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

8th Pico- and Nanosatellite Workshop (PiNa2015)

Würzburg, 2015-09-15

(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**
  - **700m^2 work shop area**
  - **150 m^2 office space**

=> R&D focussed engineering office and manufacturing company

Business Activities

Business Activities (Manufacturing) 1

Generell

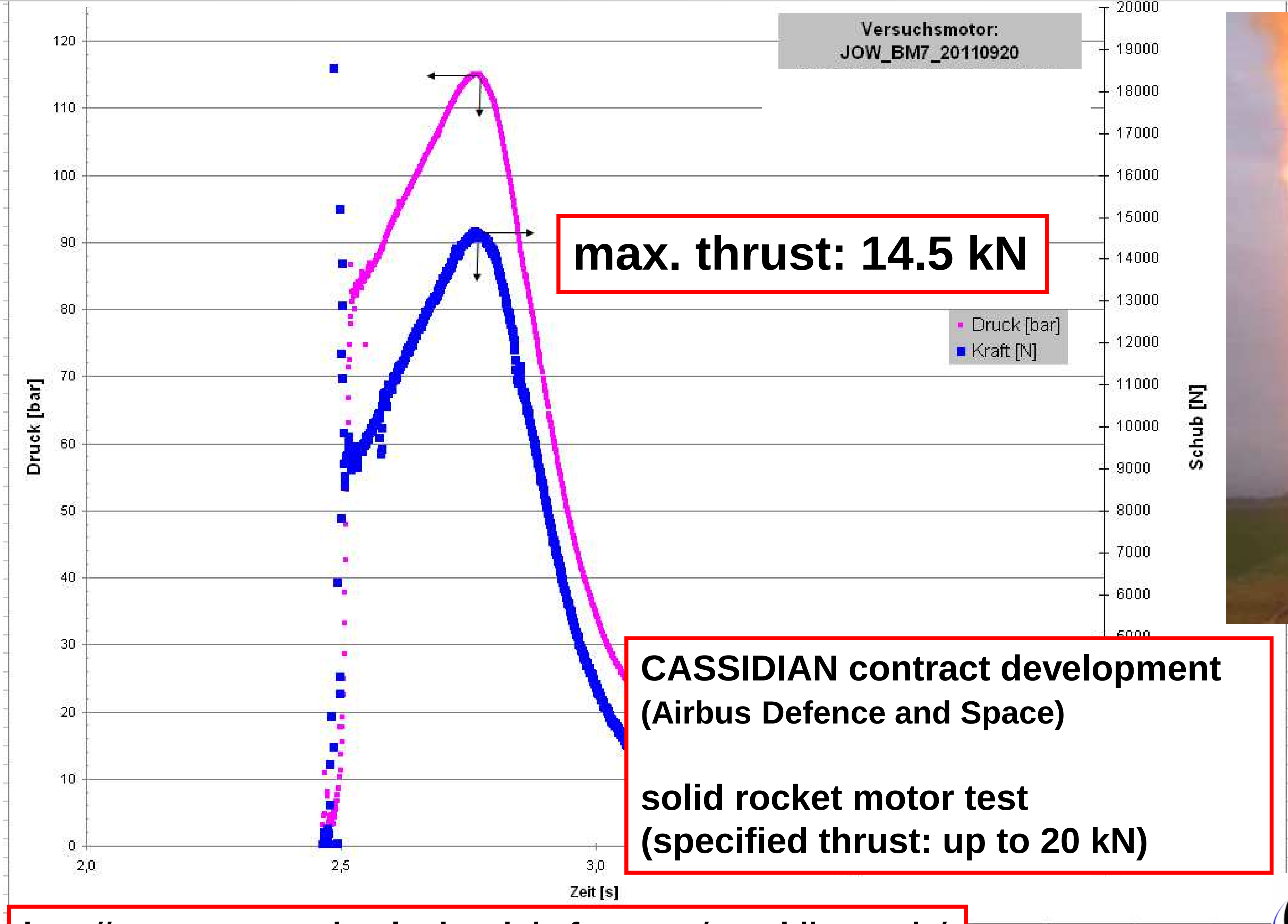
- **<u>Planning, development and realization of non-standard solutions</u>**
- **Manufacturing of prototypes and small lots (company owned workshop)**
- **Broad range of manufacturing technologies**
  - **CNC-machining**
    - **Turning (max. 1.4 m diameter x 4 m length) (up to 4 axis)**
    - **Milling (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 (H_2O_2 - concentration plant)**

