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Definition of Design Allowables for Aerospace Metallic Materials

AeroMat Presentation 2007

Jana Jackson

Design Allowables for Aerospace Industry

- Design for aerospace metallic structures must be approved by FAA certifier
- FAA accepts "A-Basis" and "B-Basis" values published in MIL-HDBK-5, and now MMPDS (Metallic Materials Properties Development and Standardization) as meeting the regulations of FAR 25.613.

OR

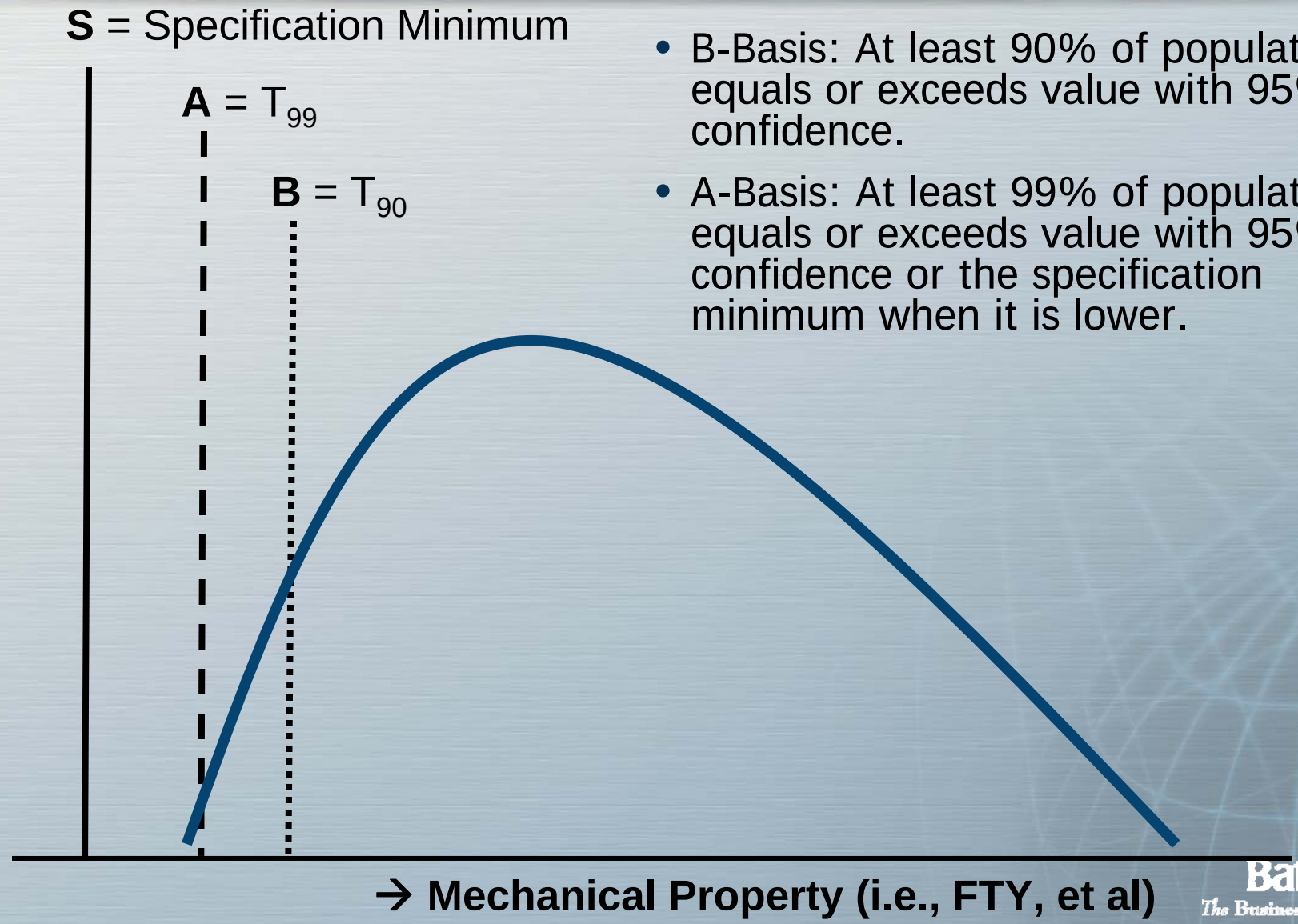
- The designer must have sufficient data to verify the design allowables used.

Design Allowables for Aerospace Industry

- The FAA views the MMPDS handbook as a vital tool for aircraft certification and continued airworthiness activities.
- Without the handbook, FAA review and approval of applicant submittals becomes more difficult, more costly and less consistent.
- There could be multiple data submission for the same material that are conflicting or other instances that would require time consuming analysis and adjudication by the FAA.

"The handbook remains the only publicly available U.S. source that the FAA generally accepts specifying material allowables, in compliance with Federal Aviation Regulations (FAR), for the material strength properties and design values associated with aircraft certification and continued airworthiness," explains FAA project manager Dr. John Bakuckas, Jr. "Moreover, it is the only publicly available source for fastener joint allowables that comply with the FARs."

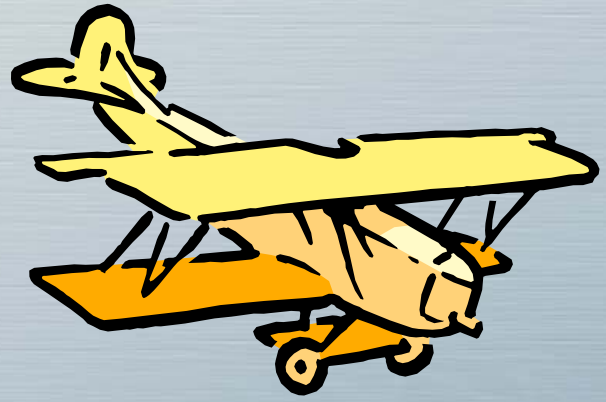
What is meant by A-Basis, B-Basis ?



- B-Basis: At least 90% of population equals or exceeds value with 95% confidence.
- A-Basis: At least 99% of population equals or exceeds value with 95% confidence or the specification minimum when it is lower.

What is the MMPDS Handbook?

