Conceptual design of Wau Bulan UAV

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Abstract. This paper presents conceptual design of an UAV that using “Wau Bulan” shape as its planform. Wau Bulan is a one type of Malaysia’s kite. Wau bulan kite has wing and tail part. Wau Bulan wing is a lens shape wing with aspect ratio 3.48. Tail part shape likes crescent moon. Tail part area is 46.23% of wing area. Wau Bulan UAV was designed to perform surveillance mission. Initial weight sizing and performance sizing was done to assure the reasonable value of aerodynamics and propulsion parameter. Joined wing and blended wing body technology concepts were used to aim the requirement parameters that defined during initial sizing process. The aerodynamics characteristic was analyzed using experimental method. Experimental results show that wau bulan planform aerodynamics characteristics fulfill designed parameter that chosen during initial sizing.

1. Introduction
From the beginning, UAV application concerns in military application, only the previous years UAV is applied in civil activity. At the first time, UAVs are designed as a bomb carriers and target drones. After avionics system get better, military use UAV to do surveillance and reconnaissance mission. And present most common issue is to combine UAV with manned aircraft in same mission. UAV will give some information and guidance to all element of defence system. The relation of UAV system and manned system will be very important [1,2].

Mostly mission of UAV for Civil application is ISR operations. Civil market usually needs to get information about situation in the preferred area. All patrol, monitoring and research mission are the data collecting mission type [2].

SensorCraft is a new concept UAV that designed by AFRL that based on ultimate sensor capability. This UAV has wide variety of the latest sensors, communications links, air vehicle components and propulsion systems. SensorCraft airframe designed to fit with various types of sensors embedded. This unusual approach to UAV design has already resulted in some radical UAV configuration. Figure 1 show the alternatives of SensorCraft configurations [3].
SensorCraft airframe was designed to maximize aerodynamic efficiency and minimize empty weight to maximize vehicle endurance. Enabling optimum performance of the airfoil to the varying flight conditions and lift coefficient over the entire mission [3].

2. Methodology
A custom conceptual design methodology was developed based on traditional design methods such as the ones described in Raymer [5], and Roskam [6], the design methodology also included the aspects of unmanned aircraft design. The first step of conceptual design is determining a first configuration layout is developed. Second step is determine the initial sizing of UAV [5]. This procedure initiates by defining payloads characteristics, the mission requirements of the aerial vehicle, design specifications, and assumed aerodynamics characteristics. The results are estimated UAV weight and performance characteristics [6].

Based on initial sizing results, UAV configurations geometry was determined. During this step, the wing airfoil, tail arrangement and fuselage design were chosen [7,8].

3. Configuration layout
This research would design UAV based on Wau Bulan planform. Wau or Kite in Malaysia is a uniquely design. General shape of Malay kites show capability to be used as airplane planform, it had wing and tail part. Basically wing of Malay kite had “lens shape”. Wau bulan kite had crescent moon (bulan) shaped tail. Figure 3 shows the picture of wau bulan kite and its generated basic geometry.

Wau Bulan planform shows its capabilities to be used as sensorcraft planform. Its has near circular wing-tail configuration [3,9].
4. Initial sizing

4.1. Payload characteristics
Wau Bulan UAV would perform several missions, such as surveillance, mapping, and monitoring. Wau Bulan standard payloads were include daylight or Infrared pan/tilt/zoom camera providing long range, low altitude, and live situational awareness capability.

4.2. Mission requirements
General capability of Wau Bulan UAV was tabulated as follow:

- Long Endurance UAV System
- Autonomous Flight Capability
- Components of the shelf (COTS)
- LOS communication and control system
- Sensor placement to cover 360° vision

4.3. Flight mission
Figure 4 shows the UAV flight mission over Putrajaya area.

Figure 4. UAV flight mission path.
Payload weight: 5 kg; Altitude: from sea level to 1000 ft; Range: 20 nm (LOS communication) Endurance: 5 hours; Cruise Speed: 80 kts; Loiter Speed: 40kts
4.4. Initial weight sizing
The results from initial weight sizing were the UAV main weight:
Take Off Weight = 30 kg; Empty Weight = 17.5 kg; Fuel Weight = 7.5 kg

4.5. Performance sizing
Performance sizing results shows in figure 5. The design point of designed UAV has wing loading equal to 18 kg/m² and power loading equal to 11.5 kg/kW. From initial weight sizing, maximum takeoff weight was equal to 30 kg. Designed UAV at least would have wing with 1.654 m² area, and 2.61 kW (3.55 hp) engine power.

![Power Loading vs Wing Loading](image)

**Figure 5.** Performance sizing results.

5. Wau Bulan configuration

5.1. Wing tail planform
Wing sizing was done based on performance sizing results. Wau Bulan had root chord = 1000 mm. Mean aerodynamics chord of front wing was 872.14 mm. (figure 6).

![Wau Bulan UAV Wing-tail Planform](image)

**Figure 6.** Wau Bulan UAV Wing-tail Planform.

5.2. Airfoil selection
Airfoil selection was based on the lift coefficients requirements that were determined during performance sizing. Thick airfoil with high lift coefficient was chosen. Kennedy Marsden Mod was an airfoil that based on Kennedy Marsden airfoil. Modification was done to improve stall characteristics. Several parts of its curve were changed into straight line and reduced thickness into 20% chord.
5.3. Tail arrangement
Two alternatives tail configuration was proposed (figure 7). They were straight tail and inverted V tail. Straight tail could be installed with two tail boom or connected with long fuselage. Main problem of straight tail type was it did not have vertical tail. Inverted V tail was better for lateral directional control. With only small additional weight, this configuration has simpler control system.

![Figure 7. Tail arrangement variations.](image)

5.4. Fuselage design
Fuselage was designed to accommodate payload, avionics and communication system. Blended wing body concept was using thick airfoil shape to make fuselage. This was the main purpose to choose thick airfoil for wing (figure 8). Thick airfoil could gave space to put all system required to control, and accomplish the mission.

![Figure 8. Wau bulan UAV Fuselage.](image)

5.5. Wau Bulan UAV general arrangement
The Wau Bulan UAV layout is shown in figure 9. This configuration was the initial layout to be proceed to UAV design phase II.

![Figure 9. Wau Bulan UAV General Arrangements.](image)

6. Conclusions
This paper proofs that wau bulan planform suitable to be used as UAV planform. Experimental results show that aerodynamics characteristics fulfill designed parameter that chosen during initial sizing. Wau bulan UAV could perform take off without flap, because its wing maximum lift coefficient already high ($C_{L_{\text{max}}} = 1.95$). Long endurance flight could perform well with L/D ratio more than 10 (assumed as 9 at initial sizing).

Surveillance mission could perform with insignificant limitation. The other mission will be performed better, such as application as UCAV (unmanned Combat Aerial Vehicle). Wau Bulan UCAV can be realized because it naturally has high maneuverability.
This paper discusses the conceptual design (phase I) of this wau bulan UAV. In this phase, define the general arrangement, basic aerodynamics configuration of wing, fuselage and tail. Result from this phase is general arrangement of wau bulan UAV.

Now in the preliminary design phase II that determine the aerodynamics, performance, WAB and define the avionic, flight control and structural concepts.

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