Range Commanders Council

Signature Measurement Standards Group

DOCUMENT 804-01
VOLUME II
(REVISED AUGUST 2001)

RADAR CROSS SECTION (RCS) CERTIFICATION FOR STATIC AND DYNAMIC RCS MEASUREMENT FACILITIES

VOLUME II
DOD RCS DEMONSTRATION PROGRAM RESULTS

WHITE SANDS MISSILE RANGE
KWAJALEIN MISSILE RANGE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER
NATIONAL TRAINING CENTER

ATLANTIC FLEET WEAPONS TRAINING FACILITY
NAVAL AIR WARFARE CENTER-WEAPONS DIVISION
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT
PACIFIC MISSILE RANGE FACILITY
NAVAL UNDERSEA WARFARE CENTER DIVISION, KEYPORT

30TH SPACE WING
45TH SPACE WING
AIR FORCE FLIGHT TEST CENTER
AIR ARMAMENT CENTER
AIR WARFARE CENTER
ARNOLD ENGINEERING DEVELOPMENT CENTER
BARRY M. GOLDWATER RANGE
UTAH TEST AND TRAINING RANGE

NEVADA TEST SITE

DOCUMENT 804-01
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MARCH 2001
(REVISED AUGUST 2001)

Prepared by

SIGNATURE MEASUREMENT STANDARDS GROUP
RANGE COMMANDERS COUNCIL

Published by

Secretariat
Range Commanders Council
U. S. Army White Sands Missile Range
New Mexico 88002-5110

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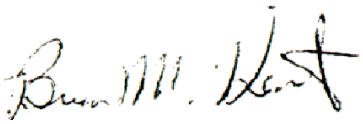
ACRONYMS

ACR	Advanced Compact Range
ADAMS	advanced dynamic aircraft measurement system
AFRL	Air Force Research Laboratory
AMTA	Antenna Measurement Techniques Association
ANSI	American National Standards Institute
APS	Antennas and Propagation Society
ATR	Atlantic Test Range
DoD	Department of Defense
D/S	decoy-skin
EC	European community
HAFB	Holloman Air Force Base
IEEE	Institute of Electrical and Electronics Engineers
ISAR	inverse synthetic aperature radar
ISO	International Standards Organization
J/S	jammer-skin
Mil Spec	military specifications
MQAP	measurement quality assurance program
MRC	Mission Research Corporation
NAWC-AD	Naval Air Warfare Center – Aircraft Division
NCSL	National Calibration Standards Laboratory
NIST	National Institute of Standards and Technology
RCC	Range Commanders Council
RCC/SMSG	Range Commanders Council/Signature Measurement Standards Group
RCS	radar cross section
RVUMS	RAMS VHF/UHF Measurement System (46TG/TGR, HAFB)
SMSG	Signature Measurement Standards Group
SRC	Syracuse Research Corporation
USAF	United States Air Force
WPAFB	Wright-Patterson Air Force Base
Z-540	ANSI/NCSL Standard Z-540-1-1994

FOREWORD

This volume summarizes an intensive in-house Department of Defense (DoD) research and development program performed by various members of the Range Commanders Council Signature Measurement Standards Group (RCC/SMSG) Radar Cross Section (RCS) Committee (hereafter referred to as the Radar Committee). The work was led, managed, and coordinated by the Signature Technology Office, Air Force Research Laboratory, Wright-Patterson Air Force Base, from January 1997 to July 2000. This volume describes the execution of the DoD Radar Cross Section Demonstration Program for RCS range certification. Organized around International Standards Organization (ISO) Guide 25 and its U.S. equivalent, ANZI/NCSL Z-540-1-1994 (referred to herein as Z-540), this program was designed to test the feasibility of using Z-540 to standardize the documentation, processes, and procedures used by all DoD RCS measurement facilities. Using three highly distinct DoD RCS test facilities as test cases, the DoD RCS Demonstration Program executed a highly successful and realistic assessment of DoD's RCS measurement capabilities. In addition, the program laid the groundwork for an industrial RCS certification process, which closely mirrors the DoD program. If industry follows through as planned, all U.S. Government and industrial RCS measurement ranges could be certified as early as January 2004.

The authors of this document acknowledge the many contributors to the DoD RCS Demonstration Program in Attachment A of this report.



Brian M. Kent, Ph.D.
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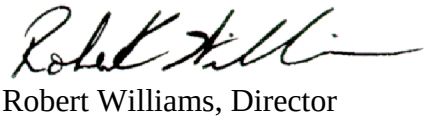
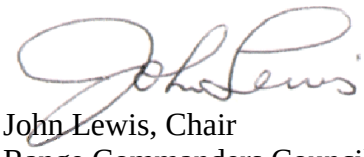
Member, RCC/SMSG(Radar)



Robert Williams, Director
Signature Technology Office
Air Force Research Laboratory



John Lewis, Chair
Range Commanders Council
Signature Measurement Standards Group (Radar Subgroup)

EXECUTIVE SUMMARY

In January 1997, the Range Commanders Council Signature Measurement Standards Group (RCC/SMSG), in coordination with the RCC Taskmaster, established RCC/SMSG Task #08 titled, "DoD RCS Certification Feasibility Demonstration for Static and Dynamic RCS Measurement Facilities." Referred to herein as the DoD RCS Demonstration Program, the task assessed the feasibility of establishing common documentation standards to describe and certify the operation and capabilities of the DoD's diverse RCS measurement facilities located throughout the United States. Through the mutual efforts of the United States Air Force (USAF) 46 Test Group, in cooperation with the RCC/SMSG Radar Committee, the demonstration program described herein was entirely successful and should lay the groundwork for similar technical or laboratory calibration certification efforts throughout the DoD RCS measurement community.

More specifically, this report describes how Z-540 was applied in a DoD demonstration program to organize RCS range documentation. This report is a follow-up to the DoD RCS Demonstration Program recently presented to the Antenna Measurement Techniques Association [2]. In June 2000, the RCC/SMSG certified that two dynamic RCS measurement facilities, the Air Force Research Laboratory's (AFRL's) Advanced Compact Range (ACR) and the Naval Air Warfare Center-Aircraft Division's (NAWC-AD's) Atlantic Test Range (ATR) met the Z-540 documentation standards established by the DoD RCS Demonstration Program. Since AFRL plans to unilaterally require mandatory Z-540 compliance for DoD contractors performing RCS measurements with AFRL after 1 January 2004, the RCS certification review process described in this report will be the model used for industrial compliance. After reviewing the Z-540 standard, this report will summarize the certification review process, and discuss the outcomes, results, and lessons learned from the DoD RCS Demonstration Program from the perspective of the ranges reviewed, as well as the volunteer range book reviewers.

CHAPTER 1

INTRODUCTION TO THE ANSI/NCSL Z-540-1-1994 STANDARD

1.1 General

This chapter presents a brief overview of the American National Standards Institute/National Calibration Standards Laboratory ANSI/NCSL Z-540-1-1994 Standard [1] (referred to herein as Z-540). The Z-540 offers a straightforward way to organize radar cross section range (RCS) documentation. We begin by discussing the major points of Z-540 and how to organize a format-universal RCS Range Book. Since Z-540 is the U.S. equivalent of International Standard Organization (ISO) 25, it is especially useful for two reasons: (1) it is applicable to RCS ranges; and, (2) its quality control requirements are consistent with the ISO 9000 series of quality standards. Properly applied, Z-540 will greatly improve the quality and consistency of RCS measurements produced by RCS measurement facilities and reported to range and DoD customers.

The signature measurement community is aware of the complexities of a modern RCS measurement range. Electromechanical systems, regardless of range type, must contain a myriad of hardware and software to operate a range within intended design parameters. Naturally, operating a range as designed helps assure that it produces consistently high-quality data. Often, the job of keeping current range documentation may seem overwhelming, especially since there are currently no standards or guidelines for organizing such documentation.

The initial purpose of RCC/SMSG Task #08, a research activity involving the Air Force Research Laboratory (formerly Wright Laboratory), the Naval Air Warfare Center-Aircraft Division Chesapeake Test Range, and the Electromagnetic Fields Division of the National Institute of Standards and Technology (NIST) is described herein. A top-level overview schedule of Task #08 is shown in Figure 1-1. This task and associated research was designed to improve the quality and repeatability of RCS data. One significant side contribution of this project has been the development and implementation of highly accurate and repeatable static RCS range calibration standards [3,4]. A second benefit has been a significant improvement in the sharing of technical information and measurement techniques between the various industrial and government RCS ranges. The annual RCC/SMSG RCS certification conference technical exchange has truly inspired the RCS industry to work together in a more cooperative environment.

