1. Naqib DANESHJO, 2. Cristian Dan STRATYINSKI, 3. Baryalai TAHZIB, 4. Christian DIETRICH

# PROPOSED CONSTRUCTION OF AN UNMANNED RESEARCH VEHICLE

1,2,4. TECHNICAL UNIVERSITY, FACULTY OF AERONAUTICS, DEPARTMENT OF AVIATION ENGINEERING, KOŠICE, SLOVAKIA
3. TECHNICAL UNIVERSITY, FACULTY OF CIVIL ENGINEERING, DEPARTMENT OF ENVIRONMENTAL ENGINEERING, KOŠICE, SLOVAKIA

ABSTRACT: The main scope of this article is to describe the structural design unmanned reconnaissance vehicle to 80kg. Apart from the design and technical and visual documentation of the work is also a detailed description of each component. This work proposes a suitable design for a simplified UAV system which promotes the autonomous movement of an UAV and includes the optimal selection of its components (avionics), such as a (Javelin Stamp) processor, GPS module, motors, gyroscopes and maneuvering equipment for an optically remote controlled drone. In the proposal, the most important part is the selection of the profile's wings, because it imparts its aerodynamic characteristics and as a result, its lift.
KEYWORDS: CATIA, GPS module, UAV, 3D structure

## INTRODUCTION

The main objective of this work is to plan the construction of an unmanned vehicle with a mass limited to 80kg. At present, unmanned aerial vehicles (UAV's) are currently in use by almost all national defence forces. This work proposes a suitable design for a simplified UAV system which promotes the autonomous movement of an UAV and includes the optimal selection of its components (avionics), such as a (Javelin Stamp) processor, GPS module, motors, gyroscopes and maneuvering equipment for an optically remote controlled drone.

In the proposal, the most important part is the selection of the profile's wings, because it imparts its aerodynamic characteristics and as a result, its lift. This allows us to create a wing dependent on the dimensions of the aircraft. When calculating the lift and resistance coefficient, the course of pressure around the wing, depends on the angle at which it strikes the wing and the results of the calculation of Reynolds number. The program, Catia V5, was used to model the 3D structure. Unmanned technology is playing an increasingly important role in modern armies. Unmanned aircraft take pride of place as they can conduct surveillance, identify targets and eliminate them.

## PROPOSED CONSTRUCTION OF AN UNMANNED FUSELAGE

The fuselage requires bearing assembly which consists of parts necessary for a stable and controlled-flight. The airframe houses the power plant which is responsible for carrying the load.

A simple fuselage consists of the following main parts: airframe, fuselage, tailfin, control system and landing gear.

The optimal shape places the propeller and engine at the rear of the hull with simple rectangular wings attached to the fuselage, but remarkably the tail is detached, joined only by connecting beams which is unlike most modern aircraft. The main load-bearing members consist of simple rectangular wings with transverse rudders. The wings are connected to the hull with a varying profile. The internal combustion engine is located in the rear of the fuselage. Stabilizers are not directly attached to the hull, because of the location of the engine. The tailfin acts as stabilizers which are located in the same plane and consist of a horizontal tail surface, which is located above the two vertical tail fins. The horizontal tail consists of a lateral surface that houses the elevator rudder which is supported by two vertical surfaces that house the yaw rudders.
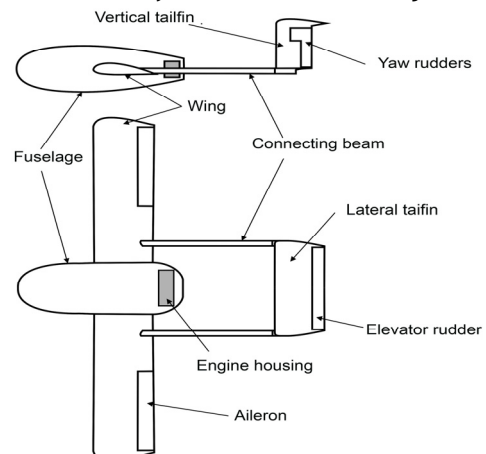


Figure 1. Preliminary design of the aircraft shape

The calculation of the dimensions of the aircraft should be based on its designed take-off weight. For this particular case, the take-off mass is m = 80kg. The maximum takeoff weight is defined as the limit at which an aircraft is able to take off with (empty aircraft, crew, cargo and fuel weight).

