of possible chemical reactions involving ballistic modifiers in the propellant, loss of nitroglycerine by diffusion into the inner structural supports, and long term dimensional changes to the grain.

"The effects of these factors were secondary to the effect of the solvation and were amenable to the solution applied to the solvation problem. We think we have the solution to the aging process and our third production gas generators will use this new curing method. We will, however, continue further studies with ABL and try to find out as much about this aging problem as we can. We have further firings. This completes the part on the gas generator aging."

"It is very difficult for me to imagine any set of procedures which would result in that straight line degradation," remarked Captain Gooding.

"I agree," Dr. Mechlin said, "but considering the number of submarines with the schedules involved, it is desirable to have a very comfortable set of hypotheses in which you can demonstrate your problem solution. This linear one allows this to be done. Nobody second guesses you by assuming a higher rate than you have assumed."

"Has enough work been done with this higher cure temperature to make sure that there is no long term effect by higher cure cycles?" asked Mr. Wetmore.

"We have looked for reactions to the ballistic modifier at these temperatures, and those reactions that do occur proceed a little and when the temperature comes down they stop," Dr. Mechlin pointed out. "We have data in which grains aged at these temperatures have been surveyed over a year without any significant trend in performance, and there have been supporting data correlations with chemical analysis and so on that indicate that, while you do have some reactions occurring at these temperatures, these all are factored into the process control so that you bias them out."

"My next topic concerns the development program that is being conducted on a non-launchable seal facing for the launch tube," continued Captain Lieber. "The facing performs the function of providing shock mitigation to the missile as well as guiding the missile during the launch, and providing the gas seal. This facing eliminates the missile shoes. Primary launch tests at PEASHOOTER were conducted last year on promising concepts. Based on this test, a model known as a combination seal was selected for further development. Teflon covered foam pads provide the shock mitigation, and the teflon covered seal rings provide the seal. The 57-inch diameter launch tube at PEASHOOTER is shown in figure 10 fitted with this combination seal used in our current series of tests.

"This seal differs in part from previous seals in that it was manufactured with soft or semi-permanent tooling rather than hand made as in the previous version. The objective of the current test series is to obtain data on durability, sealing performance, in-tube launch dynamics, and missile skin loadings. Five test launches have been completed to date. Four of the launches were conducted with the tube in a near vertical attitude, and sealing effectiveness was excellent,

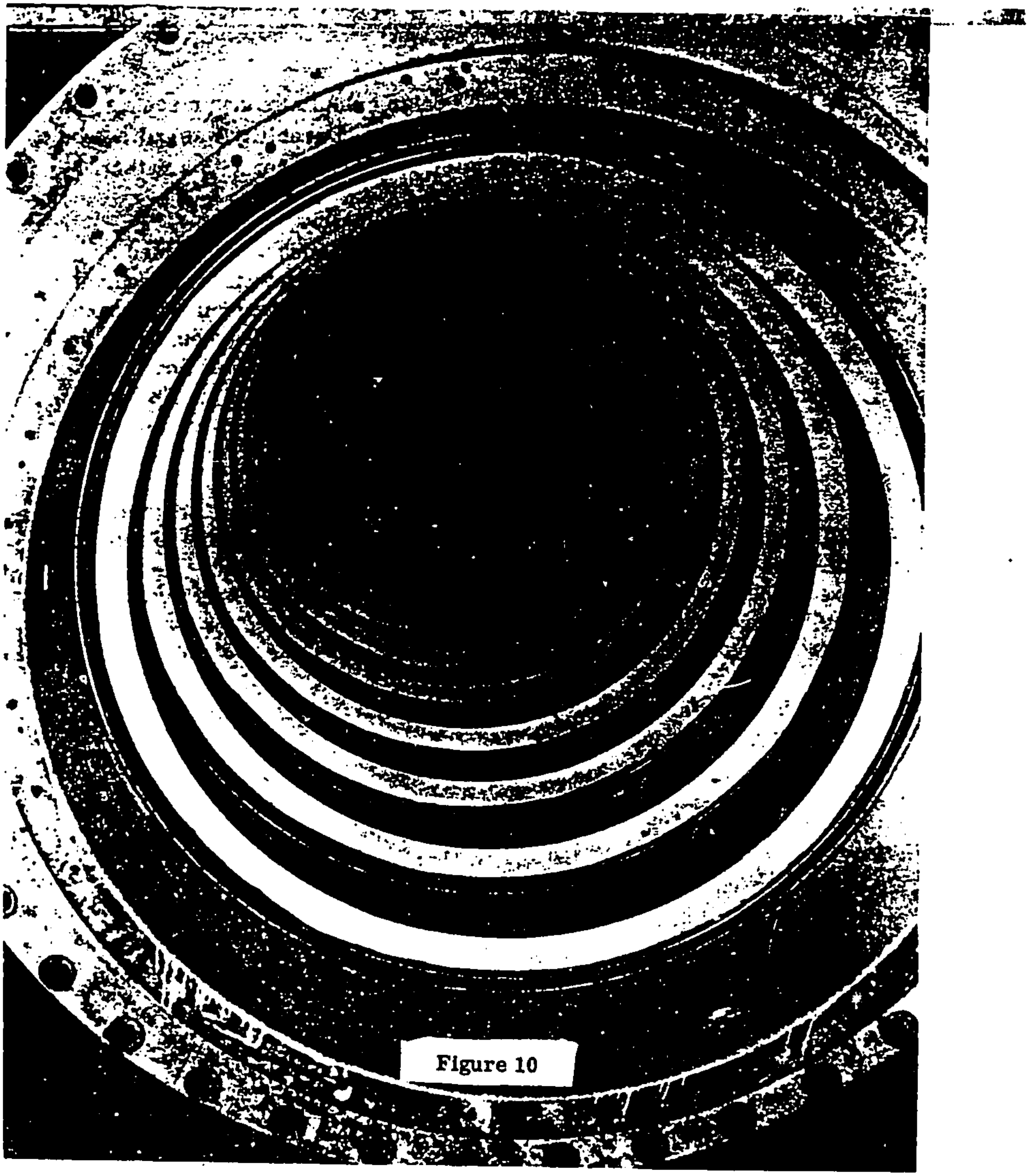


Figure 10

as was the agreement between the design calculation and measurement, and skin loading and launch tube dynamics. Durability was quite good with only minor repair required after the fourth shot with a rather rough steel and concrete test vehicle.

"The fifth shot was conducted with the launch tube inclined 30° from the vertical to provide a static gravity component force equivalent to the cross-flow sheer and coriolis forces encountered in shipboard launching. Sealing was excellent as was theoretical agreement on in-tube dynamics and skin pressure. The test program will continue with special emphasis on the reduction of the number of sealing lips and on testing the compatibility of the missile skirt and conduit with the seal facing."

At this point Captain Lieber showed a movie of the most recent 30° shot. He concluded his presentation with a second movie showing the complete POPUP test facility at San Clemente Island. He explained that they had fired their last shot from the POPUP test facility and would be dismantling the facility; he felt the STG would like a last look at it before it went.

Rear Admiral Smith presented Captain O'Neil to give the Fire Control and Guidance Report.

FIRE CONTROL AND GUIDANCE COMMITTEE REPORT DISCUSSION

"My discussion this morning," began Captain O'Neil, "concerns the program status of the major POLARIS Fire Control and Guidance equipment: Mark 1 and Mark 2 guidance; Mark 80 and Mark 84 fire control; the support equipment, principally the Mark 452 auto-tester; and the MOTS. I will also mention any difficulties that we have.

"The Mark 1 is performing very well. The system has required no changes or SPALTs in the last year and a half. None of the installations shows any signs of wearing out, and their return and repair rate is lower than expected. NAFI is doing the repair work. This, by the way, is the only current activity at General Electric with the exception of some phase-out. The inertial components are being repaired by their original manufacturers. The stock of Mark 1's seems adequate and, in general, the system presents no problems to Sp 23.

"The Mark 2 gimbal assembly pictured in figure 1 is being produced by both Minneapolis-Honeywell and GEOD. Figure 2, a comparison of actual and required delivery dates, shows that they are about one month ahead of schedule.

"Hughes and Raytheon are producing the electronic package pictured in figure 3. As shown in figure 4, they are meeting the scheduled delivery rate. This rate, crossruffed against the NWA drop-dead dates in figure 5, is within SPAN requirements.

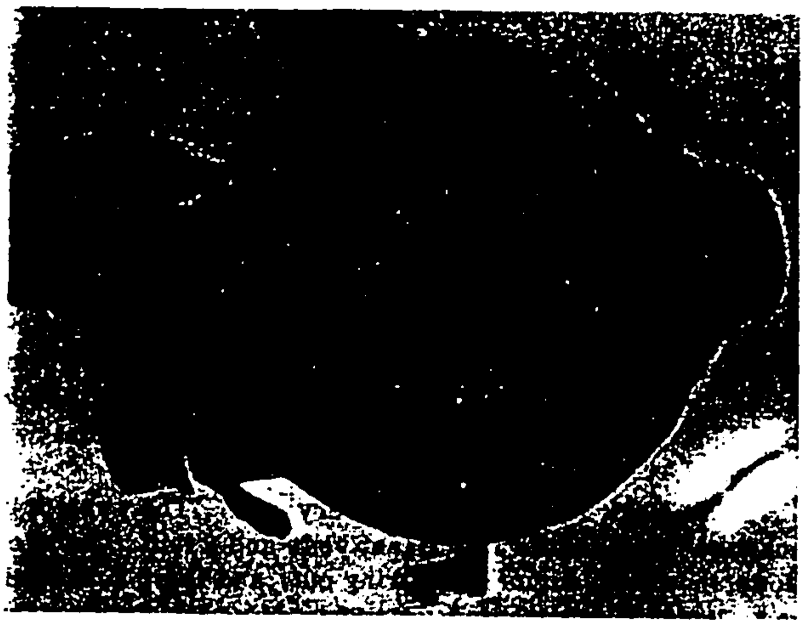


Figure 1

"We have overcome most of the major problems with Mark 2 inertial components. Even the usually erratic yield rate has recently become fairly static.

