Digital Engineering and Digital Twin of Aeronautical Structures in China

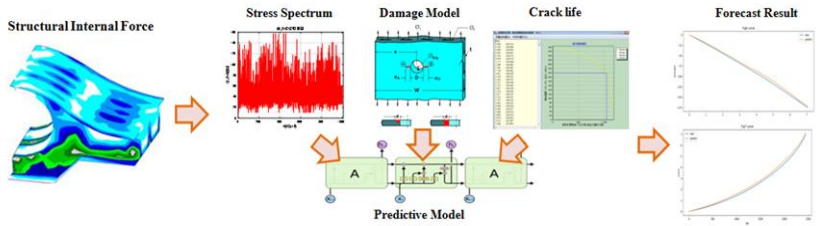
Xiasheng Sun | August 1, 2023

Outline

1. **Digital Engineering and Digital Twins (DEDT) for Aeronautical Fatigue and Structural Integrity**
2. DEDT for the Design and Validation Stage
3. DEDT for the Operation and Maintenance Stage
4. Outlook

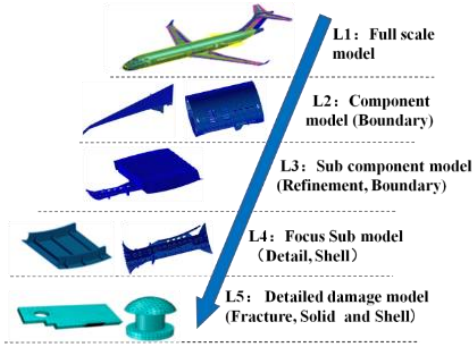
Challenges in Aeronautical Fatigue and Structural Integrity

Multidisciplinary



Structure Aerodynamics Heat

Multi-level



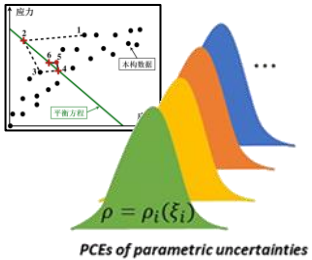
Load transfer

Buckling theory

Crack initiation and propagation

Failure criterion

Uncertainties



Epistemic uncertainty

Insufficient data

Lack of knowledge

Various models

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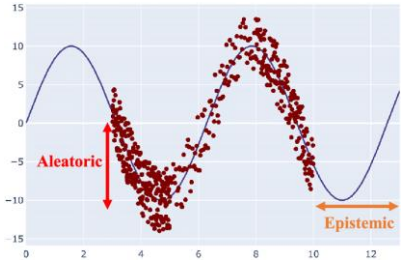

Aleatory uncertainty

Inherent variation

Noise

Parameter distribution

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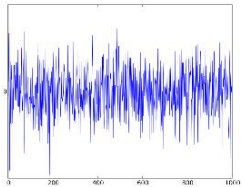
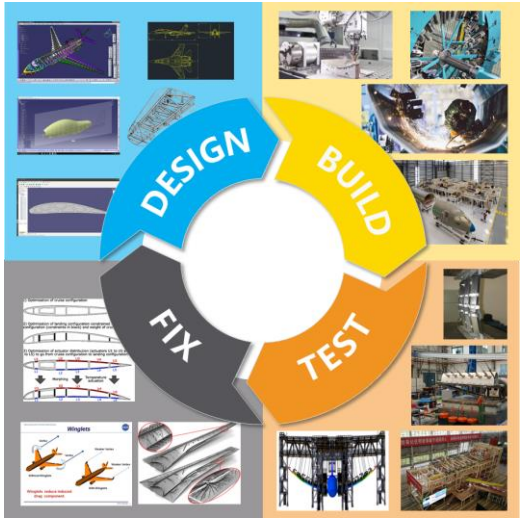


