DELTA TechOps

NDT NONDESTRUCTIVE TESTING FORUM

A look at the Future NDT Inspector – Training, AI, & More

September 19, 2023

David Piotrowski – Senior Principal Engineer, Technology Development Engineering

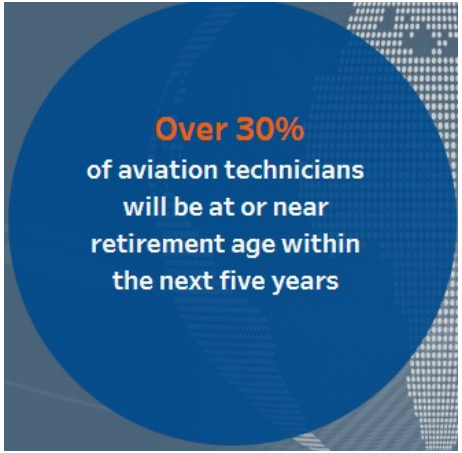
A4A NDT Forum

Outline

- HR & World Issues
- Making Inspection life better?
  - Robotics, automating NDT
  - Emerging NDT
- Artificial Intelligence, Machine Learning
- Level of Proficiency
  - Human in the loop
  - Training
  - Direct reading loophole?
- Summary/recommendations

HR & World Issues

- Pandemic & mass retirements
  - Delta TechOps: ~1900 people, 57,000 years of experience
- Still more retirement waves coming
- Outsourcing/Globalization
  - MROs: External & foreign providers
  - 'Rent-an-inspector'
  - Language issues
- Trades vs degrees = specific skills missing
- Solutions:
  - Instructions on 8th grade or even 3rd grade level
  - More automation
  - Training revamp



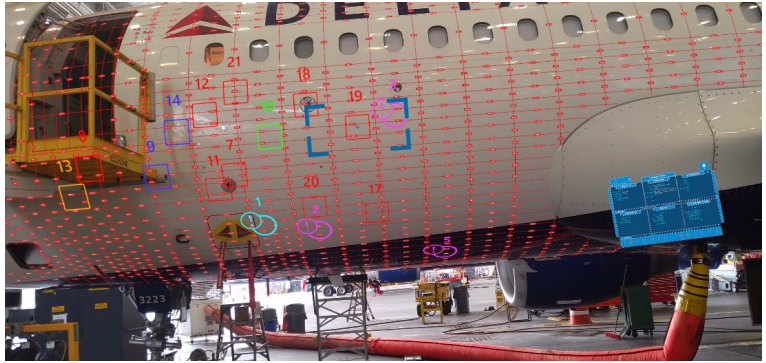
Courtesy: Boeing Pilot and Technician Outlook 2023-2042

Respondent Profile	
Full-Time Employee:	94%
Salaried:	47%
Hourly:	47%
Contractor:	6%
Male:	94%
Female:	6%
Average Age:	46 years
Average Years of Experience:	21.7 years

