Development of a Low Cost Suborbital Rocket for Small Satellite Testing and In-Space Experiments

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(extended presentation)

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WEPA-Technologies GmbH
Introduction: WEPA-Technologies GmbH
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- **Background**
  - Founded in 2011 via spin-off (origin: mechanical engineering company)

- **Company focus**
  - Engineering-, Automation- and Aerospace-Solutions

- **Business premises**
  - 700m² work shop area
  - 150 m² office space

=> R&D focussed engineering office and manufacturing company
Business Activities
Business Activities (Manufacturing)

Generell

- Planning, development and realization of non-standard solutions
- Manufacturing of prototypes and small lots (company owned workshop)
- Broad range of manufacturing technologies
  - CNC-machining
    - Turning (max. 1.4 m diameter x 4 m length) (up to 4 axis)
    - Milling (max. 3.0 m x 0.8 m x 0.8 m) (up to 5 axis)
    - Metal spinning
    - Wire eroding
  - Conventional machining
    - Grinding, welding, sheet metal work
- Public references include…
  - CASSIDIAN GmbH (Airbus Defence & Space)
  - Dynamit Nobel Defence GmbH
  - EU-customer (H₂O₂ - concentration plant)
Business Activities (Rocket Technology)

Business and development segments

- Rocket technology (development)
  - Propulsion
    - Liquid propellant rocket engines (LPRE)
    - Turbo pumps for LPRE
    - Solid rocket motors (SRM)
  - (Complete systems)
    - Suborbital sounding rockets (propulsion unit)
    - \( \text{H}_2\text{O}_2 \) - concentration plants (max. 98 %)

- Engineering (business)
  - Construction and manufacturing of mechanical parts

- Automation (business)
  - Focus on control retrofits of CNC-machine tools

CASSIDIAN contract development
(Airbus Defence & Space)
solid rocket motor test (thrust: 20 kN)
CASSIDIAN contract development
(Airbus Defence and Space)

solid rocket motor test
(specified thrust: up to 20 kN)

max. thrust: 14.5 kN

http://www.wepa-technologies.de/references/cassidian-eads/
Use of Sounding Rockets in PiNa-Development
Pre-testing of technology components

- Transport of satellites to LEO or beyond comes along with long lead time and costs up to 100 kEUR / kg (still secondary payload rides!)
  - Very reliable systems required to guarantee long term operability in orbit!

- Some pre-testing can be conducted on Earth, other require space specific conditions
  - Zero-gravity, high vacuum, cosmic radiation or communication over long distance (Earth ↔ LEO)

- Repeatability of testing important
  - Realization of test sequences via sounding rocket flights possible
Conceptional Design of Sounding Rocket „SILBERPFEIL“ („Silver Arrow“)
By far most sounding rockets use Solid Rocket Motor propulsion systems

- Surplus military motors
  - ready availability not always given
- Very high acceleration of vehicle
  - significant stress on payload
- Thrust / time profile and total impulse cannot be modified
- Safety and cost issues using solid propellants
  - regulations for “explosives” becoming even more stringent:
    - transport
    - storage
    - handling / on site integration

Conclusion: Solid Rocket Motors show significant disadvantages for frequent low cost launches!
Advantages of Liquid Propellant Rocket Engines

- Completely safe handling of rocket during payload integration, handling and transport (=> fuel tanks empty)
  - no stringent safety regulations to be followed
- Low peak acceleration
  - low stress on payload
- Launch readiness can be kept up for many weeks: responsive, very low lead time launch possible (while using storable, H$_2$O$_2$ oxidizer)
- Environmentally friendly (“green”) propellants (while using H$_2$O$_2$ or O$_2$ oxidizer and Kerosene fuel)

Conclusion:
Liquid propellant rocket engines show significant advantages for frequent launches …but have to be made low-priced!
Low cost characteristics of sounding rockets can be achieved by multiple, parallel approaches (focus: propulsion system):

- Significantly reduced safety regulations due to avoidance of explosives (solid propellants)
- Simplified design of propulsion system (rocket engine and turbo pumps)
- Low level operational parameters (chamber pressure)
- Environmentally benign and easy to handle propellant components (H₂O₂ / Kerosene)
- Simple tank structures / no thermal isolation; common bulkhead
- Low-cost materials and manufacturing technologies
  - avoid typical aerospace grade materials and manufacturing processes
- Simple guidance systems / thrust vector control for ballistic flight required

