Summary of the New AIAA Moving Mechanical Assemblies Standard

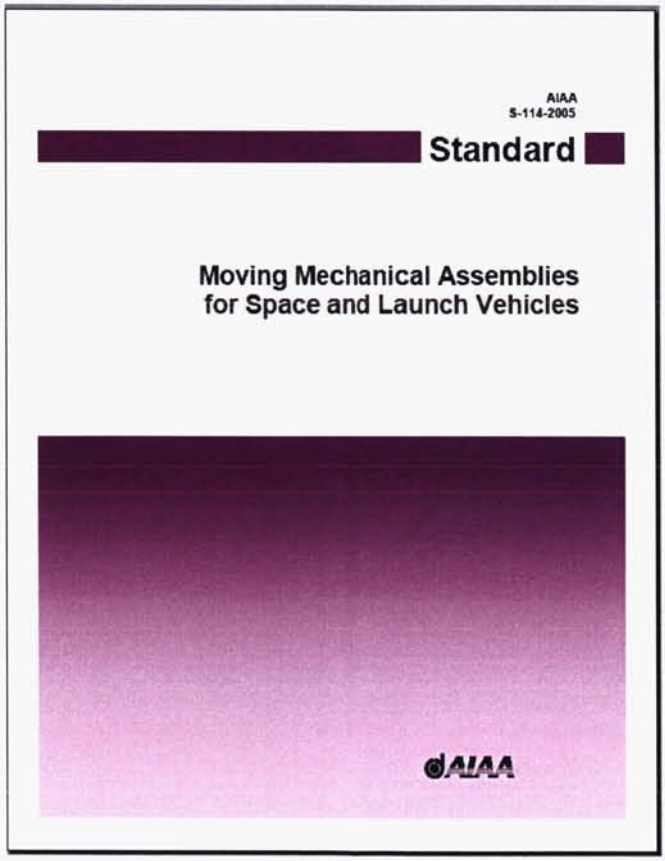
Brian W. Gore*

Abstract

A new American Institute of Aeronautics and Astronautics (AIAA) standard entitled "Moving Mechanical Assemblies for Space and Launch Vehicles," AIAA-S-114-2005, has been created. It is based on Military Specification MIL-A-83577B, which was cancelled by the Department of Defense in the mid-1990's. The new standard supersedes a Technical Operating Report (TOR) (prepared by Brian W. Gore of The Aerospace Corporation with support from the Air Force Space and Missile Center and the National Reconnaissance Office, which was a "cleaned-up," same-format version of MIL-A-83577B) and has already been used as a compliance document in several recent acquisitions and Requests For Proposals. This paper outlines some of the more significant changes and additions made in the new AIAA MMA Standard since the previous TOR and MMA specification were released.

Introduction

The U.S. Air Force (USAF) Space and Missile Center (SMC) and the National Reconnaissance Office (NRO) have recently established policies supporting and requiring government, industry, and professional society specifications and standards for new acquisitions.



* The Aerospace Corporation, El Segundo, CA

The new AIAA standard, AIAA-S-114-2005, is one of the first products of the recent Specifications and Standards Revitalization Program undertaken by the USAF's SMC. They asked the AIAA to engage appropriate subject matter experts to develop five consensus standards to be used as compliance documents for SMC (and potentially NRO) acquisition activities. These five standards were:

1. AIAA-S-110-2005, "Space Systems – Structures, Structural Components, and Structural Assemblies
2. AIAA-S-111-2005, "Qualification and Quality Requirements for Space-Qualified Solar Cells"
3. AIAA-S-112-2005, "Qualification and Quality Requirements for Space-Qualified Solar Panels"
4. AIAA-S-113-2005, "Space Systems – Criteria for Explosive Systems and Devices Used on Launch and Space Vehicles"
5. AIAA-S-114-2005, "Moving Mechanical Assemblies for Space and Launch Vehicles"

Three other standards are currently beginning the same development process, as of the time of publication of this paper; these involve

1. Space System Electrical Power System Design,
2. Space System Electromagnetic Compatibility Requirements, and
3. Space System Mass Properties Control

A memorandum from USAF Lt. Gen. Brian Arnold to SMC dated 14 January 2003 and titled "Policy Letter on Specification and Standards Usage at SMC" outlines the framework for using specifications and standards as a key part of their acquisition, contracting, and program management. Some key excerpts from that memo include:

> "The unintentional result (of reducing the use of specifications and standards as compliance documents through "Acquisition Reform") was that technical baselines and processes were compromised."
>
> "There is no intent to return to the pre-acquisition reform approach of using an excessive number of specs and standards. A list of high priority critical specs and standards is being...established for appropriate use."
>
> "The baseline list of specs and standards will be used in a less prescriptive manner than in the past."