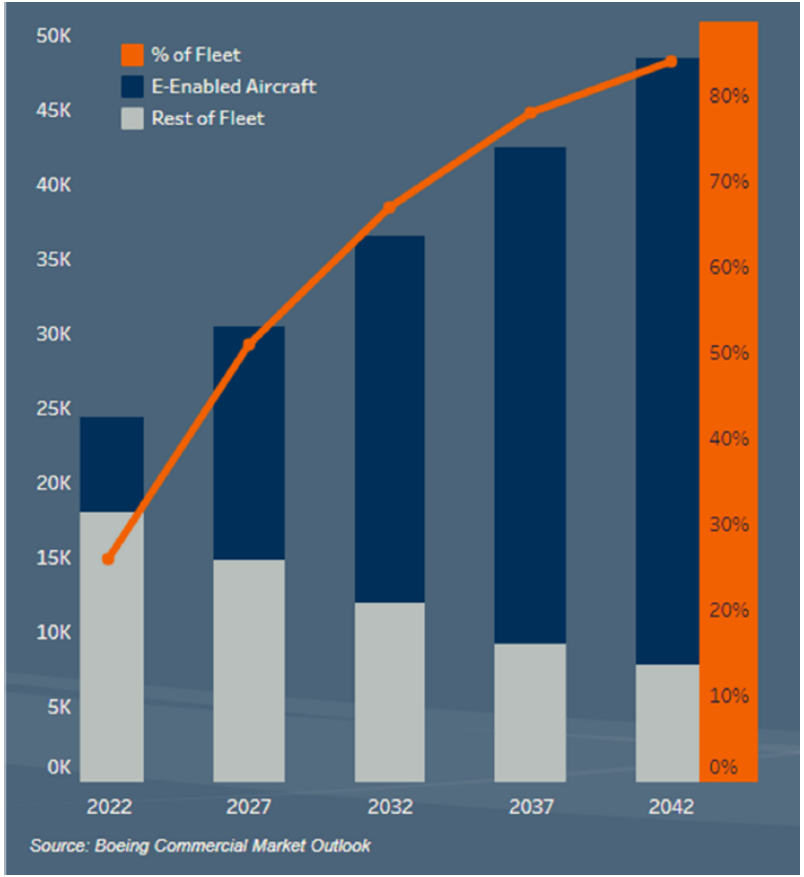
Courtesy: PQNDT Salary Survey

Technology Advancements

DELTA TechOps



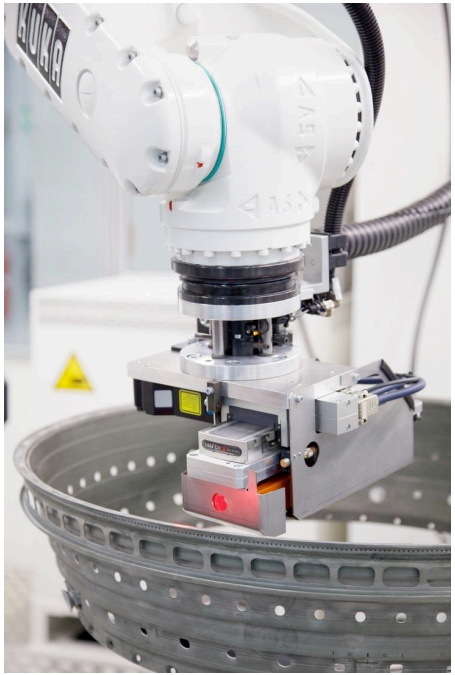
Courtesy: Waygate



Making Inspection life better (?)

- Robotics/Automated NDT
  - MAUS
  - RR snake
  - OC Robotics
  - LHT Autoinspect
  - Drones

Courtesy: OC Robotics

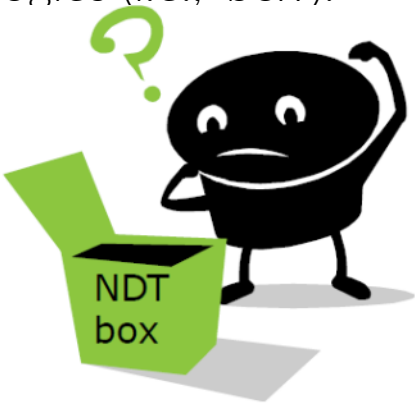


Courtesy: LHT

- SHM to alleviate onerous access
- Assisted Defect Recognition (AFRL = Assisted Data Analysis)
  - AI/ML
  - Info availability ⇧; Quality ?
- Internet/videos/CBT vs Practical

Emerging NDT & Training: 2014 NDT Forum

- Traditional, established NDT protocols don't fit new technologies (i.e., 'box').
  - Defect definition
  - Calibration
  - Validation (POD)
  - Training & Qualification
  - Guidance issues



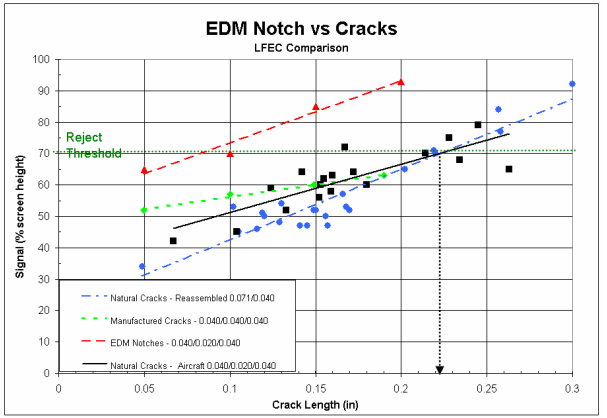
DEFECT DEFINITION:

- Hypnotized into traditional defect definitions => crack, corrosion, etc.
- Increased use of composites brings new defect types.
- Now defects include 'overtemp' microstructure, disoriented grains (Directionally solidified alloys), grinding burns, carbide precipitate clustering, resonance modes.
- Recent Pratt GTF Powder metallurgy issue
- GE CF6 Ti disks: white spots

Emerging NDT & Training

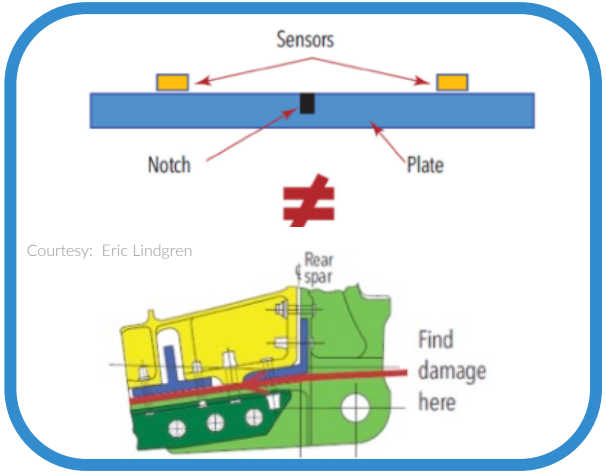
CALIBRATION FACADE:

- Years of “false calibration” ingrained into industry protocol
  - FBH/EDM notch not representative of actual defect you are looking for
  - 2006 Bode/Piotrowski paper – EDM Notch/Manufactured crack/Real crack
    - Detectability difference!



