THE WHITE HOUSE
WASHINGTON

March 4, 1958

MEMORANDUM FOR DR. J. R. KILLIAN, JR.

From: The Ballistic Missiles Panel

Subject: Whither Ballistic Missile Systems?

This memo presents a technical analysis of the future of ballistic missile systems as a component of our retaliatory capability and is a sequel to the earlier memo of this Panel on basic national decisions required in the field of ballistic missiles.

BASIC ASSUMPTIONS

1. The retention of a retaliatory capability after an initial Soviet attack with thermonuclear weapons on the United States is a national requirement.

2. Ballistic missiles must become an indispensable part of such a capability in the future, because of the increasing vulnerability of manned bombers.

3. An ever increasing number and accuracy of offensive Soviet weapons in the shape of both manned bombers and ballistic missiles must be anticipated.

4. The USSR will seek to develop an active defense against ballistic missiles as well as bombers and therefore our missiles must be provided with an increasing degree of sophistication (counter-counter-measures).

PRESENT WEAPONS

5. The first generation of ballistic missiles (Thor, Jupiter, Atlas, Titan, Polaris (as a FBM)) will provide initially retaliatory weapons of limited effectiveness because:

a. (i) The present liquid-propellant engines in Thor, Jupiter, Atlas and Titan will not be very reliable for some time to come; they make quick response difficult; the complexity of these four missiles is such that substantial degradation of performance in operational use may be expected;

(ii) Early base installations will be soft and offer to USSR a small number of targets to neutralize the missiles;

(iii) Operational cost will be high.

b. The high cost of the Polaris weapon system (which we estimate as $20 to $30 mi. capital investment per missile on station if three submarines must be built to maintain one on station) makes a large build-up of this force very painful for the taxpayer. The other limitations of this weapon system are of temporary technical nature:

(i) The complexity of the navigational-guidance system for the submarine-based Polaris may result in low accuracy at the start of IOC;

[redacted]

(iii) Polaris B with a 1500 mi. range, predicted for 1963, may not become operational on planned date because of technical difficulties; the reaction time of Polaris may be initially longer than desired because of communication problems with submarines on station. It should be emphasized, however, that even granting these difficulties, the Polaris still offers us a retaliatory weapon system of superior reliability, which has a high probability of surviving a surprise attack.

FUTURE TECHNICAL IMPROVEMENTS

Technological progress to date indicates the feasibility of greatly improved weapon systems from a second generation of ballistic missiles.

I. Propulsion. Within the last few years the progress in solid rocket propellants has reached a point where the construction of large long-range engines has become feasible. In comparison with the present liquid propellant engines the solid propellant engines are still of rather low performance and therefore it is necessary to add an extra stage (a total of 2 for an IRBM like Polaris, 3 for an ICBM) to accomplish essentially the same mission. The maximum allowable weight of a missile stage is more limited with solid than with liquid engines, because in the former the propellant is an integral part of the engine, which is also essentially the air-frame of the missile stage and must be transported as a loaded unit. The upper limit for road transportability appears to be 40-50,000 pounds. A liquid propellant missile is transported empty and so missile stages weighing loaded over 200,000 lbs. are still transportable (although not necessarily "mobile"). The great advantages of solid propellant engines are their instant readiness and high reliability, although the latter may not be fully realized in early versions of solid propellant ballistic missiles because of the introduction of novel engine components, i.e. thrust vector control and thrust termination.

In contrast to liquid propellants which even in advanced propulsion systems are comparatively simple chemicals, advanced solid propellants call for maximum exercise of chemical skill since complex new compounds must be developed which combine properties akin to those of synthetic rubber with several other properties, the most important of which is the release of maximum heat on deflagration. Research on such propellants has received insufficient support. It would not be wrong to say that a large chemical corporation invests more chemical research talent in the development of a new type of plastics than we as a Nation have invested in research on solid rocket propellants. A state of the art has now been attained which is not far from full utilization of various combinations of fairly common ingredients. Propellants now available for engine development have specific thrust of 230-240 sec. which represents a gain of some 50-60 sec. since 1945. Some further gains will result from development effort on the present level but the results will still be inferior to liquid engines. To advance faster and beyond this point, it is necessary to raise substantially the level of research effort and not only obtain the maximum effect from the more common materials but also reach into the chemistry of exotic compounds (such as metal hydrides, boraines, nitrogen-fluorine compounds). Funds involved are comparatively small (of the order of $10 mi/annum) but skilled person nel and good direction are essential. The probable result of this program after two years will be propellants with a specific impulse greater by some 20-30 sec. In the case of an ICBM this would mean a gain in payload and structural weight substantially greater tha n 10% or a correspondingly large reduction in take-off weight.

