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REVIEW REPORT

OFFICE OF AUDITS

REVIEW OF THE CONSTELLATION PROGRAM'S
REQUEST TO DISCONTINUE USING THE
METRIC SYSTEM OF MEASUREMENT

OFFICE OF INSPECTOR GENERAL



National Aeronautics and
Space Administration

Final report released by:

/signed/
Paul K. Martin
Inspector General

Acronyms

DoD	Department of Defense
EO	Executive Order
FY	Fiscal Year
ISS	International Space Station
NIST	National Institute of Standards and Technology
NMI	NASA Management Instruction
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PA&E	Program Analysis and Evaluation
SI	International System of Units

OVERVIEW

REVIEW OF THE CONSTELLATION PROGRAM'S REQUEST TO DISCONTINUE USING THE METRIC SYSTEM OF MEASUREMENT

The Issue

The Office of Inspector General (OIG) examined the Constellation Program's¹ draft request to reverse its 2-year-old decision to implement the metric system (also known as the International System of Units or SI)² as its standard system of measurement and instead use the U.S. customary system³ (e.g., feet, pounds, ounces). Our objective was to assess the basis for the Constellation Program's request to NASA's Chief Engineer for an exception to NASA's policy that requires use of the metric system in Agency programs. In addition to examining this specific request, we considered the possible long-term impact on other NASA projects and the Agency's efforts to expand use of the metric system if the exception was granted, which appears likely. Details of the review's scope and methodology are in Appendix A.

Results

We concluded that the Constellation Program's request for an exception to using the metric system as its standard system of measurement does not clearly meet NASA criteria for granting such an exception. In addition, the request does not adequately consider the long-term impact of the decision on future NASA projects.

Specifically, we found that the Program's draft request for an exception to using the metric system does not meet the criteria for exceptions under NASA Policy Directive (NPD) 8010.2E "Use of the SI (Metric) System of Measurement in NASA Programs," March 4, 2007 (see Appendix B). The request from Constellation Program officials suggests that implementing the metric system is impractical and its use could increase risk and threaten mission success. However, we found conflicting documentation attesting to the practicality of implementing the metric system as the primary system of

¹ On February 1, 2010, the President released his proposed fiscal year (FY) 2011 budget for NASA. In that budget request, the President proposed cancelling the Constellation Program. While the focus of this audit is on the Constellation Program's specific request for an exception to NASA's policy requiring use of the metric system, the issues discussed in this audit affect other Agency programs and broader policy issues.

² International System of Units (abbreviated SI from the French *le Système international d'unités*) is the modern form of the metric system. The terms "metric" and "SI" are used interchangeably in this report.

³ The system is also known as the "English," "British Standard," and "British Imperial" system of measurement.

measurement in the Constellation Program. In addition, other Constellation Program documentation we reviewed refutes the suggestion that implementing the metric system would increase risk in this Program. We also found that neither the Constellation Program nor the NASA Chief Engineer has fully assessed the long-term impact on the Agency of moving away from use of the metric system.

We also found that NASA's written policy directing use of the metric system in Agency programs is deficient in several respects. First, NPD 8010.2E does not define the term "adds unacceptable risk," which leads to differing interpretations of the risks that programs can cite when seeking an exception to using the metric system. Second, the NPD does not provide a mechanism for exceptions to be reevaluated in the event new projects are added to an exempt program or improvements are made in the availability of metric-measured parts. A previous OIG report⁴ recommended that approved exceptions should not be "open-ended," but rather reviewed approximately every 5 years to see if conditions underlying the rationale for the exception had changed. Although NASA management agreed with this recommendation and stated that the pertinent NPD would be modified to "require reassessment of opportunities and rejustification of program-wide waivers where still required, at least once every 5 years," the current version of the NPD does not contain this requirement.

During our fieldwork, NASA's Chief Engineer told the OIG that he planned to approve the Constellation Program's request for an exception based on the additional costs required to implement the metric system, which Constellation Program officials estimated at \$368 million. These implementation costs arise mainly from the reuse of hardware and software from previous NASA programs, including the Space Shuttle, that did not use the metric system, thus requiring revisions to engineering documents, test plans, test equipment, facilities, training, and operations. According to the Chief Engineer and Constellation Program management, the estimated \$368 million for metric system implementation would be better spent on mitigating higher priority Program risks.

We found that because the Department of Defense (DoD) has not fully embraced the metric system as the manufacturing standard in its projects, and because of the size of its contracts, DoD exerts an overriding influence on the U.S. aerospace industry. NASA officials stated that until DoD begins converting its major programs to the metric system, NASA will not be able to easily transition to the metric system due to a lack of aerospace parts designed in metric units.

Management Action

We recommended that the NASA Chief Engineer, prior to granting exceptions to the requirement to use of the metric system in NASA programs, should ensure that a benefit-cost analysis is conducted to determine the short- and long-term impact on the Agency of

⁴ NASA OIG. "Assessment of NASA's Use of the Metric System" (Report No. G-00-021, February 20, 2001).

not implementing the metric system. In addition, the Chief Engineer should add clarifying language to NPD 8010.2E to more clearly define how the “adds unacceptable risk” criteria should be interpreted when evaluating whether to request an exception to metric system implementation. Further, the Chief Engineer should add language to NPD 8010.2E requiring a review of approved exceptions every 5 years to ensure the exception remains applicable and justified. Lastly, the Chief Engineer should engage DoD and other interested Federal agencies to develop a strategy for broader implementation of the metric system within the aerospace industry.

In response to the OIG’s draft report (February 19, 2010), the Chief Engineer stated that two NASA policy changes have occurred that directly apply to the recommendations. First, the President’s FY 2011 Budget Request for NASA, if enacted, will cancel the Constellation Program; the Chief Engineer stated that he has, consequently, placed a hold on the Program’s request for a waiver [exception] from using U.S. customary units. Second, on March 16, 2010, NASA cancelled NPD 8010.2E when it was superseded by NPD 7120.4D, “NASA Engineering and Program/ Project Management Policy,” which includes a section addressing the “Metric System of Measurement.” The Chief Engineer noted that unlike NPD 8010.2E, the new NPD does not include the exception language “adds unacceptable risk.” Nevertheless, the Chief Engineer stated that he concurred with our recommendations; specifically, the Agency will clarify the requirement to conduct a rigorous evaluation, including a non-quantitative discussion of the costs and benefits, in future updates to the NPD; ensure that each new project will be evaluated for its ability to implement the metric system; and initiate an engagement activity with the DoD, Federal Aviation Administration, Aerospace Safety Advisory Panel, and others to develop a long-term metric system implementation strategy within the aerospace industry.

Management’s planned actions to conduct a benefit-cost analysis and to engage DoD and other Federal agencies to develop a strategy for broader implementation of the metric system are responsive to our recommendations. However, we do not agree that NPD 7120.4D adequately addresses our concerns in regard to revising NPD 8010.2E and clearly defining exception criteria or ensuring that NASA policy complies with Federal law and Executive Orders. Therefore, we recommend that the Chief Engineer establish a NASA Procedural Requirements document to ensure that NASA program and project managers effectively implement the metric system policy stated in NPD 7120.4D to the fullest extent possible. We request additional comments from the Chief Engineer on this revised recommendation by April 16, 2010.

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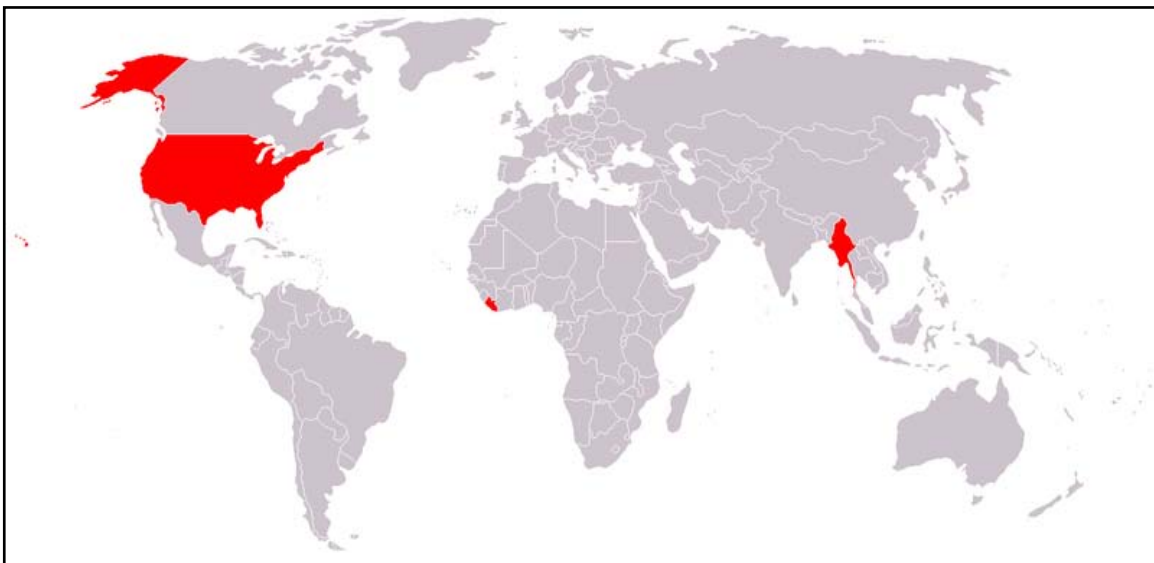
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INTRODUCTION

