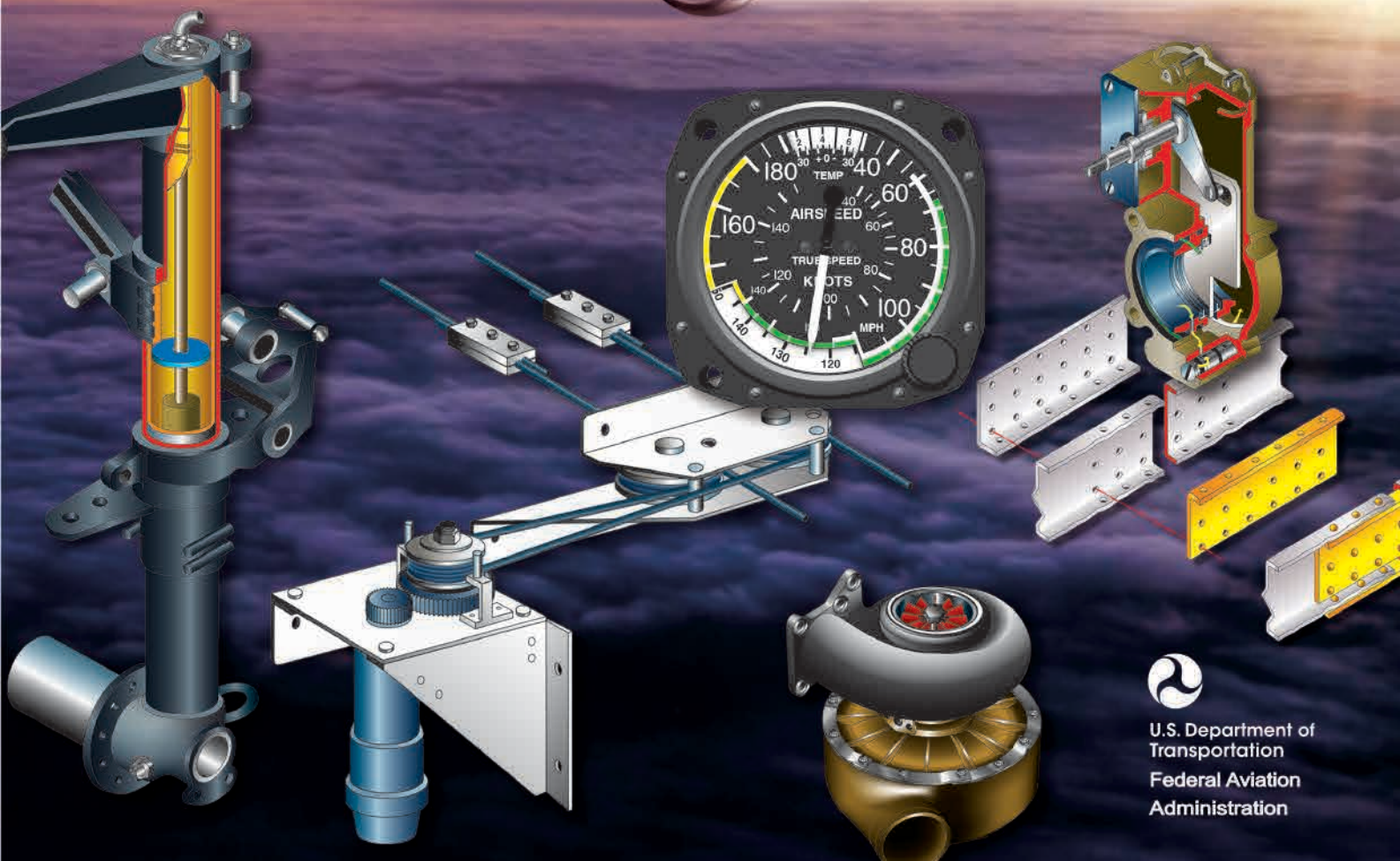




FAA-H-8083-31A  
Volume 1

# Aviation Maintenance Technician Handbook— Airframe, Volume 1



U.S. Department of  
Transportation  
Federal Aviation  
Administration

# Aviation Maintenance Technician Handbook—Airframe

## Volume 1

## 2018

U.S. Department of Transportation  
**FEDERAL AVIATION ADMINISTRATION**  
Flight Standards Service

# Volume Contents

## Volume 1

Preface.....	v
Acknowledgments.....	vii
Table of Contents .....	xiii
Chapter 1	
Aircraft Structures.....	1-1
Chapter 2	
Aerodynamics, Aircraft Assembly, and Rigging .....	2-1
Chapter 3	
Aircraft Fabric Covering .....	3-1
Chapter 4	
Aircraft Metal Structural Repair .....	4-1
Chapter 5	
Aircraft Welding.....	5-1
Chapter 6	
Aircraft Wood and Structural Repair .....	6-1
Chapter 7	
Advanced Composite Materials .....	7-1
Chapter 8	
Aircraft Painting and Finishing .....	8-1
Chapter 9	
Aircraft Electrical System.....	9-1
Glossary .....	G-1
Index .....	I-1

## Volume 2

Chapter 10	
Aircraft Instrument Systems .....	10-1
Chapter 11	
Communication and Navigation.....	11-1
Chapter 12	
Hydraulic and Pneumatic Power Systems .....	12-1
Chapter 13	
Aircraft Landing Gear Systems.....	13-1
Chapter 14	
Aircraft Fuel System.....	14-1
Chapter 15	
Ice and Rain Protection.....	15-1
Chapter 16	
Cabin Environmental Control Systems .....	16-1
Chapter 17	
Fire Protection Systems .....	17-1
Glossary .....	G-1
Index .....	I-1

# Preface

The Aviation Maintenance Technician Handbook—Airframe (FAA-H-8083-31A) is one of a series of three handbooks for persons preparing for certification as an airframe or powerplant mechanic. It is intended that this handbook provide the basic information on principles, fundamentals, and technical procedures in the subject matter areas relating to the airframe rating. It is designed to aid students enrolled in a formal course of instruction, as well as the individual who is studying on his or her own. Since the knowledge requirements for the airframe and powerplant ratings closely parallel each other in some subject areas, the chapters which discuss fire protection systems and electrical systems contain some material which is also duplicated in the Aviation Maintenance Technician Handbook—Powerplant (FAA-H-8083-32A).

This volume contains information on airframe construction features, assembly and rigging, fabric covering, structural repairs, and aircraft welding. The handbook also contains an explanation of the units that make up the various airframe systems. Because there are so many different types of aircraft in use today, it is reasonable to expect that differences exist in airframe components and systems. To avoid undue repetition, the practice of using representative systems and units is carried out throughout the handbook. Subject matter treatment is from a generalized point of view and should be supplemented by reference to manufacturer's manuals or other textbooks if more detail is desired. This handbook is not intended to replace, substitute for, or supersede official regulations or the manufacturer's instructions. Occasionally the word "must" or similar language is used where the desired action is deemed critical. The use of such language is not intended to add to, interpret, or relieve a duty imposed by Title 14 of the Code of Federal Regulations (14 CFR).

This handbook is available for download, in PDF format, from [www.faa.gov](http://www.faa.gov).

The subject of Human Factors is contained in the Aviation Maintenance Technician Handbook—General (FAA-H-8083-30).

This handbook is published by the United States Department of Transportation, Federal Aviation Administration, Airman Testing Standards Branch, AFS-630, P.O. Box 25082, Oklahoma City, OK 73125.

Comments regarding this publication should be sent, in email form, to the following address:

[AFS630comments@faa.gov](mailto:AFS630comments@faa.gov)



---

Rick Domingo  
Executive Director, Flight Standards Service

# Acknowledgments

The Aviation Maintenance Technician Handbook—Airframe (FAA-H-8083-31A) was produced by the Federal Aviation Administration (FAA) with the assistance of Safety Research Corporation of America (SRCA). The FAA wishes to acknowledge the following contributors:

Mr. Chris Brady ([www.b737.org.uk](http://www.b737.org.uk)) for images used throughout this handbook  
Captain Karl Eiríksson for image used in Chapter 1  
Cessna Aircraft Company for image used in Chapter 1  
Mr. Andy Dawson ([www.mossie.org](http://www.mossie.org)) for images used throughout Chapter 1  
Mr. Bill Shemley for image used in Chapter 1  
Mr. Bruce R. Swanson for image used in Chapter 1  
Mr. Burkhard Domke ([www.b-domke.de](http://www.b-domke.de)) for images used throughout Chapter 1 and 2  
Mr. Chris Wonnacott ([www.fromtheflightdeck.com](http://www.fromtheflightdeck.com)) for image used in Chapter 1  
Mr. Christian Tremblay ([www.zodiac640.com](http://www.zodiac640.com)) for image used in Chapter 1  
Mr. John Bailey ([www.knots2u.com](http://www.knots2u.com)) for image used in Chapter 1  
Mr. Rich Guerra ([www.rguerra.com](http://www.rguerra.com)) for image used in Chapter 1  
Mr. Ronald Lane for image used in Chapter 1  
Mr. Tom Allensworth ([www.avsim.com](http://www.avsim.com)) for image used in Chapter 1  
Navion Pilots Association's Tech Note 001 ([www.navionpilots.org](http://www.navionpilots.org)) for image used in Chapter 1  
U.S. Coast Guard for image used in Chapter 1  
Mr. Tony Bingelis and the Experimental Aircraft Association (EAA) for images used throughout Chapter 2  
Mr. Benoit Viellefon ([www.johnjohn.co.uk/compare-tigermothflights/html/tigermoth\\_bio\\_aozh.html](http://www.johnjohn.co.uk/compare-tigermothflights/html/tigermoth_bio_aozh.html)) for image used in Chapter 3  
Mr. Paul Harding of Safari Seaplanes—Bahamas ([www.safariseaplanes.com](http://www.safariseaplanes.com)) for image used in Chapter 3  
Polyfiber/Consolidated Aircraft Coatings for images used throughout Chapter 3  
Stewart Systems for images used throughout Chapter 3  
Superflite for images used throughout Chapter 3  
Cherry Aerospace ([www.cherryaerospace.com](http://www.cherryaerospace.com)) for images used in Chapters 4 and 7  
Raytheon Aircraft (Structural Inspection and Repair Manual) for information used in Chapter 4  
Mr. Scott Allen of Kalamazoo Industries, Inc. ([www.kalamazooind.com](http://www.kalamazooind.com)) for image used in Chapter 4  
Miller Electric Mfg. Co. ([www.millerwelds.com](http://www.millerwelds.com)) for images used in Chapter 5  
Mr. Aaron Novak, contributing engineer, for charts used in Chapter 5  
Mr. Bob Hall ([www.pro-fusiononline.com](http://www.pro-fusiononline.com)) for image used in Chapter 5



Mr. Kent White of TM Technologies, Inc. for image used in Chapter 5

Safety Supplies Canada ([www.safetysuppliescanada.com](http://www.safetysuppliescanada.com)) for image used in Chapter 5

Smith Equipment ([www.smithequipment.com](http://www.smithequipment.com)) for images used in Chapter 5

Alcoa ([www.alcoa.com](http://www.alcoa.com)) for images used in Chapter 7

Mr. Chuck Scott ([www.itwif.com](http://www.itwif.com)) for images used throughout Chapter 8

Mr. John Lagerlof of Paasche Airbrush Co. ([paascheairbrush.com](http://paascheairbrush.com)) for image used in Chapter 8

Mr. Philip Love of Turbine Products, LLC ([www.turbineproducts.com](http://www.turbineproducts.com)) for image used in Chapter 8

Consolidated Aircraft Coatings for image used in Chapter 8

Tianjin Yonglida Material Testing Machine Co., Ltd for image used in Chapter 8

Mr. Jim Irwin of Aircraft Spruce & Specialty Co. ([www.aircraftspruce.com](http://www.aircraftspruce.com)) for images used in Chapters 9, 10, 11, 13, 14, 15

Mr. Kevan Hashemi for image used in Chapter 9

Mr. Michael Leasure, Aviation Multimedia Library ([www2.tech.purdue.edu/at/courses/aeml](http://www2.tech.purdue.edu/at/courses/aeml)) for images used in Chapters 9, 13, 14

Aircraft Owners and Pilots Association (AOPA) ([www.aopa.org](http://www.aopa.org)) for image used in Chapter 10

Cobra Systems Inc. ([www.cobrasys.com](http://www.cobrasys.com)) for image used in Chapter 10

[www.free-online-private-pilot-ground-school.com](http://www.free-online-private-pilot-ground-school.com) for image used in Chapters 10, 16

DAC International ([www.dacint.com](http://www.dacint.com)) for image used in Chapter 10

Dawson Aircraft Inc. ([www.aircraftpartsandsalvage.com](http://www.aircraftpartsandsalvage.com)) for images used throughout Chapter 10

Mr. Kent Clingaman for image used in Chapter 10

TECNAM ([www.tecnam.com](http://www.tecnam.com)) for image used in Chapter 10

TGH Aviation-FAA Instrument Repair Station ([www.tghaviation.com](http://www.tghaviation.com)) for image used in Chapter 10

The Vintage Aviator Ltd. ([www.thevintageaviator.co.nz](http://www.thevintageaviator.co.nz)) for image used in Chapter 10

ACK Technologies Inc. ([www.ackavionics.com](http://www.ackavionics.com)) for image used in Chapter 11

ADS-B Technologies, LLC ([www.ads-b.com](http://www.ads-b.com)) for images used in Chapter 11

Aviation Glossary ([www.aviationglossary.com](http://www.aviationglossary.com)) for image used in Chapter 11

AT&T Archives and History Center for image used in Chapter 11

Electronics International Inc. ([www.buy-ei.com](http://www.buy-ei.com)) for image used in Chapter 11

Excelitas Technologies ([www.excelitas.com](http://www.excelitas.com)) for image used in Chapter 11

Freestate Electronics, Inc. ([www.fse-inc.com](http://www.fse-inc.com)) for image used in Chapter 11

