

# **Roles and Responsibilities of NIST in the Development of Documentary Standards**

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## **1 INTRODUCTION**

The National Institute of Standards and Technology (NIST<sup>\*</sup>) is a non-regulatory federal agency of the Department of Commerce and is the national metrology institute of the US. NIST's role in the development of voluntary consensus standards (VCS) is rooted in many policy decisions and government directives that happened in the 1980s and 1990s. NIST has been a leader in the development of many standards, including documentary<sup>†</sup> standards, ever since its founding in 1901.

The Dimensional Metrology Group (DMG) at NIST develops, performs, and delivers measurements, physical and documentary standards that promote US innovation and industrial competitiveness. NIST DMG has been involved in many standards committees that are a part of International Organization for Standardization (ISO), American Society for Mechanical Engineering (ASME) and more lately ASTM. Recently, DMG, along with various other organizations was involved in the development of an ASTM documentary standard for 3D imaging systems. NIST led the effort and was a major contributor in developing this standard and this activity led to the publication of the ASTM E3125-17 standard in 2017. This standards development process was systematic per the rules and regulations of ASTM, which in turn enabled a balanced approach that addressed the concerns of the stakeholders while maintaining their involvement and establishing a consensus.

This paper describes the basis for NIST's authority to participate and drive the development of documentary standards. The paper will then describe the role of DMG in the standards development process. This includes some of the technical and procedural challenges faced by the working group that published the ASTM E3125-17 3D imaging standard.

## **2 STANDARDS DEVELOPMENT & ADOPTION BY GOVERNMENT AGENCIES**

Many government agencies have been involved in the development of standards to achieve their organizational missions. The Department of Defense (DoD) was known to have over 21,000 government unique standards (GUS) in use prior to the year 1997 [1]. In 1994, the then Secretary of Defense, William J. Perry wrote a policy memorandum, now known as the "Perry Memo"[2][3]. This memorandum highlighted the increasing costs of relying on GUS and directs DoD to use non-government performance standards for its procurement process.

The non-government performance standards mentioned in the "Perry Memo" are voluntary consensus standards (VCS) that are developed by standards development organizations (SDOs)

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<sup>\*</sup> The names of the organizations mentioned in this paper varied throughout their history, but will be referred in this paper with their current name unless otherwise specified. ASTM International will be referred to as ASTM in this paper.

<sup>†</sup> According to ISO, a documentary standard is defined as a document, established by consensus, and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of optimum degree of order in each context.

using agreed-upon procedures. The next few sub-sections will detail the history of SDOs, and standards development in the US and how they shaped the events that transpired before and after the "Perry Memo".

## **2.1 Consolidation of the standards development activity in the US**

Prior to 1900s there were many organizations like the American Society of Mechanical Engineers (ASME), ASTM etc. that led the development of standards for the greater good of the society. These professional organizations took up the task of addressing various safety and commercial interests of that era. Soon, it became evident that there was a need to coordinate the standards development activities in the US. In 1918 five engineering societies and three government agencies came together to establish an organization that is known today as the American National Standards Institute (ANSI). The purpose of ANSI's founding was to coordinate standards development, approve national consensus standards and halt user confusion on acceptability. The five engineering societies that founded ANSI were the Institute of Electrical and Electronics Engineers (IEEE), the American Institute of Mining and Metallurgical Engineers (AIME), the American Society of Civil Engineers (ASCE), the ASME, and the ASTM. These five societies, who were themselves core members of the United Engineering Society (UES), subsequently invited the US Departments of War, Navy, and Commerce to join them as founders [4]. The US Departments of War and Navy eventually became the US DoD and US Department of Commerce is the parent organization of NIST.

ANSI was founded as a private non-profit organization and does not develop any standards, but accredits and assesses the competence of the numerous SDOs [5]. ANSI also approves individual documentary standards developed by SDOs and designates them as American National Standards (ANS) [6]. ANS designated standards undergo additional scrutiny that involves accreditation of consensus procedures, neutral oversight, approval process, appeals process, and procedural audit. These additional requirements generally align with the policies set forth by OMB A-119. However, it is up to the SDO to consider designating an approved standard as an ANS by following ANSI's procedures. As of 2015, there were more than 240 ANSI accredited SDOs, over 100,000 VCS published in the US and over 11,000 ANS. For example, the ASME Y14.5M-1994 for "Dimensioning and Tolerancing" is designated as an ANS. ANSI also serves as the US national standards body representative to ISO and many other regional and international standards activities [7,8,9].