Goal: 1900 – 3800 EUR / kg @ 400 kg (300 km) payload (0,75 – 1,5 Mio EUR)
  - Depending on flight rate and depreciation of development costs
  - Ground support not included
Payload section is very specific to mission requirements
   - Can be adapted to customers needs: length, diameter, total mass

Choose representative (commercial) payload size: TEXUS module (DLR, ~ 400 kg)
   - Advantages: qualified equipment could be re-used (data acquisition + downlink, power supply, telemetry, recovery systems…)

Use 35 kN technology demonstrator engine
   - Thrust / time profile could be adapted to mission’s needs
TEXUS: SRM vs. LPRE-Propulsion? Different Concepts

TEXUS Sounding Rocket

COHETE VSB-30

DLR / 

TEXUS Sounding Rocket

identification payload and recovery module

alternative concept: WEPA / TU-Dresden
(PL: 400 kg, h\text{max}: \sim 300 km)

Solid Rocket Motor(2)

LPRE-Booster: 35 kN thrust
\( \text{H}_2\text{O}_2 / \text{Kerosene} \)
35 kN @ SL

credit: H. Voigt (2015)
### Conclusion:
- Identical max. height (300 km) and payload capacity (400 kg)
- Significantly reduced maximum acceleration => lower stress on payload (4.7 g vs. 12 g)
- Comparable GLOW and outer envelope of complete system
- Reduced safety requirements: no danger during handling, transport, storage
- (Reliable availability of propulsion modules)

### Summary of results: TExUS Module via LPRE booster

#### Comparison of Main Parameters:

<table>
<thead>
<tr>
<th>Payload: TEXUS-module</th>
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<tr>
<td>VSB-30 base case</td>
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<thead>
<tr>
<th>Overall System</th>
<th>DLR-Standard</th>
<th>DLR-Standard</th>
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<tbody>
<tr>
<td>payload / communication / recovery</td>
<td>~ 270</td>
<td>~ 300 [km]</td>
</tr>
<tr>
<td>max. height of flight</td>
<td>2500</td>
<td>2700 [kg]</td>
</tr>
<tr>
<td>GLOW</td>
<td>0.57</td>
<td>0.7 [m]</td>
</tr>
<tr>
<td>max. diameter</td>
<td>12.6</td>
<td>13.2 [m]</td>
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</tbody>
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<table>
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<tr>
<th>Payload Module incl. Recovery</th>
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<tbody>
<tr>
<td>length</td>
</tr>
<tr>
<td>diameter</td>
</tr>
<tr>
<td>mass</td>
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<thead>
<tr>
<th>Propulsion System</th>
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<tbody>
<tr>
<td>number of stages</td>
</tr>
<tr>
<td>propellants</td>
</tr>
<tr>
<td>propellant mass</td>
</tr>
<tr>
<td>max. acceleration</td>
</tr>
<tr>
<td>burn time</td>
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</table>

*credit: H. Voigt (2015)*
TEXUS: alternative propulsion concept
WEPA-Technologies / TU-Dresden
(PL: 400 kg, $h_{\text{max}}$; ~ 300 km)

F: 35 kN @ SL
($\text{H}_2\text{O}_2$ / Kerosene)

Zero Gravity: ~ 7 Min

depending on recovery system

credit: H. Voigt (2015)
Alternative propulsion concept
WEPA-Technologies / TU-Dresden
(PL: 400 kg, \( h_{\text{max}} \); \( \sim \) 300 km)

\( F: 35 \text{ kN @ SL} \)
\((\text{H}_2\text{O}_2 / \text{Kerosene})\)
Enabling Technologies of Sounding Rocket „SILBERPFEIL“:
- \( \text{H}_2\text{O}_2 \)-Concentration Plants
- Liquid Propulsion Rocket Engines
- Turbo Pump Units
H$_2$O$_2$-Concentration Technology
Motivation
- Due to non-cryogenic nature of H₂O₂ overall system architecture is significantly reduced (no isolation required, no formation of ice, less complicated TPU)
- H₂O₂-based propulsion systems show very high operational reliability
- Very high strength H₂O₂ required for high performance propulsion systems
- Increase of H₂O₂ concentration (85 => 95 %): identical payload capacity compared to LOX (outer envelope kept constant !)

