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(U) The Restriction and Control of RDT&E for Ballistic Missiles and Military Space Programs

(Final Report–Volume III)

04 MARCH 1964

Prepared for
ARMS CONTROL AND DISARMAMENT AGENCY
Under Contract ACDA/ST-13

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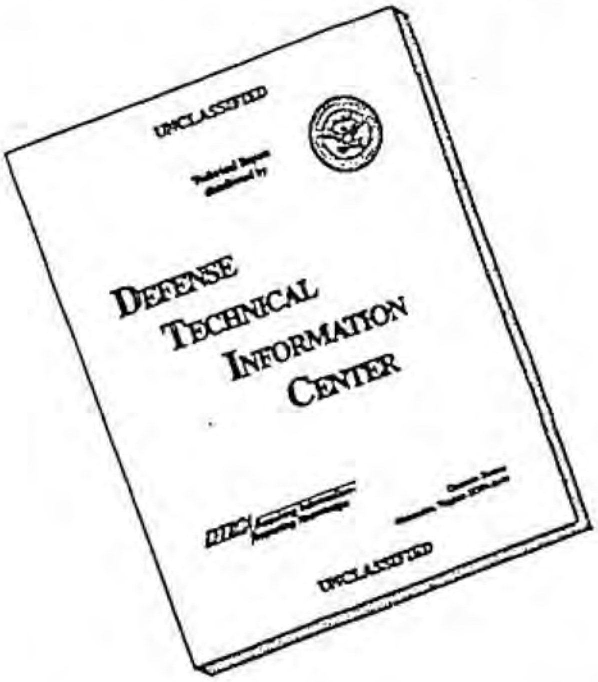

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(U) THE RESTRICTION AND CONTROL OF RDT&E FOR BALLISTIC MISSILES AND MILITARY SPACE PROGRAMS

(Final Report - Volume III)

24 March 1964

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I. THE EFFECTS OF IMPOSING RDT&E RESTRICTIONS

A. RDT&E Restrictions

The possible restrictions on research and development activities can be classified into four general categories as restrictions on funding, personnel, use of facilities, and specific activities such as flight testing. Generally the utility of both personnel and facilities can be expressed in terms of a common monetary unit; however, in this study the effects of restricting each of these resources will be investigated separately and in combination because of the different effects which their application has on the growth and development of technology and also because of the differences which might arise in controlling and verifying restrictions on these resources.

It should be pointed out that caution must be used in making generalizations regarding the application of restrictions on various resources because of the diverse manner in which the application of these resources affect the growth and development of technology. It can be shown that the effects of imposing restrictions are functions of both the nature and size of the programs whose restriction is being attempted.

1. Fiscal Restrictions

Money is the coinage by which other resources can be purchased, i.e., personnel, facilities and materials. The purpose of imposing fiscal restrictions is to limit the ability of the potential violator to finance clandestine activities or to compensate required personnel, rent facilities, and purchase materials. If the potential violator did not have to pay for the use of these resources, then fiscal restrictions would be ineffective. We face, however, the possibility of fiscal evasions and, hence, these restrictions are not considered to be sufficient in themselves for adequate control (see Volume III, Section III-B). However, restrictions on the use of money should provide some measure of control over the total RDT&E program whose control is being attempted.

2. <u>Personnel Restrictions</u>

Technological advances must come through the application of human resources to research and development programs. Thus, if personnel restrictions can be implemented, they may possibly be the most effective form of control. Perhaps the strongest relation between fiscal restrictions and other restrictions exists in the area of personnel restrictions, since it is generally necessary to pay individual workers with some form of monetary compensation. However, the effective control of personnel activities may present formidable difficulties. It may be possible to motivate a sufficient number of people to cause them to disregard the overt prohibitions of their government and engage in the forbidden activities. for example, appeal could be made on the basis of patriotism. The rulers of a nation could urge a small group of individuals to engage in clandestine development programs while overtly espousing accordance with an arms control agreement. The verification of personnel restrictions presents a particularly formidable problem since the personnel engaged in the project could lie about their activities and take other measures to deceive the international control and inspection organization. History is full of examples of deceptive behavior. It may be possible however that psychological indicators could be developed which could be used on a unilateral basis, but these may be unacceptable because they violate the constitution's guarantees of personal rights. Furthermore, there are examples of clandestine activities which were detected but no action was taken because either the authorities failed to recognize the significance of the indication or because of their apathy toward the clandestine activity. In order to impose control over personnel, a degree of intrusion into a society would be required which violates U.S constitutional guarantees regarding individual freedoms and protection against arbitrary search and seizure. It may be required to go to such extremes as the use of lie detectors and truth serums. Thus, while personnel restrictions may be potentially a most effective form of restricting research and development activities, the verification problem may have no acceptable solution.

3. Facility Restrictions

Most research and development activities require a minimal amount of facilities which may range, depending upon the type of activity, from office space, libraries, conventional laboratories and machine shop facilities to highly specialized facilities, such as rocket test stands, launch facilities, nuclear reactors, nuclear particle accelerators, and radio telescopes. In many cases facilities are a clue to the type of activities which are being pursued. Launch facilities and rocket static test stands are generally considered to be large facilities which are detectable by aircraft and satellite overflight and activities at these facilities are detectable through extra-territorial observations and electromagnetic surveillance. It would appear that restrictions on the uses of certain critical facilities may be an effective means of controlling research and development activities. However, it should be observed that by the time a new system progresses to the launch stand for test firing it may be well advanced in the development sequence and the evader may have gained from one to two years lead time over his opponent. Thus, limiting restrictions on the use of certain facilities may be destabilizing in that they allow the violator to gain a significant lead time. In addition to rocket launch facilities and rocket engine static test stands, other facilities which may be monitored are large environmental test facilities, wind tunnels, and instrumented test ranges or re-entry areas.

4. Activity Restrictions

Restrictions on activities such as flight tests are closely related to restrictions on facilities since most of the activities which are to be restricted must be carried out in specialized facilities. If a non-military space program is allowed to exist, then many of these facilities will be required for the pursuit of such a program and it may be possible to carry out certain clandestine activities at these facilities which are normally used for peaceful purposes. Thus, in addition to the inspection of the facilities, it may be necessary to monitor the activities carried out at these facilities. Such an arrangement would imply the necessity of an agreement to monitor peaceful space launches. It is also possible that the clandestine activities could be carried out at hidden facilities and consequently it may be necessary to provide for the surveillance of the entire country to assure that no clandestine activities are conducted. Again the problem of providing restrictions only over certain overt activities such as rocket launchings, presents the same difficulties as do the restrictions on the use of facilities, namely the risk that the evader will obtain a technological lead over his opponents.

B. Effects of Restrictions on the Growth of Subsystem Technology

The effects of restrictions on the growth of subsystem technology depends both upon (1) the point in the research and development cycle at which restrictions are applied; (2) the particular technology; and (3) the kind of development program. It is also true that the estimated effects of the restrictions will depend upon the assumed growth models for the particular technology and the point in the research and development cycle at which controls are being attempted. There are instances in which major projects have been completed using a minimum of personnel and facilities in less time and with less money than would normally be possible using more conventional methods of procurement and management.

1. Basic Research

Basic research has been previously characterized as the development of new knowledge which has no immediate technological application. In a sense, this exploration for new knowledge may be considered as a purely random process. According to the laws of probability, the average number of discoveries in a period of time T is equal to npT, where n is the number of research workers and p is the average probability of a discovery by a single worker in a unit interval of time. All research workers, however, are not equally productive. Shockley[1] has investigated the relative productivity of research workers on the basis of the distribution of the number of research papers written per worker, the number of workers whose papers are referenced in science abstracts, and the number of patents granted, and has found that the distribution of the productivity of research workers is best described by a log normal distribution function. Other studies have indicated that the distribution may be of the form k/n^{α}. To obtain the relative productivity of workers, a distribution of the number of research papers referenced by researchers in the fields of mathematics and the physical sciences was made and α was determined to have a value of 0.5. The rate at which discoveries are made, as a function of the number of workers will then be given by

$$R = \int_{0}^{N} p(n)\, dn$$

If $p(n) = kn^{-1/2}$, then

$$R = 2kN^{1/2}$$

If the number of research workers is reduced and the less productive workers are released first from the research force, the reduction in productivity of the force will be retarded according to the above equation. If the number of workers is reduced from an initial value of N_o to N then the fraction decrease in the productivity of the research establishment is given by

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[1] Shockley, W., "On the Statistics of Individual Variations of Productivity in Research Laboratories". Proc of the IRE, Vol 45, pp 279-290, 1957.

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$$r = \left(\frac{N}{N_o}\right)^{1/2}$$

The above equation implies that the result of subtracting the marginally productive workers from the research force results in a less than proportionate decrease in the productivity of the research establishment. Figure I-1 shows the resulting productivity as a function of the fractional decreases in the work force. From this figure it is apparent that the percentage decrease in the productivity is generally less than the corresponding percentage decrease in the work force if the least productive workers are first discharged; a 70 per cent cutback in the force results in only a 45 per cent reduction of productivity. Thus, in order to effectively retard the productivity of the basic research force, drastic cuts in the number of personnel are required.

In most fields of basic research elaborate and extensive facilities are not required. There are, however, some fields such as high energy nuclear physics and radio astronomy which require extensive and elaborate facilities. Space physics research generally requires boosters and launch activities to place the instrumented payload in space and additional facilities for vehicle tracking and data recovery. Thus in these fields restrictions on the use of facilities and certain activities such as rocket launches may effectively retard progress.

One difficulty in attempting to restrict basic research is that it is difficult to discern those discoveries which will lead to significant military capabilities until after the discovery has been made. Furthermore, most of the scientific discoveries have found greater nonmilitary applications than military applications and have led to the increased welfare of mankind. Many of the discoveries which result from basic research find their first applications in military technology and later find nonmilitary

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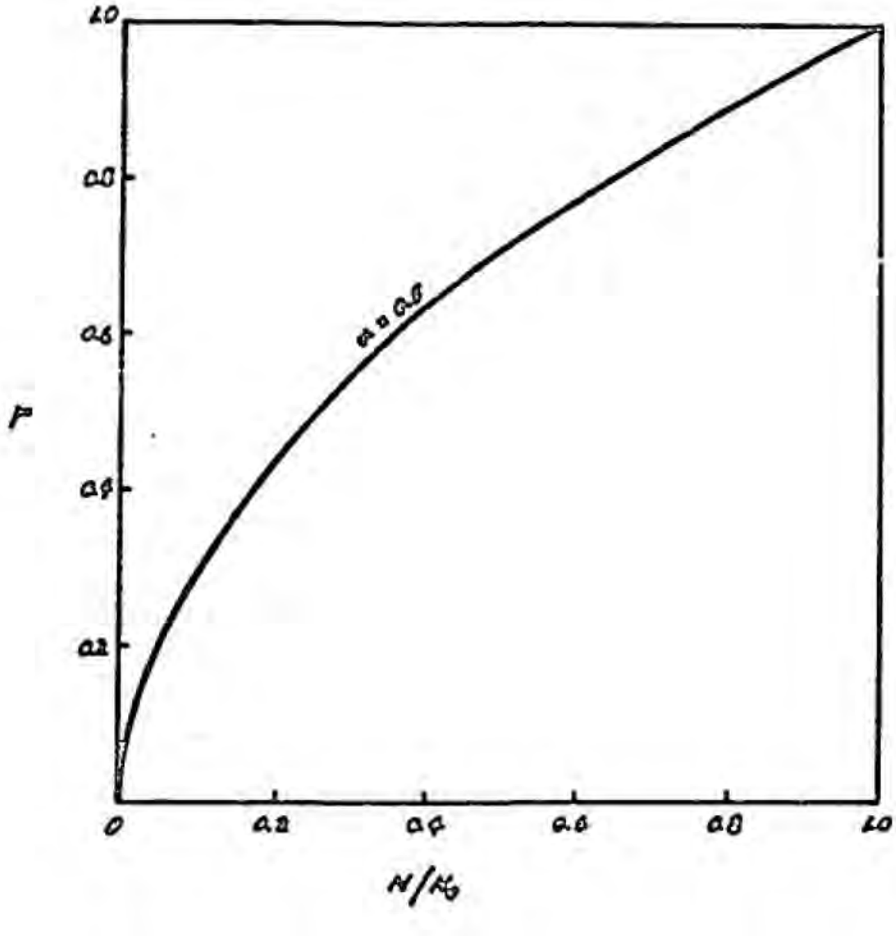

Figure I-1. Decrease in the Output of the Research Force as a Function of the Fractional Decrease in the Force.

applications. The discovery of nuclear fission and basic rocket research are examples although their nonmilitary applications were recognized at the time of discovery. Significant advances in ballistic missile and military space technology are likely to come from a variety of basic research fields such as materials technology, nuclear physics, chemistry, aerodynamics, and even from medicine and biology. All of these discoveries will probably have nonmilitary applications which can significantly benefit the wellbeing of mankind. For example, basic research in the field of viruses, communicable diseases, and cancer can lead to both new bacteriological weapons which could be delivered via ballistic missiles and also to the control and cure of certain diseases and illnesses.

It thus appears to be undesirable to attempt to restrict progress in basic research because of its adverse effects on peaceful progress and also because of the uncertain results. A much more attractive approach to the problem of controlling the application of science to military technology is to monitor basic research activity and attempt to assess those discoveries which may lead to a significant military advantage if implemented into weaponry and then attempt to control the application of this new knowledge to military technology. This approach has the advantage that it does not restrict the application of science to peaceful activity and also assures that technological parity will be maintained between opponents thus decreasing the possibility of new scientific discovery leading to a destabilizing technological arms race.

2. Applied Research

Applied research is characterized as the application of scientific knowledge to a specific goal. Generally individual applied research programs are larger in magnitude and more organized than basic research programs. Applied research can also be considered as a random process; however, in this case the search is for a class of discoveries or [illegible] breakthroughs which can lead to a specific capability. According to the laws of probability for repeated trials, the probability of achieving at least one breakthrough which will yield the desired capability is given by

$$P = 1 - e^{-np(n)}$$

where n is the number of attempts and p is the probability that a single attempt will produce the breakthrough. The number of attempts will be equal to the product of the number of individual investigating groups and the time. However, again the probability function $p(n)$ may be of the form $kn^{-1/2}$ and hence the probability of obtaining the critical breakthrough in a time T is given by

$$P = 1 - e^{-kTn^{1/2}}$$

Thus the time required to achieve the critical breakthrough is given by

$$T = \frac{1}{kn^{1/2}} \ln \frac{1}{1 - P}$$

If T_o is the time required to achieve the breakthrough with N_o workers, then the time required with N workers will be

$$\frac{T}{T_o} = \left(\frac{N_o}{N}\right)^{1/2}$$

A plot of T/T_o versus the percentage reduction in the work force is shown in Figure I-2. A decrease of 50 per cent in the work force only results in a 41 per cent increase in the time to the critical breakthrough. However, a 90 per cent decrease in the work force might increase the time by a factor of 3.16. Thus, personnel reductions of 80 to 90 per cent may be considered effective in controlling applied research.

Regarding the restriction on the use of facilities and testing activities, the remarks made in Section I-B-1 are generally applicable.

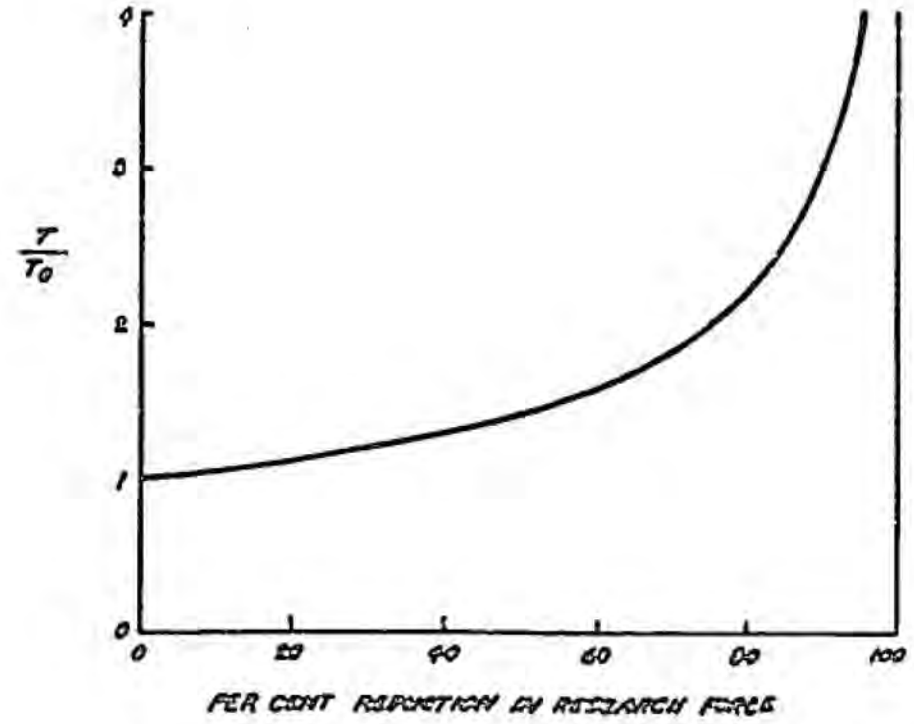

Figure I-2. Increase in Time to Critical Breakthrough as a Function of the Percentage Reduction in Work Force.

Only in specialized cases, such as the requirement for flight testing of components, would restrictions be effective. However in applied research, flight testing and rocket launches are not in general usage.

At the applied research level there tends to be a strong interaction between military and nonmilitary programs since most of the technology and components developed in a peaceful space program find application in the military program. Thus placing restrictions at the applied research level would tend to retard the growth of a peaceful space program. Again, the most logical approach to the application of new technology arising from the applied research program to military technology is to monitor the output of the applied research programs and to assess their potential military significance.

3. Advanced Development

Advanced development is characterized as a specific effort to achieve a practical application of knowledge. In the field of missile and space technology, advanced development generally involves the development of specific pieces of hardware or entire subsystems such as boosters, guidance systems or re-entry vehicles. Generally these programs involve funding levels on the order of hundreds of millions of dollars, hundreds of personnel and generally some flight testing.

Because the nature of these programs is fundamentally different than either basic or applied research, a different growth model must be assumed than the ones postulated above. The rate of growth is assumed to have a functional relationship to the rate of resource allocation of the form

$$\frac{dP}{dt} = k R^{\beta}$$

where P is the performance index, k is a constant, R is the rate of resource allocation, and β is a constant whose value is probably about 0.3 - 0.4. For purposes of discussion we shall take the value of β to be

1/3 so that the rate of progress is proportional to the cube root of the rate at which resources are allocated. On this assumption, an eightfold (88 per cent) decrease in the rate of resource allocation results in only a 50 per cent reduction in the rate of progress. The effect is even more marked if one considers a 99 per cent reduction in rate of resource allocation in which case the rate of progress will be decreased to 22 per cent of its previous value; of course this assumes that the formula is true at this extrapolation. Even for a value of β of 0.4, a 99 per cent reduction in resources will result in only an 84 per cent decrease in the rate of progress.

A more effective means of implementing controls at this level may be the restriction on test activities and the use of test facilities which may be much easier to control than personnel and funding. If all developmental flight test activities could be terminated, then it might be thought that the growth of military technology might be effectively stopped since it is doubtful that new subsystems or hardware would be employed in operational weapon systems without flight testing and proof. However, it is possible that environmental simulation could be developed to the point where a determined evader would be willing to accept the simulated tests with sufficient confidence to allow the use of new equipment in operational weapon systems.

It is also possible that new methods of analyzing test results would be developed in an environment of restricted testing which would allow the acceptance of new equipment with fewer flight tests than is currently the practice. Such techniques are currently under development the reliability of a new system is estimated on the basis of the performance of the ensemble of previously tested systems In this case the flight test history of a new system is compared with that of a number of similar programs to ascertain the reliability of the new system. Such practices lead to a significant reduction in the number of flight tests required to prove a new system.

In view of the above discussion it is concluded that in general the effects of restrictions on funding, manpower, the use of facilities, and on activities will not have a proportionate effect on limiting the rate of growth of technology, but that the effect will be somewhat less. Thus, any attempt to limit the rate of growth of technology must involve very stringent restrictions. It appears that lesser restrictions will have only a nuisance value. Furthermore, the fear of evasion may lead to a situation which is technologically destabilizing, so that one nation fearing evasion by the other may feel that it is forced to evade to limit the possibility of the other nation achieving a technologically destabilizing development. It thus appears that the best approach to research and development controls at the research and advanced technology levels is a system of monitoring technological developments to assess their military implications. Such an arrangement might reduce the possibility of one nation achieving a technological breakthrough which would give them a decisive technological superiority and hence be destabilizing.

C. Effects of Restrictions on Future Systems Developments

Improvements in weapon systems capabilities can be achieved in two ways. (1) the development of a completely new weapon system and (2) the improvement of an existing weapon system as, for example, the Wing VI Minuteman missile system. The new weapon system development program is generally characterized by the simultaneous development of a number of new subsystems which must be coordinated and provided with interfaces. Each subsystem is developed separately under the control and direction of a system management organization which is responsible for system integration, assembly, checkout and flight testing. In the United States these development programs are generally of such magnitude that they involve expenditures up to several billion dollars and employ tens of thousands of personnel. In addition to the few major subsystem contractors, which could conceivably be gathered together into a single organization, such development programs involve the procurement of many components and individual piece parts such as electronic components. Such a procurement program would appear difficult to hide. Thus, critical materials might be added to the list of restrictables, i.e., funds, manpower, facilities, and activities. Certainly the purchase of large numbers of semiconductor components, high temperature electromechanical components or certain critical raw materials would be clues to the existence of a clandestine development program. Such restrictions might be achieved through the registration and monitoring of critical materials and components.

In considering the application of restrictions to large scale development programs one must take into account the possibility of the greatly increased efficiency of a small number of personnel. An example is the development of the U-2 aircraft. In this program, only 23 engineers were employed in contrast to over 250 engineers who would have been normally used had the usual procurement and management methods been used for its development. The time from contract to first flight test was half of the normal time and the cost was less than 10 per cent of that which would have normally been required. The success of the U-2 was aided by the project management being given complete authority over the program and reporting and review were kept to an absolute minimum. It may be that the project was successful because the U-2 was a relatively simple system which did not require a great deal of coordination between a number of subcontractors. Another reason for its success may be because it was developed by Lockheed Aircraft Company which is one of the largest aircraft companies and thus could obtain all of the technical skills which were required for the successful development of the aircraft. The large size of the corporation also facilitated keeping the U-2 project a secret. The small number of persons engaged in the U-2 development also indicates that the threshold on the level of funding and personnel required to carry out such a program appears to be very low.

In the case of a very complex system, such as a ballistic missile or an advanced aircraft, a great many skills are required for the success of the project. These skills include not only scientific and engineering skills but also managerial and manufacturing skills. The accumulation of these diverse skills usually requires the creation of a large organization and large organizations have a tendency to create structural and organizational patterns of their own. Furthermore, in a labor market in which there is a shortage of workers, it becomes necessary to take on less efficient persons in order to accomplish the job. In some cases perhaps three or four workers are required to do the job that one first-rate worker could do. Generally a very complex system requires a large organization for its development. There are examples of large scale projects which have failed because of attempts to complete them on an inadequate budget. The current problems with the B-70 may be the result of not having enough funds available.

If a peaceful space program is allowed to exist it may be possible to carry out a clandestine systems development program, particularly for space weapons systems, for which the role of the inspector would be reduced to a monitoring function. The major subsystems of a new weapon system could be developed under the guise of a peaceful space program designed so that the inspector would have difficulty denying the right to undertake such a program.

In the second method for obtaining improved weapon system capabilities through the improvement of one or more individual subsystems of an existing weapon system restrictions were expected to be less effective than in the case of the development of a completely new weapon system. Subsystem development can be compared with advanced development, because a new subsystem is being developed for an existing weapon system the interfaces are well defined, thus minimizing the requirements for liaison and interface coordination. Thus it may be possible to develop a new subsystem

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with a minimum number of personnel. In many cases substantial subsystem improvements can be achieved with no ostensible changes in the system itself. For example, the accuracy and reliability of existing guidance systems are continuously being improved through better manufacturing, testing and calibration techniques. Improvements in geodetic knowledge can also lead to significant improvements in the accuracy of the guidance system. Another example is the possibility of introducing a new propellant with an improved specific impulse which would increase the payload capability of an existing missile. Only one or two test flights may be needed to assure ignition and gas flow characteristics in the operational environment after extensive 1/10 or 1/50 scale tests in the laboratory.

At the systems development level, restrictions on funding personnel and testing may be effective in limiting the development of a new very complex weapon system such as a new ballistic missile syste[illegible] aircraft.* However, for simple systems which do not involve a wide diversity of skills, these restrictions may be ineffective since it may be possible to develop these systems using very few personnel and limited funding. It also appears that individual subsystems of a complex system can be clandestinely improved using the same methods and perhaps through the use of a peaceful space program to conceal the testing of improved subsystems.

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*Note added in proof: The development of a new ballistic missile is believed to be of the same magnitude of complexity as the development of the A-11 aircraft and therefore may be accomplished clandestinely at least through the initial phases of flight testing.

II. THE VERIFICATION OF RDT&E RESTRICTIONS

A. Introduction and Definitions

"Verification" in arms control is currently used as a more inclusive term than inspection. Where inspection implies an inspector force that inspects with consent of the inspected party, verification also includes the use of information derived from intelligence operations open publications, extra-territorial observation, and open cooperative action from all sources.

In general, verification processes may be classified as follows:

Unilateral, bilateral or multilateral

Open or closed operations*

Nonintrusive to intrusive (a psychological spectrum representing the degree of discomfort or resistance experienced by being observed or inspected)

Henkin[2] defines unilateral verification as means not requiring consent or cooperation of the opposite party. The recent Partial Nuclear Test Ban Treaty is an illustration of unilateral verification where it is expected observations outside the Soviet Union can verify the presence or absence of prohibited or clandestine atmospheric tests within the USSR.

Bilateral or multilateral verification could imply a formal inspection agreement or cooperative action in providing general access by the press or other agencies or mechanisms. The exchange of military or scientific missions are examples of such general cooperation whose value in verification increases with the institution of cooperative programs in such fields as nuclear physics weather and space.

Open or closed verification operations are generally self-explanatory. Closed operations are generally associated with intelligence organizations who keep their operations secret even though a substantial portion of their information sources are openly available. A bilateral or multilateral inspection

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[2] Journal of Arms Control Vol 1, No. 3, July 1963.

*The alternate terms "overt" and "covert" are sometimes used.

arrangement or agreement is generally proposed as an open operation although some exceptions might arise.

Intrusive and nonintrusive verification is a complex spectrum involving the psychological reactions of the party being observed to the method of verification. For example, a formal inspection agreement allowing Soviet inspectors to inspect U. S. production plants would almost certainly be resisted as an invasion of private property and a threat to corporate proprietary interests as well as rights of the individual.[3] On the other hand, many U. S. corporations currently enjoy voluntarily inviting Russian observers to make detailed tours of their production plants to show them the virtues of a free enterprise industrial economy. Thus, a formal inspection arrangement always possesses a certain degree of intrusiveness due to implications of compulsion, while bilateral governmental encouragement of voluntary invitations to tour each other's research and production enterprises is felt to be less intrusive although the net information gained for verification purposes may be the same in some cases.

With this brief review of definitions, a general matrix of verification regimes is summarized in Table II-1. Classifications of degrees of intrusiveness are not included, but perusal of the table suggests that the formal inspector force is usually the most intrusive of the open operations. In closed operations, when the operations are truly secret from the public, intrusiveness is confined to the extent of inner governmental knowledge of the opposite's operations. However once a closed operation is exposed to the public, the reaction is usually regarded as the highest form of intrusion as evidenced in the U-2 episode or similar episodes in the public disclosures of Russian spies in the United States.

B. Objective of Verification of RDT&E Restrictions

It is obvious that there are interrelations between the verification processes regarding the degree to which restrictions and controls are

---

[3] These factors are analyzed in detail by Henkin, "Arms Control and Inspection in American Law", Columbia Press, 1958.

Table II-1. Verification Regimes.

	Unilateral	Bilateral or Multilateral
Open	Extra-territorial observation (with all mechanisms and results openly declared)	Formal inspection force Cooperative exchanges and programs Free press access
Closed	Intelligence (exterior and interior observation in secret)	Secret governmental agreements and exchanges

imposed on RDT&E. However, the resolution of the proper mix is also dependent on the interplay of the broad objectives in arms control of space and ballistic systems RDT&E. Briefly, these objectives are assumed to be as follows:

1. Assure the compliance of agreements to restrict, reduce, or eliminate the development and production of new weapon systems.

2. Provide simultaneous and mutual awareness of any technological breakthrough which could, if used for weapons development, upset the strategic balance if unilaterally implemented by any power.

3. Provide conclusive evidence of the clandestine exploitation of such a technological breakthrough in sufficient time to counter the potential upset in the strategic balance.

Item 3 is particularly critical and involves a continual time-phasing analysis of breakthroughs to ascertain the rapidity in which a breakthrough can be implemented into a significant weapon force. In some cases, the breakthroughs may be implemented so quickly that the situation becomes unstable even with immediate verification of clandestine exploitation. In such cases, it may be desirable to mutually implement the new weapon system for stability reasons.

C. Technology Considerations

In order to aid in understanding the relationships of verification in restriction and control of RDT&E for space and ballistic systems a technological investigation of possible restricted systems was undertaken. The possible prohibited systems are identified as follows:

New ballistic missile systems

Conversion of nonweapon space boosters to ICBMs

Anti-ballistic missile systems (ground-based)

Space offense systems (i. e., orbital bombardment system)

To control these prohibitions, a listing was made of many potential bilateral control agreements that might be negotiated and written in an arms control agreement with relation to subsystem areas which are common to all the prohibited systems. Such a tabulation is shown in Table II-2. It must be pointed out that these listings are associated only with possible written control agreements and are not necessarily indicative of the value or practicality of the actual verification process. Obviously, an agreement incorporating all of the suggested controls would be impractical. The purpose is only to show the spectrum of possibilities.

The next consideration was to explore the format suggested by Table II-2 to ascertain the nature of possible indicators of clandestine activity with reference to specific technical activity. The results of this investigation are shown in Table II-3 and constitute a summation of suggestions for technical indicators from specialists of different disciplines involved in both ballistic missile and space activity. Some of the indicators are fairly conclusive, particularly where associated with positive indication of a potential nuclear delivery vehicle, but generally speaking, the indicators are usually inconclusive by themselves and the ensemble must be integrated to attain a more correct assessment. For example, a storable or solid propellant system in itself does not positively indicate a potentially new ballistic missile weapon system and is only one factor involved in suspecting the potential implementation of a new mobile or quick reaction ballistic missile. Solid or storable propellant systems are of value in certain cases for nonweapon use. The use of multiple indicators of substantially less than certain detection provides an opportunity for the use of decision theory which is discussed in Appendix A.

Before proceeding to a discussion of verification levels, it is appropriate to examine the table of possible indicators and attempt a preliminary assessment of integrating factors in the light of previously described forecasts of development in future weapon systems.

Table II-2. Possible Restrictions on Subsystem Developments.

Subsystem or Function	Restrictions
Structures	All structure fabrication plants declared, inspected, and products registered
Propulsion	All propulsion plants declared, inspected, and products registered
Guidance and flight control	Design and equipment subject to inspection at [illegible] facilities
Recovery vehicles (including [illegible])	All recovery vehicle fabrication plants declared, inspected, and products registered All space vehicle payloads subject to inspection No vehicles with W/CdA > 600
[illegible] system launch site surveys	All [illegible] maps and deployment documents declared, inspected, and registered
Ground facilities	All launch facilities declared and subject to inspection New launch sites prohibited except for aerospace use
Aerospace ground equipment	[illegible] checkout equipment declared and registered
Command and control communications	Space control centers declared, subject to inspection and possibly joint manning
Acquisition and tracking	All acquisition and tracking stations declared, monitored, and possibly jointly manned
Fusing systems	Designs and equipment subject to inspection at [illegible] facilities
[illegible] guidance	Designs and equipment subject to inspection at [illegible] facilities
Acceptance and static test	All acceptance and static tests declared and monitored
Assembly and flight test	All assembly and flight tests declared, inspected prior to flight All vehicles to carry international flight beacons
[illegible] of weapon systems development management	All development groups declared and reviewed Limitations on numbers of technical personnel negotiated All design information released to inspection agency for review All technical personnel declared, identified, and work history subject to review
[illegible]	Funding breakdowns negotiated and financial records inspected Free access by news agencies for interviews (as in U.S.) Overall [illegible] reconnaissance permitted All facilities capable of design, development, and production of listed subsystems or functions to be declared and be subject to inspection Roving inspection teams permitted to inspect any facility at will All technical data centers declared with inspection access by inspection agency personnel Existing systems declared, reductions negotiated, and inspection of reduction operations

Table II-3. Possible Indications of Clandestine Developments.

