MMPDS & Additive Metals

AMSC Design for AM
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Doug Hall
Sr. Mechanical Engineer
Program Manager - MMPDS
Battelle Memorial Institute
614-424-6490
halld@battelle.org

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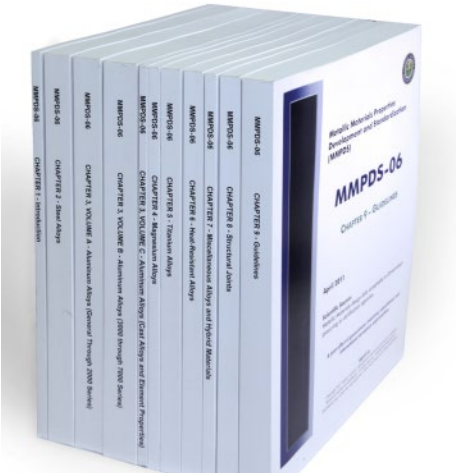
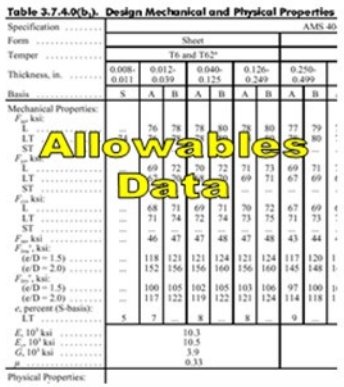
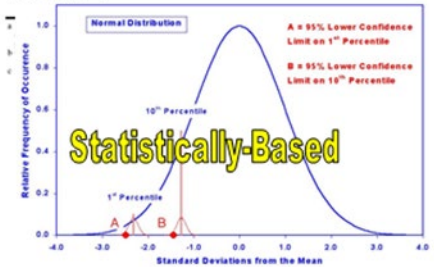
Metallic Materials Properties Development and Standardization







History

- ANC5 (1937-1954), MIL-HDBK-5 (USAF: 1954 – 2003), MMPDS (FAA: 2003-today)
- Battelle Memorial Institute - program Secretariat since 1956.
- MMPDS Handbook is the primary source of statistically-based design allowable properties for metallic materials and fasteners used in many different commercial and military weapon systems around the world.
- The MMPDS General Coordinating Committee is a collaboration between government agencies, aerospace companies, testing and data service companies, and metallic material producers.
- Biannual meetings to review and approve statistical analyses and guidelines.

Scope

- The Handbook currently contains 600+ A/B-Basis and 1000+ S-Basis entries, 400+ unique metal specifications.
- Two to five new alloys are added each year.
- For more information visit www.mmpds.org

