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USAF BALLISTIC MISSILE PROGRAMS

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USAF BALLISTIC MISSILE PROGRAMS

1967-1968

by

Bernard C. Nalty

Office of Air Force History

September 1969

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FOREWORD

This is the sixth in a series of histories outlining the planning, formulation of policies, and technical innovations that have made possible the evolution of the Air Force ballistic missile program. The earlier studies are: Plans and Policies for the Ballistic Missile Initial Operational Capability Program; USAF Ballistic Missiles, 1958-1959; USAF Intercontinental Ballistic Missiles, Fiscal Years 1960-1961; USAF Ballistic Missile Programs, Fiscal Years 1962-1964; and USAF Ballistic Missile Programs, 1964-1966.

The current study, covering fiscal years 1967 and 1968, does not attempt to examine in detail the existing features of the operational Minuteman and Titan systems, although a brief description is provided to assist the reader. Each section is intended as an integral essay, an approach which, though it results in some duplication, spares the reader the annoyance of thumbing back and forth in pursuit of elusive cross references. Among topics the author covers in this narrative are Air Force efforts to reduce missile system vulnerability, the reentry system and penetration aid programs, and advanced missile developments.

R. A. Grussendorf

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Major General, USAF
Chief, Office of Air Force History

CONTENTS

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I. THE OPERATIONAL FORCE

(U) [redacted] At the start of fiscal year 1967, the Air Force intercontinental ballistic missile (ICBM) force consisted of two dissimilar systems, Minuteman and Titan II. The latter was built around the LGM-25C missile, used a storable liquid fuel, and was launched from a protected silo by an electronic signal sent through buried cables from an underground control room. This Strategic Air Command (SAC) missile had a range of up to 6,115 nautical miles. Two nine-missile Titan squadrons were located at each of three bases: Davis-Monthan AFB, Ariz.; Little Rock AFB, Ark.; and McConnell AFB, Kan.[1]

(U) [redacted] The solid-fueled Minuteman also operated from an underground complex. Because it had been modified even as the first prototypes were being deployed, Minuteman came in various models with maximum ranges of about 5,000 to 6,200 nautical miles--depending whether the missile was the LGM-30A, -30B, or -30F. A network of six wings--composed of 19 squadrons, each with 50 missiles--and one independent squadron emanated from six support bases in the north and central United States. Wing I (three squadrons, 150 launchers) plus the independent squadron (50 launchers) were based at Malmstrom AFB, Mont. Wings II, III, IV, and VI, each possessing three squadrons and 150 launchers, were based at Ellsworth AFB, S.D., Minot AFB, N.D., Whiteman AFB, Mo., and Grand Forks AFB, N.D., respectively. Wing V consisted of four squadrons and 200 launchers and was based at Warren AFB, Wyo.[2]

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Weapons for Assured Destruction

(u) [redacted] In April 1967 the total number of Air Force ballistic missile launchers--including those under repair or off alert for other reasons--reached the previously planned total of 1,054, a thousand Minuteman and 54 Titan. In addition, a pair of Titan II test sites at Vandenberg AFB, Calif., were on war alert at least part of the time. The Minuteman force attained its peak numerical strength on 21 April when the last of 50 Minuteman sites was turned over to the independent squadron--also called the 20th squadron--at Malmstrom.[3]

(u) [redacted] Equipped with the LGM-30F, this Minuteman II squadron was distinct from Malmstrom's three Wing I squadrons. The latter worked with the oldest of the three Minuteman missiles, the LGM-30A, which initially had the shortest range (4,800 nautical miles*). Other Minuteman I units--in Wings II through V--originally were equipped with the LGM-30B. Its maximum range was 5,500 nautical miles and, unlike the A model, it was programmed to shift from one "memorized" target to another on receipt of a coded signal. Wing VI and the independent squadron operated the advanced LGM-30F, which had a range of 6,200 nautical miles and could be launched against any of eight previously programmed targets. Also, their Minuteman II launch facilities differed from the others in that they were better protected from blast.[4]

(u) [redacted] In November 1966, the Air Force had begun a modernization program to give older elements of the Minuteman force the same basic characteristics as the Minuteman II system. Modernization activities started at Wing IV at Whiteman AFB and were completed in October 1967. A

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*Later increased to just over 5,000 nautical miles.

similar project began two months later at Malmstrom to update Wing I. Until the five wings had received F missiles and undergone extensive modification, some Minuteman I units would remain in the operational force.[5]

(U) [redacted] USAF plans called for the eventual elimination of Titan II and the introduction of Minuteman III, which featured the LGM-30G missile with an entirely new third stage and a post boost vehicle (PBV) capable of releasing several reentry vehicles, each against a different target. Specifications for the G series called for a range of 7,500 nautical miles but the weapon had yet to prove it could travel this distance consistently. The Office of Secretary of Defense (OSD) planned to incorporate Minuteman III into the operational force without permitting the total number of Minuteman silos to exceed 1,000. During January 1974, the number of Minuteman III would approach 600--the limit for the foreseeable future--with Minuteman II making up the balance.[6]

(U) [redacted] The Air Force, however, hoped for a Minuteman force that, at least temporarily, would exceed 1,000. This expansion depended upon construction of so-called "dual capable facilities," underground launch complexes designed to withstand earth shock of 3,000 pounds per square inch and capable of accommodating either Minuteman III or the proposed advanced ICBM (WS-120A). In the spring of 1968, the Air Force favored installing Minuteman III in 150 of these facilities, a course of action that would bring the total Minuteman force to 1,150 sites during fiscal year 1974. Hopefully, the advanced ICBM would begin appearing in fiscal year 1975. This system would replace Minuteman III at the dual capable sites, reducing the total Minuteman force to 1,000, and the Minuteman III equipment thus released would take the place of Minuteman II in three of the older squadrons. At this time, Air Force planners were discussing the deployment of 280 advanced ballistic missiles by the end of fiscal year 1977.[7]

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(U) No shift in American missile strategy occurred during fiscal years 1967 and 1968. In one of his last statements as Secretary of Defense, before leaving that post in February 1968, Robert S. McNamara declared that American security still rested upon the country's "clear and present ability to destroy the attacker as a viable 20th Century nation" and its "unwavering will" to reply to an attack by loosing this destructive fury. Mr. McNamara continued to refer to the ability to vaporize an urban society as "assured destruction."[8]

(U) In his statement, the Secretary again dismissed the idea of increasing the size of the strategic force for the purpose of damage limitation--that is, retaliating against military targets rather than urban industrial ones in the hope of reducing the damage inflicted upon the United States. Indeed, he now appeared to define damage limitation almost exclusively in terms of defense against enemy missiles. He denied that a defensive system "no matter how extensive," could by itself insure full protection in a war between the United States and Russia, but he nevertheless recommended the deployment of a "thin" screen against missile attack. This type of defense, he said, would protect America's assured destruction force against surprise attack by the Soviet Union and also limit the damage that might be done to the United States by Chinese, rather than Russian, missiles. Because the Chinese intercontinental ballistic missile force would remain small for several years--he maintained that Peking would not attain an initial operational capability until "the early 1970's"--Mr. McNamara reasoned that even a "thin" defense would be highly effective through the 1980's.[9]

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Titan II

(U) [redacted] After 19 launchings, Titan II operational testing came to an end in April 1966 and was succeeded by a follow-on operational test program involving the firing of six missiles a year. Since Mr. McNamara did not intend to purchase replacement missiles after fiscal year 1966, steady attrition would eventually exhaust the entire Air Force inventory of Titans. OSD officials, however, were unwilling to await the inevitable disappearance of this weapon, and they advised the Air Force of a tentative plan to begin retiring Titan during fiscal 1971. Apparently OSD reasoned that Titan II, because of its large yield, would attract enemy missiles and therefore be less likely than Minuteman or the Navy's submarine missiles to survive a first strike.[10]

(U) [redacted] When advised in early July 1966 of the possible phaseout of Titan II, SAC countered with the argument that it was a unique weapon which combined long range with great weight lifting capability. The command sought, without success, to interest the Air Staff in further improving Titan by developing either a warhead fully hardened against nuclear effects or a system for dispensing multiple reentry vehicles, such as would be carried by Minuteman III. Headquarters USAF, however, did support SAC's argument that Titan II ought to remain operational until a similarly powerful weapon, such as the advanced ICBM, entered service.[11]

(U)-[redacted] Before 1966 ended top defense officials had come to accept the Air Force view that Titan was too valuable a weapon to be hastily cast aside. Initially, OSD guidance called for all 54 missiles to depart by the end of fiscal year 1973. In September 1966, Secretary of the Air Force Harold Brown proposed slowing the process by retiring one nine-missile squadron each year in fiscal years 1971 through 1973, with the remaining three squadrons to go

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during fiscal year 1974. Within the Air Force planning went ahead to execute this revised schedule, and SAC officials--who had studied the phaseout problem in terms of age of the missiles, distance from targets, and condition of equipment--decided that the squadrons at Davis-Monthan AFB would be the first to go, followed by those at McConnell and finally the two units at Little Rock. Concerning this activity, Secretary Brown pointed out to OSD that by spending about an additional $2 million in fiscal year 1968 and also slowing the pace of follow-on operational testing, the Air Force could postpone the retirement of Titan II until 1975. Mr. McNamara approved this proposal on 22 November 1966 and the tentative schedule was altered to call for the departure of three squadrons, one each in fiscal years 1971, 1973, and 1974, and the other three in fiscal year 1975.[12]

(U) [redacted] Review of the retirement schedule continued into 1967. In February, OSD indicated that only half the Titan force would be eliminated by the end of June 1975. By October it had been decided to keep all 54 missiles in service through fiscal year 1973, with the closing down of one squadron tentatively set for the following year. As of mid-1968, it was not clear what would happen after 1973.[13]

(U) [redacted] In light of the forthcoming retirement of Titan II, the Air Force was reluctant to spend large amounts to protect the system's Mk-6 reentry vehicle against nuclear detonation effects. Although a $50 to $60 million hardening program of this type was disapproved, the Air Force did proceed with two projects to protect the Titan launch complexes.[14] They were Yard Fence and Loggy Ebb, originally called Low Ebb. Begun in 1965, Yard Fence was aimed at improving the reliability of equipment installed at Titan II sites. Work done under this program included adding

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neutron shielding and acoustical lining and fitting new seals around blast doors. The project was to have been completed in the spring of 1966, but a silo fire near Searcy, Ark., in 1965 killed 53 civilian workers and compelled the Air Force to suspend work.* The last of the silos located around Little Rock AFB was not modified until February 1967, and activity continued at other sites until November.[15]

(U) Investigation of the Yard Fence accident disclosed that a small portable generator had restored electricity at the Searcy site after the fire had disrupted commercial power and averted an even worse conflagration. This current kept the ventilation and air conditioning systems functioning and thus prevented propellant heating and expansion and bursting of the storage tanks. SAC therefore requested and portable generators were provided for all Titan II sites, though some had less output than the command desired.[16]

(U) [redacted] Loggy Ebb, the other major project, was designed to provide protection against electromagnetic pulse, an effect of nuclear explosions that could damage vital electrical equipment. During the summer of 1967 workers at Little Rock began installing surge arrestors to protect Titan II circuits, generators, and buried cables. USAF plans called for completion of Loggy Ebb in October 1968 at Davis-Monthan AFB.[17]

(U) Loggy Ebb coincided with modifications to strengthen the longerons that held the Titan II missile to the thrust mount inside the silo. Cracks in these longerons first came to light in July 1966 during a routine inspection of one of the Titans. Although the cracks might reduce the ability of the

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*See Bernard C. Nalty, <u>USAF Ballistic Missile Programs, 1964-1966</u> (TS-NOFORN) (AFCHO, March 1967), p 17.

