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# RPAS SYSTEMS OVERVIEW AND CONFIGURATION TOOL

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## ABSTRACT

A tool to ease the configuration of Remotely Piloted Aircraft Systems (RPAS) is presented. Components are categorized according to ATA 100 chapter numbers and can be identified with the help of a growing database. Regulatory requirements for different RPAS classes are considered according to Austrian law, but the tool can be adapted for other countries. By this means, the overall system data for a particular unmanned aircraft is determined in terms of mass, volume and power. Additional sections in the software tool support the estimation of the system cost and provide calculation sheets for technical parameters based on performance specifications to simplify the selection of appropriate components.

## 1 INTRODUCTION

Unmanned Aerial or Aircraft Systems (UAS), often referred to as Remotely Piloted Aircraft Systems (RPAS), gain more and more importance not only for military operations, but also for civil applications, such as filming or search and rescue. Talking about RPAS is not just about a modern unmanned aircraft itself, the operation involves ground facilities, human-machine interfaces and other subsystems, as described in Figure 1.

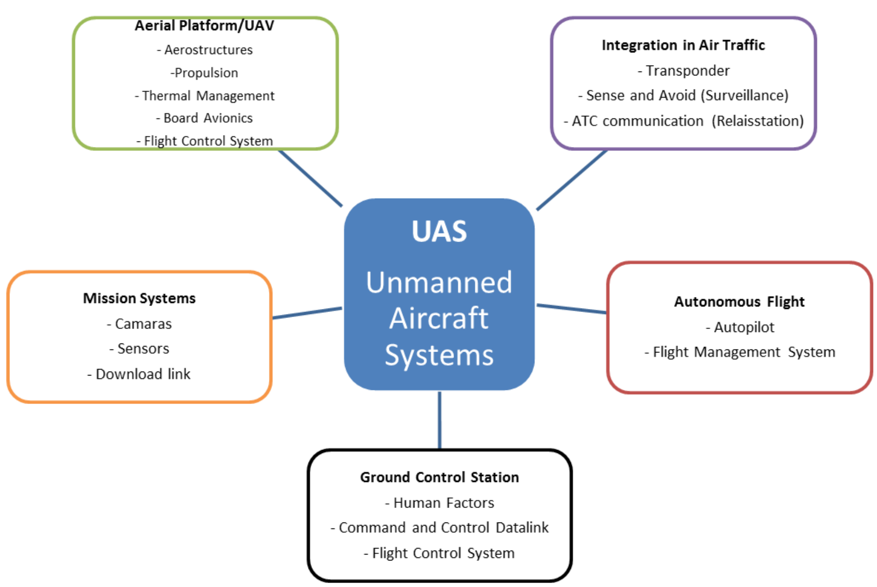


*Figure 1: Elements of Unmanned Aircraft Systems*

In this work, the focus is on supporting the development of civil unmanned aerial platforms up to 150 kg maximum take-off weight (MTOW), which are subject to national laws. Therefore a market research was conducted in order to identify potential suppliers and R&D companies for UAS components. On the other hand, possible customers were asked for their needs. Besides the development of an agenda for the focus of future research projects, one result was a database with an overview of already existing products.

## 2 LEGAL ASPECTS FOR RPAS

In Austria, according to national law, the operation of RPAS is officially possible since beginning of the year 2014. Regulations distinguish between two classes: Systems up to 150 kg MTOM (maximum take-off mass) operated within visual line of sight (VLOS) and up to an altitude of 150 meters above ground are covered within Class 1. Unmanned aircraft which do not meet these criteria need to be certified like any other civil aircraft, considering all conventional requirements (Class 2). For Class 1, systems are further divided into four categories A-D, according to the population at the area of application and MTOM, see Figure 2 [1, 2].

| | UAS Class 1 (VLOS) – Area of Operation | | | |
|---|---|---|---|---|
| | I undeveloped (no buildings) | II unpopulated | III populated | IV densely populated (except crowds) |
| MTOW up to and including 5 kg | A | A | B | C |
| MTOW up to and including 25 kg | A | B | C | D |
| MTOW above 25 kg and up to and including 150 kg | B | C | D | D |

