

ASSESSMENT OF BALLISTIC MISSILE DEFENSE PROGRAM

By the end of FY 1961, we will have spent approximately \$2.4 billion on ballistic missile defense programs, including \$1.1 billion on early warning; the amount currently planned for FY 1962 is about \$3/4 billion, with \$1/4 billion allocated to the early warning area. In spite of these large amounts of money, the prospect of developing a really effective active defense of our urban population against a mass attack from the USSR is bleak, has always been so, and there are no great grounds for hope that the situation will markedly improve in the future, no matter how hard we try.

The bleak outlook does not arise because it is impossible to destroy an ICBM. Assessment of our terminal defense systems (e. g., NIKE ZEUS), in fact, gives us a high confidence that low-rate-of-arrival targets can be effectively destroyed. It arises because of the enemy's ability, through the use of penetration aids (decoys, low radar cross-section warheads, multiple warheads) to insure our destruction at a cheaper cost to himself than it costs us to counter his move by increased firepower. In addition, in the absence of fallout shelters, it lies within the enemy's power to annihilate our population by fallout even if we succeeded in developing an effective terminal defense system.

The use by the enemy penetration aids in conventional ICBM's is sufficiently effective from his point of view that we do not need to take very seriously more sophisticated threats, such as "bombs in orbit."

If the outlook is admittedly bleak, why are we spending so much money and effort on the ballistic missile defense program?

The principal reasons follow:

1. The nuclear-armed ICBM threatens us with annihilation; the stakes are so high that we must explore every alternative of strengthening our military posture. At present, our strategy is to rely completely on our retaliatory capability for deterrence. However, the fact that no conceivable defensive system has ever, or will ever, provide an "umbrella" (i. e., 100% effective defense) should not prevent us from developing (and perhaps deploying) partially effective systems (as we have in the past in the manned bomber era). Defense measures

complicate the enemy's planning, force him to the expenditure of effort to counter them, and limit the damage he can do with a given level of attack. There is some chance that changes in technology will provide us with a means of defense which should be combined with our offensive capability to maximize our military effectiveness.

2. Our deterrent posture is clearly enhanced, specifically by the early warning provided as part of the anti-AICBM program.

3. An extremely important reason is the influence which our ballistic missile defense program exerts on our own offensive capabilities, and hence on our deterrent posture. Not only does the anti-ICBM effort provide a spur to our own penetration aids program, but also provides the necessary technological guidance.

4. Closely allied to the last reason is the fact that our ballistic missile defense program provides us with a knowledge of enemy capabilities. Knowing what is possible and feasible, for example, enabled us to make a reasonable assessment of the USSR anti-ICBM program.

5. Regardless of the effectiveness of the defense, our international prestige requires that we maintain a vigorous effort corresponding to the USSR program.

6. Finally, the technological base of knowledge, techniques and equipment which the anti-ICBM program is providing may be extremely important in a changed world situation. The effectiveness of our defense may be much higher in an arms control environment or against nations with a technological capability lower than the USSR.

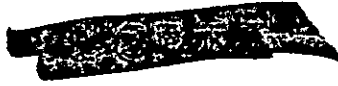
We may also ask, what value have we received from the money already spent in anti-ICBM programs?

1. First and most important, we have a much clearer understanding of the problems of ICBM defense.

2. We have the Ballistic Missile Early Warning System (BMEWS) partially operational. When fully operational, it will contribute significantly to our deterrent posture against mass ICBM raids.

3. We have the most promising active defense system (NIKE-ZEUS) well on its way to development.

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Doc #15

ODDR&E
ASSESSMENT

OF

BALLISTIC MISSILE DEFENSE PROGRAM

17 April 1961

PPD 61-33

Copy 11 of 28 copies

Pages 54

Series C

#308



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DATE 08-14-2001

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FOREWORD

This paper presents:

1. An assessment of the value and direction of the United States anti-ICBM program, and
2. A brief description of the individual anti-ICBM programs, along with their scope and approximate funding.

Only defense of the continental United States is considered.



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4. The Missile Defense Alarm System (MIDAS) is also making substantial developmental progress.

5. Significant technological advances (which bear not only on Ballistic Missile Defense but on many other technological areas) are direct outgrowths of the program. For example:

a. High powered radar transmitters. The change in this field can be measured by the fact that a few years ago to receive a radar echo from the moon was considered remarkable. Now, moon echoes are so numerous and powerful that they constitute a nuisance and must be screened out. The field of radar astronomy has been made possible by the high powered transmitters.

b. Radar-phased array techniques (electronic scanning) is now almost at the point of application.

c. The mass production of cheap precision electronic components (diodes, resistors, etc.) has been immeasurably spurred by our ZEUS development.



The following tabulation summarizes (roughly) the amount of money which has been spent, and which is planned for FY 1962, in each of the principal areas of our ballistic missile defense program.

	<u>Through FY 1961</u>	<u>FY 1962</u>	<u>To Completion</u>
	(in Millions)		
<u>Early Warning</u>			
BMEWS*	\$ 897	\$ 55	\$ 23
MIDAS	189	200	290
Other	28	3	<u>Continuing</u>
Total	<u>\$1,114</u>	<u>\$ 258</u>	
<u>Active Defense</u>			
NINE-ZEUS RDT&E	913	276	473
Other	18	9	<u>Continuing</u>
Total	<u>931</u>	<u>285</u>	
<u>Space Surveillance</u>			
Space Surveillance	47	46	<u>Continuing</u>
	9	28	<u>Continuing</u>
Total	<u>56</u>	<u>74</u>	
<u>Measurements & Techniques</u>			
Measurements	224	113	<u>Continuing</u>
Techniques	92	50	<u>Continuing</u>
Total	<u>316</u>	<u>163</u>	
 GRAND TOTAL	 \$2,417	 \$ 780	

* Operational cost excluded. After completion, this will run about \$87 million per year.

Finally, the only operational system being deployed in the entire anti-ballistic area is BMEWS. Deployment of ZEUS, at least for the present, was decided in the negative by not including procurement funds in the Kennedy defense budget. In the meantime, development of ZEUS is being pushed at the maximum rate. No active defense system other than ZEUS is even close to the deployment stage. The general measurement and techniques effort (primarily ARPA's DEFENDER) is being supported adequately.

The remaining portions of this summary will consist of individual assessments of the following subdivisions of the anti-ICBM effort: Early Warning; Active Defense; Satellite Surveillance [REDACTED] and Measurements and Techniques.

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EARLY WARNING SUMMARY

The earliest possible warning of the launching of enemy ballistic missiles is obviously desirable. The question of how much we are willing to pay for a given extra number of minutes, or to attain a greater geographical coverage of possible launching locations, is dependent on the number and type of offensive weapons available to both sides, and the concept as to their use.

As long as our Strategic Air Command consists primarily of B52 long-range bombers, obviously early warning is of the greatest importance. The warning provides time for some fraction of our bombers to become airborne and escape destruction; enough, we trust, to constitute an effective deterrent to the enemy. But, furthermore, the warning does not commit us irrevocably to a war, since the bombers can be recalled if the circumstances dictate. These compelling reasons led to the implementation of BMEWS.

Assuming ICBMs completely replace our bombers, the situation is changed. Our ICBMs cannot be launched and then recalled. They must be protected by hardening, dispersion, mobility and redundancy. Doctrine must be developed as to how to employ them if we are attacked. ~~_____~~

~~_____~~ Hence, early warning loses some of its value. It is still very desirable from the standpoint of alerting our civilian leadership and military command. It may have a small value for civil defense. It is from this standpoint that future developments in early warning should be viewed.

The Ballistic Missile Early Warning System (BMEWS), already partially operational, can make a significant contribution to our present deterrent posture. It will consist, when completed, of three large radar installations in the far north to detect enemy missiles launched across the North polar regions toward the United States. It has limitations: low angle firings can evade its beam and it cannot warn against submarine-launched or "long-way-round" missiles. But it does have the advantage of being technically feasible; the first station at Thule is now operational; and the complete three station system will probably give reliable warning of the most likely mode of attack: mass ICBM raids across the North polar regions. From 10 to 40 minutes warning will be provided, depending on location and time of flight.

The Missile Defense Alarm System (MIDAS) cannot be deployed before 1964-65 at the earliest and is therefore subject to the considerations presented above.

It will consist of orbiting satellites equipped with infrared sensors designed to detect USSR missiles on launch. Two serious problems must, and probably can, be overcome. We must demonstrate the ability of MIDAS to distinguish true targets from other radiating objects such as clouds; and great effort must be expended on reliability to assure enough life in orbit for the associated costs to be supportable. It would have the advantage over EMEWS of furnishing an additional 5 to 20 minutes warning time and of being capable, at least in principle, of world-wide coverage, including the oceanic areas from which submarines can attack us. Whether the additional warning time, in the era of its deployment, justifies the large expenditures which would be required to make the system operational should be given serious consideration. Perhaps MIDAS might contribute to world stability if its outputs were communicated to all nations, and it may prove to be a useful intelligence tool, particularly in a situation involving arms control.

