THE FLEET BALLISTIC MISSILE SYSTEM AND THE POLARIS MISSILE

BY

COMMANDER H. B. GRANT, R.N., A.F.R.AE.S., A.M.I.MAR.E.

The following article has been compiled from unclassified and publicly available material in the hope that it may prove of interest to those who have seen the many mentions of Polaris *in the press but have been unable to pursue the matter further. No guarantee of accuracy can thus be given, but the feasibility of most of the items is established.*

The importance of the seaborne bombardment weapon has always been remarkable, and this extension of it, combining mobility, power, concealment and instant readiness, is of tremendous strategic importance.

No attempt is made to assess it as a replacement for a strategic air force with nuclear capability, but its equivalence in terms of land-based weapons, even if these are of greater individual power, is very considerable.

THE FLEET BALLISTIC MISSILE SYSTEM

A public statement in December, 1958, announcing the cancellation of the multi-million dollar *Regulus* 2 contracts in the U.S.A. accentuated the tremendous activity in the submarine bombardment weapon field, due to the very great strategic importance attached to it.

Both the U.S.A. and U.S.S.R. have followed through the early German experiments on the submarine launched guided weapon, and in this brief survey of the most up-to-date system some mention will be made of the missiles which have gone before. It is important to realize, and the cancellation of the *Regulus* 2 contracts demonstrates this admirably, that progress is very rapid in weapon systems at this time and that enormous sums of money, representing a considerable proportion of the nation's product, are involved in a precarious gamble.

It is only necessary to glance at a map to see that a missile with under 2,000 miles range, fired from an off-shore site, can threaten any worthwhile target in the whole of the Asian continent, and thus to appreciate the basis of the mobile based intermediate range weapon concept.

The degree of mobility of the base and its vulnerability to attack are vital considerations ; a highly mobile base with little vulnerability to attack enables the greatest possible area to be dominated with the minimum number of units. There is, therefore, in the development of this weapon system, a great dependence on that of the possible types of mobile base.

It is equally possible to threaten, or to retaliate against, any target within the continent of Asia with long-range inter-continental missiles, and indeed, prior to the development of a suitable mobile weapon base, this appeared to be the only solution, and still remains one of the possible solutions. However, with improvements in the mobile bases and a realization that static launching sites will always be vulnerable (it being understood that it is almost impossible to ' harden ' a site sufficiently for it to remain operational during the type of nuclear bombardment it is now possible for an enemy to lay down) the mobile base solution becomes an alternative. Development of static site weapons, such as Thor, Jupiter, Atlas, Titan and Minuteman, still continues due to the

TABLE I

Name	*Range*	*Speed and Altitude*	*Weight*
Regulus 1	500 miles	M = 0·9 at 20,000 ft (approx.)	14,000 lb
Regulus 2	In excess of 1,000 miles	M = 2 at 60,000 ft (approx.)	25,000 lb

caution with which it is necessary to assess these weapon developments, to the fact that some of these may become operational earlier, and finally, because of the limitations to the payload in the necessarily smaller, mobile based, missile. The decision between these two systems, should a country find itself unable to proceed with both, will indeed be a difficult one.

The Germans showed the advantages of the mobile launching site on land in their use of the V2 missile, but when it is required to take the missile closer to the enemy coast it is necessary to consider the sea and the air as the operational media for the mobile bases. U.S. Weapon System 199B, a version of which is called ' Bold Orion ', is developing the airborne base for such a missile, and the Fleet Ballistic Missile System the seaborne base. More will be said of the Bold Orion project later.

A surface ship launching base would require the support of large numbers of vessels carrying the defensive elements necessary against air, surface and underwater attack. This would be economically prohibitive to provide for a number of dispersed missile launching units, would be impossible to conceal totally from the enemy, and would advertise the presence of the launching ship. The development of the nuclear submarine with long endurance and high speed when submerged has provided the almost ideal seaborne launching base.

German Developments

Early efforts in the submarine based guided weapon field were made by the Germans towards the end of the 1939–1945 war. The missiles were the rather primitive V1 and V2 types, but even these, had the nuclear warhead been available, would have constituted a very deadly threat.

The V1 could be launched from a simple catapult type structure on the casing of the conventional submarine of that day, and represented no more than a minor challenge in the construction of suitable watertight enclosures for the missiles, and in the drills required to surface, assemble and launch the missile. Practice by the U.S.N. after the war showed that a similar missile could be launched and the submarine resubmerged in under five minutes.

The V2 missile, with the liquid oxygen and alcohol motor, was rather more of a technical challenge. A solution was in sight at the end of the war, however. This consisted of a container enclosing the missile and fuel tanks, up to three of which containers could be towed by a submarine at one time. The launching of the missile was preceded by the surfacing of one container, the preparation and fuelling of the missile by a crew from the submarine, and the firing from the adjacent submarine when all was ready. The problems were numerous but principally concerned the use of the liquid oxygen and alcohol motor.