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)**
    - **H_2O_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)

Business Activities (Rocket Technology)



max. thrust: 14.5 kN

CASSIDIAN contract development
(Airbus Defence and Space)

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

http://www.wepa-technologies.de/references/cassidian-eads/

Technologies

Use of Sounding Rockets in PiNa-Development

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“)

Central Design Decision: Liquid- or Solid Propellant Rocket Engines ? 1

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 !

Central Design Decision: Liquid- or Solid Propellant Rocket Engines ?

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_2O_2 oxidizer)
- Environmentally friendly ("green") propellants (while using H_2O_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 !

Central Design Goal: Low Cost !

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 (H_2O_2 / 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

Preliminary Design of Sounding Rocket: Definition of Payload Section

- 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

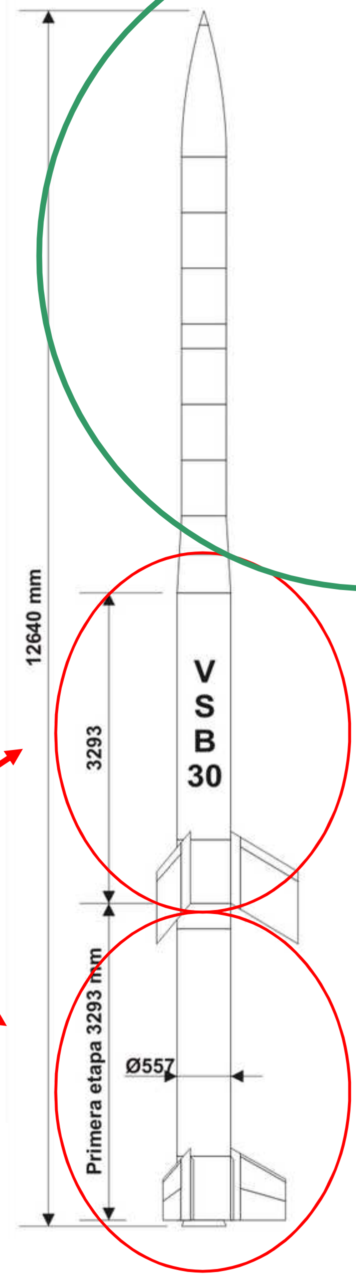
TEXUS
Sounding Rocket

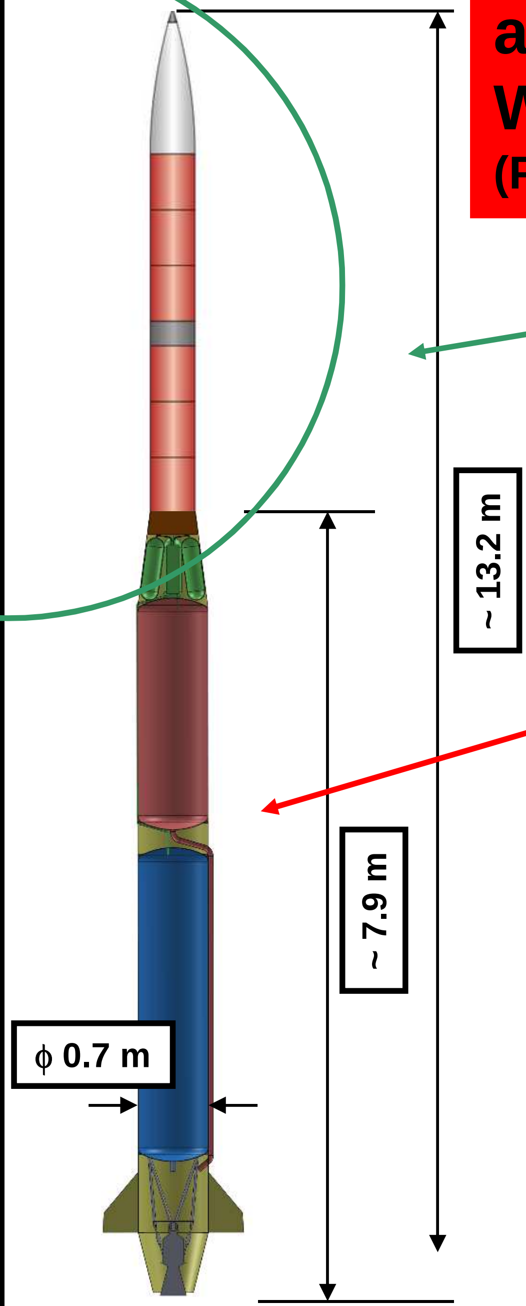
DLR /

COHETE
VSB-30

Características principales
Masa total 2579 kg
Masa de carga útil 400 kg
Apogeo estimado 270 km

Solid Rocket Motor(2)





alternative concept:
WEPA / TU-Dresden
(PL: 400 kg, h_{max}; ~ 300 km)

Identical Payload and Recovery Module

LPRE-Booster: 35 kN thrust
(H_2O_2 / Kerosene)
35 kN @ SL

credit: H. Voigt (2015)

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Summary of results: TEXUS Module via LPRE booster

Comparison of Main Parameters:

Payload: TEXUS-module

	VSB-30 base case	WEPA / TU-DD concept	
Overall System			
payload / communication / recovery	DLR-Standard	DLR-Standard	
max. height of flight	~ 270	~ 300	[km]
GLOW	2600	2790	[kg]
max. diameter	0,57	0,7	[m]
total length	12,6	13,2	[m]
Payload Module incl. Recovery			
length	4,5 - 5,5	4,5 - 5,5	[m]
diameter	0,44	0,44	[m]
mass	max. 400	max. 400	[kg]
Propulsion System			
number of stages	2	1	[-]
propellants	solid	liquid	[-]
propallant mass	~ 1575	2050	[kg]
max. accelaration	~ 12	4,65	[g]
burn time	31 (11 + 20)	125	[s]

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)

credit: H. Voigt (2015)