*Figure 2: UAS Class 1 categories in Austria*

Other countries use slightly different categorizations, for which the configuration tool would have to be extended. The UK for example specifies a weight class 1 for "Light UAS" related to systems between 20 and 150 kg maximum zero fuel weight (MZFW). In France, 7 categories were defined, "Category F" being one of them for remotely piloted aircraft with MTOM between 25 and 150 kg. Four operational scenarios further describe if they are operated within line of sight, the deployable radius and consider the population at the area of operation. Germany was also one of the first nation developing UAS regulations in the EU, having many detailed responsibilities transferred to the federal states [3]. These examples indicate the variety of national requirements for lighter RPAS within Europe, which is also a motivation for the presented support tool.

## 3 RPAS CONFIGURATION TOOL

The RPAS configuration tool provides a basic design guideline, where the mandatory minimum equipment for every class and category can be easily identified. Equipment items are categorized following the ATA 100 referencing standards (ATA: Air Transport Association of America, respectively A4A: Airlines for America) [4]. Different configurations can be set up with the help of a growing database as source of information, including an overview of the components with appropriate manufacturers, product prices and technical data.

### 3.1 Equipment Classification

ATA 100 chapters are widely used for the documentation of commercial aircraft since the 1950s. The numbers consistently identify aircraft systems and parts for maintenance, logistics, design engineers and pilots. Every aircraft certified according to FAR 25 (Federal Aviation Regulation, US) and EASA CS-25 follows this classification. Although these particular certification specifications (CS) treat larger airplanes, the system provides a standard which also seems to be convenient for the use with smaller RPAS. Therefore it was chosen for the configuration tool. Table 1 shows some examples for the ATA referencing definitions.

| ATA NUMBER | ATA CHAPTER NAME | ATA NUMBER | ATA CHAPTER NAME |
|---|---|---|---|
| **GROUP: AIRFRAME SYSTEMS** | | **GROUP: STRUCTURE** | |
| ATA 22 | AUTO FLIGHT | ATA 53 | FUSELAGE |
| ATA 23 | COMMUNICATIONS | ATA 54 | NACELLES/PYLONS |
| ATA 24 | ELECTRICAL POWER | ATA 55 | STABILIZERS |
| ATA 27 | FLIGHT CONTROLS | ATA 57 | WINGS |
| ATA 28 | FUEL | **GROUP: POWER PLANT** | |
| ATA 32 | LANDING GEAR | ATA 61 | PROPELLERS |
| ATA 33 | LIGHTS | ATA 72 | ENGINE - RECIPROCATING |
| ATA 34 | NAVIGATION | ATA 79 | OIL |
| ATA 42 | INTEGRATED MODULAR AVIONICS | ATA 85 | FUEL CELL SYSTEMS |

*Table 1: Examples for ATA 100 chapter numbers*

### 3.2 Systems Overview

The systems overview is basically a summary of commercial off-the-shelf (COTS) components already identified and applicable for the use in RPAS. It provides technical data for the configurator and gives further information about the products. The data is also used for other utilities like the cost estimation. All devices are specified by criteria expressed in uniform data fields, for example an entry could contain the following:

Equipment Class: GPS/INS
ATA Chapter Reference: ATA 34
Manufacturer: Xsens
Model: MTi-G-700
Description: GPS-aided, IMU-enhanced GPS/INS
Dimensions in mm: 57 x 42 x 23
Total mass in g: 55
Input Voltage in V: 4.5 – 34 or 3.3
Max. Power Consumption in W: 1
IP Rating: IP 67 (encased)
Temperature in °C: -40 – 85
Vibration and Shock: MIL STD-20; 22000g
Interfaces: RS232/RS485/422/UART/USB
Max. Latency in ms: 2
Max. Output Frequency in kHz: 2
Price in € excl. VAT: 4000
WWW: http://www.xsens.com/en/general/mti-g-100-series

## 3.3 Sample Configuration

The result of a generic configuration for the Austrian Class 1 is presented, although systems up to Class 2, operated according to instrument flight rules (IFR), can be generally designed by the help of the tool. The example represents the lowest category A. The other categories are more restrictive and apply for RPAS capable of carrying a much higher payload or have a higher total system weight being operated above a more crowded ground environment. Besides a detailed component list, the result not only shows a total estimate for system weight, volume (without airframe) and required power (without propulsion), but also a basic economic calculation.

