



2021 EASA – FAA AM INDUSTRY – REGULATOR EVENT

(virtual meeting)



WORKING GROUP 2:

Fatigue and Damage Tolerance (F&DT) and Non-Destructive Inspection (NDI) Considerations for Metal AM

WG2 co-chairs:

M.Gorelik, Chief Scientist and Technical Advisor – Fatigue and Damage Tolerance, FAA

A.Fischersworing-Bunk, Senior Fellow Structures, MTU AeroEngines

Core Team:

Alain Santgerma (Airbus); Andre Danzig (Liebherr); Angel Martinez (ITP Aero); Armando Coro (ITP Aero); Arnaud Longuet (Safran Group); David Mills (Rolls-Royce); Doug Wells (NASA); Federica Vico (Lilium); Hilde Larsen (Norsk Titanium); Jonathan Leblanc (Safran Group); Kishore Tenneti (LMCO); Laura Kistler (Boeing); Marjolaine Cote (PWC); Markus Heinimann (Howmet Aerospace); Stefan Hermann (Liebherr); Tom Bertenshaw (GKN Aerospace); Tomas Mansson (GKN Aerospace)



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WG2 – Monday briefing (*20 min*)

- Summary of 2020 outcomes
- Summary of 2021 WG2 pre-work
- Discussion the format of b/o sessions

Objectives of the Monday Session:

- Overview of WG2 for the entire w/s (key outcomes of 2020 + materials developed by WG2 in 2021 – very brief summary)
- Setting the stage for two b/o sessions (Tue/Thu)

WG#2 Description

Fatigue and damage toleration (F&DT) related qualification considerations and related certification requirements have historically presented more significant challenges for structural components produced using process-intensive manufacturing technologies, and additive manufacturing (AM) is no exception. While all the key tenets of the certification requirements apply to AM, *there is a number of material system specific considerations that need to be understood and properly accounted for*, including inherent material anomalies and their effect on fatigue life, residual stresses, non-destructive inspection (NDI) challenges, effects of post-processing, etc.

The need for developing a good understanding of these factors is further elevated by the *expected near-term introduction of high-criticality AM parts* in Civil Aviation that will be subject to F&DT regulatory requirements.

The intent of this working group is to discuss the most recent developments in these technical areas, while *building on the outcomes of the F&DT and NDI breakout sessions from the 2019 and 2020 AM Workshops*, and to further develop considerations for aviation application of AM.

The *desired outcomes* of this working group and the corresponding breakout sessions during the 2021 AM Workshop include:

- A. Formulating recommendations for standards development organizations (SDOs) / industry working groups as to which AM-specific F&DT and NDI topics should be addressed by public standards or specifications, and to develop initial technical considerations to seed such discussion
- B. To develop recommendations for enabling R&D work (identification of specific research topics)



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WGs - development since 2020 Event (*note – breakout sessions were used since 2018 workshop*)

- Co-chairs and Core WG Teams identified and formed in advance of the 2021 event
- WG2 theme is recognized as a carry-over from the 2020 event

WG2 - Core Team (Aerospace Industry + Government)

- 10+ people supported several preparation meetings** in 2021
- WG2 objectives and priorities defined → *see next slide for priorities*
- Need for *tangible outputs* recognized:
 - Gap Analysis
 - Input to SDOs and Consortia work
 - Input into R&D prioritization

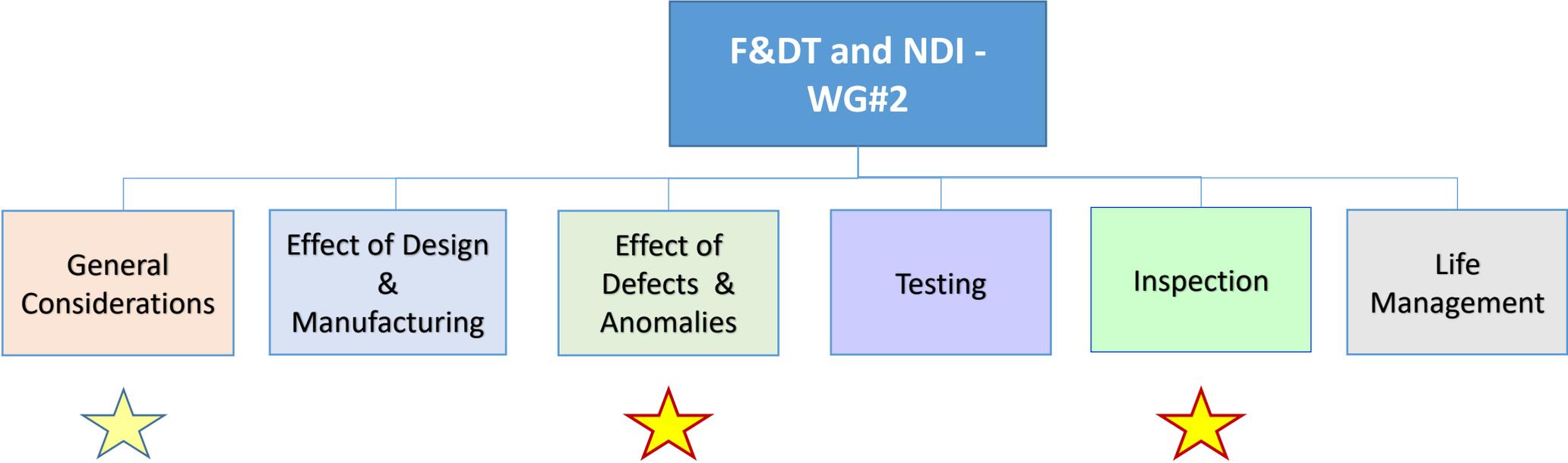
** WG2 preparation meetings held in 2021: 2nd July, 24th September, 14th October, 28th October, 5th November