[AirTrafficAtlanta.com](http://AirTrafficAtlanta.com) for image used in Chapter 11

Western Historic Radio Museum, Virginia City, Nevada ([www.radioblvd.com](http://www.radioblvd.com)) for image used in Chapter 11

Avidyne Corporation ([www.avidyne.com](http://www.avidyne.com)) for image used in Chapter 11

Kintronic Laboratories ([www.kintronic.com](http://www.kintronic.com)) for image used in Chapter 11

Mr. Dan Wolfe ([www.flyboysalvage.com](http://www.flyboysalvage.com)) for image used in Chapter 11

Mr. Ken Shuck ([www.cessna150.net](http://www.cessna150.net)) for image used in Chapter 11

Mr. Paul Tocknell ([www.askacfi.com](http://www.askacfi.com)) for image used in Chapter 11

Mr. Stephen McGreevy ([www.auroralchorus.com](http://www.auroralchorus.com)) for image used in Chapter 11

Mr. Todd Bennett ([www.bennettavionics.com](http://www.bennettavionics.com)) for image used in Chapter 11

National Oceanic and Atmospheric Administration, U.S. Department of Commerce for image used in Chapter 11

RAMI ([www.rami.com](http://www.rami.com)) for image used in Chapter 11

Rockwell Collins ([www.rockwellcollins.com](http://www.rockwellcollins.com)) for image used in Chapter 11, Figure 11-73

Sarasota Avionics International ([www.sarasotaavionics.com](http://www.sarasotaavionics.com)) for images used in Chapter 11

Southeast Aerospace, Inc. ([www.seaerospace.com](http://www.seaerospace.com)) for image used in Chapter 11

Sporty's Pilot Shop ([www.sportys.com](http://www.sportys.com)) for image used in Chapter 11

Watts Antenna Company ([www.wattsantenna.com](http://www.wattsantenna.com)) for image used in Chapter 11

Wings and Wheels ([www.wingsandwheels.com](http://www.wingsandwheels.com)) for image used in Chapter 11

Aeropin, Inc. ([www.aeropin.com](http://www.aeropin.com)) for image used in Chapter 13

Airplane Mart Publishing ([www.airplanemart.com](http://www.airplanemart.com)) for image used in Chapter 13

Alberth Aviation ([www.alberthaviation.com](http://www.alberthaviation.com)) for image used in Chapter 13

AVweb ([www.avweb.com](http://www.avweb.com)) for image used in Chapter 13

Belle Aire Aviation, Inc. ([www.belleaireaviation.com](http://www.belleaireaviation.com)) for image used in Chapter 13

Cold War Air Museum ([www.coldwarairmuseum.org](http://www.coldwarairmuseum.org)) for image used in Chapter 13

Comanche Gear ([www.comanchegear.com](http://www.comanchegear.com)) for image used in Chapter 13

CSOBeech ([www.csobeech.com](http://www.csobeech.com)) for image used in Chapter 13

Desser Tire & Rubber Co., Inc. ([www.desser.com](http://www.desser.com)) for image used in Chapter 13

DG Flugzeugbau GmbH ([www.dg-flugzeugbau.de](http://www.dg-flugzeugbau.de)) for image used in Chapter 13

Expedition Exchange Inc. ([www.expeditionexchange.com](http://www.expeditionexchange.com)) for image used in Chapter 13

Fiddlers Green ([www.fiddlersgreen.net](http://www.fiddlersgreen.net)) for image used in Chapter 13

Hitchcock Aviation ([hitchcockaviation.com](http://hitchcockaviation.com)) for image used in Chapter 13

KUNZ GmbH aircraft equipment ([www.kunz-aircraft.com](http://www.kunz-aircraft.com)) for images used in Chapter 13

Little Flyers ([www.littleflyers.com](http://www.littleflyers.com)) for images used in Chapter 13

Maple Leaf Aviation Ltd. ([www.aircraftspeedmods.ca](http://www.aircraftspeedmods.ca)) for image used in Chapter 13

Mr. Budd Davisson ([Airbum.com](http://Airbum.com)) for image used in Chapter 13

Mr. C. Jeff Dyrek ([www.yellowairplane.com](http://www.yellowairplane.com)) for images used in Chapter 13

Mr. Jason Schappert ([www.m0a.com](http://www.m0a.com)) for image used in Chapter 13

Mr. John Baker ([www.hangar9aeroworks.com](http://www.hangar9aeroworks.com)) for image used in Chapter 13

Mr. Mike Schantz ([www.trailer411.com](http://www.trailer411.com)) for image used in Chapter 13

Mr. Robert Hughes ([www.escapadebuild.co.uk](http://www.escapadebuild.co.uk)) for image used in Chapter 13

Mr. Ron Blachut for image used in Chapter 13

Owls Head Transportation Museum ([www.owlshead.org](http://www.owlshead.org)) for image used in Chapter 13

PPI Aerospace ([www.ppiaerospace.com](http://www.ppiaerospace.com)) for image used in Chapter 13

Protective Packaging Corp. ([www.protectivepackaging.net](http://www.protectivepackaging.net), 1-800-945-2247) for image used in Chapter 13

Ravenware Industries, LLC ([www.ravenware.com](http://www.ravenware.com)) for image used in Chapter 13

Renold ([www.renold.com](http://www.renold.com)) for image used in Chapter 13

Rotor F/X, LLC ([www.rotorfx.com](http://www.rotorfx.com)) for image used in Chapter 13

SkyGeek ([www.skygeek.com](http://www.skygeek.com)) for image used in Chapter 13

Taigh Ramey ([www.twinbeech.com](http://www.twinbeech.com)) for image used in Chapter 13

Texas Air Salvage ([www.texasairsalvage.com](http://www.texasairsalvage.com)) for image used in Chapter 13

The Bogert Group ([www.bogert-av.com](http://www.bogert-av.com)) for image used in Chapter 13

W. B. Graham, Welded Tube Pros LLC ([www.thefabricator.com](http://www.thefabricator.com)) for image used in Chapter 13

Zinko Hydraulic Jack ([www.zinkojack.com](http://www.zinkojack.com)) for image used in Chapter 13

Aviation Institute of Maintenance ([www.aimschool.com](http://www.aimschool.com)) for image used in Chapter 14

Aviation Laboratories ([www.avlab.com](http://www.avlab.com)) for image used in Chapter 14

AVSIM ([www.avsim.com](http://www.avsim.com)) for image used in Chapter 14

Eggenfellner ([www.eggenfellneraircraft.com](http://www.eggenfellneraircraft.com)) for image used in Chapter 14

FlightSim.Com, Inc. ([www.flightsim.com](http://www.flightsim.com)) for image used in Chapter 14

Fluid Components International LLC ([www.fluidcomponents.com](http://www.fluidcomponents.com)) for image used in Chapter 14

Fuel Quality Services, Inc. ([www.fqsinc.com](http://www.fqsinc.com)) for image used in Chapter 14

Hammonds Fuel Additives, Inc. ([www.biobor.com](http://www.biobor.com)) for image used in Chapter 14

Jeppesen ([www.jeppesen.com](http://www.jeppesen.com)) for image used in Chapter 14

MGL Avionics ([www.mglavionics.com](http://www.mglavionics.com)) for image used in Chapter 14

Mid-Atlantic Air Museum ([www.maam.org](http://www.maam.org)) for image used in Chapter 14

MISCO Refractometer ([www.misco.com](http://www.misco.com)) for image used in Chapter 14

Mr. Gary Brossett via the Aircraft Engine Historical Society ([www.enginehistory.org](http://www.enginehistory.org)) for image used in Chapter 14

Mr. Jeff McCombs ([www.heyeng.com](http://www.heyeng.com)) for image used in Chapter 14

NASA for image used in Chapter 14

On-Track Aviation Limited ([www.ontrackaviation.com](http://www.ontrackaviation.com)) for image used in Chapter 14

Stewart Systems for image used in Chapter 14

Prist Aerospace Products ([www.pristaerospace.com](http://www.pristaerospace.com)) for image used in Chapter 14

The Sundowners, Inc. ([www.sdpleecounty.org](http://www.sdpleecounty.org)) for image used in Chapter 14

Velcon Filters, LLC ([www.velcon.com](http://www.velcon.com)) for image used in Chapter 14

Aerox Aviation Oxygen Systems, Inc. ([www.aerox.com](http://www.aerox.com)) for image used in Chapter 16

Biggles Software ([www.biggles-software.com](http://www.biggles-software.com)) for image used in Chapter 16

C&D Associates, Inc. ([www.aircraftheater.com](http://www.aircraftheater.com)) for image used in Chapter 16

Cobham (Carleton Technologies Inc.) ([www.cobham.com](http://www.cobham.com)) for image used in Chapter 16

Cool Africa ([www.coolafrica.co.za](http://www.coolafrica.co.za)) for image used in Chapter 16

Cumulus Soaring, Inc. ([www.cumulus-soaring.com](http://www.cumulus-soaring.com)) for image used in Chapter 16

Essex Cryogenics of Missouri, Inc. ([www.essexind.com](http://www.essexind.com)) for image used in Chapter 16

Flightline AC, Inc. ([www.flightlineac.com](http://www.flightlineac.com)) for image used in Chapter 16

IDQ Holdings ([www.idqusa.com](http://www.idqusa.com)) for image used in Chapter 16

Manchester Tank & Equipment ([www.mantank.com](http://www.mantank.com)) for image used in Chapter 16

Mountain High E&S Co. ([www.MHoxxygen.com](http://www.MHoxxygen.com)) for images used throughout Chapter 16

Mr. Bill Sherwood ([www.billzilla.org](http://www.billzilla.org)) for image used in Chapter 16

Mr. Boris Comazzi ([www.flightgear.ch](http://www.flightgear.ch)) for image used in Chapter 16

Mr. Chris Rudge ([www.warbirdsite.com](http://www.warbirdsite.com)) for image used in Chapter 16

Mr. Richard Pfiffner ([www.craggyaero.com](http://www.craggyaero.com)) for image used in Chapter 16

Mr. Stephen Sweet ([www.stephensweet.com](http://www.stephensweet.com)) for image used in Chapter 16



Precise Flight, Inc. ([www.preciseflight.com](http://www.preciseflight.com)) for image used in Chapter 16

SPX Service Solutions ([www.spx.com](http://www.spx.com)) for image used in Chapter 16

SuperFlash Compressed Gas Equipment ([www.oxyfuelsafety.com](http://www.oxyfuelsafety.com))

Mr. Tim Mara ([www.wingsandwheels.com](http://www.wingsandwheels.com)) for images used in Chapter 16

Mr. Bill Abbott for image used in Chapter 17

Additional appreciation is extended to Dr. Ronald Sterkenburg, Purdue University; Mr. Bryan Rahm, Dr. Thomas K. Eismain, Purdue University; Mr. George McNeill, Mr. Thomas Forenz, Mr. Peng Wang, and the National Oceanic and Atmospheric Administration (NOAA) for their technical support and input.

# Table of Contents

<b>Volume Contents .....</b>	<b>V</b>	Landing Gear .....	1-35
<b>Preface.....</b>	<b>VII</b>	Tail Wheel Gear Configuration.....	1-37
<b>Acknowledgments.....</b>	<b>IX</b>	Tricycle Gear Configuration .....	1-38
<b>Table of Contents .....</b>	<b>XV</b>	Maintaining the Aircraft .....	1-38
<b>Chapter 1</b>		Location Numbering Systems .....	1-39
<b>Aircraft Structures.....</b>	<b>1-1</b>	Access and Inspection Panels.....	1-40
A Brief History of Aircraft Structures .....	1-1	Helicopter Structures .....	1-40
General.....	1-5	Airframe .....	1-40
Major Structural Stresses .....	1-6	Fuselage.....	1-42
Fixed-Wing Aircraft.....	1-8	Landing Gear or Skids.....	1-42
Fuselage.....	1-8	Powerplant and Transmission .....	1-42
Truss-Type.....	1-8	Turbine Engines.....	1-42
Monocoque Type .....	1-9	Transmission.....	1-43
Semimonocoque Type .....	1-9	Main Rotor System.....	1-43
Pressurization .....	1-10	Rigid Rotor System.....	1-44
Wings .....	1-10	Semirigid Rotor System.....	1-44
Wing Configurations .....	1-10	Fully Articulated Rotor System.....	1-44
Wing Structure .....	1-11	Antitorque System.....	1-45
Wing Spars .....	1-13	Controls .....	1-46
Wing Ribs.....	1-15		
Wing Skin.....	1-17	<b>Chapter 2</b>	
Nacelles .....	1-19	<b>Aerodynamics, Aircraft Assembly, and</b>	
Empennage.....	1-22	<b>Rigging</b>	
Flight Control Surfaces .....	1-24	Introduction.....	2-1
Primary Flight Control Surfaces.....	1-24	Basic Aerodynamics .....	2-2
Ailerons.....	1-26	The Atmosphere.....	2-2
Elevator.....	1-27	Pressure .....	2-2
Rudder.....	1-27	Density .....	2-3
Dual Purpose Flight Control Surfaces.....	1-27	Humidity.....	2-3
Secondary or Auxiliary Control Surfaces .....	1-28	Aerodynamics and the Laws of Physics .....	2-3
Flaps.....	1-28	Velocity and Acceleration.....	2-3
Slats.....	1-30	Newton's Laws of Motion.....	2-3
Spoilers and Speed Brakes.....	1-30	Bernoulli's Principle and Subsonic Flow .....	2-4
Tabs.....	1-31	Airfoil.....	2-4
Other Wing Features .....	1-34	Shape of the Airfoil .....	2-5
		Angle of Incidence .....	2-5
		Angle of Attack (AOA).....	2-6
		Boundary Layer.....	2-7
		Thrust and Drag .....	2-7