The unattractive features of present LOX-JP liquid engines have already been mentioned. These disadvantages can be eliminated in the future by further development effort. For instance, a storable system of liquid propellants (MON-UDETA) has been found by Aerojet-General Corp. which permits the use of the same missile tanks, same guidance system, same turbine-pump assembly for the engine and gives the same performance to the missile as LOX-JP, after some relatively modest changes in the rest of the engine and the elimination of a large number of components. The latter is realizable because these storable propellants ignite on contact and so eliminate the need for an electrical ignition system and for many other controls. Also, the generation of compressed gases for the turbine driving the pumps becomes much simpler. These propellants can be shipped in drums and be stored indefinitely in the missile.

II. Guidance. The doubt about the feasibility of all-inertial guidance of long range ballistic missiles, which existed in 1954, has been eliminated by subsequent developments. Within a few years all-inertial (that is self-contained in the missile) guidance will almost surely be good enough to insure a CEP of the order of 1 n.m. due to guidance alone, which would result in a total CEP [redacted] at ICBM range. At the same time, the weight of the guidance package will be reduced. The addition of a single radio link to the ground promises the reduction of CEP (due to guidance alone) to a few tenths of a mile.

III. Nose-cone. Lack of scientific data about the reentry of the nose cone into the atmosphere led to the selection of the heat sink type of nose cone for Atlas, Titan and Thor. It is now rather probable that so-called ablation type nose cones will be satisfactory, even at ICBM range, although much research and development is still to be done. Such nose cones (if successful) can be incorporated into present missiles and will offer two major advantages: (a) nearly twice as much warhead weight for the same total weight of the nose cone and (b) faster terminal velocity and therefore less dispersion due to winds and less time for enemy counter measures.

IV. Warheads. The hopes expressed in 1954 that yields approaching [redacted] will be achieved in a warhead of 1600 lbs. weight have already been exceeded. A warhead of this weight may have a yield of about [redacted] by 1959 and as much as [redacted] may be anticipated for warheads of double the weight. An even more striking progress has been achieved with lighter warheads. The warhead planned for Polaris is anticipated to have a yield of about [redacted] for a weight of [redacted] A warhead of [redacted] is proposed for the Minuteman. This is expected to have a yield of [redacted] Quite generally the lighter warheads are more costly per unit yield because proportionately more fissionable material must be used.

FUTURE PROGRAM FOR ICBM

Early Missiles. Two different ICBM's are now under development -- Atlas and Titan. The development of the Atlas is far more advanced and it is the only ICBM which offers us the possibility of having some operational capability in 1960. So much still remains to be done on the Titan project that completion on schedule in 1961 is not assured. From the technical and eventually the operational point of view, however, Titan will be distinctly superior. The Atlas is a stage-and-a-half missile, the major part of the engine (without fuel tanks) being jettisoned after most of the propellants have been consumed. The engine separation has not been tried out in flight and may prove to be a difficult problem to solve. The design of this missile is such that it can fly a 5500 mile range only if great care is taken to reduce structural weight. The booster engine of Atlas was originally designed for lower thrust and was subsequently upgraded to 300,000 lbs. There is probably little margin for further upgrading. Atlas has radio-inertial guidance, complex, costly and difficult operationally. The design of the Atlas does not allow the carrying of more than ca. 9300 lbs payload instead of the nose cone and therefore Atlas is not especially suitable for advanced space missions.

Titan is a true two-stage missile and, although its air frame design is more rugged than is that of Atlas, it should easily have the 5500 mile range. It has already been demonstrated that the rated thrust of the Titan booster engine, 300,000 lbs, can be increased approximately 30%. It is a more modern engine, the design of which benefited from some of the experience with the Atlas engine. Titan should have the capability of lifting large weights instead of the nose cone, because of its air frame construction. Its all-inertial guidance makes it suitable for underground hardened bases. Its least certain and still-to-be proven design feature is the ignition of the second stage engine in near vacuum upon separation in flight.

Improvements. Titan can be improved in several ways. The substitution of self-igniting storable propellants for LOX-JP should gain in operational simplicity, reliability and quick response time. Due to the self-igniting property of the proposed propellants, the starting of the second stage engine in flight will become more reliable. The upgrading of the engine to higher performance will permit, if desired, the enlargement of tanks and therefore either greater payload or longer range. The substitution of an ablating nose cone will also allow either longer range with the same warhead or a heavier warhead than the 1600 lbs now specified. The planned all-inertial guidance is susceptible to improvement in accuracy with no significant changes in the rest of the missile.

