Next Steps Towards Certification by Analysis

A Digital Thread Perspective

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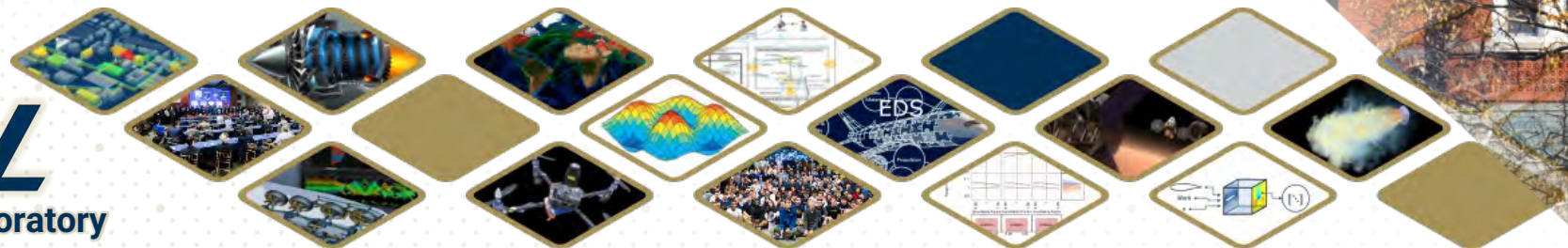

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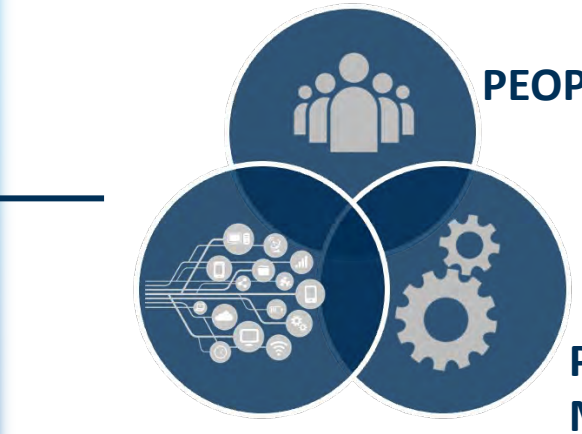
Key Enablers to Certification by Analysis



PEOPLE

PROCESSES/
METHODS

TECHNOLOGY

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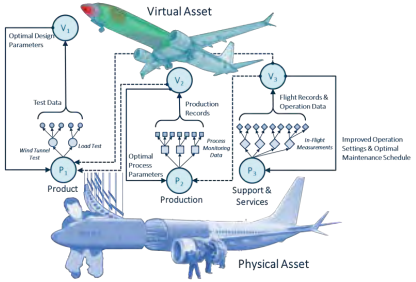
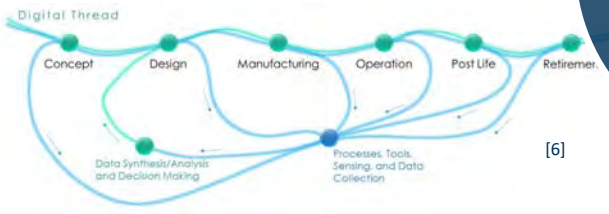
Key Enablers to Certification by Analysis

TECHNOLOGY

Digital Twin: a virtual representation of a physical connected asset [1]

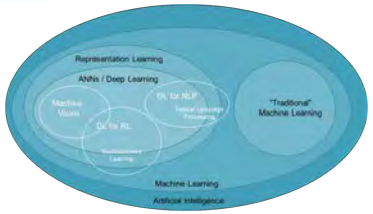


Digital Thread: Ensures data/model integrity, consistency, provenance, and retention [7]



[6]

