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Carl A. Jansen
USAF

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MANAGEMENT AND THE MINUTEMAN
Carl A. Jansen
1/Lt USAF
Patrick AFB, Florida

I. INTRODUCTION

Since the advent of the "Space Age", the United States has achieved many significant firsts in the field of technology. This is particularly evident in the development of today's advanced weapon systems. The term, weapon system, is defined as an instrument of combat integrated with all its associate equipment, support facilities and services. This includes assembly of material, personnel, installations, plans, directives and procedures required to enable the instrument of combat to accomplish its tactical mission. General Schriever, Commander of the Air Force Systems Command (AFSC) stated at the National Advanced Technology Management Conference held in Seattle, Washington, "sound management is clearly the pacing factor in technological progress. It is essential to the timely acquisition of the new Air Force Systems... in all this effort there is no substitute for technological competence and sound management practices." Application of modern management practices to the Minuteman Weapon System Development Program will clearly indicate how sound today's progressive management can be.

The purpose of this article is to analyze the key policies and procedures enacted at the various managerial levels during the Minuteman Program's implementation. The specific managerial levels which will be examined are: system program management, corporate management, and field level management. The selection of these areas is justified on the basis of the present organizational structure which denotes these levels to be the key areas of the program.

II. SYSTEM PROGRAM MANAGEMENT

The concept of the "second generation" Inter-Continental Ballistic Missile (ICBM) was developed by the Strategic Air Command (SAC) as a means of advancing the "state of the art" in nuclear weapon delivery capability. The Qualitative Operational Requirements specified by SAC determined the basic operational capabilities of the proposed weapon system. Technical feasibility studies were then conducted in the early months of 1955 by a team of specialists from the Ballistic Systems Division (BSD), formerly the Ballistic Missile Division, (AFSC), and the Ramo/Woodrige Corporation. The conclusions of this group, in 1958, indicated that such a system was technically feasible. This result allowed the Department of Defense to approve the concept and initiate the Research and Development (R&D) Minuteman Program.

NOTE: The views presented in this paper are that of the author and are not considered to be that of the U.S. Air Force.
Under the direction of General Schriever, then Commander of the Western Development Division, AFSC, the policy of management control by the military program office was emphasized for this Program. The organizational concepts developed during the Atlas and Titan programs were the forerunners to the Minuteman organizational structure. Under the Minuteman organizational plan, the Air Force was to provide program management through a BSD System Program Director. Space Technology Laboratories, Inc., (STL) was to provide systems engineering and technical direction. The integrated efforts of these two organizations (managerial and technical) proved to be the basis on which all primary decisions were to be made. "Some of the most severe problems in the aerospace industry today are not technical but management. In the world of the technological explosion, our greatest challenge is to develop our management techniques to keep pace with and control the rapid advance of technical know-how." The success of the Minuteman Program was the direct result of key decisions developed by the BSD/STL team at the outset of the program. Some of the key program policies and procedures which were established included:

(1) **Concurrency:**

The weapons system was developed and acquired under the concurrency concept. "One aspect of the concurrency concept which is quite evident in the Minuteman Program is that portions of the design, production, and operational activation phases actually overlap." The Minuteman Development Program was scheduled to extend over three key-testing phases:

(a) **Research and Development Tests (R&D).** In this phase, BSD supervised the development of the integrated system composed of component subsystems. The tests were predominately contractor efforts, with increasing military participation leading to the demonstration that design goals had been met under non-operational conditions. This was planned at two distinct test sites, Category I testing at the Air Force Eastern Test Range (AFETR), and Category II testing at the Air Force Western Test Range (AFWTR).

(b) **Demonstration and Shakedown Tests (DASO).** These tests were conducted by the Strategic Air Command (SAC) assisted by BSD in an operational environment using operational procedures. During these tests, operational and logistical procedures were refined. In addition, basic system capabilities and limitations were demonstrated. Only then was the determination made that the Minuteman Weapon System configuration had been sufficiently stabilized to perform its intended mission.

(c) **Operational Tests (OT).** This test program was designed to exercise the operational system in as near an operational environment as possible. The operational tests determined the weapon system reliability and accuracy planning factors, at specified confidence levels and intervals. This data was essential to SAC in determining the operational employment of the missiles against prime target areas. As SAC assumed additional operating command control of the Minuteman Weapon System, added tests were conducted to insure that the
established reliability and accuracy factors were preserved during the life of the weapon system. This would be on a continuing basis.