Shift to the Digital Engineering Paradigm

- Models are the core of Digital Engineering

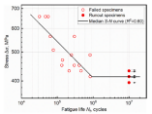


Traditional engineering procedure

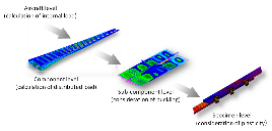
Source: 2018, U.S. DoD

Model-based Digital Engineering

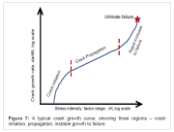
Geometric model



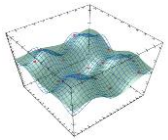
Material model



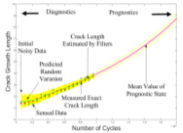
Load model



Damage model



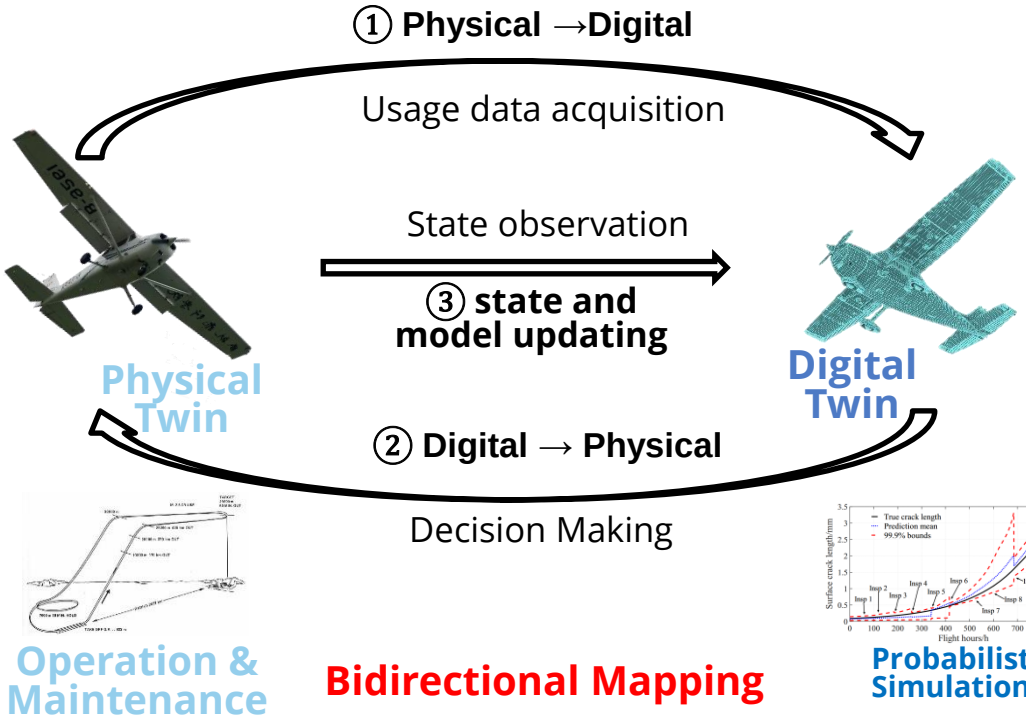
Reduced order model



Prognostic model

Digital Twin: Enhancing Virtual-Real Fusion of Aeronautical Structures

- A digital twin is a bidirectional mapping system between physical and digital space, facilitating the virtual-real fusion of aeronautical structures.



