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History of the

GAM-87 SKYBOLT AIR-TO-SURFACE BALLISTIC MISSILE

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1ST REVIEW-DATE: 2-16-07
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2ND REVIEW-DATE: 12/29/07
AUTHORITY: ADD
NAME: R Wendt
DETERMINATION (CIRCLE NUMBER(S))
1. CLASSIFICATION RETAINED
2. CLASSIFICATION CHANGED TO: FRD
3. CONTAINS NO DOE CLASSIFIED INFO
4. COORDINATE WITH:
5. CLASSIFICATION CANCELLED
6. CLASSIFIED INFO BRACKETED
7. OTHER (SPECIFY): DoE equity

5 FRD
249 pages

VOLUME I

(Narrative)

EXCLUDED FROM AUTOMATIC REGRADING; DOD DIR 5200.10 DOES NOT APPLY

[redacted]

Dept. of State, ISS/IPS, Margaret P. Grafeld, Dir.
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HISTORY OF THE

GAM-87 SKYBOLT AIR-TO-SURFACE BALLISTIC MISSILE

by

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March 1967

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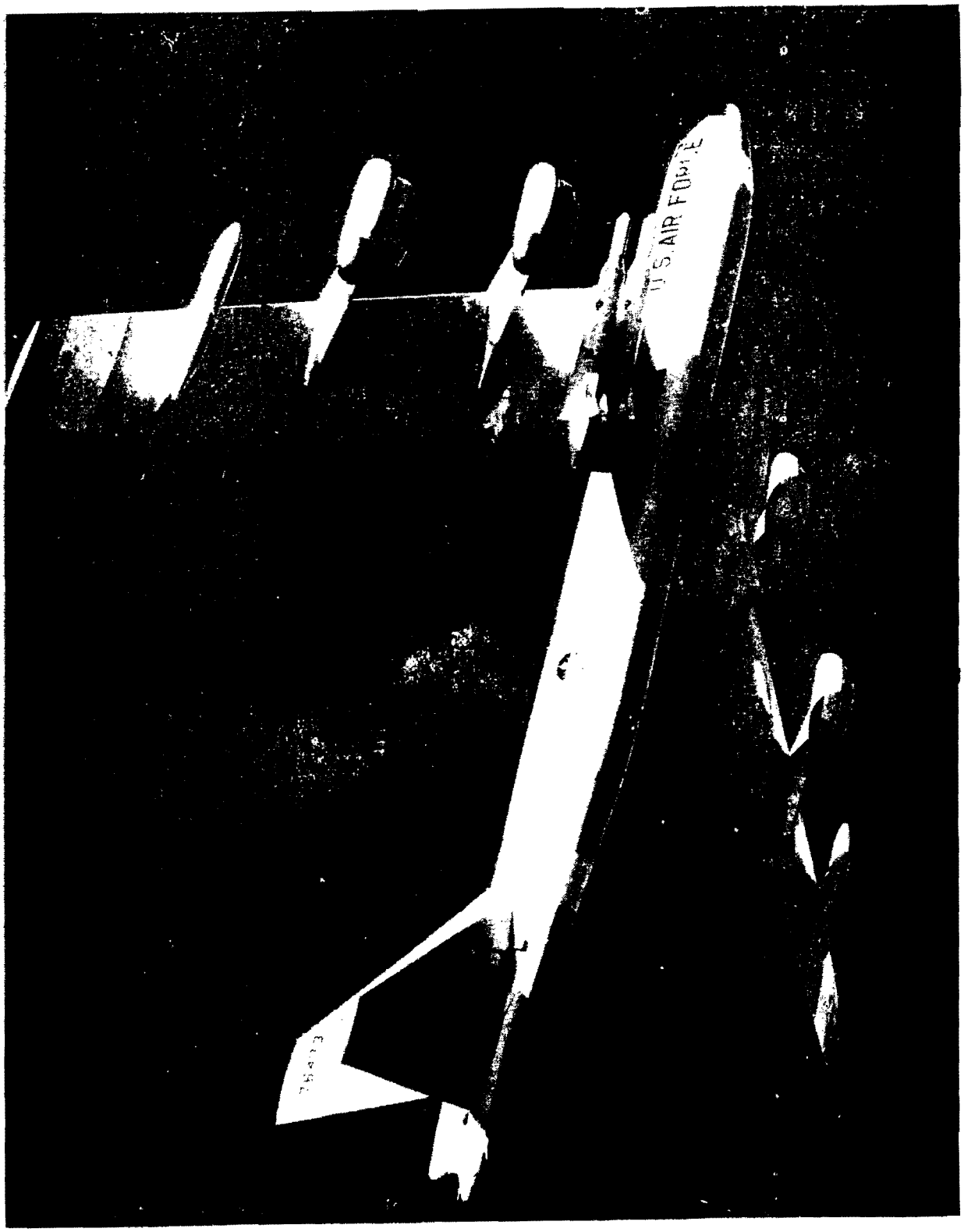

Frontispiece. "Skybolt gives new meaning to the military axiom of gaining the high ground." Lt. General James Ferguson.

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PREFACE

Although only one author's name appears on the title page, this monograph in part, is a joint effort. Much of the early history of the GAM-87A program had been written at the time this monograph was assigned to me. Mr. William D. Putnam was responsible for a significant portion of the research, writing and collection of documents covering the period to late 1959. Research on the Skybolt monograph halted when Mr. Putnam left the Aeronautical Systems Division in 1961.

The depth to which the author of a monograph examines his subject is naturally dependent upon the time which can be allotted to the study. Management of the Skybolt program obviously could be explored in much greater detail than has been done here, particularly in an analysis of the changing concepts of strategic deterrence and weapon systems management at Air Force headquarters and Department of Defense levels, and of the effects these changing concepts had on the GAM-87A program.

Research in the files of the GAM-87A program office, conducted during February, March and April of 1963, was actually a race against time. The author was often hard pressed to keep ahead of the girls who were preparing office files for retirement following program cancellation. Despite the added hindrance which my work was to them, the skeleton office staff still "on board" was extremely cooperative, particularly in permitting me access to material which had already been boxed and sealed.

Within the ASD Historical Division office, credit belongs to Mrs. Mary Yancey for her efficient work in preparing the monograph for the printers. My thanks also go to the staff at the systems command historical division office in Washington, D. C., for its assistance during my visit there. The collection of documents which they had accumulated for my use was of particular benefit to me.

Some reader may question the significant lapse between the time the research for this monograph was conducted and the actual date of publication. This can be explained by the author's three-year absence from the historical office, caused by the peculiarities of civil service.

CGW March 1967

CHRONOLOGY

1958 January	2	USAF directed feasibility demonstration of air-launched ballistic missile.
March	7	Air Force released contract to Martin Company for successful demonstration of an air-launched ballistic missile from a B-47.
July	1	General Thomas H. White, Chief of Staff, directed Aircraft and Weapons Board to determine the availability and usefulness of a ballistic air-to-surface missile as a matter of urgency.
	17	SAC established requirement for advanced air-to-surface missile.
November	17	First successful flight of Bold Orion test vehicle, launched from a B-47.
December	16	Second successful two-stage Bold Orion test flight.
	19	High Virgo test missile launched successfully from a B-58.
1959 January	12	Source selection directed by USAF for an air-launched ballistic missile.
	21	Air Research and Development Command (ARDC) System Directive 138A directed source selection.
	22	General Operational Requirement Nr. 177 was established.
	30	Request for General Management Proposals submitted to industry. Twenty-four contractors were invited to reply.
March	16	Evaluation of management proposals begun.
	28	Dr. York, Director of Defense Research and Engineering, directed program be reviewed "after source selection but before contractual commitment."
April	17	Joint Chiefs of Staff submit "split" opinion to the Secretary of Defense on air-launched ballistic missile.

1959 May	4	Douglas Aircraft Company selected as prime contractor for advanced design studies.
	5	XGAM-87A Weapon System Project Office organized.
	13	$3.0 million in fiscal year 1959 funds made available for Phase I study.
	18	Air Force headquarters directed development of air launched ballistic missile (Phase I design study).
	20	Contractual obligations limited to studies pending project determination. Dr. York directed five studies -- Operational Employment, Systems Optimization, Cost Effectiveness, Development Plan, and Problem Areas.
	26	Letter contract AF33(600)-39587 released to Douglas Aircraft.
June	22	Development Directive Nr. 109 issued by Air Force indicating program was to proceed on minimum expenditure basis pending final Defense Department decision.
July	10	Ogden (Utah) Air Materiel Area selected as support AMA for the GAM-87A.
	24	Air Force approved Douglas' selection of Aerojet-General as propulsion subcontractor.
	28	Department of Defense Scientific Advisory Committee recommended that weapon system and production status be postponed until studies are completed.
	30	Development of B-58B cancelled. Aircraft was to have been prime carrier for GAM-87.
August		Able III configuration for GAM-87 missile identified by Douglas.
	13	General Electric selected as sub-contractor for re-entry vehicle.
October	2	ARDC confirmed that funds for FY60 had been deferred for GAM-87A.
	12	Nortronics named guidance system sub-contractor.

1959 October	13	Douglas completed five preliminary studies ordered by Dr. York prior to development approval.
Nov. - Dec.		In-house study effort accomplished at Wright Field complementing similar technical evaluation of GAM-87A conducted by Douglas Aircraft.
Dec.		Joint Chiefs of Staff recommended development of advanced air-to-surface missile to DOD.
1960 January	15	In-house evaluation completed and results presented to Fletcher Committee, Department of Defense. Delta II configuration for missile adopted in preference to Able III.
February	1	Deputy Secretary of Defense Douglas approved GAM-87A development program, within specific guidelines.
	4	Air Force headquarters authorized immediate initiation of development, releasing $32 million in FY60 P-600 funds to carry program through 30 September 1960.
	8	GAM-87A Engineering Office established at Wright Field.
	24-25	First Phasing Group meeting.
March	18	Development Directive 401, superseding DD 109, reflected relaxed range and circular probable error requirements.
	29	ARDC Systems Directive 638A/138A reflected similar change in requirements.
June	4	British Joint Project Office formed at Wright Field.
	8-9	Development Engineering Inspection conducted at Boeing-Wichita, using B-52G/H mockup reflecting the -G configuration in cases where GAM-87A components were installed.
	17	Contractor development costs based on revised work statement were established at $352 million.
July	29	Full scale motor testing begun with first firing of a test weight first-stage motor.

1960 August	3-5	GAM-87A Preliminary Development Engineering Inspection held at Douglas facility at Santa Monica, California, to demonstrate the form, fit and general arrangement of missile/pylon and launcher.
	9-11	Revised system program budget presented to Air Force headquarters estimating total research and development cost at $372 million.
	16	First GAM-87A Executive Council Meeting.
September	14-20	Joint Anglo-American Planning Conference at Wright Field.
	23	GAM-87A Executive Council ordered termination of work on heavy warhead for GAM-87A.
		First full-scale, second-stage test weight motor fired successfully at Aerojet-General.
	27	Joint Technical Agreement on funding and contractual procedures signed by U. S. and United Kingdom.
November	10	Definitized Work Statement agreement reached between project office and prime contractor.
	14	First training class at Douglas held for Air Force flight test personnel from Eglin Air Force Base.
December	5	The Air Force halted all contractor commitments for GAM-87A pending a decision from Department of Defense.
	9	Contract negotiations completed between Douglas and project office.
	22-23	Project office personnel briefed Pentagon officials on impact of reduced FY61-62 funding.
	23	Secretary of the Air Force directed that the program be re-oriented to remain within $150 million ceiling for FY61-62.
1961 January	9	Project office received word that Pentagon had chosen J-21 warhead for GAM-87A.
	10-12	Development Engineering Inspection held at Boeing-Wichita demonstrating mockup of the B-52G/GAM-87A tactical configuration.

1961 January	12	First carry flight test at Boeing-Wichita on a B-52G carrying four missiles.
	13	New System Operational Requirement Nr. 177 published. Major configuration changes from those in effect in February 1960 were not to be made without prior Air Force approval.
February	10	At Air Force Undersecretary Charyk's request, Douglas Aircraft briefed him on their proposals for continuing GAM-87A program with a FY61-62 ceiling of $200 million.
	27	Initial dummy missile drop test conducted at Eglin Air Force Base.
March	2	"Washington Plan" directed, establishing a $391 million development program ceiling and extending all major milestones approximately seven months.
May	11	Director of Defense Research and Engineering published a report, Project 41, stating: "Justification for the SKYBOLT development solely as a weapon to be carried by the B-52 appears to be very marginal. No production decision for use on the B-52 appears warranted at this time."
June	1	Program office submitted System Package Program to Air Force headquarters, documenting a development cost of $392 million plus $1,124 million for production of 1,134 operational missiles.
	12	Program office presented preliminary 1 June package program to command headquarters.
August		Motor liner problem discovered.
	3	Douglas Aircraft reorganized creating two new product-oriented divisions.
September	18-28	Management structure reviewed by Air Force team headed by Brig. Gen. G. F. Keeling.
	26	Defense Secretary McNamara visited Douglas Aircraft. Secretary McNamara noted program was under-funded and directed that a better balanced program be presented to him.

1961 October	2	Interim Revision I to the System Package Program completed, expanding program with increased development costs of $492.6 million plus $1,279.2 million for 1,134 production missiles.
	20	Brigadier General David M. Jones named ASD Deputy Commander/GAM-87.
November	1	Douglas begins implementation of major reorganization at Air Force's request.
	6	Tests of the guidance system astrotracker begun at Mount Palomar Observatory.
	22	Initial guidance system sled test run made.
	30	First captive mechanical missile flight test completed.
December	1	Skybolt instrumented dummy drop program initiated by United Kingdom with drop from a Vulcan at West Frough, Scotland.
	29	Deputy Secretary of Defense Gilpatric confirms $492.6 million program ceiling for development.
		Department of Defense granted initial approval of Skybolt production program for planning purposes and approved the Interim Revision I to the package program, the so-called "McNamara Program."
1962 January		Terhune Board reviewed program management.
	23	Initial increment of pre-production planning money was approved.
February	9	Air Force issued ADO-40, "Advanced Development Objective for an Anti-Satellite Program."
April	19	First powered flight of a GAM-87A missile. Second-stage motor failed to ignite.
	28	Guidance system components flown for first time in a C-131B flying laboratory.
May	1	Revised System Package Program completed by program office. Program called for $492.6 million ceiling.
June	29	Air Force headquarters authorized production fund release.

1962 June		Second guided launch made. First stage motor failed to ignite.
July	2	Program office placed $10.14 million in production funds on contract. Procurement Authorization released $197.5 million for procurement of missiles, aerospace ground equipment, associated equipment, training and technical data.
	7	Initial United Kingdom captive mechanical missile flight test.
	9	All production funds withdrawn by Defense Department.
	13	General Jones succeeds in getting $20 million in production funds restored.
September	13	Third programed launch. Failure in programer timer circuitry.
	25	Fourth programed launch. Telemetry data was lost at time of second stage ignition.
	29	Defense Department approved Skybolt production program. Funding would continue on incremental basis throughout 1962, however.
November		Continuing rumors of possible program cancellation. Secretary of Defense McNamara flies to England to confer with British leaders.
	28	First guided launch marred by malfunction in gas generator/hydraulic subsystem causing flight to end prematurely.
		A draft of the FY64 budget proposed by the Office of the Secretary of Defense received by Air Force headquarters contained no funds for GAM-87A in FY64 or following years.
December	20-21	President Kennedy and Prime Minister Macmillan met at Nassau.
	22	State Department telegram from Pierre Salinger in Nassau summarized in unclassified form the results of the meeting.
		Second guided launch. All test objectives were achieved.

1962 December	31	Air Force headquarters instructed Aeronautical Systems Division (ASD) to terminate all aspects of the production program.
1963 February	4	ASD received direction for termination action involving an orderly phaseout in the shortest time with the maximum benefit to the Air Force but with a minimum of further expenditures.
March	25	C-131 guidance system test program terminated.
May	14	Administrative control and management responsibility for remaining termination activities passed to the Strategic Systems Program Office at ASD.

INTRODUCTION

Development of the GAM-87A Skybolt missile took place at a time when weapon system management was undergoing a metamorphosis. During this period, there was a growing tendency to pull existing project office authority upward toward Air Force headquarters or the defense department, centralizing decision-making at higher echelons. The Department of Defense -- particularly under Secretary of Defense Robert S. McNamara -- was taking an increasingly active role in determining the weapon systems which were to be developed and produced. The Skybolt program, among the first Air Force programs subjected to Washington's growing scrutiny, was an excellent example of defense department detailed direction in determining system requirements, selecting contractors, and in the actual management of the program.

During 1959 when the decision to develop an advanced air launched ballistic missile was being considered at the Pentagon, Air Force cries of indignation were widespread over the increasing direct action being taken by the Office of the Secretary of Defense in determining the future of the program. Such moves, it was asserted, would seriously undermine the established Air Force policies in weapon system management. If the trend continued, industry would lose faith in the military procedures for evaluation, source selection, and management. Contractors would sense the decreasing authority of the project office and would make overtures to defense department level agencies.

Meanwhile, the growing complexity and expense of the various elements of this nation's defensive arsenal spawned a greater emphasis on efficient program management. Program directors were more and more forced to justify in detail requirements for funds, if not the existence of the various programs themselves. In addition to the changing management concept was a growing notion of the element of defense parity rather than defense superiority. As President Kennedy once remarked, "How many times do you have to hit a target with nuclear weapon?"

The key element was cost effectiveness. An ancient principal with a new title, it involved the application of traditional input-output methods of economics to defense weaponry and then to strategy. How could the government best allocate economic and strategic resources most effectively in a world situation where strategies must change with changing conditions? In what weapon systems can the available resources be most wisely invested? The application of this yardstick was to bring about the cancellation or a major reduction of several Air Force programs of the early 1960's, including among them the GAM-87A and the RS-70 tri-sonic bomber.

CHAPTER I

BACKGROUND: CONCEPTION TO DEVELOPMENT APPROVAL

Air Force study of an air-to-surface missile for strategic bombardment aircraft can be traced back to World War II when experiments were conducted with guided bombs and other devices designed to give a bomber "stand off" capability against enemy defenses. Shortly before the end of the war, the Air Force stated requirements for the development of a missile to be carried by bombers resulting in the GAM-63 Rascal program which culminated in the development of a missile for the B-47. While the Rascal never became an operational weapon, much basic development work was accomplished from 1946 to 1958 in the area of a strategic air-to-surface missile.

Interest in an advanced air-to-surface missile was stimulated in July 1957, when the Air Force request for proposals for a B-52 missile elicited four proposals. North American Aviation, eventual winner of the competition, conceded that an air launched ballistic missile had the greatest performance potential but would necessitate an extensive development period. Since the B-52 missile program was limited by a requirement for virtually immediate availability, the air launched ballistic missile concept was deferred in favor of an air-breathing winged missile which became the GAM-77 Hound Dog.* [1]

*The GAM-77 was later redesignated (under a new Department of Defense designation system) as the AGM-28A. Likewise, the GAM-87 Skybolt -- though cancelled in late 1962 -- received new nomenclature as the XAGM-48A.

In October 1957, the Air Research and Development Command (ARDC) issued a System Requirement Nr. 168 for an advanced air-to-surface missile.* Industry began an unfunded study to determine what general requirements could be attained by 1963. This effort was to last until June of 1958, but early in January 1958 Air Force headquarters notified the development command that the Chief of Staff wanted a demonstration of an air launched, long-range, air-to-surface missile at the earliest possible date.[2]

The Concept Demonstration Programs

The research and development command's Directorate of Systems Management at Wright-Patterson Air Force Base received the task of planning and managing a demonstration program. The project would take approximately one year and would include a demonstration of a missile with a 350 nautical mile range. Two companies were considered to manage the project, Lockheed Aircraft Corporation or the Martin Company; the latter was recommended by the systems management directorate because of the firm's work in guidance and control.

On 7 March 1958, the Air Force released a contract to Martin Company calling for the successful demonstration of flights of an air launched ballistic missile from a B-47. The test vehicle was a solid rocket bottle with a moveable petal skirt and a nose cone containing flight control, electronics and guidance systems. The demonstration program, known by the nickname "Bold Orion", encompassed four missile

*See Doc. Nr. 30, Final Report ARDC SR-168, 23 June 1958.

flights between June and October 1958 which revealed a succession of discrepancies in the flight control system. Following a major modification in the control system, the fifth missile flew successfully on 17 November 1958 and attained about a 250 nautical mile range.[3]

Meanwhile, Air Force headquarters in July 1958 directed ARDC to increase the range of the Bold Orion test vehicle beyond 750 nautical miles, and Martin modified the system by adding a spin-stabilized second stage. On 8 December the first two-stage missile was launched, but the first stage motor failed to ignite. Although the second two-stage missile, launched on the 16th of the month from a B-47 flying at mach 0.75 and an altitude of 35,000 feet, lost the second stage radar beacon signal soon after ignition, an impact prediction indicated a range of 930 nautical miles. The flight completed the basic contractual requirements for the Bold Orion program.[4]

At the same time that the Bold Orion program was demonstrating the feasibility of launching from a subsonic carrier, Project 199C, nicknamed High Virgo, was underway using a B-58 as a supersonic launch platform. The project originated in a B-58 engineering change proposed by a team from Lockheed Aircraft Corporation and the Convair Division of General Dynamics Corporation for the demonstration of a ballistic air-to-surface missile. The Air Force accepted the proposal and established a program with Convair as prime contractor for the project and Lockheed Missile Systems Division as missile contractor.[5]

The High Virgo vehicle was 31 feet long with propulsion provided by an XM-20 solid propellant rocket motor rated at 50,000 pounds thrust.

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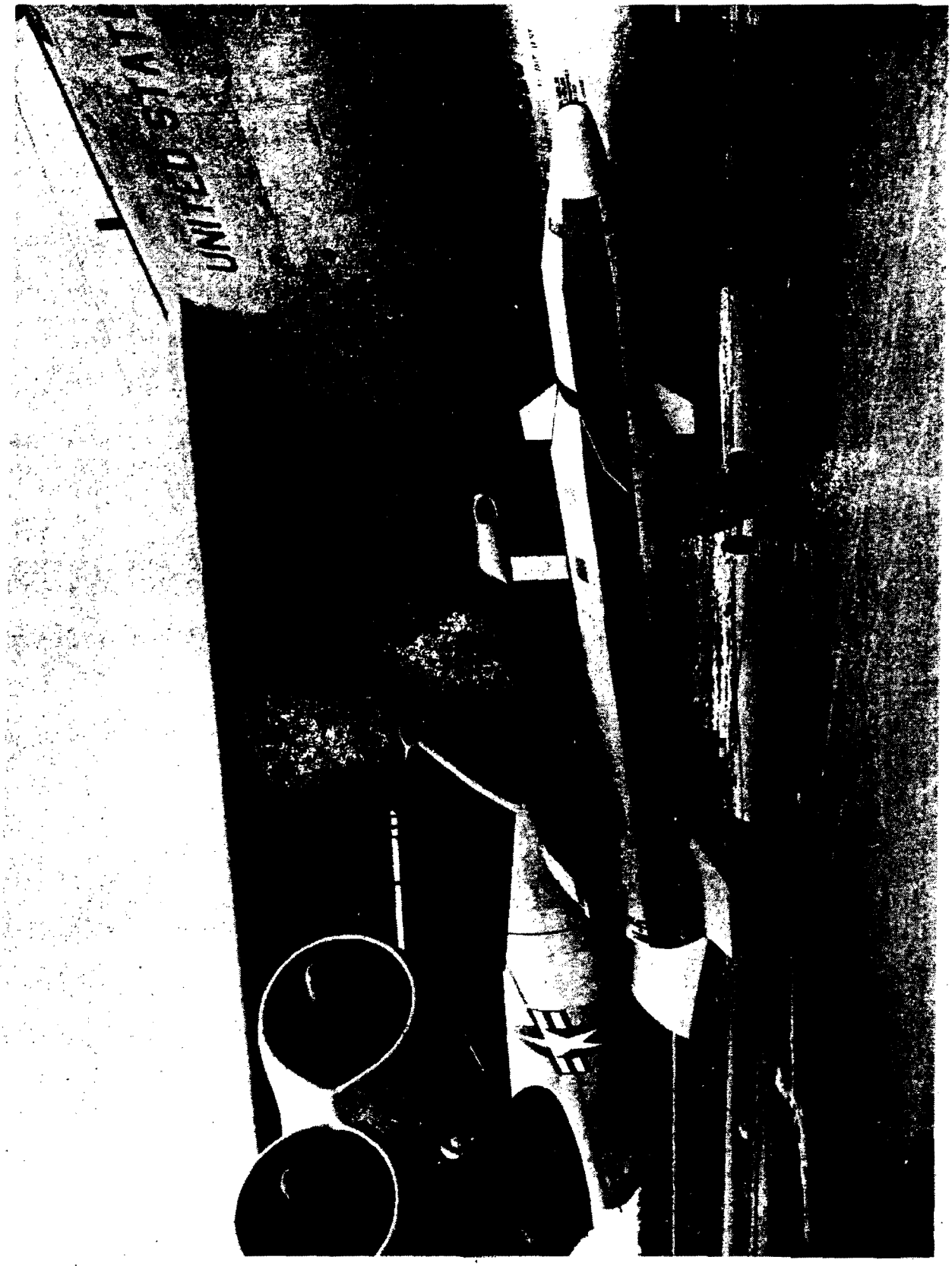

A "Bold Orion" test vehicle.

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The first launch was attempted on 5 September 1958 from a B-58 at 40,300 feet and a speed of mach .995, resulting in a failure as the missile went out of control six seconds from launch. The second launch on 19 December successfully achieved a range of 185 nautical miles with an apogee of about 44 miles. The third missile flew successfully on 4 June 1959, following a mach 1.46 launch at 40,000 feet under conditions similar to those of the second launch.[6]

By 19 December 1958, the feasibility of air launching a ballistic missile had been demonstrated effectively. The launch of a two-stage Bold Orion missile with a 930 mile flight from a subsonic platform, and the supersonic launch of the single-stage High Virgo vehicle proved the airborne launch of a ballistic missile was not beyond the existing level of technology.

The Air Force Moves to Develop a Weapon

While the demonstration programs established the feasibility of the air launched ballistic missile concept, high level interest was expressed in translating the concept into a weapon system. On 1 July 1958, General Thomas H. White, Chief of Staff, told the Aircraft and Weapons Board that it was "of extreme importance" to obtain a ballistic air-to-surface missile at "the earliest possible date." General White directed the board to determine the availability and usefulness of such a weapon as a matter of urgency and to present its recommendations to the Air Force Council.[7]

Recognizing the increasing improvement of the enemy defense posture and the subsequent effect on probable aircraft attrition, the Strategic Air Command (SAC) found that advanced air-to-surface missiles were

required to insure the penetration capability of future manned bombers. The strategic command stated there was no requirement for such missiles for the aging B-47, but saw a major need for the B-58 as a carrier. Consideration would be given to the B-52 as a carrier so long as it did not compete with the shorter range GAM-77. If an advanced air-to-surface missile were developed for another aircraft, it could be considered as a later replacement for the Hound Dog. The command foresaw an extension of the B-58 missile effort for future bombers, such as the B-70 and the nuclear propelled vehicle.

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The weapon was to be available no later than 1963 and bombers were to be able to carry the missile in addition to a normal bomb load. The missile envisioned by General White would be employed initially with supersonic bombers, an important consideration since such a weapon could extend the useful life of the strategic bomber fleet — a costly investment that seemed to be facing early obsolescence.[8]

After the demonstration of air launching a ballistic missile, the Air Force briefed Mr. W. M. Holaday, Department of Defense Director of Guided Missiles, on plans for weapon system development. Holaday cautioned that the potential cost would necessarily have some impact on the ability to produce other systems and that a careful evaluation of such impact was imperative before the Defense Department became too deeply committed to the project. Mr. Holaday's office would have to review and approve a development plan and supporting fiscal information

for the project before any additional commitments could be made.[9]

Since contractor selection involved little money, the Air Staff directed the research and development command to begin a competition leading up to source selection. On 21 January 1959, ARDC headquarters issued System Directive Nr. 138A which directed the formation of a source selection board by the Directorate of Systems Management. The system directive established the B-58 as the top priority carrier, reflecting the using command's requirement, with the B-52C and D models and the British Victor and Vulcan bombers as alternates.* Secondary consideration was to be given the B-70, the KC-135 and the nuclear powered aircraft as carriers. Since a terminal guidance system was seen as necessary if any significant improvement in accuracy was to be made over that possible with existing inertial guidance systems, development of terminal guidance was to be pursued along with the basic program.[10]

On 22 January 1959, the Air Force issued General Operational Requirement Nr. 177 establishing the formal requirement for a "Rocket Powered Strategic Air-to-Surface Missile System." The concept of use implied employment as a penetration aid to "roll back" the defenses clearing a path to the primary target for the bombers. Also stressed was its role as a stand-off weapon, to be launched at major targets from a platform outside the enemy defenses. [redacted] DOE b(3)

*Participation by the British had been discussed late in 1958 by a joint task group representing both the RAF and the USAF. (See appendix B.)

DoE b(3) DoD

Conflicts in optimum design were normally to be resolved in favor of the B-58. Compatibility with B-52 aircraft already modified for GAM-77 Hound Dog carriage was required "to the extent reasonable." Flexibility in flight characteristics was provided by the statement: "The flight path may be ballistic, boost glide, or combination thereof so long as it minimizes enemy capabilities for detection and interception."

A specific type of guidance was not directed beyond the limitations that it be independent of the carrier after launch, alignable in flight, and capable of target changes while airborne and attached to the carrier.[12]

Reliability requirements called for an 85 percent chance of success for missiles launched after extended periods of ground or airborne alert, exclusive of losses to enemy action. All requirements were subject to trade-offs in the effort to obtain a weapon which could perform the required task in the shortest possible time. The rocket-powered air-to-surface missile was needed in operational units "as soon as practicable but not later than 1963."[13]

By January 1959, the feasibility of the concept had been demonstrated and the official Air Force requirement for the weapon had been established. The process of source selection leading to the development of weapon system 138A now lay ahead.

Selection of a Prime Contractor

Source selection for a prime contractor for system 138A had been directed by the Air Force on 12 January 1959 in a letter to Headquarters

ARDC. Major General V. R. Haugen, Director of Systems Management, chaired the newly created Source Selection Board. An ad hoc committee of its members oversaw the selection of criteria to be met by potential contractors. A working group, made up of representatives from the Directorate of Systems Management, Wright Air Development Center laboratories, Air Force Special Weapons Center and the Aeronautical Systems Center of the Air Materiel Command, established a master list of 127 potential sources within industry. This group reduced the list, with the committee's assistance, from 127 to 24 tentatively qualified prospective contractors. Fourteen of these had participated in the unfunded study effort completed in June 1958.[14]

All but one of these 24 prospective contractors attended a meeting at Wright Field on 12 February 1959. The 30 January Air Force request for proposals from industry had set a deadline of 27 February for each company to declare its intention to submit a proposal. Nine firms declined to submit a proposal, while proposals from the remaining 15 potential contractors were heard by the evaluation group and source selection board between 18 and 20 March. The official Air Force decision to award the prime contract to Douglas Aircraft Company was publicly released on 5 May 1959.[15]

On 18 May, Air Force headquarters directed the development command to proceed immediately by awarding a contract for advanced studies to Douglas. The directive specified that the program was to "proceed on a minimum expenditure basis consistent with efficient management procedures pending subsequent evaluation and final decision by the Office

of the Secretary of Defense" and that funds available were limited to $3 million.* [16]

High Level Decisions

Late in March 1959, Dr. Herbert F. York, Director of Defense Research and Engineering, informed the Secretary of the Air Force that the Weapon Systems Evaluation Group study raised some questions which had to be considered prior to any final missile development commitment. Dr. York indicated that following source selection but before any contractual commitments were made, he wanted to review the schedules, the funding requirements, and the proposed solutions to the technical problems which would be encountered. The concern in the defense department was over the potential cost of the program and the impact on the strategic force structure.[17]

An Air Force briefing before the Joint Chiefs of Staff on 1 April brought system 138A to that body for evaluation. The Air Force Chief of Staff pressed for a statement from the Joint Chiefs that the air launched ballistic missile would significantly increase aircraft effectiveness and operational flexibility and should be developed

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*For miscellaneous documents covering source selection procedures, see documents 31 thru 43.

through the prototype stage. The Army and Navy chiefs took the position that a lack of positive information cast doubt on the validity of weapon requirement at that time. General Maxwell D. Taylor, Army Chief of Staff, went farther by expressing his concern that the acquisition of this weapon would create the possibility of a prolonged dependence on aircraft.[18]

Attempts to resolve these differences were to no avail and General White finally asked that a "split" reply be submitted to the Office of the Secretary of Defense. General White, generally supported by the chairman of the Joint Chiefs, recommended priority development through the prototype stage. The Army and Navy recognized the potential value of the missile, but questioned the projected schedule, estimated costs, and necessity for extending the service life of the strategic aircraft.[19]

This split decision influenced the Office of the Secretary of Defense to delay the development decision while acquiring additional data. The Pentagon therefore informed the Air Force that contracts would be limited to the acquisition of additional technical data. Dr. York, in a 20 May 1959 memo to the Secretary of the Air Force, stated his decision that five studies should be completed under the Douglas contract. This directive meant that weapon system approval from the Department of Defense would be contingent upon the results of these studies. A deadline of 15 August 1959 was set by Dr. York for the completion of studies in five areas: operational employment, system

optimization, cost effectiveness, development planning, and technical problem areas. "Since approval to proceed as a weapon system development program will depend upon the forthcoming review and assessment, costly long-term commitments, facility investments, the over-involvement of development subcontractors, etc. should be avoided," he stated.[20]

It was against this background that the Air Force and Douglas executed the $3 million letter contract AF33(600)-39587 on 26 May 1959. The question of whether the air launched ballistic missile would acquire system status and obtain development approval was still very much at issue, despite the fact the program carried an Air Force-assigned system number. The eight months that followed before a qualified development decision was finally made, were filled with controversy over program aspects, both technical and managerial.

The "Minimum Expenditure" Program

Air Force headquarters, on 22 June 1959, issued Development Directive Nr. 109, which contained the admonition to "proceed on a minimum expenditure basis consistent with effective management procedures" and to avoid long term expenditures until the Defense Department made a decision. In the light of such limitations, the Air Force initiated steps which did not involve the commitment of funds, yet would prepare the program to proceed upon the receipt of a favorable decision from the Defense Department. Air Force program guidance revisions in July included weapon system 138A in

the equippage schedule and on the 14th of the month approved the model designation of XGAM-87A for the system.* Also in July, the Ogden (Utah) Air Materiel Area was designated as the specific supply support agency for the proposed weapon system.[21]

The approval of the prime contractor's selection of subcontractors involved no direct expenditure of funds yet had to be completed before the inauguration of a full-scale development program. The first step was a Douglas presentation in early June 1959 before Air Force project office and laboratory personnel.

Douglas proposed the Light Military Electronics Department of the General Electric Company as guidance system manager. This suggested association between the prime contractor and General Electric was the same as had been outlined in the original management proposal which had specified General Electric as an associate contractor or "partner." Douglas desired a guidance manager claiming they did not have enough experienced people in the guidance area. The Weapons Guidance Laboratory at Wright Air Development Center made it clear that Douglas had been selected as prime contractor on the strength of the company's management concept rather than any technical competence in the guidance area. The

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*The XGAM-87A Weapon System Project Office (WSPO) was organized at Wright Field under the Deputy for Strategic Weapons on 5 May 1959, with a proposed management structure calling for an organization manned by 14 people. Management of the program was shifted from the Deputy for Advanced Systems to the Strategic Weapons deputate at the same time.[22]

laboratory pointed out that in the original competition, Douglas had been rated eleventh in the guidance area -- completely unsatisfactory. The Air Materiel Command's Aeronautical Systems Center rejected Douglas' suggested arrangement and directed that competitive procedures be followed, noting that General Electric would be given an equal opportunity under these conditions.[23]

On 20 June 1959, Douglas released requests for proposals on the propulsion subsystem to prospective subcontractors. From the firms of Aerojet-General Corporation, Grand Central Rocket Company, Hercules Powder Company, Incorporated, and the Thiokol Chemical Corporation, the prime contractor selected Aerojet-General. Factors influencing the choice were a good propellant formulation, a depth of technical manpower assuring reserve strength, an excellent testing plan, and the lowest requirement for government financed facilities. Following a resubmittal of Douglas' proposal to provide additional information to the Air Force Subcontract Advisory Panel, the group approved the selection of Aerojet-General on 24 July.[24]

In chosing the subcontractor for the re-entry vehicle subsystem, Douglas' choice was limited to only three potential sources, Avco Manufacturing Company of New York, General Electric, and the Goodyear Aircraft Company. The latter firm declined to submit a proposal. General Electric's greater stress on reliability and quality control, their plan to utilize no government funded facilities for development or production, and the fact that the proposed vehicle was 65 pounds

lighter than that of their competition resulted in Douglas selecting the General Electric proposal. While the Air Force considered both prospective subcontractors very capable in this field, Avco would be occupied in the Minuteman and Titan programs and the lighter General Electric vehicle held greater promise. Therefore the Advisory Panel approved the Douglas choice.[25]

The choice of a guidance subsystem contractor was complicated by the fact that Douglas had originally proposed an associate contractor relationship with the Light Military Electronics Division of General Electric. Nine firms submitted formal proposals after Douglas had released their request for proposal to industry on 8 July. The prime contractor again named the General Electric firm as winner of the competition, but on 20 August the Air Force informed Douglas that a decision on their recommendation was being withheld pending a "detailed review" by laboratory experts of the second ranked competitor, Nortronics Division of Northrop Corporation.[26]

Two weeks later, the weapons guidance laboratory produced a technical evaluation of the proposals from General Electric and Nortronics. Neither competitor, the report indicated, was realistic about schedules nor did either company recognize the considerable degree of risk involved since air alignment of an inertially guided ballistic missile had never been accomplished. Because the guidance subsystem was an item of high risk, the laboratory considered extensive background in inertial guidance a necessity and found General Electric only average in this area.[27]

On 10 September 1959, Douglas presented their findings to the Subcontract Advisory Board at Wright Field. Douglas had rated both General Electric and Nortronics about on a par in regard to technical aspects of the proposals, with the former getting a better score on management and manpower aspects, while the latter was rated higher in direct experience due to the firm's work on the Snark missile's inertial guidance system. The panel decided to require Douglas to prepare a supplemental account of the selection procedure in detail and to make a later presentation justifying their choice.[28]

Specifically, the panel objected to the heavy emphasis on management procedures when the technical difficulty was of great concern. An objection was also recorded in regard to the Light Military Electronics Division being given credit for experience on the Polaris and Atlas ballistic missiles when these guidance subsystems were designed by the Massachusetts Institute of Technology and manufactured by the Ordnance Division of General Electric. On 9 October, Douglas reported Nortronics had gained in several vital areas and the prime contractor now agreed with the Air Force's choice. On 12 October 1959, the public announcement of Nortronic's selection was made.[29]

Autumn Crisis

While the source selection for subsystem contractors proceeded, Pentagon officials continued their review of the air-to-surface missile program. Dr. Herbert F. York, Director of Defense Research and Engineering, on 15 July 1959 ordered the establishment of an Ad Hoc Group for Air-to-Surface Missiles, charging the group with responsibility for reviewing

information, performing special studies, and rendering special counsel and advice within the Department of Defense. While the group would review the major aspects of the program in general, particular attention would be paid to the GAM-87A.[30]

As a result of the initial meetings of this group, the Air Force, in August 1959, agreed to increase or redirect Douglas' effort toward satisfying more completely the contents of Dr. York's memo of 20 May 1959. This document had spelled out the principal areas within which the Office of the Director of Defense Research and Engineering (ODDR&E) review would be concentrated. At the same time, the Air Force initiated an in-house study of other possible advanced air-to-surface missile configurations, including an advanced Hound Dog.* [31]

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*General Thomas S. Power, Air Force commander, in a letter to General White gave his opinion on the possibility of adopting an improved Hound Dog missile rather than proceeding with the development of the GAM-87A.

> . . . A long range Hound Dog will not satisfy our requirement for a follow-on missile to the GAM-77. Such a model improvement operating at the same speeds and altitudes as Hound Dog will be at least as vulnerable as Hound Dog by the post-1963 time period. The GAM-77 program must certainly be continued to insure a current ASM /air to surface missile/ capability while GAM-87A is under development. However, we should strive for GAM-87A as early as possible for use on the B-52, with later adaptation to the B-70 and CAMAL /continuous airborne missile launcher and low-level aircraft/.
>
> Adequate funding from 1 October 1959 will permit us to equip B-52's at relatively small cost, since we can provision approximately 11 squadrons in currently programmed modification lines. Each month's delay will cost us one of the squadrons, commensurate saving, and a second downtime for GAM-87A capability.[32]

While the Pentagon continued to weigh the merits of the proposed weapon system 138A, Douglas foresaw the approach of a potential funding crisis. A total of $3 million had been authorized in May 1959 for the GAM-87A program and in mid-August 1959, Douglas forecast a need for $2.833 million by 1 October. Since the validity of the Skybolt program remained under question within the DOD, no release of the funds had been forthcoming from the Pentagon by mid-September. Douglas at this point announced that by 15 October, 85 percent of the available funds would have been obligated or spent. All funds would be exhausted by 1 November 1959. Project officials advised ARDC headquarters that termination instructions would have to be issued on 15 October if no funds were made available by that date. Through coordinated Air Force and contractor re-scheduling, Douglas was able to stretch the anticipated funds run-out point to 1 January 1960. Any delay beyond 1 November would seriously retard the development program.[33]

The situation climaxed on 2 October 1959 when command headquarters sent a teletype communication to the project office advising that all fiscal year 1960 funds had been frozen for system 138A due to the failure of the defense department to provide the needed go-ahead authorization. Until this occurred, no action was to be taken to initiate, commit or obligate any funds against the program. Air Force headquarters, meanwhile initiated further studies of the entire air-to-surface missile dilemma.[34]

At this point, project office personnel readied detailed briefings to comply with the Pentagon's request for further information justifying

program feasibility. Colonel J. S. DeWitt, Chief of the Weapon System Project Office (WSPO), briefed members of the House Appropriations Committee (the Wood Group) on 9 October, while four days later Colonel Lowe of the Air Force Directorate of Systems Management Detachment Nr. 1 briefed representatives of the defense department's Director of Research and Engineering, concluding with the recommendation that the defense department release $2.9 million to continue the WS-138A study program through 31 January 1960.[35]

A decision was again postponed as the Office of the Secretary of Defense requested a detailed report of the work which would be done if funds were made available. Project personnel immediately launched a new study effort aimed at detailing the research and development plan covering all areas of missile design and integration. A review of the study (and of the mockup of the configuration reached through the study) should permit a determination as to whether sufficient data existed to justify a decision on the development program. The target date for the review and completion of the study was 1 February 1960.[36]

On 3 November, the DOD authorized the release of $3 million requested by Douglas to carry out the required out-of-house technical evaluation of the proposed weapon system and to support the study through 31 January 1960. The major effort during the next few weeks was the continuation of system operational studies, limited component testing, and the assembly of a comprehensive development plan.

