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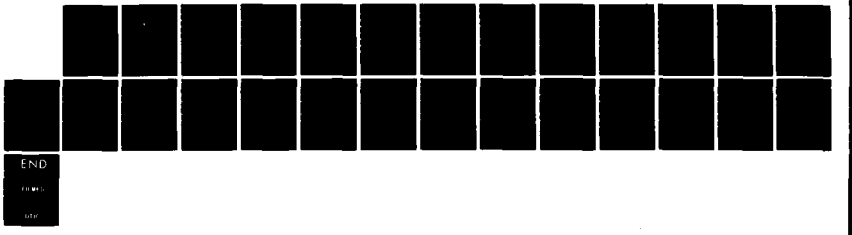

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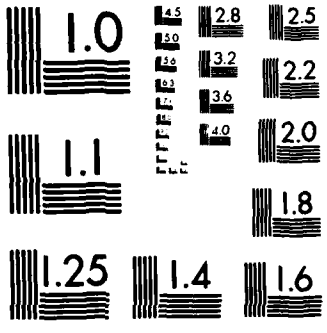

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STUDENT REPORT

GROWTH OF THE AIR FORCE METROLOGY AND CALIBRATION PROGRAM AND REASONS FOR CHANGES IN THE PROGRAM

MAJOR THOMAS SMICKER 85-2500

"insights into tomorrow"

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TITLE GROWTH OF THE AIR FORCE METROLOGY AND CALIBRATION PROGRAM AND REASONS FOR CHANGES IN THE PROGRAM

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THIS PAPER IS A BRIEF HISTORY OF THE AIR FORCE METROLOGY AND CALIBRATION (AFMETCAL) PROGRAM. IT TRACES THE GROWTH OF THE PROGRAM FROM ITS INFORMAL BEGINNING DURING WORLD WAR II THROUGH THE '50s, '60s, AND '70s. THE PAPER CONCLUDES WITH A REVIEW OF CHANGES IN THE PROGRAM OVER THE YEARS AND OFFERS REASONS FOR THESE CHANGES.

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PREFACE

This paper traces the growth of the Air Force Metrology and Calibration Program from World War II through the 1970s. Although airmen used measurements and standards well before the war, rapid technological advances during the war created a need for a formal calibration program. Mechanics, technicians, and operators had to be assured that their complex tools and equipment were calibrated to the most accurate standards in the country. The paper describes how the formal calibration program provided this assurance through a means of comparing field-level standards with the most accurate standards in the nation--those from the National Bureau of Standards. The paper discusses program growth that followed in the '50s, '60s, and '70s and concludes by detailing the impetuses for program changes from the '40s to the '70s.

ABOUT THE AUTHOR

Major Smicker received his commission in 1970 through the Air Force Officer Training School. He was awarded a B.S. degree in accounting by Indiana University and an M.S. degree in management science by the University of Arkansas. He obtained his professional military education from the Air Command and Staff College and the Air Force Squadron Officer School in residence. He has been an auditor with the Air Force Audit Agency for the past 14 years. His audit projects included management studies of precision measurement equipment laboratories (PMEL) in the Pacific theater, in the European theater, and in the CONUS. In addition, he was stationed at Newark Air Force Station--the home of the Air Force Metrology and Calibration Program. Prior to his commissioning, Major Smicker was an aircraft and missile electronic equipment repair technician. During his enlisted years, he worked extensively with precision measurement equipment, coordinated closely with PMEL personnel on a new weapon system, and gained comprehensive knowledge of the Air Force Metrology and Calibration Program.

TABLE OF CONTENTS

GLOSSARY

Air Force Measurement Standards Laboratory. The highest echelon standards laboratory in the Air Force. The laboratory, located at Newark Air Force Station, maintains Air Force primary standards certified by the National Bureau of Standards or DOD-approved sources.

Air Force Primary Standards. Standards certified by the National Bureau of Standards or DOD-approved sources for the Air Force Measurement Standards Laboratory as a basic measurement reference for the Air Force.