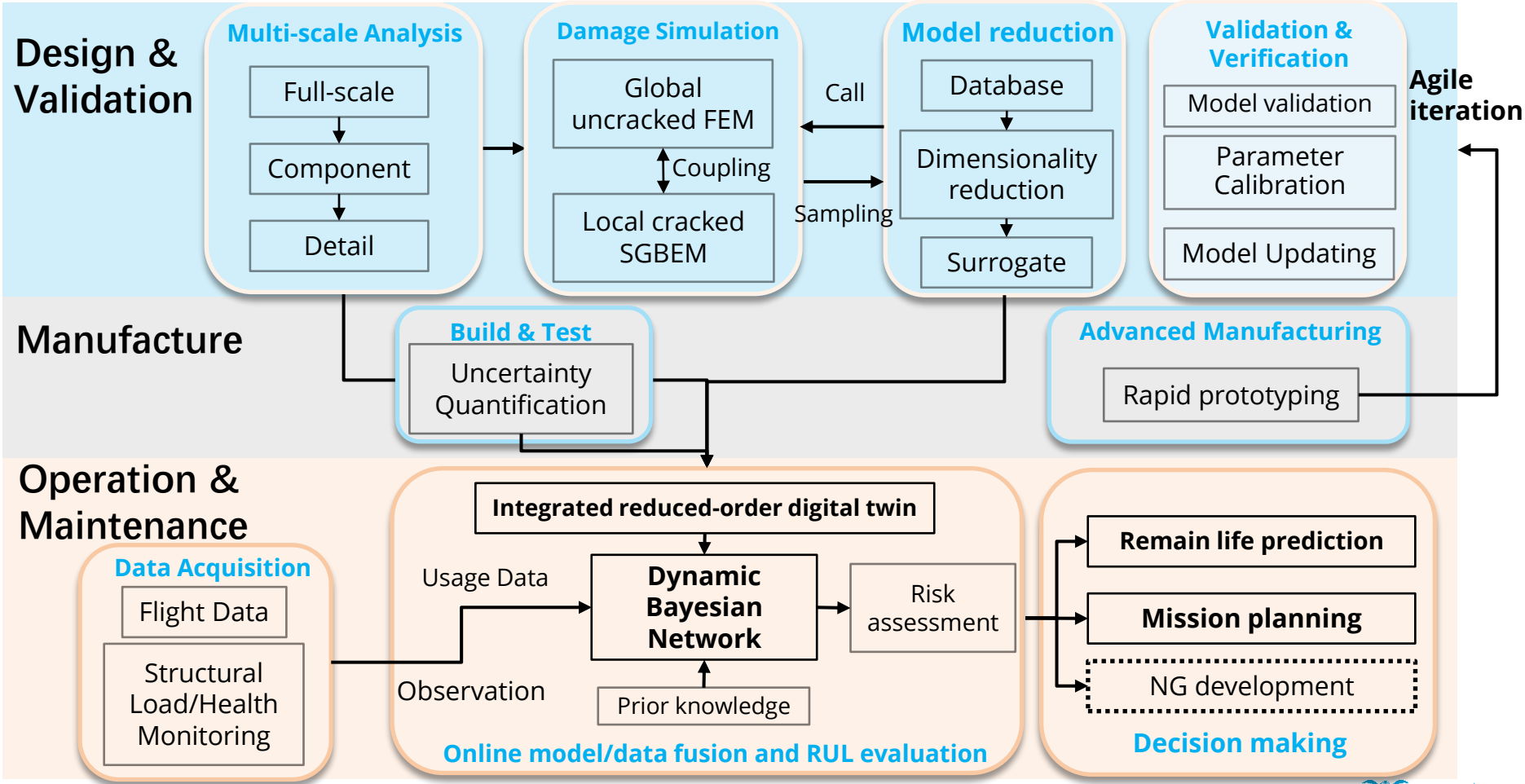
Multi-disciplinary

Multi-level

Probabilistic System Models

- Physics-based
- Data-driven
- Hybrid

Full-life Cycle Structural Digital Twin Framework



Outline

1. Digital Engineering and Digital Twins (DEDT) for Aeronautical Fatigue and Structural Integrity
2. **DEDT for the Design and Validation Stage**
3. DEDT for the Operation and Maintenance Stage
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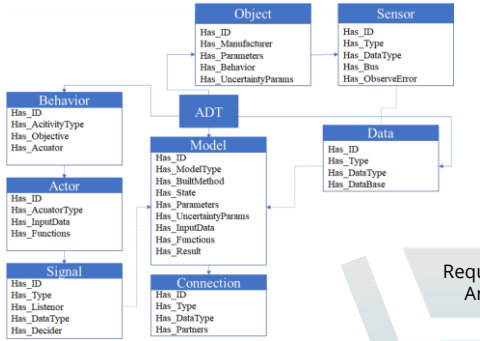
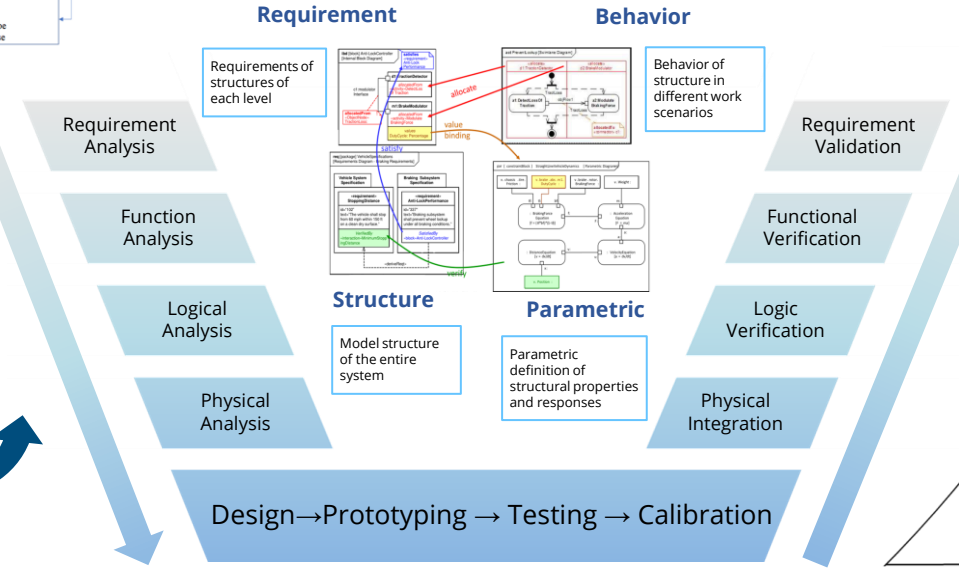
DEDT for the Design and Validation Stage

- Trends of key technologies
  - Multi-level structural model verification and validation