The Skybolt* program continued to remain in a nebulous state -- neither approved nor disapproved -- throughout the remainder of 1959.[37]

Development Approval

Activity within the project office intensified following the release of the necessary funds in November. At the request of research command headquarters, 75 technical personnel were added to the project office complement to assist in a detailed and realistic in-house technical evaluation of the proposed Skybolt system. Personnel from Wright Field, the contractor, Ballistic Missile Division, Strategic Air Command, Air Force Flight Test Center, and the Air Force Special Weapons Center composed the augmentation force. Supplementary to the out-of-house evaluation Douglas was conducting, the Air Force effort was to culminate in a report and briefing before representatives of the defense department. The Ad Hoc Group on Air-to-Surface Missiles, under Dr. Fletcher's chairmanship, was to assist in the final evaluation.[38]

By late December 1959, the in-house study effort was virtually completed and project office personnel were readying the final drafts. A rigorous schedule of presentations before groups involved with Skybolt was climaxed by the briefing given to Dr. York on 29 January 1960. On

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*On 11 January 1960, an official news release announced the use of the popular name Skybolt in connection with WS-138A. Although the nickname originally referred to the entire project, by late February 1960 it was associated with the GAM-87A missile itself. The name had been split into two words "Sky Bolt" when named by the Chief of Staff in January 1960. Since AFR 190-14 suggested popular names would normally consist of one word, the two words were combined.[39]

1 February, Deputy Secretary of Defense Douglas in a memo to the Secretary of the Air Force gave defense department approval to weapon system development. Joseph Charyk, Under Secretary of the Air Force, on 3 February replied to the memo accepting the conditions outlined in the approval. The DOD redesignated the program as Advanced System 638A through 30 June 1960,* deferring a decision on a production program until a later date. On 8 February, the command established the GAM-87A Engineering Office at Wright Field under Colonel Perry K. Bryant to provide constant engineering support. To carry the effort through 30 September 1960, the Air Force released $32 million in FY60 P-600 funds; immediately $4.6 million was committed to the Douglas contract.[40]

The Skybolt development effort would now proceed, but subject to certain technical and managerial restraints imposed by the defense department. The conditions under which the Pentagon gave its approval to the program were quite specific. The overriding consideration in every aspect of development was the necessity for providing a useful weapon in the operational inventory as early as possible. The development of improved techniques and materials was not to be a part of the program; major changes of technical specifications would be made only

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*Effective 1 July, the system was transferred to the Operational Development Program (138A). Until 30 June 1960, the system was designated as system 638A to indicate design status for funding reasons only. After 30 June, the Air Force reverted to use of the former nomenclature of "WS-138A."

with the specific approval of the DOD. Due to the program's magnitude and the amount of money involved, the defense department would maintain close surveillance over the development effort, with a quarterly review by the Secretary of Defense during the next two years to compare progress with initial plans.[41]

In granting approval for continued development of the GAM-87A, the defense department noted that:[42]

> . . . this program is considerably more difficult than the earlier ballistic missile development programs carried out by the Air Force, introducing . . . the additional requirement of a more severe environment and the necessity for launching from a rapidly moving vehicle in preference to a fixed point.

Air Force efforts to create a competent GAM-87A management structure up to the point of go-ahead received favorable comment from the DOD. The assignment of weapon system development responsibility to a single prime contractor was unique in the Air Force's ballistic missile program. In the past, similar programs had been carried out under the direction of the Ballistic Missile Division and Space Technology Laboratories using a plan employing associate contractors rather than a single prime contractor. Departure from this procedure aggravated the problem of management of the major subcontractors, it was felt. An item of serious concern was the fact that Douglas had not exercised similar responsibility for a major missile program and had had little experience in guidance system development. In the past, the firm relied heavily on other contractors for the development of guidance and computing elements. Furthermore, Nortronics, the guidance subcontractor, indicated an intention to subcontract a portion of the

development work on both the missile and pre-launch computer. Since development of the guidance subsystem was viewed as the most difficult task, this situation meant the work on this subsystem would be split among several contractors several tiers below the level of the prime contractor.[43]

Although the contingency requirements appeared on the surface to make the Defense Secretary the chief program manager, they were primarily intended to put a firm foundation under the program and to extract from the Air Force a promise to exercise aggressive technical and managerial control within the limits of the state-of-the-art. These requirements also forced the Air Force's assurance that it would provide proper funds support, recognizing that the development costs would exceed the planned cost by two or threefold.[44]

The formation of the Wright Air Development Division* was an important consideration in the approval of the Skybolt program. Had this new technical management organization not been created, it is possible that approval would not have been granted at that time.

Wright Air Development Division was to be "systems oriented" to apply engineering efforts in "full time work on specific military systems." The WADD mission statement was explicit: "Plan, program and manage the

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*WADD was formed on 15 December 1959 at the direction of Lt. Gen. Bernard Schriever, Air Research Development Center commander, with the merger of Wright Air Development Center and the Directorate of Systems Mgmt., Air Research Development Center.

development of military aerospace systems including aircraft, aerodynamic missiles, missiles associated with aircraft, and advance the technology required for the development of those systems."[45]

During the period WADD had been in existence, division management personnel had made significant contributions to program integrity by revising some of the system specifications and re-establishing others on a firm technical basis. The Air Force was required to retain throughout the development phase the nucleus of qualified management personnel which had been created, and to continue to develop and exercise the management concepts introduced by command headquarters.[46]

A more realistic approach to the problem of introducing a suitable air-launched ballistic missile within the time span dictated by operational needs resulted from changes in technical specifications following the intensive study to which the program had been subjected since May 1959. The five to eight month delay in starting concentrated redesign effort was more than compensated for by dollar savings that would probably accrue during the program due to simplified design and earlier correction of design deficiencies.

Most notable of the design changes prompted by analysis of the various studies was [redacted] USAF FOIA b(1)(3) DoE b(3)

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while the relaxation in range permitted the use of a large warhead which would accept the state-of-the-art performance of the propellants available. Although this would eliminate costly development of new propellants,

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Estimated total program development costs at the time of program approval stood at:

FY61	$82.4 million
FY62	60.6
FY63	27.9
FY64	2.0

Estimated production costs for a 1,000 missile buy were:[49]

FY62	$100.0 million	(56 missiles)
FY63	230.0	(355 missiles)
FY64	280.0	(480 missiles)
FY65	69.0	(109 missiles)

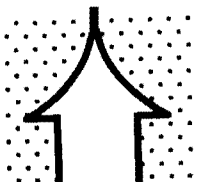

Figure 2. A B-52H and a Vulcan MK II bomber over Edwards Air Force Base, California.

The operational unit equippage of the B-52 squadrons (F, G and H models) was to be 46 missiles per squadron. The schedule in effect in February 1960 called for the first programed missile launch in August 1961 with the initial guided launch planned for January 1962. Category I testing (Douglas development tests) would extend from April 1961 to October 1962, Category II (ARDC evaluation) from October 1962 to August 1963, while Category III suitability tests would be conducted by the Strategic Air Command from August 1963 to February 1964. The Category III test squadron would be the first operational squadron and was to be in service by March 1964. Two additional squadrons would be operational by the end of FY64. Additional units would be activated at the rate of three squadrons per fiscal quarter until the total of 23 units was reached. The GAM-77 Hound Dog missiles in use by B-52 squadrons scheduled for Skybolt employment would have the GAM-77 deactivated approximately six months prior to GAM-87 equippage to permit modification of the facilities. The first Royal Air Force Vulcan squadron would be GAM-87-equipped during the third quarter of 1964. Ten Vulcan squadrons of eight aircraft per unit would be fitted with the Skybolt.[50]

The Air Force had attained approval of an actual research and development program for the GAM-87A after an unusually extensive study lasting almost eight months had clarified most of the requirements. At no time in the past had the defense department directed such detailed instructions for the acquisition of a weapon system as it had in its February 1960 Skybolt approval. The program appeared to have strong backing, and firm ground rules had established the basic development philosophy.

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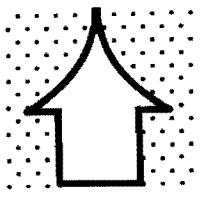

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CHAPTER II

FEBRUARY 1960 TO SYSTEM PACKAGE PROGRAM

The reaction of the Air Force to its promise of close technical and managerial control of the newly approved GAM-87A program was immediate. The Air Force elevated the status of the project office chief to that of system program director and increased the complement of the office from 16 to more than 100 persons between February and May 1960. Many of the key personnel who participated in the earlier design study were assigned to the project office as had been specified at the time of development approval.[1]

One of the first steps taken to insure effective control over the program was the introduction of electronic data processing techniques. The successful use of the Program Evaluation Review Technique (PERT) by the Navy in managing the Polaris missile program focused high-level attention on this management control device, and in late February 1960, General B. A. Schriever, ARDC commander, suggested the use of PEP* with the GAM-87A as a possible management tool. The suggestion was adopted, thus marking the first introduction of this technique in an Air Force program. The prime contractor, Douglas Aircraft, established the Program

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*The term PERT, used by the Navy, was changed to PEP (Program Evaluation Procedure) to differentiate the system used by the Air Force from that of the Navy. To prevent confusion, the Air Force soon returned to the use of the term PERT.

Evaluation Review Department on 30 March to implement PEP (or PERT) into the GAM-87A program. By May, networks had been laid out and trial runs had been made. By 3 June, PERT began reporting on the guidance subsystem on a bi-weekly schedule.* [2]

In late February 1960, Air Force representatives met with those of contractor and subcontractors involved in the Skybolt program for the initial phasing group meeting. Attendants established the phasing group organization, members' responsibilities and the procedures to be followed. Subcommittees were formed to define potential problem areas and to expedite action for timely solutions. The Ground Support and Test Equipment Subcommittee conducted its first formal meeting on 26 February.[4]

To focus high-level attention on critical areas, periodic meetings were scheduled between top government and corporate managers on a monthly or bi-monthly basis. The first of these Executive Council Meetings took place at the prime contractor's plant on 16 August 1960. Throughout the program, the most critical of the problem areas brought before this council and similar groups would be spiraling costs.[5]

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*Not all Douglas departments accepted the program readily. Some officials expressed rather negative attitudes toward its use, commenting it would be of no value until one year before production so why become involved at this early date.[3]

Escalating Costs

Costs of the development and estimated cost of production of the Skybolt missile were significant factors in the program's cancellation in December 1962. Therefore more than a cursory glance must be given to the program's cost history.

The estimated cost of the research and development program contained in the Douglas management proposal submitted on 16 March 1959 was $137 million, excluding necessary Air Force funds for government furnished aeronautical equipment (GFAE), transportation and engineering changes. The April 1959 Air Force estimate for the development program indicated an anticipated contract cost of approximately $184 million, again excluding Air Force costs. The estimate was prepared by the Advanced System Project Office at Wright Field and was relatively independent of the source selections proceedings being conducted at that time. It was based primarily on previous experience and comparisons with other weapon system development programs.[6]

By January 1960, the Air Force had made significant modifications in the development program with the stretch-out of the research and development phase to a more realistic time schedule, the redesign of the flight control system eliminating the canard control approach, an increased emphasis on automatic check-out and ground testing procedures, and the requirement for a single re-entry vehicle compatible with both light and heavy warheads. The project office in January 1960 submitted a preliminary budget estimate of $211 million in contract

cost incorporating preliminary estimates in accordance with the reorientation resulting from the Wright Field in-house evaluation. The cost estimating group had only four days in which to prepare the document, hardly sufficient to adequately study the cost impact resulting from the change from the Able 3 to Delta II configuration for the missile.[7]

An important phase of Douglas's initial efforts following development go-ahead was the analysis of program costs in detail to support contract negotiations and system program office budget plans. This was the first thorough cost review Douglas had made and resulted in an estimate of $352.6 million in contract funds. Completed in June 1960, this was a substantial increase over previous estimates and approached the lower limit of costs which the Department of Defense had indicated the Air Force should be prepared to fund. Findings of a cost survey team from Wright Air Development Division (WADD) and Aeronautical Systems Center (ASC) which visited the Douglas plant in June revealed the primary cause of the cost increased to be the contractor's lack of understanding and appreciation of the difficulty of the development program plus his underestimation of the depth of planning required to fulfill Air Force requirements. At the outset, the team's report stated, it became obvious that as all contractors studied program requirements in greater detail, their estimates reflected greater accuracy.[8]

Factors cited as influencing the rise in estimated costs were the requirement for two separate reentry vehicles, the increased emphasis on system reliability and maintainability, additional contractor engineering and publications support, and the earlier development and establishment of logistic and training systems. Initial program cost estimates had also included the premise that approximately 60 percent of aerospace ground equipment (AGE) supporting the GAM-77 missile could be utilized for the Skybolt. This, unfortunately, was an overly-optimistic percentage since later analysis indicated a commonality figure of only about ten percent. Expanded sled testing of the guidance subsystem, increased ground support equipment and increased reliability requirements caused a similar rise in the associated sub-contractor costs.[9]

The sharp rise in funding requirements between January and July 1960 for GAM-87A development brought an immediate reaction from command headquarters. On 20 July, General Schriever was briefed by Wright Field representatives at which time it became apparent to him that the program fund requirements for FY61 reflected an increase of over $100 million. Also of concern to him was the fact that the research, development, and production efforts, although interrelated, were programed separately. In his opinion, this fostered cost estimates that were both unrealistic and difficult to evaluate in total program context. Dissatisfied with the ground rules and unconvinced of the validity of the requirements presented to him, General Schriever directed the Wright division to

submit a revised program in accordance with a format that would permit accurate analysis of cost data by the command's Budget Review Committee. He requested that the preparation of the revised program be made on the basis that the GAM-87A was an "operational development program approved for inventory." In contrast to General Schriever's concurrency principle, the basic requirement for such an air-launched ballistic missile was still being questioned at the Joint Chiefs of Staff and Department of Defense levels.[10]

The program office presented the program budget to Air Force headquarters and the Secretary of the Air Force on 4 and 5 August 1960, the conclusion of an extensive effort to refine cost and schedule estimates. The budget allocated a total of $325 million to the contract, plus additional funds for engineering changes and Air Force costs which brought the total research and development budget to $372 million. The projected schedule remained as had been in effect in February 1960. A number of individuals within the Pentagon had felt the initial program cost estimates were entirely too optimistic. Therefore, the upward revision was not unexpected. At this point, the GAM-87A appeared to be on schedule and costs were now being reported more accurately and realistically.[11]

Although development plans progressed steadily, doubt remained within the Pentagon concerning certain aspects of the Skybolt program. The Office of Defense Research and Engineering expressed concern over the validity of the Douglas proposed development costs and whether the

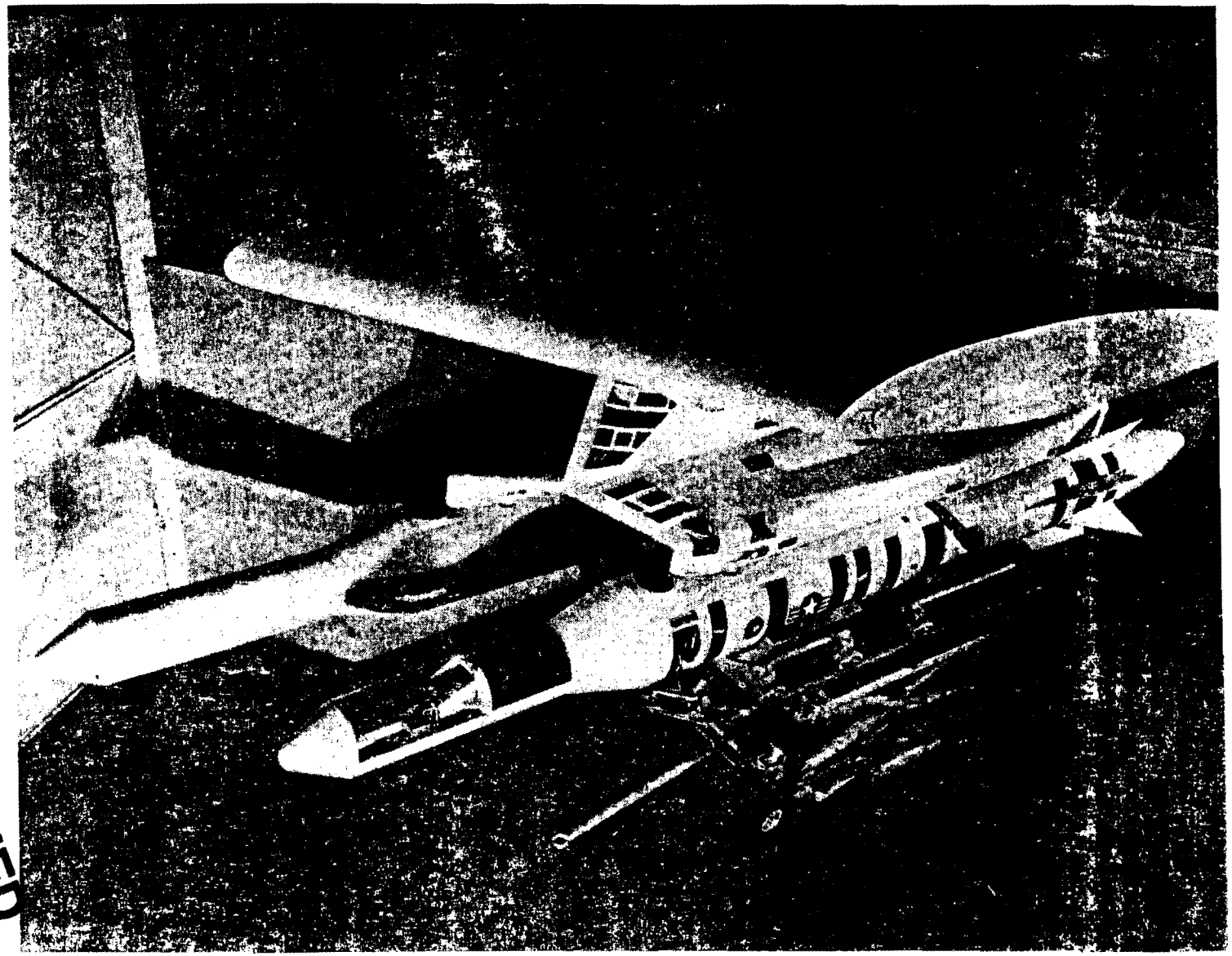

Figure 3. Missile/pylon mockup for 3-5 August 1960 Preliminary Development Engineering Inspection conducted by the prime contractor.

Air Force could fund the program as required. Some critics felt the program should have been assigned to the Ballistic Missile Division because of that organization's greater experience, although Mr. J. H. Rubel, Assistant Director (Strategic Weapons) of Defense Research and Engineering, modified his criticism after talking with General Schriever. Some doubt was also evident concerning Douglas Aircraft's ability as the prime system manager. Concern in this area and over Nortronics' relative inexperience in inertial guidance systems lessened following the design engineering inspection held in August 1960. Mr. Rubel in particular was favorably impressed with progress made in the technical field.[12]

Individuals within the civilian scientific community outside the Office of the Secretary of Defense, including members of the Fletcher Committee, continued to question the validity of the requirement itself for the GAM-87A in view of the existence of the GAM-77, Minuteman, Atlas and Polaris missiles. While the Joint Chiefs of Staff concurred with the desirability of proceeding as expeditiously as practicable with the Skybolt program, that body had not reached a conclusion as to its ultimate military importance as a weapon system. Lingering skepticism persisted as to whether the program would reach the production stage. General Holzapple, on 20 September 1960, noted that the value of the GAM-87A and the terms of Department of Defense approval indicated it was a "go" or "no-go" program. If the development effort were successful, it would probably be difficult to produce missiles fast enough. If the development were unsuccessful or delayed by more than a few months, production would never be realized.[13]

In June 1960, the project office established a FY61 requirement for $149 million; a total of $79.4 million was released by 14 November. Some $70 million in program funds and $778,500 which had been loaned to Aerojet-General from program funds had not yet been released, despite the fact the contractor and Wright Field people advised Washington of the potential impact of this delay. It appeared as though by mid-December, 85 percent of the allocated funds would be expended with the total amount spent by February 1961. Meanwhile contract negotiations were initiated.[14]

Contract Negotiation Activities

Negotiations between Douglas and the Air Force for a definitized contract began on 14 November 1960 based on the work statement agreed upon in August and September of that year. The Douglas-proposed cost for the work statement was approximately $479 million, involving $421 million in contract funds (including $22 million in United Kingdom funds) and $58 million in Air Force monies. Unfortunately this estimate was $107 million in excess of the previous figure of $372 million that had been established as a program ceiling.[15]

Air Force and contractor personnel had to take prompt action to re-evaluate overhead rates, fees and other costs to reduce the negotiated price for the work statement to a figure in line with the program ceiling. To stay within limits, steps were taken to eliminate rain erosion, radar reflection and tail cone blow-off tests there was also a reduction in the scope and quantity of items such as low altitude demonstration,

extending the temperature limitations of the propellant, operational handbooks and heavy warhead reentry vehicle design. Test missiles were reduced in number from 100 to 79, motor cases from 519 to 442, test weight motors from 442 to 398, inertial instruments from 76 to 58, ballistic computers from 78 to 58, and prelaunch computers from 24 to 15. Air Force reviewers attempted to eliminate all non-essential work and to defer long leadtime cost items wherever practical. This renegotiation and work reduction effort was completed on 9 December 1960, at which time the total research and development (R&D) contract costs were pegged at $314 million and the total development program at about $368 million.[16]

On 28 April 1961, Major General R. G. Ruegg, Air Materiel Command's Director of Procurement and Production, approved the definitive contract which covered five years of research and development, flight testing, aerospace ground equipment, logistic support, training, and United Kingdom participation in the program. The negotiated contract price was approximately $314 million.[17]

The significant feature of the document was that while negotiations were conducted for the total research and development program, the contract was incrementally funded by fiscal year. This deviation was permitted under the Air Force Procurement Instruction since the weapon was classed as an intermediate range ballistic missile.[18]

December Delay

The FY61 Appropriation Act made $80 million available for the GAM-87A program. Early in FY61, ARDC completed a reevaluation of the program

indicating that $150 million was needed in that year, with a follow-on FY62 requirement for $110 million. The Air Force approved the increase of $70 million for FY 61 and submitted a reprograming request to the DOD. While the latter approved the request for $70 million, it deleted all FY62 funds from the budget, directing instead that the $150 million approved for FY61 was to carry the program through 30 June 1962 for two fiscal years.[19]

The Air Force's evaluation of this action indicated the contractor commitment rate in effect as of November 1960 was excessive in view of this new budget reversal. Consequently, on 5 December 1960, the Air Force halted all commitments for the Skybolt program. A reevaluation would have to be made and a program formed that would be amenable to the Department of Defense and would provide the military weapon system required by the Air Force. This hold order, relayed to Wright Field from command headquarters on 8 December, brought the program to a virtual standstill, a preliminary to three months of indecision as the monthly expenditure rate was slashed from $17.5 million to $8 million.[20] An identifiable increased program cost of $50 million and a slip of six to nine months in missile development resulted from this period of uncertainty. Authority for a reasonable program was not forthcoming from Washington until late in 1961 after much of the year had been expended in funding exercises by contractor and project office management personnel.

The immediate impact of the monetary moratorium was the layoff by Douglas and other major contractors of approximately 2,000 trained workers,

many of whom were lost to the program permanently. Support Systems Engineering, which had been making progress in designing and developing aerospace ground equipment on a concurrent basis with the missile, also lost many key people.[21]

On 16 December 1960, command headquarters reaffirmed that only $150 million would be available for fiscal years 1961 and 1962 rather than the $260 million previously programed. By December, the program had reached a peak of design effort and was moving into the test hardware phase. One half of the total research and development funds were to have been used during FY61, and in FY61 and FY62 approximately $229 million of the total would have been expended. Small fluctuations in funding during this critical period could have an impact out of all proportion to the actual number of dollars.[22]

Between program approval in February 1960 and the December slow-down, a minimum of 30 percent of the engineering manhours (2,850,000 manhours) consumed by industry had been utilized to define the program, prepare schedules, estimate costs, and establish effective management tools and relationships. This work consumed about $8.5 million. Ironically, the program reached the December "slow-down" phase, at the time when the Air Force, after ten months of effort, had reached a point of research and development contract agreement with the prime contractor. By December 1960, the Air Force working with industry had created and was using as a cornerstone of program management some 40 PERT networks covering approximately 15,000 program-oriented events. This volume of

planning and management data represented a manpower investment charged against the program of 270 man-months, or a dollar investment of about $400,000. This period of indecision without finite objectives, intent or effective control was to continue until March 1961 when the broad outline of a new program was established under the new Kennedy Administration.[23]

Following a meeting between contractor and Air Force personnel in Santa Monica on 12 December, it appeared that $20 million additional FY61 funds would be made available, and that planning could be based on the availability of a total of $100 million for FY62. A series of meetings between 17 and 19 December defined a program based on these figures. Douglas was to continue on an average commitment rate of $8 million per month until 1 June 1961. This course permitted maximum program recovery and still provided a minimum level of effort for FY62.[24]

Three days before Christmas, Major General Joseph R. Holzapple, commander of the Wright Air Development Division, and Brigadier General A. T. Culbertson of the WADD Directorate of Systems Management, traveled to Washington with Colonel DeWitt where Wright Field personnel briefed the Secretary of the Air Force, the Air Staff, and General Schriever on the potential impact of the limited fund program. The Air Force secretary confirmed the fund reduction and on 29 December directed that the entire program philosophy be reevaluated to reduce costs without compromising the shcedule. Ground rules for

the evaluation included:[25]

(1) Total FY61 and FY62 funds of $150 million.

(2) Office of Defense Research and Engineering and System Operational Requirement guidance might be varied to reduce costs.

(3) There would be no stretch-out of research and development or operational dates.

(4) The program should be reoriented so the FY62 level could be accelerated if additional funds were obtained.

Early in January 1961, the Air Force agreed to permit project personnel at Dayton to plan commitments of an additional $70 million through 30 June 1962. The contractor and program office expected to utilize $35 million of this amount in FY61 to take advantage of the peak research and development effort and to provide a basis for acceleration if additional FY62 funds were approved and released.[26]

All work following the hold order was devoted to exercises determining the impact of funds reductions and reevaluating the basic development approval and philosophy. As a result of the cut-back and delay, Douglas advised the Secretary of the Air Force that the conclusion of the development program had slipped about seven months and that contract costs would rise to about $355 million, an estimate that was close to independent Air Force figures. An evaluation of the program by contractor and Wright Field personnel indicated the basic approach was sound and that reorientation would only defer costs,

not reduce them. On 8 February, Joseph Charyk requested a briefing from Douglas vice president Charles Able to define what could be accomplished on the basis of $2,000 million for fiscal years 1961 and 1962.[27] The research and development command supported by the Strategic Air Command and the Air Materiel Command, maintained that a program within this funded level was unrealistic.

Colonel DeWitt met briefly with the Douglas executive in Washington on the evening of 9 February 1961 to ascertain the Douglas position and to confirm the fact that industry and project office thinking were close. During the meeting the next day, only Major General V. R. Haugen, Assistant Deputy Chief of Staff Development, and Major General Mark E. Bradley, Jr., Deputy Chief of Staff Systems and Logistics, were permitted to sit with Mr. Charyk; project office personnel were excluded from the presentation.[28]

Following the briefing, General Haugen summarized the proceedings, noting that the $150 million program had been abandoned as being impractical. Mr. Able stressed the seven month slippage in operational date and the increase in contract costs from $314 to $355 million that had arisen. He suggested that the guidance sled tests be eliminated, pointing out that the $200 million package included no money for major technical problems or for program changes; he stated that Nortronics would be out of funds by 13 February 1961. The final point was resolved with the release of an additional $8 million in FY61 funds

on 13 February to permit the continuation of the current level of effort through March 1961.[29]

The Eisenhower Administration in December 1960, had cut the research and development program for the Skybolt thereby placing the program schedule in jeopardy by excluding any funds for FY62. The Air Force kept the program alive by stretching out the FY61 funds. Now the new Kennedy Administration gave the program a temporary reprieve restoring $50 million for the FY61-62 period.

The "Washington Plan" - Program Redirection

On 2 March 1961, Air Force headquarters issued firm program redirection -- the "Washington Plan" -- based on the Douglas proposal and establishing milestones, funding and manpower guidelines. The program called for a $391 million ceiling for development including $355 million in contract costs and $36 million for other Air Force expenses. All major milestones were extended approximately seven months. Most of this time loss was the direct result of the reduced level of effort that followed the drastic reduction in the expenditure rate ordered in December 1960. Reduced funding levels through FY62 would permit the retention of the basic scope of work as negotiated, although certain tasks were eliminated. The reoriented program removed

guidance sled testing at the Missile Development Center,* a B-52H/GAM-87A flight test program, and the motor pre-qualification tests. The number of programed launch missiles was reduced from six to four and a reduction in scope was made in the areas of motor hazard classification testing, maintainability and reliability, statistical testing of components, and motor preliminary flight rating tests.[30]

The broad outline of the new program therefore was now defined, but only in the sense of what constituted the end objectives and allowable costs to complete the development tasks. It still remained for the Air Force and industry to start over and redefine the program within the framework of time and dollars to the same degree of detail as had been accomplished previously during ten months of costly effort. Although the earlier efforts would serve as a point of departure for the reestablishment of the program, the detailed ground and flight test plans, data submittal plan, maintainability and reliability plans, cost structure and all other planning and management documentation (that was schedule or concept oriented) had

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*Douglas had felt that the Holloman sled tests in providing supplemental ground environmental data could not be time phased to improve the first guided launch within available funds. The prime contractor conducted a cost analysis for possible inclusion of these tests at a later date and found that $3.5 million would be needed in FY62 if the sled test program were to be conducted. The program office, convinced of the necessity for the tests, requested Air Force headquarters to provide the needed funds, which were granted in June 1961.[32]

to be redefined. PERT networks, for example, had to be completely realigned and adjusted, consuming approximately 186 man-months, the equivalent of 29,760 manhours or $300,000.[31]

The reoriented program preserved the basic design and development program offering a balanced research and development program with minimum slippage. It did not provide increases in the scope of development work, major design development changes, low altitude demonstration, follow-on evaluations by the contractor for B-70, B-58 or B-52H studies, major engineering change proposals, or weight reduction efforts. Statistical reliability testing, already reduced, was further decreased for lack of available time while static testing of the complete missile was deferred as were a number of items in the ground test program. Range requirements were cut by the Air Force from 1,000 to 950 miles and plans were prepared to use development models of ground support equipment for early launches.[33]

With the constrained funding came fiscal year ceilings with a cumulative maximum of $143.1 million through 30 June 1961, and $232 million through 30 June 1962. There was no funding flexibility between money allocated for the contractor and that for the Air Force. Each change or new item required additional documentation to Air Force headquarters for approval of any increase in the ceilings imposed. This lack of flexibility did delay certain actions such as the start of guidance flight testing, the acquisition of a radiographic facility at Eglin, and the implementation of design and fabrication of training equipment.[34]

The reoriented program as directed by Under Secretary of the Air Force Charyk established the following funding and development estimates:[35]

Fund estimates (in millions of dollars)

	Previous	Reoriented
FY60 and prior	38.0	38.0
FY61	150.0	111.0
FY62	110.9	95.0
FY63	56.4	95.0
FY64	16.7	45.0
FY65	0	7.0
Total	372.0	391.0

Development Milestones

	Previous	Reoriented
First programed launch	Aug. 1961	Jan. 1962
First guided launch	Jan. 1962	Oct. 1962
Completion of Cat. II testing	Sep. 1963	May 1964
Completion of Cat. III testing	March 1964	Sep. 1964
First operational squadron	March 1964	Oct. 1964

	Previous		Reoriented	
	USAF	UK	USAF	UK
Guided rounds	31	12	31	12
Programed rounds	6	0	4	0
Captive missiles	3	4	3	4
Dummy missiles	11	8	11	8
Ground test missiles	4	0	4	0
Totals	55	24	53	24

Estimated Commitment Schedules

	Previous	Reoriented
30 June 1961 cumulative	$180.0	151.0
30 June 1962	293.0	246.0
30 June 1963	349.0	340.0
30 June 1964	372.0	375.0
30 June 1965	372.0	391.0

As of 1 March 1961, the Air Force was programing an operational capability for the GAM-87A providing missiles to 23 of the 42 squadrons comprising the B-52 force. The balance of the B-52 aircraft would carry GAM-77 missiles. Production would extend from FY63 through FY66, for a total of 1,314 missiles at an estimated cost of $909 million, including 192 missiles for the United Kingdom and 1,122 for USAF. A decision would be required about 1 December 1962 to produce the FY63 buy, and additional contract funds totaling $182

million would be needed. Development program slippage negated the need for previously scheduled FY62 production.[36]

System Package Program Preparation -- Further Program Revisions

Following redirection of the Skybolt program by the Pentagon based on Douglas' presentation, three months' effort was required by the program office-contractor team to detail a program in the manner required for a System Package Program, responding to the "Washington Plan." Wright Field personnel offered a preliminary presentation of the package program at command headquarters on 12 June 1961. Colonel C. H. Bolender, program director, repeated the briefing at Strategic Air Command headquarters two days later. Coordination of the program was completed at Air Force Systems Command (formerly Air Research and Development Command) headquarters, signed by General Schriever on 16 June, and submitted to Air Force headquarters for final approval the same day. A favorable decision was anticipated no later than July 1961.[37]

Considerable portions of the originally contemplated work had to be deleted from the system package program and others delayed to remain within the funds available for the program. Efforts on parts and breadboard tests were reduced and actual design started with less background than desired. Design approval testing was delayed approximately two years and the fabrication of 28 items of aerospace ground equipment was delayed until later in the program.[38]

The system package program documented a program ceiling of $391 million for development including $355 million in contractor funds

and $36 million in Air Force money. In April 1961, the first budget estimate appeared for the production program and was included in the June package. The total estimate, based on 1,134 United States missiles, was $1.124 billion. This figure later rose to $1.516 billion in the May 1962 system package program based on a quantity of 1,137 U. S. missiles.[39]

Immediately following the development of the package program in April and May 1961, it became apparent that levels of several items of work which were initially included in the "Washington Plan" would have to be reduced to remain within the $391 million ceiling indicated in the 2 March redirection. Early in July, the Air Force requested the prime contractor to reanalyze the program using actual cost experience over the previous few months and to provide an up-to-date evaluation of funds spent versus work accomplished, and a forecast for the remainder of the program. To stay within the monthly expenditure rate under the FY62 ceiling of $95 million,* approximately $5 million of planned work at Nortronics was deleted or deferred when Douglas and the guidance subcontractor reviewed the FY62 level of work. At the prime contractor's plant, about $2.5 million in equipment for the Douglas system integration area was deferred.[40]

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*This figure was increased to $104 million by 23 September 1961 due to several additions such as the sled test program.

By late August, the prime contractor's study had determined that less was being accomplished for a given expenditure rate than forecast, although the budget ceiling had not been exceeded. Douglas needed $2.5 million more for engineering manhours required to meet instrumentation, aerospace ground equipment and flight control drawing release schedules, plus another $2.5 million for manufacturing, inspection and planning for motor cases, flight control system, and ground equipment schedule recovery. Subcontractors were also in need of additional funds. Nortronics indicated a need for $1.1 million to retain the guidance program schedule while General Electric needed $.5 million to replace funds lost by the December 1960 holding action. A sum of $.9 million at Aerojet was required to recover schedules and correct unanticipated technical problems.[41]

Following the review, Douglas indicated the cost of planned work would exceed the budget ceiling by $11.5 million in FY62. It was also evident that the work planned for FY63 would have to be reduced approximately $15 to 20 million to stay within the ceiling for that year. The contractor's analysis indicated approximately $50 million additional or a total of $405 million was required to complete the level of contractor effort proposed in the $355 million "Washington Plan" and outlined in the 1 June system package program including the United Kingdom effort as defined in August 1961.[42]

Funding was a topic of major importance at the GAM-87A Executive Council meeting at Santa Monica, California, on 29 August 1961, attended

by the Secretary of the Air Force. Direction emanating from the meeting led to a revised FY62 funding requirement presented in Addendum A to the 1 June system package program, dated 5 September.

The program had been contained within the allotted funds, but without additional FY62 funds, the scope of work would have to be reduced, milestones would slip, and technical risk would be magnified. Causes of the increased requirement included the normal technical problems, underestimates, the lack of financial "headroom" for technical difficulties, and the lack of available funds for new requirements. The 5 September document indicated a need for $140.1 million for FY62:

FY62 program in effect	$104.0 million
Recovery funds	11.5
Additional AGE and other equipment	2.9
Reduced risk funds	14.5
Mark 7A program	7.2
Total R&D funds required	140.1 million

With additional money, the planned FY62 program could be recovered, FY63 production risks reduced, and the Mark 7A reentry vehicle development initiated.[43]

On 26 September 1961, Defense Secretary McNamara visited Douglas Aircraft facilities at Santa Monica and was briefed on the status of the program. At the conclusion of the meeting, McNamara requested that

a revised program be submitted that would provide a more "reasonable" research and development program. This was submitted to Air Force headquarters on 12 October in the form of the Interim Revision I to the package program, dated 2 October, representing an effort to recover from previous funding cutbacks. The program included an expanded demonstration of the missile's operational envelope and a better balanced program properly phased on regard to testing, development of support, and the follow-on production program.[44]

The revised program estimate of $492.6 million in development costs ultimately was to become the approved ceiling, an increase of approximately $100 million over the figure budgeted in the program package. Requirements contained in the revision were:[45]

	Prior years	FY62	FY63	FY64	FY65	FY66	Total ($ in millions)
RDT&E**	$145.2	146.2	130.6	55.2	15.4	--	492.6
Production	--	4.0*	249.0	376.5	326.9	243.0	1199.4
Total	145.2	150.2	379.6	431.7	342.3	243.0	1692.0

*Pre-production planning representing planning requirements established in the 5 September Addendum A. Under the financially constrained program, this could not be absorbed by the development program.

**Research and development testing and engineering.

An estimated $50 million of this increased could be attributed to the December 1960 slow-down. At the same time, missile range was decreased by 50 miles and the operational date slipped six months. Schedule arrangements necessary to hold this slip to six months made it necessary to embark on a relatively large-scale production commitment prior to system demonstration.[46]

Command headquarters on 3 November 1961 granted the increase in the FY62 funding level requested in the addendum, raising the ceiling for that year to $115.5 million. Headquarters again raised this level on 24 November, to a total for FY62 of $119 million, exclusive of United Kingdom funds.* [47]

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*UK funds for development were negotiated separately from USAF work. A letter of agreement signed by the USAF and United Kingdom authorized expenditures up to $38 million on behalf of the UK for their portion of the research and development program. Tentative funding for the UK called for a total of $187.2 million with $25.1 million for RDT&E and $162.1 million for production.

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CHAPTER III

DEPARTMENT OF DEFENSE SCRUTINY

Air Force and Industry Reorganization

Concern among Pentagon officials over Douglas' ability to manage the program became apparent during the summer of 1961. These men increased the frequency of their visits to contractor facilities and expressed detailed interest in program progress and funding. During the program's infancy in 1959, there had been a lack of confidence in the prime contractor's evaluation of the technical feasibility in the guidance area, the firm's ability to integrate the bomb-navigation system with the missile and guidance systems, and in the company's estimates of cost, performance and timing.[1]

The Air Force had long pressed the Santa Monica firm to reorganize for more efficient program management. On 3 August 1961, Douglas announced the formation of two new, integrated, product-oriented divisions, one for missiles and space systems, and the other for military and commercial aircraft. Charles R. Able, formerly vice president of defense programs, became vice president and general manager for missiles and space. The Skybolt program naturally fell within the sphere of the new missiles division. In this month, Douglas had also revised its PERT operation, creating closer plant-wide coordination, a more accurate reflection of current program

planning, and more effective use of PERT personnel.* Other steps had been taken, but major organizational deficiencies continued to exist.[2]

Following the 29 August 1961 executive council meeting, General Schriever on 13 September directed the creation of a management survey team. Headed by Brigadier General G. F. Keeling, Commander, Western Contract Management Region, the survey team was to examine Douglas' management structure in detail and report its findings to the systems command head. The analysis was conducted between 18 and 28 September, with the group's findings approved by General Schriever on 3 October.[3]

The review revealed that the Skybolt program director at Douglas was at too low an organizational level. He lacked direct authority over important program functional areas and was handicapped with a totally inadequate staff. Systems engineering and technical direction of subcontractors, the report indicated, was ill-defined and diffused within the Douglas missile and space division. Configuration identification, control and accounting were lacking in planning and scope.[5]

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*Utilization of information furnished by PERT through November 1961 had been largely neglected by Douglas, and continuous pressure had to be applied by the system program office to induce the prime contractor to correct and utilize PERT information. This effort culminated in the establishment of a PERT analysis team within the Douglas program office in December 1961.[4]

Secretary McNamara, discussing his trip to the West Coast in September, was extremely critical of the prime contractor, convinced that Douglas was unable to do the job properly. Air Force supervision of the program also came in for criticism from the defense head. He desired an entirely new management program, including both contractor and Air Force realignments.[6] In the face of these comments, Donald Douglas, Jr., president of the firm, took prompt action. On 1 November 1961, the prime contractor began the implementation of a major reorganization in compliance with the Air Force recommendations.[7]

Two new functional groups evolved within the Douglas managerial framework -- the Systems Engineering and Technical Direction (SE/TD) Group for technical management, and the Configuration Identification Control and Accounting Group for system configuration control. Program management was centralized under J. L. Bromberg, director of the Douglas subdivision for the Skybolt. Bromberg was designated as an assistant division general manager and was given line authority over all elements of the missile division. He also received an enlarged staff with an office created under his control responsible solely for configuration identification, control and accounting.[8]

Complementing the Douglas reorganization, the Air Force Secretary selected certain systems with top priority for special management procedures, including the Skybolt program. The secretary appointed an advisory body, the Designated Systems Management Group, to assist him

in the supervision of these selected systems, and named a system program director (within the systems command) as his agent for field management of each designated system. Within Air Force headquarters, the Deputy Chief of Staff/Systems and Logistics selected a system staff officer for each system to act as the Air Staff focal point. To insure the utmost rapidity in the transmission of information between the Air Force Secretary and field elements, "red line" procedures were established allowing direct contact between the system program director and the secretary on urgent matters.[9]

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The reoriented program as directed by Under Secretary of the Air Force Charyk established the following funding and development estimates:[35]

Fund estimates (in millions of dollars)

	Previous	Reoriented
FY60 and prior	38.0	38.0
FY61	150.0	111.0
FY62	110.9	95.0
FY63	56.4	95.0
FY64	16.7	45.0
FY65	0	7.0
Total	372.0	391.0

Development Milestones

	Previous	Reoriented
First programed launch	Aug. 1961	Jan. 1962
First guided launch	Jan. 1962	Oct. 1962
Completion of Cat. II testing	Sep. 1963	May 1964
Completion of Cat. III testing	March 1964	Sep. 1964
First operational squadron	March 1964	Oct. 1964

	Previous		Reoriented	
	USAF	UK	USAF	UK
Guided rounds	31	12	31	12
Programed rounds	6	0	4	0
Captive missiles	3	4	3	4
Dummy missiles	11	8	11	8
Ground test missiles	4	0	4	0
Totals	55	24	53	24

Estimated Commitment Schedules

	Previous	Reoriented
30 June 1961 cumulative	$180.0	151.0
30 June 1962	293.0	246.0
30 June 1963	349.0	340.0
30 June 1964	372.0	375.0
30 June 1965	372.0	391.0

As of 1 March 1961, the Air Force was programing an operational capability for the GAM-87A providing missiles to 23 of the 42 squadrons comprising the B-52 force. The balance of the B-52 aircraft would carry GAM-77 missiles. Production would extend from FY63 through FY66, for a total of 1,314 missiles at an estimated cost of $909 million, including 192 missiles for the United Kingdom and 1,122 for USAF. A decision would be required about 1 December 1962 to produce the FY63 buy, and additional contract funds totaling $182

million would be needed. Development program slippage negated the need for previously scheduled FY62 production.[36]

System Package Program Preparation -- Further Program Revisions

Following redirection of the Skybolt program by the Pentagon based on Douglas' presentation, three months' effort was required by the program office-contractor team to detail a program in the manner required for a System Package Program, responding to the "Washington Plan." Wright Field personnel offered a preliminary presentation of the package program at command headquarters on 12 June 1961. Colonel C. H. Bolender, program director, repeated the briefing at Strategic Air Command headquarters two days later. Coordination of the program was completed at Air Force Systems Command (formerly Air Research and Development Command) headquarters, signed by General Schriever on 16 June, and submitted to Air Force headquarters for final approval the same day. A favorable decision was anticipated no later than July 1961.[37]

Considerable portions of the originally contemplated work had to be deleted from the system package program and others delayed to remain within the funds available for the program. Efforts on parts and breadboard tests were reduced and actual design started with less background than desired. Design approval testing was delayed approximately two years and the fabrication of 28 items of aerospace ground equipment was delayed until later in the program.[38]

The system package program documented a program ceiling of $391 million for development including $355 million in contractor funds

and $36 million in Air Force money. In April 1961, the first budget estimate appeared for the production program and was included in the June package. The total estimate, based on 1,134 United States missiles, was $1.124 billion. This figure later rose to $1.516 billion in the May 1962 system package program based on a quantity of 1,137 U. S. missiles.[39]

Immediately following the development of the package program in April and May 1961, it became apparent that levels of several items of work which were initially included in the "Washington Plan" would have to be reduced to remain within the $391 million ceiling indicated in the 2 March redirection. Early in July, the Air Force requested the prime contractor to reanalyze the program using actual cost experience over the previous few months and to provide an up-to-date evaluation of funds spent versus work accomplished, and a forecast for the remainder of the program. To stay within the monthly expenditure rate under the FY62 ceiling of $95 million,* approximately $5 million of planned work at Nortronics was deleted or deferred when Douglas and the guidance subcontractor reviewed the FY62 level of work. At the prime contractor's plant, about $2.5 million in equipment for the Douglas system integration area was deferred.[40]

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*This figure was increased to $104 million by 23 September 1961 due to several additions such as the sled test program.

