

**Airplane Design Part III:
Layout Design of the Cockpit, Fuselage, Wing and Empennage: Cutaways and Inboard Profiles
Table of Contents**

TABLE OF SYMBOLS

ACKNOWLEDGEMENT

1. INTRODUCTION

2. COCKPIT (OR FLIGHT DECK) LAYOUT DESIGN

2.1 DIMENSIONS AND WEIGHTS FOR CREW MEMBERS

2.2 LAYOUT OF COCKPIT SEATING AND COCKPIT CONTROLS

2.2.1 Civil Cockpit Layouts

2.2.2 Military Cockpit Layouts

2.3 DETERMINATION OF VISIBILITY FROM THE COCKPIT

2.4 EXAMPLES OF COCKPIT LAYOUTS

3. FUSELAGE LAYOUT DESIGN

3.1 AERODYNAMIC DESIGN CONSIDERATIONS

3.1.1 Friction Drag

3.1.2 Profile and Base Drag

3.1.3 Compressibility Drag

3.1.4 Induced Drag

3.2 GUIDELINES FOR FLYING BOAT HULL AND FLOAT DESIGN

3.3 INTERIOR LAYOUT DESIGN OF THE FUSELAGE

3.3.1 Layout of the Cross Section

3.3.1.1 Passenger cabin

3.3.1.2 Cargo hold

3.3.1.3 Military

3.3.1.4 Supersonic airplanes

3.3.2 Seating Layouts, Seats and Restraint Systems

3.3.2.1 Seating arrangements and seats for general aviation airplanes

3.3.2.2 Seating arrangements and seats for transports

3.3.2.3 Restraint systems

3.3.3 Layout of Doors, Emergency Exits and Windows

3.3.3.1 General aviation airplanes

3.3.3.2 Transport airplanes

3.3.3.3 Military airplanes

3.3.4 Galley, Lavatory and Wardrobe Layouts

3.3.5 Layout of Cargo/Baggage Holds Including Data on Cargo Containers and Pallets

3.3.5.1 Cargo and baggage volume requirements

3.3.5.2 Data on standard containers and pallets

3.3.5.3 Typical loading/unloading configurations

3.3.6 Inspection¹ Maintenance and Servicing Considerations

3.4 DESIGN DATA FOR FUSELAGE CROSS SECTIONS, CABIN AND CARGO HOLD LAYOUTS, WINDOW AND DOOR LAYOUTS

3.5 STRUCTURAL DESIGN CONSIDERATIONS AND EXAMPLES OF STRUCTURAL LAYOUT DESIGN OF FUSELAGES

3.5.1 Typical Frame Depths¹ Frame Spacings and Longeron Spacings

3.5.2 Examples of Fuselage Structural Arrangements

3.5.3 Examples of Fuselage Shell Layout

3.5.4 Examples of Door and Stair Design

3.5.5 Examples of Cockpit and Cabin Window Design

3.5.6 Examples of Floor Design

3.6 EXAMPLES OF INBOARD PROFILES

4. WING LAYOUT DESIGN

4.1 WING CONFIGURATION: AERODYNAMIC AND OPERATIONAL DESIGN CONSIDERATIONS

4.1.1 Wing Size: Large or Small? Or, Wing Loading: Low or High?

4.1.2 High, Mid or Low Wing?

4.1.3 Forward Sweep, No Sweep or Aft Sweep?

4.1.4 Variable Sweep: One Pivot or Two?

**Airplane Design Part III:
Layout Design of the Cockpit, Fuselage, Wing and Empennage: Cutaways and Inboard Profiles
Table of Contents**