Calibration. Comparison between a standard; a measuring equipment instrument; an item of equipment; and a higher accuracy standard to detect, correlate, adjust and report any variation in the accuracy of the instrument or equipment item being tested or compared.

Certification. The act of designating that standards and precision measuring equipment have been calibrated and meet established technical requirements.

Standard. Equipment which is established as an authorized or a recognized measure, especially one serving as the basic means by which the accuracy of precision measurement is derived.

Metrology. The science of measurement including the development of measurement standards and systems for absolute and relative measurements.

Precision Measurement Equipment. Equipment used to measure, inspect, calibrate, test, diagnose, or otherwise examine materials and equipment to determine if they meet the specifications established in technical documents (such as engineering drawings, technical orders, and serviceability standards).

Precision Measurement Equipment Laboratory. An activity in possession of standards and responsible for calibration and certification of precision measurement equipment.

Chapter One

INTRODUCTION

> Weights and Measures may be ranked among the necessities of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry; to the distribution and security of every species of property; to every transaction of trade and commerce; to the labors of the husbandman; to the ingenuity of the artificer; to the studies of the philosopher; to the researches of the antiquarian; to the navigation of the mariner, and the marches of the soldier; to all the exchanges of peace, and all the operations of war.
>
> John Quincy Adams
> February 1821

Man has made many exciting discoveries over the years--fire, the wheel, printing, nuclear energy. But two less known discoveries have made possible all industrial progress--measurement and standards. (23:203)

Measurement may have originated in the barter process among primitive men long ago, i.e., an animal pelt for a quantity of berries. Standards were necessarily established at an early date to ensure that barter was fairly consummated. These two discoveries have become instrumental in the progress of today's industrial civilization. Without measurements and standards we would be faced with chaos, for when we express distance, volume, time, temperature, weight, or motion we are measuring and comparing. Measurement is the comparison of an unknown with a recognized standard. (23:203)

The Egyptians devised an innovative method for measuring land and reestablishing borders after the Nile River repeatedly flooded adjacent farmland. Farmers used two sticks tied to the ends of a long rope to lay out a series of parallel and perpendicular lines. Beginning from fixed points (standards) located above the flood plain, they drew arcs in the mud and made geometrically accurate rectangles to outline each owner's field. The requirement for accurate measurements and standards have remained valid ever since. (23:205)

Today the science of measurement, including the development

of measurement standards and systems for absolute and relative measurements, is called metrology. Metrology forms the basis of the Air Force Metrology and Calibration Program, which ensures reliability and accuracy throughout the life cycles of all weapon systems and support equipment. (6:1) "The success of sophisticated weapon systems is increasingly dependent upon the confidence in precision measurement equipment." (5:36) It is this confidence that has been diligently pursued from the informal calibration program of the 1940s through the highly structured program of the 1970s.

Chapter Two

THE AIR FORCE CALIBRATION PROGRAM--THE EARLY YEARS

THE WORLD WAR II ERA

Official unit histories from World War II provide little insight as to how the Army Air Forces' calibration program was structured and functioned. However, the concept of measurement and standards was not unfamiliar to the Army Air Forces--airmen had been calibrating tools and test equipment for a long period of time. But airmen did not have a centralized system of verification that ensured the standards they used compared favorably with the accuracy of the primary standards of measurement. (4:2)

The absence of firm quality assurance may be attributable to the relative simplicity of the weapon systems and the rapid expansion of operations during the war period, as evidenced by the dramatic increase of aircraft in the field from 2,000 in 1939 to 53,000 in 1943. (3:2) A wartime supply and maintenance directive recognized the limitations of the work force when it stated that each echelon of aircraft maintenance to a very large extent was limited by the initiative, ability, and aggressiveness of personnel in the organization concerned. "In wartime, each organization in the interest of efficiency does everything it ... can and passes on up to the higher echelon only that which is necessary." (24:5)

Evidence of maintenance omissions on the home front during wartime was vividly portrayed in an organizational history of the Army Air Forces Materiel Command: (2:5)

> The urgent need for planes in 1942 had meant shortcuts in inspections; more than once planes were accepted which would never have passed the more rigid inspection of 1944 and 1945...for the mushrooming of the aviation industry had so diluted skilled personnel that sound production and inspection practices were not always in evidence.