- Metallic Materials Properties Development and Standardization
- Origination: ANC-5 in 1937 (prepared by Army-Navy-Commerce Committee on Aircraft Requirements)
- In 1946 the United States Air Force sanctioned the creation of a database to include physical and mechanical properties of aerospace materials.
- This database was created in 1958 and dubbed Military Handbook-5 (or MIL-HDBK-5 for short).
- The USAF issued a cancellation notice for MIL-HDBK-5J, effective May 5, 2004. In the notice, a pointer is made to the MMPDS-01 as the replacement document.
- The MMPDS is now the only government-recognized source in the U.S. of published design-allowable properties for metallic commercial and military aircraft structures and mechanically fastened joints.



MIL-HDBK-5J Handbook Cancellation Notice was issued May 2004 and superseded to MMPDS:

NOTICE OF CANCELLATION

INCH-POUND

MIL-HDBK-5J
NOTICE 2
24 March 2006

SUPERSEDING
NOTICE 1
5 May 2004

DEPARTMENT OF DEFENSE HANDBOOK

METALLIC MATERIALS AND ELEMENTS FOR AEROSPACE VEHICLE STRUCTURES

MIL-HDBK-5J, dated 31 January 2003, is hereby cancelled. Future acquisitions may refer to DOT/FAA/AR-MMPDS, "Metallic Materials Properties Development and Standardization (MMPDS)," as a suitable replacement for MIL-HDBK-5; however, users are cautioned to evaluate this document for their particular application before using it as a replacement document.

Copies of the current edition of MMPDS may be obtained in several forms, as described at www.mmpds.org or by e-mail at bcommpds@battelle.org.

Custodians:
Army – AV
Navy – AS
Air Force – 11

Preparing activity:
Air Force – 11
(Project 1560-2006-001)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at http://assist.daps.dla.mil.

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What is in MMPDS ?

- Mechanical property design allowables
- Physical property
- Stress-strain curves
- Effect of temperature curves
- Fatigue life curves
- Joints and Fasteners

- And More....

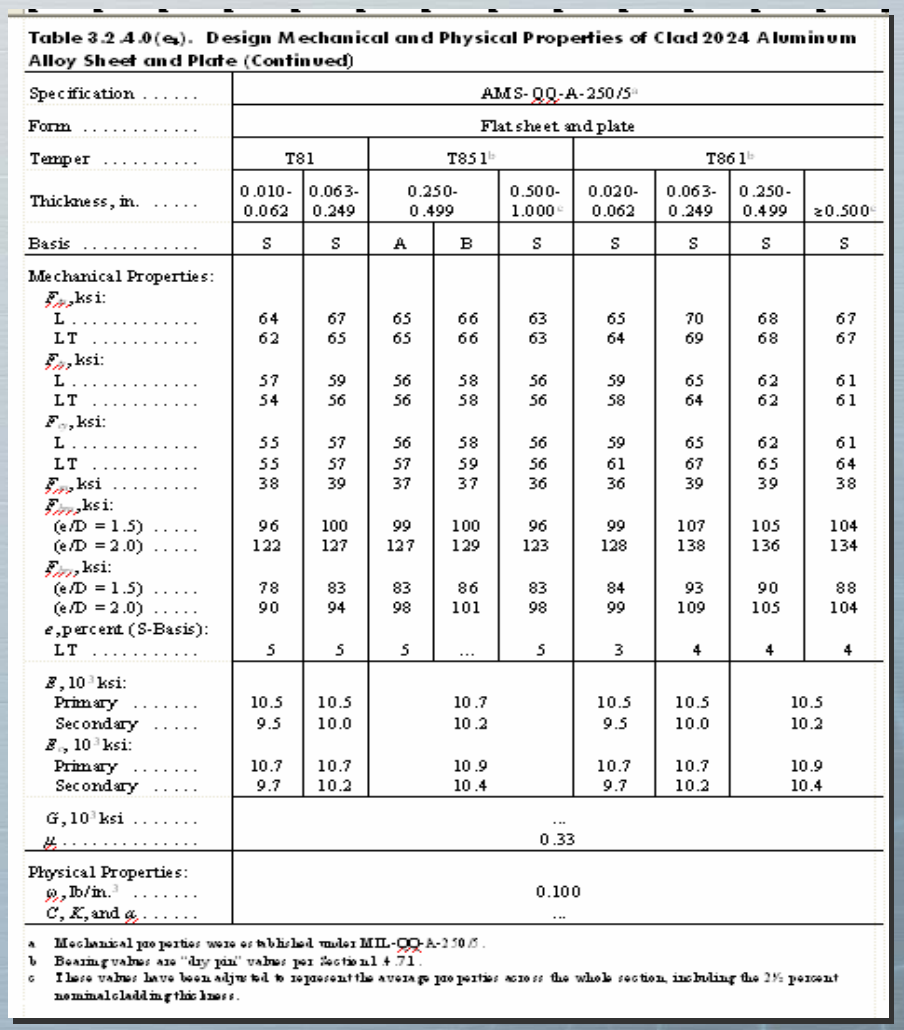
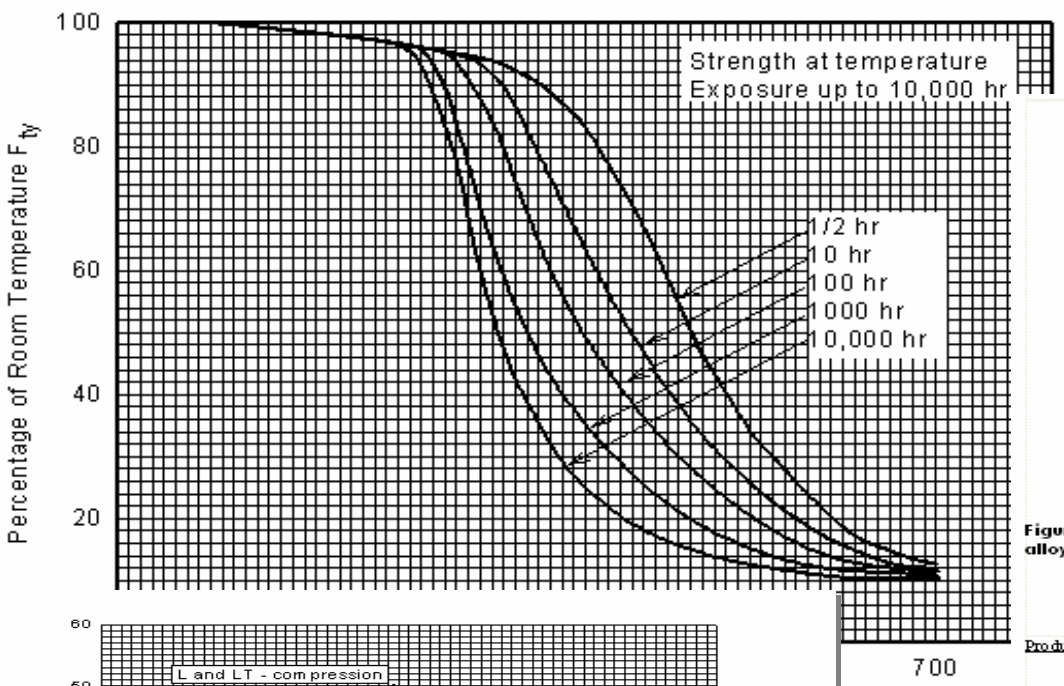