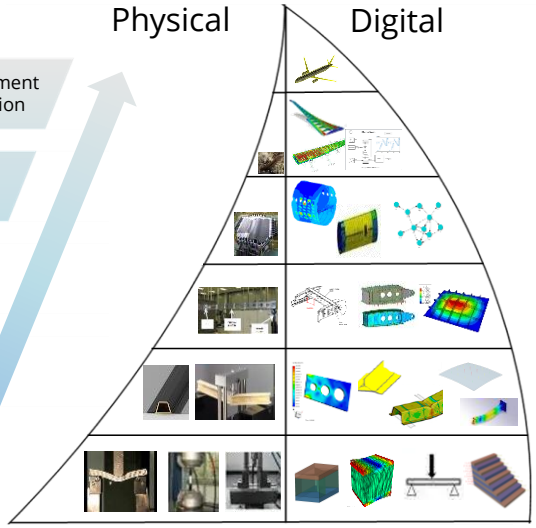


Top level Ontology of Airframe Digital Twin

Model-based System Engineering



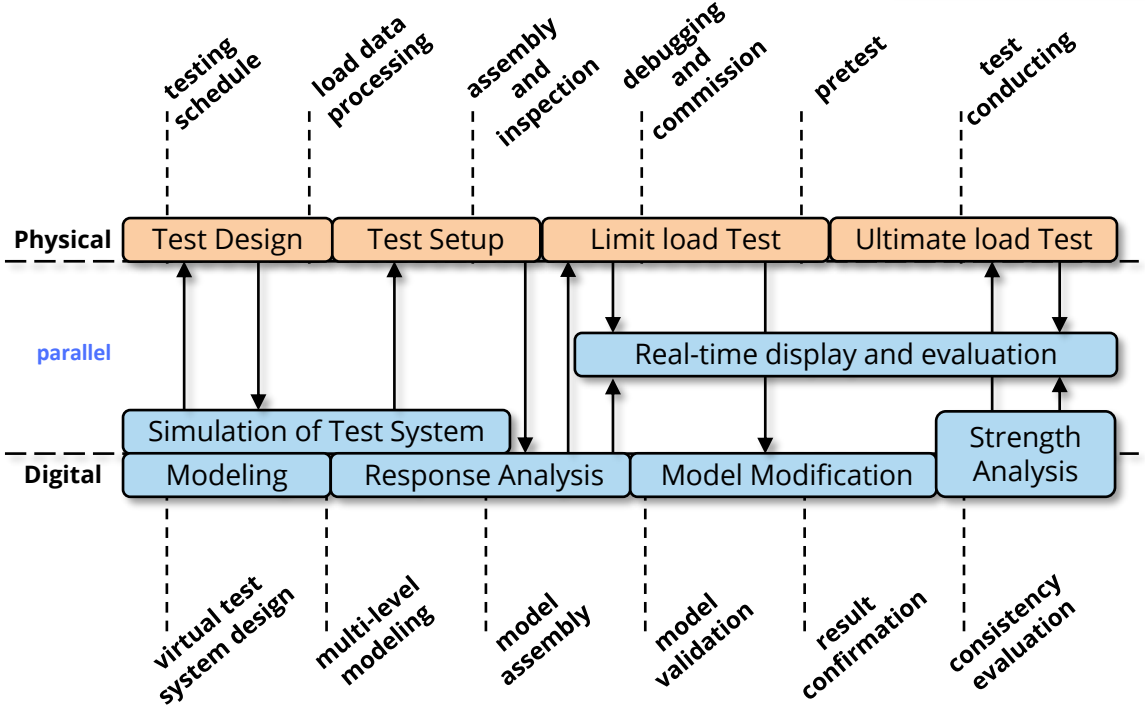
Fusion of digital and physical world

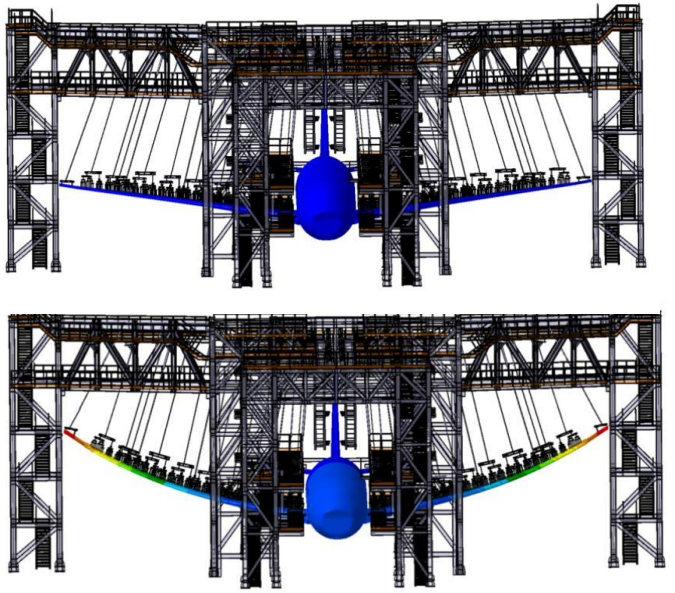


DEDT for the Design and Validation Stage

- Trends of key technologies
  - Virtual Testing System

- Virtualization of physical test system
- Simulation of structural mechanics behavior
- Integration of digital and physical models

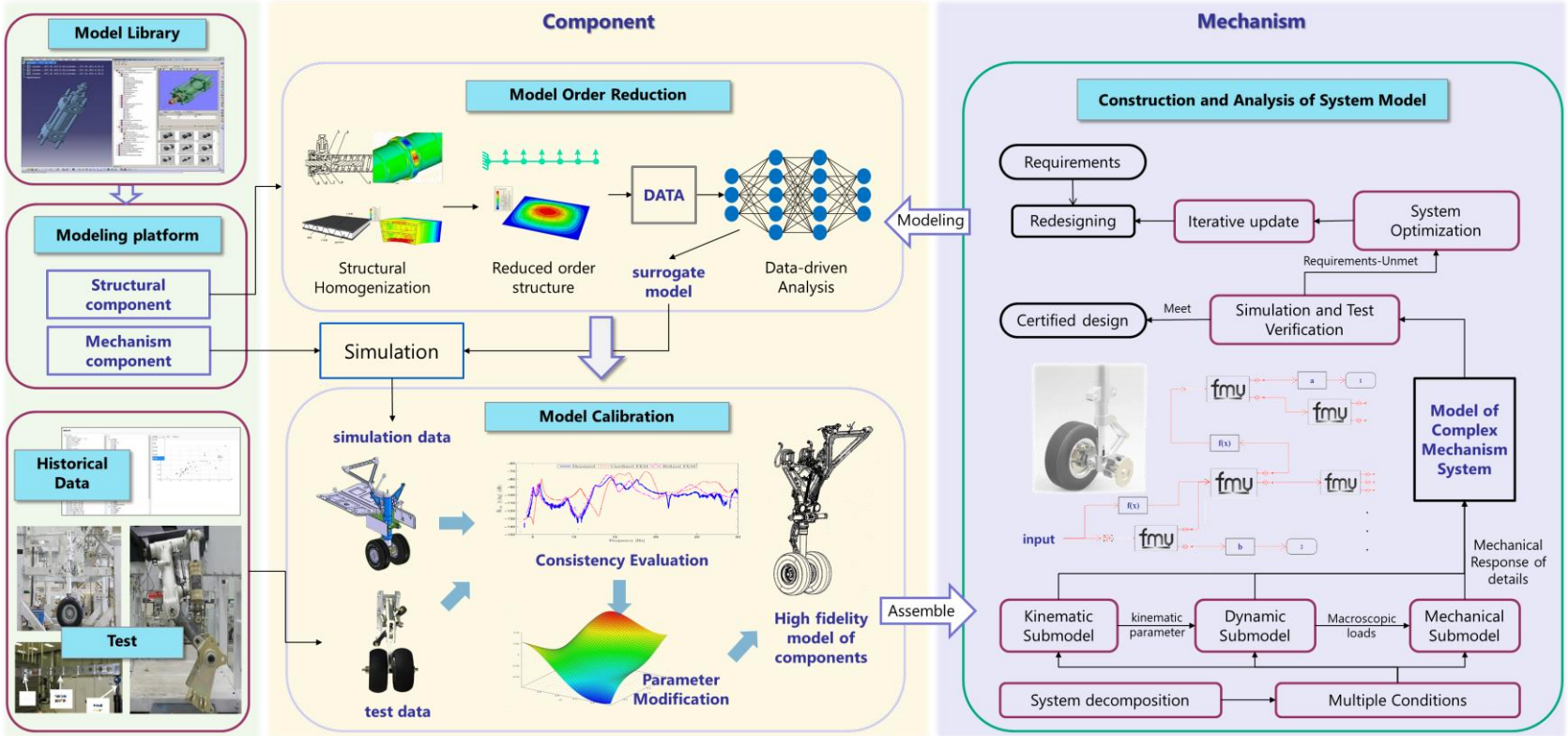




C919 virtual testing

DEDT for the Design and Validation Stage

- Recent activities in China
  - Digital design and evaluation of a landing gear

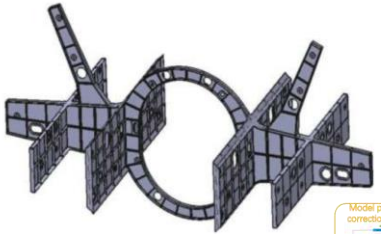


[1] Beihang University
[2] AVIC Shenyang Aircraft Design & Research Institute

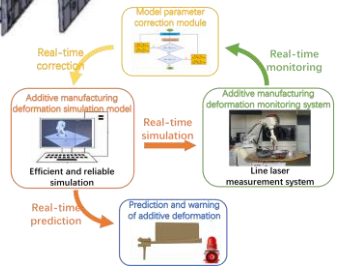
DEDT for the Design and Validation Stage