POD Difficulties:

- How to apply validation criteria developed for legacy methods to novel methods?
- Sonic IR work (Sandia/Wayne State/Siemens/FTT)
- Remote vision – high resolution borescopes using traditional optics standards; how to reconcile?
- Sandia performed POD, Gage R&R study for PCRT OT
- SHM (ARP6821) vs NDT



Emerging NDT & Training

DELTA TechOps

TRAINING REVAMP:

- Training, quals may need to be overhauled
- Legacy Training and qualification schemes may not adequately address emerging, novel methods
- Training developed with traditional six principal methods (ET, MT, PT, UT, RT & IR) in mind
  - RT vs 'Film Reading'
  - Visual: ATA105 ✖ ASNT ✔
- Divergent skill requirements => No skill or 'expert'
  - Direct reading vs 'blip on screen' vs 'Phased Array scan evaluation'
  - Workforce computer proficiency
- PCRT example (Operators see only 'pass/fail', lots of behind the curtain detail & engineering rigor)

Emerging NDT & Training

DELTA TechOps

GUIDANCE

- ATA 105 has some language around “Emerging NDT” – but aimed at Level III qualification
- NAS 410 has clear ‘Direct read guidance’, but this guidance was written in the context of traditional methods with simplified instruments in mind
- Human Factor mitigation; More automation; Recognition Software
- Path must be paved in order to progress

NAS410 - CERTIFICATION & QUALIFICATION OF NONDESTRUCTIVE TEST PERSONNEL

6.4 EMERGING NDT METHODS

6.4.1 MINIMUM HOURS

The minimum required training and experience hours for methods used by the employer that are not listed in 1.3.1, Table I, and Table II shall be established by the Responsible Level 3.

6.4.2 LEVELS 1 AND 2

When determining training or experience hours for new methods not listed in Tables I and II, the minimum hours shall be based on the requirements for a method of similar complexity listed in Table I and II. This only applies to “other” or emerging methods as defined in 1.3.2 and cannot be applied to penetrant, magnetic particle, ultrasonic, radiography, thermography, or eddy current testing.

NAS 410 - Emerging NDT

6.4.3 LEVEL 3

When approved by the cognizant engineering organization and authorized by the employer's written practice, an employer may qualify and certify its first Level 3 in a new NDT method not listed in 1.3.1 provided:

- The candidate has the skill and ability to carry out the Level 3 responsibilities in 5.1.6;
- All of the requirements in Table IV are met.

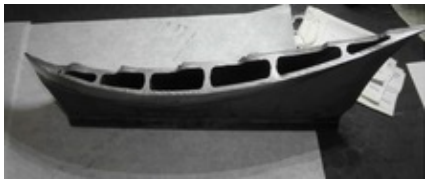
The requirements of 6.4.1, 6.4.2 and 6.4.3 only apply to "other" or emerging methods as defined in 1.3.2 and cannot be applied to penetrant, magnetic particle, ultrasonic, radiography, thermography, or eddy current testing.

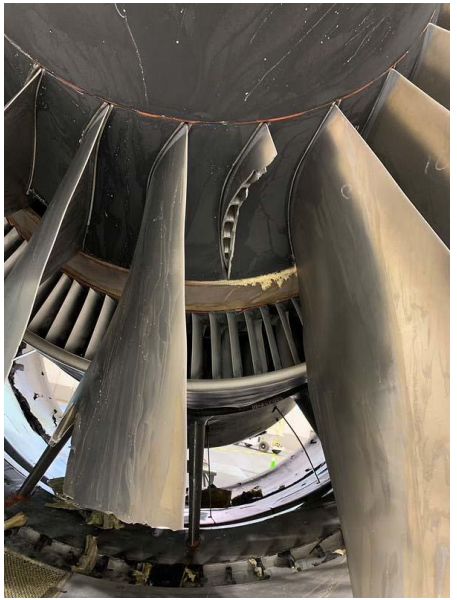
TABLE IV – MINIMUM REQUIREMENTS FOR FIRST LEVEL 3 IN AN EMERGING NDT METHOD

College or University	Instruction/ Study	Experience	Other NDT Certifications
No engineering or science study at a technical school, college or university	80 hours	300 hours	At least one previous Level 3 or two Level 2 certifications held
Two years of engineering or science study at a technical school, college or university	60 hours	200 hours	At least one previous Level 3 or two Level 2 certifications held
3-4 year science or engineering undergraduate degree	40 hours	200 hours	At least one previous Level 2 certification held

Emerging NDT - Incident

- The NTSB determined the February 2018 failure of a PW4077 on a United 777-200 was caused by low-cycle fatigue cracking in a fan blade that Pratt failed to detect on multiple occasions. *The board faulted Pratt's inadequate training for failing to prepare its technicians.*
- 2,979 cycles since its last inspection. The blade underwent thermal acoustic image (TAI) inspections in 2014 and 2016.
- Reviewed records for all 9,600 blades that had been overhauled. About 300 blades were removed, interval reduced to 6,500 cycles between TAI inspections.
- For JAL event Japanese transport officials ordered immediate visual inspections of the PW4000-series blades, reduced the maximum TAI inspection interval to 1,500 cycles.
- Interval further reduced to 1000 cycles later.