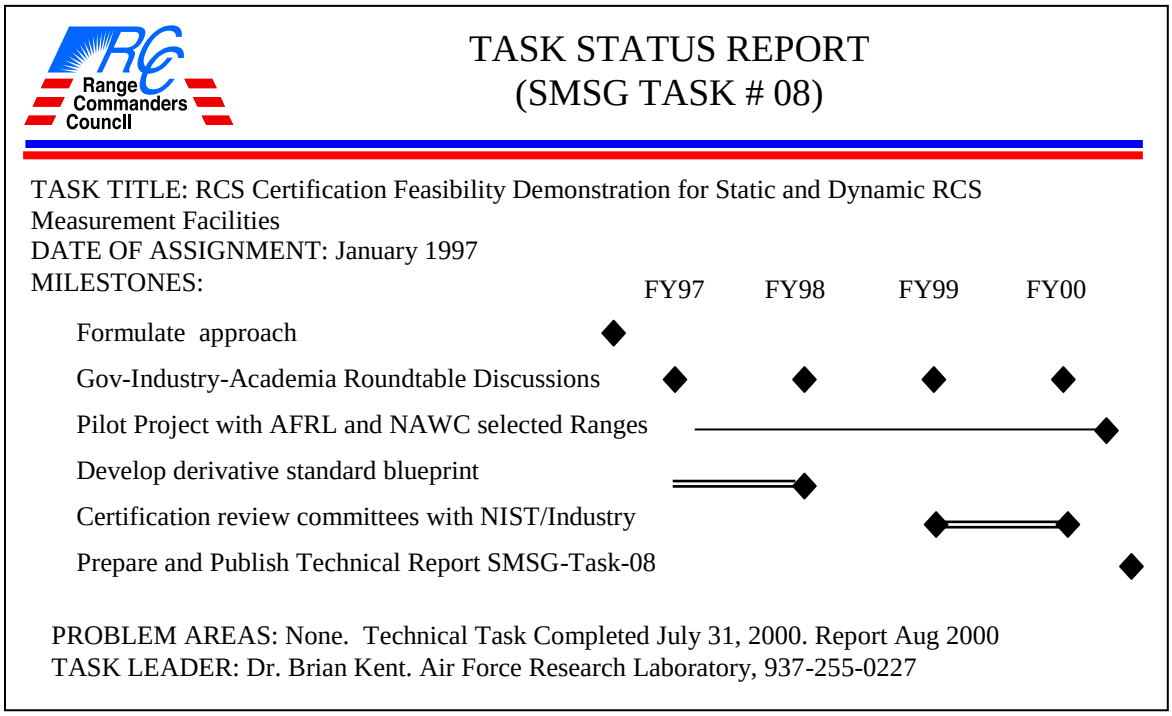


Figure 1-1. Top-Level Final Task Status Report RCC/SMSG Task #08.

The activity reported herein also focuses on the establishment and review of an RCS range documentation standard, which includes processes, procedures, quality control, and characterization information. After closely examining the technical literature and interviewing many ranges during the 1995-1997 time frame, the RCC/SMSG Radar Committee found that there is no standard method for creating and maintaining range documentation. Although some ranges had excellent and thorough documentation [4], other ranges could clearly benefit from improving and organizing their present documentation set. The Radar Committee also found that the universal availability of the range documentation to the range operating staff and customers varied greatly from range to range. Clearly, the operating staff needed the most up-to-date and thorough information available in order to produce consistently high quality, repeatable RCS data.

During the process of examining various candidates for an RCS documentation standard, several factors were considered. First, from a DoD perspective, the Radar Committee examined typical military specifications and standard federal contract report deliverables to see if such standards could be exploited and customized for the documentation of RCS ranges. In light of the new DoD 5000 series of federal acquisition regulations, we are seeing significant federal procurement and acquisition reform. In the future, DoD will quickly move away from the use of rigid military specifications (Mil Specs) in federal contracts in favor of more universally available and understood "commercial grade standards." Because future DoD contracts will rely less on Mil Specs, they were ruled out as a possible RCS range standard model.

The Radar Committee also examined the ongoing work of the Institute of Electrical and Electronics Engineers Antennas and Propagation Society (IEEE-APS) Committee on RCS, of which the National Institute of Standard Technology (NIST) is an active participant. While this

important committee's work was not complete in 1997 (and still is not complete), it is clear that the IEEE-APS will not focus on range documentation standards.

Finally, the RCC/SMSG Radar Committee examined ongoing work in the European Community (EC), which already mandates most, if not all, the ISO 9000/9002 series of regulations for their commercial business transactions. While ISO 9000 by itself is not applicable to RCS ranges, the technical standard ISO 25 appeared to satisfy most of the requirements for a quality-oriented RCS range documentation system. We, therefore, looked into the US equivalent of ISO 25, which is Z-540.

We postulated in the beginning of this program that standardized range documentation, universally available to staff and customers alike, would greatly benefit the RCS measurement community. Further, it is the view of the RCC/SMSG Radar Committee that Z-540 [1, 5] with clarification [6] is the appropriate and applicable guide for RCS ranges.

1.2 A Closer Look at ANSI/NCSL Z-540-1-1994

ANSI/NCSL Z-540-1-1994 [1] is available for a nominal fee from NCSL (tel. # 303-440-3339). The title of the standard is Calibration Laboratories and Measuring and Test Equipment - General Requirements, and it provides a framework for collecting and maintaining information to support a quality-oriented system of documentation for any range that produces calibrated data. In essence, the standard is very general, and could easily accommodate many types of calibrated scientific measurements (e.g., voltage, lumens, temperature, etc.). Basically a 13-page guide, Z-540 summarizes the general documentation requirements for any facility producing quality calibrated data. Prior to outlining Z-540, we would like to point out that an accompanying guide has been written [6], which helps the reader interpret Z-540 with respect to RCS ranges specifically.

Z-540 is organized into two parts. Part I is preceded by a three-section introduction, which includes references and standard definitions. The definition section is especially helpful in establishing a common dialog for the remainder of the standard. The main thrust of the standard is Part I itself titled, "General Requirements for the Competence of Calibration Laboratories." It consists of 13 subsections outlining the basic standard and the information needed for a range to document to the standard. Part II of the standard, "Quality Assurance Requirements for Measuring and Test Equipment," pertains to the control, usage, and calibration of individual pieces of equipment used to produce calibrated data. Part I is the most applicable and appropriate portion of this standard when applied to the specific case of RCS ranges. Part II was not used in any part of RCC/SMSG Task #08.

1.3 Using Z-540 to Establish an RCS Range Quality System

The central theme of Z-540 is the establishment and maintenance of an active and ongoing Measurement Quality Assurance Program (MQAP). Most ranges already incorporate measurement assurance as part of their normal range operations, although this phrase is rarely quantified. However, it may be helpful to briefly define the elements of an MQAP [6, 7].

A typical MQAP consists of documented technical requirements designed to insure repeatable RCS performance from a given measurement range. The MQAP documents measurement procedures, data processing procedures, range uncertainty, and error estimation analysis, while simultaneously identifying a sound management structure set up to efficiently operate and maintain the RCS range. It also strongly encourages an active inter-laboratory comparison program (within reasonable time and range availability constraints) and an ongoing research program to improve RCS data quality. At first reading, it may appear that standard Z-540 actually implies the development of a separate MQAP in addition to the documentation required by the standard. Actually, completion of the documentation required by Z-540 will, in effect, establish a documented MQAP.

1.4 A Section Overview of Z-540 - Part I

Z-540 opens with a three section "Foreword," which defines the scope of the standard (Section 1), important references (Section 2), and a set of excellent baseline definitions (Section 3). These sections all help the reader define a common frame of reference for interpreting the standard. After the Foreword, Part I (General Requirements for the Competence of Calibration Laboratories) presents the details of the standard itself. Part I consists of 13 individual sections (Sections 4-16), which present an ideal organization for a range documentation set that parallels each section of the Z-540 standard. Let us review each section by title, and provide some insight into their purposes. Later, we will define how each item is evaluated in the certification program.

Z-540 Section 4 (Organization and Management) briefly describes how to document the organization performing the calibrations. Using an open format, the organization and personnel would be identified along with their chain of command. This section also identifies the technical and quality leaders responsible for the technical and quality aspects of range operations. (Naturally, in smaller RCS ranges, these two positions may be held by the same person.) Z-540, Section 4, requires that all range individuals (and any alternates) be identified. Also, Section 4 requires that the RCS range be organized and operated in such a way as to assure that RCS data confidence, independent technical judgment, and data integrity are always maintained.