Table 3.2.4.0(e$_8$). Design Mechanical and Physical Properties of Clad 2024 Aluminum Alloy Sheet and Plate (Continued)

Specification	AMS-QQ-A-250/5[a]								
Form	Flat sheet and plate								
Temper	T81		T851[b]			T861[b]			
Thickness, in.	0.010-0.062	0.063-0.249	0.250-0.499		0.500-1.000[c]	0.020-0.062	0.063-0.249	0.250-0.499	≥0.500[c]
Basis	S	S	A	B	S	S	S	S	S
Mechanical Properties:									
F_{tu}, ksi:									
L	64	67	65	66	63	65	70	68	67
LT	62	65	65	66	63	64	69	68	67
F_{ty}, ksi:									
L	57	59	56	58	56	59	65	62	61
LT	54	56	56	58	56	58	64	62	61
F_{cy}, ksi:									
L	55	57	56	58	56	59	65	62	61
LT	55	57	57	59	56	61	67	65	64
F_{su}, ksi	38	39	37	37	36	36	39	39	38
F_{bru}, ksi:									
(e/D = 1.5)	96	100	99	100	96	99	107	105	104
(e/D = 2.0)	122	127	127	129	123	128	138	136	134
F_{bry}, ksi:									
(e/D = 1.5)	78	83	83	86	83	84	93	90	88
(e/D = 2.0)	90	94	98	101	98	99	109	105	104
e, percent (S-Basis):									
LT	5	5	5	...	5	3	4	4	4
E, 10^3 ksi:									
Primary	10.5	10.5	10.7			10.5	10.5	10.5	
Secondary	9.5	10.0	10.2			9.5	10.0	10.2	
E_c, 10^3 ksi:									
Primary	10.7	10.7	10.9			10.7	10.7	10.9	
Secondary	9.7	10.2	10.4			9.7	10.2	10.4	
G, 10^3 ksi	...								
μ	0.33								
Physical Properties:									
ω, lb/in.^{3}	0.100								
C, K, and α	...								

a Mechanical properties were established under MIL-QQ-A-250/5.
b Bearing values are "dry pin" values per Section 4.7.1.
c These values have been adjusted to represent the average properties across the whole section, including the 2½ percent nominal cladding thickness.

Graph Examples



d strength (F

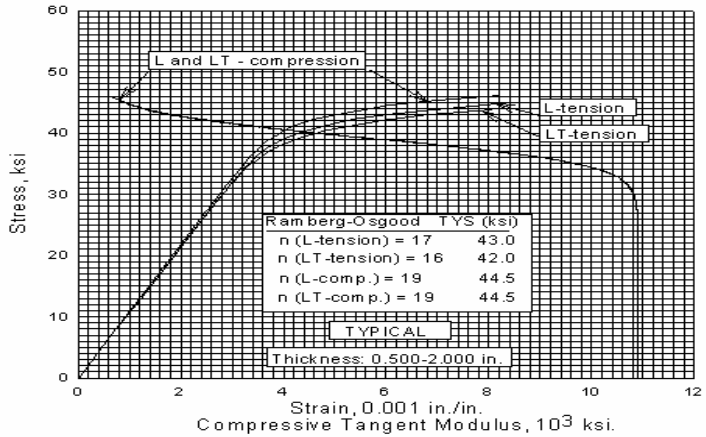


Figure 3.2.4.1.6(j). Typical tensile and compressive stress-strain and compressive tangent-modulus curves for 2024-T42 aluminum alloy plate at room temperature.

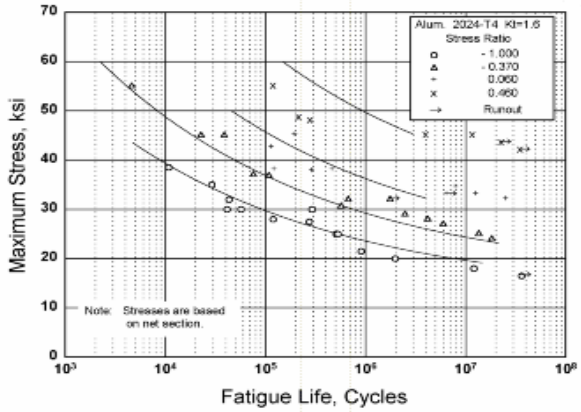


Figure 3.2.4.1.8(b). Best-fit S/N curves for notched, K_t = 1.6, 2024-T4 aluminum alloy bar, longitudinal direction.

Correlative Information for Figure 3.2.4.1.8(b)

Product Form: Rolled bar, 1.125-inches diameter

Properties:

TUS, ksi	TYS, ksi	Temp., °F
73	49	RT

Specimen Details: Semicircular V-Groove, K_t = 1.6
0.450-inch gross diameter
0.400-inch net diameter
0.100-inch root radius, r
60° flank angle, φ

Surface Condition: As machined

Reference: 3.2.2.1.8(a)

Test Parameters:
Loading - Axial
Frequency - 1800 to 3600 cpm
Temperature - RT
Environment - Air

No. of Heats/Lots: Not specified

Equivalent Stress Equation:
$\text{Log } N_f = 12.25\text{-}5.16 \log (S_{eq}\text{-}18.7)$
$S_{eq} = S_{max} (1\text{-}R)^{0.57}$
Std. Error of Estimate, Log (Life) = 0.414
Standard Deviation, Log (Life) = 0.989
R^2 = 82%

Sample Size = 38

[Caution: The equivalent stress model may provide unrealistic life predictions for stress ratios beyond those represented above.]

