REVIEW OF AIRCRAFT LANDING GEAR TESTS AS PART OF STRUCTURAL TESTING

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Agenda

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- MODERN LANDING GEAR TESTING APPROACH/CAPABILITIES
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- LANDING GEAR TESTING AS PART OF STRUCTURAL TESTING
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INTRODUCTION TO LANDING GEAR TESTING

Landing gear (L/G) is one of the key safety component of the aircraft enabling take-off, landing, and ground manoeuvres.

Main role of the L/G is to dissipate the landing loads acting on the aircraft ensuring safety of the both passengers/crew and cargo.

Source: www.tronair.com

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INTRODUCTION TO LANDING GEAR TESTING

- Regulations require but don't describe L/G testing methodology for meeting the requirements (SAE International - describe overall methodology and best practices).
- Detailed procedure for the tests is determined by the testing facility but it needs to be convincing and proven to provide testing evidence and data acceptable by the regulators. The only suggestion in aviation regulations is to use the equivalent mass method, but direct lift force simulation is also permissible.
- The certification (Airworthiness) test, is the energy absorption test done for two energies – limit (maximum operational) and extended (>1.2 limit)
- Other tests required for certification are not L/G specific but rather refer to the wide range of aircraft structural tests with landing gear is a component (1.5 safety factor proof, fatigue tests for reliability).
- Range of L/G tests includes Static/Quasistatic, Dynamic, Functional, Fatigue

INTRODUCTION TO LANDING GEAR TESTING

40/20T PRESS - parameters

- Forces: Vertical up to 392kN, Horizontal force up to 196kN
- Total vertical displacement 400mm
- Velocities: Vertical up to 300mm/min, Horizontal up to 600mm/min
- Work area: Horizontal 800 x 760mm, Vertical 190 up to 2000mm
- Force or displacement control (continuous or step)
- Force and displacement acquisition (and up to 8 external analogue signals)

Scope of tests

- Static tests
- Force-displacement characteristics
- Shock absorbers, dampers, material characteristics
- Wheel static tests

Source: Landing Gear Laboratory, Ł-ILot

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INTRODUCTION TO LANDING GEAR TESTING

10T DROP TEST STAND - parameters

- Maximum mass of test object including mounting parts: 10T
- Maximum forces in drop tests:
- Vertical: 392kN, Horizontal: 196kN, Side: 157kN
- Maximum buffer pressure (lift): 3 MPa
- Maximum wheel spin up velocity: 111 m/s
- Maximum free fall velocity up to 8 m/s – varies on test object height

Scope of tests

- Drop tests
- Wheel static tests
- Functional tests

Source: Landing Gear Laboratory, Ł-ILot

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INTRODUCTION TO LANDING GEAR TESTING

3T (6T) DROP TEST STAND - parameters

- Maximum mass of test object including mounting parts 3T (it can be extended to 6.5T for wheel testing)
- Maximum vertical force 118 kN
- Drum maximal rotational speed 800 rpm
- Drum maximal peripheral speed 58.6 m/s
- Drum moment of inertia (adjustable) to 843 kgm^2