Background of Metric System Implementation

The U.S. customary⁵ system of measurement – based on the foot, pound, and fluid ounce – is the most commonly used system of measurement in the United States. The International System of Units (SI)⁶ or metric system of measurement – based on the decimal system – is the most commonly used system of measurement throughout most of the world. As shown in Figure 1, the metric system is the official system of measurement for all nations except the United States, Burma (Myanmar), and Liberia. Although legislation in 1988 designated the metric system as the “preferred system of weights and measures for United States trade and commerce” the legislation contained no deadline for its adoption.

Figure 1. Map of the World Showing Usage of Systems of Measurement



Source: Wikipedia

Red (or black) represents countries that have not adopted the metric system as their standard system of measurement.

Federal Laws and Regulations. The Metric Conversion Act of 1975 (Public Law 94-168) declared a national policy of converting to the metric system and established the

⁵ The system is also known as the “English,” “British Standard,” and “British Imperial” system of measurement.

⁶ International System of Units (abbreviated SI from the French *le Système international d’unités*) is the modern form of the metric system. The terms “metric” and “SI” are used interchangeably in this report.

United States Metric Board to coordinate the voluntary transition, but did not include target dates for metric conversion. The Omnibus Trade and Competitiveness Act of 1988 amended the 1975 Act and declared the metric system to be the “preferred system” of weights and measures for trade and commerce in the United States. The 1988 Act directed Federal agencies to convert to the metric system to the degree economically feasible by the end of fiscal year (FY) 1992. The Act does not include consequences for agencies that fail to convert to the metric system.

In 1991, Executive Order (EO) 12770, “Metric Usage in Federal Government Programs,” directed all Executive departments and Federal agencies, including the Department of Defense (DoD), to implement the metric system by the end of FY 1992 or by another date determined in consultation with the Secretary of Commerce. EO 12770 also directed agency heads to establish a process for reviewing proposed exceptions to metric system use. Agencies were also directed to list the exceptions granted in their annual report to the Department of Commerce along with recommendations for actions to increase the use of the metric system. The Federal Reports Elimination and Sunset Act of 1995 (Public Law 104-66) repealed the annual reporting requirement but did not repeal EO 12770. Similar to the 1988 Act, the EO does not include consequences for agencies that do not convert to the metric system.

While these Federal laws and EOs did not require private companies to implement the metric system, many U.S. industrial sector companies and those in the auto industry have successfully converted. For example, U.S.-based companies such as Caterpillar, IBM, General Motors, DuPont, Black and Decker, and John Deere have responded to world market economies and converted most of their products to the metric system. In addition, the U.S. scientific community extensively uses the metric system, and NASA’s work with its international partners on the International Space Station (ISS) is based almost entirely on the metric system.

However, the U.S. aerospace industry, including companies such as The Boeing Company and Lockheed Martin Corporation, have not converted exclusively to the metric system because their largest customer, DoD, continues to base some of its new programs in U.S. customary units. For example, DoD’s Joint Strike Fighter is being fabricated using U.S. customary units. In contrast, in 2006 the Navy commissioned its first surface vessel to be fabricated in metric units, the Army Corp of Engineers uses the metric system for all new military construction projects, and virtually all DoD grant programs are administered in the metric system because the programs are in scientific and technical areas in which use of the metric system prevails.

Evolution of the Metric System at NASA. In 1980, NASA issued NASA Management Instruction (NMI) 8010.2, “Use of the Metric System of Measurement in NASA Programs,” its first Agency-wide metric system implementation policy, and designated the Chief Engineer as the executive responsible for NASA’s metric policy. The NMI required each new NASA program or project to thoroughly consider implementing the metric system as their standard system of measurement. After passage of the Omnibus

Trade and Competitiveness Act of 1988, NASA engaged in an Agency-wide effort to convert to the metric system.

In the early 1990s, NASA Centers developed metric transition plans, purchased metric measurement equipment and machine tools, and provided employees training in use of the metric system. NASA also began to assess requirements for space-quality parts fabricated in metric units and developed qualifications for commonly used parts such as threaded fasteners and fluid fittings.

In 1991, NASA published NMI 8010.2A, which identified the metric system as the “preferred” system of weights and measures for the Agency. NMI 8010.2A required new projects and programs to use the metric system unless NASA’s Chief Engineer granted an exception and further stated that by the end of FY 1992 the Agency would use the metric system to the extent economically feasible in procurements, grants, and business-related activities.

As mentioned previously, the Federal Reports Elimination and Sunset Act of 1995 repealed the requirement for each Federal agency to submit an annual progress report to the Department of Commerce on metric system implementation. In March 2004, in its last report to the Department of Commerce, NASA stated that the Agency had “substantially achieved the maximum level of SI use that is practical at this time.” NASA’s report explained that it continued to use the U.S. customary system because “. . . lack of American aerospace industry commitment to the SI system remains as a major impediment to substantially increased use of SI at this time in NASA Programs.”

Previous Office of Inspector General (OIG) Work on NASA’s Use of the Metric System. In a 2001 report,⁷ we found that NASA had provided managers with minimal guidance for using the metric system and that NASA’s use of the metric system varied from program to program and from Center to Center. In addition, we found that the Agency had not documented its metric system exception process for several years.

We made eight recommendations in our 2001 report intended to improve the use of the metric system within NASA. Among them were recommendations to reexamine the Agency’s efforts to convert to the metric system, develop a new approach for converting to the metric system, closely monitor technical interfaces between metric and U.S. customary units, reinvigorate and document the metric system exception process, and use the metric system as the preferred system for interactions with the public.

NASA management concurred with seven of the eight recommendations. The one recommendation with which NASA did not concur was a suggestion that Agency “program and functional offices should use SI as the preferred system for interactions with the external community in public events, educational materials, and Web site

⁷ NASA OIG. “Assessment of NASA’s Use of the Metric System” (Report No. G-00-021, February 20, 2001).

viewing.” Instead, NASA management said it planned to use its education initiatives to further increase the public’s use and knowledge of the metric system.

Of the seven recommendations NASA concurred with, one was not implemented. This recommendation cautioned against granting exceptions to entire programs and, if an exception was granted, that it not be open-ended but rather reviewed approximately every 5 years for continuing validity. We make a similar recommendation in this review.

Evolution of Metric System Use for the Constellation Program. In a March 2006 study, NASA’s Office of Program Analysis and Evaluation (PA&E) addressed the “Use of SI Units for Future NASA Programs.” The study was part of the larger process to select measurement units for the Constellation Program. The study stated that, “among U.S. space organizations,⁸ NASA is in the forefront of converting to SI. NASA’s choice appears to be either to continue leading or to follow.”

In October 2006, at the 57th Annual International Astronautical Congress, the NASA Administrator stated that

[i]t is important that the engineering standard for NASA architecture be specified with the international metric, or SI, standard as the base unit of measure, with the English units only by exception when it makes sense for NASA to do so. Thus, we hope for a high degree of compatibility of interfaces and standard as space faring nations explore the Moon, Mars, and near Earth asteroids together.

NASA Policy Directive (NPD) 8010.2E, “Use of the SI (Metric) System of Measurement in NASA Programs,” March 4, 2007, describes NASA’s policy of adopting the metric system as the preferred system of measurement. The policy requires the use of the metric system in all new programs and projects covered by NASA Procedural Requirements (NPR) 7120.5D, “NASA Space Flight Program and Project Management Requirements,” March 6, 2007. However, NPD 8010.2E provides a process for programs or projects to seek an exception from the Chief Engineer on use of the metric system. According to the policy, exceptions may be granted “where use of SI is demonstrated to be impractical, adds unacceptable risk, or is likely to cause significant inefficiencies or loss of markets to U.S. firms.”

