

United States Air Force Metrology And Calibration System

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ABSTRACT

This paper will discuss the impact of metrology on the United States Air Force. It will outline the Air Force's approach to establishing and executing ISO 17025, metrology management information system, laboratory certification and quality processes, interlaboratory calibrations, and metrology education & training. The Air Force Metrology and Calibration System has industrial and legal aspects.

1. Introduction

In March 1983 President Ronald Reagan outlined his vision for a system to reduce the threat of nuclear attack and end the strategy of mutual deterrence in a speech to the nation [1]. He called the system Star Wars. After 23 years and \$50B we still do not have a strategic defense "Star Wars" system. Why? The answer is metrology. The metrology necessary to manufacture and maintain such a system does not exist. In September 1999 the Mars Climate Orbiter crashed on the planet of Mars instead of orbiting the planet [2]. Why? The answer again is metrology. One engineering team provided data in metric units while another team accepted and used the same data as English units. These examples illustrate that metrology's impact is not isolated within the private sector; it impacts the public sector of society too. Within the public sector, metrology's biggest impact may be seen among the military services - especially the United States Air Force. Metrology enables the Air Force to deliver humanitarian relief and troops to any point on the surface of the Earth. Metrology also enables the Air Force to deliver lethal force with minimal or no collateral damage, when authorized by the President. The Air Force operates globally, as does its supporting metrology and calibration enterprise. This purpose of this paper is to discuss metrology's impact on the Air Force beginning with the inception of metrology in the Air Force, then the Air Force's global approach to metrology and calibration, and lastly a peek into the future.

2. Early Beginnings [3]

The origin of the USAF calibration program can be traced to the early 1950s. Lacking a structured program, calibration was haphazard in these early days. The Air Force had expertise in performing calibrations, however, there was no centralized Air Force wide system. Installations lacked the ability to trace their measurements back to a single source. They relied on contracts with local universities, power companies, directly with the National Bureau of Standards (NBS), or not at all. The evolution of electronic equipment in the years following World War II left the

Air Force in a precarious position. The calibration shortcomings and lack of standardization that was once a just a nuisance, quickly became a systemic and glaring problem. This highly visible problem was officially addressed in 1952. Shops were created at depot-level with the sole purpose of maintaining electronic equipment. Standardized maintenance procedures were created and distributed from a central office. A rudimentary recall system was also established to ensure equipment received periodic inspection. Mobile capability was created in 1953 and used to provide maintenance support for radar controlled gun sights of the F-84 Thunderjet and F-86 Sabre fighters. These gun sights needed precision repair and calibration. Over time, the need for precise calibration and metrology grew beyond the Air Force's depots. In 1957 senior Air Force leadership decided that precise calibration capability would be established at selected installation-level locations. In 1958 the USAF Single Integrated Calibration Program was presented and established 163 precision measurement equipment laboratories (PMELs). The program was organized in a pyramid fashion, measurement standards acquired from NBS were transferred to the highest echelon Type I calibration laboratory, then to the Type IIA calibration laboratories at depot, and finally to the 163 installation-level Type IIB, IIC, and III PMELs. The program had essentially abolished the haphazard calibration methodology of the 1950s. The early Air Force had postured itself to support the rigorous calibration requirements driven by the purchase of highly complex missile and aircraft systems.

3. Today

Fifty plus years later, the Air Force continues to use the pyramid approach along with centralized planning & policy, and decentralized execution to manage and operate its calibration and metrology enterprise. The scope of the enterprise is 77 PMELs across 39 states, one US territory, and five foreign countries supporting approximately 900,000 pieces of test, measurement, and diagnostic equipment (TMDE). Because the military has its own lexicon it may be easier to discuss the operational details of the Air Force metrology and calibration enterprise using a common industry accepted framework. Therefore, let's use a skeletal outline of ISO 17025, General Requirements for the Competence of Testing and Calibration Laboratories [4], to form our topical headings.

3.1 Organization [5]

The Air Force is sub-divided into activities known and major commands (MAJCOMs). Each MAJCOM owns and operates the PMELs assigned to it using policy issued by the Secretary of the Air Force, centrally procured measurement standards, and centrally developed & published calibration procedures. The internal organization structure of each PMEL is the same because each must comply with the Secretary of the Air Force issued mandatory policy. Typically each PMEL is housed in its own environmentally controlled facility and each PMEL has a general manager. Inside the PMEL facility calibration work is subdivided based on measurement parameter, e.g. microwave measurements, physical-dimensional measurements, electrical measurements, etc. The subordinates of the general manager include the technical manager, quality manager, and production control manager. PMELs possess additional capabilities as necessary to satisfy their customers' requirements. Mobile calibration capability exists in various degrees to provide support to geographical areas the size of a city, state, and small country. All workload supported by the PMEL is government workload with the exception of

contractor-operated PMELs which may have authorization to support commercial workload but only as authorized by their contract or the contract officer.