At the time, these production and inspection problems were incorrectly attributed to poor tool and gauge usage; however, in many cases, proper equipment was simply not available. Those few gauges and measuring instruments on hand had to be passed from one worker to the next. (2:5)

THE BEGINNING OF UNIFORMITY IN CALIBRATION

The "more rigid inspection of 1944 and 1945" may have been the result of the establishment of a highly structured inspection division, with well-defined responsibilities, within the Materiel Command at Wright Field. One of the functions of the division was to provide for uniformity in the calibration of instruments and gauges used to inspect equipment purchased under contract. This was done by establishing and applying technical standards and special inspection tools, gauges, and equipment. In addition, the division operated an instrument laboratory and a tool and gauge laboratory for calibration standardization and testing of precision measuring instruments used by the Army Air Forces inspectors in the field. (2:17)

Although the inspection function established uniform procedures for calibration, it didn't provide for traceability, i.e., the ability to trace the accuracy of local calibration standards to the National Bureau of Standards. Common practice for maintenance personnel in the field was to establish electrical measurement accuracies through individual contracts with local universities or electrical power companies--or to use none at all. (4:2) This lack of traceability existed into the early 1950s. But before traceability could be obtained, the Army Air Forces would have to standardize maintenance methods and procedures.

STANDARDIZATION OF MAINTENANCE METHODS AND PROCEDURES

No central office within the Army Air Forces had responsibility for developing methods and procedures at the field and organizational levels of maintenance. Headquarters maintenance publications were profusely supplemented at the command level to create what each believed to be the ideal maintenance management system. Consequently, a proliferation of maintenance systems existed throughout the service. The lack of centralization inhibited standardization, and standardization was vital to the functions of measurement and calibration.

Army Air Forces Regulation 20-31, issued on 31 August 1944, provided for uniformity among maintenance organizations by directing the Air Materiel Command (AMC) to establish "maintenance standards, maintenance techniques and procedures applicable to all Air Forces and commands." (1:152) The role of the AMC was further refined by Air Force Regulation 23-2. Issued on 22 May 1951, this new regulation made the command responsible to the Chief of Staff, USAF for "...compiling, prescribing, publishing, and distributing Air Force-wide standard methods and procedures for the maintenance and operation of Air Force materiel and equipment." (1:154) As the decade of the 1950s began, the Air Force maintenance structure was prepared to incorporate a system of traceability that would lead to a formal calibration program.

Chapter Three

THE AIR FORCE CALIBRATION PROGRAM IS FORMALIZED

LAYING THE FOUNDATION FOR A VIABLE PROGRAM

The development of numerous and sophisticated electronic equipment during the post-World War II era made the need for a centralized calibration program with traceability readily apparent. It was logical that the Air Materiel Command (AMC) should take the lead in establishing the program. The AMC's primary mission was to provide logistic support to the Air Force. Also, one of its depots, the Dayton Air Force Depot (DAFD), specialized in the repair and management of electronic equipment for the Air Force. Within the DAFD, radio, radar, and machine inspection units were assigned the responsibility for calibrating and inspecting all primary standards and test equipment located at the depot. However, this responsibility was assigned only as an additional duty, and heavy workloads detracted from its accomplishment. As a result, the Standard Inspection Unit was established in 1952 to assume sole and full-time responsibility for calibration and inspection at the depot. (4:3) As the new unit began operations, moves were under way to develop a system for coordinating the calibration of all Air Force equipment.

In October 1952, a conference was held at Headquarters AMC to discuss the feasibility of establishing standards at the Air Force level for use in calibrating electronic test equipment. (4:2) As a result of the conference, the DAFD Directorate of Maintenance Engineering established procedures for the inspection and calibration of all standards, test equipment, and measuring instruments used to maintain radio and electronic equipment at the Air Force depot level. (4:3) Shortly after the DAFD was given these initial calibration responsibilities, it was tasked to develop a new dimension in calibration--mobility.

