Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

Destructive testing methodologies and the certification of landing gear systems: impacts on compliance and operational safety

Methodologies for destructive testing and landing gear system certification: impacts on compliance and operational safety

Destructive testing methodologies and certification of landing gear systems: impacts on it compliance and operational security

Luiz Guilherme da Fonseca

Manufacturing Engineering; Technical Specialist in Aerospace Mechanics.

Summary

This article analyzes the critical laboratory processes aimed at structural validation and Certification of landing gear components in the aeronautical industry. I investigate the application of destructive and stress tests, such as fatigue, resonance, *free* fall and tolerance tests. thermal *(cold/ hot soak),* essential for compliance with the regulations of regulatory authorities. global. I discuss how accurate data collection, aided by advanced instrumentation and sensors, can improve global data collection. Temperature control allows us to establish the limits of structural integrity. The study demonstrates that... Scientific rigor in these procedures is the determining factor in preventing catastrophic failures in hydraulic systems, ensuring compliance and operational safety of modern aircraft.

Keywords: Aerospace Engineering. Destructive Testing. Aeronautical Certification. Aircraft Train Landing. Flight safety.

Abstract

This article analyzes the critical laboratory processes aimed at structural validation and certification of landing gear components in the aeronautics industry. I investigate the application of destructive and stress tests, such as fatigue, resonance, free fall, and thermal tolerance (cold/hot soak), which are essential for compliance with global regulatory requirements. I discuss how precise data collection, aided by advanced instrumentation and temperature sensors, allows the establishment of structural integrity limits. The study demonstrates that scientific rigor in these procedures is the determining factor in preventing catastrophic failures in hydraulic systems, ensuring the compliance and operational safety of modern aircraft.

Keywords: Aerospace Engineering. Destructive Testing. Aeronautical Certification. Landing Gear. Flight Safety.

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

Introduction

The structural integrity of modern aircraft depends on rigorous environmental validation.
laboratory, in which critical components are subjected to extreme conditions that simulate the cycle.
full operational life. In the context of aerospace engineering, the landing gear system
It is one of the most technically complex assemblies, requiring a combination of strength.
Mechanical precision, hydraulic precision, and reliability under severe thermal and impact variations. In
In my analysis, the certification of these systems by authorities such as the FAA (Federal Aviation Administration)
Administration) and ANAC (National Civil Aviation Agency) is the pillar that sustains safety.
global flight.
The certification process is not merely bureaucratic, but rather an engineering exercise.
In-depth testing that uses destructive testing to determine the failure limits of materials. Through
Through the application of cyclic loads and impact tests, it is possible to identify vulnerabilities.
structural issues that would be imperceptible in conventional inspections. I argue that precision in
The execution of these methodologies defines the reliability of an aerial platform, transforming
Raw sensor data provides operational assurances for operators and passengers.
This article proposes an investigation into testing methodologies and the necessary instrumentation.
to the validation of aerospace components. I explore how the integration of reading systems of
The interface and continuous monitoring of physical variables allow for a detailed understanding of
The behavior of materials under stress. The objective is to highlight that operational safety in
Executive and commercial aviation stems directly from a rigorous established scientific protocol.
in the development and engineering testing phases.

1. Impact Dynamics and Free Fall Tests

In my laboratory practice, I consider the free fall test to *be* one of the most important steps.
Critical factors for the kinematic and structural validation of the landing gear. This test aims to simulate the forces
vertical and descent speeds observed during landing, assessing the ability to
energy absorption by the shock absorber and the integrity of the structural fixings. The instrumentation in this
The scenario requires the use of accelerometers and high-frequency displacement sensors to capture the...
behavior of the hydraulic fluid and the deflection of the metal components at the exact moment of
impact.
The technical analysis of this test allows us to verify if the design meets the dissipation requirements of
Energy without transferring excessive loads to the aircraft fuselage. Through data collection.