There are hundreds of national and international SDOs around the world. Some examples of SDOs accredited by ANSI are ASTM, ASME, IEEE and Underwriter Laboratories (UL). In many countries a centralized body drives the standards activities, which typically is that country's government and is considered a top-down approach. In the US, the private sector drives the standards development activities, which is considered a bottom-up approach. Many SDOs use VCS development processes that ensure due process such as requiring openness, balance, appeals, and consensus.

## **2.2 US government directives**

The US Office of Management and Budget (OMB) issued a circular OMB A-119, in 1980, titled "Federal participation in the development and use of voluntary standards", which was then revised in October 1982. This was considered a groundbreaking policy. The revised circular in 1982 directed federal agencies to participate in SDOs and rely on VCS not just in procurement activities, but also in its regulations. However, the usage of GUS continued and as of 1996 there were still about 34000 GUS used by the federal government [10].

Subsequent to the "Perry Memo" in 1994, the policy on usage of VCS for federal agencies was reviewed. This led to the passing of the National Technology Transfer and Advancement Act of 1995 (NTTAA, public law 104-113) [11]. The NTTAA incorporated many of the policy directives of OMB A-119 into a law. OMB A-119 underwent three more revisions since the first revision in 1982 [12]. The 1993 revision [13] reflected the US trade obligations, the 1998 revision [14] was updated to reflect the requirements of the NTTAA and the 2016 revision [15] reflected the changes in numerous federal policies, trade obligations and practices.

The directive for all the federal agencies, including NIST, to participate in the development and adoption of VCS comes from the NTTAA and OMB A-119. The NTTAA mandates that all federal agencies adopt VCS wherever possible, except where inconsistent with law or impractical and avoid the development of GUS. An example of these directives is DoD replacing a government standard, MIL-L-13762 for lead alloy coatings, developed in 1983, with a consensus standard, ASTM-A308 in 1997[16]. GUS are still used by the US federal government for safety, security, and specialized military equipment where appropriate. The primary purpose of NTTAA and OMB A-119 was to eliminate the cost of developing GUS and rely on VCS for such needs wherever possible. As of fiscal year, 2016, there are only about 70 GUS reported in lieu of existing VCS used by federal government agencies (excluding DoD and the National Aeronautics and Space Administration) since reporting began in 1997 [17].

There are many more GUS that are presently in use mostly due to the lack of an equivalent VCS, older GUS that have not been replaced by VCS, or GUS developed due to statutory requirements. For example, the Federal Information Processing Standards (FIPS) published by NIST are government standards that are mandated by law [18], which in its present form address information security related issues in the federal government. Over the years, many FIPS standards were withdrawn [19], and presently only nine FIPS standards are still in use [20]. Another example of usage of GUS by a federal agency is the "Fire protection for shipyards" standard used by the Occupational Safety and Health Administration (OSHA) instead of available VCS. According to OSHA, it was determined that there was no single VCS that covered all the topics for its final ruling [17] and warrants the usage of a GUS.

Though the adoption of VCS is voluntary in nature, VCS can become a law if government agencies adopt them into regulations by a process known as incorporation by reference (IBR). For example, many standards developed by ASTM and UL have been adopted by federal, state, and local governments or codified into law [21]. Many VCS documents are not free of charge and the SDOs may hold the copyrights. However, adoption of VCS into regulations through IBR by federal agencies is permitted as long as the standard is "reasonably available" to the interested parties. The criteria for a VCS being "reasonably available" is detailed in the Office of the Federal Register IBR handbook [22].

### **2.3 Role of the Department of Commerce and NIST**

The US Department of Commerce [23,24] promotes job creation, economic growth, sustainable development, and improved living standards of all Americans by working in partnership with business, universities, and workers. It accomplishes its mission through direct assistance to businesses and communities, targeted investments in world-class research, science, and technology, and through various programs that foster innovation, entrepreneurship, and competitiveness. NIST is one of the 12 bureaus of DOC and its mission is to promote US innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life [25]. NIST has

always been at the forefront of development of documentary standards, but it is not an SDO<sup>‡</sup>[26]. With the emergence of NTTAA and OMB A-119 directives, NIST was also assigned the role of the coordinating standards and conformity assessment activities and reporting government-wide progress annually to OMB.

