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MALE UAV Resource Management

Abstract: This paper uses resource management which is one of NASA system engineering processes. It presents a system approaches to weight budget resource management during early design of new complex vehicles. The hierarchical decomposition of the system is used in weight budget management, followed by top-down allocation of weight budgets to subsystems and components. Weight savings affects directly on the cost of the system. MALE UAV example will be utilized to illustrate the method.
Keywords: MALE UAV, Resource Management, Weight Budget

1. Introduction

A project resource is a physical being, such as weight, and size, which is often restricted or controlled. Technical resources related to the resources that are used by the technical design to realize the mission, such as weight and size. Cost and schedule are not considered a technical resource.

During designing a system with controlled technical resources, resources must be properly assigned to the subsystems, devices and components that finallydevelop the larger system for which the resource restriction is taken in consideration.

At first, the resource allocation starts with current best estimates (CBE)(The current best estimate may be defined as a proper estimation of the predictable value of a certain value not including any margins – especially security margins – depending on actual information which are available) or engineering estimates, for each respective subsystem of a system.The future projection of the resource is made to take into consideration the expected growth as the design develops.This value is considered the maximum expected estimate of the resource and it is assigned to the subsystem. Therefore, a subsystem design team delivers the CBE based on everything that can be presently accounted for, but the team demands an allocation of the resource as the design is not estimated to exceed this maximum expected value.

Therefore, at any point in the project life cycle, there is a maximum possible, maximum expected and current best estimate for every technical resource. In general, the current best estimate of a resource changes as the development team improves the design, but the allocated amount would not change unless aspects of the system design requires a re-allocation of the resource.[1]

Margin is the difference between the maximum possible value of a resource and the maximum expected value of a resource. Normally margin is held at the system level, but if necessary, it could be assigned to subsystems.Margin is usually achieved by the systems engineering chief as part of the project level design process.

Margins account for unplanned growth as:

- System development challenge
- Projects face "unknown unknowns"
  - Difficult to evaluate using of new technology
  - Uncertainties in executing the design
  - Variations in manufacturing

Percent margin for a resource is the margin divided by the maximum possible value minus the margin.

$$\% \text{ margin} = \frac{\text{margin}}{\text{max possible value - margin}} \times 100$$

Contingency is the current best estimate minus the maximum expected valueof a resource. A contingency is alwaysapplied at the subsystem level and the amount of contingency is based on the development of the design and so after that the project life cycle.

Contingency accounts for planned growthas:

- Weight growth is historically expected.
- As systems mature through their development life cycle
  - Better known design => from conceptual to actual
  - Fix to a test failure, or change of a seller
  - Change in requirements often increases resource use

Percent contingency is the planned value of the contingency divided by the differencebetween the maximum expected value of the resource and the contingency.

$$\% \text{ contingency} = \frac{\text{contingency}}{\text{max expected value} - \text{contingency}} \times 100$$

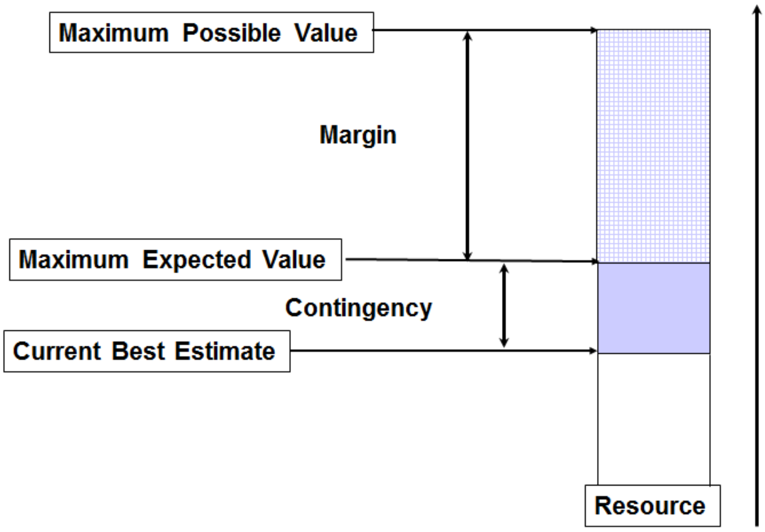

Figure 0-1 Margin and contingency with respect to any resource constraint

As the project develops, the estimate of any technical resource usually increases. Historically,this is true and, independent of precisely why, designers of the project must plan for it to take place.

2. Case study: Weight budget for MALE UAV

For all MALE UAV, weight is an essential technical resource to monitor. Other typical MALE UAV resources include for example volume, power, data rate, thrust, and data storage. Resources can be very dynamic and require much more analysis and management to ensure a successful mission.

