ICAF

International Committee on Aeronautical Fatigue and Structural Integrity

Full-Scale Fatigue Testing

Dr. Xiasheng Sun—ICAF National Delegate of China

11th June 2025

Contents

- Related presentation times and topics about full-scale fatigue testing.
- Review of full-scale fatigue testing based on ICAF National reviews from 2023-2025 with brief highlights of key advancements.
- Discussions on future trends in full-scale testing technologies.

ICAF International Committee on Aeronautical Fatigue and Structural Integrity

Related presentations

June 11 (DAY3)

Duration	Contents	Chair	Presenter	Country
8:30-8:40	Jaap Schijve Award Ceremony	Marcel Bos	Panayiotis TSOKANAS	Greece
8:40-9:00	Jaap Schijve Award Lecture			
9:00-9:30	**Topical National Review 5: FULL-SCALE FATIGUE TESTING**	**Marcel Bos**	**SUN Xiasheng**	**China**
9:30-10:00	**Session 6: FULL-SCALE FATIGUE TESTING**			
9:30-9:45	FATIGUE TESTING TECHNOLOGY FOR FULL-SCALE AIRCRAFT BODY STRUCTURE		WANG Gang	China
9:45-10:00	FUII-SCALE FATIGUE TEST TECHNOLOGY FOR LARGE-SCALE AMPHIBIOUS AIRCRAFT		DING Qi	China
10:00-10:20	**Poster Pitches Day 3 (10)**			
	FULL-SCALE FATIGUE TEST FUSELAGE LOADING TECHNOLOGY FOR A LARGE AMPHIBIOUS AIRCRAFT		ZHANG Jinhua	China
	THE WING'S LOAD OPTIMIZATION MODEL ON A FULL-SCALE AIRCRAFT STRUCTURE FATIGUE TEST		LI Tao	China
	APPLICATION OF ADAPTIVE MESH PARTITION METHOD IN FULL-SCALE AIRCRAFT FATIGUE LOAD PROCESSING		WANG Xin	China
	FATIGUE TEST LOAD PROCESSING STUDY FOR A LARGE-SCALE AMPHIBIOUS AIRCRAFT		GUO Junchen	China
	STUDY ON DATA PROCESSING METHOD FOR FULL-SCALE AIRCRAFT FATIGUE TEST		ZHANG Qingyong	China
	RESEARCH OF CONSTRAINT DESIGN TECHNOLOGY FOR FATIGUE TEST OF LARGE AIRCRAFT		LIU Bing	China
	EXPERIMENTAL STUDY ON NARROW-BAND RANDOM VIBRATION FATIGUE OF COMPOSITE PLATE STRUCTURES		FENG Xiong	China
	RESEARCH ON OPTIMIZATION DESIGN OF LOADING SCHEME FOR FULL-SCALE FATIGUE TEST		FENG Xiao	China
	EVALUATION AND PREDICTION METHODOLOGY FOR FAILURE MODES IN FULL-SCALE METALLIC AIRFRAME-COMPOSITE VERTICAL TAIL ASSEMBLY WITH BVID (BARELY VISIBLE IMPACT DAMAGE) IMPACT		YANG JunjieOu	China
	PARAMETER CALIBRATION AND STATIC ANALYSIS METHOD FOR COMPOSITE BOLTED JOINTS CONSIDERING UNCERTAINTY		LI Chengye	China

National reviews *Full-Scale Fatigue Testing*

- 5.1 Observations of Fatigue Crack Nucleation and Growth in Ti-6Al-4V Full-scale Structures under Combat Aircraft Loading – I. Field, S. Barter, M. Jones, B. Main, R. F. Rosario and M. Figliolino (DSTG, RMIT University), Australian, Isaac Field isaac.field1@defence.gov.au
- 5.2. A Fractographic Study of Fatigue Failures in Combat Aircraft Trailing Edge Flap Hinge Lug Bores in both Test and Service Assets – B. Main, S. Barer, I. Kongshavn, R. F. Rosario, J. Rogers and M. Figliolino (DSTG, RMIT University), Australian, Ben Main ben.main1@defence.gov.au
- 5.3. A Method for Imparting Small-scale Damage for Damage Tolerance Testing – I. Field, J. Rogers, M. Jones, B. Main, K. Muller and S. Barter – (DSTG, RMIT University) , Australian, Isaac Field isaac.field1@defence.gov.au
- 5.4. Technical Outcomes from the Helicopter Advanced Fatigue Test – Technology Demonstrator (HAFT-TD) Program – G. Swanton, A. Manning, M. Chipper, A. Walliker, B. Evans and J. Moonen (DSTG, RMIT University) , Australian, Geoff Swanton Geoff.Swanton@defence.gov.au
- 4.1 Damage tolerance test verification programme for Gripen E/F airframe, Z. Kapidzic, P. Haugskott, Saab Aeronautics, Linköping, Sweden
- 4.2 Fatigue and damage tolerance testing of Gripen E/F elevon, A. Gustavsson, Saab Aeronautics, Linköping, Sweden
- 4.3 Fatigue and damage tolerance testing of Gripen E/F canard, JE. Lindbäck, Saab Aeronautics, Linköping, Sweden
- 2.1 Experimental Strength and Finite Element Modeling of a Disbonded F/A18 Hornet Inner Wing Step Lap Joint, Canadian, Stephane Brunet, NRC Aerospace
- 9.1 Civil aircraft flap high-reliability sinking hinge mechanism test technology Aircraft Strength Research Institute, CHINA, Li Yao, liy389@avic.com
- 9.2 Safety protection technologies for full-scale fatigue testing of c919 aircraft Aircraft Strength Research Institute, CHINA, Wang Mengmeng, wa
- 9. f e, C
- 9. Re , liu