Subsequent American Developments

The U.S.A., who benefitted with the U.S.S.R. from the German experience, first concentrated on the easier problem of the perfection of the V1 type of missile in this submarine role. The Loon missile, with better range and reliability, was fired from submarines quite early in the post-war period, but soon gave way to the more refined Regulus programme. A great fillip to this project

FIG. 1—LAUNCHING REGULUS 2 FROM A SUBMARINE
(*Flight*, *Vol.* 74, *No.* 2599)

came when it was possible for the missiles to carry nuclear warheads, and this really marked the beginnings of the effective submarine launched weapon.

The capabilities of the Regulus missiles are summarized in TABLE 1. Both are air supported missiles with air breathing turbojet engines ; in fact, pilotless bombers carrying nuclear bombs.

Regulus 1 has been operational for some years now ; Regulus 2 was first flown in May, 1956, and launched from a submarine in September, 1958.

A contract for $26 M was awarded to Chance Vought Aircraft in February, 1958, for the continued evaluation and production of Regulus 2. Three U.S.N. submarines were earmarked for the fitting of the Regulus 2 weapon system : the nuclear powered U.S.S. *Halibut*, and the conventionally powered U.S.S. *Grayback* and U.S.S. *Growler*.

The cancellation of the Regulus 2 contract in December, 1958, as a result of the progress which had been made in the Polaris project, leaves the U.S.N. with some Regulus 1 missiles which will be used by the U.S.S. *Tunny* and U.S.S. *Barbero* which have been equipped with the missile for some years, and the U.S.S. *Growler* and U.S.S. *Grayback* which were planned originally to handle both Regulus 1 and 2.

The U.S.S. *Halibut* which was to have carried Regulus 2 will be completed as a Regulus 1 submarine, and all other nuclear submarines originally planned as Regulus carriers will be completed as conventional nuclear submarines. The only surface ship which was planned to carry Regulus 2, the nuclear powered cruiser U.S.S. *Long Beach*, will be completed with only Terrier and Talos surface to air guided weapon systems.

Some $100 M will be saved by these measures for re-application to other projects.

Subsequent Russian Developments

From the same starting point similar progress has been made.

The ' J ' series of missiles based on the V1 (air-supported and air-breathing type) finalized with a missile capable of about 600 miles range at M = 1·4.

But it seems that the greater priority was given to the ballistic type missile and in June, 1958, considerable production of the solid rocket motored Comet 2 (CH 18) was reported. This is a stop gap missile pending the development of the U.S.S.R. equivalent of Polaris. This is designated Comet 3 and will have about 1,800 miles range.

It is interesting to consider the importance of a report which maintains that the Comet 2 has been waterproofed, so that it may be towed behind the submarine (WW 11 type). This makes the deployment of the missile easier by freeing the submarine from the operational difficulties of having to tow a canister launcher for each missile, while still retaining the German idea of being able to utilize existing designs of submarines.

There is some rumour of deep launching experiments from 650 ft with an experimental missile Golem 3, which, if it can be done operationally, is of the greatest significance.

THE FLEET BALLISTIC MISSILE SYSTEM AND POLARIS

The earliest efforts to obtain a ballistic missile for use from a specially designed nuclear submarine launching platform were directed towards the development of a missile jointly with the U.S. Army. This missile, now known as Jupiter, has the following characteristics :

Warhead	*Motor*	*Length*	*Diameter*	*All Up Weight*
Nuclear	Liquid Oxygen	58 ft	9 ft	100,000 lb
(1 Megaton)	Kerosene			

It is not difficult to understand why the U.S.N. withdrew from this project just as soon as the following items appeared to be technically feasible :

(1) A lightweight nuclear warhead

(2) A solid propellant motor capable of giving the missile containing this warhead a suitable range.

A new missile known as Polaris was started in development as part of the Fleet Ballistic Missile System. This caused and continues to cause great argument through Government and Service circles. While admitting the psychological and deterrent value of the system, the U.S.A.F. holds that the whole of the nation's capability must not be sunk in this one system, which, missile for missile, has not the punch offered by either the land-based missiles or the Strategic Air Command bombers.

However, Polaris has weathered this criticism so far and promises, in return for a fairly large financial investment of some $700 M in February, 1959 (making a total to date of $1,400 M) an operational Polaris with a range of 1,200 miles in 1960, and an improvement to 1,500 miles in the final version.

Suitable nuclear powered submarines, each to carry 16 Polaris missiles, are building at the rate of about four per year.

TECHNICAL PROBLEMS OF THE DEVELOPMENT OF THE F.B.M.S.