With these ideas in mind, the Moving Mechanical Assembly Standard was created with the utmost thought toward incorporating those requirements that are common to most MMAs for space and launch vehicles. The requirements stated are a composite of those that have been found to be cost-effective for high reliability space and launch vehicle applications.

The standard is the result of contributions received from many individuals, most notably those on the AIAA MMA Committee on Standards (CoS). Although the committee started out about twice as large, at the time of approval the actively participating members of the AIAA MMA CoS were:

Stephen Brock, Liaison	AIAA
Ken Emerick, Co-Chair	Space Systems/Loral
Brian Gore, Co-Chair	The Aerospace Corporation
Michael Pollard, Co-Chair	Lockheed Martin Corporation (Denver)
Dave Putnam	Lockheed Martin Corporation (Sunnyvale)
Dave Richman	The Boeing Company
Paul Reynolds	Northrop Grumman Corporation
Bert Timmerman	Hi-Shear Technology Corporation

The above consensus body approved the document and the AIAA Standards Executive Council accepted the standard for publication in June 2005. It can be downloaded for purchase ($39.95, or $31.95 for AIAA members) from the AIAA website at

http://www.aiaa.org/content.cfm?pageid=363&id=1366&Type=StoreProduct&LayerID=51

Description

The new AIAA MMA standard specifies general requirements for the design, manufacture, quality control, testing, and storage of MMAs to be used on space and launch vehicles. It is applicable to the mechanical or electromechanical devices that control the movement of a mechanical part of a space or launch vehicle relative to another part. The requirements apply to the overall MMA as well as to the mechanical components and instrumentation that are an integral part of these mechanical assemblies.

Not all requirements in the standard are of equal importance or weight. They have been divided into three categories of importance, ranging from requirements that are imposed on all applications to examples of acceptable designs, items, and practices. The relative weighting of requirements is an important consideration when tailoring the standard to specific applications and in making trade studies of alternatives. Three weighting factors are incorporated in the standard:

1. "Shall"
2. "Shall, where practical"
3. "Preferred/Should/May"

Note that the old MMA specification designated four separate weighting factors, with this standard essentially combining the lowest two in the hierarchy. The use of the weighting factors in the standard is intended to assist in the tailoring of requirements to specific applications and to assist contractors in the design process. Detailed definitions and scope of these weighting levels are described in the standard.

Unlike the uniform, one-format-fits-all of many military specifications, this particular document reflects the general consensus of the industry in what is required for today's MMAs from a design, build, inspection, and test perspective. The document was designed to be more "user-friendly" than the old MMA specification as it was consciously re-organized to flow simultaneously from general to specific, as well as along the design and development life of MMAs. To provide an illustration of this new organization, the chapters and major subheadings are listed in Table 1.

Table 1. Organization of MMA Standard

1 Scope

2 Tailoring

3 Applicable Documents

4 Vocabulary

5 General Design Requirements
- 5.1 Performance Requirements
- 5.2 Environmental Design Requirements
- 5.3 Physical Requirements
- 5.4 Electrical and Electronic Requirements
- 5.5 Structural Requirements
- 5.6 Reliability

6 Component Design Requirements
- 6.1 Fasteners
- 6.2 Retention and Release Devices
- 6.3 Pivots and Hinges
- 6.4 Cable Systems
- 6.5 Springs
- 6.6 Dampers
- 6.7 Stops
- 6.8 End-of-Travel Latches
- 6.9 Bearings
- 6.10 Electric Motors
- 6.11 Power and Signal Transfer Components
- 6.12 Switches
- 6.13 Gears
- 6.14 Pressurized Components

7 Parts, Materials, and Processes Requirements
- 7.1 General Parts, Materials, and Processes
- 7.2 Materials
- 7.3 Lubricants
- 7.4 Hard Coatings
- 7.5 Contamination

