# Aircraft Design
# Historical Parameters

# Aircraft Design Process

**Seven Intellectual Pivot Points**

1. **Requirements** ✓
2. **First estimate of aircraft weight** ✓
3. **Critical performance parameters**
4. **Configuration layout**
5. **Better weight estimate**
6. **Performance analysis**
   **Does it meet the requirements?**
7. **Optimization**
   **Is it the best design?**

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# Aircraft Design Process

**Seven Intellectual Pivot Points**

**3. Critical performance parameters**

- **Maximum Lift Coefficient ($C_{L_{max}}$)**
- **Lift-to-Drag Ratio (L/D)**
- **Wing Loading (W/S)**
- **Thrust-to-Weight Ratio (T/W)**

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# Aircraft Design Process

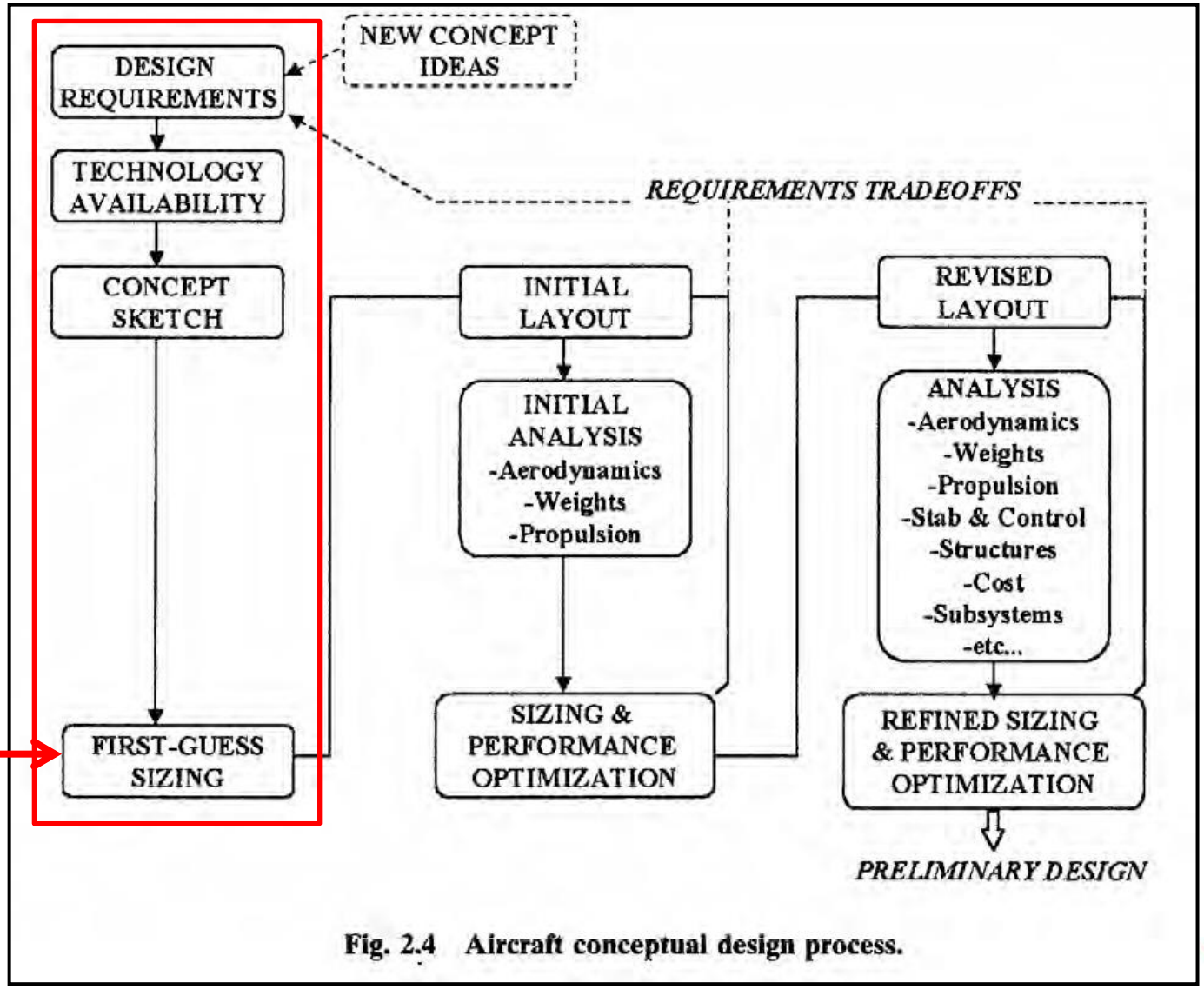


Fig. 2.4 Aircraft conceptual design process.