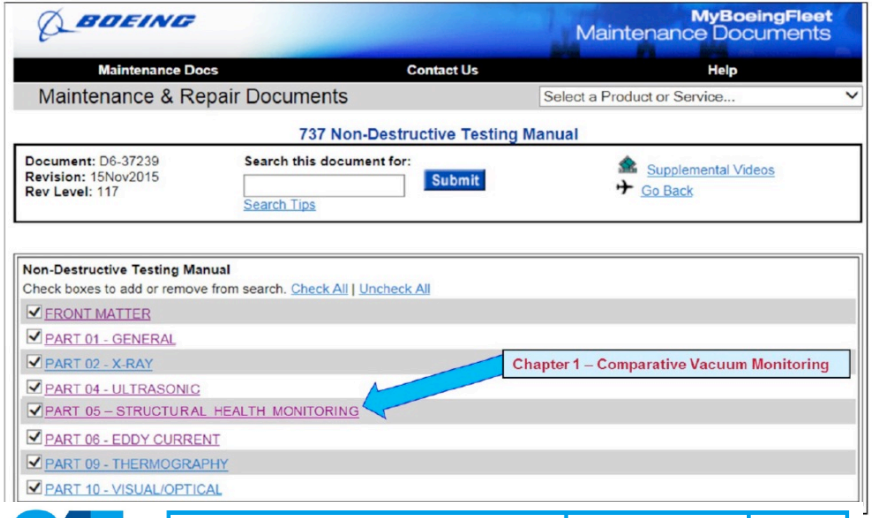
Courtesy: NTSB

Emerging NDT Incident

- The February 2018 incident's roots trace back to 2005, when Pratt developed a thermal acoustic imaging (TAI) inspection process for the interiors of hollow-core PW4000 fan blades. Pratt followed "standard nondestructive testing industry practice" and categorized it as "new and emerging," meaning it could be used while formal training requirements were being developed. But Pratt did not develop a formal, extensive training program until after the United engine failure.
- Pratt "did not have a defined training and certification regimen for the TAI inspectors" at the company's East Hartford, Connecticut, overhaul facility, the NTSB says.
- Instead, the technicians were given about 40 hr. of on-the-job training. By contrast, eddy current and ultrasonic inspection training programs include *40 hr. of classroom learning and at least 1,200 hr. of practical experience, the NTSB says.*
- The NTSB found that the lack of a formal TAI training program contributed to technicians misdiagnosing an issue multiple times on the United blade that failed, mistakenly believing the finding was a product of the TAI process, not a problem with the blade.
- "At the initial TAI accomplished on the fractured fan blade in 2010, there was a small indication at the location of the origin of the crack," the NTSB says. "Review of the records from the 2015 TAI shows that there was a larger indication in the same area. At the time of each TAI, the inspectors attributed the indication to a defect in the paint that was used during the TAI process and allowed the blade to continue the overhaul process and be returned to service."

Emerging NDT & Training

- SHM in Boeing NDT Manuals as Part 5
- Composite Inspector Training
- Emerging NDT Technology itself is not the issue
- Technology transfer to front-line
  - Training Program & OJT
- Automation & AI: Often have a view of "Just make a 2 minute refresher video"
- Train everybody vs small pool of emerging NDT Level IIs?



SAE INTERNATIONAL

AEROSPACE INFORMATION REPORT

AIR7491™ **REV. A**

Issued 2021-xx
Revised xxxx-xx
Reaffirmed xxxx-xx
Stabilized xxxx-xx
Cancelled xxxx-xx