Another technique which is being worked on is "over-the-horizon-radar," in which radars at a relatively low frequency bounce their beams off the ionosphere and thus overcome the line-of-sight limitations of the radar horizon. Enemy missiles would be detected over Russia from radars based in friendly countries, with relatively simple equipment. Its disadvantage is that it would be completely disrupted by natural ionospheric disturbances. Research and development is continuing primarily because of the potential usefulness of the technique for intelligence and as a complement to other techniques for early warning.

This paper does not deal with the methods which must be devised to handle and act on the warning provided, except to point out that the problem is fundamental to the question of "why early warning?" We must be prepared, willing and able to react to the warning provided.

ACTIVE DEFENSE SUMMARY

Active defense (by which is meant those Ballistic Missile Defense systems which are designed to shoot down an enemy missile or warhead in its flight) can be divided into three classes: terminal defense (e. g., ZEUS), midcourse AICBM, and boost intercept (the ICBM is destroyed in its boost phase--e. g., BAMBI). The first of these is by far the most advanced and feasible system with present technology. Considering mass Soviet attacks, two central technical problems of terminal defense systems are (1) the degree to which decoys can be discriminated and (2) whether or not cheap and effective kill mechanisms can be developed which will permit the firepower of our batteries to be greatly increased at comparable cost to the present system. Both of these situations are discouraging but not hopeless. Use of atmospheric sorting, and particularly the combination of optical and radar data, may ameliorate the problem of discrimination. Improvement in accuracy of our missile may allow non-nuclear warheads (e. g., pellets).

If these problems could be overcome, it is likely (although by no means certain) that a ZEUS-type system could effectively defend the physical plant of cities and key facilities. It should be emphasized that for protection of the urban population, a combination of active defense and fallout shelters are required, since the enemy can impact bursts beyond the range of the terminal defense system and let the resultant fallout be lethal to the population.

For protection of our own missiles, studies show that such measures as hardening, mobility, and redundancy are more economical than ZEUS deployment.

Decoys would probably be significantly less serious for a terminal defense system that is hardened itself and designed to defend only hard targets, i. e., one that can tolerate a closer approach by an enemy target before making a decision to attack. More time is given for the atmospheric discrimination problem, and, the time of flight of our missiles being much shorter, the firepower limitation is much less severe. Such a system (known as "hard point defense") shows more promise than most, and might be very desirable for the protection of hardened command posts. More must be known concerning the feasibility of deep-penetration decoys before an accurate assessment of hard point defense can be made.

Deployment of a ZEUS-type system might be significantly more attractive to the Soviets than to the U. S., since presumably a pre-emptive strike is not ruled out for them. Such a system might be very effective against the disorganized remnant of our ICBM force. Also, it might provide effective defense against our POLARIS missiles.

Considering the present situation with respect to decoy design, discrimination and firepower, neither ZEUS nor any other so far proposed defensive system (or combination of systems) should be broadly deployed in the hope that it would be effective for the protection of our urban population against a determined USSR attack. But if we turn to the possibilities of situations other than the all-out massive attack on the U. S. by the USSR, then a much better case can be made for deployment of a ZEUS-type system. Specifically, deployment of ZEUS might provide:

1. An effective defense against submarine-launched missiles, attacks by lesser powers, or accidental or limited attacks by major powers.
2. An intangible but real contribution to our morale and prestige.
3. Useful experience if it should later prove possible to develop defense systems that are economically competitive against major threats.
4. Perhaps most importantly, ZEUS might provide the environment in which an arms control agreement can become more acceptable, due to its capability against small numbers of clandestine weapons.


ZEUS can be deployed earlier (in about four years) than any other ballistic missile defense system, and much earlier (by at least five years) than any system not based on terminal defense.

Turning now to systems other than terminal defense, they have important theoretical advantages ("the attack is far from our shore," "the ICBM is then most vulnerable") but unfortunately are not feasible in our present state of technology due to simple technical and financial considerations. In a boost intercept system (BAMBI), tens of thousands of our interceptors would have to be placed in orbit. All suggested systems use infrared homing; here the technical problems are substantially greater than those confronting MIDAS. Development of short-burning time enemy missiles might neutralize the system. The annual cost of operating the system would run into billions and quite possibly tens of billions of dollars. The system could be saturated by launching large numbers of missiles from one area (only a relatively few of our interceptors would be overhead at any one time). All these considerations make the whole concept extremely dubious.

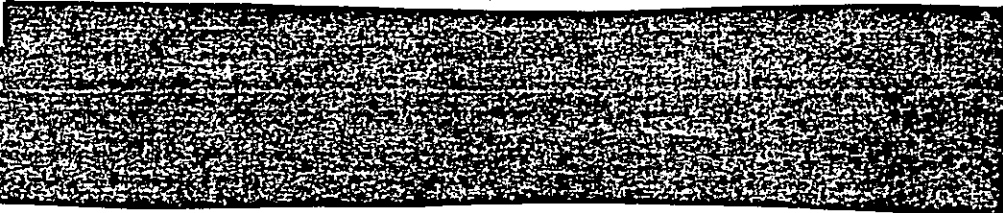
BAMBI is presently confined to a limited systems study and a techniques program principally designed to advance the required infrared technology.

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With respect to mid-course ALCBM, no one has yet suggested any solution to the problem of overcoming very simple, lightweight, nondiscriminable decoys (e.g., balloons, "bird cages").

SPACE SURVEILLANCE 

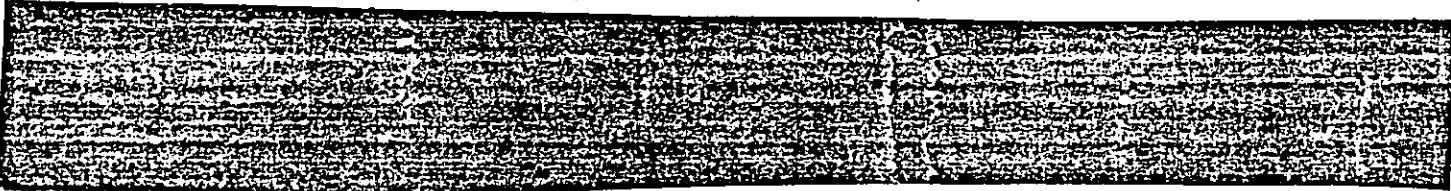
Satellites do not seem to pose an immediate military threat to the United States, if for no other reason than that the ICBM furnishes a cheaper and more effective weapon to the enemy than bomb-bearing satellites. Due to the availability of information concerning U. S. installations, use of reconnaissance satellites does not seem profitable to the USSR. Nevertheless, it is considered important that:

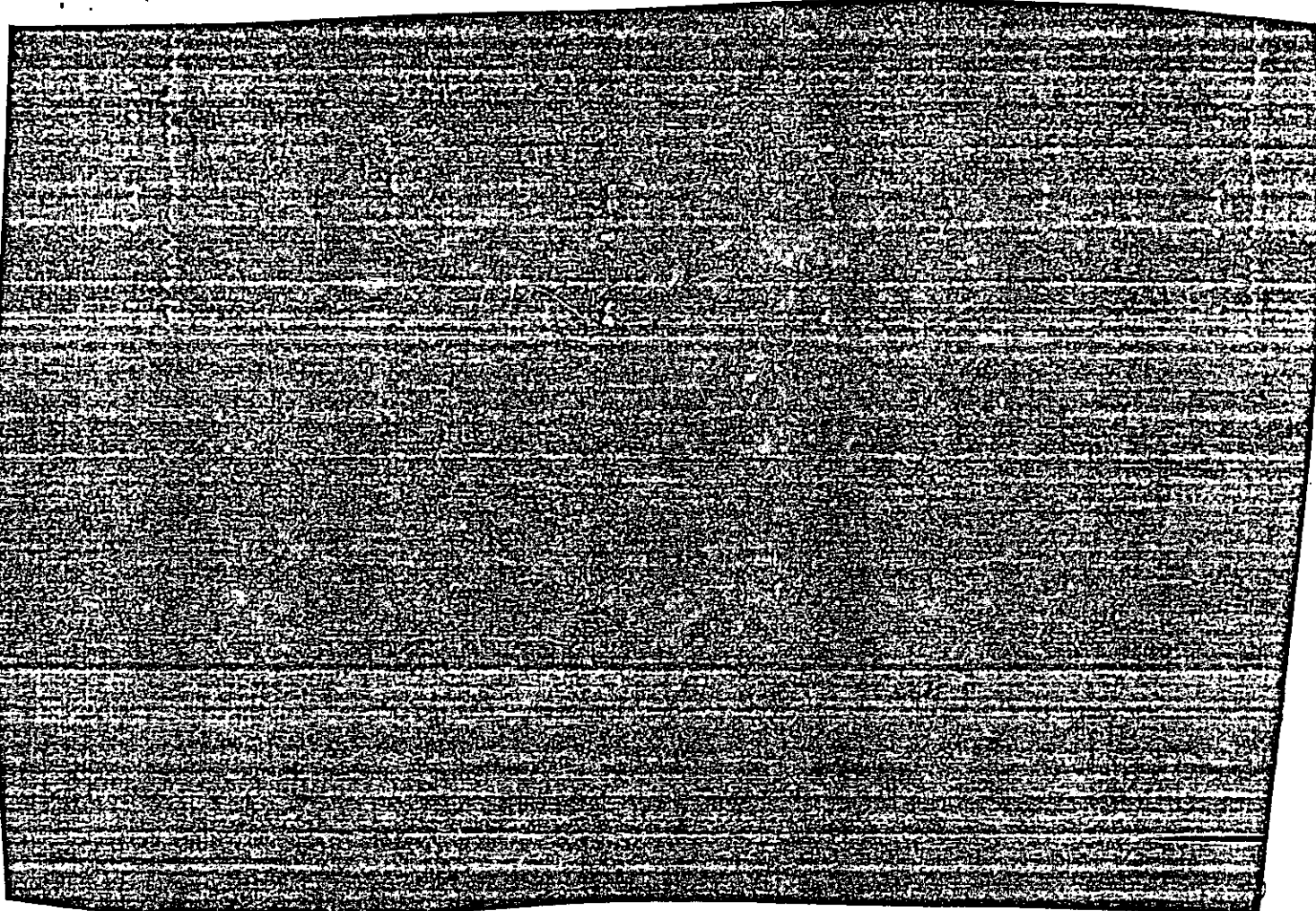
1. We know what is going on, which implies an effective surveillance system. 

