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# Weight Estimation of Camouflage Combat UAV with Surveillance Application

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**ABSTRACT:** UAV which means **Unmanned** Aerial Vehicle, the name itself conveys that it does not have any on-boards human pilot to control the aircraft, but is always under real-time human control with varying level of autonomous equipment and is controlled from ground station. UAV within it contains various application among which we specifically are interested in two areas namely surveillance and combat. Surveillance basically means monitoring, searching or keeping an eye on specific purpose. Surveillance UAV finds its use in areas where human cannot reach easily as it can risk their lives to danger. An unmanned combat aerial vehicle (U.C.A.V) is a special type of unmanned aerial vehicle (U.A.V) that usually carries aircraft ordinances such as missiles and/or bombs that are used for drone strikes and other military operations among which we are specifically using ATGMs. The aim of this project is to merge both of these applications in a single UAV as in the main aim still remains monitoring with an advanced feature of camouflage UCAV instead of only UCAV which means targeting equipment will be evident only during sudden or unexpected emergency cases.

**KEYWORDS:** Unmanned Aerial Vehicle (UAV), weight estimation, empty weight fraction, fuel fraction, weight fraction, MATLAB software, Aspect ratio, Drag coefficient, Specific fuel consumption.

## I. INTRODUCTION

In modern era, most of commercial aircrafts are operated on autonomous systems like for take-off, flying to a specific destination and landing. Even Missiles are operated without any human indulging in it and can lock target thousands of kilometers from its launch point. As well as Inter-planetary mission and satellite orbiting mission are also done without any on-board human. Still defence industry continues to buy aircrafts that have pilots on board, reason being sudden change in mission plans, avoiding risk of wrong attacks, delayed actions etc., as well as many times wrong information of attacks and sudden attacks lead to great losses.

Core element of any warfare is to maintain the rank in defence i.e., try to obtain as less life losses as possible, because if there will be no people left then even the most sophisticated or finely operating equipment/weapons would make no sense of their existence. So here UAV can play a vital role by reducing the above mentioned problem to a certain extent. Aircrafts have certain limitations on the operation considering the suitability of the condition on which it flies where as UAV can freely operate on any required condition without any hesitation.



II. METHODOLOGY

A. Comparative study

Comparative study is basically comparing few aircraft or UAV’s that fall under your desired category. Here is comparative study based on our requirement.

UAV’s	MQ-1 PREDATOR	IAI-HERON	YABON SMART EYE	IAI-SEARCHER	MQ-9 REAPER	TAI-ANKA
ENDURANCE (HR)	24	27	120	12	14	24
RANGE (Km)	1250	200	1300	200	1500	1443
WEIGHT (Kg)	513	769.4	450	206	2223	700
MTOW (Kg)	1043	1150	1000	435	4760	1500
ALTITUDE (ft)	25000	28000	23950.13	18000	---	30000
WING AREA (M^2)	11.45	13.12	---	4.9	---	---
LENGTH (M)	8.23	8.477	7	5.849	11	---
ASPECT RATIO	19	21	---	15	---	---
PAYLOAD (Kg)	640	250	550	120	1700	200
MAX. SPEED (M/S)	60.27	61.73	61.67	56.58	133.889	---
MACH NO. (MAX. SPEED)	0.17	0.18	0.179	0.16	0.393	0.17
WING SPAN (M)	14.8	16.6	21	8.57	20	17.3
CHORD LENGTH (M)	---	0.79	---	0.57	---	---
WE/Wto	0.491	0.67	0.45	0.65	0.467	0.46

Table 1. Comparative study

Therefore, based on the study,

- Range = 200km
- Endurance = 19.5hr
- Altitude = 27000ft
- Payload = 115kg

B. Weight estimation

An accurate estimation of weight of the airplane is required for the designing of an airplane. A good estimation of the gross weight is necessary for further progress in designing. The gross weight ( $W_{TO}$ ) is expressed as the sum of the crew weight ( $W_{crew}$ ), payload weight ( $W_{pl}$ ), fuel weight ( $W_F$ ) and the empty weight ( $W_E$ ) of the aircraft [1].

$$W_{TO} = W_{crew} + W_{pl} + W_F + W_E$$

$$W_{TO} - W_F - W_E = W_{crew} + W_{pl}$$

$$W_{TO} \left[ 1 - \left( \frac{W_F}{W_{TO}} \right) - \left( \frac{W_E}{W_{TO}} \right) \right] = W_{crew} + W_{pl}$$



$$W_{T0} = \frac{W_{crew} + W_{pl}}{[1 - (\frac{W_F}{W_{T0}}) - (\frac{W_E}{W_{T0}})]}$$

But, in UCAV there is no crew members.  
So,  $W_{crew} = 0$

$$W_{T0} = \frac{W_{pl}}{[1 - (\frac{W_F}{W_{T0}}) - (\frac{W_E}{W_{T0}})]}$$

Here,  $(\frac{W_F}{W_{T0}})$  = fuel fraction &  $(\frac{W_E}{W_{T0}})$  = empty weight fraction

**C. Empty weight fraction estimation**

$$(\frac{W_E}{W_{T0}}) = A * (W_{T0})^C$$

Where,  $W_{T0}$  = gross weight. The quantities A and C depend on the type of the airplane.