To comply with NPD 8010.2E, the Constellation Program issued Management Directive 030, “Use of SI as the Primary System of Measure for the Constellation Program, Projects, Systems and Mission” in December 2007. The Directive established the metric system “as the standard and default unit of measure of and throughout the Constellation Program.” It further states that “A consistent practice of units throughout the Constellation Program life cycle is critical to mission success” and stipulates why the Program should implement the metric system:

- U.S. Federal law directs use of SI;

⁸ Organizations benchmarked included Space and Missile Systems Center (SMC), National Reconnaissance Office (NRO), Missile Defense Agency (MDA), and National Oceanic and Atmospheric Agency (NOAA)

- NASA policy directs use of SI;
- SI is simpler and less error prone;
- Consolidation across NASA Science and Engineering practices;
- Alignment with NASA's international space partners;
- Increased international competitiveness of the U.S. space industry; and
- Consistency with U.S. education and skills of next generation space workers.

The Directive allowed exceptions where mixed use of U.S. customary and metric units could be continued for legacy hardware, engineering, or fabrication. However, the Directive established the Constellation Program as a leader in the transition of NASA and U.S. aerospace companies from U.S. customary to metric units of measure.

NASA's basic approach was to manage the Constellation Program in metric units, but grant exceptions to certain disciplines steeped in legacy tools, processes, and methodologies based on U.S. customary or a mixture of measurement systems. The Program approved the use of U.S. customary units of measure for several legacy hardware components and designs (as well as associated tooling and infrastructure) and allowed users the option to justify the primary use of U.S. customary units with additional safeguards in place to reduce technical risk. This philosophy of leaving legacy hardware in the measurement units in which it was originally built has been used extensively in many industries that have made the successful transition to the metric system.

Objectives

The OIG reviewed the Constellation Program's draft request to reverse its 2-year-old decision to implement the metric system as its standard system of measurement and, instead, continue to use the U.S. customary system as the primary and default system of measure. Our objective was to assess the basis for the request and to consider the possible long-term impact on the Agency if the request was granted, which appears likely. See Appendix A for details of the review's scope and methodology and a list of prior audit coverage.

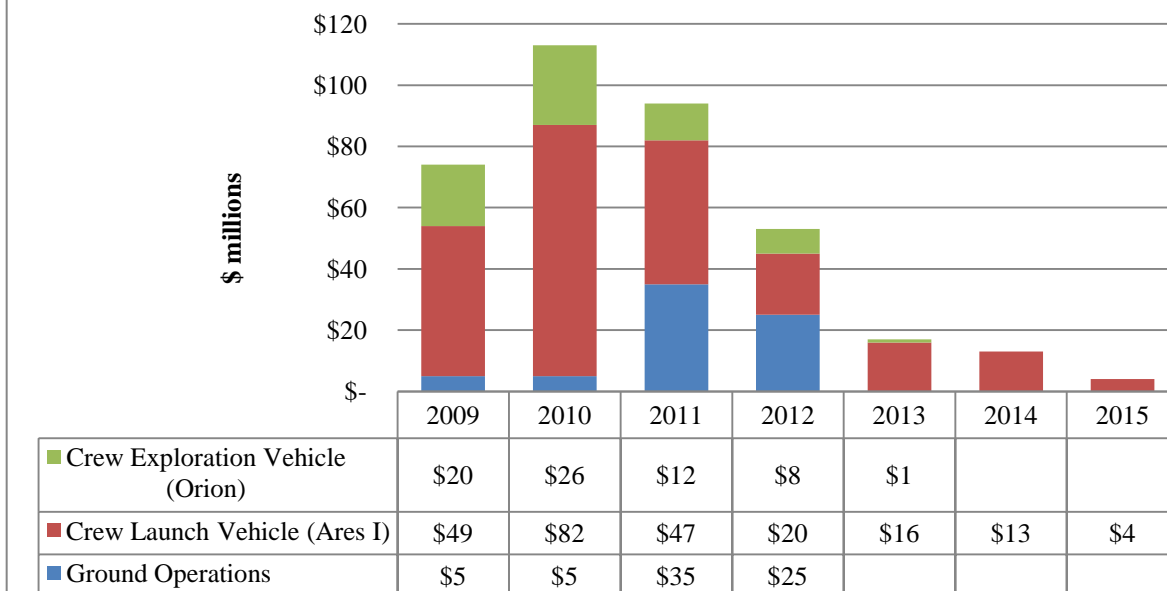
**CONSTELLATION'S REQUEST FOR
AN EXCEPTION DOES NOT
MEET NASA CRITERIA;
NASA'S METRIC SYSTEM
IMPLEMENTATION POLICY
IS DEFICIENT**

The Constellation Program's draft request for an exception to permit the use of U.S. customary system of measurement instead of the metric system does not meet NASA policy requirements for granting an exception. Moreover, the request and the process for granting approval do not consider the long-term impact of an exception on future Agency programs. In addition, NASA's metric system implementation policy, NPD 8010.2E, does not define the phrase "adds unacceptable risk," thereby leaving the criteria open to wide-ranging and inconsistent interpretations. Further, the NPD does not provide a mechanism for exceptions to be reevaluated in the event new projects are added to an exempted program or improvements are made in the availability of metric parts. Several of these issues have Agency-wide impact far beyond the Constellation Program.

The Constellation Program's Reversal of its Decision to Use SI

The Constellation Program began formally assessing the cost of implementing the metric system within the Program's various projects by developing detailed implementation plans after the release of Management Directive 030 in December 2007. By October 2008, initial cost estimates for implementing the metric system in the Constellation Program totaled \$368 million over a 7 year-period, as depicted in Figure 2.

Figure 2. Constellation Program's Estimated Costs to Implement the Metric System, per Fiscal Year (October 2008)



Source: Constellation Program

Specifically, individual project costs were estimated at \$67 million for Orion, \$231 million for Ares I, and \$70 million for Constellation Ground Operations. NASA officials attributed these costs to the reuse of hardware and software designs from previous flight programs that used U.S. customary units, thus requiring revisions to documentation and interface drawings. Of significant concern to Constellation Program officials was that more than 50 percent of this cost – almost \$200 million – was occurring in FYs 2009 and 2010 when their budget was constrained due to operational costs for the Space Shuttle and ISS programs.

In 2008, Constellation began to experience design and technical issues unrelated to metric use to the extent that the Program's overall schedule was projected to be delayed by up to 18 months and the Program would require significant additional funding. Consequently, the Constellation Program Manager took steps to improve the possibility of meeting the Program's baseline schedule of March 2015 by identifying potential deletions, modification, or simplifications of the Program's technical requirements in order to save time and money. One of the items proposed and subsequently approved at the Program level was to reverse its earlier decision to implement the metric system.

In August 2009, the Constellation Program Systems Engineering Control Board approved Change Request 000390, "Direct Implementation for Use of a Hybrid System of Units and U.S. Customary (in-pound) System as the Primary System of Measure for the Constellation Program, Projects, System and Missions," August 6, 2009, which rescinded Management Directive 030 and established use of a hybrid system of U.S. customary units with limited use of metric units in Constellation. According to the Change Request, Program management "looked at various implementation strategies and worked the

implementation details to the point of having workable implementation plans [for using the metric system] in all projects. However, the cost estimates to achieve these plans significantly exceeded the resources that could be made available in the critical years.” NASA’s Chief Engineer is required to provide final approval before the exception to the requirement that all new NASA programs use the metric system takes effect. In conversations with the OIG, the Chief Engineer indicated that he planned to approve the Constellation Program’s request for an exception.

Office of Management and Budget (OMB) Recommended Analyses

OMB Circular No. A-94, “Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,” October 29, 1992, recommends that benefit-cost and cost-effectiveness analyses be used as management tools when considering changes in Government programs or projects. The Circular defines a benefit-cost analysis as

A systematic quantitative method of assessing the desirability of government projects or policies when it is important to take a long view of future effects and a broad view of possible side-effects.

The Circular also states that

A program is cost-effective if, on the basis of *life cycle cost* analysis of competing alternatives, it is determined to have the lowest costs expressed in present value terms for a given amount of benefits. Cost effectiveness analysis is appropriate whenever it is unnecessary or impractical to consider the dollar value of the benefits provided by the alternatives under consideration.

The Circular recommends use of these analyses to help meet the goal of promoting efficient resource allocation through well-informed decision making. The Circular describes four elements of the analyses: policy rationale, explicit assumptions, evaluation of alternatives, and benefit-cost verification. Agency officials did not conduct any of these analyses when deciding to request an exception to use of the metric system in the Constellation Program. Rather, it appears their decision was based exclusively on the estimated cost and timetable for implementing metric measurements in the Program. Moving forward, we believe that NASA management could enhance its decision making process by using the four elements in OMB Circular A-94 to analyze the issue of whether to implement the metric system in any of its programs or projects.