## **2.4 NIST Dimensional Metrology Group activities in documentary standards**

The Dimensional Metrology Group at NIST has been leading and supporting the development many documentary standards for over 60 years. DMG works with manufacturers, users, and other stakeholders on committees of various SDOs in this process. Considerable amount of DMG's research and development efforts supports the development of these documentary standards, primarily as part of ISO, ASME and ASTM. NIST DMG staff also hold leadership positions in about 20 standards committees that are a part of various SDOs like ASME, ISO and ASTM. Some of the recent examples of documentary standards led by DMG were the ASME B89 series, ASTM E57 and ISO 10360 series of standards. Examples of documentary standards from these activities include ASME B89.4.19-2006[27], and ISO 10360-10:2016[28] standard for laser trackers and ASTM E3125-17[29] standard for laser scanners.

## **3 BACKGROUND OF THE ASTM E3125-17 3D IMAGING STANDARD**

The ASTM E3125-17 standard describes the performance evaluation methods for a class of 3D imaging systems called Terrestrial Laser Scanners (TLSs). An overview of the ASTM E3125-17 standard was reported by Rachakonda et. al [30]. TLSs are used in a variety of applications including reverse engineering, surveying, large scale assembly and historical artifact preservation. TLSs were investigated at NIST for use in a variety of applications starting in the late 1990s. NIST recognized the potential impact of these instruments in a range of industrial applications and that standards were needed for these class of instruments. Therefore, NIST organized three workshops between 2003 and 2006 which brought together instrument manufacturers, end users and other organizations to determine the needs and interests of all the stake holders [31,32]. The participants of these workshops agreed that the development of documentary standards would benefit the TLS users and would help promote widespread use of the technology.

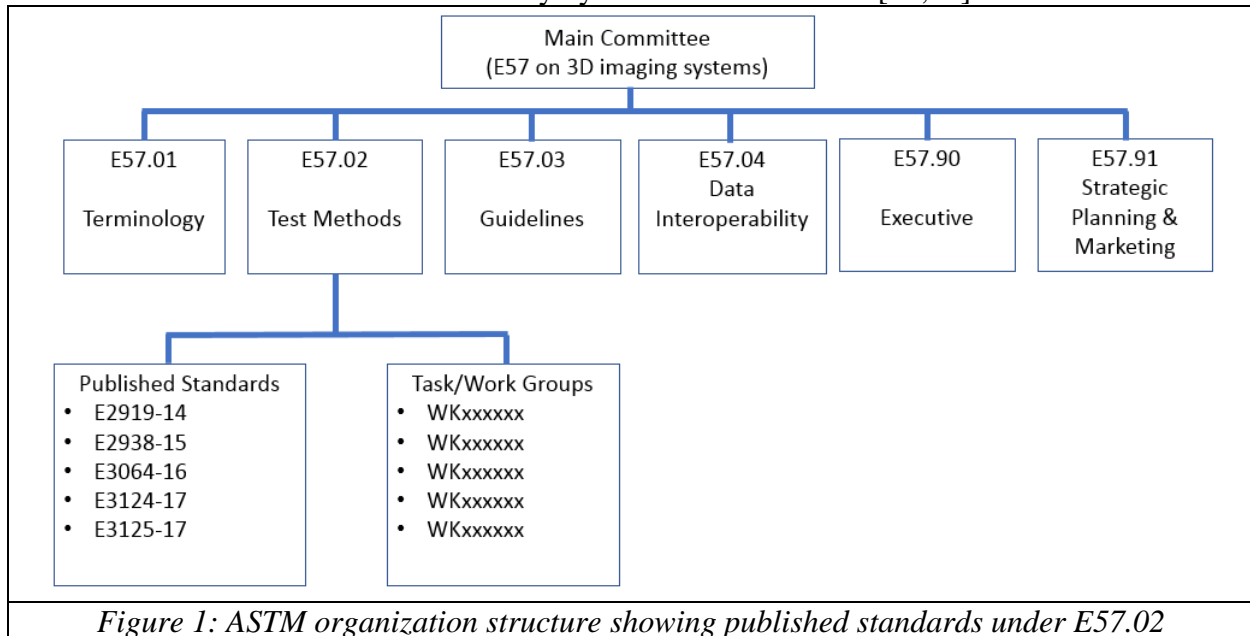
The process of selection of ASTM as an SDO for 3D imaging standards was also achieved through a consensus process by participants of the NIST workshop in 2006 [32]. Several SDOs were initially considered and the choices were narrowed down to two SDOs. These SDOs were sent questionnaires about their standards development process. The responses were then sent to the participants of the workshop and were asked to vote for an SDO. A clear majority of the participants selected ASTM as the SDO. After this workshop, the ASTM E57 committee was formally established in 2006 to address issues related to 3D imaging systems such as TLSs, optical range cameras etc. [33]. This committee presently has multiple sub-committees as illustrated in *Figure 1*. Each sub-committee may have multiple work items, which when successful are published as documentary standards. As of the writing of this paper, there are eight published standards under E57 including five standards under E57.02 sub-committee on Test Methods [34].