Superseding XXXX

COMPOSITE INSPECTOR TRAINING COURSE TO ENHANCE PROFICIENCY AND IMPROVE RELIABILITY

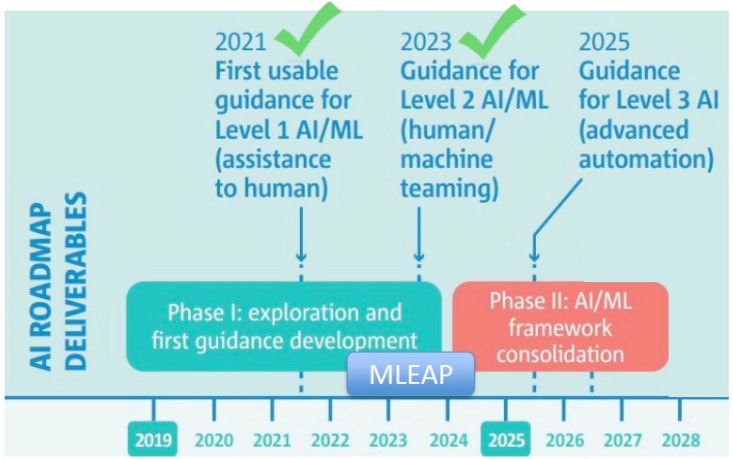
RATIONALE

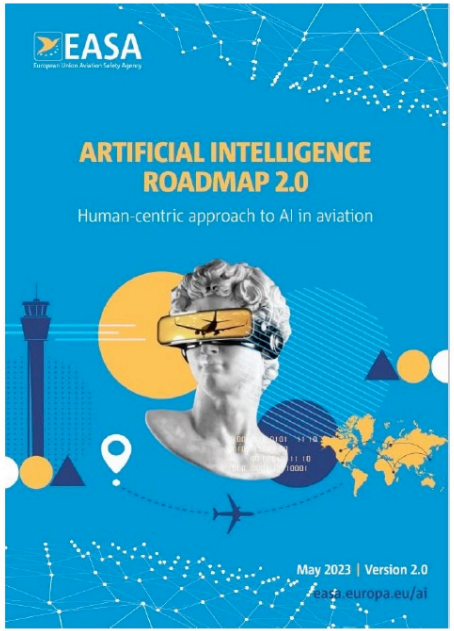
This SAE Aerospace Information Report is intended to provide comprehensive reference and background information pertaining to Non-Destructive Testing (NDT) Composite Inspector Training Course. The NDT training course is composed of a classroom lecture portion and a set of hands-on student exercises meant to teach and reinforce best practices for inspecting composite laminate structures. The information provided in each chapter in this report is intended to provide background to aid the actual classroom lectures and student exercises.

EASA AI Roadmap

EASA AI Roadmap – Towards AI trustworthiness

- → Impact on all aviation domains
- → Common issues for safety-related applications
- → « AI trustworthiness » concept is the key!





Courtesy: EASA

Courtesy: EASA

MLEAP = Machine Learning Applications Approval

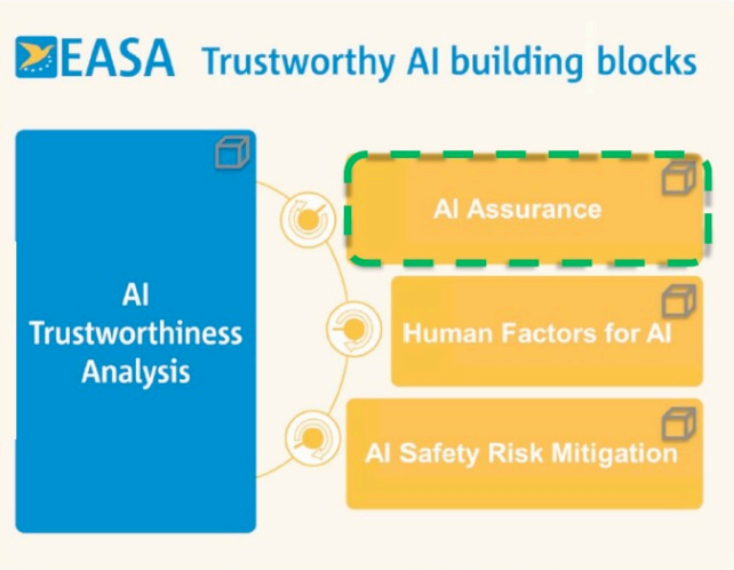
EASA AI Levels

DELTA TechOps

Increasing Automation

Autonomy

EASA AI Roadmap AI Level	High level function/task allocated to the (sub)systems
Level 1A Human augmentation	Automation support to information acquisition
	Automation support to information analysis
Level 1B Human assistance	Automation support to decision-making
Level 2 Human-AI collaboration	Overseen automatic decision-making
	Overseen automatic action implementation
Level 3A More autonomous AI	Overridable automatic decision-making
	Overridable automatic action implementation
Level 3B Autonomous AI	Non-overridable automatic decision-making
	Non-overridable automatic action implementation