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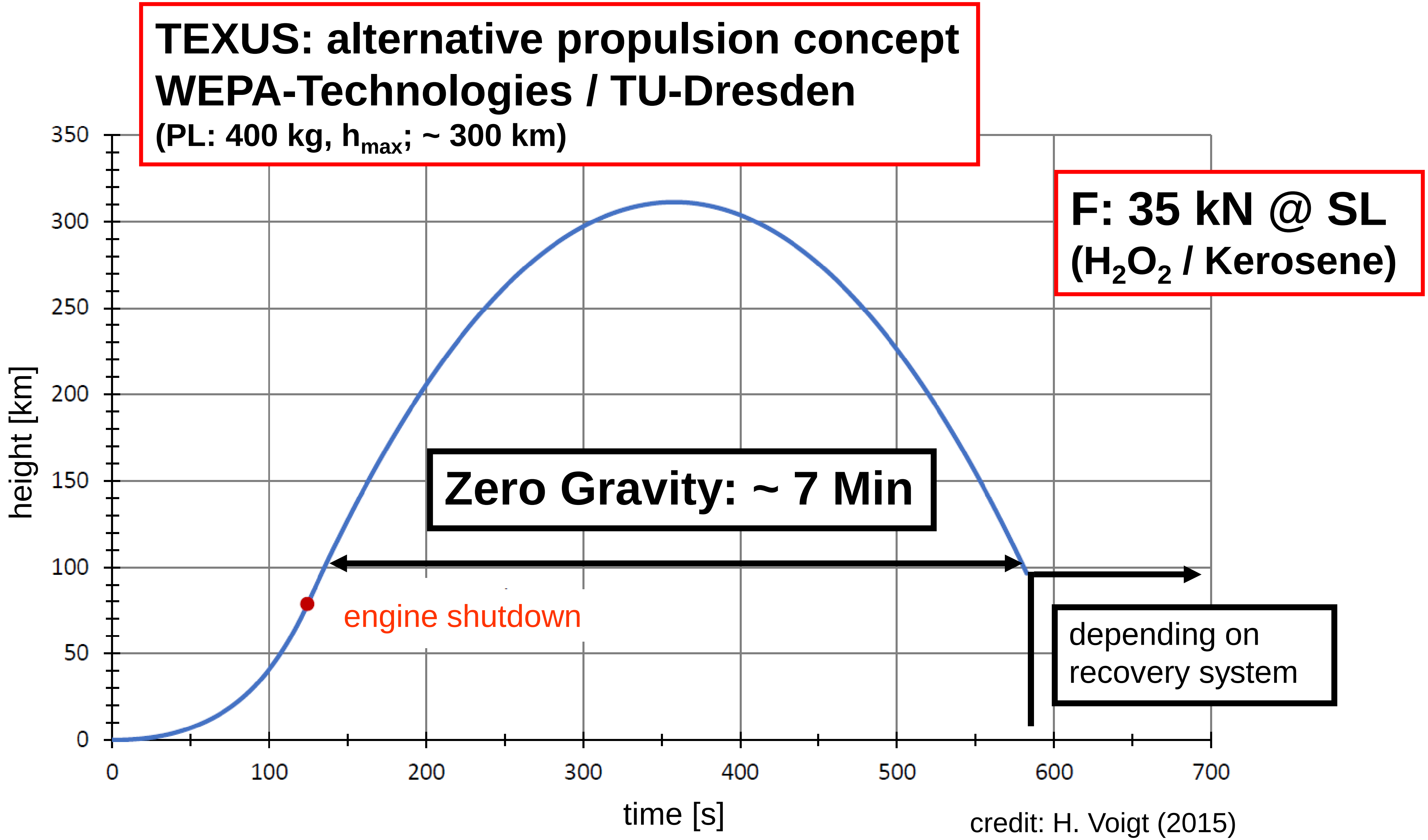