These may be divided under the following headings :

(1) The submarine

(2) The launching phase

(3) The propulsion and structural problems

(4) The guidance of the submarine and missile

(5) The control of the missile

(6) The re-entry of the warhead into the atmosphere.

The Submarine

It will be realized from the above list that the submarine is only one part of

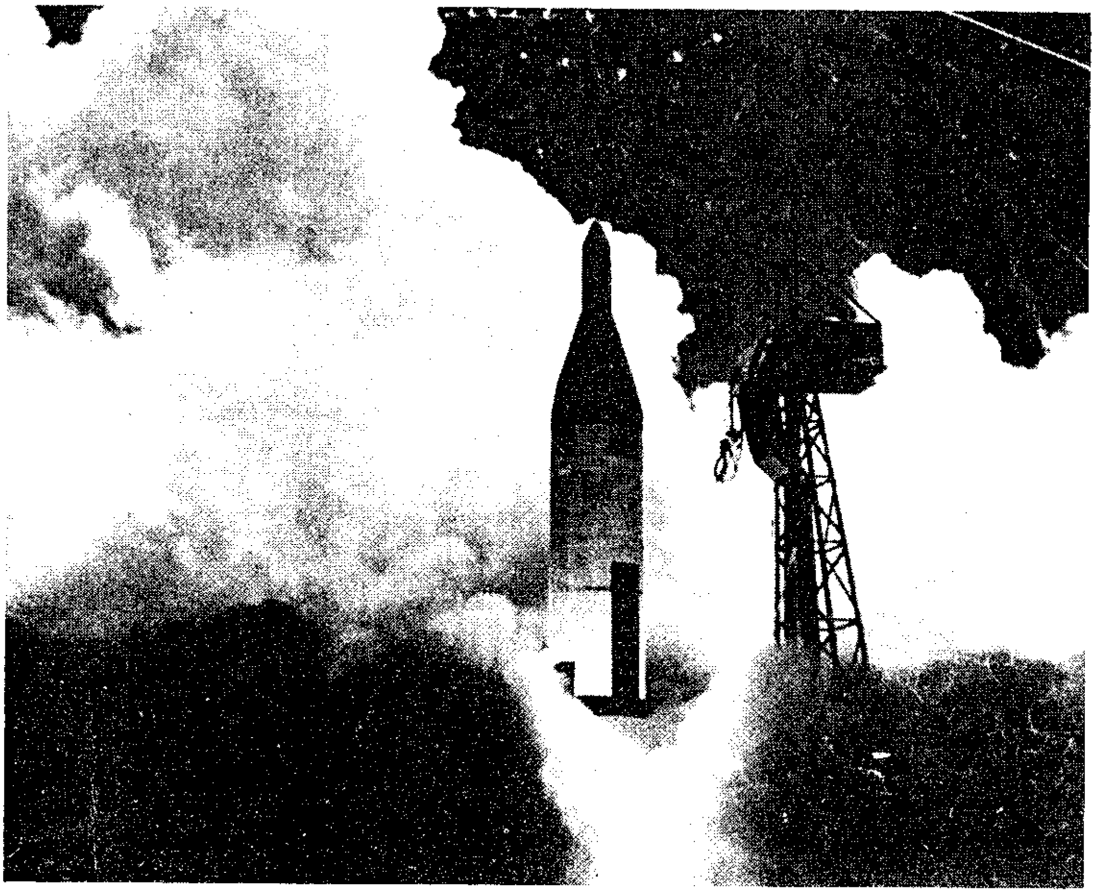

FIG. 2—AX-1 POLARIS LAUNCH
(*Missiles and Rockets, Vol. 5, No. 5*)

a complex system, and it has been accepted as a precedent that it is for all purposes subservient to the system—the Fleet Ballistic Missile System. The submarine is designated an S.S.B.N. The other U.S.N. defined components of this system are the missile Polaris, the fire control, navigation, and launching equipments.

From such information as can be found in the public press, the missiles will be stowed vertically in the submarine hull, which necessitates a diameter of about 30 feet in the appropriate length of the hull, and the overall length of the submarine will probably be about 350 to 400 feet, with a displacement of approximately 5,000 tons. A very recent report (January, 1959) states that displacement will be 5,600 tons: heavier than earlier models of the nuclear submarine.

In June, 1958, contracts for three F.B.M. submarines had been awarded. Two are being built at General Dynamics Electric Boat Division, Groton Shipyard, where also is being built the largest submarine, 5,800 tons, which also is nuclear powered. Further funds for six more were asked for in supplemental estimates and contracts for three of these have since been awarded.

It might not be appreciated that these submarines were among 17 nuclear powered submarines authorized or under construction in June, 1958.

For what it may be worth in estimating the possibility of other countries joining in this type of armament development, the estimated cost of the first nine nuclear submarines for use with F.B.M.S. is $852 M.