By late August, the prime contractor's study had determined that less was being accomplished for a given expenditure rate than forecast, although the budget ceiling had not been exceeded. Douglas needed $2.5 million more for engineering manhours required to meet instrumentation, aerospace ground equipment and flight control drawing release schedules, plus another $2.5 million for manufacturing, inspection and planning for motor cases, flight control system, and ground equipment schedule recovery. Subcontractors were also in need of additional funds. Nortronics indicated a need for $1.1 million to retain the guidance program schedule while General Electric needed $.5 million to replace funds lost by the December 1960 holding action. A sum of $.9 million at Aerojet was required to recover schedules and correct unanticipated technical problems.[41]

Following the review, Douglas indicated the cost of planned work would exceed the budget ceiling by $11.5 million in FY62. It was also evident that the work planned for FY63 would have to be reduced approximately $15 to 20 million to stay within the ceiling for that year. The contractor's analysis indicated approximately $50 million additional or a total of $405 million was required to complete the level of contractor effort proposed in the $355 million "Washington Plan" and outlined in the 1 June system package program including the United Kingdom effort as defined in August 1961.[42]

Funding was a topic of major importance at the GAM-87A Executive Council meeting at Santa Monica, California, on 29 August 1961, attended

by the Secretary of the Air Force. Direction emanating from the meeting led to a revised FY62 funding requirement presented in Addendum A to the 1 June system package program, dated 5 September.

The program had been contained within the allotted funds, but without additional FY62 funds, the scope of work would have to be reduced, milestones would slip, and technical risk would be magnified. Causes of the increased requirement included the normal technical problems, underestimates, the lack of financial "headroom" for technical difficulties, and the lack of available funds for new requirements. The 5 September document indicated a need for $140.1 million for FY62:

FY62 program in effect	$104.0 million
Recovery funds	11.5
Additional AGE and other equipment	2.9
Reduced risk funds	14.5
Mark 7A program	7.2
Total R&D funds required	140.1 million

With additional money, the planned FY62 program could be recovered, FY63 production risks reduced, and the Mark 7A reentry vehicle development initiated.[43]

On 26 September 1961, Defense Secretary McNamara visited Douglas Aircraft facilities at Santa Monica and was briefed on the status of the program. At the conclusion of the meeting, McNamara requested that

a revised program be submitted that would provide a more "reasonable" research and development program. This was submitted to Air Force headquarters on 12 October in the form of the Interim Revision I to the package program, dated 2 October, representing an effort to recover from previous funding cutbacks. The program included an expanded demonstration of the missile's operational envelope and a better balanced program properly phased on regard to testing, development of support, and the follow-on production program.[44]

The revised program estimate of $492.6 million in development costs ultimately was to become the approved ceiling, an increase of approximately $100 million over the figure budgeted in the program package. Requirements contained in the revision were:[45]

	Prior years	FY62	FY63	FY64	FY65	FY66	Total ($ in millions)
RDT&E**	$145.2	146.2	130.6	55.2	15.4	--	492.6
Production	--	4.0*	249.0	376.5	326.9	243.0	1199.4
Total	145.2	150.2	379.6	431.7	342.3	243.0	1692.0

*Pre-production planning representing planning requirements established in the 5 September Addendum A. Under the financially constrained program, this could not be absorbed by the development program.

**Research and development testing and engineering.

An estimated $50 million of this increased could be attributed to the December 1960 slow-down. At the same time, missile range was decreased by 50 miles and the operational date slipped six months. Schedule arrangements necessary to hold this slip to six months made it necessary to embark on a relatively large-scale production commitment prior to system demonstration.[46]

Command headquarters on 3 November 1961 granted the increase in the FY62 funding level requested in the addendum, raising the ceiling for that year to $115.5 million. Headquarters again raised this level on 24 November, to a total for FY62 of $119 million, exclusive of United Kingdom funds.* [47]

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*UK funds for development were negotiated separately from USAF work. A letter of agreement signed by the USAF and United Kingdom authorized expenditures up to $38 million on behalf of the UK for their portion of the research and development program. Tentative funding for the UK called for a total of $187.2 million with $25.1 million for RDT&E and $162.1 million for production.

CHAPTER II

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Area. The group was to meet monthly to monitor logistics problems for both the Air Force and United Kingdom.[10]

An additional move at Wright Field was the organizational elevation of the GAM-87A program. Brigadier General David M. Jones, formerly the Wright Air Development Division vice commander, became Deputy Commander of the Aeronautical Systems Division for Skybolt on 20 October 1961. This move placed greater relative priority on Skybolt than any other ASD project with the exception of the B-70 program, also operating under a special deputy commander. Colonel C. H. Bolender remained the titular program director although he now functioned as General Jones' deputy. Other new assignments included the move by Colonel E. H. Robertson to the Air Force Plant Representative's office at Santa Monica, succeeded as Deputy Director for Procurement and Production for the GAM-87A by Colonel Walter Nyblade. Major Victor Robinson joined the program office as the new chief of the test division. Direction of the newly formed ASD Field Management Office at Douglas was now under Lieutenant Colonel Daniel Smith, former chief of the Program Evaluation Division. Colonel R. L. Fitzgerald became chief of the SAC System Office, replaced as the SAC GAM-87A liaison officer by Lieutenant Colonel R. C. Doom.* [11] Mr. John E. Short

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*Colonel Fitzgerald had reported in the fall of 1960 as a fulltime SAC representative for the Skybolt program. This was the first instance when the strategic command had assigned a fulltime representative to a research and development program office, indicative of the command's interest in the program's progress.[12]

continued to serve as assistant system program director.

As a follow-up to previous contractor reorganization moves, General Schriever, on 5 December 1961, directed selected members of the original Keeling review board to review the status of the prime contractor up to that point. This survey was conducted on 4-5 January 1962, but the findings did not meet with the commander's complete satisfaction. A communication from General Schriever to the aeronautical division and to the Electronic Systems Division at Bedford, Massachusetts, indicated that the review team was to reconvene not later than 20 January at Douglas Aircraft. This was to be an independent review to the extent that the system program office would support the team, but would not participate as a member. The team, headed by Brigadier General C. H. Terhune, Jr., vice commander of the electronics division, was to be more responsive to Mr. Charyk's memo.[13]

A survey report was completed by the end of January. The group's findings indicated that Douglas had responded well to earlier criticisms; the new management structure appeared to "be coming rapidly into a posture to effectively manage the program." The appointment of a general officer as program head at ASD had strengthened the Air Force's position. The group did suggest a modification in the Nortronics management force when it pointed out that that firm's program manager lacked support for effective control. Nortronics, the team believed,

also had underestimated hardware costs and warned of a potential major program cost impact in this area. Except for Nortronics, the management organization as a whole appeared strong enough to enter the production phase. The configuration management system appeared stronger than that existing for any other Air Force program.[14]

The Terhune board emphasized the extremely tight schedule required to meet planned production dates. Due to funding restrictions, the level of effort for production planning had been ten to 20 percent of that actually required. Delivery of gyros, for example, was scheduled for January 1963, yet the requirement for test equipment for the production line at Kearfott Company, subcontractor for the gyros, had not yet been determined.[15]

Cost Reexamination

At the time of his review of the Skybolt program on 26 September 1961, Secretary McNamara noted the program was underfunded and directed that a better balanced, fully funded plan be presented to him. A revision was prepared by program office personnel by 2 October 1961, designated as Interim Revision I to the package program.

In the revised program submitted in response to McNamara's direction, requirements for the total development program were estimated at $492.6 million with a total estimated development and initial investment cost of $1,771.8 million. More than

$1,500 million of this total lay ahead after January 1962. Production costs for 1,134 production missiles were $1,279.2 million. Ten guided missiles were added to tests, one step in providing a better balanced program properly phased in regard to testing, logistic support and production.[16]

On 21 October, Air Force Secretary Zuckert forwarded the revised program to the Office of the Secretary of Defense, at the same time expressing his dissatisfaction with the spiraling costs. Zuckert's memo stated he was initiating a "completely independent and detailed review of the cost estimates." A discussion between General Schriever and Joseph Charyk followed, covering the impact of such a review in the light of recent management changes. An agreement was reached between the two officials as they decided on a reassessment of the total program under the direction of the Air Force Systems Command with the understanding that an independent review by Charyk's office would not be necessary. Consequently, on 31 October, Mr. Charyk directed a review of the reliability of the present program costs in view of the past history of continuing increases. The systems command was to conduct a reassessment of all aspects of the program.[17]

In a 1 December memo to the Defense Secretary, Air Force Secretary Zuckert indicated his confidence that the development program could be carried through within the limits of the $492.6 million figure. Deliveries of missiles to the operational command under this revised plan could begin in March 1964. A memo from

McNamara to Zuckert sought assurance that no additional increases in development costs would be forthcoming:[18]

> Over the strong opposition of certain of the President's advisors, I have recommended, and the President has approved, the continued development and deployment of SKYBOLT. Our actions were based upon assurance . . . that the development . . . would be satisfactorily completed on schedule at a total cost of $491 million. . . . If the Air Force is not prepared to make this commitment today, then I wish to reconsider my recommendation to the President.

Emphasizing the weapon's role in defense suppression, McNamara stated the GAM-87A was not a good choice for counter-city retaliation because of the low survival potential of the B-52 carriers and the fact they would have to be committed to attack early in a war. Nor was the Skybolt, in his opinion, a good selection as a weapon for attacking high priority military targets due to the length of time required for the carrier to reach the launch point, and the bomber's vulnerability on the ground. The GAM-77 Hound Dog, while vulnerable to anti-bomber defense, did have the advantage as a substitute for the GAM-87A in a defense suppression role since it was available and relatively inexpensive. Skybolt would be superior to the Minuteman only if it were to cost substantially less, for the latter had the advantage of being hardened and dispersed and offered a set of targets independent of the B-52 bases. If Skybolt costs exceeded estimates, the Secretary warned, the system would compare unfavorably with Minuteman for defense suppression.[19] On 29 December 1961, Roswell Gilpatric, Deputy Secretary of Defense, confirmed this $492.6

million ceiling and authorized the Air Force to proceed on that basis. Funding in excess of $492.6 million would not be permitted, however. Fiscal year 1962 funds in a deferred status amounting to $17 million, the balance of the $89 million funded for FY62, could be utilized for the approved development program. The Air Force could reprogram to make available up to an additional amount of $57.2 million for a FY62 total of $146.2 million. Programs on which funding was to be reduced to make these additonal funds available were subject to Department of Defense approval. Engineering changes were to be accomplished only when absolutely necessary since the cost of these changes and any new or modified requirements were to be absorbed within the $492.6 million.[20]

General Schriever promptly advised the logistics, strategic, and air training commands of the concern within the defense department and Air Force headquarters over rising costs and impressed upon these commands the necessity for remaining within program funds. Unless costs were held within acceptable budget limits and rigid dollar controls enforced, the commander said, the program was in danger of cancellation. To reduce the unit cost of the missile, he also ordered the program director to reassess all requirements and proposed procedures imposed by organizations that might have contributed to rising costs. Management from these commands would be called upon to validate those requirements and procedures recommended by the logistics command on a minimum essential basis. The program

was now firmly contained within a $492.6 million ceiling. The Air Force had given its assurance that development could be accomplished within this dollar framework.[21]

No action had been taken on the production program by January 1962, since pre-planning funds requested in October 1961 had not been received by the program office and no research and development funds were available for this purpose. Air Force headquarters, questioning the need for $4 million, on 25 January 1962 did release $2.5 million. Subsequently, on 2 February 1962, the Air Force released a contract to Douglas Aircraft to cover production planning.[22]

The Terhune review team had evaluated production plans, basing its conclusions largely on comparisons with other programs and on GAM-87A hardware costs accrued to that time. Results of their study indicated production costs would be much higher than estimated previously. General Schriever wanted a more detailed statement and at his direction, an April 1962 evaluation was conducted by a combined program office and Douglas team. On 4 April, the group submitted a preliminary contractor cost study to Major General W. Austin Davis, Aeronautical Systems Division commander. Subsequent to the presentation, the team of program office and Douglas management personnel visited each major subcontractor to evaluate pricing, programing and production aspects. The program was validated, pricing methods and results evaluated and revised, and production planning to

that point was documented in the system package completed on 1 May 1962.[23]

Program changes emanating from the exercises during late 1961 and early 1962 reflected an attempt to reinstate deleted or deferred testing, design and development efforts; to add testing where failure or sub-standard performance required additional design and development work; and to establish stronger system engineering and technical direction along with improved configuration management. Approximately 70 percent of the "add on" funding was allocated to increasing the level of testing, raising the assurance of success with a reduced element of risk. This added scope of testing included the addition or expansion of B-52H flight testing, electromagnetic interference investigation, environmental ground testing of the operational reentry vehicle, gyro and accelerometer stability testing, and provisions for additional missiles to explore the low altitude capabilities of the weapon system.[24]

The rise in production cost estimates submitted following the series of reviews and evaluations conducted during FY62 was particularly significant. In less than a year, production estimates climbed by nearly $400 million or about one third:

Date	Submission	Total (1963-7)
1 June 1961	First system package program	$1124 million
3 July 1961		1259 million
16 April 1961	OSD 5-year Force Structure and Financial Program	1424 million
18 May 1962	Preliminary USAF Summary by Gen. Jones	1516 million[25]

Compared with the total program figures contained in the October 1961 program revision, the May 1962 package program estimate rose by over $500 million:[26]

Oct. 1961 submission:	RDT&E	$492.6 million
	Production (AFSC)	$1110.2 million
	Production (AFLC; initial spares only)	169.0 million
	Industrial facilities (non-additive)	(4.4 million)
	Total	$1771.86 million
May 1962 submission:	RDT&E	$492.6 million
	Production (AFSC)	$1516.56 million
	Production (AFLC; initial spares)	$319.19 million
	Industrial facilities	($40.41 million)
	Total	$2328.35 million

Douglas submitted the first production estimate to the Air Force in April 1961, which became the basis for production costs contained in the 1961 package program. These figures were neither based on a detailed work statement nor on actual hardware costs since these were not available. The estimates submitted by the prime contractor for subcontractor efforts were based on data compiled several months prior to April. Douglas found itself in the middle of reprograming the development package as a result of the 2 March 1961 Air Force directive; neither the system program office nor Douglas was able to devote time or manpower to a detailed subcontractor review at that time.[27]

In October 1961, at the direction of the Defense Department, the program office had prepared an expanded program. Only ten days were allowed for the project, insufficient to reprice the production phase in detail, so a percentage factor was used based on the June 1961 estimate. Inadequate estimating techniques in some areas, including those for pylon, flight control and B-52-installed panels, were responsible for approximately a $53 million rise. Better definition of aerospace ground equipment requirements also raised the total as did the increased scope of the program.[28]

In contrast, May 1962 figures were founded on a detailed work statement, actual development hardware figures, and numerous scrubbings by both Air Force and contractor personnel. The May production estimate of $1,516.56 million reflected a total of 1,137 missiles including 113 scheduled for use as combat evaluation launch vehicles.[29]

Between 11 May and 3 July 1962, Air Force personnel examined the proposed program in detail, attempting to reduce the estimated production cost. By late June, Air Force headquarters had reduced the figure of $1,516 million by $40.2 million through a reduction of $30 million for hardware deletions and $10.2 million for "arbitrary reductions." Included among the items of hardware deleted were 60 combat evaluation launch missiles, reducing the missile total to 1,077.

The $1,476 million budget was based on hardware quantities of:* 30

Missiles	1,077	(including 53 CEL** and 12 Category III missiles)
ACE (aircraft kits)	368	
a. pylons	739	
b. launchers	1,478	
AGE (squadron sets)	22	
Trainers and training groups	26	

General Schriever expressed to Donald W. Douglas, Jr. his grave concern over the increased cost estimates required to complete the Skybolt program. To top management personnel from the prime contractor, Nortronics, Aerojet-General, and General Electric, the commander pointed out the necessity for thoroughly examining every facet of the program with the objective of reducing costs. The response his plea received was somewhat less than encouraging.

Preliminary reports from within industry indicated the general approach to cost reduction was a reduction in the scope of the program, the least acceptable move except as a last resort. As evidenced by the replies to his letters, contractors were willing to gamble on the

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*See Doc. 44, a 29 May 1962 letter from General Jones to AFSC headquarters, for a breakdown of the negotiated fee structure for the R&D contract and the proposed fee schedule for the production contract.

**CEL (combat evaluation launch).

program being continued at any price. A lack of constructive and positive suggestions from industry seemed to indicate an improper emphasis on the importance of the reduction requirement from management. As General Schriever warned:

> I would like to re-emphasize my position that the SKYBOLT system be brought into the Air Force inventory at a minimum cost consistent with over-all program objectives. Unless this position is fully supported by all levels the program will be in jeopardy of termination.[31]

Air Force headquarters authorized a production release on 29 June 1962, and on 2 July, $10.14 million were placed on contract. An initial delivery rate of seven missiles per month in March 1964 was to increase to a rate of 40 per month by December 1964. On 9 July 1962, however, the Department of Defense removed all production funds from the Skybolt program. Faced with the threat of another period of stagnation, General Jones interceded and was able to obtain the reinstatement of $20 million on 13 July to carry the program through 15 August. On this date, an additional release of $4.9 million was made to fund the program through 2 September. The reluctance on the part of the Defense Department to commit funds was diagnosed as either a result of a general lack of funds for weapons systems or an attempt to limit commitment of production funds prior to flight test demonstration of system operation. If the program were exposed to the same indecisiveness that had plagued the development phase, results would be extended schedules, increased costs, and a degree of demoralization within both industry and the military.[32]

General Schriever was one of the many individuals associated with Skybolt who was greatly concerned over the impact of indecision and redirection on the management of systems acquisition. At Department of Defense level, increasing emphasis was being placed on management procedures and details. While the Air Force attempted to respond to this emphasis, there frequently appeared to be a lack of understanding on the part of the Office of the Secretary of Defense. This was particularly evident in relation to the extensive effort in terms of manhours and dollars required to develop detailed planning and documentation necessary for effective management of the package program.[33]

The program existed in almost a constant atmosphere of change and doubt as to the validity of the requirement and its technical feasibility. Changes, indecision and inadequate funding support on several occasions invalidated much prior planning documentation. The effects of seemingly insignificant alterations in program direction or funding levels were frequently reflected in increased workload, wasted effort, and other complications effecting both the Air Force and industry.* [34]

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*Between July 1961 and January 1963, approximately 70 individual program status reviews were accomplished by the SPO or by Douglas. These included a dozen for the Department of Defense, 19 for Air Force headquarters, and 23 for command headquarters, indicative of the magnitude of reviews to which project personnel were forced to devote valuable time and manpower resources.[35]

CHAPTER III

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CHAPTER IV

SKYBOLT'S DEMISE

Gathering Clouds of Doubt

By mid-1962, Pentagon planners were viewing the future of the Skybolt program with increasing apprehension. Some elements moved toward consideration of a possible replacement for the missile in the event production should be delayed or even canceled. Air Force headquarters, on 28 May 1962, advised the systems command that the defense secretary had requested an Air Force evaluation of the feasibility of an extension of the GAM-77 Hound Dog program and of an improved Hound Dog, the GAM-77B with increased range. Among the ground rules listed for this Hound Dog evaluation was "major slippage" in the Skybolt program.[1]

A cost effectiveness study had been completed in March 1962 by ASD managers. The study had been used by the Air Force headquarters operations analysis group to satisfy requirements imposed by Air Force Secretary Zuckert, and was presented to the Designated Systems Management Group in an updated form on 31 May. The study compared five alternatives: 1) President Kennedy's proposed FY63 budget with 22 GAM-87 squadrons; 2) an increased Minuteman complement in place of the Skybolt; 3) increased Polaris missiles as a replacement for Skybolt; 4) two additional Hound Dog missiles per aircraft plus a

Minuteman increase; and 5) four additional Hound Dogs per aircraft plus the increased Minuteman complement. The conclusion presented to the group was that the GAM-87 program was considered superior to additional buys of the Minuteman, Polaris or Hound Dog.[2]

On 3 July 1962, the Air Force submitted the production program figures contained in the May 1962 package program to the Department of Defense for approval. By late August, no go-ahead had been forthcoming from the Pentagon. Earlier, on 1 August, command headquarters advised the program office at Wright Field that full production funds might not be approved until January 1963. Incremental funding probably would continue through December 1962. On 22 August, the Air Force organized an ad hoc committee to conduct a review that might assist in obtaining Defense Department approval for the production phase of the program.[3]

The group's conclusions indicated that with respect to defense suppression the Polaris was too costly and unsure of proper timing in the retaliatory role. The Hound Dog was too similar to the B-52 in terms of survivability and performance. The Minuteman intercontinental ballistic missile was acceptable, but more costly than the GAM-87A while the Skybolt was superior from the standpoint of cost and tactics. In determining cost effectiveness (and if disregarding the cost of the already purchased B-52 fleet), the GAM-87 offered the most efficient means of destroying fixed, soft targets if earliest target destruction was not the overriding

consideration. In the area of tactical flexibility, the GAM-87 offered the superior penetration of a ballistic missile with the inherent flexibility of the manned bomber, the report stated.[4]

Air Force headquarters on 29 September informed the systems command that the Skybolt program proposal had been approved. While constituting a go-ahead for the production program, it appeared certain that incremental fund releases by the Office of the Secretary of Defense would continue through 1962.

In giving his approval, Deputy Secretary of Defense Roswell Gilpatric expressed his reservations about the GAM-87 program:

> . . . I have observed that the procurement cost of the Skybolt has increased by 24 percent in the past six months. This raises some doubts in my mind as to the future value of the system. Therefore, I intend to carefully re-examine the Skybolt program when I review the strategic retaliatory force program as a whole before the completion of the FY64 budget.

The necessity for strong and austere management was again emphasized.* [5]

During the autumn of 1962, the program was still under close scrutiny by Pentagon officials. Those favoring the continuation of the system, including the Joint Chiefs of Staff and many members of

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*The System Program Directive Nr. 11 dated 26 October 1962, summarized the status of the program to that point. The B-52F, G and H squadrons were to be equipped with 46 GAM-87's each. The production program called for 1,012 USAF operational missiles plus 65 support missiles at a total investment cost of $1,771 million.

Congress, were quick to point out the flexible mixed-force capability available to the United States with the triumverate -- Skybolt, Minuteman, and Polaris. The British were particularly concerned over the status of the program.

In September 1962, Peter Thorneycroft, Harold Watkinson's successor as British Defense Minister, flew to the United States for conversations with administration officials which included a discussion of the Skybolt situation. President Kennedy's reports to the British official on the subject of Skybolt were "gloomy." British newspapers and other media responded vehemently to the persistent rumors that the program might be scrapped. A bill was proposed to the House of Commons calling for the removal of the U. S. submarine base at Holy Loch, Scotland, although the proposal was defeated by a sizeable margin. The frightening discovery of missiles in Cuba in October and the dramatic crisis which followed temporarily drew attention from the Skybolt problem.

It was not until 8 November that the British government received anything resembling a definitive statement of the Skybolt's future when McNamara informed Thorneycroft that the decision looked "unfavorable". Increasing Russian defensive capabilities and cost/effectiveness studies had convinced defense planners that an increased number of Minuteman intercontinental ballistic missiles

SKYBOLT

Figure 4. Dayton Journal Herald, 21 December 1962.

offered a better choice for the years during which the Skybolt would be operational.* 6

Early in December, McNamara flew to London where he faced British protests over the increasing frequency of cancellation talk. No decision had been reached for the program for FY64, he stated. On his arrival there, McNamara said: "It is no secret that all five flight tests attempted thus far have failed and program costs have climbed sharply. Nevertheless, we have continued to release funds, fully supported the project and nearly $500 million have been released to date." President Kennedy meanwhile announced that no decision would be made until after he had talked with Prime Minister Harold Macmillan at their scheduled meeting in Nassau later in December. High on the British prime minister's agenda obviously would be an attempt to rescue from oblivion the project in which Britain had invested $23 million.7

Britain's nuclear posture depended upon mating the Skybolt with its Vulcan bombers, destined for rapid obsolescence without the GAM-87. Phase-out of the Royal Air Force's Thor ballistic missiles had already begun and cancellation of the Skybolt would leave Britain with only its

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*On 24 November 1962, Air Force headquarters received a draft of the FY64 budget proposed by the Office of the Secretary of Defense. No funds were included for research and development or production for Skybolt in FY64 and subsequent years.

100-mile range Blue Steel air-to-ground missile. The British government canceled its Blue Water surface-to-surface missile, and in April 1960 had halted development of the Blue Streak intermediate range ballistic missile in favor of Skybolt procurement, causing some concern over Britain's self-imposed political and military dependence on the United States.[8]

In discussing possible Skybolt cancellation, the Kennedy Administration initially attempted to paint a picture of a technically impractical missile. President Kennedy called the system "the most sophisticated weapon imaginable" involving "the kind of engineering that's been beyond us." * In a December 1962 televised interview, the President inferred that the administration had decided to drop the program from the FY64 budget requests:[9]

> When we are talking about spending this $2.5 billion, we don't think we are going to get $2.5 billion worth of national security . . . . We are talking about $2.5 billion to build a weapon to hang on our B-52's when we already have billions invested in Polaris and Minuteman, and we are talking about development now of Titan 3 and other missiles. There is just a limit to how much we need, as well as how much we can afford to have a successful deterrent. I would say when we start to talk about the megatonnage we could bring into a nuclear war, we are talking about annihilation. How many times do you have to hit a target with nuclear weapons?

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*The Administration's early attempt to imply that technology involved was beyond the state-of-the-art was not continued by Secretary McNamara when he faced the House Committee on Armed Services in January 1963. Before this body, McNamara emphasized the strategic and budgetary reasons for program cancellation.

It was clear that the Skybolt production program was dead as far as the American government was concerned even before the December high-level meeting at Nassau. The problem which must be resolved between the two leaders was how the United States could sooth its ally's ruffled feathers. The offer of Hound Dog as a replacement for Skybolt was unacceptable to the British and that nation was unwilling to assume the responsibility -- and cost -- for continued development of the Skybolt by itself. Final settlement was reached, however, when President Kennedy and Prime Minister Macmillan agreed to a proposal in which the United States would sell Polaris missiles to Britain without warheads. This was subject to the condition that Britain's nuclear force eventually would be integrated into a North Atlantic Treaty Organization nuclear striking force. The bargain was made, Skybolt was dead.

The trade of Skybolt for Polaris gave Britain's Laborite forces a welcome opportunity to criticize Macmillan's Conservative government. The Laborate Daily Herald splashed its report of the deal across its front page under the bold headings "Macmillan's Surrender" and "Kennedy Wins All the Way." Viewing America's action as almost treasonable, the same paper commented "Suez to Skybolt, it has been a pretty rotten road." British-American relations took on a decided chill, as suspicion existed within some circles in London that the decision to eliminate Skybolt was a thinly veiled attempt

to blackball Great Britain out of the nuclear arms club despite President Kennedy's assurance this was not true. Elimination of Britain and France, some felt, would polarize international relations between Moscow and Washington.[10]

Although the original agreement between the two powers permitted the United Kingdom to continue GAM-87 development should the U. S. abandon the project, there was little chance of this. Obvious difficulties would exist if the British government were to attempt to carry the program through alone, dealing with American contractors without American participation, even if Britain were willing to assume the financial burden of continued development.

In this country, opposition to the cancellation was equally as loud as in the British Isles. Senator Stuart Symington, former Air Force Secretary in the Truman cabinet, threatened the possibility of Congressional retaliation if the program was scrapped. There was no future for the Air Force if production cancellation occurred, Symington warned. Chairman Richard Russell of the Senate Armed Forces Committee threatened he would call for a committee investigation if development was halted. Of the members of the Joint Chiefs of Staff, only the group's chairman, General Maxwell D. Taylor, supported the decision to cancel the Skybolt program. No detailed investigations materialized, however.

Termination Actions

Official notice of the termination of the production aspects of the program reached Wright-Patterson Air Force Base on 31 December 1962. All work in support of the production contract AF33(657)-8220 and production phases of AF33(600)-39587 halted immediately. The systems command was to prepare plans for the Air Force Chief of Staff for an "early but orderly phase-out" of development efforts.[11]

Following release of this order, contractors also initiated steps to cut back their work schedules and work forces. Northrop Corporation announced it would lay off approximately 2,000 people in its systems and equipment department at the Nortronics Division. The astro-inertial guidance system effort represented about 15 to 20 percent of the company's business and involved about 4,500 workers. General Electric made plans to cut back at its Burlington, Vermont, plant by about 700 people by 1 April 1963. Douglas, the major contractor, made plans to lay off about 4,500 to 5,000 of the 6,000 employees in the now defunct Skybolt project.[12]

With the Department of Defense's cancellation of the Skybolt and reluctance to develop the B-70 mach 3 bomber aircraft, the future of the manned strategic aircraft was placed in jeopardy. It was by now clear that reliance on the manned bomber as a primary strike weapon would soon cease.

On 30 January 1963, McNamara spoke before the House Armed Services Committee. In his presentation, he pointed out that ". . . Skybolt's

value . . . would depend upon its effectiveness in . . . 'defense suppression'. Skybolt offered a special advantage in this role as long as it was expected to be significantly cheaper than alternative systems. Unfortunately, this advantage disappeared." The cost history of the GAM-87A was particularly poor, the secretary stated. The Air Force, early in 1960, estimated Skybolt costs at $214 million to develop and $679 million to procure. By early 1961, the development cost estimate had grown to $391 million. Continuing inflation of the development cost brought the total to $492.6 by December 1961 and procurement costs to $1.424 billion. In its July 1962 program submission, the Air Force increased the estimated procurement cost to $1.771 billion. The latest estimate which the Air Force made, the secretary continued, for development and production (exclusive of warheads) was $2.263 billion. Even these last estimates were considered unrealistic; actual costs probably would be greater. To support this contention, McNamara indicated that the amount of flight time allowed in the test program was less than half the amount which was actually required for the Hound Dog system, a less complex development. "I am sure that the full development and engineering test program would have ultimately cost at least $600 million and might have cost more."[13]

"It is clear that Skybolt could not make a worthwhile contribution to our strategic capability since it would combine the disadvantages of the bomber with those of the missile," Secretary McNamara told Congressmen

in the budget presentation. The bomber-carried missile would not have the short time-to-target of the Minuteman or Polaris, disqualifying it as a good weapon against Soviet strategic air bases, missile sites or other high priority targets since it might take hours to reach the target while the Minuteman could reach them in 30 minutes. Furthermore, the Skybolt lacked the bomber's advantage of greater payload and accuracy yet would have the bomber's vulnerability on the ground. Many of the Skybolt-armed bombers would never get into the air in a surprise missile attack and it would cost about $4 million to put one Skybolt on target. The more accurate, higher-yield and almost invulnerable Minuteman could achieve greater effectiveness for the same cost, he assured his listeners.[14]

The value of Skybolt in controlled, counter-city retaliation was limited in Secretary McNamara's view, since the B-52's vulnerability on the ground meant it would have to be committed early in the war. Polaris and other systems could be withheld for days if desired, thus giving the President an element of choice. The system did not conform to the administration's theory that the President should not be forced to decide on a nuclear response in the initial stages of an attack.[15]

Unjustifiable as a weapon against primary targets, the value of the GAM-87 depended upon its effectiveness in the only remaining important target category, defense suppression — the destruction of

enemy defenses to permit bomber penetration. In this role, the missile's capability vanished if it were to become more expensive than other available systems, McNamara stated.

In effect, this meant that Skybolt had lost whatever cost advantage it once promised. The cost per missile aboard an alert bomber would approximate $4 million, close to the incremental initial investment cost for a Minuteman missile complete with its blast-resistant silo. In view of Minuteman's greater flexibility, reliability, accuracy, lower vulnerability and faster time to target, it made sense to meet our extra missile requirements by buying Minuteman: "We propose, then, that to the extent ballistic missiles are required for defense suppression, they be Minuteman. I can assure you that the missile program I am recommending is fully adequate to the defense suppression task." Cancellation of the Skybolt program, McNamara stated, saved about $2 billion even after providing money for extra Minuteman missiles to handle the proposed Skybolt missions.[16]

These remarks were in contrast with ones the Defense Secretary made on 19 January 1962 before the Senate Armed Services Committee:

> I personally met with the Douglas executives in charge of the Skybolt development on two occasions in the past several months. I have discussed it on a number of occasions with the Air Force, particularly with Gen. Schriever. I think it is our joint opinion that the development can be concluded satisfactorily.

The Secretary indicated that all the money needed for Skybolt was being provided and that the only financial problem was that the estimate of $214 million for research and development had proved low. In the same hearing, Secretary McNamara also remarked:[17]

> We must be prepared to have manned bombers in our force indefinitely into the 1970's, and to that end we must carry on development work that will permit us to bring in new manned bombers, if that seems desirable in the latter part of this decade, and that development work is being continued.
>
> Obviously, the size and kind of forces we will need in the future will be influenced . . . by the size and kind of long-range nuclear forces the Soviets could bring against us and our allies and by the effectiveness of their defensive system. If we assume, as in fact we have, that the Soviet Union will eventually build a large ICBM force, then we must concentrate our efforts on the kind of a strategic offensive forces which will be able to ride out an all-out attack by nuclear-armed Soviet ICBM's in sufficient strength to strike back decisively.
>
> In order to improve their chances of penetrating to their targets, the manned bombers will need the help of missiles for suppression of enemy air defense -- Hound Dog and Skybolt air-to-ground missiles and Minuteman ICBM's.

Despite references to "five successive failures" during flight testing made by President Kennedy and Secretary McNamara, the planned test objectives had been completely or partially achieved in most instances. Test failures had been anticipated and the test series was considered to be on schedule at the end of 1962. None of the problems encountered during flight testing appeared to be of a fundamental nature but rather in the category of random failures.

Other missile systems had encountered similar difficulties yet had evolved into reliable operational systems. The IM-99B Bomarc missile recorded nine successive test failures prior to a long series of successes. Referring to Skybolt development as being "the kind of engineering that is beyond us", therefore, was open to valid argument.

With an anticipated budget deficit of $7.8 billion, the administration was seeking military programs that could be reduced or eliminated. As General Curtis LeMay had predicted in public statements, it would be the strategic manned systems which appeared the most vulnerable "to the pruning shears." The government had already spent $353.2 million on Skybolt, $330.1 million for production as of 31 December 1962. The administration predicted possible savings of about $250 million in funds already appropriated for the weapon system, and another $2 billion needed to produce the missiles.[18]

In a speech at Ann Arbor, Michigan, Secretary McNamara stated that U. S. objectives in the event of a nuclear war "should be the destruction of enemy's military forces, not of his population." American strength would not be used for a first strike, therefore the strategic forces must be large, powerful and protected -- to be able to survive a blow and then to seek out and destroy the enemy's well-hidden and hardened weapons. The Skybolt and RB-70

aircraft were inconsistent with this new strategic policy of nuclear stalemate.[19]

Cancellation of the Skybolt program was apparently the result of cost/effectiveness considerations in an era when a gigantic defense budget was becoming less palatable, and at a time when President Kennedy was seeking means to achieve in a tax cut. The added expense of Skybolt development plus the continued operational cost of the B-52 fleet would place an unacceptable burden on this budget. Development costs for the GAM-87A had been drastically underestimated; however, this was a situation in which neither industry nor the Air Force was blameless.

The day of the manned bomber as a primary strategic deterrent was fast ending as defense planners placed increasing emphasis on manned intercontinental ballistic missiles situated deep underground in tomb-like hardened sites, or cruising undetected in the ocean depths. Continuing cost increases and the shift in defense strategy made cancellation a logical move in the eyes of many. The decision might have been a more difficult and more unpopular one had the flight test series recorded a greater number of unqualified triumphs, however. The program had been under fire since the Skybolt's conception, but at no time before had the Defense Department taken the final step to abandon the project. Nevertheless, the decision now had been made.

With cancellation of the production program, consideration had been

given to the possibility of a continuation of the Skybolt research and development phase. General B. A. Schriever, head of the systems command, had directed that a plan be prepared based on a redefinition of the program to eliminate production aspects and broadening of objectives to include space and other potential applications such as multi-purpose, long-endurance aircraft. In addition, the request asked for definition of any subsystems having special application to outer missions or objectives together with a suggested research and development program to exploit such a potential.

A frequently considered application of the Skybolt was as an anti-satellite weapon. On 9 February 1962, Air Force headquarters had issued ADO-40, titled "Advanced Development Objective for an Anti-Satellite Program." In response to a request from the Space Systems Division, the aeronautical division on 15 June had submitted a development plan for an early capability of an air-launched weapon, based on the GAM-87 launched from a B-52. Advantages of such a defense against satellites at under 500 nautical miles altitude included side-range capability to allow reasonably prompt action. The interceptor vehicle could always be launched more or less in the plane of target orbit and with the same general heading. General David Jones, ASD's Deputy for the GAM-87, recommended an abbreviated development plan incorporating a feasibility program, a kill demonstration and attainment of a small force-in-being.[20] No authorization for exploration of this capability was granted by the Pentagon, however.

On 12 January 1963, the Air Force appointed a task force consisting of members from Air Force headquarters, systems command, ASD, Ballistic Systems Division, Space Systems Division, the Department of Defense and the Royal Air Force to determine the feasibility and application of hardware and technology from the GAM-87 program to other programs. Douglas and the program office also prepared a recommended program for the unterminated portion of the research and development contract during a joint meeting which followed on 14-17 January. Agreement was reached on the configuration of 15 non-terminated missiles, specific aerospace ground equipment requirements to support them, the extent of wrap-up, summary-type engineering reports, the categories of limited ground and laboratory testing to be continued, and the extent of continued C-131 flight testing of the guidance subsystem. Program officials anticipated that an extended C-131 flight test program would be inaugurated between the Air Force and Nortronics for guidance subsystems state-of-the-art explorations.[21]

Five termination options were considered, ranging from abrupt dissolution to a continuation of flight testing. On 24 January, Air Force headquarters made its recommendations to the Defense Department suggesting a continuation of C-131 flight testing as an independent project. Headquarters suggested terminating the remaining research and development effort except for the completion of certain reports to document technology.[22] Two days later, Secretary McNamara signed a memo reorienting the program to an option calling for an orderly

closeout with contractor preparation of approximately 40 final technical reports. On 4 February 1963, the program office received direction for termination action in accordance with Option Two, an orderly phase out of the research and development program to be accomplished in the shortest possible time with maximum technical benefit to the Air Force and with a minimum of further expenditure. Douglas was to terminate all work under the research and development contract AF33(600)-39587 except for the preparation of technical and management reports and the C-131 flight test program.[23]

Personnel within the Skybolt program office at Wright-Field were gradually assimilated by other projects. Effective on 14 May 1963, administrative control and management responsibility for the remaining termination activities of the GAM-87 were assigned to the Strategic Systems Program Office in the systems management deputate. The C-131 flight test program was terminated in its entirety on 25 March.[24]

CHAPTER IV

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CHAPTER V

TECHNICAL DEVELOPMENT

Introduction: Missile Description and Equipment

The GAM-87A was an inertially guided, two-stage, solid propellant ballistic missile.* Flight control was provided by aerodynamic surfaces during the first stage boost and coast, and by a swivel nozzle augmented by roll reaction jets during second stage burning. The four missiles, to be carried on two "T"-shaped pylons, were serviced by two prelaunch computers where the guidance and targeting computations were accomplished. The British Vulcan bomber, carrying only two missiles, carried a single prelaunch computer. An operational missile could be launched 20 minutes after receipt of strike orders.

A tail fairing attached to the missile reduced drag during the aircraft carry. When the missile was released, the vehicle fell free for approximately two seconds. Frangible nuts holding the fairing in place then were detonated and first stage engine ignition blew the fairing off. First stage burning continued approximately forty seconds and the missile followed a programed flight path optimized for a ballistic trajectory for this period. After first

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* For a summary of missile characteristics see appendix K.

stage burnout, the missile coasted until the dynamic pressure decreased to approximately 300 pounds per square foot prior to first stage separation. The second stage would then be ignited and guidance signals sent from the missile computer to the flight control section to steer the missile along the prescribed trajectory. When proper velocity was obtained, a signal was transmitted to the arming and fuzing system indicating that guidance was good. Thrust reversal ports were opened to effect separation of the second stage from the reentry vehicle. This vehicle then continued in a ballistic trajectory. Upon reentry, the deceleration forces provided information to complete arming and firing of the warhead at the pre-selected burst altitude.[1]

Performance and characteristics of the Skybolt were:[2]

Gross weight	11,353 lbs.
Length, overall	39.4 ft.
Body diameter	3.0 ft.
Overall diameter	6.1 ft.

	First stage	Second stage
Diameter	36 inches	36 inches
Length	150.1 in.	94.8 in.
Weight	5,500 lbs.	2,714 lbs.
Burn time	40.7 seconds	41.3 seconds
Thrust	36,800 lbs.	18,400 lbs.
Specific Impulse	245 Isp	245 Isp
Chamber pressure	600 psia	600 psia

First stage

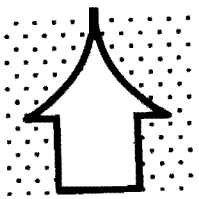
Range, max.	950 nautical miles
Range, min.	250 nautical miles
Altitude, max.	210 nautical miles
Velocity, max.	12,380 feet per second
Duration of flight, max.	710 seconds

DOE (b)(3)

The assigned role of the Strategic Air Command was the preservation of peace through the maintenance of a strong deterrent force. When operational, the Skybolt was to add significantly to the using command's flexibility by increasing the firepower and effectiveness of its manned bombers.