Center of Gravity (CG) .....	2-9	Cyclic Pitch Control .....	2-29
The Axes of an Aircraft .....	2-9	Antitorque Pedals .....	2-30
Stability and Control .....	2-9	Stabilizer Systems .....	2-30
Static Stability .....	2-9	Bell Stabilizer Bar System .....	2-30
Dynamic Stability .....	2-9	Offset Flapping Hinge .....	2-31
Longitudinal Stability .....	2-9	Stability Augmentation Systems (SAS) .....	2-31
Directional Stability .....	2-10	Helicopter Vibration .....	2-31
Lateral Stability .....	2-11	Extreme Low Frequency Vibration .....	2-31
Dutch Roll .....	2-11	Low Frequency Vibration .....	2-31
Primary Flight Controls .....	2-11	Medium Frequency Vibration .....	2-31
Trim Controls .....	2-11	High Frequency Vibration .....	2-31
Auxiliary Lift Devices .....	2-12	Rotor Blade Tracking .....	2-31
Lift Augmenting .....	2-12	Flag and Pole .....	2-31
Lift Decreasing .....	2-12	Electronic Blade Tracker .....	2-32
Winglets .....	2-13	Tail Rotor Tracking .....	2-33
Canard Wings .....	2-13	Marking Method .....	2-33
Wing Fences .....	2-14	Electronic Method .....	2-33
Control Systems for Large Aircraft .....	2-14	Rotor Blade Preservation and Storage .....	2-34
Mechanical Control .....	2-14	Helicopter Power Systems .....	2-34
Hydromechanical Control .....	2-14	Powerplant .....	2-34
Fly-By-Wire Control .....	2-14	Reciprocating Engine .....	2-34
High-Speed Aerodynamics .....	2-15	Turbine Engine .....	2-35
Rotary-Wing Aircraft Assembly and Rigging .....	2-16	Transmission System .....	2-35
Configurations of Rotary-Wing Aircraft .....	2-17	Main Rotor Transmission .....	2-35
Autogyro .....	2-17	Clutch .....	2-35
Single Rotor Helicopter .....	2-17	Centrifugal Clutch .....	2-36
Dual Rotor Helicopter .....	2-18	Belt Drive Clutch .....	2-36
Types of Rotor Systems .....	2-18	Freewheeling Unit .....	2-36
Fully Articulated Rotor .....	2-18	Airplane Assembly and Rigging .....	2-37
Semirigid Rotor .....	2-18	Rebalancing of Control Surfaces .....	2-37
Rigid Rotor .....	2-18	Static Balance .....	2-37
Forces Acting on the Helicopter .....	2-18	Dynamic Balance .....	2-38
Torque Compensation .....	2-19	Rebalancing Procedures .....	2-38
Gyroscopic Forces .....	2-19	Rebalancing Methods .....	2-38
Helicopter Flight Conditions .....	2-20	Aircraft Rigging .....	2-39
Hovering Flight .....	2-20	Rigging Specifications .....	2-39
Translating Tendency or Drift .....	2-22	Type Certificate Data Sheet .....	2-39
Ground Effect .....	2-22	Maintenance Manual .....	2-40
Coriolis Effect (Law of Conservation of Angular Momentum) .....	2-22	Structural Repair Manual (SRM) .....	2-40
Vertical Flight .....	2-23	Manufacturer's Service Information .....	2-40
Forward Flight .....	2-23	Airplane Assembly .....	2-40
Translational Lift .....	2-24	Aileron Installation .....	2-40
Effective Translational Lift (ETL) .....	2-24	Flap Installation .....	2-40
Dissymmetry of Lift .....	2-25	Empennage Installation .....	2-40
Autorotation .....	2-27	Control Operating Systems .....	2-40
Rotorcraft Controls .....	2-28	Cable Systems .....	2-40
Swash Plate Assembly .....	2-28	Cable Inspection .....	2-42
Collective Pitch Control .....	2-28	Cable System Installation .....	2-43
Throttle Control .....	2-29	Push Rods (Control Rods) .....	2-46
Governor/Correlator .....	2-29		

Torque Tubes .....	2-47	Grommets .....	3-6
Cable Drums .....	2-47	Inspection Rings .....	3-6
Rigging Checks .....	2-48	Primer .....	3-7
Structural Alignment .....	2-48	Fabric Cement.....	3-7
Cable Tension .....	2-51	Fabric Sealer .....	3-7
Control Surface Travel .....	2-53	Fillers .....	3-7
Checking and Safelying the System .....	2-54	Topcoats.....	3-7
Biplane Assembly and Rigging .....	2-55	Available Covering Processes.....	3-8
Aircraft Inspection .....	2-59	Determining Fabric Condition—Repair or Recover? ....	3-9
Purpose of Inspection Programs.....	2-59	Fabric Strength.....	3-9
Perform an Airframe Conformity and		How Fabric Breaking Strength is Determined .....	3-10
Airworthiness Inspection.....	2-59	Fabric Testing Devices.....	3-11
Required Inspections .....	2-60	General Fabric Covering Process.....	3-12
Preflight .....	2-60	Blanket Method vs. Envelope Method.....	3-12
Periodic Maintenance Inspections .....	2-60	Preparation for Fabric Covering Work.....	3-12
Altimeter and Static System Inspections .....	2-62	Removal of Old Fabric Coverings.....	3-14
Air Traffic Control (ATC) Transponder		Preparation of the Airframe Before Covering.....	3-14
Inspections .....	2-62	Attaching Polyester Fabric to the Airframe .....	3-16
Emergency Locator Transmitter (ELT)		Seams.....	3-16
Operational and Maintenance Practices in		Fabric Cement.....	3-16
Accordance With Advisory Circular (AC)		Fabric Heat Shrinking.....	3-17
91-44 .....	2-62	Attaching Fabric to the Wing Ribs .....	3-18
Annual and 100-Hour Inspections.....	2-63	Rib Lacing .....	3-18
Preparation .....	2-63	Rings, Grommets, and Gussets.....	3-21
Other Aircraft Inspection and Maintenance		Finishing Tapes.....	3-21
Programs.....	2-65	Coating the Fabric.....	3-22
Continuous Airworthiness Maintenance		Polyester Fabric Repairs .....	3-23
Program (CAMP).....	2-67	Applicable Instructions.....	3-23
Title 14 CFR part 125, section 125.247,		Repair Considerations .....	3-23
Inspection Programs and Maintenance .....	2-67	Cotton-Covered Aircraft .....	3-24
Helicopter Inspections, Piston-Engine and		Fiberglass Coverings.....	3-24
Turbine-Powered .....	2-67		
Light Sport Aircraft and Aircraft Certificated			
as Experimental .....	2-68		
<b>Chapter 3</b>			
<b>Aircraft Fabric Covering .....</b>	<b>3-1</b>	<b>Chapter 4</b>	
General History .....	3-1	<b>Aircraft Metal Structural Repair .....</b>	<b>4-1</b>
Fabric Terms .....	3-3	Aircraft Metal Structural Repair .....	4-1
Legal Aspects of Fabric Covering .....	3-3	Stresses in Structural Members .....	4-2
Approved Materials .....	3-4	Tension .....	4-2
Fabric.....	3-4	Compression .....	4-3
Other Fabric Covering Materials.....	3-5	Shear .....	4-3
Anti-Chafe Tape .....	3-5	Bearing.....	4-3
Reinforcing Tape .....	3-5	Torsion.....	4-3
Rib Bracing.....	3-5	Bending.....	4-4
Surface Tape .....	3-5	Tools for Sheet Metal Construction and Repair .....	4-4
Rib Lacing Cord .....	3-5	Layout Tools .....	4-4
Sewing Thread.....	3-6	Scales .....	4-4
Special Fabric Fasteners .....	3-6	Combination Square .....	4-4
		Dividers.....	4-4
		Rivet Spacers .....	4-4

Marking Tools .....	4-4	Types of Drill Bits .....	4-17
Pens .....	4-4	Step Drill Bits .....	4-17
Scribes .....	4-5	Cobalt Alloy Drill Bits .....	4-17
Punches .....	4-5	Twist Drill Bits .....	4-17
Prick Punch .....	4-6	Drill Bit Sizes .....	4-18
Center Punch .....	4-6	Drill Lubrication .....	4-18
Automatic Center Punch .....	4-6	Reamers .....	4-19
Transfer Punch .....	4-6	Drill Stops .....	4-19
Drive Punch .....	4-6	Drill Bushings and Guides .....	4-19
Pin Punch .....	4-7	Drill Bushing Holder Types .....	4-19
Chassis Punch .....	4-7	Drilling Large Holes .....	4-20
Awl .....	4-7	Chip Chasers .....	4-21
Hole Duplicator .....	4-7	Forming Tools .....	4-21
Cutting Tools .....	4-8	Bar Folding Machine .....	4-21
Circular-Cutting Saws .....	4-8	Cornice Brake .....	4-22
Kett Saw .....	4-8	Box and Pan Brake (Finger Brake) .....	4-22
Pneumatic Circular-Cutting Saw .....	4-8	Press Brake .....	4-23
Reciprocating Saw .....	4-8	Slip Roll Former .....	4-23
Cut-off Wheel .....	4-9	Rotary Machine .....	4-24
Nibblers .....	4-9	Stretch Forming .....	4-24
Shop Tools .....	4-9	Drop Hammer .....	4-24
Squaring Shear .....	4-9	Hydropress Forming .....	4-25
Throatless Shear .....	4-10	Spin Forming .....	4-26
Scroll Shears .....	4-10	Forming with an English Wheel .....	4-26
Rotary Punch Press .....	4-11	Piccolo Former .....	4-26
Band Saw .....	4-11	Shrinking and Stretching Tools .....	4-27
Disk Sander .....	4-11	Shrinking Tools .....	4-27
Belt Sander .....	4-12	Stretching Tools .....	4-27
Notcher .....	4-12	Manual Foot-Operated Sheet Metal Shrinker .....	4-27
Wet or Dry Grinder .....	4-12	Hand-Operated Shrinker and Stretcher .....	4-27
Grinding Wheels .....	4-13	Dollies and Stakes .....	4-27
Hand Cutting Tools .....	4-13	Hardwood Form Blocks .....	4-28
Straight Snips .....	4-13	V-Blocks .....	4-28
Aviation Snips .....	4-13	Shrinking Blocks .....	4-28
Files .....	4-13	Sandbags .....	4-28
Die Grinder .....	4-14	Sheet Metal Hammers and Mallets .....	4-28
Burring Tool .....	4-14	Sheet Metal Holding Devices .....	4-28
Hole Drilling .....	4-14	Clamps and Vises .....	4-29
Portable Power Drills .....	4-15	C-Clamps .....	4-29
Pneumatic Drill Motors .....	4-15	Vises .....	4-29
Right Angle and 45° Drill Motors .....	4-15	Reusable Sheet Metal Fasteners .....	4-29
Two Hole .....	4-15	Cleco Fasteners .....	4-30
Drill Press .....	4-15	Hex Nut and Wing Nut Temporary Sheet Fasteners .....	4-30
Drill Extensions and Adapters .....	4-16	Aluminum Alloys .....	4-30
Extension Drill Bits .....	4-16	Structural Fasteners .....	4-31
Straight Extension .....	4-16	Solid Shank Rivet .....	4-31
Angle Adapters .....	4-16	Description .....	4-31
Snake Attachment .....	4-16	Installation of Rivets .....	4-33



Rivet Installation Tools.....	4-36	Joggling.....	4-81
Riveting Procedure .....	4-40	Lightning Holes .....	4-82
Countersunk Rivets.....	4-41	Working Stainless Steel.....	4-83
Evaluating the Rivet .....	4-44	Working Inconel® Alloys 625 and 718 .....	4-83
Removal of Rivets .....	4-45	Working Magnesium.....	4-84
Replacing Rivets.....	4-46	Working Titanium.....	4-85
National Advisory Committee for Aeronautics....	4-46	Description of Titanium.....	4-85
(NACA) Method of Double Flush Riveting .....	4-46	Basic Principles of Sheet Metal Repair .....	4-86
Special Purpose Fasteners .....	4-47	Maintaining Original Strength.....	4-87
Blind Rivets .....	4-47	Shear Strength and Bearing Strength .....	4-88
Pin Fastening Systems (High-Shear Fasteners) ...	4-50	Maintaining Original Contour .....	4-89
Lockbolt Fastening Systems .....	4-52	Keeping Weight to a Minimum.....	4-89
Blind Bolts .....	4-53	Flutter and Vibration Precautions.....	4-89
Rivet Nut.....	4-56	Inspection of Damage.....	4-90
Blind Fasteners (Nonstructural).....	4-56	Types of Damage and Defects.....	4-90
Forming Process.....	4-57	Classification of Damage .....	4-91
Forming Operations and Terms .....	4-57	Negligible Damage .....	4-91
Stretching .....	4-58	Damage Repairable by Patching.....	4-91
Shrinking .....	4-58	Damage Repairable by Insertion .....	4-92
Bumping .....	4-58	Damage Necessitating Replacement of Parts .....	4-92
Crimping.....	4-58	Repairability of Sheet Metal Structure .....	4-92
Folding Sheet Metal .....	4-58	Structural Support During Repair.....	4-92
Layout and Forming.....	4-59	Assessment of Damage .....	4-92
Terminology .....	4-59	Inspection of Riveted Joints .....	4-92
Layout or Flat Pattern Development .....	4-60	Inspection for Corrosion.....	4-93
Making Straight Line Bends.....	4-60	Damage Removal .....	4-93
Bending a U-Channel .....	4-61	Repair Material Selection .....	4-93
Using a J-Chart To Calculate Total Developed		Repair Parts Layout .....	4-93
Width .....	4-67	Rivet Selection.....	4-94
How To Find the Total Developed Width		Rivet Spacing and Edge Distance.....	4-94
Using a J-Chart .....	4-68	Corrosion Treatment.....	4-94
Using a Sheet Metal Brake to Fold Metal .....	4-69	Approval of Repair.....	4-94
Step 1: Adjustment of Bend Radius.....	4-69	Repair of Stressed Skin Structure.....	4-94
Step 2: Adjusting Clamping Pressure .....	4-70	Patches .....	4-97
Step 3: Adjusting the Nose Gap.....	4-71	Typical Repairs for Aircraft Structures .....	4-98
Folding a Box .....	4-72	Floats.....	4-99
Relief Hole Location.....	4-73	Corrugated Skin Repair .....	4-99
Layout Method.....	4-73	Replacement of a Panel .....	4-99
Open and Closed Bends .....	4-73	Outside the Member .....	4-99
Open End Bend (Less Than 90°) .....	4-74	Inside the Member .....	4-99
Closed End Bend (More Than 90°) .....	4-74	Edges of the Panel .....	4-99
Hand Forming .....	4-74	Repair of Lightning Holes .....	4-99
Straight Line Bends .....	4-74	Repairs to a Pressurized Area .....	4-101
Formed or Extruded Angles.....	4-75	Stringer Repair.....	4-102
Flanged Angles .....	4-76	Former or Bulkhead Repair .....	4-103
Shrinking.....	4-76	Longeron Repair .....	4-104
Stretching.....	4-77	Spar Repair .....	4-104
Curved Flanged Parts.....	4-77	Rib and Web Repair.....	4-105
Forming by Bumping.....	4-79	Leading Edge Repair .....	4-106

