



AEROSPACE INFORMATION REPORT

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Superseding AIR5451

(R) A Guide to Landing Gear System Integration

RATIONALE

Revision A incorporates the latest information and state of the art in the landing gear industry, and conveys the information as a reference to assist in the creation of an integrated landing gear system specification for new designs. It is intended as information only, and should not be used as a mandatory requirement specification.

AIR5451A has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

The landing gear system is a major and safety critical airframe system that needs to be integrated efficiently to meet the overall aircraft program goals of minimizing the penalties of weight, cost, dispatch reliability and maintenance. As the landing gear system business develops and large-scale teaming arrangements and acquisitions become increasingly common, it may be desirable in some instances to procure an Integrated Landing Gear System. This document provides guidelines and useful references for developing an integrated landing gear system for an aircraft. The document structure is divided into four sections:

- Landing Gear System Configuration Requirements (Section 3)
- Landing Gear System Functional Requirements (Section 4)
- Landing Gear System Integrity Requirements (Section 5)
- Landing Gear System Program Requirements (Section 6)

The landing gear system encompasses all landing gear structural and subsystem elements. Structural elements include shock struts, truck beams, torsion links, braces, fittings, pins, wheels, tires, and brakes. The subsystem elements include the retraction/extension system (both normal and alternate), the steering system, the braking system (both normal and alternate, manual and automatic), the indication and monitoring systems and control systems (mechanical, hydraulic, electrical and electronic).

1.1 Purpose

The purpose of this document is to provide an airframe manufacturer or procuring agency with a framework from which a specification for an Integrated Landing Gear System may be developed and to provide guidance in the development of an integrated landing gear system. This document is not intended to be an all-inclusive detail design document or to duplicate other existing SAE landing gear documents. Rather, the intent is to provide guidance in writing and managing the top-level integration requirements, remembering that the landing gear systems must also be integrated into the airframe. This document has information applicable to both commercial and military landing gear systems

1.2 Field of Application

In the past, it has been common for airframe manufacturers to procure the landing gear and its associated systems as separate elements, and to integrate these elements into the overall aircraft design. Using this approach, the airframe manufacturers have written separate specifications for each element and have assembled the landing gear from components delivered separately by different suppliers. In some instances, the landing gear supplier simply performs the assembly work and delivers a “dressed gear” that has been built up from components procured by the airframer. In other instances, the airframe manufacturer subcontracts the design of the landing gear, including the specification and procurement of the associated systems, to an integrator. This document includes landing gear systems for large commercial aircraft certified under 14 CFR Part 25/EASA CS 25.

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 conflict between the text of this document and 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.

AIR1083	Airborne Hydraulic and Control System Survivability for Military Aircraft
AIR1569	Handling and Installation Practice for Aerospace Hose Assemblies
AIR1800	Aircraft Tail Bumpers
AIR4004	Guide for Installation of Electrical Wire and Cable on Aircraft Landing Gear
ARP994	Design of Tubing Installations for Aerospace Hydraulic Systems
ARP1107A	Tail Bumpers for Piloted Aircraft
ARP4404	Aircraft Electrical Installations
ARP4752	Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems
ARP4754	Guidelines for Development of Civil Aircraft and Systems
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
ARP4925	Aerospace Design and Installation of Commercial Transport Helicopter Hydraulic Systems
ARP5257	Tire Overspeed Landing Test
AS1145	Aircraft Brake Temperature Monitor Systems (BTMS)
AS5440	Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For
ARP6137	Tire Pressure Monitoring Systems (TPMS) for Aircraft
ARP6152	Aircraft Tires Service Overload Capability
AS8091	Aircraft Jacking Pads Adapters and Sockets Design and Installation of
AS50881	Wire Aerospace Vehicle

2.1.2 FAA Publications

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

For a sample list of applicable landing gear FARs for large transport airplanes see Table 1. This is not meant to be a comprehensive list, and as such, each user needs to ensure that the applicable documents are used for the aircraft type intended.

2.1.3 EASA Publications

Available from European Aviation Safety Agency, Ottoplatz, 1, D-50679 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu

For a sample list of applicable landing gear CSs for large transport airplanes see Table 1. This is not meant to be a comprehensive list, and as such, each user needs to ensure that the applicable documents are used for the aircraft type intended.