The GAM-87A would be employed by the B-52 alert force as an initial strike weapon against selected components of the strategic target system including counter-force targets, heavily defended targets, off-course targets, and key defensive installations. The missile normally would be launched from high altitude outside the enemy's defensive areas prior to penetration of the carrier for gravity bombing. Employing a roll-back principle, the aircraft could strike defenses as it approached them, thus exposing itself to a minimum of enemy activity. If a missile should malfunction, preventing a successful launch, it would be employed as a free-fall gravity bomb.[3]

The Skybolt would be assigned to 23 combat squadrons equipped with B-52F, G, or H aircraft at a unit equippage rate of 46 missiles per squadron. The first unit programed for the GAM-87A was the 4135th



Strategic Wing located at Eglin Air Force Base, Florida, the squadron which would conduct the Category III test and evaluation. The first 12 production missiles were to be used for B-52/GAM-87 Category III testing while the 13th missile would be the first to enter the operational inventory.[4]

Several different aircraft were potential carriers during early stages of Skybolt development. Initially the B-58B was to be the prime carrier, but on 30 July 1959 plans for development of the -B model were cancelled, leaving the B-52 as prime delivery vehicle. With cancellation of the B-58B, the requirement for carriage on any B-58 model was dropped. The B-52E, F and G models could have Group A provisions (permament wiring and brackets) installed during the IRAN (inspect and repair as necessary) program when GAM-77 provisions were being installed. This would eliminate the need for downing these aircraft a second time. Aircraft not provisioned in IRAN could be converted by field modification teams. Conversion of a two-missile, GAM-77-equipped B-52G to a four-missile, GAM-87 configuration could be performed in two to three weeks by a nine-man team. For B-52C and -D aircraft an up-graded bomb/navigation system was necessary to attain the required accuracy, plus an extensive modification of the wing structure to mount the wing pylons.[5]

Initially, the B-52/GAM-87 outfitting program involved 195 B-52C and -D aircraft with two missiles each, 187 -E and -F models with two missiles, while four missiles were to be carried by 193 -G's

and 62 B-52H's. By March 1960, equippage of the -C and -D models was no longer considered feasible and the -E was under scrutiny. A month later, the Air Force announced to Douglas that carrier aircraft had been identified as the -F, -G and -H models of the B-52, plus the British Vulcan. In the event of a conflict in design between the Vulcan and B-52, the latter was to be given preference. Planning was based on a B-52 launch at 40,000 feet altitude and mach 0.8 and Vulcan launches at 50,000 feet and mach 0.9.[6]

The B-52 equippage schedule was based on the expected life of the aircraft, the length of time the unit had been equipped with GAM-77 missiles, and the capability of the aircraft and tactical location of the squadrons involved. All -G squadrons were to have priority, followed by the -H's, and finally, the -F squadrons. During October 1960, Boeing received an Air Force contract to equip the last 45 B-52H production aircraft with Skybolt provisions.[7]

Employment of the B-47 bomber as a potential Skybolt carrier was technically feasible, but not practical. The requirement for off-loading fuel would give the aircraft very limited penetration capability; the missile would replace fuel pods outboard on the wings. Equippage of the B-47 fleet would also be competitive with more adaptable carriers for funds. Development of an air-to-surface missile for the B-70, it was thought, could stem from a growth version of the Skybolt.[8]

Several cargo aircraft were looked on as potential Skybolt platforms, particularly the C/KC-135 and C-141. All programed production of the former was committed to other specific tasks, therefore adaptation of the C-135 would involve production of aircraft designed specifically for Skybolt carriage. The C-141 with no modification other than that required to carry four missiles would not provide an aircraft with sufficient range to be useful. The necessary range could be obtained with the airframe if the normal load factor used in the structural design of transports were lowered to the standard bomber criteria. This would permit installation of a body tank in the cargo compartment to take advantage of the weight carrying capability of the wing. Wing service life would be drastically reduced by operation at the lower load factor so more detailed analysis might prove the C-141 configuration unfeasible. Increased range through in-flight refueling would necessitate the complete redesign of the fuel system.[9]

Missile Design

The approval of the research and development phase of the Skybolt program in February 1960 focused attention on missile design. The overriding consideration in each aspect of development was the necessity for introducing a useful weapon system into the operational inventory early in 1964. The stringent environmental requirements resulting from takeoffs, landings, and flights with the many cycles imposed by an air alert status were significant factors in the design of the various missile subsystems.

Engineers considered two basic approaches to the design of the air-launched missile, with a ballistic missile approach favored by Air Force and contractor personnel over a boost-glide operation. The advantages of the former included greater simplicity with increased reliability. A ballistic missile should prove less vulnerable in light of its greater speed and smaller radar cross section. A boost-glide missile, although more maneuverable in the target area, would prove a more attractive infrared target throughout a major portion of its glide trajectory and was more susceptible to a high altitude atomic burst. The boost glide missile did lend itself more readily to mid-course and terminal guidance. It also featured greater growth potential in view of the long ranges that could be obtained with minimal increase in launch gross weight. The ballistic missile was more compatible with carrier aircraft, easier to support and maintain, more economical, and -- of great significance -- should be available a year earlier than the competing design with greater early reliability.[10]

It was specified that "maximum advantage was to be taken of the results of solid rocket motor development in support of Polaris and Minuteman." Estimated completion dates for development, test, and operational evaluation were October 1962, April 1963, and October 1963, respectively. Fiscal cost estimates for development

totaled $184 million:

FY59	$3 million
FY60	$41 million
FY61	$100 million
FY62	$40 million.

Douglas designers suggested the adoption of a configuration referred to as Able III for the basic design.[11]

The evolution of the Able III configuration was the result of step-by-step evaluations of earlier contemplated configurations, developed through efforts of a detailed system optimization study. Identified as the Able III in August 1959, the Douglas-proposed configuration featured the use of the canard reaction control principle, eliminating the separate rocket engines to provide out-of-atmosphere control. Control forces resulted as a by-product of the second stage propulsion engine. After separation, the missile was to be tail-controlled primarily by reaction force of the main engine exhausting through four swiveling nozzles mounted in aerodynamic control surfaces. The change from canard to tail control was accomplished by a polarity reversal in the steering control system, activated by a signal.[12]

In the Able III configuration, the complete guidance and control subsystem was concentrated in one package, permitting quick disconnect from the propulsion and reentry subsystems and servicing, handling and checkout as a single unit. In addition, the use of the

canard reaction control principle required no technological breakthrough to develop.

As development of the two-stage Able III configuration progressed, Air Force and contractor engineers compared several more reliable and less complex single-stage missiles with the Able III design. All single-stage configurations for the GAM-87A examined by Douglas engineers proved to be deficient in some quality. To correct the discovered deficiencies, modifications were necessary which outweighed the simplicity of eliminating the staging and engine ignition from the two stage configuration. Consideration of single-stage configurations also involved some compromise in the 1,000 nautical mile maximum range capability.[13]

The two-stage Delta II configuration, also considered by the prime contractor, provided first stage aerodynamic control by tail fins powered by a hot gas, reciprocator pump hydraulic power supply. The second stage was to be reaction controlled by four single-axis swivel nozzles,* powered by a separate hydraulic power supply. Although this configuration offered fewer design problems and perhaps as much as a ten percent range increase over Able III, the guidance and control mechanisms were separated in several areas. Delta II

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* In April 1960, second-stage design was modified with the replacement of four swivel nozzles with a single nozzle. Approval of the change followed a presentation by Colonel DeWitt before Department of Defense and Air Force personnel.[15]

offered a range improvement and fewer anticipated design problems, but at the expense of additional servicing, maintenance and reliability penalties.[14]

The Air Force laboratories, including those at Wright Field, were not without some misgivings about Douglas' proposed configuration. They felt the design presented a number of problems, limitations and performance degradations, but recognized that the configuration offered some logistic advantage.

Carrying a 1,650-pound warhead, the Able III configuration offered a serious problem with center of gravity locations. As first stage burnout approached, the center of gravity shifted forward of the canard center of pressure causing a reverse of polarity of the longitudinal and directional control. The optimization study conducted at the request of the Department of Defense in mid-1959 did result in some improvements in the Able III configuration. Free-flight drag was reduced 50 percent by changing the diameter of the first stage motor from 46 to 36 inches. The capability for carrying alternate warheads was improved while greater simplification of the basic design increased reliability. Relocation of the star tracker to a position in the missile instead of in the pylon also added greater reliability to the system.[16]

By the end of 1959, however, analyses of studies made since August indicated that a change in configuration was warranted despite Douglas' apparent acceptance of the Able III configuration. Any design

selected had to offer the maximum chance of meeting an operational date in late 1963. With this in mind, the Department of Defense, in giving development approval on 1 February 1960, indicated that the Delta II configuration would be adopted in place of Able III. Approval documents also specified that the development of improved techniques and materials was not to be a part of the program; changes in design could be made only with the approval of the Director of Defense Research and Engineering.

DOE b(3)

Warhead and Reentry Vehicle

Selection of General Electric Company as subcontractor for design of the reentry vehicle was made in August 1959 by Douglas with Air Force approval. Design of the vehicle, however, was dependent upon warhead definition. Weight of the warhead composed 50 to 85 percent of the total reentry vehicle weight while the diameter of the warhead was also of importance. Engineers gave some consideration to the possible application of the Minuteman reentry vehicle to the Skybolt, but believed this to be a high risk development program rather than an "off the shelf" item.[18]

On the fourth and fifth of May 1960, Douglas and General Electric briefed personnel from Wright Air Development Division (WADD) and the

Air Force Special Weapons Center (AFSWC) on contemplated design of the reentry vehicle. Wright Field representatives at this meeting recommended that one vehicle be used for several warhead candidates, indicating that maintaining schedules was of greater importance than achieving an optimum design. The contractors objected on the technical grounds that requirements were such that one might not be capable of handling several warheads. The problem was later resolved with the ultimate adoption of a single, light weight warhead configuration.[19]

In March 1960, WADD personnel requested a study of the clustered atomic weapons concept (CLAW) using two or more nuclear warheads for maximum target damage without payload limitations. Conclusions resulting from the study indicated that no significant increase in on-target effectiveness of the Skybolt would result while such an undertaking would incur additional complexity, system unreliability program costs, and possible delays in the development schedule. The Air Force Special Weapons Center concurred with the prime contractor in recommending against investment in a CLAW development program. A single warhead with effectiveness and payload advantages equivalent to the CLAW concept would be less expensive and less complex.[20]

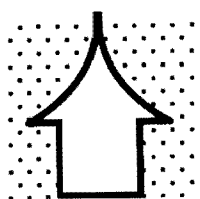
Early considerations by the Air Force Special Weapons Center during the spring of 1960 set out that body's recommendations for suitable warheads in the 1,600 and 700-pound class for the GAM-87A.

DOE b(3)

project office personnel announced the decision to discontinue work on the heavy warhead and directed General Electric to concentrate on a reentry vehicle for the light warhead. Design effort would be limited to the XW-56X1-Mod 2 only. The envelope for the warhead was such that the reentry vehicle could be made compatible with other possible light warheads with a minimum of re-design. For planning purposes, the maximum perimeters of the warhead were: weight, 675 pounds; diameter, 18 inches; and length, 48 inches. Should a decision from the Joint Chiefs of Staff call for a warhead considerably different from this in size or weight, program slippage would equal approximately the period from 1 October 1960 to warhead selection.[24] (b)(1),(b)(3):42 USC §2168(a) (1)(C)--(FRD)

DOE
b(3)
(b)(1),(b)(3):42 USC §2168(a) (1)(C)--(FRD)
DoD

The Joint Chiefs of Staff advocated that the J-21 be adapted to the weapon system. On 9 January 1961, the project office received word that the Pentagon had forwarded a Phase III warhead request for the development version of the J-21 to the Atomic Energy Commission. The first production unit was to be available by 1 July 1963.[25] Meetings between Department of Defense and Atomic Energy Commission personnel gave assurance that selection of the J-21 warhead -- planned originally for use with the Minuteman -- rather than a modified XW-56X1 would have



little effect on the program. The J-21 (later designated the XW-59) could be supplied on the same time schedule and with greater reliability. With its lighter weight and smaller dimensions, the J-21 should offer greater range potential with no significant difference in predicted yield.[26]

Following selection of the warhead, the Atomic Energy Commission received Phase III development authorization for the J-21 for use with both the GAM-87A and Minuteman. The commission in turn assigned to the Los Alamos Scientific Laboratory the responsibility for development of the nuclear device, while Sandia Corporation of Albuquerque would concentrate on warhead application to these two weapon systems, using the same nuclear device for both. The laboratory would complete development in time to meet the operational date for Minuteman which was approximately two years earlier than that for Skybolt. Therefore development of the nuclear device appeared to offer no scheduling problems. The warhead was officially designated the XW-59X1.[27]

Now that the warhead configuration was determined, the shape of the reentry vehicle was reevaluated. During the study the sphere-cone-cylinder-flare configuration gave way to a sphere-cone shape suggested by General Electric. An increase in range of 20 to 30 nautical miles should result. Unit cost would be reduced during the research and development phase because of the simplified structure and would carry over into the production program. Elimination of the

flare solved the problem of erosion of ablative material. Relief from the star tracker shock wave problem was realized, while the change in configuration also brought flexibility for installation of the United Kingdom payload and some reduction of radar cross section when viewed from the front. The sphere-cone shape was finalized in March 1961.[28]

This change in reentry vehicle configuration was of such magnitude as to drastically limit the value of much of the Boeing flight test data. Simultaneously with the change in configuration, the missile program was placed on an austere funding basis -- the 2 March "Washington Plan" following the December 1960 cutback. Therefore it was financially impossible to obtain from the prime contractor an updated reentry vehicle for use by Boeing. The Aeronautical Systems Division was found to possess an in-house engineering and fabrication capability for a "boiler-plate" reentry vehicle of the new configuration. Division personnel engineered and fabricated four vehicles which were delivered to Boeing on schedule.[29] Prototypal reentry vehicles would be flown beginning with the fifth guided round.

No state-of-the-art problems appeared to exist in development of the reentry vehicle; the program was viewed as one involving straight forward design, fabrication and testing. The Mark VII reentry vehicle used on the Skybolt was slightly more complex than the Minuteman's Mark V. The arming and fuzing was more sophisticated

due to having variable altitude fusing and bomb drop option. Stage separation was also more complex.[30] *

By the end of July 1962, "boiler plate" reentry vehicles lacking ablative material or other provision for reentry had been delivered to Douglas by General Electric's Missiles and Space Vehicle Department. On 15 August, the first captive-carry reentry vehicle for the United Kingdom was shipped from the contractor's plant. United Kingdom/General Electric and Sandia/General Electric warhead compatibility tests were successfully conducted in October, including both electrical and mechanical tests. By the 31 December contract termination, qualification of the arming and fuzing package had been 75 percent accomplished. The design, development and fabrication of those subsystem mockups used as design development tools and those test rigs and fixtures required to accomplish the subsystem testing were approximately 95 percent completed. Individual testing of all components used in the developmental and tactical reentry vehicle subsystems was almost one-fourth accomplished by the end of 1962.[31]

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* Under consideration for a time was the Mark 7A reentry vehicle which provided simple decoys, increased separation between the second stage and reentry vehicle on reentry, and a reduced radar cross section while maintaining the range of 950 nautical miles.[32]

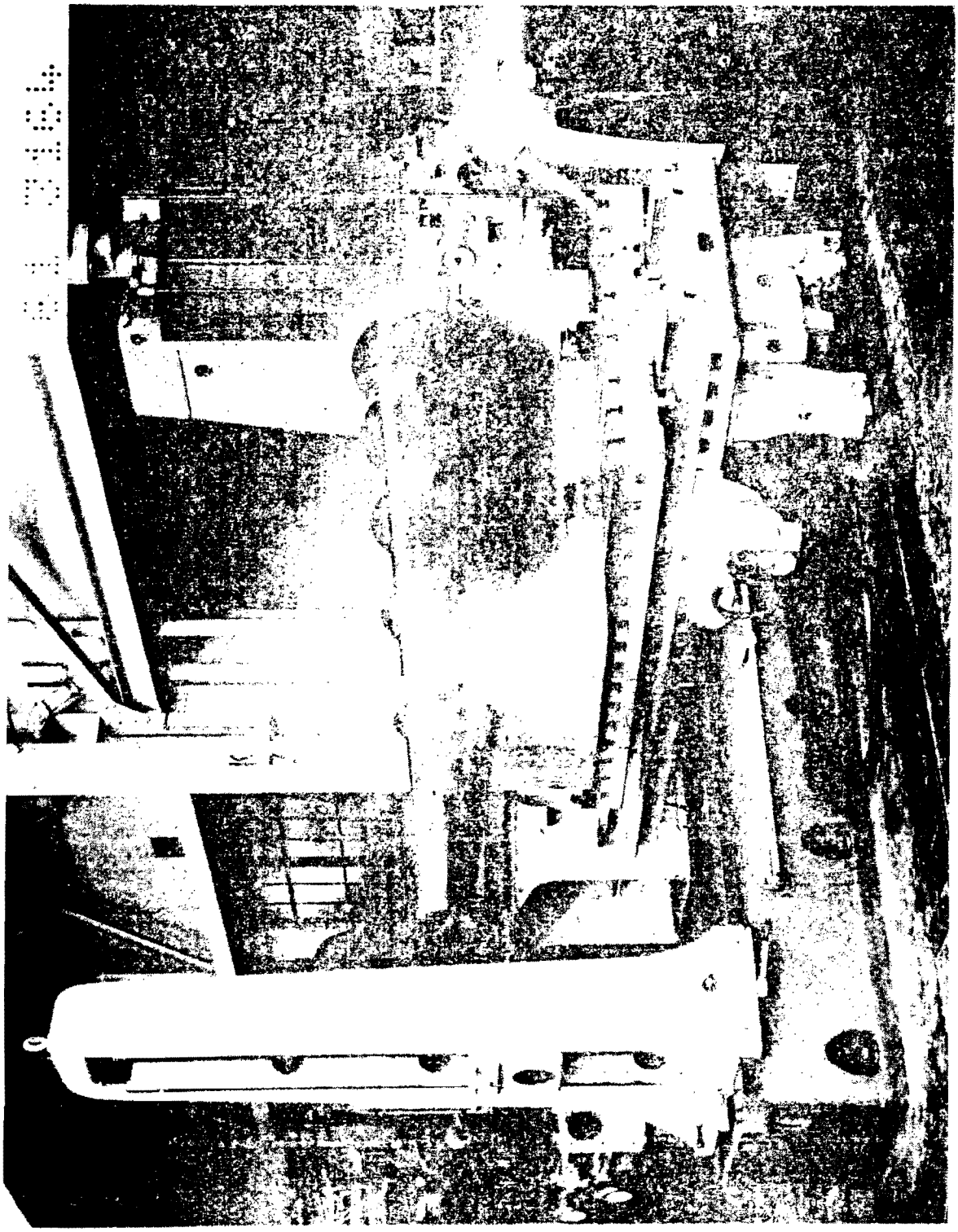

Figure 5. Subcontractor for development of the reentry vehicle was the General Electric Company.

Propulsion

As a specification of the Defense Department's program approval of the Skybolt project in February 1960, development of the propellant and the rocket motors was limited to the state-of-the-art. The projected GAM-87 temperature and vibration environments which would be encountered in operational employment, however, would be more severe than that found with other large solid propellant motors.

Three fundamental approaches were utilized to minimize environmental effects: heater blankets, an improved propellant grain design to reduce stresses and strains, and improved propellant mechanical properties to withstand environmental effects. Heater blankets would maintain the propellant at minus 30 degrees Fahrenheit in a minus 65 degree environment without excessive power demands. This blanket would permit the missile to meet the weapon system operating requirement of minus 65 degrees Fahrenheit. (Design operating temperature requirements were minus 30 degrees to plus 140 degrees Fahrenheit.) In 1960, a new grain design, "conocyl", was devised for the GAM-87 which avoided stress concentrations. The conocyl was pictured as a single cylindrical longitudinal hole joining a conical shaped slot at the head end.[33]

Work begun at Aerojet-General facilities in August 1959 involving preliminary design work continued until March 1960 when configuration optimization was completed. Development at this point moved to full scale motor testing with test weight chambers. This

first phase of testing involved a total of nine first-stage motors and 13 second-stage units. Aerojet-General engineers accomplished the initial firing of a full-scale, test weight, first-stage motor on 29 July 1960. The motor case evidenced no hot spots while the nozzle and nozzle throat areas were free of excessive or uneven erosion.[34]

A second firing occurred on 22 August with the initial firing of a second-stage test motor on 23 September. Based on preliminary data from these successful early tests, the pressure time curve appeared to be as predicted, there appeared to be no significant ignition delay, and the nozzle and nozzle throat area erosion appeared to be minor. By 31 December 1960, Aero-General had fired 11 test weight motors -- six first-stage units and five second-stage motors. Two failures had occurred to this point, a first-stage motor which had been suspected as deficient prior to firing, and a second-stage unit that burned through the nozzle bellows soon after gimballing had begun. During the test series, concluded in May 1961, eight first-stage and ten second-stage motors fired successfully. The tests had demonstrated the conocyl grain design to be satisfactory, ballistics had proven satisfactory over the temperature range, and cold aging tests and several temperature cycling tests had been conducted without difficulty. Due to a lack of facilities, vibration had not been attempted with test weight motors, and hot aging was not examined due to limited time.[35] *

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* During the summer of 1960, Wright Field received authorization from ARDC headquarters to commit and obligate $728,500 for environmental and vibration test facilities at the Aerojet-General installation in Sacramento.[37]

By the fall of 1960, the estimated over-all cost of the propulsion portion of the program dropped from $42.2 million to $37.5 million. The requirement for development and phasing of a 255 Isp (specific impulse) propellant had been deleted and the total number of test motors reduced from 513 to 484. Probably the highest risk item in the propulsion system was the second stage gimballed nozzle. While the component was of complex design, the confidence level was increased by the fact that the design was simpler than the second-stage unit for the Minuteman which operated satisfactorily. Also, the second-stage Skybolt motor with its single gimballed nozzle would probably not be faced with the severe problems of selective hot gas erosion encountered in Minuteman development.[36]

As a safety of flight requirement, the prime contractor and the project office agreed during the March 1961 GAM-87A Program Review that radiographic inspections would be made during the flight test program at the Air Proving Ground Center. All motors would be so inspected before shipment to Eglin Air Force Base. The initial 15 first-stage motors used in the flight test program would be re-inspected at least once following arrival at Eglin. This program would establish confidence in the motor's capability of withstanding the actual flight environment.[38]

The Air Force concluded motor hazard classification testing in November 1961 at Edwards Air Force Base, California. The final portion of the series at the Air Force Flight Test Center was a bullet impact

test on a first-stage motor. A .30 caliber bullet fired into the motor case caused the propellant to burn but no explosion resulted.[39]

The propellant utilized in the GAM-87A motors was an adaptation of the state-of-the-art as were other elements of the propulsion subsystem. During early testing, project engineers discovered a deficiency involving grain cracking when sub-scale motors were conditioned to zero degrees Fahrenheit for several days then subjected to lower temperatures. The substitution of Dow Corning B2000 polymer satisfactorily prevented crystallization. Another difficulty was discovered in August 1961 when technicians found that high temperature strength was slightly out of control. Minor changes were made to a material specification and to the mixing cycle resulting in the desired shift in properties. No changes were necessary after that.[40]

A more serious problem, identified in August 1961, appeared during radiographic inspection of motors in the Limited Pre-Flight Rating Test program. The situation involved what appeared to be a separation between the propellant and insulator in the forward insulated regions after an extended exposure to high temperatures in aging tests. The initial portion of a failure analysis program begun in August indicated faulty processing techniques might be responsible. As the analysis progressed, it became apparent that the problem was more serious. All motors, both first and second stage, exhibited the defect to varying degrees following exposure to temperatures of 150 degrees Fahrenheit for more than ten days.[41] Following X-ray inspection of aged motors, a low density liner was found only in areas where the liner was in contact

with rubber insulation that was bonded directly to the motor case. Removal of propellant liner specimens from these suspect areas revealed that the liner was inflated by the formation of many small bubbles within its thickness. Samples of insulation and boot rubbers were analyzed and found to contain appreciable quantities of volatile materials, primarily water.[42]

On 12 October, motor conditioning and processing was stopped and radiographic inspection of all motors began. Between 17-18 October, Douglas, Aerojet, and Air Force personnel conducted a technical review at which time this group decided upon a laboratory test program. Testing would involve additional motors needed to demonstrate the adequacy of a fix, once one was found. At least ten first-stage motors and a like number of second-stage units were needed, plus two spares of each, necessitating slippage of the qualification program completion date tentatively from October 1963 to April 1964.[43]

Thousands of laboratory tests were required and about six months' effort to duplicate the phenomenon at laboratory scale. The problem was traced to moisture in rubber insulation and revealed that insulated motors had to be thoroughly dried prior to liner application. Early laboratory tests had failed to isolate the problem since motor conditions had not initially been duplicated exactly. In April 1962, test engineers reported the problem to be

under control. The original liner would be retained but an extended drying process was necessary to dry the rubber insulation over which the liner was placed. Technicians began processing motors for the pre-qualification development program on 15 April 1962.[44]

Results of the management survey conducted, in January 1962, by the Terhune Board disclosed that propulsion development constituted less than five percent of the total development costs. The technical activity paralleled and followed the same type of basic effort performed by Aerojet-General for Minuteman development. No state-of-the-art penetrations or costly problem areas were anticipated. The only problem of major significance encountered to that point had been that involving the liner material.[45]

Due to funding cutbacks, program officials reduced the scope of the Pre-Flight Rating Test series and conducted a limited program consisting of 16 first and 15 second-stage motors. Extending from March 1961 until 18 April 1962, the series recorded all first-stage firings as partially or wholly successful while all but two of the second-stage tests were also accomplished as planned.[46] During the test weight and limited Pre-Flight Rating Test programs, 56 consecutive full-scale rocket motor firings were conducted at Aerojet-General facilities under many of the environmental conditions that would affect a tactical missile. The first ignition system component test was made in May 1960, and the first motor firing with the proto-

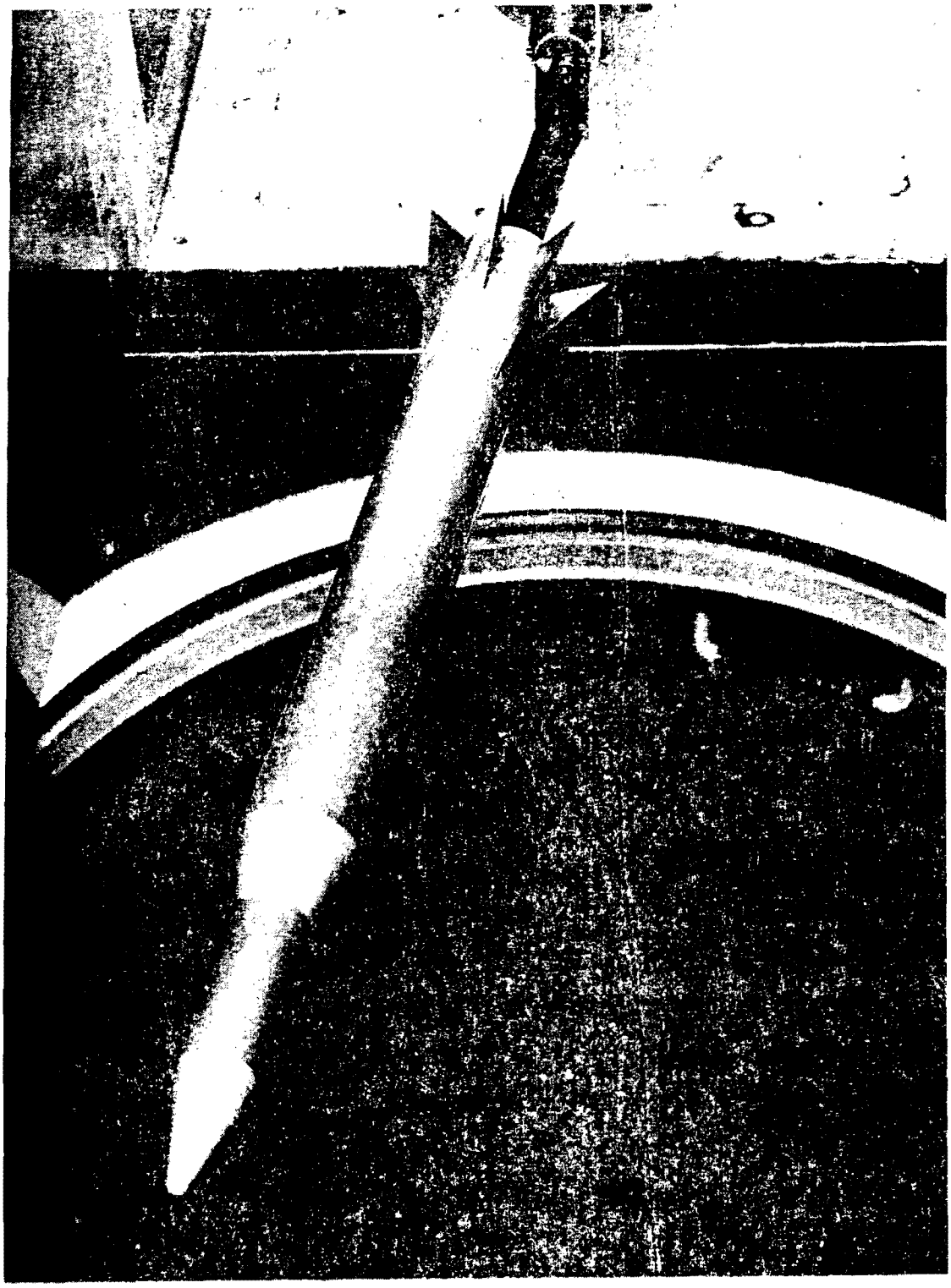

Figure 6. A 1/18 scale model installed in the two-foot supersonic gas-dynamics facility at Aeronautical Systems Division, October 1961.

typical igniter had been made in July 1960. Based on these, a review of the entire propulsion subsystem development and limited pre-flight tests was accomplished on 12 April 1962, with the conclusion that an acceptable level had been reached for assurance of successful flight tests for the first programed launch.[47]

Guidance

By the time of program cancellation, significant progress had been made in developing and testing the guidance subsystem. Despite early predictions that this subsystem involved the greatest risk, few problems of major proportions were encountered. At the time of selection of the prime contractor, the Weapon Guidance Laboratory at Wright Field had expressed concern over the apparent lack of experience and competence in the field of inertial guidance exhibited by Douglas. The source selection board had assured the laboratory that laboratory personnel would be given the opportunity to review and approve the selection of both the guidance system and the subcontractor named for its development.

The guidance system employed on the Skybolt was a non-radiating, all-inertial system with stellar alignment prior to launch. While the missiles were attached to the dual pylon, the guidance system depended upon the B-52 carrier for information to align the system

and stabilize its computations. The AN/ASQ-38(V) bombing/navigation system provided trim-heading, drift angle, range north of fix-point, range east of fix-point, altitude above sea level, and ground speed. These signals were fed to the analog-to-digital converter assembly, then to the pre-launch computer.[48]

The basic concept associated with the GAM-87 guidance subsystem appeared to be the best approach available using state-of-the-art equipment and if a high altitude launch were used. For low altitude launches, complications arose as weather conditions might prevent use of a star tracker prior to launch. Under these conditions, a degradation in the circular probable error (CEP) would result unless azimuth uncertainty could be reduced through the addition of a star tracking capability during boost or coast phases.[49]

An advantage of the air launched missile was the great flexibility it offered while for ground lauched systems, more precise application of the warhead was possible. The complexity of the guidance system for the GAM-87A was much greater than the Minuteman, however. The latter's guidance system included some 50,000 component in-line parts compared with about twice this number in the system utilized in the air-launched missile.[50]

Prior to Department of Defense go-ahead for the Skybolt development program early in 1960, detailed plans to incorporate terminal guidance provisions had been included. The 2 February 1960 program approval document specifically mentioned terminal guidance as

an "embellishment" which would probably delay the main objective of achieving a weapon system by early 1964. No further planning was carried out along these lines.[51] Technical personnel from Wright Field and the Ballistic Missile Division reviewed the guidance subsystem program on 11-12 August 1960. The observers noted that the basic concepts and methods appeared reasonable and well conceived. Test programs and methods indicated there was good organization within the Nortronics program with knowledgeable people pledged to an extremely tight schedule with no margin for error. Interface with the B-52 was a complex task, much more so than any of the Minuteman launch environments. Very little time existed for compatibility tests on the complete system at Nortronics prior to delivery of systems to the prime contractor.[52]

The basic design of the guidance subsystem was completed in early 1961 with experimental units ready by March 1961 for testing. Nortronics assembled the first research and development production model on 28 April, on schedule. General Electric completed, checked and shipped the missile computer on the same date. Of the five modules for the guidance subsystem, four were completed within three days of PERT estimates while the other was ready five months early.[53]

The "Washington Plan", redirecting the program in March 1961 on a more austere funding basis, had reduced the scope of development testing in a number of areas. The B-52H/GAM-87A flight test program

had been eliminated, the number of programed launch missiles reduced to four, with a reduction in motor hazard classification testing, motor preliminary flight rating tests, and maintainability and reliability testing. Also eliminated were the planned guidance sled tests.

Experience at the Ballistic Missile Division had shown that sled tests of all inertial ballistic missile guidance equipment had uncovered defects which required correction prior to successful flight. Consequently, the elimination of this test series would probably result in flight test missile losses while defects were being uncovered. Sled testing was the only method that would determine operation of the gyro platform under sustained acceleration conditions representative of an actual missile launch. In the post-launch or ballistic glide phase, the most significant error in operational use was due to inaccuracies in the velocity measurement system. The study of these errors was a primary subject of the sled test program. Without sled testing, Wright Field personnel felt the development program could not be considered a "reasonable risk." Douglas Aircraft took an opposing stand, arguing that conditions simulated in the sled test series could be met in laboratory environmental testing. An accumulated list of nearly 50 specific problems revealed during other sled test series had shown the majority were not associated with the linear acceleration environment provided by the sled, the prime

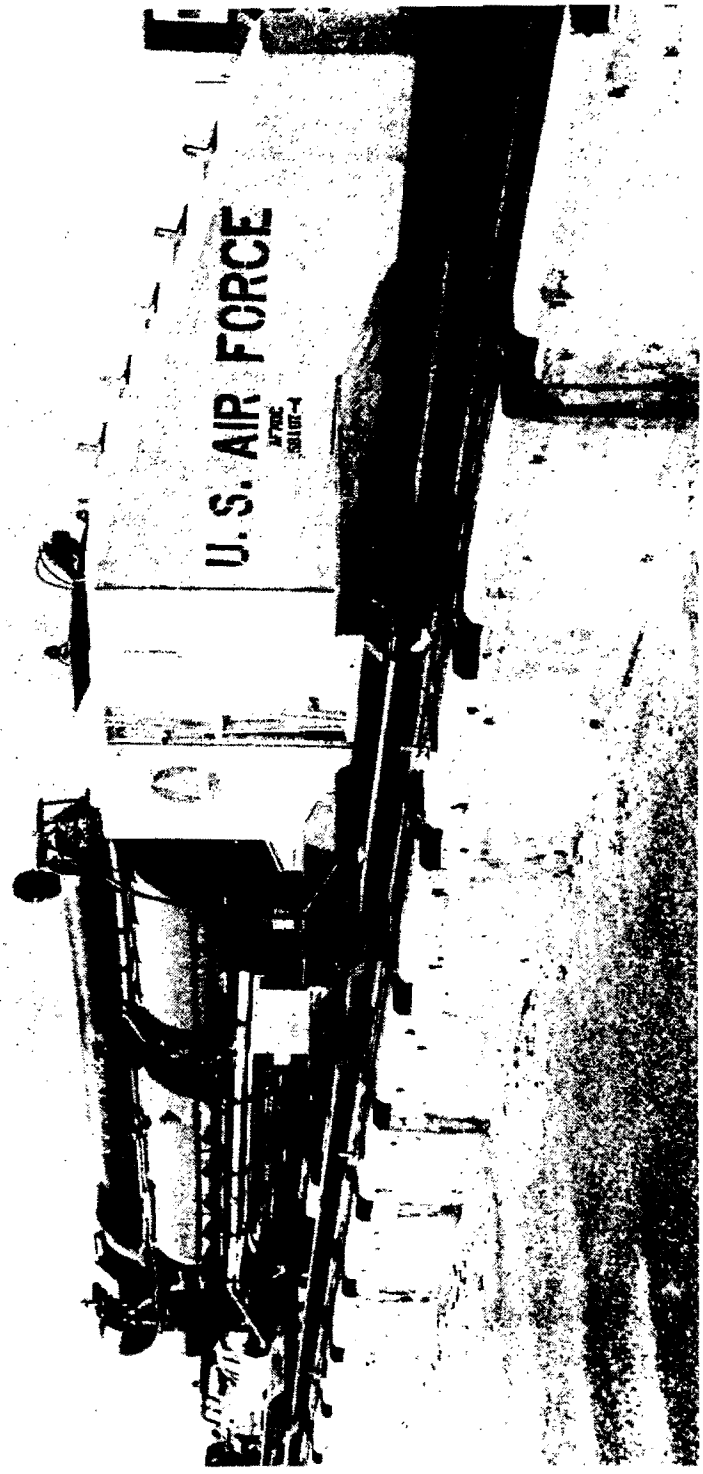

Figure 7. GAM-87A guidance rocket sled test program showing sled pusher and forebody at AFMDC, Holloman AFB, New Mexico.

contractor reported.[54]

Major General W. A. Davis, ASD commander, supported the demands of the program office recommending that $3,500,000 of fiscal year 1962 funds be made available for the contractor portion of sled testing and that $482,000 be provided to the Air Force Missile Development Center for its portion of the program. If a malfunction were to occur during flight test due to guidance malfunction, the cost of repeated tests and delays would quickly exceed that of the track test program. Both the Scientific Advisory Board and the Ballistic Missile Division supported the contention that sled testing was a necessary part of the development program.[55]

Actual rocket sled testing involved three phases. The first consisted of four runs to design the sled forebody and equipment mounts to create the desired environment. No guidance equipment was employed during these runs. The second series featured eight runs to check out the mechanical integrity and gross performance of guidance equipment and the complex track instrumentation required for accuracy tests to be made in Phase III.

The first two sled runs were made within two weeks of the established schedule, with the initial test on 22 November 1961. These first tests furnished functional verification of the instrumentation and adequate measurement of the dynamic environment. Phase II, begun on 15 May 1962, was completed on 17 October 1962 at the Holloman test site with essentially all objectives met. Mechanical integrity and

gross accuracy had been demonstrated while boost phase problems were uncovered and corrected which, if undiscovered, would have resulted in unsuccessful flights and would have been exceedingly difficult to identify. The objective of the third phase was the achievement of ten runs with 90 percent satisfactory telemetry data. Twenty runs had been scheduled, with completion planned for the spring of 1963.[56]

Further testing of the guidance subsystem was accomplished in a C-131B aircraft, providing means whereby the system could be operated in an environment simulating a tactical situation yet having available precision monitoring and malfunction isolating instrumentation. The test series resulted in: 1), a redesign of the phototube circuitry due to sensitivity to temperature changes; 2), the redesign of tracker circuitry to eliminate the effects of electrical interference; and 3), the optimization of the phototube amplifier gains to reduce star acquisition times. Also emanating from the series was the finalization of the B-52H wiring configuration and a contribution to assure the adequacy of guided launch tapes and other Eglin test range tapes. The ability of the system to provide azimuth data to the missile appeared satisfactory as did the platform's ability to establish direction of local vertical.[57]

Guidance system components were first flown in a C-131B flying laboratory on 28 April 1962. After clearing a 3,000 foot overcast, the system acquired the first star that was programed into the pre-launch

computer approximately halfway through a 12 minute search period. Three different stars were acquired with a total of 30 detections on a planned flight path from Hawthorne, California, to Phoenix, Arizona, and back.[58] Tests at the Mount Palomar observatory, begun on 6 November 1961, had demonstrated under actual sky conditions that the astrotracker was capable of detecting stars and confirming the detections using the astrotracker pointing servo.

The first three phases of the C-131 test series consisted of a dozen flights, preparatory to the advanced system performance test flights, and were concluded in July 1962. Successful star acquisition and tracking was achieved during daylight and night flights with the guidance subsystem ground and airborne alignment. Two flights on 24 July marked the beginning of the fourth phase, system performance test flights. By 31 December 1962, 48 flights involving over 150 flight hours had been conducted. Reliability data from the C-131B tests were used as the indicator of operational reliability, pending the availability of statistically significant similar data from B-52 missile launch tests.[59]

Data from these C-131 tests indicated a 38 hour mean-time-to-failure for the guidance subsystem for the standard mission and corresponded to a 90 percent figure for probability of mission success. This approximated the 41 hour figure predicted in 1961 for this point in the development program. The operational

requirement for mean-time-before-failure was 70 hours, equivalent to a 94 percent probability of mission success.[60]

DOE b(3)

Guidance played the major role in determining accuracy, with reentry vehicle characteristics constituting most of the remaining portion. Between 24 July and 7 December 1962, the radial error of the C-131-carried system decreased from a bias of 25,000 feet and oscillations of plus or minus 5,000 feet to 3,000 feet of bias, plus or minus 2,000 feet.* This bias was of known origin and was being corrected. Star tracker performance on C-131 and B-52 tests repeatedly exceeded system requirements. Over 4,300 star acquisitions were made during tests in full daylight.

DOE b(3)

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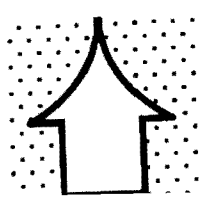
*"Bias" is defined in the Dictionary of Guided Missiles and Space Flight (ed. Grayson Merrill, published by D. Van Norstrand Company, Inc., Princeton, N. J., 1959) as ". . . a term denoting the distance from the center of the target to the center of impact of one or a group of rounds. It is not connected with the accuracy of the weapon per se, but may be due to mislocation of the target, misorientation of the weapon, windage or other constant errors. The bias is a quantity which must be identified and eliminated from consideration in any determination of accuracy." (p. 89)



a British Vulcan bomber at Edwards Air Force Base in June 1961. Castle Air Force Base was the site of more extensive electromagnetic interference testing of B-52F and -G aircraft in October and November of 1961 following Boeing-Wichita's analysis that a serious problem existed.* The susceptibility of the guidance subsystem to a simulated B-52H electromagnetic environment was measured in the C-131 test aircraft at Nortronics in April 1962 using actual B-52 Group A wiring. Nortronics engineers tested guidance modules in the simulated environment from January 1962 throughout most of the year, while Douglas engineers tested the launch subsystem, the analog-to-digital computer for the Vulcan bomber, and airborne cooperational equipment. International Business Machines Corporation tested the B-52 analog-to-digital computer.** 63

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* Support of the GAM-87A program by the Boeing Airplane Company began on 1 June 1959. The firm studied the feasibility and compatibility of various GAM-87A missile/pylon arrangements on the B-52 along with cost estimates and schedules for development and retrofit programs. Boeing also provided Douglas with engineering data and information to support the prime contractor's design studies. Wind tunnel tests in conjunction with Douglas on various missile and pylon configurations was also an area of Boeing effort.65

** Under the subcontract with Boeing, International Business Machines engineered, tested and provided the modified research and development components of the AN/ASQ-38(V) weapons control system required for GAM-87A operations. Boeing and Douglas participated in laboratory testing of this hardware at IBM, with no apparent degradation of the bombing/navigation functions. The modification only affected a Doppler amplifier and bomb/navigation system relay frame. The B-52G used for AN/ASQ-38(V) testing was the second test aircraft delivered to Eglin and was modified with complete prototype GAM-87A provisions.66

Electromagnetic Interference Task Group meetings in February and April 1962 were beneficial in identifying potential problem areas. During a June 1962 meeting at Wright Field, Air Force contractor representatives agreed that the required interference immunity could be obtained by using multi-conductor sheathed and triax cable, shortening all ground leads to the minimum possible length, and arranging all wire breaks so that continuous shielding was approched to the maximum extent.[64]

Flight Testing

Under the new command organization accomplished late in 1959, a system project office was responsible for flight test programs involving the weapon system assigned to that office. Test program management was to be exercise by the Wright Air Development Division project office until the system reached operational status. In keeping with this command policy, the GAM-87A office planned to direct flight testing through the GAM-87A Test Director at the Air Proving Ground Center at Eglin Air Force Base, Florida. Test functions previously assigned to the proving ground center were now reassigned to the weapon system project office.[68]

In response to direction from Air Force headquarters and command headquarters, Major H. Maynard of the Wright Air Development Division in April 1960 headed a cost evaluation team charged with the responsibility of justifying the choice of the Eglin/Patrick Missile Test Range complex for flight testing of the GAM-87A. The group also considered the Edwards

and Holloman installations as possible sites. Eglin already had reported a program slippage if funds were not available immediately for construction of the required facilities. The Strategic Air Command was opposed to consideration of any site other than Eglin for reasons of compatibility with Category III testing to be held there, the opportunity to utilize GAM-77 personnel, facilities and experience available at Eglin, and the proximity to the Eglin Test Range for short range drops and the Atlantic Missile Range for long range missions.[69]

The Air Materiel Command supported the strategic command in its preference since there was a serious shortage in ground support equipment and spare parts at Holloman, and no B-52 support capability available there. On 17 June 1960, the Air Force authorized the research and development command to proceed with the design and modification of the facilities required at the Air Proving Ground Center at Eglin in support of the GAM-87A program.[70] Then, on 14 November 1960, Air Force flight test personnel from Eglin Air Force Base began receiving Skybolt training as the first training class at the Douglas plant was inaugurated.