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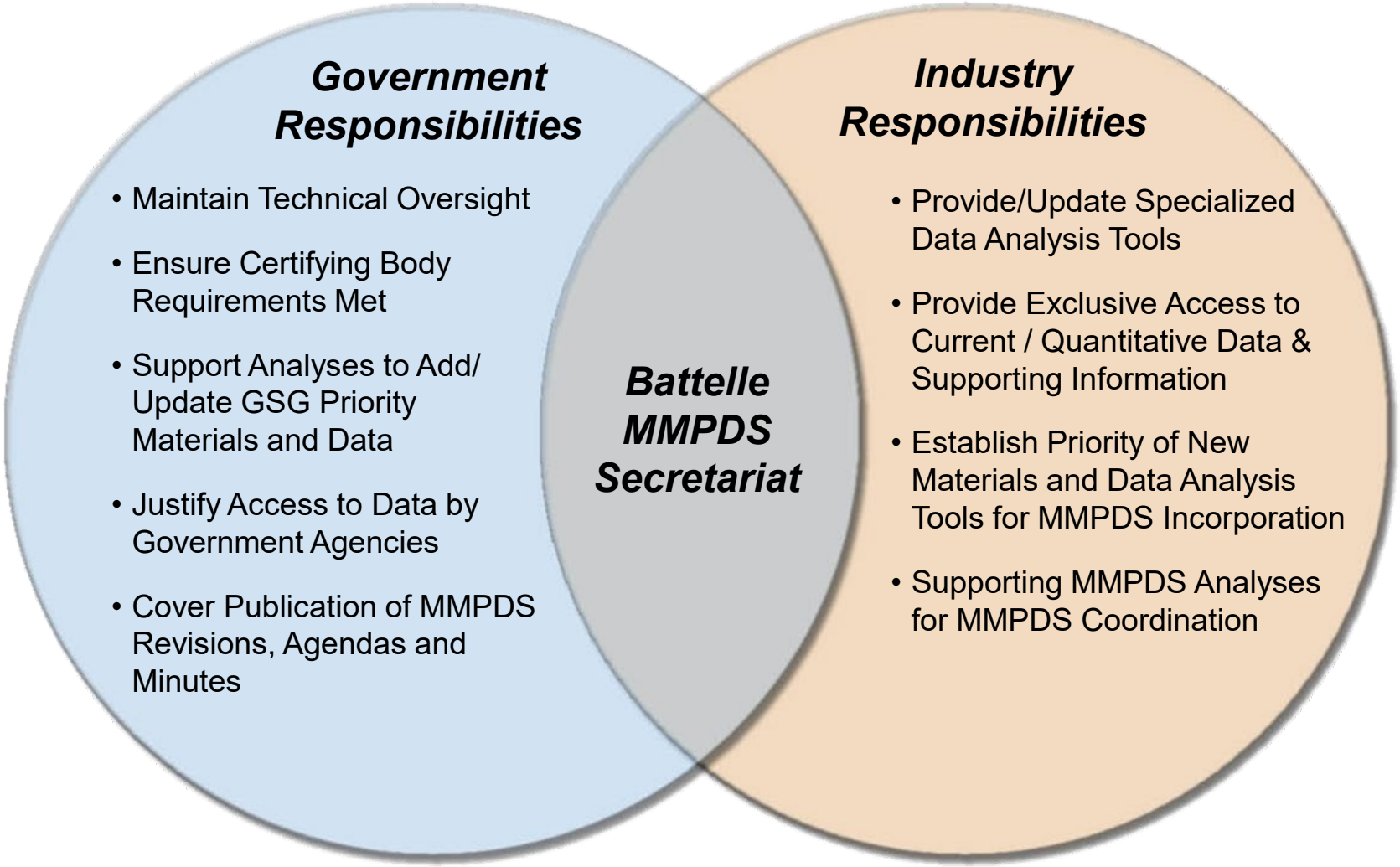
MMPDS General Coordination Committee



Task Groups:
GTG – approve **all** guidelines
MTG – approve materials (Ch. 2-7)
FTG – approve fasteners (Ch. 8)
ETTG – approve V2 content

Steering Groups:
Get industry sector inputs
ASG, MATSSG, PSG

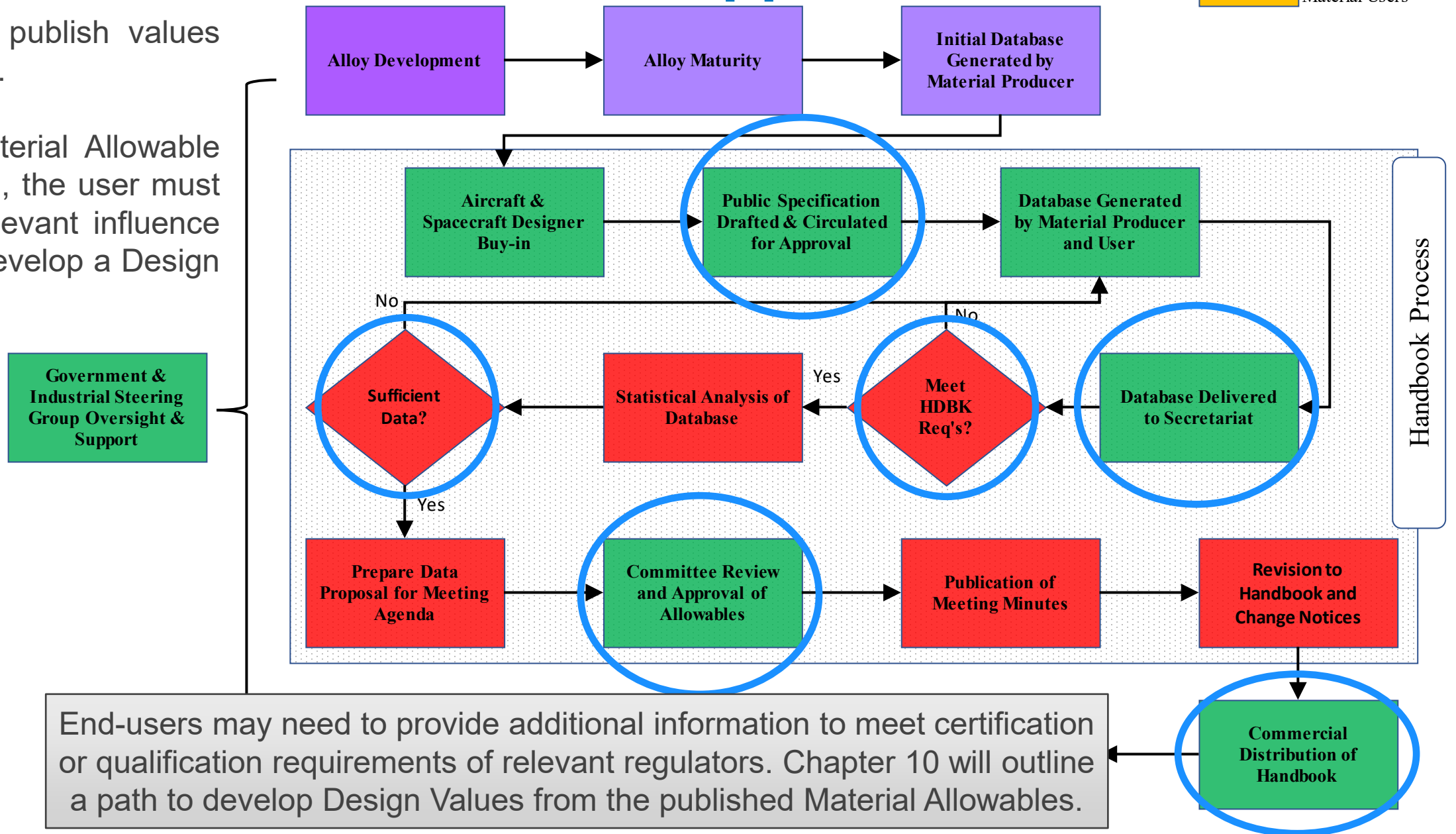
Working Groups:
Technical input from industry
FatWG, SWG, WWG
V2WG – develop V2 tech details