Z-540 Section 5 (Quality System, Audit, and Review) is one of the three major sections of Z-540 and sets the stage for the remainder of the document. It says that the range will establish and maintain an active "quality system" with appropriate internal audits and reviews suitably "appropriate to the type, range, and volume of calibration activities it maintains." This sentence is very important as it distinguishes Z-540 and ISO 25 from the overall ISO 9000/9002 series in the important phrase "appropriate to the type, range, and volume of calibration activities…" Subsection 5.2 is more specific and lays out the elements that should be included in the quality manual. Some examples include: (5.2-d) procedures to control and maintain documentation, (5.2-g) procedures for achieving traceability, (5.2-h) scope of calibration and verification activities, (5.2-k) procedures for handling (calibration) devices, (5.2-l) references to major equipment and reference measurement standards, (5.2-n) references to quality assurance practices, including inter-laboratory comparisons, proficiency testing, and internal quality control practices, (5.2-o) procedures for corrective action when RCS data discrepancies are found, and (5.2-q) procedures for dealing with customer complaints. Although Sections 5.3 - 5.6 describe a

few additional details on the audit and review process, the creation of the range-appropriate "quality manual" in Section 5.2, as it pertains specifically to RCS measurement ranges, is the main intent of standard Z-540.

Z-540 Section 6 (Personnel) describes how a range defines and maintains the appropriate staff needed to operate the RCS range. It also requires ranges to describe their initial and ongoing training programs used to maintain the technical competence of their operating staffs. This information should be easy to assemble, as most organizations routinely obtain and manage this type of information.

Z-540 Section 7 (Accommodation and Environment) requires a range to describe its environmental "accommodation" and to identify what environmental factors may affect measurement results. The latter category may be very short for some indoor ranges but lengthy for outdoor or dynamic measuring applications. For instance, an outdoor static range may wish to record temperature, winds, precipitation, inversions, or other phenomena known to affect the RCS measurement data. When the effects cannot be quantified (in RCS error terms), it is still very important to identify and record when such conditions occurred.

Z-540 Section 8 (Equipment and Reference Materials) describes how equipment, maintenance, and reference materials and records are tracked. Again, most organizations have systems to control and identify all equipment used by a typical range. By systematically organizing this information into a "range appropriate" configuration control document, one makes a good external record of the measurement system, as well as an excellent and useful internal document valuable to the range technicians and engineers. For more complex ranges (those ranges having more equipment and subsystems), this section becomes exceedingly important in managing the overall health and operational status of the individual pieces of equipment. In the DoD RCS Demonstration Program, the dynamic RCS measurement system at Atlantic Test Range (ATR) consisted of hundreds of pieces of equipment. It is no surprise that the ATR's Section 8 was a significant portion of their total range book page count. Smaller RCS range systems would have a correspondingly smaller Section 8.

Z-540 Section 9 (Measurement Traceability and Calibration) and Section 10 (Calibration Methods) together define the information needed to establish traceability to "national, international, or intrinsic standards of measurement." At RCS ranges, this is usually accomplished through indirect "ratio or reciprocity type measurements (9.3-d)," wherein an unknown target is measured, a known RCS standard is measured, and a ratio is computed with suitable adjustments using a highly accurate numeric RCS estimate of the known calibration target. Though every range performs calibrations in a slightly different manner, Z-540 requires that such procedures be rigorously documented, tested, and verified, whenever possible, with other RCS ranges. One of the most important aspects of these two sections is contained in paragraphs 10.2 - 10.4, which describe the need for written procedures to execute appropriate calibrations. Once again, having this procedural information universally available to your range staff, including archival results (e.g., what the correct calibration measurements should be) will greatly improve the quality and repeatability of RCS calibration values. In addition, specific calibration processes selected for use by a given range must be routinely tested. Calibration

procedures discussed in [2,3] are one way of meeting this requirement, though other documented methods may be used as well.

Z-540 Section 11 (Handling of Calibration Items) is self- explanatory and essentially states the need for maintaining physical control over calibration items used to produce calibrated RCS range data. Such items should be appropriately stored and protected when not being used. In addition, it points out the need to uniquely identify each primary range calibration target, so there is never confusion regarding the use of one calibration target over another.

Z-540 Section 12 (Records) is also self explanatory and basically states that the range must have a record keeping system consistent with "its particular circumstances." It also specifically states that the record keeping system should be consistent with the overall range quality system.

Z-540 Section 13 (Certificates and Reports) describes the elements that must appear in a "range certificate," otherwise called an RCS data or test report. It emphasizes that each range should have a minimum subset of information in the report, including range identity (title, name and address of range), customer identity (name and address of customer), description of the calibration item (target), dates of the calibration measurements, type of process, calibration techniques used, and so on. It is meant to provide consistency of data reporting from a specific range, as well as to establish more universal reporting standards from range to range.

Z-540 Sections 14 (Subcontracting of Calibration) and Section 15 (Outside Support Services and Suppliers That Affect Calibration Results) are both brief but important. In essence, they state that if outside suppliers furnish any of the calibrated RCS data, they are subject to the requirements of the Z-540 standard, provided the prime or supplying range conforms to this standard.

Finally, Z-540 Section 16 (Complaints) assures that the range has a formal, quality-oriented process for responding to customer complaints regarding any aspect of range operation. The best place to put this documented policy is in the quality manual (5.2q).

1.5 Organizing the RCS Range Book to Comply with Z-540

The following paragraphs provide guidelines for the construction of the RCS Range Book used to document range characteristics in accordance with Z-540. The goal of these guidelines is to maintain consistency in the layout of the documentation from range to range. Volume I of this document provides a detailed description of the layout of a typical range book, so only the general points will be repeated here.

The main goal of the range book is to organize the RCS system documentation into a format independent of those used by the ranges performing the measurements. However, within each section, company or local documentation formatting is strongly encouraged whenever possible. In this manner, substantial costs for reformatting information to Z-540 is avoided to the extent possible, while at the same time affording a common document layout. The goal here is to create a "living-breathing document" which is useful to the range staff it was created to

serve. It is the range book that is reviewed technically by a third party, and it is the basis for granting a range certification.

The range book sections will closely parallel the Z-540 standard, with few exceptions. However, it is emphasized that the importance of the range book is in its basic utility as a general reference standard for range personnel and customers alike. Thus, the utility of the range book will largely depend on the currency and relevance of the information in it and the amount of effort expended to create it.

Depending on the size and type of range, the range book may be physically small or large. For instance, we would expect the range book for a highly complex dynamic signature measurement range to be substantially larger than that of a relatively simple indoor far field range. The ranges should carefully consider whether to produce their range books in hardcopy or electronic format. While a conventional paper copy would certainly meet all the requirements of Z-540, an electronic version available to every range employee on a network server, an internal or external web page, or on a permanent CD-ROM may be a better option in the long run. Normally, if multiple hard copies of the range book are created, each must be separately updated to reflect changes in the range information over a natural lifetime. In the case of an electronic or web page version, only one copy (on the web page) would need to be updated and redistributed. Thus, maintaining current documentation electronically should prove easier than maintaining paper copies. In either case, the reader is encouraged to use whatever system is available or appropriate for their particular situation.

The range book (paper or electronic) may be the most readily available range reference for use by any range staff member. It is also the documentation reviewed by the third party certification review committee, as discussed later in this report. Once completed, it is the responsibility of each range to keep its range book current.

1.6 RCS Range Registrations and Third Party Certification Review

Compilation of the range book completes an important phase in the formal documentation of range performance. Even if a range does not proceed to third party certification, such a document set will greatly help sustain quality calibrated RCS measurements. Assuming an RCS range completes a range book, the book first needs to be reviewed internally within the company or government organization that created it. This process is called an internal audit or "self registration," using the vernacular of ISO. Once a range book is "self-reviewed" internally and checked against the published evaluation criteria [see Vol. I of this document], range management normally endorses the range book in Section 1. Their signatures attest that management has approved the range's overall quality assurance program and its accompanying range book.

The next part of the certification process is the independent third party review committee. Z-540, Section 1.3, states, "the role of the purchaser in monitoring a supplier's (range) compliance with the requirements of this standard may be fulfilled by a third party, such as a certification board." As DoD strives to test and demonstrate the applicability of Z-540, it will rely on an all-volunteer certification board composed of technical specialists drawn from

government, academia, industry, and the National Institute of Standards and Technology. All range book reviewers are volunteer technical experts active in the RCS measurement business. Such a third party review committee "certifies" that a range complies with the Z-540 standard as it pertains to the specific RCS measurement range.