Scope of tests

- Drop tests
- Shimmy/Obstacle tests
- Brake tests
- Functional tests

Source: Landing Gear Laboratory, Ł-ILot

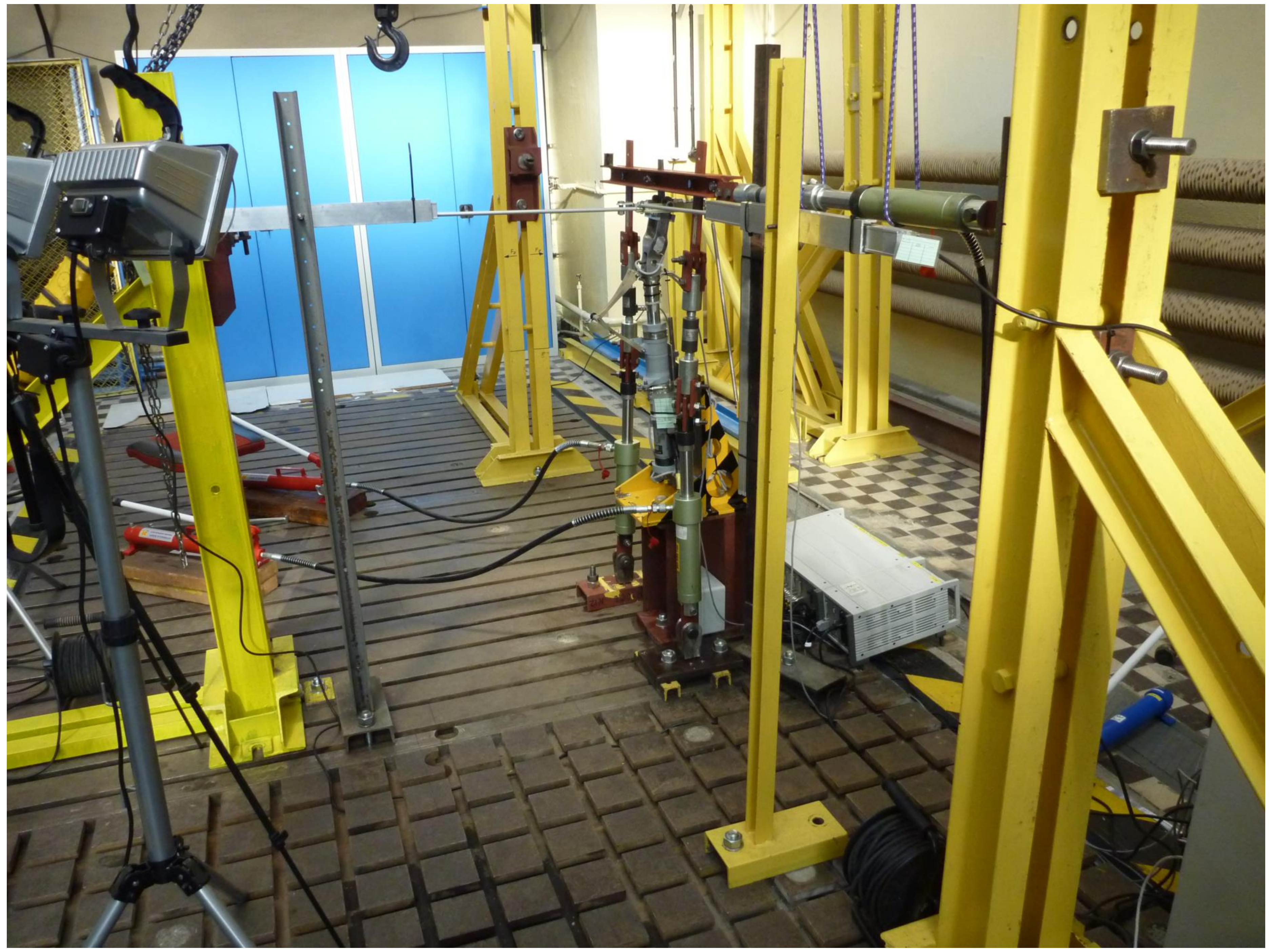
INTRODUCTION TO LANDING GEAR TESTING

UNIVERSAL STATIC TEST STAND - parameters

- Specification of the stand:
- Platform dimensions 6.6 x 2.4m
- Maximum compressing forces 20T – 5 lines
- Maximum stretching forces 20T – 5 lines

Scope of tests

- Static tests
- Functional tests
- Fatigue tests
- Modular mounting platform for various tests



Source: Landing Gear Laboratory, Ł-ILot

MODERN LANDING GEAR TESTING APPROACH /CAPABILITIES

- L/G design and testing, hasn’t much changed in many years in means of test scope/range and general approach to test execution
- Large L/G manufacturing companies (incl. Heroux-Devtek (Canada), Collins Aerospace (USA), Safran (France)) are capable of many L/G tests needed for optimization and certification purposes (e.g. drop tests, static tests).
- Many of tests incl. fatigue, wheel and brake testing, etc. are often outsourced.
- On a case-by-case basis even tests in the range of companies can be outsourced due to the costs or logistics.
- Cost is nowadays the main factor for not performing non-essential testing and the reason of seeking for cheaper alternatives in simulations

MODERN LANDING GEAR TESTING APPROACH /CAPABILITIES

L/G testing optimization comes by using advanced materials and improved measurement methods:

- Advanced materials use result in more stable, stiffer more resistant to the fatigue test stands in dynamic conditions e.g improving the lifetime of drop test carriages or stiffening structure of the test stand - mostly in new designs although in existing tests stands some of the replaceable parts are redesigned to take advantage of improved materials and manufacturing technologies.