Machine Learning / Artificial Intelligence



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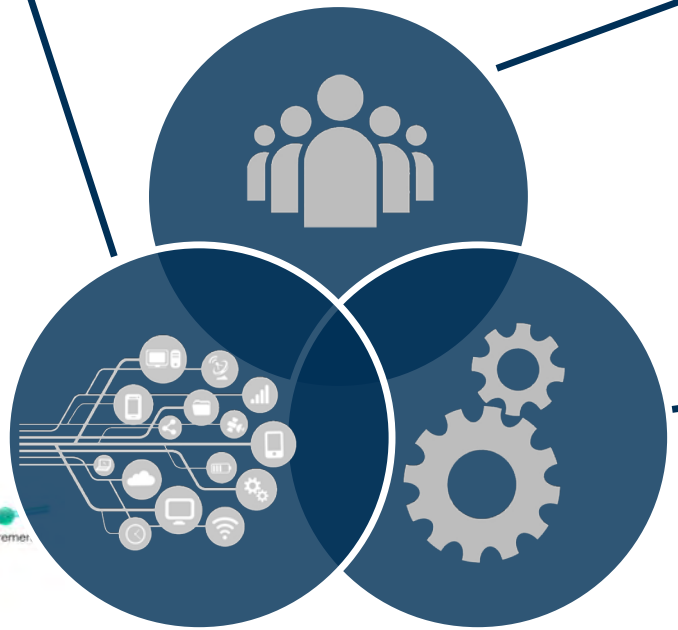
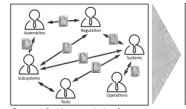


PEOPLE

- Culture
- New Roles & Responsibilities
- Workforce Development

PROCESSES/METHODS

- **Model-based** (as opposed to document-centric) **approaches** (MBSE)
- **Verification and Validation:** a key component of **establishing model trustworthiness**
- **Uncertainty Quantification:** accounting for unknowns
- **Credibility Assessment Frameworks**
- **…**



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[1] AIAA Digital Engineering Integration Committee (DEIC), Digital Twin: Definition & Value, An AIAA and AIA Position Paper, December 2020, https://www.aiaa.org/docs/default-source/uploadedfiles/issues-and-advocacy/policy-papers/digital-twin-institute-position-paper-(december-2020).pdf
[2] ASME V&V 10-2019, https://webstore.ansi.org/Standards/ASME/asme102019
[3] https://www.swri.org/sites/default/files/styles/facebook_image/public/AdobeStock_121758860%202.jpg?itok=8jG3cNoU
[6] Singh, Victor, and Karen E. Willcox. "Engineering design with digital thread." *AIAA Journal* 56, no. 11 (2018): 4515-4528.
[7] Mauery, Timothy, Juan Alonso, Andrew Cary, Vincent Lee, Robert Malecki, Dimitri Mavriplis, Gorazd Medic, John Schaefer, and Jeffrey Slotnick. *A guide for aircraft certification by analysis*. No. NASA/CR-20210015404. 2021, https://ntrs.nasa.gov/api/citations/20210015404/downloads/NASA-CR-20210015404%20updated.pdf

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The Digital Trust Infrastructure

Transparency/traceability of the entire model building process within an established data management system [7]

- The specific simulation details (e.g the geometric configuration(s) analyzed),
- The analysis tools employed,
- The tool input parameters used,
- The coupling frameworks employed,
- The analysis data generated,
- The validation data used,
- Etc.

Documentation of context of use of models

- Intended purpose of the model,
- Underlying set of assumptions,
- Domains of validation and application

Accessibility, explainability and **reproducibility** of simulation/analysis results

- Procedures that define how the tools and models were used,
- Procedures used for peer review of the simulation results,
- Quality checks performed,
- Data used for model calibration & validation,
- Linkage of flight modeling results utilized for CbA to flight configuration used for certification [7]
- Etc.