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
RCMOS - Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

In high-speed systems, I can correlate the internal pressure of the shock absorber to the load of
The impact applied ensures that the system operates within the designed safety zone. This
Monitoring is vital to avoid the phenomenon of "hard landing" *which* could
to compromise the primary structure of the aircraft.
The application of certification standards requires that the component be tested under weight conditions.
Maximum takeoff and landing speeds, including safety margins for emergency situations. In
In my view, precision in test preparation, from bench alignment to calibration, is paramount.
The technology of the sensors is what ensures the validity of the results submitted to regulatory authorities.
The scientific data generated here is what allows the model to be released for real test flights.
In addition to brute strength, the free-fall test evaluates the functionality of the systems.
locking and extension. I note that the response of the hydraulic system must be immediate and
Consistent, without leaks or pressure losses resulting from sudden mechanical stress. A
Test engineering therefore seeks not only the survival of the material, but also the
Maintaining full system operability after high load events.
The technical conclusions derived from these tests provide the parameters for the maintenance manuals and
the lifespan limits of components. Without this empirical basis, aerospace engineering would operate
based on theoretical assumptions, which is unacceptable in an industry with zero tolerance for failure. The
Impact testing is definitive proof that the CAD-conceived design possesses resilience.
necessary to face the operational reality of the field.

2. Fatigue Analysis and Structural Strength Cycles

Material fatigue is the main cause of failures in mechanical components subjected to loads.
repetitive processes in aviation. In testing laboratories, I subject landing gear components to
Thousands of compression and tension cycles to map the emergence of microcracks and the limit of
Resistance to crack propagation. Instrumentation with strain gauges is
This is fundamental at this stage, allowing the measurement of surface tensions at critical points beforehand.
identified by finite element models.
Continuous monitoring during long-duration tests is essential to detect the exact point.
of structural degradation. I use data acquisition systems that record variables, such as
Temperature, deformation, and applied load, in real time, enabling predictive analysis of service life.
of the component. This methodology ensures that the inspection intervals foreseen in the plans are met.
Maintenance should be based on scientific evidence of wear and tear, preventing in-service failures.
Regulatory compliance requires that fatigue tests simulate various mission profiles, from

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
RCMOS - Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

short flights with many landing cycles to long-distance missions. I maintain that the definition
Correctly performing these test profiles is what guarantees the operational safety of executive jets operating
at airports with runways paved at different levels. Fatigue resistance is therefore,
a measure of the aircraft's long-term reliability.

During the strength tests, the observation of the thermal behavior of the metal under cyclic load
provides *insights* into internal energy dissipation. Excessive temperature increase in
Joints or pivots can indicate inefficiencies in lubrication or design flaws that accelerate wear and tear.
Wear and tear. My technical work focuses on identifying these early signs, allowing for modifications.
in the design phase before the model goes into mass production.

In short, fatigue analysis transforms temporal uncertainty into manageable engineering data.
Understanding fatigue limits allows the aerospace industry to maximize the use of assets.
without compromising safety, establishing the concept of condition-based maintenance. This
Rigorous laboratory testing is what allows aircraft to operate safely for decades, throughout
Multiple generations of maintenance.

3. Resonance Phenomena and Vibrational Tests

The study of resonance is vital to prevent harmonic vibrations that could cause disruption.
Aeronautical components in flight or during taxiing. On test benches, I use systems
frequency sweep to identify the natural frequencies of the train components.
landing. The goal is to ensure that these frequencies do not coincide with the stimuli generated by
engines, through wheel rotation or aerodynamic vibrations, which would cause the phenomenon of
catastrophic resonance.

Vibrational instrumentation uses piezoelectric transducers to measure amplitude and
acceleration of oscillations in different coordinate axes. Through spectrum analysis, I can...
identify vibration modes that could lead to loosening of fasteners or failures in piping.
hydraulics. I argue that vibrational stability is such an important quality metric.
Regarding pure mechanical strength, especially in high-performance aircraft such as jets.
executives.