In early 1953, a team of Dayton depot personnel designed and built a mobile repair and calibration shop for use in the Korean theater. The shop, part of Project Sight-Line, supported intricate radar-controlled gunsights of F-84 and F-86 fighters. (4:3) Implementation of this concept of mobility provided precision repair and calibration for gunsights twelve times faster than if they had been returned to shops in the U.S. for support. (4:3) Mobility capabilities within the calibration function would increase, but not before the calibration program developed further at the Dayton depot.

TRACEABILITY IS ACHIEVED

A new organization had to be created within the DAFD to accommodate the expanding calibration responsibilities assigned to the AMC. The new organization, the Calibration Equipment Standards Division, was placed under the Assistant for Quality, Directorate of Maintenance Engineering in April 1954. The division included two branches, the Dimensional Standards Branch and the Electrical Standards Branch. The former maintained all Air Force basic dimensional primary standards; the latter maintained all Air Force basic electrical and electronic standards. (9: 119-120) In its expanded role, the DAFD established and maintained a test and calibration program for precision laboratory equipment throughout the AMC. In addition, it served as the final AMC authority for all dimensional, electrical, and electronic measurements and as the AMC contact with the National Bureau of Standards. The depot also provided periodic calibration service to all AMC air materiel areas (AMA) and depots. (4:4)

Traceability was now taking form. Air Force primary standards, which were located at the DAFD, would be periodically compared with the standards at the National Bureau of Standards. The AMA standards would be compared with the Air Force primary standards, and then in turn would be used to calibrate one of each type of precision measurement equipment (e.g., multimeters, oscilloscopes) at each of the Air Force bases. These calibrated samples, in turn, were used as standards to certify similar type equipment at the base level. The calibration process was aided through the use of mobile vans and a C-47 aircraft. The aircraft transported Air Force reference standards between the DAFD and the AMAs, and the vans transported standards between the AMAs and the bases they serviced. However, there was no stated policy for calibration of base equipment by the AMAs. (4:4,6)

In late 1957, Project Test-Shop was implemented at March Air Force Base, California to test alternatives to the costly and inefficient means of calibrating items at base level. (4:7) The test project established a calibration facility on March capable of calibrating most test and repair equipment used on the base. The results of the project proved that service provided by in-house calibration facilities was more effective and efficient than that provided on a mobile basis by the AMAs. Headquarters USAF officials were convinced by the results that a program for the repair, calibration, and certification of precision measurement equipment at base level was necessary. In December 1957, Headquarters USAF directed Headquarters AMC to buy 100 sets of standards to equip calibration facilities, i.e., precision measurement equipment laboratories (PMEL), at selected bases. (4:7) The basis for a system of traceability had finally been established within the Air Force. The next logical step was to establish and control a single integrated measurement standards system Air Force-wide--an Air Force Calibration Program.

USAF SINGLE INTEGRATED CALIBRATION PROGRAM

In 1958, two significant actions were taken to formalize the Air Force Calibration Program. In February, Headquarters AMC organized the USAF Committee for the Repair and Calibration of Test Equipment to develop calibration and repair concepts for test equipment at the base level. The committee increased the number of standards laboratories to equip 163 base PMELs, 8 missile sites, 11 stateside AMAs, and several overseas AMAs. The AMAs and the Dayton depot were to receive the most sophisticated standards because of their missions. In June, the committee presented its outline of the "USAF Single Integrated Calibration Program" to all major commands. It assigned DAFD as the central management and administrative agency for planning, implementing, and operating the program. (4:7) The formal calibration program was based on the following principle: "Periodic calibration and certification of precision measurement equipment at all levels of maintenance in the Air Force is fundamental in assuring accurate and reliable weapons and supporting systems." (7:1)

It became evident as the program was formalized that facilities at the DAFD could no longer accommodate the increasing demands of the program. DAFD officials called for new calibration laboratories with sophisticated environmental controls to meet the sensitive requirements of new and complex weapon technology.