$W_e/W_0 = AW_0^C K_{es}$	A	C
Sailplane—unpowered	0.86	-0.05
Sailplane—powered	0.91	-0.05
Homebuilt—metal/wood	1.19	-0.09
Homebuilt—composite	0.99	-0.09
General aviation—single engine	2.36	-0.18
General aviation—twin engine	1.51	-0.10
Agricultural aircraft	0.74	-0.03
Twin turboprop	0.96	-0.05
Flying boat	1.09	-0.05
Jet trainer	1.59	-0.10
Jet fighter	2.34	-0.13
Military cargo/bomber	0.93	-0.07
Jet transport	1.02	-0.06

$K_{es}$  = variable sweep constant = 1.04 if variable sweep  
= 1.00 if fixed sweep

Table 2. Empty weight fraction [1]

Our aircraft falls under homebuilt-composite category of aircraft's. And so the values of A=0.99 & C=-0.09.

**D. Fuel fraction estimation**

Only part of the aircraft's fuel supply is available for performing the mission ("mission fuel"). The other fuel includes reserve fuel as required by civil or military design specifications, and also includes "trapped fuel," which is the fuel which cannot be pumped out of the tanks. The required amount of mission fuel depends upon the mission to be flown, the aerodynamics of the aircraft, and the engine's fuel consumption. The aircraft weight during the mission affects the drag, so the fuel used is a function of the aircraft weight [1].

- Fuel fraction:

$$(\frac{W_F}{W_{T0}}) = 1.06 * [1 - (\frac{W_8}{W_0})]$$



Mission	Engine start warm up	Taxii	Take- off	Climb	Decent	Landing taxi, Shut down
<b>Aircraft</b>	1	2	3	4	7	8
1. Homebuilt	0.998	0.998	0.998	0.995	0.995	0.995
2. Single Engine	0.995	0.997	0.998	0.992	0.993	0.993
3. Twin Engine	0.992	0.996	0.996	0.990	0.992	0.992
4. Agricultural	0.996	0.995	0.996	0.998	0.999	0.998
5. Business Jets	0.990	0.995	0.995	0.980	0.990	0.992
6. Regional TBP's	0.990	0.995	0.995	0.985	0.985	0.995
7. Transport Jets	0.990	0.990	0.995	0.980	0.990	0.992
8. Military Trainers	0.990	0.990	0.990	0.980	0.990	0.995
9. Fighters	0.990	0.990	0.990	0.96 - 0.90	0.990	0.995
10. Mil. Patrol, bomber transport	0.990	0.990	0.995	0.980	0.990	0.992
11. Flying boats, Amphibious	0.992	0.990	0.996	0.985	0.990	0.990
12. Supersonic cruise	0.990	0.998	0.995	0.92 - 0.87	0.985	0.992

Table 3. Weight fraction [5]

From the above Table 3 the weight fraction is:

$$\left(\frac{W_1}{W_0}\right) = 0.998, \quad \left(\frac{W_2}{W_1}\right) = 0.998, \quad \left(\frac{W_3}{W_2}\right) = 0.998, \quad \left(\frac{W_4}{W_3}\right) = 0.995, \quad \left(\frac{W_7}{W_6}\right) = 0.995, \quad \left(\frac{W_8}{W_7}\right) = 0.995$$

- Weight fraction for cruise  $\left(\frac{W_5}{W_4}\right)$  & Loiter  $\left(\frac{W_6}{W_5}\right)$

$$\left(\frac{W_5}{W_4}\right) = e^{\left(\frac{-R \cdot C_j}{V(L/D)}\right)} \text{ where, } R = \text{Range, } E = \text{Endurance}$$

$$\left(\frac{W_6}{W_5}\right) = e^{\left(\frac{-E \cdot C_j}{V(L/D)}\right)} \text{ } V = \text{cruise velocity in ft/sec,}$$

$$C_j = \frac{(C_{bhp} \cdot V)}{550}$$

The value of R and E are taken from the comparative study.