	Prohibited Systems			
Subsystem or Function	New Ballistic Missile Systems	Conversion of Space Booster to ICBMs	ABM Systems (Ground Based)	Space Offense Systems
Structures	Hardened system, mobility capability, unusually strong structure for re-entry vehicle design (100 g)	Structure capable of mating to existing re-entry tanks, unchilled mobile boosters	Hardened system, high-g structure	Suitable for warhead or delivery vehicle installation
Propulsion	Storable or solid propellants	Storable or solid propellants	High-g capability	Excess ΔV in space vehicle
Guidance and flight control	Dormant systems Multiple targeting capability, re-entry vehicle arming discretes, quick reaction capability, terminal guidance + mobile capability			Extremely precise stellar inertial or high-g capability, terminal guidance delivery vehicle mechanism, passive space navigation system, dormant development
Re-entry vehicles (including penetration aids)	Radar range control W/CgA 9500 - 19.1 development (cost, battery development, fusing system, calling for re-entry vehicle, multiple re-entry vehicle payloads		Terminal or command guidance	2500 pounds in weight, ease in conversion of existing vehicle, armored vehicle
Navigation/launch site services	General location and site dispersion characteristics			
Ground facilities	New launch sites and/or equipment stockpiling, indications of hardening and/or quick reaction capability		Launch complexes, large radar areas	
Aerospace ground equipment	Checkout equipment capable of nuclear warhead checkout, fast countdown equipment Mobile missile carriers		Transfer launchers, large radar sites	
Command and control systems	Hardening, cryptographic mechanization, hard linking in transmission		X-ray, neutron hardening	Space-to-space communications
Acquisition and tracking			Development of suitable optical, development or construction of hardened phased array radar systems	
Fuzing systems	Microminiature high frequency radar or laser systems, radiation hardening beyond normal space hazards X and S band			
Terminal vehicle armament/guidance	Radiation hardening beyond normal space hazards Highly system development, X-ray hardening			
Assembly and static test	Testing implying quick reaction, hardened operations			
Assembly and flight test	Testing implying quick reaction, hardened or mobile operations Low observable heat shields, liquid injection cooling, testing of high W/CgA systems, testing at low altitude, high velocity manned system		High acceleration systems	Manned space station with deployment capability
Technical personnel and systems development management	Indications of intra-group development of covert nature, indefinite vehicle or conversion provisions. Disappearance of technical personnel			
Access-Personnel	Increased barriers to inspection and restrictions thereof, indications of covert funding, refusal of access by press or inspection agency; camouflaged and underground sites, designs suitable for rapid conversion and production expansion to weapon systems			

In new ballistic missile systems it may be recalled that either a significant increase in payload for the same weight and range or a drastic reduction in weight for equivalent point target destruction capability may be expected with forecast improvements in specific impulse, structure factor, and guidance accuracy (see Volume II, Figures VI-1 and VI-2). Also significant improvements in reliability including the possible development of dormant systems may bring pressure to bear on modernizing a missile system to effect cost savings. To implement these improvements effectively (provided the cost is justified) it is usually necessary to design a completely new missile and a number of potential indicators enter the picture. New structures must be created and tested to improve structure factor. Specific impulse improvements in solid or storable propellants and with new engines must also be created. Guidance systems of less weight, higher accuracy, and of potentially dormant operation must be devised. Finally, new re-entry vehicle design is required. Much of this will be motivated by normal progress in nonweapon space boosters, but if the pattern of observables shows a coordinated effort in hardened or mobile capability, with research in rugged potentially dormant equipment, and finally a trend toward smaller, more mobile and less observable missiles, then a tentative conclusion of a clandestine new ballistic missile activity is probably rightfully engendered.

The conversion of space boosters to ICBMs has been previously discussed in Volume II, Section VI-B with the tentative conclusion (with one exception) that a significant change in the strategic balance by such conversion is unlikely unless relatively small undetectable space boosters are clandestinely stockpiled in substantial quantity for such conversion. It must be pointed out that the proper emphasis in true space booster development is on fairly large boosters in order to minimize costs per pound of payload delivered in orbit thus, the appearance of new small space boosters must be viewed suspiciously. The one exception referred to is the situation where very large space boosters could each accept a sufficient number of separately guided re-entry vehicles to attack a number of targets with one launch, thus using the few large space booster launch sites to maximum advantage. Indicators here, of course, are associated with maneuverable terminally guided re-entry vehicles that can be packaged together in a large payload.

In anti-ballistic missile systems that are ground-based some of the best indicators are the extremely high acceleration requirements of such systems, usually large radar installations and the unique test programs which would be involved in the development program.

Space offense systems or orbital bombardment systems are extensions of ballistic missiles and, indeed, may be ground-based until a militarily propitious moment of deployment for maximum psychological effect. The spectrum of possibilities has been previously discussed, but indicators of the development of quick reaction boosters (or any manned space vehicle with an unmanned re-entry vehicle of minimum size) with precision guidance are grounds for considerable suspicion. Likewise, research breakthroughs suggesting the practicality of unmanned dormant space vehicles with precision re-entry guidance should increase awareness of indicators in this area.

In summary, the delineation and assessment of potential indicators of clandestine activity is a constant re-evaluation of interrelations in technological trends, motivating factors and systems integration considerations.

D. Verification Levels

With the previous background it is now germane to consider verification techniques that might be used to verify a prohibition on RDT&E of new space and ballistic missile weapon systems. A selection of four verification levels is made somewhat arbitrarily.

Level 1 - limited to unilateral extra-territorial and satellite observations, closed intelligence operations and existing cooperative access.

Level 2 - level 1 plus bilateral or multilateral launch inspection at RDT&E launch sites.

Level 3 - levels 1 and 2 plus bilateral or multilateral research and development plant and transportation center inspection or cooperative access.

Level 4 - unlimited inspection or cooperative access at least equivalent to the U. S. ideal in a free society.

1. Unilateral Extra-Territorial, Closed Intelligence and Cooperative Access

The first level of verification techniques is quite similar to our present situation vis a vis the USSR with most of the extra-territorial observation of ballistic missile and space flight tests being conducted ostensibly in secret by the U. S., although it is difficult to imagine the USSR not implementing surveillance of these activities. On the other hand, closed intelligence operations involving secret intrusion of the USSR are truly secret.

For the purpose of this report, observation by satellite is considered extra-territorial since this coincides with U. S. interpretation of the use of space, while possibly initially a theoretically secret activity, it may eventually become an open operation. However, aircraft overflight will be assumed not to be extra-territorial.

There are, in current relations with the USSR a number of significant sources of information from open contacts such as scientific and governmental exchanges, press tours and tourist experiences that are of some value in verification techniques. Certainly the exchange of basic knowledge in nuclear physics research is a potential aid to the simultaneous detection of a breakthrough in thermonuclear fusion that might have weapon implications. Thus, there exists a certain amount of cooperative access of some value in verification.

Table II-4 (not all-inclusive) shows the existing level of available verification techniques vis a vis the Soviet Union. It must be noted that the existing effort is most likely to continue whether open or closed. However, for the purpose of this analysis, it is assumed that at least an open overflight observation system for verification purposes would be proposed in negotiations on an initial arms control agreement. There are several reasons for this assumption including the following:

a. Precedent has been established with the Eisenhower "open skies" proposal and the consistently reiterated U.S. position on an open space policy in observation systems.

b. There is a necessity for U.S. public support of a proposed arms control agreement which requires concrete evidence to the public of satisfactory observation and verification means to reasonably assure compliance with the proposed agreement. Secret observation systems, unknown to the public, cannot assuage public fears of evasion without being disclosed

c. The potential ancillary civil benefits in such overflight observation systems.

d. The possibilities of sharing financial expenses of such overflight systems to reduce U.S. costs.

e. The rather bleak outlook for agreements involving internal USSR inspection access.

It appears that any overflight observation system would include at least a satellite observation system. Recently satellite observation systems for arms control verification purposes have been proposed by

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Table II-4. Existing Verification Techniques by the U.S. with Respect to the USSR.

U.S. Public Availability	Unilateral	Bilateral
Open	Extra-territorial Radio broadcasts - monitoring Limited seismic, atmospheric, and space monitoring Kremlinology Evaluation of USSR publications	Scientific and governmental exchanges, conferences Tourist experiences Cooperative weather and geophysics programs Disarmament conferences Limited press access Released information from high level governmental discussions
Closed	Extra-territorial Space and ballistic missile flight test monitoring Observation by satellite Seismic and atmospheric monitoring Aircraft ELINT and COMINT operations Internal intelligence operations	Periodic high level discussions

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Rochlin and McDonald.[4,5] McDonald proposes a specific system which will form the basis of the assumed system for this analysis. Optional additional overflight means would include more sophisticated satellites and the use of reconnaissance aircraft. A descriptive outline of such a system is shown in Table II 5.

2. Launch Inspection at RDT&E Launch Site

The second verification level would add an agreement which would permit bilateral launch site inspection or at least cooperative access to each other's launch facilities as exists for the press in the United States. A formal inspector force would be granted rights, at a minimum, to visually inspect all launch site activities booster and payload assembly, payload weighing, launch control center, and launch operations. Options might include radiographic or nuclear detector inspection of space vehicle payloads and disassembly rights. These options are probably impractical arrangements in any initial agreements but should be kept in mind when assessing the spectrum of alternatives. An outline of a launch site inspection system is shown in Table II-6.

3. Inspection of Research and Development Facilities and Transportation Centers

The third verification level would progressively add an agreement to bilaterally inspect research and development plants and transportation centers (the latter having been proposed by the USSR). Such an agreement obviously interlaces with space and ballistic missile production control agreements as well. Substantial preliminary study of this approach has been performed by Bendix[6] and although primarily related to production

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[4] Rochlin, Robert S., 'Observation Satellites for Arms Control Inspection Journal of Arms Control July 1963.

[5] McDonald. "Open Space and Peace the Requirements for Information and Systems". Open Space and Peace Symposium September 1963.

[6] "Techniques for Monitoring the Production of Space Boosters ICBMs and IRBMs", Bendix Systems Division Vol I August 1962.

Table II-5. Overflight Inspection.

Basic System[*]

- **Satellite**
  - Five satellites continuously in orbit, near polar, unmanned, 120-300 nautical miles altitude
  - Fifteen launchings per year, Atlas-Agena type launch capability
  - Sensors - vidicons and/or orthicons and optics for 20-foot resolution
  - Readout sites - two (northerly locations preferred)
  - Data center - one
    - Communications facilities
    - Photo interpretation - 150 analysts, processing equipment (probably similar in cost to SPADATS center at NORAD)
    - Technical intelligence staff

Options

- **Satellite**
  - Electronic ferret side-looking radar augmented capabilities
  - Film capsule return
- **Aircraft**
  - Large aircraft overflight with complete reconnaissance equipment like some SAC planes
  - Fighter type reconnaissance aircraft like TAC Recce force or U-2

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[*] Based on McDonald proposal

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Table II-6. Launch Site Inspection.

Basic System

Visual observation and photography of all launch site activities: booster and payload assembly, payload weighing, launch control center, and launch trajectory observation

Personnel (at each launch site where launch rate does not exceed average of two launches per week):

- Fifteen inspectors
- Ten support personnel (communications, photo processing, etc.)*

Options

Radiographic or nuclear detector inspection

Disassembly inspection rights

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*Support personnel for food and lodging are assumed to be indigenous to the country.

controls, is still useful in estimating the outline of a research and development inspection force. Such a descriptive outline is shown in Table II-7.

4. Unlimited Access

The fourth and ultimate level of verification would provide unlimited access at least equivalent to that presently available in the U. S. for unclassified operations. A formal inspector force would obviously be a fairly extensive and expensive operation even where operations were restricted to roving surveys by inspection teams. It is assumed that such an inspector force would, in addition to continuous and roving inspection of RDT&E facilities, monitor financial, personnel, and economic records with particular attention to the activities of outstanding scientific and engineering personnel. It is very difficult to estimate the level of personnel required for such an inspector force, but an approximate estimate might be obtained by using the U. S. General Accounting Office (an inspector force of a kind) as a model. Since considerable cooperation with the GAO reduces its manpower requirements somewhat and the GAO is not involved in personnel monitoring, it may be considered that for a less cooperative society the inspection personnel requirements might be doubled as an approximation. It may be noted, however, that such unlimited access would reduce some of the detailed inspection requirements previously described for research and development and testing facilities. The reason for this would be the access to the earlier stages of the research and development cycle providing forewarning of planned hardware.

Realistically, however, if there were an agreement allowing unlimited access, the USSR would have to become an open society like the U. S. In such circumstances it is difficult to see how the free press and free scientific and engineering personnel could be denied equivalent access. With such personnel access, the necessity for a formal inspector force might be reduced to a fraction of the initially estimated strength.

Table II-7. Research and Development Facility Inspection.

Basic System

- Continuous inspection of declared research and development institutes, laboratories and pilot plants with general access rights to interview and visually observe operations
- Continuous observation of major transportation centers
- Rights of photography
- Personnel
  - Eleven per facility (average)
  - One hundred per transportation center
- Other
  - Photographic equipment, some special sensors in limited cases, communication centers, photo processing, etc.

Options

- Research and development facilities
  - Sophisticated sensors, nuclear detectors, portable radiographic equipment, closed circuit television monitors

E. Capability of Verification at Various Levels

An attempt was made, using the technological format in Tables II-2 and II-3, to define and evaluate the relative capability of the four verification levels for assuring compliance with RDT&E prohibitions on the subject weapon systems. Table II-8 illustrates the evaluation process. An an example, a new weapon flight test would probably be detected and described grossly in size, propulsion, probable guidance, and re-entry characteristics from an assessment of the ensemble of extra-territorial and overflight observations. Preparations for the new weapon flight at the launch site might be detected from satellite overflight as well as ELINT observations. It is possible, on a limited basis, that overflight observation could detect movement of a new weapon to a launch site or observe some assemblies and static tests. However, detection and partial definition of a new weapon after it is constructed and undergoing test is about the limit of extra-territorial observation. (This is not to demean the considerable value of overflight observation to detect construction of new launch sites, facilities, and changes in deployment of mobile missile forces.)

Obviously, little or no capability exists to detect early research and development effort in design and internal laboratory testing except indirectly in the possible identification of new facilities. Certainly no capability exists in detecting the early study stages and moment of decision to implement a new weapon research and development program.

It may be instructive, before summarizing the relative capability of the four verification levels investigated, to review the development sequence of a new weapon system, particularly at the early stages, which may be summarized as follows:

Coalescence of the concept

Study and evaluation

Decision to proceed with hardware development program

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Table II-5. Verification Methods for Various Levels of Intrusion.

Subsystem or Function		
Structures	A	High resolution reconnaissance, extra-territorial launch and orbit observation, intelligence research, limited press interviews
	B	Visual launch site inspection, plus A
	C, D	Continuous roving survey by inspection teams, press interviews
Propulsion	A	High resolution reconnaissance, extra-territorial launch and orbit observation, intelligence research, limited press interviews
	B	Visual launch site inspection, plus A
	C, D	Continuous roving survey by inspection teams, press interviews
Guidance and flight control	A	Launch trajectory and telemetering observations, intelligence research, limited press interviews
	B	Visual launch site inspection, plus A
	C, D	Limited to occasional inspection on random basis, press interviews
Re-entry vehicles	A	High resolution reconnaissance, extra-territorial launch and orbit observation, intelligence research, limited press interviews
	B	Visual launch site inspection, plus A
	C, D	Continuous roving survey by inspection teams, press interviews
Navigation/launch site surveys	A, B, C	Little capability other than intelligence and limited press interviews
	D	Occasional examination of mapping and geodetic organizations
Ground facilities	A	High resolution reconnaissance, extra-territorial launch and orbit observation, intelligence research, limited press interviews
	B	Visual launch site inspection, plus A
	C, D	Continuous roving survey by inspection teams, press interviews
Aerospace ground equipment	A	Little capability
	B	Visual launch site inspection, plus A
	C, D	Limited to occasional inspection on random basis, press interviews
Command and control/communications	A	Extra-territorial ELINT
	B	Visual launch site inspection, plus A
	C, D	Continuous roving survey by inspection teams, press interviews
Acquisition and tracking	A, B	Probably little capability
	C, D	Limited to occasional inspection on random basis, press interviews, plus possible joint manning
Fuzing systems	A, B	Little capability
	C, D	Limited to occasional inspection on random basis, press interviews
Terminal [illegible] sensors guidance	A, B	Little capability
	C, D	Limited to occasional inspection on random basis, press interviews
Assembly and static test	A, B	Little capability except intelligence
	C, D	Continuous roving survey by inspection teams, press interviews
Assembly and flight test	A	High resolution reconnaissance, extra-territorial launch and orbit observation, intelligence research, limited press interviews
	B	Visual launch site inspection, plus A
	C, D	Continuous roving survey by inspection teams, press interviews
Technical personnel and weapons development management	A, B, C	Little capability except intelligence, limited press interviews
	D	Continuous roving survey by inspection teams, press interviews

Code A - Extra-territorial and overflight inspection only
B - Launch site inspection, extra-territorial, and overflight inspection only
C - Limited to plant and launch site inspection
D - Unlimited inspection

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- Organization, staffing, facilities selection, and initiation of detailed systems engineering
- Design of components and subsystems
- Fabrication and laboratory testing of components and subsystems
- Qualification testing of subassemblies and subsystems
- Integrated ground testing of complete system
- Flight testing

Coalescence of the concept is that period when a number of scientific, military, and political events join to urge a nation to proceed with a new major weapon system.[*] Detecting this concept coalescence and the initial decision to proceed appears both difficult and easy. On the one hand one may argue that as long as there is generally equal scientific competence in two nations, initial concepts may be conceived almost simultaneously and it is, primarily, awareness of political leadership and/or the state of the economy which sets the pace. On the other hand, concept coalescence and the decision to proceed certainly can be conducted in the most cloistered inner circles of a government, making detection exceedingly difficult at this stage.[**] It is not clear, however that the latter situation be necessarily so if adequate understanding of the other nation's pressing motivations is constantly exercised and a continual listing and relisting of likely and unlikely concepts in the decision stage of the other nation is maintained. Such a listing, of course, requires a unique combination of scientific, engineering, military, and political talent of the highest order. It is imperative that the advanced military planning concepts of the nation making inquiry be brought into the act. Thus the detection of concept coalescence

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[*] Laboratory proof of fission and the beginning of World War II in one case and the von Neuman Committee and the cold war in another case are some of the more dramatic examples.

[**] The initial basic Soviet decision to proceed with large launch vehicle development is a striking example.

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and decision to proceed is more a matter of parallel analysis by the opposite government than any of the verification levels previously discussed.

Organization, staffing, facilities selection, and initiation of detailed systems engineering is a step which appears very difficult to detect or statistically estimate unless access indicated by the last verification level is attained.

Design of components and subsystems, fabrication and laboratory tests of components and subsystems, and qualification testing are potentially detected by the verification level involving research and development facilities.

The previous discussions may be marshalled to summarize the capabilities of the various verification levels in intercepting the RDT&E cycle. This is as follows:

1. In the early stages of development, i.e., conceptio study, decision to proceed, and initial staffing, the most valuable verification procedures involve the monitoring of technical and managerial personnel of high caliber. Such monitoring could be enhanced by a supporting technical analysis organization which would assess the feasibility and technical requirements for new weapons. These arrangements cannot provide for positive verification, but could give indications of intent and desire to violate an agreement.

2. The verification levels involving inspection of research and development facilities, launch sites and transportation centers are of little use in detecting the above early stages but are useful in deterring the decision to proceed if their presence negates the time advantage in evasion and eventual abrogation.

3. In the middle development stages (component and subsystem design and fabrication through testing of subassemblies and components) the third verification level involving inspection of research and development facilities is probably adequate.

4. In final assembly and flight test, overflight and extra-territorial observations may detect and grossly define new weapons, but launch site inspection is a substantial increment in positive identification of new weapon system activity and somewhat earlier in time.

In more detail, the estimated relative capabilities of the various verification levels in intercepting the RDT&E weapon system cycle are shown in Table II-9. A cross-estimate of the probablities of detection of weapon system development is tabulated in the matrix as shown. Ranges of estimates are due to differences in types of weapon systems as well as uncertainties in estimating. For example a new launch vehicle suitable for use as a ballistic missile is very likely to be detected from extra-territorial observation of flight tests provided it is large enough, say greater than 30,000 pounds. On the other hand, a manned space station, while detected, could develop an orbital bombardment capability with little fear of positive detection from extra-territorial observation alone.

F. Estimated Relative Effort at Levels of Verification

Assuming formal inspector forces in correspondence with the previous discussion of verification levels, it is instructive to estimate relative annual personnel and financial requirements for such forces with the USSR as the subject nation undergoing inspection. The estimates will be quite gross and indicative of relative magnitude costs of verification levels rather than absolute.

The first verification level a basic open inspection system employing a satellite observation system is proposed (see Table II 5). A minimum annual cost of $150 million for purchase and launch of the satellites is estimated with $50 million per year required for the operation of the readout stations and the data processing center. On this basis, a minimum annual cost of $200 million for continuous observation is suggested. It may be noted that such an observation system has many potential uses for civil

Table II-9 Estimated Probability of Detecting New Ballistic Missile and Space Weapon System Developments

			←Verification Level→		
Weapon System Research and Development Stage	Extra-territorial Observation	Launch Site Inspection	Research and Development Plants and Transportation Centers	Open Society	Research and Development* Technical Analysis Organization
Concept coalescence	Nil	Nil	Nil	Medium	High
Decision to proceed	Nil	Nil	Nil	Medium	Low
Organization and staffing	Nil	Nil	Low	Medium	
Component hardware development	Nil	Nil	Medium	Medium	
Fabrication and initial assembly:					
< 35,000 lb gross weight	Low	Nil	Medium	Medium	
> 35,000 lb gross weight	High	Nil	High	Medium	
Flight test					
< 35,000 lb gross weight	Medium	Medium to high	Not applicable	Medium	
> 35,000 lb gross weight	Low to high	High	Not applicable	High	

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* Technological warning units

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observation needs and it is possible that civil agencies could partially defray costs. Further, such a system is also useful in ascertaining the deployment of weapon systems, particularly ballistic missiles, requiring substantial launch site construction. However, the full expense will be charged to this system recognizing the existence of these other factors.

The second verification level (launch site inspection) requires personnel and equipment per launch site as suggested in Table II-6. An annual cost of $5 to 10 million for three launch complexes in the Soviet Union is considered sufficient for the basic system in Table II-6.

The third verification level involving research and development facilities and transportation inspection has been outlined in Table II-9, but requires, in addition, an estimate of the number of research and development facilities and transportation centers. According to DeWitt[7] and Turkevich[8] there are approximately one million research personnel involving approximately a thousand facilities. Assuming 50 per cent of this number would require continuous inspection (or partial inspection of all), an annual inspection force expenditure of $100 to 300 million per year is required.

Concerning the last verification level involving an open society (the U.S. ideal), it was suggested that from one to two times the GAO budget was a representative figure. Recent averages of GAO personnel and expenses have been approximately 1500 personnel and $45 million per year. Thus an expenditure of $50 to 100 million per year may be representative. Of course, if the society is truly open, a free press could furnish a major part of the verification process and defray governmental costs considerably, although probably not below the U.S. GAO expenditure.

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[7] DeWitt, "Reorganization of Science and Research in the USSR", Science, 23 June 1961.

[8] Turkevich, "Organization of Science in the Soviet Union".

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Table II-10. Assessment of Verification Levels.

Verification Level	Approximate Cost (million dollars per year)	RDT&E Weapon System Cycle Interception	Detection Value	Intrusiveness		Parallel Usefulness in Weapon System Force Limitations Monitoring
				Public	Government	
Extra-territorial observation	200 (minimum)	Late	Generally [illegible] weak in small missiles and space offense development	Low	Moderate	Good
Launch inspection	5 - 10	Late	Excellent	Low	High	Very little except deterring development
Research and development facilities and transportation centers	100 - 300	Middle	Fair to excellent	High	High	Good
Open society	50 - 100	Early	Fair to excellent	Dependent on circumstances		Excellent
Technical analysis organization	30 - 50	Early warning	Excellent warning	Low	Low	Not applicable without data

In addition to the preceding verification levels, it has been shown that there is a clear necessity for an organization which conducts technical analyses of the potential feasibility of new weapon systems in relation to the continual advances in research and technology as well as aiding in assessing the nature of verification indicator data. For this purpose, an organization containing 700 to 1200 well-qualified technical personnel is suggested with an annual cost of approximately $30 to 50 million.

These relative costs are summarized in Table II-10.

G. Summary Assessment of RDT&E Verification Levels

Allowing for considerable estimation error, it is apparent that launch inspection is the least costly RDT&E verification, while permitting the highest probability of detection at the flight test and evaluation stage. Since it is localized to launch sites, there is very little intrusiveness in direct contact with the public although highly intrusive to the government. However, interception in the RDT&E cycle is obviously restricted to the late stages.

Extra-territorial observation including a satellite observation system is expensive and also restricted to late stages in the weapon system cycle, but it is also useful for monitoring weapon system force deployment and for civil needs as mentioned previously. Potential weaknesses in detection lie in small ballistic missiles or in clandestine space offense systems. Intrusiveness is minimal for the public and not quite so intrusive as launch inspection for the government.

Inspection of research and development facilities and transportation centers is also expensive but offers an earlier interception of the research and development cycle. In expanded form it is also useful in monitoring weapon system force limitations. However it is highly intrusive both for the public and the government.

In an open society with almost unlimited inspection allowed, the situation improves markedly with a suggested over-all reduction in cost of verification over that of other alternatives. Further, early interception of the research and development cycle is potentially possible although not certain. Intrusiveness could be experienced at any scale depending on the circumstances, both public and governmental.

A clear necessity is indicated for a technical analysis organization, regardless of the verification level negotiated, to assess the feasibility and potential strategic balance effects of new weapon systems in relation to the advances in technology. Such an organization offers protection in postulating the earliest stages of a potential research and development weapon system cycle and creating heightened awareness of indicators towards such systems. Intrusiveness of the organization by itself should be minimal for both public and government and the expense is relatively low to moderate.

It may be useful to conclude this assessment with a qualitative tabular matrix of these factors as is shown in Table II-10.

III. POSSIBILITIES OF EVASION OF RDT&E RESTRICTIONS

In this section we turn to the possibilities of evasion of agreed restrictions on research and development activities associated with ballistic missiles and space weapon systems. While it is difficult to hypothesize the specific environment in which such restrictions might come into effect, it is possible to delineate some of the most probable features of such an environment. First, it is doubtful whether there would be willingness to impose restrictions during the early portions of the research and development cycle because of the widespread application of these activities to nonmilitary uses. Second, it is probable that nonmilitary space programs would continue in the more technically and economically advanced nations and perhaps even in some "underdeveloped" nations such as Israel, the United Arab Republic, Communist China, and India. These nonmilitary space programs could offer a camouflage for carrying out illegal weapon system development activities. Third, only a limited degree of access into formerly closed societies such as the Soviet Union would be expected to exist. While limited access may be granted to launch facilities and certain assembly and test facilities, it is doubtful that unlimited access would be granted. Perhaps fiscal monitoring of governmental records would be allowed but it is doubtful that accounting and control methods would be reorganized to facilitate arms control verification. In fact there might be a reluctance to do so as a hedge against the future.

This evasion study assesses the possibility of the clandestine development of a maneuvering re-entry vehicle and attempts to determine those indicators which could be used to detect such a clandestine development program.

A. Clandestine Development of a Maneuverable Re-entry System

Maneuvering re-entry systems offer two advantages over pure ballistic re-entry systems, namely improved accuracy through terminal guidance and improved penetration against defended targets. The use of terminal guidance during the re-entry phase of a missile flight has the possibility of improving the accuracy of the vehicle to a CEP of approximately 1000 feet at a range of 6000 nautical miles.

While the degree of improvement in penetration provided by a maneuvering re-entry vehicle has not been clearly defined sufficiently detailed studies indicate that maneuvering capability places severe requirements on some defense systems. A typical footprint for a maneuvering ballistic re-entry vehicle is shown in Figure III-1. This maneuver is initiated at an altitude of about 50,000 feet and active control of the vehicle continues until impact.

There are two types of maneuvering re-entry vehicles which might be considered: the maneuvering ballistic re-entry vehicle and the aeroballistic vehicle. The maneuvering ballistic vehicle follows a trajectory similar to that of a ballistic missile until the re-entry phase of the flight and then, at an altitude below 100,000 feet, a maneuver is executed. Typical terminal maneuvers for the ballistic re-entry vehicle are shown in Figure III-2. A typical trajectory for the aeroballistic vehicle is shown in Figure III-3 in which the vehicle is launched into a very high altitude, short range ballistic trajectory to obtain sufficient kinetic energy. Upon re-entering the atmosphere, at an altitude of between 100,000 and 150,000 feet, a pull-up maneuver is executed and the vehicle glides to the target making use of aerodynamic lift. Just before the target is reached, a dive-in maneuver is executed.

In this study it is assumed that the evader wishes to develop a maneuvering re-entry system which will be retrofitted on an existing ballistic missile for the purpose of improving the accuracy of his missile force and also to penetrate an active defense which he believes his opponent is developing. It is the purpose of this study to define the development program which could be undertaken, to identify those indicators in the development program

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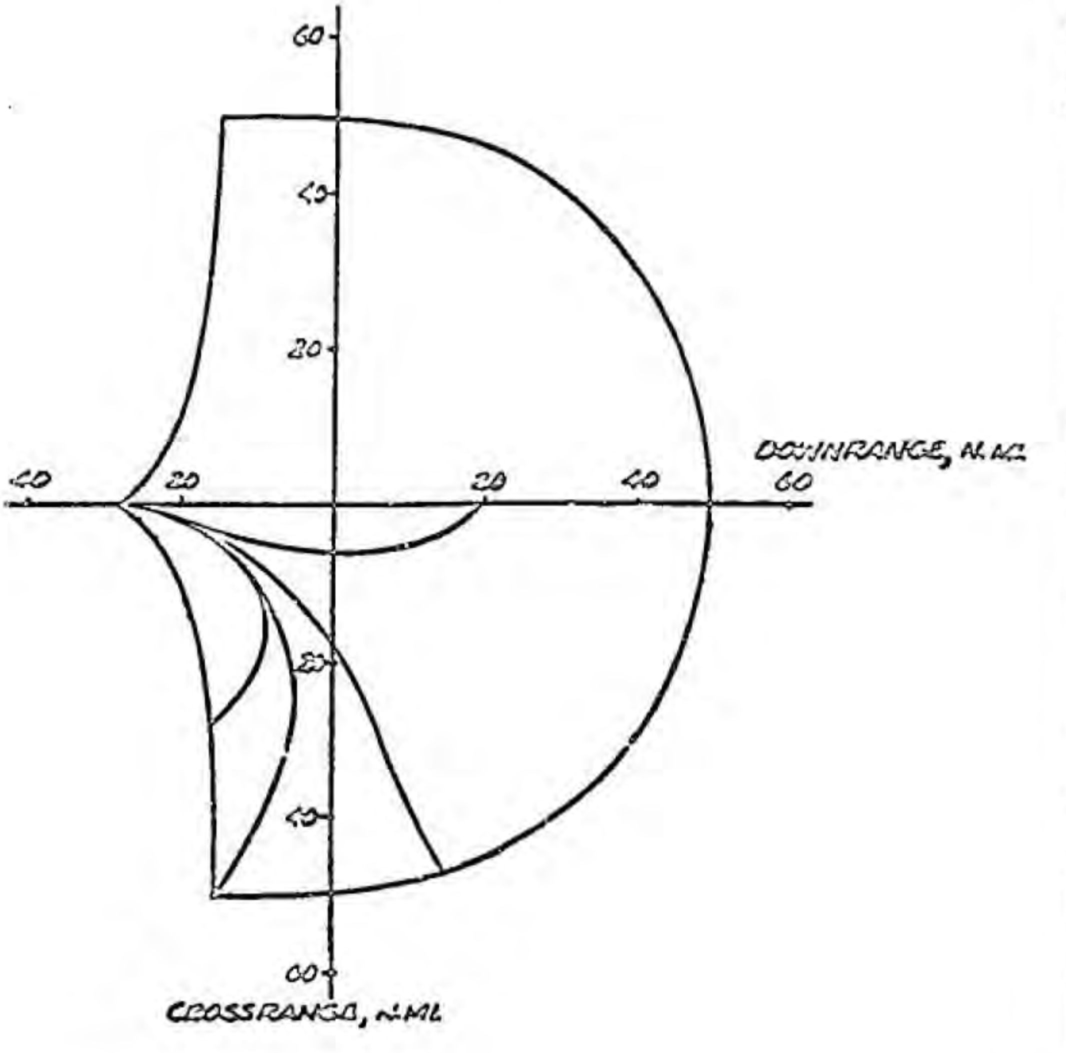

Figure III-1. Typical "Footprint" Maneuvering Ballistic Re-entry Vehicle.