The Launching Phase

This development requires extensive coastal facilities where suitable experimental firings with complete instrumentation can be carried out. The underwater launching site at San Clemente Island, on the Pacific Coast, will provide the launching test facilities. Missiles are fired from the Atlantic Missile Range and further work will be carried out from the trials ship U.S.S. *Observation Island*, and finally from an operational installation in a submarine scheduled for firings in 1960.

Anyone who has tried amateur underwater photography, seen the films of Hans Hass, or the colour film 'Blue Continent', will realize that technical photography, which is only one of the many novel problems associated with this work, is difficult under the best circumstances. The experts in underwater photography and television will need no emphasis on this problem, but perhaps will revel in the increased funds which must be made available to them if the underwater launching of the missile is to be achieved.

The launch from the stowage position will be made by air pressure as the main propulsion motor will not be started before the missile breaks the surface and some interesting photographs of Polaris type missiles breaking surface have been published. It will be understood that the change of media alone is a challenge to the missile engineer.

The Propulsion and Structural Problems

For use within the enclosed space of a submarine or surface vessel many liquid rocket propellants represent a grave hazard and an exceptionally difficult handling problem. Nitric acid and liquid oxygen are two examples the disadvantages of which are easily appreciated.

Hence the development of a high performance motor using solid propellants of the cordite or plastic type was acclaimed and immediately applied to Service weapons. This is not to say that a performance equal to that possible with liquid rocket motors has yet been achieved, nor that liquid rockets will never be used again in such projects for the prepackaging within the missile of liquid propellants with long storage lives is being actively pursued, but the solid rocket motor, with its comparative ease of handling and immediate readiness for use, is the obvious choice for a submarine launched missile for instant or controlled deliberate retaliatory use.

The development of the motor comprises the development of the following items, interrelated but nevertheless distinct :

(1) The solid propellant itself—the production of large masses of uniform high energy content material with satisfactory storage and burning characteristics being quite difficult

(2) The motor case, which, although essential to contain the pressure of combustion, is in fact a dead weight which must be reduced to a minimum

(3) The venturi or nozzle, which again must be as light as possible consistent with maintaining its shape and efficiency throughout the burning time of the motor.

These problems may be complicated by preflight temperature environment, flight stresses and the requirement to control the direction of thrust, and by the fact that it has been found almost impossible to scale up or down in any solid rocket motor design without a long programme of trials.

This, therefore, is the field of development for the motor and in the case of Polaris the solution consists of the design and production of :

(1) A propellant, consisting of a basic plastic propellant probably loaded

with aluminium powder to increase the energy release per unit mass. The combustion pressure would be between 500 and 1,000 lb/sq in. The size of propellant 'grains' or charges required represents a moderate challenge in production but this has been met and surpassed.

(2) A motor case fabricated from air quenched steel sheet giving presently 184,000 lb/sq in. tensile strength, which is satisfactory for the 1,200 mile missile, but which figure must be raised to 220,000 lb/sq in. to enable the full range of 1,500 miles to be achieved.

The fabrication of the sheet into a motor case and the attachment of end fittings is a production metallurgical problem of the highest order. There is a suggestion that a spiral wrap method of construction is being employed probably to avoid putting welds into direct hoop stress.

(3) Venturis (for a multiple venturi system is used as will be described in the control section) which will withstand the rather high gas temperature for the duration of burning which may be of the order of from 1 to 2 minutes.

The motor case forms the outside skin of the missile and carries the flight loads of the missile in most efficient missile designs and certainly Polaris would be no exception. Fortunately, from this consideration the highest loads will be mainly longitudinal during boost and the internal pressure of the motor will stabilize the tube in bending during this period.

The Guidance of the Missile and Submarine

A great deal has been said in the press recently about inertial guidance and navigation systems. These systems, which in their theory date from Newton's time, depend on the relationship between mass and its accelerating forces. It was necessary for a very great deal of technical development to take place before the components became suitable, but given :

(*a*) A stable platform maintaining a rigid orientation in space with extremely low drift (of the order of 1/50th degree/hour)

(*b*) Suitably sensitive accelerometers (which can detect 0·003 feet/sec²)

(*c*) Sufficiently stable electronic circuits with low drift over their operative time : the double integration of Newton's law of motion :

$$f = m . \ddot{s} \quad \text{into}$$

$$s = \frac{1}{m} \iint f . dt^2$$

the measurement of distance, may thus be accomplished along each of any chosen reference axes.

The *Nautilus* sub-polar navigation exploit is one published example of the practical application of this principle, and the Ship Inertial Navigation System (S.I.N.S.) used was developed by the Sperry Gyroscope Co. Although useful in such under-ice situations, the real use of the system is in the precise determination at all times of the position of the submarine which is, of course, absolutely essential for the under-water launching of the F.B.M. Polaris.