(see section “Micro Satellite Launch Vehicle” / WEPA-Presentation at SpacePropulsion 2014: http://www.wepa-technologies.de/news/june-2014/)

Commercial supply situation (present)
- Very limited availability at c > 88 %
- Transport via public ground prohibited by law
  => on site production in specialized plants required !
- Small production plants cannot be rented, only bought
  (> 1,8 Mio EUR, ~ 1 kg H₂O₂ / h)
  => not very attractive situation for developing / using H₂O₂ - based propulsion processes…. 
Supply of $\text{H}_2\text{O}_2$ (c > 88 - 98 %)

- $\text{H}_2\text{O}_2$ concentration plant developed by WEPA-Technologies for EU-customer
  - Capacity: up to ~ 40 kg / d (- 90 %)
  - Feed: 50 % - 70 % $\text{H}_2\text{O}_2$
  - Fully automatic, 24 / 7 operability

- Working packages supplied by WEPA-Technologies
  - Conceptional process design incl. safety concept
  - Detail Engineering (process-, control- and electrical diagrams)
  - Equipment purchase
  - Erection and commissioning

Reference plant open to customer visits (final commissioning: 10/2015)

- Very safe production process up to 98 % concentration under development (10 kg / h)
Supply of $\text{H}_2\text{O}_2$ (90 %) : Reference Plant

EU - customer
Development of Liquid Propellant Engines
Overview

- **Goal:** construction of low cost engines
  => Significant reduction of development and production costs required

- **Approach:** improve designs based on proven technologies
  (USA / USSR / Europe 1960 – 1980)

- **Use of ‘green propellants’** (LOX / H₂O₂ : EtOH / Kerosin)
  => No significant environmental issues (test & launch area)

- **Thrust range:** 10 – 60 kN
  - increase to level of 100 – 200 kN mid term goal

- **Present development:** 35 kN technology demonstrator
  - Chamber pressure: 5 MPa
  - Exit pressure: 0,5 MPa
  - Regenerative cooling
Turbo Pump Units
Goal: minimize engineering, testing and manufacturing effort by low level operational parameter
- Exit pressure: max. 75 bar
- Operating point: max. 30,000 RPM
- Open gas generator cycle (H₂O₂ or LOX / Kerosene)

Propellant systems: H₂O₂ / Kerosene (LOX / Kerosene)

Mass flow rate: ~ 14.5 kg/s H₂O₂ / Kerosene (35 kN engine)

Weight: max. 35 kg (incl. gas generator + control unit)

Arrangement: Turbine – H₂O₂ – Kerosene (Turbine – Kerosene – LOX)
General Development Strategy: Rocket Technology
Present Development Strategy

Key development fields

Turbo Pump

35 kN LPRE

LOX / EtOH

(p_c: 50 bar / I_sp: 250 s)

H_2O_2 – concentration
Plants (max. 98 %)

H_2O_2 (95 %) / Kerosene
- non cryogenic stage
- simplified design
- high system reliability
(relevant in upper stages !)

Potential customer applications

Micro Satellite
Launch Vehicle; f. ex.
- 50 – 100 kg LEO
- 9 – 10 to GLOW
- 3 stage design
→ stage 1: 4 x 35 kN
→ stage 2: 1 x 35 kN

Sounding Rockets
Summary
Summary

- Basic design parameter of a LPRE-propelled sounding rocket ("SILBERPFEIL") were described
  - Due to non-cryogenic nature of H$_2$O$_2$ overall system architecture is significantly reduced

- TEXUS payload module (400 kg) has been chosen for reference
  - 300 km height / ~ 7 min zero-g time
  - Other geometries / masses of payload section can be considered

- WEPA-Technologies is developing key propulsion-technologies (LPRE resp. turbo pumps) and H$_2$O$_2$ - concentration plants independent of the realization of sounding rocket projects

- To initiate development of the payload section and complete sounding rocket WEPA-Technologies is open to cooperations
Poster Session
Thank you for your attention!