Basis for Chief Engineer’s Approval of an Exception

NPD 8010.2E allows the Chief Engineer to approve exceptions to implement the metric system in NASA programs. The criteria requires the Program seeking the exception to demonstrate that use of the metric system (1) is impractical, (2) adds unacceptable risk, or (3) is likely to cause significant inefficiencies or loss of markets to U.S. firms. The NPD also states that “special emphasis shall be placed on maximum use of SI units in cooperative programs with international partners.” We analyzed each of these criteria as they relate to the Constellation Program’s request for an exception.

Impractical. The NPD defines conversion to metric units as impractical if the conversion “is demonstrated to result in substantial increases in cost or unacceptable delays in schedule to obtain SI components.” It is difficult for us to assess whether implementation of the metric system would result in a substantial increase in cost because Constellation Program management did not conduct a life-cycle cost analysis. While Program management estimated that the cost of implementing the metric system for Constellation was \$368 million, they did not evaluate the costs of not implementing the metric system over the life of the program. Furthermore, cost discussions have centered on FYs 2009 and 2010, although NASA was projected to spend approximately \$97 billion on the Constellation Program through 2020. To make a fully informed decision, we believe NASA needs to assess the long-term costs of not implementing the metric system, because such costs may not be apparent for decades if NASA approves the exception and subsequently decides to include international participation later in the Constellation Program.

Beyond the specific exception requested by Constellation managers, NASA needs to assess the long-term impacts compared to potential short-term costs when deciding whether or not to use the metric system in other new NASA projects.

Adds Unacceptable Risk. The “adds unacceptable risk” language does not originate in Federal law or Executive Order, but rather was added as exception criteria by NASA in 2004 when NPD 8010.2 was updated. The Constellation Program Manager and the Chief Engineer told the OIG that this criterion applies to the risk (acceptable or unacceptable) of expending resources on implementing the metric system in a new program versus spending those same resources to mitigate other identified risks in the program.

The Constellation Program’s Management Directive 030, issued December 2007, established the metric system as the standard system of measure and stated that use of the metric system was simpler, less error prone, and aligned with NASA’s international space partners. Therefore, we question the validity of the Constellation Program’s request for an exception only 2 years later on the basis that use of the metric system “adds unacceptable risk” to the Program.

The Mars Climate Orbiter mishap (discussed below) highlights the risks of working with and converting between the two systems of measurement and having to closely monitor components built using both metric and U.S. customary units of measure. Granting the Constellation Program an exception from using the metric system could introduce long-term risks related to use of components built in U.S. customary units and components built in metric units. The long-term risks increase if the Constellation Program involves international partners in later years – partners who, to a country, use the metric system. We recognize that the Constellation Program is using some legacy hardware built in U.S. customary units; however, the Program can minimize that risk by limiting use of that hardware and building new components fabricated in the metric system.

The Chief Engineer and Constellation Program management said they believe that the estimated \$368 million for metric system implementation would be better spent on

mitigating higher priority Program risks and therefore the Constellation Program's request for an exception meets the intent of the NPD "adds unacceptable risk" criteria. However, before waiving the requirement to use the metric system, NASA should conduct an adequate life-cycle analysis to determine whether the possible savings identified as a result of not implementing the metric system could ultimately cost NASA more in the long-term, either in the Constellation Program or its other scientific or exploration initiatives, many of which involve international partners or U.S. businesses that have made the conversion to the metric system.

Because the definition of "adds unacceptable risk" in NPD 8010.2E lacks specificity, a decision by NASA to grant the Constellation Program's request for an exception could be defended as fitting squarely within the criteria. However, the interpretation offered by Constellation Program managers and the Chief Engineer is premised on the notion that the "risk" of spending funds to implement the metric system can always be deemed "unacceptable" in any budget- or schedule-constrained program in which, from the program managers' perspectives, it would be advantageous to use the funds to address other program areas. However, such an interpretation of the risk criteria can lead to decisions that while seemingly sensible in the short term (in that funds originally designated for metric conversion can be applied to other high-priority issues), may not fully consider the longer-term impact on the specific program or broader Agency-wide interests. Moreover, given such a flexible interpretation of NASA policy, exceptions to the requirement to use the metric system have become the rule. In fact, NASA's Chief Engineer said he could not recall one denial of the numerous requests for exceptions to the requirement to use the metric system. Such historic flexibility in applying the criteria calls into question NASA's commitment to implementing the metric system in Agency programs and projects to the fullest extent possible.

Significant Inefficiencies or Loss of Markets. Although the Constellation Program did not cite this as exception criteria in their draft request, another exception included in NASA policy relates to whether use of the metric system is "likely to cause significant inefficiencies or loss of market to U.S. firms." This criteria was established in the Omnibus Trade and Competitiveness Act of 1988 (Omnibus Act) to help alleviate concerns of U.S. industries who argued that they might lose market share in the United States if they were forced to produce in metric units while foreign firms fabricated products in U.S. customary units. Twenty-two years later, this concern is generally no longer valid since almost all foreign firms fabricate their parts in metric units.

Support for Use of the Metric System in NASA Programs

Failure of Mars Climate Orbiter. In 1999, the Mars Climate Orbiter failed to enter orbit around Mars because of miscalculations resulting from its attitude-control system using U.S. customary units but its navigation software using metric units.

The following year, OIG initiated a review of the Agency's use of the metric system. Our February 20, 2001, report, "Assessment of NASA's Use of the Metric [SI] System"

(G-00-021), found that use of the metric system was inconsistent across the Agency. The Chief Engineer concurred with seven of the eight recommendations we made in our 2001 report to improve the use of metric system within NASA in accordance with national policy and Agency guidance. One of our recommendations urged NASA to move cautiously when considering exempting entire programs from using the metric system:

Recommendation 6: NASA should be cautious in granting *SI* waivers to entire programs. Some programs which, viewed as a whole, could legitimately waive use of *SI* may contain projects that might best be conducted using *SI*. If a program is granted an *SI* waiver, use of *SI* within the program should be permitted where appropriate. Any program waivers granted should not be open-ended, but should be reviewed after approximately 5 years.

NASA agreed with this recommendation, and in their official response said it would modify NPD 8010.2C to require a review of any waivers at least once every 5 years. However, interim revisions of the NPD did not include a requirement for additional reviews and the current version of this NPD (8010.2E) does not require a subsequent review of exceptions previously granted to NASA programs or projects.

NASA Program Analysis and Evaluation Study. The 2006 PA&E study, “Use of SI Units for Future NASA Programs,” analyzed the selection of measurement units for the Constellation Program. The study found that parts fabricated in metric units were readily available from U.S. sources with little cost difference compared to parts built in U.S. customary units. The study stated that risks would exist in a program that maintains the use of U.S. customary units while the economy continues its transition to the metric system. While the study did not estimate the cost of transitioning to the metric system, PA&E officials concluded and Constellation Program managers agreed that the Constellation Program should use the metric system.

As discussed previously, NASA’s international partners and most scientific organizations around the world use the metric system. While the Constellation Program does not presently have international participation, the Augustine Committee’s⁹ “Review of the U.S. Human Space Flight Plans” issued in September 2009 states more broadly that “Actively engaging international partners in a manner adapted to today’s multi-polar world could strengthen geopolitical relationships, leverage global resources, and enhance the exploration enterprise.” In addition, NASA’s Associate Administrator for Exploration Systems Mission Directorate said that several planned elements of the Constellation Program such as the Lunar Lander and Lunar Surface Systems will include the involvement of the international community.

Finally, the President’s FY 2011 budget released in early February envisions significantly expanded international cooperation, and all of NASA’s international partners use the

⁹ In May 2009, NASA chartered the Augustine Committee to identify the best options for the nation to pursue for the future of human space flight. The Committee, supported by PA&E, reports to the NASA Administrator and the Director of the Office of Science and Technology Policy (OSTP), Executive Office of the President.

metric system of measurement. NASA's plans to increase cooperation with international partners in future initiatives should merit close consideration during reviews of all requests for an exception to using the metric system.

Impact of the Constellation Program Decision on the Agency

When considering individual exception requests, NASA should consider the impact of its decision on Agency-wide operations. NPD 8010.2E states that "NASA shall encourage and accommodate increasing the use of SI system of measurement as support capabilities expand, shall acquire capabilities to support that goal wherever practical, and shall cooperate with the private and public sectors to overcome barriers to use and increase understanding of the SI system of measurement." The Chief Engineer has previously approved exceptions for programs or projects because NASA management determined that metric system implementation costs were impractical or that funds could be used in a more tangible way to fix a known risk.

