Development of VUT 001 MARABU aircraft

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Assoc. prof. Ing. Jaroslav Juracka, Ph.D.

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Technická 2, Brno, 616 69
Czech Republic
VUT 001 MARABU = Experimental aircraft to support development of systems for civil UAVs / UAS

TABLE OF CONTENTS

1. Introduction
2. Project VUT 001 MARABU
3. VUT 001 MARABU Systems
4. Prototype aircraft production and operation
5. Perspective Development and Conclusions
Major issues connected with development of UAVs:

- **Non-existence of widely accepted regulation requirements for development and operation of civil UAVs**
  
  Serious issue affecting development and testing of UAVs in civil airspace. Especially European airspace is „overcrowded“ and offers very limited possibilities for UAV development and operations. Use of special testing ranges may be very expensive.

- **Simultaneous development of 2 critical elements: Aerial Vehicle and Ground Control Station**
  
  Simultaneous development of 2 critical elements makes first flight tests risky.
Development of civil UAV platform supported by Ministry of Industry and Trade (Czech Republic), held together with industrial partners (2006-2009)

**Solution proposed by prof. Pistek**

- Development of a „Flying Platform“ *(at the first stage proposed as piloted aircraft with 600kg MTOW – to overcome legal issues)*

- Preparation of the experimental aircraft for integration of equipment and systems developed for UAVs *(based partially on COTS components)*. *and step-by-step integration of suitable UAV systems*

- Development of new propulsion units

**Project Partners**

**Coordinator:**
Letecký ústav (IAE)
FSI VUT v Brně, Technická 2, Brno,
**Responsible person:**
Prof. Ing. Antonín Píštěk, CSc.

**Partners:**
První Brněnská strojírna Velká Bíteš, a.s.,
Vlkovská 279, 595 12 Velká Bíteš

JIHLAVAN airplanes, s.r.o.,
Znojemská 824/64, 586 01 Jihlava

PLASTSERVIS-L, s.r.o.,
Nová Ves 48
Project definition

Regulation status (EASA, CAA, Traffic rules)
- Traffic at civil space .......Civil Permit to Fly, Civil standards, ....CAA approval
- UAV control equipment and application presumption, Equipment volume ......equivalent to pilot mass and volume
- Flight learning ...step by step .... 1 pilot and equipment ...Payload 180 kgs

Power plant
- Low and high altitude flights
- Long endurance .... Low consumption ....piston engine
- Testing of JET power

Future exploitation of aircraft for sport flying
- Possibility normal using of plane (2 pilots)
Industry interested in UAVs exists in Czech Republic

**Association of the Aviation Manufacturers (UAV Group)**

**Czech Unmanned Systems Manufacturers Association**

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**Brno University of Technology**
# Table of Contents

1. Introduction

2. Project VUT 001 MARABU

3. Concept Development

4. VUT 001 MARABU Systems

5. Prototype aircraft production

6. Perspective Development and Conclusions

HERTI (developed in Warton, UK).
**Early Development**

**Variant A** Czech piston engine M 132 and twin boom fuselage concept

**Variant B**
Two TJ100A jets on rear part of the fuselage

**Variant C**
Rotax piston engine and butterfly tail unit

**History of VUT 001 Marabu concepts**
Final variant uses many existing components (i.e. structure of the wing, horizontal tail unit, selected aircraft systems).

All-metal outer wing and wing centre section. Fuselage from composite materials.

Final version of VUT 001 MARABU with combination of ROTAX 912 and jet TJ100 engines.

Removable nose from glass fiber composite.
• CAD approach was used from conceptual design through preliminary design up to detail digital model of the prototype.

• Aerodynamic concept was optimized using CFD methods to enable excellent performance characteristics.

<table>
<thead>
<tr>
<th>VUT 001 Marabu characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geometry</strong></td>
</tr>
<tr>
<td>Wingspan</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Height</td>
</tr>
<tr>
<td><strong>Weights</strong></td>
</tr>
<tr>
<td>Max. take-off</td>
</tr>
<tr>
<td>Empty</td>
</tr>
<tr>
<td>Max. fuel</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
</tr>
<tr>
<td>Max. speed</td>
</tr>
<tr>
<td>Endurance</td>
</tr>
</tbody>
</table>
• Structure of the fuselage was designed using composite materials to enable light and stiff structure.