Detection of objects in space is currently being performed by the NORAD Space Detection and Tracking System (SPADATS). The system consists of two major components. One, the Air Force Space Track System, is a facility for computing satellite ephemerides using data from a number of sensors located in various parts of the world. The other major component is the Navy SPASUR system, which consists of a number of large radars in the southern United States constituting a "fence." It is the prime sensor for detecting new objects in space. It feeds its data into SPADATS. It will shortly have a capability of detection up to 3000 nautical miles on small satellites.

Since SPASUR will be traffic-limited when large numbers of satellites are in orbit, some consideration is being given to building a large radar with a "single-pass" capability of detecting and providing orbital data on each new satellite.

The need for a space surveillance capability was dramatized by the excitement which prevailed a few months ago until a "strange" satellite in the sky was finally identified as part of Discoverer V.





MEASUREMENTS AND TECHNIQUES SUMMARY

In addition to the large hardware programs and systems concept which have been described in the preceding sections of this paper, there is a variegated body of work going on in the measurements and techniques area which both (1) supports the hardware development programs such as ZEUS and MIDAS by providing new knowledge on which to base system design (e.g., Project DAMP supports ZEUS; TABSTONE supports MIDAS), and (2) looks to the future beyond the existing hardware developments and attempts to provide the technological knowledge on which new systems, if they are to come, must be based.

Most of these programs are centered in ARPA's Project DEFENDER, although the individual Services sponsor a few.

It is convenient to distinguish between Measurements and Techniques.

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Measurements

The most important measurements are those made against missiles themselves as they re-enter. Radar and optical phenomena are observed and later correlated with theoretical and laboratory research in an effort to understand the physical phenomena. Aside from an occasional opportunity to observe the flights of [REDACTED] our own ballistic missile programs to provide most of the vehicles for full-scale measurements. Scale models also can be used to advantage.

The major programs measuring re-entry phenomena are:

1. Project DAMP (Down Range Anti-Missile Measurement Program) - Uncontrolled, full-scale re-entry experiments using targets of opportunity in AMR.
2. Project PRESS (Pacific Range Electromagnetic Signature Study) - Controlled full-scale re-entry and mid-course experiments using NIKE-ZEUS target missiles in PMR.
3. Wallops Island Re-entry Physics - Controlled model re-entry experiments at Wallops Island using Trailblazer missiles.
4. Penetration Aids and MARS (Mobile Atlantic Range Station) Penetration aids experiments using R&D missiles in AMR.

In addition, the ZEUS program itself has a great deal of measurement work on re-entry phenomena planned both at AMR and Kwajalein.

With respect to launch phenomena, here the primary interest is the measurement of the optical and infrared radiation from the missile, which is directly applicable to the MIDAS and BAMBI programs. Project TABSTONE (Target and Background Signal-to-Noise Experiments) is one of the major programs in this field. Missiles will be observed in their launch phase. As the name implies, measurements will also be made of the background radiation from the earth and clouds which makes the target difficult to detect.

There is also a considerable effort in the MIDAS program itself to obtain reliable infrared launch and background data.

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The above measurements program is supported by a modest ARPA sponsored program of theoretical and laboratory work.

Techniques

There is a great deal of research and development that is relevant to early warning and AICBM defense that is being carried forward in connection with other objectives. This is particularly true, for example, with respect to radar technology. The discussion here is largely confined to work which is supported principally because of its applicability to the AICBM problem.

With respect to infrared and other optical research, there is a pressing need to develop devices of greater sensitivity and techniques that will facilitate resolution of missiles from spurious sources. A considerable effort is being sponsored, primarily by ARPA. Infrared is a promising complement to radar, and research and development in this area needs vigorous support.

In the radar area, there are special problems posed which are critical for many AICBM systems and which will not be attacked in connection with other programs. Radar has, of course, been more exploited than infrared, but there still seems to be possibilities for significant improvements in capability. The phased array (electronically scanned) radar seems to offer considerable promise, both for high power and hardness, and is being adequately supported.

Research is under way with respect to several types of kill mechanisms for use in AICBM defense, including nuclear effects, hypervelocity impact with small particles, charged particle beams, and RF beams. Probably the hypervelocity impact work is the most promising area for work at this time. There may be very real possibilities for developing warheads based on this mechanism that have significant advantages over nuclear warheads. The charged particle and RF beams work must be regarded as very high risk, distant payoff types of research.

There is a fairly substantial effort spread throughout the DOD on other techniques that might be applicable to AICBM defense. Examples are R&D on LASERS, data processing, vehicle guidance and propulsion, and fire control.

It is believed that in general AICBM techniques work is going forward at about the right level considering the problems and talents that exist.

APPENDIX 1

EARLY WARNING

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BALLISTIC MISSILE EARLY WARNING SYSTEM
(BMEWS)

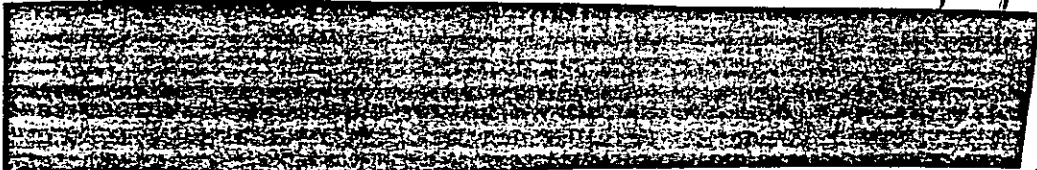
The Ballistic Missile Early Warning System (BMEWS) consists of three large radar installations in the far north designed to detect ICBMs launched from the USSR at the US over the North polar regions, and to transmit an immediate warning to NORAD and SAC. A nominal 15 minutes warning time will be provided, the actual times ranging from about 10 to 40 minutes, varying with location and time of flight.


Work began by the Air Force and its prime contractor, RCA, in 1957. The three sites selected were Thule, Greenland; Clear, Alaska; and Fylingdales, England. The radars are of two kinds: detection radars of the "billboard" type, very large and powerful, capable of detecting ICBM tankage at about [REDACTED] and tracking radars with parabolic antennas which are capable of following the missile in its flight. The latter radar can also be scanned in such a way as to provide a detection capability of about [REDACTED].


Present configurations planned for the three sites are:

- Thule: 4 detection radars covering a total of 160 degrees in azimuth, already operational (in December 1960); and one tracking radar, operational December 1961. This site will cover launches from the central portion of the USSR, leaving the US exposed to launchings from Siberian and European areas.
- Clear: 3 detection radars covering a total of 120 degrees in azimuth, operational September 1961; one tracking radar authorized by OSD but not funded (cost, approximately \$20 million). It will still be possible to attack the entire eastern half of the US undetected, with 23 degree re-entry angles, provided only that the missiles are fired from western Russia.
- Fylingdales: 3 tracking radars covering, for detection, approximately 90 degrees, operational about July 1963. When this installation is completed, all portions of the USSR will be essentially covered for trajectories [REDACTED].

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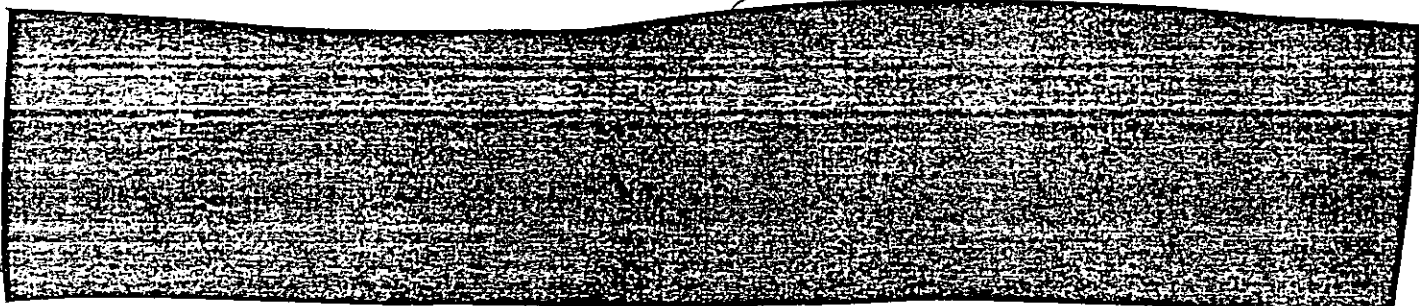
Rearward communications from the three sites back to NORAD and SAC Headquarters are being provided in time to match the above dates. 