- Better time resolution (frequencies) of recorded signals (e.g. 1kHz decade ago to 5kHz or more as a standard today). Reliable, faster and increased storage capacity combining magnetic discs for storage and solid-state drives for speed.

MODERN LANDING GEAR TESTING APPROACH /CAPABILITIES

- Ability to log data directly to the data banks via network protocols for measurement and data storage separation for avoiding losing stored data.
- High-speed video as replacement electrical sensors or as the measurement system where the more traditional methods cannot be used.
- Hardware prices make affordable to acquire large number signals with relatively high speeds.
- Gradual improvements to the exiting testing methods such as adding new measurements on the test stands for controlling more data are making the tests much closer to the actual L/G behaviour in laboratory environment

MODERN LANDING GEAR TESTING APPROACH /CAPABILITIES

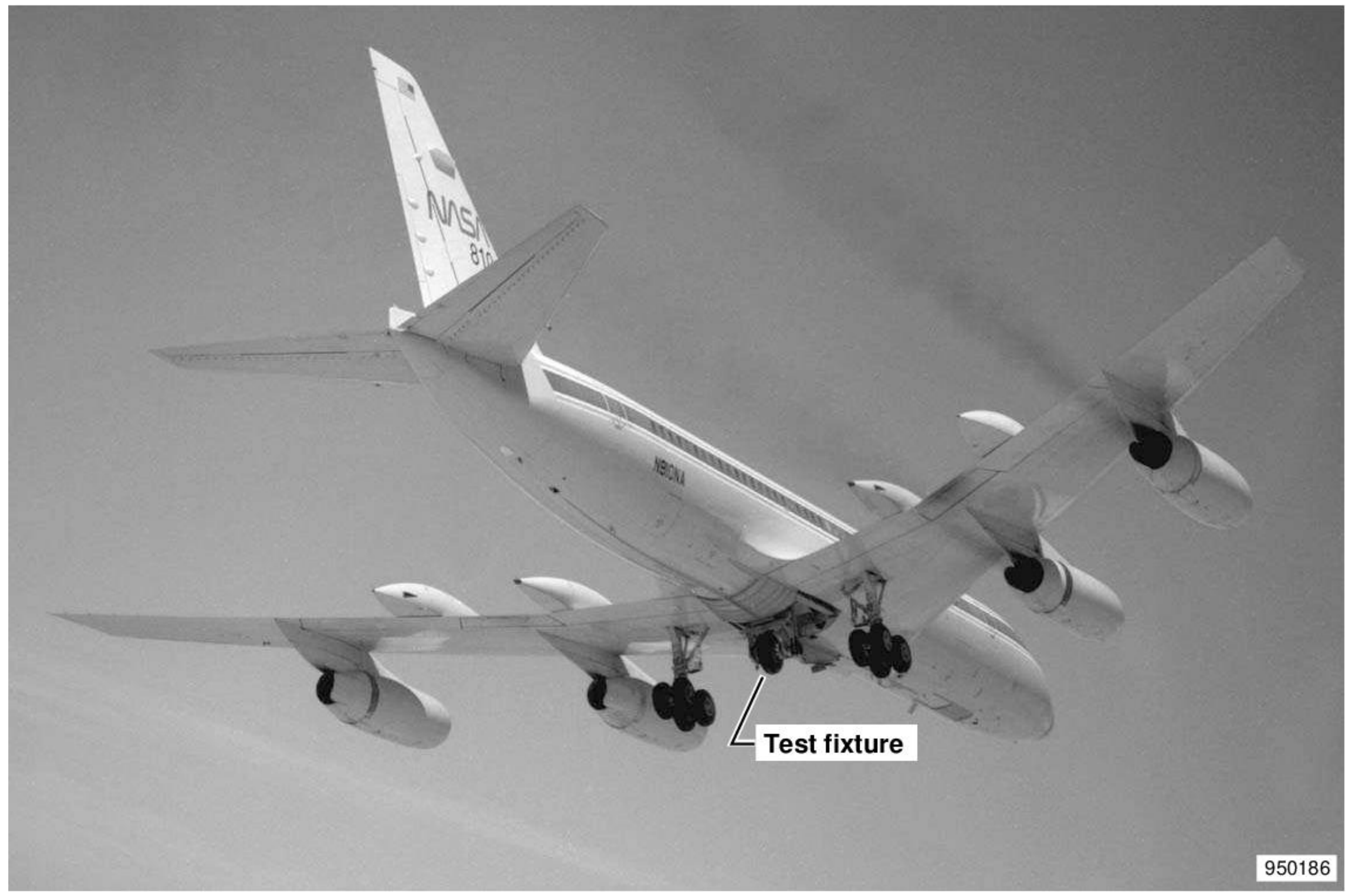
In order to be as close to the real-life operation of the aircraft one cannot forget about full scale tests made on complete aircraft in laboratory setting.