[redacted]

missile to withstand ground shock, they were not considered particularly dangerous since they neither prevented the weapon from remaining on alert nor interfered with launch procedures. A SAC inspection of the entire operational force of 54 missiles revealed 13 with evidence of this type of stress corrosion. Contractors continued to minimize the effects of these cracks, but SAC nevertheless obtained approval for reinforcing the longerons.[18]

(u)[redacted] The transition of Titan II from operational to follow-on operational testing brought a reduction in the annual number of launches from Vandenberg and enabled SAC to request that at least one of the three Titan complexes at the base be added to the alert force. A nuclear safety panel agreed to shift the complex from training to operational status, provided SAC took certain precautions against accidental launch during exercises or tests at adjacent silos. The 395th Strategic Missile Squadron, which was responsible for the Titan area, received instructions to maintain one site on alert and use another exclusively for tests, while the third alternated between the two assignments, spending roughly nine months of the year on alert. At the end of June 1968, both launchers were included in the strategic offensive force.[19]

Minuteman: Problems of Men and Money

(u)[redacted] During fiscal years 1967 and 1968 the Minuteman program ran short of skilled system managers and funds. Gen. James Ferguson, Commander of the Air Force Systems Command (AFSC), was especially concerned about the reassignment, after extremely short tours, of officers whose scientific, engineering, or managerial skills were essential

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to supervise the continuing Minuteman research and development effort. A major factor contributing to this problem was the transfer to flying duties in Southeast Asia of qualified pilots working in the Minuteman System Program Office and other important management posts. Possibly related to this turnover was the gradual blurring of lines of managerial responsibility. For example, the Aerospace Corporation--which was assigned the job of system engineering and technical direction--seemed, in Air Force eyes, to have encroached upon the rightful preserve of the Minuteman office.[20]

(u) [redacted] To stabilize the Minuteman staff, General Ferguson directed that the required number of officers be assigned, insofar as possible, to complete four-year tours of duty. An AFSC study, prepared at the direction of the Air Force Chief of Staff, resulted in other actions. For instance, the program office was reorganized to provide for more centralized control, and the Aerospace Corporation began withdrawing from Minuteman development to concentrate exclusively on advanced reentry systems.[21]

(u) [redacted] Gaining control of rising Minuteman costs was another purpose of this AFSC management survey, which also reviewed existing contracting procedures and financial techniques. One activity given close scrutiny was a program to end Minuteman II NS-17 guidance and control unit failures. This undertaking was expected to cost a total of $68 million during fiscal years 1968 and 1969. Some of this money could be saved, AFSC officials maintained, through careful supervision of the contractor, acceptance of a mean time between failures of 2,200 hours (less than half what was desired), and possibly by greater competition for production contracts.*[22]

(u) [redacted] The proposals offered by the Systems Command might help ease the financial strain, but could not end it. The fact remained that fiscal

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*For a discussion of the NS-17 problem; see below pp 15-16.

[redacted]

year 1968 funds allocated by OSD--about $907.5 million--fell some $289 million short of covering every aspect of that year's Minuteman program. Additional costs were incurred in correcting shortcomings in the NS-17 guidance and control unit, providing greater protection against radiation and other nuclear effects, improving penetration aids, and resolving various difficulties.[23]

(u) [redacted] To keep the program within the financial limits imposed by OSD, an Air Staff panel made three main suggestions. The Air Force should: (1) delay Minuteman III's initial operational capability, originally set for July 1969, until July of the following year; (2) postpone the completion of force modernization from October 1972 until October 1973; and (3) wait a year before beginning work on a solid post boost propulsion system* for use with Minuteman III and the lightweight Mk-18 reentry vehicle. Other of the panel's proposals called for deploying the basic Mk-1 Minuteman penetration aids in January 1968 as planned, introducing an improved version two years later, and completing the heavy Mk-17 reentry vehicle development program as planned.[24]

(u) [redacted] As the weeks passed, the financial pressure on Minuteman seemed to grow worse. The research and development deficit, reckoned at some $72 million in May 1967, was calculated a month later at $112 million. The revised figure included the previously tabulated costs of system improvements and also reflected unexpected deficits in reentry vehicle development and a possible requirement for funds to investigate and correct a recently discovered inaccuracy that seemed characteristic of Minuteman. In acknowledging these funding problems, Robert N. Anthony, assistant comptroller for OSD, predicted a long delay in deployment of Minuteman III.[25]

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*The post boost propulsion system would be used to position the PBV prior to successive ejection of the warheads.

(U) [redacted] Taking finances into consideration, Secretary Brown studied ways to achieve the best possible balance between research and development activities and the immediate needs of the operational force. Indicative of this approach was his decision on 3 July 1967 to postpone Minuteman II for five months--from July to December 1969--instead of a year and to suspend modernization work for five months upon completion of Wing I. The latter would delay completion of the final wing from October 1972 to July 1973 (rather than October 1973 as previously proposed). The Secretary also directed the Air Staff to postpone acquisition of the Mk-18 reentry vehicle one year to July 1972 and to reschedule the initial operational capability of the Mk-17 reentry vehicle and Mk-1A penetration aids from January to July 1969. He further authorized an 18-month delay in incorporating the status authentication device--basically a scrambler for cable traffic--into the Minuteman wings, and advised that research on the solid post boost propulsion system would receive funds through the advanced ICBM technology program.[26]

(U) [redacted] While the Minuteman program was being thus revised, Secretary Brown reviewed for Secretary McNamara the history of the current financial crisis. Dr. Brown wrote that OSD's decision on the previous year's budget had provided the Air Force some $181 million less than it had requested. Among other things, the budget reviewers had ignored an Air Force warning that bringing the NS-17 guidance and control unit to acceptable performance standards would be extremely expensive. "These unfortunate events," he continued, were "by no means entirely the result of OSD decisions." The Air Force had been late with its submissions, imprecise in estimates, and vague in justifying requests for added funds. But the Office of Secretary of Defense had, in Secretary Brown's opinion, sometimes ignored "even these tardy and underestimated amounts."[27]

(U) [redacted] Even as Dr. Brown sought to explain the situation, the Minuteman program underwent further changes. In late November 1967 the Strategic Air Command urged the Air Staff to allocate money for a number of new items including radiation sensors, a device to cancel a launch already in process, and so-called "memory augmentation" for Minuteman's airborne computer. While advocating these additions to the program, the command opposed an OSD proposal to obtain the necessary funds by cancelling the Mk-17 reentry system or delaying still further the operational appearance of Minuteman III. SAC spokesmen protested that these actions would "degrade the Minuteman force" and urged deletion of less important items instead.[28]

(U) [redacted] Despite SAC's objections, OSD prevailed, and Air Force headquarters in December 1967 issued a management directive eliminating the Mk-17 and delaying the Minuteman III initial operational capability from December 1969 to June 1970. The directive did, however, provide fiscal year 1969 funds for acquisition of the radiation sensors and launch cancellation system desired by SAC. Funds also were provided for work on a high altitude fuze, improved system hardness and survivability, and integration of missile defenses with the strategic missile force. The headquarters imposed a $5 million ceiling on Mk-18 reentry system development in fiscal year 1969. Installation of status authentication equipment was tied to the Minuteman modernization schedule. Money for the purchase and installation of the enable command timer--a safeguard of debatable value against unauthorized launch--was withheld, and the future of this device remained to be determined.[29]

(U) [redacted] Despite these cost-saving steps, it appeared unlikely that Minuteman financing would take a turn for the better during fiscal year 1969. Although a high priority program, Minuteman was in competition for funds

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with other systems, particularly those having a direct effect on the war in Southeast Asia. Contract definition of the Mk-18 was formally postponed beyond fiscal year 1969, and production--as distinct from development--of Mk-12 penetration aids was suspended until the need for them could be demonstrated. Funds remained available for the memory augmentation computer at the silo to relieve the airborne computer of functions performed before launch, but the pace of development was expected to be slow. A number of other new items also were likely to be retained, including the radiation sensing network, the launch cancellation system, and status authentication equipment.[30]

Difficulties Overcome at Minuteman Operational Sites

(U) [redacted] During the winter of 1965-1966, the operation of several Minuteman sites was disrupted after storms had severed commercial power lines and the diesel engines that were supposed to turn standby generators failed to start. The refurbishment or replacement of standby power system components began in 1966 with emergency modifications--principally to the mechanism for switching automatically to internal power--in Minuteman Wings I through V. The first series of alterations was scarcely under way when it was discovered that the new switching mechanism was overly sensitive to fluctuations in commercial current. The solution arrived at was to arrange a two-second delay between sensing a change in voltage and shutting off outside power. If the weather or some defect in the commercial system caused a minor variation in current, normal power was expected to return within that time; if the fluctuation persisted, the system would shift to standby power before any damage could be done.[31]

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(U) [redacted] Interruptions of electrical power had been unusually frequent at the Minuteman II wing at Grand Forks, N.D. During the first six months of 1966 commercial power failed on 450 occasions, and 126 times, almost one in three, the standby system did not work. Although commercial power was usually restored within a quarter of an hour, the diesel-powered system was clearly in need of modifications to make it more dependable. Repairs undertaken included modifying circuit breakers, replacing diodes and relays in generator circuits and switching panels, and providing diesel fuel pressure gauges and shut off valves. When this job seemed likely to last through 1968, the Air Force directed the Ballistic Systems Division (BSD)* to schedule the work in conjunction with routine facility update.[32]

(U) [redacted] The repeated failure of the launch site generators also imposed a severe strain on the storage batteries--32-volt for Minuteman I and 160-volt for Minuteman II--which were used as emergency sources of power. The revisions in plans and delays in overhauling the unreliable diesel system resulted in a continued reliance on emergency power to do what had been planned for the standby diesels and exacted a heavy toll in expended batteries. The Air Force soon found it necessary to purchase more batteries in order to replenish a dwindling supply of spares. Recharging exhausted batteries was a normal procedure, though the task required caution. These emergency power sources--especially the heavier one used in Minuteman II--could explode if filled too full with fluid or allowed to overheat.[33]

(U) [redacted] During routine inspections conducted in 1967, technicians at the Ogden Air Materiel Area, Utah, removed the igniters from sample

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*Later absorbed in a new Space and Missile Systems Organization (SAMSO).

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Minuteman first stage motors and discovered cracks in the propellant. These fissures varied from hairline to an eighth of an inch wide, were up to an inch deep, and extended as far as 12 feet along the long axis of the motor. Five of the cracked motors underwent static firing, and all performed perfectly. Those technicians who evaluated the tests concluded that the cracks had no effect on motor performance.[34]

(U) [redacted] By the summer of 1966, the Air Force appeared to have solved an especially serious problem--the unreliability of the NS-17 guidance and control unit used in the LGM-30F missile. The solution adopted included modifying the design, careful handling of the device while in transit to the site, and cautious starting, especially in cold weather, to avoid a "thermal shock" believed to occur when coolant was added too rapidly to a unit being brought to operating temperature. But despite these actions, NS-17's continued to fail at an alarming rate. By April 1967, for instance, there were 107 fewer units on hand for the Minuteman force than plans called for; the deficit was due to the unexpectedly large number under repair.