Building block approach and testing pyramids

Full-scale testing

↑

Component testing

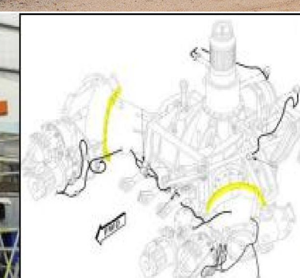
↑

Element testing

↑

Coupon testing

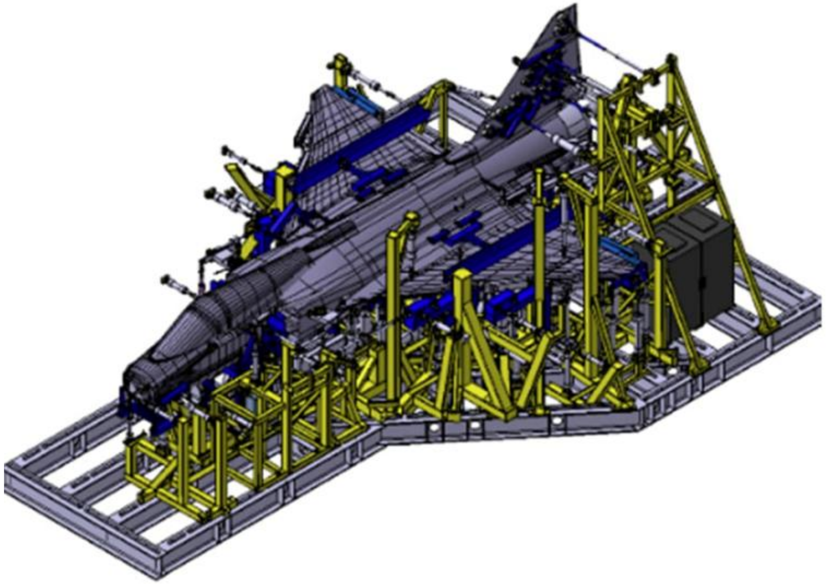
5.4 Helicopter advanced fatigue test-technology demonstrator (HAFT-TD) program



- external loads development
- load spectrum compression techniques
- advanced model-assisted control methodology for servo-hydraulic actuation
- bespoke test rig and load application systems.

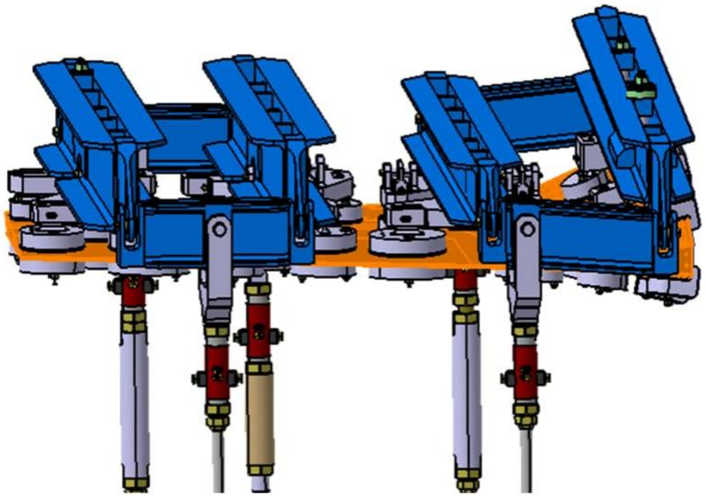
G. Swanton, A. Manning, M. Chipper, A. Walliker, B. Evans and J. Moonen (DSTG, RMIT University)
Geoff Swanton Geoff.Swanton@defence.gov.au

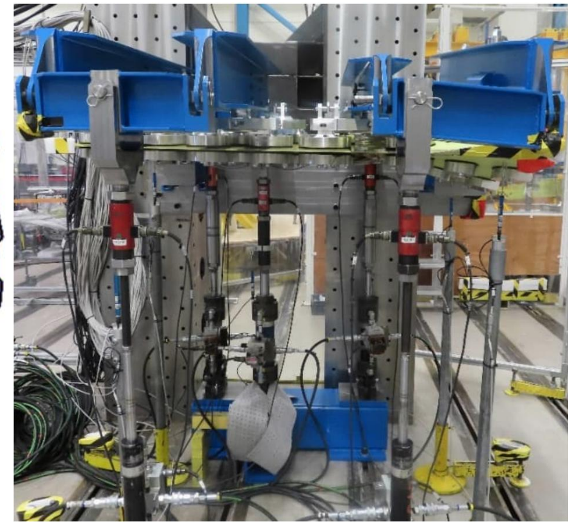
4.1 Damage tolerance test verification program for Gripen E/F airframe

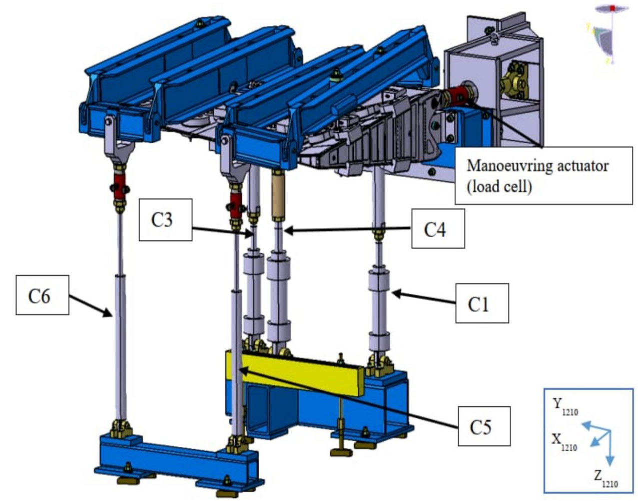


- **Robust Steel Frame:** A high-strength steel frame designed to withstand the demanding.
- **Advanced Data Acquisition System:** An extensive network of approximately 800 strain gauges provides real-time data on strain distribution throughout the structure.
- **Hydraulic Actuation System:** 126 hydraulic cylinders enable precise control and application of various load profiles.
- **Pressurization System:** Eight pressure channels facilitate the pressurization of fuel tanks, cockpit, and air ducts, simulating in-flight conditions.