Another aid to navigation in the form of an auto-tracking star telescope is also available, by means of which very rapid 'glance' star sights will be possible by day or by night through a suitable periscope thought to be designated Type 11. This will check the accuracy of the S.I.N.S. over long periods of time and will permit the correction of such low errors as remain in the components. A radio sextant like a miniature Jodrell Bank radio telescope for use in overcast conditions will also be fitted to the S.S.B.N.s.

The necessary computations to link the sextants with the S.I.N.S. will be performed by a Sperry developed computer known as NAVDAC.

The position of launch being known, the missile must also carry a complete stable platform inertial navigation system suitably adapted to its special requirements, to determine its position relative to the target. The problems are great and the production costs of these systems may never be low, but such systems, measuring displacements in angle and distance, to a satisfactory accuracy, are now in production and capable of measuring under the violent vibration conditions of motored flight. One such system with transistorised electronics is reported to weigh about 300 lb.

The pure inertial guidance system is, of course, proof against enemy counter-measures and represents an ideal for which it is very well worth paying.

The Control of the Missile

The Polaris missile has no wings or fins and consists of a long parallel cylinder with some slight coning and reduction of diameter in way of the warhead at the nose.

To cause this to remain stable and to fly in the required trajectory it is necessary to control the direction of the thrust vector of the motor. This is done by two-axis jetavators operative on each of the four nozzles giving control in pitch, roll and yaw.

When the missile has reached certain conditions of velocity and position it is necessary to remove the thrust completely, and the missile continues on a pure ballistic trajectory to its target.

The Re-Entry Phase

The average speed of Polaris is of the order of 6,000 m.p.h. and although this will vary over the trajectory it means that the final approach of the warhead (which separates from the main missile structure) to the target will be of the same order. The temperature at the stagnation point of a 1 ft diameter sphere is of the order of 3,000—4,000 degrees F. with heat transfer rates as high as 70 CHU/ft^2/sec and some means must be found to prevent this from penetrating to the warhead or from destroying the structure until warhead detonation is required.

Very considerable research (two 1958 contracts being for a total of $170 M.) has been carried out in the U.S.A. on this for all Service projects, but the most success has been claimed for the Jupiter programme, from which two successful recoveries have been made of the re-entry body (in Operation 'Gaslight') and it is reported that this type of construction will be applied to Polaris as well as to the other ballistic missiles.

It consists basically of a metal shell to which is bonded layers of plastic laminate and aggregate, the thickness of these layers being such that heat conduction into the metal shell is held to a low figure while the outer surface of the plastic 'ablates' under high velocity and high temperature conditions, carrying away the heat with it. The Jupiter nose cone was about 4 in. thick but apparently this could be reduced for the Polaris design.

There is also the possibility of transpiration cooling, in which a liquid is pumped to the outer surface of the nose cone and carries away the heat by evaporation, or of a 'heat sink' design, in which a necessarily heavy metal nose cone is permitted to heat up but is so designed that it can contain the total heating suffered by the re-entering body. Both these types have been subjected to trials, but in general they have been found to be heavier than the ablation design previously mentioned.

