



Transition of OSMA AM Responsibility from WSTF to MSFC

Jess Waller

NASA Johnson Space Center - White Sands Test Facility

NESC NDE TDT Annual Review Meeting – May 14-15, 2019

Additive manufacturing (AM) is a rapidly evolving, game changing technology requiring many disciplines (including NDE) to ensure mission safety and reliability.



SIPPING WATER

From A Fire Hydrant



HERDING CATS

There's No Feeling Quite Like It

While AM is becoming increasingly democratized and pervasive, managing risks for fracture critical L-PBF spaceflight hardware must **clearly** come from MSFC.

Background

- Activities stemming from a three-year OSMA NDE Program project are being transitioned to MSFC. The project had two parts:
 - 1. Effect-of-Defect of Unique Laser PBF Flaw Types: NASA-Industry Round Robin Study**
 - 2. NDE of Aerospace Materials VCO Standards**
- Early in the project, it became apparent AM parts could be made by industry at little or cost to NASA, facilitated by a request made to industry by America Makes/Jim Morris seeking volunteers to make parts with known defects or process variation.
- The initial plan to make only L-PBF parts (University of Louisville, Airbus, Incode3D, UTC) was expanded to include parts made by 3 other manufacturing processes: 1) laser-cused L-PBF (Concept Laser/GE), 3) EBF3 DED (NASA LaRC), and 4) EB-PBF (CalRAM).
- Funding originally allocated for WSTF destructive and nondestructive testing was reallocated to support rapidly evolving Scope changes:
 - America Makes/ANSI AM Standardization Collaborative roadmapping activities (2017, 2018)
 - NASA/ESA/JAXA trilateral AM collaboration telecons and annual meetings (2015, 2016, 2018)
 - QLF annual meetings (2016, 2017, 2018)
 - ASTM F42/E07/E08 Symposium on Structural Integrity of AM Parts support (co-chair, Nov. 2018)
 - NASA and ASTM webinars and courses on NDE-based QA of AM Parts (2017, 2018, 2019)
 - Recent: transition NDE of AM standardization and testing efforts to MSFC

Engage in international partnering



Lead NASA-industry round robin tests and effect-of-defect studies



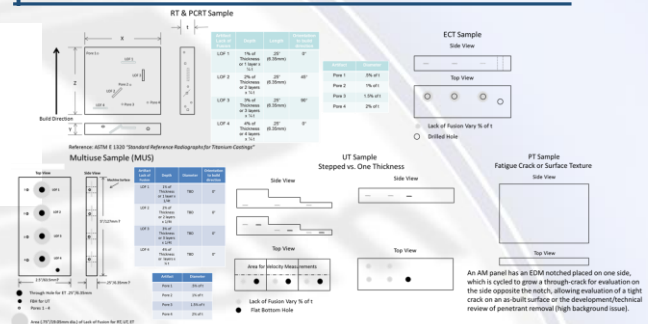
Courses, Webinars, and OSMA Publicity



OSMA NDE Program VCO Standards and AM Foundational Efforts

Integrate and Implement NASA and non-NASA guidance

Develop physical ref. stds. and phantoms with seeded flaws



Develop new NDE standards



FY19 Additive Manufacturing-related OSMA Products (to be transitioned to MSFC)

ASTM WK47031 Standard Guide Status:

- *Goal:* provide basic instruction for surface and volumetric inspection
- PBF/DED focus (L and EB)
- Covers CT, ET, MET, PCRT, PT, RT, TT, and UT
- May consider a RAM section for WK47031 after adoption (needs vetting by E07.06)
- NDE round robin testing was conducted in conjunction with development of this standard
- Balloted in E07.10 S/C June and August 2017; concurrently balloted in May and December 2018
- Last round of negatives were minor
- **In concurrent balloting: April 30th to May 30th**
- POC: Jess Waller/NASA WSTF

<https://www.astm.org/WorkItems/WK47031.htm>



Russell, R., Wells, D., Waller, J., Poorganji, B., Ott, E., Nakagawa, T., Sandoval, H., Shamsaei, N., Seifi, M., "Qualification and Certification of Metal Additive Manufactured Hardware for Aerospace Applications," Chapter 3, in *Additive Manufacturing for the Aerospace Industry*, Boyer and Froes, Eds., Elsevier, December 2019. <https://www.elsevier.com/books/additive-manufacturing-for-the-aerospace-industry/froes/978-0-12-814062-8>



ELSEVIER

Home > Books & Journals > Materials Science > Materials Science (General) >
> Additive Manufacturing for the Aerospace Industry



Additive Manufacturing for the Aerospace Industry

1st Edition

☆☆☆☆☆ Write a review

Editors: Francis Froes, Rodney Boyer

eBook ISBN: 9780128140635

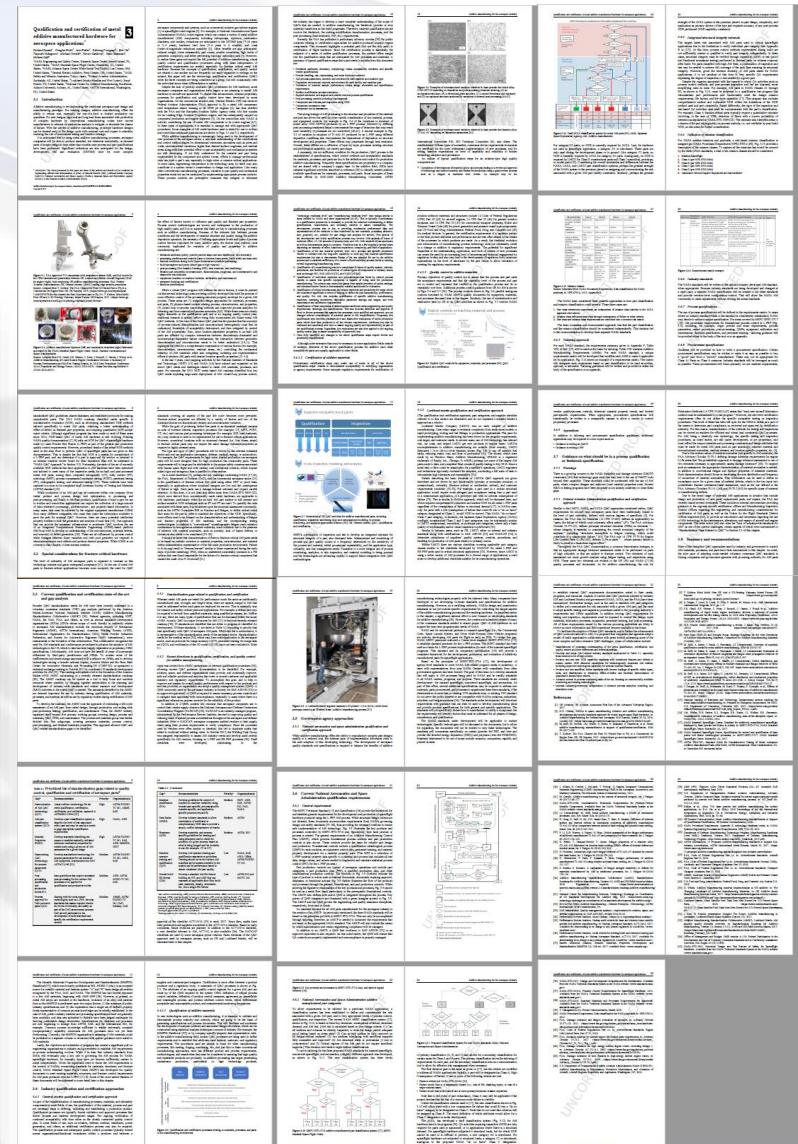
Paperback ISBN: 9780128140628

Imprint: Elsevier

Published Date: 18th February 2019

Page Count: 482

View on ScienceDirect



Four papers/five presentations given (as part of ASTM Round Robin Testing):

1. Dutton, B., Vesga, W., Waller, J., James, S., and Seifi, M., "Additive Manufacturing Defect Formation and NDE Detectability," in ASTM Symposium on Structural Integrity of Additive Manufactured Parts, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).
2. Na, J. K., Middendorf, J., Lander, M., Waller, J. M., "Nondestructive Evaluation of Programmed Defects in Ti-6Al-4V L-PBF ASTM E8 compliant Dog-bone Samples," in ASTM Symposium on Structural Integrity of Additive Manufactured Parts, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).
3. Livings, R. A., Biedermann, E. J., Wang, C., Chung, T., James, S., Waller, J. M., Volk, S., Krishnan, A., Collins, S., "Nondestructive Evaluation of Additive Manufactured Parts Using Process Compensated Resonance Testing," in ASTM Symposium on Structural Integrity of Additive Manufactured Parts, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).
4. Waller, J. M., Nichols, C. T., Burke, E. R., Wells, D. N., Brandão, A. D., Gumpinger, J., Born, M., Ghidini, T., Nakagawa, T., Koike, A., Mitsui, M., Itoh, T., "NDE-Based Quality Assurance of Metal Additive Manufactured Aerospace Parts at NASA, JAXA, and ESA," in ASTM Symposium on Structural Integrity of Additive Manufactured Parts, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).