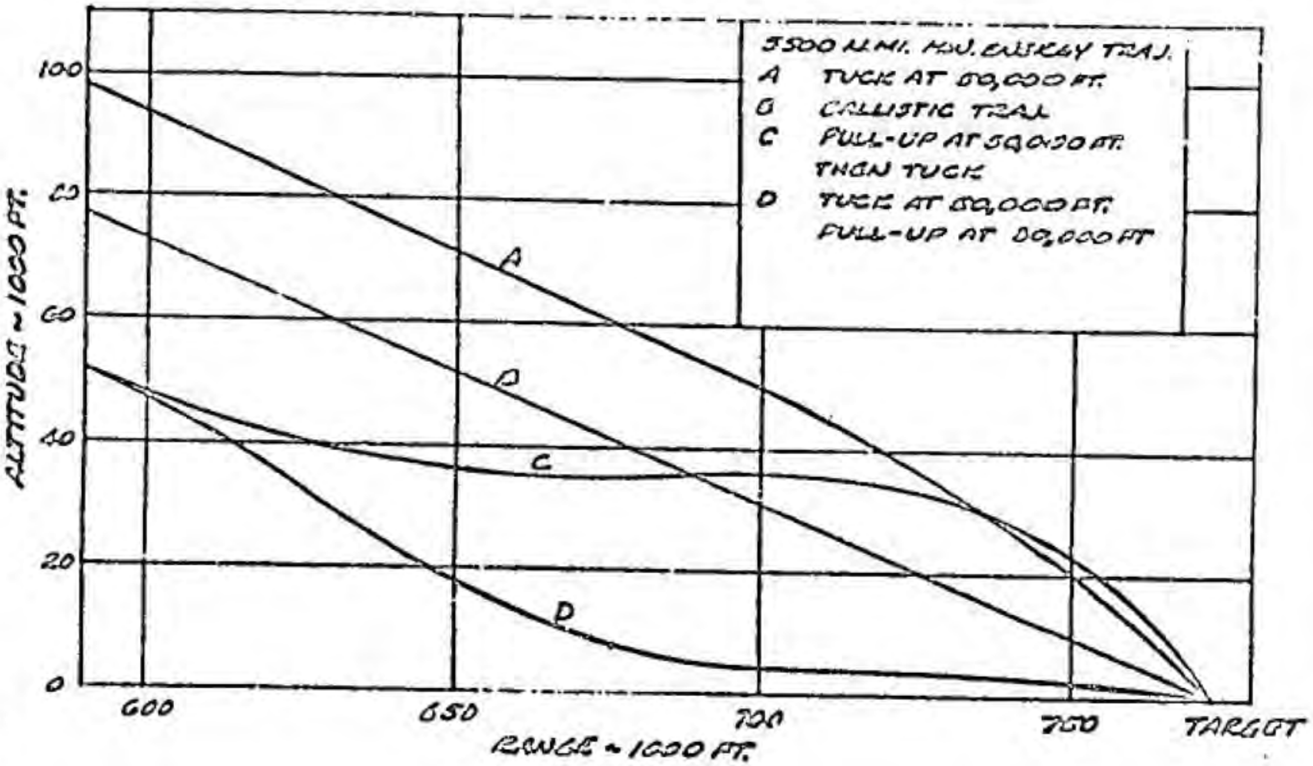

Figure III-2 Typical Terminal Maneuver Trajectories - Maneuvering Ballistic Re-entry Vehicle.

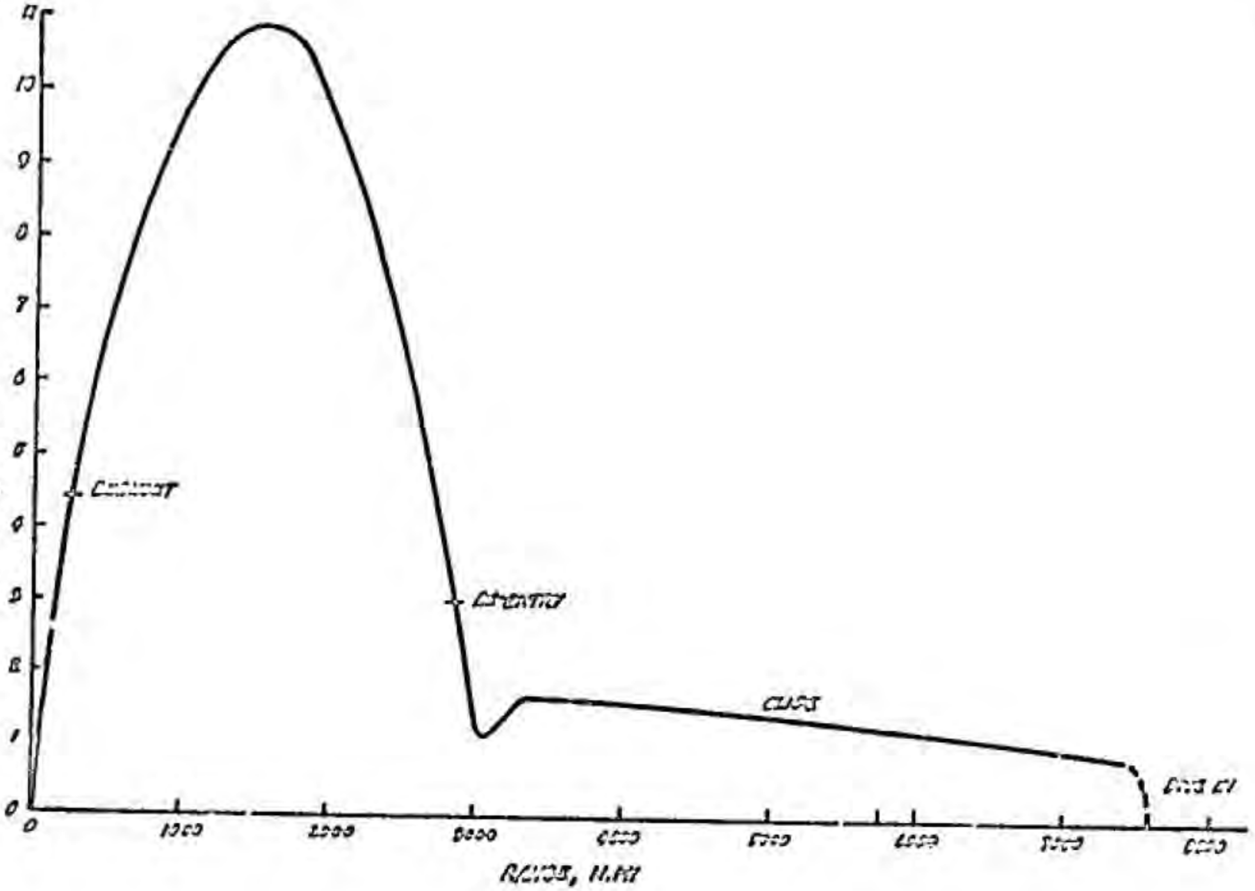

Figure III-3. Typical Aeroballistic Trajectory.

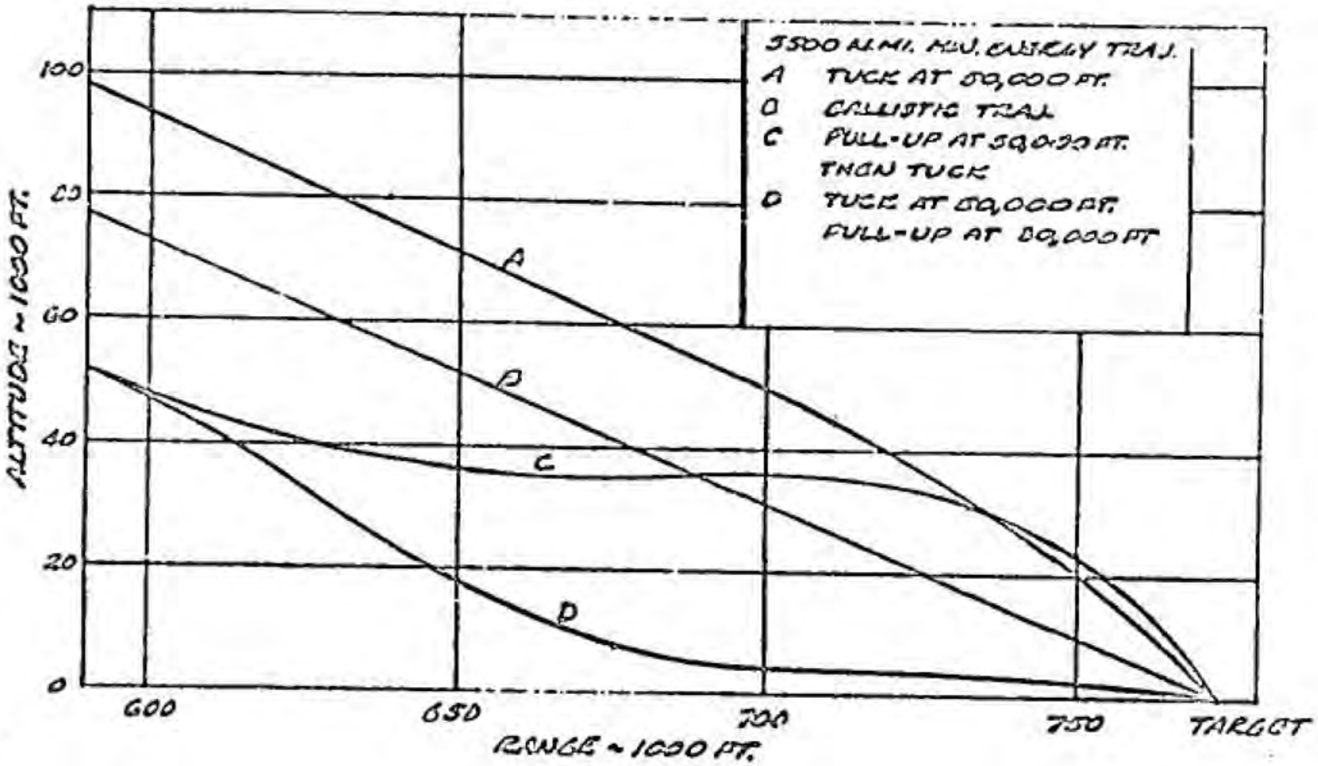

Figure III-2 Typical Terminal Maneuver Trajectories - Maneuvering Ballistic Re-entry Vehicle.

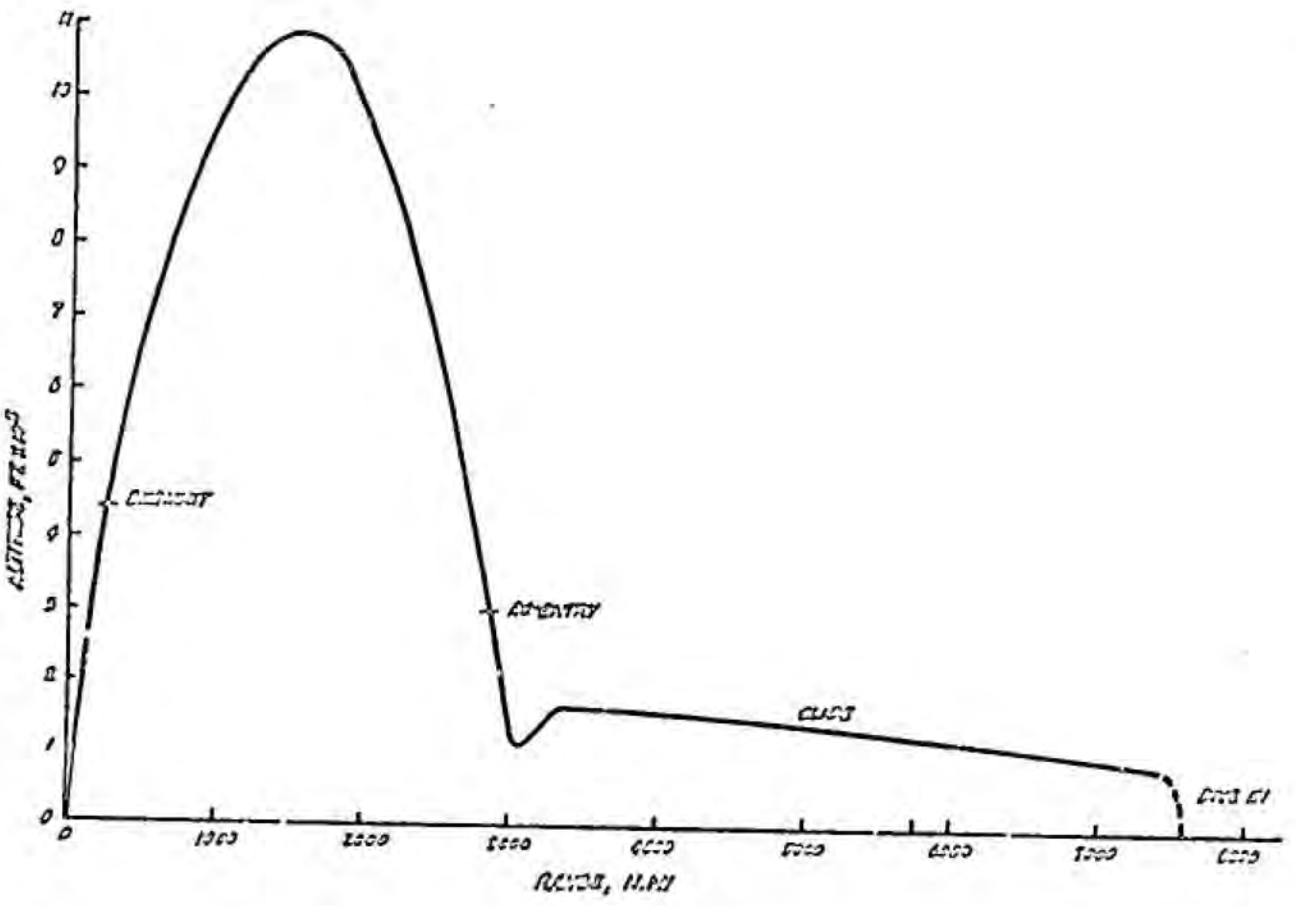

Figure III-3. Typical Aeroballistic Trajectory.

which might indicate that evasion was being attempted, and to determine how far the developmental flight testing could proceed before a positive identification of the program could be made. It is assumed that such a program is undertaken in the environment of an unrestricted nonmilitary space program.

However, in order to achieve this capability, significant improvements in all of the vehicle subsystem areas, vehicle structure and materials, guidance and control, and arming and fuzing, are required. These subsystem areas a.e the subject of continuing technology improvement studies and much of the required improvement can probably be achieved in general nonrelated studies and as portions of nonmilitary development programs.

Maneuvering re-entry vehicles and their related subsystems have been the subject of preliminary design, feasibility studies and some experimental work. The results of these studies have been sufficiently favorable to warrant further detailed design, development and experimental work to establish the capability of these systems. The specific areas requiring further work at the present time are aerothermodynamics, vehicle dynamics, guidance systems, control systems and the operational effectiveness of the system.

1. Subsystem Development Programs

The previous discussion has indicated the reasons for studying ballistic maneuvering re-entry systems development programs in an arms control environment, the systems purposes and some of the systems capabilities that would be desirable. The design and development of a ballistic maneuvering re-entry vehicle is not yet a straightforward problem of current technology. There are requirements for applied research, development and testing in all of 'he subsystem areas. A meaningful examination of the effects of arms control restrictions on the development of a system requires a quantitative definition of the subsystems and their characteristics. The ballistic maneuvering re-entry vehicle subsystems are:

Re-entry vehicle
Control system
Guidance reference system
Arming and fusing
Warhead and firing set

The requirements, desirable capabilities and development problems will be discussed for each subsystem.

a. Re-entry Vehicle

The ballistic maneuvering re-entry vehicle requirements have been partially indicated during the definition of the types of maneuvering systems of interest. The two systems utilize different re-entry vehicles, however, so each will be considered in more detail.

The system requirements affecting the re-entry vehicle design for the ballistic maneuvering re-entry vehicle are a ballistic coefficient of about 2000 psf, low optical and radar observables and a low altitude maneuvering capability. The re-entry vehicle configuration that will best meet these requirements is a pointed cone of less than 15 degrees half-angle with an ejectable base covering the control flaps. A re-entry vehicle configuration of this type is illustrated in Figure III-4. The conical re-entry vehicle has been flight tested for both the TVX and REX configurations. neither design has control flaps.

The TVX flights have indicated an instability during re-entry that is attributed to the effects of mass addition to the flow field by the heat shield ablation products. This has not occurred on the REX flights. Work is currently in progress in this area, and a solution is necessary to predict performance of conical re-entry vehicles, whether maneuverable or not. This work will require the determination of the aerodynamic characteristics of an ablating cone.

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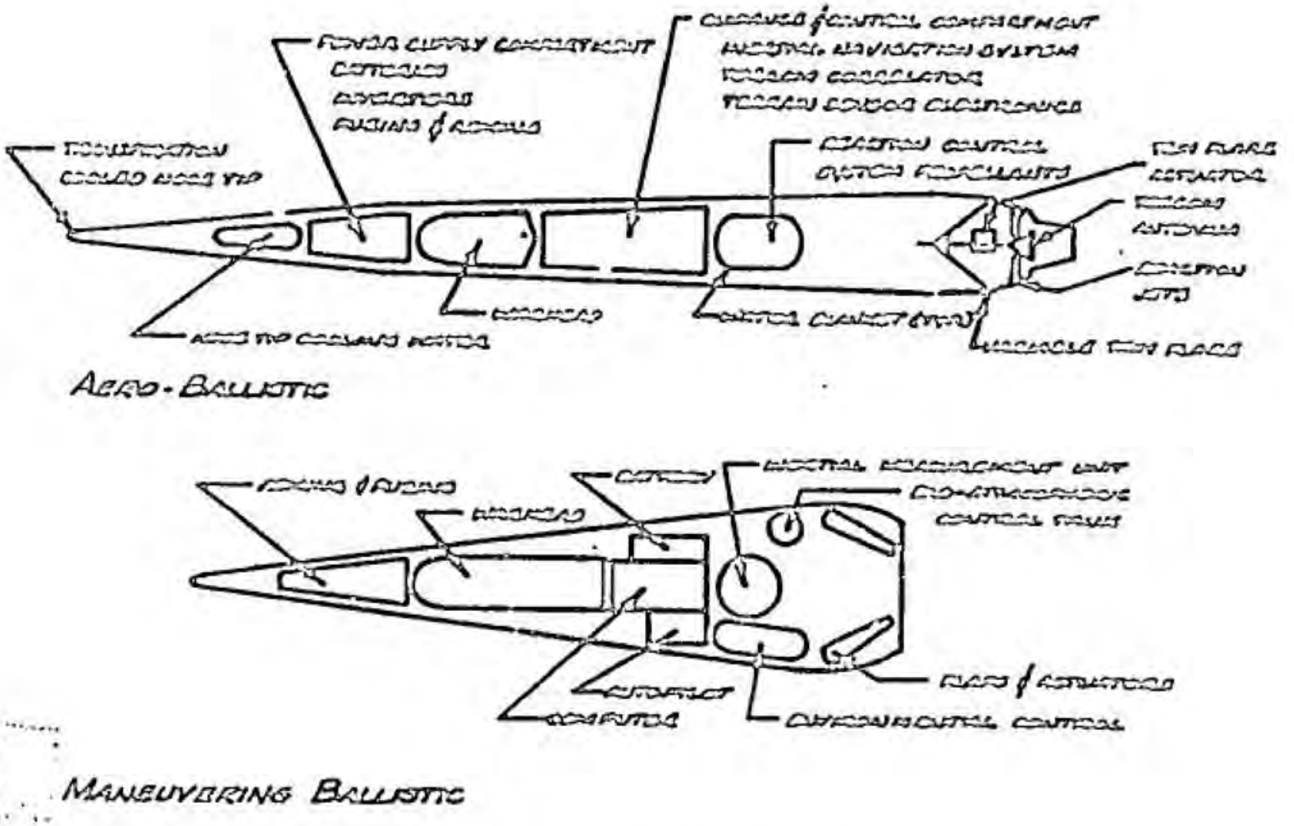

Figure III-4. Re-entry Vehicle Configurations for Aeroballistic and Maneuvering Ballistic Vehicles.

The ablation products and the physics of the boundary layer and flow field about the body would influence the operations of subsystems that rely on microwave or optical transmission to and from the re-entry vehicle, such as active terminal guidance during re-entry and radar fuzing. The radar and optical observables are also influenced by the reactions in the flow field. Recent flight test data on relatively sharp conical re-entry vehicles have indicated that low frequency microwave transmission (as might be required for terminal guidance) from the nose of the vehicle has not been the problem anticipated. The location of antennas or windows on the aft portions of the vehicle, such as would be probable with an active terminal guidance system, could be influenced by sheath effects. The effect of the sheath and the wake on the subsystems and observables can only be adequately determined by flight testing the configuration.

The heat shield must also provide thermodynamic protection at a reasonable weight as well as minimum sheath and wake effects. Study results have indicated that this can be most efficiently done with a composite heat shield design using an ablation material with a high effective heat of ablation over an efficient insulation material. This would be of particular interest for a maneuvering re-entry vehicle with asymmetric heat loading so as to minimize any asymmetric ablation effects. While graphite-cloth-phenolic appears promising as an ablation material, and there are candidate insulation materials, the composite heat shield is not a tested technique.

The re-entry vehicle structure would probably be a ring-shell design with a 300-g longitudinal load capability and at least an 80-g lateral load capability. This type of conical re-entry vehicle would probably have a lift-to-drag ratio (L/D) of 1.0 to 2.0 for good maneuvering capability. The cone with a shaped base will provide a nose-on, exoatmospheric radar cross-section of approximately 10^{-3} square meters at L-band (1000 mc).

The aeroballistic re-entry vehicle is most likely to be a high fineness ratio body such as a slender cone or flat-bottomed configuration. This configuration is necessary to obtain the high L/D ratios required for the aerodynamic portion of the trajectory. A typical vehicle of this type is illustrated in Figure III-4. This type of configuration has been subject to some wind tunnel and flight test evaluation. However, the critical L/D has not been verified for the flight regions of interest.

The body flow field and boundary layer physics will also influence communications and sensing subsystems for this configuration. The type of heat protection system, whether ablative or mass injection plus radiative, has not been defined as yet. Either of these systems may possibly cause some transmission and receiving gain and distortion problems for low frequency (uhf-vhf) microwave or optical systems, such as a map-matching system.

The heat protection system, as indicated above, is an unresolved problem area. The mass injection plus radiative cooling concept has not been adequately demonstrated. The continuous slow roll necessary to this concept may also involve reliability problems for some subsystem components for long flight times. If the rotation concept is used, then the same materials would be studied as for the maneuvering ballistic re-entry vehicle.

b. Control System

The re-entry control system design is a continuation of the re-entry vehicle design, and is inter-dependent with the re-entry vehicle configuration chosen. The re-entry maneuvering capability is provided by a flap system that is hydraulically actuated. The system will contain the usual components such as a pump, reservoir, accumulator, servo valves and actuators. The pump will probably be of the hot gas type. There is nothing unusual in this type of system; there is however a question as to its reliability in the re-entry operating environment.

The control flap effectiveness and heating are very dependent on the flow field generated by the body. This flow field is a function of the body geometry, the altitude and the flight speed. The slender pointed cone will have nearly Newtonian flow conditions at the flaps when the interaction effects do not predominate. The flaps for the blunt configuration are in a much lower velocity region as a result of the bow shock, and are much less effective than for the pointed configuration. This implies that the control effectiveness must be determined by test for each specific configuration. Similarly, the heating of the flaps due to flow separation that is likely to occur at moderate to large flap deflection angles requires a careful examination of variations of a specific design.

The heat protection for the control flaps of the maneuvering ballistic re-entry vehicles will require a high effective heat of ablation material such as pyrolytic graphite or graphite-cloth-phenolic. This application of these materials or of new materials will require a development and test program.

The heat protection of the control flaps for the aeroballistic vehicle may not require the same materials as for the maneuvering ballistic vehicle. It may be possible to use a cobalt base alloy with protective coatings. These coatings have not yet been proven experimentally, and a test program will be required.

The exoatmospheric control will be provided by a three-axis cold jet system. This should involve no design or development problems since similar systems are currently in use for orientation and trajectory correction of satellites and re-entry vehicles.

c. Guidance Reference System

The term guidance reference system is used here to designate that portion of the total guidance system that provides the location, reference, and dynamic status inputs to the guidance computer subsystem.

Since improved accuracy is a primary justification for development of a maneuvering re-entry vehicle, the system must offer a significant improvement over current technology. This will require that the system be capable of removing the burnout errors and providing accurate guidance during the terminal maneuver.

The basic guidance reference system would probably consist of an improved inertial measurement unit and an autopilot system based on existing hardware. The inertial unit would contain three rate integrating gyros and three accelerometers. These components, like others in the system, must operate normally and accurately at load factors up to at least 80 g's laterally and 100 g's longitudinally. They should not be made inoperable by defense system effects such as blast acceleration loadings or high radiation fluxes. This may be partially accomplished by good design and shielding of vulnerable components.

An additional improvement in accuracy might be obtained by adding a terminal guidance reference of one of the map-matcher types to the system. These are either active systems using radar, or passive, using heat-sensing, to establish location. Prototypes of these map-matchers have been flight tested in airplanes, but would require considerable test and development to become operational. In addition to achieving satisfactory operational capability, the hardening and vulnerability requirements given in the previous paragraph are also applicable to this subsystem.

d. Guidance Computer

The maneuvering re-entry vehicle will require the development of a miniature computer capable of operating in a high acceleration environment and remaining operable after exposure to high radiation fluxes. Since the present computers are designed for launch accelerations only and are located in a compartment exterior to the re-entry vehicle, they are too large and too vulnerable for direct application and consequently new computers must be developed. There are, however, a number of computers under development which would fulfill the requirements as far as size and weight are concerned but may not withstand the acceleration environment.

e. Arming and Fuzing

The selection of a fuzing system is dependent on the type of vehicle (ballistic or maneuvering ballistic), the weapon yield, and the ballistic coefficient. The airburst fuzing criterion is an allowable error of $50\ W^{1/3}$ (W in kilotons). The best inertial systems have an altitude error of approximately 300 feet, so that they cannot meet the height-of-burst accuracy requirements for a warhead of less than 200 kt, but are quite adequate for large yields. This accuracy also applies to a straight, nonmaneuvering, ballistic trajectory. Application of all-inertial fuzing to a maneuvering trajectory would require development and testing.

The ground burst fuzing has been by impact sensors. The time delay of this system makes it unsatisfactory for high ballistic coefficient re-entry vehicles with impact velocities greater than 3000 to 4000 ft/sec.

Therefore, a combination of inertial and radar fuzing would be the most probable type of fuze. The inertial system provides the general trajectory monitoring and activates the radar fuze for accurate detonation. The inertial system and impact fuzing would back up the radar system.

Radar fuzing is still in the early development stage, and will require considerable further development work to provide a reliable unit that is not subject to jamming. The present designs operate at frequencies in the S-band (3000 mc) to X-band (10,000 mc), and should not be subject to "black out" by the ionized flow field.

f. Warhead

The warhead would be an off-the-shelf item furnished by the AEC from stockpile. Some present technology warheads are capable of withstanding the environment of maneuvering re-entry. The problem here is to provide the correct design interface. This may be more difficult than it would appear due to restrictions on warhead mounting attachments, power requirements and other wiring requirements.

2. Research and Development Restrictions - Methods and Effects

The effects of arms control restrictions and verification procedures will depend greatly on the type and degree of restrictions imposed and on the extent of the nonmilitary space program which is undertaken.

The most simple, and probably most negotiable, type of inspection would be visual inspection at flight test launch sites and instrumented downrange observation of the test. The inspection of critical test facilities and laboratories might also be arranged. The numbers of trained inspection personnel and the amount of their equipment might become excessive beyond this, both as a strain on the inspecting country and on the hospitality of the host country. Assuming the flight test range and critical test facility type of inspection, the problem areas and the comparison of military and nonmilitary system provide indicators to the development of ballistic maneuverable re-entry vehicles. The problem areas and the comparison results provide indicators for inspection at ground test facilities and launch areas for flight test monitoring.

The utilization of problem areas as an indicator source and inspection aid is dependent on defining problems on tests unique to ballistic maneuvering re-entry vehicle development. The problem areas mentioned previously may provide indications of varying validity.

a. Cone Model

In several of the problem areas, the importance of testing with the correct body configuration is stressed. This would indicate that any cone test would be an indicator or, in the extreme, that the conical configuration shall be banned. However, the cone is a basic configuration in gas dynamics research because it is a simple axisymmetric shape for which theoretical solutions are more readily attainable. Therefore, it is likely to be used as a research configuration, particularly for ground testing, where no direct re-entry application is involved. It is only certain types of testing on a cone configuration, such as control effectiveness, that have some significance.

b. Dynamic Stability

The destabilizing effect attributed to mass addition during re-entry due to ablation on a pointed cone is a problem area for high fineness ratio re-entry vehicles. This problem has been studied by NASA in connection with mass addition cooling for general application. Therefore, such testing is probably justifiable for nonmilitary application and is a highly ambiguous indicator. Obviously the testing of such effects on a cone with base control flaps in a dynamic test facility would be a good indicator.

c. Control Flap Effectiveness and Heating

The requirement to determine control flap effectiveness for the specific configuration and flight conditions can only be completely accomplished by flight testing the design configuration. Ground facility tests of flaps on cone or high fineness ratio configurations under the best flight simulation conditions available are a good indicator where both the effectiveness and heating tests include the extreme conditions required for maneuvering at hypersonic speed below 100,000 feet altitude.

d. Body Flow Field

The determination of the composition of the body flow field is a problem pertinent to microwave or optical transmission and sensing. This field is currently receiving considerable study based on ballistic re-entry

a. Configuration Design

The more desirable configuration for the maneuvering ballistic re-entry vehicle was indicated to be one capable of high ballistic coefficient re-entry typified by the cone or slightly blunted cone with a high efficiency heat shield, base flaps, actuators and structure capable of operating in a high structural and heat loading environment. Such a vehicle would be distinguishable by observation and its appearance would be an excellent indicator. The low altitude maneuvering test of such a vehicle would be quite definite. It is not likely that the developer will provide so complete a situation unless he is ready to abrogate the agreement. Conical re-entry vehicles of less than 10 degrees half-angle have been proposed for lifting re-entry and booster recovery so that there is a legitimate nonmilitary purpose in the testing of such a vehicle; such a test is a highly ambiguous indicator of definite maneuvering ballistic re-entry vehicle or aeroballistic re-entry vehicle development. This low cone angle, high fineness ratio type of vehicle is particularly suitable for application to a booster recovery vehicle.

b. Structure

The vehicle structural requirements necessary for 80-g lateral loading and 300-g axial loading provide some indication in the obvious structure of the vehicle and the mounting of internal components; however, this is a difficult area of judgement and a highly ambiguous indicator without specific determination of materials, cross-sections, spacing, gages, and a detailed analysis.

c. Radiation Shielding

The radiation hardening of electronic components, particularly in conjunction with rugged structure, would be typical of a re-entry vehicle to be used against a defended target. The radiation protection might be justifiable for a space probe where high X-ray fluxes (as from solar flares) might be encountered. Therefore, this is also an ambiguous indicator.

d. Heat Shield

The materials and thicknesses of the heat shield provide a good indication if high heat of ablation material, such as graphite, is used for the control flaps and a similar material, such as graphite cloth phenolic, is used for the body. This degree of protection is probably not necessary for the protection of the lifting recovery application of the cone and therefore may be considered a fairly certain indicator of the development of a maneuvering ballistic re-entry body.

e. Radar Absorbing Materials

The appearance of radar absorbing materials, which are not heat shielding materials but "lossy" dielectrics characterized by ferrites or carbon addition to Teflon or phenolic refrasil, are almost certain indicators. The unknown areas of bonding between materials and the effects on ablative material characteristics will require flight test verification.

f. Control System

The control system required for low altitude maneuvering at high Mach numbers will require larger hydraulic cylinders and stronger linkages than for the high altitude maneuvering or lower maneuver capability of the nonmilitary system. The capacity of the control system is not readily determined without a detailed check of the system components and materials and an analysis of the system actuation. This is less difficult than for an electronic system, so that this may be a fairly certain indication to an inspector who is expert in such systems.

The determination of the purpose and capabilities of a "black box" without detailed instrumented checking which requires partial disassembly is virtually impossible. Therefore, the inspection of these assembled subsystems will provide an ambiguous indication as to their purpose and capability and defense interest. However, the study has progressed sufficiently that it might continue in some degree for general scientific interest. Further, microwave transmission definition is necessary for nonmilitary space and re-entry application so that this area would be a highly ambiguous indicator.

e. Heat Shield Material

The definition of heat shield material characteristics is necessary for both military and nonmilitary applications. The use of pyrolytic graphite has been suggested and studied for both cases. The difference would be in the degree and duration of the heat pulse. This would involve different test conditions and insulation requirements and appears to be a good indicator when a potential low altitude maneuvering configuration is involved.