2.1.4 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA/DO-160-D Environmental Conditions and Test Procedures for Airborne Equipment

RTCA/DO-178B Software Considerations in Airborne Systems and Equipment Certification

RTCA/DO-254 Design Assurance Guidance for Airborne Electronic Hardware

2.1.5 TSO Publications

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

TSO-C62e Aircraft Tires

TSO-C135a Transport Airplane Wheels and Wheel and Brake Assemblies

2.1.6 Military Specifications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

MIL-A-8860 Aircraft Strength and Rigidity, General Specification for

MIL-A-8861 Airplane Strength and Rigidity Flight Loads

MIL-HDBK-454 Military Handbook: General Guidelines for Electronic Equipment

MIL-STD-704 Department of Defense Interface Standard: Aircraft Electric power Characteristics

2.2 List of Acronyms

AC Aircraft

AIR Aerospace Information Report

ARP Aerospace Recommended Practice

AS Aerospace Standard

ASIC Application Specific Integrated Circuit

BOM Bill of Material

CCA Common cause analysis

CDR Critical design review

CE	Concurrent engineering
CG	Center of gravity
DD	Dependence diagrams
DFMA	Design for manufacturing and assembly
EASA	European Aviation Safety Agency
EICAS	Engine Indication and Crew Alerting System
F	Fahrenheit
FAA	Federal aviation administration
FAR	Federal aviation regulation
FHA	Functional hazard assessment
FMEA	Failure mode and effects analysis
FMECA	Failure mode, effects and criticality analysis
fps	Feet per second
FTA	Fault tree analysis
HIRF	High intensity radiated fields
HVOF	High Velocity Oxygen Fuel
JAA	Joint aviation administration
JAR	Joint aviation regulation
JDP	Joint Definition Phase
LRU	Line replaceable unit
MA	Markov Analysis
MEL	Minimum Equipment List
MLG	Main Landing Gear
MTOW	Maximum Take-Off Weight
NATO	North Atlantic trade organization
NLG	Nose landing gear
OEM	Original equipment manufacturer
OSP	Outside purchased
O&S	Operating and Support
PDR	Preliminary design review

PLD	Programmable Logic Device
psig	Pounds per square inch, gauge
RTCA	Radio Technical Commission for Aeronautics
RTO	Rejected take-off or Refused take-off
SSA	System safety analysis
TAS	True airspeed
TBD	To be determined
U.S.	United States of America
WOW	Weight-On-Wheels

3. LANDING GEAR SYSTEM CONFIGURATION REQUIREMENTS

The Landing Gear System Configuration Requirements section should include an overview of the aircraft type and its purpose, accompanied by a description of the landing gear system configuration.

3.1 Aircraft Type, Purpose, and Use

This section should give a brief description of the aircraft and the purpose for which it is to be used. A three-view drawing of the aircraft should be included that specifies the ground contact point of each gear (maximum taxi weight, mid CG condition), and the ground angle limit (angle between floor and line tangent to bottom of unloaded tire and tail strike point). The aircraft operational characteristics such as engine thrust, ground speed, runway flotation, altitude and temperature should also be specified, as well as the weight and cg envelopes (lateral, longitudinal, and vertical). This section should also specify the number of flights per day, the expected turnaround time, the expected life of the aircraft, and the expected life of the landing gear system and scheduled overhauls. Aircraft level configuration definitions are also needed such as hydraulic or electrical power balance, aircraft software, and avionics architecture (e.g., IMA use). An operational spectrum should be provided from which a landing gear fatigue spectrum can eventually be generated. This section should also provide the certification basis of applicable certifying authorities to which the airplane is to be certificated.

3.2 Landing Gear System Definition

This section should contain the structural configuration of the landing gear as well as the landing gear sub-system schematics. The functional interfaces (structural and systems) should also be specified. The “not-to-exceed” weight requirements and expected growth potential of the landing gear systems and sub-systems to be supplied should be specified in this section.

3.2.1 Landing Gear System Structural Configuration

A centerline diagram of the landing gear containing all structural joints and constituting the basis for the landing gear definition should be provided. The extent to which the design of the landing gear is “firm” should be specified here. It may provide the best opportunity for weight and cost avoidance if the firm gear configuration is defined as the baseline against which trade studies are performed within the context of these requirements. The airframe manufacturer must approve any changes to the baseline landing gear configuration which will certainly arise from design iterations and the successive loads loops.

The aircraft should have reached firm structural configuration by the time the associated landing gear contract is awarded to avoid the consequence of any major structural changes on the landing gear configuration (e.g., wing rear spar shifts can cause major changes in landing gear configuration). A “firm” structural configuration may be defined as a structural centerline drawing for which enough layout and sizing work has been accomplished to provide confidence that the centerlines will not change. However, this does not mean that the supplier should not have an input in establishing the firm structural configuration or the sub-system configuration prior to the contract award, and in fact early involvement with the supplier during this preliminary design phase is recommended.

3.2.2 Landing Gear Structural Interfaces

The structural joints connecting the landing gear structure to the airframe need to be specified. Also, the minimum clearance requirements with all major structures and aircraft loft lines, including minimum tire clearance using the grown tire envelope (per the Tire and Rim Association guidelines) need to be included in this section.