Figure 3 shows the section of the configuration tool used for the propulsion system. The ATA 100 reference is specified and mandatory items for the relevant category can be identified. The system data for the reference design is based on its aerodynamic behavior.

**RPAS Configuration Tool** FH JOANNEUM Luftfahrt / Aviation

| Equipment | | Mandatory Equipment | | | | | | System Data | | | | | RPAS Data | | | Total System Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Classification according Austrian Aviation Act (LFG 2013 §24c) | | | | | | (Reference Design: Class 1, MTOW 5 kg) - All-electric A/C | | | | | 4,39 kg | 0,401 dm³ | 21 W | 727 [EUR] |
| Class Category | ATA Ref. | Class 1 (A) | Class 1 (B) | Class 1 (C) | Class 1 (D) | Class 2 (VFR) | Class 2 (IFR) | No. used | Manufacturer /Type | Reference Mass | Reference Volume | Power rating | Mass [kg] | Volume [cm³] | Power [W] | Cost [EUR] |
| **2. Propulsion/Power Plant** | | | | | | | | | | | | | **2. Propulsion/Power Plant** | | | |
| Propeller/Rotor | 60 | (1) | (1) | (1) | (1-2) | (1-2) | (1-2) | 1 | Graupner CAM Prop | | | | 0 | 0 | | 7 |
| Engine | 72 | 1 | 1 | 1 | 1 | 1-2 | 1-2 | 1 | LiPolice LPA-3014/1 | 0,111 | 43 | | 0,111 | 43 | | 35 |
| Engine controls (per engine) | 76 | | | 1 | 1 | 1-2 | 1-2 | 1 | LiPolice ESC 40A | 0,36 | 18 | | 0,36 | 18 | | 45 |
| Fuel, Control/Drive Battery | 73, 24 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | LiPo Pack 3300mAh | 0,266 | 118 | | 0,532 | 236 | | 62 |
| Exhaust | 78 | | | | | | | | | | | | 0 | 0 | | |
| Oil | 79 | | | | | | | | | | | | 0 | 0 | | |
| Accessory gearboxes | 83 | | | | | | | | | | | | 0 | 0 | | |

*Figure 3: RPAS configuration for Class 1 UAS, propulsion system and final results*

### 3.4 Calculation Utilities

The required engine power can be determined by considering aircraft performance and design data like cruising speed, lift-to-drag ratio, total weight, motor and propeller efficiency. Such an estimation for cruise flight is shown in Figure 4, following Equations (1) - (4), where

$$F_L = L = m \cdot g \tag{1}$$

$$F_D = D = F_L \cdot \frac{1}{L/D} \tag{2}$$

$$P_D = P_c = F_D \cdot v_c \tag{3}$$

$$P_{Mot} = \frac{P_c}{\eta_{Mot} \cdot \eta_{Prop}} \tag{4}$$

| | | |
|---|---|---|
| Aircraft mass | m | 25 kg |
| Gravity | g | 9,81 m/s² |
| Motor efficiency | $\eta_{Mot}$ | 0,8 |
| Propeller efficiency | $\eta_{Prop}$ | 0,8 |