Mass injection and radiative cooling are also quite pertinent to nonmilitary re-entry vehicle studies. The recoverable booster studies would, in particular, offer an excellent means of development, test and application of this technique of heat protection. Therefore, this type of heat protection system development would be a highly ambiguous indicator of direct development, but a fairly certain indicator of capability.

f. Radar Absorbing Material

The development, installation and testing of this material represents an area for suspicion. Radar absorbing material may be applied as a separate material over or under a heat shield and may also be an addition to certain types of heat shield. Its detection in any of these applications is an almost certain indicator of very low radar observable re-entry vehicle development. It may or may not be a requirement depending on the vehicle shape and tactics used, but would probably be most useful for the aeroballistic vehicle.

g. Development of Computers and Inertial Platforms with a High Acceleration Capability

The development of components capable of operating during high acceleration loadings is critical to the development of a maneuvering ballistic re-entry vehicle. However, this type of system has other applications since the primary concept under consideration may be less expensive to manufacture than current designs and will be more suitable for use in high vibration and noise environments. The use of any component in an acoustical or vibration environment provides a requirement for high strength and durability, and an excuse for the necessary ground tests. Therefore, the development, production and ground testing of these systems are highly ambiguous indicators. The flight testing of the system in a maneuvering ballistic re-entry would be an almost certain indicator. The detailed disassembly and testing inspection required to detect a high g system or special guidance system is not likely to be permitted.

h. Arming and Fuzing

The development of a reliable and nonjammable radar fusing system is necessary. However, there are sufficient requirements for the development of miniature microwave transceivers to make this a poor indicator. The detection of the testing of a unit with varying frequency and doppler shift capability would be a fairly certain indicator of advanced fusing development.

3. Comparison of Military and Nonmilitary Requirements

The appearance of system or subsystem designs that match the indicated requirements for military more than nonmilitary application is not conclusive, but requires a suitable explanation from the developer. Such an explanation is probably readily available. This type of inspection will probably be done visually at the launch area and confirmed by observation of the flight.

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3. Internal Design and Components

Space and attachment points must be provided in the military vehicle for the warhead while the nonmilitary vehicle is usually a fairly dense package of instrumentation. The weight of the vehicle will provide a check of the ballistic coefficient. The type, location, and amount of instrumentation provide a check of the utilization of payload space. However, this is an ambiguous indication since the small variations in cone angle and size will provide a reasonable test vehicle which is not an obvious military application.

4. Flight Test Observation

The observation of a flight test with the appropriate downrange instrumentation and with access to, or parallel recording of, the data from the test vehicle will provide the most reliable indication of the developer's capability and status of producing a maneuvering ballistic missile.

Downrange stations for ZI ranges would be necessary for adequate monitoring. Downrange monitoring would definitely indicate the complete test of either a maneuvering ballistic or aeroballistic re-entry vehicle. Flight tests in which subsystems were evaluated would not be so obvious. The type of information to be determined by downrange observation is:

- Trajectory
- Ballistic coefficient
- Maneuver capability
- Maneuver altitude
- Types of signals from re-entry vehicle
- Sheath and wake radar observables
- Optical observables

The access to the on-board instrumentation and data results would be extremely useful to the inspectors. This would essentially provide data on which of the problem areas were possibly being investigated or what information was being obtained that was more pertinent to military application than nonmilitary. The indicator value of this information has been discussed. The indicators discussed are summarized in Table III-1.

5. Effects of Arms Control on the Development Program

The development of a ballistic maneuvering re-entry vehicle includes a large number of subsystems which may serve as indicators; the subsystems may be detected and identified, particularly if a normal direct development program is followed. The program changes that might result from an effort to avoid detection are:

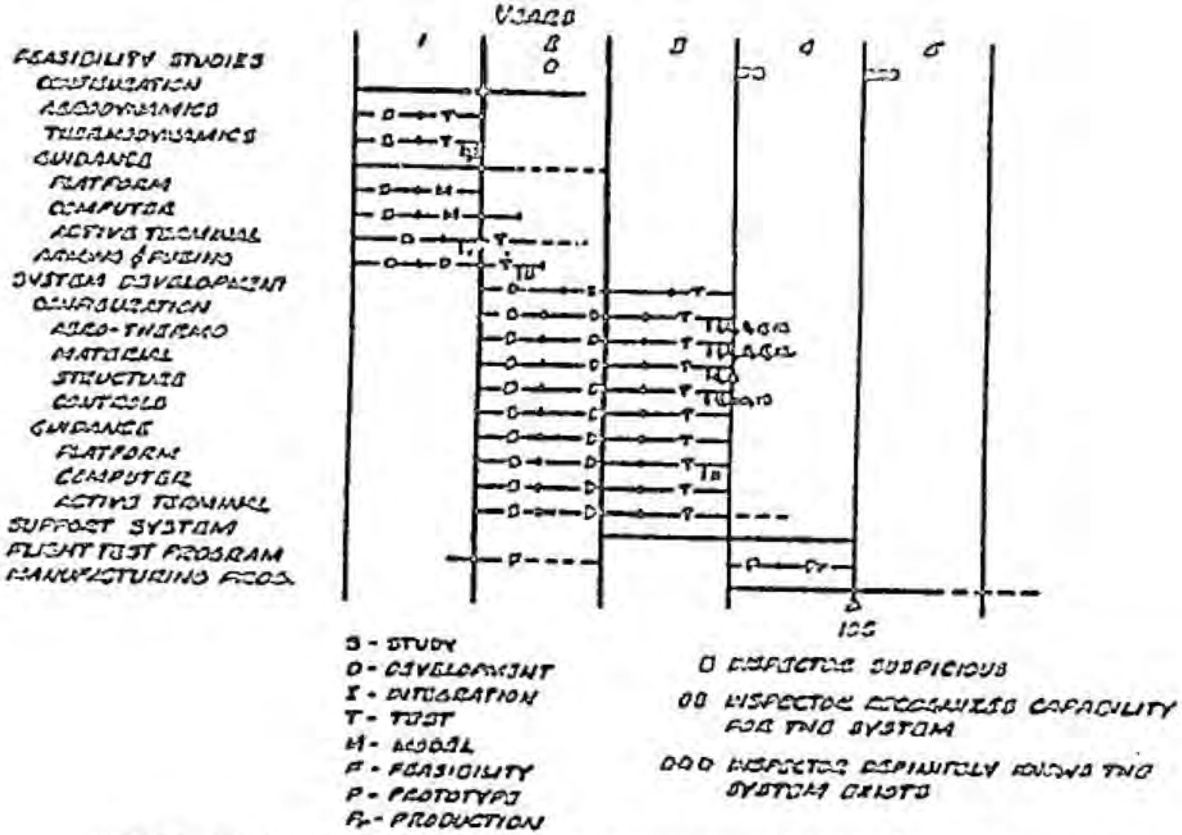
Divide the development program
Institute relevant nonmilitary programs
Clandestine development in whole or in part
Lower system performance
Choose an alternative method
Abandon the concept

The actual course followed by the developer is likely to include a combination of these unless the difficulties of compromise force abandonment. It is obvious that dividing the program, instituting cover programs and clandestine programs are all going to increase the cost of the system and the difficulty of management.

Since some natural division of a program by subsystem areas and technology areas is possible, a degree of covert development may be readily available. A simplified program plan without arms control is shown in Figure III-5; the major indicators are also shown. The asterisk symbols indicate the degree of awareness of the inspectors where they do not have direct access to organization and design areas, but only monitor ground tests and flight tests. The right to monitor location of personnel and organizational structure, and to request inspection design areas would move the recognition of capability ahead by 6 to 12 months and the recognition of a definite military design would move ahead by 12 to 18 months.

Table III-1. Manoeuvering Ballistic Re-entry Vehicle Development Indicators.

Indicators	Rating	Facilities Required	Possible Cover
Control effectiveness on cone body	Fairly certain	Shock tunnel, hot shot tunnel	Decoder recovery, precision data recovery
Control heating on a cone body	Fairly certain	Arc jet, ballistic tunnel, static test, high speed	Precision data recovery
Cone dynamic stability	Highly ambiguous	High speed and hot shot tunnel, dynamic testing	Injection cooling
Heat shield material	Ambiguous	Arc jet, boundary layer thickness, shock tunnel	Re-entry vehicle development (scale)
Body flow field study	Highly ambiguous	Boundary layer thickness, shock tunnel	Re-entry communications instrumentation and techniques
Radar absorbing material	Almost certain	Radar range, arc jet	None
Homing computer and platform	Highly ambiguous		Acoustical or vibration environment precision data recovery
Arming and fuzing	Ambiguous		Communications none for doppler
Structural design	Highly ambiguous		Protection for satellite or solar environment
Radiation hardening	Highly ambiguous		Protection for satellite or solar environment
Electronics design and packaging	Highly ambiguous		
Heat shield materials and thickness	Fairly certain		
Attachment to structure	Ambiguous		
Control system capability flight test trajectory			
Ballistic coefficient	Fairly certain		
Maneuver and maneuver altitude	Fairly certain		
Types of signals	Relatively ambiguous		
Full flight test of operable vehicle	Almost certain		



1, 2, 3, ETC, SMALL NUMBERS DENOTE WHEN INDICATORS (TABLE I) FIRST BECOME DETECTABLE TO THE INSPECTOR

Figure III-5. Program Plan for the Normal Development of a Maneuverable Re-entry Vehicle.

A similar program for the arms control environment is shown in Figure III-6. The feasibility studies have been changed to separate research and development studies in several technology areas. The particular work necessary to the ballistic maneuvering feasibility effort would be carried on in conjunction with other studies, and would result in an extension of the program to achieve the desired results. The applied development program is carried out by developing subsystems for nonmilitary systems with the same requirement. Again, there is an increase in the time necessary to develop the desired subsystem. However, the parallel research and development programs that are apparently unrelated require close observation and correlation to note the appearance of several indicators. Therefore, the inspectors will not be likely to be seriously suspicious of the possible development of a ballistic maneuvering re-entry vehicle until a number of different programs have been completed. The capability to build the systems will become obvious during the flight test program and nonmilitary system procurement.

The military system with the ground support systems and the manufacturing program must be developed clandestinely. This can probably be done by utilizing the nonmilitary programs to design some equipment, and utilizing personnel in special staff positions to monitor and integrate the covert results and accomplish the systems design. Since inspection will probably include some general monitoring of the output from production facilities, it would seem unlikely that any significant number of vehicles could be produced. However, with the design completed and the tooling available for nonmilitary programs, rapid production could be implemented.

The flight proof testing of the system would be difficult, but might be accomplished with a "failure" in the test of a nonmilitary system. The failure would permit the necessary maneuvering gyrations and the range safety destruct or impact would prevent a useful post-flight examination.

The apparent significant point is that the development and design of a maneuvering ballistic re-entry vehicle can probably be carried

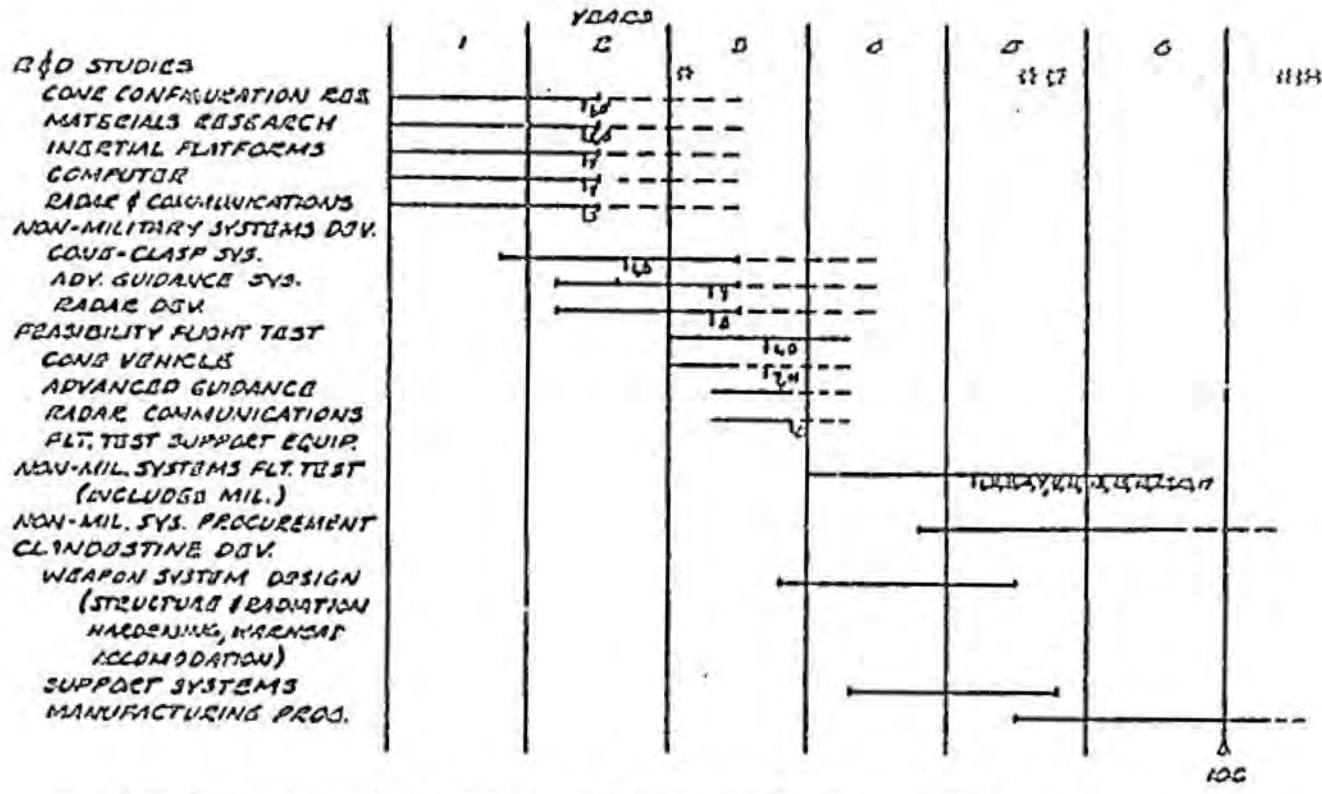


Figure III-n. Possible Development Plan for the Development of a Maneuvering Re-entry Vehicle in an Arms Control Environment.

to the point where a reasonably high confidence design is available for production. The tooling and skills necessary to implement rapid production can be developed under the nonmilitary programs. A limited number of vehicles could probably be clandestinely produced, but if the requirement is in the hundreds, then production probably will not be implemented until the "last minute".

Subsystems other than the vehicle could probably be covertly and clandestinely produced. The developer would probably not urge production until the international situation warranted it. Many of the subsystems could be stockpiled so that only the final vehicle and assembly would be required.

6. Conclusions

The primary conclusion to be drawn from this investigation is that it is probable that a ballistic manoeuvering re-entry vehicle, either manoeuvering ballistic or aeroballistic, could be developed and partially tested in an arms control environment. However, the inspecting power would be aware, depending on his own alertness and perception, of the developer's capability to build the system before its final evaluation or deployment. The developer might produce and deploy a limited number of systems without certain detection if he is willing to proceed on the basis of what would normally be considered to be an inadequate number of evaluation and demonstration flight tests.

The development program in the arms control environment might take at least half again as long as the normal program, and may involve as much as twice the number of people and facilities, just considering the first order estimates of Figures III-5 and III-6. This could readily result in trebling the RDT&E costs of obtaining the system. However, a good part of this cost and capability utilization could be charged against the nonmilitary systems if they should prove to be useful systems.

The increased cost and capability requirements for the covert development of a system will reduce the number of systems that a nation can develop, and possibly restrict the capability of exploiting new weaponry concepts. The inspection capability requires a considerable program of weapons research and analysis to be able to recognize the indicators in the developer's program. The general result could be a slowing down in the development of new weapons. This applies only to new weapons that are extensions of the state-of-the-art. A completely new weapon concept based on the results of fundamental research would not necessarily have the same characteristics as the system of this study.

B. Ballistic Missile Improvements with Restrictions on External Characteristics

This section considers the feasibility of imposing verifiable restrictions on external characteristics of missiles which would sufficiently confine improvements in missile capability in accordance with the objectives of a potential arms control agreement. Specific restrictions that are considered are restraints on external dimensions and materials, weights, and propellants, in association with variations in access for verification. Improvements in missile capability that could be legally exploited in conformity with the negotiated restrictions are investigated for potential increases in payload, accuracy, and re-entry vehicle(s) performance.

It is apparent there exist matrices of possible restrictions on external characteristics in conjunction with possible inspection arrangements with resulting differences in opportunities for RDT&E improvements. It will be instructive to consider these in turn, in an attempt to reduce the spectrum of alternatives to manageable proportions and within boundaries of practical considerations.

1. Dimensions and Volume Constraints

The external dimensions (size) and/or volume of a missile are clearly direct candidates for restrictions. Less clear are restrictions on changes in external materials or in missile weight. Yet, even in dimensional restrictions there are alternatives that must be interrelated with the verification process.

For example, if verification is confined to separate inspection of the missile propulsion stages only, then dimensional restrictions must be confined to the propulsion stages to be relevant. Negotiated dimensional restrictions on the guidance and re-entry vehicle sections, with no access for verification, would be irrelevant.

Further, dimensional restrictions may be confined to not exceeding certain external dimensions with no restrictions on smaller dimensions. This is similar to a go/no-go gauge where any object smaller than the gauge is passed as opposed to requiring the object to match a template closely within certain tolerances. More freedom in design of a new missile exists with the go/no-go dimensional restriction than in matching a template, but from a practical point of view the maximum dimensional restriction is likely to prevail with no restrictions on lesser dimensions.

Assuming restrictions only on maximum dimensions or volume for a certain type of missile or missile section, there arise considerations in the detail to which such dimensional or volumetric restrictions should be imposed and their relation to the verification process. One method would be to establish a profile template through which a new missile or missile section would be required to pass. In the case of volume, a missile or missile section might be required to be immersed in an appropriate fluid to ascertain that it did not displace the maximum volume permitted. The latter case would, under proper arrangements, reveal the least detail about dimensional characteristics but generate severe practical problems as to the permissibility of such immersion. Practical problems also arise in using a profile template since missiles usually require obscuring supporting structures (unless vertical) which might require expensive new facilities and procedures at the point of inspection. In fact, these practical problems suggest that simpler methods must be found for dimensional verification. Clearly, the use of photography would be much simpler.

The use of photography with a fully exposed missile or missile section would not only confirm dimensional restrictions in considerable detail but reveal facts about external materials, engines, structural construction and sectioning, access hatches, fueling and protuberances that might be considered too revealing by the party being inspected. As a result, there might be insistence on preventing access to the missile unless it is partially obscured, either by a shroud (as practiced in the U. S. in moving a new military airplane or missile on public thoroughfares) or a container open only at points exposing the missile in less sensitive areas. In the use of a cloth or plastic shroud, the obscuration would serve to confine restrictions to gross dimensions in length and diameter versus length. The use of a rigid container would result in further obscuration and eliminate the intriguing interplay of disguising and counter-guessing the nature of a shrouded missile. A rigid container, depending on its shape and thickness, would probably result in confining restrictions to more general dimensions than the shrouded case.

There is another alternative which would be an even grosser dimensional restraint but might be proposed by the USSR to minimize access to their missiles. This would be to agree to constrain missile dimensions to internal silo dimensions and allow silo inspection only at times when the silo is empty either before original missile installation or between replacement of missiles.

As a practical example of these alternatives, consider the Minuteman. Figure III-7 shows representative dimensional drawings of the Minuteman three-stage propulsion sections (1) fully exposed, (2) shrouded, (3) in a rigid container (such as the transporter-erector), and (4) empty silo, as might be derived from photographs. For the fully exposed missile, much more detail would be available from the photograph than is shown in

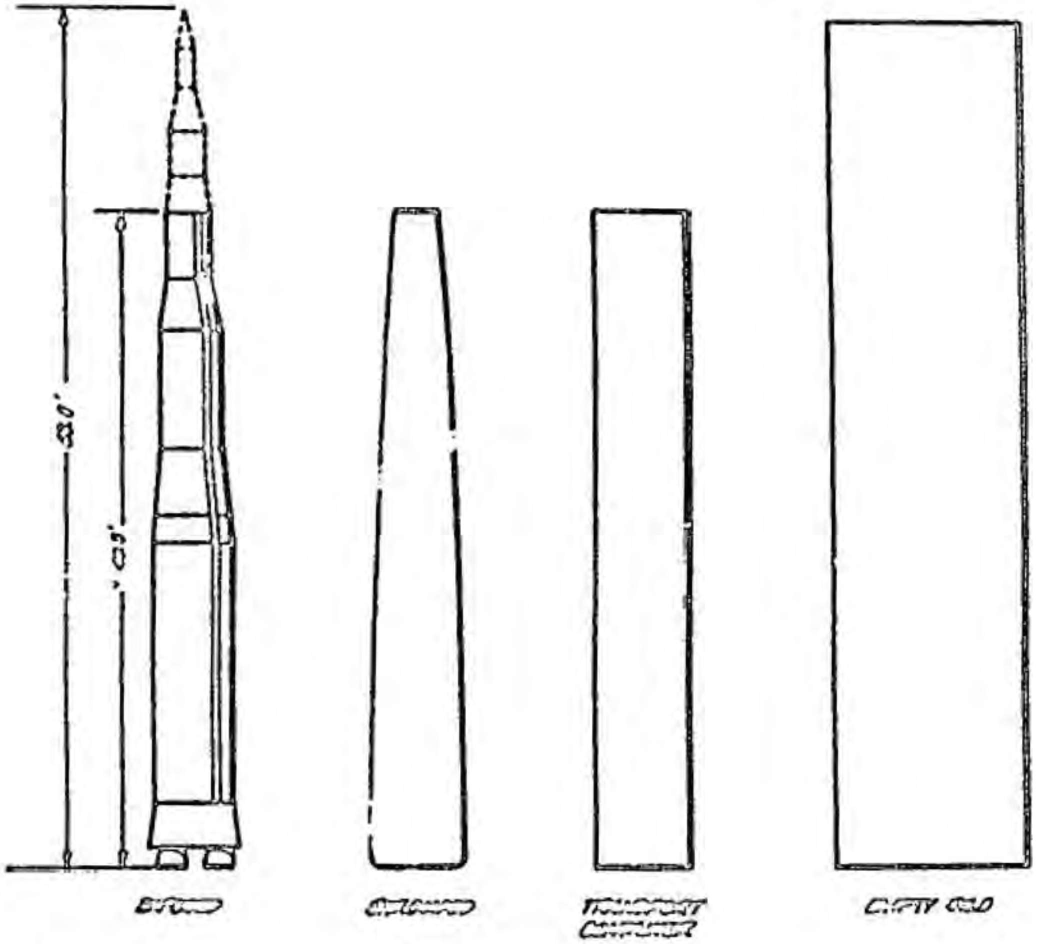


Figure III-7. Possible Derivations of Maximum Missile Dimensions and Appurtenances from Photographs of a Wing VI Minuteman Propulsion Section.

Figure III-7, as is evident from photos in current trade journals. In the shrouded case, it is assumed the missile propulsion section is actually lying in a horizontal cradle as it is transported in an assembly plant. The shapes derived are representative of the dimensional restrictions that might be negotiated. The pertinence of considering access to the missile propulsion section only is that the guidance and re-entry vehicle section on the Minuteman is not installed except at the launch site.

As another practical example, consider the Titan II. In this case, the propulsion stages are not mated until installed in the silo although they are kept in close proximity during transportation. The propulsion sections are never fully exposed except at the production facility or while being checked and installed at the launch site. At one stage in transportation, a tarpaulin is used which discloses sufficient detail to verify gross shape and dimensions by photography. It must be noted that, unlike the Minuteman, the guidance is installed at the production facility and attached within the second stage. Of course, the propulsion sections are transported without fuel.

It is obvious that the shrouded or boxed missile section methods provide more opportunity for changes in an existing missile or the insertion of a new missile design, but there do exist general volumetric and dimensional restrictions that are verifiable as indicated. The shrouding and containing operations can compromise verification by the original insertion of extra dimensions to both conceal the true missile dimensions and provide room for growth in a subsequent new missile. This could be done by the inspection party insisting on using any existing large transport rigs and claiming it was too costly to manufacture new inspection rigs. Another alternative is in using a complete missile and claiming that this is only the propulsion section. Actual negotiations on dimensional restrictions would require considerable analysis of such possibilities.

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The discussion on dimensional restrictions is summarized as follows:

a. Practical considerations in cost and simplicity dictate the use of photography as the most probable verification means of dimensional restrictions.

b. Negotiated dimensional restrictions are only relevant to the missile section to which access for photographic verification has been established. This may involve the complete missile or separate propulsion, guidance, and re-entry vehicle sections. At a minimum, it is assumed that access to at least all of the propulsion sections is required.

c. Photographic access may be with substantially full views of the exposed missile section or limited to photography of the missile or section shrouded in flexible material or enclosed in a rigid container with physical access for identification marking[*] restricted to a limited surface area.

d. Obviously, dimensional restrictions become more gross in relation to the increase in obscurations in visual and photographic access.

e. The diversity in assembly and delivery procedures for different types of missiles and for RDT&E missiles versus production missiles suggests that dimensional restrictions and verification access to new missiles for each class must be individually negotiated.

2. Restrictions on External Materials

It would appear that restrictions on changes in external materials such as the propellant cases might be a candidate for restrictions in new missiles in the hope that this might substantially confine improvements in missile performance. However, the question remains as to whether verification and enforcement of such restrictions is practical.

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[*] This has not been previously mentioned, but is required to verify conformity with restrictions in numbers, whether for production or RDT&E.

In order to verify such restrictions on changes in external materials, substantially greater access to the missile surfaces is required than in dimensional verification. While photography and close visual observation are helpful, missile surfaces are either covered with heat insulation material (for silo firing) or could be easily camouflaged with suitable paints. Thus, physical access to either remove a section of paint or rapping techniques to acoustically identify rocket case material would be required. Even these processes might result in ambiguity in identification and are complicated by negotiating details as to what areas on the missile are accessible.

Further, the missile maker could claim that a new external material, such as in propellant cases, is required because it is cheaper and he can not afford to continue to use the old material of which he has exhausted his supply. This may very well be applicable in our own U. S. experience in changing from titanium cases to filament wound glass. The missile maker might also claim that it would be dangerous to allow physical access to certain materials (such as beryllium interstages used in the Minuteman) due to their high toxicity.

Finally, some materials could be improved with no obvious change in material identification. Maraging of steel rocket cases is an example and is also possible in the future proposed changes in filament wound glass to filament wound boron composite cases.

The complications briefly discussed above suggest that restrictions on changes in external materials, while potentially confining missile performance improvements, are too unwieldy, complex, and subject to severe problems in verification access to be practical.

3. Restrictions on Weight

Weight is a promising candidate for consideration for restriction. Weight is almost always measured by external means, and there exists a long history of the use of weight restrictions from restrictions on vehicles crossing bridges or traversing roads to restrictions on the tonnage of naval vessels as was negotiated at the Washington Naval Conference in 1922. Certainly, weight restrictions require more than a passing glance in relation to ballistic missile controls.

In restricting weight of missiles, not only does the problem of complete missiles versus separate propulsion, guidance, or re-entry vehicle sections arise as was shown in dimensional restrictions, but, in the case of liquid fueled missiles, weighing may be confined to the propulsion section without fuel aboard. This poses some difficulties unless access is negotiated to require the missile or propulsion sections to be weighed in the fueled state. At this point, if insistence on substantial obscuration of the missile is maintained, the interrelationships of weighing possibly empty, partially empty, or fully fueled missiles or only sections of missiles becomes complex. Further, agreements must be established on the accuracy of the weighing method, calibration procedures, etc. With modern scales and weighing methods involving electronic sophistication, the potentialities of evasive action bear study in depth.

Of course, weighing stations could be negotiated at the cost of the inspector, which, being supervised and operated by inspector personnel, might be designed to minimize evasive action. However, for large missile propulsion sections, this certainly appears more intrusive than verifying dimensional restrictions and with the complications of liquid fueling restraints the evasion complications are more severe.

In a practical sense the production Minuteman and Titan II propulsion sections are not weighed in the assembled state but separately and sometimes on a piece parts basis. The production Titan II is not weighed in the fueled state at all, but uses metering and level indicator techniques to establish proper propellant quantities. Thus, there is an

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*Since all known USSR ICBMs are liquid fueled, the problem is pertinent.

element of interference in normal production processes in insisting on weighing of assembled propulsion sections and, again, the additional cost coupled with liquid fueling problems suggests propulsion section weighing as being impractical.

For smaller sections, namely the guidance and re-entry vehicle sections, weighing restrictions may be more appropriate particularly in prelaunch inspection. Less expensive scales are required and the insertion of additional payload (unless intentionally oversubscribed in the declaration stage) subsequent to weighing becomes more difficult. There exists some possibility that a combination of weight and dimensional restrictions on payload sections are required to confine payload improvements in multiple re-entry vehicles.

The preceding paragraphs suggest that weight restrictions are of lesser priority, although not clearly eliminated from consideration, than dimensional restrictions in missile propulsion sections, particularly those which are liquid fueled. However, weight restrictions on the payload stage, either alone or in combination with dimensional restrictions, may be more relevant.

A conclusive reassessment of dimensional and weight restrictions must await an investigation of missile performance improvements versus time that can be expected under different conditions of volume or weight constraints. The subsequent sections will delve into these areas.

4 Missile Improvements with Restrictions

Under volume or weight constraints there exist basic questions in the evolution of possible improvements conforming to these restrictions. This requires a survey of subsystem improvements and their implication in over-all missile performance. At this juncture, it must be pointed out that previous discussion in Volume II[*] of this report has examined subsystem improvements which can and probably could be carried out in "peaceful"

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[*] Volume II, Section V

space programs even if (in the unlikely event that a practical means could be found) restrictions on military subsystems RDT&E were imposed. Thus the investigation of subsystem improvements, at least in structures, propulsion, and guidance, is equally valid for missiles with dimensional or weight restrictions. The problem centers around how these subsystem improvements affect improvement if the missiles or missile sections must conform to the defined constraints. As a base point it will be assumed that the re-entry vehicle is not accessible for verification purposes[*] or there has been an original deliberate declaration of oversized and/or overweight re-entry vehicles to anticipate the expected improvements in payload.

Under this assumption, the motivation exists to improve missile performance by increasing the re-entry vehicle payload as a result of incorporating propulsion and structures improvements that develop with time to be sufficiently reliable and practical.

5. Vehicle and Propulsion Improvements

Fortunately, as a result of recent studies carried out by Aerospace Corporation for USAF,[9] it is possible to show expected improvements in payload versus the estimated dates of initial operational capability (IOC) for volume constrained Minuteman and Titan missiles. The data is for both constant missile volume and constant silo volume, the latter consideration being pertinent to the retrofit of existing U.S. silos in the future and equally pertinent to the negotiation of volume restrictions that are deliberately oversized or where verification access is confined to inspecting empty silos.

Figure III-8 summarizes the results of the Aerospace Corporation investigation recalculated as relevant to this study. The missile

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[*] Normally the re-entry vehicle is not assembled with the missile where the propulsion sections are assembled and is usually the last assembly operation at an operational launch site.

[9] Krause, E., "Future Strategic Missile Concepts", Aerospace Corporation, ATR-269-(S9990)-1, October 1963.