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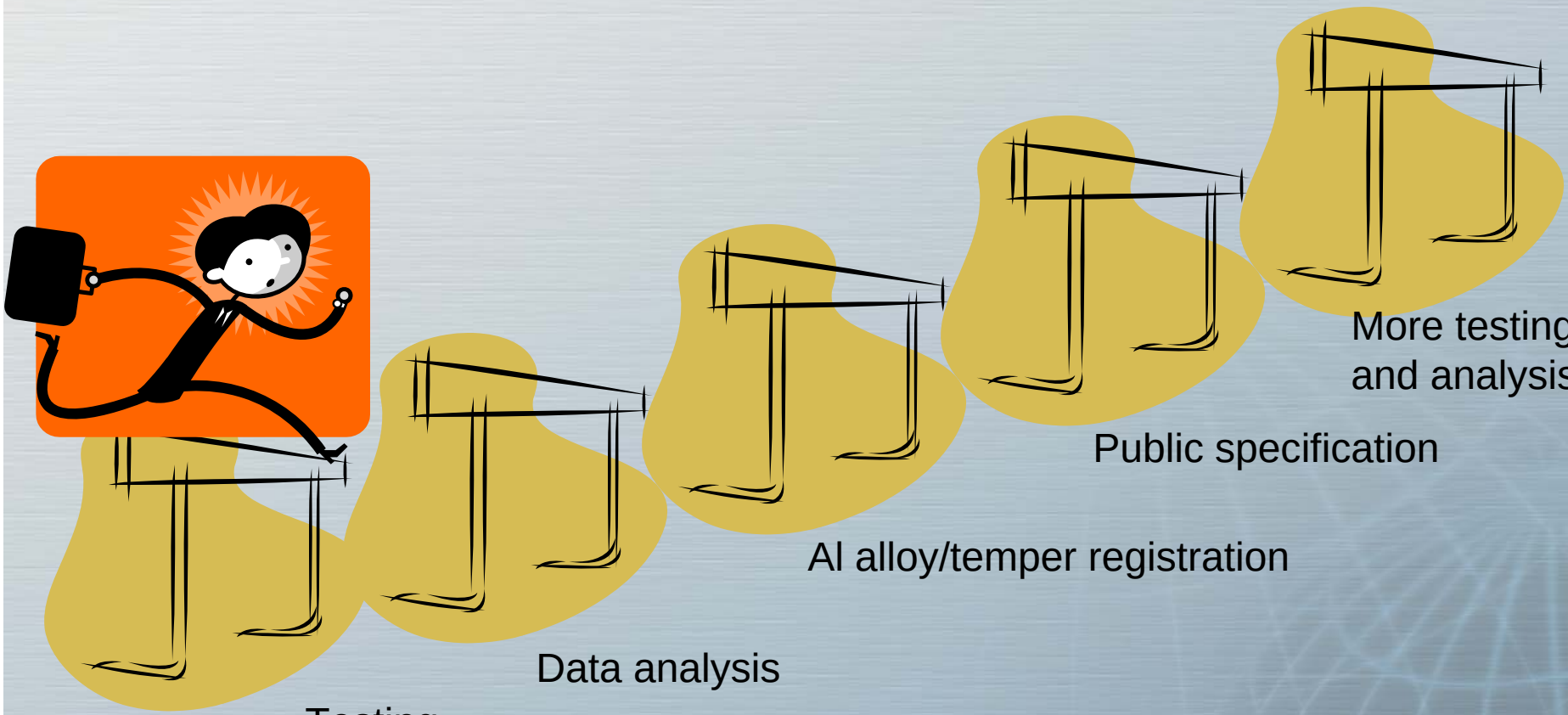
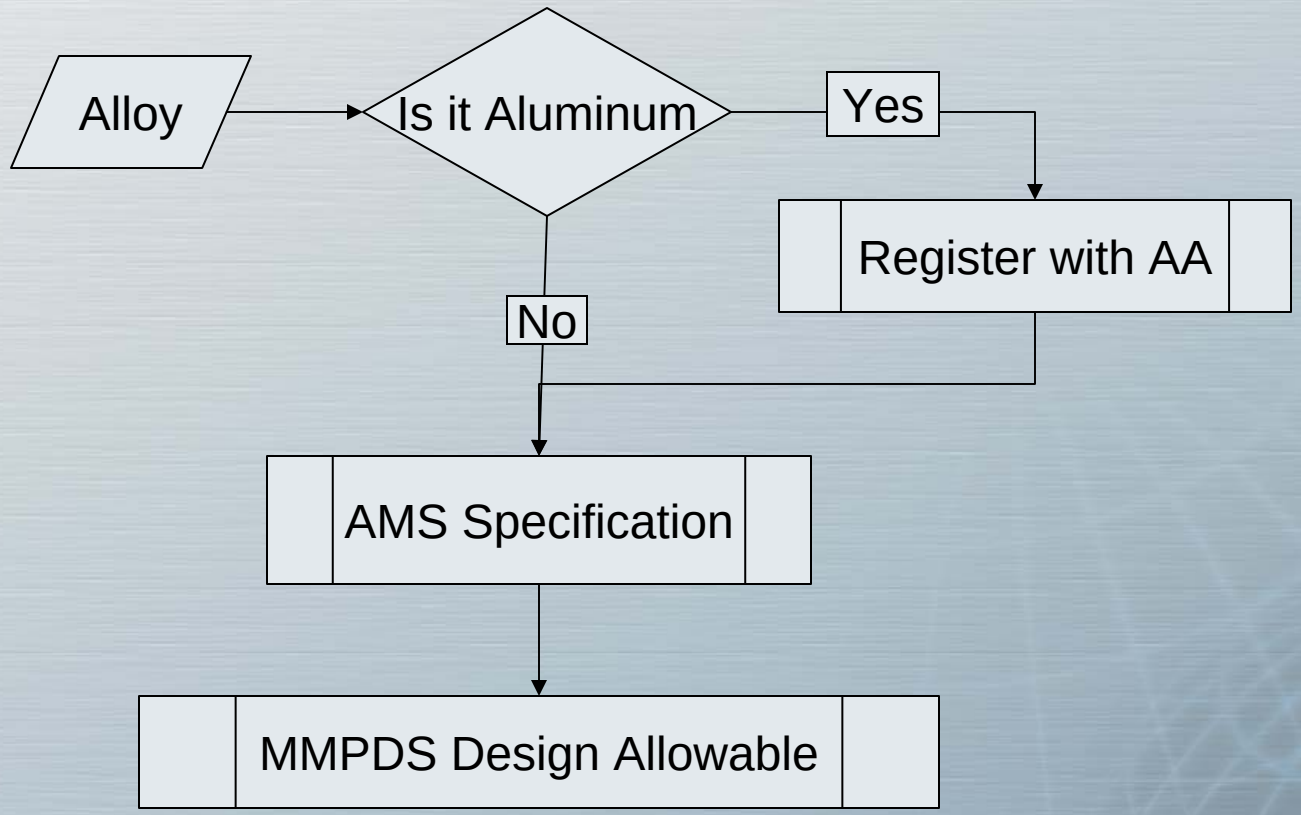
What does it take to get design allowables in MMPDS?