Chapter Four

IMPROVEMENTS TO THE CALIBRATION PROGRAM

NEW FACILITIES

In 1958, Dayton calibrators pressed for physical and technical improvements in laboratory facilities, which had not kept pace with increased taskings during the decade. Specifically, they wanted an underground facility which could provide preferred environmental controls. Headquarters USAF opposed new construction, but it was receptive to conversion of existing Air Force structures. Air Materiel Command (AMC) personnel considered hardened sites in underground mines, locations in the Rocky Mountains, and vacant industrial plants. (4:19) In July 1958, the Commander, Dayton Air Force Depot (DAFD) noted: (4:19)

> It appears that there is no AMC facility at an Air Force base that will be suitable for calibration....Considerable research is being done by Headquarters AMC personnel to determine what type of structure could be constructed to provide the necessary environment. In connection with Headquarters AMC personnel, we (Dayton AFD) have located a facility at Newark, Ohio that seems to come close to providing the necessary environment. At least we are certain that it surpasses any other AMC structure in this respect.

Shortly thereafter, DAFD officials selected Air Force Industrial Plant #48 located at Newark (Heath), Ohio as the desirable site for the new laboratories.

The selection of the Heath plant was a wise decision because the facility met key criteria associated with effectiveness and efficiency in laboratory operations. The region was physically stable, i.e., it wasn't susceptible to seismic activity. (4:19) And because of the existing industrial facilities at the site, the new laboratories could be constructed in half the time and at half the cost of constructing similar facilities at the DAFD. Plant #48 was originally constructed to support the Air Force heavy press program for aircraft production, which was subsequently cancelled. Therefore, its deep and massive concrete pit could provide the physical stability required to calibrate sensitive devices. Also, the site could provide total darkness needed for testing infrared systems, and it could maintain the

stable temperatures vital for precise measurements. (10:41) Additional benefits of the new site were its remote location, away from noisy residential and industrial areas, and its close proximity (100 miles) to the DAFD. Based on these positive attributes, the DAFD annexed the site in early 1959 and redesignated it as the Heath Maintenance Annex. (11:56)

Conversion of the Heath facility to calibration laboratories began immediately after annexation. Initial preparatory action, i.e., removal of heavy presses and tools, was begun. However, congressional funding delays impeded further construction and modification of the facility. Funding was finally approved in early 1961. Construction began during May of that year, and on 13 December 1962 the Heath Maintenance Annex was formally dedicated. (11:57; 4:29)

REORGANIZATION

The move from the DAFD to the Heath Annex brought both the calibration function and an organic maintenance function for the repair of missile guidance systems. By the end of 1962, the two functions were aligned under the 2802 Inertial Guidance and Calibration Group at the redesignated annex--Newark Air Force Station. Within the group, the calibration function was organized under the Calibration Division, which included four branches: Advanced Weapons Standards, Electrical Standards, Mechanical Standards, and Scientific Standards. (4:36,37,129) The laboratories in the branches provided many new and highly specialized capabilities.

Examples of improved capabilities could be found in the Advanced Weapons Standards Branch. Branch personnel reviewed and evaluated highly specialized calibration requirements unique to new and advanced weapon systems and provided engineering evaluations of weapon hardware. In addition, they developed standards for measurement in advanced weapon areas. Branch personnel also worked with special test platforms which supported test devices and separated them from the influences of temperature, magnetic fields, humidity, earth motion, and noise while remaining perpendicular to true vertical. (13:53)

With the completion of the move and reorganization, further centralization of the Air Force Calibration Program continued.