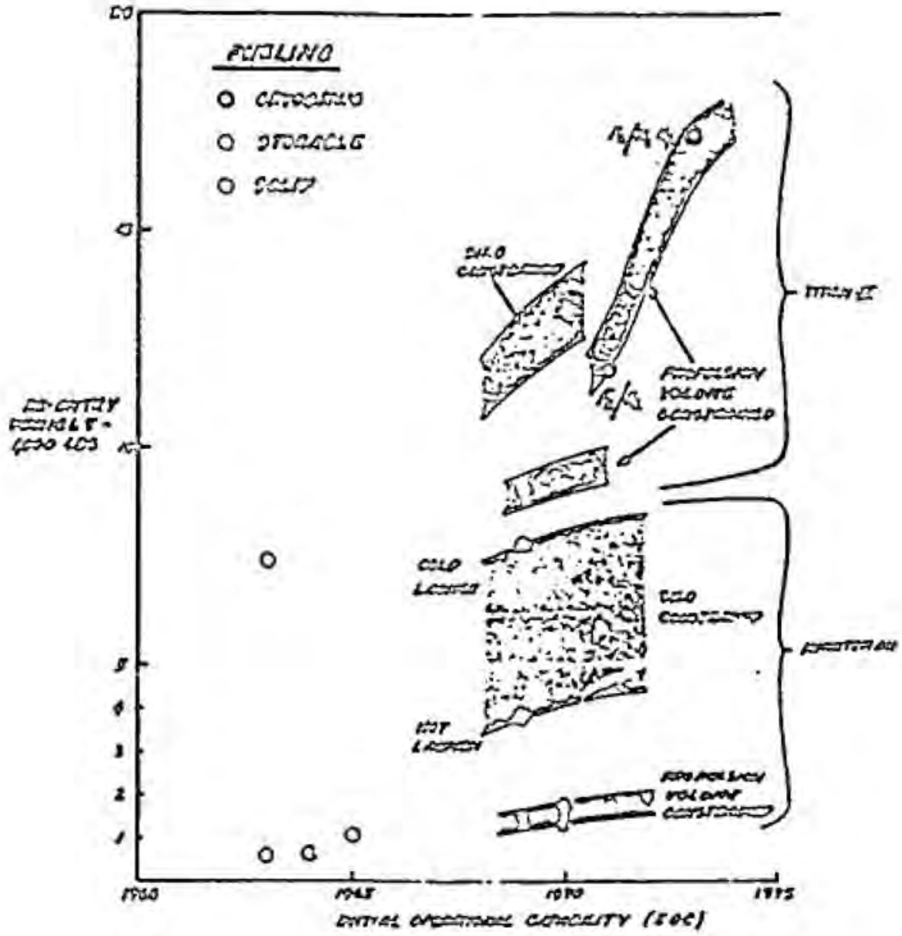

Figure III-8. Re-entry Vehicle Weight Improvements Possible with Time for Minuteman and Titan Type Missiles Under Various Volume Constraints (6500 Nautical Mile Range).

volume constraints are applicable to the propulsion and guidance sections only. Data shown for the Minuteman assume that solid propellants are continued in use. Actually, conversion to storable or cryogenic fuels would increase the payload improvement even further and should be kept in mind as a potential U. S. expedient for the Minuteman not currently available to the USSR.

In the course of these studies it must be emphasized that a multiplicity of factors enter into the process of optimizing the improvements under these volume constraints. For example, this includes such factors as the toxicity and detonation safety of new propellants, the trade-offs in engine sizes and thrust vector control (numbers of engine thrust chambers and gimballing versus fluid injection thrust vector control) versus propellant volume, the compatibility of new engine exhaust conditions in existing silos and the changes required in ground systems equipment both at the launch site and in transportation and fueling. In short, a complete optimization process must be exercised to exploit such improvements under volume constraints that are at least equally as rigorous as the design of a completely new missile system. An appreciation for this process has been demonstrated by Barton.[10]

In Figure III-8, the constrained missile volume is assumed to be that equal to the existing Titan II and future Wing VI Minuteman (less re-entry vehicle volume). Dimensionally, insofar as shape is concerned, there are very minor changes so as to be effectively identical with the original Titan II and Minuteman dimensions where practical negotiated dimensions are concerned. This serves to illustrate the general point that volume and dimensional restrictions are nearly synonymous (which was accomplished in the original missile optimization process and does not vary substantially thereafter).

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[10] Barton, M. V., "Integrated Design Analysis", Space Technology, Chap. 20, John Wiley and Sons, 1959

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It is appropriate to describe the improvements in propellants and case materials in Figure III-8 to appreciate the texture of technological enterprise that must be employed to implement the over-all payload improvements. For the Minuteman whose propulsion volumes are constrained to Wing VI dimensions the 1969 IOC payload improvement would be obtained with structural changes in the utilization of filament wound glass for all stages (only the third stage currently employs a filament wound case), AL/AP/HMX/DB propellants, interstage structures of mag-thorium, redesigned motor nozzles and optimization of chamber pressures consistent with the increased structural strength. For a 1970 IOC, three payload improvements were calculated, the lower value representing a more conservative utilization of essentially current Wing VI technology and the middle value representing all glass cases, interstage structures of beryllium, improved [illegible] single nozzles for all stages and aluminum/nitronium perchlorate with rubber binder (AL/NP/PBAA) for the first and second stages and beryllium/ammonium perchlorate double base propellant (Be/AP/TAZ/DB) for the third stage. As a cross-check on the referenced study, a special computation (upper value at 1970 IOC in Figure III-8) was performed for this report using titanium cases for the first and second stages, AF994 glass for the third stage and high energy propellants (CH$_2$/NP/AL for the first stage and NC/TMETN/IHA/Be for the second and third stages). The first stage would maintain the four swivelled nozzles with the second and third stages using single nozzles with fluid injection thrust vector control. The choice of materials and engines is conservative with the possible exception of the propellants which might delay implementation beyond the 1970 IOC.

For the 1972 IOC the major change involves use of boron fibers for the cases with propellants and other materials the same as for the middle value in the 1970 IOC. As mentioned in the referenced study, this is considered a relatively high risk program.

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For the silo constrained Minuteman (normally designated ICM, for Improved Capability Minuteman) there are two configurations which can be retrofitted in a Wing VI silo. One is an 80-inch diameter hot launch configuration and the other is a 119-inch diameter configuration that would use eject-launch or cold-launch techniques. Payload capabilities are obtained utilizing essentially current technology in propulsion and structures for the Minuteman.

For the propulsion volume constrained Titan II, the 1969 IOC represents the utilization of nitrogen-tetroxide/alumizine 45 as the storable propellant with the conservative use of metal cases. The propellant is a metallized gelled fuel now undergoing testing. However, the development of new handling and cooling techniques will be required for operational use and it is interesting to note, for further analysis, the extensive changes required in external operations during missile installation and fueling.

It is possible that developments in cryogenic fuel handling will overcome the current disadvantages in reaction time and separate fuel supply facilities at launch sites. Thus, in Figure III-8, payload improvements using cryogenic F_2/H_2 for an estimated 1971 IOC, and F_2/N_2H_4 for an estimated 1973 IOC are shown. These propellant combinations are highly toxic and require significant system development.

A silo constrained Titan II-A has been proposed for IOC implementation around 1970 with payload capability as shown in Figure III-8. This system would use the same propellant (N_2O_4/alumizine 45) with a longer propulsion section requiring extensive retrofitting operations to fit in the Titan II silo. There are also possibilities of a cryogenic fueled Titan II-A whose payload capabilities may be estimated by extrapolating the values shown in Figure III-3 for a cryogenic Titan II with propulsion volume constraints.

A word is in order with respect to dates shown in Figure III-8 for an initial operational capability. As presented to USAF, the dates

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represent an initial operational capability (usually defined as ten operational missiles) provided that a firm program is initiated in 1964 or 1965 at the latest. Thus, the IOC date follows the program go-ahead date by four to seven years. Even then, there are increasing uncertainties in the IOC dates for later systems due to the increasing technological uncertainties with time as previously discussed. Obviously, the proposed IOC dates were presented without anticipation of an arms control agreement at all and thus there enters the question of how much an arms control agreement could delay such IOC dates.

At this point, the arms control agreement and its verification provisions must be defined before estimating the extension of the IOC dates. Clearly a multitude of possibilities arise that interrelate with the intent of a nation to legally comply with an agreement but exploit improvements possible within the specified restrictions, evade the agreement, or unilaterally place further restrictions on itself to refrain from exploiting even legal improvements in payload. As an example, and bordering on speculation, if verifiable dimensional restrictions on missile propulsion sections were agreed upon (and current RDT&E flight test rates were allowable), and it was the intent of the U. S. to legally exploit payload improvements, it is estimated that the IOC dates shown in Figure III-8 would be delayed only by a time commensurate with the uncertainties in U. S. planning during the negotiation process. However, the operational life of the Titan II and Minuteman is three and seven[a] years, respectively, and the missiles must either be replaced by (1) newly produced missiles of the same configuration, (2) a new missile system, or (3) expand another system in the absence of an agreement or with an agreement freezing at existing numbers. These decisions must be made in the next few years to avoid an eventual rapid attrition in force structure around 1970. Thus, if the intent were to exploit payload improvements, the IOC dates in Figure III-3 cannot be delayed too long.

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[a] Official Minuteman life is stated as three years for the propulsion stages, but recent experience has suggested lengthening this to seven years.

6. Volume Versus Weight Restrictions

Would weight restrictions in the missile propulsion section be more confining in restraining payload weight increases and thus more productive to arms control even though verification is more complex and costly? On examining this problem, it was found that there is a difference in results depending on whether the missile is liquid or solid fueled.

In the Minuteman volume constrained case (referring to Figure III-8) there were both slight increases and decreases in propulsion weight associated with different calculated payload values shown. Restricting these weight increases would reduce these payload increases only slightly and, if volume restrictions were not present, weight restrictions alone would allow the use of propellants and c[illegible] with smaller bulk density but of larger dimensions so that the end result would be to cancel out these slight payload degradations. Thus, for solids there is not a significant difference in weight or volume restrictions in restraining payload weight increases.

In the case of the Titan II, Figure III-9 shows gross payload factor improvements using different propellants for volume constrained missiles referenced to the current Titan II. Note that the use of O_2/H_2 propellant, which gives a substantial increase in specific impulse, actually results in reduced payload performance under volume constraints. This is due to the lower bulk density of O_2/H_2 and a larger missile would be required to exploit the advantages of such fuel. Some appreciation for this may be derived from the large size of the Saturn launch vehicles which use O_2/H_2 in the upper stages. This may be further appreciated by referring to Figure III-9 which shows that if the Titan II propulsion stages were only weight constrained then O_2/H_2 could be used at an earlier time period to realize a payload weight improvement of about 260 per cent. Of course, the missile volume must increase substantially.

This assessment of weight restrictions in conjunction with the practical problems discussed previously, suggests that weight restrictions

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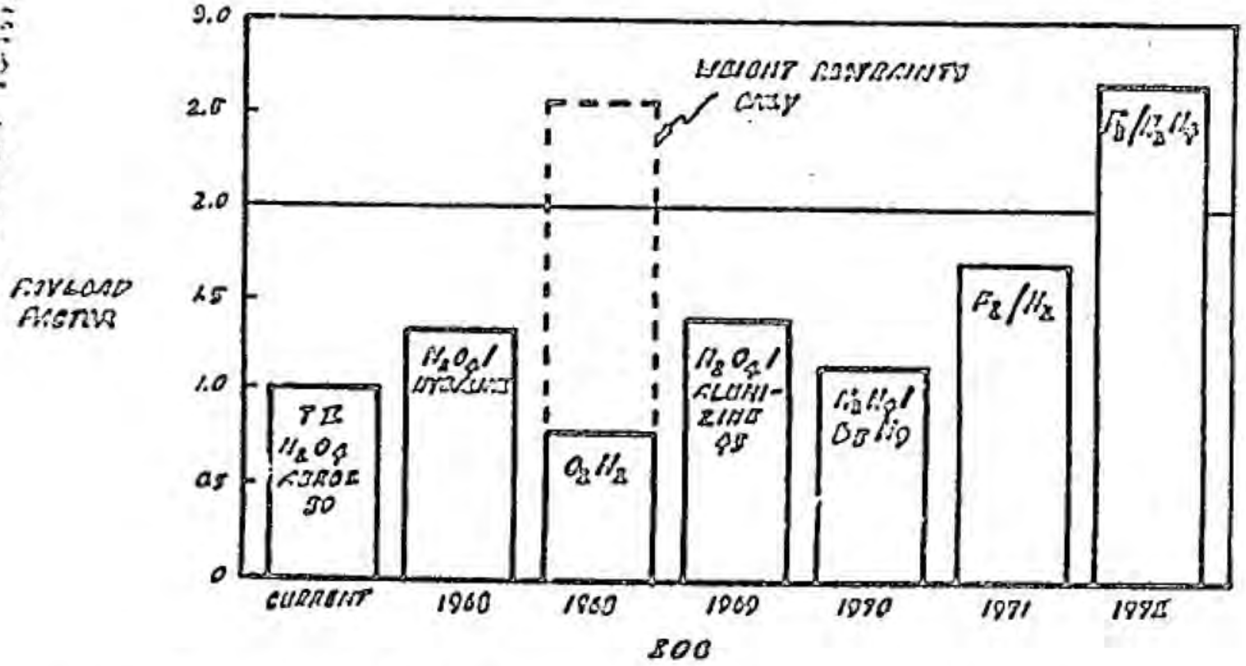

Figure III-9. Impact of Liquid Propulsion Technology Relative to a Volume-Constrained Titan II Propulsion Envelope.

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for missile propulsion sections is impractical and expensive to verify with little gain in confining improvements such that it should be eliminated from consideration. This is not to eliminate weight restrictions on payload, however, which must receive further analysis.

7. Accuracy

Dimensional and/or weight restrictions on the missile guidance section do not appear to have any effect on limiting missile improvements in accuracy. If anything, the trend is toward reduction in weight and volume of the guidance equipment, although a later discussion on multiple re-entry vehicle guidance may reverse this trend. Thus, the forecast accuracy improvements previously analyzed[*] without restrictions are still valid, at least for single re-entry vehicles.

Since Minuteman improvements have been discussed in this section, it is relevant to refer to Table III-2 which shows current accuracies forecasted for Wing VI Minuteman and estimated 1970-1975 accuracies exploiting expected improvements in both guidance and nonguidance errors. The last column in the table is for an inertial guidance system used to guide during the re-entry portion of the flight. The bottom row shows the current Wing VI payload and the payload for a propulsion volume constrained improved Minuteman for various lofting angles at 5500 nautical miles range. With the exception of the last column, the accuracies shown are expected to develop with normal growth in performance using the current Wing VI guidance system.

These accuracy improvements create a motivation to consider smaller yields for the same kill probability and, in an environment where the numbers of missiles are not restricted, could make the small ICBM particularly attractive. But what of the situation where numbers of missiles are restricted along with the dimensions or weight? With improving accuracy

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[*] Volume II. Section V

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Table III-2. Error Budget for Wing VI Minuteman (5500 Nautical Mile Range).

Error Source	Mid-1965 (feet)	1970-1975 Not Lofted ρ = 20° (feet)	1970-1975 Lofting ρ = 30° (feet)	1970-1975 Lofting ρ = 40° (feet)	1970-1975 Lofted and Inertial Re-entry Guidance (feet)
Inertial System	1630	750	640	620	650
Geophysical and Geodetic	} 2250	350	280	250	250
Re-entry		680	370	260	250
Targeting	300-5000	250-600	250-600	250-600	250-600
Total CEP	2900-5700	1100-1200	830-1000	760-930	700-960
Payload, lb	1080	2140	1830	1260	1030

there is little motivation to utilize the expected payload increase to increase yield with a single re-entry vehicle, particularly for counterforce purposes. Brute yield increases for increased population destruction might be attractive for a finite deterrent improvement but hardly provides the flexibility in posture that might accrue if both accuracy and payload improvements were exploited. Thus the use of multiple re-entry vehicle payloads develops as a serious consideration.

[illegible]. Multiple Re-entry Vehicles

Until recently the potential difficulties in guidance using multiple re-entry vehicles deterred serious proposals to implement the delivery of multiple warheads to separately targeted targets. Consequently, multiple re-entry vehicle effort has been centered on (1) exploiting payload improvements in penetration aids to confuse and saturate potential enemy defenses, and (2) using multiple nuclear re-entry vehicles of lesser yield to pattern-bomb certain targets more effectively. Currently, re-entry vehicles are being designed to employ flexibly (with various optional configurations) a mixture of penetration aids and nuclear re-entry vehicles for the Minuteman and Titan missiles. With 350-pound nuclear re-entry vehicles, one may estimate that up to three such re-entry vehicles could be delivered from the Wing VI Minuteman and fifteen from the Titan II. However only a single target is attacked.

While the difficulties of multiple targeting have not yet been fully resolved or studied in sufficient detail, there exists some optimism not prevalent heretofore. Two methods are available, (1) individual guidance packages for each re-entry vehicle and (2) one master guidance system or "bus" which individually targets and releases each re-entry vehicle as required. The first method suffers from introducing guidance weight at the expense of nuclear weight and thus partially counters the expected payload increases. The second method is less demanding of guidance weight increase but at a potential loss in accuracy, although there are recent claims of no loss in accuracy in pursuing this method in conjunction with some lightweight strap-down guidance components on each re-entry vehicle. At any rate, developments have taken on the aspects of practical possibility and it is relevant to examine combined payload improvements of the Minuteman and Titan II missiles by calculating the maximum number of re-entry vehicles that could be obtained per missile versus IOC. Note that separate targeting is not necessary per se and that such multiple re-entry vehicles may be advantageous in pattern bombing of one target area.

Figure III-10 depicts these calculations for a 450-pound re-entry vehicle.[a] Since the technology for separate targeting is not expected to develop for operational deployment until after 1970, the multiple re-entry vehicles possible before 1970 are only for pattern bombing. Thus, Figure III-9 indicates that the Minuteman could increase to three or four 350 to 450-pound re-entry vehicles while an improved Titan II could start in 1970 with twenty re-entry vehicles. Since the Titan II is more relevant to the USSR missile., this is particularly important.

It must be added that while the re-entry vehicles are separately targetable, their area of potential deployment is obviously constrained. Currently, this is thought to be an elliptical area restriction of approximately 200 miles (crossrange) by 500 miles. Even this area is sufficient to blanket ICBM basings at least at wing level or greater.

Thus, an improved Titan II with twenty re-entry vehicles and 1970-1975 separate targeting capability with accuracies approaching those in Table III-2 is equivalent to twenty current Minuteman missiles targeted within the same elliptical area mentioned above.

It must be further noted that the values shown in Figure III-10 are, in general, for 6500 nautical miles range and for lesser ranges (which are more pertinent to a majority of USSR targets from northern U.S. based

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[a] The extra 100 pounds allotted is for additional weight in propulsion and guidance required to maneuver for separate targeting using the "bus" concept.

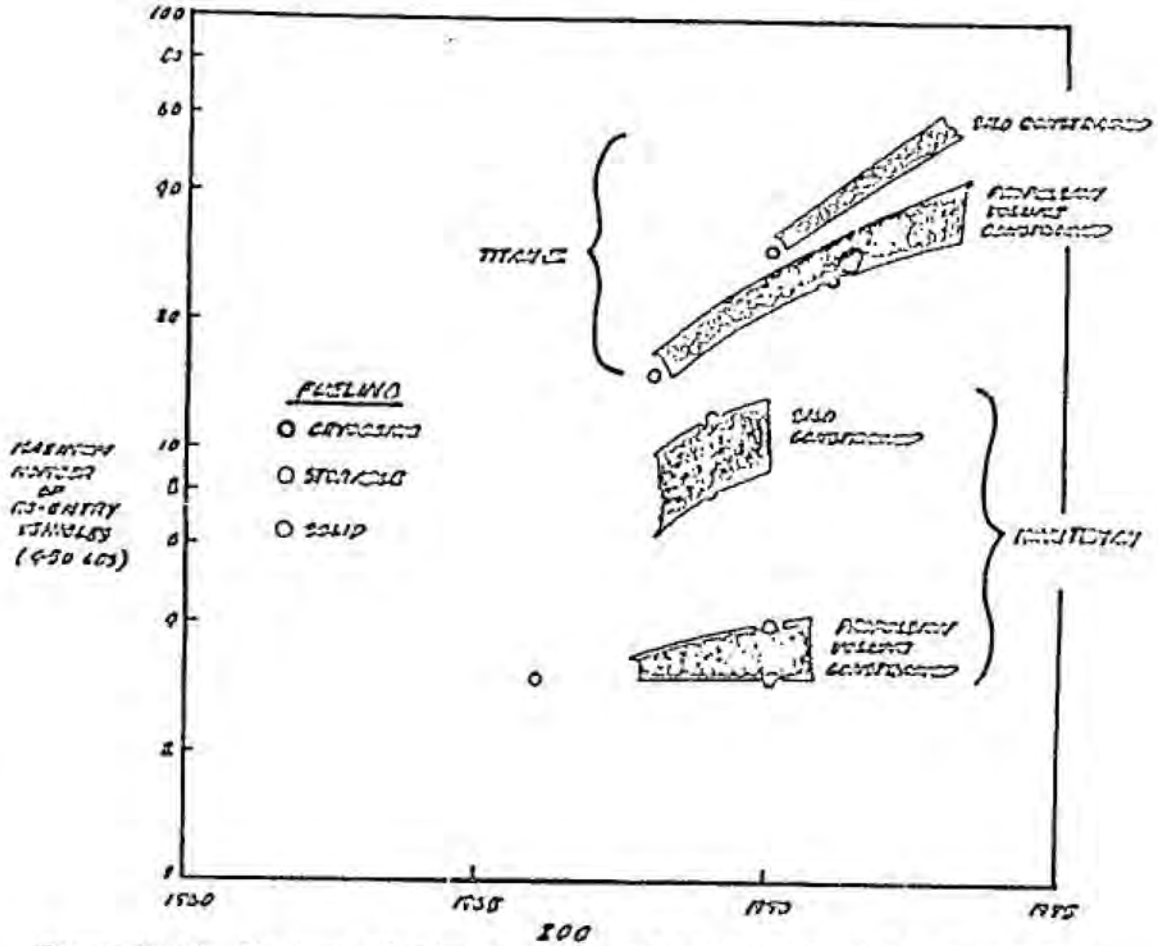

Figure III-10. Maximum Number of 450-Pound Re-entry Vehicles Versus IOC for Minuteman and Titan Type Missiles Under Various Volume Constraints.

sites), a substantial increase in the number of re-entry vehicles is possible (for example at 4500 nautical miles, the current Titan II payload may be increased by 40 per cent over that at 6500 nautical miles).

If increased yield is desired for hard target destruction by doubling the re-entry vehicle weight, then one-half the number of re-entry vehicles shown in Figure III-10 are possible. This would still mean ten multiple re-entry vehicles of substantial yield for the volume constrained Titan II. These potential developments have profound implications in agreements which would restrict numbers of missiles but that might be avoided by multiplying the number of re-entry vehicles. Certainly there must be some consideration of restricting re-entry vehicle improvements with proper verification access to the re-entry vehicle itself.

9. Implications of Verified Restrictions on Re-entry Vehicle Improvements

The salient problem in a verified restriction of re-entry vehicle development and production is access to verify the provisions of such an agreement. If access to production and assembly facilities is denied, then indirect means such as the observation of flights must be used. However, the U.S. is currently flight-testing multiple re-entry vehicles along with penetration aids, weakening the USSR case for a restriction on flight testing unless the U.S. offers not only to "freeze" but revert to single re-entry vehicle tests without penetration aids. However, even with such a restriction, there remains the potential of developing multiple re-entry vehicles by separate flight tests of single vehicles. Granted that there is less incentive for the U.S. to evade under such restrictions (particularly where restrictions on the number of flight tests are involved and a positive verified agreement is made to "freeze" the expansion of USSR defenses), there is still the problem of the USSR incentive with their nonparity in numbers of deliverable re-entry vehicles. This is particularly difficult if the U.S. insists on the scheduled deployment of its multiple re-entry vehicle systems and penetration aids, since the U.S. might argue that multiple re-entry vehicles are desirable as AICBM insurance. With the potential evolution of separate targeting, which does not appear to be amenable to verification of restrictions without the most detailed and intrusive form of inspection, the problem multiples in complexity.

There are a multitude of possible restrictions that could be negotiated for re-entry vehicles. Some possible restrictions are as follows:

a. "Freeze" at the operational status quo declared on a given date with replacement confined to strictly specified types and characteristics of re-entry vehicles. At the moment, verification appears to require detailed and periodic inspections of the re-entry vehicle itself at the flight test and operational launch site and also inspection of the impact area during test firings, since the re-entry vehicle is assembled to the missile at this point with rare exceptions. Under the above conditions, there would be in existence a number of U.S. missiles with multiple re-entry vehicles and penetration aids. Further, it would be absolutely necessary for the U.S. to insist on a verified restriction to prevent the expansion of USSR defenses and would also require the continued inspection of research and development and production activity to reasonably verify the absence of clandestine action to produce and stockpile prohibited re-entry vehicles for rapid installation on missiles subsequent to an abrogation of the arms control agreement.

b. A prohibition and destruction of multiple re-entry vehicles and penetration aids in exchange for a dismantling of USSR missile defenses. Verification would, of course, require inspection to at least the detail specified previously.

c. No restrictions on modifications on re-entry vehicles other than verified dimensional restrictions of missile propulsion sections. This would restrain the use of re-entry vehicles within the payload weight increases that could be expected with such dimensional restrictions but allow the continued development of multiple re-entry vehicles and eventual separate targeting. Under such circumstances, a missile technology race could ensue depending on the suspicions of each side.

d. Dimensional and weight restrictions on re-entry vehicles with periodic access to the operational vehicle for verification. This would require detailed declaration of numbers deployed, external dimensions, weights, and detailed negotiations on replacement rules. Obviously, declaration of deliberately oversized re-entry vehicles using inexpensive dummies is possible if evasion is planned. Further, without internal access, multiple re-entry vehicles might be inserted clandestinely although confined in implementation to the shape originally declared.

10. Restrictions on Changes in Propellants in Combination with Dimensional Restrictions

Since the previous analyses have shown that even with dimensional restrictions on missile propulsion sections there are potentially substantial payload improvements that can be implemented with time, how about restricting changes in propellant in combination with dimensional restrictions to further confine such payload improvements? While propellant restrictions are clearly a restriction on internal materials, there are possibilities of reasonable verification of compliance with propellant restrictions, if access is granted to observe propellant loading operations for all missiles and spectroscopic photography of test firings is permitted.

An initial appreciation of payload improvements that are both volume and propellant constrained in the propulsion sections can be derived by referring back to Figure III-8. It may be remembered that for the improved Minuteman in the 1970 IOC (middle value) to the improved Minuteman in 1972 there was no change in nozzles, interstages or propellants except for the second stage, but that the cases were changed from glass to boron fibers, with a net reduction in over-all structure factor of approximately 0.006

to 0.034. Using the approximation previously derived[*] we may calculate, using the same propellants, the percentage payload improvement to be less than 5 per cent. Of course, improvements in engine efficiency, engine specific weight, and some redesign to squeeze out more propellant volume could raise this slightly but it is evident that a severe restraint has been placed on payload improvement by such restrictions on solid propellant missiles.

With reference to the volume constrained Titan II in Figure II-9 the Aerospace Corporation study for USAF (previously referenced) estimates that metal cases would still be required for the foreseeable future and thus no appreciable improvement in structure factors could be obtained. With a restriction on propellant changes in addition, gross payload improvements would be severely constrained at least through 1975. One possibility would be to develop a lightweight guidance system for the Titan II (the guidance system is fairly heavy) to gain a re-entry vehicle payload improvement at an earlier date.

Since the Titan II is most closely related to the USSR SS-7 in estimated characteristics, one is tempted to apply the above Titan II observations directly to the SS-7. Care must be exercised, however, in such a natural inclination, since the SS-7 appears to have a poor structural factor now with more to gain than the U.S. in exploiting case and engine improvements even with the same propellants. Further, the SS-7 is estimated to be approximately 20 feet longer than the current Titan II although of about the same diameter, giving a basic volume advantage in a dimensional restriction agreement.

The above analysis is only introductory in nature and has involved approximate calculations that may or may not be proved correct with detailed analysis. However, the indicated severe restraints in payload improvement with combination volume and propellant restrictions,

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[*] Volume II, page 128

coupled with less intrusive inspection arrangements that might be involved with re-entry vehicle inspection, merits such further analysis. The problem of multiple re-entry vehicle development for existing large payload missiles such as the Titan II and SS-7 still remains, however, although to a lesser degree.

While additional access is required to verify restrictions on propellant changes, such access appears more related to access requirements for dimensional restrictions on missile propulsion sections. Further, for liquid propellant changes, it has already been noted that substantial changes in ground systems fuel handling equipment is required. Possibilities for evasion exist as always, but for the propellants surveyed so far, the evasion operations would be quite expensive if given proper access for verification as indicated above.

11. Conclusions

A marshalling and assessment of the previous discussion is in order. For this purpose, Table III-3 shows a summary of possible negotiated restrictions, improvements possible, verification comments and a general assessment of the feasibility and practicality of the various restrictions. Restrictions are shown in order of estimated effect in restraining payload improvements.

While the table indicates general assessments, it is clear that the complexities of different situations, depending on the initial conditions of missiles under negotiation, can vary widely with asymmetric relations vis-a-vis the USSR. Specific force structures need analyzing with specific numbers and characteristics of missiles based upon the latest intelligence.

From the table, it appears unfortunately true that, for the moment, to even reasonably verify restrictions on the total number of deliverable nuclear re-entry vehicles it would be necessary to internally

Table III-3. Summary Assessment of Restrictions on Ballistic Missile External Characteristics.

Possible Negotiated Restrictions ([illegible] order of [illegible])	Payload Improvements Possible (while legally complying with restrictions) Liquid Propellant	Payload Improvements Possible (while legally complying with restrictions) Solid Propellant	Verification Comments (assuming proper access)	General Assessment
[illegible]				
Weight	[illegible] weight increase (1)	About same as volume restrictions	Not normal procedure	Not recommended
External Materials Changes	Substantial weight increase	Substantial weight increase	Ambiguous, physical contact with missile required	Impractical, involves too much detail and [illegible]
Volume and Dimensions				
[illegible] "box"	200-[illegible]% weight increase (1)	200-[illegible]% weight increase (1)	Empty silo or "box"	Generally practical
Exposed or [illegible]	50-[illegible]% weight increase (1)	50-[illegible]% weight increase (1)	Photographic verification possible	Deserves serious consideration. Increase in payload and multiple reentry vehicles still a serious problem
Combination of Dimension and Propellant Changes	5-[illegible]% weight increase (1)	5-[illegible]% weight increase (1)	Requires observation of all propellant loading and propellant sampling [illegible] observation of flight tests	Good potential, deserves [illegible] analysis. Multiple reentry vehicles still a problem
[illegible]				
[illegible]	Some payload accuracy improvement as with no restrictions except possibly time constraints on eventual separate targeting of multiple reentry vehicles		Possible	Not recommended
[illegible]				
[illegible]	Dependent on amount of [illegible] reentry vehicle [illegible] stage		Periodic reentry vehicle [illegible] at all launch sites	Questionable; multiple reentry vehicles a problem
Weight	Same as above with [illegible] weight but more difficult to predict		Periodic weighing at all launch sites; costly	More pertinent, multiple reentry vehicles a problem
Weight and Volume	Same as above with [illegible] weight [illegible] more difficult to predict		Photos and weighing both required	Most pertinent [illegible] multiple reentry vehicles [illegible] but still a problem
Number and Type of [illegible] Reentry Vehicles [illegible]			Periodic internal access to or radiographs of all reentry vehicles required at launch sites	Only apparent solution to multiple reentry vehicle problem at this time appears [illegible] to negotiate

(1) [illegible] missiles might [illegible] greater payload weight increase [illegible]

SECRET

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

inspect each re-entry vehicle at all launch sites on a periodic basis. The next best alternative is to restrict the weight and volume of all re-entry vehicles with less re-entry vehicle access required as indicated. If access to re-entry vehicles is denied under all circumstances, then the most pertinent verifiable restriction appears to be combined volume and propellant restrictions on missile propulsion sections, although USSR missiles might not be sufficiently constrained, dependent on further analysis. Further, the opportunities for multiple re-entry vehicles with eventual separate targeting in even existing missiles remains a serious problem.

C. Fiscal Practice as an Aid to Disarmament Inspection

The [illegible] es of finance are almost as old an institution as war. In fact, the use of the former to support the latter has almost always been the rule. It is the purpose of this section to explore the feasibility of the inverse relationship; can the science and practices of finance, under an arms control treaty, be used to detect clandestine violations of the treaty?

The various elements of finance cover such a large area of application and their manifestations are so numerous and diverse that it is difficult to encompass the subject in an over-all definitive concept. Primarily, our consideration will be limited to the area of public finance, i. e., government fiscal systems whose essential purpose is to control public monies, keeping in mind that the term "monies" also denotes a somewhat extensive and even elusive concept. The British economist, Ralph Hawtrey,[11] is well known for his statement that, "Money is one of those concepts which, like a teaspoon or an umbrella, but unlike an earthquake or a buttercup, are definable primarily by the use or purpose they serve." But it is the universal character of money which prompts consideration of fiscal practice as an aid to disarmament inspection. The many uses of money, not just as a medium of exchange but as a means of measuring, storing and controlling social energy, make it as essential to the generation of endeavors as language is to the generation of ideas.

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[11] Hawtrey, Ralph G., "Money and Credit"

Money, as a means for releasing social energy, is a source of power, which is a function of governments to wield. In order to control power, governments employ fiscal systems as a significant part of the governmental process. Typically, fiscal systems may be divided into three main functions: the collection, distribution and expenditure of public funds. The collection of funds is largely obtained through taxation and borrowing, with somewhat smaller revenues available from various government enterprises. The distribution of funds is provided by the creation of the budget which, however determined, constitutes the plan to be accomplished. In turn, the expenditure of funds is the process by which the government plan is actually implemented. These functions are controlled largely through accounting practices which involve the classification and measurement of the monetary value of all government transactions and which are recorded in the form of fiscal records. It is a necessary requirement that fiscal methods of bookkeeping exhibit a balance of appropriations to expenditures and that evidences of each are maintained. Further control is exercised by performing an audit of records, in which proofs of payment, verification of goods and services and the appropriate use of funds are determined.