**Historical Parameters**

*"Aircraft Design: A Conceptual Approach"* by Daniel P. Raymer, page 9

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# Historical Wing Loading

| | $(W/S)_{TO}$ |
|---|---|
| Long Range | **110 - 130** |
| Short/Medium Range | **80 - 110** |
| Short Takeoff & Landing | **40 - 90** |
| Light Civil | **10 - 30** |
| Combat Fighter | **40 - 70** |
| Combat Intercept | **120 - 150** |
| High Altitude | **30 - 60** |

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# Historical Thrust / Weight

| | $(T/W)_{TO}$ |
|---|---|
| Long Range | **0.20 – 0.35** |
| Short/Medium Range | **0.30 – 0.45** |
| Short Takeoff & Landing | **0.40 – 0.60** |
| Light Civil | **0.25 – 0.34** |
| Combat Fighter | **0.60 – 1.30** |

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# Historical $(L / D)_{max}$

| | $(L/D)_{max}$ Range | Average $(L/D)_{max}$ |
|---|---|---|
| Propeller Personal / Utility | **9.6 – 14.2** | **12.1** |
| Commercial Propeller Transport | **13.8 – 18.5** | **16.3** |
| Business Jet | **13.0 – 15.6** | **14.3** |
| Commercial Jet Transport | **15.0 – 18.2** | **14.4** |
| Military Transport / Bomber | **17.5 – 20.5** | **18.9** |
| Military Fighter | **9.2 – 13.9** | **11.0** |

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# Historical Aspect Ratio

| | Aspect Ratio |
|---|---|
| Personal | **5.0 – 8.0** |
| Commuter | **9.0 – 12.0** |
| Regional Turboprops | **11.0 – 12.8** |
| Business Jets | **5.0 – 8.8** |
| Jet Transports | **7.0 – 9.5** |
| Military Fighter / Attack | **2.4 – 5.0** |

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# Historical Subsonic $C_{f_e}$

| | $C_{fe}$ - subsonic |
|---|---|
| Bomber and Civil Transport | **0.0030** |
| Military Cargo | **0.0035** |
| Air Force Fighter | **0.0035** |
| Navy Fighter | **0.0040** |
| Clean Supersonic Cruise | **0.0025** |
| Light Aircraft – Single Engine | **0.0055** |
| Light Aircraft – Twin Engine | **0.0045** |