(2) Reliability:

"Reliability was firmly established as one of the prime development requirements and was considered in virtually every management and technical decision. Reliability was not considered as an afterthought as was the case in many other systems." To enforce this concept, a distinctive Reliability Program Plan was designed to become part of the contractor's work statement. "These program plans, written by the contractor and subject to the approval of BSD/STL, contained distinct reliability tasks, specific procedures, responsibilities, schedules and criteria for completion. Numerical reliability requirements were made part of every contract."

(3) Cost-effectiveness:

In order to minimize the cost for a given task, cost-effectiveness was determined to be one of the fundamental factors used in the evaluation of all contractor programs. This approach was also applied to decisions regarding proposed design changes for increasing the system's reliability. "Cost-effectiveness was made the yardstick by which the various reliability efforts would be judged." This cost standard proved successful in all phases of the program.

(4) Contractors:

A major company was scheduled to handle the integration and test of the weapon system. Other associate contractors were responsible for the Guidance and Control sub-system (G&C), the Re-entry Vehicle sub-system (RV), and the three motor sub-systems (stages 1 to 3). A total of six major contracts were scheduled for bidding. This contracting method allowed for a wider field of bidding which ultimately lowered the overall cost of the system.

(5) Information Control:

Sound managerial control was maintained over the entire weapon system program through the application of the latest informational control techniques. Computers and nationwide communication networks were utilized to maintain effective interface control between the associate contractors. In addition, the contractors were constantly required to maintain a current status of all functions in the program. Mr. T. A. Wilson, Minuteman Manager for the Boeing Company, recently commented, "it is this common communication link of the functional analysis program which enables us to describe every element of the weapon system, lay it out on the table, agree on a concept or configuration and prevent deviations by either military or contractor participants." This type of configuration control was emphasized with every contractor associated with the Minuteman Program. It proved to be a significant asset to all levels of management.
The selection of the specific associate contractors was also based on important engineering design criteria which was correlated to the managerial procedures explained above. The basis for these specifications were formulated before the program's activation. The basic design criteria established for the contractor bidding phase included:

1. Design range - 6,300 miles.
2. Propulsion system - three stage, solid propellant motors. (This design was selected on the principle of greater simplicity and reliability as compared to liquid propellant systems. In addition, its' instant readiness reduced the preparation time for an operational launch).
3. Guidance and Control (G&C) subsystem - all inertial unit with no external commands needed except the launch command once the target was set into the airborne computer.
4. Re-entry Vehicle (RV) - designed for a ballistic re-entry. In addition, it contained a thermonuclear warhead.
5. Airframe - consisted of the following units: three motor casings; G&C section; RV; two interstages; and the first stage skirt.
6. Missile assembly - assembled at a centrally located production depot under conditions where the environment was conducive to precision assembly and check-out.
7. Operational deployment - deployed in hardened and dispersed silos and also railroad launchers. (The railroad launcher concept later proved to be unsound on the basis of cost and reliability. It was, therefore, discarded as a secondary launch mode.)
8. Operational personnel - a two man crew with a multi-launch capability from a central control center.

The aforementioned criteria was based on maximizing both cost-effectiveness and reliability. All the aspects of the proposed weapon system including the operation and maintenance requirements in the field were considered. As a result, "the Minuteman ICBM is designed to have the best cost-effectiveness of any current weapon system." Figure 1 denotes the basic design configuration of the airborne hardware.

Based on the preceding concepts regarding management and engineering design, The Boeing Company was selected as the successful bidder to integrate and test the Minuteman Weapon System. The remaining major associate contractor responsibilities were assigned to the following companies:

Re-entry Vehicle (RV) subsystem: AVCO Corp.
First Stage engine: Thiokol Corp.
Second Stage engine: Aerojet General Corp.
Third Stage engine: Hercules Powder Co.
MISSILE CONFIGURATION INDEX
In addition to the development of the weapon system, plans were initiated to construct the first operational SAC Wing at Malmstrom AFB, Montana. The two major air commands involved in the Project (AFSC and SAC) were primarily responsible for selecting and activating this site. The U.S. Army Corps of Engineers was assigned the primary task to oversee the basic "brick and mortar" construction phase of the silos and launch control centers. Employing the integration efforts of Boeing, BSD was designated to certify the acceptability of the weapon system installation. Figure 2 indicates the organizational structure for all phases of the program.

The application of the concurrency concept to the overall Minuteman Program Schedule indicates that the planners were very optimistic as to the program's outcome. Drafted in early 1958, the R&D schedule called for the first flight test by the end of December 1960. In addition, the first Minuteman Wing was to become operational by mid-1963. This schedule established a precedent in the total deployment time for an operational ICBM weapon system.