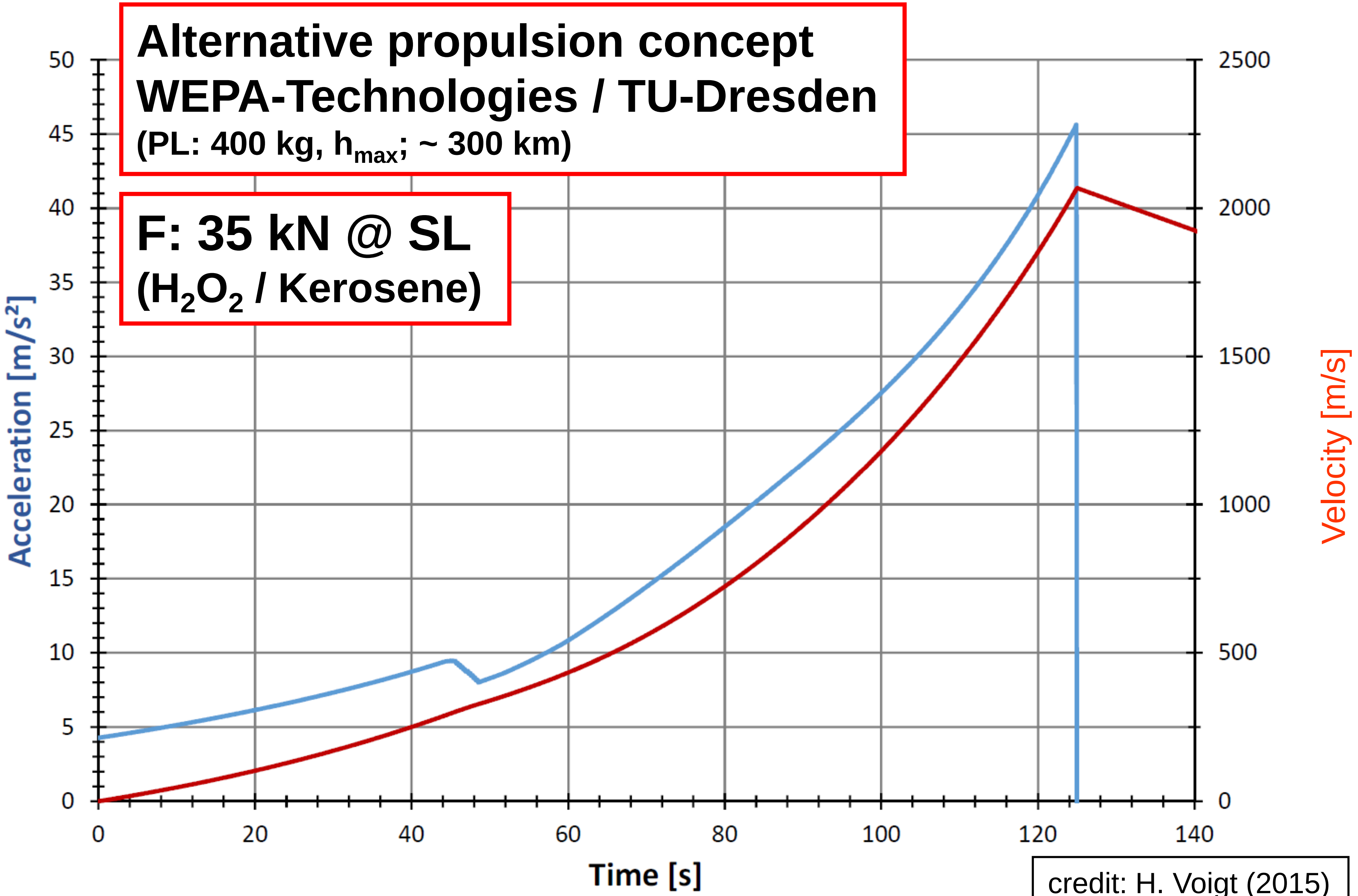
TEXUS Module via LPRE Booster: Simulated Trajectory 1