4.2 Fatigue and damage tolerance testing of Gripen E/F elevon



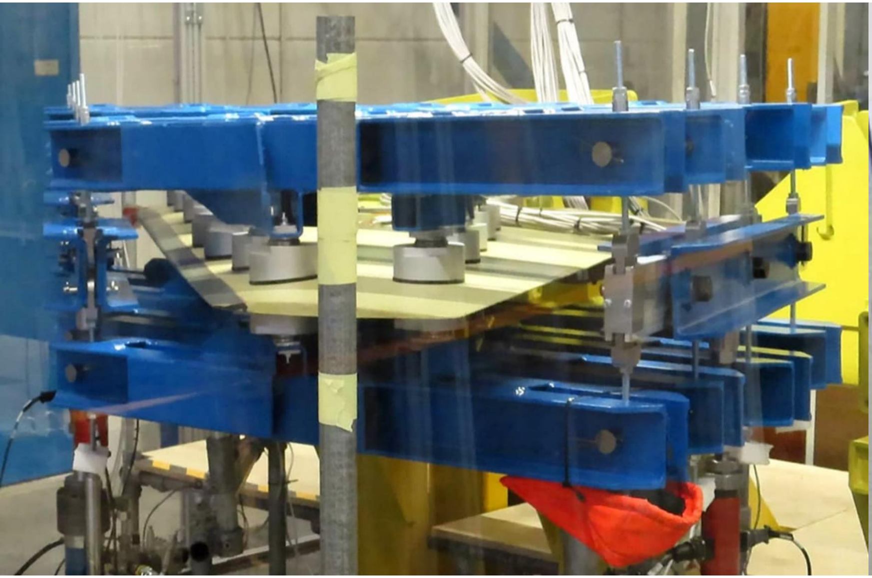


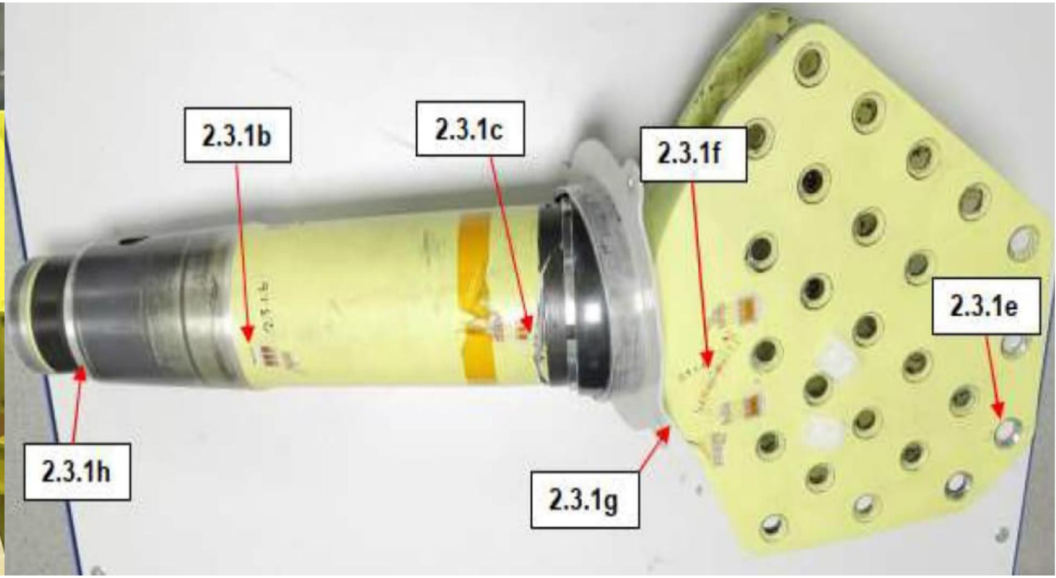


- Two design load sequences, one for 39E-version and the other for the 39F-version.
- 6 artificial crack was introduced for the two last design lives.
- The test was run for 5.0 design lives in total.

The elevon tests were successful and the structures showed out to be robust from a fatigue respective a damage tolerance point of view.

4.3 Fatigue and damage tolerance testing of Gripen E/F canard





Objective:

- To validate 4 design life fatigue strength.
- To validate no or limited crack growth for the 2-design life load spectrum in the Damage Tolerance test.
- To show residual strength for selected static load cases to 120%LL after 4 design life.
- To cover both 39E and 39F.

2.1 Experimental & FEA of Disbonded F/A-18 Hornet Wing Joint

◆ Test Loads:

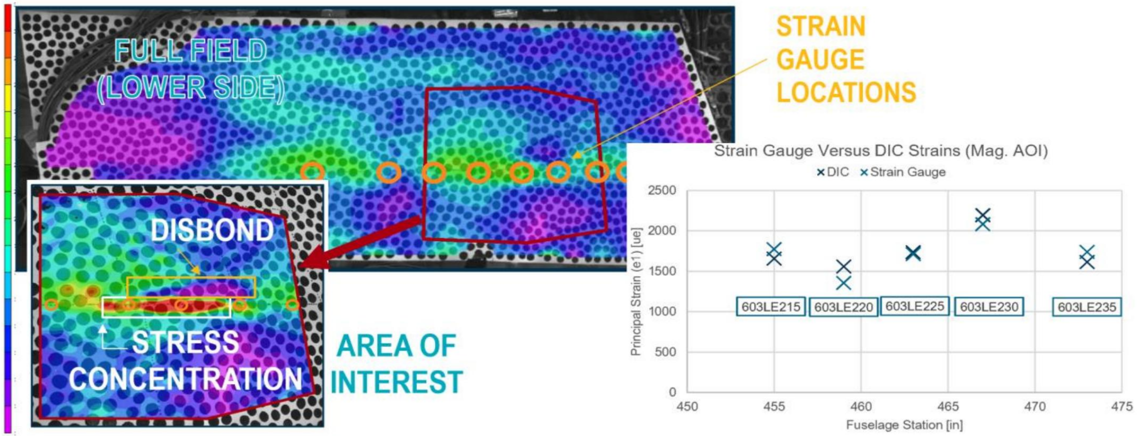
1. Fatigue: +77.3%/-7.1% DLL → +5% increments
2. Ultimate: 136.8%↑/153.6%↓ DLL static bends

◆ Key Findings:

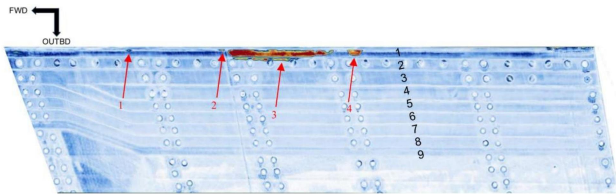
1. Disbond grew chordwise (fasteners blocked spanwise spread)
2. No failure at 50%+ beyond design loads