The first B-52 test aircraft, a -G model, flew from the Air Proving Ground Center to the Boeing-Wichita plant on 10 October 1960, on schedule. Modification work on the aircraft began 15 days later to prepare it for flight testing. Meanwhile, the Strategic Air Command had directed that a B-52G be used in electromagnetic interference control testing the following month at Beale Air Force Base. At the

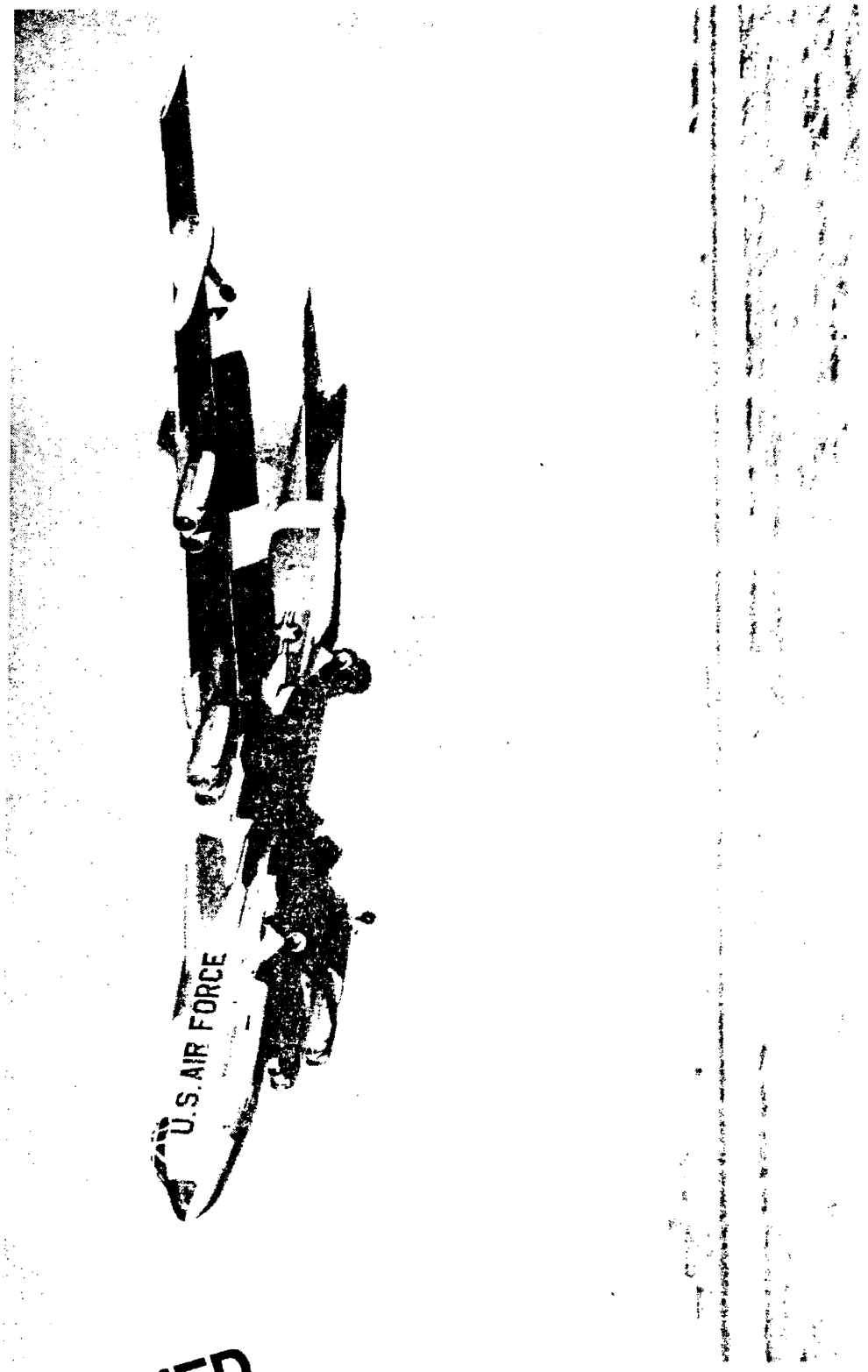

Figure 8. First Skybolt take-off as a B-52G carries four dummy missiles aloft on 12 January 1961.

contractor technical compliance inspection (CTCI) at Boeing-Wichita during the first week of December 1960, the first GAM-87A operationally configured pylon was shown mounted on a B-52G. Contrary to reports published in trade journals at this time, the Wichita test program was on schedule.[71]

Test personnel conducted the initial dummy missile drop test at the Eglin range on 27 February 1961 as the dummy missile dropped from the right inboard position of a B-52G at 40,000 feet and a speed of mach 0.8. The missile impacted 300 feet from the predicted point, exhibiting excellent stability during the free fall. The second drop test, conducted by personnel from Boeing-Wichita at the Eglin range, occurred on 3 March 1961. Released at 16,000 feet altitude, the missile dropped clear without noticeable change in pitch, roll or yaw attitude. Results of these tests indicated that the free-fall trajectory of the missile was predictable for high altitude drops. Aircraft handling and stability were satisfactory.[72]

The first "carry" flight test of four missiles on a B-52G was conducted at the Boeing facility at Wichita on 12 January 1961, a week after the first public appearance of the GAM-87A missile.* The five hour flight was completely successful and the pilot reported no

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* The occasion of the first public display was the B-52H rollout ceremony at Wichita. The demonstration included the first production line B-52H with two mockup Skybolt missiles on each pylon.[74]

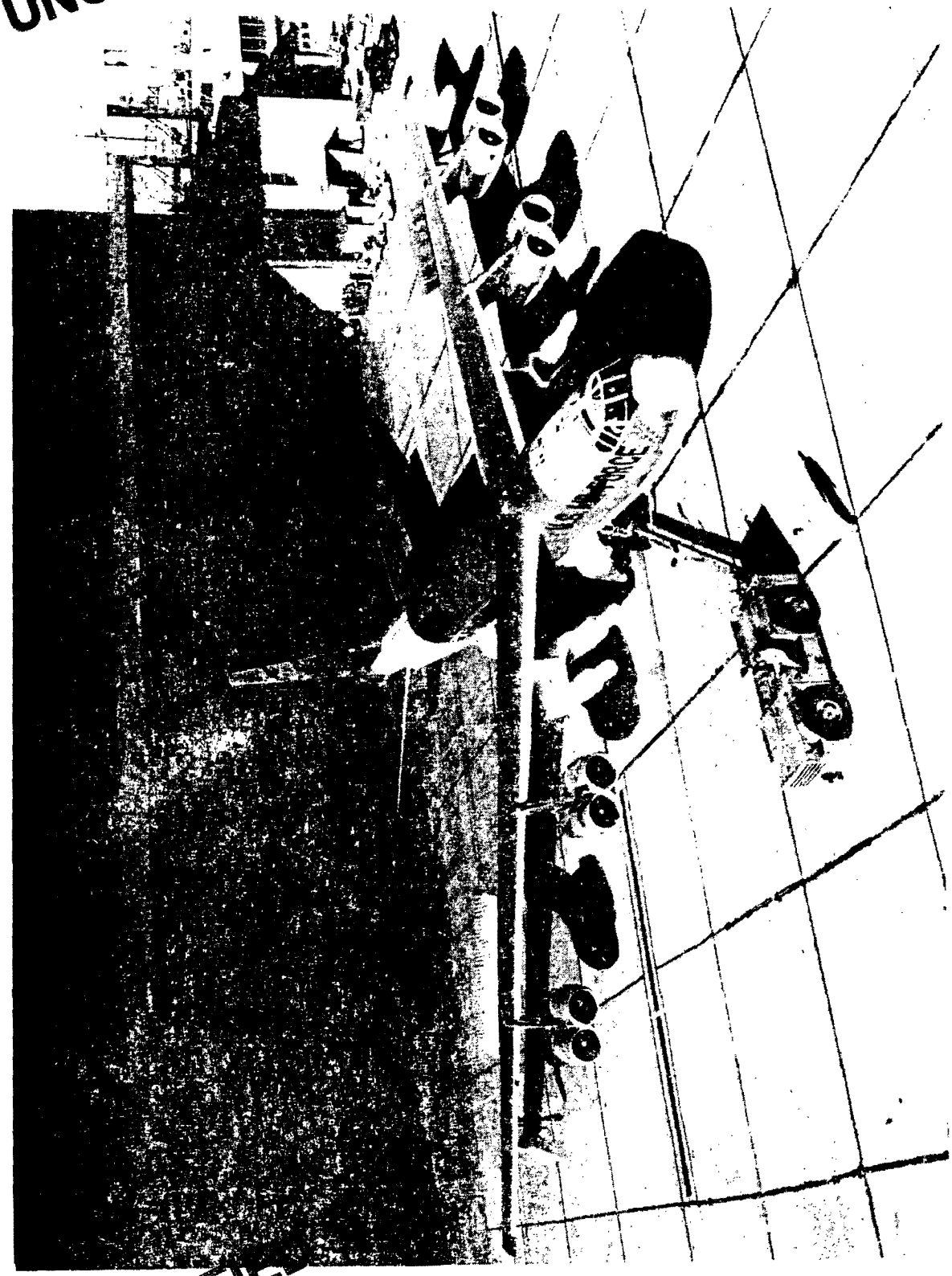

Figure 9. Roll-out of the first production B-52H marked the first public appearance of the GAM-87A.

adverse or unusual flight handling characteristics of the bomber with dummy missiles ballasted to the correct weight and center of gravity for launch missiles. This was the first of a series of Category I flights and was made to demonstrate aerodynamic and structural compatibility. In May, the initial B-52G modified for testing at Eglin reached the test site.[73]

Instrumented missile drops made by Douglas Aircraft personnel beginning on 25 July 1961 followed the two dummy missile tests made by Boeing. These later drop tests involved missiles instrumented with rate gyros and accelerometers to establish the separation dynamics of the missile from the launcher under various conditions and to establish the bomb drop mode trajectory. These drops were completely successful and proved that the missile control system could control the missile after being dropped. The third and instrumented final drop test was made over the Eglin Range on 6 October 1961.[75]

A seven hour flight on 30 November marked the first captive mechanical missile test, during which motor case and motor grain temperatures were gathered. The flight also checked the Azusa and C-band tracking equipment over the Atlantic Missile Range. Motor heater blankets maintained proper propellant temperatures throughout the flight. Other flights in the same series provided information on shock and vibration, sound pressure level measurements, performance of telemetry and the command destruct receiver, and strain gauge

measurements in the missile structure during various conditions in the "carry" mode. Since the major portion of the required data was obtained using the first captive mechanical missile, the Air Force was able to cancel its requirement for a second missile in this configuration.[76]

In Great Britain, the first GAM-87A captive mechanical flight test took place on 7 July 1962 with the missile mated to a Vulcan MK II bomber. Additional environmental and compatibility testing continued during July and August. A second series of captive flight tests was inaugurated on 16 October using a structurally modified Vulcan bomber, permitting the performance of aircraft maneuvers at a higher level of acceleration. United Kingdom test personnel earlier had completed their instrumented dummy drop program with a successful drop over the West Freugh, Scotland, range with the last of six drop tests on 8 February 1962.[77]

The Skybolt missile made its maiden powered flight over the Atlantic Missile Range on 19 April 1962. The test was conducted by prime contractor personnel supported by the Air Force. The first of four programed missile flights, the missile contained an interim programed guidance package and a non-ablative reentry vehicle. All systems were to be tested during these programed launches except the reentry vehicle and guidance subsystem. "Carry" flights made prior to actual launch familiarized the crew with procedures as they checked subsystems.

In the words of the B-52 pilot, the missile ". . . presented a beautiful sight" as it streaked away from the bomber. After a smooth

drop, the missile was properly oriented and controlled by the interim guidance and flight control systems. First-stage operation was normal except for a control system limit cycle which did not appreciably affect the trajectory. Although the first-stage separated at the proper time, tumbling of the second-stage resulted when the engine failed to ignite. Interim guidance and control systems attempted to control the missile and the reentry vehicle separated at the correct interval, impacting in the water about 151 nautical miles from the launch point. Launch had been made at 40,600 feet altitude and a speed of mach 0.8. Flight apogee — its greatest distance from the earth — was 255,000 feet. Analysts could find no specific cause for the failure of the second-stage motor to ignite. Test objectives were to determine performance characteristics of the propulsion and control systems, aerodynamic characteristics of the missile, and the structural integrity and mechanical and thermal environments of the missile. All were partially achieved except the aerodynamic characteristics category which was completed.[78]

On 29 June 1962, the second guided launch was attempted. Launched with a clean drop, the missile operated normally until the first-stage motor failed to ignite. Elevons unlocked and properly oriented the missile, the tail fairing unlatched and the missile continued to fall toward the sea while responding to command elevon deflections. The missile then pitched up beyond its stability limit, the nose dropped below the horizontal position, and the "bird" developed a "coning" motion which

increased until first-stage separation. The second-stage igniter fired properly, but ignition of the propellant did not occur until 13.8 seconds later, by which time the missile was tumbling end-over-end. Two seconds after the second-stage ignited, the missile was destroyed by command when it fell below 10,000 feet. No structural failure seemed to occur.* [79]

Ignition failures after the first two launches prompted the formation of a special group to analyze and evaluate all ignition test data. This joint Air Force-industry body was headed by Charles Perry, Douglas's deputy program director, and convened initially at the Douglas plant on 3 July 1962. A marginal condition apparently existed in the ignition process and the most expedient correction was to redesign the igniter to provide more ignition energy directly to the propellant surface over a longer time interval.[80]

Three contemplated igniter redesigns were designated as Mod I, I-A and II. The first was the same as the original design except holes were drilled in the aft end to provide a "shower head" flame distribution.

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*In a memo dated 20 March 1967 to Mr. John E. Short, Mr. Lorell V. Larson noted that he recalled no indication from telemetry of igniter operation during this flight test:

> There normally would be a small pressure rise in the motor chamber from igniter operation which . . . would rapidly drop back to ambient if the propellant did not ignite. This trail was noticed in records from the second stage of the first launch and enabled us to conclude that ignitor had operated but motor did not ignite. With no pressure rise trail the failure would be chargeable to the programing and sequencing system, not to ignition. I believe this was the true source of failure and not ignition (for PL-2) . . . .

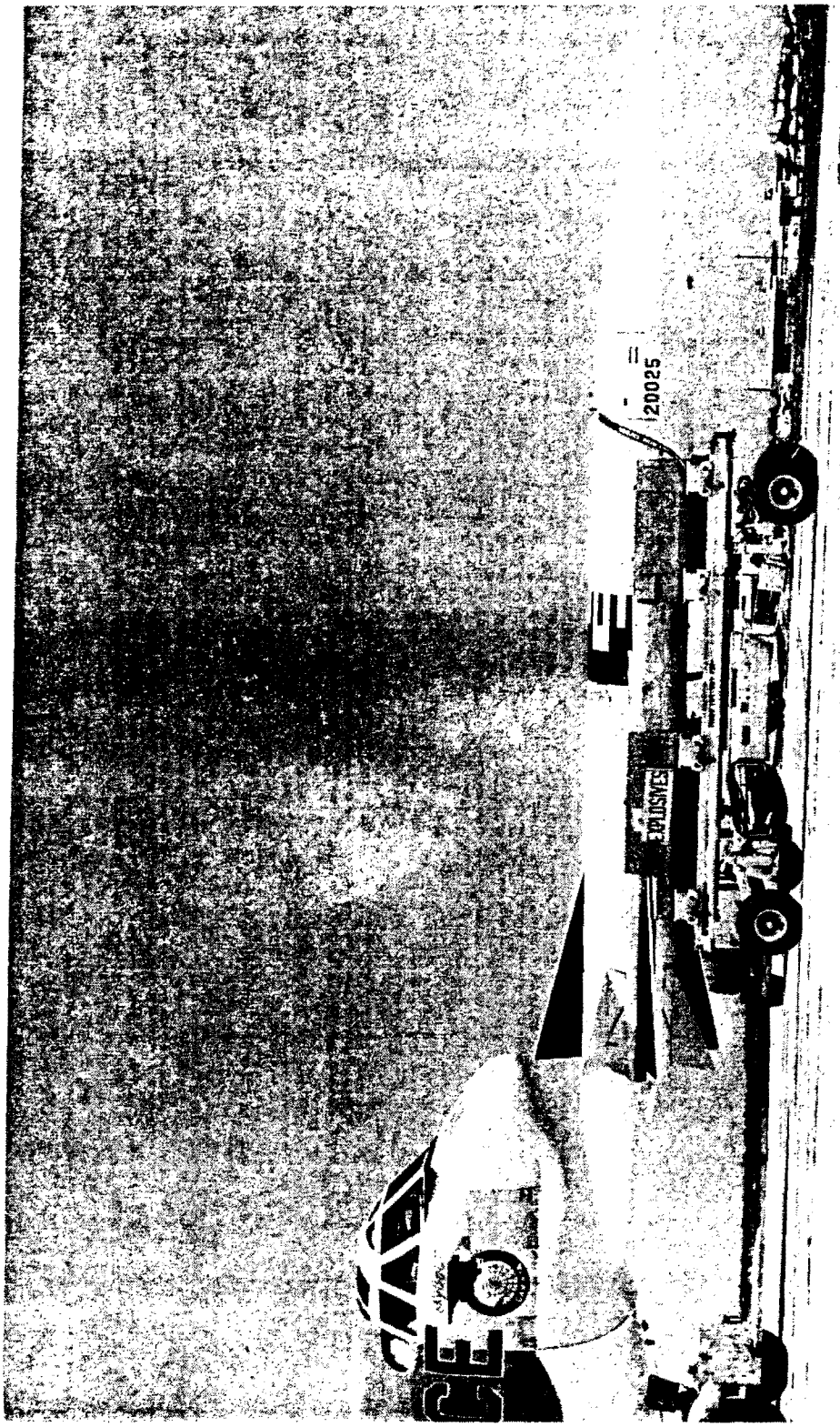


Figure 10. GAM-87A missile Nr. 20025, used for the initial powered free flight on 19 April 1962.

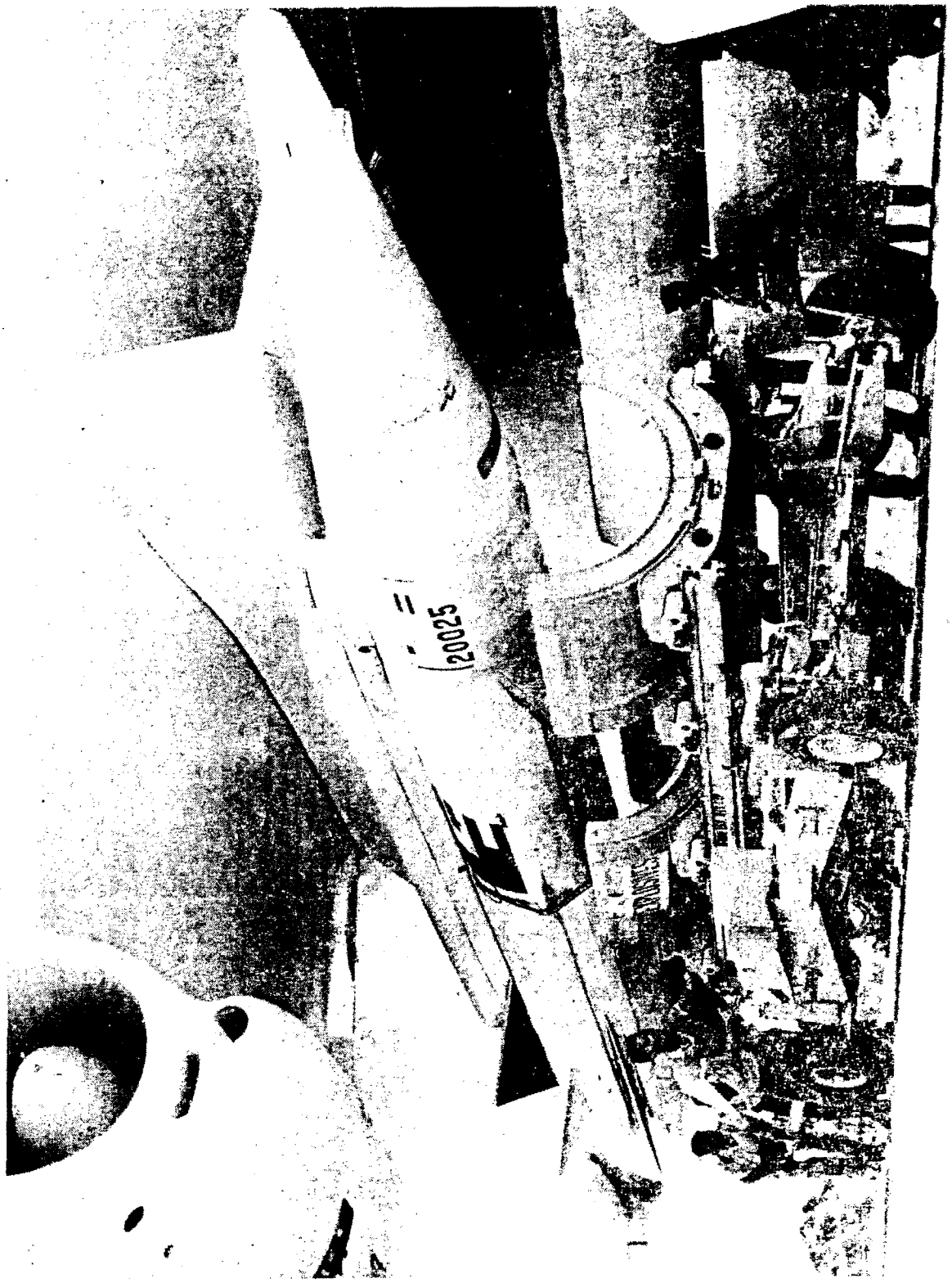


Figure 11. Missile Nr. 20025 mated to a B-52 carrier pylon preparatory to flight testing.

The Mod I-A unit included about 50 percent more charge and more exhaust holes than the original, providing a 50 percent increase in burning duration. Technicians expected this design to provide a backup to the primary redesign configuration, the Mod II.[81]

This varient used a modified "Alclo" composition and included new packaging of the charge to give an anticipated three times greater burn duration and a 50 percent increased in total energy. It featured a shower head flame distribution but had no aft end opening. The design incorporated all the desired improvements, but had to be fabricated and tested. After extensive testing, a variation designated as the Mod II-C was selected. Eighteen first and 24 second-stage igniters of the new design were examined, indicating improved ignition characteristics with no significant damage revealed at post-firing examination of the hardware. Three first-stage and four second-stage motors using the Mod II-C unit were fired successfully in an altitude simulation chamber at the Aerojet-General Corporation's facility, showing improved ignition characteristics. Following up, Douglas and Aerojet-General engineers initiated a long term study project aimed at improving ignition system reliability. The redesigned igniter appeared to have satisfactorily solved the problem of ignition failures, increasing the confidence for the launch of the third programed missile following eight successful full scale motor firings and 34 ignition module tests.[82]

On 13 September, the launch of the third programed missile, Number 20027, met with little success. Due to a failure in the programmer timer circuitry, the missile failed almost immediately after launch permitting accumulation of only a limited amount of test data. Immediately after

launching, the second-stage gas generator ignited at the same time as normal ignition in the first-stage gas generator. Within a few seconds, when the first-stage safe-and-arm devices armed, the first-stage with tail fairings still attached separated and underwent automatic destruction. Second-stage motor ignition occurred when the second-stage safe-and-arm devices armed about 40 seconds after. Ignition was followed by chamber pressure buildup and burning until command destruct was ordered when the erratically flying second-stage approached the range safety limits. All indications did point to satisfactory operation of the redesigned igniter, however.[83]

The fourth and last programed missile, Number 20028, was launched from its B-52G carrier on 25 September 1962. Although first-stage performance appeared normal, all telemetry data was lost at the time of second-stage ignition. Thrust reversal action occurred early during second-stage performance, resulting in less than the programed range and trajectory.[84]

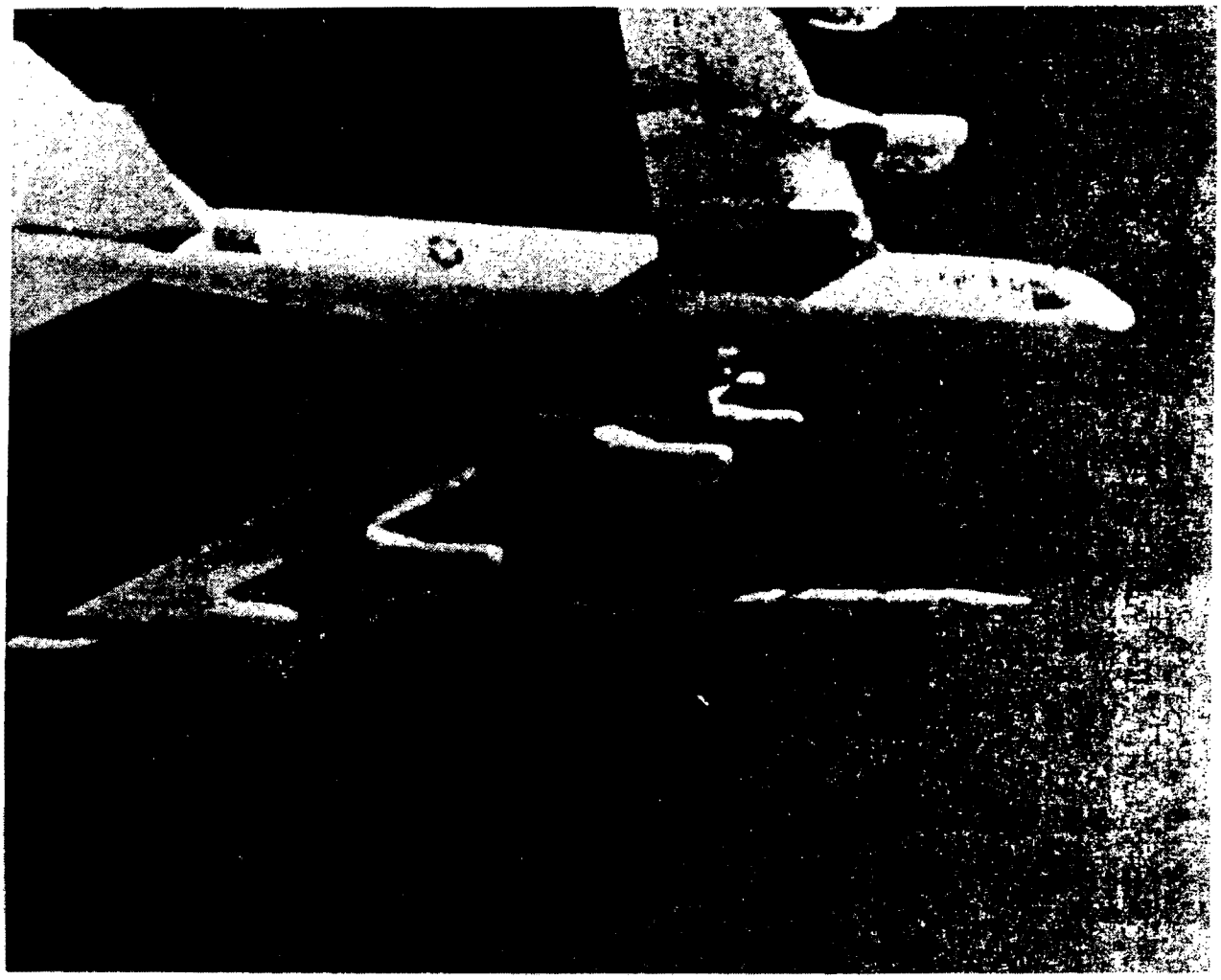
The results of the programed launches indicated that 80 percent of the primary test objectives had been achieved. Primary first-stage objectives were completed while second-stage objectives were 60 percent complete. The motor ignition problem resulted in a successful igniter and ignition train redesign. Autopilot instability evidenced in the limit cycle oscillation in the first programed launch was solved through additional bungee testing and filter network change prior to the second launch. Flight control instability encountered on the first and last programed launches was countered with additional wind tunnel testing,

reduced angle-of-attack on early guided launches, and new roll orientation on the third launch. While sequencing failures limited the amount of second-stage data obtained, functional operation of all first-stage systems was verified in the two successful first-stage flights. Operation of the guidance system during the critical prelaunch period had been particularly successful.[85]

The primary objective of the early guided rounds was to verify the functional operation of the guidance system in both the prelaunch and post-launch mode, and to verify the compatibility of the guidance system with the flight control system. The fifth and sixth launches in the flight test program were fully guided launches and employed the tactical guidance system. On 28 November 1962, the prelaunch alignment and navigation function was satisfactorily demonstrated for four and a half hours. Then on 22 December the equipment operated flawlessly for three more hours. These tests included 292 successful star acquisitions with stars down to 2.75 magnitude in full daylight; a total of 25 hours flight test time was accumulated on the tactical system carry flights.[86]

While the prelaunch operation of the guidance system was successful, the initial guided launch on 28 November terminated prematurely. The primary in-flight failure occurred during first-stage burning and involved the hydraulic power unit. The ballistic computer malfunctioned after 37 seconds of flight including 23 seconds at vibration levels which exceeded those for which the equipment was designed. A mission review panel, convened at Eglin Air Force Base on

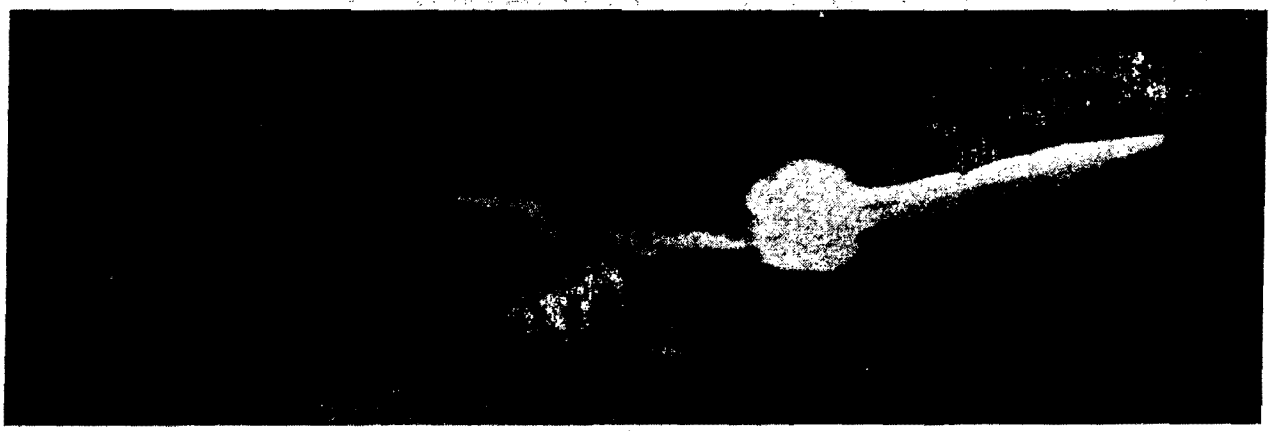
A typical sequence of operation for a Skybolt missile launch from a B-52 carrier aircraft is shown in the following pictures.



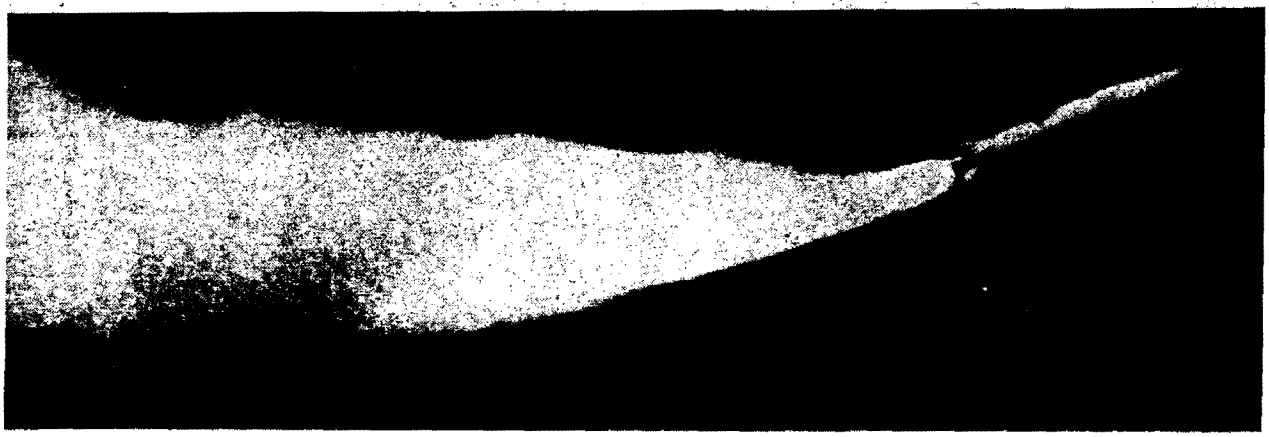
Missile in free flight immediately after release from the carrier.

Figure 12.

Missile prior to first stage ignition. Smoke trail provided from hot gas system operation.



First stage firing of the missile.



Full power, pitch up condition shows missile is ready to continue on its programmed flight.

Figure 13.

29 November, concluded that the missile loss of stability after 14 seconds of free flight was the direct result of a malfunctioning gas generator and hydraulic subsystem. All other systems operated within mission limits to the time of failure; abnormal performance of various systems could be explained by the erratic performance of the missile until time of impact in the sea.[87]

The second guided launch occurred on 22 December 1962, one day after the meeting between President Kennedy and Prime Minister Macmillan. It was hardly the most auspicious occasion since the British were outraged by the program's cancellation. A Department of Defense spokesman indicated that on 21 December Air Force Undersecretary Dr. Joseph V. Charyk discussed the test plan with acting Secretary of Defense Roswell L. Gilpatric "who decided not to instruct the Air Force to cancel or postpone the test on December 22."

Missile Number 20032 soared into the blue Atlantic sky from under the wing of its B-52 carrier giving every indication of a successful flight. Although no ablative reentry vehicle was used Air Force computations made from the missile's position and velocity at the precise time that the guidance system commanded thrust termination and reentry vehicle separation indicated that the vehicle would have impacted approximately 847 nautical miles downrange.* Duration of the flight would have been approximately 700

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* The Department of Defense later argued that further calculations indicated the missile's impact point would have been about 100 statute miles beyond its predicted target area. Wording of the Air Force news release on 22 December brought criticism from Arthur Sylvester, Assistant Secretary of Defense for Public Affairs, who took issue with the misleading release which

seconds and all planned test objectives appeared to have been achieved.[88]

A few hours after the test, Mr. Gilpatric issued a statement indicating the test firing had been scheduled prior to the Kennedy-Macmillan meeting. In his remarks, he noted: "Today's single test did not conclusively demonstrate the capacity of the missile to achieve the target accuracy for which the Skybolt system was designed . . . It is always expected that some tests of this sort should succeed and that others will fail . . . Doubts as to the prospect of success of the Skybolt system in its entirety and its reliability when operational were among the factors responsible for the recommendation of the Secretary of Defense against further funding the program. The results of today's test have not caused any change in that position."[89]

Various elements of the news media trumpeted the test success, predicting a possible reversal of the decision to cancel production. Despite the clamor raised among proponents of the air launched ballistic missile in both houses of the U. S. Congress, (with threats of retaliation or investigation) the program died a relatively peaceful death, as mourners soon turned their attention to other vital issues of the day.

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stated the missile had "impacted in the target area hundreds of miles down range." A Defense Department spokesman pointed out that the missile had no reentry vehicle and had burned up in the air.[90]

CHAPTER V

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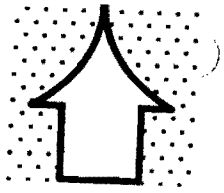

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APPENDIX A

R&D Cost Comparison Summary[1]

	January 1960 Contractor Est.	June 1960 Contractor Proposal	August 1960 Budget AF Adjustment Costs
Douglas	91.2	135.9	125.6
Aerojet-General	42.2	37.4	32.6
GE	9.5	36.0	32.6
Nortronics	51.7	119.0	113.0
Boeing		.5	.5
Other sub-contractors	2.9	1.6	1.6
Fee	13.8	22.2	18.4
Subtotal	211.3	352.6	324.3
Training			5.0
ECP's			32.4
GFAE			9.5
Facilities			.8
Total			372.0

R&D Costs (AF Estimates in Millions of Dollars)

	April 59	January 60	August 60
FY 59	3.0	3.0	3.0
FY 60	41.2	35.0	35.0
FY 61	100.0	79.3	149.0
FY 62	40.0	71.6	110.9
FY 63		27.3	57.4
FY 64		3.0	16.7
Total	184.2	219.2	372.0

(Ibid.)

Production Costs (Total Procurement 1000 Missiles)

	May 59	January 60	August 60	
FY 60	40.1			
FY 61	142.8			
FY 62	87.2	125.3	162.2	
FY 63	105.0	230.0	368.6	
FY 64	14.2	280.0	417.6	
FY 65		69.0	45.6	
Total	389.3	704.3	994.0	(Ibid.)

APPENDIX B

United Kingdom Participation

The United Kingdom expressed an interest in the proposed air-launched ballistic missile while the program was still in its infancy. The initial Joint United States Air Force -- Royal Air Force Task Group for strategic air-to-surface weapons met in Washington in April 1958. On 2 March 1960, in London, United States representatives briefed the Ministers of Defense and Aviation, Lord Mountbatten, Air Marshall Pike and others, providing a basis for the British decision to participate in the program.