- Recent activities in China
  - Rapid prototyping and Agile iteration

Assist Rapid Prototyping

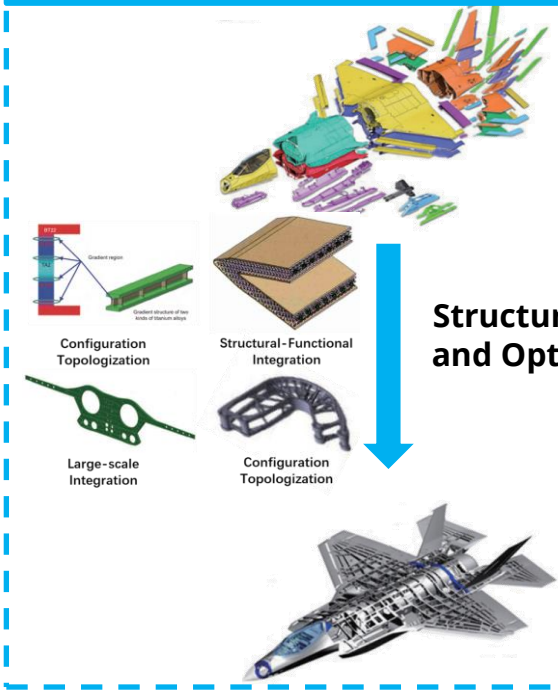


Prediction and Alert for Manufacturing Processes



Agile design iteration

Empower Agile Iterations



Structural Design and Optimization

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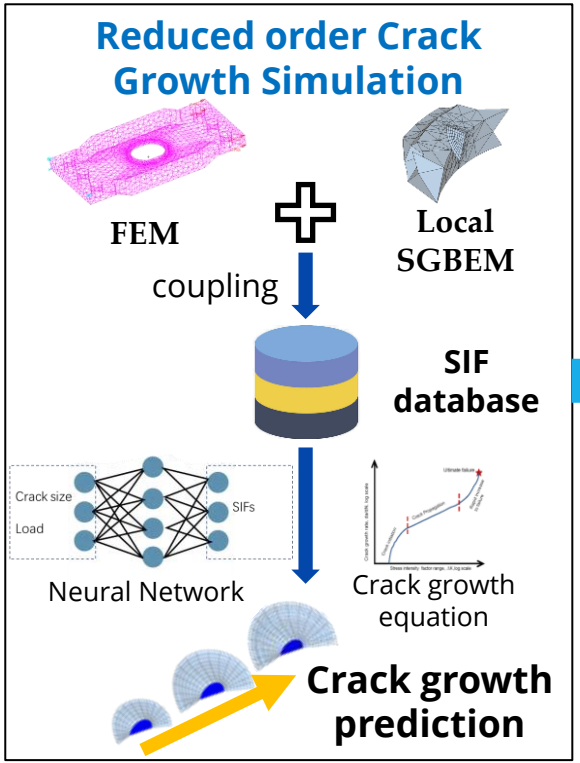
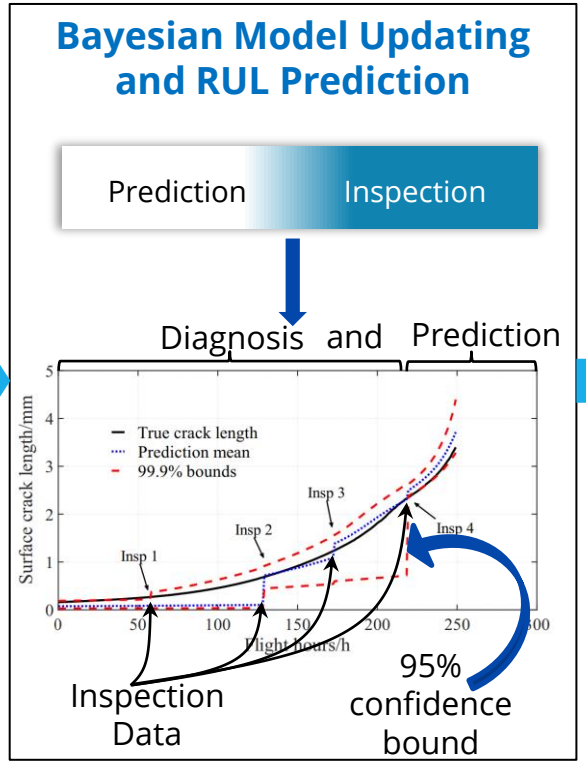
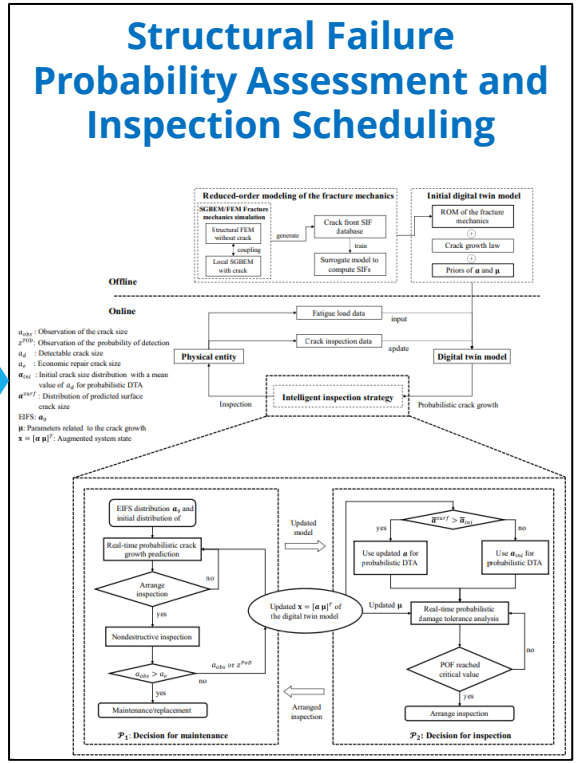
DEDT for the Operation and Maintenance Stage