The landing gear structural interfaces to the aircraft must be specified, and agreed to between system and structure suppliers, in interface control drawings during the Joint Definition Phase. Specifically, the interfaces for the trunnions, brace attach points, and actuators will need to be defined and agreed to. Other structural interfaces such as those required for the mounting of the various landing gear system sub-components such as valves and actuators also need to be specified on interface definition drawings.

3.2.3 Landing Gear System Architecture

The preliminary or suggested architectures of each landing gear sub-system (steering, braking, extension system, etc.) should be included in this section and presented in the form of schematics. A detailed list of each LRU composing the sub-systems should also be proposed to complete the definition of the overall Landing Gear System. The suggested sub-system architectures and LRU breakdowns should be considered preliminary and are to be refined by the supplier during the Joint Definition Phase. Failure cases such as tire failures also need to be addressed when considering the layout of the landing gear and the associated equipment in the gear bay.

3.2.4 Landing Gear System Functional Interfaces

The landing gear system functional definition can take the form of a context diagram that shows the basic relationship of the landing gear system with other aircraft systems, such as the electrical system, the hydraulic system, the maintenance computer, the flight data recorder, etc. An overview of the landing gear system architecture following its sub-functions (e.g., extend/retract, steering, braking, etc.) is also recommended to be included in this section. General system requirements for each sub-function should be developed to encompass the overall expectation vis-à-vis the landing gear system. Similarly, as for the structural interfaces, the system functional interfaces with other aircraft systems must be specified, and agreed to between system and structure suppliers during the Joint Definition Phase.

3.2.5 Landing Gear System Detailed Requirements

Detailed requirements or specific design constraints, such as particular use of seals, grease fittings, use of HVOF, etc., pertaining to the sub-systems or the components should be indicated when applicable. Other constraints such as maximum noise levels, environmental requirements, protection against HIRF and Lightning, corrosion protection means, etc., should also be specified.

3.2.6 Weight

Weight control is of critical importance to the success of an aircraft program. Every effort should be made to minimize the landing gear system weight without compromising the program design, reliability and safety objectives.

A guaranteed not-to-exceed weight should be specified by the airframe manufacturer that will meet the overall airplane weight objectives. The not-to-exceed weight should be agreed upon by the landing gear system supplier. A detailed weight breakdown by component should be provided by the system supplier.

3.2.7 Growth Potential

The aircraft manufacturer or procuring activity shall determine if a performance growth capability is to be designed in the landing gear forging design. As a goal, this shall not impact the basic weight of the system design, but shall be achieved by space provision for modification where necessary.

4. LANDING GEAR SYSTEM FUNCTIONAL REQUIREMENTS

This section should include requirements that will allow the system to perform its intended function. For the purpose of this document, the requirements are sub-divided in terms of the Landing Gear System's top-level functions: Taxi/Takeoff, Maneuvering, Landing, Braking, Stability, Landing Gear Actuation, Landing Gear Control and Indication and Special Purposes. In certain areas, there could be a need for a refinement of the top-level function into a more detailed functional requirement, such that all functional requirements are covered in the specification document of the Landing Gear System.

Each landing gear functional requirement will contain three sections:

- Functional Requirements
- Verification
- Other Associated Functional Requirements

The Functional Requirements and Verification sections are for stating each top-level integration requirement as simply as possible along with the rationale for the requirement. The Verification Plan specifies how the functional requirement will be verified in terms of inspection, analysis, component testing, system testing, flight testing or a combination of these. A table clearly showing each of the listed requirements and the means by which it will be verified is recommended to be included in the specification document. The Other Associated Functional Requirements section is used to identify other functional requirements, which together with the functional requirement may influence the design solution.

Each landing gear functional requirement will tie to Regulatory Requirements as ruled by the FAA and EASA or other certification agencies. Table 1 includes the relationship between each Landing Gear System function and Regulatory Requirements. In principle, the basis of certification should be established and Means of Compliance (MOC) at least drafted prior to contract award.

Similarly, Table 2 includes the relationship between each Landing Gear System function and related SAE documents. The referenced SAE documents form an integral part of this AIR document and should be referred to for the specification of the Landing Gear System's requirements. SAE documents may provide guidance, recommended practices, and information related to the functional requirement.