*The profile of the airfoil (wing cross-section in the vertical plane) depends on its geometrical dimensions and aerodynamic characteristics.*

*The basic dimensions of the wing include the calculation of the chord length, its relative thickness, the relative curvature, the radius of the leading edge and trailing edge thickness. Relative profile thickness has a considerable effect on the degree of aerodynamic characteristics of the profile, especially drag coefficient.*

$$\overline{c} = \frac{c_{max}}{b}. \qquad (1)$$

*where:$\overline{c}$ - [-] relative profile thickness, $c_{max}$ - [mm] max profile thickness, b - [mm] length of profile chord*

*Parameters of the wings profile:*
 *max lift factor $c_L$: 1,847*
 *max lift coefficient at angle: 15°*
 *angle of zero lift : -4,5°*

*The calculation of the wing area is based on the calculation of the minimum airspeed. A minimum flight speed of 60 kph was selected-1 (16.667 ms-1).*

$$v_{min} = \sqrt{\frac{G}{\frac{1}{2} \cdot \rho \cdot c_{Lmax} \cdot S}}. \qquad (2)$$

$$S = \frac{G}{\frac{1}{2} \cdot \rho \cdot c_{Lmax} \cdot v_{min}^2} = \frac{80,9,81}{\frac{1}{2} \cdot 1,2 \cdot 1,847 \cdot 16,667^2} = 2,549 m^2. \qquad (3)$$

*where: S – wing area [$m^2$], G - mass of aircraft [kg], ρ - air density, cLmax – maximum coefficient of lift for a given profile, vmin – minimum flight speed[$ms^{-1}$]*

*The shape of the wing is a simple rectangle.*
*Wing dimensions:*
 □ *wingspan: 4m,*
 □ *chord length: 0,650m*
 □ *max wing thickness : 0,137m*

## CALCULATION OF THE OPTIMAL FLIGHT SPEED

*The optimal lift coefficient is based on the NACA profile 4421. The polar profile corresponds to the optimal value of the maximum strike angle, 6°, where the lift coefficient cL = 1.0758. It is then possible to calculate the flight speed using the relation:*

$$v_{let} = \sqrt{\frac{G}{\frac{1}{2} \cdot \rho \cdot c_L \cdot S}} = \sqrt{\frac{80 \cdot 9,81}{\frac{1}{2} \cdot 1,2 \cdot 1,0758 \cdot 2,6}} = 21,62 m.s^{-1} = 77,84 km.h^{-1}. \qquad (4)$$

## CALCULATION OF REYNOLDS NUMBER

*The profile V2.22a was used for the calculation of Reynolds number: airspeed: 78km.$h^{-1}$, wing chord: 0,65m*

*Reynolds number for the given parameters equals:*
 *Re=964136*

*This Re is sufficient for the rectangular wing. Reynolds numbers on actual gliders ranges between 600,000 and 3500 000.*

## PROPOSED FUSELAGE USING CATIA V5 - Proposed fuselage structure, wing attachment and engine fitting

*The fuselage which is constructed around the aircraft's frame plays a very important function. In*

*terms of design, the wings, tail, landing gear, management, power train parts and equipment and weapons are integrated into a single unit. Certain requirements are placed on the fuselage which needs to be considered from the outset. These include: aerodynamics (optimal aero-dynamic characteristics of the fuselage, regarding the reduction of drag caused by the unfavorable effect created were the fuselage joins the wing, tail, and possibly other parts of the aircraft), strength, design, manufacture and service.*

*Aerodynamic requirements call for optimal fuselage aerodynamic characteristics, especially the minimization of resistance due to an adverse effect on the body where it joins with the wing, tail, and possibly other parts of the aircraft.*