Source: Full Scale Aircraft Drop Test Program for the F-35C Carrier Variant

Naval version of F-35 aircraft tests in multiple landing scenarios.

Source: Landing Gear Laboratory, Ł-ILot

Full scale shimmy testing



Source: The NASA landing gear test airplane

NASA tyre and landing gear test facility onboard Convair 990 aircraft

LANDING GEAR HEALTH MONITORING AS COMPLEMENTARY TEST METHOD

- Health monitoring is a growing trend due to both safety and economic benefits.
- Real-time knowledge about condition (state) of the mechanical system enables detection of the possible faults, premature wear or help with lifetime prediction during normal operation and can induce protective measures when failure occurs.
- Gathering real-time data through the longer time can supply with information helpful in closer approximation of the fatigue data to the reality.
- Possible extension or reducing the safe lifetime of the components according to the data collected.
- Health monitoring can be treated as extension/complement and/or feedback to the laboratory tests.

LANDING GEAR TESTING AS PART OF STRUCTURAL TESTING

- Most of the tests made on L/Gs – including required most important drop tests – are made on specific tests stands dedicated to the L/G testing.
- This can give the false feeling that L/Gs can be treated as the outside system to the structure.
- This is not true since the L/Gs are a deeply integrated part of the aircraft structure acting on the wing or fuselage with various high loads especially during landing.
- Static and most of the fatigue tests on the L/Ss are done the same way as on other parts of the aircraft structures, except for the dynamic fatigue tests which are performed as the drop tests.