• Modern FEM for structural analysis were applied to further reduce weight of the structure and to enable quick definition of dimensions for critical structural parts.
| 1. Introduction |
| 2. Project VUT 001 MARABU |
| 3. VUT 001 MARABU Systems |
| 4. Prototype aircraft production and operation |
| 5. Perspective Development and Conclusions |
Major requirements on VUT 001 MARABU systems:

• **Movement to More-Electric-Aircraft (MEA) concept:**
  Target is to make as many systems as possible electrically driven. This will enable smooth step-by-step transition from fully piloted aircraft (today) into fully automatic aircraft (in the future).

• **Step-by-step integration of UAV systems should be enabled:**
  Based on the statistical analysis, most UAVs are designed with max. take-off weight of 600kg or less (88% of designed UAVs).
  Proposed experimental aircraft provides enough space and typical electric system for integration of majority of developed equipment.

• **Provisions for back-up of critical systems:**
  Provisions to optionally attach second alternator were made to provide back-up function and to increase an overall capacity of the electric system for future experimental applications.
Comparison of systems in typical conventional aircraft and VUT 001 Marabu

<table>
<thead>
<tr>
<th>System</th>
<th>Conventional Aircraft (FAR-LSA, CS-VLA)</th>
<th>VUT 001 MARABU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Flight Controls</td>
<td><strong>Mechanical</strong> (push/pull rods, cables, etc.)</td>
<td><strong>Mechanical</strong> (push/pull rods, cables, etc.) – provisions are done to mount autopilot servos</td>
</tr>
<tr>
<td>Trim System</td>
<td><strong>Mechanical</strong> (cables, etc.)</td>
<td><strong>Electrical</strong> (elevator, rudder)</td>
</tr>
<tr>
<td>Flaps Extension/Retraction</td>
<td><strong>Mechanical</strong> (push/pull rods)</td>
<td><strong>Electrical</strong> (electromechanical strut)</td>
</tr>
<tr>
<td>Electric System</td>
<td>Simple with <strong>1 alternator</strong> and <strong>1 battery</strong> (optionally, second alternator to increase capacity is used interconnected with the single battery used also for ALT1)</td>
<td><strong>2 alternators</strong> and <strong>2 batteries</strong> create redundant system with two independent channels. Additional independent channels can be supplied by own energy sources (batteries, fuel cell stacks, etc.).</td>
</tr>
</tbody>
</table>
VUT 001 Marabu Controls

electro-mechanical strut (FLAPS)

trim servos

elevator controls
aileron controls
rudder controls
control sticks
wing flap controls

autopilot servos
1. Introduction
2. Project VUT 001 MARABU
3. VUT 001 MARABU Systems

4. Prototype aircraft production and operation

5. Perspective Development and Conclusions
Prototype aircraft production

Fuselage production
Specific at academic environment

All activities were in large extend performed by young engineers, researchers and students at the university. This could be done as a result of IAE’s long time activities focused on building of capacities for research and development.
Prototype aircraft production

First positive model

Final bonding of prototype
Prototype aircraft production

First engine test

Fuselage test
Required structure tests:
- Wing tests – Ultimate load
- Centroplane test – Ultimate load
- Test of Ailerons – Ultimate load
- Test of Flaps – Ultimate load
- Winglet test – Ultimate load
- Fuel tank test - Ultimate load
- Fuselage test – Ultimate load
- Stabilizer and elevator tests – Ultimate load
- Seats and seat belts joint tests – Ultimate load
- Engine mount test – Ultimate load
- Control system – Limit load
- Nose landing gear – drop tests
- Main landing gear – drop tests
- ...
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- Wing tests – Ultimate load
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- Engine mount test – Ultimate load
- Control system – Limit load
- Nose landing gear – drop tests
- Main landing gear – drop tests
-...
Prototype aircraft production

Final prototype assembly
Requirements of Czech CAA (before first take-off)

- Ground tests:
  - Mass and centre of gravity definition
  - Airplane leveling, real control surfaces definition
  - Test of pitot-static system
  - Engines test + static thrust measurement
  - Board instruments calibration
  - Test of electric system
  - Test of fuel system
  - Test of flaps operation
  - Taxing capability and stability

- Flight manual
- Maitenance manual
- Instruction for test flights
Permit to Flight