◆ Tech Leap:

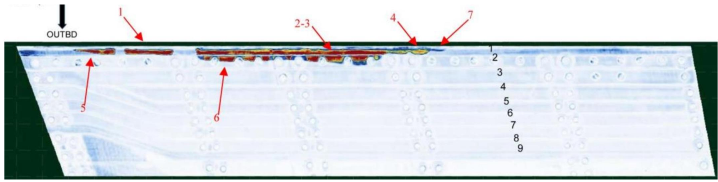
1. DIC + 182 gauges → predict disbond size from strain spikes



Digital image correlation strain map showing local effects of the disbond



Baseline inspection result



Final inspection result

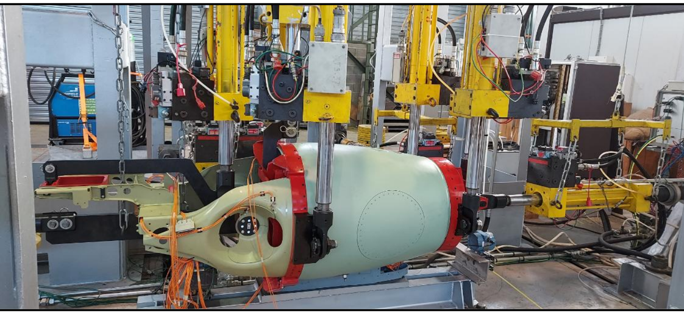
Stephane Brunet, NRC Aerospace

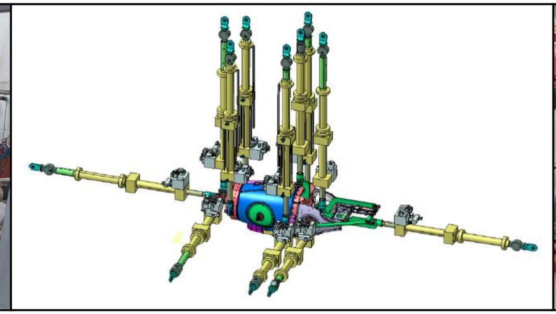
ICAF
International Committee on Aeronautical Fatigue and Structural Integrity

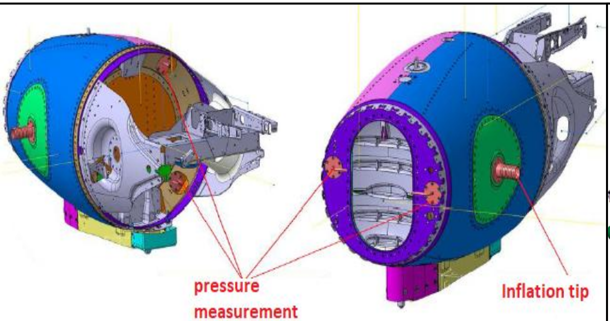
Fatigue tests for NARANG aerial refueling pod

Objective: Qualify pod for quasi-static fatigue on French Navy fighters

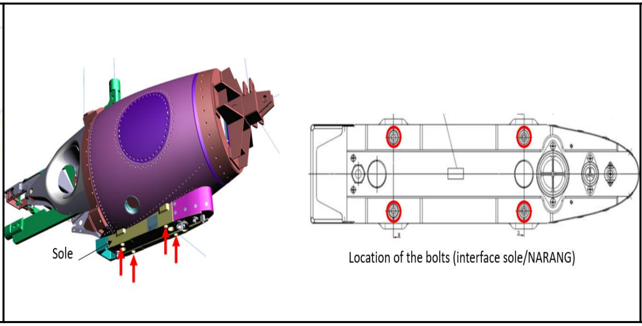
Test setup and validation: 12 hydraulic jacks, validate the fatigue life of the structure with a safety factor.



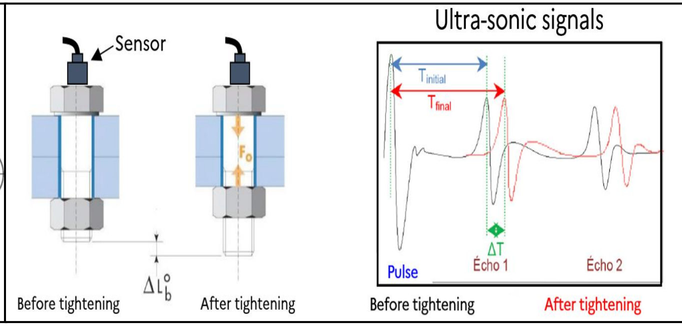




strain gauges, displacement sensors, pressure stitches



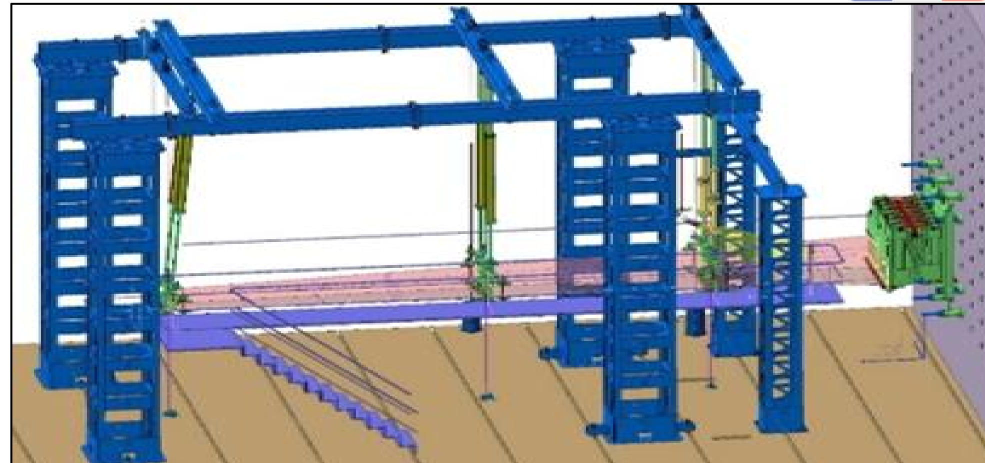
Tensile preload bolts to check boundary conditions