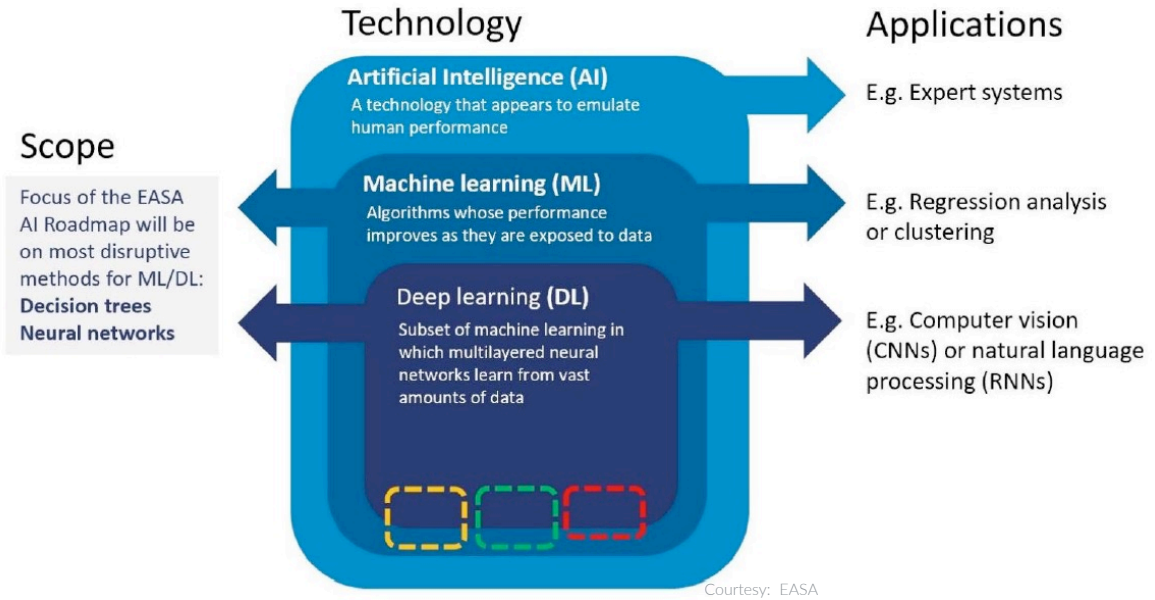


Courtesy: EASA

AI explainability: *Capability to provide the human with understandable, reliable, and relevant information with the appropriate level of details and with appropriate timing on how an AI/ML application is coming to its results.*