Prioritization Result from 2020 Workshop

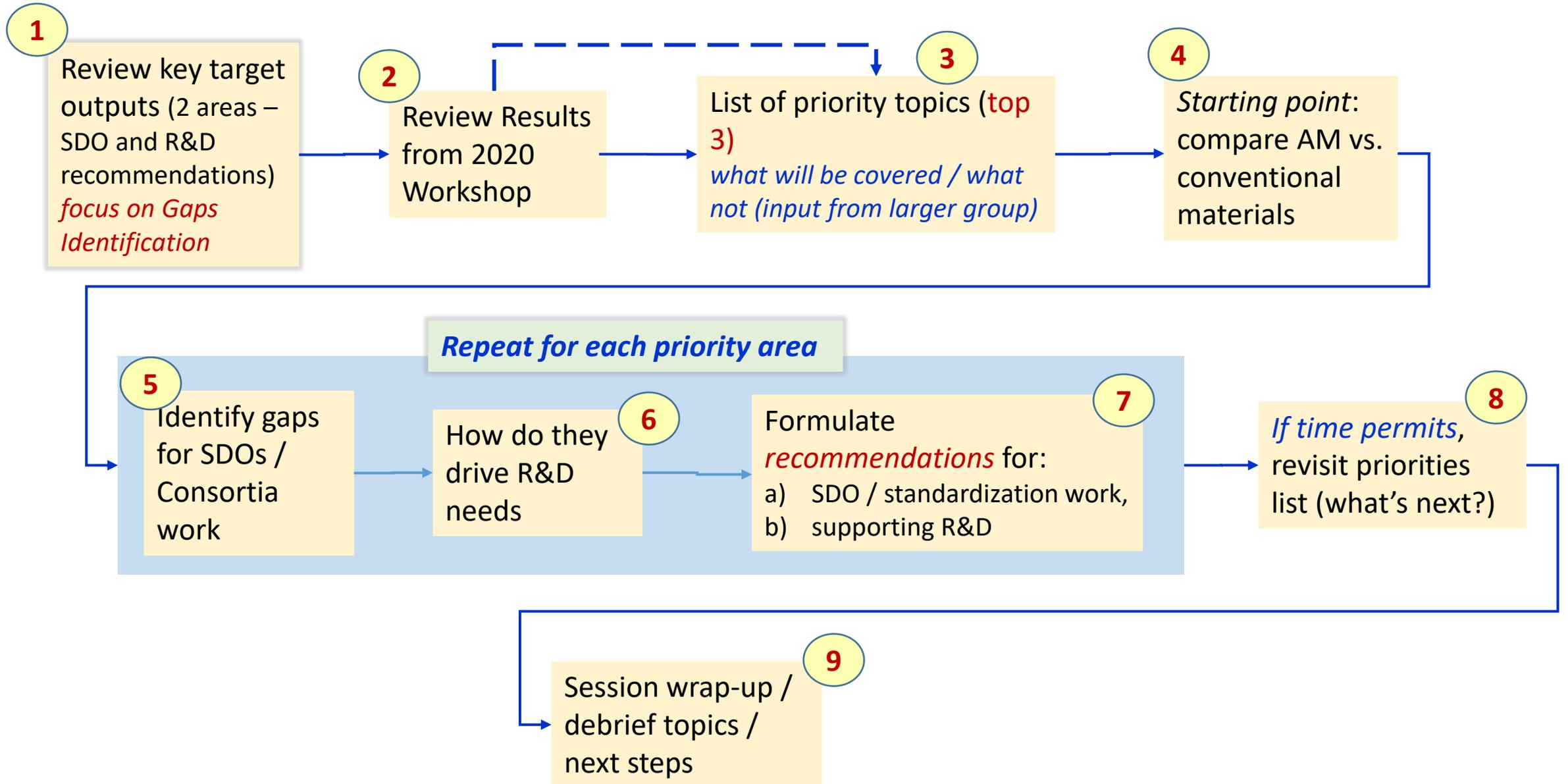
The 2020 prioritization results (“Top 3”) are still deemed relevant and will be carried forward in 2021

