Low Cost Propulsion Systems for Launch- , In Space- and SpaceTourism Applications

Space Propulsion (Rome, 02 – 06/05/2016)

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Introduction: WEPA-Technologies GmbH

1. Introduction: WEPA-Technologies GmbH

- **Mechanical Engineering, General Automation and Rocket Technology**

- **R&D focussed engineering office and manufacturing company**
  - **Planning, development and realization of non-standard solutions**

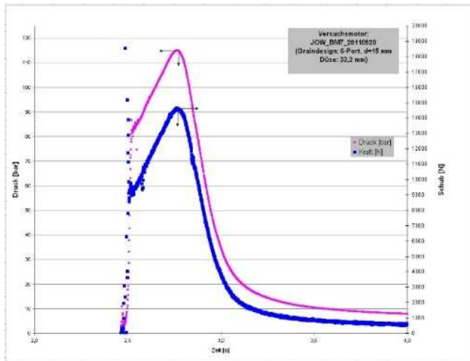
- **Manufacturing of prototypes and small lots**
  - **company owned 700 m² workshop**
  - **broad range of manufacturing technologies (CNC- and conventional machining)**

Development Activities

2. Development Activities (Rocket Technology)

- **Propulsion**
  - **Liquid propellant rocket engines (LPRE)**
  - **Turbo pumps for LPRE**
  - **H_2O_2 - concentration plants (max. 98 %)**
  - **Solid rocket motors (SRM) (Chlorine free)**

- **Public references include…**
  - **CASSIDIAN GmbH (Airbus Defence & Space)**
  - **Dynamit Nobel Defence GmbH**
  - **EU-customer (H_2O_2 - concentration plant)**



CASSIDIAN (now: Airbus Defence & Space)
contract development
Solid rocket motors (thrust: up to 20 kN)

Development Strategy: Rocket Technology

3. Key Development Fields

Technology Demonstrator Units
LOX / Ethanol (LCH_4 , Kerosene, H_2O_2)

Turbo Pump

35 kN LPRE

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

Potential customer applications

Sounding Rockets

H_2O_2 – concentration plants (max. 98 %)

H_2O_2 / Kerosene LPRE

3.1 Development Strategy

Low cost propulsion systems are (one) key component to realize low cost launch- and in space applications !

How to achieve low cost propulsion ?

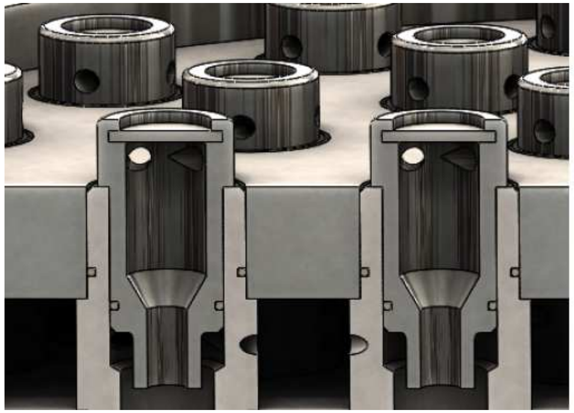
- Simplified design of rocket engines and turbo pumps
- Moderate operational parameter (chamber pressure, temperature)
- Prefer industrial materials and matured manufacturing technologies instead of “high-tech”
- Prefer numbering-up instead of scale-up
  - Consider unification of propulsion system design for first and second launcher stages via clustering
- Environmentally benign and easy to handle propellant components
  - LOX resp. H_2O_2, EtOH, LCH_4, Kerosene => avoid NO_2 / N_2O_4 and hydrazine !
- Approach
  - Expandable engines: improve designs based on proven technologies (USA / USSR / Europe / Japan)
  - Reusable engines / turbo pumps: focus on (partially) ceramic systems

Development of Liquid Propellant Engines

Technology demonstrator: Type 1

- Development of expendable rocket engines: focus on metallic thrust chambers

- Process Parameter (35 kN thrust @ SL)
  - Chamber pressure: 5 MPa
  - Propellant feed rate: ~ 14 kg / s (LOX + Ethanol)



credit: J. Aurich
(TU-Dresden 2015)

- Design overview
  - Regenerative cooling
  - Use series production enabling technologies (welding / brazing)
  - Coaxial injector

- Increase to higher thrust classes depending on market demand

4.1 Development of Liquid Propellant Engines

Technology demonstrator: Type 2

- Development of re-usable rocket engines: focus on ceramic thrust chambers
- Ceramic thrust chambers are very promising candidates for multiple reusability
  - Low thermal expansion
  - System simplification → cost reduction, high reliability
  - High specific strength at elevated temperatures
  - Oxidation resistance
  - Improved lifetime
    - Thermo-shock resistance
    - Thermal cycling ability

credit: DLR (M. Ortelt)

Ref.: M. Ortelt. 2005. Effusion cooled CMC rocket thrust chamber. 56th International Astronautical Congress, Fukuoka, Japan.