*This can be avoided by shaping the body and using a well-designed transition between the wing, fuselage and tail.*
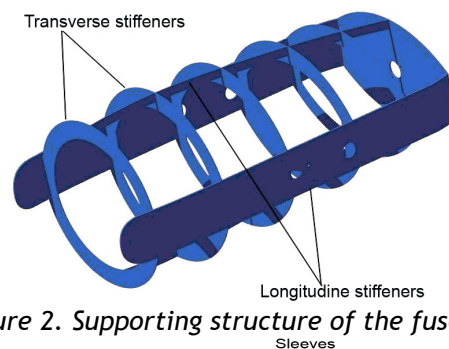


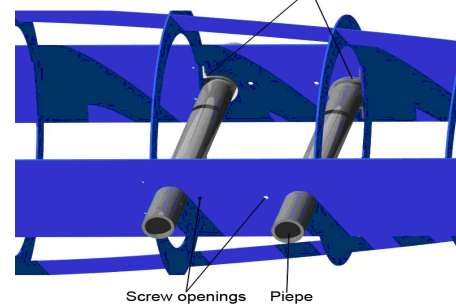*Figure 2. Supporting structure of the fuselage*



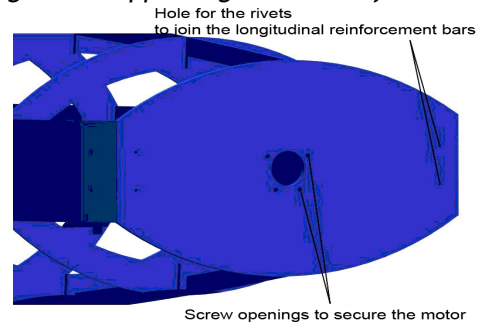*Figure 3. Supporting structure of the wings*



*Figure 4. Supporting structure of the engine mount*

*A well-designed structure should have a minimum weight in relation to its size and use advanced materials and manufacturing technologies. An optimal solution is to preferably implement a circular cross section or circular parts.*

*The supporting structure of the fuselage has undergone various forms of organization over the years. At present, two forms are used. Rod (rarely used) and semi shell hull structures which house the load-bearing part of the transverse and longitudinal direction and cover the carrier).*

The wing will be constructed from two load bearing beams and exhibit a circular cross section. The mountings consist of two aluminum tubes with an outer diameter Ø50mm and thickness of 5 mm. The Limbach L 275 E engine was selected.

## Proposed wing construction

The whole wing beam design requires suitably spaced supporting parts, reinforced using longitudinal stiffeners and ribs. The main beam withstands substantial bending moment induced by normal forces.

The wings are composed of one auxiliary beam, three longitudinal stiffeners, one of which performs as the leading edge and eight ribs. The main and auxiliary beams are made of tubes with an outer diameter of Ø40mm and a thickness of 3 mm.
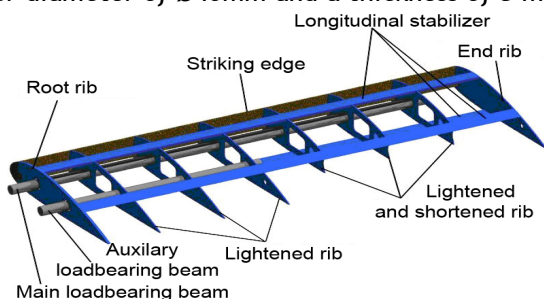


Figure 5. Wing construction

Lateral control rudders (ailerons) are control bodies whose activities produce a moment about the longitudinal axis of the aircraft, causing the aircraft to roll. The most common type of wings currently used are normally designed as deflective and located at the end of the trailing edge.

The frequent use of an aileron is justified, because it is structurally similar to the wing construction. Besides shortcomings in the moment, there are also limitations due to torque which is created by moment. Lateral control is provided by one aileron deflecting upwards, while the other deflects downwards.