| |
|---|
| Inputs |
| Results |

**Motor power $P_{Mot}$ required during cruise**

| Lift-to-drag ratio L/D | Cruising speed $v_c$ 10 m/s (36 km/h) | 15 m/s (54 km/h) | 20 m/s (72 km/h) | 25 m/s (90 km/h) | 30 m/s (108 km/h) | 35 m/s (126 km/h) | 40 m/s (144 km/h) | 45 m/s (162 km/h) | 50 m/s (180 km/h) |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 1,92 kW | 2,87 kW | 3,83 kW | 4,79 kW | 5,75 kW | 6,71 kW | 7,66 kW | 8,62 kW | 9,58 kW |
| 3 | 1,28 kW | 1,92 kW | 2,55 kW | 3,19 kW | 3,83 kW | 4,47 kW | 5,11 kW | 5,75 kW | 6,39 kW |
| 4 | 0,96 kW | 1,44 kW | 1,92 kW | 2,40 kW | 2,87 kW | 3,35 kW | 3,83 kW | 4,31 kW | 4,79 kW |
| 5 | 0,77 kW | 1,15 kW | 1,53 kW | 1,92 kW | 2,30 kW | 2,68 kW | 3,07 kW | 3,45 kW | 3,83 kW |
| 6 | 0,64 kW | 0,96 kW | 1,28 kW | 1,60 kW | 1,92 kW | 2,24 kW | 2,55 kW | 2,87 kW | 3,19 kW |
| 7 | 0,55 kW | 0,82 kW | 1,09 kW | 1,37 kW | 1,64 kW | 1,92 kW | 2,19 kW | 2,46 kW | 2,74 kW |
| 8 | 0,48 kW | 0,72 kW | 0,96 kW | 1,20 kW | 1,44 kW | 1,68 kW | 1,92 kW | 2,16 kW | 2,40 kW |
| 9 | 0,43 kW | 0,64 kW | 0,85 kW | 1,06 kW | 1,28 kW | 1,49 kW | 1,70 kW | 1,92 kW | 2,13 kW |
| 10 | 0,38 kW | 0,57 kW | 0,77 kW | 0,96 kW | 1,15 kW | 1,34 kW | 1,53 kW | 1,72 kW | 1,92 kW |
| 11 | 0,35 kW | 0,52 kW | 0,70 kW | 0,87 kW | 1,05 kW | 1,22 kW | 1,39 kW | 1,57 kW | 1,74 kW |
| 12 | 0,32 kW | 0,48 kW | 0,64 kW | 0,80 kW | 0,96 kW | 1,12 kW | 1,28 kW | 1,44 kW | 1,60 kW |
| 13 | 0,29 kW | 0,44 kW | 0,59 kW | 0,74 kW | 0,88 kW | 1,03 kW | 1,18 kW | 1,33 kW | 1,47 kW |
| 14 | 0,27 kW | 0,41 kW | 0,55 kW | 0,68 kW | 0,82 kW | 0,96 kW | 1,09 kW | 1,23 kW | 1,37 kW |
| 15 | 0,26 kW | 0,38 kW | 0,51 kW | 0,64 kW | 0,77 kW | 0,89 kW | 1,02 kW | 1,15 kW | 1,28 kW |
| 16 | 0,24 kW | 0,36 kW | 0,48 kW | 0,60 kW | 0,72 kW | 0,84 kW | 0,96 kW | 1,08 kW | 1,20 kW |
| 17 | 0,23 kW | 0,34 kW | 0,45 kW | 0,56 kW | 0,68 kW | 0,79 kW | 0,90 kW | 1,01 kW | 1,13 kW |
| 18 | 0,21 kW | 0,32 kW | 0,43 kW | 0,53 kW | 0,64 kW | 0,75 kW | 0,85 kW | 0,96 kW | 1,06 kW |
| 19 | 0,20 kW | 0,30 kW | 0,40 kW | 0,50 kW | 0,61 kW | 0,71 kW | 0,81 kW | 0,91 kW | 1,01 kW |
| 20 | 0,19 kW | 0,29 kW | 0,38 kW | 0,48 kW | 0,57 kW | 0,67 kW | 0,77 kW | 0,86 kW | 0,96 kW |

*Figure 4: Utility to estimate engine/motor power required by the RPAS*

A continuative calculation gives an estimate for the weight of the energy source, see Figure 5 and [5]. For practical reasons, so far only batteries and fossil fuel are considered, but fuel cells and renewable energy sources could also be implemented in the future.

| | |
|---|---|
| Input values | |
| Equations | |

**ENVIRONMENT**

| | | | |
|---|---|---|---|
| Gravity | g | 9,81 | m/s² |
| Density | ρ | 1,225 | kg/m³ |