"Nortronics, a third source producer new to the program, is turning out the Mod 2 IRIG, figure 6. They had some difficulties in initial production which required schedule changes. However, their current production, summarized in figure 7, is at the desired level.

"The faulty operation of another inertial component--PIPs--gave us some difficulty. A certain block of PIPs have microsyn rotors with ferrite end plates. These are supposedly impregnated but they have been absorbing damping fluid, a condition which produces either a scale factor or a bias shift, or some combination of both. The bad components are being culled out. After this month, the high rejection rate at NWA should drop.

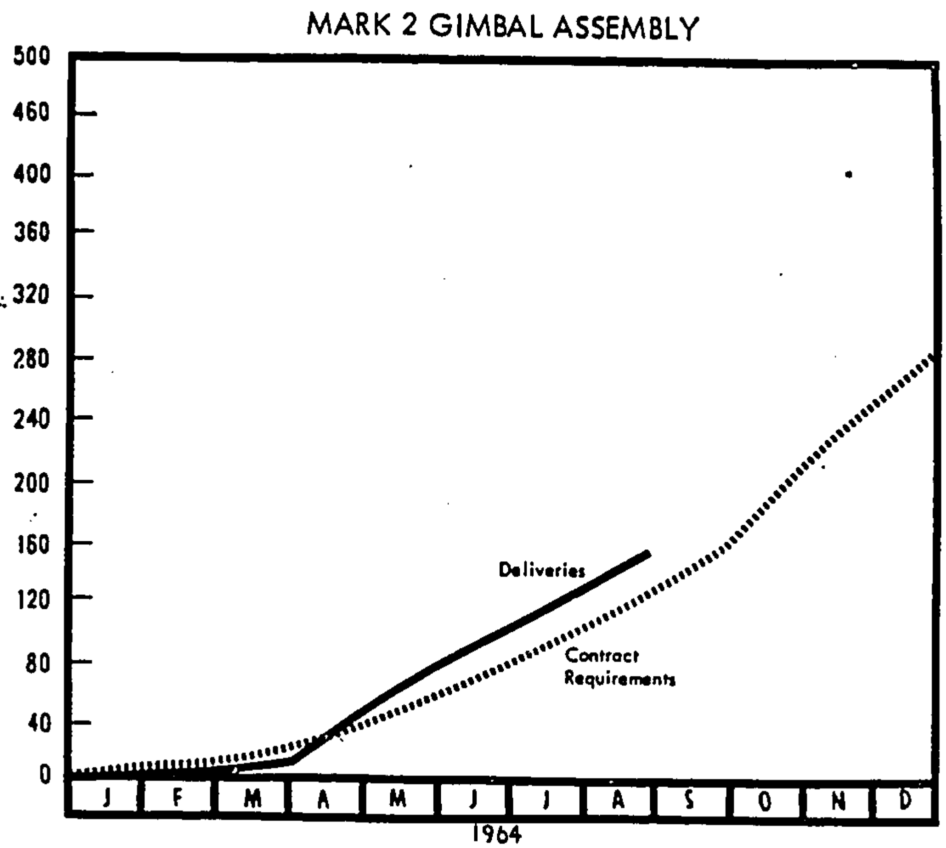


Figure 2

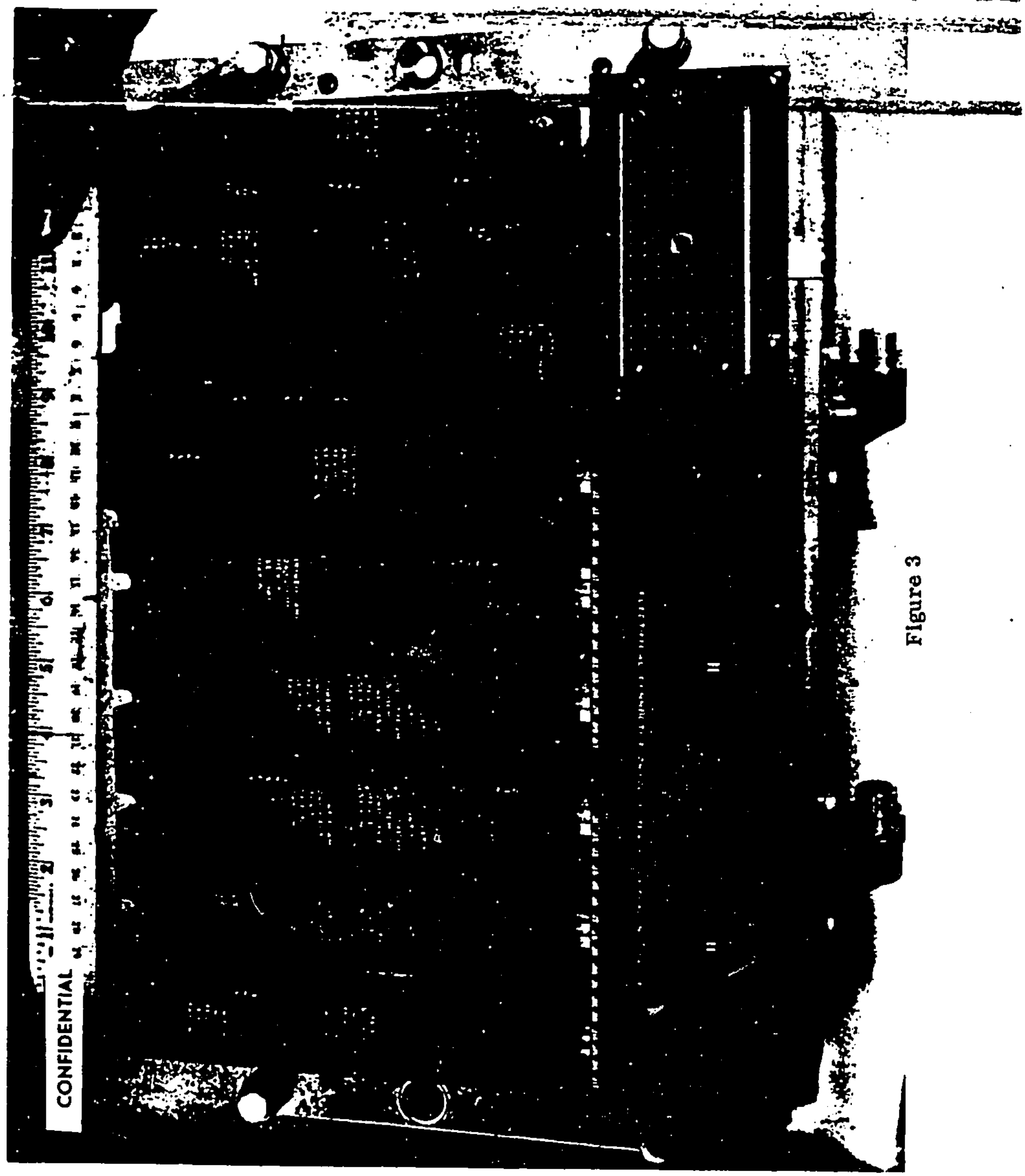


Figure 3

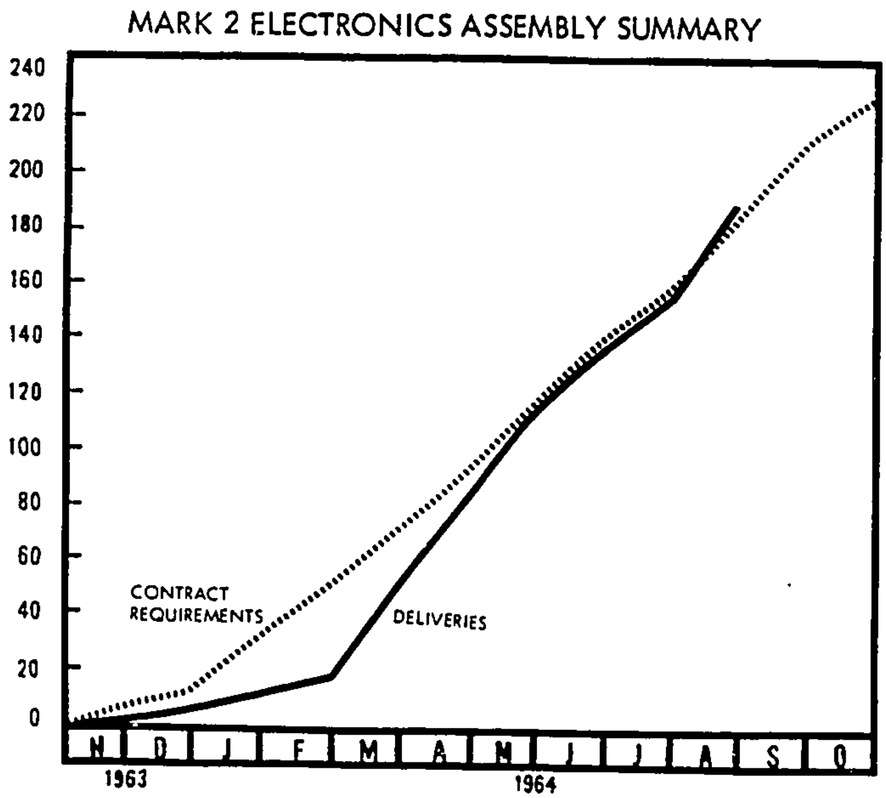


Figure 4

"The Mark 80 program is on schedule. The Mark 80 fire control system in the SSB(N) 598, figure 8, is being converted. No problems should arise because the Dam Neck system has been completely SPALTed and proven out.

