



AEROSPACE RECOMMENDED PRACTICE

ARP1598™**REV. D**

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Superseding ARP1598C

(R) Landing Gear System Development Plan

RATIONALE

This document has been revised to include technical and editorial improvements and to use terminology and practices that are in line with other SAE committees.

FOREWORD

The development of a landing gear system for a modern high-performance air vehicle is an engineering, manufacturing, and program management process which covers many years in calendar time and also crosses over many disciplines and abilities. The process is subordinate to, and dependent upon, the plan for the development of the air vehicle itself. A good, documented development plan allows the design team to perform the task more effectively. Landing gear system development should be per the specific sections herein and using ARP4754 for guidance.

The total plan might be prepared by a contractor to describe a development program for a specific aircraft and be submitted for approval before initiation of the actual work. The plan should be revised and updated at intervals during the development program as influencing factors dictate. A milestone chart using a commercially available software package should be a part of the plan and should show the interrelationships between phases of development and various functions involved in the work to be performed. Design reviews should be identified and scheduled. The progressive design verification process to demonstrate compliance with requirements should be delineated.

Some of the steps covered are mandatory, and others are elective or dependent upon customer requirements or desires. Economics is a very significant factor and, for each analysis or test performed, more confidence and assurance of success is gained—but at a price. Some of the steps are performed as a matter of “good engineering practice” and without special recognition. Others are unique to the particular landing gear system, and all together comprise a complete development.

The development has been divided into six functional/chronological phases, although each phase overlaps and affects the others.

These general divisions are:

- Preliminary design
- Design integration
- Component

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Documents

Standard, visit Sharing Hub

- Subsystem
- Air vehicle
- Post delivery

A discussion of these six major development phases is given in the following pages.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) documents the process of landing gear system development. This ARP includes landing gear system development plans for civil/military, fixed-wing, and rotary-wing air vehicles.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS1424	Fluid, Aircraft Deicing/Anti-Icing, SAE Type I
AMS1428	Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV
AMS1431	Solid Runway Deicing/Anti-Icing Product
AMS1435	Liquid Runway Deicing/Anti-Icing Product
AIR1780	Aircraft Flotation Analysis
AIR4894	Landing Gear Stability
AIR5451	A Guide to Landing Gear System Integration
AIR5699	A Guide for the Damaging Effects of Tire and Wheel Failures
AIR5937	Information on Electric Brakes
AIR6168	Landing Gear Structural Health Monitoring
ARP1070	Design and Testing of Antiskid Brake Control Systems for Total Aircraft Compatibility
ARP1311	Landing Gear Structures and Mechanisms
ARP1493	Wheel and Hydraulically Actuated Brake Design and Test Requirements for Military Aircraft
ARP1595	Design and Verification of Aircraft Nose Wheel Steering Systems
ARP1821	Aircraft Ground Flotation Analysis Methods
ARP4754	Guidelines for Development of Civil Aircraft and Systems
ARP5644	Landing Gear Shock Absorption Testing of Civil Aircraft

- AS4833 Aircraft New Tire Standard - Bias and Radial
- AS6053 Tests, Impact, Shock Absorber Landing Gear, Aircraft
- AS8860 Landing Gear Structural Requirements as Listed in the MIL-886X Series of Specifications

2.1.2 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at <https://www.ecfr.gov>.

- 14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes

2.1.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

- CS 25 Certification Specifications for Large Aeroplanes
- ETSO C26 Aircraft Wheels, Brakes, and Wheel/Brake Assemblies for Parts 23, 27, and 29 Aircraft
- ETSO C135 Transport Airplane Wheels and Wheel and Brake Assemblies

2.1.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

- TSO C26 Aircraft Wheels, Brakes, and Wheel/Brake Assemblies for Parts 23, 27, and 29 Aircraft
- TSO C135 Transport Airplane Wheels and Wheel and Brake Assemblies

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

- AIR4004 Guide for Installation of Electrical Wire and Cable on Aircraft Landing Gear

2.2.2 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at <https://www.ecfr.gov>.

- 14 CFR Part 23 Airworthiness Standards: Normal Category Airplanes
- 14 CFR Part 27 Airworthiness Standards: Normal Category Rotorcraft
- 14 CFR Part 29 Airworthiness Standards: Transport Category Rotorcraft

2.2.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany,
Tel: +49 221 8999 000, www.easa.europa.eu.

CS 23	Certification Specifications for Normal, Utility, Aerobatic and Commuter Aeroplanes
CS 27	Certification Specifications for Small Rotorcraft
CS 29	Certification Specifications for Large Rotorcraft
ETSO C62	Aircraft Tyres

2.2.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591,
Tel: 866-835-5322, www.faa.gov.

TSO C62	Aircraft Tires
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2.2.5 Books and Reports

Chai, S.T. and Mason, W.H. (1997). *Landing gear integration in aircraft conceptual design* (Report No. MAD-96-09-01). Virginia Polytechnic Institute and State University, Supported by NASA Ames Research Center.

Conway, H.G. (1958). *Landing gear design*. Chapman & Hall Ltd.

Currey, N.S. (1988). *Aircraft landing gear design: Principles and practices*. American Institute of Aeronautics and Astronautics, Inc.

Roskam, J. (2017). *Airplane design part IV: Layout design of landing gear and systems*. DARcorporation.

Schmidt, R.K. (2021). *The design of aircraft landing gear*. SAE International.

2.3 Definitions

AIRFRAME MANUFACTURER: This is the designer of the aircraft.

AIR VEHICLE: This is the airplane, aircraft, or other vehicle to which the landing system is attached.