**AIRCRAFT DESIGN**

| | | | |
|---|---|---|---|
| Aircraft mass (MTOM) | $m_a$ | 19 | kg |
| Wing reference area | $S_{ref}$ | 2,746 | m² |
| Lift coefficient | $C_L$ | 0,233 | |
| Drag coefficient | $C_D$ | 0,0346 | |

**AERODYNAMICS**

| | | | |
|---|---|---|---|
| Lift force (level flight) | $F_L$ | 186,39 | N |
| Drag force (cruise) | $F_D$ | 27,68 | N |
| Lift to drag ratio | L/D | 6,734 | |
| Speed | v | 21,81 | m/s |
| | | 78,51 | km/h |
| Dynamic pressure | q | 291,32 | N/m² |
| Cruise power | $P_c$ | 603,63 | W |

**BATTERY-POWERED**

**MOTOR**

| | | | |
|---|---|---|---|
| Torque at cruise | $\tau_c$ | 1,52 | Nm |
| rpm at cruise | $n_c$ | 4750 | 1/min |
| Motor voltage at cruise | $U_m$ | 37 | V |
| Motor current at cruise | $I_m$ | 26 | A |
| Motor power at cruise (electrical) | $P_m$ | 962,00 | W |
| Angular velocity at cruise | $\omega_c$ | 497,42 | rad/s |
| Motor efficiency | $\eta_m$ | 0,79 | |

**PROPELLER (TURBINE)**

| | | | |
|---|---|---|---|
| Thrust achieved at cruise | $T_{AC}$ | 27,68 | N |
| Propeller efficiency | $\eta_p$ | 0,80 | |

**PERFORMANCE**

| | | | |
|---|---|---|---|
| Endurance at cruise | t | 1 | h |
| **Electrical Energy** | **E** | **962,00** | **Wh** |

**BATTERY**

| | | | |
|---|---|---|---|
| Battery specific energy | $e_b$ | 0,15 | kWh/kg |
| **Battery mass** | $m_b$ | **6,41** | **kg** |

**FOSSIL FUEL**

**ENGINE**

| | | | |
|---|---|---|---|
| Torque at cruise | $\tau_c$ | 1,52 | Nm |
| rpm at cruise | $n_c$ | 4750 | 1/min |
| Engine power at cruise (shaft) | $P_e$ | 756,08 | W |
| Angular velocity at cruise | $\omega_c$ | 497,42 | rad/s |
| Engine efficiency (combustion) | $\eta_e$ | 0,3 | |

**PROPELLER (TURBINE)**

| | | | |
|---|---|---|---|
| Thrust achieved at cruise | $T_{AC}$ | 27,68 | N |
| Propeller efficiency | $\eta_p$ | 0,80 | |

**PERFORMANCE**

| | | | |
|---|---|---|---|
| Endurance at cruise | t | 1 | h |

**FUEL**

| | | | |
|---|---|---|---|
| Fuel specific energy | $e_f$ | 11,5 | kWh/kg |
| **Fuel mass** | $m_f$ | **0,22** | **kg** |

**LIMITATIONS / NOTES**

Cruise only (level flight, no acceleration)
No gear box (gear ratio = 1)
No reduction of mass considered for combustion engines

*Figure 5: Utility to estimate fuel/battery weight required by the RPAS*

Such additional sections in the configuration tool support the selection process of actual products based on these technical specifications. Summarizing all values for the physical measures and total costs leads to the final result for the given RPAS concept, as shown in 3.3. Another optional part of the tool not shown here allows specifying overhead costs, resulting in an estimated sales price for manufacturers.

## 4 SUMMARY

The RPAS configurator provides a handy tool not only to identify minimum requirements for an UAS in a technical manner, but also supports the selection of single products by manufacturers, specifications and costs. The current implementation represents Austrian legislation, but can also be modified to meet regulations of other countries. The component database itself can be maintained independently of the configuration sheets. All that can be helpful for companies in order to ease the process of developing RPAS according to given law, and therefore stimulate a high potential market within a currently often conservative industry.

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