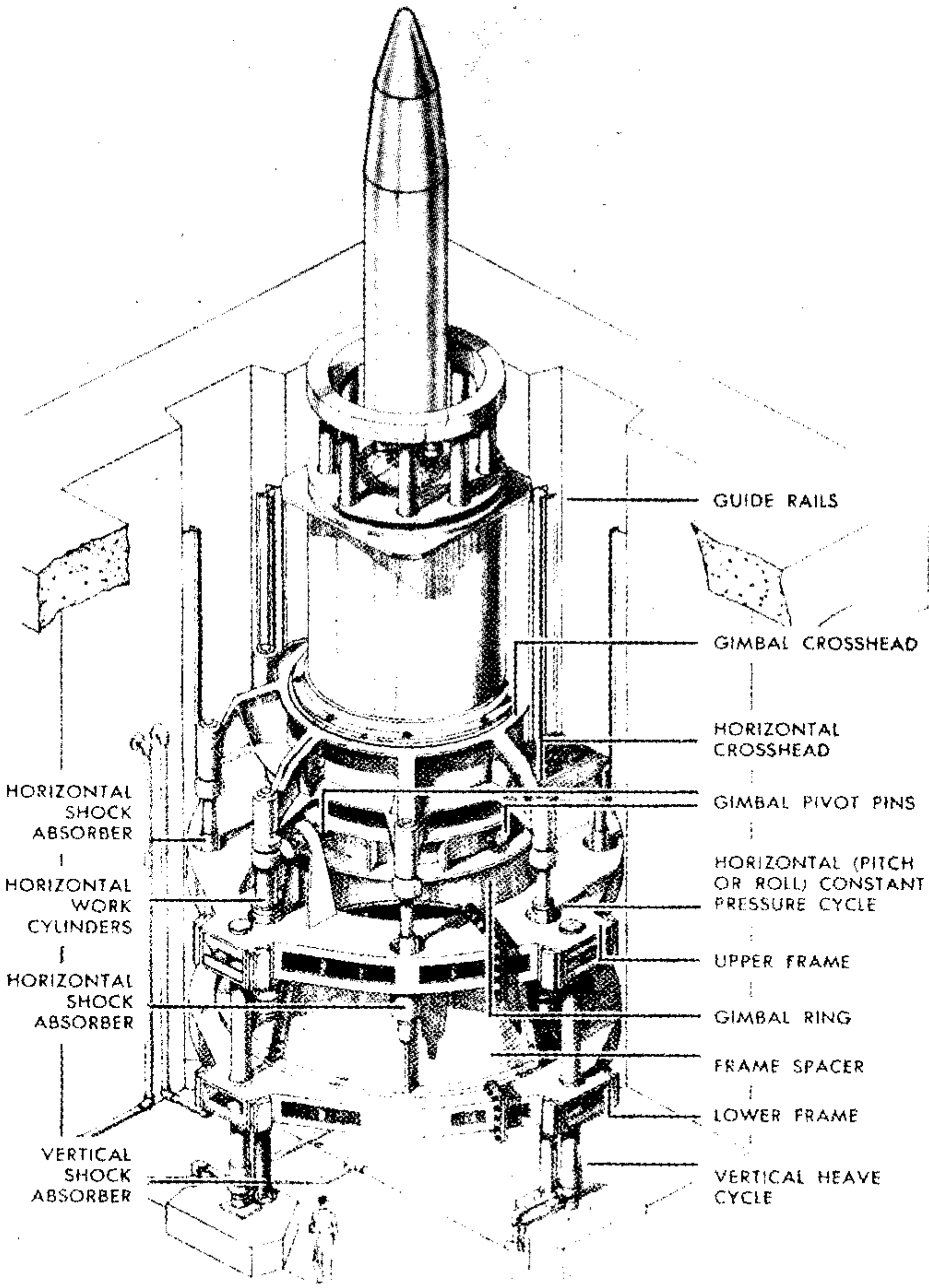

FIG. 3—SHIP MOTION SIMULATOR AND ARTIST'S CONCEPTION OF POLARIS
(*Missiles and Rockets, Vol. 4, No. 17*)

MAJOR TRIALS FACILITIES FOR THE F.B.M.S.

Shore

(1) *Atlantic Missile Range* at Cape Canaveral. Ship Movement Simulator, representing on dry land the roll, pitch and heave components of ship motion for missile check-out and firings, and static firing sites

(2) *San Clemente Island* Under-water Firing Site

(3) *San Francisco Naval Shipyard.* A 'reverse sling-shot' for use in the 'Sky Hook' project to catch Polaris concrete dummies at the top of their launching trajectory

(4) *Lockheed Under-Water Missile Test Facility*, consisting of a tank, 24 ft deep, with a traversing cradle for representative model launching, with underwater photographic equipment in addition to wave-making devices.

Ships

(1) U.S.S. *Observation Island* reported to have Polaris firing facilities and which is now in service

(2) U.S.S. *Compass Island* is the U.S.N. navigation trials ship and is fully equipped to carry out trials on the following gear of importance to the F.B.M.S. :

(*a*) *S.I.N.S.*—Ship Inertial Navigation System, of which mention has already been made

(*b*) *Farrand Star Tracker*—Which is an automatic day/night star telescope, which would enable very rapid verification of position to be made

(3) An operational installation in a submarine for firings in 1960.

OPERATIONAL SUBMARINES FOR F.B.M.S.

The first Polaris squadron in the U.S.N. will be squadron 14 which will consist of two divisions and total 8 to 12 boats.

The first six :—the U.S.S. *George Washington*,
U.S.S. *Patrick Henry*,
U.S.S. *Theodore Roosevelt*,
U.S.S. *Robert E. Lee*,
U.S.S. *Abraham Lincoln*,
U.S.S. *Ethan Allen*,

have been commenced. The U.S.S. *George Washington* was launched in the spring of 1959, and will be the first to complete.

A further three more Polaris equipped submarines were authorized in August, 1958, making a total of nine. The vote for the last four was reported as $638 M.

Some talk is also heard about the fitting of Polaris to all types of surface ships, and this has raised the possibility of bringing some reserve ships out of mothballs in the near future for trials installations.

STRATEGIC CONSIDERATIONS ON THE F.B.M.S.