At a meeting at Camp David, Maryland, the same month, President Eisenhower and British Prime Minister Harold Macmillan reached an agreement by which the United States would sell Skybolt missiles to Britain for application to the United Kingdom's force of Vulcan jet bombers. The March agreement also provided that American Polaris-armed submarines would be permitted berthing rights at a base in Scotland. "There was no quid pro quo between the Skybolt and Polaris programs," J. H. Rubel, Assistant Director of Defense Research and Engineering, stated. A month after this March agreement, Britain announced the cancellation of its land-based Blue Streak missile program.[2]

On 4 June 1960, the British Joint Project Office was created at Wright-Patterson Air Force Base to work with American project office personnel in coordinating United Kingdom participation. Two days later,

Defense Secretary Thomas Gates and Britain's Defense Minister Watkinson signed a general agreement confirming the two nations' plans for the joint venture. The United Kingdom was to participate in development of the system and would pay all costs directly relating to adaptation of the missile to the Vulcan and to flight testing. The initial order was for 100 missiles. A Joint Anglo-American Planning Conference at Wright Field on 14-20 September 1960, enabled representatives to define tentative areas of responsibility, schedules and potential problem areas. On 27 September, officials of the two nations signed a Joint Technical Agreement on funding and contractual procedures.[3] *

Under the technical and financial arrangement, the Air Force would make available to the British Ministry of Aviation on a reimbursable basis, missiles and associated equipment, spare parts and modifications kits, and necessary operating data. Both parties would cooperate at all stages of warhead development to insure the maximum practical compatibility between the American and British warheads, reentry vehicle and missile. All Air Force-incurred costs that would not have arisen but for United Kingdom participation would be borne by the British government. If the United States at some future

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*In October 1960, only a month after the British-American agreement was concluded, the program was in "jeopardy". According to Aviation Week, only combined British and Air Force pressure kept it alive. In December 1960, Defense Secretary Gates, a member of a lame-duck administration, informed British Defense Minister Harold Watkinson that the program was having heavy going.

date were to decide not to proceed with the project at a time before the United Kingdom requirements had been fulfilled, the Air Force was to furnish full details of the progress achieved and would endeavor to insure continued cooperation of American contractors if the British elected to continue the program alone.[4]

Although original plans called for Skybolt compatibility with both the British Vulcan and Victor bombers, the latter aircraft was eliminated soon after a visit to this country by Royal Air Force officials in August 1960. At that time, Britain stated it would adopt its warhead to fit the Skybolt reentry vehicle then under consideration for the light warhead configuration. As of November 1960, the estimated cost of the United Kingdom's portion of the research and development program was $47 million.[5] *

The first of ten Royal Air Force squadrons of eight Vulcan bombers was to be GAM-87 equipped during the third quarter of calendar year 1964. Unit equippage was 18 missiles per squadron. Delivery of operational missiles to the United Kingdom was to begin in September 1964.[7]

British officials planned to launch 12 guided missiles during the research and development program, with the test series to begin in December 1963, and terminate the following September. Flight testing

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*As of 31 December 1962, Mr. Rubel estimated that the United Kingdom had spent $25 million in the United States to cover the cost of testing Skybolt with the Vulcan bomber.[6]

of the GAM-87 with the Vulcan MK II began on 7 July 1962 with a captive mechanical missile test flight. Adequate performance of the missile and carrier was recorded as the capabilities of ground, aircraft and missile instrumentation and telemetry systems were tested. The second flight of the series occured on 31 July at Woodford, England. The sixth and final flight of the Vulcan captive mechanical missile tests took place on 31 August. Modifications made on another Vulcan test aircraft permitted the inauguration on 16 October of a second test series involving more severe carrier aircraft maneuvers.[8]

APPENDIX C

GAM-87A Schedules as of Program Termination[9]

R&D Milestones	1 February 1960 Orig. Est. Date for Accomplishment	1 June 1961 System Program Package	Actual Date of Accomplishment	Forecast Date for Accomplishment
R&D Go-ahead	Feb. 1960	Feb. 1960	Feb. 1960	
DEI	Aug. 1960	Aug. 1960	Aug. 1960	
First Drop Missile	Feb. 1961	Feb. 1961	Feb. 1961	
Start Cat. I Testing	April 1961	July 1961	July 1961	
Start Vulcan Compat. Test (U. K.)	March 1961	Sep. 1961	Aug. 1961	
1st Programed Launch	Aug. 1961	Jan. 1962	April 1962	
Start Vulcan Environ. Tests (U. K.)	April 1962	April 1962	April 1962	
Production Funds	March 1962	July 1962	July 1962	
1st Guided Launch	Jan. 1962	Oct. 1962	Nov. 1962	
Start Vulcan Trials (Eglin)	March 1963	April 1963		March 1963
Start Cat. II Testing	Oct. 1962	Oct. 1963		Nov. 1963
Start Cat. III Testing	Sep. 1963	April 1964		April 1964
1st Sqd. Operational (USAF)	March 1964	Oct. 1964		Oct. 1964
1st Station Operational (UK)	Sep. 1964	March 1965		March 1965

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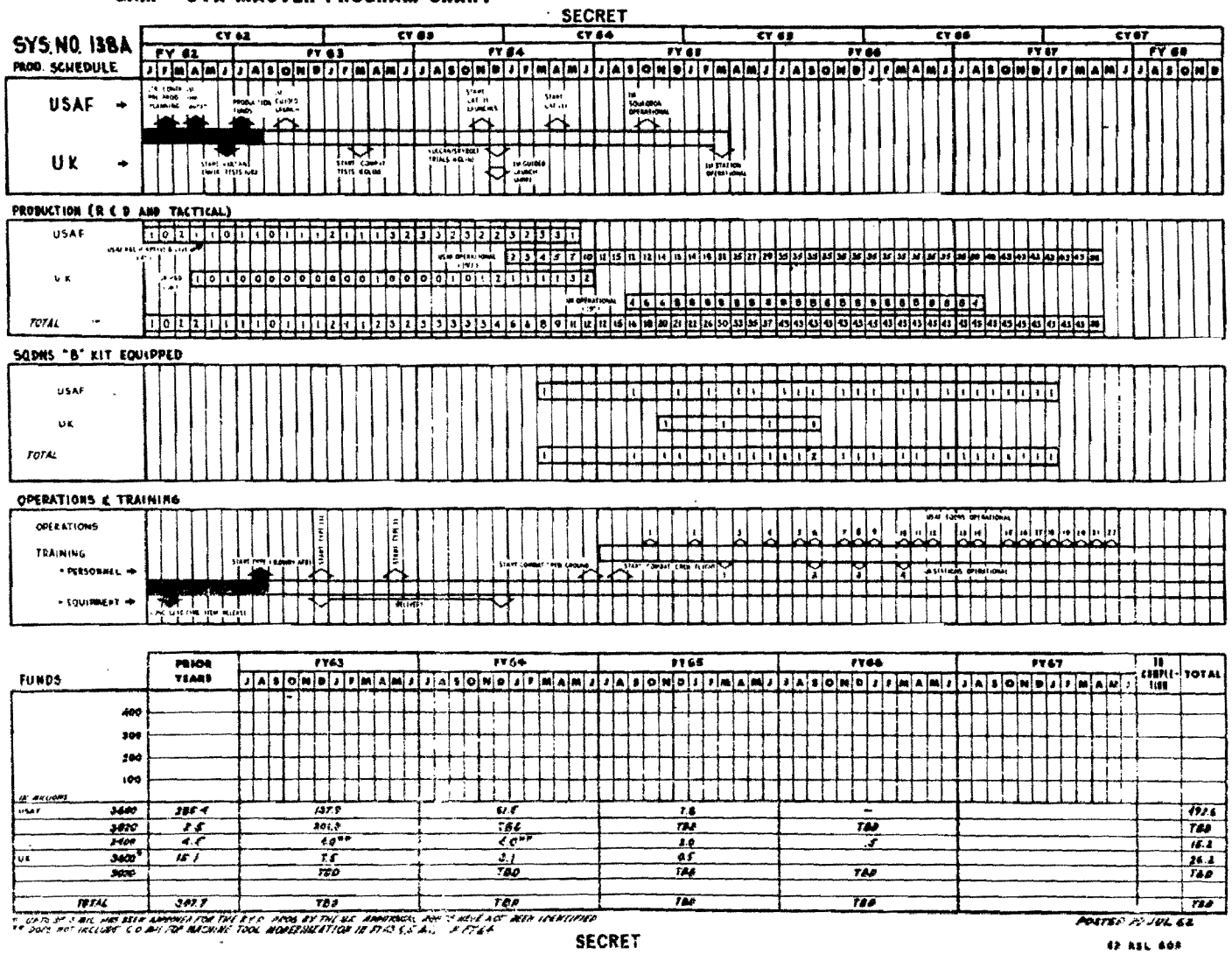
(Extracted from GAM-87A Hist. Rpt., Jan—June 1962)

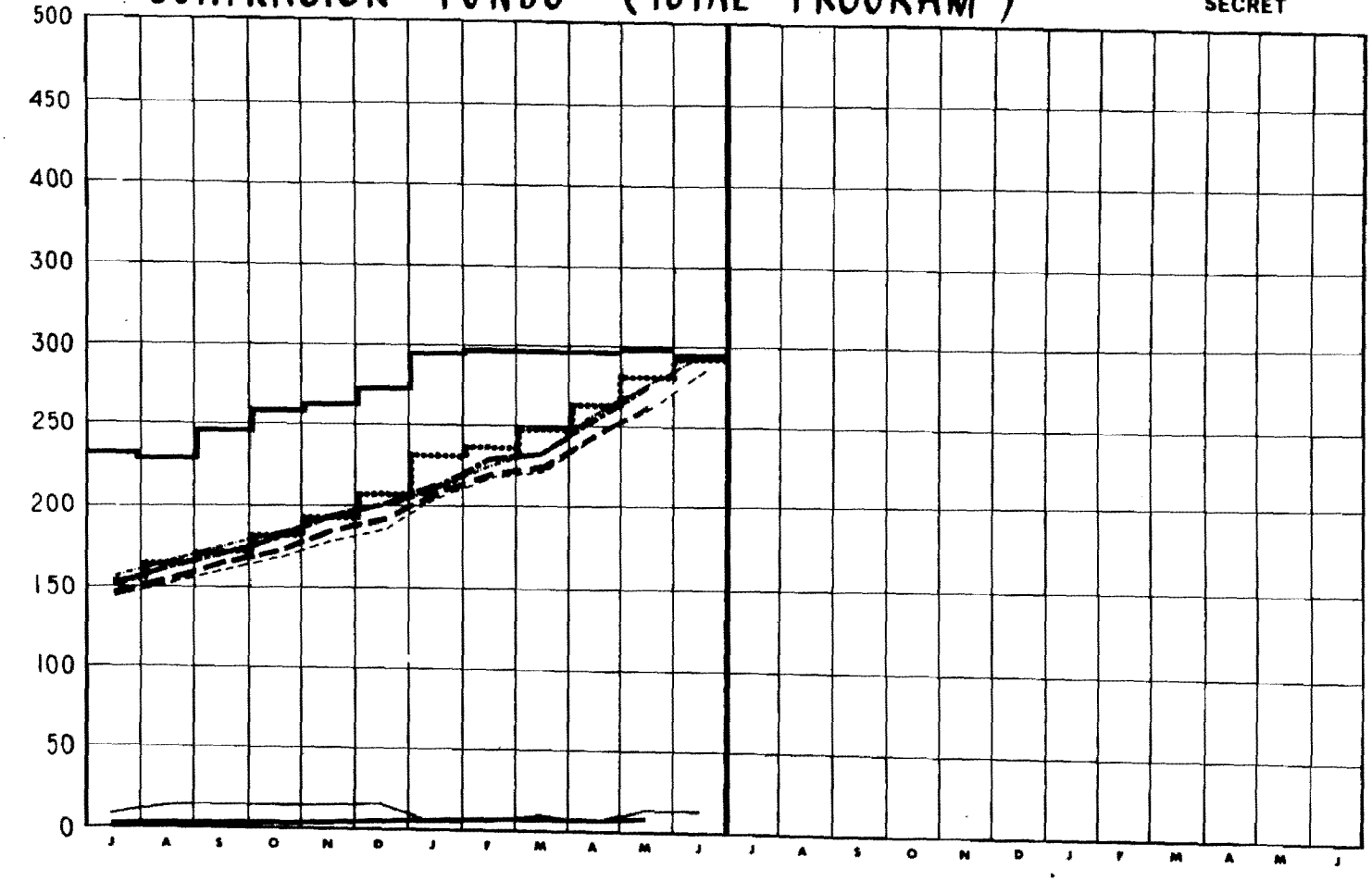


APPENDIX D

July 1962 Master Program, contractor funds, contractor manpower and government financial charts.

CONTRACTOR FUNDS (TOTAL PROGRAM)

GAM-87A

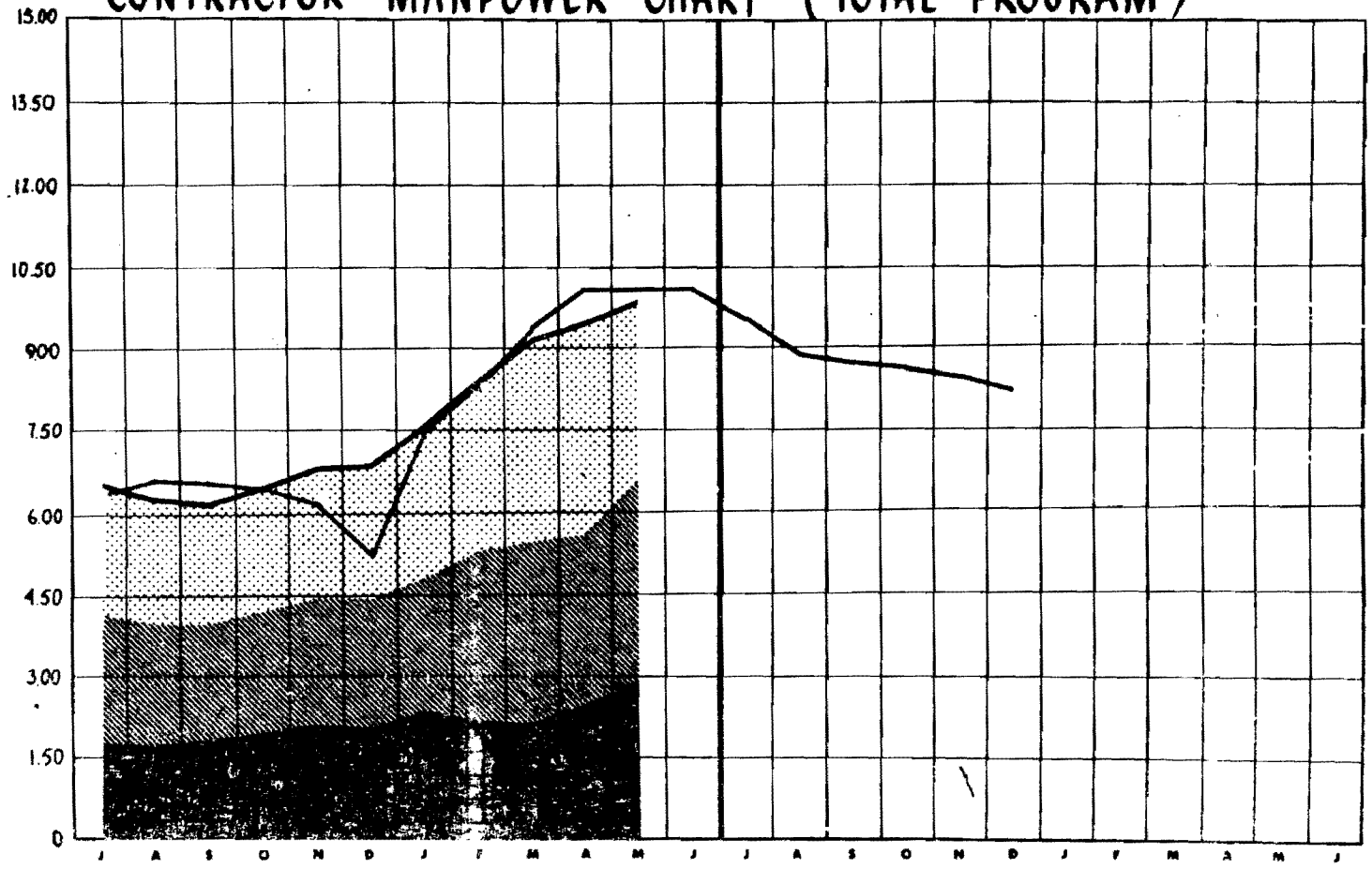


LEGEND	J	A	S	O	N	D	J	F	M	A	M	J
APPROVED PROGRAM	241.0	238.5	247.8	259.3	262.5	272.7	296.6	298.1	298.1	298.1	298.9	294.1
AF OBLIGATION	155.9	166.3	171.1	183.1	193.1	217.7	231.3	237.3	249.3	263.1	280.0	294.1
CONTR COMMIT FORECAST	156.0	165.5	174.0	182.6	191.2	200.0	213.4	226.4	242.7	257.0	275.5	292.5
CONTR COMMIT ACTUAL	152.6	162.6	171.3	181.5	192.6	200.9	216.0	229.2	243.1	257.4	276.2	
CONTR EXPEND FORECAST	146.0	153.0	160.0	168.8	177.6	186.5	205.9	218.5	233.4	247.8	263.2	279.9
CONTR EXPEND ACTUAL	147.1	156.5	165.1	174.8	185.7	193.8	208.0	220.1	233.0	247.7	266.1	
UNLIQ COMMIT FORECAST	10.0	12.5	14.0	13.8	13.6	13.5	7.5	7.9	9.3	9.2	12.3	12.6
UNLIQ COMMIT ACTUAL	5.5	6.1	6.1	6.7	6.9	7.1	8.0	9.1	10.1	9.7	10.1	

62 ASL 1041

GAM-87A

CONTRACTOR MANPOWER CHART (TOTAL PROGRAM)



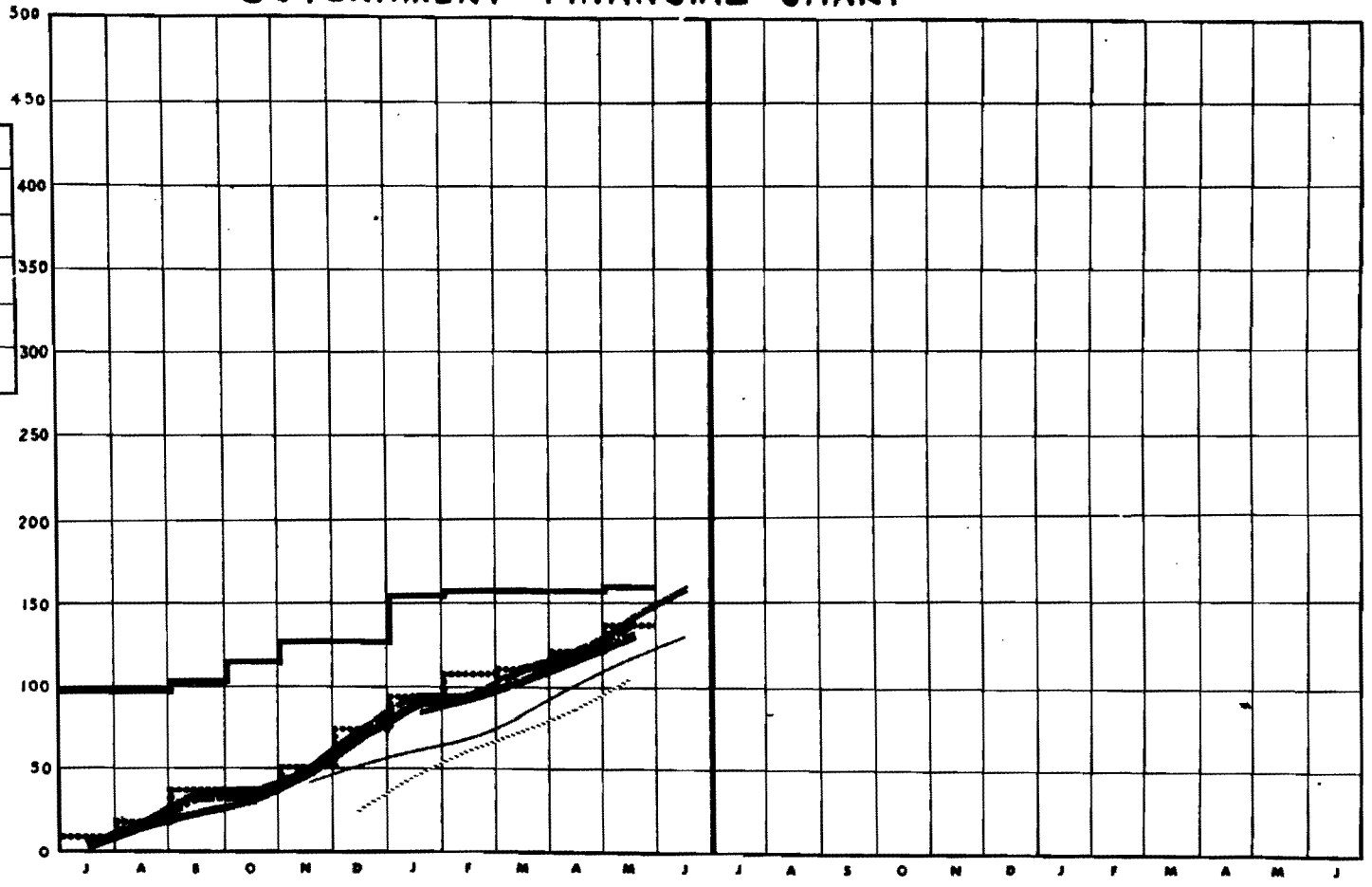
LEGEND		FY 1962											FY 1963											
TOTAL FORECAST		6.32	6.58	6.56	6.41	6.12	5.75	8.03	8.58	9.36	9.79	10.11	10.03	9.57	8.82	8.78	8.46	8.30	7.93					
TOTAL ACTUAL		6.41	6.18	6.10	6.42	6.78	6.92	8.10	8.78	9.28	9.43	10.02												
SCIENTIFIC & ENGR.		2.39	2.22	2.15	2.27	2.36	2.45	2.86	3.11	3.28	3.28	3.19												
ENGINEERING SUPPORT		INCLUDED IN SCIENTIFIC & ENGINEERING LINE																						
MANAGEMENT & ADMIN.		2.33	2.28	2.16	2.25	2.37	2.44	2.92	3.17	3.41	3.46	3.73												
CRAFTS & PRODUCTION		1.61	1.62	1.73	1.86	1.99	1.97	2.26	2.42	2.49	2.58	2.98												
OTHERS		0.07	0.07	0.06	0.05	0.05	0.06	0.06	0.08	0.10	0.10	0.13												

GOVERNMENT FINANCIAL CHART

GAM-87A

PRIOR YEARS FY 59, 60 & 61	
PROGRAM $	155 06
UNINITIATED	0
UNCOMMITTED	0
UNOBLIGATED	0
UNEXPENDED	0

DOLLARS IN MILLIONS



LEGEND

APPROVED PROGRAM		99.0	99.0	104.5	115.8	129.7	129.7	157.0	158.5	158.5	158.5	158.4	
BUDGET AUTH		10.0	19.0	39.0	39.0	51.3	75.3	95.8	107.6	111.6	123.6	139.5	
INITIATIONS	FORECAST	7.5	19.0	38.9	38.9	50.7	73.8	94.8	96.8	115.3	123.5	141.0	159.4
	ACTUAL	* 7.5	19.0	38.5	38.5	50.8	75.1	95.7	95.6	110.7	122.9	137.9	
COMMITMENTS	FORECAST	7.5	19.0	37.6	37.6	47.6	72.5	94.2	94.7	114.4	121.6	141.0	159.4
	ACTUAL	* 7.5	19.0	37.1	37.1	47.6	73.5	93.9	93.9	107.0	120.8	137.7	
OBLIGATIONS	FORECAST	7.5	19.0	25.6	37.6	47.6	72.5	91.8	92.7	108.9	119.5	139.7	158.2
	ACTUAL	* 7.5	17.9	25.1	37.1	47.6	72.2	88.5	92.6	105.2	119.1	136.3	
EXPENDITURES	FORECAST	-	-	-	-	42.0	92.0	62.0	67.8	84.1	100.7	115.8	132.4
	ACTUAL	0	0	0	0	0	29.0	45.3	62.0	74.8	86.5	103.2	

* 2.5 M FY 61 FUNDS INITIATED, COMMITTED & OBLIGATED IN JULY 61, RESULTING IN TOTAL I, C & O IN JULY OF 10.0 M.

CONFIDENTIAL
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APPENDIX E

Financial Status Recapitulation, Contract AF33(600)-39587[10]

Funded to Date Instrument	Funded to Date (January 1963) Increase	Total Value of Contract
Definitive	$136,636,800.00	$136,636,800.00
ASC-POOD-61-1	3,280,800	139,916,800
ASC-POOD-61-2	43,200	139,960,000
ASC-POOD-61-3	260,000	140,220,000
ASC-POOD-61-4	780,000	141,000,000
C. O. #4	2,100,000	143,100,000
ASC-POOD-61-5	500,000	143,600,000
S. A. #8	4,818,186.56	148,418,186.56
POOD-62-6	1,000,000	149,418,186.56
S. A. #9	4,181,813.44	153,600,000.00
C. O. #11	1,295,000	154,895,000
S. A. #12	3,591,584.56	158,486,584.56
POOD-62-7	1,600,000	160,086,584.56
S. A. #13	3,808,416	163,895,000.56
C. O. #15	1,091,584	164,986,584.56
POOD-62-8	1,500,000	166,486,584.56
S. A. #16	4,613,416	171,100,000.56
S. A. #17	10,325,000	181,425,000.56
POOD-62-9	1,730,000	183,155,000.56
POOD-62-10	1,200,000	184,355,000.56
S. A. #18	8,800,000	193,155,000.56
S. A. #19	19,000,000	212,155,000.56
POOD-62-11	5,600,000	217,755,000.56
POOD-62-12	10,000	217,765,000.56
POOD-62-13	10,000	217,775,000.56
POOD-62-14	6,000,000	223,775,000.56
S. A. #20	13,510,000	237,285,000.56
S. A. #23	5,235,000	242,520,000.56
POOD-62-15	5,000,000	247,520,000.56
POOD-62-16	845,000	248,365,000.56
S. A. #24	11,200,000	259,565,000.56
POOD-62-17	1,100,000	260,665,000.56
S. A. #25	13,549,000	274,214,000.56
POOD-62-18	3,349,000	277,563,000.56

Financial Status Recapitulation, Contract AF33(600)-39587

Funded to Date Instrument	Funded to Date (January 1963) Increase	Total Value of Contract
S. A. #27	$ 12,245,000	289,808,000.56
POOD-62-19	1,200,000	291,008,000.56
C. O. #28	576,298.04	291,584,298.60
S. A. #29	7,614,000	299,198,298.60
POOD-63-20	1,898,000	301,096,298.60
POOD-63-21	2,000	301,098,298.60
POOD-63-22	86,000	301,184,298.60
C. O. #30	1,000,000	302,184,298.60
S. A. #31	15,400,000	317,584,298.60
POOD-63-23	2,000,000	319,584,298.60
S. A. #33	8,700,000	328,284,298.60
POOD-63-24	2,000,000	330,284,298.60
POOD-63-25	160,000	330,444,298.60
POOD-63-26	140,000	330,584,298.60
S. A. #34	29,800,000	360,384,298.60
POOD-63-27	5,420,000	365,804,298.60
POOD-63-28	100,000	365,904,298.60
POOD-63-29	180,000	366,084,298.60
S. A. #37	10,975,000	377,059,298.60
POOD-63-31	275,000	377,334,298.60
POOD-63-32	500,000	377,834,298.60
S. A. #39	950,000	378,784,298.60
S. A. #40	12,450,000	391,234,298.60

Figure 14. BRIGADIER GENERAL DAVID M. JONES,

ASD Deputy Commander/GAM-87

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APPENDIX F

Biography of Brigadier General David M. Jones

General Jones born on 18 December 1913, served in the armed forces since his enlistment in the National Guard in 1932. After a year on active duty with the 8th U. S. Cavalry, he entered pilot training in the summer of 1937. In March 1942, Jones volunteered for the secret Doolittle Project and was instrumental in the planning and training for the attack on the Japanese mainland. After the raid, he bailed out over China, later receiving the Distinguished Flying Cross for his role as a Flight Commander on the mission.

In September 1942, he was assigned as Group Commander of the 319th Bomb Group in North Africa. Shot down on his fifth raid in December 1942, he spent two and a half years as a prisoner of war in Stalag Luft III. His constant agitation and harassment of the enemy earned him a letter of commendation from the senior American officer in Stalag Luft III.

General Jones started formal work in research and development in 1956 while being assigned as Deputy Chief of Staff/Plans and Operations at the Air Proving Ground Center. He was later selected as director of the B-58 test force organized in February 1958 as the first such force (over 1,000 men) formally organized by the Air Force.

Until his assignment as Vice-Commander of the Wright Air Development Division in September 1960, he had flown more hours testing the B-58 than any other Air Force pilot. From 1 April 1961, he filled the post of vice-commander of the newly formed Aeronautical Systems Division until his move to the position of Deputy Commander/GAM-87 in October 1961.[10]

APPENDIX G

Operational Sequence of the GAM-87 Guidance System

When all elements of the guidance subsystem reached their respective operable temperature ranges, the system was placed in operation. Gyros came up to speed, the platform gimbal control servos were activated, and the platform was slewed to approximately a vertical position. The best available present position information then was transferred to the prelaunch computer upon initiation of a signal by the B-52 navigator. The heading of the B-52 carrier continuously was transferred to the prelaunch computer from the bomb/navigation system through the analog-to-digital computer in the bomber. The computer then initiated fine leveling of the platform and star search by the astrotracker mounted on the inertial platform. The prelaunch computer then searched the list stored in memory for stars in the astrotracker's field of vision at which time the computer selected a bright star for the initial search, computed telescope azimuth and elevation angles, and commanded the telescope to them.

When the star was found, the astro-tracker switched from a search to a track mode, using a 13-pointed star pattern. Detection points taken by the prelaunch computer as the position of the star in relation to that of the platform. The prelaunch computer then

selected the next star to be tracked and corrected the estimate of platform inertial attitude based on the newer data with two star lines determining the orientation of the platform.

As the carrier aircraft came within range of the target, the launch sequence was initiated. At this time, the prelaunch computer determined a predicted time-zero position by extrapolation from its present position and velocity. The time of flight and range angle to the target were then fixed and the trajectory plan and target bearing at time-zero computed. The initial velocity-to-be-gained vector was computed in platform coordinates from range angle, time of flight, latitude, and target bearing. The ballistic reference frame was defined and rotation from accelerometer system was computed. The prelaunch computer generated co-efficients for Q-guidance, programed steering, autopilot gains, arming and sequencing commands. Targeting parameters were then transferred to the ballistic computer in the missile and data transfer verified. The actual launch occurred soon after time-zero.

At the time of launch, the ballistic computer began a continuous computation of velocities-to-be-gained in the ballistic trajectory coordinate system. The first portion of flight was a free-fall lasting approximately two seconds. During first stage motor operation, the ballistic computer generated commands to the flight control system for a programed pitch-up steering maneuver. A coasting period of five to 30 seconds followed first-stage burnout, depending on launch conditions.

During second stage operation, commands to the control system were based on computed velocities-to-be-gained. Pitch and yaw commands were generated to drive lateral velocities to zero. When longitudinal velocity-to-be-gained reached a predetermined value based on the thrust decay profile, a thrust reversal signal was generated. Depending upon target range, second stage burning varied from 10 to 42 seconds. Thrust reversal caused the second stage to back away from the reentry vehicle, which continued on its ballistic path to the point of detonation.[11]

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APPENDIX H

GAM-87 ENGINEERING MEMORANDUM NO. 11 11 April 1961

SUBJECT: Vulnerability of GAM-87A To SA-5 Defensive System, Preliminary Study (S)

1. Recent studies by ATIC indicate that the Soviet Union may have in development a missile defense system designated the "SA-5" with the radar and missile capabilities and parameters as listed in Table I. One such system with a battery of 12 missiles could be in operation near Moscow or other selected site by late 1964. The total radar system includes Early Warning radars but it is most probable that the GAM-87A will be fired from behind these radars or so close to them that it is doubtful that they will ever see it. The following analysis therefore assumes that no early warning is available. It is furthermore probable that no useful tracking information will be available from Soviet AC & W sites because of the small target size, the altitude of most of the trajectory and choice of launching positions.

2. If the above assumptions hold true, initial trajectory analysis must come from the acquisition radar. This radar probably has a sweep time over its 40° azimuth range of 12 seconds. At least three "hits" on the GAM-87 re-entry vehicle will be required to compute a rough trajectory and identify the vehicle as dangerous to the target being protected by the system of which the acquisition radar is part. The pickup ranges shown on the trajectory graphs (Fig.2, 3, 4,) are based upon 50% probability of a radar return being above the noise level. It is therefore probable that six sweeps across the target will be required for identification and trajectory analysis. This would take 6 x 12 = 72 seconds. Since the GAM-87 may be coming through the maximum range of pickup during any portion of the horizontal sweep of the acquisition radar, another 0-12 seconds delay is involved. The average of this, 6 seconds, added to the identification time results in a total time of 78 seconds.

3. Assuming that the defense has been alerted for attack, a not unreasonable assumption considering that the GAM-87A cannot be fired for hours after the commencement of hostilities, ATIC estimates a further minimum delay of five seconds before a anti-missile missile may be fired. This, plus time for communications between the defensive site and any central control point, adds at least 7 seconds to the 78 seconds required for identification for a total of 85 seconds.

4. ATIC estimates the SA-5 site to be located about 20 miles from the center of the target. It is doubtful that a stern chase on the re-entry vehicle would be attempted or that it would be feasible. Therefore, intercept must take place at the latest directly over the SA-5 site. Here the re-entry vehicle is 18 seconds from impact assuming the 1040 mile

trajectory of Fig. 3 and is at an altitude of 90,000 ft. With the estimated 10 G acceleration of the defensive missile 7.6 seconds are required to reach this altitude.

5. For intercept to take place, the acquisition radar must then see the GAM-87 about 110.5 (85 + 7.5 + 18) seconds before impact. Re-entry vehicle equivalent radar cross sections for various range of radar pickups are shown on the trajectory of Fig. 3. It may be seen that a radar cross sectional area of approximately .001 square meters is sufficient to prevent the missile from being picked up by the acquisition radar before 106 seconds. The equivalent radar cross section of the re-entry which must then be .001 square meters or less to prevent identification and destruction.

6. As may be seen from Fig. 2, sub-ranging results in considerably lower velocity of the re-entry vehicle and to prevent acquisition radar pickup by 130.5 seconds before impact a radar cross section of .0002 square meters is required. This is one fifth of the target size a full range vehicle must have. Sub-ranging increases vulnerability.

7. At present the sphere-cone configuration presents a target area of approximately 0.2 square meters when viewed from within approximately 50 degrees of head on. This area goes up two orders of magnitude for greater angles off the head on view.

8. It is obvious that any attempt to minimize the radar cross section must start with pitch and yaw positioning and position stabilization of the re-entry vehicle shortly after separation. A memo on this is being written which will indicate that such control will require minor modification of second stage control and involve approximately 10 pounds of increased weight mass of the re-entry vehicle. The radar cross section is still 200 times too large. Unofficially, Mr. Bahrett of WWRNE estimates that by vehicle shaping and the use of radar absorptive materials the radar cross section may be reduced to .005 square meters. This is five times the desirable maximum value but is fairly close in comparison to the present cross section. It will involve a weight penalty of 70-100 pounds.

9. Assuming that the Soviets have the SA-5 system in operation, the GAM-87A will be extremely vulnerable to it. It is possible to reduce this vulnerability considerably though not totally. Whether the SA-5 will operate as ATIC estimates is, of course, open to question. However, the design of a missile of the stated capability is not too difficult. The radar information is based almost totally on the observed size of Soviet antenna plus brute power estimates. Radar pick up range assuming a given antenna size is a function of peak and average transmission powers and receiver noise level. The radar powers assumed are well within reason and the receiver noise figures are based upon other Soviet radars which have fairly high figures compared with the present state-of-the-art. No real radar sophistication was assumed.

10. It may seem from the above that the achievable radar cross section of the GAM-87A is so much higher than the required minimum to prevent interception, that it is hardly worth the effort to try to reduce the radar cross section. However, all information used here is questionable and a far greater disparity between the estimated achievable and estimated requirements would have to exist before further study should be negated. Given the possibility that reduction of the GAM-87A radar cross section may be necessary and useful, work toward this end must be started before complete data is available or it will be too late to do anything.

T A B L E I

SA-5 System Parameters

Missile

1st Stage Acceleration	10G for 10 sec.
2nd Stage Acceleration	10G for 10 sec.
3d Stage - variable thrust liquid rocket	
Spherical Error Probability with 10 seconds of tracking -	600 ft.
Destruction Range for GAM-87A	3500 ft.

Acquisition Radar

Frequency	1000 mc
Pulse Repetition Frequency	70 pps
Pulse Width	50 ms
Pulse Power per Beam	5 mw
Horizontal Beam Width	0.8°
Vertical Beam Width per beam	1.6°
Number of Vertical Beams	10
Horizontal Sweep	±20°
Sweep Time	12 sec.
Antenna Length	833 ft.
Range for 50% probability of detection on one pulse	see figures 1,2 and 3

Tracking and Detection Radar

Frequency	3000 mc
Pulse Repetition Frequency	200 pps
Pulse Width	10 ms
Pulse Power	3 mw
Beam Width	0.5°
Spiral Seam for Detection	
Monopulse for Tracking	
Antenna Diameter	45 ft.
Range for Tracking- see Figures 1,2 and 3	

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SECRET

11. All the above has assumed the SA-5 in operation and in force. This is an expensive proposition. Before any conclusion is reached, the following should be considered.

a. ATIC knows at present of no efforts of the Soviets to achieve decoy discrimination in the SA-5 radars. Would they deploy this system, as expensive as it is without this capability?

b. A full deployment of the SA-5 system for total protection of a target would require nine systems per target as each acquisition radar can handle but 40 degrees in azimuth (360/40=9). Are the Soviets willing to go to the required expenses? If they are not, reduction of the GAM-87A radar cross section would be very effective against leaser systems.

c. The GAM-87 is by nature a second wave device. It is probable that Soviet defenses, the SA-5 system in particular, will be working at peak effectiveness after the first wave of attack? If they are not, any reduction of GAM-87A radar cross section, though it does not protect it from Soviet peak capabilities, may be sufficient.

d. The first SA-5 system is not expected to be in operation prior to late 1964. Will the system be fully deployed before the GAM-87 and B-52 are totally obsolete and scrapped?

12. A letter was forwarded to ATIC 6 April 1961 requesting that they perform a study of the GAM-87 vulnerability to the SA-5 system. A series of radar cross section areas and two sample trajectories were supplied. The letter was a result of a suggestion of Mr. Laxson and Mr. Picklesimer who provided most of the information contained herein. The ATIC study should allow considerable refinement of the information and conclusions of this memorandum.

13. Appropriate agencies should be contacted in reference to the questions of paragraph 11. A decision concerning the steps to be taken to reduce vulnerability must be made soon to be of any effect and such a decision is impossible without some notion of probable numbers and deployment of Soviet defenses.

14. This document is classified SECRET because it discusses deficiency details of a weapon system.

PREPARED BY:

Capt Ralph C. Graves Jr.
Avionics Branch
GAM-87A System Program Office

APPROVED BY:

D. J. Dietrich

61WWDG-286

SECRET

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APPENDIX I

(Extracted from System Package Program for GAM-87A, 1 May 1962)

SPP INTELLIGENCE INPUT

SECTION 4 - INTELLIGENCE ESTIMATES

4.1. General. The details of the intelligence estimate for the GAM-87A Weapon System program are covered in separately published or to be published documents which are incorporated in this section by reference and brief description only. All available intelligence information which would affect the GAM-87A design, programming or operational employment will be referenced herein.

4.2. Responsibilities. SAC will be responsible for the initial submission of the intelligence estimate, subject to review and approval by Headquarters USAF. Headquarters USAF and ATIC will provide inputs to Headquarters SAC. These documents will be reviewed and revised as necessary, at least every six months, at an intelligence review. These reviews will be conducted by an Intelligence Panel chaired by Headquarters USAF, at which Headquarters ARDC, SAC, the GAM-87A SPO, and ATIC will be represented. Headquarters USAF will be responsible for calling these meetings.

4.3. Sino-Soviet Bloc Targets. Estimates of the numbers, locations, and composition of the different types of targets which can be expected in the 1965-1970 time period will be published by Headquarters SAC in a separate document entitled, "Sino-Soviet Bloc Targets," on or about 1 April 1961. Estimates for later time periods will be incorporated as revisions to this document.

4.4. Sino-Soviet Offensive Threat. Estimates of the Sino-Soviet offensive threat for the 1965-1970 time period will be contained in Volume 2 of the SAC EWO Intelligence Planning Guides (SEIPG) entitled, "The Threat, 1960-1976," on or about 1 May 1961. Estimates for later time periods will be incorporated by revisions to this document.

4.5. Sino-Soviet Defensive Threat. Estimate of the Soviet anti-ballistic missile threat for the 1965-1970 time period will be contained in Volume 4, of the SAC EWO Intelligence Planning Guides (SEIPG), entitled, "Missiles and Space", to be published prior to 1 July 1961. This document contains the inputs of SAC, ATIC and Headquarters USAF. Estimates for later time periods will be incorporated by revisions to this document. ATIC will be responsible for expanding the details of the estimated threat in response to the requirements.

4.6. Other Threats. As estimates become available relative to the capabilities of the Soviets against the GAM-87A during the mid-course and boost phase of flight, they will be included in the threat contained in Volume 4, SEIPG.

(Extracted from System Package Program, GAM-87A, 1 May 1962)

SECTION 4 - INTELLIGENCE ESTIMATE

4.1 GENERAL. The purpose of the intelligence estimate for the GAM-87 Weapon System is to estimate the Soviet anti-ballistic missile threat in terms of technical capabilities and probable programs which will affect the Skybolt or the Strategic Air Command, and to define the threat's major performance characteristics and dates of operational availability.

4.2 SOVIET ANTI-BALLISTIC MISSILE DEFENSIVE THREAT. Present estimates indicate that the USSR will attain an initial operational capability with an anti-ballistic missile system during the 1963-1966 time period. For planning purposes, SAC estimates limited deployment will begin in 1963 with significant deployment occurring in 1965. This capability will be against US ICBM's in their terminal phase only. It is possible that a similar, related system may be available during 1963 for use against IRBM type vehicles. No direct intelligence is available relative to the deployment philosophy of the Soviet anti-ballistic missile system; however, it is estimated that by the end of 1968 some fifty key, high-priority, soft complexes within the USSR will be defended against the Western ICBM threat. Positioning of adequate defenses along the most likely avenues of ballistic missile attack is considered well within their capabilities, and will provide omnidirectional coverage when desired.

4.3 CHARACTERISTICS. The principle intelligence inputs used in the formulation of this estimate have been developments of the research and development anti-ballistic missile complex at Sary Shagan, the impact area for Soviet MRBM's, and the Soviet ICBM impact area on the Kamchatka Peninsula, radar and electronic intelligence, collateral, state-of-the-art type intelligence, and their interpretation by SAC, FTD, and Headquarters USAF. A simplified tabular summary of the various component system parameters follows:

4.3.1 THE MISSILE:

Arbitrary Reference Number	SA-4
Configuration	Three stage with solid propellant booster and sustainer and gimballed liquid propellant third stage.
Maximum Velocity	Mach 7.5

INTERCEPT RANGES

1000 NM TRAJECTORY
GROUND RANGE/ALTITUDE (THOUSANDS OF FEET)

CROSS SECTION	MAXIMUM WITH EW	MAXIMUM WITHOUT EW	MINIMUM
1.00 Sq M	1175/850	420/395	45/120
0.20 Sq M	905/700	280/300	45/120

0.03 Sq M	440/410	145/200	45/120

400 NM TRAJECTORY

(b)(1),(b)(3):42 USC §2168(a)(1)(C)-- (FRD)

1.00 Sq M	530/420	505/410	30/125
0.20 Sq M	530/420	435/380	30/125
0.03 Sq M	530/420	240/270	30/125

b(3) DoD

Damage Radii Against Mark 7 R/V	350,000 Ft & above: 14,400 Ft 245,000 Ft: 7,200 Ft 120,000 Ft: 7,900 Ft unshielded - 6,500 Ft cadmium shielded 60,000 Ft: 28,000 Ft blast effect
Accuracy	600 Ft against 1 Sq Meter at 150 NM
Guidance	Radar track/Command all-the-way
Gross Weight	Approx 40,000 lbs

4.3.2 EARLY WARNING RADAR (HEN ROOST)

RF	400 MC Nominal
PRF	40 PPS Nominal
PW	1,000 Micro-Seconds Nominal
Peak Power	5 MW/Beam Nominal
Horizontal Search Angle	Plus or minus 30 degrees-Phased array
Horizontal Search Rate	2 Degrees/Sec (6 Hits/Scan)
Antenna Gain	45 DB
Receiver Noise Figure	5 DB
Losses (System)	9 DB
Polarization	Horizontal
Azimuth Resolution	6 Mils (0.32 Degree) Nominal
Azimuth Accuracy	3 NM
Vertical Resolution	2.5 Degrees Nominal
Vertical Accuracy	20 NM
Range Resolution	80 NM
Range Accuracy	20 NM
Range	2000 NM Vs. 0.1 Sq Meter

4.3.3 ACQUISITION RADAR (HEN HOUSE) Segmented antenna using a phased array track-while-scan-system

RF	1000 MC Nominal
PRF	70 PPS Nominal
PW	50 Micro-Seconds Nominal
Peak Power	5 MW/Beam Nominal
Antenna Gain	42.8 DB Per Section
Horizontal Search Angle	Plus or minus 20 Degrees
Vertical Coverage	Plus 15 degrees to plus 60 degrees - any 16 degree increment

Noise Figure	6 DB
Horizontal Search Rate	3.5 degrees/Second (16 Hits/ Scan)
Losses	9 DB
Scanning	Electronic Phase-Shifting technique in the horizontal; lobe comparison in the vertical
Azimuth Resolution/ Horizontal Beam Width	14 Mils (Approx 0.8 Degree/Beam)
Azimuth Accuracy	2 NM
Vertical Resolution/ Beam Width	1.6 Degrees/Beam (16 Degrees total with 10 beams stacked vertically)
Vertical Accuracy	4 NM
Range Resolution	4 NM
Range Accuracy	2 NM
Maximum Range	
10 Sq Meter	1750 NM
1 Sq Meter	965 NM
0.1 Sq Meter	550 NM
.01 Sq Meter	310 NM

4.3.4 TRACKING RADAR (HEN NEST/EGG)

RF	3000 MC Nominal
PRF	200 PPS Nominal
PW	10 Micro-Seconds Nominal
Peak Power	3 MW Nominal
Antenna Gain	50 DB
Antenna Beam Width	0.5 Degree
Scanning	Spiral (For Acquisition)
Track Mode	Monopulse
Total Angular Coverage	Horizontal - 360 Degrees; Vertical - 90 Degrees (0 to 90 Degrees)
Noise Figure	10 DB
System Losses	12 DB
Azimuth Resolution	0.5 Degree
Azimuth Accuracy	0.4 Mils
Elevation Resolution	0.5 Degree
Elevation Accuracy	0.4 Mils
Range Resolution	5,000 Ft
Range Accuracy	1,000 Ft
Detection Ranges	
10 Sq Meter	1,000 NM
1 Sq Meter	550 NM
0.1 Sq Meter	310 NM
0.01 Sq Meter	175 NM
Tracking Ranges (Lock On)	
10 Sq Meter	750 NM
1 Sq Meter	310 NM
0.1 Sq Meter	175 NM
0.01 Sq Meter	100 NM

4.3.5 MISSILE BEACON TRACKING RADAR (FIRE WHEEL TYPE)

RF	3,000 MC
PRF	200 PPS
Range	1,300 NM using S-Band Beacon
Peak Power	400 KW
PW	1 Micro-Second
Angular Accuracy	0.185 Milliradian
Beam Width	3 Degrees
Receiver Bandwidth	1 MC
Receiver Noise Figure	10 DB

4.4 ESTIMATED MODE OF OPERATION: (See Attachment 1)

4.4.1 HEN ROOST: An early warning radar that provides warning time against ballistic missiles, threat evaluation, target identification, and trajectory determination. This large, high-gain, antenna system, with its estimated electronic parameters, provides a 2,000 NM detection range against a 0.1 sq. meter target. Based on optimum site deployment for this radar, 15 to 18 minutes of early warning could be realized. The output of the HEN ROOST will be fed directly to a computer which computes threat trajectory and predicts impact area. The computer output will be digital data transmitted to a central processing center and appropriate acquisition radar sites. For planning purposes, five HEN ROOST radars deployed along the far north periphery would provide coverage.