- 4.1.5 Bi-plane, Braced Wing or Joined Wing?
- 4.1.6 Wing Aspect Ratio: High, Low and/or Winglets?
- 4.1.7 Wing Thickness Ratio: Large or Small?
- 4.1.8 Wing Taper Ratio: Large or Small?
- 4.1.9 Straight Taper or Variable Taper?
- 4.1.10 Twist: How Much?
- 4.1.11 Wing Dihedral: How Much?
- 4.1.12 Wing Incidence on the Fuselage: How Much?
- 4.1.13 Variable Camber (MAW = Mission Adaptive Wing)?
- 4.1.14 Leading Edge Strakes (Lexes)
- 4.1.15 Planform Tailoring: Why and How?
- 4.1.16 Area Ruling: When is it Required?
- 4.1.17 Wing Span: When is it Too Large?
- 4.1.18 Aerodynamic Coupling
- 4.1.19 Flaps: What Size and Which Type?
- 4.1.20 Lateral Controls: Type, Size and Location?
- 4.1.21 Review of Wing Drag Contributions
- 4.2 STRUCTURAL DESIGN CONSIDERATIONS AND EXAMPLES OF STRUCTURAL LAYOUT DESIGN
 - 4.2.1 Typical Spar, Rib and Stiffener Spacings
 - 4.2.2 Examples of Wing Structural Arrangements
 - 4.2.3 Examples of Wing/Fuselage Integration
 - 4.2.4 Examples of Wing Cross Section Design
 - 4.2.5 Examples of Lateral Control Mechanizations
 - 4.2.6 Examples of High Lift Device Mechanizations
 - 4.2.7 Examples of Wing Skin Gages
 - 4.2.8 Maintenance and Access Requirements
- 4.3 MILITARY DESIGN CONSIDERATIONS
- 4.4 DETAILED OVERALL STRUCTURAL ARRANGEMENTS
- 5. EMPENNAGE LAYOUT DESIGN
 - 5.1 EMPENNAGE CONFIGURATION: AERODYNAMIC AND OPERATIONAL DESIGN CONSIDERATIONS
 - 5.1.1 Conventional (Tails Aft), Canard or Three-surface?
 - 5.1.2 Additional Empennage Configuration Choices
 - 5.1.3 Empennage Size: Stability, Control and Handling Considerations
 - 5.1.3.1 Longitudinal considerations
 - 5.1.3.2 Lateral-Directional considerations
 - 5.1.4 Stall and Spin Characteristics
 - 5.1.5 Empennage Planform Design
 - 5.1.6 Empennage Airfoil Design or Selection
 - 5.1.7 Review of Empennage Drag Contributions
 - 5.2 STRUCTURAL AND INTEGRATION DESIGN CONSIDERATIONS FOR THE EMPENNAGE
 - 5.2.1 Typical Spar, Rib and Stiffener Spacings
 - 5.2.2 Examples of Empennage Structural Arrangements
 - 5.2.3 Examples of Fuselage/Empennage Integration and/or Vertical/Horizontal Tail Integration
 - 5.2.4 Examples of Empennage Cross Section Design
 - 5.2.5 Examples of Longitudinal Control Mechanizations
 - 5.2.6 Examples of Directional Control Mechanizations
 - 5.2.7 Examples of Empennage Skin Gages
 - 5.2.8 Maintenance and Access Requirements
- 6. INTEGRATION OF THE PROPULSION SYSTEM
 - 6.1 PRESENTATION OF ENGINE AND PROPELLER DATA
 - 6.1.1 Propellers
 - 6.1.2 Piston Engines
 - 6.1.3 Turbopropeller Engines
 - 6.1.4 Turbojet and Turbofan Engines

**Airplane Design Part III:
Layout Design of the Cockpit, Fuselage, Wing and Empennage: Cutaways and Inboard Profiles
Table of Contents**

- 6.1.5 Propfan Engines
- 6.2 RELATION BETWEEN FLIGHT ENVELOPE AND ENGINE TYPE
- 6.3 INSTALLED THRUST, POWER AND EFFICIENCY CONSIDERATIONS
 - 6.3.1 Power Extraction
 - 6.3.2 Propeller Installations
 - 6.3.3 Piston-Engine Installations
 - 6.3.4 Subsonic and Supersonic Turbojet and Turbofan Installations
- 6.4 STABILITY AND CONTROL CONSIDERATIONS
 - 6.4.1 Effect of One or More Engines Inoperative and Effects of Power Transients
 - 6.4.2 Tractor Versus Pusher
 - 6.4.3 Effect of Engine/Propeller Thrust Line Location and Inclination
- 6.5 STRUCTURAL CONSIDERATIONS
 - 6.5.1 Transmission of Thrust into the Airframe
 - 6.5.2 Lateral Disposition of Engines over the Wing
 - 6.5.3 Extension Shafts and Propeller Blade Excitation
 - 6.5.4 Flutter
- 6.6 MAINTENANCE AND ACCESSIBILITY CONSIDERATIONS
- 6.7 SAFETY CONSIDERATIONS
 - 6.7.1 Installation Safety
 - 6.7.2 Safety During Ground Operation
 - 6.7.3 Foreign Object Damage (FOD)
 - 6.7.4 Engine Reliability and Shutdown Rates
- 6.8 NOISE CONSIDERATIONS
 - 6.8.1 Interior Noise Design Considerations
 - 6.8.2 Exterior Noise Design Considerations
- 6.9 EXAMPLE ENGINE INSTALLATIONS
 - 6.9.1 Piston-Propeller Installations
 - 6.9.2 Turbo-Propeller Installations
 - 6.9.3 Turbojet and Turbofan Installations
 - 6.9.4 Propfan and Ultra-Bypass Installations
 - 6.9.5 Nozzles and Thrust Reversers
- 7. PRELIMINARY STRUCTURAL ARRANGEMENT, MATERIAL SELECTION AND MANUFACTURING BREAKDOWN
 - 7.1 PREPARING A PRELIMINARY STRUCTURAL ARRANGEMENT
 - 7.2 PRELIMINARY SELECTION OF STRUCTURAL MATERIALS
 - 7.3 PRELIMINARY SELECTION OF MANUFACTURING BREAKDOWN
- 8. COLLECTION OF CUTAWAY DRAWINGS
- 9. REFERENCES
- 10. INDEX