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<sup>‡</sup> Only one laboratory of NIST, the Information Technology Laboratory(NIST/ITL), is accredited by ANSI as an SDO and primarily retains this status due to various historical reasons that precede NTTAA.

After establishing the ASTM E57 committee, a working group started work on evaluating the ranging capability of 3D imaging systems, as this was the fundamental measurement of these systems. In 2015, this working group published the ASTM E2938-15 standard for 3D imaging systems to evaluate relative-range [35]. The scope of this standard was limited to the relative-range as the main source of error was from the range measurement of the instrument.

In 2013, another working group was convened under ASTM E57 (WK43218), to address the volumetric performance of the TLS. This was since, both range and angular errors contribute to the instrument errors when any point-to-point distance is measured. This effort was led by DMG staff as they had considerable experience on laser trackers due to their efforts towards ASME B89.4.19-2006[27] standard. Laser trackers and TLSs are very similar in construction and both these instruments were studied extensively by Muralikrishnan et.al. [36,37].



*Figure 1: ASTM organization structure showing published standards under E57.02*

NIST role in this standards development process was both as a facilitator as well as to provide subject matter expertise on TLSs and dimensional metrology instrumentation. In these roles, NIST could not exert any more authority than other stakeholders in influencing the direction of the standard. All the decisions that were taken during this process had to be agreeable to all the stakeholders and it was NIST's responsibility to facilitate consensus. NIST DMG staff worked through both technical and procedural hurdles to achieve this task. As part of the ASTM sub-committee, many of the guidelines and procedures set forth by ASTM were consulted to handle many of the issues that cropped up during this process. Some of the issues encountered by the WK43218 working group are described next.

### 3.1 Stakeholders

Many of the stakeholders that constituted WK43218 were a part the working group that published ASTM E2938-15. Their objectives remained the same – to standardize the performance evaluation of TLSs, but in the entire work volume of the instrument. NIST publicized the activities of this working group at various venues, websites, conferences, symposia, and invited participants to contribute to this effort. The participants of this working group consisted of national metrology institutes, instrument manufacturers, distributors, end users and other subject matter experts.

### 3.2 Technical challenges

There were many technical challenges during the development of the ASTM E3125-17 standard. NIST DMG was uniquely positioned to address these challenges due to its technical expertise, facilities, and resources. Two of the notable hurdles were the availability of artifacts and algorithms to process TLS data. If not chosen appropriately, both the artifact and the algorithms could introduce an error in the performance metrics that are not representative of the instrument.

Spheres were chosen as ideal targets for this activity for reasons that are detailed in [38,39]. The challenge was the availability of commercial spheres that were suitable to be measured both by the instrument under test and the reference instrument. Early on, it was decided that the test procedures at NIST would be using a laser tracker as the reference instrument. Measuring large reference lengths was challenging on stationary CMMs and laser trackers provided a way to perform in-situ measurements. A variety of artifacts were considered by the ASTM working group and the breakthrough came with the availability of a commercial artifact known as "Integration sphere" depicted in Figure 2. This sphere had a circularity of  $< 10 \mu\text{m}$  and it was designed to be measured by both the TLS and the laser tracker.

Algorithms to process the TLS data were the second major challenge. As increasing amount of data was being collected, it was observed sphere datasets were littered with a lot of phantom or spurious points that did not belong to the sphere. The location of these spurious points varied based on the instrument and its ranging technology and had to be excluded. A variety of algorithms were considered for this activity and an algorithm known as the "Cone-Cylinder algorithm" was developed for this activity and this algorithm resulted in minimal number of spurious points. The details of these algorithms were reported by Rachakonda et. al [40].

Following are some of the other technical challenges that were encountered by this working group:

1. Instrument downtime, due to repair, servicing, or calibration
2. Proprietary nature of instrument's construction, data format etc.
3. Lack of resources, facilities, equipment, software, and artifacts to independently examine the technical issues by all the stakeholders.