Resonance tests also validate the effectiveness of vibration dampers installed in
system. I note that the response of the ensemble must be damped quickly to avoid the
propagation of shock waves through the wing or fuselage structure. In my practice, the collection
Vibrational data from the soil provides the basis for the development of mathematical models that
They predict the aircraft's behavior in transonic flight conditions.

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

Certification by regulatory bodies requires that the landing gear system demonstrate...
Stability across the entire operating speed envelope. Laboratory vibration tests.
They allow these conditions to be simulated in a controlled and safe manner, protecting the aircraft and the pilots.
testing. The precision in identifying vibrational "critical points" allows for structural reinforcements.
localized, optimizing the final weight of the aircraft without compromising safety.
Therefore, vibrational testing engineering is a tool for failure prevention.
unforeseen dynamics. By mastering the frequency spectrum of a component, I ensure that it
It will operate harmoniously with the rest of the aircraft. This scientific analysis is indispensable both
for passenger comfort as well as for the continued structural integrity of the aircraft.
high-caliber female executives.

4. Thermal Tolerance and Cold/Hot Soak Tests

Long-range aircraft face extreme temperature variations, operating in temperatures that...
Temperatures range from -55°C at cruising altitude to +50°C on runways in desert regions. In the laboratory,
I perform *cold/hot soak* tests to validate the behavior of seals, hydraulic fluids and
Electronic components under these harsh conditions. The instrumentation requires climate chambers.
equipped with PT100 temperature sensors strategically distributed throughout the component
tested.

The functionality of the landing gear should remain unchanged even after hours of exposure to...
extreme temperatures, which could make the rubber seals brittle or increase the
viscosity of the hydraulic fluid. I monitor the extension and retraction times during the test.
thermal protection is needed to ensure that the motors and actuators maintain the torque required to operate the...
The system operates within the required time limits. Any delay in operation under severe cold conditions is...
considered a point of failure that requires design review.
At the opposite extreme, the heat test validates the resistance to thermal expansion and the effectiveness of
Cooling in critical systems. Heat dissipation in brake assemblies during braking.
Intense radiation is a point of special attention in my tests. The use of infrared thermography in
Real-time data allows you to view the component's heat map, ensuring that temperatures are not...
reach the point of degradation of the mechanical properties of aluminum or steel alloys.
Climate certification ensures that the aircraft is operable anywhere in the world.
regardless of extreme weather conditions. I maintain that rigor in these tests is the
which ensures the daily reliability of the global fleet, reducing operational delays caused by
System failures in adverse weather conditions. Thermal science applied to aeronautics.

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

It protects passengers against failures in pressurization and hydraulic control.
Consequently, understanding the thermal behavior of materials is fundamental to...
Selection of components and lubricants. Based on empirical laboratory data, I define the...
safe operating windows and the necessary preheating or cooling procedures
for ground operations. The climate test ensures the physical integrity of the landing gear in all
the layers of the atmosphere and on all continents.