"The Mark 84 for the 616-Class, shown in figure 9, is now being produced under firm fixed price contracts with penalty clauses for late deliveries.

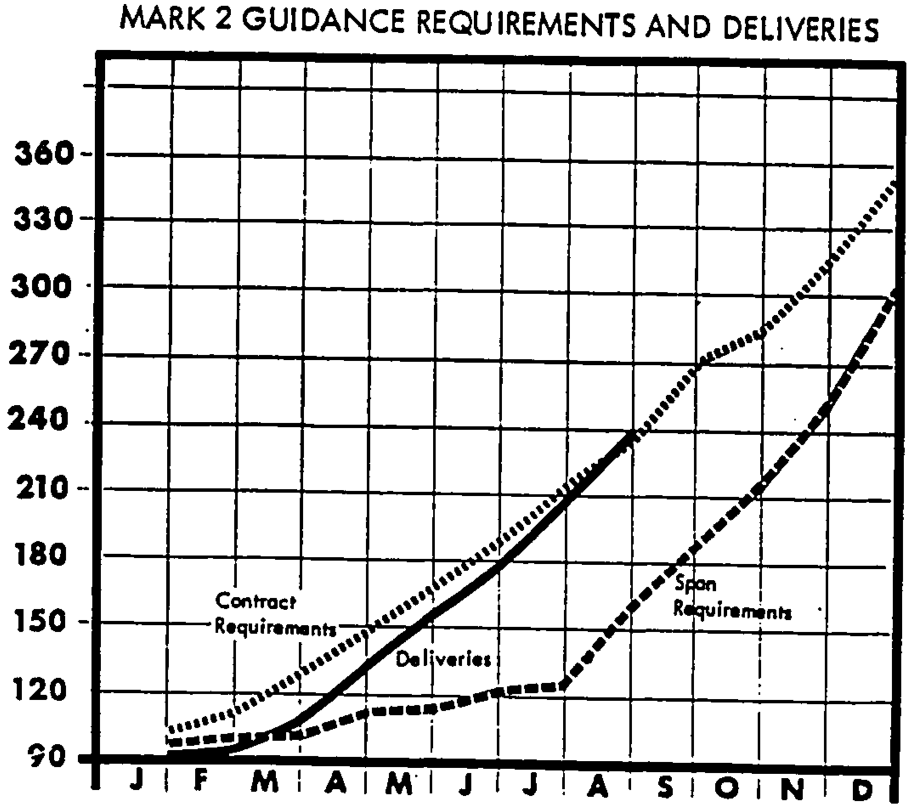


Figure 5

"We are running well ahead of the ready-for-sea schedule, in some cases 16 to 18 months as shown in figure 10. Of course, this is not due to our design, but to schedule changes for the 640-Class, resulting from the safety program initiated after the USS THRESHER incident.

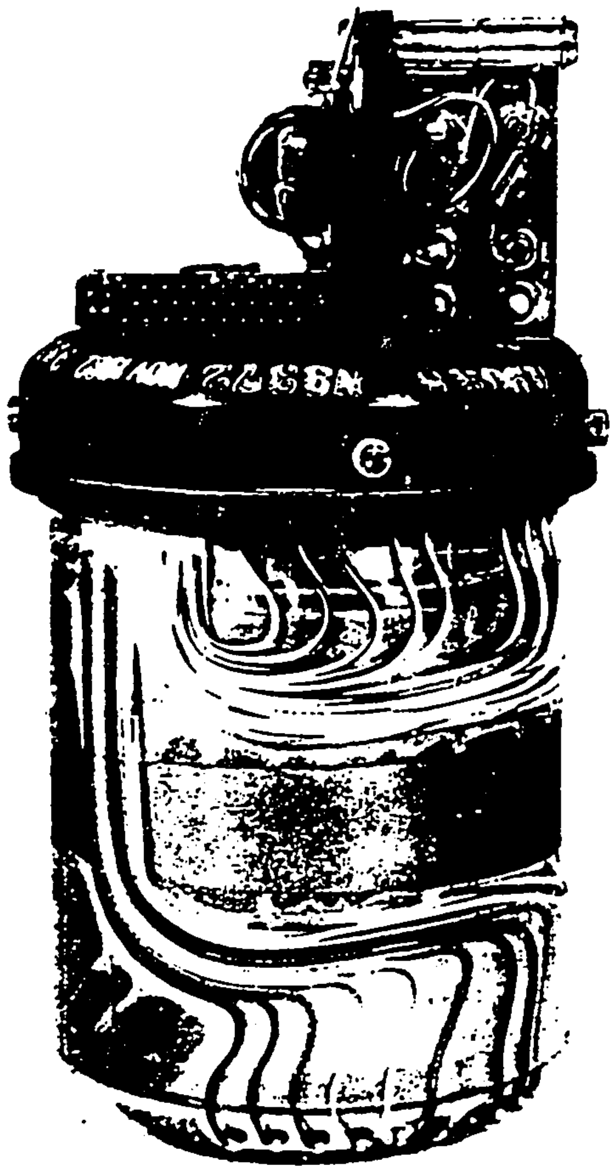


Figure 6

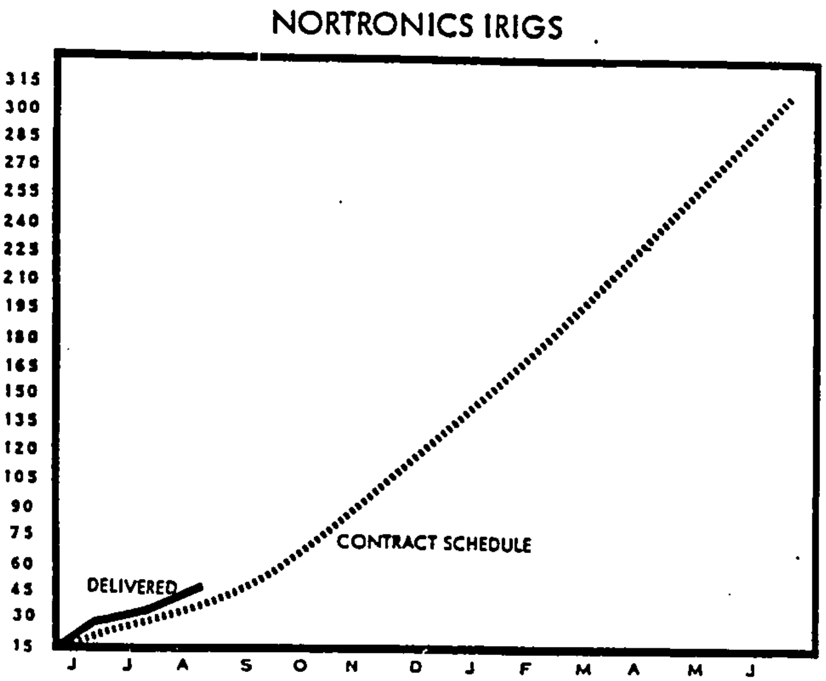


Figure 7

"Deliveries of the Mark 84 systems listed in figure 11 include 23 to the 616-Class boats. An additional eight submarines are scheduled to receive the system. The hangar queen at GEOD can be used for checking out SPALTs for training or for any other applications that arise.

"Our installation progress summarized in figure 12 includes a start on the 640-Class and three systems in storage. Although the schedule calls for delivery 12 months prior to ready-for-sea, nine or ten months seems to be sufficient.