 Displays are being provided at the headquarters.

Expenditures through FY 1961 total approximately \$900 million, excluding operational costs, and through FY 1964, the last construction year, will total almost \$1 billion. After this time, the operating cost, including military personnel, will run about \$87 million per year.

The detection radars can furnish only crude impact prediction (within a few hundred miles). Much more accurate prediction can be obtained from the tracking radars (within a few miles) but here the traffic handling ability is severely limited.

The tracking radar at Thule, when used in the detection mode, will give partial coverage of the ICBM approaches later to be covered by the UK site. It can be made to furnish back-up to the detection radars, can be used to identify selected targets with more confidence, and thus reduces the false alarm rate. A tracking radar at Clear would also decrease false alarms and increase user confidence.



BMEWS can be jammed, either from aircraft, into a low elevation angle sidelobe, or from satellites, or by putting chaff in orbit. None of these alternatives is really easy to do, due to the multiplicity of beams on differing frequencies, and at different sites. If the enemy chose an all-out jamming action to mask his attack, this in itself would provide early warning. If he chose to jam us periodically, he must take into account the increased international tension which would result, as well as possible countermeasures on our part.

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As almost invariably occurs when a complex system is made operational, some troubles have occurred with respect to the data from the Thule site, particularly with regard to false alarm rates. There is no reason to believe that these troubles will not be satisfactorily overcome.

BMEWS can perhaps be overflowed, and certainly avoided completely by ICBMs fired over the Antarctic region, both of which would degrade the accuracy of the enemy's attack, reduce his payload, greatly increase his time of flight, and expose him to the chance that we might obtain greatly increased early warning time by other means.

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MISSILE DEFENSE ALARM SYSTEM
(MIDAS)

MIDAS, which is under development by the Air Force, is a system of orbiting satellites, each equipped with an infrared sensory device designed to detect, but not track, enemy ICBMs in their launch phase, thus increasing the number of minutes of early warning available from BMEWS (10-40 minutes) by an additional 5 to 20 minutes. Although studies have been made of world-wide coverage, the present system under design is intended only to detect launchings from the USSR. To accomplish this, eight MIDAS satellites in carefully controlled circular polar orbits will be required, four in each of two orthogonal planes at 2000 n.m. altitude. (Serious consideration is being given to 12 randomly spaced satellites, 6 in each of two orthogonal planes since without station-keeping the individual satellites can be made more reliable.)

Since MIDAS will have some appreciable false alarm rate, it is conceived to have its main value against mass raids. In this respect it is similar to BMEWS.

Three ground readout stations will be necessary, now planned for installation in Alaska, Greenland, and the United Kingdom. The design of the system is such that there is a very high probability that at least one satellite will always be within line of sight of both the launch site in Russia and at least one readout station.

Data from the readout stations will be instantaneously sent by communication lines (BMEWS circuits will be utilized) to a central computing and display center located in the United States.

The ATLAS booster will be used, along with an AGENA second stage. The AGENA contains the electronic payload; hence the AGENA itself is the MIDAS satellite.

Two test launches have been made; the first failed to achieve orbit; the second achieved orbit and some infrared data were secured before telemetry failed on the fifth pass. The next launching is scheduled for May 1961.

The two most important problems facing MIDAS are reliability and infrared detection capability.

With respect to reliability, the design goal is one year average life per satellite. The present estimate of the life of the next few R&D MIDAS

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satellites is about 500 to 1000 hours (which seems optimistic); hence reliability must be improved by at least a factor of ten to reach the design goal. Although not impossible, this will be difficult to achieve.

The main problem with respect to infrared performance is whether or not the target can be distinguished from the heat radiation coming from the earth and clouds. Various plausible discrimination circuits have been incorporated into the design of the infrared receiver, but until more test data are available, this problem will be unresolved. A comprehensive measurements program has been planned to extend our knowledge in this area. Some recent analysis of background and target radiation has been encouraging.

Enemy spoofing tactics are possible (e. g. , rockets with doped fuels), but seem improbable. Since MIDAS will only be useful against mass raids, simulation of one target would be of no particular benefit to the enemy. Simulation of a mass attack would invite our mass retaliation.

The system might become operational in 1964 or 1965. No go-ahead for an operational system has been granted.

R&D expenditures through FY 1961 will total about \$190 million; \$200 million is being requested in FY 1962; and it is estimated that an additional \$290 million will be required to complete the R&D program, for a total of almost \$700 million. This will pay for a total of 24 R&D launchings through calendar 1963.

To attain an operational system will require approximately \$500 million more; annual operating costs will range from \$100 million to \$400 million, depending on the reliability attained (the lower figure assumes an average satellite life of one year).

If world-wide coverage is desired, for early warning against other areas (e. g. , China) and against submarine launched missiles; studies have been made showing that 12 or more satellites will be required, and 9 additional readout stations (12 total) scattered around the world. The additional investment will be about \$500 million, and additional annual operating cost will range from about \$100 to \$300 million depending on reliability. It should be noted that the detection problems will be even more difficult for the submarine launched missiles, due to their lower radiation and shorter burning time, and therefore a redesign of the infrared receiver is required. It is not certain that this redesign can be made effective.

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It is probable that MIDAS can be developed to the point that it will be effective against ATLAS-type missiles; whether or not it can be made effective against Polaris or Minuteman-type missiles is problematical.

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OVER-THE-HORIZON RADAR

Over-the-Horizon Radars depend for their operation on the conditions of the ionosphere. They will never provide a self-sufficient warning system but during the time ionospheric conditions permit they will contribute useful information on launchings in the USSR. In addition to its corroborative value as a warning system, Over-the-Horizon Radars may make important contributions for intelligence purposes.

BMEWS operates at a wavelength of 0.7 meters. Electromagnetic radiation shorter than 10 meters is infrequently reflected by the ionosphere and therefore the trajectory of the waves does not bend to follow the curvature of the earth. This limits BMEWS radars to line of sight detection.

To extend the range on the earth to distances beyond the horizon use has to be made of the reflections by the ionosphere. Research and development has been conducted in Over-the-Horizon or Ionospheric Radars which operate in the HF band (wavelength of the order of tens of meters).

A system could be developed out of three different techniques which have been tested for the last two years. All three techniques involve multiple bouncing of the radar signal between the earth and the F layer of the ionosphere (about 250 KM altitude). One of the techniques consists of reflecting the signal at the missile and trail and the ionosphere is used only to bounce the signal. In the other two techniques (ground-forward and ground-backward scatter) the detection is not effected on the missile itself but on the disturbance produced by the missile in the F layer which persists for minutes and alters the radar signal.

Such a system will provide accurate time information on launchings 200 to 300 seconds after launch at distances as large as 4,000 KM or more. The probability of a false alarm has not been measured but it is expected to be low enough to be useful. The system will detect long-time burning missiles (ATLAS-type) and some short time burning missiles (MINUTEMAN-type) but whether or not a system capable of detecting POLARIS missiles will be developed depends on the outcome of experiments to be carried out during the next few months.

An important limitation of all the present techniques is that they require knowledge of the launching site in advance. An urgent problem for research is to find out means to survey an extensive area for possible unknown launching sites.

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The more serious limitations of all the present Over-the-Horizon Radars are due to the very fact that makes possible the long range. This is the use of the ionosphere. It is doubtful that the radar can be used for more than 50% to 90% of the time depending on the geography due to natural ionospheric disturbances (such as magnetic storms and diurnal variations of the ionosphere). With the existing equipment for ionospheric exploration, it is possible to make an accurate estimate of the reliability of the radar data simultaneously with the gathering of the launching information. This works both ways and it is therefore possible to schedule the launchings for the time when the radars are out of operation.

There is a possibility of developing ionospheric radars operating at the very low frequency band (wavelength of the order of 15 KM). These radars would use the D layer of the Ionosphere (75 KM altitude) which is more stable than the F layer and this would make the radar operative at times when the F layer is not useful, and vice versa. More research is needed before any predictions are possible.

Before a complete operational Over-the-Horizon Radar system should be deployed a tactical evaluation of its usefulness must be made.

The current level of research and development by ARPA and the Services is considered to be appropriate in light of the present state of technology and the need for specific tactical evaluation cited above.

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APPENDIX 2

ACTIVE DEFENSE

NIKE ZEUS

NIKE ZEUS, under development by Bell Telephone Laboratories for the US Army, is the only active defense anti-ballistic missile system under hardware development in the United States or allied countries. Over \$900 million has been budgeted on the program through FY 1961, and the total development cost will approximate \$1.7 billion through FY 1965.

The system is a terminal defense system in which the incoming targets are detected and tracked by radar; the ZEUS missile is launched and, by command guidance, steered to an intercept point; and its nuclear warhead is detonated by ground command. A special radar provides some capability of discrimination between warheads and decoys. Each battery has a maximum range of about 75-100 nautical miles against low-arrival rate targets; in an all-out mass attack in which the enemy is assumed to use multiple warheads or decoys, this range is rapidly degraded, due to the necessity of holding fire until atmospheric discrimination is effected.