The ailerons have the same plan outline as the main rectangular wing. Its dimensions differ from the wings through simple relative values, where the length of the wings, is ¼ the wingspan and the width is ¼ leaf the width.
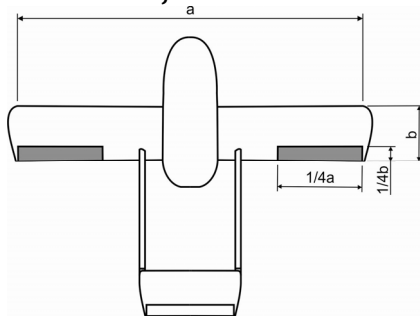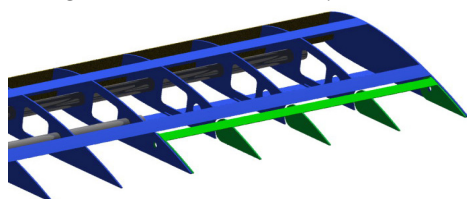


Figure 6. Ratio values of ailerons



Figure 7. Model of the ailerons – lateral rudder

Length of aileron:

$$a_k = \frac{1}{4} \cdot a = \frac{1}{4} \cdot 4 = 1\text{m}. \tag{5}$$

where: $a_k$ - [m] length of aileron[m], $a$ -wingspan[m]
Width of aileron:

$$b_k = \frac{1}{4} \cdot b = \frac{1}{4} \cdot 0,65 = 0,1625\text{m}. \tag{6}$$

where: $b_k$-width of aileron[m], $b$-width of aileron[m]
Length 1m and width 0,165m, which results in an aileron area of 0,165m$^2$.

## Proposed connections of stabilizers and wings

The aircraft's fuselage is independent to the stabilizers which are anchored to the supporting surface (wings):
- ☐ wing rib attachments
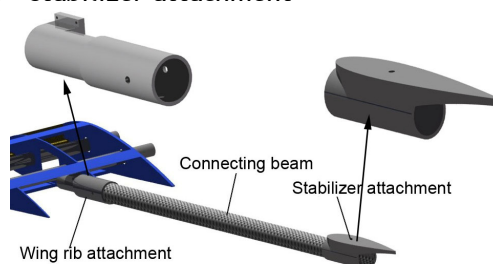- ☐ connecting beam (cylindrical)
- ☐ stabilizer attachment



Figure 8. Wing stabilizer connections

## Proposed stabilizer

Stabilizers are usually separated into horizontal and vertical wing segments which are located at the end of the fuselage. Horizontal tail surfaces provide longitudinal stability and maneuverability of the aircraft, while the vertical tail surfaces provide directional stability and maneuverability of the aircraft. Both areas consist of fixed and flexible parts. The fixed horizontal surface act as the stabilizer and the movable surface acts as the elevator. The fixed vertical part acts as a fin and the movable part is used to change direction (yaw).

### A. Vertical tail area:

The vertical tail surface area is 0.066 times the wing area.

$$A_{zp} = 0,066 \cdot S = 0,066 \cdot 2,6 = 0,1716\text{m}^2. \tag{7}$$

where:$A_{zp}$ - area of vertical tail fin [m$^2$], S - area of load bearing wing [m$^2$]

The selected rectangular shape has a vertical tail surface width of a = 0.36 m. The height B should be calculated from the width of the selected area b and vertical tail area $A_{zchp}$.

$$b_{zp} = \frac{A_{zp}}{a_{zp}} = \frac{0,1716}{0,36} = 0,477\text{m}^2. \tag{8}$$

where:
$A_{zp}$- vertical tail area [m$^2$],
$a_{zp}$- width of vertical tail surface [m]
$b_{zp}$ – height of vertical tail surface [m]
According to previous calculations $b_{zp}$ = 0.48m and width $a_{zp}$ = 0.36m was selected.
The resulting single vertical tail surface area of Azp = 0.1728 square meters.
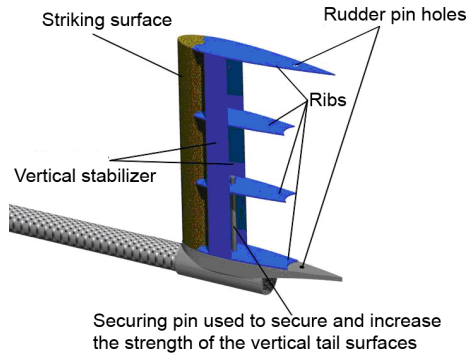
Figure 9. Vertical tail surface construction

**B. Yaw rudders:**

When calculating the directional (yaw) surface area we used the same ratio values that were used previously which is ¼ of the vertical tail surface area.