Digital Thread:
Ensure data/model integrity, consistency, provenance, and retention

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[7] Mauery, Timothy, Juan Alonso, Andrew Cary, Vincent Lee, Robert Malecki, Dimitri Mavriplis, Gorazd Medic, John Schaefer, and Jeffrey Slotnick. *A guide for aircraft certification by analysis*. No. NASA/CR-20210015404. 2021,, https://ntrs.nasa.gov/api/citations/20210015404/downloads/NASA-CR-20210015404%20updated.pdf

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Relevance and Benefits of Digital Thread to Certification

- Provides a repository to **organize**, **manage**, **mine**, **search/discover** the data generated from research to full production

- **Bi-directional Traceability:** Allows to trace [8]
  - The evidence and rationale that led to a decision, or
  - The provenance of data or requirements - and their maturation through the lifecycle
  - Maintains the complex relationship between the material, part geometry, individual processes, as well as the subsequent physical and virtual testing

  → Understanding and **quantifying the impact of specific inputs and variables on specific behavior as well as performance**

  → Establishing **correlations and relationships among parameters that experimental studies cannot easily couple/identify**

  → Predicting performance and validating those results against physical test results

  → Quantifying and reducing uncertainties

- **Consistency:** helps ensure that all authoritative derivative or successor information is fully compatible with its authoritative parent or predecessor information [8].

- **Increased Communication, collaboration across teams, stakeholders and customers:**

[8] AIAA Digital Engineering Integration Committee. "Digital Thread: Definition and Value - An AIAA and AIA Position Paper." American Institute of Aeronautics and Astronautics (AIAA), To be published in 2022
[9] Lubell, J., Chen, K., Horst, J., Frechette, S., Huang, P., "Model Based Enterprise/Technical Data Package Summit Report," National Institute of Standards and Technology (NIST), Technical Note 1753, August 2012, http://dx.doi.org/10.6028/NIST.TN.1753.
[10] Kraft, Edward M., "A Disruptive Application of Digital Engineering to Optimize Aircraft Developmental Test & Evaluation." AIAA 2018 Aviation Systems Conference, Atlanta, GA. 2018.

Thank you

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Towards Certification by Analysis for Flight Characteristics:

Why necessary now, and what is needed?

Cord Rossow
Institute of Aerodynamics and Flow Technology

Main Challenge of Civil Aviation:
Decoupling of Growth and Climate Impact

Perspectives of Future Technologies (CCR):