Task 1.5 Volume II Review & Approval DRAFT

Material Producers
Collaboration
Secretariat
Government
Material Users

Process to publish values in Volume II.

Once a Material Allowable is published, the user must consider relevant influence factors to develop a Design Value.



End-users may need to provide additional information to meet certification or qualification requirements of relevant regulators. Chapter 10 will outline a path to develop Design Values from the published Material Allowables.

Volume II Material Allowables vs. Design Values

- Material Allowable – A bulk material property derived from the statistical reduction of data from a stable process. The amount of data required to derive these values is governed by the statistical significance (or basis) and the methods defined in Chapter 9. Application of allowables may require additional considerations for use in design.
- Design Value – A material property that is established to represent the finished part property. These numbers are typically based on material allowables and adjusted, using building block tests as necessary to account for the range of part geometry features (*e.g.,* holes, notches, surface finish) and in-service environmental conditions (*e.g.,* temperature, moisture, and fluid.) Design values are used in analysis to compute structural design margin (*i.e.,* margin of safety.)

19-20: Data Requirements for Volume II

Mechanical or Physical Property	Customary Statistical Basis	Relative Importance in MMPDS Volume II	Extenuating Circumstances for Special Material Usage Requirements	Minimum Data Requirements				
				Sample Size	No. of Heats[g]	No. of Mfg. Lots	Machines[f]	Build Cycles
Bearing Yield and Ultimate Strength	S-Basis	Mandatory	Except for elevated temperature applications	30	3	3	3	3
Compression Yield Strength[a] (Derived)	Same as Tensile Properties	Mandatory		20	3	10	3	3
Density	Typical	Mandatory		3	3	3	3	3
Elastic Modulus - Tension Elastic Modulus - Compression Elastic Modulus - Dynamic Elastic Modulus - Shear	Typical	Mandatory Mandatory Recommended Recommended	Dynamic modulus is strongly recommended for some engine applications	9	3	3	3	3
Elastic Modulus (T, C, D) - Elevated Temperatures	Typical	Mandatory	For anticipated usage temperature range	9	3	3	3	3
Elongation	S-Basis	Mandatory	Two-inch gage length preferred	30	3	3	3	3
Shear Ultimate Strength[a]	S-Basis	Mandatory	Except for elevated temperature applications	30	3	3	3	3
Stress/Strain Curves (To Yield) Tension and Compression	Typical	Mandatory	Desirable to have accurate plastic strain offsets from 10^{-6} to 3 x 10^{-2}	6	3	6	3	3
Stress/Strain Curves (Full Range) Tension	Typical	Mandatory	The strain rate should be constant through failure.	6	3	6	3	3
Tension Yield and Ultimate Strength	S-Basis	Mandatory		30	3	3	3	3

Other requirements apply.