(U) [redacted] Because of the importance of these units to the Minuteman II force, the Air Force asked for and OSD provided $13.7 million for modifications to begin in the summer of 1967. This sum, however, turned out to be a little more than a third of the amount needed. Meanwhile, AFSC and BSD investigators studied the performance record of the NS-17 to determine the circumstances under which units were failing and scrutinized both the design and the method of manufacture to identify probable cause of failure.[36]

(U) [redacted] The TRW Systems Corporation, which participated in the NS-17 probe, concluded that poor quality control and sloppy workmanship were among the major causes of failure. Another factor, according to the

BSD program manger, was that the manufacturer, Autonetics Division of North American Aviation, had been overly bold in attempting to advance the science of microminiaturized electronics. He suggested that a more conservative approach would have eliminated the need for many of the modifications now required by the NS-17. As a result of these assessments, Systems Command tried to persuade Autonetics to do a better job, mainly by reminding the firm's executives of the importance of the Minuteman II system to the nation's security.[37]

(U) [redacted] In the aftermath of the investigation came improved methods of production and numerous changes in the units themselves. Each group of modifications was identified by a color code, and SAC at one time found itself with yellow, blue, and red dot NS-17's in stock. By June 1967, however, the modifications had been standardized so that there were only two types of NS-17's: the old and the new, with the latter having increased radiation shielding as well as other improvements. As a result of the corrective program, mean time between failure of guidance and control units increased from 1,400 hours in March 1967 to about 2,950 hours in July 1968. Some of the newer units, however, had operated in excess of 4,000 hours.[38]

(U) [redacted] Another problem of yet undetermined gravity appeared in March 1967 when an entire flight of Minuteman I missiles at Malmstrom went abruptly off alert. Extensive tests at Malmstrom, Ogden Air Materiel Area, and at the Boeing plant in Seattle revealed that an electronic noise pulse had shut down the flight. In effect, this surge of noise was similar to the electromagnetic pulse generated by nuclear explosions. The component of Minuteman I that was most vulnerable to noise pulse was the logic coupler of the guidance and control system. Subsequent tests showed that the same part in Minuteman II was equally sensitive to this same phenomenon. At the end of fiscal year 1968, however, filters were being installed to suppress electromagnetic effects, and these might also screen out noise.[39]

Modifications to Improve Minuteman Effectiveness

(u) [redacted] Among the modifications under development in June 1966 was the enable command timer, a device to provide additional insurance against unauthorized launch. This electronic timing unit made certain that, in the event of a break in communications within the wing, a period of time would elapse before a launch control center received authority to enable* its missiles. This delay gave wing headquarters an opportunity to restore contact if the break was accidental or to arrange for other control centers to cancel the enabling command if it had been issued deliberately by two combat crews collaborating to circumvent normal procedures.

(u) [redacted] The proposed system, modified to give an airborne launch controller the same degree of access to the individual launchers as the underground launch crews already enjoyed, passed its tests during June 1967. As of December of that year, the Air Force planned to install the modified command timer in Wing VI and one squadron of Wing I. Afterward, installation would insofar as possible coincide with the incorporation of the status authentication system. When, if ever, this work would actually begin was uncertain. At the close of fiscal year 1968, funds for the enable command timer were being withheld.[40]

*Four switches controlled the status of the missiles: enable, inhibit, lock, and unlock. The first alerted the missiles for launch, the second cancelled the command to enable, the third prevented launch, and the fourth returned positive control to the combat crew.

[redacted]

(U) [redacted] The status authentication system was separated from the command timer installation and linked to another improvement, the launch facility processor. This was a general purpose computer which was to be installed at the missile silo. This combination not only could encode cable signals but also could serve as a key component in a command and control system for a new type of silo anchored in hard rock to minimize ground shock and able to accommodate more than one type of missile.* Estimated development and production costs were $92.9 million for status authentication and $235.6 million for the launch facility processor.[41]

(U) [redacted] The launch facility processor assumed an added importance when Secretary McNamara in the fall of 1967 approved the deployment of the anti-ballistic missile (ABM) to defend at least part of the Minuteman force and certain urban areas. Any exchange of information between the strategic forces and the Army units defending them would require new computers at every silo to supplement or replace the existing ones. There was a possibility, however, that cable conversation would be unnecessary and that a simple coded command could tell the computer at the missile site whether or not to launch. If no exchange of data were needed, an increase in the number of plates in the memory bank would prove adequate. While the Air Force was collecting additional information on the relationship between offensive and defensive systems, it became interested in using the launch facility processor to supplement the airborne computer installed in the missile itself.[42]

(U) [redacted] Like the computer currently in use at the silo, the airborne computer was operating near capacity in storing instructions for Minuteman II.

*See Chapter IV, pp 59-61.

[redacted]

However, Minuteman III--with multiple reentry vehicles, more elaborate penetration aids, and possibly the enable command timer--would require as many as 600 additional words. To forestall inundation of the airborne computer, SAC reviewed the information currently stored there. One out of 10 words, it discovered, dealt with preparations for launch, and these might be transferred to a computer within the silo. As of the summer of 1968, the answer to Minuteman memory saturation seemed to be to let the launch facility processor assume some of the burden being carried by the airborne computer.[43]

(u) [redacted] For several years the Air Force had worked on development of airborne launch control centers (ALCC's) as a form of insurance against the possible destruction of Minuteman underground control centers. Late in 1965, Air Force headquarters had ordered acceleration of this program. Work proceeded satisfactorily and the airborne system became operational on 31 May 1967. The Strategic Air Command reported in February 1968 that sufficient aircraft and launchers had been fitted out with the necessary radio equipment to permit the ALCC's to launch 470 Minuteman missiles.[44]

(u) [redacted] Another innovation that came into operational use during 1967 was the emergency rocket communications system designed to ensure that SAC headquarters could unleash the retaliatory force during or after a nuclear strike upon the United States. In August 1966, the Air Force awarded the Bendix Corporation a contract to manufacture transmitters, capable of broadcasting automatically for 30 to 90 seconds, to be launched by Minuteman boosters on high ballistic trajectories. In an emergency, a modernized squadron at Whiteman AFB would launch six missiles, three on an eastward trajectory and three to the west. One successful launch in each direction would provide the necessary coverage. This system attained an initial operational capability in October 1967 and became fully operational in January 1968.[45]

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(U) [redacted] The coming of the emergency rocket communications system, along with improvements in low frequency communications, persuaded SAC that there no longer was need for high frequency single sideband radios in every Minuteman launch control center, though the sets might still prove useful in wing and squadron command posts. This type of radio, installed as a supplementary link between SAC headquarters and the launch sites, was too vulnerable to nuclear effects to be a satisfactory means of signaling the retaliatory force into action.[46]

(U) [redacted] Several other projects studied or actually undertaken during fiscal years 1967 and 1968 represented an effort to protect airborne digital computers from the effects of enemy nuclear detonations. These projects were aimed at detecting and reporting the presence of radiation, and enabling launch crews to avoid exposing their missiles to X-rays or gamma rays. In the first category were a high altitude radiation detection (HARD) system and a proposed trans-attack environmental probe. The second category involved a mechanism for postponing launch after a valid command had been given.[47]

(U) [redacted] The high altitude radiation detector served to indicate the presence of nuclear effects that might inflict damage on a missile during powered flight. In 1967 the Air Force began work on a network of ground and airborne sensors that could detect and report both radiation and florescene, the latter phenomena another indication of a nuclear detonation outside the atmosphere. The first sensors deployed, costing $30,000 each, were to be installed in five airborne launch control centers and at one underground launch control center in each Minuteman wing. On 1 January 1968 this provisional system attained an initial operational capability, but false alarms caused by defects in airborne antennas persisted for about a month before technicians could isolate the source and correct it.[48]

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(U) [redacted] The provisional system was to be supplanted by a network of hardened sensors, each costing about $1.8 million. Eventually detectors were to be located in all post-attack command and control aircraft, all Minuteman launch control facilities, and at two control centers in each Titan wing.[49]

(U) [redacted] The so-called trans-attack environmental probe, under study but not yet approved for development, was similar to a trajectory accuracy prediction system canceled earlier because of high costs and limited effectiveness. Whereas the trajectory accuracy prediction device would merely signal the successful completion of powered flight--an indication, but not positive proof, that no disabling radiation was present in the vicinity of the launcher--the probe reported whether nuclear effects were present in sufficient strength to cripple the missile.[50]

(U) [redacted] In the fall of 1967 OSD released $3.5 million in fiscal year 1968 funds to begin development of both the radiation detector and a companion device called cancel launch in process (CLIP). With existing equipment, if the sensor network should detect hazardous radiation after a launch order had been received at the silo, the combat crew could not intervene to prevent the missile from hurtling upward through the deadly X-rays or gamma rays. CLIP would remedy this failing by providing the crew a method of canceling a launch that could be invoked until the moment the silo lid opened.[51]

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II. TESTING THE OPERATIONAL FORCE

(U) The best known form of system evaluation was the flight test in which a missile fitted with special monitoring equipment was launched down the Eastern or Western Test Range, signaling to ground stations detailed information on its performance. The ICBM force underwent other types of test, however. Among these were the spectacular high explosive simulations, in which engineers set off primacord over a missile silo or control center to provide the kind of shock wave created by a nuclear blast, and other experiments to determine system vulnerability to nuclear effects.

Flight Tests

(U) [redacted] Once a missile emerged from research and development testing, it began a series of flight tests that continued throughout its operational life. Demonstration and shakedown operations came first and were aimed at the refinement of the system and the procedures for its use. Next operational tests were undertaken to establish system reliability and accuracy factors needed in preparing the single integrated operations plan. Once these factors had been established, it was necessary to check them by launching a representative sample of the ICBM's chosen at random from the operational force. This verification, which continued for the life of the system, took place during follow-on operational tests.[1]

(U) [redacted] For several years the Weapons Systems Evaluation Group (WSEG) had evaluated missile test data and assigned to the various systems reliability and accuracy factors. In October 1965, however, the Joint Chiefs of Staff (JCS) directed the group to limit its evaluation to the initial tests of certain new and rather complicated systems--the Army's Pershing missile as a

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quick reaction alert weapon, the Navy's Polaris A-3, and Minuteman II with the LGM-30F missile. Appropriate commanders of unified and specified commands--in the case of Air Force missiles, the Commander in Chief, Strategic Air Command (CINCSAC)--assumed responsibility for other systems. Under this arrangement CINCSAC evaluated Minuteman I and Titan II, then submitted his estimate to the JCS for review. In April 1967, WSEG's director, Vice Adm K.S. Masterson, asked the JCS to relieve his group of all responsibility for test evaluation because of a shortage of men and money. The Air Staff, requested to comment on the WSEG request, expressed concern about the possible loss of the group's "experience, technical competence, and objectivity." The Joint Chiefs apparently felt the same way and assured Admiral Masterson that, assuming Congressional cooperation, the necessary money would become available. For the time being at least, the group retained its limited responsibilities for test evaluation.[2]

(U) [redacted] Four operational Air Force systems underwent one phase of testing or another during fiscal years 1967 and 1968. Minuteman I, with the LGM-30A missile, completed its follow-on operational series late in 1966 and awaited retirement from the operational force early in 1969. Minuteman I, with the LGM-30B missile, underwent follow-on operational tests, and Minuteman II, LGM-30F, began demonstration and shakedown operations. Titan II was engaged in follow-on operational launches. Of those that remained under test in the summer of 1968, only Titan II had encountered no serious difficulties.[3]

(U) [redacted] Between 11 July and 22 September 1966, a dozen LGM-30B missiles were launched in follow-on operational tests of the Minuteman I system. Seven of the flights ended in failure. An AFSC analysis group,

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which included representatives from the missile industry, sought to discover some flaw that might have contributed to all the failures, but no pattern emerged. On one test, for example, the retro-rockets which were to slow the third stage after reentry vehicle separation fired too soon, so that their exhaust struck the reentry vehicle and propelled it some eight miles beyond the target. Two other failures were caused by defects--a hollow retaining pin that could not withstand the tension generated during launch and faulty motor insulation--that already were being corrected. The remainder appeared to be random failures.

(u) [redacted] By the summer of 1967, a problem arose with the LGM-30B. As the weight of its test reentry vehicles increased, the missile became progressively less accurate. The error was not characterized by the random enlargement of the impact pattern--though the pattern tended to become eliptical rather than circular--but by a shift of the center of this pattern away from the desired point of impact. Taking into account this bias--as the distance between the actual center of impact and the desired ground zero was called--the heaviest reentry vehicles had a circular error probable of 1.029 miles. To determine why weight thus affected accuracy, SAC proposed a series of special tests. If they did not disclose the solution, follow-on testing would have to be suspended and a more intensive investigation begun.[5]

(u)-[redacted] The bias which affected Minuteman I manifested itself during test flights from Vandenberg AFB into the Eniwetok target complex. To determine whether range was a factor, the missiles were launched toward Midway, a less distant impact area used since 1966. The Midway series definitely eliminated range as a contributing factor, and a check of the launch sites revealed no survey error that could have caused the inaccuracy.