Alternative Propulsion Technologies: Batteries, Fuel Cells, H2

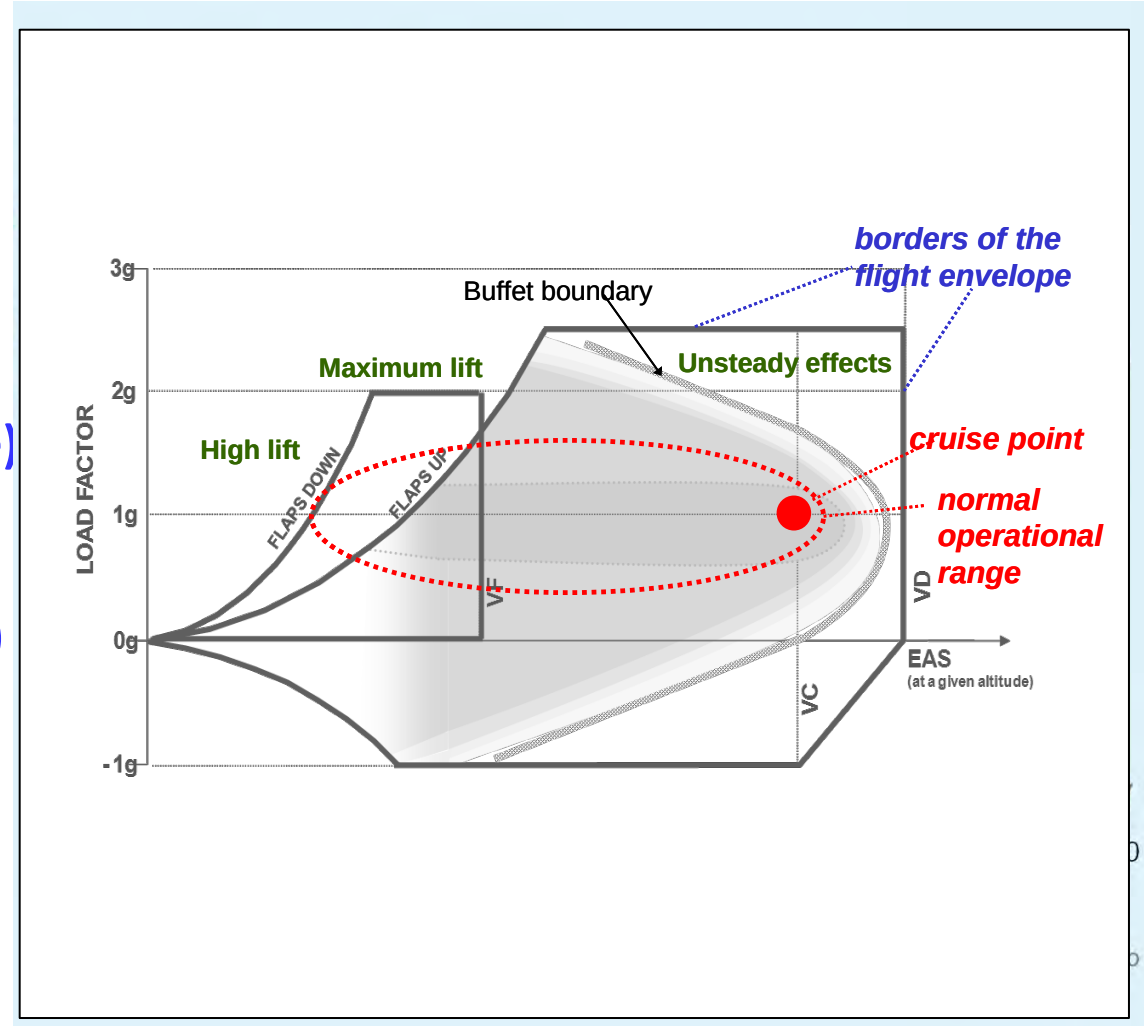
- Batteries for Small A/C (Energy Density)
- Fuel Cells for Regional A/C (Power Density, Infrastructure)
- H2 for Short- and Medium Range A/C (Tanks, Infrastructure)

Synthetic Fuels (SAF)

- For Long Range A/C only possible Alternative (Availability?)

Drastic Increase of Efficiency: Reduction of Fuel Burn by 50%?

- Direct Reduction of Emissions
- Mitigation of Extremely High Fuel Prices (H2, SAF, etc.)



Development Conditions until 2050:

High Risk
High Cost
Short Time

Digitization will be key technology for aviation readiness in 2050;
Corresponding certification processes will require CbA

Note: CbA then has to cover the whole flight envelope

Main Challenge of Civil Aviation:
Decoupling of Growth and Climate Impact

Requirements for CbA (CCR):

