History review of aircraft performance improvement

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Abstract. This paper is a review of trends in performance improvement of all-purpose military remotely piloted aircrafts in the last years. The review results are intended for use by designers of such aircrafts. Performance improvement of a machine, aircrafts in particular, is aimed at cost-effective optimization. The fundamental of a design specification for a new all-purpose aircraft is drafting requirements to its military characteristics. It is required to determine if an aircraft requires new or improvement of existing functions that influence the aircraft’s weight taking into account novel technologies to appear soon. No look-ahead analytic base available makes it difficult to determine needs and capacities of the future engineering period. This paper focuses on an analysis of the past period to forecast the aircraft engineering future. A history chart is built to show the design improvements of all-purpose military remotely piloted aircrafts starting from 2005.

1. Introduction
A study of aircraft performance allows finding principles to be used for selecting a right aircraft design concept when developing a design specification [1–4]. A new design of a military remotely piloted aircraft (“aircraft”) must consider many interconnected requirements, among them are: target load, flying distance, course speed, take-off and landing characteristics [5–12]. Each factor has qualitative constituents achievable by increased aircraft’s size and take-off weight, specific wing load, improved aircraft’s aerodynamic and weight characteristics and engine capacity [10, 13].

The review of aircraft performance evolution is the review of design innovations improving the aircraft’s performance and eventually its functions [14].

2. Aircraft Performance Improvements
Selection of specific performance measures of an aircraft design depends on its purpose, operation conditions, manufacture and maintenance costs and other factors [2–4]. Let us look at typical measures.

2.1. Transport Performance
The aircraft’s transport performance defines the ability to transport a target load to a point. It can be evaluated by delivery parameters such as consumed power, capacity, flying duration and distance [15, 17–19]. In terms of “transportation-costs”, the process efficiency must be studied: hourly capacity $m_{\text{thw}} \cdot V$ or flying capacity $m_{\text{thw}} \cdot L$ where $m_{\text{thw}}$ is a target load weight, kg; $V$ is course speed, m/s; $L$ is flying distance, m. Then the transport performance TP can be found by formula [10] taking into account consumed power:
\[ TP = m_{thw} \cdot V^2 \cdot L. \]  

Therefore, the squared target load delivery speed is most important in improving the transport performance.

2.2. Aircraft Engineering Level
Engineering level of an aircraft is evaluated by comparing its performance with previous designs. As high engineering level can be achieved not only by innovations but also by an increased weight, then the compared aircrafts must be of a similar type and same weight. Engineering level (EL) increase is a full differential of function of several variables \( d\text{EL} \) of the aircraft design and transportation process:

\[ d\text{EL} = \frac{\partial \text{EL}}{\partial W} dW + \frac{\partial \text{EL}}{\partial m_{\text{tw}}} dm_{\text{tw}} + \frac{\partial \text{EL}}{\partial V} dV + \frac{\partial \text{EL}}{\partial L} dL + \frac{\partial \text{EL}}{\partial m_0} dm_0, \]  

where \( W \) is effective performance probability, unsized [20]; \( m_0 \) is the aircraft maximum take-off weight, kg.

3. Example of All-Purpose Aircraft Performance Improvement History

The example uses a known all-purpose reconnaissance and strike MQ-1B Predator 2005 [16], ref. figure 1. Predator has a traditional aerodynamic design with a one-beam body and aft propeller and with a reverse V-tail and Rotax engine.

\[ \text{Figure 1. Reconnaissance and Strike MQ-1B Predator.} \]

Target load (radiotronics and missiles) is placed in the fuselage and on external slings. This aircraft is a classic MALE-aircraft (Medium Altitude Long Endurance), a prototype of most of other developed all-purpose aircrafts. Table 1 contains transport functions of four MALE-aircrafts with the design trends from 2005 to 2015.
Table 1. Aircraft Transport Functions.

| Parameter                  | MQ-1B Predator | Heron 1 | Hermes 900 | Dozor-600 |
|----------------------------|----------------|---------|------------|------------|
| Year                       | 2005           | 2007    | 2011       | 2015       |
| Maximum take-off weight, kg | 1020           | 1250    | 970        | 720        |
| Maximum payload, kg        | 204            | 250     | 300        | 120        |
| Course speed, kph          | 130            | 130     | 130        | 130        |
| Flying distance, km        | 1100           | 1000    | 1500       | 3700       |
| Engine                     | Rotax 914 F    | Rotax 914 F | Rotax 914 F | Rotax 914 F |

Figure 2 illustrates a history chart of the aircraft’s main transport efficiency elements represented as: L/Lr is flying distance; m0/(m0)r is maximum take-off weight; mwt/m0 is specific take-off weight where “r” refers to MQ-1B Predator. Figure 2 illustrates a trend chart of increased flying distance with the same course speed. Maximum take-off weight and target load weight show an unclear reduction tendency. The course speed is the same for all aircrafts due to gasoline reciprocating engine Rotax 914 the screw jack ram is based on. The screw jack ram is not likely to be changed. For low flying speeds, such screw jack ram design is more efficient comparing to gas-turbine engines: screw or reactive. Figure 3 illustrates a change of the integral parameter of the aircraft transport efficiency TP that is calculated by formula (1). Aircraft transport performance has been improved by 2.8 times in 10 years of the design upgrading.

![Figure 2](image-url)

**Figure 2.** Historic All-Purpose Aircraft Performance Trends.

![Figure 3](image-url)

**Figure 3.** All-Purpose Aircraft Transport Performance Trends.
4. Conclusion
The study of all-purpose aircraft performance improvement trends with the study of performance changing trends shows that the new military aircrafts have not demonstrated a brainstorm design. Yet, engineering based on the aircraft development trends is quite promising.

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