Although the projected costs for implementing the metric system in various Agency programs initially may appear high, NASA should consider the full life-cycle cost benefits prior to granting an exception. Such long-range considerations were not evaluated for previously granted exceptions. The Chief Engineer stated that calculating long-term benefits for the Constellation Program request was of little value in light of insufficient funding in the near term to implement the metric system. We recommend that the Chief Engineer not view exception requests as an "all or nothing" decision. One option would be for NASA to distinguish between projects within programs, authorize an exception to the metric system if warranted, but press forward with metric system conversion on other aspects of the program to move the Agency closer to realizing the goals of NPD 8010.2E, the Omnibus Act, and EO 12770.

Impact of the Constellation Program Decision on Metric System Implementation in the United States

The National Institute of Standards and Technology (NIST) directs and coordinates Federal efforts to implement the metric system in Government agencies and establish the metric system as the preferred system of weights and measures for U.S. trade and commerce. In response to the Constellation Program's decision not to use the metric system, NIST's Metric Coordinator in the Weights and Measures Division stated on June 10, 2009:

Prolonging the transition to the SI will continue to increase the long term costs to the agency, especially for a project that will establish a long lived physical infrastructure on the lunar surface. NASA's original plans to use SI measurements on the moon would have immediately brought SI into greater use among thousands of engineers and other technical staff within the agency and its contractors as launch vehicles and other lunar projects were designed and constructed. The initial decision by NASA management would have pulled the SI into greater use in the domestic aerospace industry, not to mention the long term impact of increased SI use in the U.S. economy

resulting from new technological developments from NASA research and other spin-offs.

In addition, on October 16, 2009, the Deputy Director of NIST sent a letter to the NASA Administrator (see Appendix C) “to support and emphasize the importance of [NASA’s] decision to implement an agency metric policy for Constellation Program operations when the United States returns to the moon.” The Deputy Director stated that “[t]he successful voluntary U.S. transition to the metric system is a critical factor in the competitive success of companies and the country. NASA is a flagship federal agency to which other agencies and industry look for leadership and inspiration.”

NASA’s response to NIST on November 10, 2009 (see Appendix D), while stating that limited funds forced NASA to discontinue use of metric units for the Constellation Program, held out hope for the future:

New elements (e.g. Lunar Lander and Lunar Surface Systems), not relying on heritage systems, are still in the early requirements and operations concept development stage. These projects will have the most involvement with the International community. NASA expects to utilize SI based systems for beyond Low-Earth-Orbit in the coming years.

The DoD Influence

In its last progress report to the Department of Commerce in March 2004, NASA stated that the Agency had “substantially achieved the maximum level of SI use that is practical at this time.” NASA explained that “. . . lack of American aerospace industry commitment to the SI system remains as a major impediment to substantially increased use of SI at this time in NASA Programs.”

During this review, NASA officials repeatedly expressed the opinion that until DoD, the dominant entity in the U.S. aerospace industry, completely embraces the metric system, NASA would not be able to noticeably influence the industry’s transition on its own. We note that DoD and other Federal agencies have made efforts to implement the metric system in certain programs. For example, the amphibious transport dock, USS San Antonio (LPD 17), built by Northrop Grumman Ship Systems and commissioned in January 2006, is the first Navy ship to be designed in metric measurements. In addition, Lockheed Martin, the prime contractor for the Constellation Program, entered into a contract with the National Reconnaissance Office¹⁰ in 2007 that requires “all supplies, components, reports, documentation, or services designed, fabricated, assembled, delivered or performed . . . to utilize the Metric System of Measurement.” However, other major programs such as DoD’s Joint Strike Fighter, estimated to cost more than \$300 billion,¹¹ continue to be designed and manufactured in U.S. customary units.

¹⁰ Lockheed Martin. Prime Flowdowns for NRO 000-07-C-0107, ACE (ATC076, 2/19/07 http://www.lockheedmartin.com/suppliers/bu_info/space/site_7742/atc_flowdown/ATC076_2-19-07.doc (accessed January 29, 2010).

¹¹ Government Accountability Office. “Joint Strike Fighter: Strong Risk Management Essential as Program Enters Most Challenging Phase” (GAO-09-711T, May 20, 2009).

Conclusion

In our February 2001 report, “Assessment of NASA’s Use of the Metric [SI] System,” we stated that

[b]y law and policy, SI is the preferred system of measurement within NASA. As the United States continues its slow transition to the metric system, NASA must decide whether it wants to be a leader or a follower in the transition process. Both roles come with a cost. If NASA chooses to push forward with the Agency’s use of the metric system, near term costs may increase and short-term risk (both to schedule and mission success) may rise to some degree. However, if the Agency follows the aerospace industry’s slow transition to SI, the protracted period during which NASA uses mixed metric and English systems may further increase costs and risks for NASA programs.

NASA is the nation’s most visible science and technology agency, and is involved in highly publicized cooperative projects with a world that almost exclusively uses the metric system. Certainly an argument could be made that as the nation’s symbol of technological prowess, NASA has a role in promoting acceptance and use of the metric system. We believe the Agency should reassess its conversion to the metric system and determine the most appropriate approach for the Agency to successfully transition to SI.

These words are as applicable today as they were in 2001. Almost 10 years since issuance of that OIG report, NASA’s Chief Engineer has approved every request for an exception to using the metric system in Agency programs. Moreover, NASA’s criteria to evaluate requests for exceptions to using the metric system remains ambiguous and lacks appropriate specificity.

The Constellation Program’s Management Directive 030, issued in December 2007, established sound reasons for implementing the metric system; prime among them was that the metric system is simpler, less error prone, and aligns with NASA’s international partners. We understand that NASA will not fully realize the value of the metric system of measurement until this standard is universally adopted by the U.S. aerospace industry. We also understand that if the major entities in the aerospace and defense industries are not moving consistently toward metric system usage, no Federal agency apart from DoD likely will be able to significantly accelerate the transition. However, NASA has the opportunity, in the words of the OIG’s 2001 report, to decide “whether it wants to be a leader or a follower in the [SI] transition process.”

Finally, while we believe that Constellation’s draft request does not meet NASA policy criteria for granting an exception, we urge the Chief Engineer in this and other cases to consider the long-term impacts of any decision to waive implementing the metric system. In addition, while NPD 8010.2E does not require NASA to re-examine previously approved exceptions to implementing the metric system, we believe NASA may be missing significant opportunities to implement the metric system in discrete projects because of an exception previously granted to the overall program.

Management's Comments on the Report and Evaluation of Management's Comments

The Chief Engineer provided comments in response to our February 19, 2010, draft report (see Appendix E for the full text of management's comments). Although we carefully considered these comments in preparing this final report, we did not make a series of requested changes as described below:

Management's Comments on the Report. The Chief Engineer stated that since the issuance of the OIG's draft report, two NASA policy changes have occurred that directly apply to the recommendations. First, the President's FY 2011 Budget Request for NASA, if enacted, will cancel the Constellation Program and all its projects. Second, on March 16, 2010, NASA cancelled NPD 8010.2E when it was superseded by NPD 7120.4D, "NASA Engineering and Program/ Project Management Policy," which includes a section addressing the "Metric System of Measurement."

The Chief Engineer stated that because of the potential cancellation of the Constellation Program, he has placed a hold on the Program's request for a waiver [exception] from using U.S. customary units. In addition, the Chief Engineer requested deletion of several references in the report regarding long-term risks of engaging international partners if Constellation does not adopt an SI strategy. The Chief Engineer said he believes those issues have been adequately mitigated and should be removed from the report since it is the intent of NASA to utilize SI units on vehicle projects that have lunar content. The Chief Engineer stated that the Constellation Program waiver [exception] was intended for the Low Earth Orbit projects, not for projects intended for beyond Low Earth Orbit.

Evaluation of Management's Comments. The Chief Engineer stated in his response to the draft report that NASA will use the metric system on vehicle projects that have lunar content and involve international participation. NASA made the same comments in its response to the NIST Deputy Director (Appendix D). However, the Constellation Program's Change Request does not support the position that NASA will use the metric system when developing future lunar vehicles. As discussed earlier, Change Request 000390, as well as the draft exception request sent to the Chief Engineer, states that the decision to use U.S. customary units "applies to all constituents and aspects of the CxP [Constellation Program], including organizations, personnel, missions, systems, products, processes, plans, operations, communications, data, documents, hardware, software, contracts, contractors, vendors, and deliverables."

Furthermore, in the change request approved by the Constellation Program Systems Engineering Control Board, the following statements appear:

- The Orion/Ares I stack for ISS and lunar missions will be managed solely in U.S. Customary.
- The Ares V vehicle will be managed solely in U.S. Customary.