$$A_{sk} = \frac{1}{4} \cdot A_{zp} = \frac{1}{4} \cdot 0{,}1728 = 0{,}0432 \mathrm{m}^2.$$

(9)

where: $A_{sk}$ - area of the yaw rudders [m²]

The rudder height bs is determined by the height of the construction of the vertical tail surface and will therefore be equal to its height, ie:

$$b_{sk} = b_{zp} = 0{,}48 \mathrm{m}.$$

The width of the yaw rudder should be calculated according to the equation:

$$a_{sk} = \frac{A_{sk}}{b_{sk}} = \frac{0{,}0432}{0{,}48} = 0{,}09 \mathrm{m}.$$

(10)

where: $a_{sk}$ - width of yaw rudder [m],
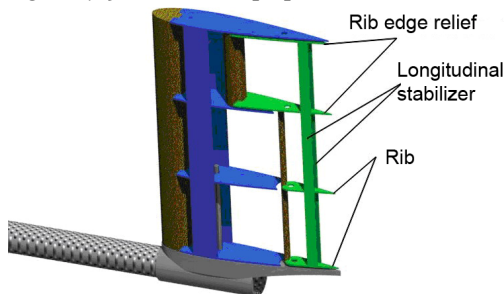$b_{sk}$ - height of yaw rudder [m],



Figure 10. Construction of yaw rudder

**C. Horizontal tail surface:**

The calculation of the tail area is based on the ratio of the values that were previously calculated. The horizontal tail surface area is 0.2 times the wing area.

$$A_{vp} = 0{,}2 \cdot S = 0{,}2 \cdot 2{,}6 = 0{,}52 \mathrm{m}^2.$$

(11)

where: $A_{vp}$- horizontal surface area [m²],
S-area of load bearing wing [m²]

A rectangle with a length $b_{vp}$= 1m was chosen for the shape of the horizontal tail surfaces. The width of the $a_{vp}$ must be calculated according to the equation:

$$a_{vp} = \frac{A_{vp}}{b_{vp}} = \frac{0{,}52}{1} = 0{,}52 \mathrm{m}.$$

(12)

where: $a_{vp}$ - width of the horizontal tail surface [m]
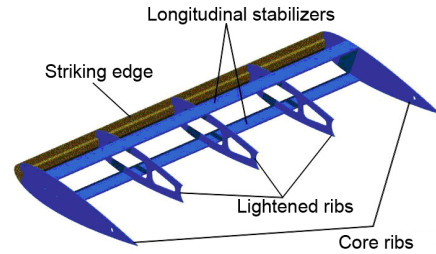$b_{vp}$ - length of the horizontal tail surface [m]



Figure 11. Construction of horizontal tail surface

**D. Elevator rudder:**

When calculating the area of the elevator rudder, we use the same ratio values that were used for the calculation of yaw and transverse rudder (aileron) which is ¼ the horizontal tail surface area.

$$A_{vk} = \frac{1}{4} \cdot A_{vp} = \frac{1}{4} \cdot 0{,}52 = 0{,}13 \mathrm{m}^2.$$

(13)

where: $A_{vk}$ -area of the elevator [m²]

The length of the elevator bvk is determined by the construction of the horizontal tail surface and is therefore equal to its length, ie:

$$b_{vk} = b_{vp} = 1 \mathrm{m}.$$

Width of the elevator rudder is calculated as:

$$a_{vk} = \frac{A_{vk}}{b_{vk}} = \frac{0{,}13}{1} = 0{,}13 \mathrm{m}.$$

(14)

where: $a_{vk}$ - width of horizontal [m]
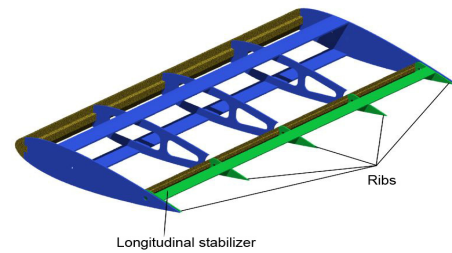$b_{vk}$ - length of horizontal [m]