A third-party review committee can never guarantee that a "certified" range will not make errors. We believe that since Z-540 is extremely process-oriented, proper documentation of normal range processes and procedures will produce a quality system that greatly reduces the occurrence of data problems related to poor procedural execution. The Z-540 standard is an excellent approach to organize, maintain, and present RCS range information. The RCS Range Book should be very useful to the range and range customer alike. Assuming that a well-managed RCS range has much of the required documentation in hand, complying with the Z-540 standard should be a gradual, transitional process as the range book is formalized. If omissions are found in the RCS range's documentation, the process of implementing a measurement quality assurance program (MQAP) as part of the Z-540 compliance process should fill those omissions, thereby improving the quality and consistency of RCS range data supplied to external customers.

CHAPTER 2

THE DOD RCS DEMONSTRATION PROGRAM – AFRL PERSPECTIVE

2.1 General

The following paragraphs describe the results of the Air Force Research Laboratory (AFRL) and the Naval Air Warfare Center–Aircraft Division (NAWC-AD) joint DoD RCS Demonstration Program, which was designed to improve the quality and repeatability of RCS measurement data taken on any government or industrial RCS measurement facility. This chapter will address activities at AFRL's Advanced Compact Range (ACR) and Chapter 3 will focus on the certification activities at NAWC-AD's Atlantic Test Range (ATR).

As mentioned in Chapter 1, RCS measurement systems represent extremely complex electromechanical systems containing a myriad of complex hardware and software subsystems. To maintain a high level of confidence in RCS data produced by these ranges, a quality assurance program was established in 1997. The RCC/SMSG co-sponsored the AFRL and NAWC-AD joint project to test and demonstrate a single standard for documenting the procedures and processes for the three distinct DoD RCS ranges shown in Figure 2-1. Officially adopted by the RCC as RCC/SMSG Task #08, the DoD RCS Demonstration Program began by

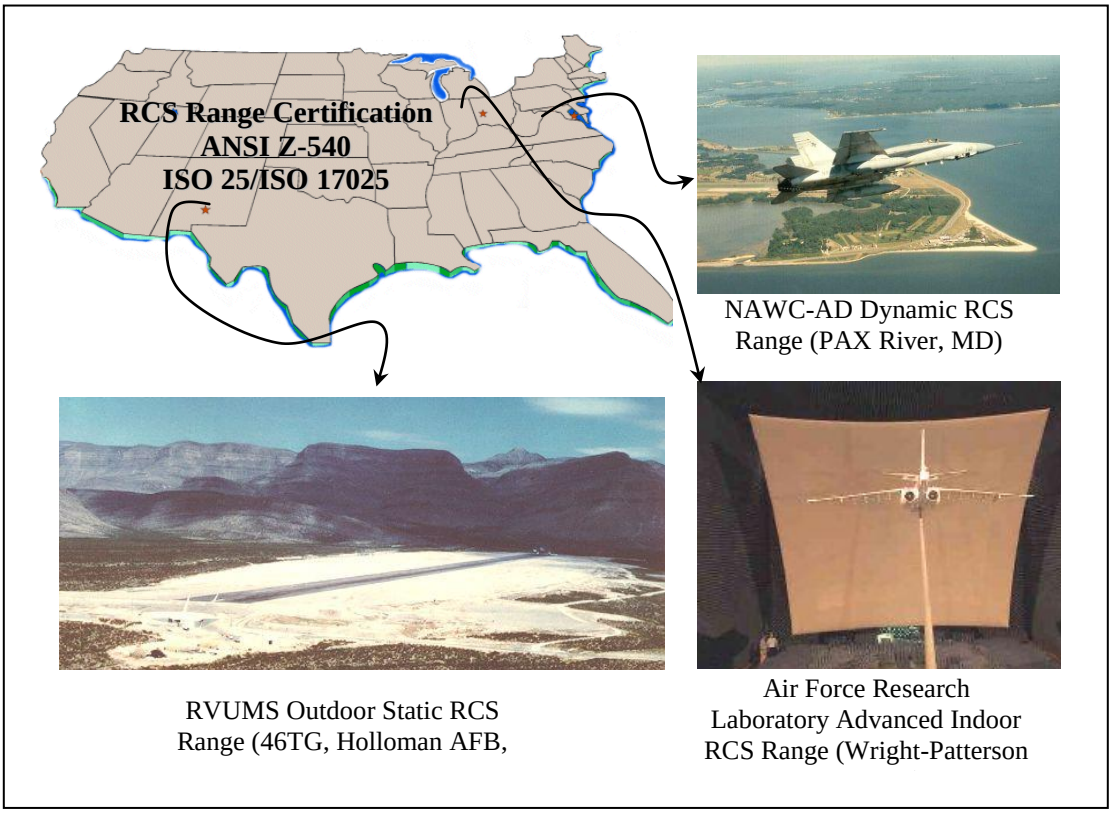


Figure 2-1. DoD RCS Demonstration Program Ranges.

establishing a customized Z-540 RCS-based quality assurance documentation handbook [1, 5, 6]. Though this document provided a context for the documentation standard, it provided few details regarding the evaluation criteria and certification review processes needed to complete RCS certification. The remainder of this report describes the establishment and use of objective evaluation criteria, the certification review process, and the overall success of the two ranges at AFRL and NAWC-AD, which have successfully fulfilled the certification review process to date. (The third range, 46TG-RVUMS at Holloman Air Force Base (HAFB) in New Mexico, is undergoing certification review, and the review should be complete by December 2000.)

2.2 Defining Z-540 RCS Certification

To avoid repeating the background information in Chapter 1, we begin by precisely defining "RCS certification." From [6,7]:

> "RCS certification, as used in the DoD demonstration program, is hereby defined as having successfully completed a detailed review of an *RCS Range Book* by a *peer review committee* using *published evaluation criteria*."

The detailed review is essentially a compliance assessment that a range has met the relevant quality assurance documentation standards for Z-540. In the DoD RCS Demonstration Program, certification is a review committee's positive assessment of compliance with the Z-540 standard and an endorsement of the range's measurement processes. RCS certification is NOT a rating system or a specific review committee endorsement of day-to-day quantitative capabilities (accuracy, uncertainty, and so forth).

To better understand certification contextually, let's review each major element of the certification statement. We begin by defining the RCS Range Book. From [6], an "*RCS Range Book*" is a detailed technical and quality assurance document written in accordance with the Z-540 standard by the range to be certified. The range book thoroughly describes all aspects of the RCS measurement range. Its 20 distinct sections describe every major aspect of range operations, procedures, calibration, and equipment. The range book also explains how the range is organized and operated on a day-to-day basis. The range book is meant to be a ready daily reference for the range staff, as well as a document a potential customer could review prior to using the RCS facility for a test.

The *"published evaluation criteria"* [see Vol. I of this document] are a set of approximately 140 specific written evaluation criteria that the range book must fulfill to become RCS certified. The evaluation criteria provide a complete listing of the specific minimum information required for each of the 20 range book sections. Since the range knows the evaluation criteria up front, they provide a definitive guide for the range staff to help prepare the range book material. The evaluation criteria are also used by the range to "self review" or "register" the range book prior to certification review by a third party.

The *"peer review committee"* consists of three volunteer RCS experts from government, industry, and/or academia who review the RCS Range Book for compliance with the Z-540 standard using the evaluation criteria mentioned above. The volunteer reviewers provide feedback to the range on non-compliant range book sections and work with the range in question to help revise the

range book and make it fully compliant with the standard. Literally, the review committee is there to help the range complete the certification process. Note that ACR and ATL were solely reviewed by RCS experts employed outside DoD to avoid any perceived conflict of interest. (The decision to use external range book reviewers employed outside DoD was coordinated and approved by the RCC.) The ongoing 46TG RMS VHF/UHF Measurement System (RVUMS) certification review also employs non-DoD reviewers. All range book reviewers must meet minimum qualifications set by the RCC/SMSG Radar Committee, and must be assigned to a specific review committee by the Chair of the RCC/SMSG. As a courtesy, the names and current employers of potential range book reviewers are provided to the RCC/SMSG, who carefully screen potential reviewers for financial or programmatic conflicts of interest. If an apparent conflict of interest is identified by the RCC/SMSG, the potential reviewer is assigned to another certification review team where no such conflict exists.