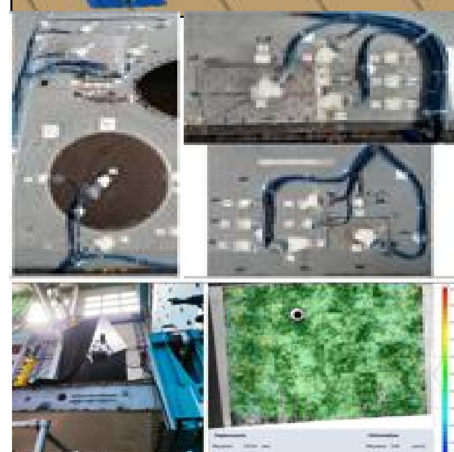


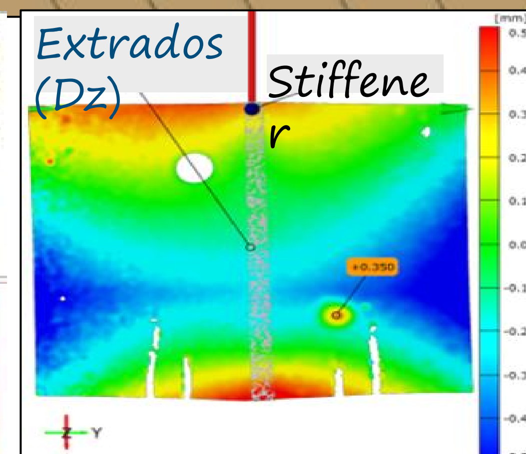
Ultra-sonic measurement methode

ATL2 Wing Debonding & Repair Validation (ACCROCS)

- **Challenge:** Aluminum sandwich wings →Corrosion/debonding risks
- **Objective:** Study debonding propagation & repair solutions
- **Test Setup:**
  - 12m wing section
  - 6-point bending/torsion loading
  - Dedicated support frame
- **Innovations**
  DIC with fractal pattern film
  Multi-sensor monitoring (strain/FBG)
  Novel repair techniques
- **Outcome**
  Validated large-field measurement accuracy
  Captured deformation heterogeneity







Supplementary Fatigue Validation for Aircraft Life Extension

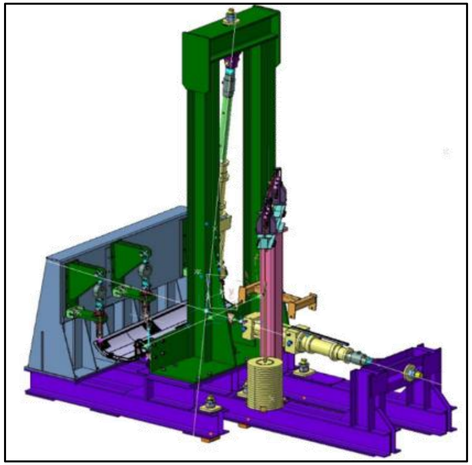
◆ **Objective:**
Validate front trap fittings' service life
→ Match main structure safety factor
→ Achieve higher safety margin

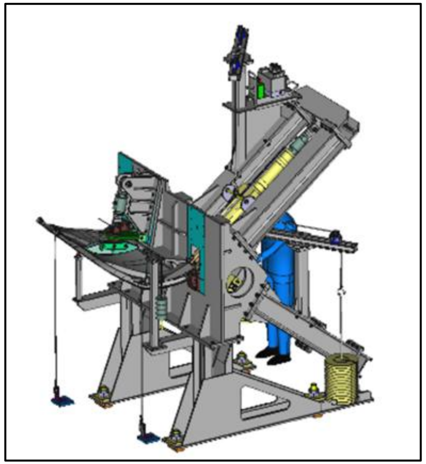
◆ **Test Specimens:**
Front/main landing gear traps
(composite | NIDA core | Metallic parts)

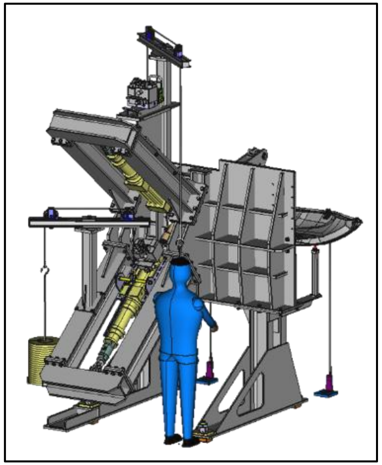
◆ **Load Spectra:** All flight phases
• Takeoffs/landings | Catapults/arrests
• Touch and Go (TAG) | Ground maneuvers

◆ **Test Sequence:**

- Fatigue test → Residual strength test
- Ultimate load validation
- Post-test specimen analysis