Final prototype assembly

10th European Workshop on Aircraft Design Education

ÚřAD PRO CIVILNÍ LETECTví
CIVIL AVIATION AUTHORITY

ČESKÁ REPUBLIKA
CZECH REPUBLIC

ÚŘAD PRO CIVILNÍ LETECTví
CIVIL AVIATION AUTHORITY

ČESKÁ REPUBLIKA
CZECH REPUBLIC

ZVLÁŠTNÍ OSVĚDČENÍ LETOVÉ
ZPŮSOBILOSTI

SPECIAL CERTIFICATE OF AIRWORTHINESS

Č/No ZOLZ-5530

<table>
<thead>
<tr>
<th>1. Název a šifra</th>
<th>2. Výrobce a typ letadla</th>
<th>3. Výrobní číslo</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK-VUT</td>
<td>Výsoké učení technické v Brně</td>
<td>001</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Číslo okruhu</th>
<th>Název okruhu</th>
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<td>OK-VUT</td>
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<table>
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<tr>
<th>4. Kategorie</th>
<th>Categorie</th>
</tr>
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<tbody>
<tr>
<td>Experimental - Experimental</td>
<td></td>
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</tbody>
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<thead>
<tr>
<th>Poznámky:</th>
<th>Rozsah provedení výkonnosti:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Pilot musí být držitelem kvalifikace &quot;zkušený pilot bez omzezení&quot;, dle AIC 4/94</td>
<td></td>
</tr>
<tr>
<td>1. (a) lety v letech 1,1.a) a 1,1.b) Li/II dodatek C musí být provedeny za dodržení podmínek stanovených v SOUHLASU S PROVEDENÍM ZKUŠEBNÍHO LETU (série letů) č. 4176-69-481 a pouze v rozsahu programu schváleného Úřadem.</td>
<td></td>
</tr>
<tr>
<td>2. Pilot musí být všichni vyvolaní záchranným padákem</td>
<td></td>
</tr>
<tr>
<td>3. Pilot musí informovat v souladu s Č.40. Li/II dodatek C</td>
<td></td>
</tr>
</tbody>
</table>

Tímto letadlo není přizpůsobeno pro lety nad územím jiného státu nebo povoleným jiným letci.

This aircraft shall not be operated over any other country without Civil Aviation Authority permission of that country.

Datum vydání: 30-11-2009

Místo vydání: Brno

VUT v BRNĚ

Úřad pro civilní letecké České republiky
Výkonné centrum v Brně

Úřad pro civilní letecké České republiky
Výkonné centrum v Brně

Výkonné centrum v Brně

ROZHODNUTÍ

Společnost: Firma strojírenství pro letecký let

Souhlas s provedením zkoušebního letu

Výslovnost číslo: 3-491-14-491

Rozšíření: Technická 2896/2

Rozšíření: 6144-69-691

Dle čl. 36 letová licence

Úřad pro civilní letech České republiky

Výkonné centrum v Brně

Úřad pro civilní letech České republiky

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Úřad pro civilní letech České republiky
VUT 001 Marabu took-off for the first time on 29th April 2010.

First test flights were performed in Kunovice (south east part of the Czech Republic).

Test-pilot Stanislav Sklenar reported excellent handling and performance characteristics.
Experimental airplane VUT 001 Marabu was recently awarded with Gold Medal MSV 2010.

MSV 2010 = the largest presentation of industrial technologies in the area of Central Europe.
First cross-country fly

Fly from LKKU to LKJI for next test flights

Test-pilot Jaromir Hammer

Brno University of Technology
Aerodynamic polar – significant influence of fuselage-wing interference drag
10th European Workshop on Aircraft Design Education

Flight Tests

Brno University of Technology
# Table of Contents

1. Introduction
2. Project VUT 001 MARABU
3. Concept Development
4. VUT 001 Marabu Systems
5. Prototype aircraft production

6. Perspective Development and Conclusions
Applications and perspective development of VUT 001 Marabu

A) UAV activities

• **Finalization** of full UAV version – automatic control system
• **Development of sensors and components** for critical systems of UAVs
• **Low cost testing** of equipment for various missions
• **Simulation** of different mission profiles

B) Non-UAV applications

• **Flight measurements of characteristics** for developed jet engines
• **Development and production of VUT 061 Turbo** – modification for turboprop engine TP-100 (180kW)
• **Development and production of VUT 051 Ray** – modification for non-conventional propulsion (electric engine, on-going activity)
Small jet engine developed in PBS, Velká Bíteš.

**TJ 100M**

**TJ100M** jet engine with thrust up to 1100N designed for UAV applications

Yabhoon aerial target (uses TJ100)
Perspective Development of VUT 001 Marabu

VUT 061 Turbo
Thank you for your attention ...

Acknowledgment

Some of the presented activities were supported by Ministry of Industry and Trade (in the frame of grant project FI-IM3/041).
READ 2012
Brno, June 2012

RRDPAE 2008

Detail information will be published on http://lu.fme.vutbr.cz
We are looking for aerodynamics, structure experts

Detail information are published on

http://www.cedesa.eu