Testing of parts of the system, including limited-range missile firings, has begun at White Sands Missile Range. Future tests are scheduled at Ascension Island, where a Target Track Radar will observe Atlantic Missile Range ICBM re-entries; Pt. Mugu, where the ZEUS missile will be tested to its full range; and Kwajalein Island in the Pacific. The latter location will have a complete ZEUS system, and actual intercepts will be flown against ICBMs fired from Vandenberg. These firings are scheduled to begin about January 1962. There are some recent indications that this program may slip about six months.

It is believed that the Kwajalein tests, in addition to influencing the design of the ZEUS system itself, will also provide invaluable data for our own penetration aids program.

If a decision to deploy ZEUS is made, the first batteries can become operational in about four years. Approximate total costs of varying levels of deployment are: 4 batteries, \$1.2 billion; 12 batteries, \$2.3 billion; 30 batteries, \$4.3 billion; and 70 batteries, \$8 billion.

The most important limitation of ZEUS is that its fire power will probably not be able to handle the number of simultaneous targets which can reasonably be expected in an all-out war with the USSR. Such targets may be multiple warheads or a combination of warheads and sophisticated decoys. (A standard two-battery configuration can handle six simultaneous targets approximately every 30 seconds, until its missiles are exhausted.) Since the ZEUS radars are relatively soft, one enemy warhead exploded nearby will destroy them.

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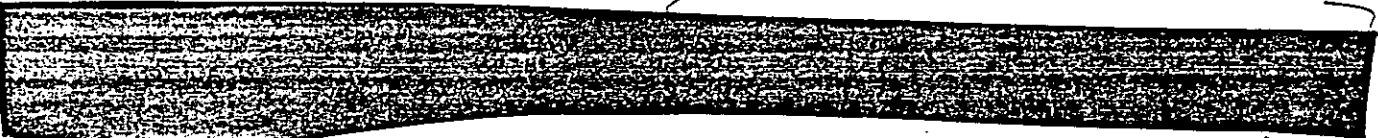
The firepower limitation could be drastically improved if a cheap, effective, non-nuclear missile could be developed. This would permit marked improvement in the ratio of costs to the enemy and to us for each ICBM destroyed. Studies in this area are only moderately encouraging.

Discrimination capability is being designed into ZEUS which may be effective against lightweight decoys and tank fragments.

Another important consideration applicable to any point defense system like ZEUS is that city populations cannot be protected against mass attack by such a system without a major program of fallout shelters. The enemy has merely to explode surface bursts outside the range of the ZEUS battery and the resultant fallout will be lethal against the population.

ZEUS can be expected to be quite effective against low rate-of-arrival targets such as might be launched from enemy submarines, or from enemy countries (e. g., China) having only first generation, unsophisticated missiles. It might also add certain intangible but real factors to civilian morale, and thus strengthen our international posture.

One important way in which ZEUS might help create world stability is that, if arms limitation negotiations are successful, ZEUS would be quite effective against a small number of clandestine missiles.



ZEUS can be deployed earlier than any competing system, and much earlier (at least five years) than any system not based on terminal defense.

Key problems as to ZEUS's effectiveness are the degree to which its discrimination techniques against decoys can be made effective, and whether or not an effective, cheap (non-nuclear) ZEUS missile can be developed which will allow greatly increased firepower.

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ARPA TERMINAL
(ARPAT)

ARPAT (from ARPA Terminal) is a terminal-defense system concept which was formulated in 1959 in an attempt to get around some of the problems of target identification that beset NIKE-ZEUS. During 1960, twelve paper feasibility studies were conducted on critical elements of the ARPAT concept. These study results were sufficiently promising to warrant a more intensive feasibility investigation during FY 1961 and 1962. Approximate cost of this program is \$10 million through FY 1962.

The ARPAT concept is based on the assumption that moderately heavy decoys (20-200 pounds) can be built which will defy discrimination, while light decoys (20 pounds or less) may not be discriminable until they descend to about 200,000 feet altitude. To counter a threat with many decoys, ARPAT would delay final weapon commitment until targets have reached 150,000 - 200,000 feet altitude, and employ interceptors which would be sufficiently inexpensive to justify attacks on all undiscriminated objects as a matter of doctrine.

To accomplish the late final commitment, a large number (50-500) of small interceptors would be lofted to 100,000 feet altitude upon radar warning of an attack upon the area defended. These small interceptors (50-75 lbs.) would be assigned to undiscriminated targets by a specialized ground radar, and then proceed independently by homing on infrared emitted by the aerodynamically-heated re-entry bodies. Kill would be accomplished by hyper-velocity impact of portions of the interceptor structure on the target.

ARPAT, a terminal defense system like ZEUS, could not be used to defend population against a fallout attack, and if deployed for population defense, should be paralleled by a fallout shelter program.

Systems embodying the ARPAT concept appear (on the basis of the limited paper studies conducted so far) to be capable of defending localized targets against missiles accompanied by a few tens of heavy decoys. However, it may turn out that ARPAT would be inherently vulnerable to other types of countermeasures. The FY 1961-1962 program has been planned to verify experimentally the critical new technology involved in the ARPAT concept as well as to estimate system cost, effectiveness, and vulnerability to enemy countermeasures.

If this program turns out favorably, a decision made in 1963 to develop and deploy ARPAT could be accomplished by about 1970. The cost per city defended would be comparable to ZEUS projected costs. It may also turn out to be possible to integrate ARPAT and ZEUS at a cost not greatly exceeding, but with effectiveness higher, than either alone.

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DEFENSE OF HARD POINTS

Defense of the United States retaliatory force (including command and control centers) against ICBM attack can be accomplished to some degree by: increasing numbers, hardening, concealment, and active defense.

A plausible case can be made to show that hardening plus active defense offers economic and reliability advantages over the other alternatives for some important elements of the United States retaliatory arsenal. This claim must be tempered, however, by an appreciation of technological uncertainties which prevent a positive statement at this date that active defense of hard points is technically feasible at a level of deployment which makes it economically attractive.

Hard point defense is, beyond much question, easier and less expensive to accomplish than defense of soft areas. Since the target is hard, the incoming missile may be allowed to come within about ten thousand feet of its target prior to interception. In consequence, commitment of the AICBM weapon may be delayed until the ICBM is within ten-to-twenty miles of the target, rather than the sixty-to-one hundred miles minimum commitment range for ZEUS, for example. This results in less expensive interceptors and very likely reduces the cost of other system elements as well. The decoy problem is also eased, as decoys to be effective must be capable of surviving the most rigorous re-entry problems without disclosing their characteristics to observing radars, and must have been precisely deployed in order to appear to impact within ten thousand feet of the target.

The Air Force has recently concluded eight studies (six unfunded, two funded, for a total of \$140,000) of the means of defending a hardened restricted area against ballistic missile attack. The RAND Corporation and Bell Telephone Laboratories have also recently concluded similar studies. These studies indicate that reasonably good defense of small sites hardened to about 100 psi can be bought at a five-year cost in the range of ten-to-fifty million dollars, depending upon the severity of the postulated threat.

While it seems quite likely that a hard point defense system costing fifty million per defended site or somewhat less could be built with the capability of handling perhaps ten decoys per missile attack, the costs would rise almost linearly with increasing numbers of re-entry decoys. As of now it is not known whether it is possible to perfect decoys which weigh a few tens of pounds or less, and which can survive re-entry while matching medium or large warheads in CEP and characteristics observable by radar.

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Until this crucial uncertainty is resolved, the feasibility of hard point defense at reasonable cost cannot be determined.

A technically different approach to hard point defense (for example, HELMET) is being given some consideration. Rather than employing anti-missiles which seek out incoming missiles and are therefore vulnerable to decoying, these concepts involve lofting a barrage of pellets through which dangerous objects would have to fly. Warhead and decoy alike would be destroyed if the barrier were sufficiently high (so that atmospheric slowdown had not occurred) and the pellets of the barrage sufficiently heavy to accomplish kill. Considering the uncertainty of our current knowledge, the weight of pellets required may range from one million to one hundred million pounds per attack for each hard target defended. Systems of this kind have not yet been examined closely enough to determine their cost or susceptibility to specific countermeasures.

Another significant uncertainty relates to the feasibility of countering the effects on defense systems of large, low-altitude, nuclear bursts; or alternatively, the possibility of successfully attacking with weapons which deny the possibility of the enemy's warheads detonating.

The Penetration Aids program as well as the decoy discrimination research carried on in ZEUS and DEFENDER will go a long way toward resolving the uncertainties in decoy capability. Resolving the questions raised by possible nuclear detonations is not possible without testing; but theoretical studies based on available data may furnish a useful degree of knowledge.

The Air Force has estimated that about [REDACTED] would be required between the start of weapon system development and IOC. Some research in hard point defense technology is being conducted at present, and some of the system problems are closely related to those experienced in ZEUS and ARPAT. Increasing the effort on technology related to hard point defense (especially work on high thrust, short-burning time interceptors) is desirable at this time. Some limited systems work should be undertaken to pin down costs and prepare for possible weapon system development.