Trailing Edge Repair.....	4-107	Handling of the Torch.....	5-13
Specialized Repairs.....	4-107	Oxy-acetylene Cutting .....	5-14
Inspection Openings .....	4-108	Shutting Down the Gas Welding Equipment .....	5-14
<b>Chapter 5</b>		Gas Welding Procedures and Techniques.....	5-15
<b>Aircraft Welding.....</b>	<b>5-1</b>	Correct Forming of a Weld .....	5-16
Introduction.....	5-1	Characteristics of a Good Weld.....	5-16
Types of Welding.....	5-2	Oxy-Acetylene Welding of Ferrous Metals.....	5-16
Gas Welding.....	5-2	Steel (Including SAE 4130) .....	5-16
Electric Arc Welding.....	5-2	Chrome Molybdenum .....	5-17
Shielded Metal Arc Welding (SMAW) .....	5-2	Stainless Steel.....	5-17
Gas Metal Arc Welding (GMAW) .....	5-3	Oxy-Acetylene Welding of Nonferrous Metals.....	5-17
Gas Tungsten Arc Welding (GTAW).....	5-3	Aluminum Welding.....	5-18
Electric Resistance Welding.....	5-6	Magnesium Welding .....	5-19
Spot Welding .....	5-6	Brazing and Soldering.....	5-19
Seam Welding.....	5-6	Torch Brazing of Steel .....	5-19
Plasma Arc Welding (PAW) .....	5-6	Torch Brazing of Aluminum .....	5-20
Plasma Arc Cutting .....	5-7	Soldering .....	5-21
Gas Welding and Cutting Equipment .....	5-7	Aluminum Soldering .....	5-21
Welding Gases.....	5-7	Silver Soldering .....	5-21
Acetylene .....	5-7	Gas Tungsten Arc Welding (TIG Welding).....	5-22
Argon .....	5-7	TIG Welding 4130 Steel Tubing.....	5-23
Helium .....	5-7	TIG Welding Stainless Steel .....	5-23
Hydrogen .....	5-7	TIG Welding Aluminum .....	5-24
Oxygen.....	5-7	TIG Welding Magnesium.....	5-24
Pressure Regulators .....	5-7	TIG Welding Titanium.....	5-24
Welding Hose.....	5-8	Arc Welding Procedures, Techniques, and	
Check Valves and Flashback Arrestors.....	5-8	Welding Safety Equipment .....	5-25
Torches .....	5-8	Multiple Pass Welding .....	5-26
Equal Pressure Torch.....	5-8	Techniques of Position Welding .....	5-27
Injector Torch .....	5-9	Flat Position Welding.....	5-28
Cutting Torch.....	5-9	Bead Weld .....	5-28
Torch Tips .....	5-9	Groove Weld.....	5-28
Welding Eyewear .....	5-9	Fillet Weld .....	5-29
Torch Lighters .....	5-10	Lap Joint Weld.....	5-29
Filler Rod .....	5-10	Vertical Position Welding .....	5-29
Equipment Setup .....	5-10	Overhead Position Welding.....	5-29
Gas Cylinders.....	5-10	Expansion and Contraction of Metals.....	5-29
Regulators .....	5-10	Welded Joints Using Oxy-Acetylene Torch .....	5-30
Hoses.....	5-11	Butt Joints.....	5-30
Connecting Torch .....	5-11	Tee Joints.....	5-31
Select the Tip Size .....	5-11	Edge Joints .....	5-31
Adjusting the Regulator Working Pressure .....	5-12	Corner Joints .....	5-31
Lighting and Adjusting the Torch .....	5-13	Lap Joints .....	5-32
Different Flames.....	5-13	Repair of Steel Tubing Aircraft Structure by	
Neutral Flame .....	5-13	Welding.....	5-32
Carburizing Flame .....	5-13	Dents at a Cluster Weld.....	5-32
Oxidizing Flame .....	5-13	Dents Between Clusters.....	5-32
Soft or Harsh Flames .....	5-13	Tube Splicing with Inside Sleeve Reinforcement ....	5-33
		Tube Splicing with Outer Split Sleeve	
		Reinforcement .....	5-33

Landing Gear Repairs.....	5-34	Unidirectional (Tape).....	7-3
Engine Mount Repairs.....	5-36	Bidirectional (Fabric).....	7-3
Rosette Welding .....	5-36	Nonwoven (Knitted or Stitched).....	7-4
<b>Chapter 6</b>		Types of Fiber .....	7-4
<b>Aircraft Wood and Structural Repair .....</b>	<b>6-1</b>	Fiberglass.....	7-4
Aircraft Wood and Structural Repair .....	6-1	Kevlar®.....	7-4
Wood Aircraft Construction and Repairs .....	6-2	Carbon/Graphite .....	7-5
Inspection of Wood Structures .....	6-3	Boron .....	7-6
External and Internal Inspection .....	6-3	Ceramic Fibers.....	7-6
Glued Joint Inspection .....	6-4	Lightning Protection Fibers .....	7-6
Wood Condition .....	6-5	Matrix Materials .....	7-6
Repair of Wood Aircraft Structures.....	6-7	Thermosetting Resins .....	7-6
Materials.....	6-7	Thermoplastic Resins.....	7-8
Suitable Wood .....	6-7	Curing Stages of Resins .....	7-8
Defects Permitted .....	6-9	Pre-Impregnated Products (Prepregs) .....	7-8
Defects Not Permitted.....	6-9	Dry Fiber Material.....	7-8
Glues (Adhesives).....	6-10	Thixotropic Agents.....	7-9
Definition of Terms Used in the Glue Process .....	6-10	Adhesives .....	7-9
Preparation of Wood for Gluing.....	6-11	Film Adhesives .....	7-9
Preparing Glues for Use.....	6-11	Paste Adhesives .....	7-9
Applying the Glue/Adhesive .....	6-11	Foaming Adhesives .....	7-10
Pressure on the Joint .....	6-12	Description of Sandwich Structures.....	7-10
Testing Glued Joints .....	6-13	Properties.....	7-11
Repair of Wood Aircraft Components .....	6-13	Facing Materials .....	7-11
Wing Rib Repairs .....	6-13	Core Materials .....	7-11
Wing Spar Repairs .....	6-15	Honeycomb.....	7-11
Bolt and Bushing Holes .....	6-19	Foam .....	7-12
Plywood Skin Repairs .....	6-20	Balsa Wood.....	7-13
Fabric Patch .....	6-20	Manufacturing and In-Service Damage .....	7-13
Splayed Patch.....	6-20	Manufacturing Defects .....	7-13
Surface Patch .....	6-20	Fiber Breakage.....	7-13
Plug Patch .....	6-21	Matrix Imperfections .....	7-13
Scarf Patch .....	6-24	Delamination and Debonds.....	7-14
The Back of the Skin is Accessible for Repair .....	6-24	Combinations of Damages.....	7-14
The Back of the Skin Is Not Accessible for		Flawed Fastener Holes.....	7-14
Repair.....	6-26	In-Service Defects .....	7-14
		Corrosion .....	7-15
		Nondestructive Inspection (NDI) of Composites .....	7-15
		Visual Inspection.....	7-15
		Audible Sonic Testing (Coin Tapping) .....	7-16
		Automated Tap Test .....	7-16
		Ultrasonic Inspection.....	7-17
		Through Transmission Ultrasonic Inspection.....	7-17
		Pulse Echo Ultrasonic Inspection .....	7-17
		Ultrasonic Bondtester Inspection.....	7-18
		Phased Array Inspection .....	7-18
		Radiography .....	7-18
<b>Chapter 7</b>			
<b>Advanced Composite Materials .....</b>	<b>7-1</b>		
Description of Composite Structures .....	7-1		
Introduction .....	7-1		
Laminated Structures.....	7-2		
Major Components of a Laminate .....	7-2		
Strength Characteristics .....	7-2		
Fiber Orientation.....	7-2		
Warp Clock .....	7-3		
Fiber Forms .....	7-3		
Roving.....	7-3		

Thermography .....	7-19	Curing of Composite Materials .....	7-32
Neutron Radiography .....	7-19	Room Temperature Curing .....	7-32
Moisture Detector .....	7-19	Elevated Temperature Curing .....	7-32
Composite Repairs .....	7-19	Composite Honeycomb Sandwich Repairs .....	7-33
Layup Materials .....	7-19	Damage Classification .....	7-34
Hand Tools .....	7-19	Sandwich Structures .....	7-34
Air Tools .....	7-19	Minor Core Damage (Filler and Potting Repairs) .....	7-34
Caul Plate .....	7-20	Damage Requiring Core Replacement and Repair to One or Both Faceplates .....	7-34
Support Tooling and Molds .....	7-20	Solid Laminates .....	7-37
Vacuum Bag Materials .....	7-21	Bonded Flush Patch Repairs .....	7-37
Release Agents .....	7-21	Trailing Edge and Transition Area Patch Repairs .....	7-40
Bleeder Ply .....	7-21	Resin Injection Repairs .....	7-40
Peel Ply .....	7-21	Composite Patch Bonded to Aluminum Structure .....	7-40
Layup Tapes .....	7-21	Fiberglass Molded Mat Repairs .....	7-40
Perforated Release Film .....	7-21	Radome Repairs .....	7-41
Solid Release Film .....	7-21	External Bonded Patch Repairs .....	7-41
Breather Material .....	7-21	Bolted Repairs .....	7-44
Vacuum Bag .....	7-22	Fasteners Used with Composite Laminates .....	7-46
Vacuum Equipment .....	7-22	Corrosion Precautions .....	7-46
Vacuum Compaction Table .....	7-22	Fastener Materials .....	7-46
Heat Sources .....	7-22	Fastener System for Sandwich Honeycomb Structures (SPS Technologies Comp Tite) .....	7-46
Oven .....	7-22	Hi-Lok® and Huck-Spin® Lockbolt Fasteners ...	7-46
Autoclave .....	7-23	Eddie-Bolt® Fasteners .....	7-46
Heat Bonder and Heat Lamps .....	7-23	Cherry's E-Z Buck® (CSR90433) Hollow Rivet .....	7-47
Heat Press Forming .....	7-24	Blind Fasteners .....	7-47
Thermocouples .....	7-25	Blind Bolts .....	7-48
Types of Layups .....	7-26	Fiberlite .....	7-48
Wet Layups .....	7-26	Screws and Nutplates in Composite Structures ...	7-48
Prepreg .....	7-27	Machining Processes and Equipment .....	7-49
Co-curing .....	7-28	Drilling .....	7-49
Secondary Bonding .....	7-28	Countersinking .....	7-52
Co-bonding .....	7-28	Cutting Processes and Precautions .....	7-52
Layup Process (Typical Laminated Wet Layup) .....	7-28	Cutting Equipment .....	7-52
Layup Techniques .....	7-28	Repair Safety .....	7-53
Bleedout Technique .....	7-29	Eye Protection .....	7-53
No Bleedout .....	7-29	Respiratory Protection .....	7-53
Ply Orientation Warp Clock .....	7-29	Skin Protection .....	7-53
Mixing Resins .....	7-30	Fire Protection .....	7-53
Saturation Techniques .....	7-30	Transparent Plastics .....	7-54
Fabric Impregnation With a Brush or Squeegee ...	7-30	Optical Considerations .....	7-54
Fabric Impregnation Using a Vacuum Bag .....	7-30	Identification .....	7-54
Vacuum Bagging Techniques .....	7-31	Storage and Handling .....	7-54
Single Side Vacuum Bagging .....	7-31	Forming Procedures and Techniques .....	7-54
Envelope Bagging .....	7-31		
Alternate Pressure Application .....	7-32		
Shrink Tape .....	7-32		
C-Clamps .....	7-32		
Shotbags and Weights .....	7-32		