- Trends of key technologies
  - Model/data fusion for structural inspection and maintenance

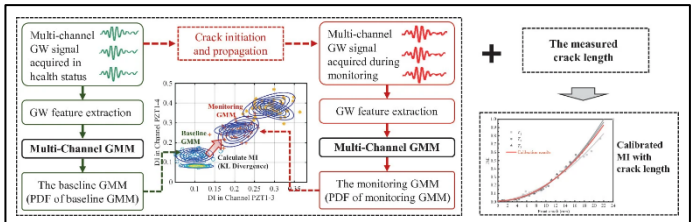




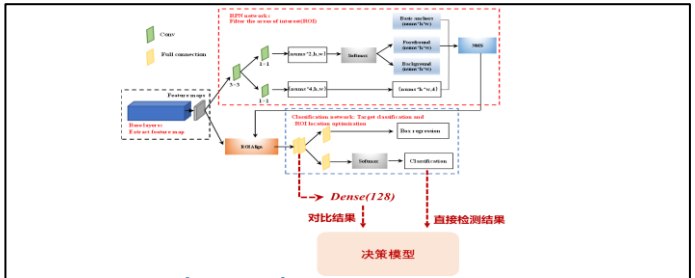


DEDT for the Operation and Maintenance Stage

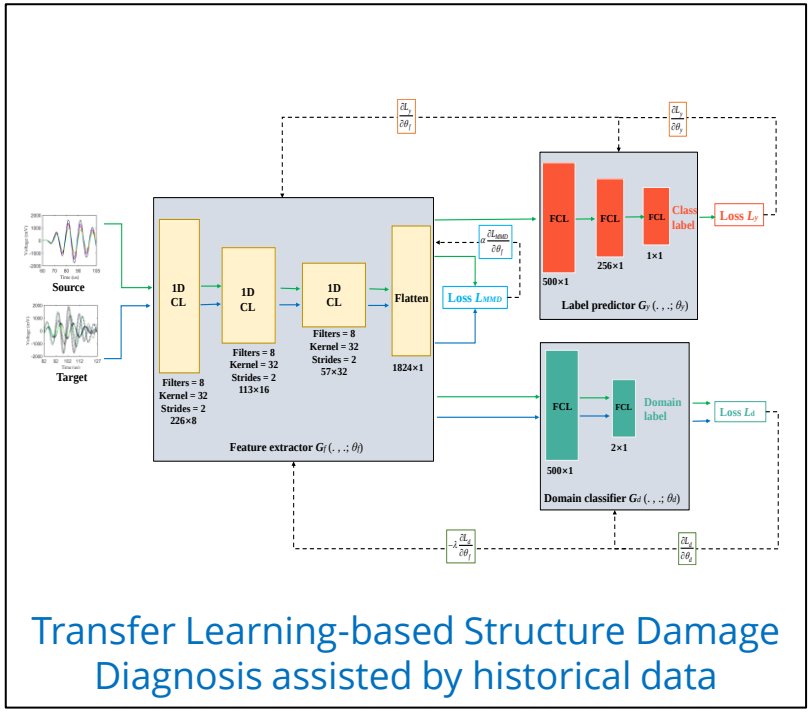
- Trends of key technologies
  - Advanced structural health monitoring



Advanced Damage Sensing
（e.g., Guided Wave Identification）



Vision-based Automatic Damage Identification for Large Structures

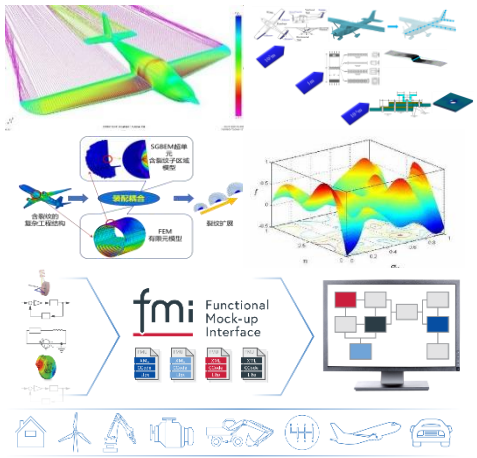


Transfer Learning-based Structure Damage Diagnosis assisted by historical data

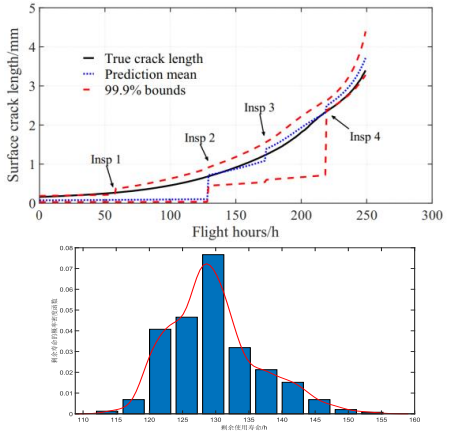
[1] Nanjing University of Aeronautics and Astronautics
[2] AVIC Aircraft Strength Research Institute