A brief description of the Atlas given above indicates that only some of these advantages will be gained from an equivalent program of improvement on that missile.

The Minuteman. The Air Force has made a proposal of the Minuteman solid propellant ICBM with 1963 as the initial operational date. It is to be a small three stage missile of comparatively low cost, installed in inexpensive but dispersed and hardened launchers. Simple in operation, it will require small numbers of operational personnel. In all these respects the Minuteman appears to be a very good advanced version of an ICBM and should provide us for many years with an effective retaliatory capability.

The proposed operational date, however, which calls for another crash program, is rather questionable.

The proposed missile* is based on propellants to be available for engine development either now or very shortly and their comparatively low thrust has made it necessary to accept marginal design in other respects: (a) the engine casings must be made very light and hence introduce problems of reliability; (b) the weight is just at the limit of road transportability and yet only [redacted] lbs warhead can be carried to 5500 mile range, even upon assuming that the weight of the all-inertial guidance will be drastically reduced against present practice; the payload of [redacted] lbs should provide by 1963 a yield of perhaps only [redacted] (c) the assumed light weight guidance might add to unreliability and CEP; the Minuteman would hardly be a point-target missile. The advantage of this proposal appears to be that the introduction of the Minuteman into operational use by 1963 would eliminate the need for substantial improvement programs on Atlas and Titan.

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*These data are taken from the December 1957 presentation by the U.S. Air Force.

Alternative Plans. The desirability of either implementing or replacing our ICBM force with solid propellant missiles cannot be doubted. There are, however, alternatives to the Air Force proposal.

One alternative plan would be to focus the immediate effort on two objectives; (a) Improvements in the Titan (particularly the storable propellants and the ablating nose cone) which should result, about 18 months after the first operational availability of the Titan, in a missile of improved reliability and simplicity, a missile of essentially unlimited range and a payload which will allow use of warheads with up to [illegible] yield or of elaborate counter-counter-measures. (b) Development of high performance solid propellants, pending which the hardware development of the Minuteman would be postponed for 12-24 months.

This plan should give improved Titans by 1963. The total Titan force should grow at least through 1965, and concurrently a gradual replacement of early Titans by the advanced model should be planned. During this period, the Atlas should be phased out as soon as practicable. Starting in 1965, a Minuteman based on advanced propellants could become operational, which could have a heavier and therefore possibly more reliable guidance system, a heavier payload and therefore more yield for lower cost or a considerably reduced take-off weight. The total operational force would eventually consist of Titans, with provision for complex counter-counter-measures and of more numerous Minutemen. This mixed force may offer considerable operational advantages. USSR might be forced to devise its active missile defense as if all our weapons had counter-measure capabilities of the Titan nose cones. At the same time, it might have to provide for the large numbers of our weapons which the low cost of Minutemen would permit us to deploy.

A second alternative plan would be initially to set a more modest range of about 4000 miles for the Air Force's Minuteman. The bases for this Minuteman could be planned as far North on the North American continent as possible, which would permit coverage of many targets. Meanwhile a vigorous development of solid propellants should be undertaken, with an objective of ..nging the propellants in the engine of the Minuteman by ..out 1965 and so extending the range to the 5500 miles in the subsequent missiles. These could be then deployed throughout USA. This program for the Minuteman should still be accompanied by an improvement program for the Titan, but perhaps with lower procurement of operational missiles. The end result would be a mixed force, consisting of Minutemen of short and long range and of a smaller number of Titans. Whether the Minutemen should be in dispersed hardened bases or be a mobile rail-based force is a matter that should be studied by an organization like WSEG, before a decision is made, because this problem is of such great importance.

Recommendation. Either of these latter programs is preferable to that proposed by the Air Force. The program which proposes to postpone the all-out hardware development work on the Minuteman for one to two years, while maximum effort is devoted to the improvement of solid propellants as well as to other basic components, appears to offer real advantages.

IRBM's

The currently authorized programs are IOC's of Thor, Jupiter and Polaris. A land based version of Polaris, to be operational with a range of 1000-1200 n.m. in 1961 and an IRBM made up of the two upper stages of the Minuteman with an expected range of 1500 n.m., to be operational later, are being proposed.