There are several recent developments in relevant fields which give cause for much general thought on the F.B.M.S. and allied or opposing projects, and some of these are outlined below :

Second Generation Polaris

Although it at first appears that Polaris in the proposed F.B.M.S. would be almost the ideal weapon system, there is already talk of the successor, but no guide can yet be given as to the direction in which change is thought to be necessary, apart from an increase in range.

Inter-Service Rivalry on Strategic Issues

It is reported that the U.S.S.R. has set up ballistic missile bases on Franz Josef Land, which brings the Strategic Air Command base at Thule, Greenland, within range. Some 25 firings have been made during the I.G.Y. and I.R.B.M.s and I.C.B.M.s reportedly equipped with nuclear warheads have been fired in the current Arctic atomic tests. This information is not at all improbable and such developments are to be expected ; the position of all S.A.C. bases is bound to be compromised in this way in the next few years, the only difficulty being to find out which and when. It is not likely that they will be withdrawn into continental America as such concentration of military objectives among industrial complexes is not advisable.

Two very recent press releases confirm this development. The first : in conversation with an American Senator, Mr. Kruschev spoke of Russian I.C.B.M.s with 8,000 miles range, and of compact thermo-nuclear warheads of 5 Megaton effect, and of such plenitude of nuclear weapons that dismantling of the earlier ones for re-use of the components is taking place.

The second : the Rand Corporation has reported to the U.S. press that the U.S.S.R. will have 300 operational I.C.B.M.s within the next 18 months, at least 50 per cent of which will be able to land within three miles of their targets. This opens up the possibility of the elimination of the main Western deterrent, the Strategic Air Command, in one blow.

Mention has already been made of the U.S.A.F. project Bold Orion, in which the carriage of 1,000 mile range nuclear missiles in aircraft is being pursued. The missile is said to be a two-stage solid propellant ballistic device designed for air to surface use from existing and future S.A.C. bombers. The maximum range will be 1,000 miles, and it may be one of the first ballistic missiles which will be controlled during and after re-entry, with the object of permitting the choice of alternative (primary or secondary) targets. It will be the successor to ' Hound Dog ' which is a ' stand off ' bomb limited to about 500 miles range at 50,000 ft altitude. The Hound Dog (GAM 77), the missile portion of W.S. 131B, is in production ($19 M. was allocated for this in December, 1958) and will be used first with the B 52 G bomber. The missile is powered by a J 52 turbo-jet engine and carries an inertial guidance system.

There is intense rivalry between the U.S.N. and the U.S.A.F. to provide the strategic defence of their country : almost bitter since the U.S.N. wants Strategic Air Command funds passed over for use on the F.B.M.S., since it is maintained that the usefulness of this Command is now waning.

Anti-Ballistic Missile Weapon System

An essential for the protection of not only the outlying bases but also of the very industrial core of the nation is the anti-ballistic missile weapon system, which, if perfected, might provide the counter argument to the U.S.N. case for the F.B.M.S.

The difficulties are immense and commence, as in anti-submarine work, with the detection of the target. New techniques as well as vast improvement in existing radar detection techniques must be studied and in December, 1958, it was announced that $100 M. basic research was being started into anti-ballistic missile work by tracking U.S. missiles at Cape Canaveral and of this sum over $60 M. worth of contracts had already been let.

This announcement of a basic research programme came after a report in February, 1958, that the Missile Detection System would cost $721 M., to provide sites and very high powered transmitters for detection ranges up to 3,000 miles. One report in April, 1958, wrote of a 21 Megawatt radar-like transmitter engaged on I.C.B.M. detection, and that this is obviously only a start is clear when the problem is studied.

U.K. work in this field has been mentioned in the press, with particular reference to the use of infra-red detection at long ranges. The high thrust motor during boost and the aerodynamically heated structure during re-entry both will give intense radiation, by the detection of which information may be gained.

A great deal more must also be found out about the re-entry aerodynamics and the effect of nuclear warheads on nuclear warheads, both fields promising to be expensive and intractable.

Some thinking is apparently being done in U.S.A. under U.S.A.F. contract on the use of manned space vehicles as launching platforms for anti-missile missiles. Even in this rapidly advancing field this time may yet be far off, but would perpetuate the pilot for a further space of time and hence it is in the U.S.A.F.'s interests to back it !

Underwater Detection and Communication

The present strength of the argument in favour of the F.B.M.S. lies to a great extent in the agreed difficulty of detection of such a submarine running quietly and deep.

The U.S.N. is showing considerable activity in the ' Herald ' submarine warning project, but no significant details or detection ranges have been released.

It is realized that so little is known in the field that underseas exploration of all kinds is being sponsored in the U.S.A. ; particularly so as it is voiced quietly that the U.S.S.R. is probably ahead in this field.