Heating.....	7-54	Spray Equipment.....	8-6
Forms.....	7-55	Air Compressors.....	8-6
Forming Methods.....	7-55	Large Coating Containers.....	8-7
Sawing and Drilling.....	7-55	System Air Filters.....	8-7
Sawing.....	7-55	Miscellaneous Painting Tools and Equipment.....	8-7
Drilling.....	7-55	Spray Guns.....	8-7
Cementing.....	7-56	Fresh Air Breathing Systems.....	8-9
Application of Cement.....	7-56	Viscosity Measuring Cup.....	8-9
Repairs.....	7-57	Mixing Equipment.....	8-10
Cleaning.....	7-57	Preparation.....	8-10
Polishing.....	7-57	Surfaces.....	8-10
Windshield Installation.....	7-57	Primer and Paint.....	8-10
Installation Procedures.....	7-57	Spray Gun Operation.....	8-11
		Adjusting the Spray Pattern.....	8-11
		Applying the Finish.....	8-11
		Common Spray Gun Problems.....	8-12
<b>Chapter 8</b>		Sequence for Painting a Single-Engine or Light	
<b>Aircraft Painting and Finishing.....</b>	<b>8-1</b>	Twin Airplane.....	8-13
Introduction.....	8-1	Common Paint Troubles.....	8-13
Finishing Materials.....	8-2	Poor Adhesion.....	8-13
Acetone.....	8-2	Blushing.....	8-13
Alcohol.....	8-2	Pinholes.....	8-14
Benzene.....	8-2	Sags and Runs.....	8-14
Methyl Ethyl Ketone (MEK).....	8-2	Orange Peel.....	8-14
Methylene Chloride.....	8-2	Fisheyes.....	8-15
Toluene.....	8-2	Sanding Scratches.....	8-15
Turpentine.....	8-3	Wrinkling.....	8-15
Mineral Spirits.....	8-3	Spray Dust.....	8-16
Naphtha.....	8-3	Painting Trim and Identification Marks.....	8-16
Linseed Oil.....	8-3	Masking and Applying the Trim.....	8-16
Thinners.....	8-3	Masking Materials.....	8-16
Varnish.....	8-3	Masking for the Trim.....	8-16
Primers.....	8-3	Display of Nationality and Registration Marks.....	8-17
Wash Primers.....	8-3	Display of Marks.....	8-17
Red Iron Oxide.....	8-3	Location and Placement of Marks.....	8-17
Gray Enamel Undercoat.....	8-4	Size Requirements for Different Aircraft.....	8-18
Urethane.....	8-4	Decals.....	8-18
Epoxy.....	8-4	Paper Decals.....	8-18
Zinc Chromate.....	8-4	Metal Decals with Cellophane Backing.....	8-18
Identification of Paints.....	8-4	Metal Decals With Paper Backing.....	8-18
Dope.....	8-4	Metal Decals with No Adhesive.....	8-18
Synthetic Enamel.....	8-4	Vinyl Film Decals.....	8-18
Lacquers.....	8-4	Removal of Decals.....	8-19
Polyurethane.....	8-5	Paint System Compatibility.....	8-19
Urethane Coating.....	8-5	Paint Touchup.....	8-19
Acrylic Urethanes.....	8-5	Identification of Paint Finishes.....	8-19
Methods of Applying Finish.....	8-5	Surface Preparation for Touchup.....	8-20
Dipping.....	8-5	Stripping the Finish.....	8-20
Brushing.....	8-5	Chemical Stripping.....	8-21
Spraying.....	8-5	Plastic Media Blasting (PMB).....	8-21
Finishing Equipment.....	8-6		
Paint Booth.....	8-6		
Air Supply.....	8-6		



New Stripping Methods .....	8-21
Safety in the Paint Shop .....	8-21
Storage of Finishing Materials .....	8-21
Protective Equipment for Personnel .....	8-22

## Chapter 9

### Aircraft Electrical System.....9-1

Introduction.....	9-1
Ohm's Law .....	9-2
Current.....	9-2
Conventional Current Theory and Electron Theory .....	9-3
Electromotive Force (Voltage).....	9-4
Resistance.....	9-4
Factors Affecting Resistance .....	9-4
Electromagnetic Generation of Power .....	9-5
Alternating Current (AC) Introduction.....	9-9
Definitions .....	9-9
Opposition to Current Flow of AC.....	9-12
Resistance .....	9-12
Inductive Reactance.....	9-12
Capacitive Reactance.....	9-14
Impedance.....	9-15
Parallel AC Circuits.....	9-18
Power in AC Circuits.....	9-20
True Power.....	9-20
Apparent Power .....	9-20
Power Factor .....	9-20
Aircraft Batteries.....	9-21
Types of Batteries.....	9-21
Lead-Acid Batteries .....	9-21
NiCd Batteries .....	9-22
Capacity .....	9-22
Aircraft Battery Ratings by Specification.....	9-23
Storing and Servicing Facilities.....	9-23
Battery Freezing.....	9-23
Temperature Correction.....	9-23
Battery Charging.....	9-24
Battery Maintenance.....	9-24
Battery and Charger Characteristics .....	9-25
Aircraft Battery Inspection .....	9-26
Aircraft battery inspection consists of the following items: .....	9-26
Ventilation Systems .....	9-26
Installation Practices .....	9-26
Troubleshooting.....	9-27
DC Generators and Controls .....	9-27
Generators.....	9-27
Construction Features of DC Generators.....	9-29

Types of DC Generators .....	9-32
Generator Ratings .....	9-33
DC Generator Maintenance .....	9-33
Generator Controls .....	9-34
Theory of Generator Control .....	9-34
Functions of Generator Control Systems.....	9-35
Generator Controls for High Output Generators ..	9-35
Generator Controls for Low-Output Generators...	9-36
DC Alternators and Controls.....	9-38
DC Alternators.....	9-39
Alternator Voltage Regulators .....	9-40
Solid-State Regulators .....	9-40
Power Systems .....	9-41
AC Alternators .....	9-41
Alternator Drive .....	9-42
AC Alternators Control Systems.....	9-45
Aircraft Electrical Systems .....	9-47
Small Single-Engine Aircraft .....	9-47
Battery Circuit .....	9-47
Generator Circuit .....	9-48
Alternator Circuit.....	9-48
External Power Circuit .....	9-50
Starter Circuit.....	9-50
Avionics Power Circuit.....	9-51
Landing Gear Circuit.....	9-52
AC Supply .....	9-55
Light Multiengine Aircraft .....	9-57
Paralleling Alternators or Generators .....	9-57
Power Distribution on Multiengine Aircraft.....	9-58
Large Multiengine Aircraft .....	9-60
AC Power Systems .....	9-60
Wiring Installation .....	9-65
Wiring Diagrams .....	9-65
Block Diagrams .....	9-65
Pictorial Diagrams .....	9-65
Schematic Diagrams .....	9-65
Wire Types .....	9-65
Conductor .....	9-67
Plating .....	9-68
Insulation .....	9-68
Wire Shielding .....	9-68
Wire Substitutions .....	9-69
Areas Designated as Severe Wind and Moisture Problem (SWAMP) .....	9-69
Wire Size Selection .....	9-69
Current Carrying Capacity.....	9-71
Allowable Voltage Drop.....	9-75
Wire Identification .....	9-77

Placement of Identification Markings .....	9-77
Types of Wire Markings .....	9-77
Wire Installation and Routing .....	9-78
Open Wiring .....	9-78
Wire Groups and Bundles and Routing .....	9-78
Conduit .....	9-83
Wire Shielding .....	9-85
Lacing and Tying Wire Bundles .....	9-88
Tying .....	9-89
Wire Termination .....	9-90
Stripping Wire .....	9-90
Terminal Strips .....	9-91
Terminal Lugs .....	9-91
Emergency Splicing Repairs .....	9-92
Junction Boxes .....	9-92
AN/MS Connectors .....	9-93
Coaxial Cable .....	9-96
Wire Inspection .....	9-96
Electrical System Components .....	9-96
Switches .....	9-96
Type of Switches .....	9-98
Toggle and Rocker Switches .....	9-98
Rotary Switches .....	9-99
Precision (Micro) Switches .....	9-99
Relays and Solenoids (Electromagnetic Switches) .....	9-99
Solenoids .....	9-99
Relays .....	9-99
Current Limiting Devices .....	9-100
Fuses .....	9-100
Circuit Breakers .....	9-100
Aircraft Lighting Systems .....	9-101
Exterior Lights .....	9-101
Position Lights .....	9-101
Anticollision Lights .....	9-102
Landing and Taxi Lights .....	9-103
Wing Inspection Lights .....	9-104
Interior Lights .....	9-104
Maintenance and Inspection of Lighting Systems .....	9-105

<b>Glossary .....</b>	<b>G-1</b>
-----------------------	------------

<b>Index .....</b>	<b>I-1</b>
--------------------	------------

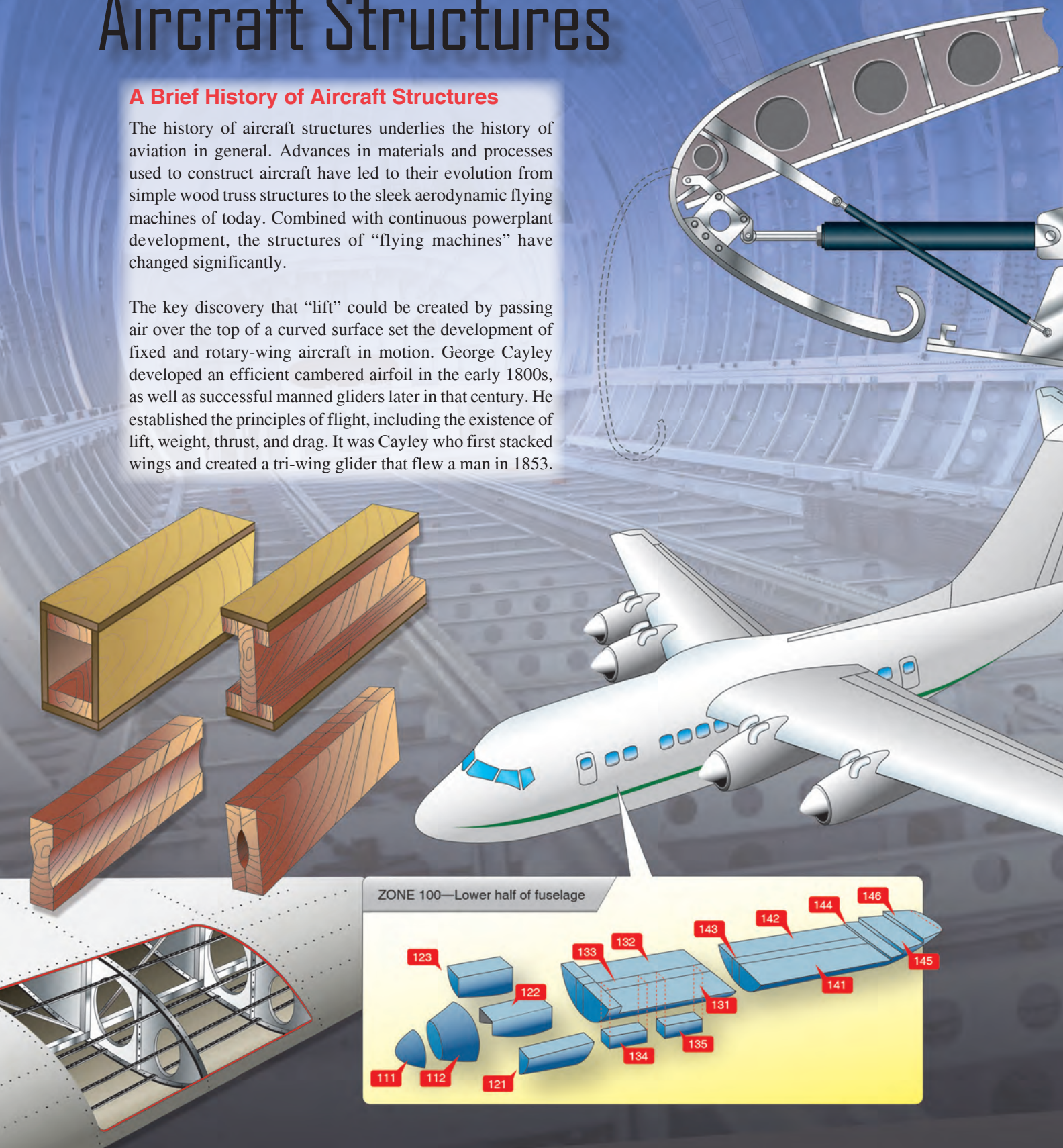
## Chapter I

# Aircraft Structures

### A Brief History of Aircraft Structures

The history of aircraft structures underlies the history of aviation in general. Advances in materials and processes used to construct aircraft have led to their evolution from simple wood truss structures to the sleek aerodynamic flying machines of today. Combined with continuous powerplant development, the structures of “flying machines” have changed significantly.

The key discovery that “lift” could be created by passing air over the top of a curved surface set the development of fixed and rotary-wing aircraft in motion. George Cayley developed an efficient cambered airfoil in the early 1800s, as well as successful manned gliders later in that century. He established the principles of flight, including the existence of lift, weight, thrust, and drag. It was Cayley who first stacked wings and created a tri-wing glider that flew a man in 1853.

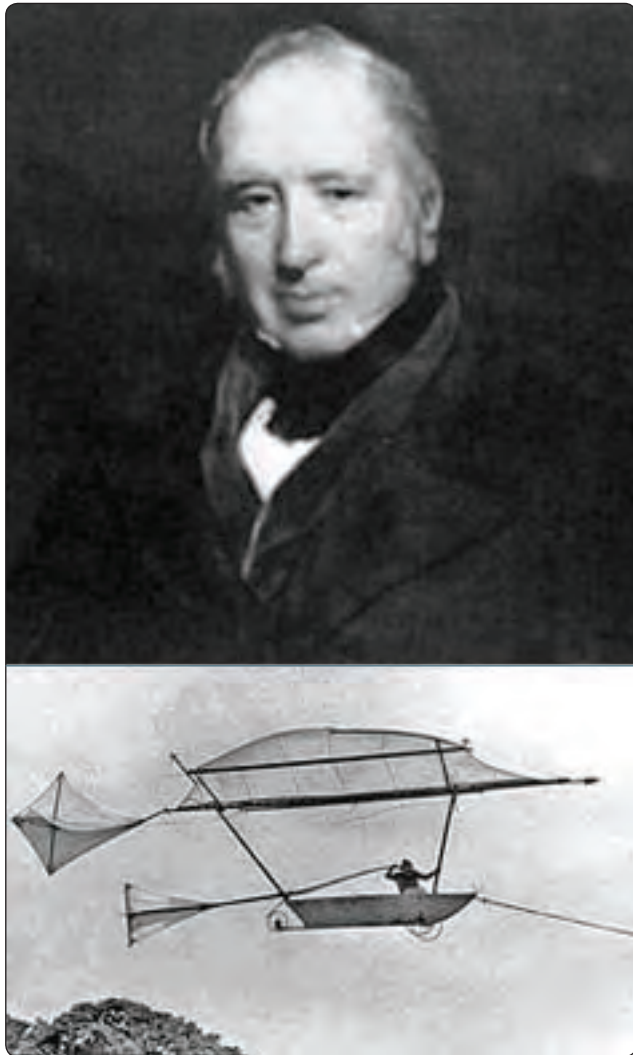




Earlier, Cayley studied the center of gravity of flying machines, as well as the effects of wing dihedral. Furthermore, he pioneered directional control of aircraft by including the earliest form of a rudder on his gliders. [Figure 1-1]

In the late 1800s, Otto Lilienthal built upon Cayley's discoveries. He manufactured and flew his own gliders on over 2,000 flights. His willow and cloth aircraft had wings designed from extensive study of the wings of birds. Lilienthal also made standard use of vertical and horizontal fins behind the wings and pilot station. Above all, Lilienthal proved that man could fly. [Figure 1-2]

Octave Chanute, a retired railroad and bridge engineer, was active in aviation during the 1890s. [Figure 1-3] His interest was so great that, among other things, he published a definitive work called "Progress in Flying Machines." This was the culmination of his effort to gather and study all the



**Figure 1-1.** George Cayley, the father of aeronautics (top) and a flying replica of his 1853 glider (bottom).



**Figure 1-2.** Master of gliding and wing study, Otto Lilienthal (top) and one of his more than 2,000 glider flights (bottom)

information available on aviation. With the assistance of others, he built gliders similar to Lilienthal's and then his own. In addition to his publication, Chanute advanced aircraft structure development by building a glider with stacked wings incorporating the use of wires as wing supports.