Metal Additive Manufacturing Defect Formation, Suggested Terminology, and NDE Detectability

Ben Dutton, Wilson Vesga, Jess Waller, James Walker, William Tilson, Arthur Brown, Steve James, Mohsen Seifi

ASTM Symposium on Structural Integrity of Additive Manufactured Parts
November 6-8, 2018 Washington, DC



Nondestructive Evaluation of Additive Manufactured Parts Using Process-Compensated Resonance Testing

R. A. Livings, E. J. Biedermann, C. Wang, T. Chung, S. James, J. M. Waller, S. Volk, A. Krishnan, S. Collins

Presentation for ASTM Symposium on Structural Integrity of Additive Manufactured Parts
November 6th, 2018

NDE-Based Quality Assurance of Metal Additive Manufactured Aerospace Parts at NASA, ESA, and JAXA

Jess M. Waller, Eric R. Burke, Charles T. Nichols, Douglas N. Wells, Ana D. Brandão, Johannes Gumpinger, Tommasi Ghidini, Martin Born, Tsuyoshi Nakagawa, Akio Koike, Masami Mitsui and Tsuyoshi Itoh

ASTM Symposium on Structural Integrity of Additive Manufactured Parts
1:00 PM Tuesday, November 6, 2018 Washington, DC

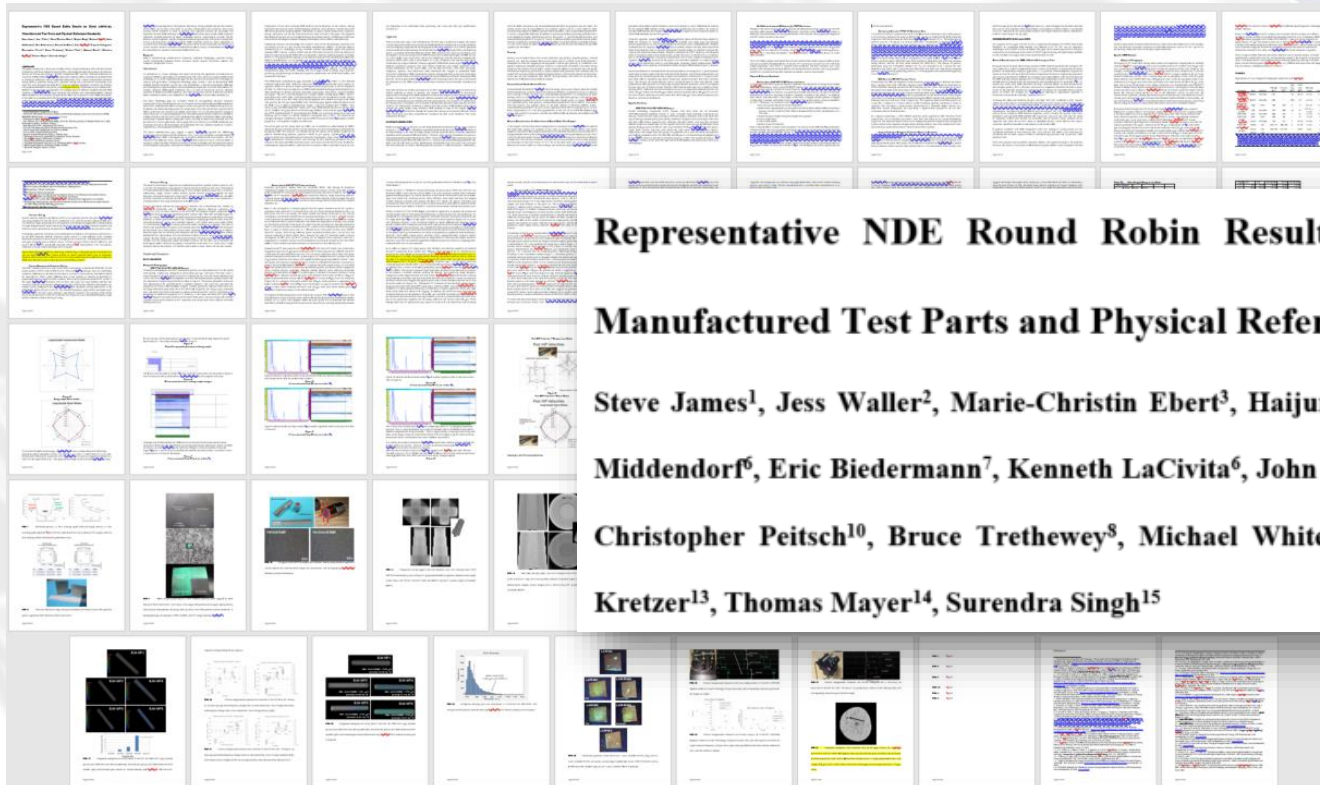
NDE Round Robin Results on Metal Additive Manufactured Test Parts

Steve James, Jess Waller, Charles Nichols, Eric Biedermann, Marie Ebert, Haijun Gong, Christian Kretzer, Thomas Mayer, Masami Mitsui, Tsuyoshi Nakagawa, Karen Taminger, John Middendorf, Shane Collins, Scott Volk, Michael White, Mark Warchol, Janelle Chambers, Bonnie Wang and many others

ASTM Symposium on Structural Integrity of Additive Manufactured Parts
8:30 AM, November 6, 2018 Washington, DC

Fifth paper summarizing Round Robin Test findings has taken longer to complete (currently in review):

5. Steve James, Jess Waller, Marie-Christin Ebert, Haijun Gong, Richard Grylls, John Middendorf, Eric Biedermann, Kenneth LaCivita, John Brausch, Tsuyoshi Nakagawa, Christopher Peitsch, Bruce Trethewey, Michael White, Edward Ginzel, Christian Kretzer, Thomas Mayer, Surendra Singh, "Representative NDE Round Robin Results on Metal Additively Manufactured Test Parts and Physical Reference Standards," *Material Performance and Characterization*, ASTM International, West Conshohocken, PA (in review).



Representative NDE Round Robin Results on Metal Additively Manufactured Test Parts and Physical Reference Standards

Steve James¹, Jess Waller², Marie-Christin Ebert³, Haijun Gong⁴, Richard Grylls⁵, John Middendorf⁶, Eric Biedermann⁷, Kenneth LaCivita⁶, John Brausch⁸, Tsuyoshi Nakagawa⁹, Christopher Peitsch¹⁰, Bruce Trethewey⁸, Michael White¹¹, Edward Ginzel¹², Christian Kretzer¹³, Thomas Mayer¹⁴, Surendra Singh¹⁵

Transition Status of Specific NDE of AM Tasks to MSFC

Bring NASA strength and depth to the table for Additive Manufacturing

- Core MSFC Team:
 - Walker, Lanigan, Wells, and West
- Transition in progress for NASA MSFC to lead the following AM activities: (**done/in progress**) – all may require funding for MSFC
 - Lead NDE portion of 1st ASTM Additive Manufacturing Center of Excellence Workshop on March 25, 2019 (led by MSFC, EWI and Auburn University)
 - Participate/lead NDE portion of Oct. 8-9, 2019 Symposium on Structural Integrity of Additive Manufactured Parts (Washington, D.C.)
 - Determine value to NASA of draft NDE-related standards on Seeded Defects (F42 WK56649), In-Situ Monitoring (E07.10 WK62181), CT Metrology (E07.01 WK61161 and WK61974), and Data Fusion (current E07.10 action)
 - Lead efforts for effect-of-defect, Probability of Detection, and NDE inspection categories, especially for fracture critical metal spaceflight hardware. NASA MSFC is working with NIST (Kim), linkage also made with the MTC (Dutton).
 - Lead future ASTM classes on NDE of metal AM hardware (transferred to Steve James, formerly of Aerojet Rocketdyne)
 - Lead June 3rd NDE of AM discussions at E07.10 Taskgroup meetings
 - Lead NASA NDE discussions with JAXA and ESA

1st ASTM AM COE Workshop
March 25, 2019
(transitioned to MSFC)



ASTM INTERNATIONAL
Helping our world work better

1st ASTM Additive Manufacturing Center of Excellence Workshop

March 25, 2019

Auburn Marriott
Opelika Resort & Spa
at Grand National
Opelika, AL

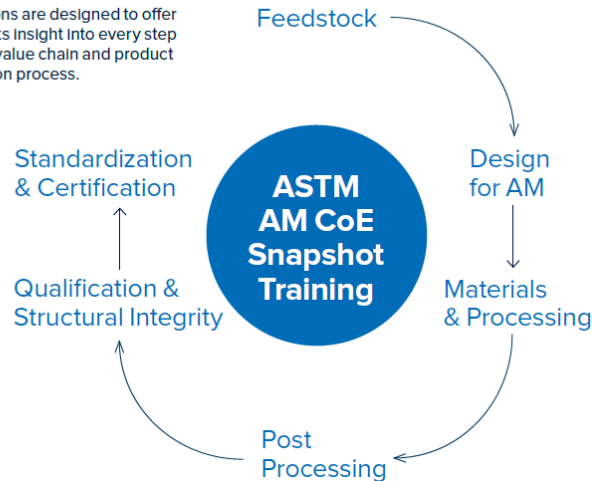
www.astm.org

Registration
is limited to
150
participants



Session Topics

The sessions are designed to offer participants insight into every step in the AM value chain and product qualification process.



