**Figure:** Considerations for system specifications (from [2]).
Determining system requirements involves comprehensive, system-wide analysis. The main components or sub-systems are illustrated below.

Figure 1.1 UAV system – functional structure
Requirements

The definition of requirements for the design.

Challenges

- From the previous diagram, one it is apparent that one of the difficulty is due to the system of systems.
- Sub-systems are interacting and therefore typically cannot be specified independently of the other components.
- Balancing capability and cost
- Make sure the requirements are feasible!
- Too narrow vs. too broad
Design Synthesis

Ingredients to design problem

- Objective function: dimension that is optimized.
- Constraints: define acceptable design (from design rules or requirements).
- Design variables: parameters that are modified.

System Performance Metrics

Examples of performance metrics include:

1. Total endurance
2. Maximum radius of operation
3. Time to target
4. Area coverage rate
5. Mission availability
6. Payload capacity
7. Sensory performance
8. Number of personal required for operation
## Airframe Sizing and Characteristics

| Geometry                  | • General configuration  
  |                          | • Geometry rules (tail volume coefficient)  
  |                          | • Packaging constraints (transportation modes, storage box dimensions)  
| Mass properties           | • Avionics and communication systems size, weight and power (SWAP)  
  |                          | • Payload SWAP  
| Systems                   | • Subsystem configurations (electrical power system, environmental control system, hydraulics and pneumatics)  
| Propulsion                | • Propulsion type  
  |                          | • Specific engine (if known)  
| Performance               | • Mission profile  
  |                          | • Field performance requirements  
| Aerodynamics              | • Airfoil families  
  |                          | • High lift device arrangement  
  |                          | • Laminar flow rules (i.e., all turbulent assumption or free transition)  
| Launch and recovery       | • Launch and recovery techniques  
  |                          | • Required launch and recovery performance  
| Structures                | • Materials type and general structural arrangement  
  |                          | • Load cases of interest  
| Mission effectiveness     | • Sensor field-of-regard requirements  
  |                          | • Survivability features and requirements  

**Figure:** Design information (from [2])
**Design Variables**

Focus on the variables that have the greatest design impact.

| Geometry                               | • Span, wing area, aspect ratio, or root chord (any two)  
|                                       | • Taper distribution  
|                                       | • Semispan locations of taper changes  
|                                       | • Sweep angles (leading edge, quarter-chord, trailing edge, or other $x/c$)  
|                                       | • Fuselage length  
|                                       | • Fuselage shaping (fineness ratio, distribution of upper surface, lower surface, sides, and cross-section shaping parameters)  
| Mass properties                        | • Fuel weight or fuel mass fraction  
| Propulsion                              | • Thrust or power (sea level uninstalled)  
|                                        | • Thrust-to-weight or power-to-weight ratios  
|                                        | • Propeller diameter  

**Figure:** Design variables (from [2])
**Design Space and Constraints**

It is also important to delineate the design space.

<table>
<thead>
<tr>
<th>Performance constraints</th>
<th>• Stall speed or minimum airspeed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Climb gradients or climb angles (engine out)</td>
</tr>
<tr>
<td></td>
<td>• Rate of climb</td>
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<td></td>
<td>• Dynamic pressure limits</td>
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<td></td>
<td>• Mach limits</td>
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<td></td>
<td>• Balanced field length</td>
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<td></td>
<td>• Landing field length</td>
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<tr>
<td></td>
<td>• Service ceiling</td>
</tr>
<tr>
<td></td>
<td>• Mission profile satisfaction (climb, range, endurance segments)</td>
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<tr>
<td>Weight constraints</td>
<td>• Maximum weight (landing weight, takeoff gross weight)</td>
</tr>
<tr>
<td></td>
<td>• Weight convergence</td>
</tr>
<tr>
<td>Geometric constraints</td>
<td>• Maximum dimension (i.e., MAV must have less than 6-in. maximum dimension)</td>
</tr>
<tr>
<td></td>
<td>• Storage/transportation box constraints</td>
</tr>
<tr>
<td></td>
<td>• Folding geometry for airborne deployment or storage</td>
</tr>
<tr>
<td></td>
<td>• Field-of-regard requirements for payloads and communications systems—line-of-sight blockage</td>
</tr>
<tr>
<td></td>
<td>• Landing-gear geometric constraints (tip-back)</td>
</tr>
<tr>
<td>Structures</td>
<td>• Tip deflections</td>
</tr>
<tr>
<td></td>
<td>• Aeroelastic constraints (flutter, divergence, aileron reversal)</td>
</tr>
<tr>
<td></td>
<td>• Special load case satisfaction (i.e., tool dropped on skin without damage)</td>
</tr>
<tr>
<td>Systems</td>
<td>• Fuel volume required must not exceed the available fuel volume.</td>
</tr>
<tr>
<td></td>
<td>• Avionics and payload power requirements must not exceed available power.</td>
</tr>
<tr>
<td></td>
<td>• Avionics and payload must be cooled.</td>
</tr>
</tbody>
</table>
Design Optimization

The detailed design process requires iterative approach.

Fig. 18.2 UA sizing approach.
References

- Chapter 18, System Synthesis and Mission Effectiveness [2].
- Chapter 1-16, Unmanned Aircraft Systems [1]

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