5. Burst Tests and Hydraulic Integrity

The hydraulic systems of executive aircraft operate under high pressures to ensure force.
necessary for the movement of the control surfaces and landing gear. In the laboratory,
I subject pipes and cylinders to a *burst* test , in which the internal pressure is increased to
component failure. This destructive test is vital to establish safe operating pressure and
the safety factor required by aerospace engineering, which generally ranges from 1.5 to 3 times the
nominal pressure.
The instrumentation in this test uses fast-response pressure transducers and systems of
containment armor. I monitor the pressure versus time curve to identify the point of
plastic deformation before final rupture. This data is essential for validating the processes of
manufacturing processes, such as welding and tube forming, ensuring that each unit produced...
Meet global hydraulic safety certification standards.
Hydraulic integrity is a cornerstone of flight safety, as fluid loss can lead to...
inability to extend the landing gear or loss of directional control. In my view, the
A *burst* test is the ultimate guarantee that the system will withstand pressure spikes resulting from...
Sudden or fluctuating maneuvers in hydraulic pumps. The mechanics of fluids under high pressure.
It guides the selection of materials and the design of leak-resistant connections.
In addition to the explosion, I perform cyclic pressure impulse tests to simulate the effect of a hammer.
hydraulic system. This analysis allows us to verify if pressure fluctuations cause fatigue.
Premature cracking in the pipe walls. The collection of statistical data on failures resulting from
Cyclic pressure forms the basis for guidelines on preventive replacement of hoses and components.
hydraulics throughout the aircraft's life cycle.
Therefore, rigorous pressure testing is what protects the aircraft against systemic failures.
catastrophic. The ability to predict where and how a component will fail under extreme pressure.
This allows engineering to create redundant systems and fault protection mechanisms.
Commitment to hydraulic integrity is what keeps aviation as a means of transportation.

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

the safest in the world.

6. Advanced Instrumentation and Data Acquisition via LabVIEW

The modernization of aeronautical test engineering is driven by the ability to process
Massive volumes of data with extreme precision. In my essays, I use data acquisition systems.
data based on the LABVIEW platform, which allows the integration of hundreds of sensors.
different natures (thermal, mechanical, electrical) in a single logical interface. This technology
It enables real-time monitoring of complex variables and the automation of protocols.
Long-duration testing, ensuring the repeatability and reliability of results.
Advanced instrumentation allows for the detection of transient anomalies that would otherwise go unnoticed.
unnoticed in traditional analog systems. When using FTI *(Flight Test Instrumentation)*
Adapted for laboratory use, I can map the dynamic behavior of components at different scales.
milliseconds. I maintain that the quality of technical certification is directly proportional to
resolution of the collected data; more accurate data generates more robust security models and
more efficient aircraft.

Software-based automation allows destructive testing to be conducted using load profiles.
Extremely precise, eliminating human error in the application of force. The system can
to interrupt the test instantly upon detecting a variation outside the parameters, preserving the
Hardware for detailed post-failure analysis. This surgical approach to data collection is what
This distinguishes cutting-edge laboratories in the American and global aerospace industry.
In addition to data collection, the capabilities include post-processing of data and generation of technical reports.
Automated systems are vital for streamlining the approval processes with the FAA and ANAC. The use of automated systems is essential.
The use of digital filters and statistical analysis algorithms allows for the extraction of wear trends that
They guide product engineering towards continuous improvement. Data science applied to testing.
It is, therefore, the engine of continuous innovation in high-tech aerospace manufacturing.
I conclude by emphasizing that advanced instrumentation is what enables integration between the world.
The physical world of the laboratory and the digital world of simulation: Validating theoretical models with real-world data.
With high precision, I reduce the technical risk of new developments and ensure that future generations...
Aircraft exceed current safety standards. The commitment to excellence in
Data acquisition is the invisible pillar that underpins confidence in every takeoff.

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

Conclusion

The research developed in this article demonstrates that scientific rigor in the execution of tests
Destructive capabilities are the non-negotiable basis of operational safety in the contemporary aerospace industry.
Through detailed analysis of critical components under extreme fatigue and impact conditions.
Regarding temperature, I demonstrated that test engineering acts as the ultimate barrier against failures.
catastrophic failures in landing gear systems. Translating laboratory data into parameters.
Certification ensures that highly complex manufacturing operates according to the most stringent standards.
global compliance standards.
It was observed that the precision of the instrumentation and the use of advanced data acquisition systems
They allow for a comprehensive understanding of the behavior of materials. By establishing limits of
Based on empirical evidence, I ensure structural integrity, including maintenance cycles and...
The lifespan of components should be managed based on sound technical criteria.
Commitment to data accuracy is what enables the safe scalability of business aviation.
in a market with high demand for agility and technological reliability.
Vibrational analysis and the study of resonance phenomena have proven fundamental to...
Aerodynamic and structural stability of the aircraft. By identifying and isolating natural frequencies.
Critical ground operations, test engineering prevents serious incidents in flight, protecting
Lives and property. Harmonic stability consolidated in the laboratory is, therefore, a pre-
a requirement for the comfort and safety that define the standard of excellence in the aerospace industry.
modern.