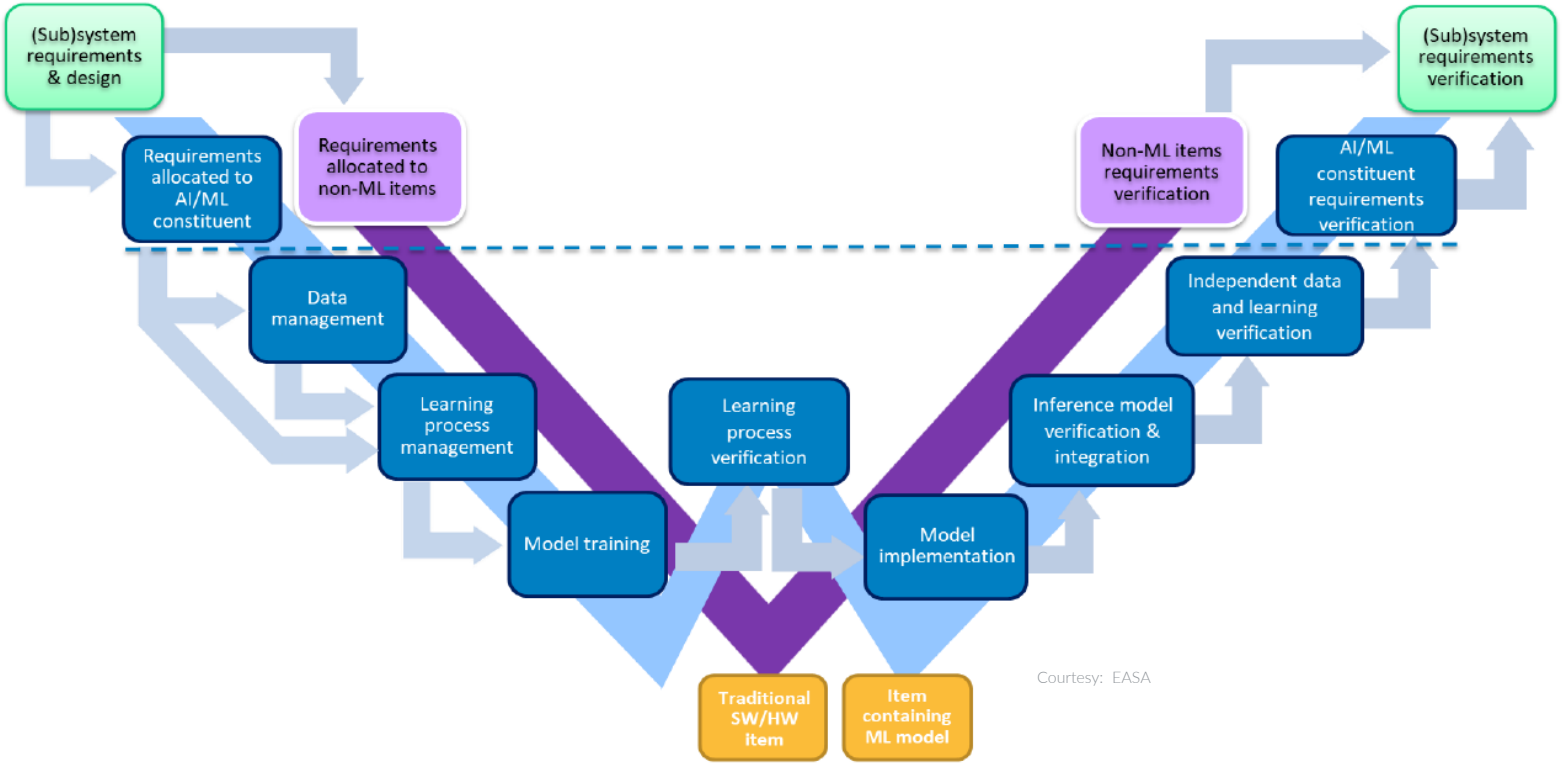
EASA AI Levels

EASA AI Roadmap – Definitions and Scope



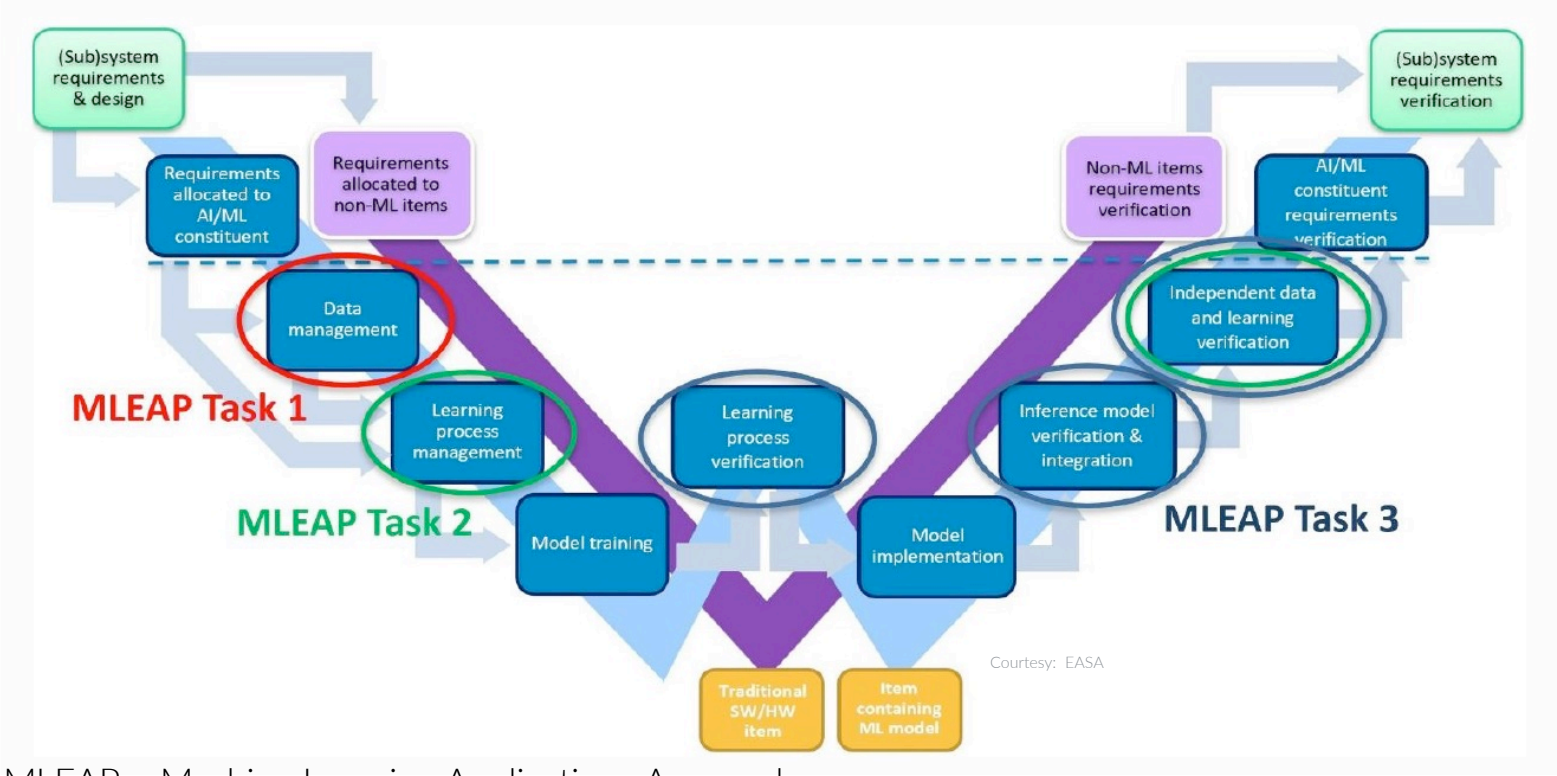
Type of ML — Supervised - Unsupervised - Reinforcement Learning