1. Applicability & Prediction Capability

Flight Characteristics @ whole flight envelope

2. Reliability

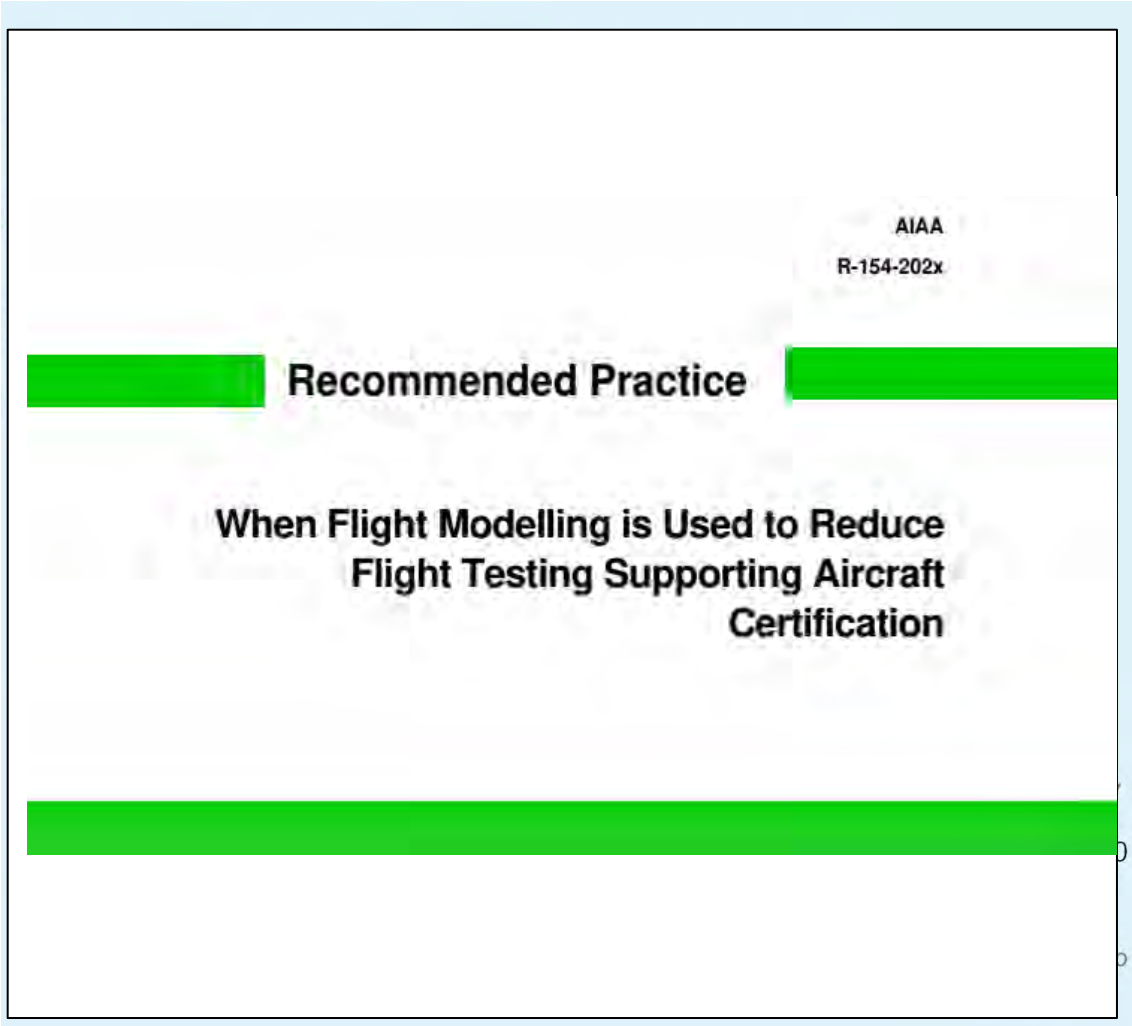
"Conservative" results => always to be on the safe side

3. Understandability

Applicant and authorities must understand process

4. Repeatability & Protectability

Documentation, archiving, manipulation protection



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First Step by CoI to provide Recommended Practice for CbA

Current discussion: what is required to achieve 1. and 2.?

Main Challenge of Civil Aviation:
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Challenges on the way towards CbA wrt 1. & 2.:

- *Flight characteristics are an interaction of Aerodynamics, Structures and Flight Control*
- *Wind tunnel data may be insufficient*
- *Accurate flight test data very difficult to achieve*
- *Flight test data of commercial a/c proprietary*
- *Scaled flight characteristics demonstrator as means to demonstrate prediction capability?*
- *How much M / Re / Aeroelasticity similarity?*
- *Is UQ sufficient for "conservative" results?*
- *…*

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