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Consequently, Air Force headquarters approved suspension of follow-on operational tests in order to begin a series of launchings designed to investigate the problem. At the end of June 1968, the cause remained unknown.[6]

(U) [redacted] The LGM-30F missile emerged from R&D testing with a record of 20 successes, two partial successes, and no failures. Despite this impressive performance, Secretary Brown ordered a delay in starting the demonstration and shakedown phase. He considered a two-month postponement to July 1966 necessary to permit maintenance crews to eliminate a work backlog--principally the replacement of defective guidance and control units--at the operational sites. The second phase of the test cycle began on 1 August 1966 with a launch that was a resounding success. Not only did the missile perform as planned, but the launch controller succeeded in changing azimuths prior to launch and the system rejected a launch command deliberately sent before the enable command.[7]

(U) [redacted] Two minor defects soon appeared, however. During subsequent tests, wet tantalum capacitors, used in the guidance and control unit and in all three stages, were found to leak electrolyte through defective seals. When primary power was applied during a system test or an actual launching, a reversal of voltage sometimes occurred that short-circuited the weakened capacitors. This problem was resolved by replacing the wet capacitors with solid ones and providing for better grounding to avoid the voltage reversal.[8] The second minor flaw in Minuteman II surfaced when a test missile failed to lift off despite a proper command. Investigation disclosed that a safety device, installed to prevent damage during exercises, had automatically disarmed the explosive squib which cast off the guidance and control umbilical. A minor modification enabled crews to override the safety device during an actual launch.[9]

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(u)[redacted] While these corrections were being made, SAC missilemen encountered a more serious problem--a tendency of Minuteman II reentry vehicles to fall consistently short of the desired point of impact. A hasty examination by BSD suggested that the cause was a tubular housing--called a raceway--that carried cables down the exterior of the missile and passed closer to one of the third stage thrust termination ports than to another. BSD technicians theorized that at termination of thrust gases escaping through the near port struck the raceway (whose position was unique to missiles fired from Vandenberg) and imparted a spin that affected the flight characteristics of the third stage and the attached reentry vehicle.[10]

(u)[redacted] SAC advised Air Force headquarters against completing demonstration and shakedown operations until accuracy proved satisfactory. It suggested a series of tests to demonstrate whether the raceway was at fault, to isolate the true cause if it was not, and to verify the effectiveness of any changes in design or procedures. Air Force headquarters, which had earmarked a million dollars to solve this problem, accepted SAC's reasoning as did the JCS. On 9 May, the Joint Chiefs formally instructed CINCSAC to undertake a nine-missile test program to include two launchings formerly listed as demonstration and shakedown operations. Missiles thus expended would be accounted for "in future missile operational test authorizations."[11]

(u)[redacted] While this special series, called Olympic Trials, was being run, technical advisers from TRW Systems Corporation discovered an error in transcribing the gravity measurement survey notes for Vandenberg's Minuteman II launch complex. This, according to the strategic panel of the Air Staff Board in Washington, was "undoubtedly the major contribution to

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the inaccuracy of the LGM-30F." Correcting the error brought the probable point of impact sufficiently close to the desired ground zero.[12]

(U) [redacted] At the time of this discovery, Olympic Trials had not been completed. SAC wanted to go ahead with the remaining two launches both to confirm the findings of the TRW organization and to obtain data that might aid in the quest to improve LGM-30B accuracy. On 6 January 1968, SAC representatives discussed the subject with Dr. Robert H. Cannon, Air Force Chief Scientist, who suggested that launching an F missile on a trajectory of 20 degrees might provide data applicable to Minuteman I's continuing problem. The final Olympic Trials launchings verified that the clerical error in copying gravitational measurement was at fault as far as Minuteman II was concerned but furnished no cure for the aiments afflicting Minuteman I.[13]

(U) [redacted] Between 1966 and 1968, the Air Forces' test ranges had undergone changes and further alterations were being planned. The first test reentry vehicles plummeted into the Midway target area in August 1966. This new complex provided a shift in azimuth of nine degrees from the Eniwetok impact area and offered a reduction of 1,500 miles in range. Because of its desire to launch on a more northerly course--a track somewhat closer to the probable wartime azimuth--SAC headquarters favored the opening of still another impact area, this one in the Aleutians.[14]

(U) [redacted] Planners at Air Force headquarters also realized that existing impact areas, radars, and telemetry equipment at the Eastern and Western Test Ranges were inadequate to handle the weapon systems that would be undergoing test within the next few years. For example, Minuteman II required telemetry monitoring for only three minutes after launch; Minuteman III's LGM-30G missile would have to report electronically for more than 11 minutes. An LGM-30G carrying three Mk-12 reentry vehicles might require

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a target area as large as 10,000 square miles; WS-120A, with 28 Mk-18's, might need 440,000 square miles. Early in 1968, the Air Force took the first steps to obtain the additional facilities. It awarded contracts for new telemetry antennas at both ranges and began an ambitious expansion program at the Western Test Range. At Vandenberg it took steps to centralize telemetry data processing, among other things by acquiring and modernizing a Navy telemetry station at Point Mugu, and made plans to move a radar from the Eastern Test Range to Eniwetok.[15]

Tests at Operational Sites

(U) [redacted] March 1965 had seen the first launching of a modified Minuteman missile from an operational site temporarily isolated from squadron control. An LGM-30B capable of only seven seconds of powered flight had leapt from a silo at Ellsworth AFB, S.D., soared aloft until fuel was exhausted, and then plunged to earth. Since this type of Minuteman had performed so well, planners selected an LGM-30F for the next shot in what was then called the Long Life series.[16]

(U) [redacted] The Minuteman II launcher for the second Long Life flight was furnished by the 447th Strategic Missile Squadron at Grand Forks AFB, N.D. Late in September 1966, the team conducting the test isolated the particular silo from the squadron's cable network and installed an F missile with seven seconds' fuel, a functioning guidance and control unit, and a Mk-11A training reentry vehicle. On 2 October the modified missile went on alert. The flight was scheduled for the 12th, but on the 5th a power failure occurred in the second stage. The test team removed the missile from the silo and shipped it to Ogden Air Materiel Area, Utah, where technicians replaced faulty components in the electrical system.[17]

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(u)[redacted] The repaired missile arrived back at Grand Forks on the 14th and went on alert three days later in preparation for a test on 19 October. Just 40 minutes before launch, the missile again failed. This time the cause was faulty diodes in a power supply drawer at the launch facility. A new drawer was inserted, but on 28 October, seven minutes prior to launch, the guidance and control unit failed as did a nozzle control unit in the inert third stage. Ogden Air Materiel Area examined the defective missile and fixed the blame on leaking capacitors--the same wet tantalum variety that caused trouble during Minuteman II demonstration and shakedown operations. Because the extent of the capacitor problem was not yet clear, the 1966 launch effort was suspended.[18]

(u)[redacted] No LGM-30F missile had yet undergone a Long Life test. Even before the series of failures at Grand Forks, the Strategic Air Command had wanted to follow the Wing VI test with a similar seven-second flight from a modernized silo. However, a survey of Whiteman AFB, Mo., where the modernized system was first installed, disclosed no site from which a modified missile could safely be launched.[19] As a result, the Air Force decided to continue the series, redesignated Giant Boost in November 1967, by attempting another launch from the Minuteman II wing at Grand Forks. On 14 August 1968, less than seven seconds before the scheduled time of ignition, the test missile shut down for the fourth successive failure in the program. Subsequent investigation attributed the malfunction to a faulty connector pin--it was too short--that was to have provided electrical contact between the missile and its ground equipment. The defective pin was one of four that could not be checked by remote control during the countdown.[20]

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(u) [redacted] Secretary Brown discussed this latest failure with Secretary of Defense Clark M. Clifford, who had succeeded Mr. McNamara in February 1968. They agreed that the Giant Boost test at Grand Forks should be abandoned in favor of a seven-second flight from Vandenberg AFB. The California test, conducted on 1 September 1968, was a success. According to Secretary Brown, it helped dispel the doubts about the Minuteman system that had arisen among members of Congress as a result of the series of setbacks at Grand Forks.[21]

(u) [redacted] Besides pursuing Giant Boost, the Air Force urged long-range flights from operational silos to impact areas in the Pacific. This proposal, called Glad Game (formerly Wire Net), was not carried out during 1967 or 1968. Nothing, it appeared, would be done until the Air Force had acquired sufficient safety data from additional LGM-30F launchings, analyzed the hazards attendant on such a flight, and obtained the necessary airborne and earthbound range and safety equipment.[22]

The Effort to Reduce Missile System Vulnerability

(u) [redacted] For some time the Air Force had been concerned about the vulnerability of missile systems to the effects of nuclear blasts, which endangered both launch complexes and missiles in flight. For example, the silos and launch control centers were more vulnerable to shock (overpressure) and electromagnetic pulse than to bombardment by X-rays, gamma rays, and neutrons, while missiles and reentry vehicles that had survived within the silo emerged to face the menace of electromagnetic pulse and various forms of radiation. By timing the bursts of nuclear weapons high above the silos, an attacker could theoretically create a radioactive barrier capable of crippling any unshielded missiles, a possibility that might force a defender to postpone his own launchings. Similarly, there was some concern that the first warheads to detonate on an enemy target might create a radiation barrier which would disable the reentry vehicles following after.[23]

(u) [redacted] For some time the Air Force had studied the problem of protecting launch sites. Its most spectacular experiments, the high explosive simulation tests (HEST's), helped to determine their vulnerability to earth shock from nuclear detonation. The essential element in these tests was a grid of primacord attached to a wooden frame that was centered over the launcher or launch control facility. A plywood platform covered the frame, and the earth was heaped upon this roof to prevent the force of the explosion from escaping upward. Through the progressive detonation of the explosive cord, the sort of rolling earth shock characteristic of nuclear weapons was produced.[24]

(u) [redacted] The first simulation test--during which a Minuteman I launcher survived pressures estimated at 300 pounds per square inch--was conducted near Warren AFB, Wyo., in December 1965. In the second test detonation at Warren in July 1966, the launch control facility continued to function despite a blast that exerted a force of 1,000 pounds per square inch. The third test, on 22 September 1966, subjected a Minuteman II launch facility near Grand Forks, N.D., to overpressures estimated at 1,000 pounds per square inch. Although the launcher remained operational for 72 minutes following the blast, the facility suffered severe damage. Loose soil, apparently common in the region, and a high water table contributed to displacement and flooding of the underground launch equipment room and some flooding in the

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tube itself. Normally, the water within the launcher could have been pumped out, but the movement of the shock-mounted floor of the equipment room had been violent enough to break the emergency power line, leaving the pumps useless. The shock wave also forced mud into the air conditioning system, disabling it and insuring the gradual overheating of delicate electronic equipment. Mud buried the batteries that provided emergency power but did not disable them.[25]

(U) [redacted] The three tests disclosed numerous weaknesses within Minuteman launch complexes that made them vulnerable to earth shock. For instance, a blast might crush ducts or force dirt into brine strainers thus depriving electronic components of the air conditioning they required. Flooding was a clear threat, creation of toxic gases in the launch control center was a possibility, and the loss of emergency power could not be ruled out. Subsequently, the Air Force initiated a so-called shock improvement effort which included some changes in the design of pipes, blast valves, conduits, and the like, but consisted for the most part of correcting faulty welds, insuring sufficient cable slack, and otherwise adjusting existing equipment. The estimated cost was $49.5 million.[26]

(U) [redacted] Following the third test, AFSC suggested abandoning the program, but Gen. John P. McConnell, Air Force Chief of Staff, directed it to be continued. One test, labeled HEST 4, was deferred, so the next scheduled event, again the test of a launch facility at Grand Forks, was designated HEST 5. Tentative plans also called for conducting HEST 6 in August 1969 in conjunction with a Giant Boost flight. If necessary, the series could continue beyond the summer of 1969.[27]

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(u)[redacted] To prepare for HEST 5, the Air Force in October 1967 conducted a scale model test in the Grand Forks area. Its principal purpose was to correct a flaw in the simulation technique. During the first three tests the earth covered roof, after being forced upward, had collapsed upon the facility being tested, thus creating a second shock wave believed stronger than the first. The revised procedure employed during the scale model test caused the debris to scatter, reduced the secondary jolt, but did not interfere with creation of the rolling shock wave.[28]

(u)[redacted] The next full-scale simulation test, HEST 5, took place on 5 September 1968, again near Grand Forks. The preliminary report indicated that the launcher withstood the earth tremor far better than the silo complex tested two years before. Even the air conditioning system performed adequately after the explosion. The test crew shut down the missile for inspection, returned it to alert for 11 hours, and then subjected it to a launch exercise.[29]

(u)[redacted] During the second of the HEST exercises at Warren, three launchers went off alert for experiments designed to improve methods of measuring electromagnetic pulse and calculating its effects. The measuring techniques refined at Warren, employed at modernized sites near Whiteman AFB, provided evidence that high voltage pulses, such as might be produced by a nuclear blast, could break down electrical surge arrestors and disrupt the hardened cable network linking the silos to the launch control centers. Electromagnetic pulse, it was found, could knock out cable communication within a flight, although in some circumstances an automatic restart device would restore the command link between launcher and control console. To overcome this threat, steps were taken to insert electronic filters in the cable network to protect it against electromagnetic pulse and the false signals.