In September, 1958, a release stressed that, even in the event of war, there would be no way of communicating with submarines doing under-ice patrols as did the *Nautilus* and *Skate*, which necessitates yet another research closely allied to the first. This alleged weakness in communications gives the anti-F.B.M.S. argument some strength, for what is the use of submarines carrying Polaris widely dispersed over the world and separated from all friendly surface vessels if the signal for retaliation cannot be passed ?

Underwater Pursuit and Destruction

The U.S.N. has long been interested in this vital problem and from an early stage developed the ' Rat ', which was an acoustic homing torpedo which could be flown by missile to a point over a target and dropped to complete its mission underwater.

Developments of this nature have continued and recently the Rat project was reported cancelled in favour of the ASROC and SUBROC projects.

Nothing is published of these yet, but that SUBROC is to be used from conventional submarines torpedo tubes and is reputed to be able to break surface and fly for some miles and then re-enter and again operate under-water as a homing torpedo. It will be equipped with a nuclear head and the idea promises well if supported by suitable detection means.

To cope with the high underwater speeds of which the nuclear submarine is capable the anti-submarine torpedo requires very considerable speed. A published figure of 155 knots was given in June, 1957, for an Aerojet experimental underwater engine. As the power of the nuclear submarine is reported greater than 30,000 h.p. and with improvements in hull shape as the result of intensive research it can be understood that submarines speeds of 60 knots or more may be achieved, and will thus require torpedo speeds of the order of 150 knots.

A contract worth some $19 M. was awarded to Aerojet in late 1958 for an anti-submarine torpedo and it was received as one of the most important projects ever to be given to this organization.

Mapping and Reconnaissance

Given sufficient accuracy in the ship's inertial navigation and in the missile guidance systems the proper pin-pointing of the target becomes a critical item.

Large errors exist in the international surveys of the world and constant refinement of existing surveys to take account of recent reviews of the earth's shape is necessary. A considerable amount of work has been done photographically from aircraft during and since the last war but even in areas where access is possible some further errors have been discovered and rectified as a result of man-made satellite observations.

One published example of this is the claim by U.S. Army Map Service to have reduced errors in the Pacific area from $\frac{3}{4}$ of a mile to 300 feet as a result of the Explorer satellites observations already made, and a hope for an ultimate reduction to 30 feet throughout the world by similar means.

For deep survey of potential enemy territory the un-manned satellite has been proposed for many years and, of course, would be realizable now by both U.S.A. and U.S.S.R. Politically it is dangerous to advertise a satellite as being for reconnaissance purposes, but, on the other hand there is at present no means of detecting whether a satellite is for warlike reconnaissance or peaceful research once it has been launched, unless the communication code can be broken.

The U.S. ' Sentry ' project which has been called a reconnaissance satellite project is reported to be ready to fire the first shot using an Atlas booster from Cape Canaveral. The satellite is to be about 250 lb in weight, and is the prototype of a larger (1,000 to 1,500 lb) version. The direction of launch will be N.E. (as for the ' Explorers ') in order to sweep a maximum area of the earth's surface.

Thus it may be that this form of reconnaissance may be near and with improvements may give the ' open sky ' conditions which are not possible today with manned aircraft, but entails tremendous advance in techniques.

Training

In keeping with the general U.S.N. practice on new weapons, the Lockheed Missile Systems Division is under contract to the U.S.N. Bureau of Naval Personnel for the training of specialist personnel required for the F.B.M.S.

This training is to be conducted at Lockheed's Sunnyvale, Palo Alto and Santa Cruz Mountains facilities, also at Aerojet General Corporation. General Electrics (Pittsfield) and Westinghouse's Sunnyvale Plant.

Formal classroom instruction and job training supplemented by classroom work is planned and more than 1,000 students are expected for the first nine F.B.M.S. submarines, in an effort to provide trained crews simultaneously with the operational submarines.

The provision of specialized instruction personnel and equipment for fast developing limited production and expensive projects other than at the contractors' factories appears to have been discounted, and our own experience in distributing such new equipment as can be spared among the various training establishments indicates that this may be the more sensible approach.

SUMMARY

Some attempt has been made to show the vast compass of this important weapon system and to give some idea of the probable state of development and near future consequences of the realization of the design.

That the U.S.S.R. recognizes the importance of this weapon is most probable and, commencing from the same starting point as the U.S.A., parallel advances are most likely. That the U.S.S.R. recognizes the submarine as an important weapon in its conventional role is obvious from the size of their Fleet, and it would be unrealistic to imagine that they have not put the very highest priority on the improvement of this powerful weapon in the manner described.

It is to be hoped that events will not require the use of this type of weapon and even that, one day, an understanding may be reached which will enable the enormous scientific resources tied up in this type of development to be released for the more apparent benefit of man.