Agenda

7 a.m.	Breakfast	2 p.m.	Non-Destructive Evaluation & Inspection <i>James Walker, NASA Marshall Space Flight Center</i>
	Feedstock		
8 a.m.	Powder Specification <i>Nick Weeks, LPW/Carpenter Additive</i>	2:45 p.m.	Break
9:30 a.m.	Powder Characterization <i>Steven Hall, The MTC</i>		Qualification & Structural Integrity
10:15 a.m.	Break	3 p.m.	Mechanical Characterization of AM Metallic Materials <i>Nima Shamsaei, Auburn University</i>
	Design for AM		
10:30 a.m.	Design for AM <i>David Rosen, Georgia Tech University/ SUTD</i>	3:45 p.m.	Mechanical Characterization of AM Non-Metallic Materials <i>Rachael Andrulonis, NIAR</i>
	Materials & Processing		
11:15 a.m.	Materials & Process Development <i>Frank Medina, EWI/UTEP</i>	4:15 p.m.	Break
11:45 a.m.	Lunch		Standardization & Certification
12:45 p.m.	Process Qualification <i>Doug Wells, NASA</i>	4:30 p.m.	AM Standardization <i>John Slotwinski, John Hopkins University</i>
	Post Processing		
1:30 p.m.	Post Processing <i>Alex Kitt, EWI</i>	5 p.m.	Aerospace Certification <i>Michael Gorelik, FAA</i>
		5:30 p.m.	Medical Certification <i>Matthew DiPrima, FDA</i>
		6 p.m.	Social Networking Event



4th ASTM Symposium on
Structural Integrity of AM Parts
October 8-10, 2019
(transitioned to MSFC)



October 8-10, 2019
Gaylord National Resort
and Convention Center
Washington, D.C.



2019 Scientific & Technical Committee (STC):

Anil Sachdev, General Motors

Ben Dutton, MTC

Charles Park, Boeing

Chee Kai, NTU

Chris Holshouser, NIAR

Doug Wells, NASA Marshall

Filipo Berto, NTNU

Frank Medina, EWI

Johannes Gumpinger, ESA

Matthew DiPrima, FDA

Matthew Donovan, Oerlikon

Michael Gorelik, FAA

Mohsen Seifi, ASTM Interntl.

Nik Hrabí, NIST

Nima Shamsaei, Auburn Univ.

Rachael Andrulonis, NIAR

Rod McMillan, Johnson & Johnson

Stefano Beretta, Polytechnic of Milan

Steve Daniewicz, Univ. of Alabama

Thomas Niendorf, Univ. of Kassel

Tony Thornton, Micromeritics

This event will provide a forum for the exchange of ideas regarding the structural integrity of materials and components fabricated using additive manufacturing with a focus on the lack of industry standards, design principals, as well as qualification and certification criteria. This event is designed for professionals within the AM community including industrial (aerospace, medical, automotive and defense), academic, government and regulatory.

To participate in the symposium, authors must submit a 200-250 word preliminary abstract using the online Abstract Submittal Form, **no later than May 15th, 2019.**

Erin Lanigan, Doug Wells, and Brian West of MSFC and Rick Russell of the NESC participated in the 2018 3rd Annual Symposium



NDE of AM Courses and Webinars (transitioned to MSFC, LaRC, and others)

Quality Engineering Webinar (Waller):¹

May 30, 2017



¹ Satern Course SMA-DFS-011,
Sponsoring organization: NASA
Safety Center Quality Engineering.
Hosts: Mike Lipka and Gene Monroe

Other presentations given by D.
Wells and D. Jegley

<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170005627.pdf>

ASTM NDE of AM Webinar (Waller, James):²

Feb. 6 and 13, 2018 (Waller)
Apr. 9 and 16, 2019 (James)



² New content presented by S. James
(Aerojet Rocketdyne, ret'd.) in April

2018 content:

<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20180001858.pdf>

NASA Safety Center Course (Burke and Wells):³

Dec. 11, 2018

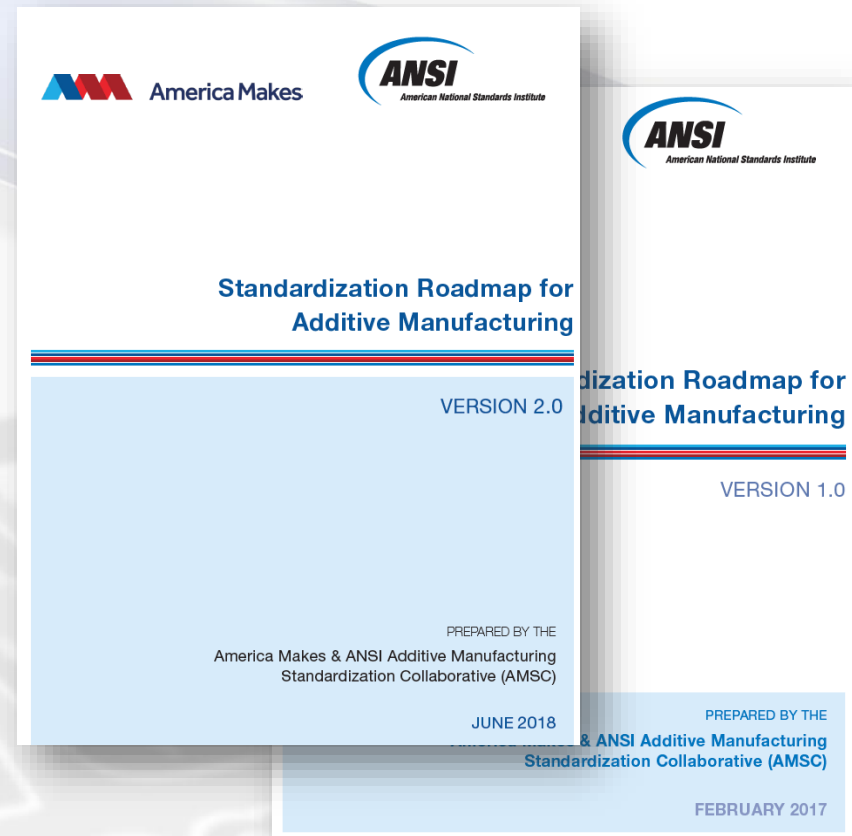
Qualification & Certification of Additively Manufactured Parts for NASA Applications