The work of all of these men was known to the Wright Brothers when they built their successful, powered airplane in 1903. The first of its kind to carry a man aloft, the Wright Flyer had thin, cloth-covered wings attached to what was primarily truss structures made of wood. The wings contained forward and rear spars and were supported with both struts and wires. Stacked wings (two sets) were also part of the Wright Flyer. [Figure 1-4]



**Figure 1-3.** *Octave Chanute gathered and published all of the aeronautical knowledge known to date in the late 1890s. Many early aviators benefited from this knowledge.*

Powered heavier-than-air aviation grew from the Wright design. Inventors and fledgling aviators began building their own aircraft. Early on, many were similar to that constructed by the Wrights using wood and fabric with wires and struts to support the wing structure. In 1909, Frenchman Louis Bleriot produced an aircraft with notable design differences. He built a successful mono-wing aircraft. The wings were



**Figure 1-5.** *The world's first mono-wing by Louis Bleriot.*

still supported by wires, but a mast extending above the fuselage enabled the wings to be supported from above, as well as underneath. This made possible the extended wing length needed to lift an aircraft with a single set of wings. Bleriot used a Pratt truss-type fuselage frame. [Figure 1-5]

More powerful engines were developed, and airframe structures changed to take advantage of the benefits. As early as 1910, German Hugo Junkers was able to build an aircraft with metal truss construction and metal skin due to the availability of stronger powerplants to thrust the plane forward and into the sky. The use of metal instead of wood for the primary structure eliminated the need for external wing braces and wires. His J-1 also had a single set of wings (a monoplane) instead of a stacked set. [Figure 1-6]



**Figure 1-4.** *The Wright Flyer was the first successful powered aircraft. It was made primarily of wood and fabric.*





**Figure 1-6.** *The Junker J-1 all metal construction in 1910.*

Leading up to World War I (WWI), stronger engines also allowed designers to develop thicker wings with stronger spars. Wire wing bracing was no longer needed. Flatter, lower wing surfaces on high-camber wings created more lift. WWI expanded the need for large quantities of reliable aircraft. Used mostly for reconnaissance, stacked-wing tail draggers with wood and metal truss frames with mostly fabric skin dominated the wartime sky. [Figure 1-7] The Red Baron's Fokker DR-1 was typical.

In the 1920s, the use of metal in aircraft construction increased. Fuselages able to carry cargo and passengers were developed. The early flying boats with their hull-type construction from the shipbuilding industry provided the blueprints for semimonocoque construction of fuselages. [Figure 1-8] Truss-type designs faded. A tendency toward cleaner mono-wing designs prevailed.

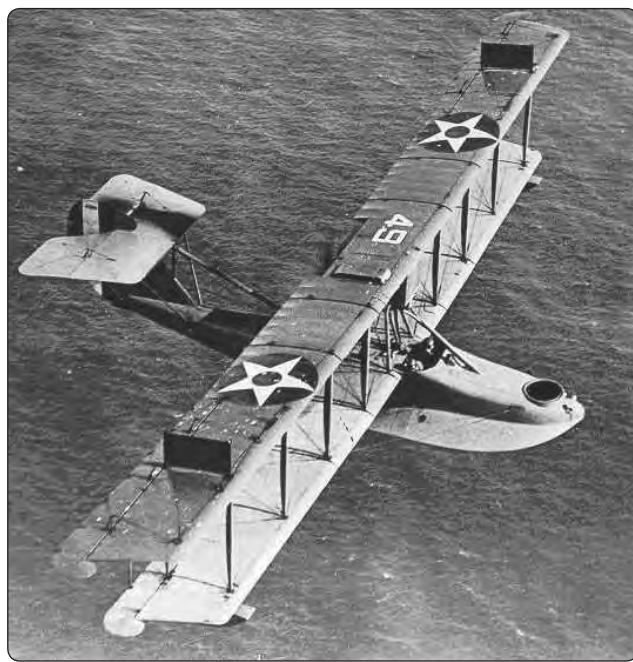
Into the 1930s, all-metal aircraft accompanied new lighter and more powerful engines. Larger semimonocoque fuselages were complimented with stress-skin wing designs. Fewer truss and fabric aircraft were built. World War II (WWII) brought about a myriad of aircraft designs using all metal technology. Deep fuel-carrying wings were the norm, but the desire for higher flight speeds prompted the development of thin-winged aircraft in which fuel was carried in the fuselage. The first composite structure aircraft, the De Havilland Mosquito, used a balsa wood sandwich material in the



**Figure 1-7.** *World War I aircraft were typically stacked-wing fabric-covered aircraft like this Breguet 14 (circa 1917).*

construction of the fuselage. [Figure 1-9] The fiberglass radome was also developed during this period.

After WWII, the development of turbine engines led to higher altitude flight. The need for pressurized aircraft pervaded aviation. Semimonocoque construction needed to be made even stronger as a result. Refinements to the all-metal semimonocoque fuselage structure were made to increase strength and combat metal fatigue caused by the pressurization-depressurization cycle. Rounded window and door openings were developed to avoid weak areas where cracks could form. Integrally machined copper alloy aluminum skin resisted cracking and allowed thicker skin and controlled tapering. Chemical milling of wing skin structures provided great strength and smooth high-



**Figure 1-8.** *The flying boat hull was an early semimonocoque design like this Curtiss HS-2L.*



**Figure 1-9.** The De Havilland Mosquito used a laminated wood construction with a balsa wood core in the fuselage.

performance surfaces. Variable contour wings became easier to construct. Increases in flight speed accompanying jet travel brought about the need for thinner wings. Wing loading also increased greatly. Multispar and box beam wing designs were developed in response.

In the 1960s, ever larger aircraft were developed to carry passengers. As engine technology improved, the jumbo jet was engineered and built. Still primarily aluminum with a semimonocoque fuselage, the sheer size of the airliners of the day initiated a search for lighter and stronger materials from which to build them. The use of honeycomb constructed panels in Boeing's airline series saved weight while not compromising strength. Initially, aluminum core with aluminum or fiberglass skin sandwich panels were used on wing panels, flight control surfaces, cabin floor boards, and other applications.

A steady increase in the use of honeycomb and foam core sandwich components and a wide variety of composite materials characterizes the state of aviation structures from the 1970s to the present. Advanced techniques and material combinations have resulted in a gradual shift from aluminum to carbon fiber and other strong, lightweight materials. These new materials are engineered to meet specific performance requirements for various components on the aircraft. Many airframe structures are made of more than 50 percent advanced composites, with some airframes approaching 100 percent. The term "very light jet" (VLJ) has come to describe a new generation of jet aircraft made almost entirely of advanced composite materials. [Figure 1-10] It is possible that noncomposite aluminum aircraft structures will become obsolete as did the methods and materials of construction used by Cayley, Lilienthal, and the Wright Brothers.



**Figure 1-10.** The nearly all composite Cessna Citation Mustang very light jet (VLJ).

## General

An aircraft is a device that is used for, or is intended to be used for, flight in the air. Major categories of aircraft are airplane, rotorcraft, glider, and lighter-than-air vehicles. [Figure 1-11] Each of these may be divided further by major distinguishing features of the aircraft, such as airships and balloons. Both are lighter-than-air aircraft but have differentiating features and are operated differently.

The concentration of this handbook is on the airframe of aircraft; specifically, the fuselage, booms, nacelles, cowlings, fairings, airfoil surfaces, and landing gear. Also included are the various accessories and controls that accompany these structures. Note that the rotors of a helicopter are considered part of the airframe since they are actually rotating wings. By contrast, propellers and rotating airfoils of an engine on an airplane are not considered part of the airframe.

The most common aircraft is the fixed-wing aircraft. As the name implies, the wings on this type of flying machine are attached to the fuselage and are not intended to move independently in a fashion that results in the creation of lift. One, two, or three sets of wings have all been successfully utilized. [Figure 1-12] Rotary-wing aircraft such as helicopters are also widespread. This handbook discusses features and maintenance aspects common to both fixed-wing and rotary-wing categories of aircraft. Also, in certain cases, explanations focus on information specific to only one or the other. Glider airframes are very similar to fixed-wing aircraft. Unless otherwise noted, maintenance practices described for fixed-wing aircraft also apply to gliders. The same is true for lighter-than-air aircraft, although thorough





**Figure 1-11.** Examples of different categories of aircraft, clockwise from top left: lighter-than-air, glider, rotorcraft, and airplane.



**Figure 1-12.** A monoplane (top), biplane (middle), and tri-wing aircraft (bottom).

coverage of the unique airframe structures and maintenance practices for lighter-than-air flying machines is not included in this handbook.

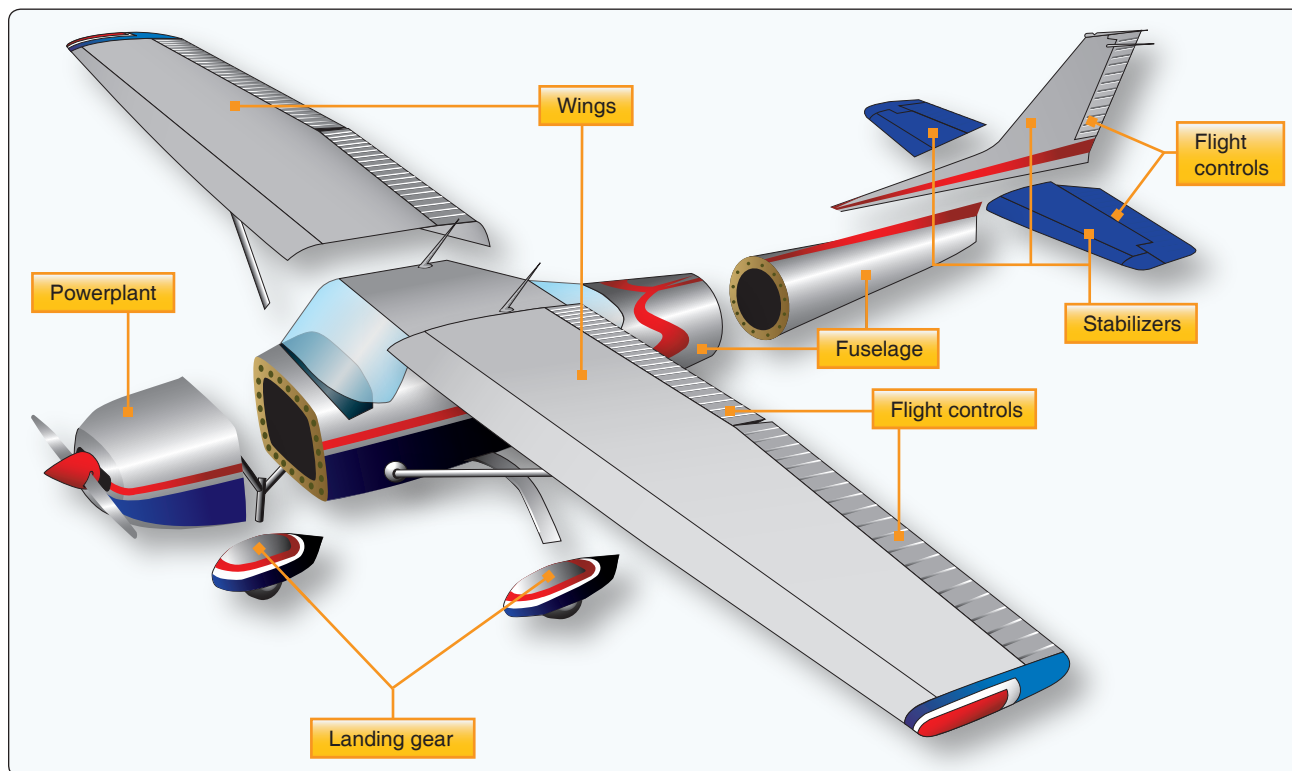
The airframe of a fixed-wing aircraft consists of five principal units: the fuselage, wings, stabilizers, flight control surfaces, and landing gear. [Figure 1-13] Helicopter airframes consist of the fuselage, main rotor and related gearbox, tail rotor (on helicopters with a single main rotor), and the landing gear.

Airframe structural components are constructed from a wide variety of materials. The earliest aircraft were constructed primarily of wood. Steel tubing and the most common material, aluminum, followed. Many newly certified aircraft are built from molded composite materials, such as carbon fiber. Structural members of an aircraft's fuselage include stringers, longerons, ribs, bulkheads, and more. The main structural member in a wing is called the wing spar.