- Specific fuel consumption

$$\text{Propeller: } C_{bhp} V / (550 \eta_p)$$

$$\text{Typical: } C_{bhp} \text{ and } \eta_p$$

- L/D Estimation

$$\frac{L}{D} = \frac{1}{\frac{q \cdot C_{d0}}{W/S} + \frac{W/S}{q \cdot \pi \cdot AR \cdot e}}$$

Where,

q = dynamic pressure,

e = Oswald's efficiency,

C<sub>d0</sub> = coefficient of drag at zero angle of attack,

W/S = wing loading,





AR = aspect ratio,

$$e = 1.78 * (1 - 0.045 * (AR^{0.68})) - 0.64$$

$$W/S = q * \text{sqrt}(\pi * e * AR * C_{d0})$$

Sailplane equivalent \* aspect ratio - 4.464 (best L/D)<sup>0.69</sup>

	Cruise	Loiter
Piston-prop (fixed pitch)	0.4/0.8	0.5/0.7
Piston-prop (variable pitch)	0.4/0.8	0.5/0.8
Turboprop	0.5/0.8	0.6/0.8

Table 4. Specific fuel consumption [1]

The value of Aspect Ratio and Drag Coefficient at zero lift are taken from Table 5 and Table 6 given below.

Propeller aircraft	Equivalent aspect ratio
Home built	6.0
General aviation - single engine	7.6
General aviation - twin engine	7.8
Agriculture aircraft	7.5
Twin turboprop	9.2
Flying boat	8.0

Table 5. Aspect ratio [1]

Aircraft type	C <sub>d0</sub>
High - subsonic jet	0.014-0.020
Large turboprop	0.018-0.024
Single engine piston aircraft with fixed gear	0.020-0.030
Single engine piston aircraft with retractable gear	0.025-0.040
Agricultural aircraft without spray system	0.60
Agricultural aircraft with spray system	0.070-0.080

Table 6. Drag coefficient for different aircraft

$$\left(\frac{W_8}{W_0}\right) = \left(\frac{W_1}{W_0}\right) * \left(\frac{W_2}{W_1}\right) * \left(\frac{W_3}{W_2}\right) * \left(\frac{W_4}{W_3}\right) * \left(\frac{W_5}{W_4}\right) * \left(\frac{W_6}{W_5}\right) * \left(\frac{W_7}{W_6}\right) * \left(\frac{W_8}{W_7}\right)$$

The iterative analysis shown above is done through MATLAB software, when the assumed value of W<sub>T0</sub> (taken during the calculation of empty weight fraction) and obtained value of W<sub>T0</sub> at the end comes out to be nearby then the calculated value of W<sub>T0</sub> becomes the final approximate value of takeoff weight, which in this case comes out to be **908.9027 kg**



Iteration	Assumed $W_{T0}$ (kg)	$\frac{W_E}{W_{T0}}$	$W_{T0}$ Calculated(kg)
1	550	0.5611	1125.7
2	600	0.5567	1079
3	650	0.5527	1040
4	700	0.5490	1006.6
5	750	0.5456	977.5053
6	800	0.5424	951.9365
7	850	0.5395	929.2327
8	900	0.5367	908.9027

Table 7. Iterative Analysis

From the empty weight fraction & fuel fraction, we get the value of empty weight and fuel weight which comes out to be **487.8325 kg & 306.0701 kg** respectively.

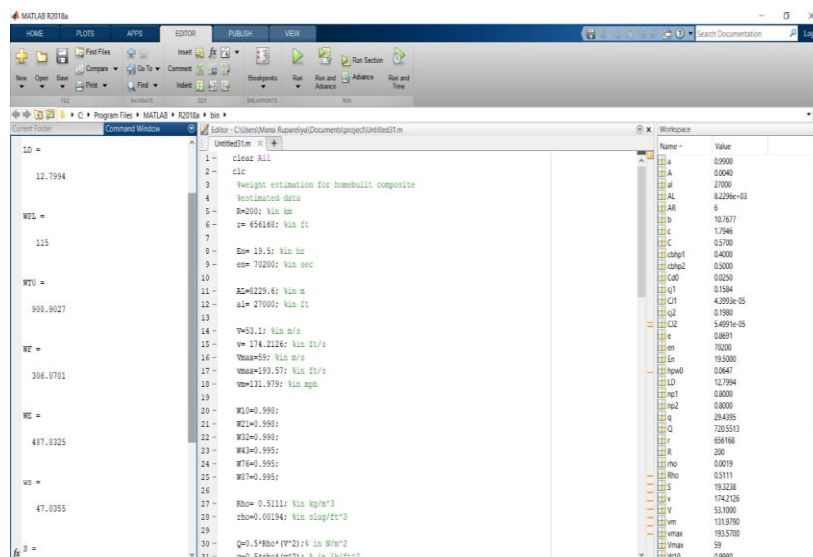


Figure 1. MATLAB coding

### III. CONCLUSION

Weight estimation is the most essential part of aircraft design and this paper gives a clear vision on how to perform weight estimation provided it gives estimated values of takeoff weight, empty weight and fuel weight of their desired unmanned aerial vehicle which comes out to be **908.9027 kg, 487.8325 kg and 306.0701 kg** respectively.

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