3.2 Management System

Each PMEL creates its own quality manual tailored to its locality and customer base. Much of the typical quality manual elements are codified in policy from the Secretary of the Air Force, so it is not unusual to find Air Force PMEL quality manuals referring to Air Force policy documents. Examples include standard of service and commitment to professional practices.

3.3 Document Control [6]

Procedures to control documentation were present in Air Force PMELs before the issuance of ISO 17025. Policy issued by the Secretary of the Air Force mandates that offices create and maintain a system of records. Filing rules and document disposition instructions exist to manage documents associated with metrology and calibration.

3.4 Review of Requests, Tenders, and Contracts [7]

A professional corps of government contracting officers writes, issue, amend, and terminate contracts for Air Force PMELs. They accomplish these tasks in accordance with the government Federal Acquisition Regulation (FAR). The procedures in the FAR cover competitive bidding, and purchasing services, and supplies.

3.5 Service To The Customer and Complaints [8]

These requirements are fulfilled through Secretary of the Air Force issued policies mandating customer-supplier relationships and exceeding your customers' requirements whenever possible. The Air Force has a formal complaint resolution system and complaints are encouraged to be resolved at the lowest level possible.

3.6 Control Of Nonconforming Testing And/Or Calibration Work [9]

The Air Force's formal system for control of nonconforming work includes correction and assessment by quality personnel prior to releasing the work to the customer. An intricate system of codes exist in the internet based PMEL management information system [10] to document the nonconformance, the root cause analysis outcome, the corrective action, and record the event for monitoring and future trend analysis.

3.7 Control Of Records [11]

The Air Force designed software dedicated to collecting, indexing, accessing, and filing of quality and technical records. The internet based PMEL management information system [10] is used by Air Force PMELs worldwide, contractors included.

3.8 Internal Audits and Management Reviews [12]

With tailoring, the Air Force self-inspection system fulfills the internal audit and management review requirements. The self-inspection system relies on quarterly or semi-annual inspection of work activities against published policy requirements. Monitoring corrective actions until closure is accomplished by assigning and tracking action items.

3.9 Personnel

The success of Air Force PMELs lies in its personnel (military, civilians, and contractors). The dedication and devotion to duty exhibited by thousands of faces has made the Air Force calibration and metrology program the best in the free world. Air Force enlisted personnel arrive at their PMELs only after completing rigorous education and training at Randolph Air Force Base, Texas and the Keesler Technical Training Center (KTTC) at Keesler Air Force Base, Mississippi. The primary focus of the KTTC is the training of Air Force enlisted personnel in the initial skills needed to repair and calibrate test, measurement, and diagnostic equipment (TMDE). Initial skills training consist of two courses, the Common Electronic Training Program and the Precision Measurement Equipment Laboratory (PMEL) Apprentice course. They also teach the Metrology Craftsman Course and five supplemental courses covering advanced metrology techniques. Throughout a career, personnel advance from apprentice (3-skill level), to journeyman (5-skill level), to craftsman (7-skill level), and ultimately to superintendent (9-skill level). Correspondence courses are part of the highly structured and formalized On-The-Job training program for the journeyman and craftsman trainees. PMEL training documents cite tasks by equipment part number, not measurement parameter or calibration methodology. The courses are written and maintained by KTTC personnel. The resources of the KTTC are only available to employees of the Department of the Air Force (military and civilians). Contractors are required to provide personnel with skills and competencies necessary to support the contracted workload, and training records must be maintained.

3.10 Accommodation And Environmental Conditions [9]

Air Force PMEL facilities maintain controlled temperature and humidity levels. Annually technical grounds are certified at a specific threshold. Lighting, vibration, noise, dust, and electromagnetic interference are all controlled and monitored to ensure they do not exceed preset parameters.

3.11 Test And Calibration Methods And Method Validation [9]

A centralized cadre of professional engineers is retained to develop, write, issue, and change calibration procedures in accordance with Department of Defense publication MIL-PRF-38793B *Technical Manuals: Calibration Procedures - Preparation*. Air Force calibration methods, known as calibration technical orders, are issued under the authority of the Secretary of the Air Force. Air Force PMELs (military, civilian, and contractor-operated) are prohibited from using procedures, methods, or documents that have not been evaluated and approved by the cadre of professional engineers. The technical orders are validated prior to Air Force wide release and estimations of measurement uncertainty are incorporated into the technical orders. The cadre of

professional engineers also develop and validate automatic test equipment software containing calibration parameters.