CENTRALIZATION

Progress toward centralization of the Air Force Calibration Program began again in 1962. The Calibration Division initiated a program to exchange standards directly with base precision measurement equipment laboratories (PMEL). Previously, the base

laboratories relied on the air materiel areas (AMA) to verify their standards. By centralizing the exchange of standards at Newark Air Force Station, management was able to reduce the number of reference standards in the system. (4:75)

Another step toward centralization was taken in 1965 when a program was designed to evaluate PMEL capabilities. Headquarters USAF assigned the Director of the Calibration and Metrology Division (formerly the Calibration Division) as the manager of the world-wide program. The program provided for better quality control over the PMEL system. The basic premise of the program was that base PMELs would be evaluated by teams from nearby AMA PMELs, and they in turn would be evaluated by teams from Newark. This certification program ensured that established standards of proficiency and competency were met at each laboratory. However, these procedures were not cost effective. Therefore, in 1972, the Directorate of Metrology (formerly the Calibration and Metrology Division) was given the responsibility for evaluating and certifying all PMELs in the Air Force. In addition to providing cost savings, the change assured standardization throughout the evaluation process. (16:75)

Beginning in the mid-1960s, central scheduling and reporting of items calibrated in AMA laboratories were enhanced by the use of computers. The growing complexity of weapon systems required a larger quantity of precision measurement equipment. For example, one AMA had more than 27,000 units of such equipment. The heretofore manual process of monthly scheduling and reporting simply did not meet the challenges brought on by the expanding workload. The computer process enabled laboratory personnel to rapidly initiate, change, or delete equipment inventory records. The updated inventory data base then provided timely identification of equipment that were due calibration and a projection of quarterly workloads for planning purposes. In addition, management reports identified causes of backlogs and suggested changes to calibration intervals. The successful introduction of computers at the AMA laboratories resulted in Air Force-wide application of the scheduling and reporting enhancement. (14:6-7)

Chapter Five

MATURATION OF THE AIR FORCE CALIBRATION PROGRAM

BREADTH

By the early 1970s, the calibration program had developed into the Air Force Metrology and Calibration (AFMETCAL) Program managed by the Directorate of Metrology, Aerospace Guidance and Metrology Center, Newark Air Force Station. The growing program was comprised of measurement standards and equipment, professional metrologists, Air Force-wide precision measurement equipment laboratories (PMEL) with traceability to the National Bureau of Standards, and technical research for improved measurement techniques and equipment. The composite of program parts ensured that precision measurement equipment was accurate and uniform. It accomplished this by ascertaining all measurement standards were maintained, controlled, and available Air Force-wide to PMELs and base-level maintenance shops where calibration was performed. (6:1; 5:17) The program was extended to provide services to customers outside the Air Force community.

Because of the highly specialized capabilities of the laboratories supporting the AFMETCAL Program, the Directorate of Metrology was requested to provide support services to agencies of the Department of Defense (DOD) and to foreign governments. For example, the directorate developed the DOD standards of irradiance, primarily in the infrared spectrum, and it determined and provided specific measurement requirements for the Apollo range instrumented aircraft. Also, the directorate provided key PMEL evaluation services to the armed forces of the Republic of Korea and to the Egyptian Air Force, and it assisted the Royal Saudi Air Force in establishing its own PMEL program. (21:100-101; 15: 17)

As weapon system capabilities continued to advance, support equipment for testing and measuring these capabilities became more complex. Naturally, this equipment required critical calibration at all levels from the operational site to Newark Air Force Station. To guarantee that critical calibration services would be available when new weapon systems became operational, all-encompassing calibration support plans were developed by the Directorate of Metrology. The plans included identification of new measurement standards, development of calibration techniques

and procedures, modification of laboratory space and environment, and programming of training needs. (15:57) Planning for measurement requirements was further enhanced by joint meetings held between officials from the Directorate of Metrology and the Air Force Systems Command. Requirements were identified and analyzed at these meetings to determine the priority of needs which justified immediate funding. Through these productive sessions, logistic resources were effectively directed at areas of profitable technological breakthroughs and state-of-the-art advancements. (17:115)

DEPTH

Earlier coordination by the Directorate of Metrology in "bare base" feasibility tests provided laboratory engineers with the logistics support insight to modify calibration support packages of standards for meeting tactical mobility requirements of the future. In early 1974, engineers designed and built the first transportable measurement system to support mobility in the F-15 aircraft program. Later that year, the system (officially designated the Electrical Standards Set) was transferred to the first F-15 operational and training base. (17:115; 19:1)