C919 Aircraft Full-Scale Fatigue Test Program

Full-scale Structure Fatigue Test

Full-scale Structure Fatigue Test

rear fuselage and vertical tail

slat kinematic

windshield

aileron

flap

hatches

motion mechanism

C919 aircraft rear fuselage and vertical tail fatigue test

Integrated Full-Scale Test Platform

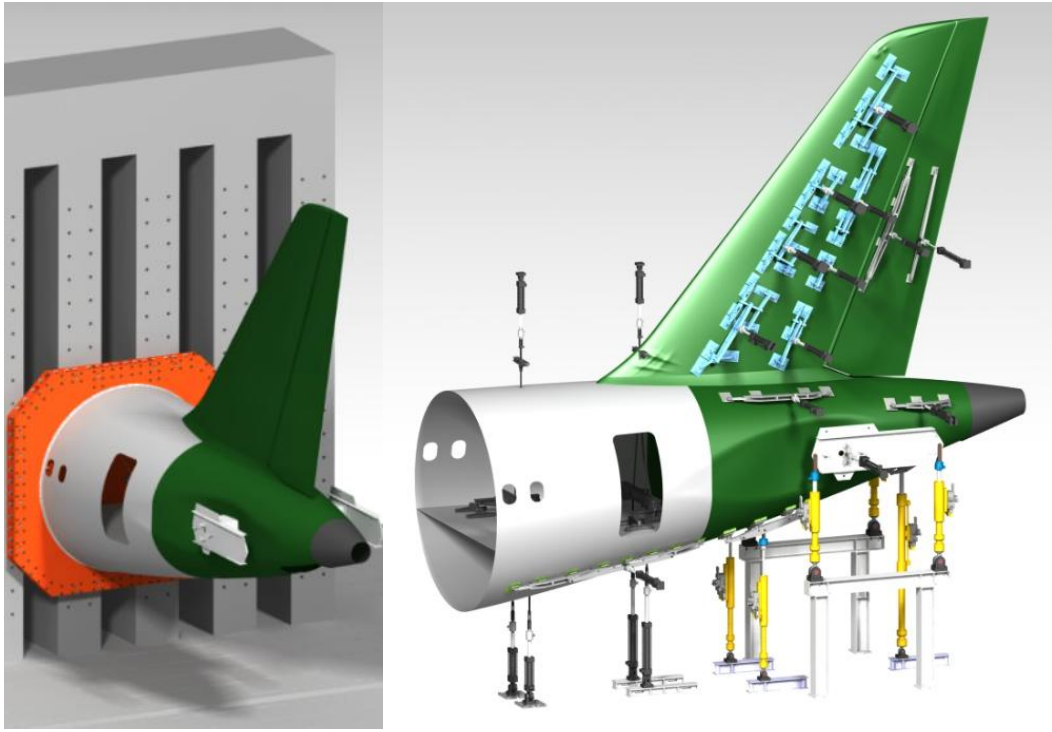
- Structures beyond Frame 64 (mid-rear fuselage, rear fuselage, vertical tail)
- Dummy horizontal tail with box-shaped end-cap fixation
- 27-point loading system

Fully Rigid Loading Method

- Tension-compression pad-lever systems
- Synchronized cabin floor beam/joint loading

Distributed Data Acquisition

- Proximal analog-to-digital conversion
- 60% on-site cabling reduction
- Enhanced anti-interference performance



Static/fatigue verification: **333 days**

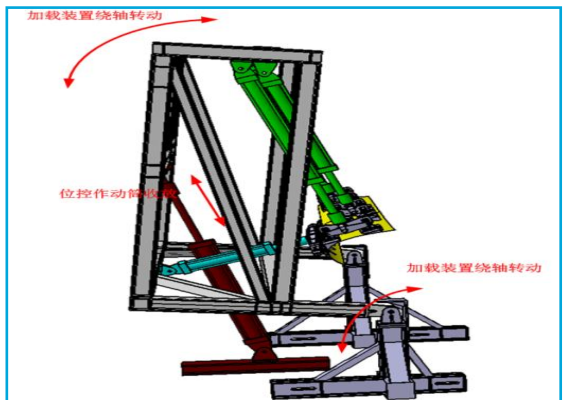
Damage tolerance verification: **265 days**

Aircraft Strength Research Institute, Liu Wei, liuw103@avic.com

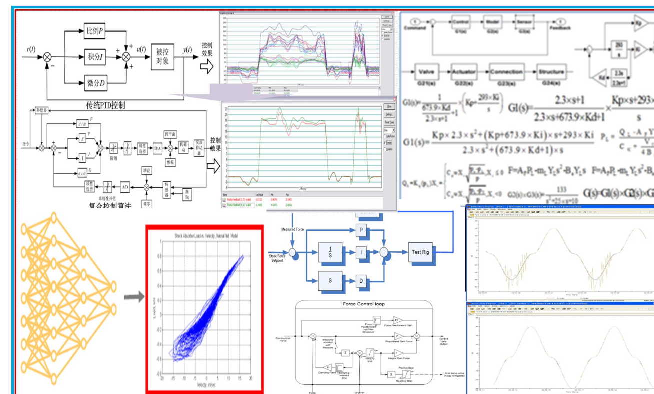
Fatigue test of slit-wing kinematic mechanism of C919 airplane

- High-precision load-following loading technology based on accurate boundary simulation
- Multi-system collaborative precision control based on motion modeling, with an error of no more than 1°.
- Multi-level security protection based on real-time state sensing

Unilateral bi-directional homogeneous constraints



Movable airfoil follower loading mechanism



Adaptive control algorithms

Aircraft Strength Research Institute, Wang Zheng, wangz123@avic.com

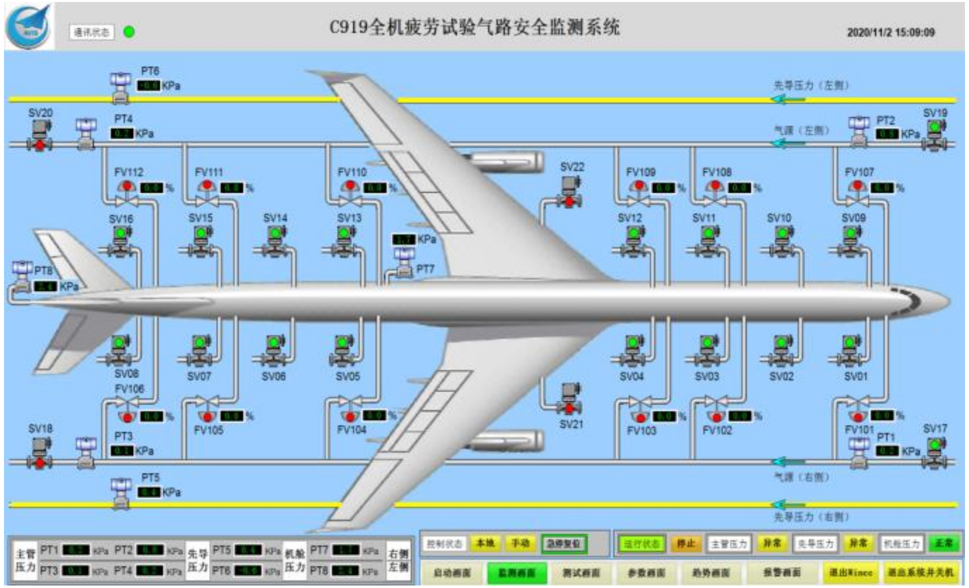
Safety protection technologies for full-scale fatigue testing of C919 aircraft