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BALLISTIC MISSILE BOOST INTERCEPT
(BAMBI)

The BAMBI program is concerned with intercept of enemy ballistic missiles during the launch or pre-burn out part of the trajectory or in some cases shortly thereafter. Location of BAMBI interceptors on satellites in orbit seems to be the only approach offering any promise of making possible intercept during the short time period available: 150-to-300 seconds burning time for present ICBM designs and even less for IRBMs and possible advanced ICBMs. Those concepts considered so far differ in detail but all involve the placing and maintaining of large numbers (tens of thousands) of interceptors in orbit. Those considered to date rely primarily on infrared radiation from the plume of the hostile missile for detection, tracking, and intercept and on hypervelocity impact with small pellets for kill of the hostile missile. By operating in parts of the infrared spectrum where water and/or carbon dioxide molecules are strongly absorbing these systems, like MIDAS, use the earth's atmosphere as a natural filter so that there will not be a response to radiation emanating from sources on the earth's surface. This also means, of course, that the BAMBI systems can detect ballistic missiles only after they have risen above the sensible atmosphere, a factor which cuts the total time available for response well below the figures given above.

One of the attractions of the BAMBI-type concept is that it may permit attack when the enemy missile is most vulnerable, i. e. , during the powered part of the trajectory. Also, decoy problems will be different and quite possibly easier to deal with than those with which terminal phase AICBM systems are plagued.

BAMBI-type satellites and interceptors would be expected to burn up as their orbits decayed and they re-entered the earth's dense atmosphere. Nevertheless, the political acceptability of such systems would undoubtedly be questionable. Particularly, an effective BAMBI system would intercept Soviet (and perhaps other) space flight launchings unless special provisions, including preannouncement of such launchings, were made to preclude intercept.

Moreover, the technical feasibility of the BAMBI-type concepts is dependent on the solution of a number of critical problems. The information on infrared radiation from missile plumes and from cloud tops is very inadequate, but there exists the very real possibility that discrimination between missiles and clouds, and possibly other spurious sources such as

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decoys, may be a problem requiring much more sophisticated infrared and data processing equipment than some of the present concepts envisage. It is clear that it will be very difficult to achieve reliability adequate to permit long term operation, and this is absolutely essential. Even with operating times of the order of a year, and even with a substantial reduction in costs of boosting mass into orbit, annual costs of maintaining a system that could exact a reasonable high attrition (say 75%-90%) against plausible enemy threats would run into billions and quite possibly tens of billions of dollars. Enemy countermeasures such as pellet attack against the BAMBI system, development of very short burning time enemy missiles, and really large scale synchronization of launch of ICBMs from a relatively small area may seriously degrade the system's effectiveness.

To date, some \$3 million has been spent by ARPA on BAMBI concepts. These concepts continue to be sufficiently attractive so that they may merit further research. However, a development and deployment program would be grossly premature at this time.

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MIDCOURSE AICBM

An ICBM travels for 1,200 seconds or more in midcourse; i. e., between the end of boost and the beginning of re-entry. This time may be compared to 200-300 seconds spent in boost and 100 seconds or less between re-entry and impact.

The midcourse phase is particularly attractive from the point of view of defense for a number of reasons, including:

- a. Time is not as critical as in boost or terminal phase systems;
- b. Local saturation of the defense is avoided;
- c. The anti-missiles may be ground-based (as opposed to BAMBI systems);
- d. A second shot (via a terminal system) is possible;
- e. Any nuclear detonations would occur outside of the atmosphere.

In consequence very much thought and hope has gone into midcourse AICBM systems.

In midcourse, however, the decoy problem is much more severe than in the boost or terminal phases. Since missiles are in "free fall" in midcourse, the trajectories of warheads and warhead-shaped balloons are indistinguishable. Such balloons (weighing about one pound, and requiring only a few cubic inches for stowage and launch mechanism) constitute an almost insurmountable problem for midcourse AICBM, as balloons can closely match the appearance of warheads to radar, visual, or thermally-sensitive instruments.

Consideration has been given to lofting large nuclear weapons to the vicinity of an incoming target cloud to melt or deflect balloons over the long path (200 miles or more) that elements of a single ICBM launch may easily fill. This has led to the invention of other midcourse decoys (for example, "bird cages") which would survive a nuclear explosion at a range of ten miles or so; and would, to radar at least, be indistinguishable from a balloon.

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Many system configurations have been explored, but to date 3 salient features of all the systems examined seem to be:

- a. The systems are all significantly more expensive than the enemy force they purport to counter;
- b. The enemy -- by an expense small compared to the cost of his offensive force -- could add decoys and other features which would effectively counter the defense systems so far examined.
- c. The time it would take an enemy to accomplish these modifications is short compared to the time required to develop and deploy the defense system.

For these reasons, midcourse AICBM activities are essentially limited to general phenomenological research, with only a "keep alive" trickle of systems-oriented effort.

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APPENDIX 3

SPACE SURVEILLANCE

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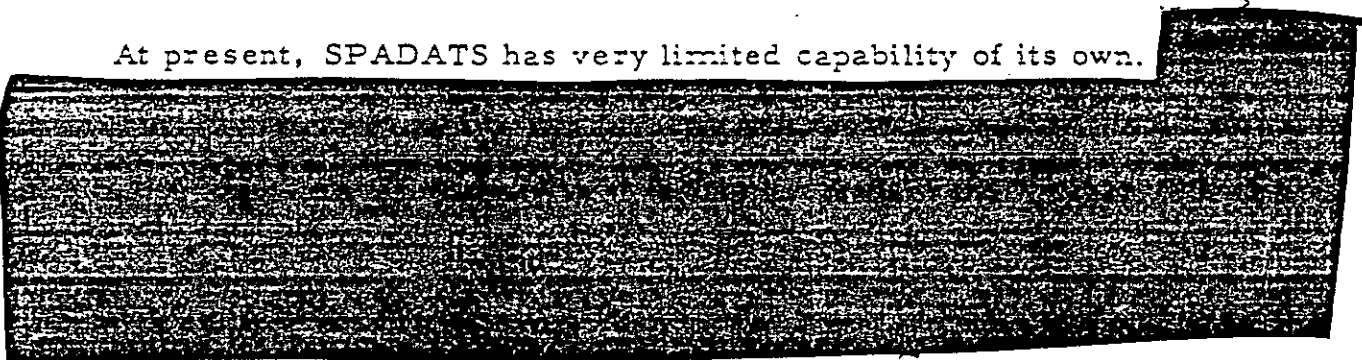
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SPACE SURVEILLANCE

There are now a few tens of satellites in earth orbits. If a significant number of satellite programs among those now being considered is carried out, a satellite population of as many as 10,000 is possible, if not probable, in less than ten years. From a military point of view, many of the satellites placed in orbit by foreign powers may threaten our security. Information about these satellites must be made available to appropriate military commands. In addition, it is necessary to keep track of our own military satellites.

The space surveillance mission is now being performed by the NORAD Space Detection and Tracking System (SPADATS). This system, under operational control of CINCNORAD, consists of two major components. One, the Air Force Space Track System, is a facility for computing satellite ephemerides using data from a number of sensors located in various parts of the world. The other major component of SPADATS is the Navy SPASUR system. It is the prime sensor for detecting new objects in space.


At present, SPADATS has very limited capability of its own.



SPASUR, a fixed beam CW system, is being upgraded so that the probability of . The present system in its simplest and most attractive form will become traffic limited as the satellite population increases. SPADATS needs badly a radar  sufficiently accurate to avoid ambiguity. In order to provide this capability, a SPASUR type system becomes more complex and alternatives to it must be considered.

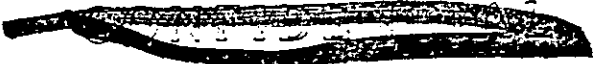
In October 1960, the Air Force was requested by the Secretary of Defense "to submit a detailed development and funding plan for improvement of the national space surveillance system which carries the coordination of the Department of the Army and the Department of the Navy, and which will satisfy the requirements of the Joint Chiefs of Staff and their designated operational command." This plan is now in preparation.

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It is felt to be desirable that a significant increase in our space surveillance capability be achieved, beginning immediately. It is estimated that an expenditure of \$30 million in FY 1962 is needed to make a vigorous start toward improving SPADATS. The exact nature of the sensor has not yet been decided. A possibility being considered is a large electronically scanned radar. The use of such a radar would serve the dual purpose of providing a sensor for SPADATS and advancing the art for other applications (e. g., Ballistic Missile Defense). Alternatively, a more conventional radar may well serve the SPADATS purpose. It would take about five years and cost about \$50 million to obtain an array radar. Additional expenses of SPADATS could make the five year total cost (including radar) approximately \$80 million. A more conventional radar could be obtained in less than three years at a cost of about \$20 million, for a five year total cost of approximately \$50 million. However, there will probably be no over-all saving to the Department of Defense since additional money in the latter case would undoubtedly be spent in another program (e. g., NIKE ZEUS) for an array radar.

The cost of SPADATS and its predecessors through FY 1961 has been approximately \$47 million.



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APPENDIX 4

MEASUREMENTS & R&D TECHNIQUES

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DOWN-RANGE ANTI-MISSILE MEASUREMENT PROGRAM
(DAMP)

DAMP is an ARPA sponsored program which was started by the Army to make re-entry measurements on IRBM's and ICBM's in AMR. The principal measuring platform is the American Mariner, a Liberty-type ship which has both radar and optical measuring devices on board. The DAMP program which includes the ship and supporting land facilities has cost about \$10 million during FY 1961 and will cost about \$8 million in FY 1962, the difference being improvements to the technical equipment added during FY 1961.