Figure 12. Longitudinal stabilizers; - ribs
Construction of elevator rudder
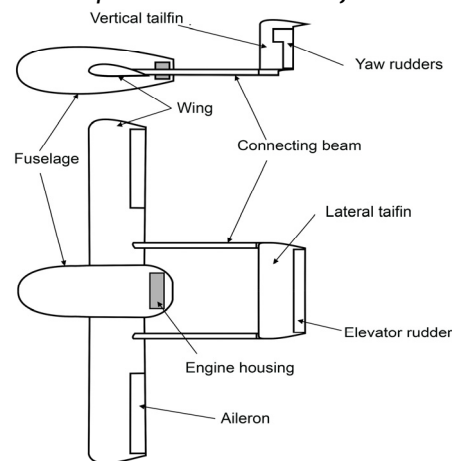


Figure 13. Complete construction of the drone (UAV)



Figure 14. Proposed and calculated dimensions of the drone (UAV)

*The flow diagram illustrates the results of the calculations.*

## Mass and centre of gravity

- ☐ *total construction mass: $m_D$=39kg*
- ☐ *dry mass of engine: $m_m$=7,2kg*
- ☐ *avionics weight without battery: $m_s$=0,25kg*

*The total mass of the drone (UAV) was calculated with the aid of CATIA V5 program where the construction materials were chosen according to their material density. The mass of the engine and avionics are specified by the manufacturer. Since the total mass of the exploratory UAVs are limited to 80 kg, fuel, batteries and other equipment are limited to 33.55 kg, which is a sufficient margin. An increase in the mass would also increase the minimum flight speed. The centre of gravity is indicated in Figure 22.*

*Centre of gravity coordinates:*

$$x_T=1334mm, \; y_T=0mm, \; z_T=28mm$$

*Additional transfer of gravity and balance may be set by the positioning fuel, batteries and avionics of the aircraft.*

## CONCLUSIONS

*The work deals with UAVs. It clarifies current issues regarding UAVs, their use and continuous development. The work proposes a step by step structural design for an aircraft and provides descriptions and pictures, which can also be used as a guide in designing new types of UAVs. Special effort was paid to create an interesting and simple design. The structural design is not final and may be further modified and extended.*

## REFERENCES

[1] *Čalkovský, A.- Pávek, J.- Daněk, V.: Konstrukce a pevnost letadel 1.díl. 1984, 547 s. U-1165/1.*

[2] *Hlubeňová, Jana - Líška, Ondrej Hlubeň, Daniel:Metodika výberu simulačného programu. 2009. 1 elektronický optický disk(CD-ROM).*

[3] *[3] Pauliková, A.: Modelovanie dynamických systémov pracovného prostredia technologickej prevádzky, habilitačná práca, Košice, 2008, 166 s.*

[4] *Michal Fabian, Róbert Boslai, Jaroslav Šeminský Reverse engineering na báze 2D pohľadovpomocou intuitívneho modelára: Imagine&Shape v CATIA V5, 2010. - 1 elektronický optický disk (CD-ROM).*

[5] *Kopas, M. - Pauliková,A.: Specifics of belt conveyor as part of checkout counters and their impacts on operational staff, In: Zdvihací zařízení v teorii a praxi. No. 2 (2009), p. 41-45.ISSN 1802-2812.*

[6] *Ižaríková, G.: Matematické modelovanie pracovných priestorov výrobných prostriedkov a systémov. In: Transfer inovácií. Č. 14 (2009), s. 181-184. - ISSN 1337-7094*

[7] *Kuderjavý, P.: Modelovanie a simulácia automatizovaných výrobných systémov v edukačnom procese. In: Perspective Directions and Ways of Realizing Innovative Technologies in the System of European Higher Education: international scientific herald: the collection of scientific articles containing the materials of the 19th International scientific - practical conference: (December 8-11, 2009), Uzhhorod (Ukraine) - Vysoke Tatry (Slovakia): book 1. - Uzhhorod: Ministry of Education and Science of Ukraine, 2010 P. 177-186.*

[8] *http://www.slavetind.cz/stavba/konstrukce/kridlo/Profil_kridla.aspx*