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Installation of these devices became a part of force modernization. Cost was placed at $5.4 million in fiscal year 1968, $4.6 million in 1969, and $7 million in 1970.[30]

(u) [redacted] To counter the threat posed to inflight missiles by radiation, the Air Force had directed installation of zircalloy shielding to prevent hot X-rays from penetrating the LGM-30F's guidance and control mechanism and burning out its electronic components. By the summer of 1966, however, tests showed that tantalum shielding offered the "best compromise for effectiveness and weight." Air Force officials estimated 170,000 pounds of tantalum sheet, roughly .025 inches thick, would be required to protect the guidance and control units of all F missiles, replacing zircalloy where necessary.[31]

(u) [redacted] Besides providing protection for the guidance and control package from X-rays, the Air Force approved the installation of radiation shielding elsewhere in the missile. Certain nozzle components, for example, were vulnerable to X-rays. Also, the angular accelerometer and related electronic guidance circuitry had to be kept secure from neutron bombardment.[32]

(u) [redacted] The second nuclear phenomenon that menaced missiles in flight was electromagnetic pulse. Tests conducted during summer and fall of 1966 disclosed that safeguards previously installed against this nuclear effect were inadequate. In the LGM-30F, for example, existing grounding and shielding did not protect antennas and inductive loops that were especially vulnerable to electrical overload. Modifications to provide additional protection were undertaken, while experiments continued to verify the adequacy of the changes and to determine if other alterations were needed.[33]

(u) [redacted] The effect of nuclear detonations on missiles during powered flight opened the way for a new tactic. As has been indicated, an

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attacker, by detonating warheads some 300,000 feet above the silo that protected the Minuteman force, could create a radiation barrier--X-rays, gamma rays, and neutrons--through which U.S. missiles could not safely pass. This tactic was called "pindown" because it would force SAC to delay launching the retaliatory force until after the radiation had dispersed.[34]

(u) [redacted] In March 1967, the Director of Defense Research and Engineering (DDR&E), Dr. John S. Foster, Jr., requested the JCS to examine its "operational doctrines" to determine if the influence of a pindown, whether the result of a direct pindown attack or an inadvertent by-product of any nuclear exchange, could be minimized. In addition, he inquired whether if pindown could not become an effective American tactic "in case Soviet missiles... exhibit a serious radiation vulnerability."[35]

(u) [redacted] The "inadvertent by-product" of which Dr. Foster spoke included the possibility that too many reentry vehicles might plummet into the same area within too short a time, so that detonations of the first would release radiation capable of disabling the arming and fuzing circuits of later arrivals. In SAC jargon, the accidental "killing" of warheads within the attack force became "fratricide," which the command did not consider a particularly serious problem. Unless extra shielding was installed to protect the circuits, the solution lay in timing the launching of missiles so that the cloud of radioactive dust caused by one wave would dissipate before the next reentry vehicle arrived.[36]

(u) [redacted] The JCS responded to Dr. Foster's request with a series of briefings, held during May, which outlined several proposals for countering the pindown threat. These included installing the three new devices mentioned earlier--the high altitude radiation sensor, the cancel

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launch in process device, and the trans-attack environmental probe.* The briefings also disclosed that the fly-by-wire (mechanical linkage) guidance systems and the analog computers used in Soviet missiles did not seem vulnerable to pindown.[37]

(u) [redacted] The changes suggested to Dr. Foster were simple and would serve as interim measures until a detection network was fully established. When completed and tied in with other systems, this net would provide information on the pattern of enemy attack and predict where pindown was likely to occur. In the meantime, the JCS proposed to delay launch as soon as pindown was detected and resume the countdown when the radiation had dissipated. A second interim suggestion, which could not be put into effect without a revision of national policy, was to fire at least part of the retaliatory force either upon warning of an attack or in the event of strikes against missile warning radars, even if outside the United States.

(u) [redacted] Discussion of pindown continued. Dr. Alexander H. Flax, Assistant Secretary of the Air Force for Research and Development, called Mr. Brown's attention to the possibility that the very defensive system deployed to disable enemy reentry vehicles streaking toward missile launchers in the United States could be equally as deadly to Minuteman missiles as they rose from their silos bound for targets in other continents. He suggested a war game to learn the effect of pindown during a nuclear conflict. His main recommendation, however, was to harden Minuteman so that it could survive the radiation caused by a defensive anti-missile system. "If we can do this," he declared, "the Soviet pindown threat should be secondary."[38]

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*See pp 20-21.

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(U)[redacted] Concerning the possible U.S. pindown of enemy missiles, Secretary McNamara on 6 December 1967 directed the Air Force to initiate work on a high altitude fuze to be incorporated into 150 Mk-11C Minuteman reentry vehicles. This device, first discussed as a means of disrupting Soviet defensive radar, represented a hedged bet as far as pindown was concerned. The Defense Atomic Support Agency, which had advocated development of the fuze, pointed out, however, that vulnerability to pindown depended upon missile construction, and detailed information on the construction of the Soviet weapons was not available. Apparently the Air Force soon concluded that information of this sort would not become available in the near future. Within six months it had suspended work on the Mk-11C fuze, although it retained the option to provide one for the Mk-18, a reentry vehicle that had not yet begun development.[39]

III. REENTRY SYSTEMS AND PENETRATION AIDS

(U) [redacted] The Advanced Ballistic Reentry Systems (ABRES) program--managed by the Air Force for the Department of Defense--continued to provide data applicable to various existing systems and to lay the technological foundation for future development projects. Emphasis was upon reentry systems that could dispense several low or moderate yield warheads against individual targets. Penetration aids, especially for reentry vehicles already in service, formed a major part of the program. Besides small multiple reentry vehicles and penetration aids, ABRES planners and engineers worked on materials for reentry systems, maneuvering vehicles and similar new designs, the radar signatures of different vehicles, low angle reentry systems, warhead arming and fuzing, vulnerability and hardening, and terminal guidance.

(U) [redacted] During fiscal years 1967 and 1968, the SAMSO project office concentrated upon two aspects of the program--solving certain problems that had arisen in the use of small reentry vehicles and improving the ability to penetrate enemy defenses. The two merged in the multiple independently targeted reentry vehicle (MIRV), an idea for using several small reentry vehicles to foil missile defenses. Test flights of ABRES devices continued at Vandenberg AFB, using full-scale systems, and from Green River, Utah, where scale models were launched toward an impact area at White Sands, N. M.[1]

ABRES Projects

(U) [redacted] In October 1967 SAMSO successfully completed a maneuvering ballistic reentry vehicle test program, which demonstrated that such a vehicle could execute terminal maneuvers. This program had gotten off to a poor start when the first two launchings from Vandenberg failed, the first in August 1966 because of booster malfunction and the second in March 1967 because the inertial measurement unit in the reentry vehicle did not work properly. On 29 July, however, a reentry vehicle was successfully launched and maneuvered as planned to strike a target some distance from the aiming point. The maneuver involved a "pull-down" 10 nautical miles short of where the vehicle would otherwise have struck. On the fourth and final shot, on 14 October 1967, the vehicle successfully performed a "pull-up/pull-down and out of plane" maneuver to strike 20 nautical miles short and 10 nautical miles to the right of the aiming point.[2]

(U) [redacted] After the maneuvering vehicle had thus demonstrated its capability, the Director of Defense Research and Engineering on 5 March directed the Air Force to begin developing a prototype maneuvering vehicle, with terminal guidance, that could "simulate" the Mk-12. He proposed to start the program as part of ABRES for fiscal year 1969 and then set up a separate program element for fiscal year 1970. SAMSO submitted a technical development plan in May 1968, which was under review by DDR&E at the end of June.[3]

(U) [redacted] The boost glide reentry vehicle program* was to have continued with a launch to demonstrate that a booster could actually perform the pitch-over maneuver required to place such a vehicle on a suitable trajectory. Unfortunately, the booster failed during an October 1966 test firing but a similar experiment in May 1967 was a success. In the interim, however, ABRES officials had reexamined the project and concluded

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*Nalty, USAF Ballistic Missile Programs, 1964-1966, p 33.

that it had "no clear technological applicability to potential maneuvering systems." Since immediate cancellation would have saved only a small fraction of the total cost, the Air Force elected to proceed with three launches already planned.

(U) [redacted] The first launch of a functioning boost glide reentry vehicle took place in November 1967. The flight, however, came to an abrupt end when the range safety equipment inadvertently destroyed the vehicle approximately three seconds after separation from the booster. A second test flight, on 27 February 1968, was a complete success. The vehicle changed from a ballistic track to a glide path as it neared the impact area and was only two seconds behind schedule when it struck the ocean some 4,000 miles from the point of launch. Since this flight had achieved all the program objectives, the third launch was canceled.[4]

(U) [redacted] The year 1968 saw work begun on the so-called pre-damaged vehicle program in which reentry systems exposed to simulated nuclear effects were launched down the Western Test Range. A Mk-12, damaged to represent bombardment by cold X-rays while passing outside the atmosphere, yielded information on how a reentry vehicle exposed to this sort of radiation would behave while descending from 500,000 feet to the point of impact.[5]

(U) [redacted] Chaff experiments, which were carried aloft by sounding rockets at White Sands and Kwajalein and Atlas boosters launched from Vandenberg, also were conducted during the period. The MK-1A chaff system, which carried prestressed titanium foil, proved more effective than Mk-1 bag chaff and the improved system was selected for development.