Use of automation in AFMETCAL laboratories at Newark advanced during the 1970s. Automatic data acquisition was used to capture in-progress and final test and calibration results. This new dimension in laboratory operations provided metrologists with easy and rapid access to performance and test data, which resulted in more efficient calibration operations. Because calibration techniques varied in each laboratory, data acquisition systems varied among laboratories. For example, the Physical Standards Laboratory had the Automatic Gage Block System which, when interfaced with the Automatic Length and Angle Measurement System, was capable of computing and printing the measurement results within 140 minutes. (18:84-86) However, data acquisition systems only accumulated data and could not do calibration and test functions.

Engineers in the directorate completed an Automatic Calibration System (ACS) in 1974 that had been in the design and development stages for years, awaiting the advent of mini-computerization and programmable laboratory standards. When these limiting factors were finally overcome, a two-function system was produced which automatically calibrated 275 different oscilloscopes and voltmeters in 10 to 15 percent of the manual calibration time. Improvements to the system software in 1978 permitted the capabilities of the ACS to be expanded to 800 items. (19:1)

By the end of the 1970s, the measurement laboratories within the AFMETCAL Program at the Aerospace Guidance and Metrology Center achieved phenomenal measurement capabilities. These capabilities encompassed all disciplines, including electrical, mechani-

cal, electronic, and physical. Specialized and unique capabilities included infrared, ultraviolet, and laser parameters. Attainable accuracies within the laboratories were, for example, absolute measurements to one millionth of an inch and direct current measurements to one part per million. (21:35)

EVOLUTION

As the 1980s approached, the formal AFMETCAL Program had successfully evolved from the informal inspection system of the early 1940s. The system came out of World War II better structured and with uniformity of calibration procedures. Standardization of maintenance methods and procedures laid the foundation for a system of traceability in the 1950s. Traceability was achieved through a formal Air Force Calibration Program which was established at Dayton Air Force Depot and later moved to Newark Air Force Station. The program was improved in the 1960s with the construction of new standards laboratories, reorganization of functions, and centralization of responsibilities. During the 1970s, the AFMETCAL Program was given added breadth and depth that assured all Air Force weapon systems and equipment around the world, however remotely deployed, performed to operational requirements. (22:35)

Systems and programs are born out of need. They are retained if they continue to meet imposed requirements. So it was with the AFMETCAL Program.

Chapter Six

REASONS FOR CHANGES IN THE AIR FORCE METROLOGY AND CALIBRATION PROGRAM

The Air Force Metrology and Calibration Program (AFMETCAL) was born of a need for a centralized system of measurement to ensure that equipment accuracies were based upon universal primary standards of measurements. Changes to the program and to its predecessor programs were directed to that end.

As World War II drew to a close, it became evident that inspection practices would have to be improved. The development of numerous and more sophisticated electronic equipment dictated that inspection organizations be structured to meet the challenge presented by the advanced equipment. Since the Materiel Command was the manager for Air Force electronic equipment, it was apparent that the command would be the first to reorganize its inspection function to include uniformity in its calibration procedures. The challenges offered by the advanced equipment were thus pursued but only within the Materiel Command.

Lack of centralized management within the Air Force for the development of maintenance methods and procedures inhibited the restructuring of inspection functions Air Force-wide. Air Force directives rectified the shortcoming by tasking the Air Materiel Command (formerly the Materiel Command) to develop uniform maintenance standards and procedures applicable to all commands. However, provisions were not made for tracing calibration standards back to a primary source, such as the National Bureau of Standards (NBS). This omission created many inaccuracies in local test equipment and tools. (4:2)

In 1954, a central Air Force agency for calibration control of precision measurement equipment was established as the Calibration Equipment Standards Division at the Dayton Air Force Depot (DAFD). Its establishment was a recognition of the growing requirements for precise support equipment and the need for developing policies and procedures for calibrating the equipment. By 1958, the division was installing precision measurement laboratories on bases throughout the Air Force. These new means of providing calibration services proved to be more effective and efficient than that provided by the air materiel areas (AMA) on a mobile basis. They also enabled the Calibration Equipment Standards Division to establish traceability of standards from

bases to the NBS through the AMAs and the DAFD.