In limiting consideration to government fiscal systems, it is true by definition that the use of financial practices and the monitoring of fiscal data would not detect clandestine activity carried out independent of the governmental fiscal system. This is probably not a major shortcoming to the use of fiscal inspection, since it is difficult to conceive of many methods of clandestine activity which could operate effectively without both the knowledge and participation of the government. If this is true, it is highly probable that a government would have to resort to the manipulation of fiscal records, which would theoretically admit the possibility of detection by fiscal inspection.

For purposes of discussion, let us construct from plausible assumptions a case of arms treaty violation which would not be either too easy or too difficult to evade or detect. Let us suppose that an inspection team is operating within the United States using fiscal data and that a concealed research and development project is being conducted. Further, let us assume that the purpose of the project is to improve an ICBM within two years at an average annual expenditure of $100 million. Assume also that the United States environment is roughly the same as is now current, i.e., nationalism is fairly widespread, individual rights and purposes are as we know them, the over-all size of the budget has not diminished and fiscal data is available (not only the fiscal data which is now published, but the detail budgets and accounts of any government agency).

An open society such as the United States is chosen for several reasons. In the first place, if evasion is probable here, it is more so in a closed society. However, any advantage to inspection that an open society provides is more than offset by the large over-all size of the U.S. budget. In fact, as Jesse Burkhead[12] has shown, budget size is a critical factor in assessing the feasibility of fiscal inspection.

A research and development project (with emphasis on development) makes a good median for discussion, since research alone would probably be too difficult to detect, whereas production would be too easy. In assuming the development of an ICBM, it should be stated, since the state-of-the-art is already somewhat developed, that the intent of the project would be to appreciably improve over the guidance, payload, evasive tactics, etc., of existing weapons. Although it is felt that this is not possible with an expenditure of $200 million within two years, it would be such a breakthrough that would make evasion tempting.

The U.S. Government fiscal practice comprises an effective system of financial responsibility. Income is stringently monitored by the Internal Revenue Service and other bureaus within the Treasury Department; the Bureau of the Budget is authorized to critically review requests for funds

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[12] Burkhead, Jesse, "The Control of Disarmament by Fiscal Inspection"

and to give continuing attention to the execution of the budget, and authorizations and appropriations are granted on a basis of detailed study by the Congress and its subcommittees. A governmental structure has evolved to cope with the problems stemming from an increasingly complex financial environment.

However, while these organizations display a determined role in the receipt, budgeting and appropriations phases of the fiscal system, they have virtually no direct control over the expenditure of the appropriated monies. A limited extent of indirect control is available to Congress in the "post facto" investigations carried out by the General Accounting Office and special Congressional hearings. But the responsibility for the spending of the money lies largely with the heads of the various government agencies and it is with a good deal of freedom that they decide upon the ultimate expenditure of the appropriated dollars. It is a fairly common occurrence for programmed funds for one project to be transferred to another project. In hearings before the Senate Subcommittee of Reorganizations and International Organizations, which is an arm of the Committee on Government Operations, Dr. Harold Brown testified to the influence that the military services employ in "...changing a program to meet changing conditions" and stated that "...almost 20 per cent...of the RDT&E funds within the Department of Defense are moved from one item to another item."[13]

Research and development, in general, are dependent upon long-range planning and appropriations are made to "longevity funds" which are intended to be expended over a period of years. Supplemental appropriations to these "no year" appropriations are not uncommon. This latitude in reprogramming funds and supplemental appropriations is especially evident in the areas of research and development where a dynamic technology affects the progress of a project.

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[13] Federal Budgeting for Research and Development, Hearings before the Senate Committee on Government Operations, Part I, 1961.

The problem of fiscal evasion involves two major possibilities, the diversion of income or the diversion of expenditure. Diversion of income presents a somewhat unique method in that a single service within the Department of the Treasury seems to hold the key. Within the Internal Revenue Service, and more specifically within the offices of the Commissioner and several of his assistants, is concentrated most of the operational mechanism for not only enforcing the collection of income, but also the generation of the records that depict the collection process. While it is not intended to imply that this creates any weakness or inefficiency in the system under current or normal conditions, in a hypothecated government-sponsored evasion the actual number of active participants could be quite small. The offices of Assistant Commissioners for Data Processing, Compliance, Inspection, and Technical Assistant to the Commissioner exert more than sufficient policy and practice to permit a quite sizable income diversion, with very little evidence of evasion appearing at levels above the Internal Revenue Service.

The relationship of financial practices to actuality is strongest in the realm of expenditures. A fundamental concern of auditing is the result of an expenditure and it is the expectation of an audit to realize tangible products or services. While the major emphasis in utilizing financial practices to detect clandestine research and development should be directed toward analyses of the expenditures, budgetary data provides an assemblage of information pertinent to advanced governmental planning and may well be used to designate areas for inspection.

In assuming that $100 million, which represents one-tenth of 1 per cent of the 1964 federal budget, were to be diverted from normal avenues to finance a clandestine effort, one can consider the feasibility of two diversionary methods.* These two methods depict techniques at opposite ends of a spectrum of diversionary tactics with a variety of related methods interposed.

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*It is thought that the cost of the A-11 development program was about $100 million.

The first method entails a distribution of proportionate parts of the diverted sum to many agencies and departments whereby the allocations to the organizations contain relatively small and equal percentages of "padding." The padding ratio of each organization's funds remains approximately equal to the ratio of the total diverted sum to the total federal budget, or very nearly one-tenth of 1 per cent. In this instance, since a large number of organizations would be involved, an auditing of the organizations at random would provide an increased possibility of detection. However, the percentage of the money being diverted by each of the organizations retains a diminutive significance and is equitable to all the organizations and could probably be made plausible to the auditors. A major fault of this method (which is, incidentally, external to fiscal data) is the involvement of a large number of people, but if granted their dedication to the accomplishment of the goal, fiscal detection of this method would be highly improbable.

The second method employs a more restrictive, hierarchical padding of accounts and entails the participation of fewer organizations. In this method, a funneling type of fund distribution exists in which the magnitude of allocations to departments diminishes conjointly with the hierarchical level of the organization. As the "funnel" narrows, or as the organization becomes more subordinate, the magnitude of the allocation decreases, but the diverted sum becomes a more significant percentage of the funds allocated to the organization. This technique entails a lesser degree of clandestine financial organization since fewer departments and people are involved, but the degree of responsibility and the difficulty of explaining the purpose of the funds increases as the hierarchical relationships decrease.

Figures III-11 and III-12 are useful in illustrating the difficulty of attempting to detect $100 million hidden within the total U. S. budget. Figure III-11 shows a section of the federal budget breakdown of new obligational

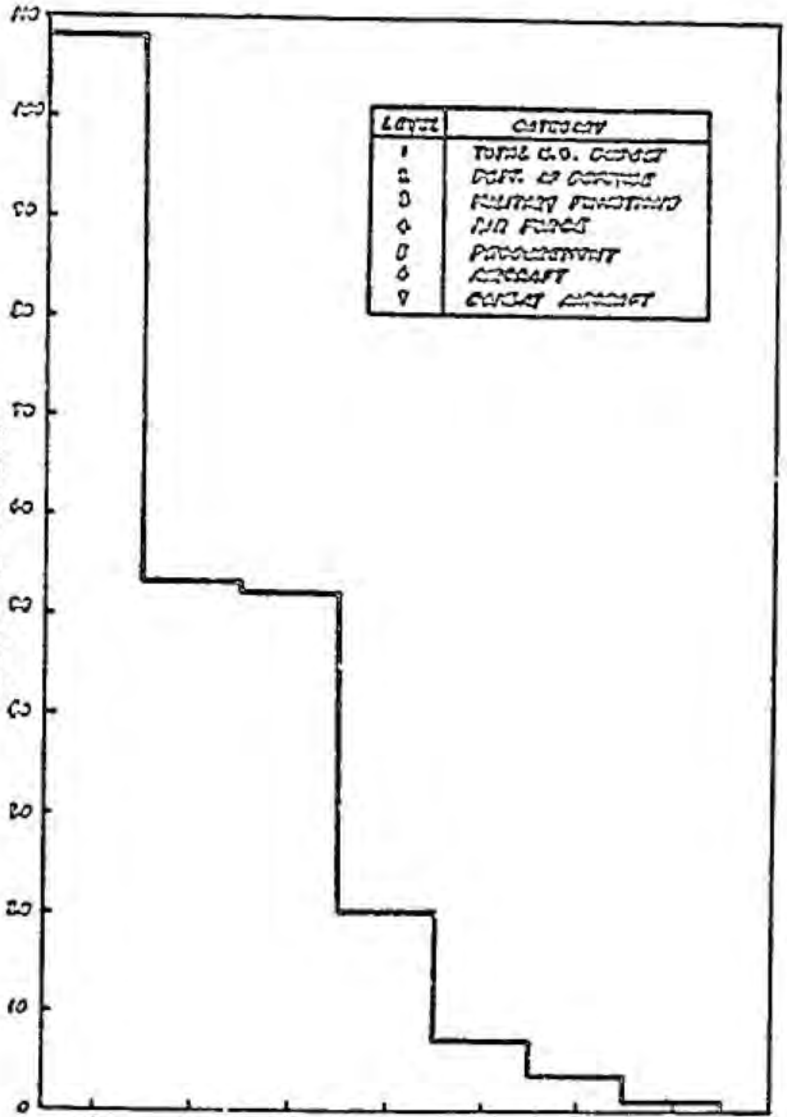

Figure III-11. New Obligational Authority Versus Highest Organizational Level Budget.

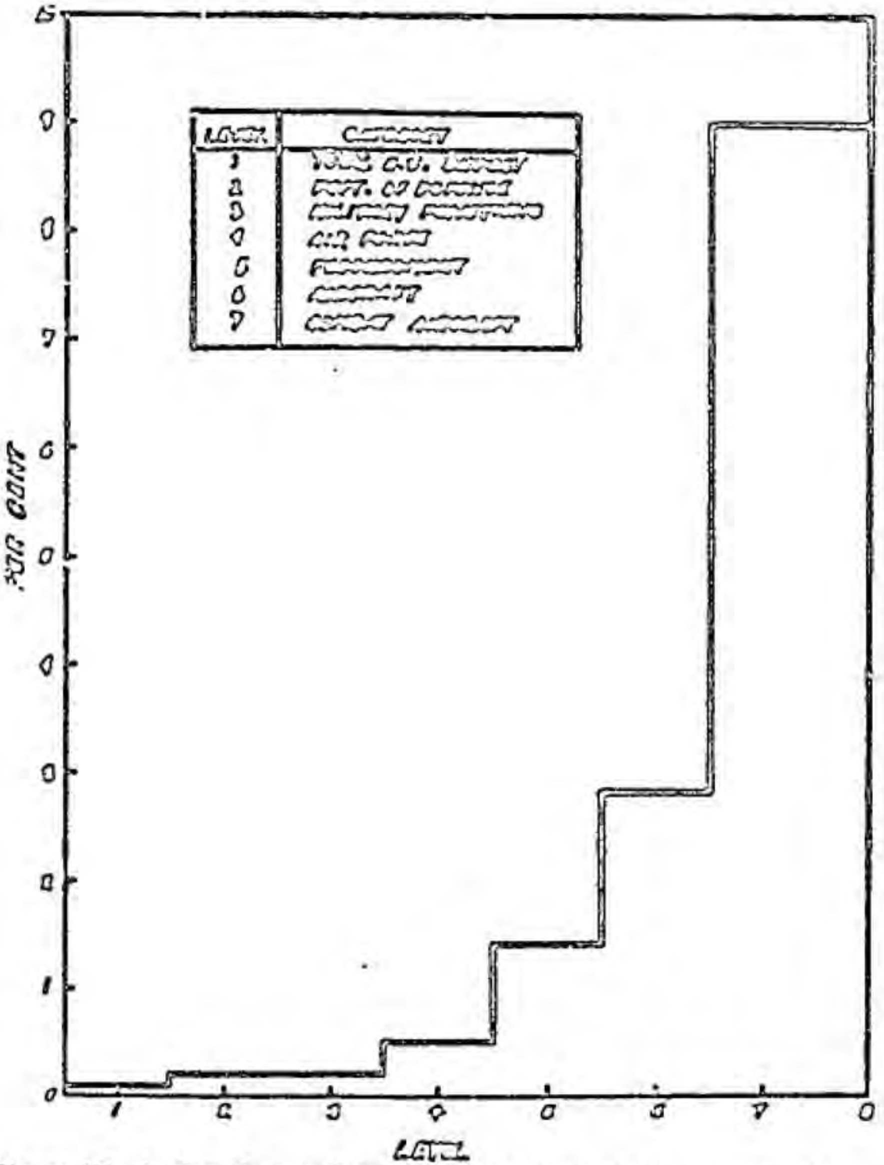

Figure III- 1 Per Cent of $100 Million to Highest Organizational Level Budget.

authority over the Department of Defense, DOD military functions, Air Force, Air Force procurement, etc., and exemplifies the funneling of funds through a hierarchy of organizations. This particular organization breakdown has been chosen because it represents the largest budgets on each level which in turn makes it the most difficult case. It can be noted that the magnitude of dollars diminishes quite rapidly through seven levels of organization from $108 billion at the first level to approximately $1 billion at the seventh level. The new obligational authority to the Defense Department is roughly one-half of the federal budget. The DOD military functions receive almost the total DOD allocation, of which 38 per cent is distributed to the Air Force. The Air Force in turn budgets about one-third of all its funds for procurement. As shown on level six, approximately one-half of the procurement funds are directed to aircraft procurement and 29 per cent of aircraft procurement is for combat aircraft on level seven.

The rapid decrease of budget magnitude would indicate that the prospect of isolating "unreasonable" funds might be promising. However, Figure III-12, in projecting the $100 million percentage of the total at the seven levels, shows that $100 million is still not too significant in each budget even though the percentages increase appreciably from 0.1 per cent at level one to about 9 per cent at level seven. While the increment of the percentage between levels takes on a factor of 2 through the first six levels, the percentage does not reach a point of dominant significance until the seventh level, and the 2.8 per cent at level six could be considered to have only questionable significance in fiscal detection.

In any attempt to hypothesize a semi-worldwide arms control agreement, it seems apparent that it is not so much a question of the efficacy of detection with any one class of data, but rather the need for relating various classes of data in such a way as to determine significant coincidences that bear further investigation. It seems certain that financial data, along with physical sensor data, and other economical, political and sociological facts must be utilized within a total information system, the exact nature of which can only be determined as a result of extensive system analysis. An equally exhaustive task is to assess the environment in which we could expect the information system to operate. The following section describes some of the factors that will affect the design and operation of the system.

The effect of strong nationalism on a worldwide arms control agreement is difficult to accurately determine. Any attempt to qualify it seems to present a very small probability of success, so a generalized example will be stated to illustrate the point. It is obvious that any information system is initially beset with the problem of gathering data, as all data processing, evaluation, output, etc., is no better than the quality of the input. There is a colloquial phrase in data processing circles to the effect, "garbage in - garbage out"; so it is in this light we must consider the likelihood of receiving either accurate or complete financial input to an information system to support an arms control agreement. If a significant percentage of the population believes such an international agreement may not be in the best national interest, then we must conclude the quality of input information from this sector will be minimal and quite possibly deliberately inaccurate.

One of the senior executives from a leading airframe company, an internationally known aircraft designer, gave an excellent example of the effect of strong nationalism on clandestine activity. In a direct interview he stated that he was absolutely positive he would have no trouble recruiting a team of top designers who would be delighted to work on a top secret clandestine project, despite prohibitions stated in international agreements. He felt such men could be easily persuaded to participate by appealing to their nationalism, by describing the project in terms of "for the nation's defense" and to offset the "complete untrustworthiness of our adversaries". This nationalism could be further enhanced during the early stages of a program by espousing the rationale that it is not intended to produce the weapon or device, just to develop it, so as to be ready for production should our adversaries violate the agreement.

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The environment that most people in the "defense industry" have worked in for many years further enforces attitudes that could easily be turned to suit the directors of a hidden project. Restrictions of secrecy and "need to know" have existed for so many years, always justified in terms of national defense, that a slight redirection of philosophy does not seem difficult. The degree of redirection is not as great as it would initially seem. There are probably cases of such procedures being turned to suit purposes other than those originally intended.

On projects of extremely high classification, a high fence, armed guards and an aura of secrecy can be used to minimize interference from outside a project. Sometimes the intent may be to exclude company auditors, schedulers, policy and procedure analysis, most visiting military personnel, and perhaps governmental committees on general inspection tours. Also excluded are many of the reporting techniques so often imposed by the government and the contractor. So, while these precautions are primarily intended to promote security, another benefit may be in terms of privacy and a diminution of "red tape." This technique, while sometimes concealing inefficiency and waste, has also sometimes resulted in significant time and cost savings; incidentally, certain attitudes and precedents were also established. In such an environment the project becomes central, and requirements and policies imposed from outside the project become subject to revision or cancellation at the discretion of project management. It is obviously implied that project management knows better what is good for the project than either corporate or government management, and while their motives may be acceptable the project must be guarded from their ineptitude. This attitude and precedence seems almost ideal for a clandestine project.

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In addition, many of our existing laws and customs would seem to provide excellent cover and concealment. There are numerous state and federal laws assuring individual and corporate rights concerning financial

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data, as well as laws defining invasion of privacy, property, search, seizure and, of course, wiretapping. Within the United States, many of the laws that are intended to assure us our individual freedoms and protect us from oppressive actions by private individual or government agency, will also assure a measure of privacy for a clandestine project and, in addition, conflict with inspection "need to know".

How can such a project be financed without leaving a rather obvious trail, particularly if the project is of the magnitude we have assumed? A vice president of a major defense contractor has stated that his company could conceal from stockholders, board of directors and external examiners the diversion of corporate funds of up to $15 million a year for several years. The financial direction of another defense contractor stated that he believes up to 2 per cent of the corporate operating expenditure could be successfully diverted by the management of most large corporations.

There are numerous methods by which the government might conceal remuneration. Pre-treaty diversion of government income has been suggested by several authorities, the theory being that funds which never enter the federal accounting system would leave less to trace in government records. This might be done by granting an advantageous equipment or facility write-off or other concessions on corporate earnings, overhead, taxes, etc. Another form of diversion of income, preferably done pre-treaty, would be the unrecorded disposal of government assets (property, metals stockpiles, etc.). This would have to be concealed by fraudulent records or inventories, but should prove fairly practical due to the complexities presented to an inspection team in inspecting and balancing an inventory of government assets. This is very difficult when all agencies cooperate, but when faced with indifference or active resistance, the problem defies description. There is some question as to the ability of the federal government to state accurately the quantity of many of the commodities currently being stockpiled. This is not unique to the federal government, since there are several large defense contractors that have been unable to balance their facility and equipment inventories for over fifteen years; some inventory people predict the discrepancy exceeds 10 per cent. In such an environment of uncertain inventories the clandestine transfer of assets should not be a difficult matter. The receiving corporation could elect to create a dummy company rather than take the risk of introducing the receipts or disbursements into their own bookkeeping systems. The use of a dummy company with no history of defense work should further complicate the problem of detection. If the dummy company should "borrow" equipment, covered by clumsy inventory practices, and "borrow" personnel, covered by fraudulent charge numbers, inaccurate time-keeping, and poor personnel records, a rather sizable shop could be set up quite quickly. In this example, a whole company is formed as an underground unit. While physically it is in plain sight, its purpose and product remain undetected to the extent that its relationship to its anonymous parent corporation or to federal government financing remains hidden.

A number of other possibilities exist. Excessive remuneration for legitimate products or services can provide funds to finance other projects. If the necessary government agencies (or more precisely, those few people in the critical position within the government agencies) actively participate, then sizable overcompensation should be possible. A few years ago, General Motors Corporation was involved in a government action which charged the corporation had received an excessive profit on a government contract with the amount of overprofit exceeding $25 million. If this can occur, in spite of the existing government offices and agencies whose function and intent is to preclude such overpayment, then it seems likely that with the active support of relatively few government officials, such "generous" contracting practices could become a very efficient means of financing clandestine projects. In this circumstance the monies would directly enter the contractor's bookkeeping and accounting systems, therefore corresponding charges would have to appear. This should prove no problem as many defense contractors use false charge or account numbers now in order to augment security measures when special projects require especially stringent security. Therefore, if the contractor takes reasonable care in his method of establishing his dummy charge numbers, then the cost records presented to the government could conceal some rather sizable sums, particularly if the government plant representatives and auditors are not overly diligent.

The problem of detecting clandestine development is, of course, further complicated if it is possible to convert the product of a legitimate project. This type of activity is typified by a school for airline pilots that, in reality, is training fighter and bomber pilots. While it is almost impossible to predict the nature of such convertible projects in the future, there are problems in insuring that all the efforts and funds of a large research and development project are truly spent in the approved manner. Within the maze of personnel, facilities, equipment, tests, plans, financial statements, and budgets that will be required for much of our future civilian space exploration there can be the very real danger of relatively small "side" projects, with charge numbers, personnel and facilities neatly blended to disappear within the larger background.

It then seems apparent that there are undoubtedly a number of methods of avoiding financial detection with a significant probability of success. Our existing financial systems become confused with the complexities and swamped with the apparent volume of information that effective detection would require. Yet, despite these technical difficulties and the doubtful environmental background, it seems most unwise and shortsighted to contemplate an effective method of arms control without some indication of a nation's financial activities. Then to what extremes are we prepared to go in altering our existing fiscal system in attempting to make it of value?

Does an international arms agreement require extensive changes to our legal and fiscal systems? Our present legal and fiscal systems are what they are in response to what we have created to suit our way of life, our political and social and economic attitudes. Over the years, these systems have changed as we have changed. As a nation we amend our laws and our legal and financial systems when a sufficient portion of our population is insistent that such changes be made. Thus, while it seems evident that our existing laws and systems are far from ideal, if judged by how effectively they seem to support the gathering of data for enforcement of an arms control agreement, it is obvious this was not, and is not, our national intent. It would be an incredible coincidence if our legal and financial system, or any other nation's system, should prove to be well-suited for any use so far from what was intended at the time of its creation.

Will the changes required be of a drastic nature? In considering financial information, the basic intent of all budget and expenditure records is not dissimilar to the requirements of an arms control agreement. The essential questions are where is it coming from and where is it going, and does management receive sufficiently detailed and correct answers to insure the proper operation of the system? For a moment, let us ignore the requirements of an arms control information system and examine, in a general sense, the rather drastic changes that are now occurring in our fiscal systems.

In the last ten years a substantially different kind of data processing technology, electronic data processing equipment, has come into use. Since the beginning of the industrial revolution our systems have changed as the equipment or hardware has developed to facilitate the change. We now have data processing equipment with cycle and access times measured in nanoseconds, and read/write speeds in excess of 100,000 characters per second. The result has been the development of information systems many orders of magnitude more complex than even that predicted just a decade ago. And, as this is just the beginning of a chain of development, we must conclude our information systems and our data processing hardware will continue to advance for many years to come. As our information systems become more automated and our ability to interrelate information improves, our financial systems and our laws change with them. Government and corporate records become reels of magnetic tapes, machines converse with machines over telephone lines, and the federal government will accept a reel of tape as a legal and proper medium for presenting corporate tax records.

In spite of the fact that we must conclude that existing fiscal systems and data are not adequate to sufficiently support an international arms agreement, neither are we as individuals or as a nation, prepared to support such systems. If international arms control is to succeed in achieving even a partial disarmament, many world attitudes and mores must change, and a degree of international trust and respect must be developed. In the face of it, this would seem to be a process involving some years. In truth, it is not the financial system itself that will determine the feasibility of utilizing fiscal data in support of our arms control agreement, but rather the future environment within which it must operate. If at that time all nations are prepared to think of themselves as a permanent member of an international community, and to change their laws and customs accordingly to establish popular laws that provide the legal mechanism for the collection of information, for search where required, and punishment and reward where applicable, then financial data can be most meaningful. As to the technological requirements of handling and interrelating such a mass of information, our present capabilities and developments seem to assure that the capacity of future hardware is relatively one of the smaller problems.

IV. MONITORING OF RESEARCH AND DEVELOPMENT

Whatever else is forbidden in an arms control and disarmament agreement the most likely activity to continue, even though it may have ultimate military application, is research. The disparity in living standards throughout the world and the problems of maintaining even current standards under increasing population, can be solved only by continued research. This research, although stimulated by nonmilitary needs, will inevitably discover new knowledge with military application which will circumvent any existing agreements to restrict specific weapons.

It may be decided that it is desirable to retard the pace of military research and development. Much of this report is concerned with types of controls and their effects. It is clear, from even casual examination of the problem that the most obvious point of application of controls to military RDT&E in furtherance of an arms control agreement is at the test and evaluation stage. Such controls may, nevertheless, be expected to shift the emphasis on new weapons development to the earlier research and development stages, just as the presence of nuclear weapons has shifted military planning emphasis to "non-nuclear limited war".

Both basic and applied research are so vital to the growth of the civilian economy that they should be neither controlled nor restricted. If arms control agreements are not to be abruptly upset by discoveries outside the scope of the treaties, plans must be made from the beginning for the institution of monitoring procedures which will alert treaty participants to the growing importance of new areas of weapon potential.

The Washington Naval Treaty of 1922 was intended to restrict world arms races. It did, in fact, temporarily halt an impending arms race for the development of massive naval power among the signatories. But its consequences were a redirection of effort from battleships to "pocket battleships", and an accelerated growth of the tonnage, fire power of destroyers, and the capabilities of submarines. It also freed funds for the development of military aviation which, as a technology with peaceful applications, was not constrained by the treaty (see Appendix B), and advanced the aircraft armies.

The central question in restriction of military research and early development is the means for giving visibility to significant new developments. This will require a continuing evaluation of discoveries and technological developments from the point of view of their military applications. If arms control begins with the control of specific weapons, further rollback in military capability will increase the significance of uncontrolled areas. Thus, attention would next be directed to expanded and new uses of uncontrolled weapons, and finally to weapons applications of peaceful technology.

The intermediate review stage of remaining weapon capabilities will undoubtedly be the vital concern of all treaty participants. However, it is suggested that early consideration may be given to the institution of a science review committee, perhaps under United Nations auspices, to review world basic and applied research with regard to military significance. It could begin with the appointment of members who have no military ties in order to reduce the problem of security of classified information.

It is also suggested that any third stage agreement would include provision for the maintenance of such a permanent science review committee with rotary membership. Appointment to the committee might be for a two or three year period and on the basis of recognized international stature in science. The committee would, through subpanels, prepare annual reviews of world scientific progress, critically examined for military applications, and annually recommend amendments to the basic arms control treaty for the control of new processes which might have decisive military applications.

The assignment could be attractive to committee members since it would offer them (1) recognition; (2) the opportunity to be apprised of world progress in their specialties; and (3) the opportunity of exchanging information with their contemporaries.

Although the primary product of the group would be control recommendations, the secondary product, namely a series of annually updated reports on scientific progress by outstanding scientists, would stimulate the application of science to peaceful pursuits and improvements of world standards of living.

The foundation for such a committee already exists in UNESCO. In the thirteenth session (1950), the General Assembly of the United Nations adopted a resolution on the coordination of results of scientific research.

> "In this resolution, the Assembly requested the Secretary-General, 'in co-operation with the United Nations Educational, Scientific and Cultural Organization and the other specialized agencies concerned with the peaceful application of science, as well as the International Atomic Energy Agency, to arrange for a survey to be made on the main trends of inquiry in the field of the natural sciences and the dissemination and application for peaceful ends of such scientific knowledge, and on the steps which might be taken by the United Nations, the specialized agencies and the International Atomic Energy Agency towards encouraging the concentration of such efforts upon the most urgent problems, having regard to the needs of the various countries...', and requested the Secretary-General 'to submit this survey to the Economic and Social Council at its thirteenth session' in July 1960.
>
> "The Administrative Committee on Co-ordination (ACC), at its twenty-seventh session (20-21 October 1950), studied the means of implementing that resolution, particularly the distribution of responsibilities between the various competent organizations. It was agreed that UNESCO would act as centralizing body for the survey and that the other organizations would send its contributions relating to their respective fields of competence. The Committee also expressed the opinion that the United Nations and UNESCO, after consulting other interested organizations, should jointly appoint someone to direct the survey called for in the resolution and prepare the final report.
>
> "The General Conference of UNESCO was informed of the General Assembly resolution and the opinion expressed by the Administrative Committee on Co-ordination; at its tenth session, the General Conference authorized the Director-General to take the necessary steps to enable UNESCO to discharge its responsibilities in the matter.

> "In accordance with the opinion expressed by the Administrative Committee on Co-ordination, the Secretary-General of the United Nations and the Director-General of UNESCO, in agreement with the specialized agencies concerned and the International Atomic Energy Agency, appointed as Special Consultant Professor Pierre Auger (France), former Director of the Department of Natural Sciences of UNESCO.
>
> "The Secretary-General of the United Nations and the Director-General of UNESCO jointly convened a Special Advisory Committee composed of representatives appointed by the United Nations, the ILO, FAO, UNESCO, WHO, ICAO, WMO and the International Atomic Energy Agency.
>
> "This Committee, whose function was to advise the Special Consultant on the preparation of the survey and report, held three meetings at UNESCO House, Paris, on 2 March and 13 April 1960, with Mr. Rene Maheu, Assistant Director-General of UNESCO, as Chairman."

The report (UNESCO/NS/ES/19: Paris, 1 February 1960), titled, "Survey on the Main Trends of Inquiry in the Field of the Natural Sciences, the Dissemination of Scientific Knowledge and the Application of Such Knowledge for Peaceful Ends" by Pierre Auger, is an excellent example of the kind of world survey of science which can be accomplished. What is proposed is a similar activity, but one in which the last phase of the title is changed from "...the Application of Such Knowledge for Peaceful Ends" to "...the Possible Application of Such Knowledge to Military Applications and the Significance with Regard to Existing Arms Control Agreements and Their Possible Modification."

Can such an activity really accomplish a useful end? Consider the development of nuclear weapons. The possibility of such weapons was well known to scientists before World War II. Even aside from the early realization of such possibilities in the minds of advanced researchers in 1938, a casual review of the world literature in physics would have noted the following paragraphs in a standard text published in 1942 (written in 1940):

"A further and very important feature of nuclear fission is the following. Since any heavy atom contains an excess of neutrons as compared with the stable isotopes of its possible fission fragments, we might anticipate that free neutrons might also be found among the products of fission. In the case of uranium, it is actually found that 2 or 3 neutrons are emitted in each fission process.

"Now this phenomenon seems to open up startling possibilities. If each neutron emitted could be made to cause a fresh fission, accompanied by the emission of more neutrons, a "chain reaction" would occur; the number of neutrons and the rate of fission would increase rapidly. Thus a tremendous amount of energy might be released in a fraction of a second. In this way a bit of uranium might perhaps be made to act as a tremendously strong explosive; or, if the process could be controlled, we should have an atomic source of power. The energy released by the fission of all the atoms in a pound of uranium would be 1 million times as great as that obtainable by burning a pound of coal.

"Several factors, however, militate against the occurrence of a practically usable chain reaction. The neutrons may be captured in other ways; they will be slowed down by successive elastic impacts with nuclei; and they tend to leave the mass by diffusion. At the moment (1940) it is not known whether or not it is feasible to procure the necessary conditions for a chain reaction."[14]

It is clear that a military applications review committee would have flagged nuclear research for observation and control as early as 1939.

As a result of the great expenditures for military applications of research in the immediate past, it may be questioned whether such obvious examples exist today. If, however, the arms race is slowed by initial controls on, and reduction of, existing armament, and world military expenditures are reduced, the amount of research effort within the military forces for new weapons may slacken drastically, with the result that new areas of scientific development with military applications may appear which can be used to the advantage of the first country which discovers them (in the absence of a systematic search). One might expect that such areas would be those not

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[14] Richtmyer and Kennard, "Introduction to Modern Physics", McGraw-Hill, New York, 1942, p. 642.

normally considered to have military applications, where the step from a discovery to military use is not related to any past history of weapon development and employment so that there would be the normal resistance of most military planners with limited budgets to exploit a new and untried weapon at the expense of existing weapon types Aggressive nations would be less limited.

Such areas might include the biological and medical sciences, agricultural research, and weather control.

The magnitude of surveillance of world research is apparently great. There are about 500,000 scientists and engineers engaged in research and development in the U.S., and a roughly equal number in the USSR; worldwide the total is, perhaps, 1.5 million. Moreover, world expenditures for research and development continue to increase at an exponential rate. About 70,000 scientific and technical journals are published in the world monthly.