- For the Altair vehicle the units of development and operations will be decided . . . no later than PDR [Preliminary Design Review] or initiation of procurement contracts, whichever occurs first.
- For lunar surface systems provide by the United States, the units of development and operations will be decided . . . no later than PDR or initiation of procurement contracts, whichever occurs first.
- For lunar surface operations the environment is expected to be mixed units (similar to the ISS Program).

We could find no language in Constellation Program documents that reflects the Chief Engineer's statement that NASA intends to use the metric system for lunar projects.

Recommendations, Management's Response, and Evaluation of Management's Response

Recommendation 1. The Chief Engineer should, prior to granting a program or project an exception to NPD 8010.2E, consider the results of an OMB Circular A-94 type analysis to determine the benefit-cost impact to the program, project, and Agency of not implementing the metric system.

Management's Response. NASA's Chief Engineer concurred with the intent of the recommendation. The Chief Engineer stated that the requirement for a benefit-cost evaluation will be added to future NPD updates, though the Chief Engineer stated that "OMB Circular A-94 type analysis is problematic at best and the NPD language will allow for a non-quantitative discussion of cost benefit." The estimated completion date for revising the NPD is December 31, 2010.

Evaluation of Management's Response. Management's proposed actions are responsive. Because NASA cancelled NPD 8010.2E, the recommendation will be closed upon verification that the requirement to conduct a benefit-cost analysis has been added to appropriate NASA policy.

Recommendation 2. The Chief Engineer should revise NPD 8010.2E to

- a. adequately define the "Adds Unacceptable Risk" exception criteria and
- b. require individual projects added to complex or long-term programs to periodically re-evaluate their ability to implement the metric system.

Management's Response. The Chief Engineer stated that on March 16, 2010, NASA cancelled NPD 8010.2E when it was superseded by language added to NPD 7120.4D, "NASA Engineering and Program/Project Management Policy." The Chief Engineer said because NPD 7120.4D does not include the language "adds unacceptable risk." he considers the recommendation to define the exception criteria no longer valid. Management concurred with the second part of the recommendation to periodically re-evaluate new projects added to ongoing programs to assess their ability to implement the

metric system. The estimated completion date for implementing this latter recommendation is the onset of the next Agency project.

Evaluation of Management’s Response. Management’s proposed actions are not responsive to the intent of the recommendation. We believe that the language concerning metric system implementation in NPD 7120.4D does not adequately meet the intent of Federal Law and Executive Orders. NPD 7120.4D states:

1. POLICY (i). Metric System of Measurement. It is NASA policy for all new programs and projects subject to NPR 7120.5 [“NASA Space Flight Program and Project Management Requirements”] to use the International System of Units (commonly known as the Systeme Internationale (SI) or metric system of measurement) for design, development, and operations; in preference to customary U.S. measurement units, for all internal activities, related NASA procurements, grants, and business activities. Exceptions to this policy may be granted by the NASA Chief Engineer based on program/project recommendations by the responsible Mission Directorate Associate Administrator.

5. RESPONSIBILITY (j). Managers and engineers responsible for the realization of a program, project, service, or activity shall:

...(9) If subject to NPR 7120.5, identify method for implementing the SI system of measurement prior to completion of the Systems Requirements Review or equivalent milestone during new Program/Project Formulation. Document approved deviations and waivers.

(10) Document determinations on where and how the SI system of measurement is to be used in the Program or Project Plan, including use of SI units in related mission support and institutional projects.

The intent of the first part of our recommendation was to have NASA more clearly define the parameters for an exception to Federal Law and Executive Orders to implement the metric system. NPD 7120.4D does not identify criteria for granting exceptions to using the metric system. The intent of part b of the recommendation was to ensure that blanket exceptions were not granted to large programs when smaller projects within that Program could logically implement the metric system. Although NPD 7120.4D states that exceptions should be documented, it does not state where, how, or who keeps the record, or for how long the exception lasts. NASA officials stated in both their response to the NIST Deputy Director (Appendix D) and in their response to the draft IG report (Appendix E) that the metric system will be implemented on vehicle projects that have lunar content since these are the projects in which international participation will most probably be involved. Moreover, NPD 8010.2E stated that “[s]pecial emphasis shall be placed on maximum use of SI [metric] units in cooperative programs with international partners.” However, this language does not appear in the recently approved version of NPD 7120.4D. Thus, with NPD 8010.2E cancelled, the requirement to apply special

emphasis to implement the metric system in programs with international participation no longer appears in any NASA policy documents.

Consequently, we recommend that the Chief Engineer create an NPR based on the relevant language in NPD 8010.2E and the recommendations contained in this report. While NPDs are policy statements that describe what is required by NASA management to achieve its vision, mission, and external mandates and who is responsible for carrying out those requirements, NPRs provide Agency requirements to implement NASA policy as delineated in an associated NPD. We request that the Chief Engineer provide additional comments on Recommendation 2 in response to this final report by April 16, 2010.

Recommendation 3. The Chief Engineer should engage DoD and other Federal agencies to develop a strategy for the long-term implementation of the metric system within the aerospace industry.

Management's Response. NASA's Chief Engineer concurred with the recommendation. The Chief Engineer stated that he will engage DoD, Federal Aviation Administration, Aerospace Safety Advisory Panel, and other relevant Federal agencies and interested commercial aerospace parties in an effort to develop a long-term metric system implementation strategy within the aerospace industry. The Chief Engineer said NASA plans to staff an Industrial Base Liaison by October 2010 to lead this task.

Evaluation of Management's Response. Management's proposed actions are responsive and the recommendation will be closed following verification of the corrective action.

Scope and Methodology

We performed this review from September 2009 through February 2010 in accordance with generally accepted government auditing standards. We limited our review of internal controls to NASA's metric system policy and the granting of exceptions. Those standards require that we plan and perform our work to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on the objectives. We believe that the evidence obtained during this review provides a reasonable basis for our findings and conclusions based on our objectives. We performed our review at Johnson Space Center and NASA Headquarters.

To assess the reversal of the Constellation Program's decision to use the metric system as the standard unit of measure and its long-term impact on the Agency, we reviewed the following Federal laws, and NASA regulations, policies, procedures, directives, and presentations:

- "Metric Conversion Act of 1975;" Public Law 94-168, enacted December 23, 1975; Title 15 of the U.S. Code -- 15 USC 205a;
- "Metric Usage in Federal Government Programs," Executive Order 12770, 56 Federal Register 35801, July 25, 1991;
- Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418);
- OMB Circular No. A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," October 29, 1992;
- NPD 8010.2E, "Use of the SI (Metric) System of Measurement in NASA Programs," March 4, 2007;
- NPR 7120.5D, " NASA Space Flight Program and Project Management Requirements," March 26, 2007;
- Constellation Program Management Directive No. 030, "Use of SI as the Primary System of Measure for the Constellation Program, Projects, Systems and Missions," December 17, 2007;
- Constellation Program Draft Management Directive, "Use of a Hybrid System of Units, and English as the Primary System of Measure for the Constellation Program, Projects, Systems and Missions," no date;

- Constellation Program Control Board Directive No. 000390, “Direct Implementation for Use of a Hybrid System of Units and U.S. Customary (in-pound) System as the Primary System of Measure for the Constellation Program, Projects, System and Missions,” August 6, 2009;
- “Use of SI Units for Future NASA Programs,” Office of Program Analysis and Evaluation, March 20, 2006;
- “Constellation Program Units Directive Workshop,” August 26-27, 2008; and
- “Constellation Acceleration Study Report,” December 18, 2008.

We interviewed personnel from the Office of Chief Engineer, Program Analysis and Evaluation Office, Exploration Systems Mission Directorate, Constellation Program, Commercial Crew and Cargo Office, and ISS Program. We also interviewed personnel from NIST.

We did not use computer-processed data to perform this review.

Prior Coverage

NASA OIG and the Government Accountability Office (GAO) have issued two reports of particular relevance to the subject of this memorandum. Unrestricted reports can be accessed over the Internet at http://www.hq.nasa.gov/office/oig/hq/old/inspections_assessments/index.html (NASA) and <http://www.gao.gov> (GAO).