LANDING GEAR TESTING AS PART OF STRUCTURAL TESTING

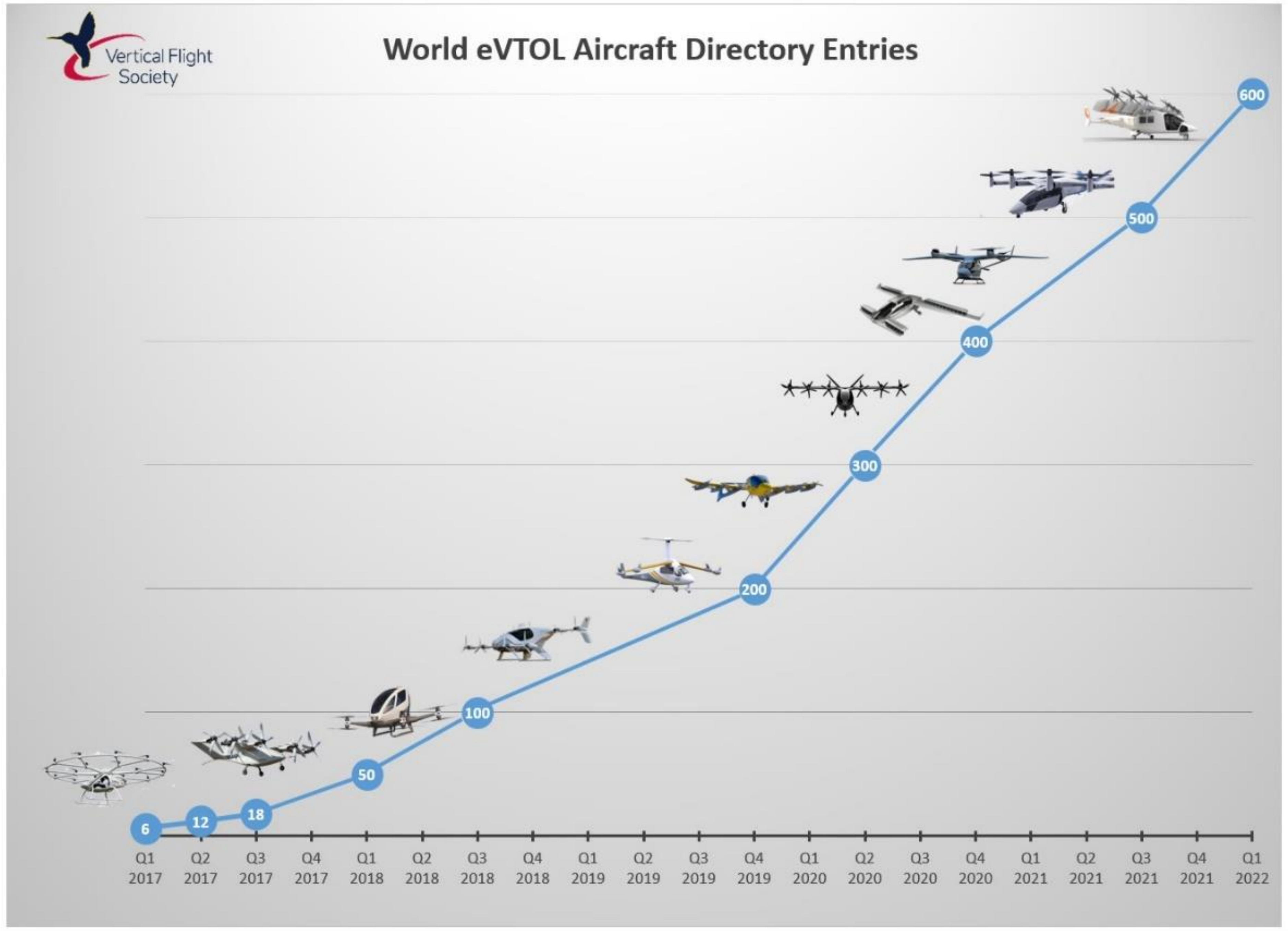
Source: Messier-Dowty

Source: Landing Gear Laboratory, Ł-ILot

eVTOL AIRCRAFT AS MARKET AND CERTIFICATION EXAMPLE

eVTOLs are planned to be personal and flexible their intended use is as air taxis or personal mobility aircraft and are being seen as one of the future directions in aviation industry due to two main principles:

- vertical takeoff and landing
- electrical propulsion
  (limiting now to smaller aircraft
  up to pilot plus four or five passengers)



Currently there are more than 600 projects of eVTOL aircraft being in various development stages ranging from concept stage to flying prototypes

eVTOL AIRCRAFT AS MARKET AND CERTIFICATION EXAMPLE

There is a bit of confusion how to classify the configuration of the eVTOL aviation requirements that are not exactly covering unique nature of the modern eVTOLs but a logical way would be to take regulation that fits mostly as a basis, and then fill the special conditions with requirements from the second regulations:

- if the eVTOL is mostly the airplane the certification basis would be Part 23, but if it has tilted rotors and can behave like helicopter, there will be special requirements based on Part 27.
- Joby aviation S-4 was certified using the FAA's Part 23 (Small Airplanes) requirements with the special conditions listed in the G1 added to account for its unique nature. In May 2022 it was successfully certified under FAA Part 135 (Air Carrier and Operator Certification)
- The FAA Part 23 (CS-23 in EU, CAR523 in Canada) seems to be flexible enough for airplane-like eVTOLs as well as Part 27 (CS-27 in EU, CAR527 in Canada) for helicopter-like eVTOLs.

SUMMARY

- L/G testing has not changed dramatically over the years. The regulations approach and test methodology are similar.
- More simulation is present during the testing phase as the pre-processing activities to make tests as efficient as possible lowering overall costs.
- Certification still requires essential tests to be done to prove the operation and strength of the landing gears.
- Development in the digital technologies has made it possible to acquire more data faster and be able to store it for further offline analysis if necessary.
- Health monitoring, can be used to improve test efficiency, detect faults and dangers or to provide real-time data for optimizing testing processes.
- As the L/Gs testing requires specialized test stands for dynamic tests, the static or some of the fatigue tests can be made using the typical equipment from structural integrity testing.
- eVTOL aircraft as a new category for regulations - test requirements would be more likely the mixture of multiple certification categories.

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