- **Start time: 2021**
- **3 times life fatigue test**
- **124 Load Channels, 1500 strain measure channels**

Aircraft Strength Research Institute, Wang Mengmeng, wangmm011@avic.com

Safety protection technologies for full-scale fatigue testing of C919 aircraft

Air inflation overpressure protection system

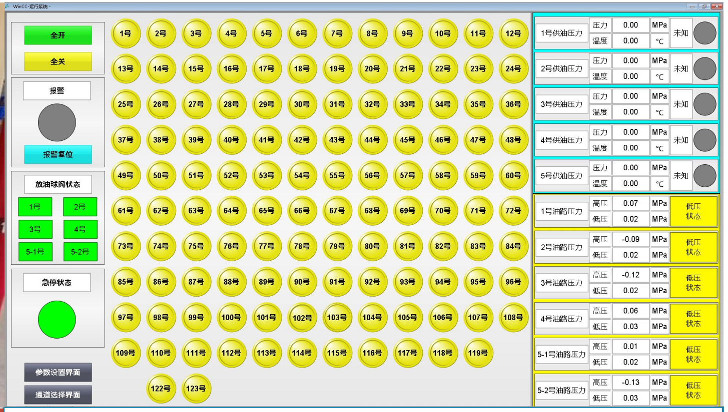


- Rapid Inflation/Deflation for Large Volumes
- High-Flow Noise Reduction Systems
- Multi-Layer Safety for High-Pressure Operations
- Dynamic Pressure Equalization in Large Chambers
- Synchronized Inflation/Deflation for 40 Windows
- 55% Efficiency Improvement
- 99.99% Safety Assurance
- 20dB Noise Reduction

Aircraft Strength Research Institute, Wang Mengmeng, wangmm011@avic.com

Safety protection technologies for full-scale fatigue testing of C919 aircraft

Hydraulic pipeline overpressure protection and monitoring



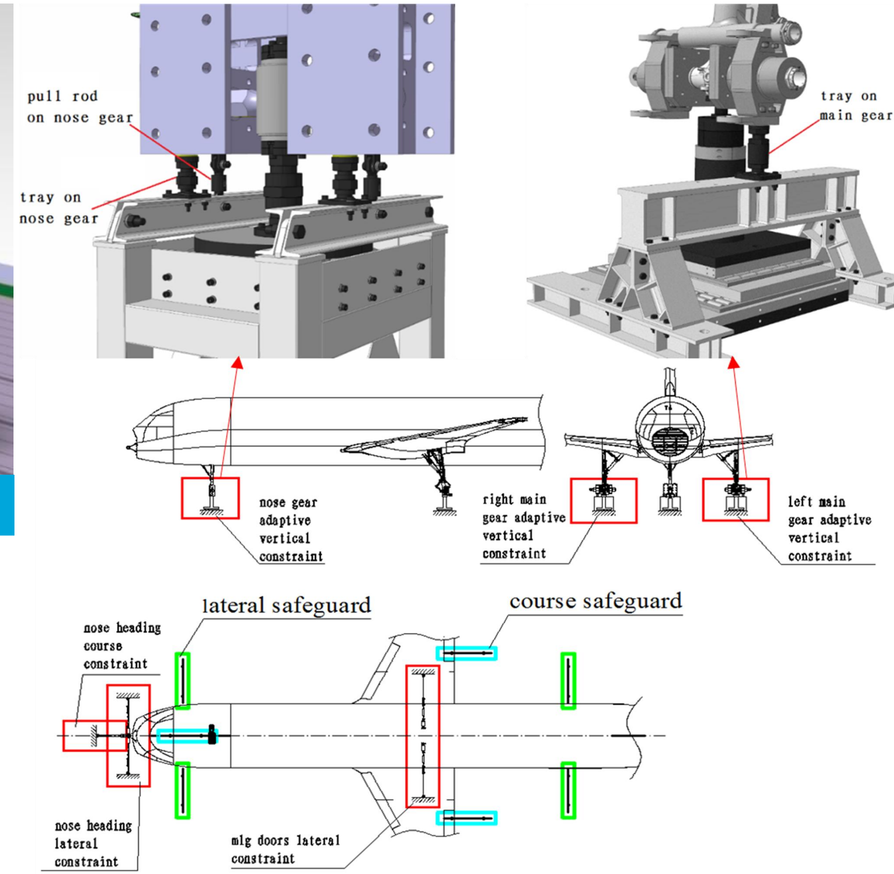
- Real-time Pressure/Flow Monitoring
- Integrated Control Distributor Status Visualization
- Overflow Valve Emergency Pressure Relief

Aircraft Strength Research Institute, Wang Mengmeng, wangmm011@avic.com

Safety protection technologies for full-scale fatigue testing of C919 aircraft

Aircraft constraint protection system

6-DOF Displacement Compensation System



- **Nose Gear Protection**: Tray-pull rod assembly prevents tilt & pitch anomalies
- **Main Gear Protection**: Dummy wheel trays reduce support collapse risks
- **Actuator Cylinder Limiters**: Emergency heading/lateral deviation control

Aircraft Strength Research Institute, Wang Mengmeng, wangmm011@avic.com

The Large-Scale Fire Extinguishing/water Rescue Amphibious Aircraft Fatigue Test Program

Full-scale Aircraft
Fuselage
Wings
Empennage

Slat
Inner slat
Outer slat

sponson

Landing gear
Front landing gear
Main landing gear

The large-scale fire extinguishing/water rescue amphibious aircraft fatigue test

Unique Design Challenges:

- Hydrodynamic/aerodynamic dual requirements
- Structural & load distribution differences vs. land-based aircraft

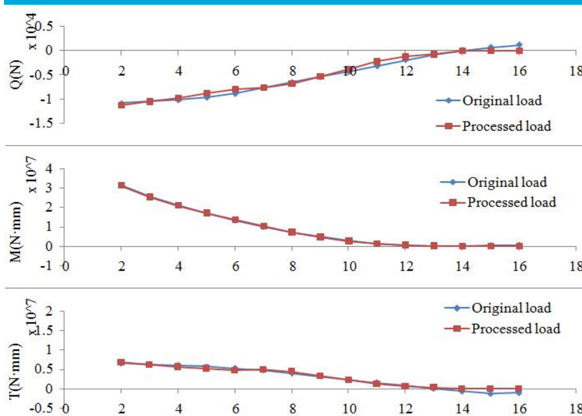
Breakthrough Technologies:

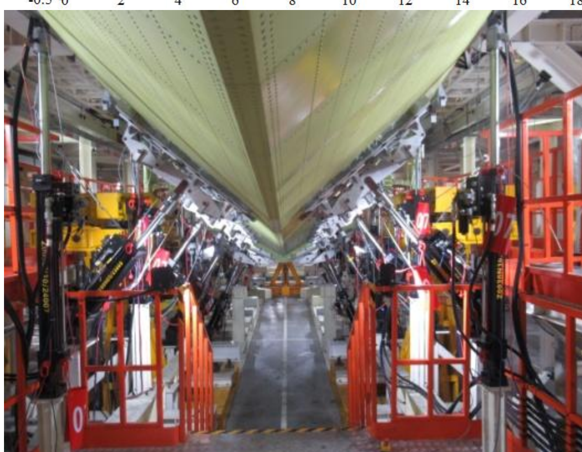
- Precise load processing for complex marine/aerial loads
- Micron-level loading accuracy across test platforms
- "0g" simulation via weight-offloading systems

Aircraft Strength Research Institute, Wang Zheng, wangz123@avic.com

The large-scale fire extinguishing/water rescue amphibious aircraft fatigue test

Load handling and application



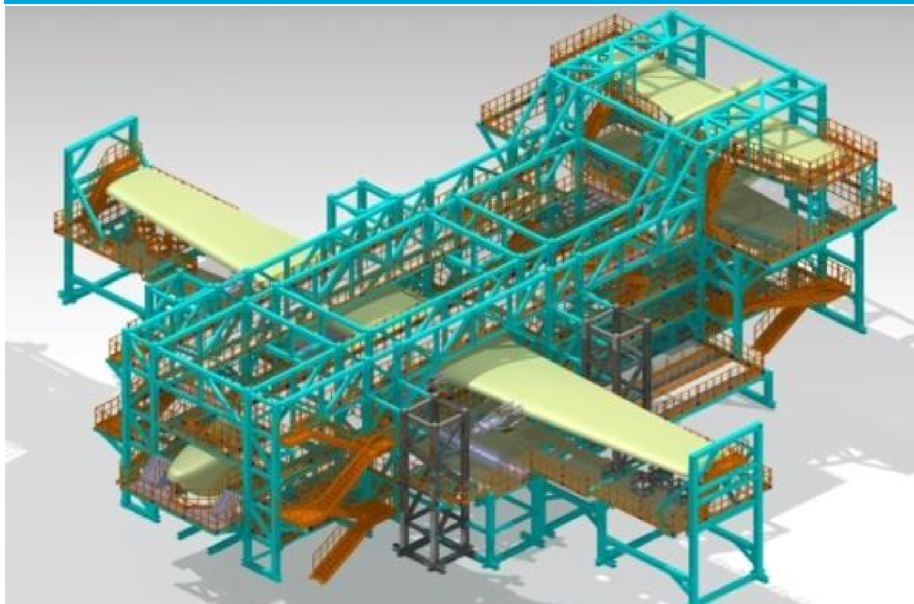


- **Mission Profiles:**
  Water scooping/injection fire suppression, airdrop/water landing rescue
- **Load Simulation Challenges:**
  Hydrodynamic + Aerodynamic + Inertial load conversion
  Limited actuators → Advanced load processing methods
- **Structural Uniqueness:**
  Complex environment adaptation vs. land-based aircraft
- **Test Implementation:**
  151 hydraulic actuators

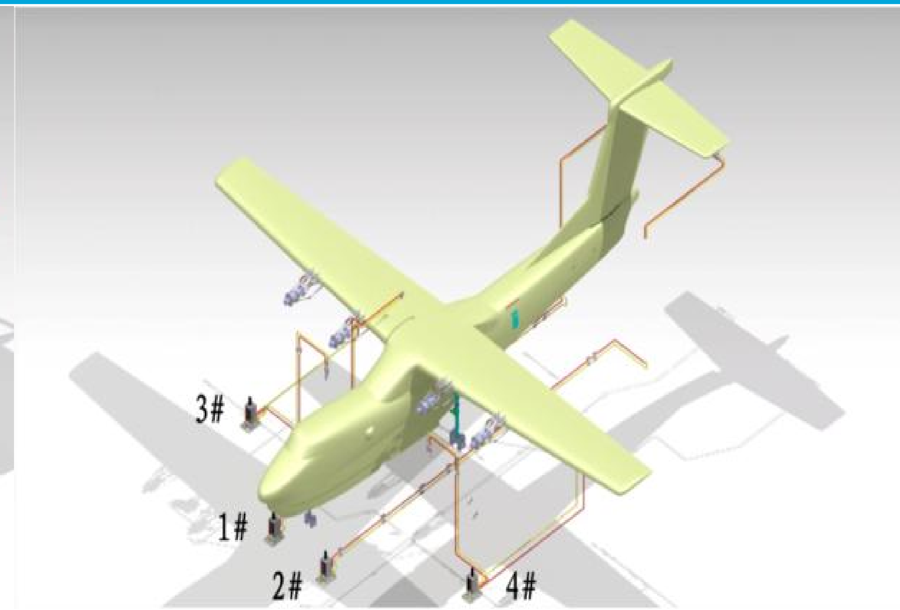
Aircraft Strength Research Institute, Wang Zheng, wangz123@avic.com

The large-scale fire extinguishing/water rescue amphibious aircraft fatigue test

Test Platform



multi-functional test loading platform



hydraulic infrastructure

ICAF
International Committee
on Aeronautical Fatigue
and Structural Integrity

Trends and prospects

Digital Twins

—Multi-level model-based precision prediction

Fatigue Acceleration

— Enhanced test efficiency methodologies

Condition Awareness

— Real-time damage detection & health monitoring

Data Intelligence

— High-precision measurement & real-time analytics

THANKS!