4.4.2 HEN HOUSE: An acquisition radar employed to provide refined target data to the target tracking radars, resolve multiple threats, and provide raid assessment. This radar is estimated to be capable of detecting a 0.1 sq. meter target at 550 NM, with a vertical coverage, achieved by 10 vertical beams, of plus 15 to plus 60 degrees. It is estimated to possess a track-while-scan capability, the output being fed to a computer. Thus it will be able to scan the assigned sector continuously while providing dynamic data on each threat to one or more associated target tracking radars, minimizing the search and antenna slewing times required for the target trackers to lock on target. Each HEN HOUSE could control from 1 to 5 fire units.

4.4.3 FIRE UNITS (SITE): Composed of target tracking radars, missile tracking radars, and launchers: Located 25-35 NM from defended complexes along likely avenues of attack: (See Attachment 2)

4.4.3.1 HEN NEST/EGG: This target tracking radar is used to furnish fine grain target data to the interceptor missile guidance command computer. It is a powerful, narrow beam radar, highly sensitive, and possessing a maximum range capability of 310 NM and an automatic lock-on tracking range of 175 NM against a 0.1 sq. meter target. This radar will be able to furnish fine track data on a continuing basis until weapon detonation, thus providing inputs to the guidance system for final course corrections of the interceptor. It will also be able to provide some evaluation of the target kill. Each HEN NEST is estimated to be able to handle only one target at a time; thus, multiple target tracking radar are anticipated at each fire unit

(site) to allow simultaneous target engagements. The HEN NEST's high antenna slew rate will enable it to recover quickly from one target and lock on another. Target tracking data will be supplied to the guidance computer which will probably be physically located in the immediate general area. For planning purposes, SAC estimates each fire unit will contain 3 of these radars.

4.4.3.2 INTERCEPTOR MISSILE GUIDANCE RADAR: Based on Soviet fire-control radar developments and known missile tracking methods, it is estimated that a modified FIRE WHEEL tracking radar could be utilized. This guidance radar will receive commands and data from the weapons system computer, and will control the interceptor missile flight and warhead detonation. Missile commands will be transmitted in a coded pulse format at the pulse repetition frequency rate. Using a missile-borne beacon for tracking, FIRE WHEEL is capable of a 200 ft. accuracy at 150 NM. Each radar will be capable of guiding only one intercept missile at a time, thus each defensive missile complex could have as many missile guidance radars as Soviet firing doctrine might dictate. For planning purposes, SAC estimates each fire unit (site) will contain 6 of these radars.

4.4.3.3 LAUNCHERS: Each operational fire unit is estimated to be equipped with 12 to 30 launchers (for planning, SAC estimates 12 launchers), with one missile per launcher. As yet, there is no intelligence available on Soviet doctrine concerning the number of SA-4 missiles to be launched against each inbound target to achieve the desired degree of probability. However, for planning purposes, SAC estimates that two missiles will be assigned against each target.

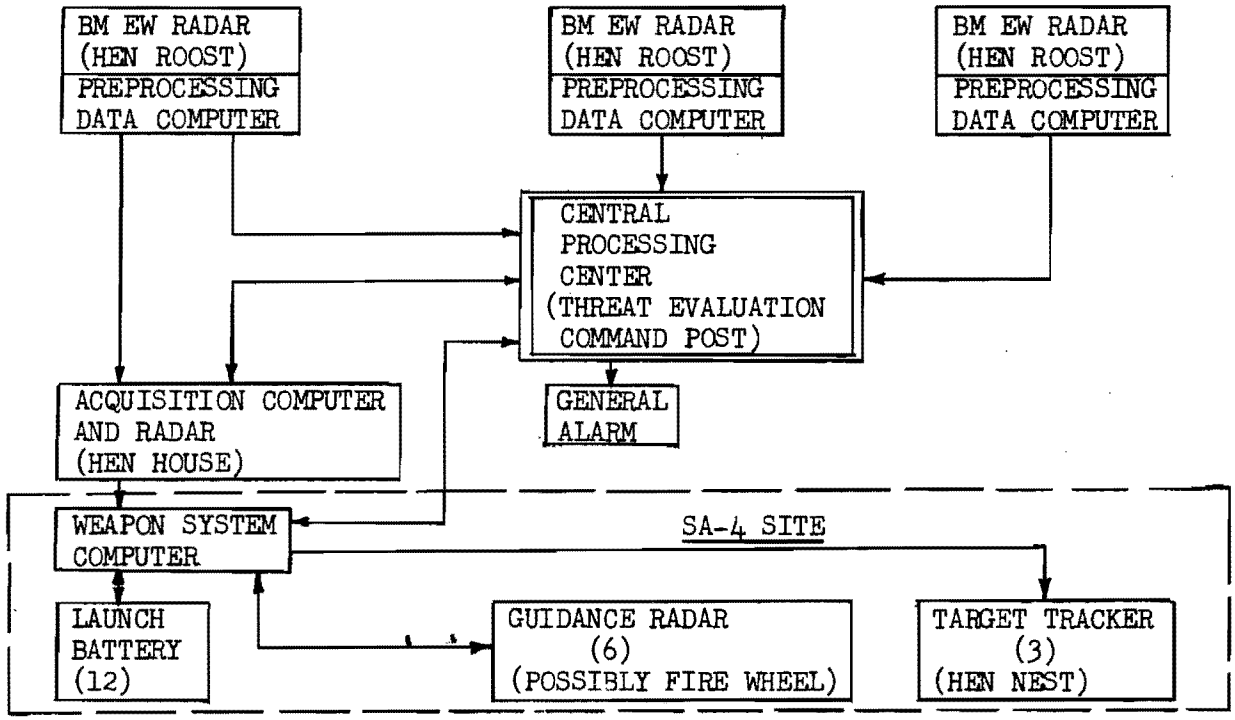
4.4.4 GUIDANCE COMPUTERS: Computers will play an important role in the control and operation of an anti-ballistic missile system. In order to facilitate transmission of information, it is estimated that each radar location will have an autonomous computer installation which will preprocess raw data on site. This data will then be sent in a digital form to the next level or lateral levels of the air defense net. Computers will also be used in the control processing center, which will be a command post maintaining a continuous overall evaluation of the ballistic missile threat. Uncorrelated data, such as known or unknown satellite orbits, aircraft, air-to-surface aerodynamic missiles and outbound Soviet ballistic missiles, received from various early-warning sites will be sorted out by the central computer. It should be noted, however, that Soviet logic might lead to other conclusions concerning the data processing problem. For instance, the Soviets might prefer to design a system to pinpoint incoming ballistic missiles by trajectory without resorting to a centralized system. In that way the Soviets could have a maximum of independence in the operation of the components of these air defense systems.

4.4.5 DECOY DISCRIMINATION: The estimated electronic subsystems indicate that the Soviets have placed considerable emphasis in the anti-ballistic missile defense program, and it is expected that they will continue efforts in its improvement and sophistication. The system as estimated is configured as a first-generation defense system

against the early and relatively simple ballistic missile threat. However, the system will have good growth potential for the addition of discrimination techniques as they become available. The Soviets undoubtedly recognize the need for the capability to perform ballistic missile discrimination in a decoy environment. However, intelligence information to date does not indicate that decoy discrimination tests have been conducted. Also, none of the antiballistic missile radar equipments located near Sary Shagan are estimated to be sufficiently sophisticated to perform the ballistic missile decoy discrimination function. However, it is likely that the Soviets have been experimenting with determination of target signatures of various ballistic missile types. Although the present HEN HOUSE equipment may not discriminate against decoys, the track-while-scan capability and the large antenna aperture are desirable features of a discrimination radar. To further increase target resolution, such techniques as pulse compression, beam splitting, pulse doppler, and other signal processing schemes are distinct possibilities for future exploitation by the Soviets. At IOC, the system is estimated to have a discrimination capability against dangerous tube and nose-cone/gross tankage type penetrations; partial discrimination capability against placement in a fragment cloud, precursor, and atmospheric deceleration tactics; and no capability against tumbling scintillations, infrared/ultraviolet, backward prediction, and reentry wake tactics.

4.5 ATTACHMENTS.

4.5.1 SYSTEM MODE OF OPERATION. (Attachment 1)



4.5.2 ESTIMATED DEPLOYMENT SCHEME. (Attachment 2)

The following is a SAC estimate of ABM deployment for various time periods:

	End 63	End 64	End 65	End 66	End 67	End 68
Complexes	-1	1+	11	25	38	50
Fire Units	2	17	50	92	118	142
Missiles	24	204	600	1104	1416	1704
TTR's	6	51	150	276	354	426
MTR's	12	102	300	552	708	852
COMPLEXES/FIRE UNITS						
1. Moscow	2	15	15	15	15	15
2. Leningrad		2	8	8	8	8
3. Kiyev			3	3	3	3
4. Dnepropetrovsk			3	3	3	3
5. Kharkov			3	3	3	3
6. Novosibirsk			3	3	3	3
7. Saratov			3	3	3	3
8. Ufa			3	3	3	3
9. Tashkent			3	3	3	3
10. Sverdlovsk			3	3	3	3
11. Gorkiy			3	3	3	3

COMPLEXES FIRE UNITS (Cont'd)

		End 63	End 64	End 65	End 66	End 67	End 68
12.	Baku				3	3	3
13.	Omsk				3	3	3
14.	Kazan				3	3	3
15.	Stalino				3	3	3
16.	Kuybyshev				3	3	3
17.	Perm				3	3	3
18.	Chelyabinsk				3	3	3
19.	Minsk				3	3	3
20.	Tbilisi				3	3	3
21.	Alma Ata				3	3	3
22.	Volgagrad				3	3	3
23.	Voronezh				3	3	3
24.	Magnitogorsk				3	3	3
25.	Zaporozhye				3	3	3
26.	Rostov					2	2
27.	Odessa					2	2
28.	Riga					2	2
29.	Nizhniy Tagil					2	2
30.	Krasnoyarsk					2	2
31.	Irkutsk					2	2
32.	Zhdanov					2	2
33.	Yerevan					2	2
34.	Stalinsk					2	2
35.	Yaroslavl					2	2
36.	Khabarovsk					2	2
37.	Lvov					2	2
38.	Dneprodzerzhinsk					2	2
39.	Groznyy						2
40.	Krasnodar						2
41.	Vilnyus						2
42.	Ashkhabad						2
43.	Kishinev						2
44.	Krivoy Rog						2
45.	Barnaul						2
46.	Lugansk						2
47.	Tula						2
48.	Kemerovo						2
49.	Tallin						2
50.	Karaganda						2

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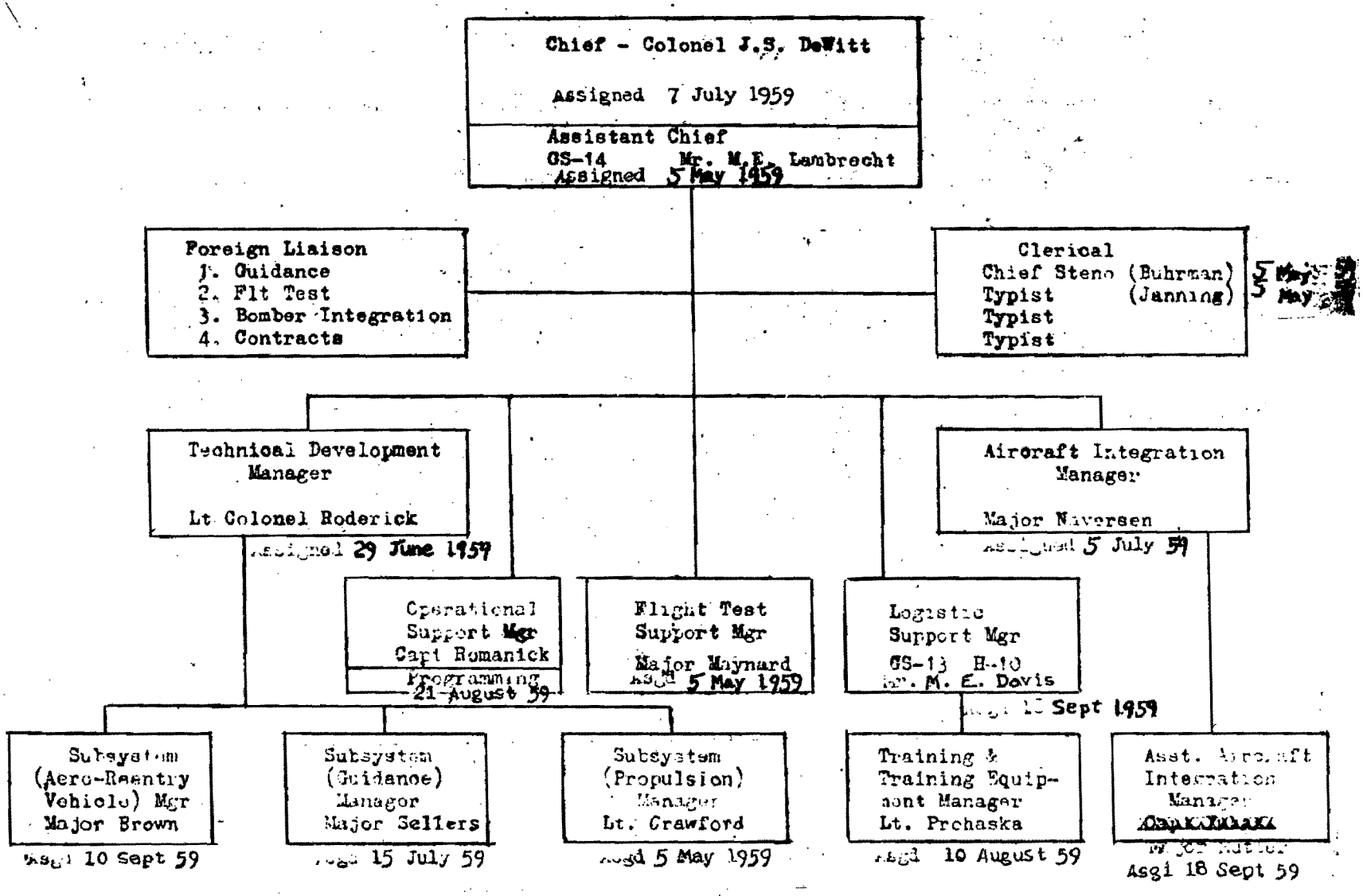
(Extracted from WS-138A Hist. Rpt., July—Dec. 1959)

WS-138A

ROCKET POWERED
STRATEGIC AIR-TO-SURFACE MISSILE
MANAGEMENT STRUCTURE

GAM-87A



APPENDIX J

28 July 1959

Organization charts (GAM-87 SPO, contractors, and United Kingdom representatives).

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(Extracted from GAM-87A Hist. Rpt., Jan--June 1961)

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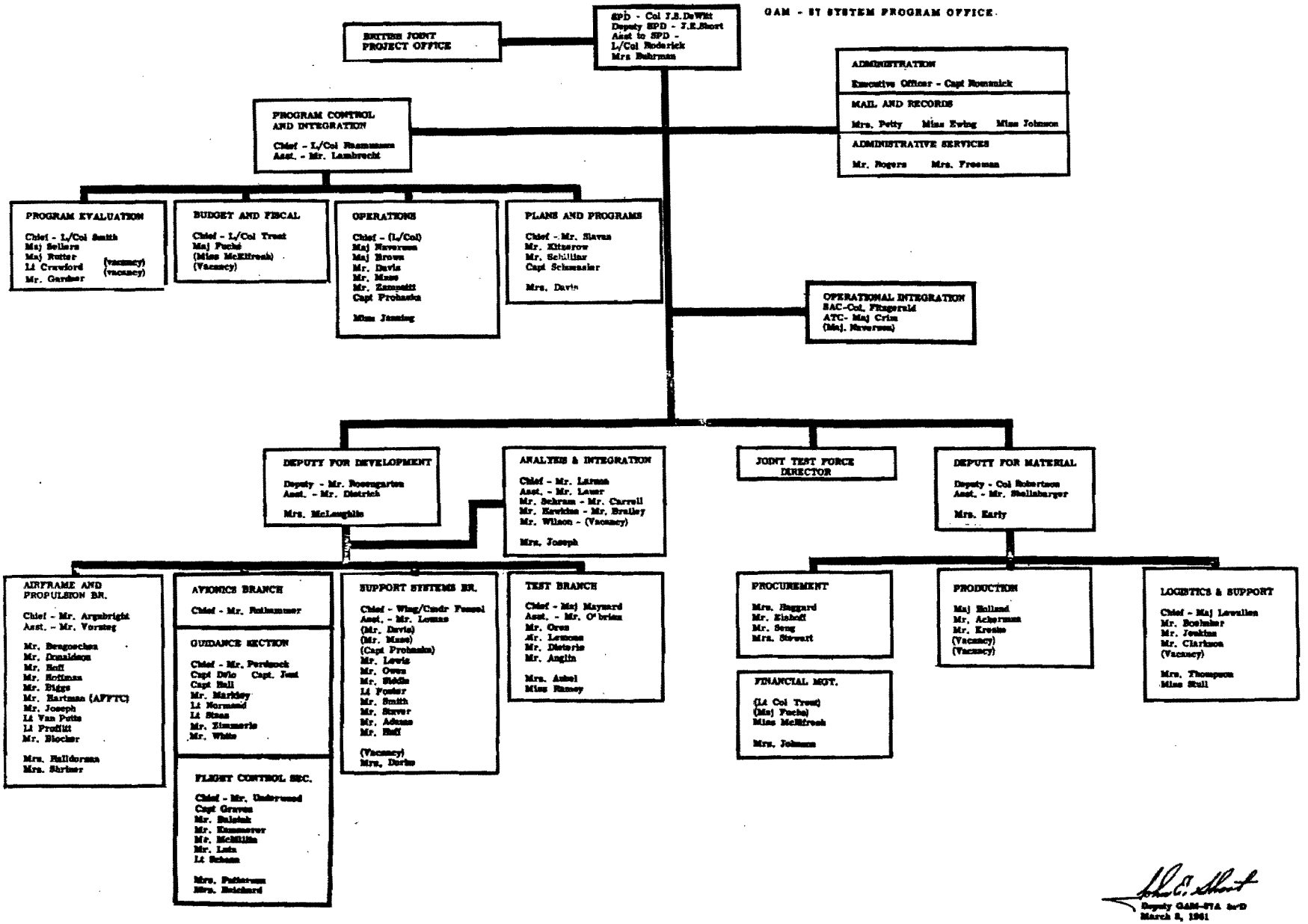

Deputy GAM-87A SPD
March 8, 1961

UNCLASSIFIED

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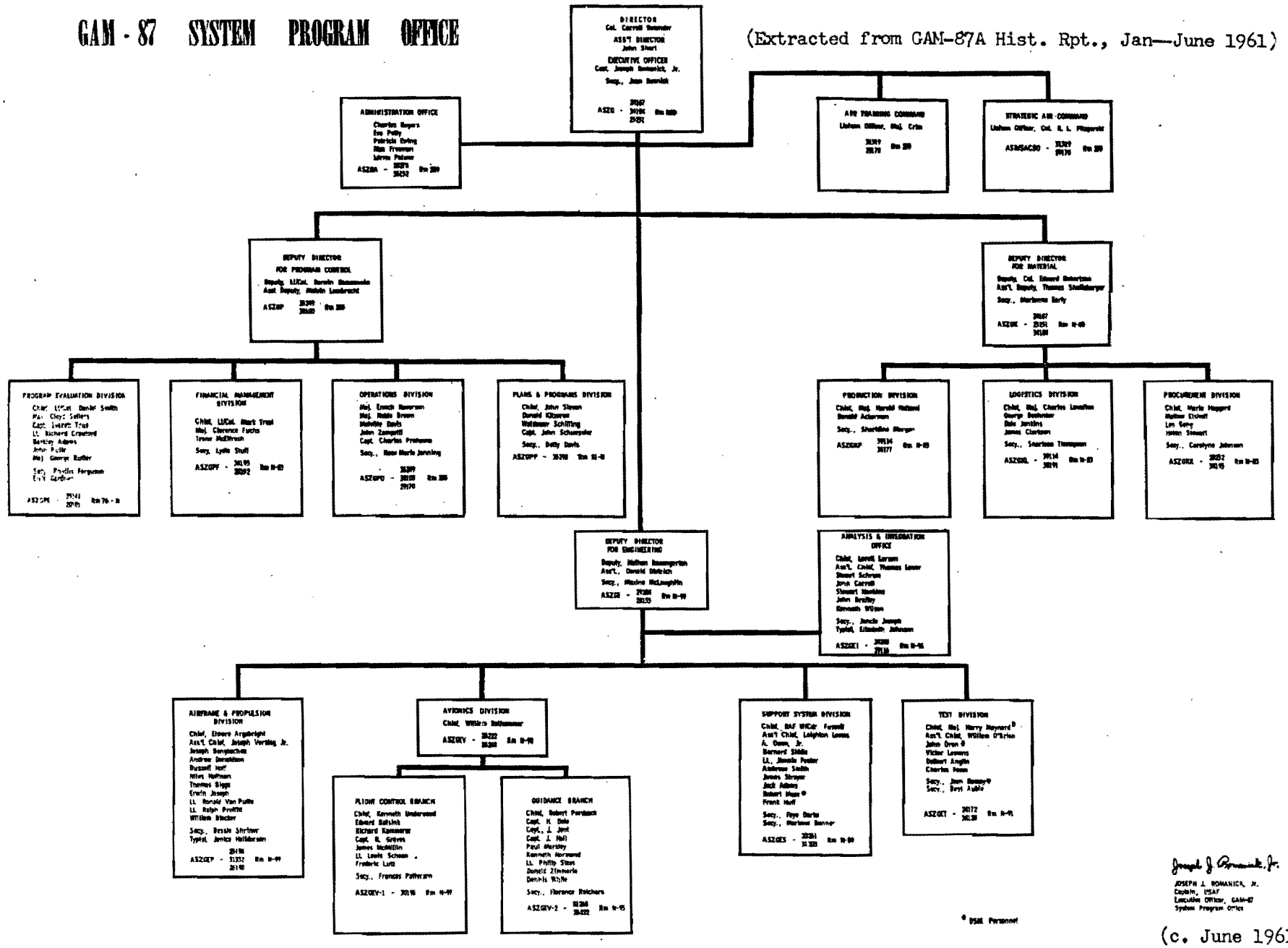
GAM - 87 SYSTEM PROGRAM OFFICE

(Extracted from GAM-87A Hist. Rpt., Jan—June 1961)



* USAF Personnel

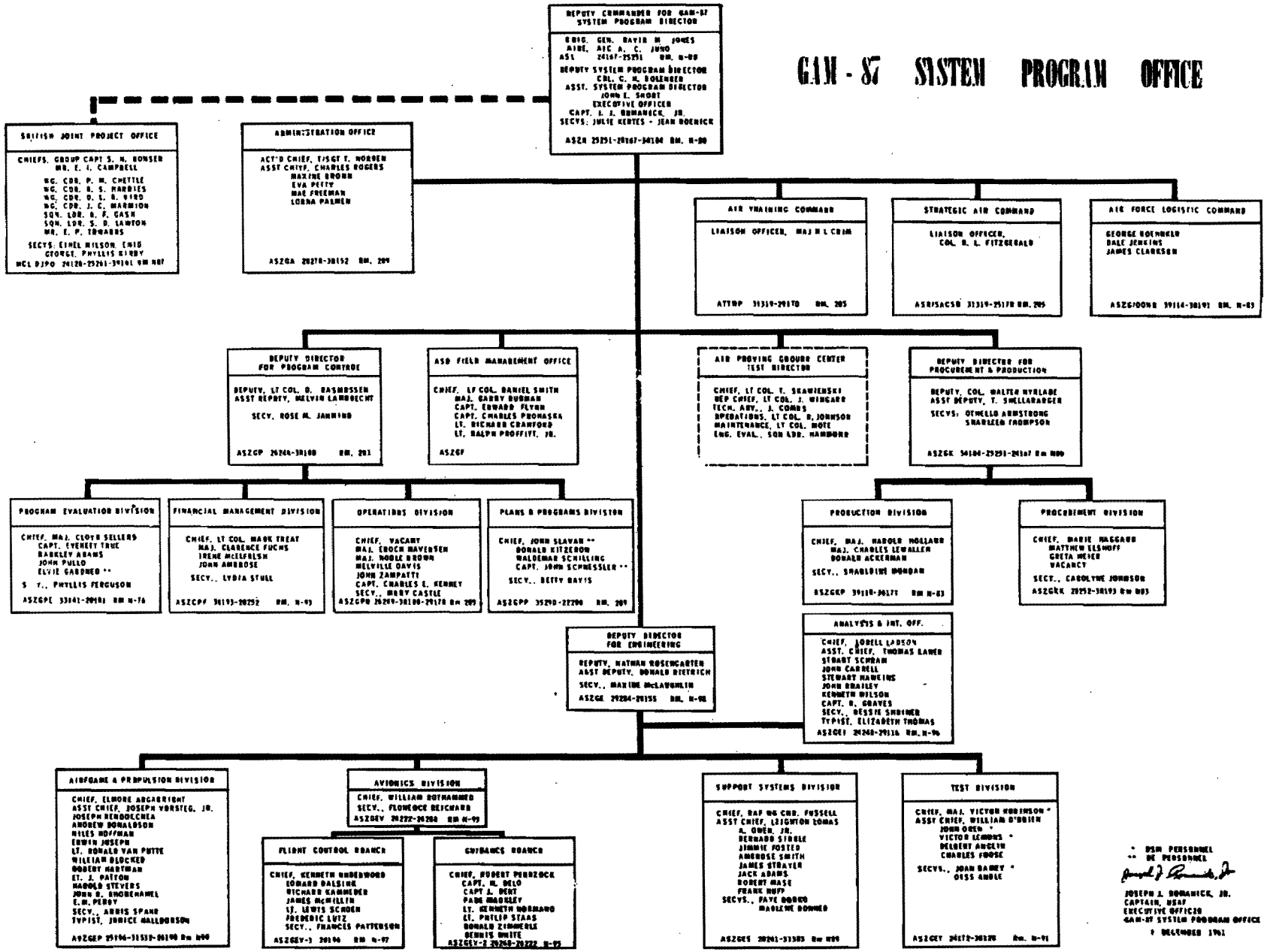
Joseph J. Romanick, Jr.
JOSEPH J. ROMANICK, JR.
Captain, USAF
Executive Officer, GAM-87
System Program Office

(c. June 1961)

UNCLASSIFIED

(Extracted from GAM-87A Hist. Rpt. July--Dec. 1961)

GAM - 87 SYSTEM PROGRAM OFFICE



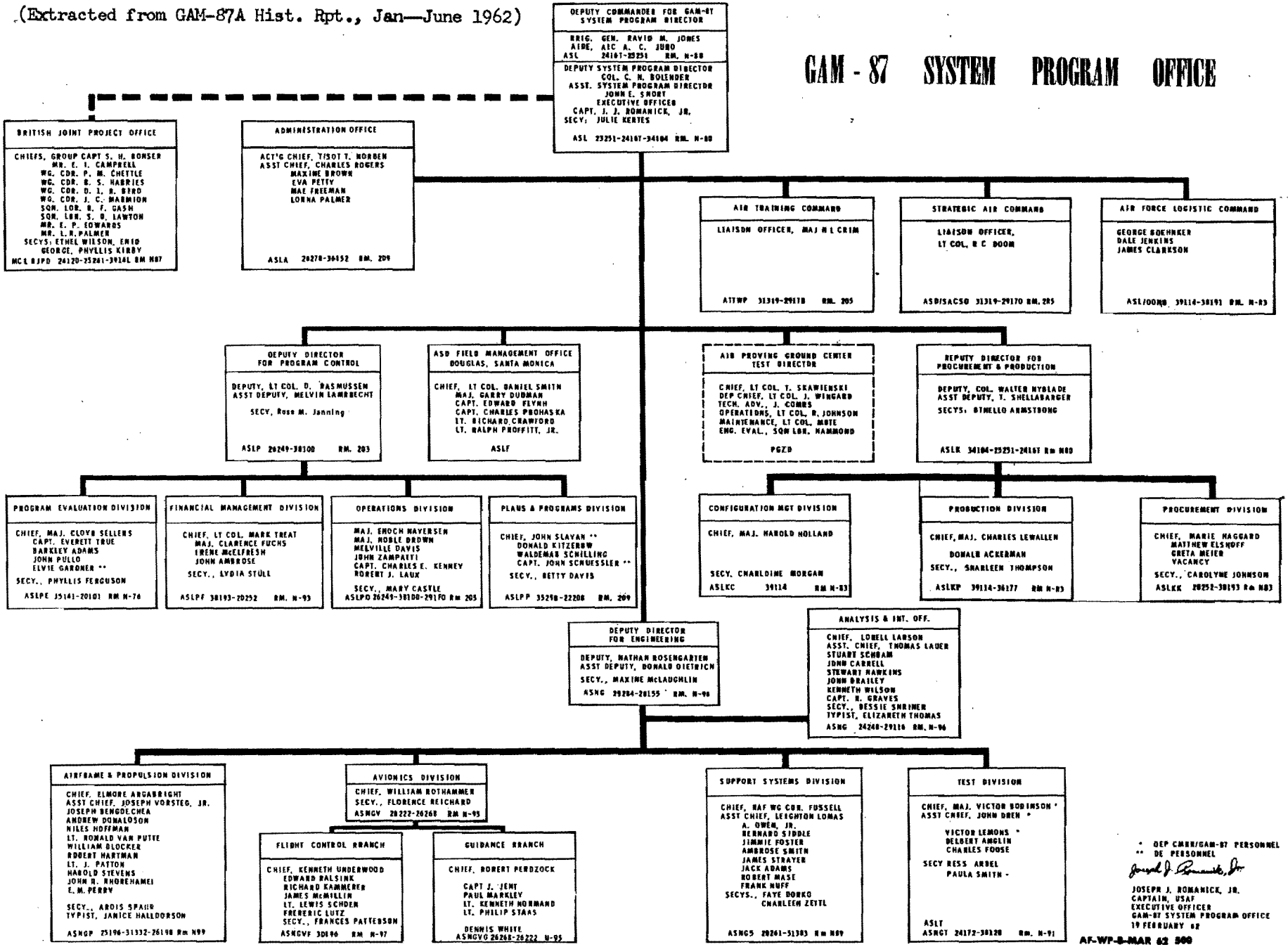
* DSM PERSONNEL
** BE PERSONNEL

JOSEPH J. BOHANICK, JR.
CAPTAIN, USAF
EXECUTIVE OFFICER
GAM-87 SYSTEM PROGRAM OFFICE
1 DECEMBER 1961

(Extracted from GAM-87A Hist. Rpt., Jan—June 1962)

GAM - 87 SYSTEM PROGRAM OFFICE

UNCLASSIFIED



* DEP CMDR/GAM-87 PERSONNEL
** DE PERSONNEL

JOSEPH J. ROMANICK, JR.
CAPTAIN, USAF
EXECUTIVE OFFICER
GAM-87 SYSTEM PROGRAM OFFICE
19 FEBRUARY 62

AF-WP-S-MAR 62 500

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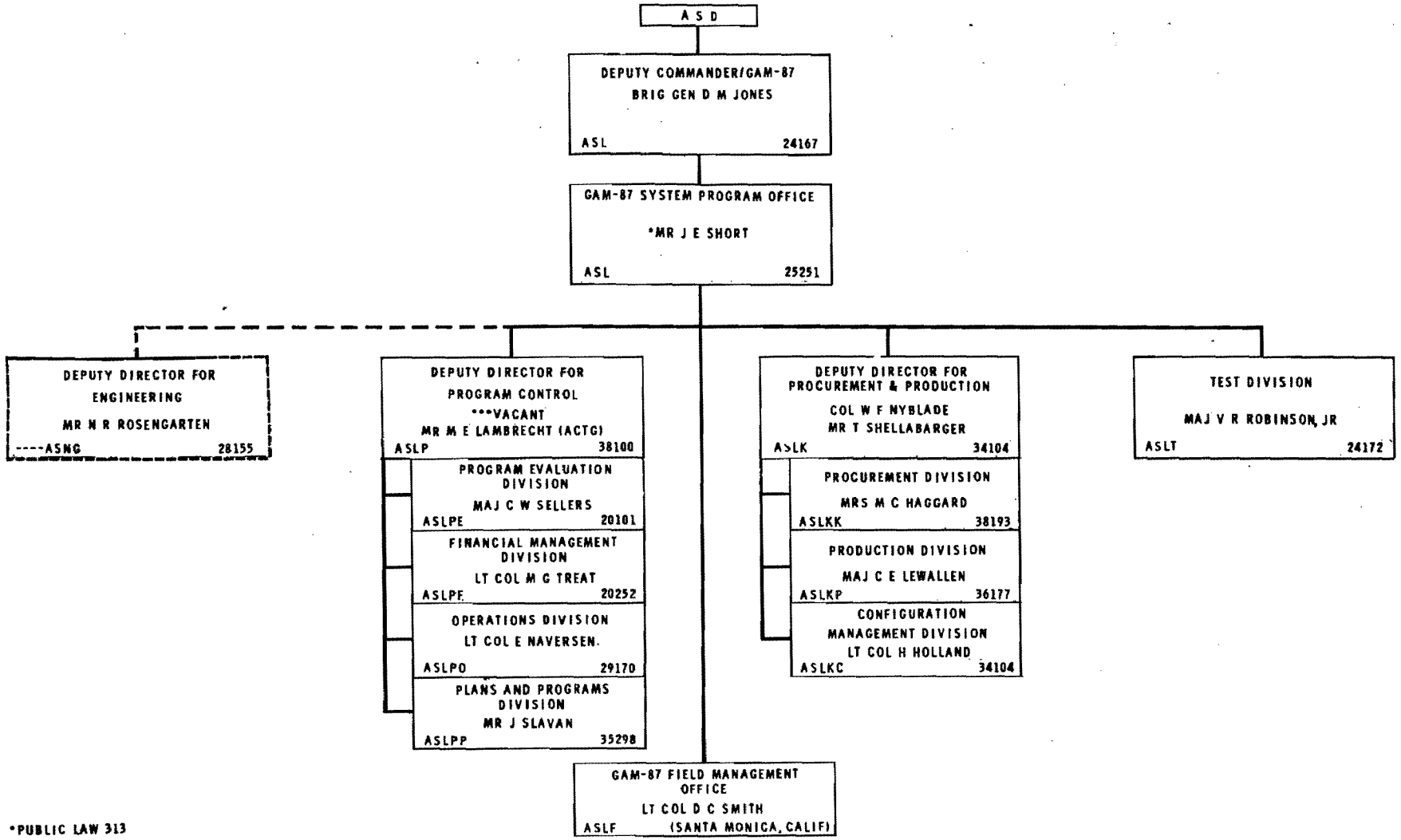


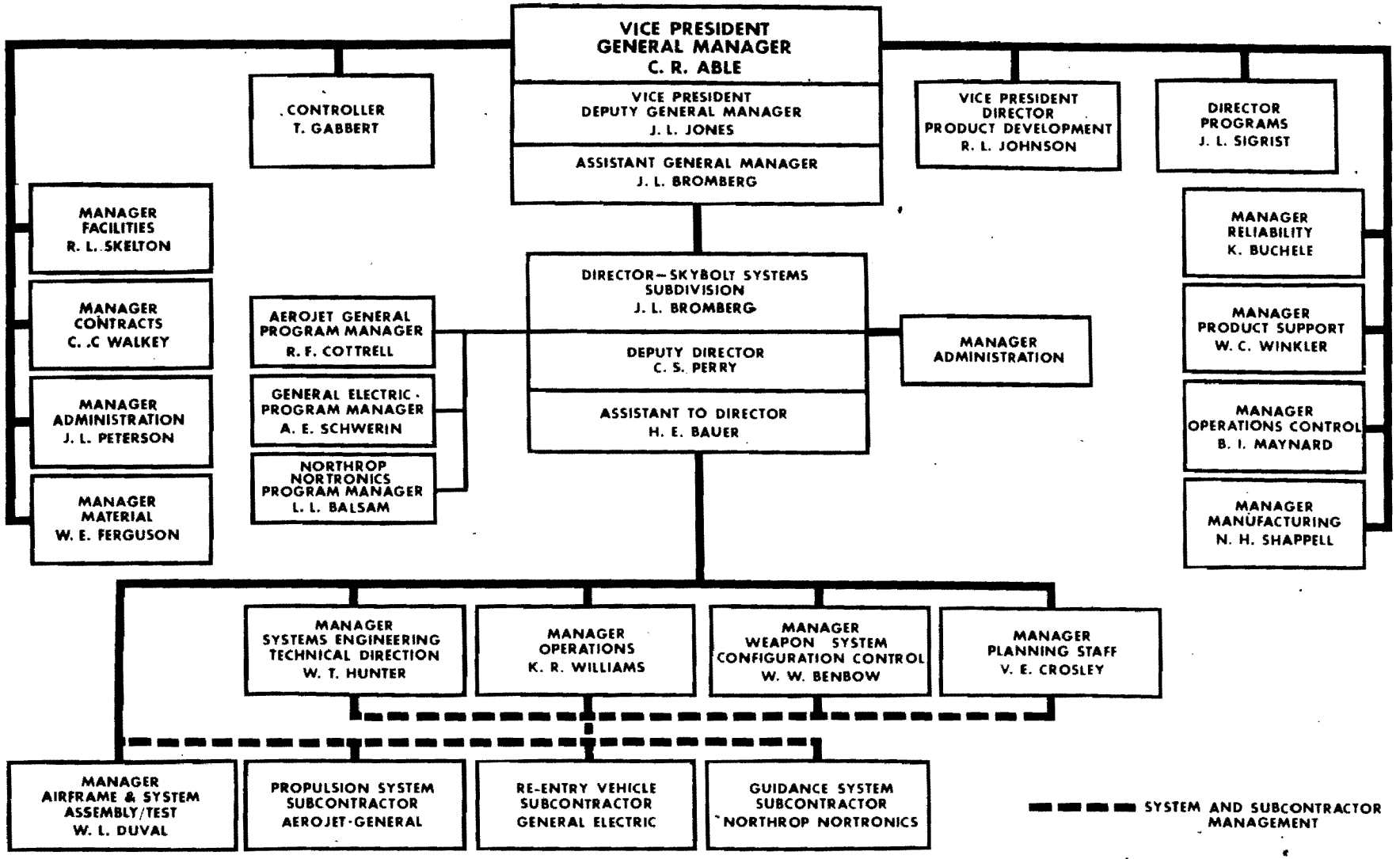
*PUBLIC LAW 313
**PUBLIC LAW 313 AUTH
***COLONEL AUTH
----ORGANIZATIONALLY A PART OF THE DEPUTY FOR ENGINEERING, ASN

FOR OFFICIAL USE ONLY

1 AUGUST 1962

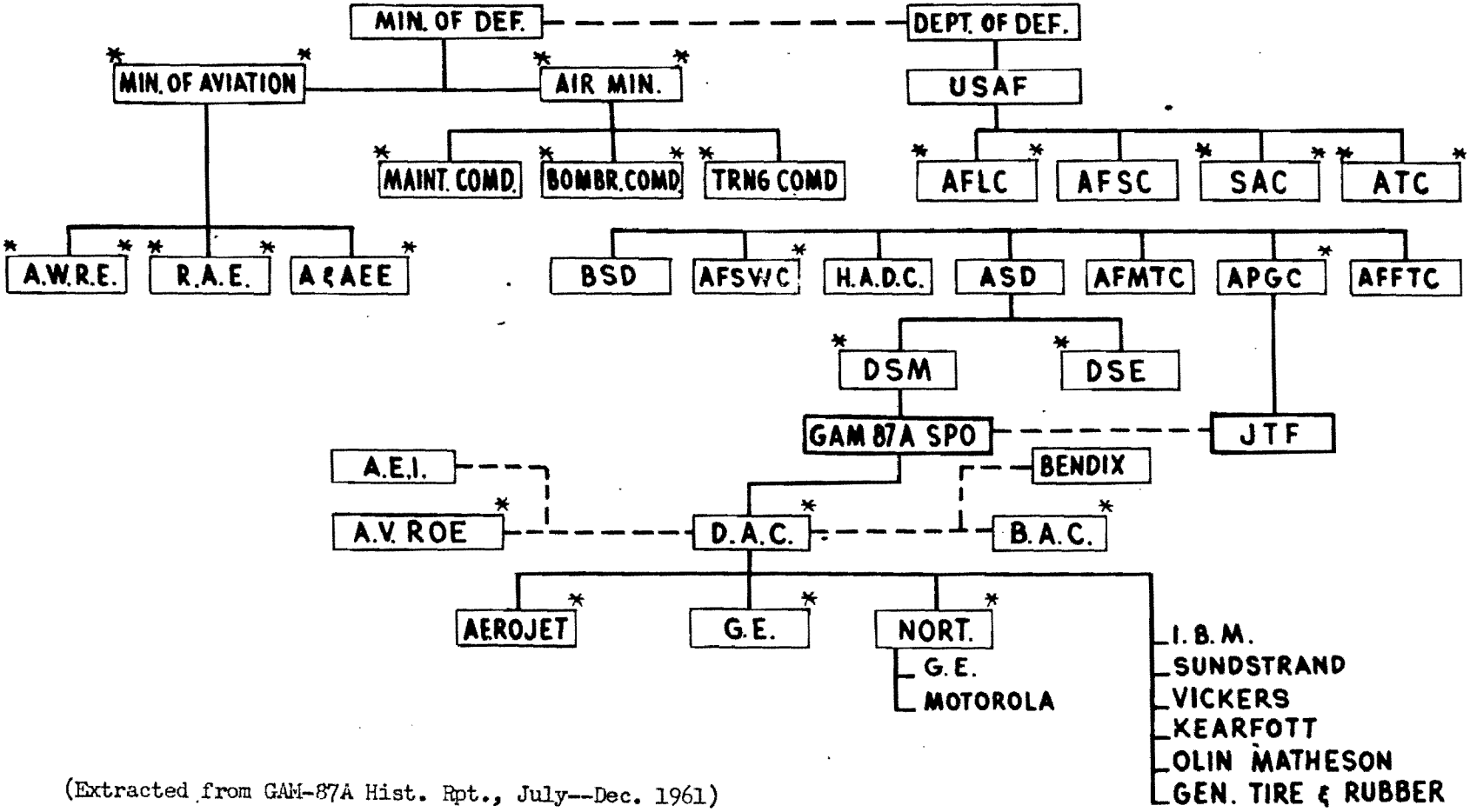
SKYBOLT SYSTEMS SUBDIVISION ORGANIZATION

(Extracted from GAM-87A Hist. Rpt., July—Dec. 1961)



SKYBOLT AIRFORCE-U.K.