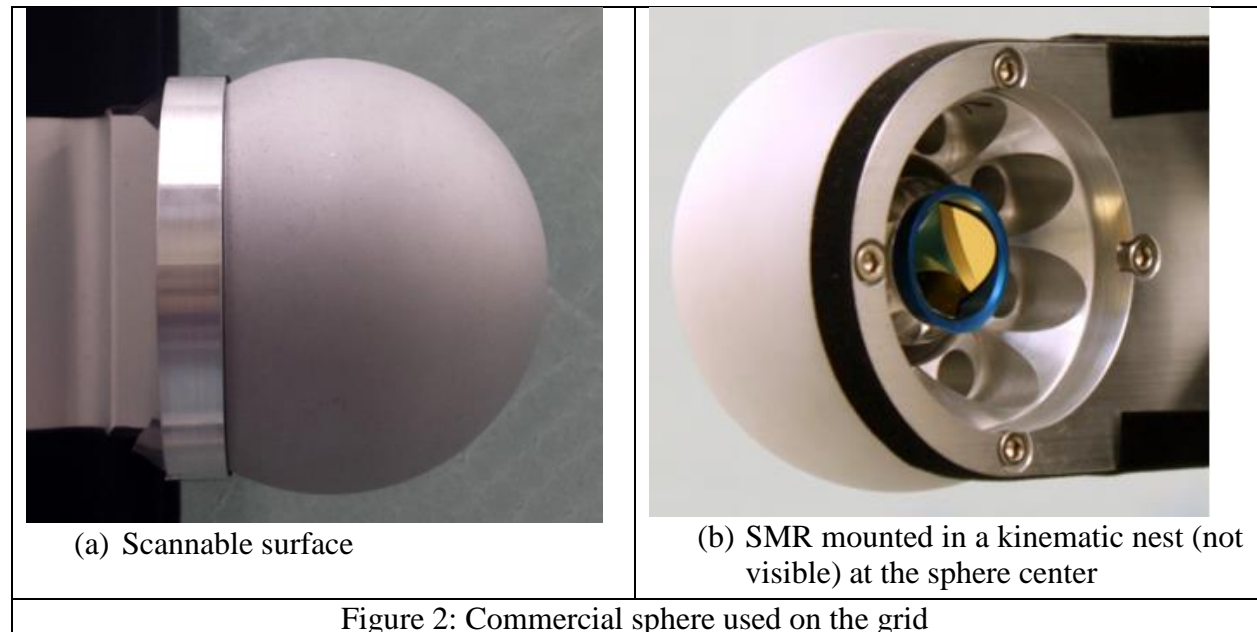


Figure 2: Commercial sphere used on the grid

### **3.3 Procedural challenges**

One of the major procedural challenge happened at the start of this activity and it was to define the scope of the standard. This is one of the most common challenges encountered by many working groups that develop documentary standards. The ASTM E2938-15 standard can be used to evaluate any 3D imaging system, however, ASTM E3125-17 limits the standard only for 3D imaging systems that have a spherical coordinate system such as TLSs. This was because, the TLS error sources were well understood prior to the start of the standards activity [36,37]. Based on this work, the scope was limited to using test positions that were sensitive to the instrument error sources. The scope was also limited to the usage of reference lengths instead of consistency checks and the usage of targets that have optical and mechanical properties suitable for a TLS to scan the target in its test volume.

A significant procedural challenge that was encountered during this activity was new stakeholders participating in the midst of development of the standard and stakeholders participating on an intermittent basis. Concerns about the direction of the standard and the requisite time commitment are a couple of factors that affect stakeholder participation. A considerable amount of effort was expended to satisfy stakeholders about the direction of the standard.

One other challenge was negative votes from non-participating members of the ASTM E57 subcommittee. For a standard to be approved, it must be voted on by the subcommittee members. ASTM requires responses from about 60 % of the subcommittee members and 90 % of those responses must be in favor for the standard to be approved. All the negative votes had to be addressed per ASTM procedures. The negative votes were discussed at length to determine if they were persuasive or not and technical responses were drafted. The recommended changes to proposed standard were then submitted to the subcommittee for approval. Once approved, the standard had to be re-balloted as some of the changes were substantial and not editorial.

Following are some of the other procedural challenges that were encountered by this working group:

1. Lack of sustained interest from subject matter experts.
2. Long lead times for procurement, instrument repairs and manuscript publication.
3. Organizational budgetary cycles not matching the standards development life cycle.

## **4 SUMMARY**

NIST has historically been a leader in supporting the development of many documentary standards. As new market driven requirements emerge NIST provides its expertise to both the private industry and the US government in the development of VCS. In this context, this paper describes NIST's role which is defined by its statutory authority and further set out in the NTTAA and OMB A-119. The paper then describes some of the challenges faced during the development of one VCS, ASTM E3125-17, that was developed according ASTM rules and regulations.

## **5 DISCLAIMER**

Commercial equipment and materials may be identified to specify certain procedures. In no case does such identification imply recommendation or endorsement by the NIST, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

## **6 ACKNOWLEDGEMENTS**

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