8 Testing and Inspection Requirements
- 8.1 Parts, Materials, and Process Controls
- 8.2 Test Fixtures
- 8.3 Test Instrumentation
- 8.4 Test Plans and Procedures
- 8.5 Development Tests
- 8.6 Qualification and Proto-qualification Tests
- 8.7 Component and Subsystem Level Acceptance Tests
- 8.8 Vehicle Level Acceptance Tests
- 8.9 Pre-launch Validation Testing and Inspection
- 8.10 Modifications, Rework, and Retesting

9 Bibliography

Annex A (Informative) Static Torque or Force Margins at Different Coordinate Points

Highlighted Changes

Overall flow – easier to use/find information

As stated above, it was an early and deliberate action by the CoS to reformat the AIAA MMA Standard to be easier to use and find information than the previous military specification document. Before any work was done on the technical content, the co-chairs spent a notable – and ultimately worthwhile – amount of time determining the current organization, deleting obvious subject items and inserting placeholders that were later filled in regarding new areas of interest and importance.

The co-chairs then rearranged the remaining text into the corresponding sections of the new format, and the committee went to work to generate and compile a list of discussion comments. It was this list that formed the focus of the CoS efforts. Teleconferences on a bi-weekly, then weekly, then almost daily basis toward the end were the main forum of CoS communication, augmented by a members-only, AIAA-hosted website which stored and organized pertinent and necessary documentation.

Approximately 400 comments generated, submitted, and dispositioned.

After the CoS reviewed the base document and compiled the aforementioned list, they used the teleconferences and two, multiple-day, face-to-face "summit" meetings to work through the list. Several of the committee members passed the working document [initially issued as The Aerospace Corporation Technical Operating Report TOR-2004(8583)-1] to their colleagues or certain specialists to solicit additional insightful comments. The CoS spent the majority of these meetings discussing the merits of the particular comments submitted, grouped as either general, editorial, or technical; a breakdown of the comments in the list is shown in Figure 1.

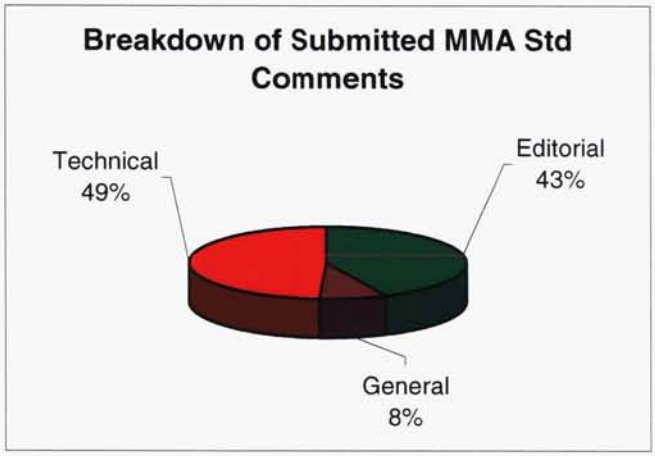


Figure 1. Breakdown of Submitted MMA Standard Comments

Moreover, after the final draft of the standard was prepared, AIAA initiated a 30-day public review period, which yielded still more comments, for a grand total of approximately 400 submissions by members of Aerospace, many contractors, NASA, etc. Figure 2 illustrates the approximate number of comments by submitting individuals. Some of the people listed were points of contact from their entire organization.