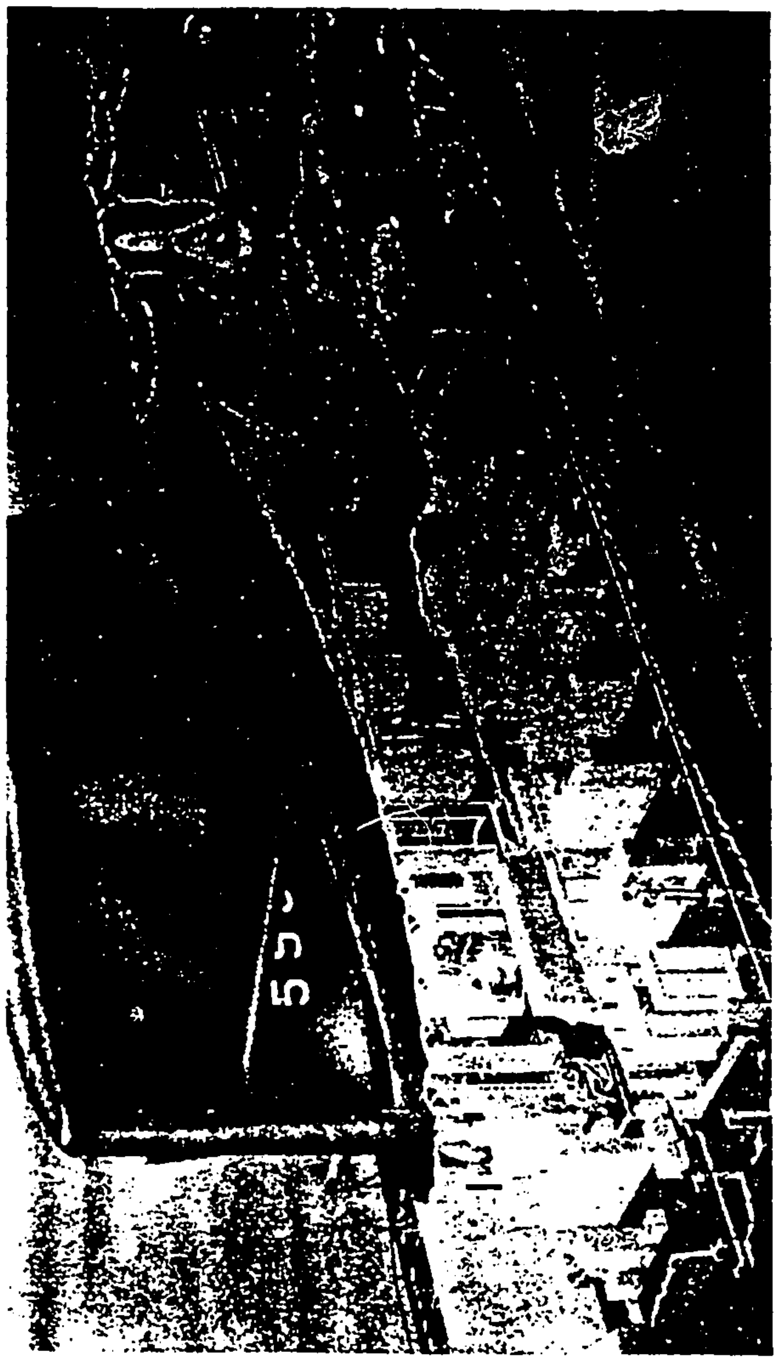


Figure 8

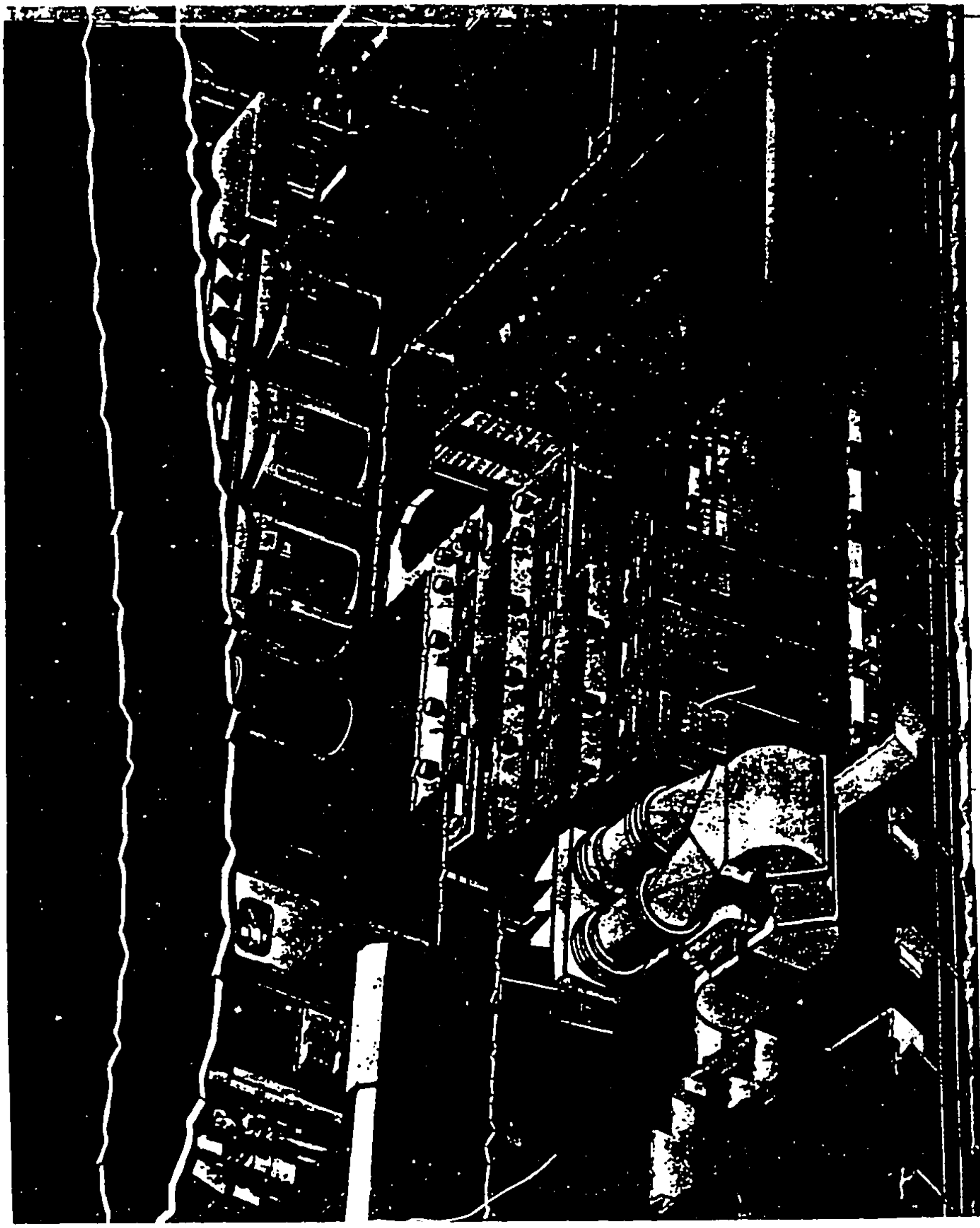


Figure 9

MARK 84 FIRE CONTROL SYSTEMS DELIVERIES

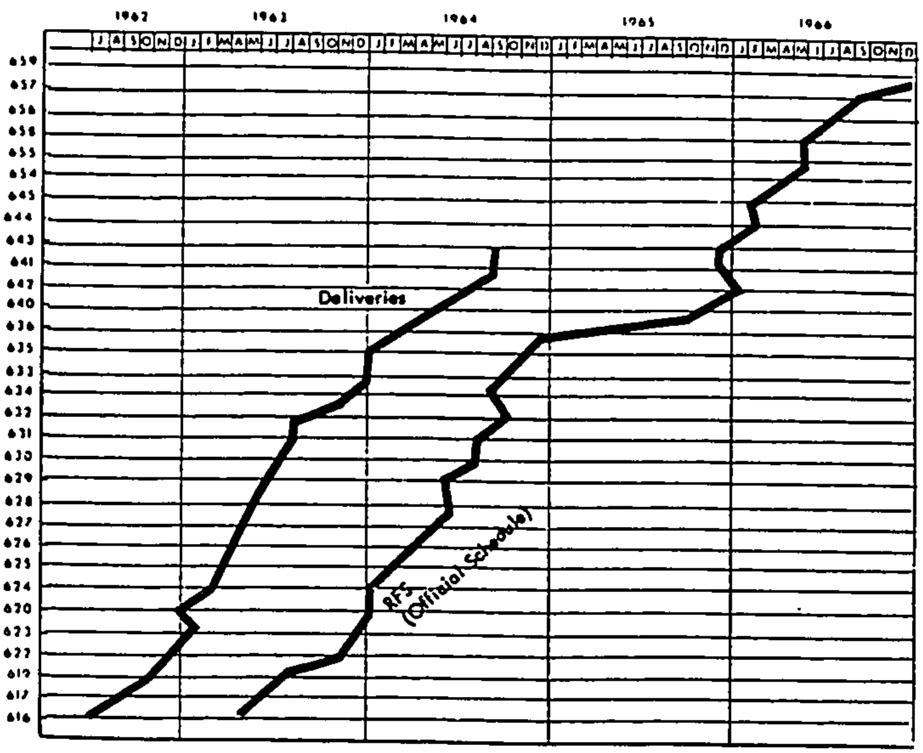


Figure 10

MARK 84 FIRE CONTROL SYSTEMS

Delivered to SSB(N)	23
TRNG Systems at Dam Neck	3
TRNG System at Pearl Harbor	1
TRNG System at Charleston	1
Unit Labs at Dam Neck	2
Hanger Queen at GEOD	1
TOTAL	31

Figure 11

MARK 84 FIRE CONTROL SYSTEM INSTALLATION TEST PROGRESS

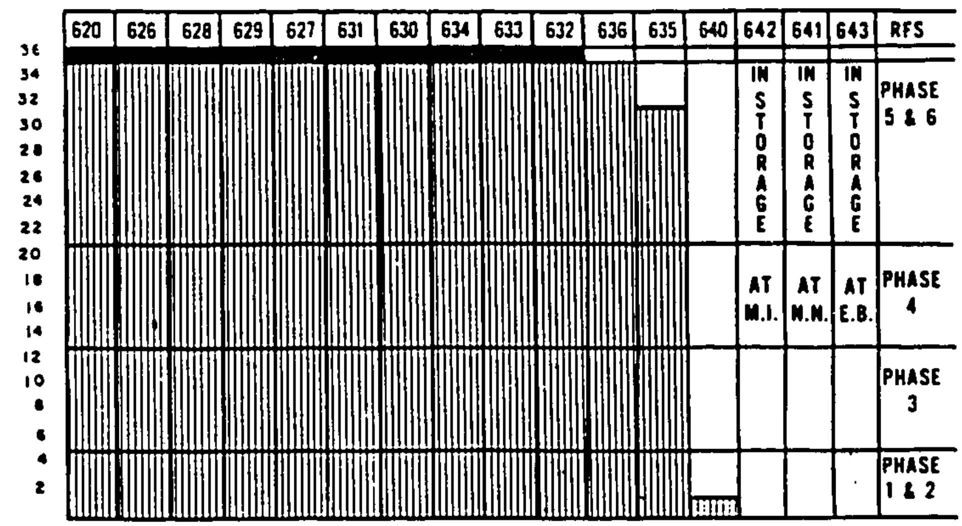


Figure 12

"Figure 13 is our SPALT schedule. The SPALTs shown as completed have become design changes. An average of 25 SPALTs, or about 400 man-hours of work, per installation are not yet completed. Certain of these will always appear as incomplete because they are designed to be accomplished only when a failure occurs. For example, if a trolley system cam selector is working, it is not necessary to install vernier cams. But we supply the ship with a kit that can be installed if there is a failure."