2.3 The Detailed Z-540 RCS Certification Process

The RCS certification review process created by the RCC/SMSG may seem complicated at first glance, but it's actually a manageable, easy-to-follow, step-by-step recipe. To illustrate the overall review process, refer to Figure 2-2. The process begins with the "Registered" Phase when a range decides to become "registered" to the Z-540 standard. This involves generating a range book (paper or electronic), which meets the published evaluation criteria [see Vol. I of this document] for RCS certification. For most ranges, this process can take 6-24 months depending on the complexity of the RCS range measurement system and the range's initial state of documentation. If a range has organized documentation and thoroughly documented measurement and calibration procedures available at the onset, the process can be quickly completed. If these documents need to be created by the range staff, the process obviously takes longer. Once the range book draft is generated, the range performs an internal "self review" of the range book, using the same evaluation criteria used by the third party review committee. Once this "self review" is successfully completed, the range's designated quality manager normally endorses the range book in Section 1 (Introduction and Endorsements). Once reviewed and signed internally, a range is considered "Registered to Z-540." A range must become RCS "registered" prior to requesting a third party certification review, a practice consistent with ISO standard review procedures.

The next step in the certification process is the Notification Phase. A range desiring certification contacts the Chair of the RCC/SMSG (as of the date of this publication, Mr. Dale Bradley, USAF Arnold Engineering Development Center, tel. # 931-454-4242, e-mail: dale.bradley@arnold.af.mil). The range requests the formation of an RCS Certification Review Committee. Within 30 days of being contacted, the Chair assigns a third party committee of three RCS experts to review the range book in question. This third party committee consists of experts in RCS recommended by the RCC/SMSG Radar Committee. As stated earlier, the RCC/SMSG Chair assigns the review committee members to assure there is no perceived conflict of interest between the reviewers and the range. Once the review committee membership has been named, the committee meets to elect a chairperson. By charter, the review committee chairperson is the single focal point between the review committee and the range under review for the duration of the review process.

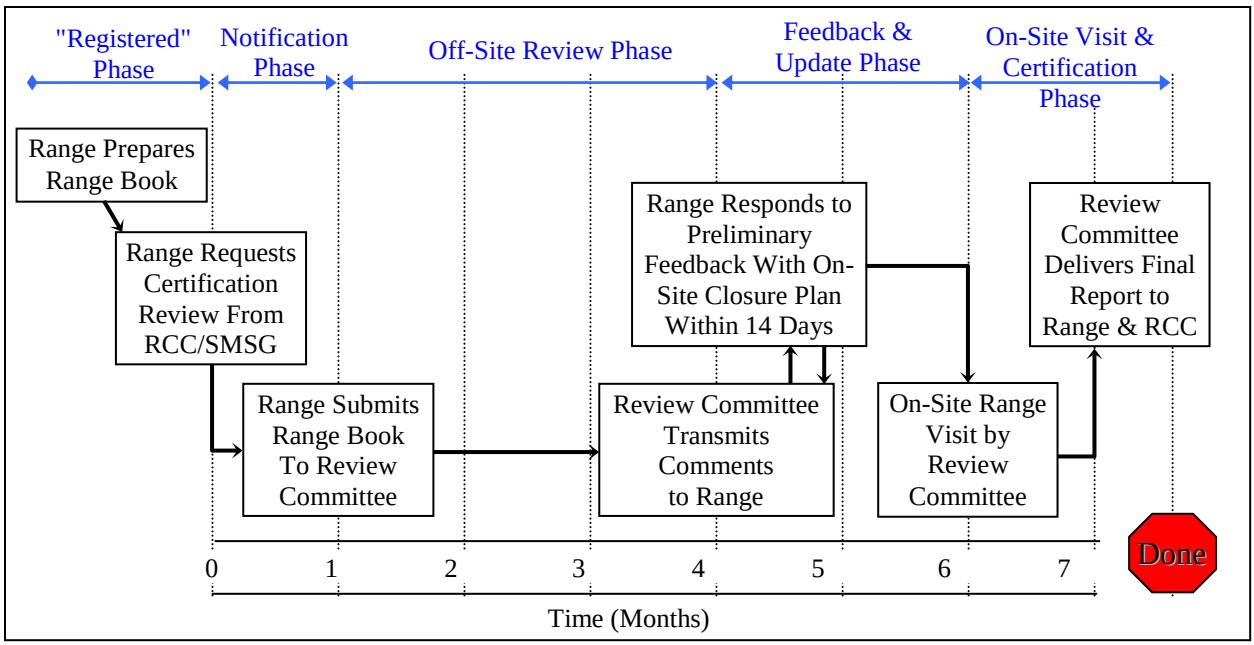


Figure 2-2. RCS Certification Process and Timeline.

Once the review committee has been formed, the review timeline officially starts, and the review moves into the Off-Site Review Phase. The range sends a copy of the range book to each review committee member. The review committee has three months to review the range book, and grade it in accordance with the evaluation criteria. The chairperson gathers the individual grades and issues "composite" or committee grades for each evaluation criterion. At the end of the three-month off-site review, the chairperson transmits the committee's "mid-review" assessment to the range. The mid-review assessment will likely reveal areas where the reviewers require additional documentation, clarification, or improvement in some or all range book sections. Also, about 30 percent of the evaluation criteria are initially ungraded by the review committee as they are evaluated later during the on-site staff interviews. If the review committee identifies any marginal or unsatisfactory range book sections, the review committee must include positive corrective comments showing the range how to reach satisfactory compliance in each noncompliant area.

Next, the certification review process moves into the Feedback and Update Phase. Once the range receives the mid-review report, the range responds to the feedback within 14 days and is then given a minimum of 60 days to accomplish range book revisions and prepare for the on-site review. (Naturally, more time may be requested at any time in the process by the range under review, if needed.) The range makes every effort to correct all high priority deficiencies identified by the review committee. Such corrections are normally accomplished by adding written revisions to the range book to address specific deficiencies. The range also prepares for the upcoming review committee "on-site" visit. This on-site visit generally addresses three areas: (1) the overall range organization and technical operations, (2) deficient areas and the steps the range has taken in the last 60 days to correct them, and (3) staff interviews and the "on-site" audit questions from the evaluation criteria.

All on-site questions are known in advance. The on-site interviewers will not deviate or add additional on-site questions from those present in the evaluation criteria.

The final phase is the On-Site Visit and Certification Phase. During this period, the review committee typically spends 2-4 days at the range for an on-site visit of the facility. In addition to going over the formal changes and revisions to the range book described previously, it provides an opportunity for the reviewers to get a "real world" feel for the day-to-day range conditions and environment. During this period, the remaining "on-site" staff interview questions are asked, and any final questions and comments from the committee are addressed. At the conclusion of the on-site, the review committee is required to give the range an "out-brief" of the new composite evaluation scores. Under most circumstances, if the range successfully accomplishes the required range book revisions in advance, the range "passes" and becomes certified at this point. If, however, the review committee requires closure on a few evaluation criteria, the range simply resubmits final corrections to the committee. Once the range has met the sufficient number of evaluation criteria to "pass," the review committee issues a final report to the RCC/SMSG Chair with a copy to the range. This report provides the final composite grades and concludes with a statement that the range has passed sufficient criteria to become "Z-540 RCS certified." The final range book evaluation report issued by the review committee also becomes a permanent part of the range book.

2.4 Organizing the RCS Range Book to Comply with the Z-540 Evaluation Criteria

The following information provides suggested guidelines for the construction of the RCS Range Book. The goal of this guidance is to maintain consistency in the layout of the documentation from range to range, thus reducing the time needed to review and assess compliance to the Z-540 standard. Although Volume I of this document provides a detailed description of the layout of a typical range book, there are several lessons learned in the construction of the first three range books that are worth sharing. We hope range managers pay attention to these lessons so that ranges desiring certification in the future do not repeat the same mistakes encountered by AFRL and NAWC-AD during the DoD RCS Demonstration Program.

As stated many times earlier, the main goal of the range book is to create and organize the RCS system documentation into a format independent of those used by the RCS ranges performing the measurements. While there is a great deal of latitude given to the range organizing the information, we must be mindful of the time constraints of the volunteer range book reviewers. The ACR and ATR had the unfortunate disadvantage of having their range books written before the evaluation criteria were formally released. As a result, spread throughout their range books were many pages of general information that answered multiple evaluation criteria. Because they wrote the books, their internal reviewers found the answers to the evaluation criteria in minutes. When the third party certification review committee tried to find the same answers, it frequently took them hours. This meant that the review committee had to read and reread many range book sections to gather and evaluate all the information present in the range books. It also meant that AFRL and NAWC had many mid-review revisions to accomplish, since their range books were not organized in exact line with the evaluation criteria.