$$C_{D_0} = \frac{S_{wet}}{S_{ref}} C_{f_e} \qquad k = \frac{1}{\pi AR e}$$

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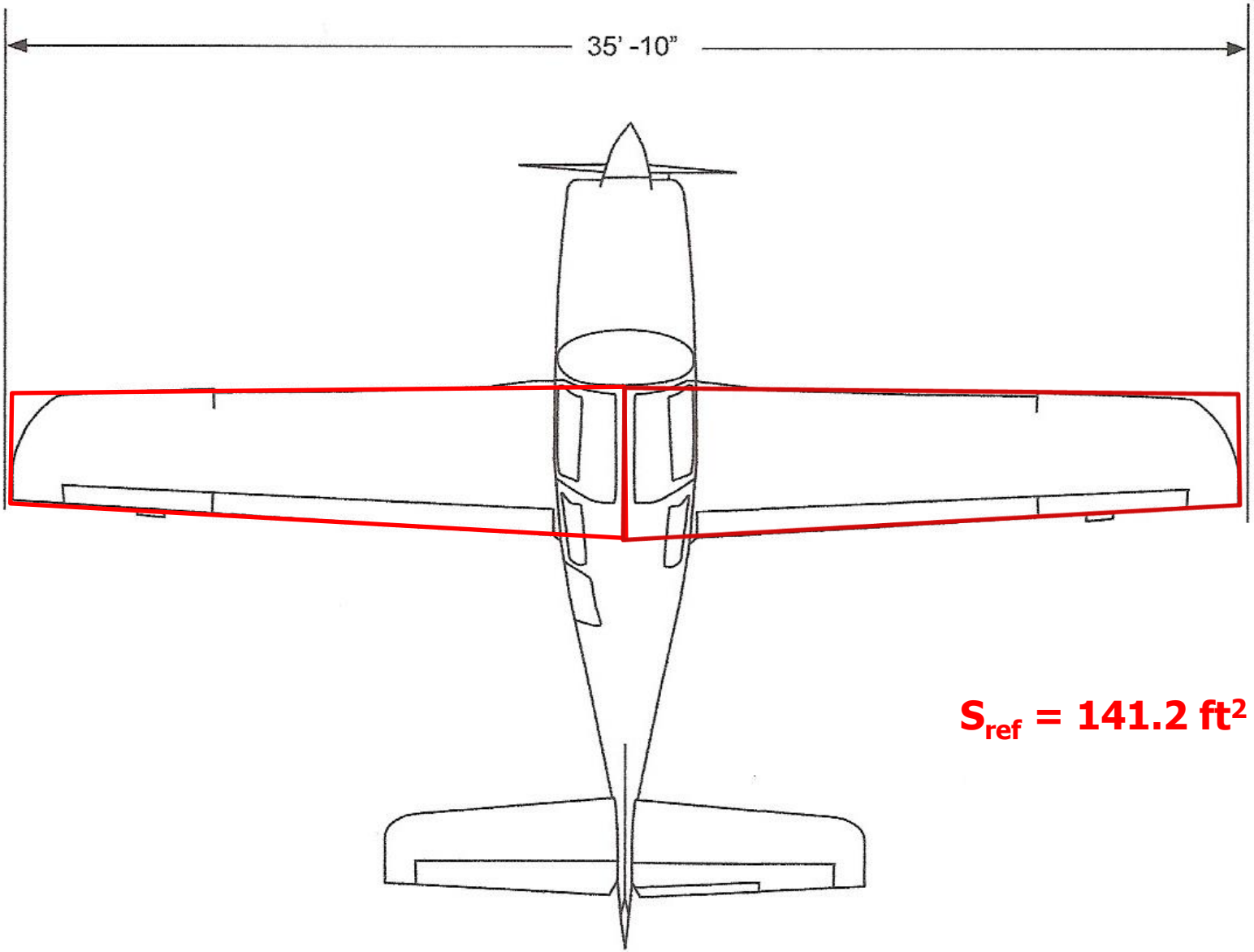
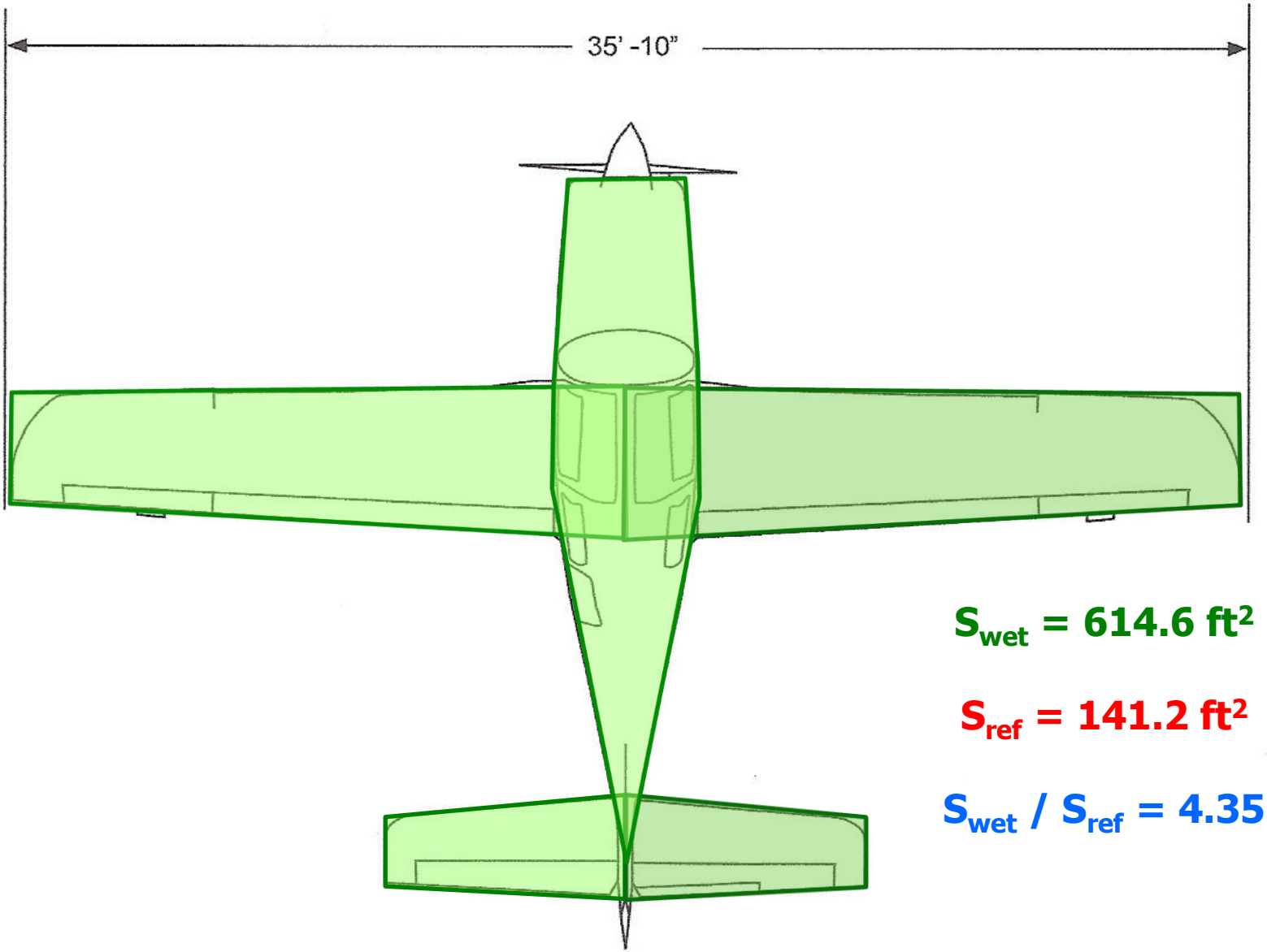
# What is $S_{wet} / S_{ref}$ ?