Appropriate weight margins between a conceptual design and the final delivered product can range from 5–10%. Long-endurance UA have a relatively high fuel weight fraction, perhaps reaching 20–30% of the takeoff gross weight.[2]

Weights are typically defined in categories such as

W0 = We + Wpay + Wf + Wmisc Equation 1

Where W0 = Gross weight ≈ Takeoff weight

We = Empty weight

Wpay = Payload weight

Wf = Fuel weight

Wmisc = Other weights (trapped fuel, oil, pylons, special mission, equipment, etc.)

Empty weight is also defined in categories such as:

We = Waf + Wlg + Weng + Wfe + Wos Equation 02

Waf = Airframe (structure) weight

Wlg = Landing gear weight

Weng = Propulsion system weight

Wfe = Fixed equipment weight (avionics, etc)

Wos = Other systems

Another commonly used form of weight parametric.

From Equation 6.1

We/W0 + Wpay/W0 + Wf/W0 + Wmisc/W0 = 1 Equation 3

Where by definition

We/W0 = Empty Weight Fraction (EWF)
Wpay/W0 = Payload Weight Fraction (PWF)
Wf/W0 = Fuel Weight Fraction (FWF)
Wmisc/W0 = Misc. Weight Fraction (MWF)

There is a similar form of Equation 2

EWF = Waf/W0 + Wlg/W0 + Weng/W0 + Wfe/W0 Equation 4

Waf/W0 = Airframe (structure) weight fraction
Wlg/W0 = Landing gear weight fraction
Weng/W0 = Propulsion system weight fraction
Wfe/W0 = Fixed equipment weight fraction (avionics, etc.)

Empty weight fraction, payload weight fraction and fuel weight fraction are key design parameters. They vary widely with design mission and vehicle class(Range and/or endurance, speed, maneuver, payload and technology level).

In our case, for a MALE UAV we will estimate weight fractions following:

- Empty weight fraction ranges from 0.44 to 0.48
- Airframe (structure) weight fraction ranges from 0.26 to 0.28
- Landing gear weight fraction ranges from 0.03 to 0.05
- Propulsion system weight fraction ranges from 0.04 to 0.05
- Fixed equipment weight fraction ranges from 0.1 to 0.2
- Payload weight fraction ranges from 0.36 to 0.38
- Fuel weight fraction ranges from 0.20 to 0.30
- A typical value of the miscellaneous weight fraction would be 0.02

Often the result from most conceptual sizing procedures start with an assumed empty weight, fuel or payload weight fractions is a significant difference between initial size estimates and subsequent ones.

Each of estimating weights is influenced by some of design drivers, e.g.

- Payload weights are defined by mission requirements
- Fuel fraction is determined by mission requirements and aero-propulsion performance
- Airframe weight is influenced by the weight of wing, fuselage, and tail.
- Landing gear is driven by maximum vehicle weight (W0)
- Engine weight is driven required air vehicle thrust-to-weight (TO/W0), etc.

Drag reduction or engine fuel consumption improvements can impact required fuel weight and can therefore impact design gross weight just as much as the elements comprising the empty weight.

We will illustrate some examples for contingencies and their reasons for MALE UAV in table 1.[2]

Table 1 Contingencies and their reasons for MALE UAV

Systems	**Contingency (%)**	**Reason**
Wing group	6.9%	New finite element model results
Fuselage group	2.0%	Front bulkhead material change
Nacelle group	40.9%	Engine mount configuration change
Landing gear group	6.9%	Larger tire size
Structure total	6.0%	
Engines	4.0%	Rear bearing change
Air induction system	15.2%	Change from composite to metal
Fuel system	–8.5%	One fuel pump eliminated
Propulsion system	9.2%	A new vibration isolation mounts
Power plant total	0.9%	
Avionics and instrumentation	5.3%	GPS antenna change to SAASM
Flight control system	10.1%	Changed actuator vendor
Electrical system	14.4%	Changed from NiCd to LiPo batteries
Paint	51.2%	Customer specified paint change
Fixed equipment total	–0.9%	

3. Conclusions

Weight management is critical for MALE UAV design, because vehicle performance depends strongly on dry mass. Also, Weight management affects on the total cost of development and operations. All contingency guidelines supposean average level of uncertainty; adjust upward for items with higher uncertainty, and adjust downward for items with lower uncertainty.In order not to over-budget, contingency may be applied individually to portions of the system and then summed to define the system contingency.Increased dollar contingency may be used to offset lower contingency in other areas, e.g., technical performance or unknown development schedules.

Reference

[1]. S. NASA, "NASA systems engineering handbook," *National Aeronautics and Space Administration, NASA/SP-2007-6105 Rev1*, 2007.

[2]. J. Gundlach, *Designing unmanned aircraft systems: A comprehensive approach*: American Institute of Aeronautics and Astronautics, 2012.