National Aeronautics and Space Administration

“Assessment of NASA’s Use of the Metric System” (G-00-021, February 20, 2001)

Government Accountability Office

“Constellation Program Cost and Schedule Will Remain Uncertain Until a Sound Business Case is Established” (GAO-09-844, August 26, 2009)

NPD 8010.2E "USE OF THE SI (METRIC) SYSTEM OF MEASUREMENT IN NASA PROGRAMS"

NPD 8010.2E -- main

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NASA Policy Directive

COMPLIANCE IS MANDATORY

NPD 8010.2E

Effective Date: March 04, 2007

Expiration Date: March 04,
2012

Printable Format (PDF)

 (NASA Only)

Subject: Use of the SI (Metric) System of Measurement in NASA Programs

Responsible Office: Office of the Chief Engineer

1. POLICY

Federal requirements for use of the SI system of measurement are established by the authorities referenced in Sections 3.a. and 3.b below. NASA policy for systems of measurement to be used on NASA programs/projects is as follows:

- a. The International System of Units (commonly known as the SI - Systeme Internationale - or metric system of measurement) is the preferred system of weights and measurement for NASA programs and projects. Usage of SI for NASA programs and projects is defined by the references of Sections 4.a and 4b. below.
- b. All new programs and projects covered by NPR 7120.5 shall use the SI system of measurement for design, development and operations, in preference to customary U.S. measurement units, for all internal activities, related NASA procurements, grants, and business activities. Exceptions to this requirement may be granted by the NASA Chief Engineer based on program/project recommendations by the responsible Mission Directorate Associate Administrator where use of SI units is demonstrated to be impractical, adds unacceptable risk, or is likely to cause significant inefficiencies or loss of markets to U.S. firms. Special emphasis shall be placed on maximum use of SI units in cooperative programs with international partners.
- c. For the purposes of this policy, use of SI units may be considered impractical where it is demonstrated to result in substantial increases in cost or unacceptable delays in schedule to obtain SI components.
- d. Each NASA program and project subject to NPR 7120.5 shall identify proposed use, exceptions, limitations, and support requirements for implementing the SI system of measurement prior to completion of the Systems Requirements Review or equivalent milestone during new Program/Project Formulation, as per Section 4.c. below.

NPD 8010.2E -- main

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Determinations on where and how the SI system of measurement is to be used shall be documented in the Program or Project Plan, including use of SI units in related mission support and institutional projects.

e. Where full implementation of the SI system of measurement is not practical, as determined per Section 1.b above, hybrid configurations (i.e., a controlled mix of SI/non-SI system elements) may be used to support maximum practical use of SI units for design, development and operations. Where hybrid configurations are used, specific requirements shall be established to control interfaces between elements using different measurement systems.

f. Programs and projects shall minimize risk of errors by consistent labeling of measurement units throughout all documentation.

g. Soft SI units (numerical representation of non-SI measurements by SI units solely for the purpose of representing data in SI units) and dual units (data represented in both SI units and customary U.S. units of measure) shall not be used except where there is a specific need for ensuring compatibility, e.g., at hybrid interfaces or for clarity, such as in public affairs information. Dual units on drawings, when required, shall be in accordance with the requirements of the reference in Section 4.d below.

h. Existing programs and projects may permit continued use of non-SI units for projects currently designed in and based on non-SI units.

i. NASA shall encourage and accommodate increasing the use of the SI system of measurement as SI support capabilities expand, shall acquire capabilities to support that goal wherever practical, and shall cooperate with the private and public sectors to overcome barriers to use and increase understanding of the SI system of measurement.

j. NASA shall establish and maintain an inventory of internal resources to support increased SI system of measurement use by programs and projects.

2. APPLICABILITY

This NPD is applicable to NASA Headquarters and NASA Centers, including Component Facilities, and to the Jet Propulsion Laboratory to the extent specified in the contract. The requirements of this NPD shall be included in NASA contracts, grants, and business activities, where applicable.

3. AUTHORITY

a. 15 U.S.C. §205b, Section 3 of the Metric Conversion Act of 1975, Public Law 94-168, as amended by the Omnibus Trade and Competitiveness Act of 1988, Public Law 100-418.

b. EO 12770, Metric Use in Federal Government Programs, dated July 25, 1991.

4. APPLICABLE DOCUMENTS

a. NPR 7120.5, NASA Program and Project Management Processes and Requirements.

b. ANSI/ASTM/IEEE SI-10, American National Standard for Use of the International

System of Units (SI), the Modern Metric System.

c. Federal Standards 376B, Preferred Metric Units for General Use by the Federal Government.

d. ANSI/ASME Y14.5M, American Society of Mechanical Engineers Standard for Dimensioning and Tolerancing.

5. RESPONSIBILITY

a. The Chief Engineer is responsible for:

(1) Serving as the Metric Executive for NASA to meet the requirement of Sections 3.a and 3.b.

(2) Coordinating and overseeing implementation of this policy, including acting as the final decision authority for approval of exceptions set forth in Section 1.b. above.

(3) Consulting with the responsible Mission Directorate Associate Administrator to evaluate recommendations for use/exceptions to the SI system of measurement on programs/projects.

(4) Evaluating measurement system decisions and implementation for consistency with decisions and with this policy during program/project reviews conducted in accordance with NPR 7120.5.

(5) Maintaining an inventory of SI support capabilities within NASA.

b. NASA Mission Directorate Associate Administrators are responsible for:

(1) Consulting with the Chief Engineer on opportunities for increasing use of the SI system of measurement.

(2) Recommending to the Chief Engineer planned use of and demonstrated need for exceptions to the SI system of measurement programs and projects in accordance with Section 1.b. above.

(3) Ensuring that measurement system decisions are properly implemented and do not result in undue risk.

c. Program/Project Managers are responsible for:

(1) Conducting analyses and trade-off studies to evaluate use of the SI system of measurement for programs/projects and related NASA procurements, grants, mission support, institutional requirements, and business activities during the formulation process specified in NPR 7120.5.

(2) Recommending to the responsible Mission Directorate Associate Administrators during the Systems Requirements Review or equivalent activity where use of SI units for new programs/projects can be accomplished and demonstrating where it is impractical, adds additional unacceptable risk, or is likely to cause significant inefficiencies or loss of markets to U.S. firms.

(3) Documenting requirements and approved exceptions to use of SI units in program and project plans.

(4) Ensuring appropriate interface controls are established for use of hybrid configurations in accordance with Section 1.e above.

(5) Reporting progress and issues resulting from use of the SI system of measurement for programs/projects during design reviews and providing summary information to the Mission Directorate Associate Administrator.

(6) Reporting significant changes in proposed implementation of the SI system of measurement for programs/projects to the responsible Mission Directorate Associate Administrator and to the Chief Engineer for review.

d. Directors of NASA Centers are responsible for:

(1) Ensuring timely analysis, evaluation, documentation, and review of opportunities and requirements for use of the SI system of measurement on those programs/projects for which they have responsibility.

(2) Planning for and supporting use of the SI system of measurement except where the NASA Chief Engineer has approved an exception to use of the SI system of measurement as impractical, adding unacceptable risk, or is likely to cause significant inefficiencies or loss of markets to U.S. firms.

(3) Identifying needs, establishing, and maintaining institutional capabilities for providing effective and consistent support of the SI system of measurement for design, analysis, fabrication, test, and operations on current and future NASA programs/projects.

6. DELEGATION OF AUTHORITY

None.

7. MEASUREMENTS/VERIFICATION

None.

8. CANCELLATION

NPD 8010.2D, Use of the Metric System of Measurement in NASA Programs, dated May 14, 2004.

/s/ Michael D. Griffin
Administrator

ATTACHMENT A: (TEXT)

None.

(URL for Graphic)

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None.

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NIST LETTER TO NASA



UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
 Gaithersburg, Maryland 20899-
 OFFICE OF THE DIRECTOR

OCT 16 2009

Mr. Charles F. Bolden, Jr.
 NASA Administrator
 300 E Street, SW
 Washington, DC 20546

Dear Mr. Bolden:

I am writing to support and emphasize the importance of the National Aeronautics and Space Administration's (NASA) decision to implement an agency metric policy for Constellation Program operations when the United States returns to the moon. The National Institute of Standards and Technology (NIST), an agency of the United States Department of Commerce, directs and coordinates federal agency efforts to implement government metric usage in accordance with 15 U.S.C. 205b and Presidential Executive Order 12770 to achieve the national goal of establishing the International System of Units (SI, metric system) as the preferred system of weights and measures for U. S. trade and commerce.

NASA metric policy recognizes the importance and fundamental benefit of SI use is simplicity and interoperability. Use of a single measurement system can result in the reduction of costly measurement conversion errors and eliminate space system conversion interfaces. Future NASA collaborations with international space partners that solely use SI measurements will significantly save government resources by maximizing cost effectiveness as lunar projects implement a single coherent system of measurement. The long-term impact of constructing an inch-pound infrastructure on the lunar surface will likely create a legacy of high space exploration costs for future generations.

The successful voluntary U.S. transition to the metric system is a critical factor in the competitive success of companies and the country. NASA is a flagship federal agency to which other agencies and industry look for leadership and inspiration. NASA's decision to use SI measurements will impact the U.S. economy in multiple levels, including the creation of new SI based technology spin-offs for the industrial and consumer marketplace and immediately bring the SI into greater use among agency technical staff, contractors, and other federal agencies. NIST stands ready to assist NASA in this effort, and I encourage you to contact me with any questions.