NASA Safety Center, Webinar
December 11, 2018

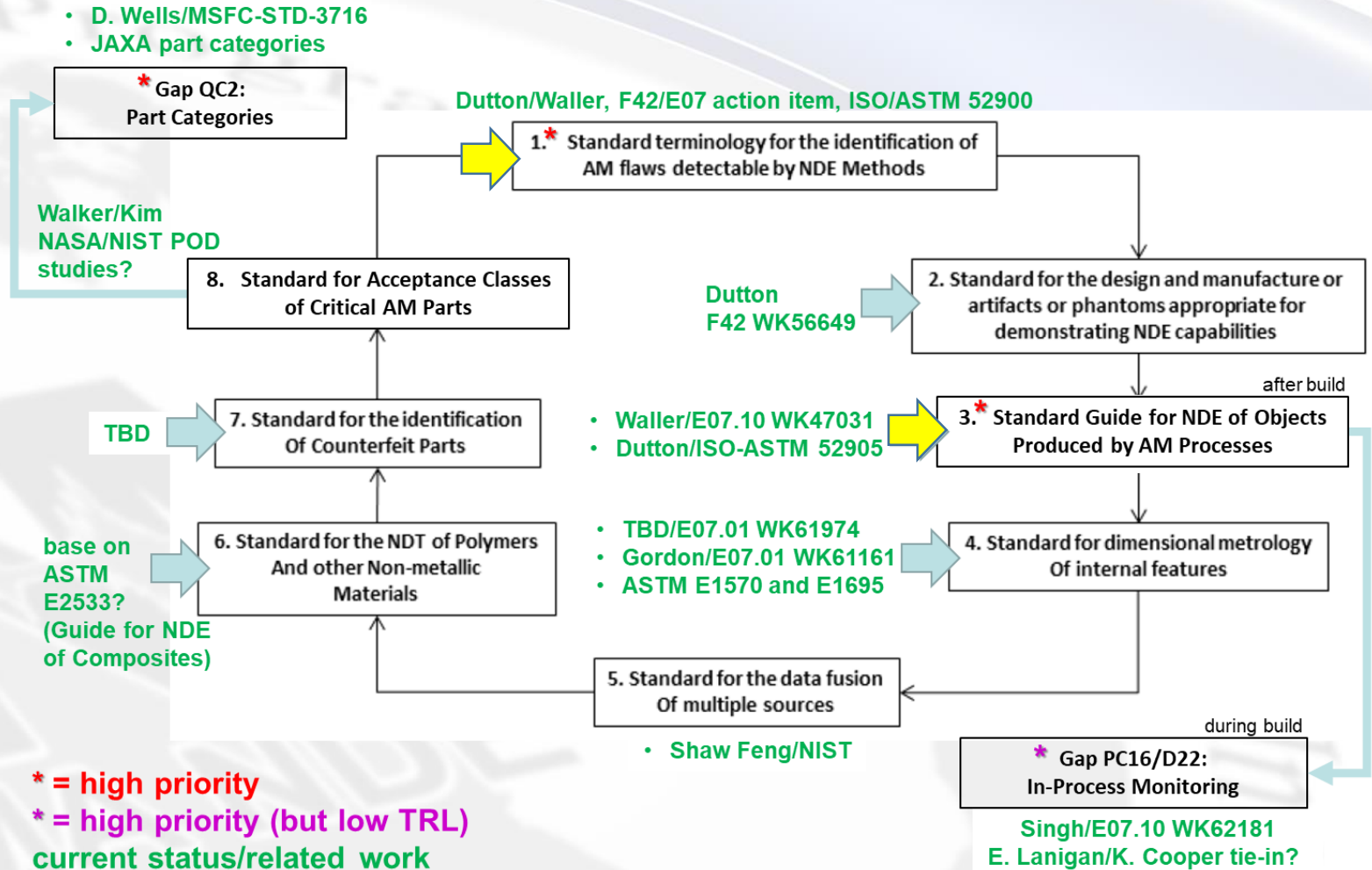
³ Satern Course SMA-QE-WBT-202,
Customer: Michael P. Kelly, NSC
Quality Engineering Technical
Discipline Team Lead

Additive Manufacturing NDE Voluntary Consensus Standards (being transitioning to MSFC)

- 89 standards gaps identified
 - 26 design gaps
 - 7 precursor materials gaps
 - 17 process control gaps
 - 6 post-processing gaps
 - 5 finished materials gaps
 - **8 NDE gaps**
 - 15 Q&C gaps
 - 8 maintenance gaps
- Gaps were ranked low (19), medium (51), or high (19) priority depending on criticality, achievability, scope, and effect.



NDE of AM Standards In Progress or Planned



- Upcoming June 3, 2019 meeting will focus on Round Robin testing close-out, anything MSFC wants to cover related to AM, WK47031 balloting, and upcoming PMC/COPVs standard revisions (E2981, E2982, and E2533).

AGENDA

ASTM E07.10, Subcommittee on Specialized NDT Methods TASK GROUP ON NDT OF AEROSPACE MATERIALS

Monday, January 21, 2019
11:00 am to 2:00 pm EST (GMT-05:00)
Fort Lauderdale, FL

11:00 **Call Meeting to Order; Introductions around the table, plus roll call for remote WebEx meeting attendees (Jess Waller, NASA WSTF, Las Cruces, NM)**

11:05 Round Robin Testing

- 11:05 Summary of America Makes/ANSI NDE of AM Standardization Roadmap and Associated Activities Including Round Robin Testing (Jess Waller)
- 11:15 Invited Talk: *Towards the Detection of Defects and their Effect on Mechanical Properties of AM Components*, Griff Jones, Penn State University, CIMP-3D
- 11:45 Future Talks (tentative)
 - CT Research Activities and Development of POD Curves for AM Parts, Felix Kim, NIST
 - Data Fusion of In-situ and Ex-situ Measurements for Additive Manufacturing, Shaw Feng, NIST
 - CT Round Robin Testing, Anton Du Plessis, Stellenbosch University, Central Analytical Facilities
 - Neutron Tomography of Ti-6Al-4V Porosity Bars, Anna Paradowska, Australian Centre for Neutron Scattering
 - Concept Laser CT Physical Reference Standards Results
 - Eric Karlan, UTAS/Collins (findings in export control)
 - Justin Jones, NASA GSFC (deferred to a later date)
 - Cliff Bueno, GE Global Research (current custodian)
- 11:55 Future Meetings
 - 1st ASTM Additive Manufacturing Center of Excellence Workshop, Opelika, AL, March 25, 2019 (sponsored by ASTM, Auburn University, EWL, NASA MSFC and others)
 - 4th ASTM Symposium on the Structural Integrity of Additive Manufactured Parts, Washington DC, October 15-17, 2019 (sponsored by ASTM F42, E08, and E07)

12:00-1:00 **Lunch on your own**

1:00 **ASTM E07.10 NDE of AM standard**

- WK47031 *Guide for Nondestructive Testing of Metal Additive Manufactured Aerospace Parts After Build* (POC: Jess Waller)
 - 18-05 balloting results (closed 1/11/2019):
 - Negatives (4)
 - Comments (6)
 - Future balloting

1:40 **Other ASTM Standard with relevance to NDE/Additive Manufacturing**

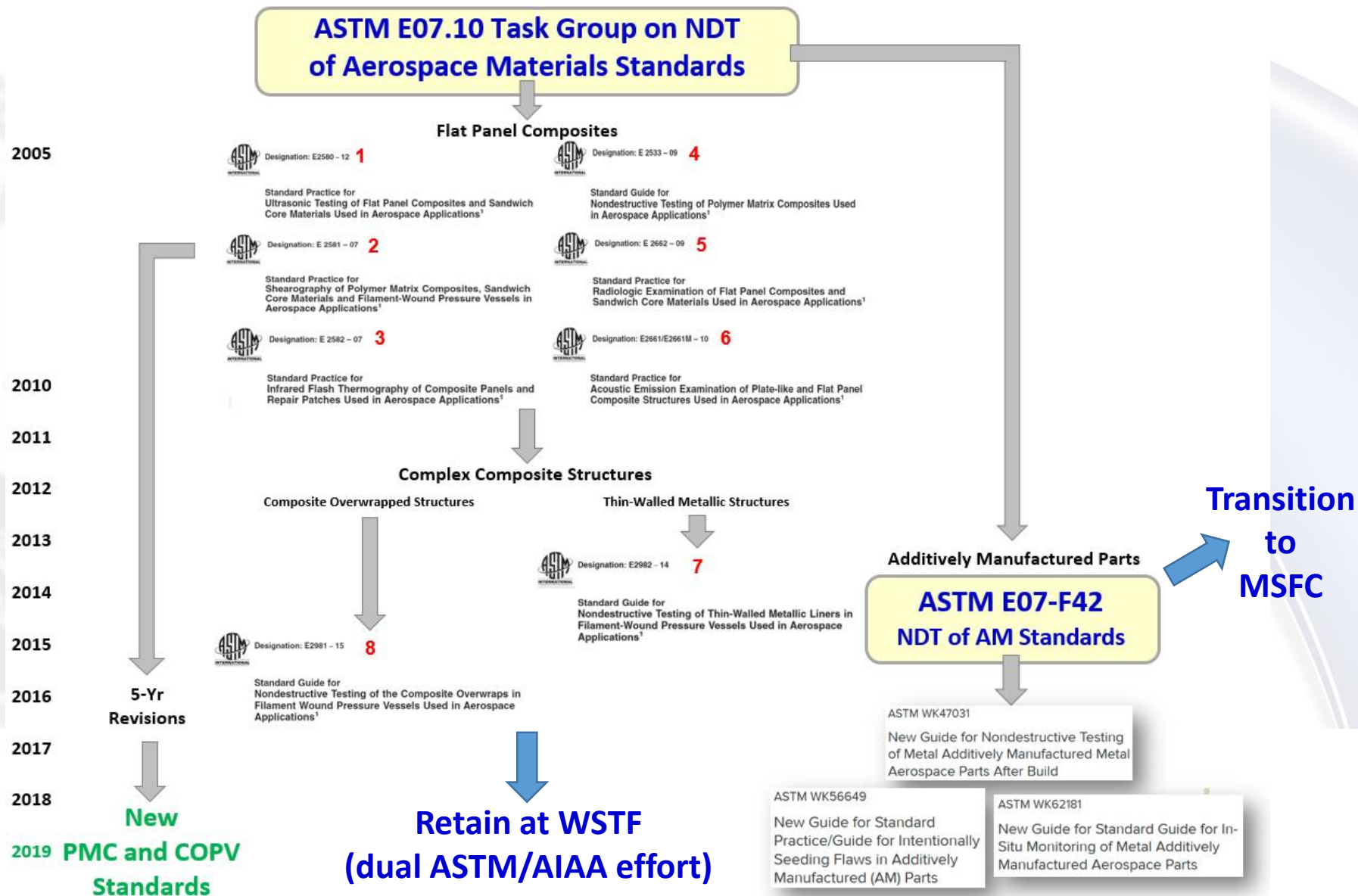
- ASTM F42.01/ISO TC 261 JG59 WK56649 *Guide for Intentionally Seeding Flaws in Additive Manufactured Parts* (POC: Ben Dutton)
- ASTM E07.01 standards
 - ASTM WK61161 *New Practice for Volumetric Computed Tomographic (CT) Examination Using Digital Detector Arrays* (POC: Trey Gordon, SpaceX)
 - ASTM WK61974 *New Practice for characterization of computed tomography systems for dimensional measurement* (POC: Thomas Wentzel, YXLON)