Learning from these mistakes, the 46 Test Group (RVUMS) organized their range book draft much more efficiently. The RVUMS range book sections displayed specific chapters of information directly in parallel with the evaluation criteria questions. The RVUMS range book listed each evaluation criteria, followed immediately by the information needed to address the criteria. By organizing in this manner, the 46TG made their range book sections considerably shorter in total length, and much more focused to the point of the evaluation criteria. This subtle change greatly reduced the time needed by the third party reviewers to evaluate the range book. (The overall RVUMS range book certification review was ongoing at time this report went to press, although preliminary feedback from the RVUMS reviewers indicate that the information is much better organized than the first two range books from ACR and ATL.)

2.5 Third Party Review of the Range Book – AFRL Experience

Since AFRL was the original architect of the RCS certification review program, they felt extremely confident that ACR's range book would sail through the evaluation process. They had performed an internal "self evaluation" to become Z-540 "registered" and were confident they could quickly pass any review. Imagine their collective surprise when their mid-review assessment showed less than 53 percent compliance on the 140 evaluation criteria. After the initial shock of the poor assessment wore off, they carefully examined where they had gone wrong and set about to make the required revisions. Their first major revelation was that much of their range information was disjointed and unfocussed. They immediately set about revising the high priority (must pass) sections of the range book and organizing them to specifically address the evaluation criteria. Next, they drafted a response to the review committee chair acknowledging all the deficient areas and their plan to reach closure. Finally, they focused their activities to succinctly rewrite the deficient sections and to present the revisions at the on-site review. Since the review committee had provided excellent and thorough comments, AFRL knew exactly what they needed to do, and accomplished all the revisions within the allotted 60 days. The on-site review, while intense, ended on a totally satisfactory basis for both the range and reviewers. Their final compliance grade exceeded 93 percent, with no unsatisfactory criteria in any range book section.

There is no doubt that the third party review of their range book forced them to concisely rewrite many of their core processes. While difficult, there is no doubt that the revised documentation sections were more readable and better organized for both the committee and the AFRL employees. Once AFRL adopted the mantra that "the reviewers are right," the whole attitude within the staff shifted dramatically to a positive outlook. The AFRL staff came up with succinct and innovative methods and graphics to illustrate points they spent many pages of text describing in their original range book draft, making critical points far easier for their technicians to understand and comprehend. In addition, since their primary technicians were closely involved in the range book revisions, they became intimately familiar with the purpose and content of the range book.

During the range book "on-site" review interviews, the review committee picked up on the "whole team" cohesion. The review committee expressed extreme satisfaction that the quality assurance processes and purposes of the range book were understood from the lowest technician to the highest range technical manager. The review process forced AFRL to take a much harder and discerning look at our processes and documentation, resulting in the overall improvement of several

key procedures. Though it took more of an effort than they originally anticipated, there is no doubt that the ACR is a better organization having gone through the Z-540 RCS certification process.

2.6 The Range Book Reviewers

The range book reviewers are volunteer experts from government, academia, and industry who have documented experience in RCS measurements. The entire certification process is centered on the concept of a "third party peer review." Consistent with ISO practices, the certification reviewers are specialists who understand the technical details of RCS ranges. In the DoD RCS Demonstration Program, no DoD employees were used as reviewers to avoid the appearance of conflict of interest, though many such RCS experts certainly reside in the government. Reviewers for the three DoD demonstration ranges (Figure 2-1.) came from Boeing Phantom Works, Northrop Corporation, EG&G Corporation, Syracuse Research Corporation, Mission Research Corporation and the National Institute of Standards and Technology (NIST). The reviewers represented themselves as RCS technical experts, rather than representatives of their corporations or organizations.

The process of becoming an RCS range book reviewer is straightforward. Those interested in becoming reviewers must prepare two documents: (1) a one-page resume describing RCS design experience and/or a minimum of five years of relevant RCS measurement experience, and (2) a corporate letter of commitment from the applicant's employer stating that the applicant may participate in two range reviews in three years, and that release time will be granted the applicant to support the on-site range reviews. This resume and corporate commitment letter is transmitted to the RCC/SMSG Radar Committee (as of the date of this publication the Chair is Mr. John Lewis of NAWC-AD, tel.# 301-342-1193, e-mail lewisja@navair.navy.mil.) The Radar Committee Chair then reviews the resume and submits it to the RCC/SMSG Radar Committee for evaluation. Upon acceptance of the applicant reviewer's qualifications, the individual's name is added to the pool of RCS review team candidates, as discussed previously in this report. A reviewer is selected for a specific range book review based on two main criteria: (1) the availability of the reviewer for a specific review period, and (2) the lack of any perceived or financial conflict of interest between the reviewer and the range under review.

Finally, one may ask, "Why become a reviewer?" For ranges anticipating RCS certification in the future, it is strongly recommended that at least one person from that organization volunteer to be a reviewer for another range. To avoid inefficient, small dollar money transfers between companies in this program, we have operated the program on the quid-pro-quo foundation that if a range wants to be reviewed (certified), it should be prepared to review another range. In this manner, solid RCS experience and best practices will migrate throughout the RCS measurement industry, raising both the overall quality of measurement practices while instilling "generally accepted measurement practices" throughout the RCS measurement industry.

CHAPTER 3

THE DOD RCS DEMONSTRATION PROGRAM – NAWC-AD PERSPECTIVE

3.1 General

This chapter describes the Naval Air Warfare Center-Aircraft Division (NAWC-AD) portion of the DoD RCS Demonstration Program, focusing on the NAWC-AD Atlantic Test Range (ATR) range book review processes, outcomes, and lessons learned.

To facilitate evaluation of the ATR range book, a set of evaluation criteria based on those listed in Z-540 (ISO 25) were developed. Upon receiving word that the respective range books were ready for evaluation, the RCC/SMSG chose evaluation teams from industry and the government to assess conformance to Z-540 by the Air Force Research Lab (AFRL), NAWC-AD, and NRTF. Two of the three range book assessments are now complete. This chapter discusses the assessment of the ATR an outdoor dynamic range.

3.2 Atlantic Test Range (ATR) Description

The Atlantic Test Range (ATR) is a dynamic in-flight test facility performing RCS measurements on aircraft for U.S. military, foreign, and civilian customers. The ATR is part of the Atlantic Ranges and Facilities, a department of the Naval Air Warfare Center-Aircraft Division. Located at the mouth of the Patuxent River overlooking Chesapeake Bay and controlling 2400 square miles of restricted airspace, the facility is able to conduct measurements in a low-clutter environment.

The ATR uses a coherent RCS measurement system, the Advanced Dynamic Aircraft Measurement System (ADAMS), to obtain real-time data for Doppler signatures, down-range profiles, inverse synthetic aperture radar (ISAR) images, as well as whole-body RCS data. ADAMS is also used to collect chaff RCS, jammer-skin ratio (J/S), decoy-skin ratio (D/S), and antenna patterns.

The ADAMS collects data at 153.5 MHz, 230 MHz, 425 MHz and 2 - 18 GHz, and at 35 GHz non-coherently. Up to 80 frequencies can be simultaneously transmitted at pulse rates ranging from a few samples per second to a maximum of 200,000 samples per second. These data are statistically processed off-line to produce probability distribution functions, minimum and maximum values, and mean, variance, and standard deviation and percentile data.

3.3 ATR Initial Range Book Evaluation

At the 1999 RCS Range Certification Conference, the RCC/SMSG Radar Committee presented the draft RCS certification process to the RCS measurement community. As described in Chapter 2 of this report, this process was meant to be in draft form until its evaluation was completed in the DoD RCS Demonstration Program. References [8, 9, 10] show the timeline

and discuss the rationale behind the DoD demonstration program. At the conclusion of the demonstration program, the actual certification teams and review team members would recommend minor modifications to the draft certification process, so the RCC/SMSG could make final changes to the processes before industrial certification implementation began in 2001. As will be seen later in this paper, this philosophy worked so well that less than five percent of the evaluation criteria or processes were changed at the conclusion of the demonstration program.

The timeline for the RCS certification review process called for an initial three-month off-site evaluation period, during which time the evaluation team would review the submitted range books and evaluate them for compliance with Z-540. After this three-month evaluation period, the range would normally be given approximately 60 days to correct any deficiencies found during the initial review. Next, the evaluation team would conduct an on-site review of the range and look at corrective actions from the initial review, interview range personnel, observe calibration activities, and the like. If the on-site review is executed properly, the review team and the range should quickly reach closure on any outstanding evaluation criteria.