DEDT for the Operation and Maintenance Stage

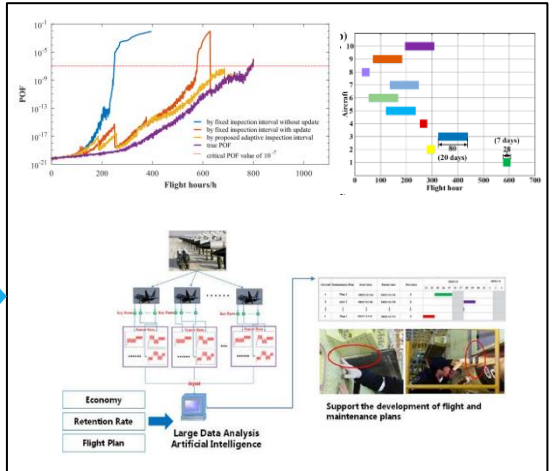
- Recent activities in China
  - Ongoing structural integrity management of aging GA aircrafts



Reduced Order Model and Integrated Real-time Simulation



Improving Life Prediction Accuracy by the Fusion of Prediction and Observation

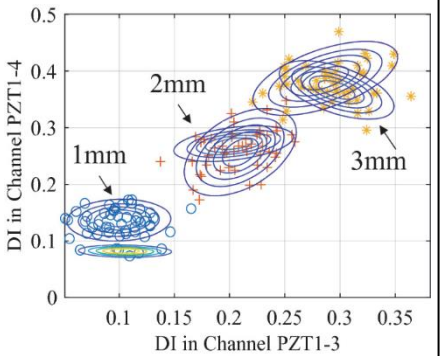


Scheduling Individualized Inspection and Maintenance

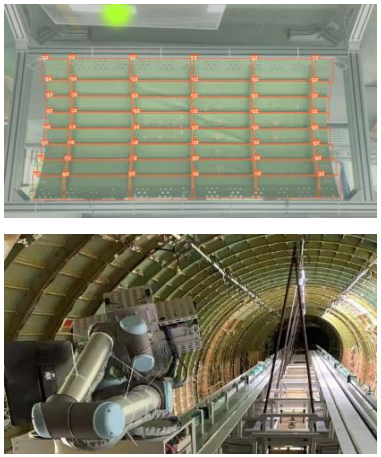
[1] Beihang University
[2] Civil Aviation Flight University of China

DEDT for the Operation and Maintenance Stage

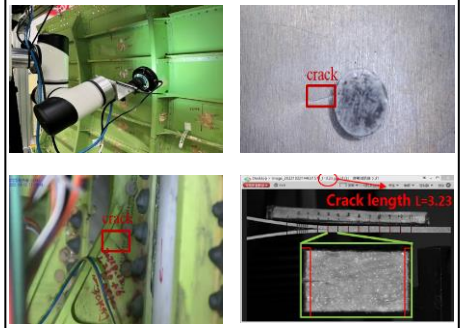
- Recent activities in China
  - Application of SHM in the structural fatigue test