III. CORPORATE MANAGEMENT

Examination of the management philosophy of The Boeing Company provides a common understanding as to how the remaining associate contractors operated during the program. The interfaces between each associate required close overall liaison. This was particularly true for Boeing which was the integrator for the weapon system.

The assignment of the Minuteman contract was the first time Boeing had been associated with the development of an ICBM. Boeing, therefore, was faced with an entirely new set of complex development problems concerning high reliability and cost-effectiveness design criteria. The concept of concurrency on the scale of the Minuteman contract was relatively new to the top management of the company. It was essential for the company to develop unique integration functions which would meet the performance and schedule requirements. Four primary factors were set up to meet this challenge; functional analysis, interface control, the Minuteman Production Board, and master schedule and allocations. (1) Functional Analysis was used to define and control acquisition of all elements of the weapon system - equipment, facilities, data, and personnel. This process established all functional requirements to fulfill the Air Force Weapon System Specification for the Minuteman. (2) Interface Control was the detailed mating specification between hardware supplied by various contractors. This function has had its counterpart in every major weapon system. (3) The Minuteman Production Board concerned itself with the delivery of the operational bases on schedule. The ability to meet this requirement was dependent upon the timely delivery of government-furnished equipment to the sites from all contractors, including Boeing. (4) Master Schedule and Allocations provided for the orderly, in-sequence planning of equipment allocations. It provided a consolidated listing of all equipment required at each base, the dates needed, and supplier's capability to produce. This information was assembled, published and controlled by Boeing for the USAF.
AIR FORCE SYSTEMS COMMAND

- Ballistic Systems Division, Headquarters — Strategic Air Command (BSD, HQ) (Systems Program Director)
- Strategic Air Command Operating Command

Space Technology Laboratories Engineering, Technical Direction

- The Boeing Company (Integrate & Test)
- AVCO (Re-Entry Vehicle)
  - SANDIA (Warhead)
- Autonetics (Guidance & Control Subsystem)
- Thiokol Corp. (First Stage Motor)
- Aerojet General Corp. (Second Stage Motor)
- Hercules Powder Co. (Third Stage Motor)

Corps of Engineers (Site Activation)

- Ellsworth AFB
- Malmstrom AFB
- Minot AFB
- Whiteman AFB
- Warren AFB
- Grand Forks AFB

6555th ATW Minuteman Weapon Division (Eastern Test Range)

6595th ATW Minuteman Weapon Division (Western Test Range)

FIGURE 2
RESEARCH, DEVELOPMENT AND OPERATIONAL ACTIVATION ORGANIZATION
In addition to the above important initial steps in the program, Boeing also realized the need for an efficient managerial information system which would present critical information required for the key decision makers in the program. BSD had recognized the need for this significant effort with time-phased goals to develop management tools that could keep up with the dynamic pace of the technical work involved. Therefore, in order to direct their efforts in a manner compatible with Air Force requirements, Boeing created a series of management event-logic networks. This presentation technique was an extrapolation of the Program Evaluation Review Technique (PERT) which was developed by the Navy for the Polaris Program. The event-logic network functions are noted in Figure 3.

![Event-Logic Network Diagram](figure3.png)

**FIGURE 3**

The Boeing Company's Event-Logic Network

"These networks depicted all acquisition events within Boeing and the interchanges between Boeing and all other government and contractor organizations. It is a functional analysis of the management job necessary to acquire a particular weapon system." 11 The event-logic network was essential for all complex functions. This fact is evident by the number of management interfaces between Boeing and BSD. Exclusive of normal financial and schedule status reporting, there are actually over 600 categories of management interfaces between these two organizations. "Since each category may involve hundreds of repetitive occurrences of such things as criteria submittals, specification approvals, etc., the total picture involves approximately 100,000 actions." 12
Mr. T.A. Wilson recently stated, "management's function is to control by providing direction and support. This means sound and timely planning... We must not forget that management tools are like many other potent tools - they work both ways." In order to better evaluate the applications of such tools as the event-logic network and other integration techniques, it would be advantageous to enumerate Boeing's primary responsibilities in the Minuteman Program. These functional areas included:

1. Supplying substantial portions of the operational ground and maintenance support equipment, missile transportation and handling systems, missile interstage structure, and the airborne and ground instrumentation for both AFETR and AFWTR test programs.