Rear Admiral Smith asked if this situation was typical of the remaining 25.

SPALT STATUS OF THE MARK 84 FIRE CONTROL

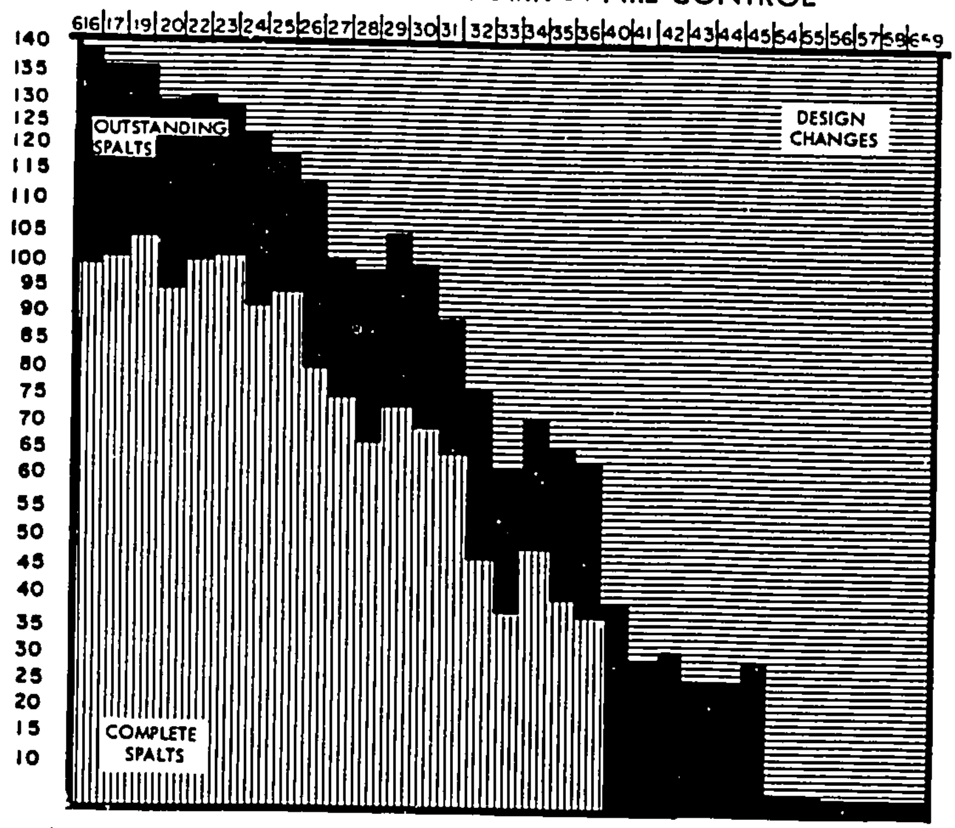


Figure 13

Captain O'Neil replied, "It accounts for several of them, but remember that the actual number is not too important. Some of the SPALTs are very minor and the Type Commander has set up a schedule for their incorporation.

"Test Set Mark 452 is our guidance checkout equipment for the guidance systems Mark 1 and Mark 2. It is the large piece of equipment shown in figure 14 with the Mark 1. We have SPALTed all the Mark 137 guidance checkout equipment to Mark 2 capability.

"The number at the location indicated in figure 15 include two at POMFLANT and one each at POMFPAC, GEOD, and NAFI. POMFLANT and POMFPAC will rely heavily on the Mark 452, but will retain one Mark 137 for correlation. The tenders will also have the Mark 137. GEOD and NAFI will use their own test equipment but will receive one Mark 452 to be used for correlation.

"The MOTS Mark 412 shown in figure 16 is modularized. It contains 1207 Type-3 modules, 89 different kinds. Sixty-nine are unique to MOTS, while twenty are also used in the Mark 84. It has the same door and post construction as the Mark 84. The MOTS semi-automatically checks AC and DC measurements, pulse measurements, frequency, and complex impedence measurements. Figure 17 is a close-up of the control tape.

"Figure 18 summarizes our delivery schedule. The most important installations are those in the SSB(N)616 and the SSB(N)631 which to date have a total running time of 6800 hours. We are preparing the other boats. Each has been equipped with a so-called first stage consisting of door frames, IPJPs, and cabling. If we have a follow-on MOTS program the only installation remaining will be hanging Type 2 modules on the doors.

"The present module testing capability of MOTS is shown in figure 19. The type 2 modules were installed alongside the tender by tender personnel under the supervision of the GEOD Product Service Group. Installation took two days; check-out about three weeks. The SSB(N) 616 reported that MOTS was operational during its last patrol.