	A	B	C	D	E	F	G	H	I	J
1			1A.Fatigue		1B.DT		2A.NDI (connected to F&DT)		2B. NDI for QA	
2	What are the key Q&C technical challenges									
3	Data availability/data generation									
4	1.1		a) Relevance of coupon data to part-level data	9	a) Development of defects distribution (including exceedance curves)	7	a) Development of POD data - point value vs. POD vs. a?	1	a	
5	1.1		b) Generic material allowables vs. feature-based characterization (library?)	2	b) Effect of post-processing on DT (e.g. HIP -> volume defects, surface improvements -> surface integrity, RS mitigation, heat treatment -> homogeneity and anisotropy)	1	b		b) Effect of post-processing on NDI (e.g. HIP -> volume defects, surface improvements -> surface inspectability, heat treatment -> homogeneity and anisotropy).	2
6	1.1		c) Effect of post-processing on LCF (e.g. HIP -> volume defects, surface improvements -> surface integrity, RS mitigation, heat treatment -> homogeneity and anisotropy)	3	c) Relevance of test coupons to part properties	1	c) Develop in-process inspection POD	2		
7	1.1		d) Relevance of test coupons to part properties							
8										
9	Methods and tools									
10	1.2	a			a) Zoning	3	a) Selection and validation of appropriate NDI methods for given application and anomaly types	5	a	
11	1.2	b) Part family considerations		1	b) Deterministic vs. Probabilistic Assessment (DT)	5	b		b	
12	1.2	c			c) Conventional S-N vs. anomaly-related framework?	2	c) Effect of post-processing on NDI (e.g. HIP ->	2	c) In-situ monitoring - longer-term objective of displacing some conventional QA/NDI	2
13	1.2	d) Conventional S-N vs. anomaly-related framework?		2	d) Assessment of geometrically complex parts	2	d) Use NDI to help understand some of the eff	1	d	
14	1.2	e) Assessment of geometrically complex parts		3	e) Effect of post-processing on DT	2	e) Develop models to predict defect effect of	3	e	
15	1.2	f) Definition and use of "knock-down" factors for fatigue		1						
16	1.2	g) Effect of post-processing on LCF (e.g. HIP -> volume defects, surface improvements -> surface integrity, RS mitigation,		3						
17										

WG#2 Scope at a Glance



Thought Process for WG2 Breakout Sessions



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Agenda: B/O Session - Day 1 (Tuesday, November 9) – 2 hrs

- **Summary of 2020 outcomes – 10 min**
- **Summary of 2021 WG2 pre-work – 10 min**
- **Discussion the format of b/o sessions – 10 min**
- **3 brief (NTE 10 min) level-setting technical presentations**
 - **Doug Wells, NASA – 10 min**
 - **Andreas Fischersworing-Bunk, MTU AeroEngines, ‘Use of a modified IQI Standard – a way forward in NDI?’ – 10 min**
 - **Armando Coro, ITP Aero, ‘The relevance of AM anomalies, dimensions, amounts and locations’ – 10 min**
- **Technical discussion – start with a list of pre-set questions, and start working through them (allowing time for the larger group’s input) – 55 min**
- **“Homework assignment” – ask b/o session members to review the list and provide additional questions before Thursday – 5 min**



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Agenda: B/O Session - Day 2 (Thursday, November 11) - 4 hrs

- **Agenda review (including additional questions) – 10 min**

Note: may not have time to address all the questions on Thu; can propose to add them to the list and continue working after the 2021 W/S (and to invite questions' authors to join)

- **Technical discussion (cont. from Tuesday) – continue working through the list of pre-set questions (allowing time for the larger group's input) – 200 min (*includes 15-20 min break, or two 10-min breaks*)**
- **Summary and next steps – 30 min**



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WG2 – Friday (Nov. 12) De-brief for the Workshop Participants

- **Summary of the WG2 key outcomes (PowerPoint)**
 - **B/O Sessions Highlights and Summary**

Recommendations for:

- Future Work
- Development of guidance content, e.g. input to SDOs work w.r.t. F&DT and NDI
- R&D Topics (enablers for the above)

Note: WG2 co-chairs to provide 1-2 page written summary of B/O Session #2 outcomes within 2 weeks from this Event for inclusion in the proceedings