3.12 Equipment

Equipment for Air Force PMELs is centrally acquired by two sources: (a) precision measurement standards are procured by the same cadre of professional engineers developing and publishing calibration procedures and (b) less precise measurement standards and common TMDE is procured by Air Force's depot charged with conducting centralized support equipment procurements. The PMEL defines the requirement based on what is required to support their customers and the two aforementioned sources conduct competitive bidding to satisfy the requirement.

3.13 Measurement Traceability [13]

The hallmark of the Air Force's calibration and metrology program is the acknowledged requirement to maintain measurement traceability to the National Institute Of Standards and Technology (NIST) or other approved source. This is a Secretary of the Air Force mandated policy. An established chain of traceability may only be broken with the express written approval of the cadre of professional engineers. Contractors calibrating Air Force TMDE must also provide measurement traceability to the NIST or other source as approved by the cadre of professional engineers.

Air Force Measurement Standards (also known as reference standards) and Air Force Base Measurement Standards are the sole property of the cadre of professional engineers. Air Force Measurement Standards are calibrated and maintained by NIST or other source with direct traceability to SI Units of Measurement. Air Force Base Measurement Standards are issued to Air Force installation-level PMELs on a loan basis; they are calibrated and maintained by the cadre of professional engineers using Air Force Measurement Standards. The Air Force Base Measurement Standards are compared to NIST maintained standards and the results are retained and tracked for the life of the standard. Reference materials are acquired locally by each PMEL from sources approved by the cadre of professional engineers. Each Air Force PMEL randomly samples their equipment monthly for intermediate check. The results of the intermediate checks are performed and recorded in the internet based PMEL management information system [9].

3.14 Sampling [10]

Statistical random sampling is performed by the internet based PMEL management information system. Preset programs assure that all Air Force PMELs uniformly apply sampling. Items are sampled for intermediate check and quality verification; event driven processes are sampled for compliance with published policy.

3.15 Handling Of Test And Calibration Items [9]

TMDE inducted for maintenance, repair, or calibration and in queue status can be identified at any step of the PMELs processes. A receipt system embedded in the internet based PMEL

management information system [10] is used to ensure that property is returned to the correct owner. TMDE is secured and segregated based on the equipment condition. Customers are responsible transporting, handling, securing, and storing their TMDE when it is not in the custody of the PMEL.

3.16 Assuring The Quality Of Test And Calibration Results

Air Force PMELs utilize a unique quality control procedure. Equipment ready for customer pick-up is randomly selected for verification in conjunction with the associated PMEL processes. The internet based PMEL management information system [10] enables event driven processes to be sampled at a higher or lower rate. Personnel performance of the process is evaluated against the published policy to assess compliance.

3.17 Reporting The Results

Detailed reports of measurement are provided only as requested by the customer. Every calibration event is documented in the internet based PMEL management information system [10] and a calibration label is affixed to each calibrated item. Each label cites the officially sanctioned technical order or technical data used, the date due re-calibration, and all uncertainties changed to accommodate the customer or equipment condition.

3.18 PMEL Certification [9]

The Air Force internally certifies each of its PMELs every two-years. The certification process is a comprehensive assessment of equipment condition and personnel competency, along with adequacy of the facility and environmental control system. Personnel are evaluated by re-calibrating completed work under the scrutiny of an USAF PMEL Evaluator. There are no time constraints associated with the over the shoulder assessment, it takes as much time as required. PMELs that are not certified receive re-assessment after six months and their higher echelon management is notified, including the Pentagon.

3.19 Proficiency Testing / Measurement Assurance Program [9]

Air Force PMELs participate in proficiency testing as part of their certification process. Proficiency Testing on unique artifacts is the process used to assess PMEL performance by means of comparing and evaluating calibrations or tests on a measurement artifact.

4. Future

The Air Force is developing "smart" automated calibration procedures that allow the user to accept the default equipment or select equivalent substitute equipment from a list of locally available equipment. This is the latest example of how the Air Force leads the way. The Air Force calibration and metrology program has embraced change for the last 50+ years. It copes with the present as it plans for next generation of technologies. The Air Force calibration and metrology program remains the leader in its field, both private and public sectors.

5. Summary

The public sector Air Force metrology and calibration was thoroughly discussed and the metrology impact on the public sector was observed by two well-known examples. Metrology impacts the person using a produce scale, the person filling his gas tank, and the person flying a \$1B fighter jet. The remnants of "Star Wars" are becoming reality because metrology R&D has matured sufficiently to support the measurement requirements of emerging technologies such as the airborne laser and space-based laser. Metrology's impact will forever be present in society, private and public sectors, as long as there is a need to measure or quantify the unknown.

6. References

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