Process to get an Alloy into MMPDS



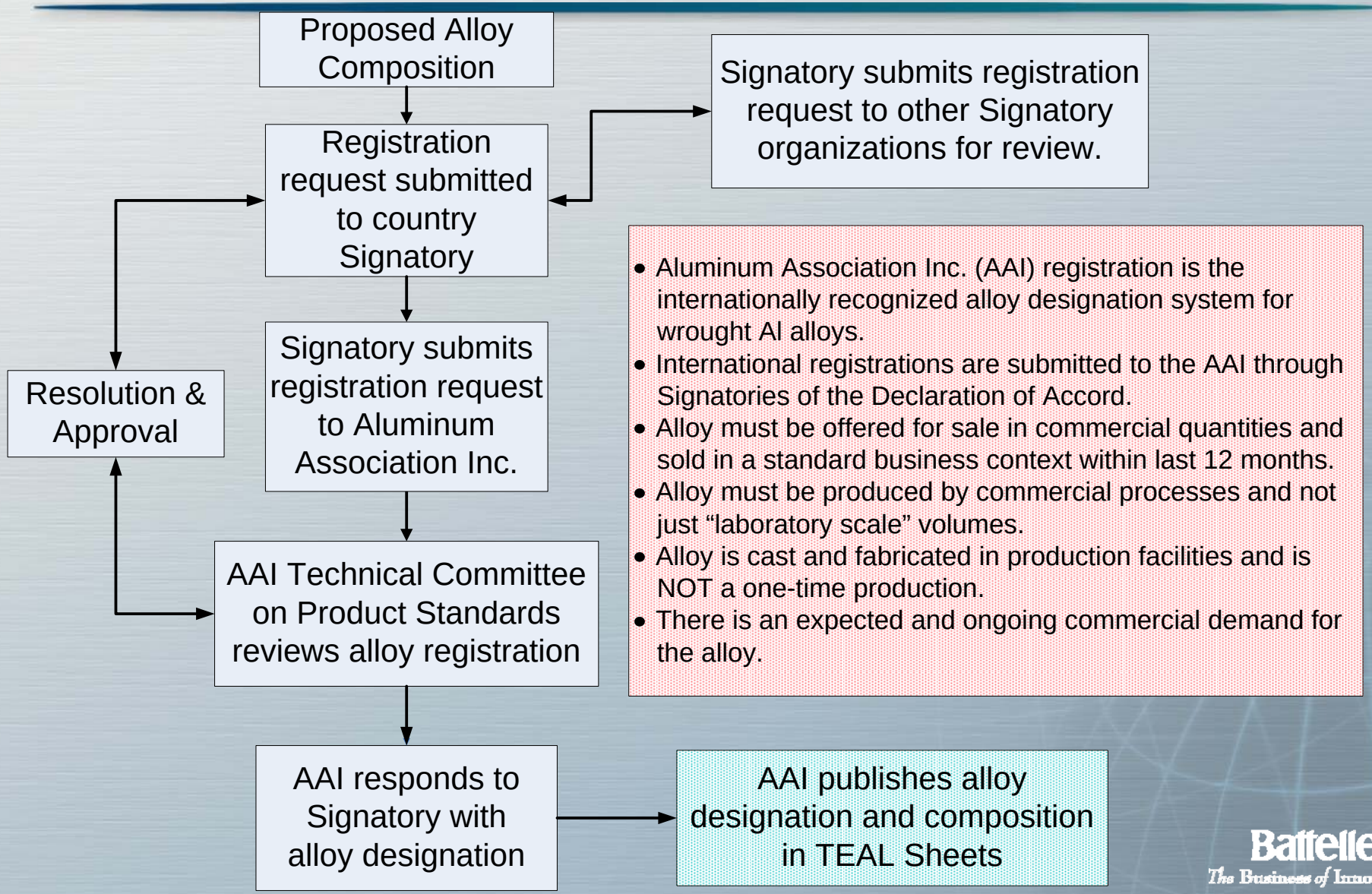
Requirements for MMPDS

- Must have a public specification, typically an SAE AMS (Aerospace Materials Specification)
- Required Tests; Tensile, Compression, Shear, Bearing, Stress-strain curves, Modulus, Physical properties
- Recommended tests; Elevated temperature, Fatigue, Fracture Toughness, Crack Growth
- Exceptions; High temperature applications do not require secondary properties, fasteners and joints (different requirements)

Aluminum Alloys

- Alloy and temper must be registered with AA
  - Contact: Parvaneh Shafiee, Manager, Alloy and Temper Registration
  - pshafiee@aluminum.org
- Aluminum alloy/temper registration requires sample size of 100 tests from 10 lots.
- Tentative minimums may be registered for smaller sample sizes.
- Aerospace alloys typically use same analysis as AMS or MMPDS as appropriate.