1:45 **Status on E07 Flat Panel Composite and Composite Overwrapped Pressure Vessel (COPV) Standards**

- Flat Panel Composite Standards**
 - Status: **Ballot Action Required**
 - E2582-07(2014) *Practice for Infrared Flash Thermography of Composite Panels and Repair Patches Used in Aerospace Applications* (POC: Engels (E07.10))
 - Status: **Ballot Action Required**
- COPV Standards**
 - E2982-14 *Guide for Nondestructive Testing of Thin-Walled Metallic Liners in Filament-Wound Pressure Vessels Used in Aerospace Applications* (POC: Waller (E07.10))
 - Status: **Ballot Action Required**

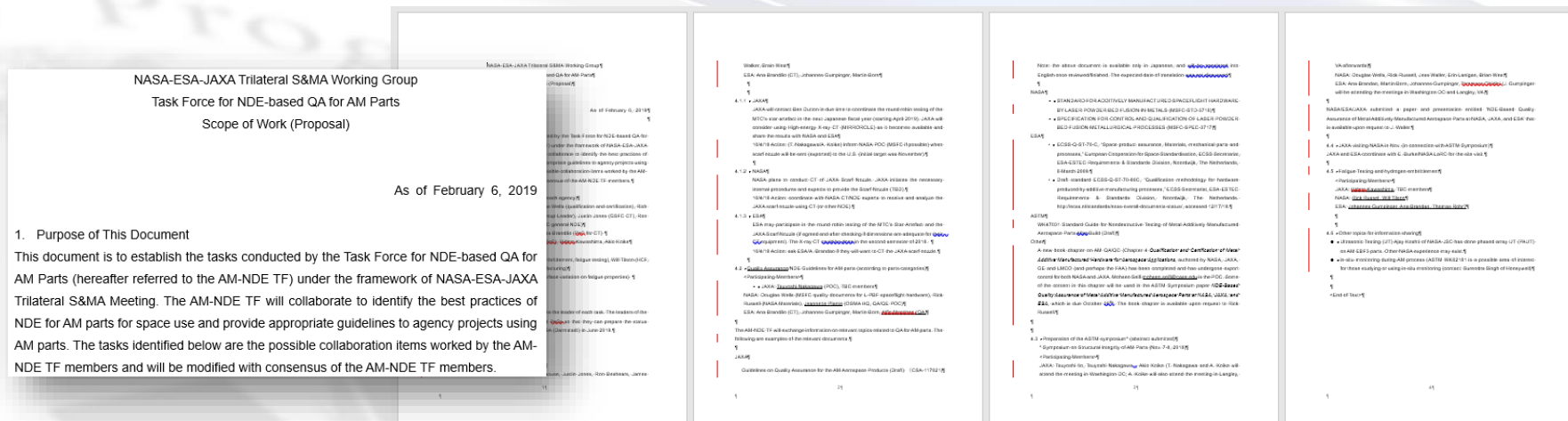
1:50-2:00 **Break**

- 14-year effort funded by OSMA and the NTSP0



NASA-JAXA-ESA Trilateral Collaboration on Additive Manufacturing (transition to MSFC?)

NASA/ESA/JAXA Statement of Work (Feb. 2019):



Annual Trilateral/TRISMAC meeting on June 7, 2018:

NDE Qualification of Metal Additive Manufactured Spaceflight Hardware

OSMA Trilateral Meetings - NASA

Additive Manufacturing at ESA

Martin Born
 Product Assurance & Safety (PA&S) Manager at ESA for
 European Data Relay Satellite System (EDRS)

June 7th, 2018

JAXA Activities on Quality Assurance of AM Parts for Space Use

June 7th, 2018

Safety and Mission Assurance Department
 Japan Aerospace Exploration Agency

Thank you!
with gratitude and humility

Gratitude is marked by a sense that one has benefited from the actions of others.
Humility is characterized by low self-focus, secure sense of self, and increased valuation of others.

Back-ups

Background

- Ongoing voluntary consensus organization (VCO) standards effort managed under the jurisdiction of ASTM Committee E07 on NDT can be subdivided into four areas:
 - Polymer matrix composite flat panels (E2580, E2581, E2582, E2661, E2662, and E2533)
 - Composite overwrapped pressure vessels (E2981 and E2982)
 - Metal structures (E07.07 ECT of thin-walled metals liners, E07.05 neutron digital radiography of fairings and frangible joints) (possible standards not pursued)
 - Metal additively manufactured parts:
 - E07 WK47031 (NDE of AM) POC: Waller
 - E07 WK62181 (*in-situ* monitoring) POC: Singh (Honeywell)
 - F42 WK56649 (seeded defects) POC: James, Dutton (MTC)

Current Schedule

- **Balloting of NDE of AM Standard** May 2019
 - **WK47031 (NDE of metal AM Aerospace Parts)**
- **June Committee Meeting (attend remotely if necessary)** June 2019
 - **Discuss above balloting results**
 - **Register E2981 work item (NDE of COPV composite overwraps)** AM
- **Balloting of COPV Standard** July 2019 no AM
 - **E2982 WK67293 (NDE of metal COPV liners)**
- **Future balloting of E07 E2981, E2982, and E2533 (& G04 G114)** (requires funding)
- **January E07 Committee Week Meeting (& Apr. G04 telecons)** January 2020
(requires funding)
- **June E07 Committee Week Meeting (& Oct. G04 telecons)** June 2020
(requires funding)

The NASA Technical Standards Program Office is a possible alternate source for General VCO Support for the **above**



- Biannual E07.10 Taskgroup meetings held each Jan/June.
- Support and interest from industry, government, and academia has been excellent (50+ members per meeting, see next 3 slides).
- Taskgroup meetings have split time between PMC/COPV and AM standards. Except for AM Round Robin Testing close-out and WK47031 balloting and adoption, future meetings will focus on NDT of PMCs/COPVs exclusively.
- The plan is to have NASA MSFC step into role of interfacing with ASTM Committee E07 for AM standards (James Walker intends to join E07 to represent NDE of AM standardization activities).
- J. Waller (technical POC for each) still on hook to coordinate balloting of:
 - E2533 (PMC Guide)
 - E2981 (COPV composite overwrap Guide)
 - E2982 (COPV composite overwrap Guide)
- Ed Generazio (since 2005) and Paul Gill (split effort with Ed from ca. 2005-2007) provided generous support for Committee E07 involvement:
 - 2005-2012: George Matzkanin E07.10 Task Group chair
 - 2012-present: Jess Waller E07.10 Task Group chair
- Both E07 and the NESC NDE TDT represent great opportunities for NASA to engage with industry NDE experts.
 - E07 membership currently has over 500 members with roughly 100 members attending each of the biannual meetings