An advanced chaff dispensing techniques program was begun and some test flights were completed.[6]

(U) [redacted] At the Green River launch site, encouraging advances were recorded in Athena reliability with several dozen firings, all but two successful, including both "triple" and "dual" launches. The gloomy days of 1964, when Athena failures had for a time outnumbered successes, seemed only a memory. ABRES experiments carried on these flights included, among other things, a fuzing and arming device, a Navy-sponsored reflector deocy, an advanced atmospheric decoy, an experiment dealing with radar "signatures," and a "hard point" decoy for the Advanced Research Projects Agency.[7]

(U) [redacted] Toward the close of fiscal year 1968 SAMSO studied the possible advantages of developing an improved Athena booster (H model) to support ABRES beyond 1975. Completed in May, the study was submitted to Air Force Headquarters in June 1968. Among its conclusions were that: (1) the more powerful Athena H was required for future ABRES payloads, possibly including Mk-18 reentry vehicles; and (2) the cost of Atlas launchers for ABRES would increase when the Army stopped using them in 1970 since cost-sharing would cease and, with fewer launches, expenditures would rise.[8]

(U) [redacted] In the search for ways to reduce expenditures, OSD officials during the period chose ABRES as a prime target for budget cuts. Part of the program's reduction in its funds was attributable to the completion of various undertakings, but it was mainly because of using Vietnam costs that ABRES suffered a financial drought. RDT&E funds, for example, sagged $10 million between fiscal years 1966 and 1967, some $31 million between 1967 and 1968, and a projected $1.5 million between fiscal

1968 and 1969. The total budget for fiscal year 1968 declined during the course of the year from a planned $125 million to $120 million and finally to $106.5 million, a figure that included $2.8 million for the operation and maintenance of radars at White Sands.[9]

Programs Related to ABRES

(u) [redacted] Two programs--Nike targets and the self-aligning boost and reentry (SABRE) system--were closely related to ABRES. In the former, the Air Force designed, developed, and launched a variety of reentry vehicles to aid the Army with its Nike missile defense system. Test bodies fired from Vandenberg to Kwajalein provided the Army with data on methods of picking out an incoming warhead from among decoys and employing an anti-missile system against it. This continuing program, for which $7 million was available in fiscal year 1968, called for the firing of 52 missiles, 46 of them surplus Minuteman ICBM's, over a five year period. Fourteen of the launchers would involve "joint-use" payloads fired as part of the ABRES program or during Minuteman or Titan II operational tests.[10]

(u) [redacted] The SABRE project, initiated in 1964, was aimed at providing the Air Force an advanced ICBM guidance system. Designed to guide multiple independently targeted vehicles through a 100 "g" reentry maneuver to strike within 600-900 feet of the target after traveling 5,500 miles, it differed radically from the standard inertial guidance device. SABRE featured an inertial measurement unit (IMU) floating within a spherical shell which eliminated the gimbals--shafts or bearings upon which a normal unit rotated--found in the ordinary system. The floated unit needed no external auto-collimator to maintain vertical alignment since it was gyro-stabilized. The

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advantages of these features was that SABRE could be aligned along any azimuth and could shift target instantaneously upon receipt of the proper command.[11]

(U) [redacted] During the period, however, the project encountered the sort of financial difficulties experienced by ABRES. The Air Force requested $13 million for SABRE in fiscal year 1968 but instead was allotted $6 million. As a result orders for additional gyros were canceled, aerospace support was reduced, and the test program at Massachusetts Institute of Technology (M.I.T.) was postponed. Meanwhile, evaluation of early test data, including a centrifuge test of an IMU which subjected it to 42 times the pull of gravity, indicated that the SABRE system would exceed the hoped-for accuracy.[12]

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Reentry Vehicles

[redacted] In June 1966 the Air Force was at work on three new Minuteman reentry vehicles. During the next two years one was canceled, while work continued on the other two.

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(U) [redacted] Attaining the desired Mk-17 weight, something SAC insisted upon, proved difficult because of the requirement to include greater protection against nuclear effects than originally planned. By November 1966 engineers had successfully trimmed some 36 pounds from the vehicle, but it still weighed 938 pounds, 38 more than was acceptable.* In December the Atomic

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*The Mk-17 included an ascent shield, a phenolic silica nose cone and primary heat shield, an attitude control system, and a 675-pound warhead. Comments made by officers of the Missile Systems Division, Directorate of Development, HQ USAF, indicate that 900 pounds was "somewhat of an emotional number" and that "poor personal relationships across the interface" between Air Force and AEC caused a misunderstanding about the importance of this specification. Fortunately, "This was rectified (without change of personnel) and the two groups jumped on the problem," trimming "some 36 pounds" from the estimated weight. [Atch B, to Ltr, Ch, Msl Sys Div, Dir/Dev, to AFCHO, 11 Jun 69, subj: AFCHO Historical Study.]

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Energy Commission (AEC) Directorate of Military Applications called the Air Force's attention to a lightweight fuzing and arming system being investigated by Sandia Corporation. The directorate believed such a device would reduce the system's weight without reducing the warhead's mass or total yield. AFSC soon dispelled this illusion, however. Its studies indicated that the alternative fuzing and arming system not only involved serious technical risks but, even if successful, would save only about 17 pounds.[14]

(U) [redacted] In July 1967, following a review of the entire Minuteman program, Secretary Brown recommended that Mk-17's entry into service be delayed six months until July 1969. While action on this recommendation was pending, in September the Director of Defense Research and Engineering announced that Poseidon would not carry the Mk-17, or the smaller Mk-12, as had been planned. Both would now be for the exclusive use of the Air Force.[15]

(U) [redacted] As time passed, the Office of Secretary of Defense became convinced that Minuteman expenditures would have to be cut still further, and the Mk-17 reentry vehicle became a logical candidate for extinction. It originally had been designed for so-called "damage limiting" attacks against targets such as missile sites whose destruction might reduce the damage inflicted on the United States. OSD officials, however, considered limiting damage less important than "assured destruction"--i.e., the ability to respond to nuclear attack by destroying the urban industrial foundations of an enemy's society. Although the Mk-17 was intended to be slightly more powerful, somewhat more accurate, and a great deal less vulnerable to nuclear effects than the operational Mk-11C, the differences were such that the new system could not do a markedly better job of assured destruction.

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As a consequence, Secretary McNamara on 6 December 1967 announced cancellation of the Mk-17.[16]

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[redacted] The Mk-18 was to serve in multiple independently targeted vehicles for either Minuteman III or the proposed advanced ballistic missile. In January 1967, the Air Force decided to begin development in 1968 in order to achieve an initial operational capability (IOC) in July 1971. At the end of the year, however, shortages of funds caused Secretary Brown to recommend postponing the IOC to July 1972. The Secretary of Defense accepted the proposal, which meant delaying the start of Mk-18 development until Fiscal year 1969.[17]

(U) [redacted] Scarcely had instructions for the year's delay been issued than the Space and Missile Systems Organization suggested December 1972 as an appropriate date for Mk-18's initial operational capability. Although SAC considered the weapon a "significant improvement over Mk-12," it expressed a willingness to do without the Mk-18 if funds would be provided to expand Minuteman's computer "memory." Since OSD seemed willing to postpone the program, further slippage of the date for initiating work on the system appeared probable.[18]

[redacted] Cancellation of the Mk-17 and delay of Mk-18 left the Air Force with the Mk-12 as the only new reentry vehicle under full-scale development. [redacted]

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[redacted] The PBV with its post boost control [redacted]

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system, was a reentry vehicle dispenser able to direct each Mk-12 at a different target. In this fashion, the Mk-12 served as a key component of a new multiple independently targeted reentry vehicle.[19]

(u) [redacted] Mk-12 flight testing, begun in the spring of 1966, got off to a discouraging start when the first three test vehicles broke up after reentering the earth's atmosphere. Examination of data collected during these tests disclosed several problems involving the nose tip and heat shield. Of these, the heat shield seemed to have the most serious defect. Technicians concluded that the resin that held the binding in place melted early in reentry, thus exposing the edges of the ablative wrapping and permitting the miniscule ridges to act like turbine blades in imparting spin to the reentry body. As altitude decreased and air grew thicker, the spin rate built up to 2,000 revolutions per minute, a rate capable of exerting forces 1,000 times that of gravity and tearing the vehicle apart.[20]

(u) [redacted] To help dissipate reentry heat in the fall of 1966 engineers placed a teflon cap over the Mk-12 nose tip and strengthened the antenna windows and the vehicle's internal structure. They also covered the heat shield so that the wrapping formed an angle or less than one-half degree with the long axis of the vehicle. A Mk-12 modified in this fashion performed successfully in January 1967.[21]

(u) [redacted] This success, the first in four attempts, did not mean that all Mk-12's problems were solved. Although subsequent flights disclosed that the increasing rate of spin and resulting buildup of destructive forces no longer occurred, the Mk-12 still had to contend with the loss or reversal of spin. If rotation stopped or reversed, the vehicle suffered no structural damage, but it did stray from its planned trajectory. Indeed,

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the dispersal pattern could become so erratic--up to 3,000 feet exclusive of booster error--as to be unacceptable for a warhead of only moderate yield.[22]

(u) [redacted] Minor additional changes in the nose and nose cap helped ease this newest problem but did not guarantee satisfactory accuracy. In the summer of 1968, the Minuteman System Program Office endorsed a proposal made by the General Electric Company. The firm's technicians suggested increasing the programmed rate of spin from one to two revolutions per second, a simple change that would all but eliminate the likelihood of a vehicle's losing or reversing its spin. This proposal was under study at the end of the period.[23]

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(u) [redacted] Cost of the Mk-12 development, meanwhile, soared dramatically. From 1963 through 1967, the total value of contracts rose from $148 million to some $306 million. Much of the increase was due to negotiated changes. These included: two increases to provide hardening against nuclear effects, $13.5 and $23.9 million; penetration aids, $68.8 million; adjustments to provide for the projected use of multiple independent reentry vehicles, $44.6 million; and changes resulting from the selection of a new third stage for Minuteman III, $30.8 million. Also included in the total was a $16.4 million increase negotiated in 1963 to permit the use of Mk-12 with the Poseidon

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fleet ballistic missile, an effort later abandoned. Of the total increase of over $158 million, slightly more than 10 per cent was attributed to increased overhead on the part of contractors.[25]

(u) [redacted] Pending completion of Mk-12 development, the ICBM force was dependent on two reentry systems, the Mk-6 for Titan II and the Mk-11 series for Minuteman. Two problems affected the latter. A routine inspection of warheads used in the Mk-11A disclosed cracks in certain polyethelene tubing that could cause a loss of air pressure in the reentry vehicle. This, in turn, would lead to a breakdown of electrical circuits and a misfire. To correct the defect, a new type of tubing more resistant to corrosion was placed in production in November 1967 and plans were made to replace the defective tubes. The other problem, also solved by substituting an improved component, involved the failure of the electrical circuit used to trigger ground bursts. The culprit was an argon tube that aged more quickly than anticipated. It was replaced by a more serviceable neon bulb.[26]

(U) [redacted] As financial and technical problems with the Mk-17 and other reentry vehicles developed, the Air Force became concerned about the possibility of a shortage of Minuteman reentry vehicles sometime in fiscal year 1968. To avoid this situation it decided to modify Mk-11B's into more satisfactory Mk-11C's by, among other things, providing additional shielding for the arming and fuzing circuits. By the end of June 1968 some 60 Mk-11B's were rebuilt in this fashion, and 91 new Mk-11C's left the production line. At this time the Air Force had on hand 151 of the C model, not quite one-third of the 494 to be either rebuilt or manufactured. The large number was deemed necessary because of the OSD decision to cancel Mk-17 and use Mk-11C in its place.[27]

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Penetration Aids

(U)[redacted] Fitting Air Force strategic missiles with penetration aids proved a slow process. By mid-1967 the Titan II's, which carried decoys, constituted the only portion of the fleet that was so equipped, but work was in progress to install tumble rockets on 160 Minuteman I's at three bases. This modification, which was to be completed during fiscal year 1968, would insure sufficient separation of the reentry vehicle from the third stage to deprive the enemy defense of a convenient aiming point. Tests also were in progress at this time on a chaff dispenser, the Mk-1 penetration aid, for use with Minuteman. In addition, two more advanced systems, Mk-1A and Mk-12, were in the process of development.[28]

(U)[redacted] The Mk-1 program made little headway at first. Early designs required extensive change, and the first tests of the completed system revealed that the clouds of chaff released from the dispenser did not fully screen the reentry body and the third stage from defensive radar. Despite improvements in the quality of the chaff, the density of the clouds, and the timing of their release, Mk-1 remained somewhat erratic in its ability to conceal the Minuteman third stage. This imperfection was acceptable, however. Lt Gen Joseph R. Holzapple, Deputy Chief of Staff for Research and Development at Air Force headquarters, voiced the prevailing sentiment when he declared that Mk-1 would be adequate against existing Soviet defenses. The first Mk-1 units were installed as scheduled at Wing I, Malmstrom AFB, in January 1968.[29]

(U)[redacted] In the spring of 1967, Air Force planners concluded that Mk-1 would require extensive changes if it was to counter the types of radar likely to appear within a few years. For this reason, the Air Force decided to deploy only 150 Mk-1's--15 others would serve as spares--and to begin development of a new chaff dispensing system, Mk-1A, to join the strategic force in January 1969. Changes to the Mk-1 electrical system and substitution of foil dispensers for chaff bags would, in effect, convert Mk-1's into Mk-1A's. 30