International Alloy Designation & Chemical Composition Registration of Wrought Aluminum Alloys



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AMS Specification

- Information about the AMS Metals Group, the AMS NonMetals Group, and each of the individual committees that make up the AMS Division, available at the following URL: <http://www.sae.org/technicalcommittees/aermtd.htm>.

- Public posting of basic information is on line at the following URL: http://www.sae.org/standardsdev

- Contact Kerri Rohall at SAE <kerrir@sae.org>

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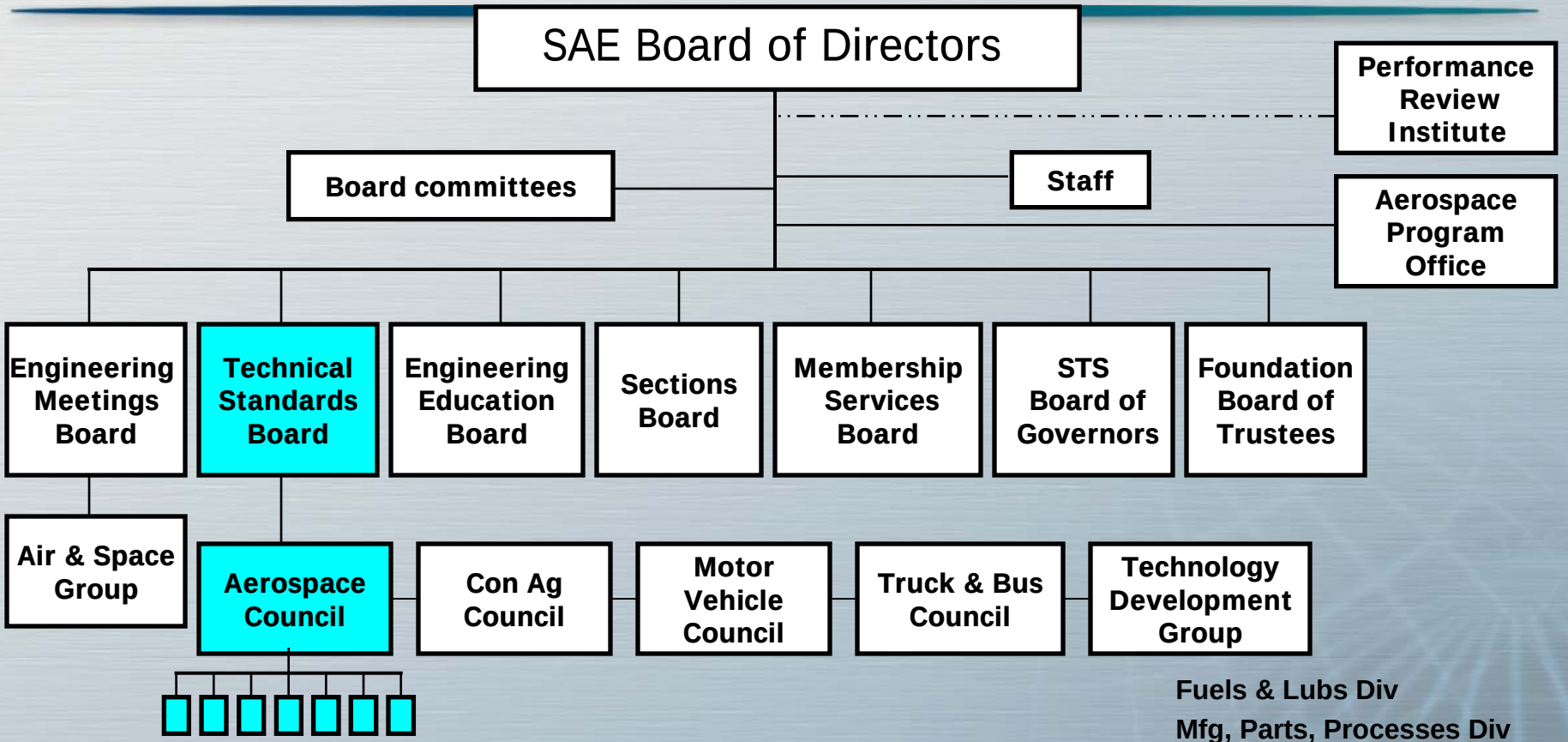

The above is a graphical display of SAE's primary organizational structure.

There are many other committees within SAE that are not depicted in this chart.