2. Primary responsibility to assemble and assist in testing the weapon system under the direction of BSD and STL. This involved the missile assembly, integration, and functional testing of the weapon system at AFETR and AFWTR as well as the assembly and initial checkout of the weapon system at operational SAC bases. Boeing's extensive Seattle Test Facility was also used to test the compatibility of the operational ground support equipment in a controlled environment.

The need for functional control in all these related areas clearly indicated why it was essential for Boeing to initiate the unique functional integration procedures. The employment of these tools has worked effectively, and has contributed significantly to Boeing's success in assisting the development of the final product, a fully operational Minuteman Weapon System.

IV. FIELD LEVEL MANAGEMENT

Examination of the Minuteman Program at a field level reveals how successful the overall program management concepts were applied at the local level. The organizational structure and control of the R&D flight testing at AFETR was typical of a field level organization in the Minuteman Program. The flight testing program was set up through the cooperation of the Air Force Eastern Test Range (AFETR) formerly the Atlantic Missile Range (AMR), under the sole direction of BSD.

The primary mission of the Minuteman Program at AFETR was, "to demonstrate that a functional ballistic missile has been developed, to obtain data for design improvements and to demonstrate that performance capabilities of the missile meet the operational requirements." These mission functions have been broken down into seven key operational areas for each missile test.

1. Receiving inspection and functional test of the individual missile sub-systems and systems.

2. Prelaunch assembly and checkout of the missile.

3. Acceptance by the Air Force of each delivered missile.
4. Acquisition and handling of preflight test data.

5. Launch of the missile.

6. "Quick-look" analysis of the flight test data.

7. Preparation of field and flight test reports on each missile.

Other operations at AFETR include tests and reports covering facility checkout and mechanical and electronic checkout of associated ground support equipment.

The organizational structure of the Minuteman Test Facility at AFETR has proven to be the key to effectively flight testing the Minuteman under the basic concepts of high reliability and low cost-effectiveness. Figure 4 denotes the prime related functional areas among the various military and civilian organizations. The Minuteman Weapon Division, 6555th Aerospace Test Wing (ATW), is responsible for the management of the AFETR Minuteman Flight Test Program and the operation of the Minuteman Launch Area, including the missile launches. In addition, the utilization of "Blue Suit" launch crews has been a significant asset to the program in terms of cost reduction and management control.

Under the concurrency program, the initial planning effort included the design of a Missile Assembly Area and a Missile Launch Area (Complex 31). The support facilities at Complex 31 included ability to launch from three different modes; railroad transporter, launch pads, and silos. This was a true indication of the effort in which the concurrency concept was envisioned for a field test site. In addition, the establishment of dual facilities for each mode of launch, with the exception of the single railroad system, created the ability for a faster launch rate. Figure 5 indicates the launch area configuration after all the dual facilities were completed.

The initial test objective at AFETR was to flight test the entire airborne systems during the first launch. This was proven to be a complete success when the first Minuteman, Flight Test Missile 401, was launched from Pad 31 at 11:00 AM EST on Wednesday, February 1, 1961. Approximately twenty-five minutes later, the RV impacted on target into the Atlantic Ocean, 4600 miles down range from the test site. This flight alone proved to be a milestone in missile technology. The complete airborne system was functionally tested during its initial flight. This concept of multiple functional tests of combined subsystems, as indicated by the first launch, was one of the key concepts which was stressed throughout the Minuteman Program. It proved to be a significant asset in developing a complex operational weapon system a year ahead of schedule.

The close cooperation between all organizations, both military and civilian, has to a high degree been responsible for the early detection of crucial design improvement areas which could prove costly under a concurrency program. The System Integration and Test Plan, under which the major responsible organizations at AFETR are governed, explains the primary related interfaces between each contractor. Major work items performed by Boeing and the other Associate Contractors at AFETR are defined by engineering drawings and procedures. Air Force
FIGURE 4
Primary Organizational Interfaces to Support Mission at the Air Force Eastern Test Range
FIGURE 5

minuteman launch area
acceptance of the work is based upon review of the results from the tests prescribed by engineering procedures, upon STL recommendations concerning technical adequacy, and upon Quality Control verification that the work was performed in accordance with approved engineering instructions. This concept has proven to be very effective in maintaining configuration control of all phases of assembly, test and launch of the Minuteman. The end result has been the immediate availability of critical information to both management and engineering in the event modifications are needed to correct major malfunctions in the weapon system, both R&D and Operational. Again, this success has been attributed to the broad management policies developed at the outset of the Minuteman Program.