Item 19-20 was approved with changes at the 37th MMPDS GCC. Other requirements apply.

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19-20: Data Requirements for Volume II (Task 1.2)

Mechanical or Physical Property	Customary Statistical Basis	Relative Importance in MMPDS Volume II	Extenuating Circumstances for Special Material Usage Requirements	Minimum Data Requirements				
				Sample Size	No. of Heats[g]	No. of Mfg. Lots	Machines[f]	Build Cycles
Coefficient of Thermal Expansion	Typical	Strongly recommended	For anticipated usage temperature range	6	3	3	3	3
Poisson's Ratio	Typical	Strongly recommended		6	3	3	3	3
Specific Heat	Typical	Strongly recommended	For anticipated usage temperature range	6	3	3	3	3
Tension Yield and Ultimate Strength	D-Basis	Strongly recommended	Especially for strength critical applications; a parametric representation of data is possible	100	10	10	5	10
Tension Yield and Ultimate Strength	C-Basis	Strongly recommended	Especially for strength critical applications; a parametric representation of data is possible	100	10	20	5	20
Tension Yield and Ultimate Strength	C-Basis & D-Basis	Strongly recommended	Especially for strength critical applications; a parametric representation of data is not possible	299	10	20	5	20
Thermal Conductivity	Typical	Strongly recommended	For anticipated usage temperature range	6	3	3	3	3

Other requirements apply.

Item 19-20 was approved with changes at the 37th MMPDS GCC. Other requirements apply.

Introducing C- and D-basis Allowables in Vol. II (Metal AM)

- Statistical definitions for A-/B- vs. C-/D- (i.e. 99/95 and 90/95, respectively) are the same (*see next slide*)
- Differences:
  - Underlying test matrices (e.g. Tables for Vol. II on pp. 6-7 of this presentation)
  - Unlike A- and B- allowables in Vol. I, ***C- and D- allowables require "further showing"***

A- and B-basis Allowables
Conventional Alloys (Vol. I)

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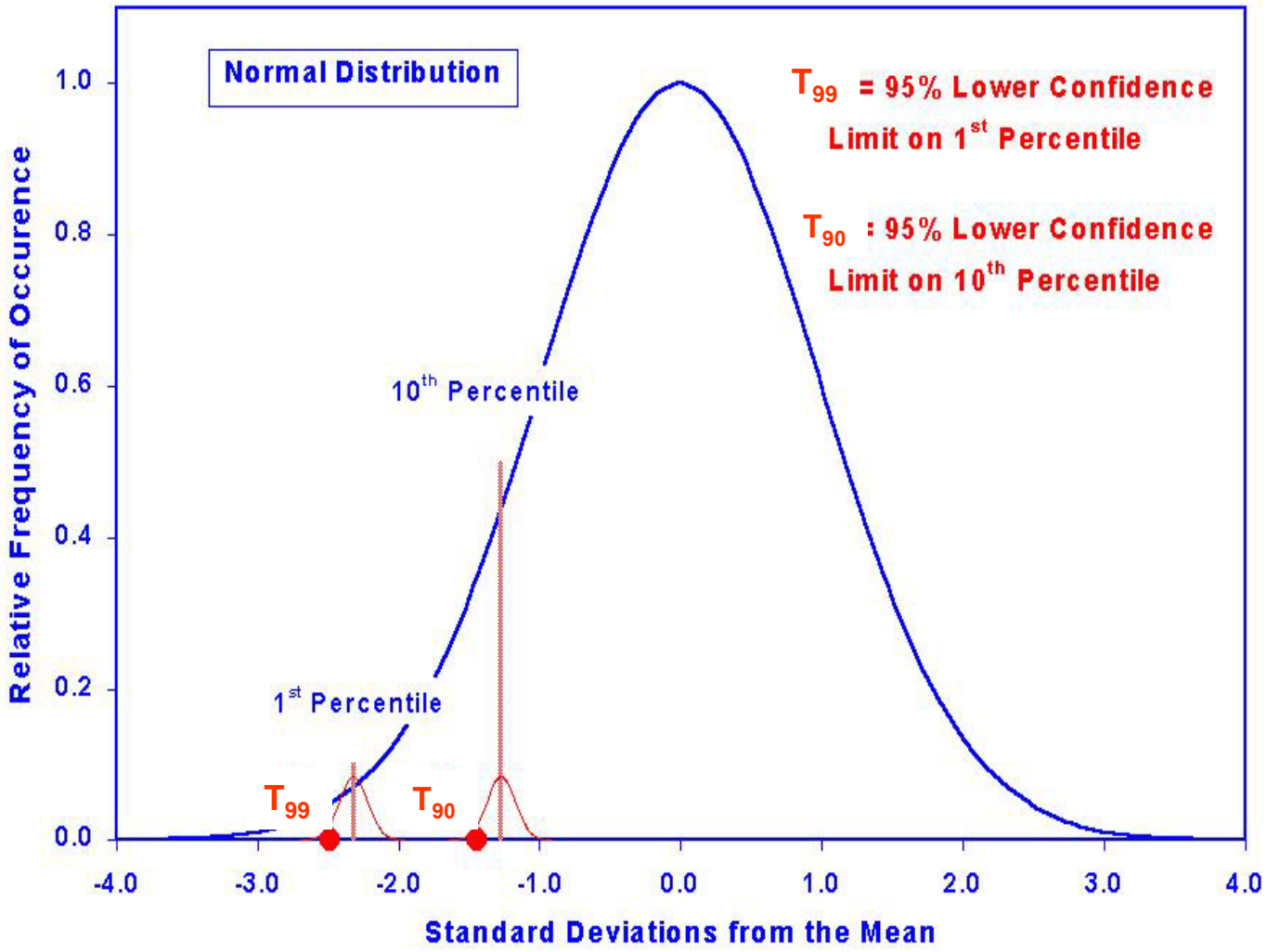
C- and D-basis Allowables
Metal AM (Vol. II)