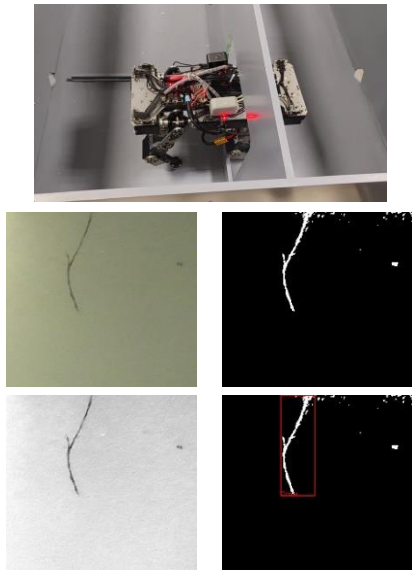
Guided-wave-based Damage Detection



Object-recognition-based Path Planning



Machine vision inspection in the C919 full scale structural fatigue test

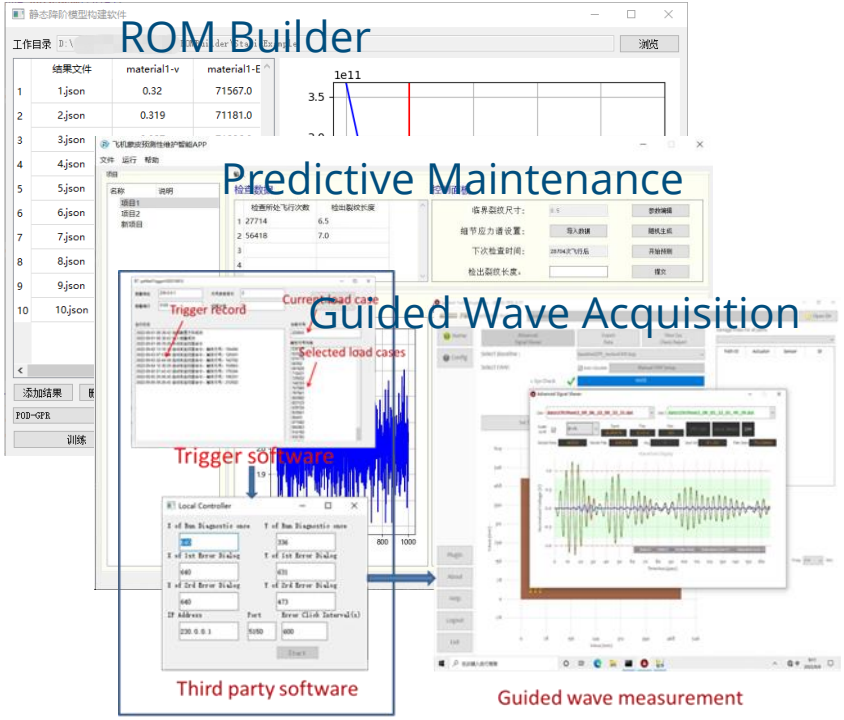


Narrow Space Crack Detection

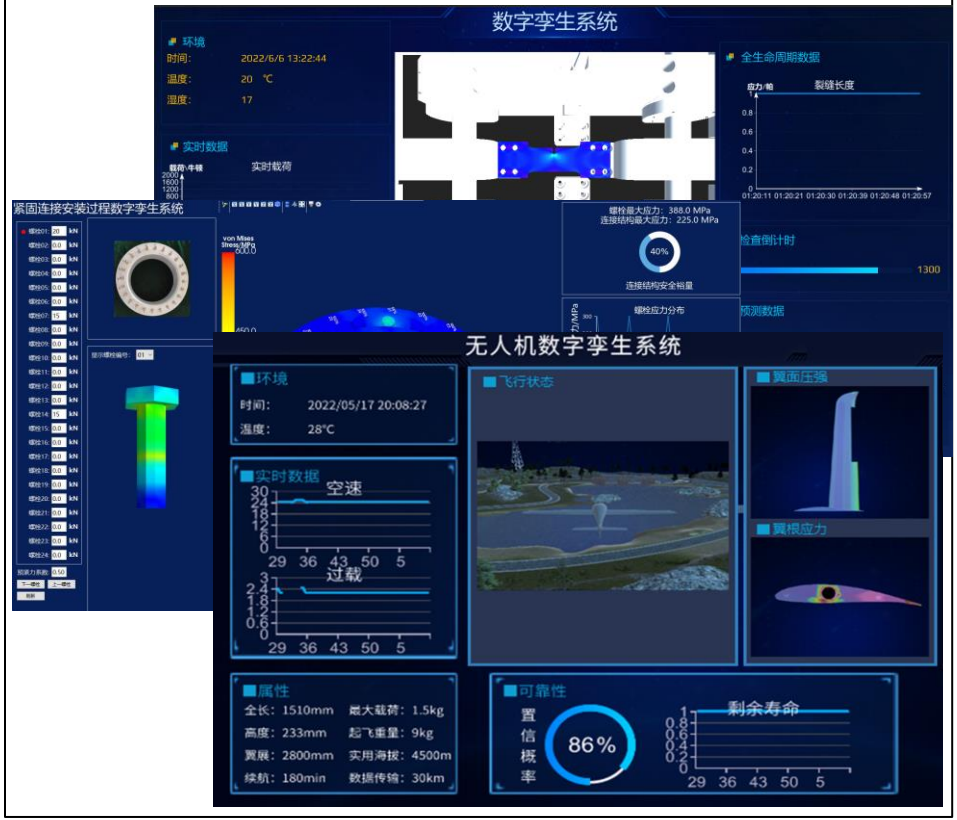
[1] AVIC Aircraft Strength Research Institute
[2] Nanjing University of Aeronautics and Astronautics

DEDT for the Operation and Maintenance Stage

- Recent activities in China
  - Software development



Digital Twin Visualization for Various Structures



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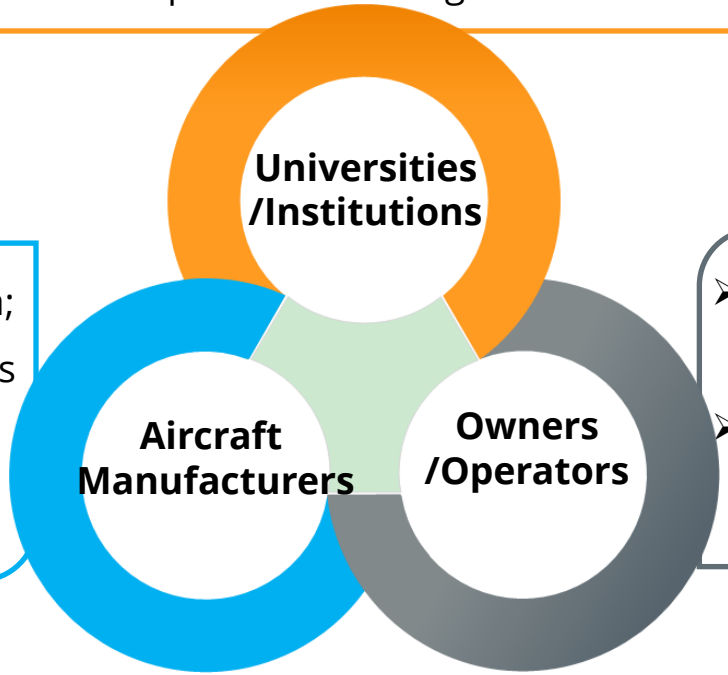
Calls for Cooperation among All Stake-Holders

- Develop digital methods for aeronautical fatigue and structural integrity;
- Provide education and training for owners/operators and engineers.



- Provide design and test data;
- Formulate strategic solutions to structural integrity management.

- Understand the need for fatigue and structural integrity issues;
- Provide flight and maintenance data following the guidance.

Calls for Closer Academic Communication

- **Establish Industry Standards that Advance Aerospace Engineering:** Ensure product consistency, safety, and reliability.
- **Launch Reputable Journals for Knowledge Exchange:** serve as platforms for collaboration among researchers, industry professionals, and academia.
- **Strengthen Collaboration through Academic Associations:** Cultivate a collaborative culture, providing resources and support, and creating platforms for interaction.
- **Empower Communication through Academic Conferences:** Foster interdisciplinary dialogue and knowledge sharing.

Upcoming Events

ICAF 2025:

Welcome to Xi’an, China!