Table 1 – FAA and EASA certification requirements

FAR/CS	TITLE	FUNCTION							
		TAXI/TAKEOFF	MANEUVERING	LANDING	BRAKING	STABILITY	LG ACTUATION	LG CTRL & INDICATION	SPECIAL PURPOSES
	SUBPART B - FLIGHT								
	GENERAL								
25.25	Weight Limits	X							
	PERFORMANCE								
25.101	General				X				
25.107	Take-Off Speeds	X			X				
25.109	Accelerate-Stop Distance				X				
25.125	Landing				X				
	GROUND HANDLING CHARACTERISTICS								
25.231	Longitudinal Stability and Control				X	X			
25.233	Direction Stability and Control		X						
25.235	Taxiing Condition	X							
	SUBPART C - STRUCTURE								
	GROUND LOADS								
25.301	Loads								X
25.471	General	X		X					
25.473	Ground Load Conditions and Assumptions			X					
25.477	Landing Gear Arrangement			X					
25.479	Level Landing Conditions			X					
25.481	Tail-Down Landing Condition			X					
25.483	One-Wheel Down Landing Condition			X					
25.485	Side Load Conditions			X					
25.487	Rebound Landing Conditions			X					
25.489	Ground Handling Conditions	X							
25.491	Taxi, Takeoff and Landing Roll	X		X					
25.493	Braked Roll Condition				X				
25.495	Turning	X	X						
25.497	Tail-Wheel Yawing		X						
25.499	Nose-Wheel Yaw and Steering	X	X						
25.503	Pivoting	X							
25.507	Reversed Braking								X
25.509	Towing Loads								X
25.511	Ground Load: Unsymmetrical Loads on Multiple-Wheel Units	X		X					
25.519	Jacking and Tie-Down Provisions								X
	FATIGUE EVALUATION								
25.571	Damage-Tolerance and Fatigue Evaluation of Structure	X							
	LIGHTNING PROTECTION								
25.581	Lightning Protection		X		X			X	

Table 1 – FAA and EASA certification requirements (continued)

FAR/CS	TITLE	FUNCTION							
		TAXI/TAKEOFF	MANEUVERING	LANDING	BRAKING	STABILITY	LG ACTUATION	LG CTRL & INDICATION	SPECIAL PURPOSES
	SUBPART D – DESIGN AND CONSTRUCTION								
	GENERAL								
25.601	General	X					X		
25.603	Materials	X					X		
25.605	Fabrication Methods	X					X		
25.607	Fasteners	X					X		
25.609	Protection of Structure	X					X		
25.611	Accessibility Provisions	X					X		
25.613	Material Strength Properties and Design Values	X					X		
25.621	Casting Factors	X					X		
25.625	Fitting Factors	X					X		
25.631	Bird Strike Damage	X					X		
	CONTROL SYSTEMS								
25.671	General						X		
25.683	Operation Tests						X		
25.685	Control System Details						X		
25.689	Cable Systems						X		
25.703	Take-Off Warning System				X				
	LANDING GEAR								
25.721	General			X					
25.723	Shock Absorption Tests			X					
25.729	Retracting Mechanism						X	X	
25.731	Wheels				X				
25.733	Tires				X				
25.734 CS only	Protection against Wheel and Tire Failures								X
25.735	Brakes				X				
25X745	Nose-Wheel Steering	X	X	X					X
	PERSONNEL AND CARGO ACCOMMODATIONS								
25.777	Cockpit Controls							X	
25.779	Motion and Effect of Cockpit Controls							X	
25.781	Cockpit Control Knob Shape							X	
	FIRE PROTECTION								
25.863	Flammable Fluid Fire Protection		X		X		X		
	MISCELLANEOUS								
25X899	Electrical Bonding and Protection Against Lightning		X		X				

Table 1 – FAA and EASA certification requirements (continued)

FAR/CS	TITLE	FUNCTION							
		TAXI/TAKEOFF	MANEUVERING	LANDING	BRAKING	STABILITY	LG ACTUATION	LG CTRL & INDICATION	SPECIAL PURPOSES
	SUBPART F - EQUIPMENT								
	GENERAL								
25.1301	Function and Installation	X	X	X	X	X	X	X	X
25.1302	Installed Systems and Equipment for Use by the Flight Crew (=Human Factors)								X
25.1309	Equipment, Systems and Installations	X	X	X	X	X	X	X	X
25X1315	Negative Acceleration						X		
	INSTRUMENTS: INSTALLATION								
25.1322	Warning, Caution and Advisory Lights		X		X			X	
	ELECTRICAL SYSTEMS AND EQUIPMENT								
25.1353	Electrical Equipment		X		X		X	X	
	MISCELLANEOUS EQUIPMENT								
25.1381	Instrument Lights		X		X			X	
25.1431	Electronic Equipment		X		X			X	
25.1435	Hydraulic Systems		X		X		X		
25X1436	Pneumatic Systems-High Pressure						X		
	SUBPART G – OPERATING LIMITATIONS AND INFORMATION								
	OPERATING LIMITATIONS								
25.1515	Landing Gear Speeds						X		
25.1533	Additional Operating Limitations						X		
	MARKINGS AND PLACARDS								
25.1541	General								
25.1555	Control Markings						X	X	
25.1563	Airspeed Placard						X		
	AIRPLANE FLIGHT MANUAL								
25.1583	Operating Limitations						X		
	SUPPLEMENTARY INFORMATION								
25X1591	Supplementary Performance Information	X		X					