credit: H. Voigt (2015)



credit: H. Voigt (2015)

Enabling Technologies of Sounding Rocket „SILBERPFEIL“:

- H_2O_2-Concentration Plants
- Liquid Propulsion Rocket Engines
- Turbo Pump Units

WEPA Technologies

H_2O_2-Concentration Technology

Supply of H_2O_2 (c > 88 - 98 %)

- **Motivation**
  - Due to non-cryogenic nature of H_2O_2 overall system architecture is significantly reduced (no isolation required, no formation of ice, less complicated TPU)
  - H_2O_2-based propulsion systems show very high operational reliability
  - Very high strength H_2O_2 required for high performance propulsion systems
  - Increase of H_2O_2 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

    => <u>on site production in specialized plants required !</u>
  - Small production plants cannot be rented, only bought (> 1,8 Mio EUR, ~ 1 kg H_2O_2 / h)

  => not very attractive situation for developing / using H_2O_2 - based propulsion processes….

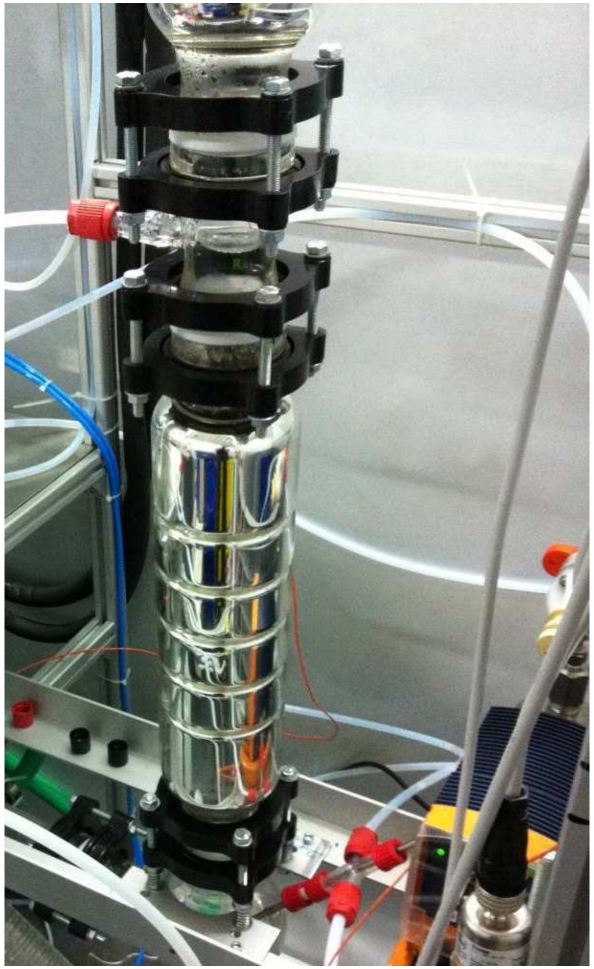
Supply of H_2O_2 (c > 88 - 98 %)