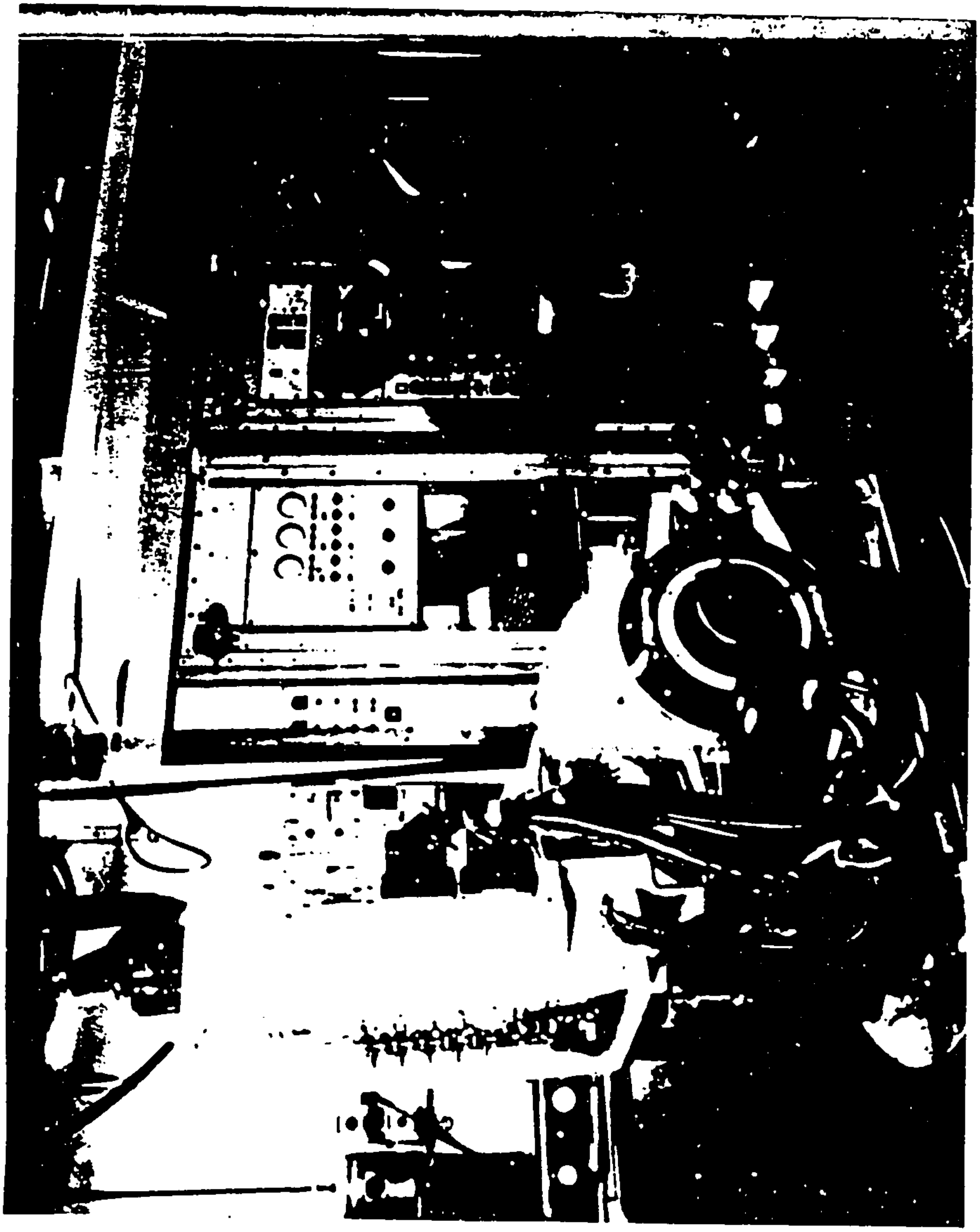


Figure 14

MARK 452 GUIDANCE TEST SET

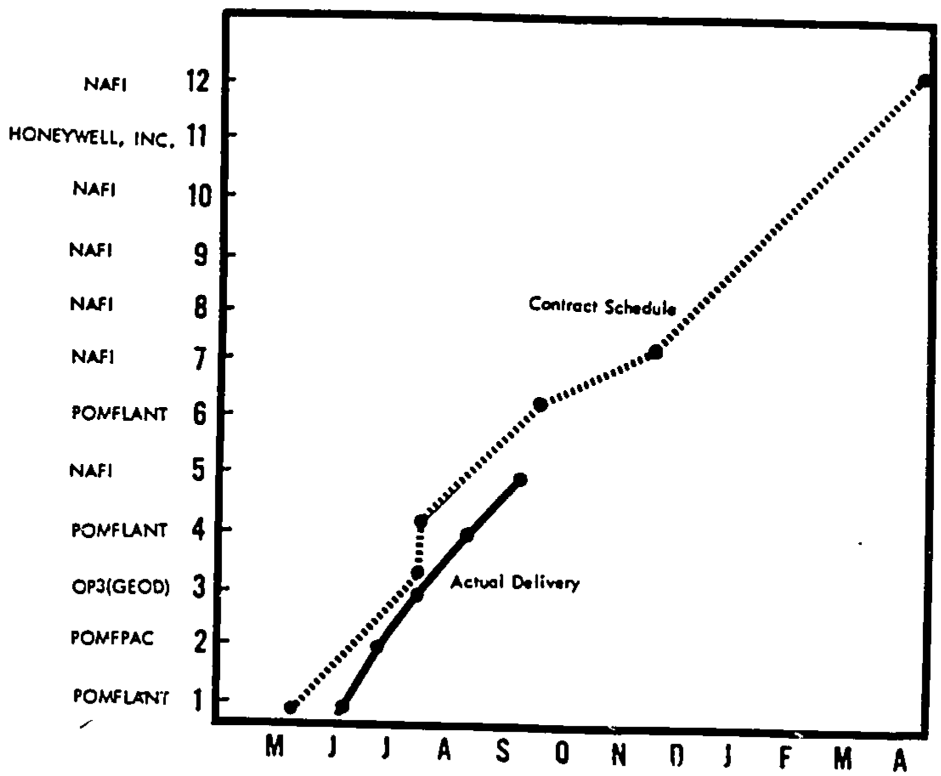


Figure 15

"Figure 20 shows some of the modules that we can check with the MOTS. The original design of the MOTS included the testing of the Type 3 module of the Fire Control System Mark 84, Guidance System Mark 1 and Mark 2, and modules for the MOTS Mark 412 itself, MTRE's Mark 6 and Mark 7, with a probable expansion to SINS and other navigation equipment.

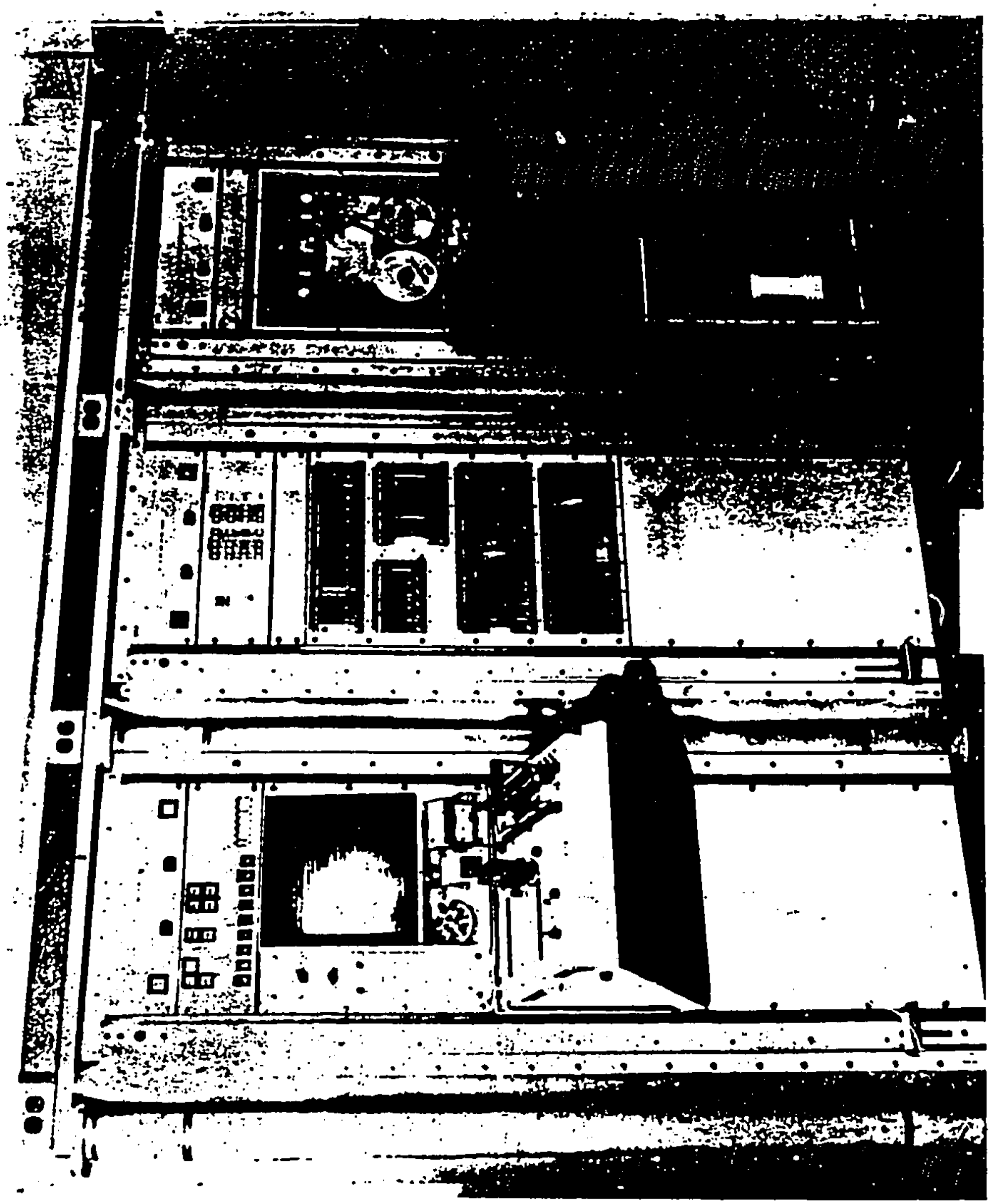


Figure 16

Figure 17

MARK 412 MOD 0 MODULE TEST SETS INSTALLATION

MOTS	DELIVERY	LOCATION
1	3/19/64	Dam Neck MCC Lab
2	11/18/63	AS-32
3	12/26/63	Dam Neck MCC Lab
4	3/3/64	O. D. Hangar Queen
5	2/19/64-4/3/64	O. D./SSB(N) 631
6	3/26/64	SP 24/NSS Hangar Queen
7	5/15/64	Charleston Training
8	*9/11/63-5/12/64**	SSB(N) 616
9	6/19/64	AS-19
10	7/30/64	AS-33
11	8/7/64	AS-31
12	10/2/64 (promised)	O.D./AS-34
13	10/15/64 (promised)	Pearl Harbor Training
14	10/28/64 (promised)	CNSY MMF

*First Stage Delivery
**Second Stage Delivery
Total Running Time: 6800 Hours

Figure 18

MARK 412 MODULE TESTING CAPABILITY

System	Total Module Types in System	Planned Testing Capability (4/65)	Currently in Field (9/30/65)
Mk 84	215	202	116
Mk 412	70	70	37
Mk 2 (Analog)	6	5	0
Mk 1 (Analog)	3	3	0
TOTAL	294	280	153

Figure 19

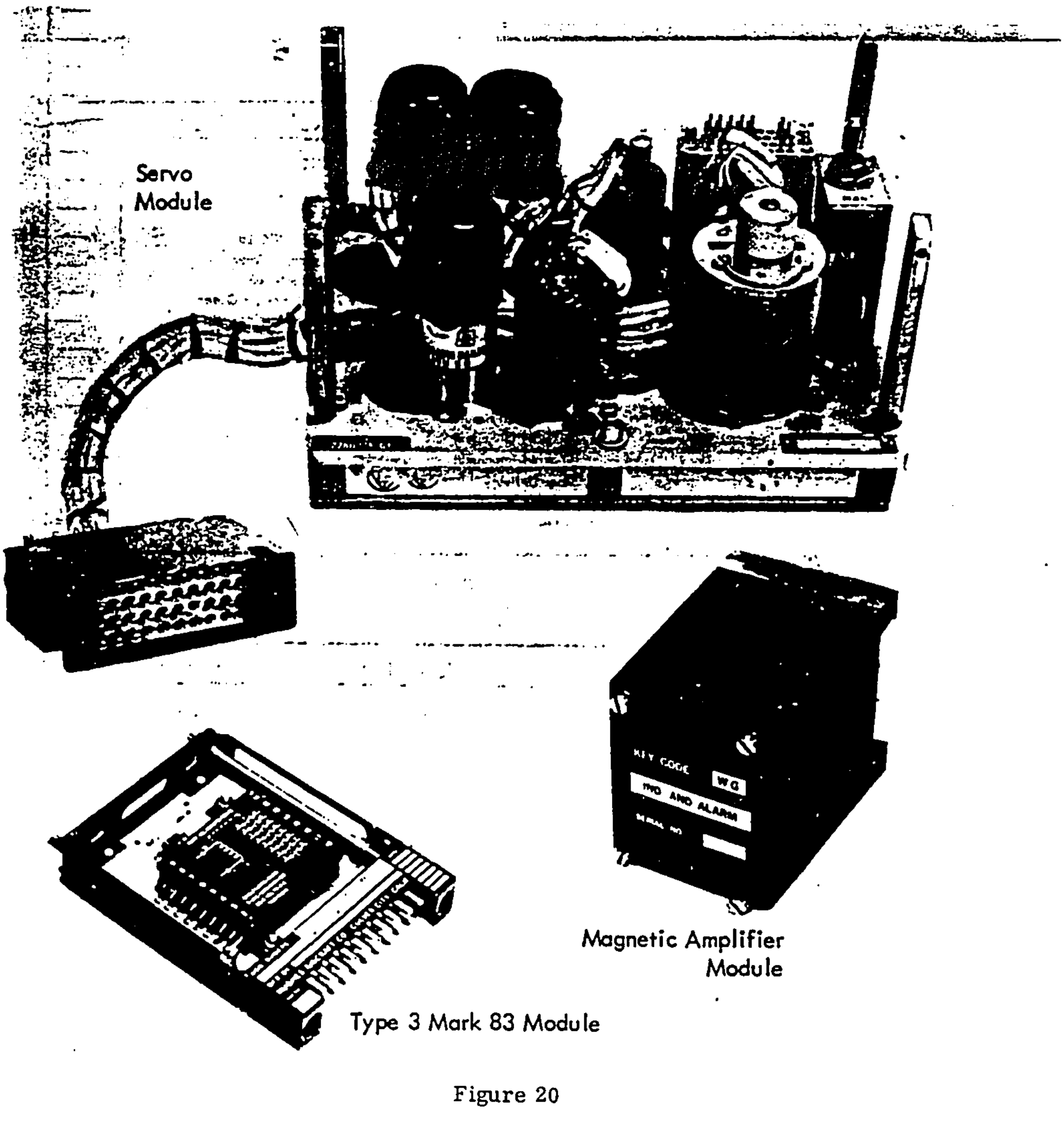

Servo
Module
Magnetic Amplifier
Module
Type 3 Mark 83 Module

Figure 20

"However, we confined the program to the Mark 84 and the MOTS itself until we got the show on the road. So MOTS has potential application, without being redesigned, to test modules for many additional FBM sub-systems. This would be accomplished by designing and compatibility testing of the appropriate accessories: adaptors, shown in figure 21; switching cards, shown in figure 22; and films.