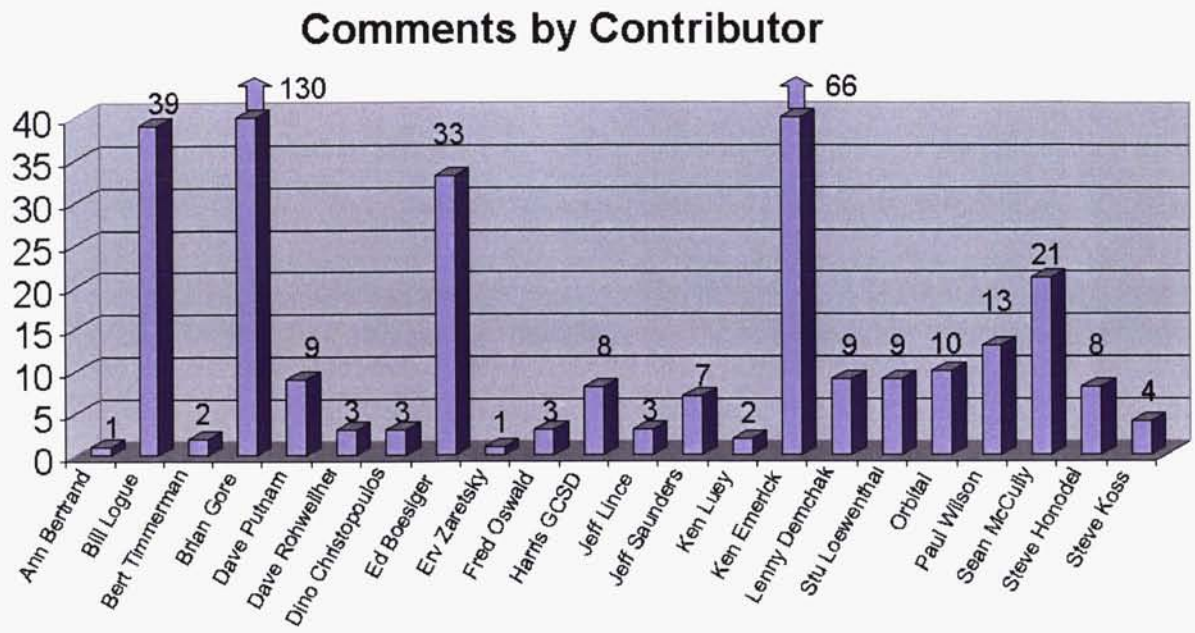


Figure 2. Number of Comments by Contributor

Conciseness/deletion of peripheral areas

There were many areas of the old MMA specification that were deemed by consensus to be out of scope for a modern moving mechanical assembly standard. Since we were no longer bound by the standard template, there was freedom to make this document more relevant overall. As such, several sections were deleted altogether in recognition that there were virtually always other documents or specifications, either governmental or internal to contractors that existed to govern those areas. Some of these subject areas included identification and marking, certain details on processes and controls, structural requirements, specific environmental conditions, etc. However, many such sections were minimized and maintained as a consideration guide for younger engineers, or simply as a reference pointer to the appropriate document, such as the new AIAA Structures Standard, MIL-STD-1540E (the environmental testing standard), etc. This scope is one of the main utility features for which the CoS was striving. One metric of this conciseness may be indicated by the relative word counts of the documents, as illustrated in Table 2.

Table 2. Word Count of Evolving MMA Documents

Document	Approx. Word Count
MIL-A-83577B	23,000
TOR-2004(8583)-1	24,000
AIAA-S-114-2005	19,000

Areas rechecked for modern validity

There were several peripheral areas relating to MMAs that were also verified for modern validity, such as contamination, lubrication, electrostatic discharge, etc. For these particular areas, Aerospace and contractor experts were consulted to obtain an insight as to what governing documents existed for their respective disciplines. These were, in turn, referenced in the MMA standard where appropriate, leaving the details to those other documents, unlike the original MMA specification that contained many of the details.

Applicable documents

One evident change that appears early in the document is the far fewer number of Applicable Documents called out in the AIAA standard. The only documents in this section of the standard are the ones specifically mentioned in the body of the text. In a parallel effort, each one of the documents named in the original MMA specification was validated regarding its status (active, cancelled, superseded, etc.). Many of them, if not mentioned in the text, were moved to the new Bibliography section at the end, provided the CoS consensus agreed that they still contained useful information. One important note to point out is that, simply because the government decided to cancel a document during acquisition reform, it does not mean the contents of that specific document are automatically null and void. After all, the MMA specification falls into the "cancelled" category and the industry still recognized it as valid, just not eligible as a contractual compliance document.

Acceleration term removed from static torque margin

After significant debate, the CoS decided to remove the acceleration term from the equation to calculate static torque margin. Since the true meaning of this particular margin is to show how much force exists above and beyond all static resistances, the acceleration term was deemed irrelevant. A moving mechanical assembly must have sufficient motive force to begin motion, as evaluated with a free-body diagram. Forces required for a given acceleration are deemed performance requirements, and are thus captured in the dynamic force margin requirement.

New section on stepper motor margin in force/torque margin section

One of the areas without clear definition in previous forms of this document was the lack of attention given to force/torque margins with the use of stepper motors. A section was added which describes two ways to calculate stepper motor margin:

1. using motor available torque (pull-in torque) and comparison to friction loads, and
2. using a step stability analysis

Guidelines and conditions are also given regarding which of the two methods should be used in various applications.