The introduction of missiles and manned space vehicles in the late 1950s and early 1960s provided perhaps the strongest impetus to the growth of the AFMETCAL Program. These new systems required accuracies that were heretofore unattainable. It was no longer feasible to "test fly and fix" new systems. The systems were too complex for such methods. Also, they were too expensive and often designed for only one flight; therefore, the systems had to be properly tuned the first time--prior to the launch. (12:47) But such was not the case as observed by one calibration administrator at the DAFD: (4:39-40)

> A specific incident I recall vividly followed two spectacular missile launch failures from the West Coast at Vandenberg AFB. We volunteered to send a group of experts out to help them. They had a PMEL of sorts there although it was primarily contractor operated. There were few in-house launches. Most of the things that were done there were done by contractors. Some of those contractors had laboratories, but we had established a PMEL at Vandenberg that was primarily for electronic equipment. In reviewing the launch failures it was obvious to us that there were measurement requirements that were not being satisfied, particularly for flow rates, volume of fuel, thrust rates and other similar readings. The group sent out from Dayton AFD were people that knew the significance of precision measurements and how they should be made prior to a successful launch. As I recall, there were five or six (of our) people that went out there at that time. After the equipment was supposedly calibrated and was operational, it was their job to recheck everything to ensure accuracy. What they found was that either the people didn't know how to make precision measurements or they were using standards that were not adequate to make those kinds of measurements. I think there was a little of both. Our people took our standards, our measuring equipment, our knowledge, put them together and went through a complete calibration of all the launch equipment. They found some incredible things, such as pressure gages that were 100 percent off. Given the deplorable conditions of the launch equipment, how they ever got a missile off the ground was a mystery to us. It just so happened on that particular launch they went through the countdown without a hold and the missile went off and had almost a perfect flight. That impressed a lot of people at HQ USAF, also. That particular incident was a real turning point as far as gaining recognition and approval for the programs that we established later on. Interestingly enough, from that point on we had very little difficulty in getting funds.

Although participants denied many of the specifics in the above quote, the observation illustrates the close connection between missiles and the calibration program. (4:40)

Further observations by DAFD calibrating experts at Vanden-

berg and Cape Canaveral launch sites supported the administrator's concern. They found that contractors working on the missile program had no coordinated calibration program. Moreover:

> Visits to various contractors' plants and a general inspection of their standards program by qualified engineers have indicated a vast difference between approaches used to assure calibration accuracy of their final product. Some manufacturers have made great strides towards quality assurance through calibration and others seem to disregard the problem. There appears to be very few cases where the manufacturer returns all his master standards to NBS for calibration as part of a planned program. In most cases, it appears that calibration is obtained from many sources even though several of the standards may be used together to establish still another standard measurement. It has also been noted that the sources providing these calibrations may likewise go to several places for their calibration. There were cases of standards having never been rechecked after purchase even after eight to ten years of service. Some manufacturers having master standards still have no program for using the standards to assure accuracy of their production equipment. (4:22-23)

These revelations and subsequent studies provided support for relocating and expanding the AFMETCAL Program laboratories at Newark Air Force Station, and collocating them with the missile inertial guidance repair facility.

At Newark Air Force Station, the AFMETCAL Program was organized, centralized, and enhanced to provide broadened, in-depth support to increasingly complex weapon systems and other vital equipment throughout the Air Force. The expanded capabilities of the program were widely recognized, bringing support requests from Department of Defense agencies and foreign governments.

As the program continues in the 1980s and beyond, further changes can be expected and, in fact, are being anticipated. These changes will be dictated by improvements to weapon system supportability and by rapid advances in technology, e.g., those to be found in the B-1 and MX systems as well as in the systems of the new strategic defense initiative. Whatever the changes, they will be made from a broad, solid base of support provided by a mature and effective AFMETCAL Program.

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