INDUSTRY TEAM



(Extracted from GAM-87A Hist. Rpt., July--Dec. 1961)

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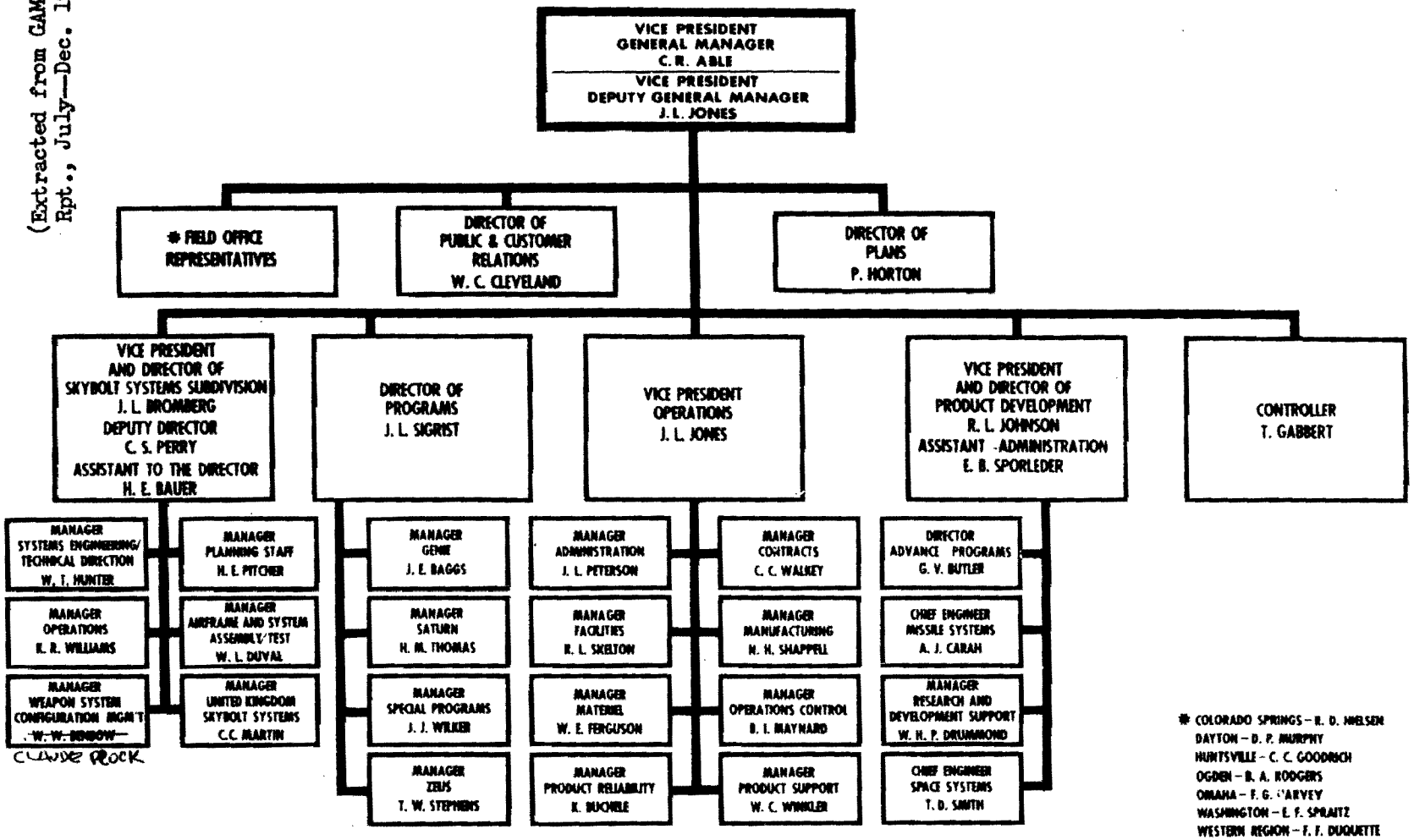
(Extracted from GAM-87A Hist. Rpt., July—Dec. 1962)

MISSILE & SPACE SYSTEMS DIVISION ORGANIZATION



* COLORADO SPRINGS – R. D. NIELSEN
DAYTON – D. P. MURPHY
HUNTSVILLE – C. C. GOODRICH
OGDEN – B. A. RODGERS
OMAHA – F. G. HARVEY
WASHINGTON – E. F. SPLATTZ
WESTERN REGION – F. F. DUQUETTE

DM20-5023
REV. JUL-62

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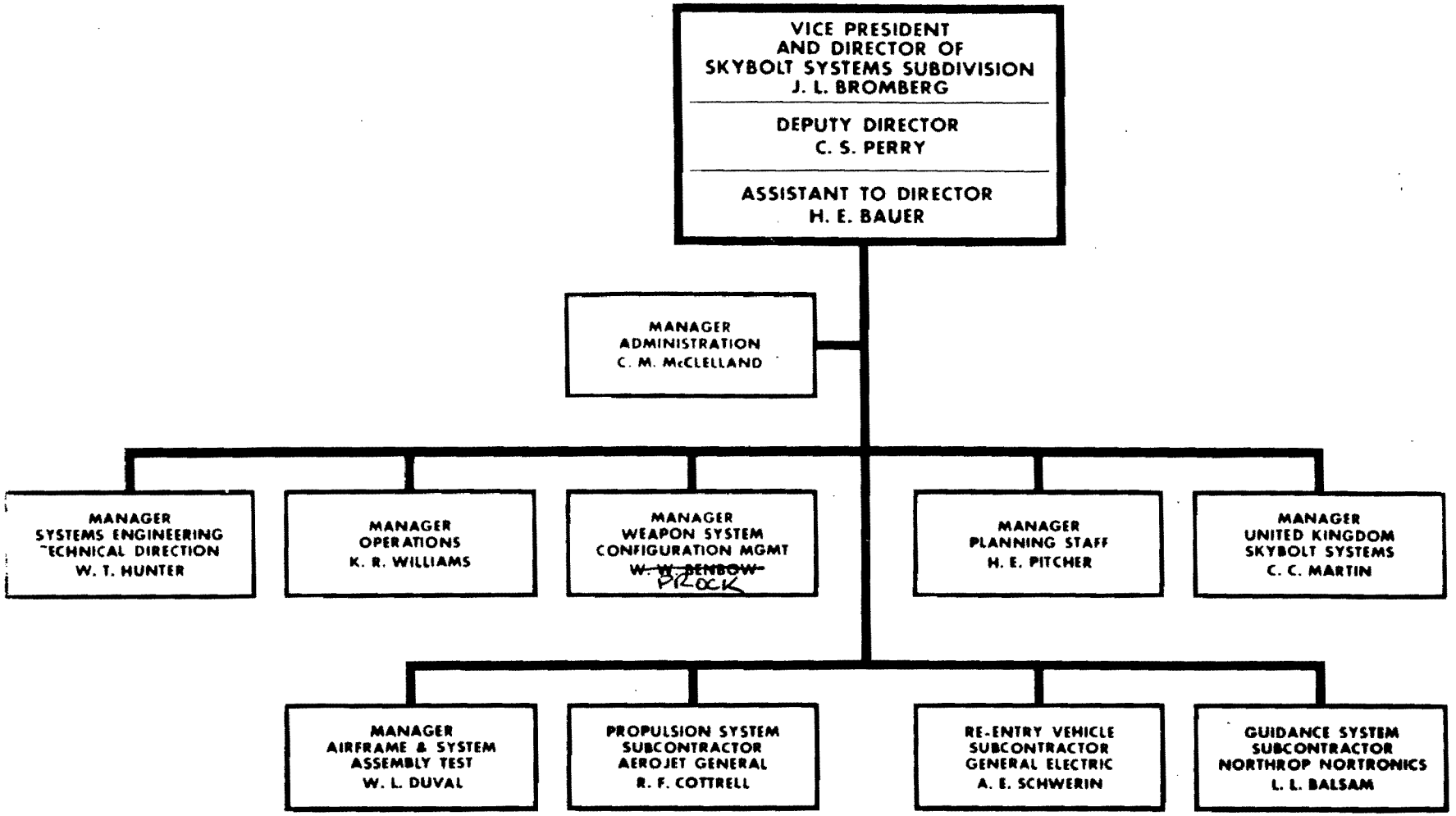
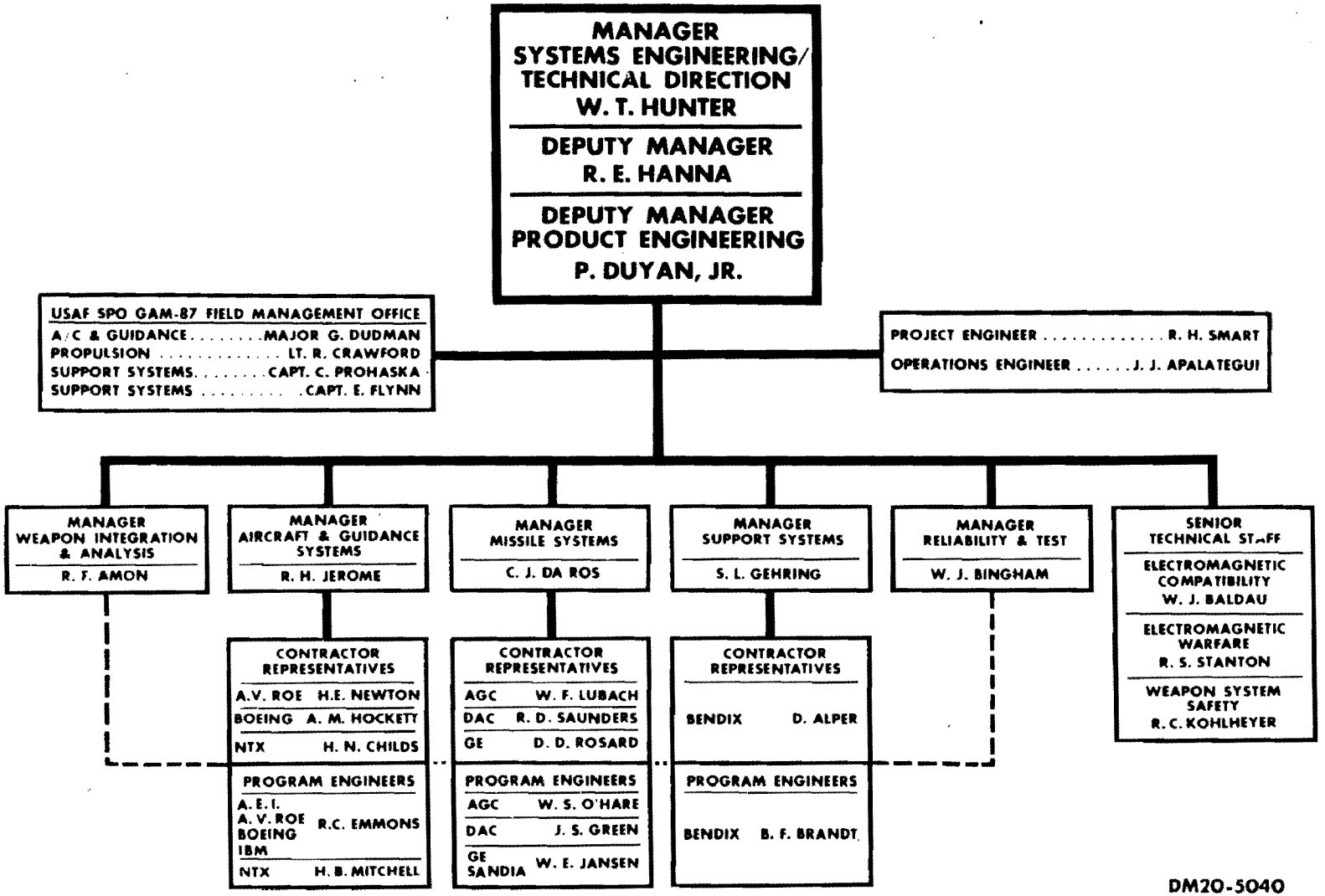
SKYBOLT SYSTEMS SUBDIVISION ORGANIZATION

UNCLASSIFIED



DM20-5075
REV. JUL-62

SKYBOLT SYSTEMS SUBDIVISION
SYSTEMS ENGINEERING/TECHNICAL DIRECTION ORGANIZATION



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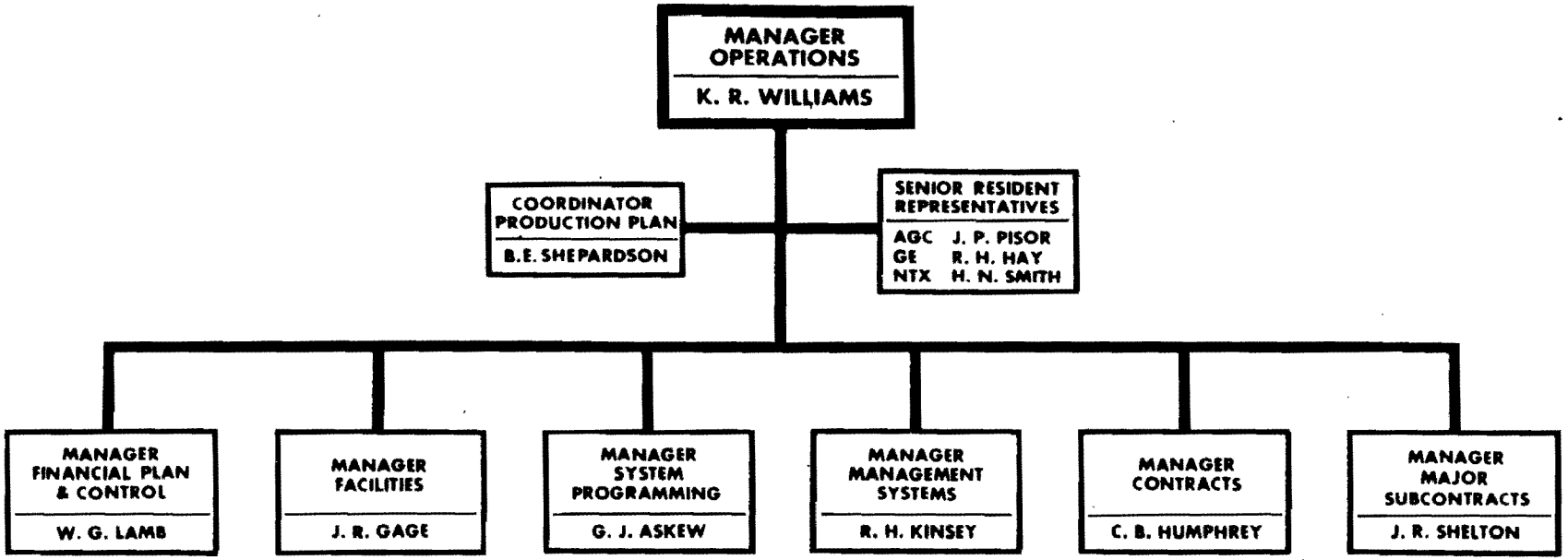
REV. JUL-62

SKYBOLT SYSTEMS SUBDIVISION OPERATIONS ORGANIZATION



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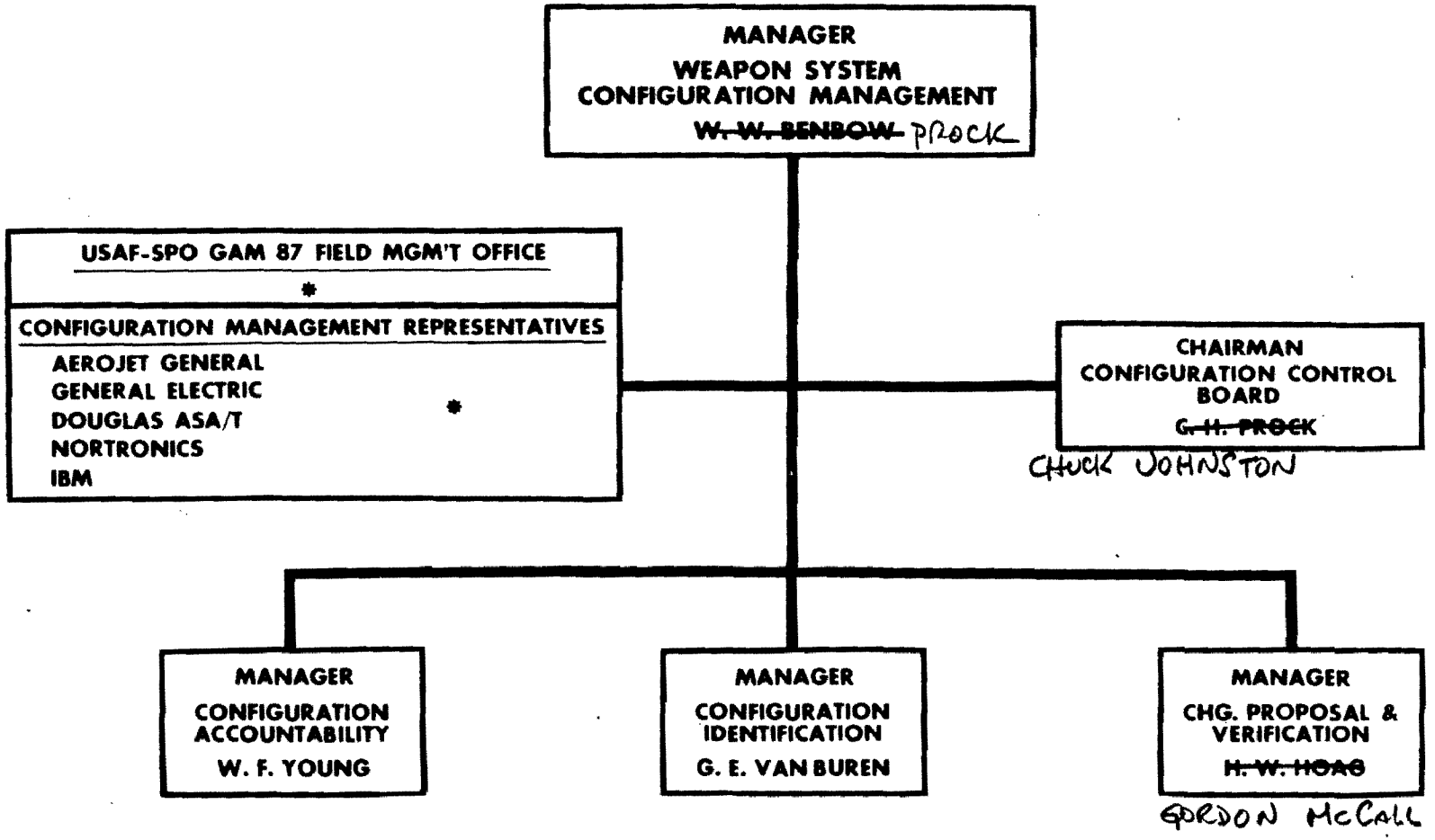
SKYBOLT SYSTEMS SUBDIVISION
WEAPON SYSTEM CONFIGURATION MANAGEMENT ORGANIZATION



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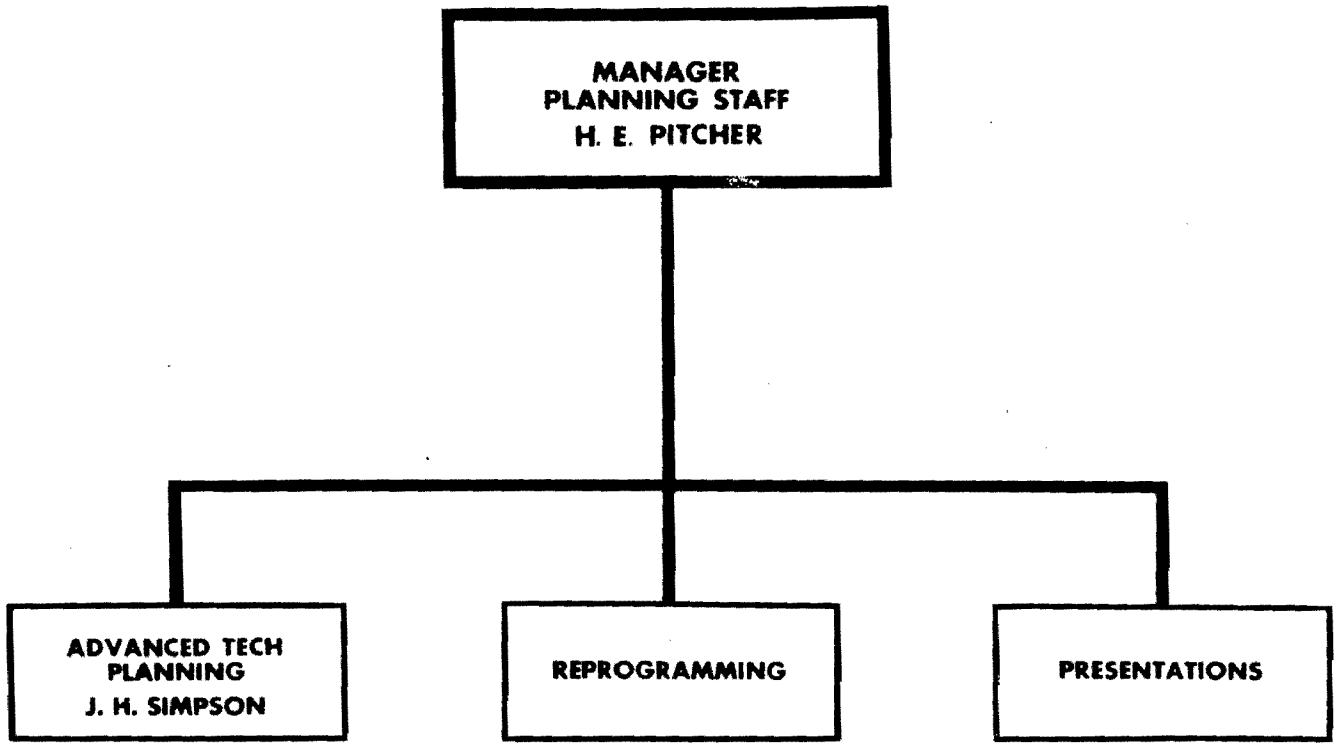
* PERSONNEL ASSIGNED AS REQUIRED

DM20-5038
REV. JUL-62

SKYBOLT SYSTEMS SUBDIVISION
PLANNING STAFF ORGANIZATION



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REV. JUL-62

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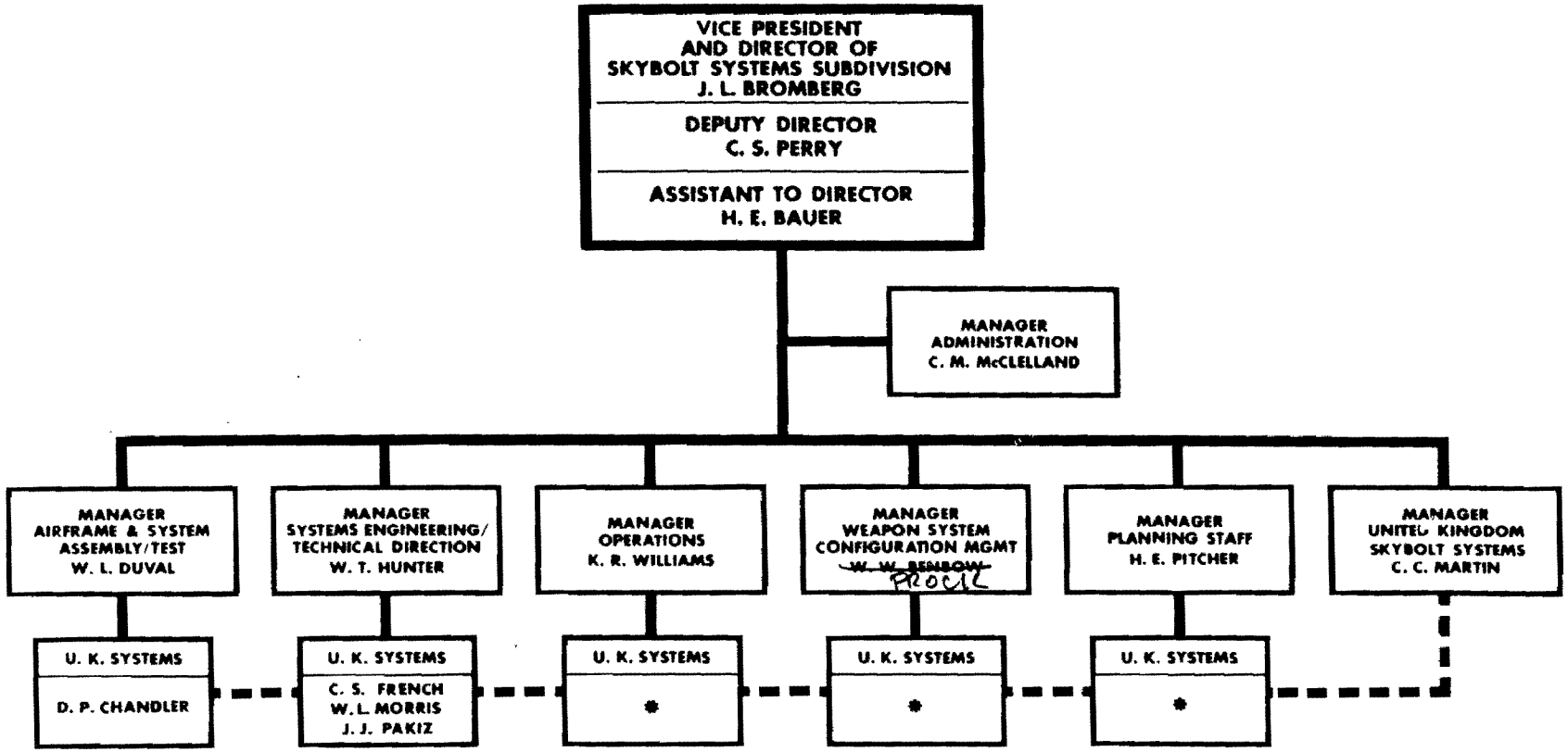
SKYBOLT SYSTEMS SUBDIVISION
UNITED KINGDOM SKYBOLT SYSTEMS ORGANIZATION



* PERSONNEL ASSIGNED AS REQUIRED

FUNCTIONAL LINE MGM'T

LOCAL SUPERVISION & OPERATIONAL CONTROL

DM20-5041
REV. JUL-62

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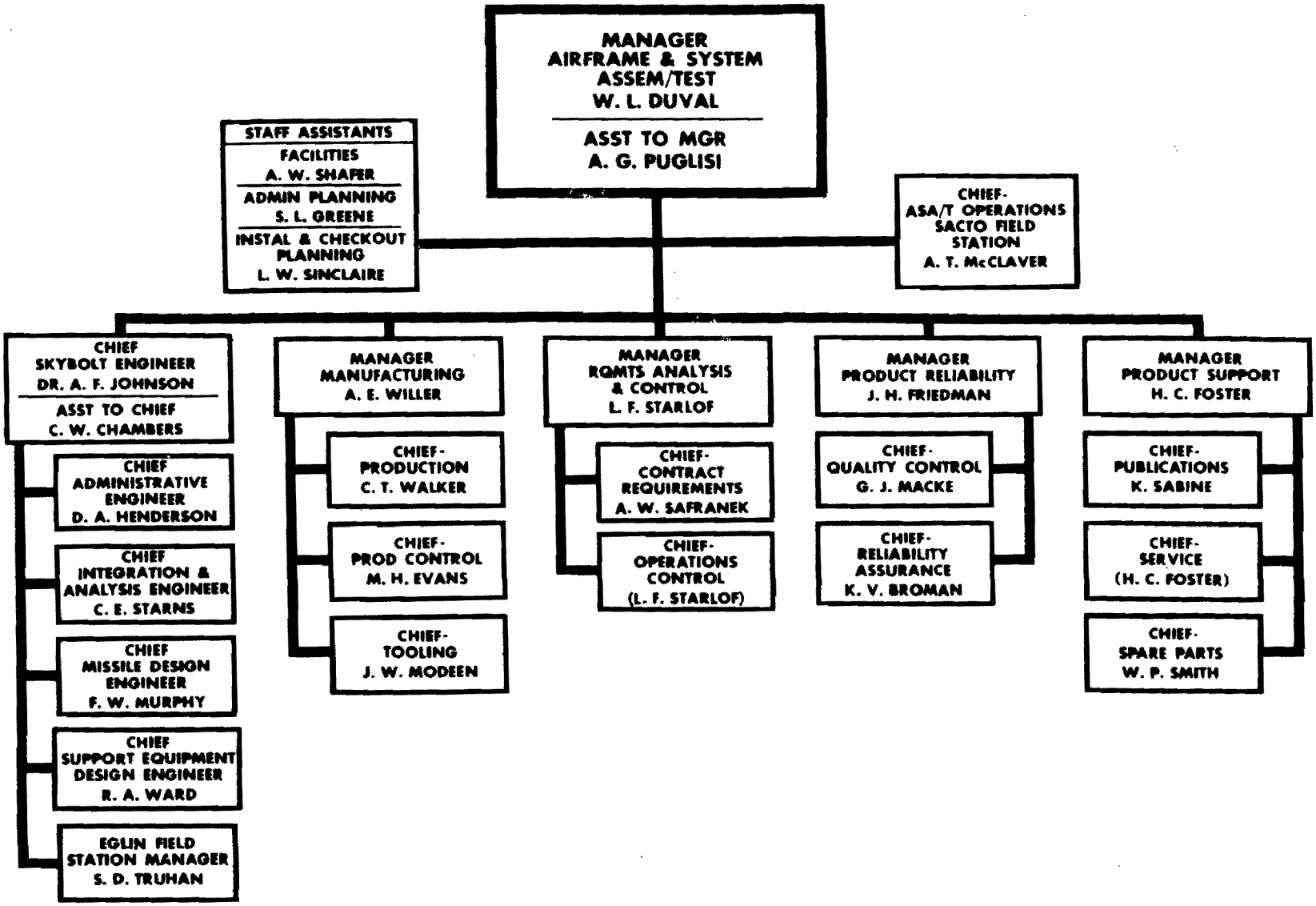
SKYBOLT SYSTEMS SUBDIVISION
AIRFRAME & SYSTEM ASSEMBLY/TEST ORGANIZATION



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REV. JUL-62

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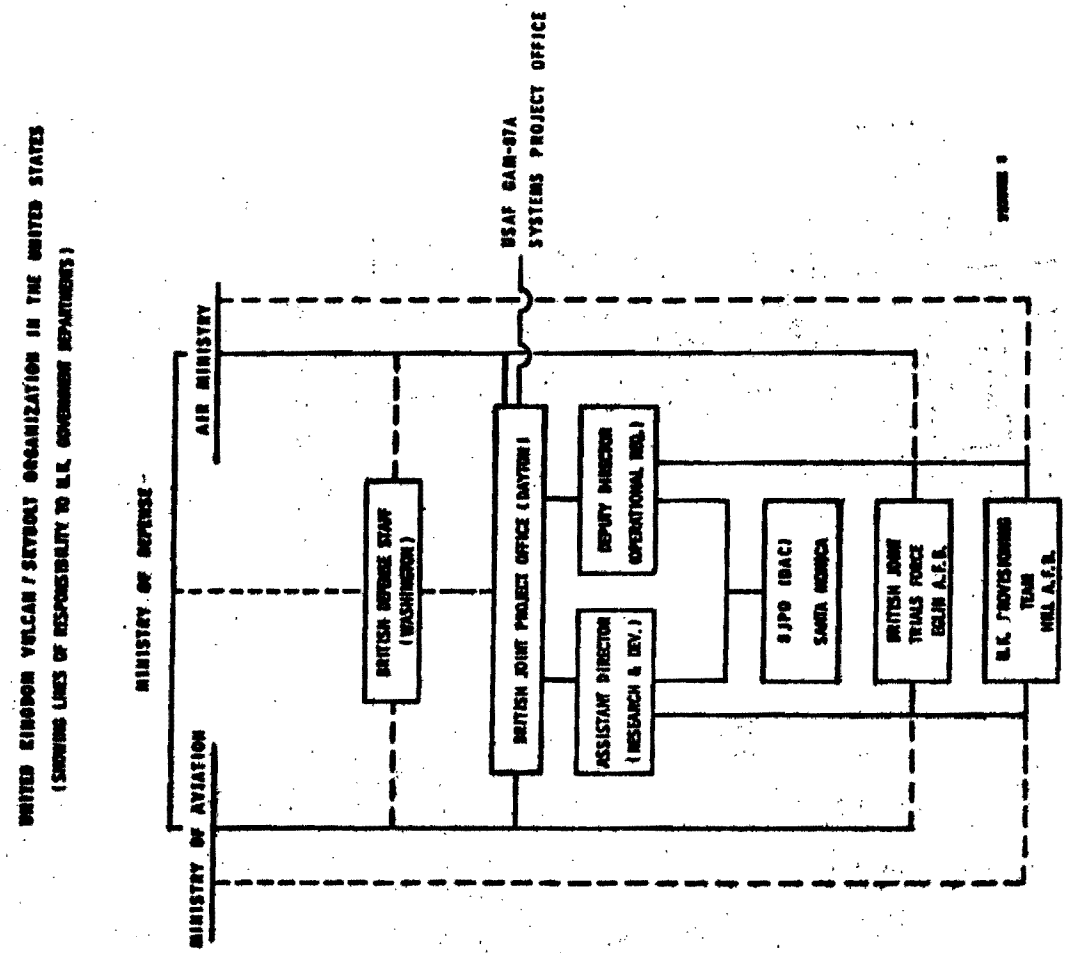

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(Extracted from GAF-87A Hist. Rpt., Jan—June 1962)

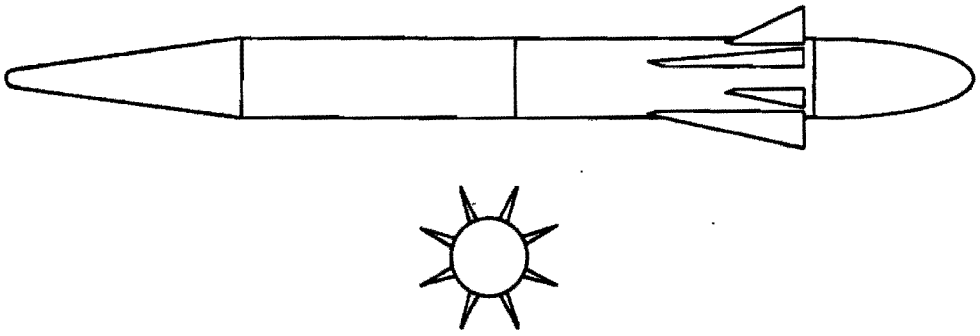
UNITED KINGDOM VULCAN/SKYBOLT ORGANIZATION IN THE UNITED STATES

AGENCY	NAME	ADDRESS
B.J.P.O.	Gp. Capt. Bonser E.I. Campbell Gp. Capt. Chettle Wg. Cdr. Harries Mr. L.R. Palmer Wg. Cdr. Marmion Sqn. Ldr. Gash Sqn. Ldr. Lawton	MCL BJPO Wright-Patterson AFB, Ohio
B.J.P.O. (S.M.)	Mr. McIvor Wg. Cdr. Hirons Mr. Dickison	Douglas Acft. Co. (BJPO-A2) Santa Monica Calif.
AVRO REP. D.A.C.	Mr. H. Newton	A.V. Roe, Representative DAC, Santa Monica Calif.
BRITISH JOINT TRIALS FORCE	Wg. Cdr. C.E. Ness, Commander BJTF. Mr. J.K. Moakes Sqn. Ldr. Hooks Sqn. Ldr. Moreau F/Lt. J.P. Maling F/Lt. V.C. Fruin-Ball	APGC (PGZD)

UNCLASSIFIED

Characteristics Summary

ALBM GAM-87A



"SKYBOLT" DOUGLAS

Length (overall) . . . . . 39.4 ft
Gross Wt. (Design objective) . . . 11,353 lb
Body Diameter . . . . . 3.0 ft
Overall Dia (max) . . . . . 6.1 ft

AVAILABILITY

Number available		
TEST	INVENTORY	TOTAL
0	None	0

PROCUREMENT

FY		62	63	64	65	66		TOTAL
R&D	USAF	5	15	27	0	0	47	63 Note 2
	UK	2	1	13	0	0	16	
PROD	USAF	0	58	256	350	413	1077	1257 Note 3
	UK	0	0	88	80	12	180	

STATUS

1. R&D authorized (WS 138A) . . . . . Feb 60
2. Contract Nr. . . . . AF 33(600)-39587 Apr 61
3. DEI of System Installation . . . . . Jan 61
4. First Dummy Drop (Boeing) . . . . . Feb 61
5. First Instrument Drop . . . . . Jul 61
6. First Program Launch . . . . . Apr 62
7. First Guided Launch . . . . . 28 Nov 62
8. Category I Test . . . . . Start Jul 61, Complete Nov 63 (est)
9. Category II Test . . . Launches Start Nov 63 Complete Jul 64 (est)
10. Category III Test . . . . . Start Apr 64, Complete Sep 64 (est)
11. First B-52 Squadron Operational . Oct 64 (est)
12. U.K. Tests at Eglin AFB . . . Start Mar 63, Complete Oct 64 Test)

POWER PLANT

Solid Rockets
2-S 40-KS-18,400 (XM81)
1-S 40-KS-36,800 (XM80)
Mfr Aerojet

		STAGE I	STAGE II
Diameter	(in)	36	36
Length*	(in)	150.1	94.8
Weight**	(lb)	5500	2714
Burn Time	(sec)	40.7	41.3
Specific Imp. (Isp)		245	245
Chamber Press. (PSIA)		600	600

*Including nozzle
**Propellant only

Propellant Composition:
Ammonium Perchlorate Plasticised Polyurethane Solids

FEATURES

A two stage, solid propellant, air launched ballistic missile designed to fulfill the requirements of SAC and RAF for a long range atomic weapon to arm existing bombing forces.
First Stage Controls:
Conventional tail aerodynamic fins
Second Stage Controls:
Single full swivel nozzle with roll reaction jets
Re-entry Vehicle spin stabilized
Gravity bomb capability
Carrier Aircraft:
B-52F, G & H
RAF-Vulcan

GUIDANCE

Stellar aligned, Doppler damped inertial guidance prior to launch; pure inertial guidance during ballistic flight. Missile guidance weight: - 228 lb.

WARHEAD

XW-59 X-1

Length	47.9 in.
Diameter (outside)	23.75 in.
Weight	565 lb
CG from front	17.8 in.

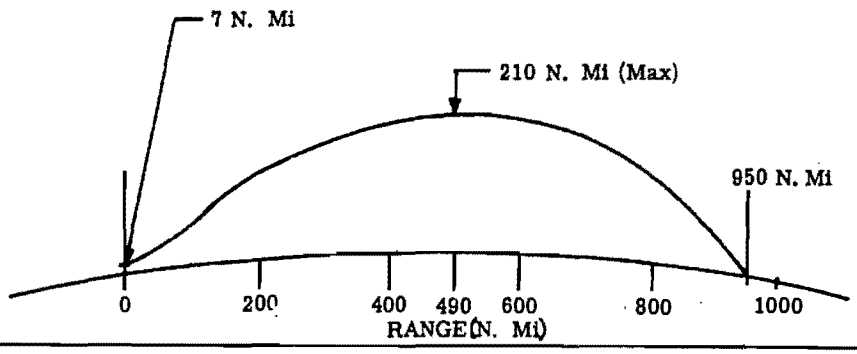
Airburst with contact burst backup.

RESTRICTED DATA
ATOMIC ENERGY ACT 1954

EXCLUDED FROM AUTOMATIC REGRADING; DOD DIR 5200.10 DOES NOT APPLY

DOE (b) 1 20D

Characteristics Summary Basic Mission GAM-87A



PERFORMANCE REQUIREMENTS

(SOR 177, dated 22 Jan 59, revised 13 Jan 61)

Range . . . . . 950 n. mi
Trajectory . . . . . Ballistic

DoE b3

(b)(1),(b)(3):42 USC §2168(a)(1)(C)–(FRD)

RESTRICTED DATA
ATOMIC ENERGY ACT 1954

DoD

PERFORMANCE—ESTIMATED

Re-entry vehicle weight	812 lb
Range (n. mi) max	950
min	250
Alt (n. mi) max	210
Velocity (fps) max	12,380
Duration (sec) max	710

DoE b(3)

NOTES

1. Performance Basis: Estimated data
2. These quantities are the prime contractor's estimate of prototype and test articles required to prove performance. As such, they do not require acceptance or delivery to the Air Force. The types of the 47 R&D missiles for USAF by quantity are: 41 guided launch, 4 programmed launch and 2 captive electrical. The types of the 16 R&D missiles for UK are: 12 guided launch, 2 captive electrical, and 2 mechanical.
3. Number to be placed on contract in fiscal year. Of the 1077 USAF missiles 1012 are squadron missiles, 53 are combat evaluation launch missiles and 12 are Category III test missiles.

REFERENCES -- for Appendices

(A) 1. Cost History; Appendix B, subj.: Cost Increase Analysis, GAM-87A, January-June 1960, attachment to ltr., Lt. Col. H. C. O'Neill, Costing Br., Advanced Sys. Div., Dir/Prod., to GAM-87A WSPO, subj.: Program Price Analysis -- GAM-87, 25 July 1960.

(B) 2. GAM-87A Quarterly Progress Rpt., 1 July 1960, DAC Rpt., SM-37643, p. 21; rpt., Joint USAF/RAF Task Grp. on Strategic Air-to-Surface Weapons, Nov. 1958, doc. Nr. 66; Journal and Register, 26 Jan. 1963; The Reporter, 11 April 1963, p. 19, "The Scrapping of Skybolt," by Ward S. Just.

3. GAM-87A hist. rpt., July-Dec. 1960; Journal and Register, 26 Jan. 1963.

4. United States Dept. of the Air Force and United Kingdom Ministry of Aviation Technical and Financial Agreement Concerning the Skybolt, 27 Sep. 1960.

5. Dep/Sys. Mgmt. Wkly. Activity Rpt., 18 Aug. 1960; TWX, LMSL462, GAM-87 Sys. Proj. Ofc. to Hq USAF, 14 Nov. 1960.

6. Journal and Register, 26 Jan. 1963.

7. Memo., Sec. of Def. to Eugene Zuckert, Sec. of the Air Force, subj.: GAM-87A Prog., 21 Oct. 1961; Air Launched Ballistic Missile Development Plan, 1 Oct. 1960 Revision, GAM-87A Program.

8. Preliminary Report, Vulcan Captive Mechanical Flight Test Nr. 1, 21 July 1962, DAC Rpt. SM-42236; Flight Test Nr. 2, 14 Aug. 1962, SM-42262; Flight Test Nr. 3, 20 Aug. 1962, SM-42265; Flight Test Nr. 4, 5 Sep. 1962, SM-42266; Flight Test Nr. 5, 11 Sep. 1962, SM-42267; Flight Test Nr. 6, 13 Sep. 1962, SM-42268; and Flight Test Nr. 7, 30 Oct. 1962, SM-42290.

(C) 9. Skybolt Report, 9 Jan. 1963, Figure 4.

(D) 10. Air Force Contract AF33(600)-39587.

(E) 11. System Flt. Testing Eval. Prog. for WS-138A, 1 Dec. 1960, Revised 26 Jan. 1963, DAC Rpt. SM-37609, reprinted 1 May 1962; USAF Film Rpt. Nr. 33311, GAM-87A Skybolt Guidance Sys. Dev.; rpt., GAM-87A (WS-138A) Rocket Powered Strategic Air-to-Surface Missile, prepared by GAM-87A proj. Ofc., 2 Oct. 1959, doc. Nr. 56.

(F) 12. Fact Sheet, Biography of Brig. Gen. David M. Jones, prepared by ASD Information Ofc.

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