PMC and COPV standards



Designation: E2580 – 12

**2nd 5-Year Reapproval
Completed 2017**

Standard Practice for
Ultrasonic Testing of Flat Panel Composites and Sandwich
Core Materials Used in Aerospace Applications¹



Designation: E2661/E2661M – 10

**5-Year Reapproval
Completed 2015**

Standard Practice for
Acoustic Emission Examination of Plate-like and Flat Panel
Composite Structures Used in Aerospace Applications¹



Designation: E2581 – 14

**5-Year Reapproval
Completed 2014**

Standard Practice for
Shearography of Polymer Matrix Composites and Sandwich
Core Materials in Aerospace Applications¹



Designation: E2662 – 09

**5-Year Reapproval
Completed 2015**

Standard Practice for
Radiologic Examination of Flat Panel Composites and
Sandwich Core Materials Used in Aerospace Applications¹



Designation: E2582 – 07 (Reapproved 2014)

**5-Year Reapproval
Completed 2014**

Standard Practice for
Infrared Flash Thermography of Composite Panels and
Repair Patches Used in Aerospace Applications¹



Designation: E2533 – 09

**5-Year Reapproval
Completed 2016,
edited 2017**

Standard Guide for
Nondestructive Testing of Polymer Matrix Composites Used
in Aerospace Applications¹



Designation: E2982 – 14

Adopted in 2014

Standard Guide for
Nondestructive Testing of Thin-Walled Metallic Liners in
Filament-Wound Pressure Vessels Used in Aerospace
Applications¹



Designation: E2981 – 15

Adopted in 2015

Standard Guide for
Nondestructive Testing of the Composite Overwraps in
Filament Wound Pressure Vessels Used in Aerospace
Applications¹

PMC and COPV standards



Designation: E2580 – 12

**2nd 5-Year Reapproval
Completed 2017**

Standard Practice for
Ultrasonic Testing of Flat Panel Composites and Sandwich
Core Materials Used in Aerospace Applications¹



Designation: E2581 – 14

**2nd 5-Year reapproval
Due (Newman)**

Standard Practice for
Shearography of Polymer Matrix Composites and Sandwich
Core Materials in Aerospace Applications¹



Designation: E2582 – 07 (Reapproved 2014)

**5-year revision begun
WK66824 (E07.10)**

Standard Practice for
Infrared Flash Thermography of Composite Panels and
Repair Patches Used in Aerospace Applications¹



Designation: E2982 – 14

**5-year revision begun
WK67293 (Waller)**

Standard Guide for
Nondestructive Testing of Thin-Walled Metallic Liners in
Filament-Wound Pressure Vessels Used in Aerospace
Applications¹



Designation: E2661/E2661M – 10 **5-Year Reapproval
Completed 2015**

Standard Practice for
Acoustic Emission Examination of Plate-like and Flat Panel
Composite Structures Used in Aerospace Applications¹



Designation: E2662 – 09

**5-Year Reapproval
Completed 2015**

Standard Practice for
Radiologic Examination of Flat Panel Composites and
Sandwich Core Materials Used in Aerospace Applications¹



Designation: E2533 – 09

**5-Year Reapproval
Completed 2017,
edited 2019**

Standard Guide for
Nondestructive Testing of Polymer Matrix Composites Used
in Aerospace Applications¹



Designation: E2981 – 15

**5-year revision begun
WK TBD (Waller)**

Standard Guide for
Nondestructive Testing of the Composite Overwraps in
Filament Wound Pressure Vessels Used in Aerospace
Applications¹

Customers, Products

- Customers:

- For COPVs/PMCs: SpaceX & Boeing/Commercial Crew Program: Kathy Lueders, Commercial Crew Program Manager, Gateway Program: Orion SLS EM-1, EM-2, and moon missions: Dan Hartman, Gateway Program Office Lead, NESC: Bill Prosser, NESC NDE Technical Fellow, NESC: Lorie Grimes-Ledesma, Composite Pressure Vessel Working Group Leads, Human Spaceflight: Nate Greene, NASA-JSC, Pressure Systems/Fracture Technical Discipline Lead, Orion MPCV and ESA crew modules: Ian Juby, Pressure Systems Engineer for COPVs, Boeing CST-100/ULA Atlas 5 rocket: Aaron Laney, Pressure Systems Engineer for COPVs.

- FY18-FY19 Products:

- NASA Safety Center course on NDE-based Qual & Cert of L-PBF AM Hardware: Dec. 11, 2018
- NASA-JAXA-ESA AM Collaboration telecons, TRISMAC presentation, and draft Statement of Work
- Co-chaired 3rd ASTM Symposium on Structural Integrity of AM Parts (NDE portion): Nov. 6-8, 2018
- QLF and JAPC presentations (QA/QE audience): March 15, 2018 and Feb. 7, 2018
- 1 book chapter on Qual & Cert of L-PBF Metal AM Aerospace Hardware
- 1 magazine article on CT of metal AM Parts
- 5 peer-reviewed NDE of AM articles (4 ASTM STP 1620 publications + 1 ASTM MPC publication)
- Transfer of NDE of AM tasks to NASA MSFC (primarily James and Erin)
- ASTM Charles W. Briggs Award for continuous and outstanding contributions to the work of Committee E07 on Nondestructive Testing: March 2018

- Future NDE Standards Products:

- One new standard (WK47031) (accomplish with existing funding)
- Two 5-year revisions of current NDE of PMC/COPV standards (E2981, E2982) and technical editing of E2533 based on E2981, E2982 revisions (requires new funding)

2019 Products (Publications):

- du Plessis, A. and Waller, J. M., "Simple and standardised X-ray CT testing in metal Additive Manufacturing," *Metal AM* 4(4), 87-96, Winter 2018. https://issuu.com/inovar-communications/docs/mam_winter_2018_sp?e=32443561/66482405
- Dutton, B., Vesga, W., Waller, J., James, S., and Seifi, M., "Additive Manufacturing Defect Formation and NDE Detectability," in *ASTM Symposium on Structural Integrity of Additive Manufactured Parts*, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).
- S. James, J. Waller, M.-C. Ebert, H. Gong, E. Biedermann, K. LaCivita, J. Brausch, T. Nakagawa, C. Peitsch, B. Trethewey, M. White, E. Ginzel, C. Kretzer, T. Mayer, S. Singh, and J. Middendorf, "Representative NDE Round Robin Results on Metal Additively Manufactured Test Parts and Physical Reference Standards," in *Materials Performance and Characterization*, ASTM International (in preparation).
- Na, J. K., Middendorf, J., Lander, M., Waller, J. M., "Nondestructive Evaluation of Programmed Defects in Ti-6Al-4V L-PBF ASTM E8-compliant Dog-bone Samples," in *ASTM Symposium on Structural Integrity of Additive Manufactured Parts*, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).
- Livings, R. A., Biedermann, E. J., Wang, C., Chung, T., James, S., Waller, J. W., Volk, S., Krishnan, A., Collins, S., "Nondestructive Evaluation of Additive Manufactured Parts Using Process Compensated Resonance Testing," in *ASTM Symposium on Structural Integrity of Additive Manufactured Parts*, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).
- Waller, J., Rojdev, K., Peters, B., Shariff, K., Litteken, D., Hagen, R., Valle, G., Nichols, C., "Simulated Space Radiation Effects on Inflatable Habitat, Composite Habitat, Space Suit, and Space Hatch Materials," *WSTF-IR-1250-001-18*, NASA Johnson Space Center White Sands Test Facility, Las Cruces, New Mexico (in review).
- Waller, J.M., Nichols, C. T., Burke, E. R., Wells, D. N., Brandão, A. D., Gumpinger, J., Born, M., Ghidini, T., Nakagawa, T., Koike, A., Mitsui, M., Itoh, T., "NDE-Based Quality Assurance of Metal Additive Manufactured Aerospace Parts at NASA, JAXA, and ESA," in *ASTM Symposium on Structural Integrity of Additive Manufactured Parts*, ASTM STP 1620, M. Seifi and N. Shamsaei, Eds., ASTM International, West Conshohocken, PA (in press).
- Russell, R., Wells, D., Waller, J. M., Poorganji, B., Ott, E., Nakagawa, T., Sandoval, H., Shamsaei, N., Seifi, M., "Qualification and Certification of Metal Additive Manufactured Hardware for Aerospace Applications," Chapter 3, in *Additive Manufacturing for the Aerospace Industry*, Boyer and Froes, Eds., Elsevier, December 2019. <https://www.elsevier.com/books/additive-manufacturing-for-the-aerospace-industry/froes/978-0-12-814062-8>