ASSEMBLY DRAWING: This is a drawing that is classified as one which provides information required for the manufacture of a part or component which consists of two or more detail parts.

BLOCK DIAGRAMS: These are simplified representations of a system where each function is illustrated in a “block.”

BREADBOARD TESTS: These are system tests conducted with components arranged in a test fixture (or “breadboard”) which is not necessarily 100% representative of the air vehicle installation.

DESIGN LAYOUT TYPE DRAWINGS: These are initial drawings which show the arrangement of the components along with critical sizing dimensions, as an aid to the production of more detailed drawings by a range of people.

DETAIL DRAWING: This is a drawing that provides information required for the manufacture of a single part.

FIRST FLIGHT ARTICLE: This is a production conforming part which is prepared and verified for first flight.

INSTALLATION DRAWINGS: These are drawings that provide the information necessary for installing detail parts and assemblies or components into the aircraft or a major subassembly of the aircraft

LANDING GEAR SYSTEM INTEGRATOR: This is the organization responsible for ensuring the landing gear system performance is appropriate for the air vehicle. The “landing gear system integrator” may be the “airframe manufacturer” or the “landing gear system supplier.”

LANDING GEAR SUBSYSTEM SUPPLIER: This is the component system supplier contracted by the integrator for the development of landing gear subsystems such as wheel and brake, anti-skid control, steering, etc.

NOTE: The landing gear system supplier may be the airframe manufacturer or the landing gear system supplier.

2.4 Abbreviations

CAE	computer-aided engineering
EASA	European Union Aviation Safety Agency
ETSO	European Technical Standard Order
FAA	Federal Aviation Agency
MLG	main landing gear
NLG	nose landing gear
NW	nose wheel(s)
PDR	preliminary design review
SHM	structural health monitoring
TSO	Technical Standard Order

3. PRELIMINARY DESIGN DEVELOPMENT

The preliminary design stage of an aircraft (and all of the structures and systems which comprise the vehicle) is a process in which the designer strives for the optimum overall aircraft configuration to best meet the designated air vehicle requirements. Adequate attention should be given to the landing gear system and integration into the aircraft at this time to prevent compromises which may eventually result in increased maintenance costs, excess weight, and expensive rework. After the preliminary design phase, the preliminary design review (PDR) should be held.

3.1 Design

3.1.1 Documentation

In all stages of design, it is of paramount importance to establish the design requirements and objectives for the system and to document them. Requirements are nonnegotiable, while objectives are negotiable. This may be done in the form of a “System Definition Manual,” “Basic Data Manual,” or any similar form. This documentation should be updated as the system design progresses. Initially, requirements only will be shown. In addition to all regulatory requirements, the airframe manufacturer’s specific requirements need to be added as well. Before the completion of the PDR, the means by which each requirement will be verified should be identified. The design should be reviewed at the PDR and be shown to meet all of the requirements and the verification method agreed upon.

3.1.2 Geometric Arrangement

The geometric arrangement of the landing gear legs, structures, wheel arrangements, and other features which affect the vehicle/ground relationship, including shock strut/tire/axle strokes, should be established and shown on a layout-type drawing. Careful consideration should be given to the number of wheels and their spacing to meet flotation requirements for the initial configuration and all reasonable growth configurations of the aircraft family. This does not mean that the initial configuration should have this many wheels, but there should be a plan for growth up to 20%. Careful consideration should also be given to tip-back angle, turnover angle, the center of gravity limits, ground clearance to engines and deflected surfaces, cabin egress height, landing attitude limits, and takeoff rotation limits.

3.1.3 Shock Absorber/Tire/Wheel/Brake Sizing

The selection of tire and wheel size should be made using the best weight and load information available and revised as required during the preliminary design phase until concept freeze. This should be done in conjunction with sizing the brake to fit the wheel cavity and meet the design deceleration and kinetic energy and durability requirements. In sizing tires, particular attention should be given to ground flotation requirements, peak dynamic taxi and landing loads, and takeoff load-speed-time curves. Wheel, tire, and brake sizing should be considered for all reasonable growth (up to 20%) configurations of the aircraft family as well. The shock strut design, with respect to its influence on design limit load factor and avoidance of bottoming, should be considered for all reasonable growth (up to 20%) configurations of the aircraft family.

3.1.4 Additional Requirements for Carrier-Based Aircraft

The tire/wheel should be selected to be compatible with deck strength, cable crossing, and catapulting.

3.1.5 Ground Flotation

The number of tires/wheels, and their spacing and sizing, should be selected in a manner compatible with ground flotation requirements for the operation of the aircraft. Design studies are required in support of the analysis (refer to AIR1780 and ARP1821).

3.1.6 Component Sizing

Rough sizing of shock strut piston, cylinder, trunnion, braces, supporting structure, spun, and grown tires, etc., should be made to support stowage space requirements in the vehicle.

3.1.7 Kinematics

Retraction/extension/locking kinematics and configurations should be established to provide the required transition of the gear/wheel/tire assemblies from the down and locked position to the up and locked position. Compatibility of the system with the A/C structure and other basic features, not only in the extreme positions (up locked/down locked) but also in all intermediate positions, should be demonstrated. Due consideration should be given to the free-fall capability of the assemblies in emergency conditions.

3.1.8 Trade Studies

The preliminary design phase is the proper time for the determination of basic design concepts. This requires trade studies in many cases which should include life cycle costs. Some examples of such studies might include:

- a. Configuration trade
- b. Brake material—steel, carbon, etc.
- c. Landing gear materials—aluminum, steel, titanium, composite, etc.
- d. Auxiliary braking methods—drag chutes, arresting hook, etc.
- e. Need for tail bumpers and other auxiliary installations or devices