In addition to the primary test objective, SAC later established a secondary objective for early participation of the operating command in the development tests and evaluation of the Minuteman at AFETR. "This was necessary in order to provide familiarization, training, and experience required to achieve the earliest operational and logistic support capability." The Launch Operations Area has been the primary focal point where the majority of the SAC personnel have been utilized. This has proved to be a significant asset to BSD also, since the required compliment of Test Wing personnel has been reduced without degrading the launch capability.

The mission success at AFETR clearly indicates how the key program policies and procedures were applied to a regional organization. Efficient overall managerial control was an absolute necessity when launch operation requirements were to be satisfied.

V. OVERALL PROGRAM DEVELOPMENT

The Minuteman was the first solid-propellant ICBM and represented a significant economic advance in the development of the U.S. Ballistic Missile Program. It is a weapon system predicated on high reliability, maximum simplicity, decreased reaction time, and a greatly improved cost-effectiveness concept. "The countdown and flight reliability of the system is currently exceeding its operational requirements and appears to have stabilized at this high value... In no case is there a major subsystem which has failed to measure up to its operational requirement. This means that the G&C, propulsion, airframe, RV, and inline operating ground equipment (OGE) subsystems are all meeting or exceeding their operational requirements.""

In addition to the high performance rating of the final product, the time factor is also noteworthy. The first wing of the Minuteman (Malstrom AFB, Montana) was brought to an operational status one year ahead of the original schedule. Four other major wings are or will be operational within a year. These wings are located at Ellsworth AFB, South Dakota; Minot AFB, North Dakota; Whiteman AFB, Missouri; and Warren AFB, Wyoming. These scheduled accomplishments established a precedent in the acquisition of a major ICBM weapon system. Figure 6 summarizes the primary functions involved in the acquisition of the weapon system at the respective operational SAC wings. Under the program's concurrency concept all functions are continuous. The primary operations at present, however,
Feasibility Design and Management Criteria Established (AFSC)

Qualitative Operational Requirements (SAC)

Preliminary Contractor Designs Formulated (AC)

Detailed Designs Produced (AC)

Production of Missile Subsystems and Ground Equipment (AC)

Drawings and Specifications Produced (AC)

Critical Review of Weapon System Modifications (AFSC)

USAF Subsystem Acceptance for R&D and Operational Tests (AFSC)

Operational Weapon System Activation (AFSC)

Demonstration and Shakedown of Weapon System (SAC)

R&D Airborne Systems Test (AFSC)

Weapon System Operational (SAC)

FIGURE 6
WEAPON SYSTEM ACQUISITION FLOW DIAGRAM

AFSC - Air Force Systems Command Responsibilities

SAC - Strategic Air Command Responsibilities

AC - Associate Contractor Responsibilities
center about the modification network loop. All major modifications are based on updated reports from all related activity areas. This error detection process will continue to be utilized until the weapon system is declared obsolete.

The completion of the five operational wings will not end the Minuteman Development Program. A new advanced Minuteman II has already been flight tested at AFETR on 24 September 1964. It represents an increase in both range and deployment capabilities compared to the operational Minuteman I. Minuteman II is scheduled to be operationally deployed at Grand Forks AFB, North Dakota.

VI. CONCLUSIONS

The significance of these accomplishments both in performance and schedule requirements must be attributed primarily to the sound management disciplines which were developed at the outset of the Minuteman Program. The basis for every key decision in the program can be traced to certain specific managerial principles. The key policy was the utilization of BSD as the primary management organization. This created greater control over all the contractor functions. In addition, the concurrency, cost-effectiveness, configuration control and reliability standardization techniques contributed significantly to the program's success. General Schriever has stated that one of the "most serious problems in space and missile development concerns the development of management's methods." The success of the Minuteman was due to the introduction of new managerial tools. The Minuteman is not considered the ultimate in weapon system management complexity and effectiveness. Future advanced development programs will require added support through the application of new managerial methods. The tools and concepts implemented in the Minuteman Program are the forerunners of new approaches towards greater managerial efficiency.
FOOTNOTES


3 Ibid., p. 51.


5 Powell, op. cit., p. 53.

6 Ibid., p. 60.

7 Ibid., p. 53.


9 Schriever, op. cit., p. 184.

10 Wilson, op. cit., pp. 229-231.

11 Ibid., pp. 233-234.

12 Ibid., p. 234.

13 Ibid., p. 232.


15 Ibid.

16 Ibid., p. 5.

17 Powell, op. cit., p. 51.