Round Robin Testing of AM Parts

ASTM WK47031 Round Robin Testing

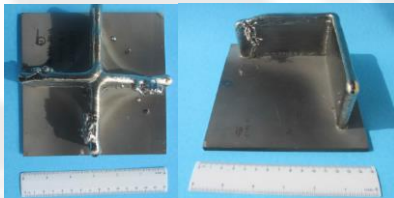
Coordinated by S. James and J. Waller

Electron Beam Freeform Fabrication (EBF³)

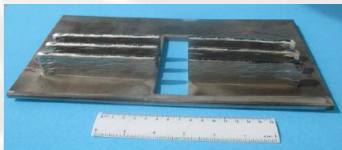
NASA LaRC
Inconel 625 on copper



Ti-6Al-4V (4)



SS 316



Al 2216

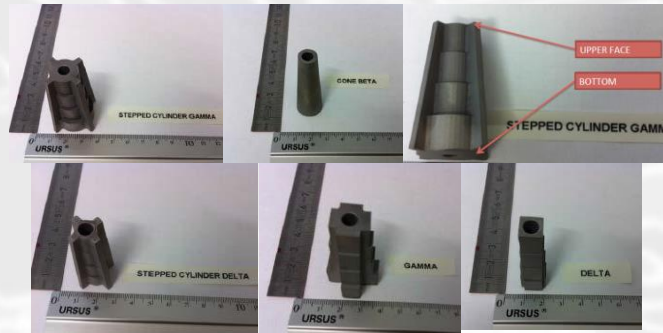


Laser-PBF (L-PBF)

Concept Laser Inconel 718 inserts (6)
w/ different processing history



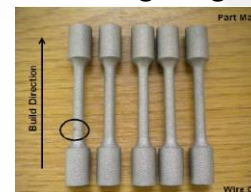
Concept Laser Inconel 718 prisms
for CT capability demonstration



Gong/Univ. of Louisville
Ti-6Al-4V bars

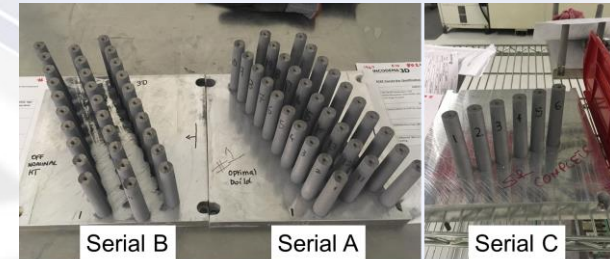


Airbus
Al-Si-10Mg dog bones

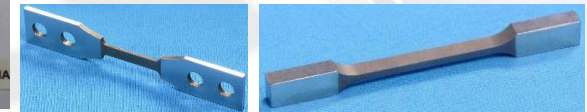


Laser-PBF (L-PBF)

Incodema3D
Al-Si-10Mg cylinders

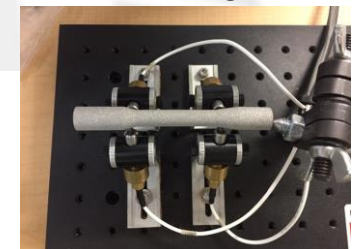


UTC/Southern Research
Inconel 718 and Ti-6A-4V dogbones



Electron Beam-PBF (E-PBF)

CalRAM
Ti-6Al-4V dogbones

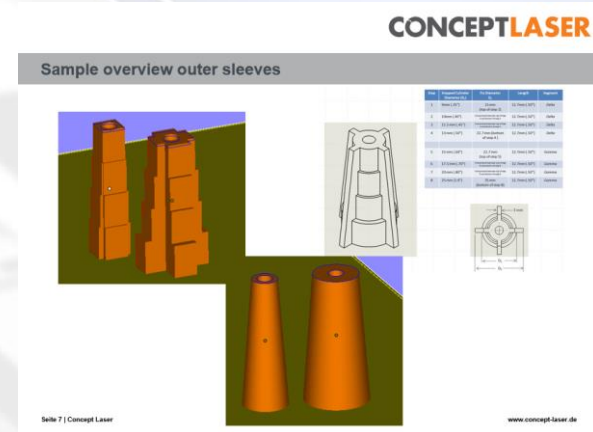
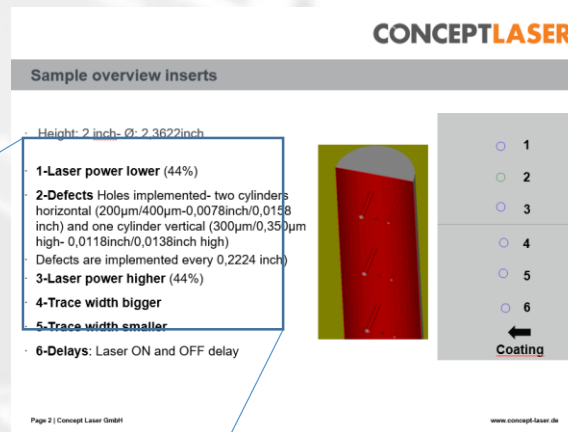


Characterized to date by various NDE methods (CT, DIC, PT, PCRT, RT, UT)

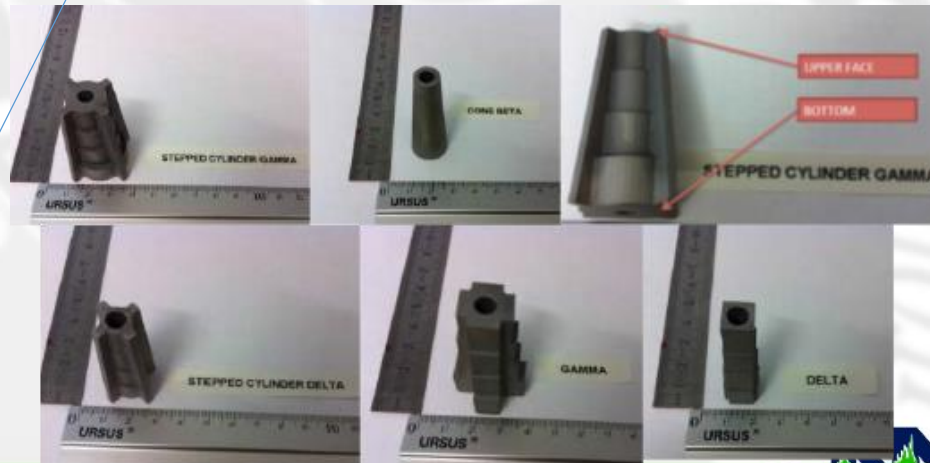
Concept Laser/GE CT Capability Demonstration Samples

Inconel® 718 inserts and sleeves fabricated in early 2016 and distributed to participants with CT capability

Inserts

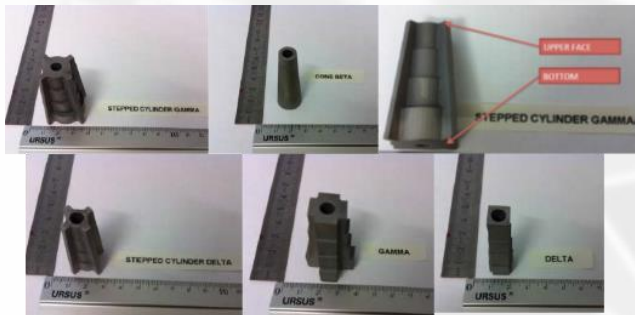


- 1-Laser power lower (44%)
- 2-Defects Holes implemented- two cylinders horizontal (200µm/400µm-0,0078inch/0,0158 inch) and one cylinder vertical (300µm/0,350µm high- 0,0118inch/0,0138inch high)
- Defects are implemented every 0,2224 inch
- 3-Laser power higher (44%)
- 4-Trace width bigger
- 5-Trace width smaller
- 6-Delays: Laser ON and OFF delay



CY19 Concept Laser/GE CT Sample Distribution

- Inconel[®] 718 inserts & sleeves fabricated in Jan. 2016 and distributed to participants
- CT results on this and other samples summarized in paper posted on WK47031 Collaboration Area



- 1-Laser power lower (44%)
- 2-Defects Holes implemented- two cylinders horizontal (200µm/400µm-0,0078inch/0,0158 inch) and one cylinder vertical (300µm/0,350µm high- 0,0118inch/0,0138inch high)
- Defects are implemented every 0,2224 inch)
- 3-Laser power higher (44%)
- 4-Trace width bigger
- 5-Trace width smaller
- 6-Delays: Laser ON and OFF delay

Schedule

Affiliation	contact	finish date
UTAS	Karlen	Feb-18
JHU-APL	Peitsch	Jun-18
NASA GSFC	Jones	Sep-18
GE Aviation	Bueno	Oct-18
Pratt & Whitney	Warner	Feb-19
NSI	Brinkhoff	Mar-19
LMCO	Barnes, Boss	2019
Pinnacle X-ray	Gormley	2019
Alloyweld Inspection	Kleven	2019
EWI	Kitt, Brooks	2019
Stellenbosch Univ.	Du Plessis	2019
Visiconsult	Schulenburg	2019
ESA	Brandao	2019
Return to Concept Laser/GE Additive	Ebert	EOCY19

Europe; Fraunhofer Development Center X-ray Technology, Yxlon, GE (Europe)

Japan; JAXA/Kobelco/NDI Corp.