- **H_2O_2 concentration plant developed by WEPA-Technologies for EU-customer**
  - **Capacity: up to ~ 40 kg / d (- 90 %)**
  - **Feed: 50 % - 70 % H_2O_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 H_2O_2 (90 %) : Reference Plant



EU - customer

WEPA Technologies

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 / H_2O_2 : 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

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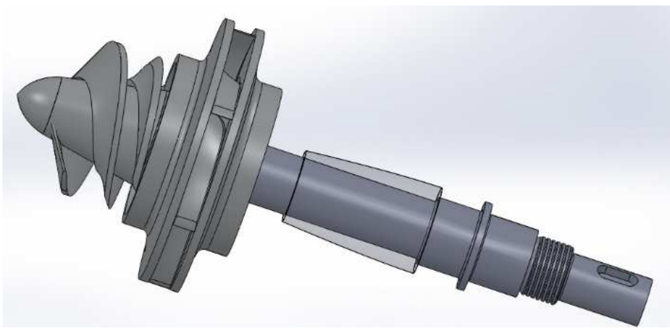
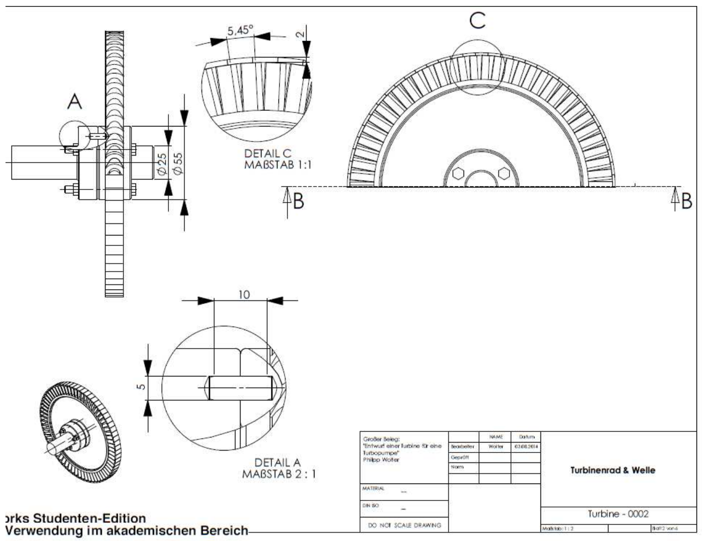
Turbo Pump Units

Current Development: Turbo Pump Units – overview 1

- 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 (H_2O_2 or LOX / Kerosene)
- Propellant systems: H_2O_2 / Kerosene (LOX / Kerosene)
- Mass flow rate: ~ 14.5 kg/s H_2O_2 / Kerosene (35 kN engine)
- Weight: max.35 kg (incl. gas generator + control unit)
- Arrangement: Turbine – H_2O_2 – Kerosene (Turbine – Kerosene – LOX)





credit: H. Zetschke / H. Wolter (2014)