The DAMP ship has provided the only radar measurements we have on re-entering IRBM and ICBM nose cones. These data have been invaluable in verifying the theoretical and laboratory re-entry physics work. Although the DAMP ship does have limitations in both range of its radars and speed of the ship, its continued use is clearly indicated at least until in CY 1962 when the MARS ships are scheduled to become available. Data have not yet been obtained on such missiles as the MINUTEMAN nor on the decoys being developed under the Penetration Aids program. The NIKE-ZEUS target tracking radar (TTR) on Ascension Island is now becoming available for re-entry measurements in AMR. This radar has greater capabilities than the DAMP ship radar, but is obviously not mobile and, therefore, is restricted to observing firings which impact in the Ascension area.

The continued use of the DAMP ship beyond CY 1962 is doubtful in light of the expected availability of the two MARS ships which will have significantly greater capability and the initiation of the PRESS program which will permit fullscale controlled re-entry experiments.

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PACIFIC RANGE ELECTROMAGNETIC SIGNATURE STUDY
(PRESS)

PRESS is an ARPA field experimental program to investigate the physical effects associated with the flight of ballistic missiles from mid-course through re-entry. The total cost of this program over a four-year period, FY 1960 through FY 1963, including equipment, installation, and operation is approximately \$100 million. The amount programmed in FY 1961 is \$46 million and in FY 1962, \$24 million. The facility is being located at Roi-Namur in the Kwajalein Atoll, and will be operational about June 1962. Some limited experiments and observations will be made several months prior to this date.


The immediate objective of the research is to learn as much as possible about the physical interactions which take place in flight, especially during re-entry. The program has a later objective of determining whether ICBM bodies (re-entry vehicles, decoys or other) intrinsically produce observable physical effects from which their identity can be derived; hence, attempts will be made eventually to test specific discrimination methods -- in real time, if possible.

The proximity of Roi-Namur to the NIKE-ZEUS test installation on Kwajalein Island will enable the PRESS experiments to use the 47 ATLAS target missiles and communications provided by the ZEUS program. These missiles will be controlled by the NIKE-ZEUS system calibration and demonstration requirements. They will serve many of the needs of the PRESS program, but it is expected that a few missiles with special payloads for PRESS will be required.


At the present time, the radar instrumentation programmed for PRESS is the TRADEX two-frequency (UHF and L-Band) radar being built by RCA. It is scheduled for emplacement on Roi-Namur in late 1961. Three aircraft based on Eniwetok and ground installations on Roi-Namur and Kwajalein will be used to make optical and infrared measurements.

Lincoln Laboratory has been selected to undertake the scientific direction of PRESS. Lincoln Laboratory also conducts the Wallops Island model experiments which will permit close correlation of the model and fullscale experiments.

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Project PRESS will be the only program of controlled fullscale research experiments conducted downrange with scientific personnel and computational facilities with the measuring instruments. As such, it is the keystone to the re-entry physics and discrimination programs. The NIKE-ZEUS equipment on Kwajalein will contribute to the research program in a limited way, on a noninterference basis with the ZEUS prime objective, which is a system demonstration.



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WALLOPS ISLAND RE-ENTRY PHYSICS

Lincoln Laboratory is conducting a re-entry physics program sponsored by ARPA with a major portion of its effort devoted to field experiments at Wallops Island using special re-entry vehicles, Trailblazer, designed by NASA. Laboratory and theoretical studies in support of the field measurements are carried on to establish a model for predicting the events to be observed in the field and to analyze and interpret the results. The total cost of the program through FY 1961 has been \$13 million and \$4 million is projected for FY 1962.

The Wallops Island firings provide controlled experiments on special re-entry bodies of 5" and 15" diameter at ICBM re-entry velocities. The primary advantage and disadvantage of this program as compared to fullscale programs are similar to any model program, namely, inexpensive controlled experiments versus the difficulty of scaling the model results. The program will provide valuable assistance in the design of the PRESS experiments as well as permit additional model work to examine results obtained from PRESS.

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TARGET AND BACKGROUND SIGNAL-TO-NOISE EXPERIMENTS
(TABSTONE)

Project TABSTONE is an ARPA program designed to provide a detailed understanding of the optical and IR phenomena associated with the launch phase and also the expected background conditions against which detection and tracking equipments of launch type systems will have to operate. This program is just being started and is estimated to cost \$5.2 million the first year and \$4 million the second year. The program includes airborne and rocketborne measurements of targets and backgrounds and the necessary laboratory and theoretical research.

Current system concepts such as BAMBI and weapon development programs such as MIDAS are proceeding without a detailed understanding of either the target or the background. Although the MIDAS system may work in the narrow infrared region for which it is designed, the program does not include investigation of alternatives. The BAMBI system concepts involving kill during boost and not just detection as in MIDAS impose much more stringent requirements on data needed for the definition of targets and background.

Although TABSTONE will obtain information vital to MIDAS and BAMBI, its broad objective is to learn about the launch phase of missiles. It is the first coordinated program of measurements and analysis in the launch phase. It has been preceded by the relatively uncoordinated Inter-Service Radiation Measurement Program (IRMP) which has been something of a disappointment. The cost of IRMP 59-60 was approximately \$10 million.

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PENETRATION AIDS

AND MOBILE ATLANTIC RANGE STATION (MARS)

Although this program is part of our over-all development of offensive capability, it is covered here because it is so closely related to Ballistic Missile Defense. It is the existence of defense concepts and the substantial effort in AICBM that motivates and defines the Penetration Aids program.

It is easy to duplicate a nose cone in all its observable characteristics with a very light object as long as it is outside the atmosphere. It is also easy to duplicate the slow-down characteristics of a nose cone in the atmosphere with a very light object to an uncomfortably low (for the defense) altitude. It is not as easy to duplicate both slow-down and signature characteristics. The Penetration Aids program is designed to produce from study and experiment the knowledge required to:

1. Reduce the radar cross section of nose cones. This has the twofold effect of delaying detection of the nose cone by the defense, and making easier the job of duplicating the signature of the nose cone.
2. Produce lightweight decoys with re-entry characteristics indistinguishable from those of nose cones.
3. Modify nose cones to control the observables in ways which confuse the defense.
4. Produce integrated penetration packages making use of decoys, electronic countermeasures, multiple warheads, tank disposition, etc., where appropriate.

Fiscal Year 1961 and prior effort on penetration aids is \$38 million; FY 1962 funding is \$32 million.

Closely associated with the Penetration Aids program is the MARS program of mobile instrumentation. Two ships, equipped with an array of sensors (radar, IR, optical) will be positioned so as to observe missiles equipped with various penetration aids. These observations will be used by those working on AICBM as well as for penetration aid development. MARS ships also serve to produce firing tables

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for the missile designers. The funding for the MARS ships is approximately \$50 million in FY 1961 and \$30 million in FY 1962. Airborne instrumentation will also be provided.

The Penetration Aids program has been slow starting. While it is the collective opinion of the scientific community that the offense has a great potential advantage over the defense, complacency in the matter is not justified. A determined defense would be highly effective against missiles employing no penetration aids. The Air Force Penetration Aids program must not be allowed to suffer from budgetary restrictions.

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OBSERVATIONS OF SOVIET MISSILES

All of the major programs discussed in detail in this section are ones in which we are observing our own and not Soviet missiles. From the longer term research viewpoint, this is not a serious handicap since we hope to understand the physical phenomena well enough to predict effects for any type of re-entry vehicle. In fact, we must avoid the trap of designing a defense system which will normally take at least five years to develop and deploy, based on observations of Soviet missiles today.

However, we have profited from the Soviet observations made in January and July 1960, both from intelligence and research aspects. These observations were made using aircraft and instrumentation diverted temporarily from observation programs in AMR. A separate aircraft operated by the intelligence community under the Nancy Rae Program will be available after June 1961 for optical and infrared re-entry measurements of Soviet missiles in the Kamchatka area. The potential value of these measurements is great. In practice, we may get very little since the Soviets will have the capability of interfering with this aircraft operating about 100 miles from its territory.

Another program to obtain radar re-entry measurements on Soviet missiles is being evaluated at this time.

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MISSILE, SPACE AND UPPER ATMOSPHERIC PHYSICS RESEARCH

In addition to the specific programs such as DAMP, PRESS, Wallops Island and TABSTONE, there are numerous smaller programs concerned with theoretical and laboratory work on missiles, space and atmospheric physics. Most of these programs are in the \$300,000 to \$600,000 per year range. The total cost in FY 1961 was approximately \$10 million and the amount programmed for FY 1962 is approximately \$11 million.

The primary purpose of these programs is to provide a comprehensive theoretical understanding of the phenomena produced by missiles and the environment in which the missiles operate. There is some duplication among these programs and between these programs and the larger ones such as Wallops Island which also includes theoretical work. This duplication is justified at this time in view of the present state of knowledge but should be expected to be reduced when the theoretical models of the phenomena become reasonably well accepted by the scientists in the field.