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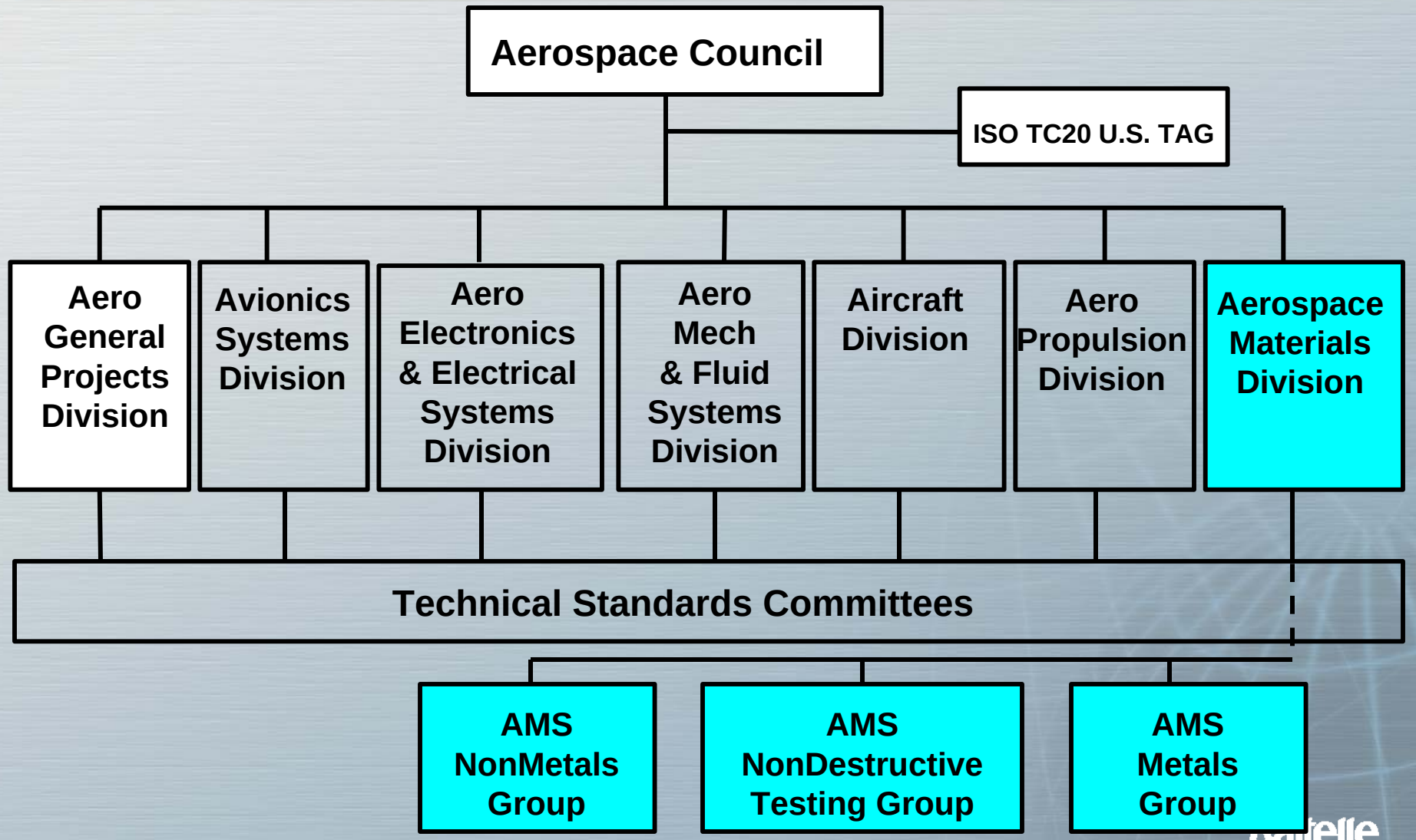
SAE Aerospace
An SAE International Group

Overview of SAE Aerospace Council Organization



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AMS Metals Group

- Six committees dedicated to creating and maintaining more than 2400 AMS specifications covering metals and metals processes.
- Participants include OEMs, suppliers, processors, consulting firms, government, and others across the aerospace and defense industries.

Commodity Committees - Dedicated to Maintaining Specifications

AMS-B	Finishes, Processes, & Fluids
AMS-D	Nonferrous Alloys (Aluminum, Magnesium, & Copper)
AMS-E	Carbon & Low Alloy Steels, Specialty Steels & Alloys
AMS-F	Corrosion & Heat Resistant Alloys
AMS-G	Titanium, Beryllium & Refractory Materials

Engineering Committee - Dedicated to Leading Edge Technical Issues

AMEC	Aerospace Metals Engineering Committee (providing technical resources for cooperative activities and the synergistic interchange of ideas and member experience)

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Creating an AMS Specification

1. Committee/chairperson validates need for specification and assesses the maturity of the material/process.
   - Support from at least two aerospace users
   - Proposed properties substantiated by Battelle analysis.
2. Sponsor drafts the new specification after obtaining assistance from SAE Editorial Consultant for format, consistency, and technical clarity.
3. Draft specification balloted to SAE technical committee of jurisdiction for comment over a 28-Day review period.
4. Each technical (requirements-based) comment is debated and resolved by consensus process.
5. Final version balloted to SAE Aerospace (industry VPs) for approval.
6. Document published by SAE.

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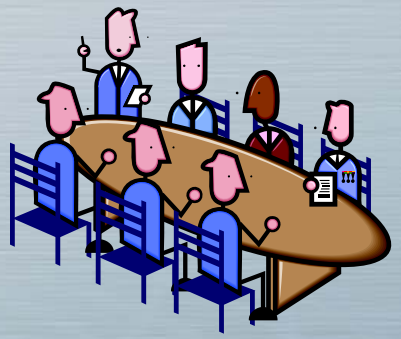
Committee Interactions

- Specification balloting and debate occurs year-round through committee website, email, and electronic communication tools.
- Meetings are open to all interested parties
  (two meetings each year for most committees)
- Committee officers & membership approved by SAE Aerospace Council
- Committee chairpersons are responsible for maintaining committee membership balance (user, supplier, & liaison members)
- Only committee members vote on draft documents
  - Supplier member participation is highly valued, but final approval votes are “User Member Only” (OEM/transport operator/government).
- Individuals participate on committees as technical experts and not as representatives of their organization/business.



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Data Requirements

- AMS minimum data requirements
  - Aluminum alloys and tempers must be registered with AA
  - Sample size 30 (per thickness range for wrought product unless regression analysis used)
  - 3 Heats
- Statistical analysis
  - Normal analysis
  - Spec min = Mean – (k_{99} * Std. Deviation)
    - k_{99} = one-sided tolerance tolerance-limit factor corresponding to a proportion at least 0.99 of a normal distribution and a confidence coefficient of 0.95
  - Larger sample sizes (100) use MMPDS guidelines
- Proposed minimums must be supported by data (can be slightly lower, but cannot be higher)

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Statistical Analysis

- Minimum properties are determined for all 3
  - AA
  - AMS
  - MMPDS
- However, not necessarily in the same way
- Most demanding analysis is MMPDS
- Necessary cooperation between all groups

Battelle Analysis

- All analysis is done by Battelle (non-partial) using SAE AMS guidelines or MMPDS guidelines as appropriate.
- All data received by Battelle is considered company confidential and is not shared with any other source without permission of company which supplied the data.
- Analysis result is sent to whomever supplied the data.
- The data supplier can decide if they want to proceed or acquire more data for
  - AA registration (if aluminum alloy)
  - AMS minimums
  - MMPDS design allowables

MMPDS

- Information about MMPDS can be found on www.mmpds.org

- Contacts for handbooks: Anne Mundy mundya@battelle.org

- Contacts for technical questions:

  Jana Jackson jacksonj@battelle.org

  Rich Rice ricerc@battelle.org

MMPDS - 03

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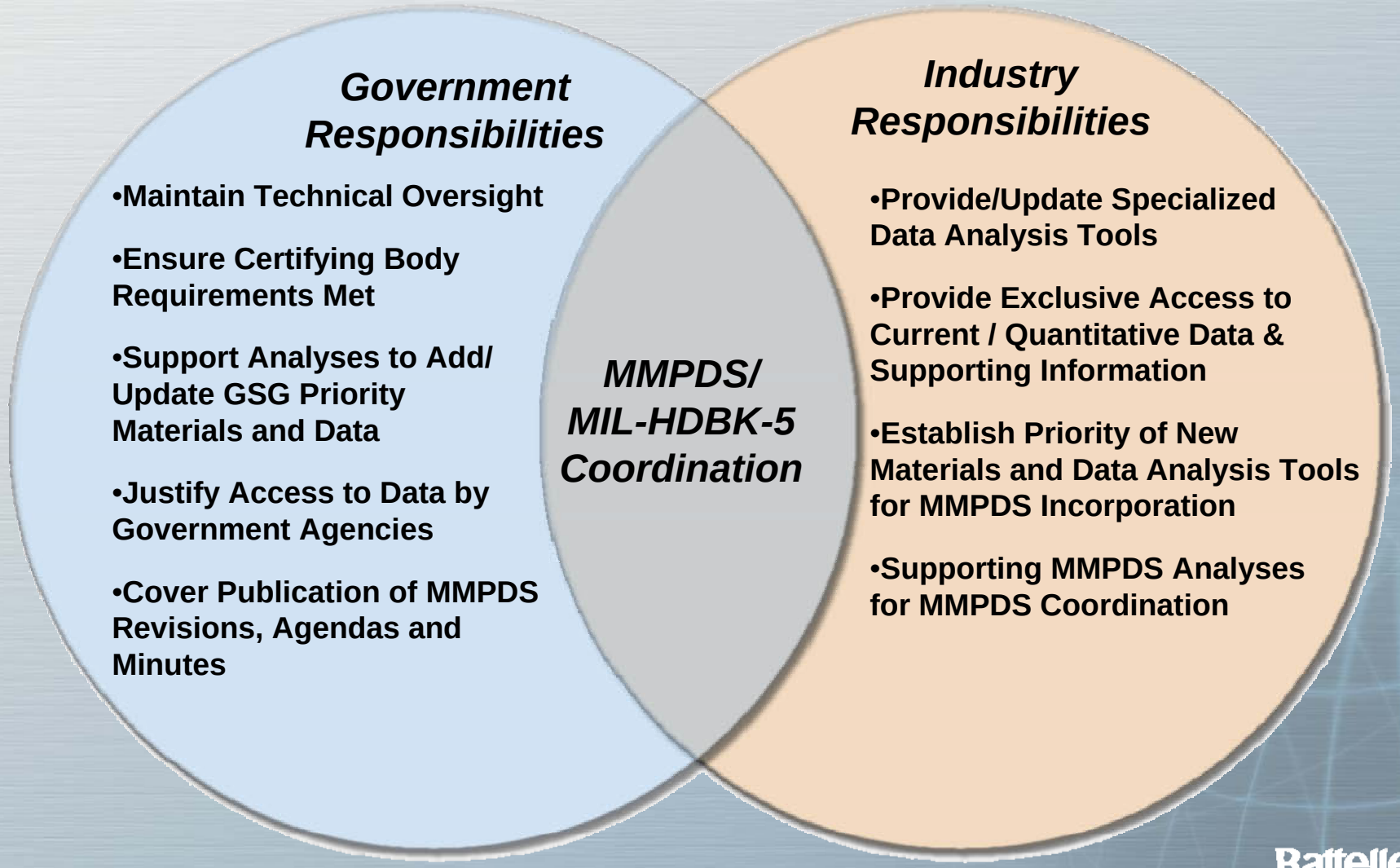
MMPDS Organization



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ISG/GSG Current Members

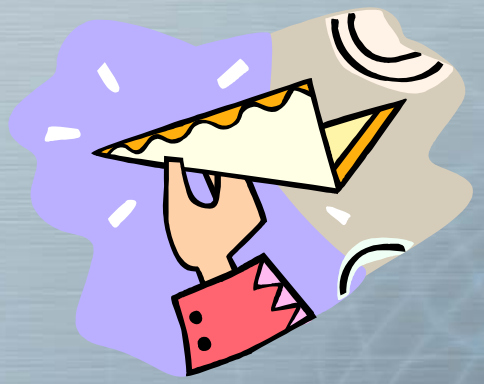
- There are 23 current, active ISG member companies

-Airbus	- Alcan	- Alcoa
-Allfast	- Alu Menziken	- Aubert & Duval
-Boeing	- Bombardier	- Corus Aluminum
-Embraer	- Goodrich Aero.	- Granta
-Haynes Intl.	- ITP	- Kaiser Aluminum
-L3 Comm. (new)	- Lockheed Martin	- Northrop Grumman
-Raytheon Aircraft	- Spirit Aerosystems	- Sumitomo Light Metal
-Textron (Cessna)	- Westmoreland	

- GSG members for the current program year are expected to include: FAA, Navy, DLA, and NASA
- GSG memberships on the part of the Air Force and Army are anticipated in the future

MMPDS Data Requirements

- Tensile properties
  - For A- & B-Basis, minimum of 100 tests, 10 heats/ 10 lots
- Secondary properties; compression, shear, bearing
  - Paired ratios
  - 3 heats/ 10 lots, 20 samples (prefer duplicate/lot)
- Elongation (from specification)
- Modulus
- Physical properties
- Stress-Strain curves



Additional info

- Desired
  - Elevated temperature effects
  - Fatigue
  - Crack growth
  - Fracture toughness
  - Stress corrosion cracking resistance

- Fasteners and joints (Chapter 8 of MMPDS)

MMPDS Coordination Committee

- Proposed inclusions/changes to MMPDS are presented to MMPDS Coordination Committees for approval
- Meetings held in spring and fall
- Information on meeting www.mmpds.org

Summary

- MMPDS Handbook is the approved source for design allowables by FAA
- Requirements:
  - Public Specification
  - Data Analysis done by Battelle
  - Approval by MMPDS Coordination Committee

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- Helpful websites:
  - www.sae.org
  - www.mmpds.org

- Contact: (Jana) JacksonJ@Battelle.org

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