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

$\Rightarrow$ stage 1: 4 x 35 kN
$\Rightarrow$ stage 2: 1 x 35 kN

Sounding Rockets

Summary

Summary

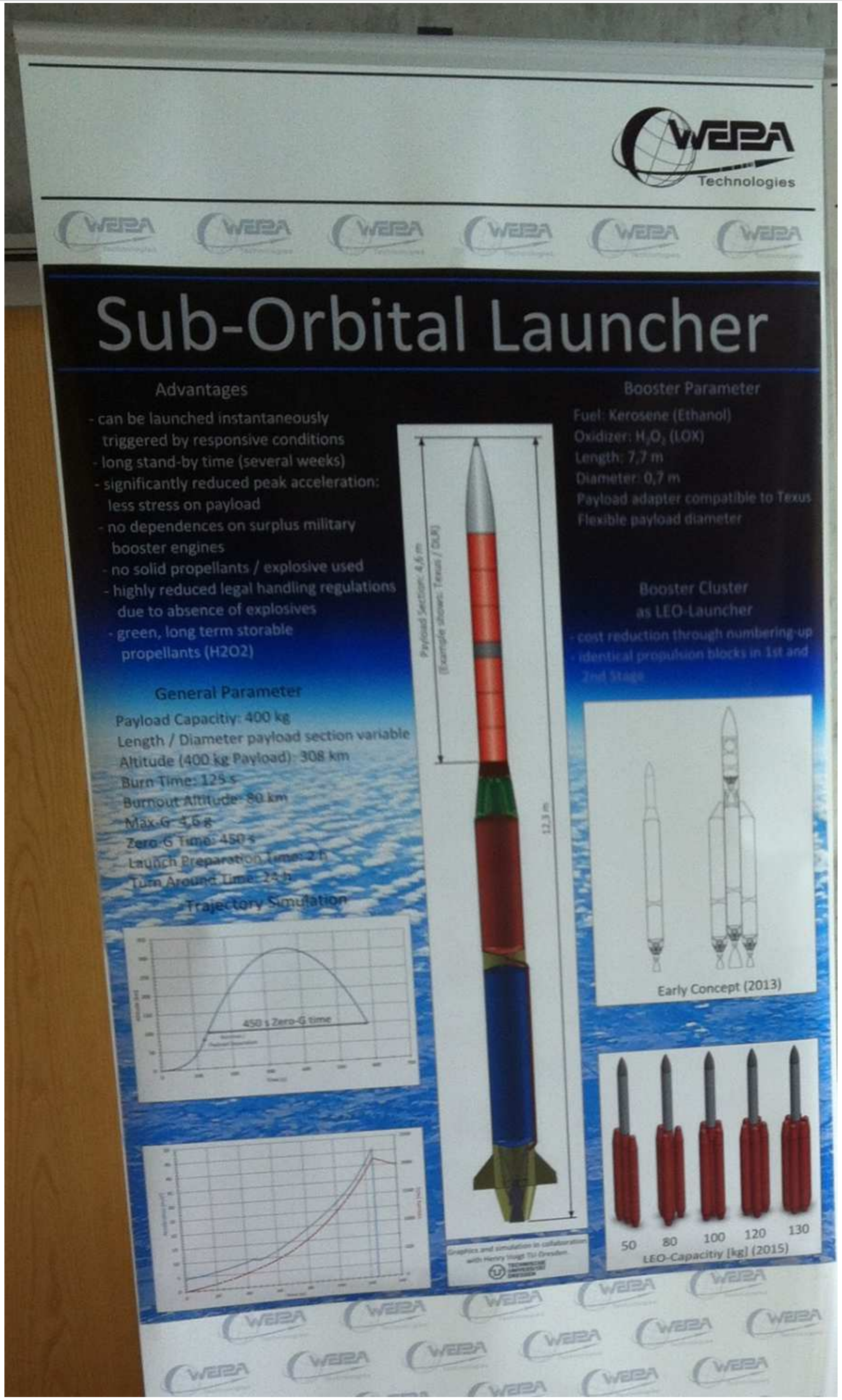
- **Basic design parameter of a LPRE-propelled sounding rocket ("SILBERPFEIL") were described**
  - **Due to non-cryogenic nature of H_2O_2 overall system architecture is significantly reduced**

- **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_2O_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 !

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