"Figure 23 portrays some further possible applications of MOTS. We feel that the MOTS can successfully test about 70 to 75 percent of the modules used in systems aboard the SSB(N). This amounts to about a thousand modules and we have others that we feel MOTS can test.

"Another possibility that we have looked into is described in figure 24. It is a computerized program called a compiler which substitutes a computer program for a pencil and paper matching of MOTS capability to module test requirements. The compiler translates module test requirements written in the proper engineering test language into MOTS program language test tapes in inputs required to compare the simulated MOTS functions, which are put into the computer on a memory core, test limits, and inner connections for the module that can be tested. It would yield the sub-routines, and when they are not compatible it would compile a print-out and identify specific problem areas.

"With the Mark 412 computer program, it will be unnecessary for a module test engineer to know either the MOTS language or the MOTS characteristics. He simply standardizes and formalizes his test specs and puts them into a computer. They are cross-ruffed with the 412 simulator and the results are the sub-routines. This will save doing the job by hand.

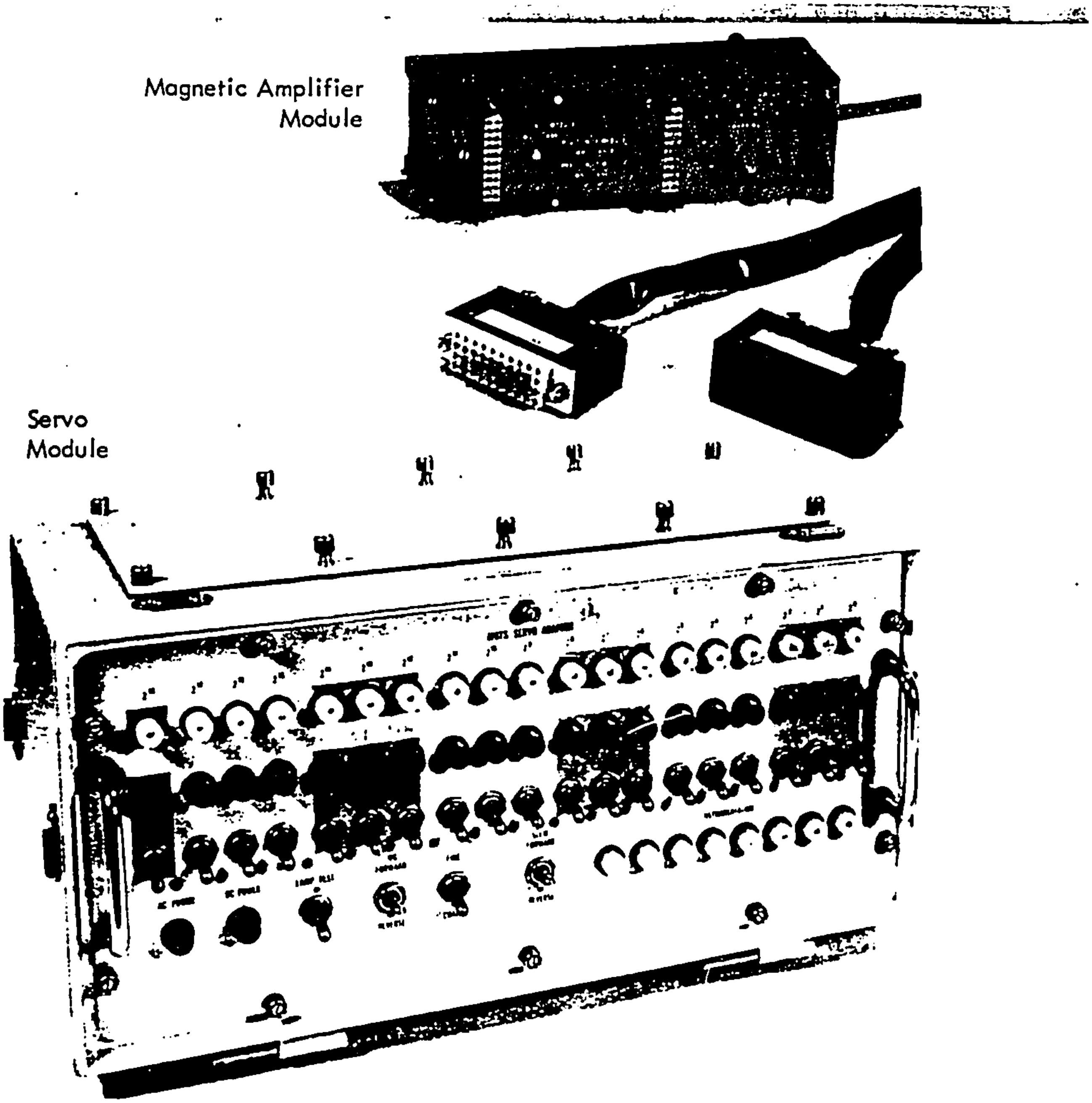
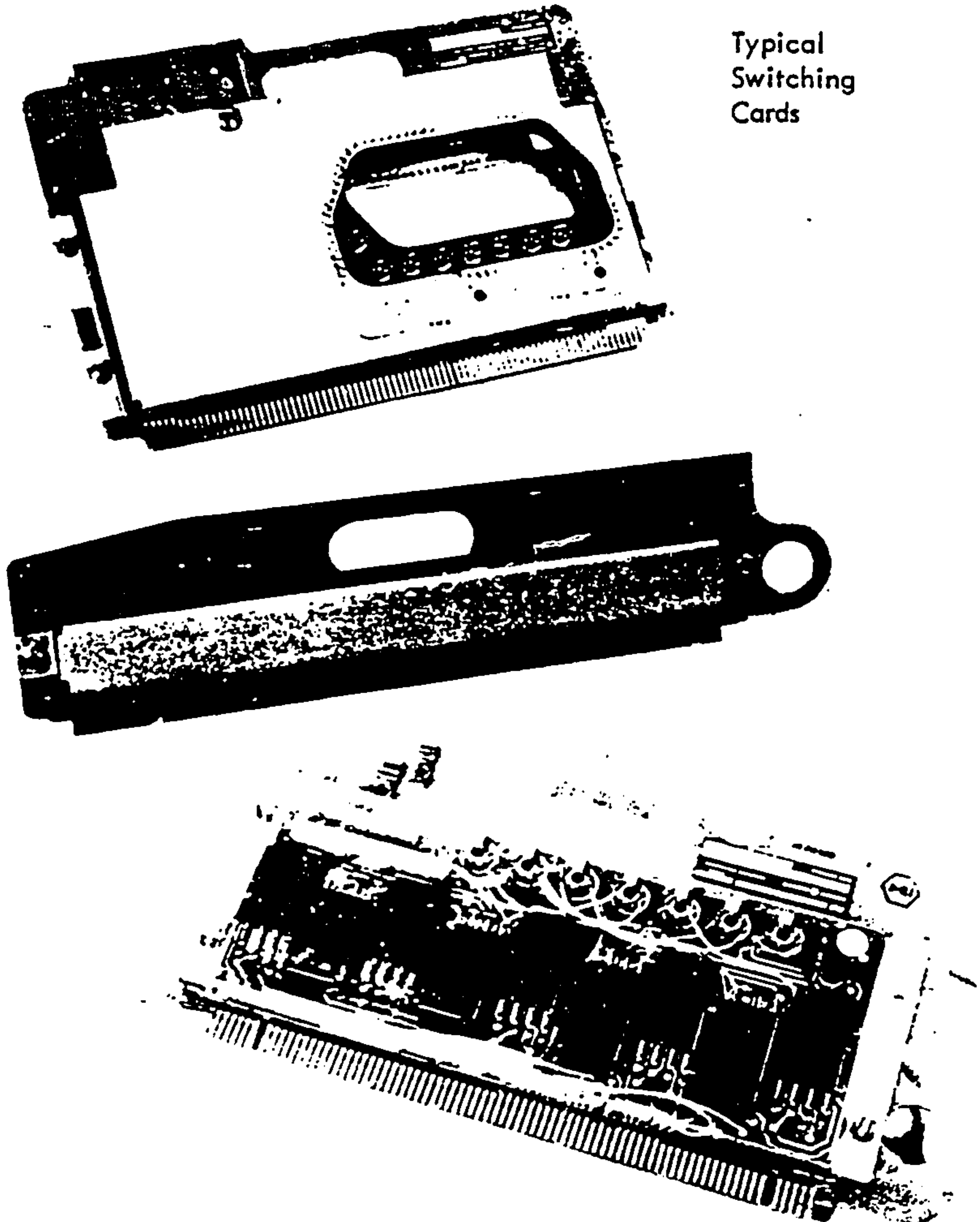