IOC. The simultaneous IOC of Jupiter and Thor leads to operational and technical complexities as well as additional expense. The missiles are sufficiently similar that no advantage accrues from their simultaneous use. The missiles have so far performed in tests roughly equally, with Thor showing to some advantage. Thor is much closer to quantity production and operational readiness. We recommend that the land based IRBM IOC be made up only of Thor missiles.

Future Program. The rest of the IRBM program is far less amenable to technical analysis because of complex political, operational and financial factors. These should be studied carefully by competent groups, composed of the personnel of the Department of State, Bureau of the Budget and WSEG and their reports made use of in policy making decisions. Thus the extent to which foreign governments and populations are willing to accept missile bases on their soil affects the optimum balance between land based IRBM's and the Fleet Ballistic Missiles. Another factor which affects the same balance is the relative costs of these missile systems. The third is the ability of the two missile systems to survive a surprise attack. By improving Thor, it could be deployed further away from USSR borders. Are territories available for such a deployment? At about the same time that an improved Thor could be made available, a solid propellant missile of shorter range could also be available. It could be used either in hard bases or as a mobile system. Which is preferable, or is the deployment of missiles comparatively near to USSR borders altogether not advantageous for political and military reasons? These are only some of the problems which profoundly affect the planning of the future IRBM retaliatory force.

Future of Thor. The present plan for 4 squadrons comprising sixty Thors at fixed soft bases in the UK provides a marginal retaliatory capability, because these missiles can be neutralized by a much smaller number of Soviet missiles. The requirement for a 15 minutes reaction time of Thors is inadequate in the face of a well executed surprise attack. The use of Thor in some other type of missile system appears to be essential to insure retaliatory capability. Should it be the hard dispersed base system or a mobile system? The latter, in view of the size and complexity of a Thor (or a Jupiter) does not seem feasible, but the problem deserves study.

A program of improvements on Thor should include the conversion of its engine to storable self-igniting propellants and the provision of an ablating nose cone. The latter change, when coupled with the introduction of a lighter warhead than the present could result in the extention of range to more than 2000 n.m. and hence permit the deployment of Thor on bases less subject to attack by Soviet missiles. This program, if vigorously pursued, could result in operational missile systems by 1960-61. Will territories be available for these bases?

Land Based Polaris. Also in 1960-61 a land based Polaris missile system could become operational. Polaris weighs less than 30,000 lbs.; because of its solid propellant engine it is more adaptable to quick response and requires smaller operational personnel. Its initial range of only 1000-1200 n.m. requires its deployment nearer to Soviet borders. Polaris could be far more readily adapted to the mobile concept than Thor, but will the result be superior to fixed hardened bases? Is the cost of developing the land based Polaris commensurate with the advantages of its deployment comparatively near to Soviet borders?

Minuteman IRBM. Somewhat later than Polaris (1963-65) a still lighter solid propellant IRBM, obtained by using the two upper stages of the Minuteman, could be made operational. It might have a range of about 1500 n.m. It does not seem that additional costs justify the development of both, the land based Polaris and this IRBM. Which should be chosen? The decision depends largely on the required range as it relates to the planned system of bases and on the timing required for the formation of this force.

Fleet Ballistic Missile. The FBM can add greatly after 1960-61 to our IRBM retaliatory capability. But, as noted earlier, the cost of this missile system is high and there may be some initial technical difficulties. If land based IRBM's in quantity are politically acceptable a decision must be made about the optimum balance between the numbers of these and of the FBM. The factors involved include the relative costs of the two types of missile systems and their relative ability to survive surprise attack. The former probably favors land based missiles, the latter the submarine system.

If political opposition makes the growth of land based missile force a practical impossibility, the Fleet ballistic Missile becomes the only means for providing IRBM retaliatory capability. In this case and as an interim measure of only temporary value, the proposal of mounting Polaris launchers on the fantails of the existing carriers should be evaluated because of possible large reduction of costs and rapid build-up of operational force. As a long term deterrent force, submarine based Polaris has probably no equals if costs are disregarded.

Planning of Development. In conclusion a general remark: the preceding discussion should have revealed a tendency of the Services to plunge into rigidly fixed hardware development programs, without due allowance of time for advanced development. Our present ballistic missiles suffer from this policy, although the urgency of the original programs is a justification for the decisions' taken. We must, however, make sure that the second generation ballistic missiles are good not only by the standards of today, but also by the standards applicable to their operational dates. This can be insured only by vigorous development not restricted by narrow operational requirements of planned missile systems. This development should be directed at the entire missile system as well as the various missile components. The result will be weapons which will serve us effectively for longer periods of time, and so conserve our national resources.

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