Expansion of related electrical and electronic requirements

Although seemingly contradictive of the section above describing the deletion of peripheral areas, it was recognized that there are a significant number of electrical/electronic subjects that are particularly germane for design and testing of MMAs. A short paragraph exists for each of the following subjects:

- Cables and Wiring
- Connectors
- Cable Supports and Strain Relief
- Cable Loops
- Current Draw
- Grounding
- Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC)
- Electrostatic Discharge
- Flight Instrumentation

For some subjects, little more is given than a statement of consideration to ensure an area is not overlooked, but for others, pertinent reference documents are cited, and lessons learned are described. Again, the CoS was focused on MMA-related requirements, but felt at least this level of detail was justified.

Additional recognition of newer, common devices

Since the last release of the MMA specification in 1988, many new technologies have been developed and/or are more widely used, and thus warranted recognition. Non-explosive devices, including wax actuators, shape memory actuators, and split spool release devices are examples of these "next-generation" items. There is actually a reduction of information in this standard regarding pyrotechnic

devices, instead deferring to the new AIAA Standard for Ordnance, AIAA-S-113-2005. Clampbands and retention cables are also included in a new section. Although these hardware items were used prior to 1988, no considerations or requirements were provided in the former MMA specification.

Bearing stresses for new steel materials
The development and increased use of hybrid bearing material combinations such as Si_3N_4 (silicon nitride) balls and M62 (bearing steel) races required a certain level of attention. Allowable stress levels in prior documents only corresponded to 440C, but the new standard recognizes and provides requirements for 52100, M50, and M62 steels as well. Varying levels of allowable stresses for all of these materials are provided for quiet-running as well as non-precision, short duration applications.

Life testing for long life mechanisms
In one of the more significant changes, and one that easily generated the most discussion and debate by the CoS, life test requirements were revisited, motivated by the increasing duration of today's missions as compared to those typical of two and three decades ago. A distinction is now made between "low-cycle MMAs" (such as release devices, spring driven "one-shot" deployables, etc.) and "high-cycle MMAs" (such as solar array drives, momentum wheels, tracking gimbals, etc.), with different corresponding life requirements now given for each.

Run-in testing modifications
Another moderately noteworthy change in the testing requirements involves run-in testing. Run-in testing can be expressed in terms of cycles or a percentage of expected life. A slight reduction in the potential number of minimum run-in cycles has been incorporated. This was a result of some common sense being applied, particularly in the area of release devices, or other "one-shot" MMAs. It is generally accepted that the design life for these types of mechanisms is about 50 cycles, given the number of expected tests on the ground, plus on-orbit use(s), plus margin. The current minimum number of required cycles in the AIAA standard brings it closer to correspondence with the minimum percentage of life for these types of MMAs.

"Informative" annex on static torque/force margins at different coordinate points
This was the subject of a paper at the 37th Aerospace Mechanism Symposium by R. W. Postma of The Aerospace Corporation, and it was chosen to be included as an informative appendix, not necessarily subject to contractual compliance. This section describes the basic methodology overview for MMAs that have drive forces (or torques) and resisting forces (or torques) applied to mechanical elements that do not all move at the same velocity. A common example would be the ratio of the rotation of a jackscrew relative to its translation (e.g., rad/in).

Summary

U.S. Air Force (and effectively NRO) policy is swinging back to previous practices of requiring the use of specifications and standards. Subsequently, several subject matter documents have been reviewed, edited, and updated. Incorporation of those documents has started in the proposal phase of new acquisitions. One of the first new standards to be developed under these new guidelines is the AIAA Standard, "Moving Mechanical Assemblies for Space and Launch Vehicles," AIAA-S-114-2005. It is based on the former MMA military specification, but reorganized and technically scrutinized by a committee of industry experts to reflect the current state of the art in designing, fabricating, and testing space mechanisms. This standard will begin to be required as a compliance document for future Air Force space acquisitions, and can be purchased through the AIAA website.

References

- AIAA-S-114-2005, Moving Mechanical Assemblies Standard for Space and Launch Vehicles, American Institute of Aeronautics and Astronautics standard, July 2005.
- MIL-A-83577B, Military Specification – Assemblies, Moving Mechanical, For Space And Launch Vehicles, General Specification For, 1988.
- Gore, Brian W., Moving Mechanical Assemblies Standard for Space and Launch Vehicles (Draft 1), The Aerospace Corporation Technical Operating Report, TOR-2004(8583)-1, July 2004.

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