Sincerely,

Patrick Gallagher
 Deputy Director

✓ cc: Lawrence Neu

NIST

NASA'S RESPONSE TO NIST

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001



November 10, 2009

Reply to Attn of: Exploration Systems Mission Directorate

Dr. Patrick Gallagher
Deputy Director
Office of the Director
U.S. Department of Commerce
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

Dear Dr. Gallagher:

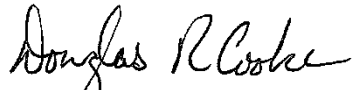
Thank you for your October 16, 2009, letter concerning NASA's decision to implement an Agency International System of Units (SI) policy for the Constellation Program Operations when the United States returns to the moon. NASA remains committed to implementing the SI system of measurements for the reasons you cited in your letter. Unfortunately, due to budgetary constraints to convert much of the legacy NASA hardware and infrastructure, NASA will not be able to completely convert to SI units. The Constellation program in the near term will be using U.S. customary consisting of both U.S. (in-pound) with limited use of SI. The goal, however, will be to design and operate the Lunar Systems in SI.

The Constellation program utilizes elements of existing flight heritage that were originally designed and built using the U.S. customary system of measures. These elements include Ares 1st stage, Ares 2nd stage engine, and contractor and NASA test facilities. The program conducted an extensive and detailed analysis to implement a primary SI unit based system for design, analysis, test, and operations while allowing U.S. customary (in-pound) units for most of the hardware. This effort looked at various implementation strategies to the point of having workable implementation plans in all the projects. The cost estimates to achieve these plans by converting these legacy systems to SI significantly exceeded the resources that could be made available in the early critical years of the program. The program has therefore revised its previous management directive to utilize primarily U.S. customary (in-pound) units with limited usage of SI.

New elements (e.g. Lunar Lander and Lunar Surface Systems), not relying on heritage systems, are still in the early requirements and operations concept development stage. These projects will have the most involvement with the International community. NASA expects to utilize a complete SI based system for beyond Low-Earth-Orbit in the coming years.

To summarize, we are pursuing the goal to utilize the SI system within our technical and budget constraints, always being mindful of balancing the risks for converting to the SI system of measures versus maintaining and operating in the U.S. customary system. Thank you again for your support of our decision to implement an SI policy for the Constellation program.

Sincerely,



Douglas R. Cooke
Associate Administrator for
Exploration Systems Mission Directorate

MANAGEMENT COMMENTS

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001



March 19, 2010

Reply to Attn of: Office of the Chief Engineer

TO: Assistant Inspector General for Auditing
FROM: Chief Engineer
SUBJECT: Draft Report on the Review of the Constellation Program's Request to Discontinue Using the Metric System of Measurements (Assignment No. S-09-010-00)

The following is in response to the three recommendations:

The Chief Engineer should

1. *Prior to granting a program or project an exception to NPD 8010.2E, consider the results of an OMB Circular A-94 type analysis to determine the benefit-cost impact to the program, project, and Agency of not implementing the metric system;*
2. *Revise NPD 8010.2E to*
 - a. *adequately define the "Adds Unacceptable Risk" exception criteria; and*
 - b. *require individual projects added to complex or long-term programs to periodically re-evaluate their ability to implement the metric system;*
3. *Engage DoD and other Federal agencies to develop a strategy for the long-term implementation of the metric system within the aerospace industry.*

Office of the Chief Engineer (OCE) Response to Audit Report

To provide context to the OCE recommendations, it should be noted that two NASA policy changes have occurred which directly apply to the OIG Audit report and all three recommendations. Specifically:

- 1) The FY2011 President's Budget Request, if enacted, will cancel the Constellation Program and all its projects, effective October 1, 2010.
- 2) NPD 8010.2E has been cancelled, as of March 16, 2010. It has been superseded by NPD 7120.4D which was signed on 16 March 16, 2010. SI units is specifically cited in Section 1 Paragraph i.

Overall Report Comments

Given the potential for cancellation of the Constellation program if the FY2011 President's Budget Request is fully enacted, the Chief Engineer has put the Constellation Program's waiver approval for using U.S. customary units for the program's initial Phase 1 projects (those sending crew and cargo to the ISS) on hold.

To add clarity to the audit report, there are several references on pages 9, 10, 11 and 12 regarding long-term risks of engaging international partners if Constellation does not adopt an SI unit strategy. The Chief Engineer believes these issues are adequately mitigated and should be removed from the final report because it is the intent of the Constellation Program and the Exploration Systems Mission Directorate to utilize SI units on vehicle projects that have lunar content. These will be the Constellation vehicles that would significantly interact and interface with any potential future international partner's vehicles. This intent is cited in the November 10, 2009, Doug Cooke memorandum to Patrick Gallagher (page 20), "NASA expects to utilize a complete SI based system for beyond Low-Earth-Orbit in the coming years".

Page 12 of the audit document states: "One option would be for NASA to distinguish between projects within programs, authorize an exception to the metric system if warranted, but press forward with metric system conversion on other aspects of the program to move the Agency closer to realizing the goals of NPD 8010.2E, the Omnibus Act, and EO 12770". The Constellation Program waiver was intended for the Phase-1 (Low Earth Orbit) projects. Not the beyond Low Earth Orbit projects. So the program and mission directorate's intent of waiving only the Low Earth Orbit projects at this time fulfills this option.

Recommendation 1 Prior to granting a program or project an exception to NPD 8010.2E, consider the results of an OMB Circular A-94 type analysis to determine the benefit-cost impact to the program, project, and Agency of not implementing the metric system;

Chief Engineer Response

The Chief Engineer concurs.

In general and where possible to do so in an appropriately rigorous manner, the evaluation should be done and will be done. Language clarifying the requirement will be added to NPD updates. To be clear, however, while it is generally possible to determine the costs of converting to use of SI units with reasonable accuracy, the benefits and risks are most commonly not quantifiable with sufficient certainty to be useful; thus OMB Circular A-94 type analysis is problematic at best and the NPD language will allow for a non-quantitative discussion of cost benefit. For example, while there is risk of using mixed units, the mixed-units mitigation strategies, put in place following the Mars Climate Orbiter mishap, have been completely successful in mitigating these risks over many dozens of missions with minimal identifiable costs. Similarly, a commonly cited benefit to use universal use of SI units is to lower costs and risks when doing missions with International partners, yet almost every NASA science mission includes international partnerships in a mixed units system and attempts to define the "excess cost" have shown very small numbers. Boeing Commercial

Aircraft, a profit making entity, has chosen to produce their new 787 aircraft using US customary units even though much of each aircraft is sourced outside the US and a large fraction of the sales market is non-US. These facts lend credence to the argument that NASA is unlikely to find a positive argument on a cost-benefit basis as long as the US Aerospace industry remains dominantly a non-SI units entity.

Expected Completion Date

OCE will modify NPR 7120.5E to incorporate benefit-cost language by December 31, 2010.

Recommendation 2 Revise NPD 8010.2E to: a. adequately define the “Adds Unacceptable Risk” exception criteria; and b. require individual projects added to complex or long-term programs to periodically re-evaluate their ability to implement the metric system;

Chief Engineer Response

Part a: NPD 8010.2E has been cancelled, as of March 16, 2010. It has been superseded by NPD 7120.4D which was signed on March 16, 2010. The updated SI unit language in Section 1 Paragraph i of this newly signed document does not include the language “Adds Unacceptable Risk.”

Part b: The Chief Engineer Concur

As programs evolve and additional projects are added, the Chief Engineer and their staff will ensure that each new project evaluates its ability to implement the metric system, in line with NPD 7120.4D.

Expected Completion Date

At onset of next Agency project.

Recommendation 3 Engage DoD and other Federal agencies to develop a strategy for the long-term implementation of the metric system within the aerospace industry.

The Chief Engineer Concur

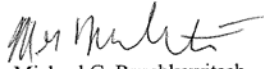
The lack of commitment to the metric system by the U.S. aerospace industrial base, particularly the DoD community, remains a major impediment to NASA’s use of SI at this time. The Chief Engineer will initiate an engagement activity with the DoD, FAA, the Aerospace Safety Advisory Panel, other relevant Federal Agencies and interested commercial aerospace parties in an effort to develop a long-term metric system implementation strategy within the aerospace industry.

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Expected Completion Date

NASA plans to staff an Industrial Base Liaison for the Agency by October 2010, to lead this task.

If you have any questions about this response, please feel free to contact me.



Michael G. Ryschkewitsch

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