As previously discussed, the chair of the RCC/SMSG gathered both the AFRL (ACR) and NAWC-AD (ATR) evaluation teams from a pool of qualified volunteer RCS measurement experts. Each team was composed of two industry experts plus one representative from the U.S. Department of Commerce (National Institute of Standards and Technology -NIST).

The evaluation teams made use of a set of over 140 evaluation criteria [8] derived from sample evaluation criteria contained in the Z-540 handbook and rewritten to specifically address topics relevant to RCS measurement ranges. As described in Chapter 2, when the AFRL and NAWC-AD ranges were assembling their initial range book submissions, they did not have the initial evaluation criteria as a reference. Therefore, their initial range book submissions did not directly answer the criteria. Instead, they submitted their entire range documentation sets for evaluation. This posed a major logistical problem for the evaluators as they were performing this task on a part-time basis.

In the case of the ATR team, this meant reviewing over 560 pages of ATR documentation spread over three printed volumes. Since the ATR and ACR range books were originally designed to be totally web-based electronic books, the review process became complicated because the range books were not initially designed to be printed. As a result, areas that were logically linked in their native web format were not linked on paper at all. For the review team members, this meant that chasing down references in the text tended to be very laborious and time consuming.

In general, the ATR range book review team found the initial written submissions to be poorly put together. Since ATR did not use the evaluation criteria as a guide, the submission evolved into an ad hoc collection of (sometimes hastily put together) discussions on calibration and measurement procedures, along with checklists taken out of context. Forcing a hard-copy printout resulted in poor technical editing (due to the time constraints), and irregular hard-to-read figures and graphs. Everyone realized after the books were delivered that it truly did not represent the quality the team members were accustomed to seeing from ATR.

Eventually, the initial RCS certification review team mid-review report was completed. The result was a 21-page document submitted to ATR detailing the various deficiencies found in the documentation, as well as various requests for clarification. As required, after each listed deficiency the review team included suggestions on how the problem could be solved. Thus, the mid-review report was used as an improvement tool, not a hammer. The report also included a mid-review grade which reflected the percentage of evaluation criteria the review team felt ATR met. It must be noted here that this was merely an initial findings report, again with the purpose of allowing ATR the opportunity to explain and/or rectify any problems prior to the on-site review.

Put bluntly, the report was eye opening to ATR personnel. After all, ATR had put considerable time and effort into their range book and felt they had all bases covered. They were aware that some issues were still open; however, the magnitude of the problems uncovered by the evaluation team was unexpected. Given the initial set of grades received, which were significantly below the passing threshold, the review team mid-review report could easily have been interpreted by the ATR staff as a slap in the face. To their great credit, ATR viewed the report objectively and accepted the criticism at face value, resulting in a sustained and cooperative recovery effort of the highest quality.

3.4 ATR Response to the Initial Review Committee Evaluation

Once the initial shock of the low scores was overcome, the ATR team immediately responded to the report. The response consisted of two items: a line-by-line response to the initial findings, and a reformatted submission that closely followed the evaluation criteria.

The line-by-line responded to each and every question posed in the initial findings. The individual responses in many cases were simple acknowledgments of the questions and the implementation of the suggested solutions. A large number of criteria required significant explanation of what the original submission discussed, why and how the new submission differed, and the evaluation criteria.

Many questions posed in the initial findings caused the ATR team to re-examine its procedures (which, of course, was the point of the exercise). Sometimes this re-examination resulted in a change in a procedure, at other times the result was a task for future study. In the first instance, for example, ATR decided to use the average sphere diameter from their sphere shipments in the Mie equation calculations, rather than a nominal value.

The reformatted submission took the list of evaluation criteria and addressed them sequentially. It was a much more succinct and direct method of ensuring compliance with Z-540, and is being recommended as a template for future ranges to use in submitting their range books for review. As mentioned in Chapter 2, the RVUMS range book submission has already incorporated these lessons learned.

3.5 The ATR On-Site Review

The next critical portion of the RCS certification review process is the on-site review phase. This gives the range under review the opportunity to showcase their range and procedures to the review team. It also offers the opportunity to discuss the required improvements and changes to the ATR range book brought about by the initial RCS mid-review report. The certification review team also has the opportunity to see the day-to-day operations at the range, to interview range personnel (some 30 percent of the evaluation criteria are "on-site" questions), and review the changes made to the range book.

The review team made a visit to ATR during the last week of April 2000 (following a similar trip to AFRL). For consistency in the demonstration program, it was decided that both the AFRL and NAWC-AD review teams would attend each other's respective on-site reviews. It was felt that this would provide a level of grading continuity, as well as an extra set of viewpoints for those reviewers in advisory (non-voting) roles.

During the on-site ATR review, range personnel conducted a comprehensive tour of the range, which gave the review team a feel for the extreme complexity of flight test operations. Range personnel also conducted a calibration sphere launch and tracked it out to the limits of their system. The review team had the opportunity to meet with ATR management and gauge their knowledge of and support for the range book process. It was immediately obvious to the team that ATR management was fully supportive of the process and was looking at ways to apply the certification and quality assurance ideas to other facilities at NAWC-AD.

Finally, the ATR measurement team simulated a measurement by replaying an actual flight from tape and discussing the procedures as the flight proceeded. Flight paths were reproduced and discussed, flight controller duties were outlined, and data collection tasks and procedures were reviewed. The review team came away from the simulation extremely impressed with the way complex procedures were executed and problems were resolved, and with the overall professionalism of the measurement team.

After the orientation segments, the real on-site review work began. The review team sat down with several ATR range representatives and discussed the revised range book in detail. As mentioned, ATR had extensively re-worked their range book submission. Even though the review team had the opportunity to review the revisions prior to their arrival at ATR, the changes were substantial enough to require thorough on-site discussion and review. The revised ATR range book review was much easier the second time around since ATR now used the evaluation criteria as a guide.

As with any committee activity, the process did not go entirely smoothly. Even with the evaluation criteria in hand, there were differing review team interpretations of the meaning and/or applicability of several of the evaluation criteria. These differences had to be discussed and common interpretations hammered out. Furthermore, there was considerable discussion (especially in the closed-door team-only sessions) as to what was required to satisfy several critical criteria. The diversity of the review team meant that the severity with which the

evaluation criteria were interpreted varied among the review team members. The composite grading concept used in the review process resolved some disagreements if two of the three review team members felt the criteria were sufficiently satisfied. Despite these splits, the three review team members were in complete agreement on most of the final scores.

Discussions dealing with these exit criteria were probably the longest and most difficult of all, though in the end satisfactory solutions were adopted. The review team commitment was substantial during the on-site review. Team members often arrived with the earliest arriving ATR personnel and left when the building was vacated in the evening. In the end, ATR was pleased to report that the team was able to come to a unanimous consensus on the evaluation. As mentioned, the initial evaluation returned a grade substantially below that necessary to pass. After the on-site review, the scores in all categories rose precipitously. Although Priority 2 and 3 sections passed with large margins, ATR initially fell just short of passing in a couple of critical Priority 1 sections.

The ATR took the news of the shortfalls in Priority 1 sections in stride. Since the ATR range manager anticipated the shortfalls identified by the review team, ATR was already executing a solid correction strategy. The review team left NAWC-AD confident ATR would correct enough deficiencies to receive a passing grade by the 4th RCS Conference, held 20-22 June 2000 at Boulder, CO).

3.6 ATR Wrap-Up Actions

During the ATR on-site review, the tight interconnections between some of the Z-540 evaluation criteria became obvious. If a weakness was found in one critical process, that weakness tended to cascade through several different criteria. On the positive side, that also meant a single fix could correct several criteria needing improvement.

One area identified during both the AFRL and NAWC-AD reviews was the need to tie the uncertainty analysis directly to calibration measurements. To satisfy this requirement, all parties agreed a Report of Measurement would be produced. This report was to contain a complete measurement of two objects using a method similar to that in [12], wherein a known object was used to calibrate the measurement system, then another known object was measured and the uncertainty analysis applied [13]. Since the second object was known, the resulting errors should fall within the uncertainty bounds calculated for that measurement. The report had a succinct format, allowing a good deal of information to be presented in a small number of pages.

The ATR and the ACR both completed the required RCS Report of Measurement and submitted the results to the review team for consideration. After reviewing the ATR report, the RCS certification review team agreed that ATR had passed sufficient criteria to receive a passing certification grade. This result was documented in the final report and awarded during the June 2000 RCS Range Certification Conference in Boulder.