Figure 21



Typical
Switching
Cards

Figure 22

MARK 412 POTENTIAL TEST CAPABILITY

MODULARIZED SYSTEMS	MODULE TYPES
MK 7 MTRE	134
MK 6 MTRE	45
AN/WPN-3 LORAN C	50
MK 2 SINS	216
TRANSIT RECEIVER AN/BRN-3	103
TRANSIT COMPUTER	39
AN/BQN-2A TIME & FREQ. STANDARD	18
STABILIZATION DATA COMPUTER	157
NAV DAC - 2	119
NAVIGATION CONTROL CONSOLE	29
MULTI-SPEED REPEATER	21
TYPE II D AND B PERISCOPE	7
AN/BQN - 3 SONAR	48
	986
MK 80 CARD COMPUTER	10
MK 80 FIRE CONTROL SYSTEM	72
MCC AND UNIT LAB TRAINER SIMULATORS:	
598 CLASS	7
616 CLASS	22
SHIPBOARD TRAINER 21A36	44
TEST INSTRUMENTATION - PORI	28
NON-TACTICAL	69
MATS	7
MK 452 AUTOTESTER	6
	265
TOTAL	1251

PROSPECTIVE YIELD, TESTABLE ON MK 412, WITH SWITCHING CARDS, ADAPTERS, TAPES AND FILMS - 70 to 75% (875 to 940 MODS)

Figure 23

"Also, if we get MOTS and if a SPALT is dictated, we will be able to run all these test tapes through the computer to find out if by SPALTing the MOTS we have ruined a tape. If we have, we can correct it very rapidly with a run on a standard 704 computer.

MARK 412 COMPILER BLOCK DIAGRAM

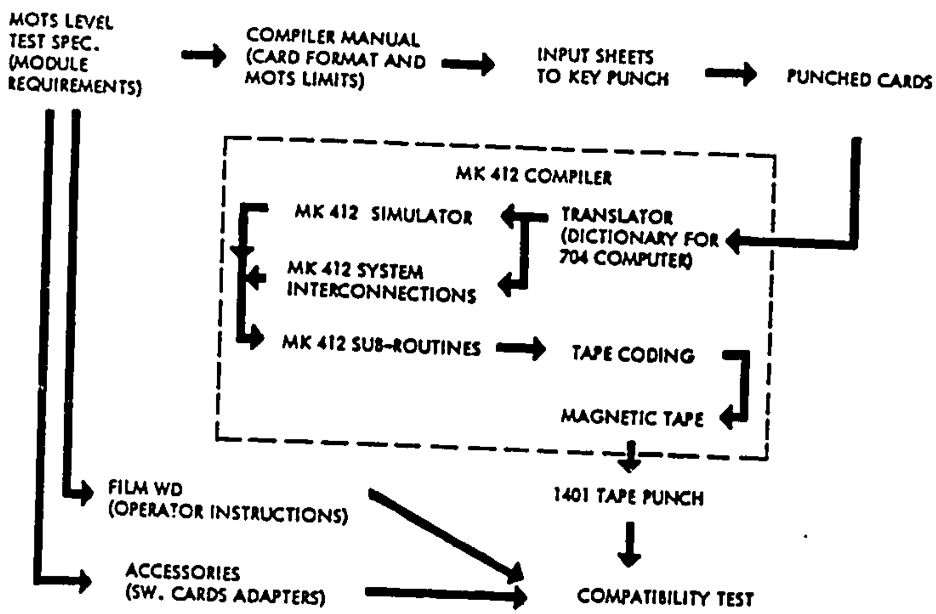


Figure 24

"Figure 25 summarizes the results of a SSB(N)616 patrol."

"These are from one patrol?" asked Admiral Smith.

"Yes," replied Captain O'Neil. "Don Lawrence was the Weapons Officer and he made many favorable comments.

"I have only one other thing to say and that is that I think we have slowly been converted from a technical branch into an administrative or budget branch. Our technical problems seem to have subsided. I am available for questions and Mr. Mitchell can answer any questions you might have about MOTS.

HIGHLIGHTS FROM 616 PATROL REPORT

MOTS Is Good for Isolating Intermittent Failures

MOTS Reduces Downtime for Catastrophic Failures

MOTS Permits Emergency Repairs of Type 3 Modules

MOTS Was Used to Test 171 Modules of 33 Different Types

MOTS Will Be More Useful as Mark 84 Ages

MOTS Should Be Expanded to Include MTRE Mark 7 and, Ultimately, NAV System Modules

CONCLUSION: Strongly Recommend that MOTS Be Retained Aboard SSB(N)

figure 25

As there was no more discussion relating to Captain O'Neil's report, Admiral Smith asked for comments or questions on any other area covered during the conference.

TERMINAL DISCUSSION

Rear Admiral Smith asked for comments that anyone might wish to make before the conference adjourned. Mr. Stevenson raised the problem of Class C waiver approval which Captain Christman had discussed in the report of the Missile Committee. Admiral Smith pointed out that the new policy was not retroactive and did not apply to present contracts.

"But while this is not an immediate problem, I think we should discuss it," Mr. Stevenson replied. "The new policy is going to be applied sooner or later. We need a clarification of the C and D categories. At the present time, we have about 1500 Class C waivers per month. Under the new policy these would all have to come back to Sp 27 for approval. This would cause a very bad situation. But, as Mr. Buescher and Captain Praeger have noted, most of these could be redefined as Class D if we studied them carefully. We still should try to estimate how many we will have to deal with and what we will do with them."

"Getting these straightened might give you some indication of how ready you are for firm fixed price contracts," Admiral Smith added.

"Would this be applicable to sub-contracts as well as primes with the Navy?" Mr. Wetmore inquired.

Mr. Buescher pointed out that the waivers under discussion all related to Sp-approved documentation, whether they were applied to direct contracts or sub-contracts.

"This policy would only apply if the prime is a fixed price contract," Admiral Smith stated. "But what is really important here is that the new policy will only apply to future firm fixed price contracts. The purpose of the memorandum that Captain Christman referred to was to provide ample warning of the situation that will exist so that serious consideration will be given before awarding such contracts."

Admiral Smith then referred to the skirt corrosion problem which Captain Christman had discussed. He stated, "One thing that I do not believe he mentioned is that the test environment that we have had is much more severe than the expected patrol environment. For almost all of the SABOT shots, the tubes were dunked in salt water. There was no attempt to control the water or to clean out the tubes, as has been the usual procedure with A2's."

"I think we should recall our experience with the A1's," Mr. Wetmore added. "When some of the early A1's returned from their first patrol they were rather badly rusted. But after a few patrols this situation was cleared up. There is a reasonable chance that the present A2 skirt will hold up. The present situation does not require a decision on whether or not we should change the skirts. However, I think we should make some decision on buying materials for the launcher changeover mentioned by Captain Lieber."

"Yes, and I guess that once developed, the procedures and materials for the launcher changeover could be kept in reserve," Admiral Smith observed. "The changeover could then be made at any rate that patrol experience demanded."

"At this point, we think there are no technical problems in delivering the system Captain Lieber described," Dr. Mechlin said.

"Isn't there supposed to be a production change point for the skirts?" Mr. Eyestone inquired.

"No, a decision on that has not yet been made," Mr. Stevenson answered. "It is still under consideration. But, as Mr. Wetmore has pointed out, production of the skirts is so near to the end that unless a really severe problem exists a change should probably not be made."

Admiral Smith agreed and the discussion turned to the details of the changeover system that Captain Lieber described in his report. Mr. Wetmore asked Dr. Mechlin about the material used for the insert. Dr. Mechlin replied that they needed maximum toughness and minimum absorption and this had given them a number of materials from which to chose.

Captain Gooding began discussion of the storage of equipment needed for the changeover. He noted, "There are certain things you could do alongside a tender after each patrol for upkeep, which might determine how many of these tooling sets you would put on board a tender. One set might do it, and then again you might need three. What I mean is that there is probably some reasonable number of missiles which they can remove per upkeep."

"A set per missile removed certainly lets you keep up with all missiles removed," Dr. Mechlin observed.

"Yes, but the basic problem with that is that if the corrosion is severe during this changeover period, there will be a number of motors with bad skirts; there will not be enough time for launcher modifications to be made," Mr. Wetmore noted. "The only solution would be to change the missile skirt."

"You could complete the hold-down ring change program at any scale necessary within six months," Dr. Mechlin replied. "This would include sufficient time to ship the quantity of materials needed overseas. Within that period of time, certainly a large number of skirts will not corrode so badly that they will have to be changed."

[redacted]

[redacted]

"It depends on how you judge the data that we have received up to now," Mr. Wetmore commented. "Some of the data from the AIMs shows bad corrosion after thirty days. It would depend on how the environment compared to that which the AIMs have seen."

"Have any criteria for severity been established?" asked Admiral Smith.

"We have been working on this," Mr. Wetmore replied. "If the clamp rings are left closed, the skirt could probably corrode all the way and still support the normal load. A few thousandths of an inch of aluminum would be sufficient."

"We do not know the answer yet, Admiral," Mr. Stevenson added. "From extrapolations, we know that anything we have seen so far is structurally quite safe. But we simply do not know if this will be borne out in actual experience."

At this point, discussion of Captain Christman's report ended. Admiral Smith suggested adjournment. The dates for the next meeting were agreed upon as 18 and 19 November.