$S_{ref} = 141.2\ ft^2$

# What is $S_{wet} / S_{ref}$ ?




$S_{wet} = 614.6\ ft^2$

$S_{ref} = 141.2\ ft^2$

$S_{wet} / S_{ref} = 4.35$

# Historical $S_{wet} / S_{ref}$

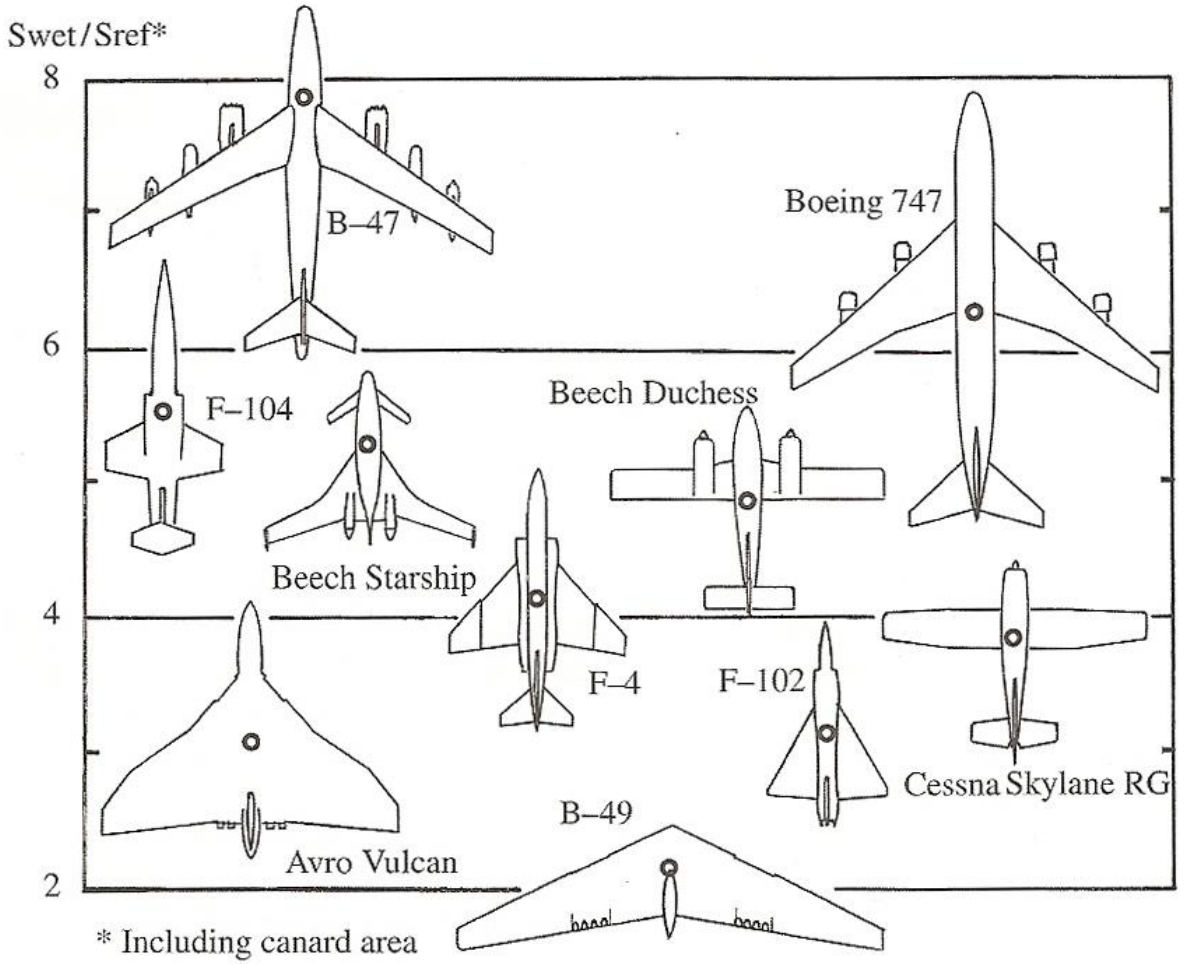
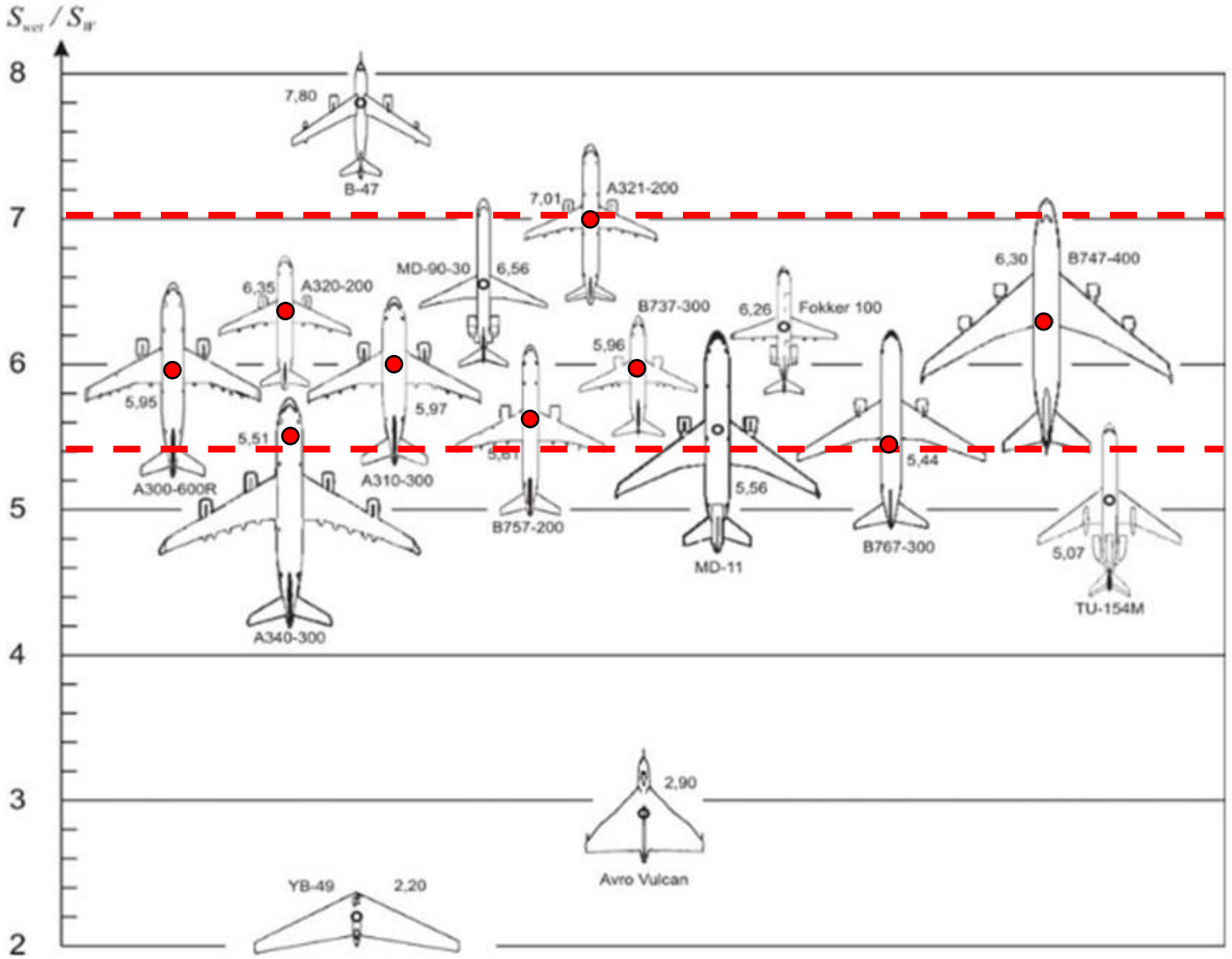