Fortunately, all of this is not important. The number of creative workers in each field is comparatively few, and each of them probably knows of almost all the others. It is thus possible for a comparatively small group of outstanding scientists to identify those producers whose work should be more carefully reviewed. The real problem is in identifying the "unknown geniuses" whose findings are outside the mainstream of present research and, for this reason, have difficulty in passing the review boards of journals or in attaining recognition of the validity and significance of their work when they do publish; typical are Heaviside, Einstein (in his early papers), Cristophilos etc. Since current science has its own inertia with regard to the innovation of new fields and diversion of current effort, the review committee must be particularly careful to screen all published and present research in one manner or another.

With regard to publications and proposed publications, it is noted that the review boards of scientific and engineering journals are composed of recognized authorities in the various disciplines; these same men would presumably have consulting and participating relationships with the military applications review committee. They might thus serve as preliminary reporters on significant discoveries.

The problem of unreported research is more difficult. It is suggested that it might be resolved by an exchange program of scientists. Again, such a program would be only an extension of present visiting scientist arrangements. It would, however, be systematized so that all laboratories of significance in all countries would be visited by outstanding scientists from all of the major signatories to an arms control agreement as well as some persons of the required competence from those smaller countries which have qualified talent only in a few disciplines. This would provide firsthand opportunities for the uncovering of important developments.

The industrial laboratories would be more difficult to penetrate because of the desire of private industry to protect proprietary information. But there are only a few laboratories in private industry capable of making significant new discoveries, and most of these report regularly and communicate freely with nonindustrial research centers; these could be easily included in the review process.

Proprietary information in industry should be studied carefully in this context. It is believed that it will be found that much of it can be identified with sufficient definition to serve the purpose of arms control monitoring. The fields in which industry works are usually both announced and exaggerated to give a "growth stock quality" to its securities; the proprietary information will probably be found to consist largely of knowing how to produce at lower cost, or to process some known product. Here it might be sufficient to record the manpower and dollars involved and monitor the characteristics of new products as they are released to the public.

In summary, the monitoring of world research for military applications seems worth considering. The process would, moreover, encourage and facilitate the dissemination and application of the results of research for peaceful purposes. Since world scientific manpower is a scarce commodity, the whole process is one that has very desirable aspects.

D

V. STRATEGIC IMPLICATIONS OF RDT&E RESTRICTION

The thesis to be developed in this section is that although across-the-board restrictions on all new weapon systems developments might retard or even stop the development of those weapons and capabilities which are provocative and upset the strategic balance, such restrictions might also limit the ability of the antagonists of the cold war to implement characteristics into their strategic force structures which would lead to a more stable situation and thus a policy of blanket restrictions on the development of new weapon systems could itself be destabilizing. Therefore, any program for the restriction of new weapon system developments should be selectively applied only to the development of those weapon systems and improvements in existing systems which are either provocative or otherwise destabilize the strategic balance. This conclusion will be shown to be valid in the situations in which (1) no limitations on the deployment of missiles exists, and (2) both antagonists agree to limit the size of their forces and each maintains a finite deterrent capability.

B

A. The Strategic Arms Race and the Development of Strategic Doctrine

It is difficult to know the precise reasons behind the development of national doctrine. The following paragraphs attempt to rationalize the sequential changes in strategic systems in a logical manner. In the arms race which has existed since the beginning of the cold war, each improvement in weapon capabilities has elicited a response from the opponent in the form of new weapons with improved capabilities. Thus a spiraling technological arms race has resulted in which the supersonic bomber was the response to the supersonic fighter and the Mach 2 fighter was in turn a response to the supersonic bomber. In the missile age this technological race developed into one between the survivability of the missile systems against attack and their offensive capabilities against enemy missiles. The first U.S. missiles to be deployed, the Atlas D and Titan I, were soft cryogenic missiles which had a

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reaction time of 15 minutes. These missiles could be fueled and launched between the time enemy bombers crossed the DEW line and the time they reached the missile sites and thus were survivable in the face of a manned bomber attack. However, as the Soviet ICBM threat developed these missiles were replaced by hardened missiles deployed in hardened silos. This quest for survivability led to the development of the Minuteman missile which was a smaller solid fueled missile with a short reaction time and the Polaris missile which achieved its survivability by submarine basing.

Because of the lack of an effective defense against the ballistic missile the U. S. adopted a policy of deterrence as its defense policy whereby a potential attacker is threatened with unacceptable massive retaliation in the event of his aggression. While the U. S. missile buildup was in response to the developing USSR missile threat, the growing U. S. missile force similarly appeared to be provocative to the USSR and was thus interpreted by their military leaders.[15] Thus the Soviets apparently considered their missile force as a deterrent against an attack by the U. S. on the USSR, and a situation of mutual deterrence against massive attack is considered to exist. However, the Soviet missiles depended upon secrecy of location for survivability rather than upon hardness. The Soviet missiles were deployed with two launchers to a complex and two missiles to a launcher; these complexes were spaced about 4 miles apart and formed groups of three or four complexes. In this situation a well-placed 1-mt nuclear weapon would effectively negate twelve Soviet missiles since the lethal radius of a 1-mt bomb with an overpressure of 3 psi is 30 000 feet.

A major instability in the hypothesized balance of mutual deterrence, from the Soviet point of view, occurred with the development of the U-2 reconnaissance aircraft which presumably revealed the location of the Soviet missiles, made them vulnerable to a U. S. first strike, and invalidated their credibility as a deterrent. The USSR has subsequently begun to deploy their missiles in hardened and dispersed launch facilities.

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[15] Sokolovsky, V. D., "Military Strategy, Soviet Doctrine and Concepts", Praeger, N. Y., 1963.

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However, above 1000 psi, increasing hardness is ineffective because the radius of the lip of the crater extends beyond the radius of the overpressure contour. If the accuracy, yield, and reliability of the opponent's missiles are such as to assure a high kill probability at a 1000 psi overpressure, increased hardening is ineffective and other methods of assuring survivability must be sought. These may include increasing the numbers of missiles to maintain numerical superiority or developing alternate basing methods such as land mobility, undersea mobility, and space basing.

Because of the effectiveness with which we were able to implement the doctrine of massive retaliation, it was thought that the Soviets might attempt a limited military provocation.[*] The U.S. announced, in late 1960 and 1961, a new doctrine of controlled or selective response whereby it would be possible to respond to limited Soviet nuclear provocations in a limited way and thus show our resolve to employ our strategic force without inevitably escalating a possible conflict to its ultimate limit. This modified doctrine required greater flexibility in the command and control system and in missile targeting. These requirements led to the development of Minuteman Wing VI which is an improved missile with a larger payload capability, an accuracy of 0.4 nautical mile, and can be fired against any of ten prestored targets.

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As more and more missiles were deployed by the U.S. and USSR, some persons believed that the Soviet missile force could deter the use of the U.S. missile force as a response to a conventional military attack on Western Europe. The British first, and later the French, argued that since the U.S. was vulnerable to a Soviet nuclear attack, the U.S. would not use its strategic force if the USSR attacked Western Europe. Thus, both nations decided to develop their own deterrent forces, the British, for the purpose of committing the U.S. to its doctrine and the French to have an independent nuclear deterrent.

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[*] That is, a provocation against which massive retaliation would be unjustifiable on military and political grounds.

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Because the U S. was concerned about the dangers associated with independent nuclear forces, i. e., that the initiative to begin a nuclear war which we must participate in would pass out of our hands into those of an ally, the U.S. announced its adoption of a counterforce doctrine in the Ann Arbor speech of Secretary of Defense McNamara.[16] In this speech, the secretary announced that the U.S. was adopting a policy of initially targeting only USSR military forces in the event of a war and was avoiding striking Soviet civilian population unless driven to it by an attack on U.S. population, and hence ". . we are giving a possible opponent the strongest imaginable incentive to refrain from striking our cities." In this statement he intended to make clear our resolve to defend our allies in the event of an attack and thus continue the credibility of our deterrent strategy.

The effective implementation of such a counterforce strategy depends upon the characteristics of the weapons available which are high accuracy, flexible targeting and effective command and control. These characteristics, however, are exactly those required to implement a first strike capability, especially if coupled with a great superiority in numbers of weapons. Thus this doctrine may well be interpreted by the USSR as an intention on the part of the U.S. to develop a pre-emptive strike capability In the light of the current Soviet force deployment, their response may be to seek alternate basing schemes to improve survivability and also to deploy more missiles. If they adopt the latter course, then the arms race may increase its pace.

B. Technological Innovation, Strategic Capabilities, and Response

The preceding discussion has attempted to show how the need to implement a specific capability in a weapon system has led to technological innovation and how these innovations are responded to by the opponent This process of innovation and response can be interpreted in terms of a stability

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[16] New York Times, 17 June 1962.

criterion for the dynamics of the continuing changes in the strategic forces of contending opponents. This process of the continuing development and deployment of new weapon systems can lead to a number of possible situations.

1. Arms Races

The first is a spiraling arms race in which each contender attempts to improve his own position relative to that of his opponent by either deploying more weapons or weapons of improved characteristics. There are a number of ways in which such an arms race can develop. The first is that each side believes the intentions of his opponent are aggressive and each side attempts to build up a capability greater than that of his opponent. A second way is one in which one contender has only incomplete information regarding the other's strategic capabilities and responds on the basis of the maximum estimate of his opponent's strength. A third way is one in which one side believes the other to be aggressive and implements a deterrent posture. The implementation of the deterrent posture is in turn interpreted by his opponent as a further indication of an aggressive intention, and the opponent further accelerates his arms buildup. The possibilities of such misinterpretations are enhanced in an environment in which the same weapons are used for defensive and offensive purposes, as is the case with ballistic missiles.

It is now generally realized that in order to obtain a decisive advantage over one's opponent, one must have the capability of destroying enough of one's opponent's strategic forces to reduce the damage of a retaliatory blow to an acceptable level. Such a capability implies the necessity of having a numerical superiority in delivery systems and sufficient accuracy and destructive capability so that the enemy's force can be destroyed. Furthermore, in order for such a capability to be useful, it must be used as a first strike. If one side attempts to obtain a first strike capability the other side is forced to increase the survivability of his force to the point where he is able to maintain a deterrent capability. There are a number of ways in which one side can obtain a first strike capability over the other, one of which may be to out-spend the opponent.

2. The Unique Weapon

A second strategic situation is one in which one side develops a weapon system of a different kind. Such a situation is believed to have existed in Europe from the end of World War II to about 1952 when the Western nations possessed an effective monopoly of nuclear weapons and thereby were able to effectively deter Soviet aggression by the threat of large scale nuclear retaliation. Such a situation is always a transient one because the opponent without the new capability seeks to obtain it. In the post-war era the USSR did nothing to jeopardize their ability to obtain nuclear weapons and the Baruch Plan for the control of atomic weapons failed because of this reason, since the USSR would be giving up its desire for technological parity with the U.S. if it had agreed to the Baruch Plan. The maintenance of technological parity, even among allies, appears to be a fundamemtal axiom of international relations. If an adequate deterrent is not available for the unique weapon then its possession by an aggressive power may be decisive. One can contemplate the consequences if either Germany or the USSR had been the first to obtain nuclear weapons and had maintained that monopoly.

3. Mutual Deterrence

In this strategic situation, each side feels that it is impossible to obtain a decisive advantage over its opponent and is content with maintaining a force strong enough to deter his opponent. Such a position, if it can be achieved and maintained, can be considered as a stable and hence strategic balance. If both opponents are attempting to establish such a balance then each must be sure that it undertakes no force improvements which are interpreted as an attempt to move away from this position to a first strike position.

Furthermore, one or both sides may wish to undertake changes in its force structure which will enhance the balance and thus demonstrate to its opponent that it desires such a situation.

There are difficulties in reaching and maintaining balanced mutual deterrence. First is the problem that the estimates of what constitutes a stable situation may differ among opponents. This is particularly true if the characteristics of the weapon systems of each side are considerably different. At the present time the U.S. maintains a superiority of numbers of delivery systems whereas the USSR maintains a superiority in the deliverable yield per weapon. In such a situation, each side may maintain that the other possesses a pre-emptive capability.

The second difficulty is the pressure for technological change. This may arise from a number of sources including the desire for lower costs, improvements in performance and survivability, pressures caused by changes in allies and opponents, and the desire to break the strategic deadlock. Finally, there is the difficulty of the misinterpretation of enemy intentions. The slowdown in the rate of Soviet buildup in armament may be due to economic pressures, yet the intent to reach a first strike capability may still exist and its implementation may be merely postponed.

4. Multi-National Forces

One of the difficulties with the mutual massive deterrence posture is that it provides an umbrella under which aggression by conventional warfare can be carried out with relative impunity and thus becomes ineffective in deterring such aggression. In such a situation, an ally doubting the resolve of the nation possessing the strategic deterrent, may create its own independent nuclear forces to appear to be useful (whether really useful or not) either as a deterrent or to force the first ally to use its strategic weapons. Thus, effective control of the principal deterrent may pass out of the hands of its owner. A satisfactory solution for this situation has not as yet been found.

C. Effects of Future Technological Developments on Strategic Stability

In examining possible strategic situations it appears that the only reasonably stable one is that of mutual deterrence. It is on this basis that technological changes will be assessed. Strategic capabilities which may be acquired through technological change include improved survivability of strategic force, first strike capability, reduced collateral damage, improved intelligence, and counterforce capability. In attempting to assess these capabilities as stabilizing or destabilizing, it must be considered whether the improvement can be interpreted by the enemy as an improved first strike capability in such a way that the opponent can respond by threatening the survivability of the first force.

Improved survivability of the strategic force is considered to be stabilizing because it reduces the danger from a first strike and thus makes a nation less prone to launch a pre-emptive strike. Survivability, however, can change rapidly and thus make an invulnerable force suddenly become vulnerable. Improved accuracy and target location intelligence can destroy the survivability of hardened emplaced missiles. According to the above argument, it follows that neither side should attempt to increase the vulnerability of the opponent's forces; however, one side may use the gambit of increasing the vulnerability of his opponent's force to cause him to increase the survivability of his forces and thus reduce the motivations for preemption. The danger of such a gambit is that the opponent may either over-respond or misinterpret one's intent. However, each side should attempt to increase the survivability of its strategic forces and such attempts should be interpreted as defensive and stabilizing. If survivability is achieved with weapons which can be clandestinely produced and deployed so that the opponent is unsure of the size of the force, or its accuracy, which confronts him, he may be motivated to create a larger force to assure its survivability.

A first strike capability capable of reducing the damage from retaliation to an acceptable level is clearly destabilizing because it forces the opponent to increase his force size and to deploy new weapons which continues the arms race.

An attempt to develop a counterforce capability would also lead to a capability for a first strike and would probably be thus interpreted by the enemy. Consequently, the development of a counterforce capability is considered as being destabilizing unless supported by a convincing national policy of not striking first. However, there may be circumstances under which such a capability may be properly chosen regardless of stability implications; for example, the use of counterforce by the U.S. to reduce damage from those USSR forces remaining after a USSR first strike.

Accurate intelligence prevents response on the basis of overestimates of the opponent's capabilities and in this way is stabilizing. However, intelligence-gathering systems have been criticized as being destabilizing because they provide targeting information necessary for a pre-emptive strike. The stabilizing aspects of the first effect are considered to be more important than the destabilizing effect of the second and hence intelligence-gathering systems are considered as being stabilizing in the long run.

From the preceding discussion it can be concluded that those improvements which tend to increase the survivability of the strategic retaliatory force, but which do not require increases in number of weapons deployed, and systems which improve information regarding the opponent's force structure are stabilizing. Those which might yield a pre-emptive capability may be considered destabilizing subject to policy and other considerations beyond the scope of this study.

Now let us consider the effects of specific technological developments upon the strategic balance in an environment of mutual deterrence, within the limiting assumptions as given above.

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1. Ballistic Missile Developments

Possible improvements in ballistic missile systems include improved accuracy, increased survivability which may be achieved through increased hardness, land mobility, underwater mobility, long term concealed storage in a dormant state, large payload missiles, improved penetration aids, small missiles with the same or increased performance of current missiles, improved command and control systems, increased range, and flexible targeting.

a. Increased Accuracy

Improved accuracy appears to be destabilizing because it forces the opponent to either deploy more missiles or to develop alternate basic schemes to maintain the same force survivability. However, this counteraction after completion may result in a position of greater "stability". The development of new basing concepts would also imply the deployment of new missiles in addition to the ones currently deployed and thus appear to be pre-emptive to the opponent, if they are also highly accurate and effective in the countermissile role. The increasing accuracy can provoke the opponent into an apparently pre-emptive position. Finally, increased accuracy may reduce total damage caused by an aggressor if that portion of his force not launched in the first strike can be destroyed by the retaliatory force.

b. Hardening

The hardening of missiles is considered to be stabilizing because it increases the survivability of the missiles. However, effective hardening can only be provided to about 1000 psi overpressure and if greater hardening is required, other means of providing survivability must be sought which may include active defense systems or alternate basing schemes.

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c. Underwater Mobility

Undersea mobility is considered to be an attractive means of achieving survivability because of the extensive concealment volume afforded by the oceans. At the present time, submarines enjoy considerable safety against attack. Because the construction of submarines appears to be relatively easy to monitor there seems to be little danger of the covert deployment of submarine-launched missiles and consequently this means of achieving survivability is considered stabilizing if adequate production controls are placed on the submarines and adequate command control is always present.

d. Land Mobility

Land mobility is sometimes thought of as a means of providing survivability because of the hiding afforded. However, it is difficult to harden a mobile system beyond about 10 psi and it may be possible to completely blanket the area in which these missiles are deployed with a greater overpressure. Another difficulty with the road mobile missile concept is the fact that these systems may be covertly produced and deployed and it is difficult for the opponent to determine the threat against him; he may therefore respond on the basis of an overestimate of the number of missiles which would be destabilizing.

e. Encapsulated and Hidden Missiles

Encapsulated and hidden missiles, as discussed in Volume II, Section VI, appear to be an effective method of increasing the survivability of the missile force. However, survivability in this concept may be obtained by deploying a large number of decoys thus giving the appearance of a great many more missiles than are actually deployed. Such a system is considered to be destabilizing if it causes the enemy to consider his force to be vulnerable to attack by these missiles.

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f. Very Large Payload Missiles

The development of very large payload missiles may possibly be destabilizing. A large payload missile could be used for the delivery of a single large yield warhead, a multiple warhead, or to increase the penetration capability against an active defense system if one existed.

Since, in general, a large missile costs more than a small missile (but not proportionately so), one would expect fewer large missiles for a given expenditure. Against a numerous, highly accurate force, these would be vulnerable to first strike if fixed and even if hardened. Hence the deployment of small numbers of large missiles in fixed installations is considered to be destabilizing, unless they are supplemented by large numbers of other missiles, since they represent provocative targets.

g. Small ICBMs

The motivation for the development of a small ICBM may be to increase survivability because these missiles are easier to harden, make mobile, deploy in the hidden and encapsulated mode, or that more can be bought for a given budget level. The effects on stability have already been discussed and depend upon the method of deployment. One destabilizing aspect of small missiles is the ease with which they may be covertly produced.

h. Penetration Aids

The availability of effective penetration aids against an active defense system may be an effective means of deterring the opponent from attempting to deploy an anti-ballistic missile system. It is current thought in the U. S. that the offense has the advantage over the defense and that any foreseeable defense system can be countered. Thus, if the opponent is deterred from the development of an active ballistic missile defense system, the strategic balance is not upset. Consequently, the development of effective penetration aids tends to stabilize the technological arms race.

i. Command and Control Systems

Improved command and control systems with greater survivability tend to increase the survivability of the entire force and to increase the controllability of the missile force in a post-attack environment, thus enhancing the effectiveness of the surviving force in a retaliatory strike. Hence, improved command and control systems are considered to be stabilizing.

j. Improved Range

Increased range on the part of the U. S. may be used to increase the credibility of our missile deterrent against other powers such as Communist China and thus increased range can be considered as a stabilizing development from the U. S. standpoint. Greatly increased range improves survivability by allowing attack on a target from any direction. However, range improvement in Soviet ICBMs to intercontinental ranges would offer a destabilizing threat

k. Improved Targeting Flexibility

Targeting flexibility in the post-attack environment provides a number of advantages; one is that the highest priority targets of the enemy remain vulnerable in spite of weakening of the retaliatory force since the targeting list of the retaliatory force can be up-dated on the basis of those missiles surviving a first strike. Also, if post-attack reconnaissance information is available, the surviving missiles can be fired against unfired missiles and thus limit the potential damage in subsequent attacks. A flexible targeting capability is dependent upon the guidance system and computer capabilities and also upon the capabilities of the command

and control system. Because flexible targeting increases the capabilities of the deterrent force in the post-attack environment it should be considered as a stabilizing development.

From the preceding discussion it is concluded that increased hardness, undersea mobility, the development of penetration aids, improved command and control, targeting flexibility and extended range of the missile force all tend to enhance the deterrent capability of the missile force and are relatively stabilizing. Nearly all of these developments can be achieved without the development of a completely new missile system by improving various subsystems of the missile. However, the development of a road mobile ICBM, an encapsulated missile, a large payload missile, and small ICBMs would all require the development of a new missile system. Consequently, many of the destabilizing developments with the possible exception of improved accuracy could be restricted if the development of new missile systems could be reliably stopped.

2. Orbital Bombardment Systems

Although the orbital bombardment system does not appear to be economically feasible with currently available technology, there are a number of motivations for the development of such a system which include, first, increased survivability of the retaliatory force by basing it in space and second, reduced collateral population deaths compared with those which would result from an attack using a land-based retaliatory force. For example, an ill-advised and irrational attack on U.S. based missiles and air bases could result in almost complete destruction of the attacker's homeland by the surviving U.S. retaliatory force, yet there would be tens of millions of U.S. casualties. A similar attack on a U.S. space-based force would not result in U.S. population deaths. A third motivation is diversification of the threat, while a fourth motivation is the possibility that positive command and control may be more easily achieved than for other basing systems.

It is currently thought that an unmanned, low altitude OBS is not likely to be deployed because of its low reliability and also because it may be relatively vulnerable to attempts to negate or destroy it. Because of the problems of reliability and vulnerability, an effective OBS is considered to be a manned system deployed in a high altitude orbit, perhaps with the capabilities for evasion or self-defense in the event of attack. If such a system can be made sufficiently invulnerable to attack it may represent an effective deterrent force and thus might be considered as a stabilizing influence on the strategic balance

3. Anti-Ballistic Missile and Anti-Satellite Systems

Anti-ballistic missile systems fall into two classes; point defense systems and area defense systems. Point defense systems are those used to defend a single installation such as a missile launcher or a command center whereas area defense systems are used to defend extended target areas such as cities or larger areas Active point defense systems may become attractive as the accuracy of the opponent's missiles increases in order to maintain the survivability of critical installations such as command centers. Area defense systems have been criticized as being destabilizing because the possessor might be able to launch a pre-emptive attack while parrying much of the effective retaliatory strike on his population. However, since it is believed that these systems can be relatively easily countered by the use of penetration aids, it appears that active defense systems cannot decisively defeat a ballistic missile attack at the present time. However, the development of such a system does stimulate the development of penetration aids by the opponent.

Anti-satellite systems would probably be deployed against orbital bombardment systems although here again the question of use of decoys by the bombardment system arises. A nation would probably wish to continue the research and exploratory development of these systems just

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as is the case of the AICBM. If effective, they would destabilize a situation in which an orbital bombardment system constituted a major portion of the retaliatory force.

4. Nonweapon Military Space Systems

Nonweapon military space systems include reconnaissance, warning, and communication satellites and satellite inspection systems. These systems, particularly warning and reconnaissance satellites, are useful in preventing pre-emption and maintaining stability. The reconnaissance satellite affords one means of gaining information required for accurate estimates of the opponent's force structure and thus is considered stabilizing. Early warning satellites such as Midas are considered stabilizing to the extent that they reduce the effectiveness of a first strike.

Satellite inspector systems may be useful in determining whether the opponent has deployed provocative systems in space and are stabilizing to the extent that the information gained prevents surprise.

Communication satellites used for military purposes might be part of a global command and control system and could enhance the military capabilities of a nation at all levels of military conflict. In times of peace, communication systems are not generally vulnerable to attack and sabotage and there seems to be little danger that these systems would become subject to attack under normal conditions. Furthermore, communication satellites can be used for both peaceful and military purposes and in some cases the same satellite can be used for both purposes. These systems are considered stabilizing in conjunction with a stable force because they improve force effectiveness and control.

The above analysis was made in a situation in which there are no restrictions on the deployment of strategic weapons. However, the discussion is generally applicable to the situation in which there are limitations

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on the deployment of strategic weapons. If a situation of finite or minimal deterrence is postulated in which each side maintains an agreed-upon number of strategic weapons the stability of this situation is enhanced as the survivability of the forces is increased.

D. Effects of RDT&E Restrictions on Strategic Capability

The effects of RDT&E restrictions on future strategic capabilities and stability will depend upon the time the restrictions are implemented. The implementation of broad RDT&E restrictions on development programs at the present time might have an asymmetric effect on the weapons technology of the two major antagonists because of the varying emphasis placed on weapon characteristics. It would prevent the U.S. from achieving those improvements in its force structure which would enhance the deterrent capability of its force structure and hence strategic stability. [illegible] the imposition of across-the-board RDT&E restrictions [illegible] planned force improvement is completed would decrease our potential capabilities for deterrence. The stability effects of such restrictions on the USSR are not known because of the limited knowledge regarding their future plans.

Table V-1 summarizes the effects of certain systems on the strategic balance. For each system improvement the table shows earliest estimated initial operational capability (IOC) dates for both the U.S. and the USSR, the added strategic capabilities which these developments might afford, and the possible responses which the enemy might take to the development. From the table it is apparent that any new development has the potential of requiring technological response and new weapons deployment. For example, increasing the hardness of one's missile force may cause the opponent to increase the accuracy of his force; this increase in accuracy may cause the first nation to consider the development of a new kind of system which has increased survivability such as an OBS or to increase the size of his existing missile force. To dampen this interaction, each nation should recognize that there are certain activities whic

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Table [illegible]-1 Strategic Capabilities and Possible Responses of New Developments

System or System Characteristics	Possible IOC Date U.S.	Possible IOC Date USSR	Added Strategic Capability	Possible Responses
Ballistic Missiles				
[illegible]	[illegible]	[illegible]	Increased survivability	Increased accuracy
[illegible] ICBM	[illegible]	1964-71	Pre-emptive strike (1)	Land mobile ICBM, increase force size
[illegible] encapsulated ICBM	1975	1975	Increased survivability (1)	Hidden and encapsulated ICBM
[illegible]	1972	1972	Counterforce or pre-emptive strike	Submarine basing, OBS, increase force size
Target [illegible]	[illegible]	[illegible]	Counterforce and improved survivability	Submarine basing, OBS, increase force size
[illegible]	[illegible]	[illegible]	Pre-emptive strike (1)	Increase force size and survivability
[illegible]	[illegible]	[illegible]	Increased survivability (1)	Increase force size and survivability
[illegible]	[illegible]	[illegible]	Maintain force size [illegible]	Retard ABM development
[illegible]	A	[illegible]	Increased survivability	Respond in kind
[illegible] Systems				
[illegible]	[illegible]	[illegible]	Pre-emptive strike or retaliation	Develop anti-satellite system
Manned [illegible]	[illegible]	[illegible]	Safe [illegible] and reduce collateral damage	Develop similar system
Anti-Ballistic Missile System				
Point defense		[illegible]	Increase city [illegible]	Develop penetration aids
Area defense		[illegible]	Protection of targets	Develop penetration aids
Anti-satellite System	[illegible]	[illegible]	Space offense capability	Improve OBS survivability
Satellite Inspector System	[illegible]	[illegible]	Intelligence gathering	Stop development of OBS
Warning Satellites	[illegible]	[illegible]	Reduce damage	Anti-satellite system
[illegible] satellites	A	A	Intelligence gathering	Anti-satellite system
Communication satellites	A	[illegible]	Improved global command and control	Anti-satellite system

[illegible]

A [illegible]

(1) [illegible] in a different [illegible] and if enemy force location is known

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are not necessarily provocative and should not incur response. These activities include increasing the survivability of a limited missile force.

An examination of the IOC dates for these systems and improvements shows that if across-the-board RDT&E restrictions were imposed in 1965 the capabilities for improved survivability through Polaris type missiles for the USSR, active point defenses, and targeting flexibility would not be achievable. By 1970 most of these improvements could be implemented but hidden and dispersed missiles, very small ICBMs, manned orbital bombardment systems, and anti-ballistic missile and anti-satellite systems would require completion of their development programs. However, by 1970 new concepts may be devised or invented which, if implemented into the force structure, could materially change the strategic balance.

It is concluded that while some technological developments could be provocative and destabilizing there are others which should be undertaken to improve the security of deterrent forces. These latter developments would appear to merit first priority in weapons development programs of all nations.

The fact that both the Partial Nuclear Test Ban Treaty and the U. N. Resolution Prohibiting Weapons of Mass Destruction in Space were consummated and the fact that the USSR is apparently taking steps to harden its missile force may be indicators that both nations are interested in achieving a strategic balance and will refrain from the development and deployment of those weapon systems which are provocative and destabilizing. The effects of attempting to impose blanket restrictions on weapons development programs at the present time might retard or even limit the ability of both sides to achieve those developments which are considered stabilizing and hence be a destabilizing act in itself. It is concluded that blanket restrictions or prohibitions on military RDT&E are currently undesirable.

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VI. THE FORMATION OF A POLICY FOR THE RESTRICTION OF RDT&E ACTIVITIES

A. Possible Control Policies and Their implementation

In the preceding discussion there have emerged several policies which could be adopted for restricting ballistic missile and military space system RDT&E activities. The choice of such a policy should be consistent with the over all strategic objectives of the nation. In this discussion, it will be assumed that this objective is the creation of a stable balance of strategic forces while at the same time allowing for a viable program of strategic arms reduction. The possible RDT&E control policies which might be adopted include: (1) halting all RDT&E activities having military application; (2) restricting the development of all new ballistic missile and military space systems and improvements in existing systems; (3) restricting the development of those systems which are provocative and destabilize the strategic balance; and (4) adopting no formal policy towards the restriction of RDT&E activities.

The first of these policies, that of halting all RDT&E activities which have military applications, has a number of disadvantages which include the difficulties of defining military versus nonmilitary applications, the ineffectiveness of control at the research end of the spectrum and the possibilities of obtaining significant military developments as the result of fallout from a nonmilitary space program. Thus this policy, while it may be effective in restricting the development of destabilizing systems, has the disadvantage of restricting those developments which tend to enhance strategic stability.

The second policy, that of restricting the development of all new ballistic missile and space weapon systems, avoids the difficulties of attempting to restrict research activities but has the same difficulties as the previous policy with regard to the effects on strategic stability, namely that stabilizing improvements are restricted along with destabilizing developments.

The third policy, that of restricting the development of provocative and destabilizing systems, seems to be the one most consistent with the overall strategic objectives outlined in the first paragraph. Under this policy, only those systems which are clearly destabilizing or provocative would be restricted and each nation would be allowed to develop those systems and improve existing systems to the extent to which stratetic stability is enhanced.

Finally, the fourth policy, no formal restrictions on RDT&E activities, attempts to achieve stability through encouragement and motivation of other nations to refrain from the development of provocative and destabilizing systems. Such a policy can be fostered by refraining from development of these systems on a unilateral basis, maintaining a sufficient deterrent force so that the opponent gains little or no advantage from engaging in the development of the undesirable systems, and by being certain that the opponent understands one's own desires for stability. This policy is also in accord with the objective chosen and, although compliance may be less certain than for restrictions involving formal agreements, it may be an easier policy to implement and, in the long run, be as effective.

Since the latter two policies best meet the requirements of the chosen objective, attention will be directed to them. The question thus arises as to what systems and system improvements are to be considered stabilizing. These questions were investigated in Section V and the improvements were assessed on the basis of the strategic capabilities which they provided. Table VI-1 lists these improvements and new systems according to the strategic capabilities which they provide. The strategic capabilities which may be provided include increased survivability, first strike, counterforce, intelligence gathering, and protection of civilians. Some improvements, such as improved accuracy and reconnaissance satellites, provide a multiple capability for both a first strike and a tactical counterforce capability. On the basis of this classification, and the possible responses which the opponent can make to these new systems and system improvements, the conditions under which these improvements are stabilizing or destabilizing are listed in Table VI-2.

Table VI-1. Classification of Systems and System Improvements According to Strategic Capability.