The skin of aircraft can also be made from a variety of materials, ranging from impregnated fabric to plywood, aluminum, or composites. Under the skin and attached to the structural fuselage are the many components that support airframe function. The entire airframe and its components are joined by rivets, bolts, screws, and other fasteners. Welding, adhesives, and special bonding techniques are also used.

## Major Structural Stresses

Aircraft structural members are designed to carry a load or to resist stress. In designing an aircraft, every square inch of wing and fuselage, every rib, spar, and even each metal fitting must be considered in relation to the physical characteristics of the material of which it is made. Every part of the aircraft must be planned to carry the load to be imposed upon it.



**Figure 1-13.** *Principal airframe units.*

The determination of such loads is called stress analysis. Although planning the design is not the function of the aircraft technician, it is, nevertheless, important that the technician understand and appreciate the stresses involved in order to avoid changes in the original design through improper repairs.

The term “stress” is often used interchangeably with the word “strain.” While related, they are not the same thing. External loads or forces cause stress. Stress is a material’s internal resistance, or counterforce, that opposes deformation. The degree of deformation of a material is strain. When a material is subjected to a load or force, that material is deformed, regardless of how strong the material is or how light the load is.

There are five major stresses [Figure 1-14] to which all aircraft are subjected:

- Tension
- Compression
- Torsion
- Shear
- Bending

Tension is the stress that resists a force that tends to pull something apart. [Figure 1-14A] The engine pulls the aircraft

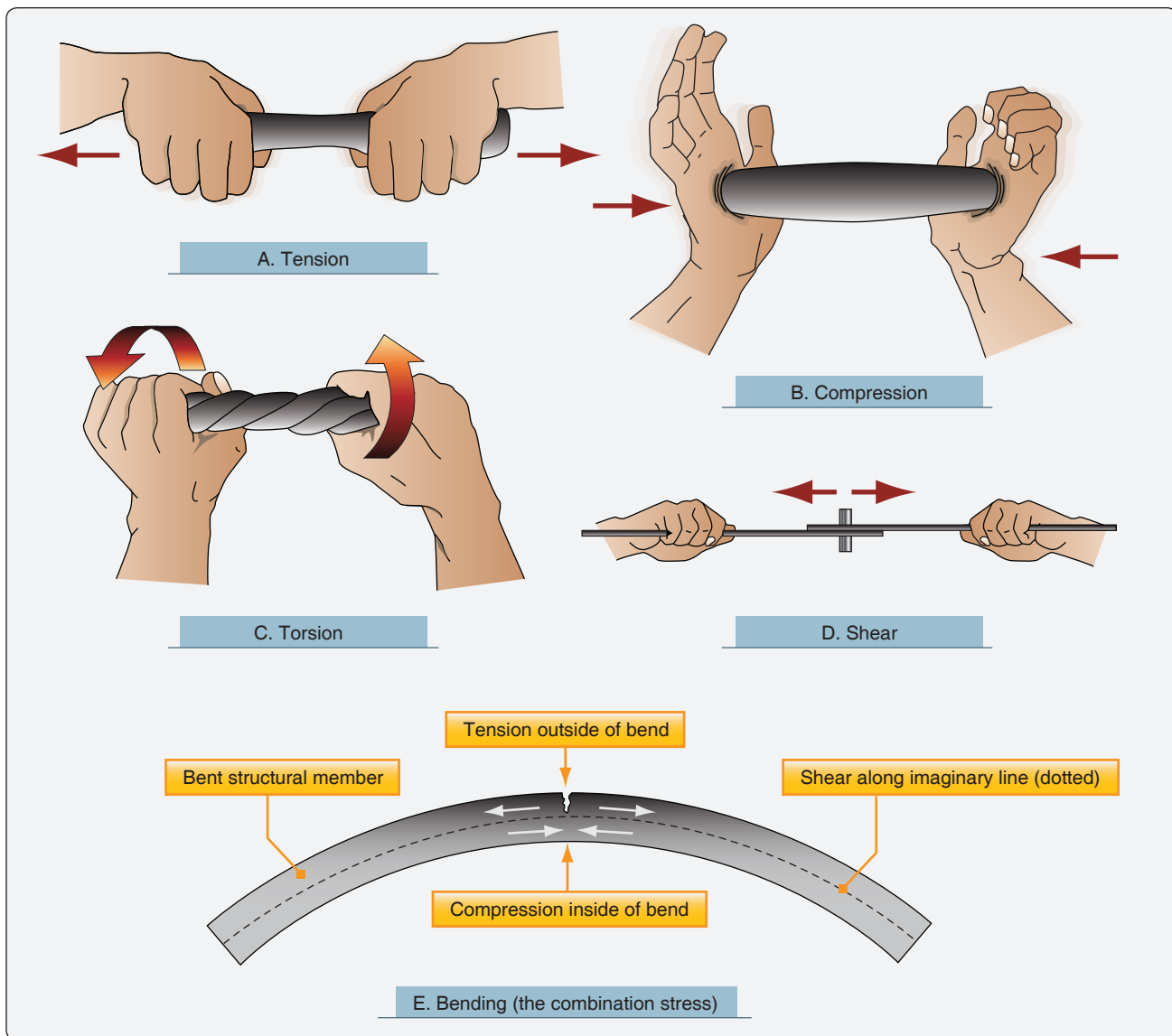
forward, but air resistance tries to hold it back. The result is tension, which stretches the aircraft. The tensile strength of a material is measured in pounds per square inch (psi) and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

Compression is the stress that resists a crushing force. [Figure 1-14B] The compressive strength of a material is also measured in psi. Compression is the stress that tends to shorten or squeeze aircraft parts.

Torsion is the stress that produces twisting. [Figure 1-14C] While moving the aircraft forward, the engine also tends to twist it to one side, but other aircraft components hold it on course. Thus, torsion is created. The torsion strength of a material is its resistance to twisting or torque.

Shear is the stress that resists the force tending to cause one layer of a material to slide over an adjacent layer. [Figure 1-14D] Two riveted plates in tension subject the rivets to a shearing force. Usually, the shearing strength of a material is either equal to or less than its tensile or compressive strength. Aircraft parts, especially screws, bolts, and rivets, are often subject to a shearing force.

Bending stress is a combination of compression and tension. The rod in Figure 1-14E has been shortened (compressed) on



**Figure 1-14.** *The five stresses that may act on an aircraft and its parts.*

the inside of the bend and stretched on the outside of the bend. A single member of the structure may be subjected to a combination of stresses. In most cases, the structural members are designed to carry end loads rather than side loads. They are designed to be subjected to tension or compression rather than bending.

Strength or resistance to the external loads imposed during operation may be the principal requirement in certain structures. However, there are numerous other characteristics in addition to designing to control the five major stresses that engineers must consider. For example, cowling, fairings, and similar parts may not be subject to significant loads requiring a high degree of strength. However, these parts must have streamlined shapes to meet aerodynamic requirements, such as reducing drag or directing airflow.

## Fixed-Wing Aircraft

### Fuselage

The fuselage is the main structure or body of the fixed-wing aircraft. It provides space for cargo, controls, accessories, passengers, and other equipment. In single-engine aircraft, the fuselage houses the powerplant. In multiengine aircraft, the engines may be either in the fuselage, attached to the fuselage, or suspended from the wing structure. There are two general types of fuselage construction: truss and monocoque.

### Truss-Type

A truss is a rigid framework made up of members, such as beams, struts, and bars to resist deformation by applied loads. The truss-framed fuselage is generally covered with fabric. The truss-type fuselage frame is usually constructed of steel



tubing welded together in such a manner that all members of the truss can carry both tension and compression loads. [Figure 1-15] In some aircraft, principally the light, single-engine models, truss fuselage frames may be constructed of aluminum alloy and may be riveted or bolted into one piece, with cross-bracing achieved by using solid rods or tubes.

### Monocoque Type

The monocoque (single shell) fuselage relies largely on the strength of the skin or covering to carry the primary loads. The design may be divided into two classes:

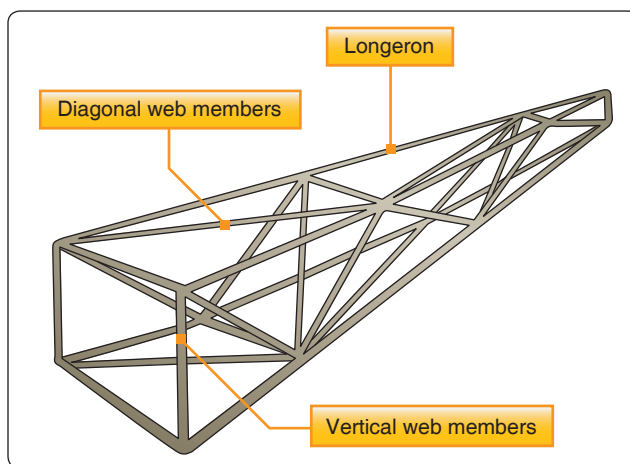
1. Monocoque
2. Semimonocoque

Different portions of the same fuselage may belong to either of the two classes, but most modern aircraft are considered to be of semimonocoque type construction.

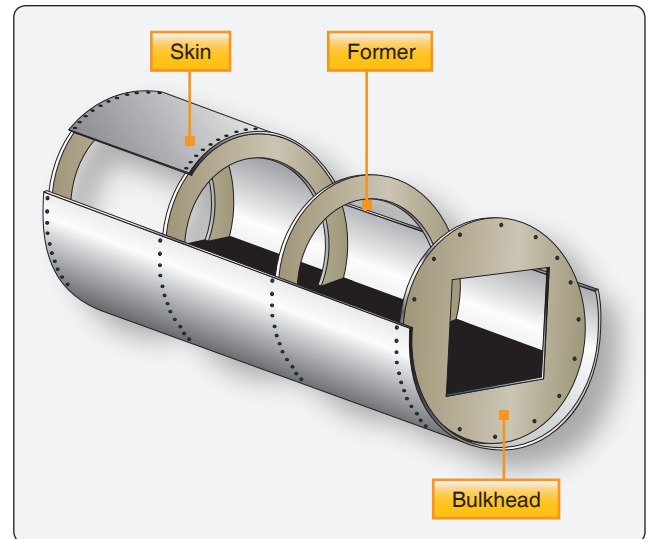
The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage. [Figure 1-16] The heaviest of these structural members are located at intervals to carry concentrated loads and at points where fittings are used to attach other units such as wings, powerplants, and stabilizers. Since no other bracing members are present, the skin must carry the primary stresses and keep the fuselage rigid. Thus, the biggest problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits.

### Semimonocoque Type

To overcome the strength/weight problem of monocoque construction, a modification called semimonocoque construction was developed. It also consists of frame assemblies, bulkheads, and formers as used in the monocoque design but, additionally, the skin is reinforced by longitudinal



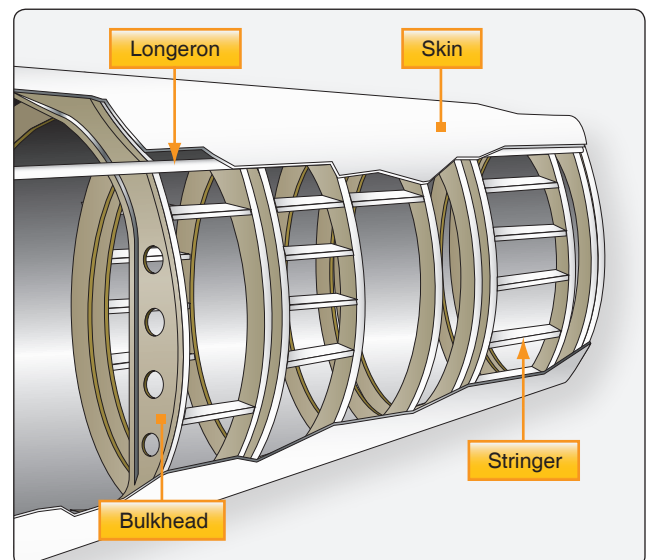
**Figure 1-15.** A truss-type fuselage. A Warren truss uses mostly diagonal bracing.



**Figure 1-16.** An airframe using monocoque construction.

members called longerons. Longerons usually extend across several frame members and help the skin support primary bending loads. They are typically made of aluminum alloy either of a single piece or a built-up construction.

Stringers are also used in the semimonocoque fuselage. These longitudinal members are typically more numerous and lighter in weight than the longerons. They come in a variety of shapes and are usually made from single piece aluminum alloy extrusions or formed aluminum. Stringers have some rigidity but are chiefly used for giving shape and for attachment of the skin. Stringers and longerons together prevent tension and compression from bending the fuselage. [Figure 1-17]



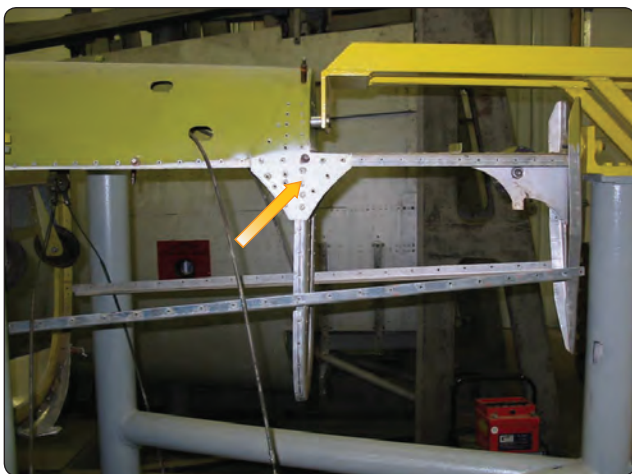
**Figure 1-17.** The most common airframe construction is semimonocoque.

Other bracing between the longerons and stringers can also be used. Often referred to as web members, these additional support pieces may be installed vertically or diagonally. It must be noted that manufacturers use different nomenclature to describe structural members. For example, there is often little difference between some rings, frames, and formers. One manufacturer may call the same type of brace a ring or a frame. Manufacturer instructions and specifications for a specific aircraft are the best guides.