(U) [redacted] Although Mk-1A development moved ahead without encountering serious difficulty, General McConnell became concerned about the exacting schedule that would have to be met if the new system was to attain an initial operational capability as scheduled. In February 1968, because the Soviets did not seem to be improving their radar as rapidly as expected, he suggested easing pressures by postponing the debut of Mk-1A until July 1969. The Air Staff agreed, and in May 1968 Secretary Brown approved the delayed deployment subject to two conditions. The first, subsequently rescinded, required the Air Force to obtain funds to purchase 50 additional Mk-1's for use during the six-month postponement. Second, the phasing out of Mk-1, scheduled to begin in November 1969, would have to be postponed three months. 31

(U) [redacted] Meanwhile, the Air Force had initiated studies to determine the type of penetration aids required for the Mk-12 reentry system. It investigated two concepts. The first, intended to overcome combined area and terminal defenses, called for 10 decoys and 12 chaff clouds to be released from a carrier that also contained two Mk-12 vehicles. The second, designed to cope with high-altitude area defense, employed no decoys. Instead, the post boost vehicle contained three Mk-12's and 15 clouds of chaff. The Air Force's ultimate goal was to devise a combination of chaff and decoys capable of confusing the defenders until the actual reentry vehicles

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were about 50,000 feet above the earth. Although development of Mk-12 penetration aids got under way, production and deployment would wait until intelligence provided evidence that these devices were really needed.[32]

(U) [redacted] Masking the reentry body in chaff and misleading the defenders with passive decoys were the two simplest approaches in the development of penetration aids. Both chaff and decoys were bulky, however, and active jamming devices--more compact though infinitely more complex--appeared attractive. SAC maintained that more than 300 tiny transmitters capable of jamming the main beam of defensive radars could be stored in the space used by the nine bags of chaff in the Mk-1 system. By the end of 1966, however, little progress had been made in overcoming the technological obstacles that blocked the development of these miniature devices. In fact, the only experimental jammers tested had proved so heavy, mainly because of their batteries, that they had to be installed in large reentry shells.[33]

(U) [redacted] While the Strategic Air Command was considering the merits of using large numbers of active jammers, the MITRE and Bendix corporations suggested another method of using radio waves to disrupt enemy radar. They proposed to use the emergency rocket communications system--designed as a last-resort method of issuing an attack order to the retaliatory force--to broadcast signals that would impede enemy radar. SAC, taking about the same stand as AFSC, rejected the idea because the transmitter used in the emergency system would be vulnerable to the effects of nuclear weapons and to other countermeasures.[34]

(U) [redacted] Convinced that chaff and passive decoys soon would become obsolete, SAC urged Air Force headquarters to turn its attention to

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devising "a system capable of deploying several hundred individual jamming transmitters covering the required broad spectrums in either separate clouds or in one giant swarm that may deny all range and velocity information until the reentry cloud is within 100-300 nautical miles of the defensive radar." Air Staff officials agreed that active jammers of this sort would prove valuable, but the development of dependable miniature transmitters would take several years. Meanwhile, experiments with active jamming devices, already in progress at White Sands missile range as part of the ABRES program, would continue.[35]

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IV. MISSILES AND LAUNCH FACILITIES OF THE FUTURE

(U) Although the Air Force made satisfactory progress in the development of Minuteman III, it failed to obtain OSD approval to begin contract definition of the proposed Advanced ICBM, WS-120A. Studies of this advanced missile led to the consideration of new and improved launch facilities which could provide three times more protection against earth shock than the Minuteman II system. Investigation of the more durable launch complexes showed the value of having them accommodate either Minuteman III or the Advanced ICBM, and the Air Force undertook to design a dual purpose launch facility. Other development activities also continued, among them a program to perfect a Short-Range Attack Missile (SRAM).

Minuteman III

(U) [redacted] Two innovations--a post boost vehicle and an improved third stage--helped distinguish Minuteman III from its predecessors. The liquid-fueled control system, which enabled the PBV to maneuver for the release of the reentry vehicles it carried, became the subject of debate during the summer and fall of 1966. From the purely technological viewpoint, a post boost system employing storable fuels similar to those used in Titan II was the easiest to design. SAC, however, disliked the idea of introducing liquids into a solid system because of the danger of leaks. In late June 1966 the command recommended against a liquid control system for Minuteman III. It argued that the need to install leak detection gear and to make more frequent inspection of alert missiles might "exceed the cost of a parallel solid development."[1]

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(U) [redacted] The Ballistic Systems Division, which looked into the matter, later reported that two firms were at work on "solid approaches" that showed great promise. And it seemed a solid system would be simpler in its workings and easier to store than a liquid post-boost propulsion unit under development. Unfortunately, only theoretical calculations had been completed by these contractors, and neither had done this theorizing with the new Minuteman missile in mind.[2]

(U) [redacted] Air Force Headquarters accepted SAC's reasoning and in November 1966 asked OSD for $27.3 million to begin work in fiscal year 1967 on a solid system to replace the liquid fueled device. However, the system which was described to the Director of Defense Research and Engineering also would include liquid fueled reaction motors and, in his opinion, would therefore have leakage and safety problems of its own. Since the choice appeared to lie between a hybrid using both kinds of fuel and a system using liquids only, he directed the Air Force to proceed with the latter, upon which more work had already been done.[3]

(U) [redacted] Although liquid fuels made the task somewhat easier, development of a reliable post boost control system remained difficult. The July 1969 deadline established for the initial operational capability of Minuteman III allowed little margin for error. Because the technological risks in the liquid system were serious, and also partly for financial reasons, the Air Force decided to delay the debut of the new Minuteman until December 1969.[4]

(U) [redacted] Another factor contributing to this postponement was the emergence of technical problems during third stage development. Air Force management specialists voiced concern that Aerojet General, the firm responsible for its development, was taking "substantial risks" in order to save time and thus benefit from incentive features in its contract. For example, the contractor could find no reliable way of making sure that the third stage motor would stop burning upon receipt of a thrust termination signal. Subsequently, Aerojet General and the Space and Missile Systems Organization solved the problem by reversing thrust rather than shutting down the motor. This method, though it worked satisfactorily, involved a weight penalty.[5]

(U) The development of the more powerful third stage also ran into cost problems. Thus, when Aerojet General received notice of the five-month postponement of Minuteman III, it submitted an estimate of costs that more than doubled the price of each third stage motor manufactured. General Ferguson, AFSC commander, concluded that "the contractor 'bought in' during competition" by submitting too low an estimate and was "now attempting to recoup his R&D and projected production losses with this contract change." The general suggested and steps were taken to solicit bids to manufacture the remaining 392 motors--343 were covered by the earlier contract--from Aerojet's design. The new contract, signed in October 1968, went to Thiokol.[6]

(U) [redacted] In the meantime, a tight budget forced still another postponement of Minuteman III's initial operational capability. In December 1967 OSD issued a management directive which delayed the IOC from December 1969 to June 1970. Although the additional delay was due primarily to a shortage of funds for fiscal year 1969, the move could be justified by intelligence reports that the Soviet Union was working more slowly than anticipated to strengthen its antiballistic defenses.[7]

(U) [redacted] As Minuteman III's initial operational capability thus receded into the future, Secretary Brown expressed concern to OSD that delays in the program and the retirement of aging bombers would stretch USAF strategic forces too thin. He felt that the two postponements to Minuteman III, plus the need for B-52's in Southeast Asia, were "compelling arguments" for the retention of four B-52 units scheduled for retirement during fiscal 1969. OSD disagreed, however, and endorsed the existing schedule.[8]

(U) [redacted] Although the Secretary's concern for Minuteman III was not unjustified, the program did enjoy its moments of triumph. For example, the first research and development launching, which took place on 16 August 1968, was an unqualified success. The third stage, the post boost vehicle and its propulsion system, and the reentry shroud performed as planned, and each of three unarmed reentry vehicles on board hit its target.[9]

(U) [redacted] Even before Minuteman III R&D test launches got under way, Air Force officials discussed further improvements to the Minuteman system. Two possibilities for more powerful weapons evolved from informal conversations within the Space and Missile Systems Organization. One would consist of Minuteman III's second and third stages, a new first stage, and a new and much larger post boost vehicle. The second would be the largest missile--all stages 90 inches in diameter--that could be fired from existing silos without using some form of "cold" launch such as ejection by compressed air before first stage ignition.[10]

An Advanced Ballistic Missile

(U) [redacted] By the summer of 1966 the Air Force was eager to proceed with the development of the Advanced ICBM, WS-120A, which would be capable of hurling 7,000 pounds a distance of 5,500 nautical miles (later extended to 6,500 NM) and achieve a CEP of .2 nautical miles.* Earlier,

*See Nalty, USAF Ballistic Missile, 1964-1966, p 47.

OSD had provided funds for advanced ICBM studies and technical development, but refused to approve contract definition, the initial step in a formal development program.

(U) [redacted] Secretary Brown had recommended to OSD spending $26 million in fiscal year 1968 to begin the contract definition phase. The plea fell on deaf ears because, or so Secretary Brown believed, OSD wanted the Air Force to select a "basing concept" that was "viable" despite the possible Soviet use of multiple independent reentry vehicles. To meet this supposed objection, in early November 1966 he advised OSD that studies already completed showed three kinds of bases that could survive attack by multiple reentry systems. The advanced missile could soar aloft from mobile transporter-launchers, from caissons sunk in pools that were connected by canals, or from silos similar to those used by Minuteman. He indicated the Air Force leadership wanted to get on with developing the missile. Choosing the best type of launcher seemed a lesser challenge, since so many good possibilities were available. OSD, however, still would not approve development until the Air Force specified a type of launch complex.[11]

(U) [redacted] In December Secretary Brown renewed his request, asking again for $26 million to begin contract definition plus $10 million for advanced ICBM technology. As an alternative he suggested that OSD might provide the full $10 million for the advanced technology projects in fiscal year 1968 while trimming to $9 million the amount spent on contract definition. On 9 December 1966 OSD approved the alternate proposal, which would spread over two or more years work the original recommendation would have done in one. The $26 million would have permitted an industry competition for the WS-120A contract; the $9 million would postpone selection of a contractor until fiscal year 1969, assuming that the balance of $17 million was approved for expenditures in that year.[12]

(U) [redacted] Air Force officials meanwhile, continued their studies of possible kinds of launchers. Officers from Strategic Air Command headquarters witnessed a demonstration of a mobile transporter-launcher that, after extensive changes, might serve as a prototype for a mobile system. The RAND Corporation had already introduced a water basing concept and a great deal of time and energy was spent examining the feasibility of encasing missiles in portable caissons which could be towed through a maze of canals and hidden in deep pools. Neither of these methods, however, seemed preferable to a silo hardened to resist overpressures of 3,000 pounds per square inch.[13]

(U) [redacted] In early 1967 Air Force headquarters dispatched a requirements action directive to AFSC and other affected commands, requesting submission of a preliminary technical development plan by 1 September to substantiate a formal Air Force request to start contract definition in January 1968. While work on the plan proceeded, DDR&E on 8 May 1967 published a guidance letter on the Advanced ICBM, indicating tentative funding of $9 million in fiscal year 1968 for contract definition.[14]

(U) [redacted] In late August, General McConnell reviewed the status of the Advanced ICBM studies and the preferred basing concept--hardened silos capable of withstanding pressures of 3,000 psi. He endorsed this concept and directed that it be established as the formal Air Force position for the Advanced ICBM. Subsequently, the preliminary technical development plan, coordinated with several commands, was completed and forwarded to OSD

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on 29 September 1967. In October, however, Secretary McNamara disapproved full-scale contract definition in fiscal years 1968 or 1969 because other alternatives--presumably involving Minuteman III--would be available, if the Soviet missile threat should prove greater than expected. In December the Air Force, in an internal budget action, allocated $6 million in fiscal year 1969 to continue work on advanced technology.[15]

(U) [redacted] The next major USAF effort to gain OSD approval for WS-120A contract definition came in the spring of 1968. The Air Force prepared a new position paper, which suggested starting contract definition in fiscal year 1970 to achieve an initial operational capability with the Advanced ICBM in fiscal year 1975. It proposed building a WS-120A force totaling 280 missiles by the end of June 1977. Under Secretary of the Air Force Townsend Hoopes forwarded the request to OSD on 24 May, pointing out that it would be better to develop a wholly new weapon for 1975-1985 than to continue to try to improve Minuteman. Action on this recommendation was not yet completed when the fiscal year ended.[16]