Increased Survivability

- Increased hardness
- Undersea mobility
- Hidden encapsulated ICBMs[a]
- Small ICBMs
- Invulnerable OBS
- Active point defense
- Communication satellites
- Penetration aids
- Improved command and control
- Targeting flexibility

First Strike

- Land mobile ICBMs[a]
- Vulnerable large payload missiles
- Improved accuracy
- Small ICBMs[a]
- Low altitude OBS

Counterforce

- Improved accuracy
- Targeting flexibility
- Anti-satellite system
- Reconnaissance satellites
- Small ICBMs
- Improved command and control

Protection of Population

- Active area defense
- Early warning satellites

Intelligence Gathering

- Satellite inspector system
- Reconnaissance satellites

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[a] Depends upon numbers deployed

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Table VI-2. Stabilizing and Destabilizing Systems and System Improvements.

New System or System Improvements	Conditions Under Which It is Stabilizing	Conditions Under Which It is Destabilizing
Ballistic Missiles		
Increased hardness	All	None
Land mobile ICBM	If widely dispersed over large area and numbers are known to opponent	If concentrated in small area
Hidden and encapsulated ICBMs	If widely dispersed over large area and numbers are known to opponent	If clandestinely produced and deployed If decoys are good
Increased Accuracy	If used as counterforce only and yields are decreased	If precise location of existing [illegible] force location is known and if enough missiles are deployed to effectively negate the opponent's force If it forces the opponent to increase his force size
Targeting Flexibility	All (except possibly some n-country situations)	None
Large Payload Missiles	If they can be made as survivable as a force of small missiles delivering the same payload	If they are vulnerable
Small ICBMs	If they can increase survivability of total retaliatory force and numbers are known to opponent	If they can be clandestinely produced and deployed
Penetration Aids	All	None
Undersea Mobility	All (with positive command and control)	If submarines can be clandestinely produced and without positive command and control
Orbital Bombardment System		
Rudimentary low altitude	If they are not launched prior to attack	If they are vulnerable
Manned high altitude	If they are invulnerable and capabilities known	If they are vulnerable
Anti-Ballistic Missile Systems	Point defense for strategic installations	If they can defend retaliatory force
Anti-Satellite Systems	If effectiveness is demonstrated before OBS is developed	If OBS constitutes a major portion of retaliatory force and is vulnerable
Satellite Inspector System	If they can detect nuclear weapons aboard a space vehicle	None
Warning Satellites	All	None
Reconnaissance Satellites	By yielding information regarding opponent's force size	If locations of fixed missiles are revealed for an effective first strike
Communication Satellites	--	None

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It appears that most developments which are considered to be destabilizing, except improved accuracy, involve major systems development programs. The development of land mobile missiles, small missiles, very large payload missiles, and orbital bombardment systems, will require flight testing of a new missile system. Orbital bombardment systems and land mobile systems become a credible threat only if they are deployed in sufficient numbers and consequently production restrictions are more appropo to these systems than research and development restrictions. It therefore can be concluded that the combination of restrictions on research and development flight testing and production monitoring could remove the threat of these systems, if the restraints were effective.

Very large yield weapons are considered to be destabilizing because they are more difficult to make survivable and a single large yield nuclear weapon may be able to destroy a hardened and dispersed retaliatory system such as the Minuteman system by reason of those weapon effects which are not clearly understood. These weapon effects include the effects of earth movements on the silos, the missile suspension system and the guidance azimuth reference system, the electromagnetic pulse phenomena and the effects of scattered debris. Some of these effects cannot be assumed to scale linearly from test data obtained from lower yield weapons and consequently it is difficult to design a system whose survivability can be assured.

Regarding the development of an effective high altitude orbital bombardment system it is believed that all of the components of such a system could be developed in an orbital manned space station program. The re-entry vehicle itself could be developed as part of the logistics supply system and would not have to be tested with a warhead aboard. Even a low ballistic coefficient vehicle could be used with a terminal guidance system to remove the dispersions arising from atmospheric re-entry.

Another aspect which must be addressed in the consideration of RDT&E restrictions is the technological advantage which would accrue from either clandestine activity or a sudden abrogation of the treaty. If one party to the agreement secretly developed a new system up to the point of flight testing, and either attempted to carry on the flight test program clandestinely or abrogated the treaty, a major technological lead might accrue to that nation and it may take considerable time for the offended nation to recover. During this period the violator might be able to gain considerable advantages from its lead such as may have accrued during the period between the breaking of the nuclear test moratorium and the Partial Nuclear Test Ban Treaty. In an environment of RDT&E restrictions there may be increasing pressures with continuing time for the abrogation of the treaty to resume testing in critical technological areas such as re-entry physics, guidance and control for anti-ballistic missile systems, and non-nuclear kill mechanisms for anti-ballistic missile systems.

Finally, the possibility exists of carrying out significant research and development activities which would have direct military applications as part of a peaceful space program. While it may be possible to effectively restrict the development of a new ballistic missile, much of the technology required for both ballistic missile improvements and for other military space systems could be obtained from the peaceful space program and, consequently, it is felt that it is impossible to effectively restrict military research and development activities below the level of systems development. Even at this level, the OBS and the large ballistic missile could be developed as part of the peaceful space program.

Most of the improvements to existing systems could be undertaken without any ostensible changes in the existing systems. Most weapon systems programs incorporate an improvement program as part of their normal life cycle. This was true in the case of the manned bombers where both the B-47 and the B-52 went through a series of modifications to improve their capabilities and is currently true of our ballistic missiles including the Atlas, Titan I and II, and the Minuteman system. Accuracy improvements can be obtained without any ostensible changes in the system through better manufacturing and calibration techniques, and better geophysical and geodetic information.

B. Feasibility of the Implementation of RDT&E Restrictions

We now turn to the problem of the feasibility of implementing RDT&E restrictions. The feasibility of implementing a particular arms control agreement depends upon the amount of access to a nation required for the verification of compliance with the agreement and thus, in turn, depends upon the feasibility of obtaining the required access.

In order to determine the feasibility of obtaining the required access, a number of hypothetical arms control agreements for the restriction of military RDT&E activities requiring various degrees of access have been formulated and are listed in the following paragraphs.

1. Prohibit All RDT&E Applicable to Ballistic Missiles and Military Space Systems

In order to verify compliance with a total prohibition of all RDT&E activities applicable to ballistic missiles and military space systems, it would be necessary to institute a degree of inspection which would imply a completely open society. While this degree of openness might be attainable in the United States it is doubtful whether the USSR would agree to such openness in the foreseeable future. Since most of the significant discoveries which yield a major advance in military capabilities come from basic and applied research which is not specifically directed to military applications, these discoveries would continue although perhaps at a slower pace. However, it might be possible to prevent their application to new military technology.

Such an extensive penetration into the engineering and scientific community of a nation would probably impede nonmilitary research if it is to be effective since engineers and scientists would be required to review their work before the inspectorate and thus such extensive restrictions may be harassing and create antagonisms toward the inspectorate.

2. Prohibit Development of All Ballistic Missiles and Military Space Systems with Only Launch Site Inspection

Between this and the preceding agreement, there is a spectrum of agreements which include restricting all military systems developments with inspection rights at various levels including all personnel and development facilities to those personnel and facilities which have been previously engaged in military systems developments. The first of these requires a degree of intrusiveness similar to the above policy whereas the second of these is too easily evaded. While it might be possible in the United States to obtain names of all persons engaged in military development programs and the location of facilities, this may not be possible in a previously closed society where the inspectorate is dependent upon the government for lists of names and facilities. Even in an open society this might not be possible since there are capable engineers and scientists who would someday assume prominent positions but at the current time are largely unknown.

While this policy would limit the degree of intrusion required and therefore may be more feasible than the requirement for unlimited access it also has certain disadvantages. The first is that it would require the inspectorate to have knowledge of existing weapon systems in order to verify that no new ones were being tested. This might be an unacceptable level of intrusion since weapon system characteristics is one of the last areas in which a nation might be willing to give up secrecy. It would prevent the development of stabilizing systems and it would also increase the time between initiation of a clandestine project and its detection and thus introduce technological instabilities. Furthermore, the assymetries between the open and closed societies may allow the closed society to carry on clandestine activities prior to the flight testing of the systems.

3. Prohibit the Development of Selected Systems with Only Launch Site Inspection

While this agreement has the advantage of restricting the development of only those systems which are considered to be provocative it has all of the disadvantages of the previous agreement. The fundamental difficulty of this agreement is that of reaching agreement on those systems which are to be prohibited. While it might be possible to agree upon certain systems, such as orbital bombardment systems, agreements on small ICBMs appear to be difficult since each party might have a different idea of what constitutes a small ICBM. On the one hand we might wish to place the size below that of the current or projected Polaris missile which has a gross weight of 30,000 pounds whereas the USSR might attempt to set the limit at a higher figure to prevent us from making improvements in the current Polaris missile system. Furthermore, the USSR might attempt to limit the development of those improvements which we are contemplating and they are not.

4. Limit the Development of Selected Systems with No Inspection

This policy is similar to the one which is currently in effect regarding the testing of nuclear weapons and the deployment of orbital bombardment systems and avoids the issues of inspection and penetration. Inspection is limited to normal intelligence gathering and extra-territorial monitoring. The major disadvantage of this policy is that it allows for the development of the system up to the point of flight testing, and even through the flight testing phase, detection might be ambiguous. Thus, this system is the most susceptible to evasion.

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5. Informal Agreements to Prohibit RDT&E Activities

This method of restricting the development of new weapon systems depends upon the achieving of a mutual understanding of the dangers associated with the development of provocative and destabilizing systems and also upon a community of interests in desiring to achieve a stable international situation. This method has the disadvantage of minimal reprisal in the event of "abrogation" and the possibility of a technological advantage developing as illustrated by the breaking of the nuclear test moratorium by the USSR. This policy was again practiced before the U. N. Resolution Prohibiting Weapons of Mass Destruction in Space by the U. S. renunciation of an intent to develop an orbital bombardment system. The fact that neither the U. S. nor the USSR engaged in the development of such a system is because both nations rated the military effectiveness of a system, which could be currently developed and deployed, rather low. This method may be workable in such situations and may be adopted as an interim measure while more formal negotiations are being conducted. Its success depends upon the ability of each nation to assure itself that the other nation is complying with the tacit agreement.

Because of the limited possibilities for verification the latter two policies may be considered only as indications of intent not to develop the undesirable weapons and may necessitate a posture of preparedness against the eventual abrogation of the agreement, whether explicit or tacit.

In order to assess the feasibility of each of the above hypothetical agreements, it is necessary to determine the required degree of intrusion into a nation to verify compliance with the agreement and then to determine under what conditions the required amount of access can be achieved. The possible levels of intrusion can be classified as follows:

a. None - although there is no ostensible intrusion into the society, verification may be possible through covert intelligence gathering methods as are currently practiced by both the U. S. and the USSR.

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b. Cooperative efforts - it may be possible to obtain information regarding the compliance with an agreement through cooperative efforts which are not directly associated with an arms control agreement, particularly if the cooperative efforts involve scientific personnel and information exchanges in the areas where restrictions are implemented. These might give some indication of the technological capabilities of the host country.

c. Governmental - inspection rights would be limited to specific facilities which were wholly under the control of the government such as launch facilities, final assembly and checkout areas and governmental research and development establishments.

d. Private business - this level represents an asymmetry between the U. S. and the USSR since there is no private business in the USSR. However, there might be great resistance to inspection of private business on the grounds that it violates constitutional guarantees against unwarranted search and seizure. If this degree of intrusion is prohibited in the U. S., the degree of intrusion within the USSR may be limited only to those facility types which are open to inspection within the U.S.

e. Personnel - the inspectorate would have the right to question personnel and inquire into their activities. This level might range from the right to question to the use of lie detectors and truth serums. Within the U. S., this might be resisted on the grounds of unconstitutional invasion of privacy.

f. Unconstitutional - the inspectorate would have unlimited powers of search and questioning of personnel regardless of constitutional guarantees and would probably not be negotiable for the U. S.

These levels of intrusiveness can be matched with the various arms control agreements postulated earlier. However, negotiability for a given degree of intrusion depends upon the hostility which exists between the

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negotiating parties. One method of analyzing the degree of intrusion which is possible to negotiate is to hypothesize a number of possible world situations in which negotiations might take place and then match these situations with the degree of intrusion which might be negotiable. The possible world situations chosen for this analysis are listed below.

a. Extreme hostility characterized by two nations which are at war or about to go to war. In the cold war such a condition existed perhaps during the Berlin Blockade or during the Cuban Crisis. In an extended condition of extreme hostility cooperative efforts would be expected to cease and only covert intelligence operations would exist.

b. Suspicion exists on both sides but both are willing to cooperate to a limited degree, particularly toward avoidance of all-out war. This condition might involve some implicit agreements to limit conflict or not to molest each others extra-territorial intelligence operations.

c. One side suspicious of the others intentions and the other side maintains a closed society. Both are willing to cooperate to a limited degree.

d. No suspicion of aggression but ideological differences remain in the form of "peaceful coexistence".

e. Both sides wish to reduce hostility and are seeking areas of agreement but ideological differences remain.

f. Both sides seek an extreme degree of cooperation against a mutual enemy as for example the cooperation which exists between the U.S. and Great Britain

These possible world situations can be correlated with the degree of allowed intrusiveness in a matrix as shown in Table VI-1. The entries in the matrix are probabilities of achieving the degree of intrusiveness

D

Table VI-3. Degree of Intrusiveness Which is Negotiable for Various Degrees of Hostility.

Hostility ↑	Intrusiveness → a	b	c	d	e	f
a	0.4	0.1	0	0	0	0
b	0.6	0.3	0.1	0	0	0
c	0.9	0.4	0.2	0.1	0	0
d	1.0	0.6	0.5	0.2	0	0
e	1.0	0.8	0.7	0.3	0.1	0
f	1.0	1.0	1.0	0.9	0.3	0

in the particular world situation described previously. These probabilities are subjective and, for the purposes used here, are only suggestive. However, the matrix can be used in the following way: If one assesses the current world to be best described by world situation (c), then it is likely that verification would have to be limited to covert methods with the possibility of some cooperative exchanges. However, it is likely that the governments involved would be careful to limit these exchanges to those which would give no indication of the status of current operational military systems. These exchanges might be useful, however, in assessing the current status of a nation's scientific capabilities. If, on the other hand, one assumes that the world is best described by situation (d), then one could expect covert intelligence operations to proceed for the most part unprotected. Both nations would be seeking cooperative efforts and one might expect that some intrusion at the governmental level would be possible. Consequently, in this world situation, it may be feasible to negotiate launch pad inspection of space vehicles.

It does not seem unreasonable that, with the passage of time, the world might move to a situation described by situation (e) in which case a greater degree of intrusion is possible which may allow for the inspection of research and development facilities.

The degree of intrusion required to implement the control policies outlined at the beginning of this section can be assessed. A complete prohibition of all RDT&E for military systems would probably require a degree of intrusion to the personnel level for reasonable verification. However, this degree of intrusion would only be possible in an extremely cooperative world. The limitation of all military systems with rights for on-pad inspection would require intrusion at the governmental level and may be possible in a world situation similar to the present one, however, the motivation to seek a prohibition of all military RDT&E is not very strong at the present time and each side can be expected to seek improvement of their present forces and thus the policy of attempting to restrict the development and testing of specific systems seems more realizable at the present time. Finally, the policy of restricting the development of specified systems with no inspection seems to coincide with the present world situation.

It thus seems apparent that in order to achieve the next level of intrusion, the inspection of launch facilities and launches, would require a lessening of tensions and suspicions between the two antagonists. To date, the USSR has rejected any meaningful inspection in relation to a ban on the underground testing of nuclear weapons, and the subject of launch site inspection of space vehicles has been avoided in the negotiations on the ban of weapons of mass destruction in space.

In order to implement inspection at the launch site it seems necessary to give the USSR some reason for lifting its curtain of secrecy. It seems doubtful that they would be willing to do so unless they were seriously afraid that the U. S. was developing a new weapon system which would give us a significant advantage over them or they were sufficiently motivated to join the U. S. in a cooperative space program such as the Joint Lunar Expedition proposed by President Kennedy in his U. N address of 20 September 1963. Without these motivations, launch site inspection does not appear to be very attractive to the Soviets at the present time.

In looking toward the future when a disarmament or arms control agreement for restricting the deployment of ballistic missiles may be reached, it is necessary to consider the requirements for the restriction of ballistic missile and space weapon system RDT&E activities. In such an environment it is most likely the potential evader will deploy those weapons previously tested and proven since he can gain an offensive capability most quickly with a weapon system which is already developed and with which he is familiar. Secondly, any new weapons which are developed are likely to be of a different kind than those which were previously deployed and these new weapons are most likely to be the result of basic and applied research activities for which achievement of effective restriction has been shown to be very difficult. An international weapons technology monitoring board, as discussed in Volume II, Section IV, may be able to discover such research and point out its potential military applications and thus other nations could develop an awareness for indicators of the implementation of the new weapon into an operational capability.

Finally, there is the possibility of quickly converting nonmilitary space systems such as a manned space station into a military system. However, if the inspection of all space launches is permitted, the deployment of nuclear weapons in such a system could probably be detected. It is also possible that the residual missile deterrent forces allowed, under an agreement to limit the number of ballistic missiles, would be large enough to minimize the additional capability which would be gained from the space deployment of a small number of nuclear weapons in such an environment.

C. The Choice of a National Policy

In the previous sections of this report, the various aspects of the problem of restricting ballistic missile and military space system RDT&E have been explored. On the basis of this discussion, the following conclusions can be drawn:

1. It is not only undesirable to impose restrictions on basic and applied research because of the applicability of results to nonmilitary activities, but the results of such restrictions are uncertain. Merely lowering the probability of achieving new discoveries or breakthroughs does not assure that these will not be achieved.

2. Although comprehensive restrictions on new weapon system developments might retard or even stop the development of these systems

and capabilities which are provocative and upset the strategic balance, such restrictions might also limit the ability of the antagonists of the cold war to implement improvements into their strategic forces which could lead to a more stable situation. In fact, a policy of universal restrictions on the development of new weapon systems could itself be destabilizing.

3. While it appears possible to provide adequate verification of restrictions for the development of complex new systems at the test and evaluation level, the resulting time lead may or may not, however, be sufficient to give the violator an important advantage. The development of relatively simple systems and improvements of existing systems may be accomplished clandestinely and avoid detection even at relatively high access levels into a nation.

In order to effectively implement an arms control agreement, verification is required and it may range between formal agreements for the inspection of facilities, monitoring of operations, questioning of personnel and the monitoring of records to extra-territorial national surveillance systems and covert intelligence operations. The need for formal inspection methods depends upon the reliability of the national and covert intelligence-gathering means. At the present time, the verification of arms control agreements depends upon national inspection systems such as the radar surveillance of launch facilities and impact areas, ELINT and COMINT operations, and the Vela Program when it becomes operational. There are several disadvantages in relying solely on national and extra-territorial verification methods. The first is that the observable overt operations are generally preceded by a period of activity which is not observable and hence increases the lead over one's opponent which the agreement attempts to reduce. The second disadvantage is that the indicators are sometimes ambiguous and it is not possible to ascertain the nature of the activities being observed. Thus it may be difficult to distinguish between training and confidence tests of a ballistic missile and the development testing of an improved version of the missile, particularly if an attempt to disguise the development launches is made.

Access into a country is required in order to overcome the limitations of extra-territorial inspection. The lowest level of access at which compliance with a systems development restriction can be directly verified is launch pad inspection with payload verification. However, if verification requires knowledge of existing military systems, this degree of intrusion may not be negotiable. This attitude of secrecy is characteristic of the USSR. Even if the rights for launch pad inspection could be negotiated, the problem of the technological lag remains, although it is not as great a problem as relying only on production and deployment monitoring.

Other problems associated with limited access are those concerning the possibility of clandestine evasion. In the previous discussion several possibilities for evasion have been cited which include making system improvements which require a minimum amount of flight testing (carried out as part of the training and reliability assurance testing allowed under a treaty), the development of subsystems as part of a peaceful space program, and the conversion of large space boosters to large payload missiles.

There are three problems associated with an agreement to restrict the development of specific systems; first, the problem of negotiating those specific systems which are to be restricted, and second, an agreement not to develop a specific system may force the establishment of elaborate covers and drive the development program behind a curtain of absolute secrecy. Thus, while indications of its development would be possible through covert intelligence sources, the security imposed on the program reduces this possibility of detection. Finally, it would probably be impossible to negotiate the restriction of development of a system which one side intended to develop in spite of the other nation's feelings about its undesirability.

A more positive approach toward controlling the development of new weapon systems is to attempt to convince our opponent that it is to his best interests to engage in only those activities which tend to increase the stability of the strategic balance of forces. If a nation has only limited resources to devote to its strategic forces, the use of its resources for these activities will limit its ability to deploy more missiles and engage in the development of provocative and destabilizing systems. At present there is some indication that the USSR is moving in this direction. The Partial Nuclear Test Ban and the U. N. Resolution Prohibiting Weapons of Mass Destruction in Space are two examples and there is also evidence that the Soviets are deploying their SS-7 ICBMs in hardened launch facilities. In the past we have demonstrated our determination to meet and counter any strategic threat which the Soviets can make and consequently we may have convinced them of the futility of attempting to gain a military advantage at the strategic level. At the same time, the U. S. must consider the implications of developing systems which appear to constitute a first strike threat to the USSR, both with regard to the technological response which might be stimulated and the heightening of tension.

Such a program of continued persuasion may be more successful in achieving limitations on the development of provocative and destabilizing weapon systems than to rely solely on the possibilities of achieving successful agreements with effective verification procedures for restricting these developments. At the same time, the U. S. should attempt to negotiate these controls on a formal level. Thus, the policy of negotiation should be directed toward communicating to the USSR that it is to their best advantage not to engage in provocative and destabilizing developments and also be directed toward an attempt to remove the barriers of Soviet secrecy. Eliminating this curtain of secrecy will be necessary before any meaningful formal agreements can be reached in any area of significant disarmament.

As a result of the investigations and conclusions drawn during the course of this study, the following recommendations have been formulated regarding the formation of a U. S. position on the restriction of ballistic missile and space weapon system RDT&E.

1. Comprehensive or across-the-board restrictions on ballistic missile and military space systems RDT&E activities should not be advocated.

2. Any negotiated restriction on new weapon system developments should be selectively applied only to those weapon systems and improvements in existing weapon systems which clearly destabilize the strategic balance.

3. Any proposals for limiting weapon force size should include proposals for monitoring RDT&E activities applicable to the controlled systems.

APPENDIX A

THE USE OF MULTIPLE INDICATORS IN THE VERIFICATION OF AN ARMS CONTROL AGREEMENT

An estimate of the probability of the violation of an arms control agreement through the use of multiple indicators has been indicated by Basore[1] through the use of Bayes' Theorem for conditional probabilities. The following derivation of his results and discussion is presented here because of its applicability in the estimation of violations to RDT&E restrictions.

Bayes' Theorem states that the probability that the hypothesis (event) a_i was the cause of event y_j is given by the formula

$$P(a_i|y_j) = \frac{P(y_j|a_i)\,P(a_i)}{\sum_{k=1}^{n} P(y_i|a_k)\,P(a_k)} \qquad (1)$$

where $P(y_i|a_i)$ is the probability that the event y_i on the condition that the hypothesis a_j has occurred and $P(a_j)$ is the probability of the occurrence of the hypothesis a_j.

Let us assume that there are two mutually exclusive hypotheses, i.e., a_1 = (the hypothesis of compliance with an agreement) and a_2 = (the hypothesis of violation of an agreement). Then there are only two terms in the denominator of Equation (1) and the equation can be written as

$$P(a_1\ y) = \frac{P(y|a_1)\,P(a_1)}{P(y|a_1)\,P(a_1) + P(y|a_2)\,P(a_2)} \qquad (2)$$

If both numerator and denominator of this expression are divided by $P(a_2\ y)$ and if

$$R = \frac{P(y|a_1)}{P(y|a_2)} \qquad (3)$$

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[1] Basore, B., "Probability of Detection of a Test Ban Violation", ACDA Memorandum to Dr. Rathjens, 26 March 1963.

so that Equation (2) can be written as

$$R = \frac{R\,P(z_1)}{R\,P(z_1) + P(z_2)} \qquad (4)$$

But since the hypotheses z_1 and z_2 are exhaustive and mutually exclusive

$$P(z_1) + P(z_2) = 1 \qquad (5)$$

Equation (4) can be written as

$$P(z|y) = \frac{R\,P(z)}{R\,P(z) + 1 - P(z)} \qquad (6)$$

The following interpretation of Equations (3) and (6) can now be made. Let y be a pattern of observed events and let z_1 be the hypothesis of compliance with an agreement then z_2 will be the hypothesis of a violation. Thus $P(y\ z_1)$ is the probability of occurrence of the observed pattern of events y under the assumption of compliance and $P(y\ z_2)$ is the probability of the occurrence of the observed pattern of events under the assumption of a violation or

$$R = \frac{P\,(\text{observed pattern}\,|\,\text{compliance})}{P\,(\text{observed pattern}\,|\,\text{violation})} \qquad (7)$$

By the use of Equation (6) the change in the apriori knowledge of compliance or violation from the information gained from the observation can be estimated. The difficulty, however, in using Equation (6) is the requirement to know the apriori probability of compliance or violation which is in fact seldom known and consequently the formula has the same difficulty that all applications of Bayes' Theorem suffer from. However, the formula does point out the utility of the quantity R which can be called the confidence factor of the test. For R = 1, Equation (6) reduces to $P(z|y) = P(z)$ and consequently the verification techniques provides no new information. However, when R departs from unity then the a priori probability maps into a different value of the a posteriori probability $P(s|y)$ and consequently new information regarding the probability of compliance or violation has been obtained. For example, assume that the a priori probability of compliance is 0.10 and for a particular test $R = 20$; the a posteriori probability then becomes 0.69 which suggests that R is a good indicator of the significance of a particular inspection technique. Figure A-1 is a plot of Equation (5) for various values of R.

The following interpretation can be given to the results presented above. Supposing that we believe that the Soviets are not complying with an agreement and we assign a probability of 0.1 to Soviet compliance. If the verification technique is such that it yields a value for R of 20 to an observed sequence of events, then the a posteriori probability of compliance becomes 0.69. On the other hand, if we had no predisposition of compliance or non-compliance and if the sequence is observed, under these conditions we might assign an a priori probability of 0.5 to the probability of compliance. Then for a verification technique which yielded an R of 20, the a posteriori probability would be 0.92.

Another property of the R function is that the Rs for sequential tests can be multiplied together. To show this, let P_o be the a priori probability before the first test and R_1 the confidence factor associated with the first test. Then the a posteriori probability after the first test becomes

$$P_1 = \frac{R_1 P_o}{R_1 P_o + 1 - P_o} \quad (7)$$

This a posteriori probability is the a priori probability for the second test and after the second test we have

$$P_2 = \frac{R_2 P_1}{R_2 P_1 + 1 - P_1} \quad (8)$$

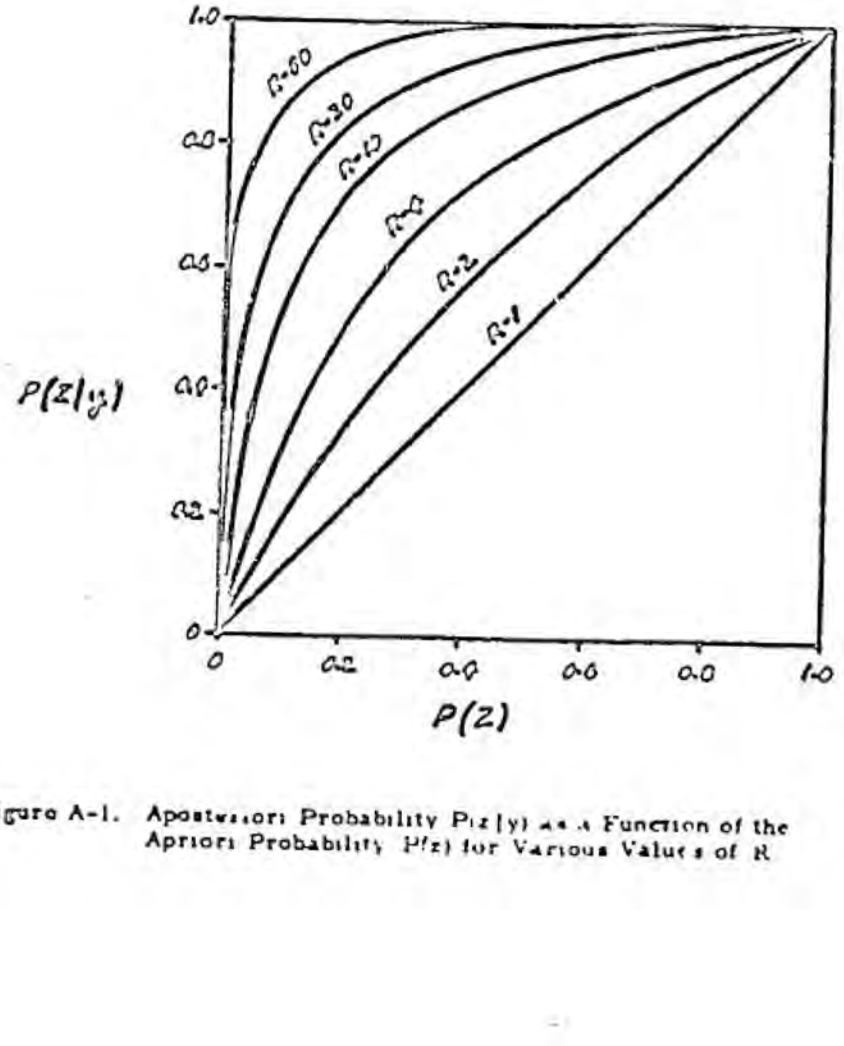

Figure A-1. Aposteriori Probability P(z|y) as a Function of the Apriori Probability P(z) for Various Values of R

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Now substituting from Equation (7; for P_1 into Equation (8) yields

$$P_2 = \frac{R_1 R_2 P_o}{R_1 R_2 P_o + 1 - P_o} \qquad (9)$$

which demonstrates that the R for the two tests is just the product of the Rs for the individual tests. Of course, this process can be repeated indefinitely.

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APPENDIX B

DISCUSSION OF LIMITATIONS ON AIRCRAFT AT THE 1922 DISARMAMENT CONFERENCE

The problem of controlling military space activity while permitting peaceful space research, development, and operation is analogous to the problem of limiting aviation, which was considered at the Conference on the Limitation of Armament held in Washington from 12 November 1921 to 6 February 1922. A somewhat biased account is given in the Aircraft Yearbook for 1922.

It is stated that the conference was "... the most profoundly significant gathering the world had witnessed since the peace treaty was signed at Versailles and far surpassing even the treaty in its certain effect upon the future peace of the nations." It was stated that "...at this conference the first definite, practical steps were taken to release the great powers of the world from the bondage of competitive armament, which had not been spared the worst conflict in history and which in 1921 threatened economic ruin."

"The immediate net results of this conference were the scrapping of 68 capital ships..."

A committee on aircraft, chaired by Rear Admiral William A. Moffett, Director of the U.S. Naval Air Service, and having as the other member from the United States Brigadier General William Mitchell, prepared a report attempting to ascertain the influence which aircraft would have upon the future and to determine what limitation should be imposed upon this "new arm". While observing that the question of whether aircraft should be subject to restrictions was a policy matter for the conference to resolve, the committee stated, "It must be understood distinctly that if the conference decides to limit the development of commercial aircraft in order to retard the development of airpower, the immediate result will be the retarded development of means of transportation and communication, which will itself, if unrestricted, largely act to bring about the same result - the removal of some of the causes of warfare."

After considering various possible methods of control and limitations on numbers, character, and use of civil and commercial aircraft with regard to their utilization in war, the committee agreed that such limitations was not practical except in the case of lighter-than-air craft. It is interesting to note the following phrase in the committee's report, "Any system of international inspection would be almost certain to arouse ill feeling and would tend to cause friction rather than to insure harmony and good feeling between friendly powers."

The final conclusion of the committee was that it was not practicable to impose any effective limitations upon commercial or military aircraft with the exception of lighter-than-air craft, and the committee felt that the use of aircraft in war should be governed by the rules of warfare as adapted to aircraft - the adaptation to take place at a later conference.

The conference met only a few months after aircraft of the Army Air Force, under the control of General Mitchell, had demonstrated their ability to sink major naval vessels in a series of tests off the Virginia capes. The final target, the German dreadnought Ostfriesland, was sunk in a series of attacks. The tests were discussed vigorously in Congress, and Senator Borah announced that "... the battleship as it is now being built is practically obsolete... with sufficient airplane and submarine protection, this country is perfectly save from attack from any other country."

In commenting upon these happenings, the writer of the Aircraft Yearbook says, "The Conference on the Limitation of Armament, which was thus brought to a successful conclusion, was inspired by two universal desires;

first, removal of the obvious provocations for war (the fear of rival nations' rising military power); second, relief from the financial burden of competitive armament and diversion of this money into economic channels. The problem was to obtain both objectives yet retain adequate sense of security. The solution came through aircraft, which have demonstrated themselves to both vehicles of peace and instruments of war."

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