Planned Evaluation (9)

N America; NASA MSFC, UTAS, JHU APL, NASA GSFC, GE Global, Pratt & Whitney, NSI, LMCO, Pinnacle X-ray, Alloyweld Inspection, EWI

So. Africa, Europe; Stellenbosch Univ., Visiconsult, ESA

Participation Rules

- Samples will be shipped as one set
- 1 month loan period
- Present findings at WK47031 Link Call
- Ship to next participant on list

List with addresses will accompany the samples



Guide for NDT of Additive Manufactured Aerospace Components
ASTM E07.10 Task Group on NDT of Aerospace Materials
FORT LAUDEDALE, FL
Monday, January 22, 2018
MINUTES

Attendees:

Present:

1Mark Carlos
Patrick Carlson
Terry Clausing
John Crnko
5Heather Dreiling
Lionel Gay
Denny Gorczyca
Matt Gormley
Trey Gordon
10Richard Gostautas
John Flaherty
Patrick Howard
Chad Henry
Ryan Johnson
15David Johnson
Sean Larkin
Vic Marconcini
Bill McKessy
Alan Metzel
20Jim Mitchell
Jim Neal
Jeff Pryor
Stephen Rice
Lennart Schulenburg
25Surendra Singh
Ed Stenger
Richard Stiff
Pat Thompson
Iirka Virkkonen
30Jess Waller

Mistras Group
NSI
Virtual Spectrum
Analytical Services, Inc.
Arconic
Safran
Pratt & Whitney
Pinnacle X-ray Solutions
SpaceX
Mistras Group
Fujifilm
GE Aviation
GKN Aerospace
Fujifilm
GE Aviation
Lickenbrock Technologies
Aerojet Rocketdyne
Arconic Howmet
Northrup Grumman
Structural Diagnostics
Fujifilm
ORNL
GE Aviation
VisiConsult X-ray
Honeywell Aerospace
ULA
Aerojet Rocketdyne
Honeywell Aerospace
Trueflaw
NASA WSTF HX5

Remote:

1Devin Barnes
Eric Biedermann
Mitch Boss
Janelle Chambers
5David Craig
Jeff Donahue
Matt Donovan
Ben Dutton
Donna Dykeman
10Marie Ebert
Andrew Good
Ben Green
Steve James
Alex Kitt
15Muzibur Khan
J Kozub
Greg Loughnane
Catalin Mandache
Rob Mason
20John Middendorf
Christopher Peitsch
Hank Phelps
Keith Randolph
M. Hashimi Rosli
25Evgueni Todorov
Scott Volk
Peter Woolliams

LMCO
Vibrant Corporation
LMCO
Southern Research
Pratt & Whitney CA
SpaceX.com
Oerlikon
MTC
Granta Design
GE
Jesse Garants Assocs
NASA WSTF/Jacobs
Aerojet Rocketdyne
EWI
NRC CNRC
Precision ADM
UTC Dayton
NRC CNRC
CTC
UTC Dayton
JHU APL
LMCO
Aerojet Rocketdyne
MTC
EWI
Incodema3D
NPL UK



Guide for NDT of Additive Manufactured Aerospace Components
ASTM E07.10 Task Group on NDT of Aerospace Materials
SAN DIEGO, CA
Monday, June 25, 2018
MINUTES

Attendees:

Present:

¹Eric Biedermann
Nick Brinkoff
Justin Byers
Pat Carlson
⁵Damaso Carreon
Terry Clausing
Klaus Bavendiek
Duane Dominick
Jim Engel
¹⁰Uwe Evert
Andy Ferro
Patrick Howard
Chad Henry
¹⁵David Johnson
Stewart Kleven
Thomas Maeder
Bill Meade
Joel Mohnacky
²⁰Stephen Pflanz
Stephen Rice
Tyler Ripperger
Jason Robbins
Don Roth
²⁵Lennart Schulenburg
Ed Stenger
Peter Takunju
Jess Waller

Vibrant Corporation
North Star Imaging
Pratt & Whitney Canada
North Star Imaging
USAF NDI Program Office
Virtual Spectrum
Yxlon Intl. GmbH
ATI Specialty Materials
consultant
BAM Berlin
GE Aviation
GE Aviation
GKN Aerospace
GE Aviation
Alloyweld Inspection Co.
Boeing
Blue Origin
UTC Aerospace Systems
Carestream NDT
GE Aviation
GE Aviation
Yxlon
Baker Hughes/GE Inspection
VisiConsult X-ray Systems
consultant
Arconic
NASA WSTF HX5

Andy Washabaugh
³⁰Uwe Zsherpel

Jentek Sensors
BAM Berlin

Remote:

¹Andrea Arguelles
Ana Brandao
Adam Brooks
Thomas Chung
⁵Christopher Kube
Anton Du Plessis
Roger Engelbart
Eric Fodran
Griffin Jones
¹⁰Justin Jones
Felix Kim
Catalin Mandache
John Middendorf
Joeng Na
¹⁵Christopher Peitsch
Scott Poveromo
Phillip Riegler
Evgueni Todorov
Bonnie Wang
²⁰Roxanne Warren
Lynne Webster

PSU CIMP3D
ESA
EWI
Northrup Grumman
Univ. Nebraska at Lincoln
Stellenbosch University
Boeing
Northrup Grumman
PSU CIMP3D
NASA GSFC
NIST
NRC CNRC
UTC Dayton
Wyle
JHU APL
Northrup Grumman
Norsk Titanium
EWI
Northrup Grumman
Norsk Titanium
Mitre



ASTM E07.10 Task Group on NDT of Aerospace Materials FORT LAUDERDALE, FL Monday, January 21, 2019 MINUTES

Attendees:

Present:

¹Frederick Beck
Justin Byers
Terry Clausen
Michael Coulton
⁵John Crnko
James Drechsel
Joshua Ford
Robert Francoeur
Matt Gormley
¹⁰David Gray
Harry Hahn
Bob Henchaor
Chad Henry
Edward Hohman
¹⁵Patrick Howard
Lemna Hunter
Griff Jones (speaker)
Stewart Kleven
Frederick Kaiser
²⁰Matt Meade
Alan Metzel
John Molinaro
Adrian Mondragon
Jim Neal
²⁵Mark Pompe
Tyler Ripperger
Don Roth

TAC Tech. Instrument Corp.
Pratt & Whitney Canada
Virtual Spectrum
TAC Tech. Instrument Corp.
Analytical Services, Inc.
Cummins Inc.
SpaceX
Pratt & Whitney
Pinnacle X-ray Solutions Inc.
Mitchell Laboratories
N/A
Test Equipment Distributors
GKN Aerospace
Bell Helicopter Textron
GE Aviation
Vibrant Corp. NDT
PSU CIMP3D
Alloyweld Inspection Co.
VisiConsult X-ray Systems
Blue Origin
Northrop Grumman
Fujifilm
N/A
Fujifilm Ndt Systems
WPTG
Baker Hughes/GE Inspection
Baker Hughes/GE Inspection

Lennart Schulenburg
Surendra Singh
³⁰Kristy Straiton
Peter Takunju
Chris Udell
Michael White
Zhan Zang

Remote:

¹Devin Barnes
Ana Brandão
David Craig
Carl Dekker
⁵Jim Engel
Eric Karlen
Ajay Krishnan
Jason Jones
Jason Kozub
¹⁰Rob Mason
Bill Meade
Anne-Francoise Obaton
Tom Ott
Christopher Peitsch
¹⁵Gerben Sinnema
Scott Volk
Jess Waller (POC)
Bonnie Wang

VisiConsult X-ray Systems
Honeywell Aerospace
ASTM
Arconic
Proceq SA Inc.
Met-L-Chek
Iowa State

LMCO
ESA
Pratt & Whitney Canada
Met-L-Flo
consultant
UTAS
Incodema3D
Moog Inc.
Precision ADM
Concurrent Technol. Corp
Blue Origin
LNE/France
Proceq USA Inc.
JHU APL
ESA
Incodema3D
NASA WSTF HX5
Northrup Grumman