As part of these programs, some scientific tools are being built which have application to basic research beyond ballistic missile defense research. One of these tools is the 1000-ft. radio telescope being constructed in Puerto Rico as the principal instrument of DODIRF (Department of Defense Ionospheric Research Facility). The cost of this facility through FY 1962 is estimated to be \$6.8 million.

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R&D TECHNIQUES

Infrared - Optical Research

In addition to the effort previously discussed to provide a better understanding of the nature of the infrared and other optical radiation from missiles, and the transmittance through the atmosphere, there are serious problems, and great possibilities for improvement, in detection devices, and devices that will facilitate discrimination of missiles from other light sources such as sunlit clouds.

The major possibilities for discriminating between missiles and spurious sources probably are in the development of devices that:

- (a) can measure and compare the intensity of radiation from a source at two or more parts of the spectrum.
- (b) can make scan-to-scan correlation of intensity and source positions.
- (c) have appropriate optics so that very small fields of view can be used.
- (d) have sufficient sensitivity.

Work is being supported in all these and other areas of technology. Devices with improved sensitivity at longer wavelength are important and are being investigated, particularly for detection and tracking of aerodynamically heated warheads (as distinct from boosters). For the re-entry problem, techniques to deal with multiple targets are necessary and are being supported. The total support in the IR-optical area for FY 1962 amounts to about \$15 million. Considering that the feasibility of MIDAS and several proposed AICBM systems is absolutely dependent on infrared technology, this level of effort seems none too large. It is probable that techniques can be developed within the next few years that will meet most of the demands of these systems, though in many instances the levels of sophistication may be far higher than was originally thought necessary.

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Radar Techniques

While much of the general radar technology is applicable to AICBM problems, there are some areas that are being developed primarily because of the demanding requirements of ballistic missile detection and defense.

(a) The need for detection of targets of relatively small cross section (fractions of a square meter) at extreme ranges (thousands of miles) has made necessary the development of high power components and especially high power tubes. Further work in this area is being supported and is of great importance. The problems are likely to get much worse as there now appear to be very real possibilities of developing warheads with effective cross sections of the order of a thousandth of a square meter.

(b) Because of the very great speeds involved, the large antennas needed, and the necessity to handle multiple tracks, electronic scanning techniques have great advantage over techniques used in the past. A great deal of effort is under way to develop technology in this area.

(c) The need to discriminate between decoys and warheads has posed special problems for radars. Extremely high resolution has become especially important. This is true, of course, because of the need to resolve tracks of separate objects, but also there is the hope that with sufficiently high resolution it may be possible to measure the sizes of incoming objects.

(d) Especially for defense of hardened targets, radars that can withstand considerable over-pressure from a nuclear blast may be of great importance. The electronically scanned phased array type radars offer hope of reaching about 100 psi hardness.

The amount funded for Fiscal Year 1962 for radar development that can be charged to the AICBM research is about \$30 million. Of this, about \$20 million is being spent on developing the technology for electronically scanned radars. Most of this last amount is supported under the ZEUS program.

LASER Research

Within the last year the feasibility of an optical type radar, the LASER, has been demonstrated. This may have some very great advantages over conventional radars; particularly, the energy can be concentrated in an

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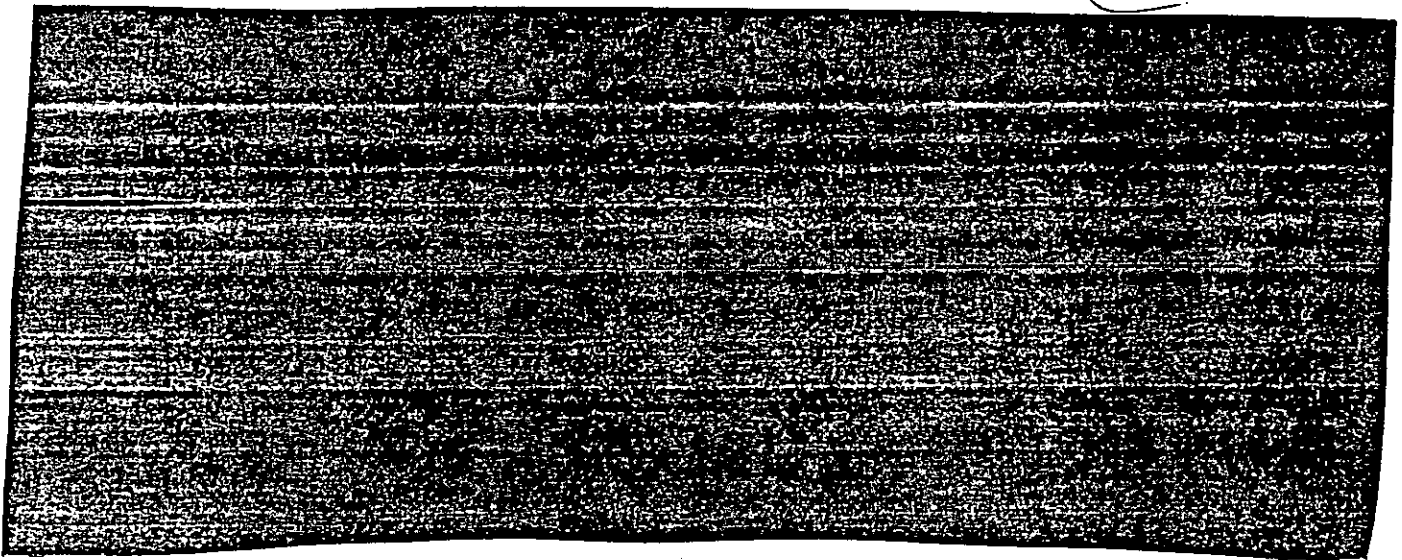
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extremely narrow beam. Development in this area is in its infancy. About \$1 million is funded by DOD for Fiscal Year 1962. There is, incidentally, a larger amount of research in this area being supported by corporate funds.

Kill Mechanisms and Vulnerability

A ballistic missile nose cone, capable of surviving re-entry into the atmosphere, is a very difficult object to destroy by means now available. The kill mechanisms effort is a vigorous research program to define more closely the kill capabilities of the mechanisms now relied on for destruction and to discover techniques offering greater effectiveness. The vulnerability effort is concerned with side effects, such as radio and radar interference or blackout which may accompany the employment of nuclear weapons in ballistic missile defense.



(b) Feasibility studies of the use of charged particle beams as a kill mechanism show that many problems need more detailed study, and several critical experiments will be required to check current theories. Research is under way aimed at producing a high energy, large current, beam of electrons or protons to investigate problems in beam stability, beam spreading and target damage. Theoretical and experimental work is being conducted for a high energy plasma accelerator which, in theory, can provide a relativistic high current beam. The probability of developing a feasible charged particle beam defense system seems at this time to be very low. However, it has not yet been demonstrated to be infeasible. The amount of research funded for Fiscal Year 1962 is about \$2 million, most of which will be spent in completing and doing critical experiments on devices that have been under development for some time.

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(c) Both experimental and theoretical studies are being conducted to determine the feasibility of using microwave electromagnetic radiation as a kill mechanism. The prospects for an effective defense system based on this mechanism are at best no more promising than for the charged particle beam. One of the most important questions is efficient transfer of energy from the beam to the target. Some work in this area may be justified. Other areas being examined are propagation and breakdown effects, extremely high power microwave generation, antennas, and power sources. Much of the latter effort may be unwarranted at this time considering the dim prospects and the criticality of the concept to the solution of the energy transfer problem. Some of the work is of fundamental interest as physics and should perhaps be supported as such rather than in connection with kill mechanisms. About \$5 million is being funded for Fiscal Year 1962 for radio frequency kill work.

(d) There are major disadvantages to using nuclear warheads in AICBM defense; need to detonate at high altitude to avoid damage to one's own personnel and facilities, high cost which may be prohibitive if one is forced to engage many objects (decoys as well as warheads), and nuclear and IR blackout effects (see below). For these reasons, kill techniques using high velocity solid material impacts has received increasing attention recently. However, little is known about the relationship of destructive effect to pellet size, velocity or composition or about possible warhead destruction mechanisms. For example, much more needs to be learned as to how small the damage to a nose cone can be and still insure its destruction during re-entry. Hypervelocity pellet warhead development is probably one of the most promising leads for radical improvements in AICBM capability; research in this area should go forward with high priority. About \$5 million is funded for Fiscal Year 1962.

(e) It is necessary to assume that nuclear detonations will be significant factors in any ballistic missile or space defense system, either in the vehicle under attack or as part of the over-all defense system. There are unresolved problems regarding nuclear interference with RF, IR and optical signals and effects on electronic components. The effects, such as radio or radar blackout, caused by ionization produced by high altitude nuclear bursts are being studied. In addition, damage can occur in electronic systems or components from transient radiation pulses emitted by a nuclear explosion. Transient radiation effects on electronics are not sufficiently understood and extensive theoretical and experimental research is being conducted to provide definitive information.

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Vehicles

About \$13 million is funded for Fiscal Year 1962 for research on such problems as guidance, fire control, propulsion for vehicles that might be used for AICBM or space defense systems. Much of the effort here is in the nature of parametric studies that would support systems work on such concepts as BAMBI. There is a limited amount of component development and test work involved. A significant research and development effort in these areas is desirable. It should precede and have higher priority than much of the detailed systems work.

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