**Fig. 3.5 Wetted area ratios.**

# Historical $S_{wet} / S_{ref}$



# Historical $C_{L_{max}}$

| | $(C_{Lmax})_{TO}$ |
|---|---|
| Long Range | **1.6 – 2.2** |
| Short/Medium Range | **1.6 – 2.2** |
| Short Takeoff & Landing | **3.0 – 7.0** |
| Light Civil | **1.2 – 1.8** |
| Combat Fighter | **1.4 – 2.0** |

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# Aircraft Design Process

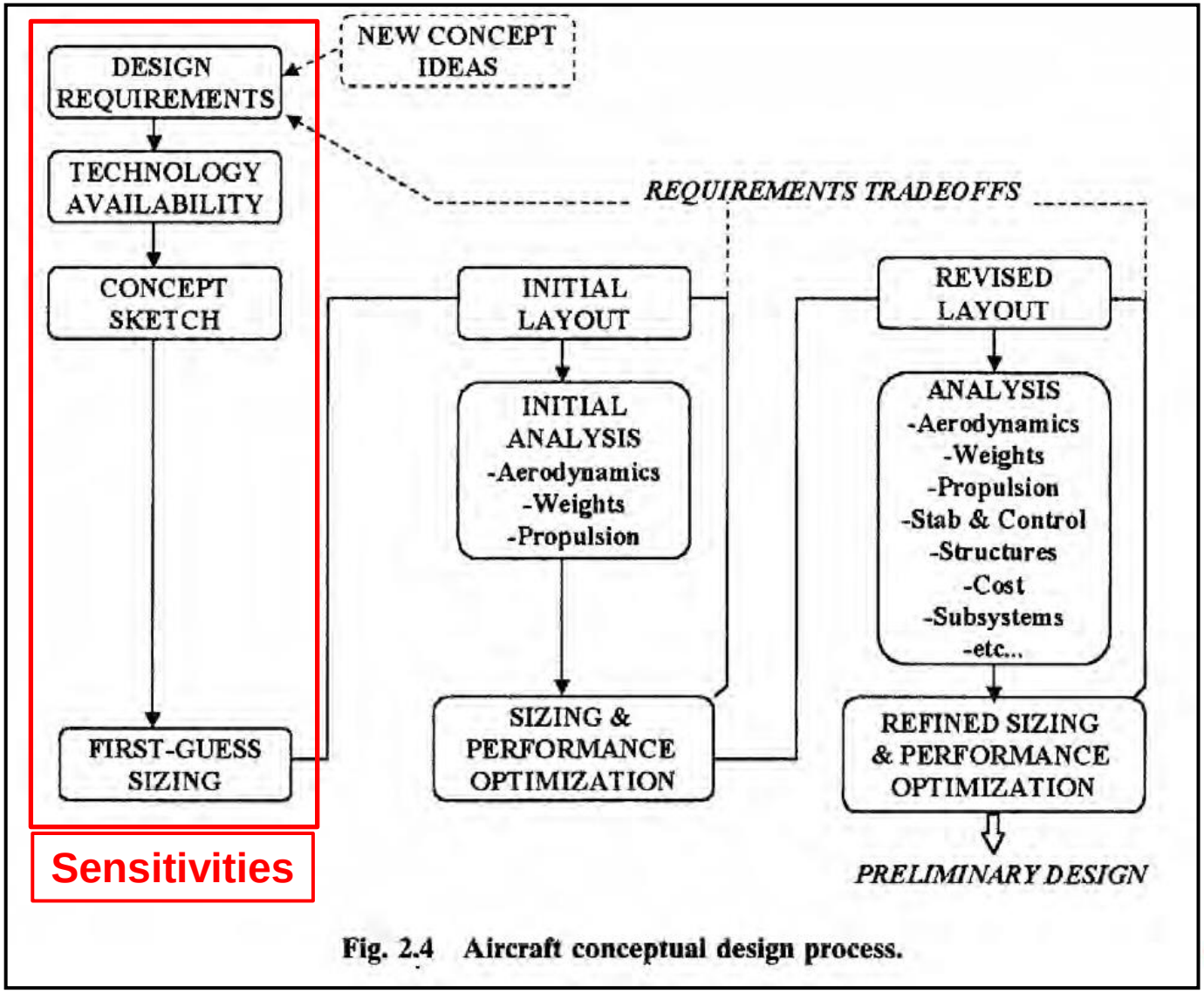


Fig. 2.4 Aircraft conceptual design process.

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# HW #20 - Design Sensitivities

**Now that you have a working "model" of a particular aircraft:**

**What happens if you change the input parameters slightly?**

**Which parameters are most affected by these changes?**

| Sensitivities to Perform | | Affected Parameters |
|---|---|---|
| Cruise Mach number | ± 0.02 Mach | Takeoff Weight |
| Operational Radius | ± 10% | Fuel Weight |
| Aspect Ratio | ± 10% | Empty Weight |
| Reserves Loiter Time | ± 15 minutes | |
| Structure Factor | ± 10% | |
| Payload | ± 10% | |
| TSFC | ± 10% | |

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# HW #20 - Design Sensitivities

| Cruise Mach Number | -0.02 Mach | Baseline | +0.02 Mach |
|---|---|---|---|
| Value | 0.80 | 0.82 | 0.84 |
| Δ Takeoff Weight | | 0 | |
| Δ Fuel Weight | | 0 | |
| Δ Empty Weight | | 0 | |
| | | | |
| **Operational Radius (NM)** | **-10% Radius** | **Baseline** | **+10% Radius** |
| Value | 3,600 | 4,000 | 4,400 |
| Δ Takeoff Weight | | 0 | |
| Δ Fuel Weight | | 0 | |
| Δ Empty Weight | | 0 | |

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# HW #20 - Design Sensitivities

| Cruise Mach Number | -0.02 Mach | Baseline | +0.02 Mach |
|---|---|---|---|
| Value | 0.80 | 0.82 | 0.84 |
| Δ Takeoff Weight | +6,000 | 0 | -5,500 |
| Δ Fuel Weight | +3,500 | 0 | -2,900 |
| Δ Empty Weight | +2,500 | 0 | -2,600 |
| | | | |
| **Operational Radius (NM)** | **-10% Radius** | **Baseline** | **+10% Radius** |
| Value | 3,600 | 4,000 | 4,400 |
| Δ Takeoff Weight | -25,000 | 0 | +29,000 |
| Δ Fuel Weight | -13,000 | 0 | +15,000 |
| Δ Empty Weight | -12,000 | 0 | +14,000 |

**Δ Weight = Sensitivity Weight – Baseline Weight**

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# *Homework Assignment*

**HW #20 – Aircraft Design - Sensitivities (due by 11:59 pm ET on Monday)**

**<u>HW Help Session</u>**
**Monday 4:00 – 5:00 pm ET**

**<u>Posted on Canvas</u>**
**HW #20 Assignment with instructions, tips, and checklist**
**HW #20 Template for data table in Excel**

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# Questions?

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