Volume II C-Basis, D-Basis, S-Basis: Material Allowables



T_{99} and T_{90} are one-sided lower tolerance bounds. Both are calculated from data.

C-Basis is the lower of the specification minimum or T_{99} value.

D-Basis = is the T_{90}. It is not related to the spec minimum.

S-Basis = is a T_{99} that does not meet C-Basis requirements for sample size or distribution fit.

Metallic C-/D-/S-Basis published in MMPDS Volume II require "further showing."

For Volume II, C-/D-/S-Basis allowable values are reviewed and approved by the MMPDS General Coordinating Committee for metallic materials.

Item 19-20 was approved with changes at the 37th MMPDS GCC. Other requirements apply.

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37th MMPDS Coordination Meeting Results

- Volume II is under development. Information subject to further change.
- Agenda Items associated with Volume II
  - ✓19-17: Minimum Content Requirements for a Public Specification – Approved at 36th
  - ✓19-20: Data Submission Requirements for Volume II – Approved at 37th
  - ✓19-26: Definitions for Process Intensive Materials & Technologies - Approved at 34th
  - ✓20-20: Definitions for Volume II – Approved at 37th
  - ✓20-31: Definitions of “Design Allowable”, “Design Value”, and “Material Allowable” – App. 37th
  - 21-04: Required Test Methods/Procedures for Volume II – Continued at 37th
  - ✓21-11: Interim Data Analysis Methods: Volume II – Approved at 37th
  - 21-20: Microstructural Submittal Requirements – Continued at 37th
- Full Minutes of MMPDS meetings are shared with ISG, GSG, and attendees.

These approve items are a small part of the Chapter 9 Guidelines. Other requirements apply.

Coordination with SDOs & Other Organizations

- ASTM
  - General test specifications
  - AM CoE & F42 Committee
- EWI
- NIAR
  - Air Force/FAA funded project to develop a specification and allowables for PBF Ti 6-4
- NIST
- SAE AMS
  - Additive Manufacturing Data Consortium – Battelle is a Liaison member
  - SAE AMS AM Metals Committee – drafting an update to the AM Data Submission Guideline
    - Materials/Parts: AMS7000A (625), 7011 (Ti64), 7016 (17-4PH), 7024 (718), 7028 (Ti 6-4), 7030 (AlSi10Mg), 7036 (316L), 7038,
    - Feedstock: AMS7002A, 7006, 7009, 7012A, 7015, 7017 (Ti 64),7020 (F357), 7023 (TiAl), 7026 (Ti5553), 7033, 7037 (316L)
    - Processes: AMS7003A, 7006, 7010, 7031 (recycling), 7032 (Machine Qual), 7035,

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It can be done

800.201.2011 | solutions@battelle.org | www.battelle.org