Hardrock Silos

(U) [redacted] The investigation of what sort of launchers were best suited to the Advanced ICBM had aroused interest in building silos anchored in rock and able to withstand shocks up to 3,000 pounds per square inch. As Air Force headquarters was reaching its decision that this was the best kind of facility for the WS-120A, Secretary Brown suggested examining the possibility of putting Minuteman missiles in these new silos. A subsequent study disclosed that it would be possible to begin installing Minuteman missiles and related equipment as early as fiscal 1973, thus providing a

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"hedge" against delays in WS-120A development. The proposed hard rock launch complexes, because of their versatility, received the grotesque title of "dual capable facilities." On 30 October 1967 the Secretary of Defense approved development of such facilities.[17]

(U) [redacted] Strategic Air Command headquarters liked the idea, though with some reservations. First, the command wanted to be sure that Minuteman III's comparatively short range did not restrict the entire force to bases in the northern United States. Second, it insisted that the 3,000 pounds per square inch hardness include a comparable degree of protection against radiation and electromagnetic pulse. On this second point, the approved program--called hardrock silo development--aimed at providing "a well balanced nuclear hardness" which would include consideration of effects "other than blast or thermal." Goals established for the effort were a silo, suitable for either Minuteman III or WS-120A, that could withstand pressures of 3,000 pounds per square inch--the equivalent of a one-megaton blast at 1,000 feet--and a launch control center able to survive 6,000 pounds per square inch--one megaton at 800 feet.[18]

(U) [redacted] Exactly where the new silos were built would depend upon geological conditions as well as military considerations. Tentative Air Force plans called for the first 10 sites to become operational in fiscal year 1972, with 100 to 150 Minuteman III's eventually being deployed in the complexes. When WS-120A missiles became available, they would replace Minuteman III at the rate of 140 launchers--one wing--per year.[19]

(U) [redacted] The proposed Air Force schedule called for starting contract definition, at a cost of $4 million, in 1968. The following year, for which an estimated $38 million was sought from OSD, would see the

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completion of contract definition and the start of system design, development, and testing. On 25 April 1968, the Office of Secretary of Defense indicated that $1.8 million would be available to begin the hardrock silo development program, and the following month it released $1.2 million.[20]

Other Related Programs

(U) [redacted] Related to hardrock silo development was the advanced ICBM and basing program, an Air Force research undertaking that had the objective of establishing "a technical base for subsequent... weapon systems" and advancing "general ballistic missile technology through the exploitation of selected critical technologies." This project included studies of the survivability of missile facilities and equipment, guidance for independently targeted reentry vehicles, and new methods of launch ejection. In fiscal year 1968, working with a budget of up to $5 million, the Air Force placed the emphasis upon technology to support hardrock silo development. In 1969 USAF officials planned to concentrate on technical problems associated with the development of a hardened, high-speed computer for future ballistic systems.[21]

(U) [redacted] High performance solid rocket motor development had for its goal the discovery of some lighter weight substitute for the aluminized propellants currently in use. As reentry systems--with multiple vehicles, decoys, and larger warheads--grew heavier, rockets would have to become more powerful, but existing propellants were very bulky. The designers of new missiles thus found themselves under constraints because they had to reduce their products to fit silos of practical dimensions. Lighter weight, more compact fuels offered a possible means of increasing lift without increasing volume. Beginning in fiscal year 1969, the Air Force planned to spend $1 million to identify and purchase promising fuel ingredients.[22]

(U)[redacted] Besides the investigation of lighter materials, four other research programs dealt with such aspects of rocket propulsion as improved insulation, new fuels, and improved solid and liquid motors. All were continuing programs.

The Short-Range Attack Missile

(U)[redacted] Although sometimes compared to the cancelled Skybolt, a ballistic missile designed for launching from B-52 bombers, the Short-Range Attack Missile actually was a complex air-to-ground missile rather than a true ballistic system. Like the Hound Dog missiles already carried by SAC bombers, SRAM was to be used either to suppress defenses or to destroy targets before the aircraft came within range of defensive weapons. Unlike Hound Dog, however, the shorter range SRAM could be launched on a variety of trajectories: low-altitude like Hound Dog; near-ballistic, though sufficiently different to frustrate defenses against ballistic missiles; and finally, in the so-called "skip trajectory," a combination of both.[23]

[redacted] During the summer of 1966, OSD studied proposed changes in the characteristics of SRAM. Among the issues was whether the Air Force should omit the skip trajectory in which the missile followed a near-ballistic path, restarted its motor, and continued at low altitude toward the target. By omitting this feature, the Air Force hoped to obtain greater range at low altitude.

DOE b(3)

Such an innovation--especially if it were accompanied by a device enabling the missile to home on sources or radar waves--would increase SRAM's effectiveness against targets of opportunity. The Air Force, however, was unable to find a homing device suitable for this missile, and it therefore favored leaving space for a possible future installation rather than incorporating an interim device that might be less than satisfactory. On 1 July 1966, the Director of Defense Research and Engineering advised Dr. Flax that all these recommendations had been approved.[24]

(U) [redacted] Meanwhile, the Air Force had been evaluating the project definition proposals submitted in March 1966 by two competing contractors--Martin-Marietta and Boeing. Not until the end of October did Air Force announce that Boeing would develop and manufacture the weapon. On 21 November the company received an engineering development and acquisition contract for some 700 missiles. The original target price was $143.3 million. They were to be used initially to equip the FB-111 force of 525 aircraft and would provide the option for incorporation into the B-52G and H bombers. Concerning the latter, the Secretary of Defense on 11 December 1967 approved modification of two B-52H squadrons to carry the SRAM.[25]

(U) [redacted] As the development program got under way, a number of technological problems arose. During laboratory tests at the Air Force Inertial Guidance Test Facility, Holloman AFB, N.M., the gyros and accelerometers produced for use in the SRAM guidance unit failed. Work began to correct the deficiencies in design of the guidance and control mechanism. Another annoying problem was the lack of compatibility between the SRAM and the FB-111. For example, it was found the missile fin scraped the roof of the weapon bay when the plane was engaged in certain maneuvers. Moreover, the kind of instruments desired for the missile exceeded the basic capacity of the FB-111 instrument panel. Questions arose whether the pivoting pylon devised for the "swing wing" bomber could accommodate SRAM without subjecting the missile to unendurable aerodynamic forces. The answers to these questions hopefully would be resolved in wind tunnel tests.

(u) ~~(S-Gp 3)~~ Besides failure of guidance components and the problem of integrating the missile with the plane, engineers suffered disappointments with SRAM's two-pulse rocket motor. In order to intensify the burning of the solid propellant, the manufacturer used ferrocene catalysts. These additives unfortunately tended to crystallize at low temperature and to escape at high temperatures from the propellant itself into the insulation lining the rocket casing. Also of concern were failures of the rocket nozzles and the second stage igniter.[26]

(u) ~~(S-Gp 3)~~ During the period several drops of a SRAM dummy were made from a test B-52 bomber. The first from the B-52 pylon was made on 25 January 1968 over the Smoky Hill bomb range at Salina, Kans., at Mach .6 and 1,000 foot altitude.[27]

(u) ~~(S-NOFORN-Gp 3)~~ At the end of June 1968, the SRAM motor still had not demonstrated its reliability. Propulsion development lagged a half year behind schedule and threatened to delay the weapon's appearance in the bomber fleet, set for February 1970. The slow pace of development did, however, give the Air Force an opportunity to replace an FB-111 test craft which had been destroyed in a crash.[28] The stubborn problems that plagued motor development contributed to a startling increase in research and development costs. By August 1968, SRAM development had cost roughly $149 million, some 42 percent more than anticipated for this period.[29]

(u) ~~(S-Gp 3)~~ Even as the SRAM program lurched forward, the Air Staff began thinking in terms of an air-to-ground missile to replace it when an advanced manned strategic aircraft entered service. The new plane--under study but not yet approved for development--would require an air launched missile with much greater accuracy and "wider range of yield options" for use in "a carefully controlled strategic response."[30]

NOTES

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ABBREVIATIONS

ABM	Anti-ballistic Missile
ABRES	Advanced Ballistic Reentry Systems
AEC	Atomic Energy Commission
Aerosp	Aerospace
AF	Air Force
AFB	Air Force Base
AFCHO	Office of Air Force History
AFSC	Air Force Systems Command
Analys	Analysis
Apr	April
Ariz	Arizona
Ark	Arkansas
ASB	Air Staff Board
Asst	Assistant
Atch	Attachment
Aug	August
BSD	Ballistic Systems Division
C	Confidential
Ch	Chief
CINCSAC	Commander in Chief, Strategic Air Command
CJCS	Chairman, Joint Chiefs of Staff
CLIP	Cancel Launch in Process
Col	Colonel
Comd	Command
Comdr	Commander
Comm	Communication(s)
CSAF	Chief of Staff, United States Air Force
DAF	Department of the Air Force
DASO	Demonstration and Shakedown Operations
DCS	Deputy Chief of Staff
DDR&E	Director of Defense Research and Engineering
Dec	December
Decn	Decision
Def	Defense
Dep	Deputy
Dev	Development
Dir	Director Directorate
Div	Division
DSMG	Designated Systems Management Group

ECP	Engineering Change Proposal
EMP	Electromagnetic Pulse
Encl	Enclosure
Engrg	Engineering
et al	and others
Eval	Evaluation
Exec	Executive
FATE	Fuzing and Arming Test and Evaluation
Feb	February
Fin	Financial
FOT	Follow-on Operational Test
FY	Fiscal Year
Gen	General
Gp	Group
HARD	High Altitude Radiation Detection
HEST	High Explosive Simulation Test
Hist	History
ICBM	Intercontinental Ballistic Missile
IDA	Institute for Defense Analysis
Instl	Installation
Jan	January
JCS	Joint Chiefs of Staff
JCSM	Joint Chiefs of Staff Memorandum
Jr	Junior
Jul	July
Jun	June
Kans	Kansas
LFP	Launch Facility Processor
LGM	Silo Launched, Surface Attack, Guided Missile
Logs	Logistics
Lt Col	Lieutenant Colonel
Ltr	Letter
Maj	Major
Maj Gen	Major General
Mar	March
Memo	Memorandum
Mgt	Management
Mil	Military
Mk	Mark
Mo	Missouri
Mont	Montana
Msg	Message
Msl	Missile
Mtg	Meeting

N.D.	North Dakota
n.d.	no date
N.M.	New Mexico
NOFORN	Not Releasable to Foreign Nationals
Nov	November
NSC	National Security Council
Oct	October
Ofc	Office
Op	Operation
Opl	Operational
OSAF	Office of Secretary of the Air Force
p	page
PBV	Post Boost Vehicle
PCR	Program Change Request
pp	pages
Prgm	Program
Prgming	Programming
RAD	Requirements Action Directive
RD	Restricted Data
R&D	Research and Development
RDT&E	Research, Development, Test and Engineering
Re	Regarding
REXX	Recall
RL	Records Library
Rprt	Report
Rqmts	Requirements
Rsch	Research
S	Secret
SABRE	Self Aligning Boost and Reentry Vehicle
SAC	Strategic Air Command
SAF	Secretary of the Air Force
SAMSO	Space and Missile Systems Organization
SAS	Status Authentication System
S.D.	South Dakota
SecArmy	Secretary of the Army
SECDEF	Secretary of Defense
Sep	September
Sig	Signature
S&L	Systems and Logistics
SRAM	Short-Range Attack Missile
Strat	Strategic
Subj	Subject
Sys	System
TEP	Trans-attack Environmental Probe
TS	Top Secret

U	Unclassified
USAF	United States Air Force
VCS	Vice Chief of Staff
Vice Adm	Vice Admiral
vol	volume
w	with
Wpn	Weapon
WS	Weapon System
WSEG	Weapons Systems Evaluation Group
Wyo	Wyoming
Yr	Year

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