3.7 ATR RCS Certification - Lessons Learned

The range book is intended to help each range organize its documentation in a useful manner. The Z-540 provides the minimum set of requirements a documentation set must satisfy to pass the RCS certification process. The review committees learned that a solid method to organize the range book around the Z-540 evaluation criteria is absolutely essential. The evaluation criteria in Vol. I of this document provides the necessary template.

As mentioned earlier, the most important lesson learned from the NAWC-AD demonstration program is the need to answer the evaluation criteria questions directly and concisely. Although the initial submissions did not have the evaluation criteria from which to work; future ranges will have them available as an open-book test. Since the evaluators are part-time volunteers and have their own jobs to perform, direct, concise answers to the evaluation criteria are not only helpful but also critical to the timely completion of the certification review.

Another general lesson learned is the need for a printed or printable copy of the submission so that the evaluator can physically do the evaluation. Hard copies also eliminate problems with different computer platforms and make note taking easier.

The Report of Measurement [13] is also a critical item because it ties together the calibration and uncertainty analysis and demonstrates proficiency in both. It does so in a very compact and straightforward format which is available from the AFRL or NAWC-AD demonstration program participants.

CHAPTER 4

DOD RCS DEMONSTRATION PROGRAM SUMMARY AND FUTURE RCS CERTIFICATION REQUIREMENTS

4.1 General

The primary emphasis of this program is to improve the quality and repeatability of RCS data acquired at DoD RCS ranges. The DoD RCS Demonstration Program is designed to show both industry and the government ranges that this is a worthwhile, value-added quality assurance initiative. As such, many industrial RCS measurement facilities, including those owned by Boeing, Northrop, and Lockheed, are now actively pursuing RCS range certification. Today, there is no requirement to obtain RCS certification. Beginning on 1 January 2004, however, all industrial RCS measurement facilities supplying deliverable RCS data to AFRL will be required to obtain RCS data on a certified RCS measurement range. Thus, the voluntary aspect of range certification will revert to a requirement within three years for much of the RCS measurement industry. There is more than sufficient time for most ranges to create a range book in accordance with Z-540. In addition, there is much documentation available from the demonstration program to help any range quickly come up to speed on the certification process. Since industry is actively working to comply, it only makes sense for the remaining U.S. Army, Navy, and Air Force facilities performing RCS measurements to comply with the Z-540 certification requirements as well.

4.2 Certifying to Z-540

Certifying an RCS range to the Z-540 standard is an excellent approach to organizing, maintaining, and presenting RCS range information. Any range book that passes the third party review to become "certified" will produce a document useful to the range and range customer alike. In addition, it will permanently capture critical process information that is retained by the range even as personnel turnover or are assigned to other duties.

We believe that with the overall emphasis on quality systems and ISO 9000 in the commercial sectors, Z-540 (ISO 25) is an appropriate technical standard for RCS measurement facilities. Certifying RCS ranges to this standard should greatly reduce measurement errors and generally improve the operational efficiencies of all RCS ranges. In addition, certification will allow a range to assemble, in one paper document or on an internal web-site, all the relevant information needed to operate an RCS measurement facility. This should help any range sustain its measurement quality during periods of personnel turnover, since the processes and procedures will be there even after employees depart. In light of career mobility, and a national aging technical workforce, this benefit alone should be a powerful incentive for any organization to get and stay RCS certified.

The DoD RCS Demonstration Program has already shown benefits in new calibration techniques, new methods of uncertainty analysis, and a better understanding of error sources. The project has also resulted in a workable and useful standard for organizing range documentation.

4.3 RCS Certification Process

Probably the most surprising aspect of the DoD RCS Demonstration Program is how robust the initial draft certification process really was. Despite early teething problems and the need to train the RCS review teams on the process, in the end the reviewers and ranges both agreed the process was fair, impartial, and value-added. In addition, a post examination of the review process (as a whole), and the individual evaluation criteria after the ACR and ATR reviews, revealed that only minor changes to the process were needed. Therefore, it is likely that the RCS industrial certification program will be nearly identical to the DoD program already completed.

As for side benefits, both ACR and ATR personnel remarked how much easier it is to find often-used information within the structure of their revised range books, as opposed to the prior ad hoc random access methods. With the measurement community becoming older, smaller, and more mobile, the resulting consolidation of RCS documentation should help alleviate the impact of training and personnel retention problems, thereby helping each range sustain its high-quality measurement efforts.

As DoD is now paying more attention to ISO 9000-like processes, the DoD RCS Demonstration Program for RCS certification is a relevant way for each range to preemptively hold off management dictates concerning quality processes. The RCS review process works, and the results make creating the range book worth the effort. It is our collective opinion that it is time for this RCS certification effort to become the norm. Our RCS customers will only expect quality to improve in the future, and it is our job to deliver the promise.

4.4 Conclusion

In summary, the DoD RCS Demonstration Program participants believe that the program, as executed, was entirely successful in achieving its goals. For the first time in history, an RCS range documentation standard exists, and it is flexible enough to work at any type of RCS range. The Z-540 standard is a universally understood and adopted commercial standard, and its applicability to RCS has been conclusively demonstrated. The three RCS ranges participating in this demonstration program found that their newly documented processes and procedures were extremely valuable to the staff and range managers alike. The DoD RCS Demonstration Program also included 4 three-day DoD RCS certification conferences hosted by the National Institute of Standards and Technology, Boulder, CO in March 1997, March 1998, March 1999, and June 2000. The proceedings of each conference have been widely distributed, resulting in an early start by industry in the RCS certification process. Currently, Boeing, Lockheed, Northrop, Ball Aerospace, and General Electric are following the AFRL and NAWC-AD lead in creating

their own range books. This industrial buy-in would not be possible in this budget-limited environment if industry did not see the collective wisdom and payoff in RCS range certification.

There is nothing magic about the Z-540 standard that restricts it to radio frequency RCS ranges. Its processes and procedures are general enough to cover all types of scientific measurements, including laser cross section, infrared emissions and emissivity testing, radio frequency property of materials testing, antenna testing, pressure and temperature testing, and so forth. If government laboratories and measurement facilities hope to continue to sustain the finest test capabilities possible for supporting DoD's future weapons system test and evaluation requirements, the Z-540 standard should be looked at in a broader context for application to these other diverse measurement problems. It is clear to the RCC/SMSG Radar Committee that this standard may revolutionize the way DoD maintains and documents its in-house test capabilities. The committee strongly recommends that the RCC look for other opportunities for Z-540 to establish and document quality technical measurement systems for future U.S. military hardware.

ATTACHMENT A

ACKNOWLEDGMENTS AND REFERENCES

ATTACHMENT A

ACKNOWLEDGMENTS

The authors would like to thank our many sponsors including the Range Commanders Council; Colonel David Hamilton of the Special Projects Office, Assistant Undersecretary for Acquisition (Air Force) [SAF/AQLL]; and Major Russell Miller, Captain M. Larkin Hastriter, and Bryan Kurner of the Air Force Information Warfare Center Signatures Branch. Also earning our appreciation are John Lewis, Roger Davis, and Martin Stuble of ATR, and ATR team members Dr. Andrew Repjar (NIST), Dr. Carl Mentzer (MRC Dayton), and Travis Hestilow (SRC). We also wish to thank Robert Williams, the director of AFRL's Signature Technology Office; Mark Bushbeck and Barry Shaw (Boeing Phantom Works); Dr. Randy J. Jost (Johnson Controls); and AFRL review team members Dr. Andrew Repjar (NIST), Tim Conn (EG&G), and Bruce Melson (GE Aircraft Engines). In addition, we would like to express our collective gratitude to many other contributors to this project including Reserve Major Brian Fischer (AFRL/SNS); Dr. Lorant Muth, Dr. David Novotky, and Dr. Robert Johnk (NIST-Boulder); Professor W.D. Burnside (Ohio State University); and William Parnell (46TW-Eglin). Also commended for their contributions are AFRL consultants Edwin Utt, Major William D. Wood Jr., Dr. Kueichien Hill and Richard Porter; former RCC/SMSG Chair, Frank Carlen (Aberdeen Test Center); and the current RCC/SMSG Chair, Dale Bradley (Arnold Engineering Development Center). Finally, we wish to extend a special thanks to all the members of the RCC/SMSG Radar Committee for persevering throughout this long project and supporting it even as issues arose that threatened its success. The professionalism and integrity of this dedicated group are to be highly commended.

A portion of this project was supported by the Air Force Information Warfare Center under contract F41621-97-D5200 and by several additional contracts and subcontracts sponsored by AFRL and NAWC-AD. Our appreciation to these organizations for this invaluable assistance.

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