EASA Assurance Diagram



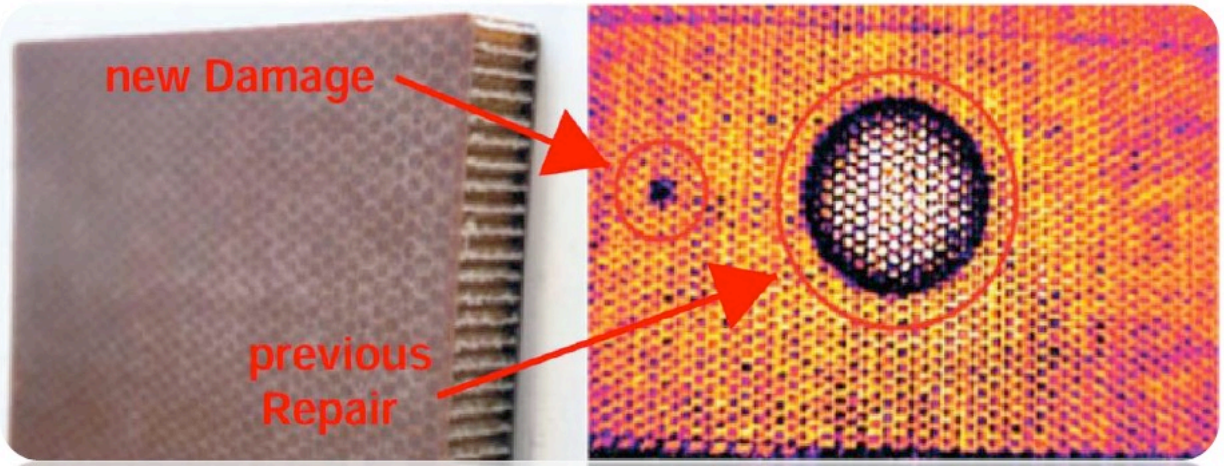
Courtesy: EASA

EASA Assurance Diagram



MLEAP = Machine Learning Applications Approval

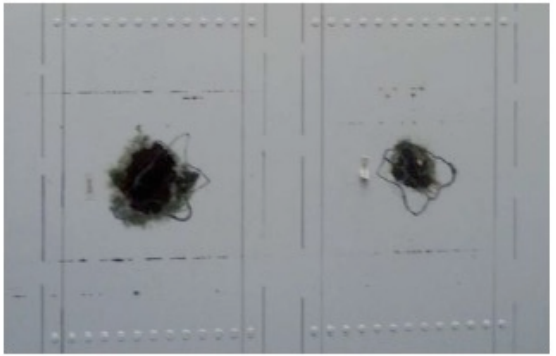
EASA AI Use Cases (w/Airbus)



Optical and thermographic image of a GFRP (Glass fiber reinforced plastic) sandwich panel

Dents Damages (1)

Courtesy: EASA

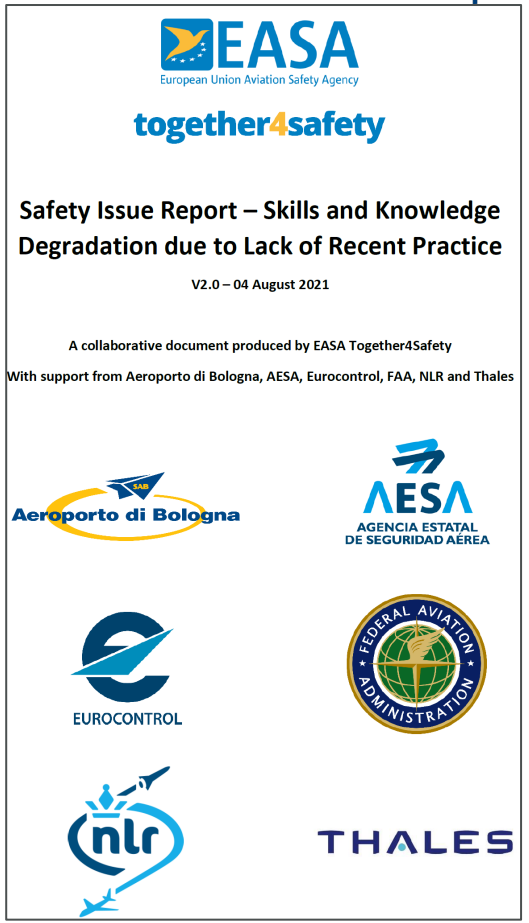


Lightning Strike impacts (2)

Level of Proficiency?

Are we at risk of having proficiency eroded by using more automation & emerging methods?

- Recency of experience is most important
- More automation => less ‘feel’
- Regulators: Qualified & Certified Human in the loop
- Image reading vs entire area NDT (2D vs 3D)
  - DR image reading cert
  - Drone
  - Borescope
  - IR/PAUT/ECA
- OJT hours
- Practicals, audits
- Direct reading loophole?
  - Mtc vs NDT inspection Job Codes



Summary

DELTA TechOps

Future NDT Inspector:

- Younger
- More tech savvy
- Global collaborator (remote inspection)
- Ability to access more info
- Inspection ‘assistants’ vs automation ‘babysitter’
- Challenged to maintain inspector ‘intuition’, critical thinking
- Data everywhere – including post inspection archiving

Recommendations:

- Level IIIs must be on top of Emerging NDT
  - Design Program with practicals, OJT
- Be wary of Direct-reading loophole
- Challenged to maintain inspector proficiency
- Just culture vs blame culture