Research into thermal tolerance reinforces the need to validate each seal and each fluid.
hydraulic in relation to the extremes of the operating envelope. The guarantee of functionality in
Arctic or tropical climates are what allow for global mobility without operational restrictions.
operators. The thermal data generated in the climate chamber is the guarantee seal that the integrity
The aircraft's physics are resilient to any atmospheric variations that occur during the mission.
Hydraulic pressure tests and burst tests confirmed that the safety factor in
Aviation is not an estimate, but a proven reality through controlled disruption.
By pinpointing the exact failure point of a pressurized system, engineers can design
Safety margins that protect the flight against unforeseen operational events. Hydraulic integrity.
Laboratory-proven technology forms the backbone of flight control in high-performance aircraft.
and complexity.
Technological integration, through data acquisition platforms such as LABVIEW,
This represents the cutting edge of technical knowledge management. This monitoring capability

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Machine Translated by Google
IRCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year VI, v.1 2025 | Submission: October 30, 2025 | Accepted: November 3, 2025 | Publication: November 6, 2025

Multiparametric testing ensures that tests are repeatable and results are auditable by
International aviation authorities. The digitization of testing is the link that connects the execution.
by applying practical application to theoretical validation, minimizing technical risk and accelerating the innovation cycle.
aerospace industry.

I argue that leadership in the aerospace sector is not sustained solely by assembly capacity.
but also for excellence in the validation and certification of each screw and each component.
Hydraulic. Flight safety is an asset built daily behind the scenes in the laboratories.
of tests, where materials science is applied with zero tolerance for error. The professional who
Mastering these methodologies makes one the guardian of the nation's technological trust and sovereignty in space.
global aviation.

This article finally confirms that the evolution of aeronautics is inseparable from the development...
Continuous scientific development of testing and analysis methods. By investing in laboratory rigor and in
With in-depth technical expertise, the industry ensures not only compliance with regulations, but also...
also the continuous pushing of safety and efficiency limits. The future of business aviation
Commercial success will continue to be designed based on accurate data and rigorous testing that ensures...
the safe return of each aircraft to the ground.

References

ANDERSON, JD **Fundamentals of Aerodynamics.** 7. ed. New York: McGraw-Hill, 2023.

ASM INTERNATIONAL. **Metals Handbook: Properties and Selection: Irons, Steels, and High-Performance Alloys.** 10. ed. Materials Park: ASM International, 2022.

CALLISTER, WD; RETHWISCH, DG **Materials Science and Engineering: An Introduction.** 10th ed. Rio de Janeiro: LTC, 2021.

FEDERAL AVIATION ADMINISTRATION. **Airworthiness Standards: Transport Category Airplanes (Part 25).** Washington, DC: FAA, 2024.

KNUDSON, D. **Fundamentals of Biomechanics.** 3rd ed. New York: Springer, 2023.

NIELSEN SPORTS. **Data Analytics and the Future of Sports Performance.** Global Insights Report, 2023.
NORTON, RL **Machine Design: An Integrated Approach.** 6th ed. Porto Alegre: Bookman, 2021.

PORTER, ME **Competitive Advantage: Creating and Sustaining Superior Performance.** New York: Simon and Schuster, 2021.

ROSCAM, J. **Airplane Design.** Lawrence: DARcorporation, 2021.

ZATSIORSKY, VM **Kinetics of Human Motion.** Champaign: Human Kinetics, 2021.

This article is published in open access under the Creative Commons Attribution license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.