The semimonocoque fuselage is constructed primarily of alloys of aluminum and magnesium, although steel and titanium are sometimes found in areas of high temperatures. Individually, not one of the aforementioned components is strong enough to carry the loads imposed during flight and landing. But, when combined, those components form a strong, rigid framework. This is accomplished with gussets, rivets, nuts and bolts, screws, and even friction stir welding. A gusset is a type of connection bracket that adds strength. [Figure 1-18]

To summarize, in semimonocoque fuselages, the strong, heavy longerons hold the bulkheads and formers, and these, in turn, hold the stringers, braces, web members, etc. All are designed to be attached together and to the skin to achieve the full-strength benefits of semimonocoque design. It is important to recognize that the metal skin or covering carries part of the load. The fuselage skin thickness can vary with the load carried and the stresses sustained at a particular location.

The advantages of the semimonocoque fuselage are many. The bulkheads, frames, stringers, and longerons facilitate the design and construction of a streamlined fuselage that is both rigid and strong. Spreading loads among these structures and the skin means no single piece is failure critical. This means that a semimonocoque fuselage, because of its stressed-skin construction, may withstand considerable damage and still be strong enough to hold together.



**Figure 1-18.** Gussets are used to increase strength.

Fuselages are generally constructed in two or more sections. On small aircraft, they are generally made in two or three sections, while larger aircraft may be made up of as many as six sections or more before being assembled.

## Pressurization

Many aircraft are pressurized. This means that air is pumped into the cabin after takeoff and a difference in pressure between the air inside the cabin and the air outside the cabin is established. This differential is regulated and maintained. In this manner, enough oxygen is made available for passengers to breathe normally and move around the cabin without special equipment at high altitudes.

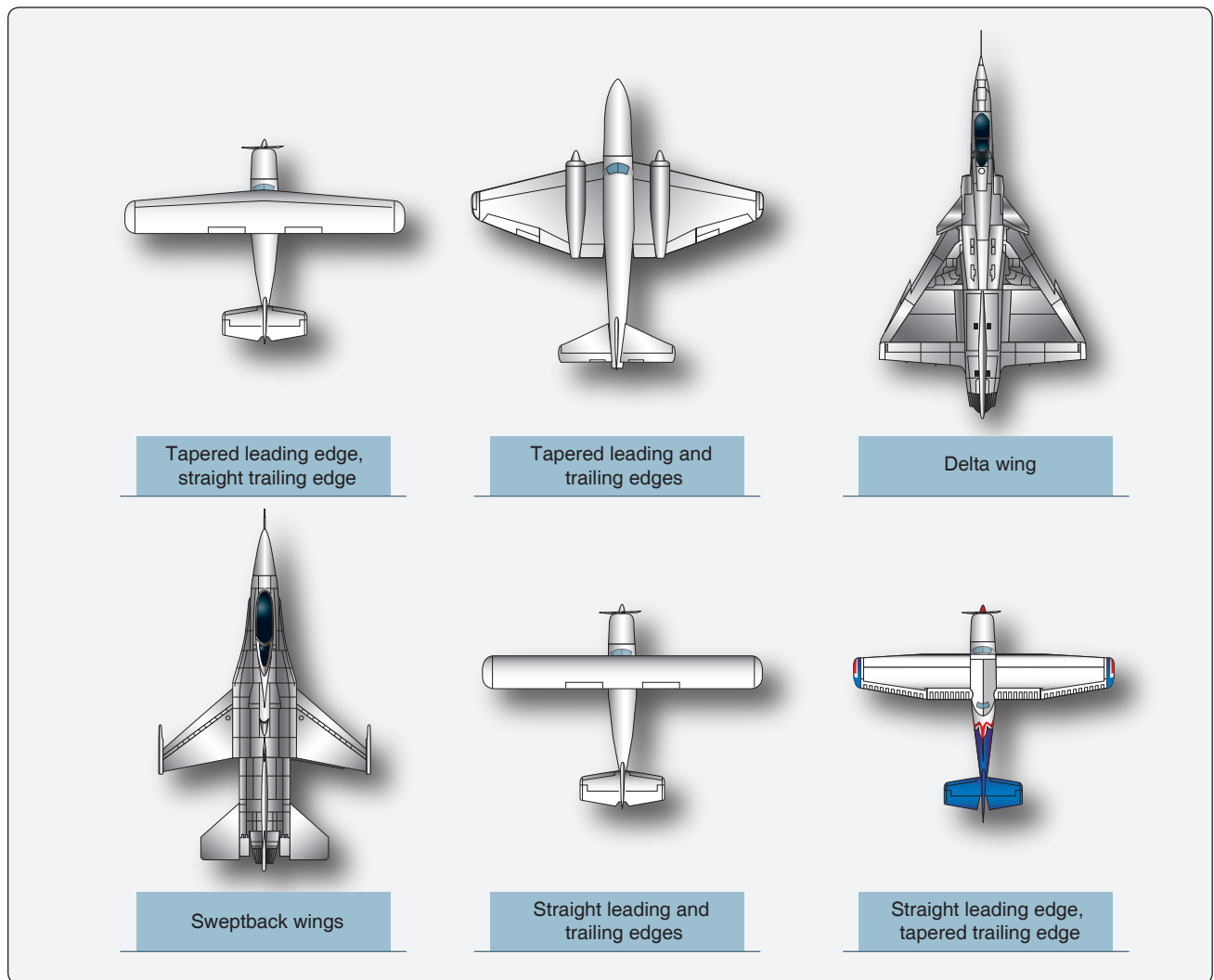
Pressurization causes significant stress on the fuselage structure and adds to the complexity of design. In addition to withstanding the difference in pressure between the air inside and outside the cabin, cycling from unpressurized to pressurized and back again each flight causes metal fatigue. To deal with these impacts and the other stresses of flight, nearly all pressurized aircraft are semimonocoque in design. Pressurized fuselage structures undergo extensive periodic inspections to ensure that any damage is discovered and repaired. Repeated weakness or failure in an area of structure may require that section of the fuselage be modified or redesigned.

## Wings

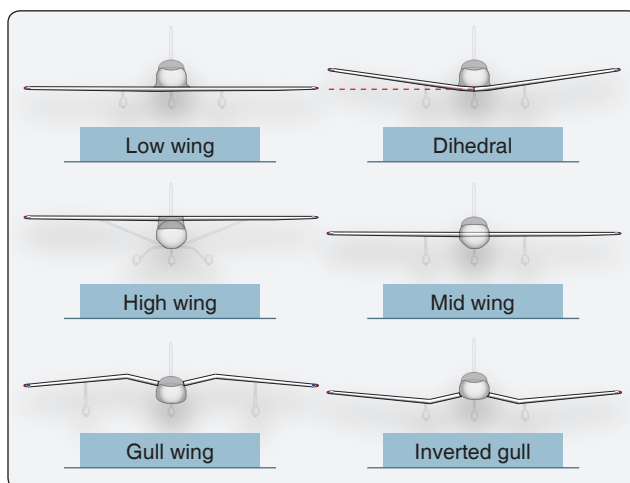
### Wing Configurations

Wings are airfoils that, when moved rapidly through the air, create lift. They are built in many shapes and sizes. Wing design can vary to provide certain desirable flight characteristics. Control at various operating speeds, the amount of lift generated, balance, and stability all change as the shape of the wing is altered. Both the leading edge and the trailing edge of the wing may be straight or curved, or one edge may be straight and the other curved. One or both edges may be tapered so that the wing is narrower at the tip than at the root where it joins the fuselage. The wing tip may be square, rounded, or even pointed. *Figure 1-19* shows a number of typical wing leading and trailing edge shapes.

The wings of an aircraft can be attached to the fuselage at the top, mid-fuselage, or at the bottom. They may extend perpendicular to the horizontal plane of the fuselage or can angle up or down slightly. This angle is known as the wing dihedral. The dihedral angle affects the lateral stability of the aircraft. *Figure 1-20* shows some common wing attach points and dihedral angle.



**Figure 1-19.** Various wing design shapes yield different performance.

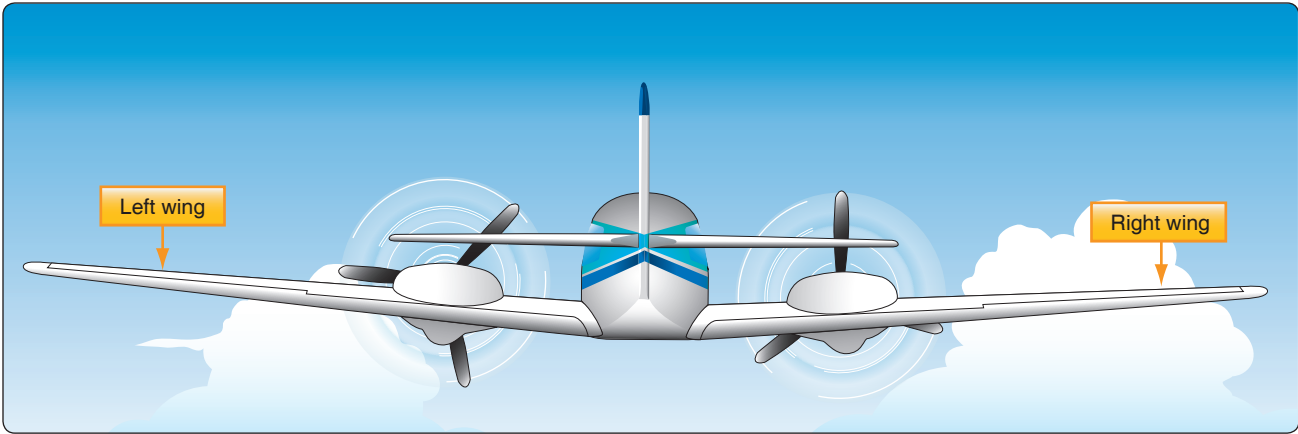


**Figure 1-20.** Wing attach points and wing dihedrals.

## Wing Structure

The wings of an aircraft are designed to lift it into the air. Their particular design for any given aircraft depends on a number of factors, such as size, weight, use of the aircraft, desired speed in flight and at landing, and desired rate of climb. The wings of aircraft are designated left and right, corresponding to the left and right sides of the operator when seated in the cockpit. [Figure 1-21]

Often wings are of full cantilever design. This means they are built so that no external bracing is needed. They are supported internally by structural members assisted by the skin of the aircraft. Other aircraft wings use external struts or wires to assist in supporting the wing and carrying the aerodynamic and landing loads. Wing support cables and struts are generally made from steel. Many struts and their



**Figure 1-21.** “Left” and “right” on an aircraft are oriented to the perspective of a pilot sitting in the cockpit.

attach fittings have fairings to reduce drag. Short, nearly vertical supports called jury struts are found on struts that attach to the wings a great distance from the fuselage. This serves to subdue strut movement and oscillation caused by the air flowing around the strut in flight. *Figure 1-22* shows samples of wings using external bracing, also known as semicantilever wings. Cantilever wings built with no external bracing are also shown.

Aluminum is the most common material from which to construct wings, but they can be wood covered with fabric, and occasionally a magnesium alloy has been used. Moreover, modern aircraft are tending toward lighter and stronger materials throughout the airframe and in wing construction. Wings made entirely of carbon fiber or other composite materials exist, as well as wings made of a combination of materials for maximum strength to weight performance.

The internal structures of most wings are made up of spars and stringers running spanwise and ribs and formers or

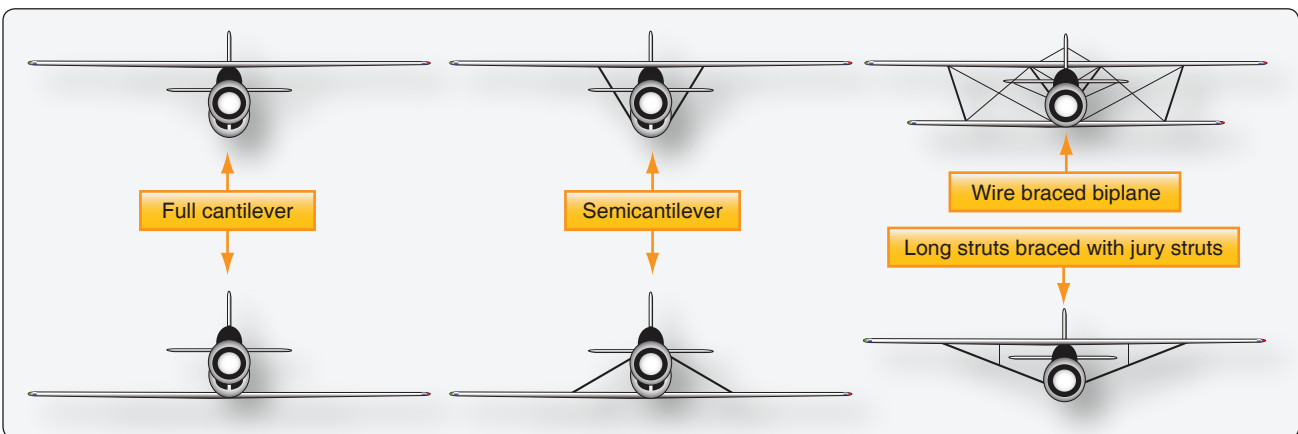
bulkheads running chordwise (leading edge to trailing edge). The spars are the principle structural members of a wing. They support all distributed loads, as well as concentrated weights such as the fuselage, landing gear, and engines. The skin, which is attached to the wing structure, carries part of the loads imposed during flight. It also transfers the stresses to the wing ribs. The ribs, in turn, transfer the loads to the wing spars. [*Figure 1-23*]

In general, wing construction is based on one of three fundamental designs:

1. Monospar
2. Multispar
3. Box beam

Modification of these basic designs may be adopted by various manufacturers.

The monospar wing incorporates only one main spanwise or longitudinal member in its construction. Ribs or bulkheads



**Figure 1-22.** Externally braced wings, also called semicantilever wings, have wires or struts to support the wing. Full cantilever wings have no external bracing and are supported internally.