- Design overview
  - Use of highly effective transpirational cooling preferred
  - LOX + LCH_4 or Ethanol
  - Injector: coaxial type; use series production enabling technologies (welding / brazing)
- Process Parameter (35 kN thrust @ SL)
  - Chamber pressure: 5 MPa
  - Propellant feed rate: up to14 kg / s

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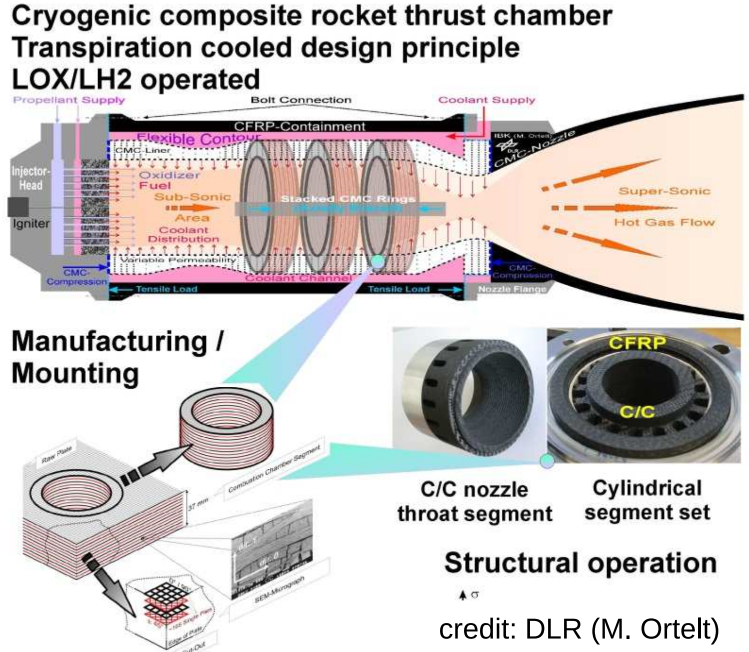
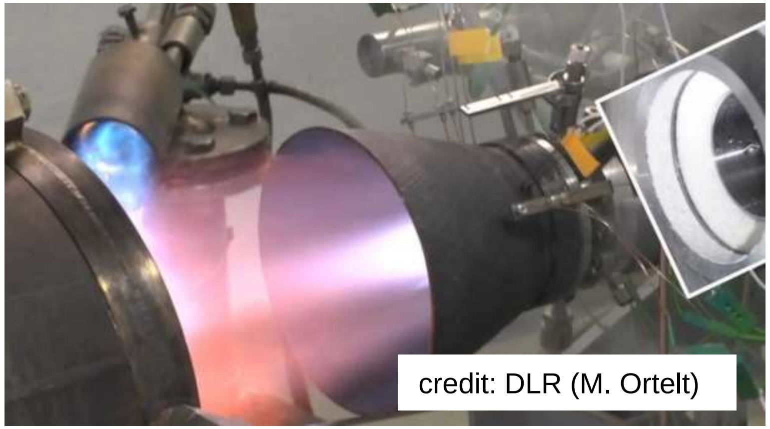
4.2 Development of Liquid Propellant Engines

Ceramic Thrust Chamber

- Commercial exploitation of ceramic technology intended: WEPA – DLR joint evaluation of market potential in progress
  - <u>long term experience with ceramic thrust chambers (DLR)</u>
    - Multiple successful tests with LOX / LH_2 (GH_2)
    - Chamber pressures up to 100 bar / huge upside potential
  - Use of non-oxide and oxide ceramic matrix material (CMCs)
- **Next steps**: design / manufacturing of technology demonstrator engines using for LOX / LCH_4 and LOX / Ethanol



Ref.: M. Ortelt, H. Hald, A. Herbertz, I. Müller. 3 – 7 October 2011. Application potential of combined fibre reinforced technologies in rocket thrust chambers. 62nd International Astronautical Congress, Cape Town, South Africa.



Ref.: M. Ortelt, H. Hald, I. Müller. 2014. Status and future perspectives of the CMC rocket thrust chamber development at DLR. 65th International Astronautical Congress, Toronto, Canada.

Development of Turbo Pump Units

5. Development of Turbo Pump Unit – overview

- Technology demonstrator unit
  - Exit pressure: max. 75 bar
  - Max. 30,000 RPM; single shaft design
  - Open gas generator cycle (LOX / fuel)
  - Designed for reusability: focus on bearings

- Propellant systems: LOX / Ethanol and LOX / LCH_4

- Mass flow rate: ~ 12 – 14.5 kg/s (35 kN demonstrator engine)

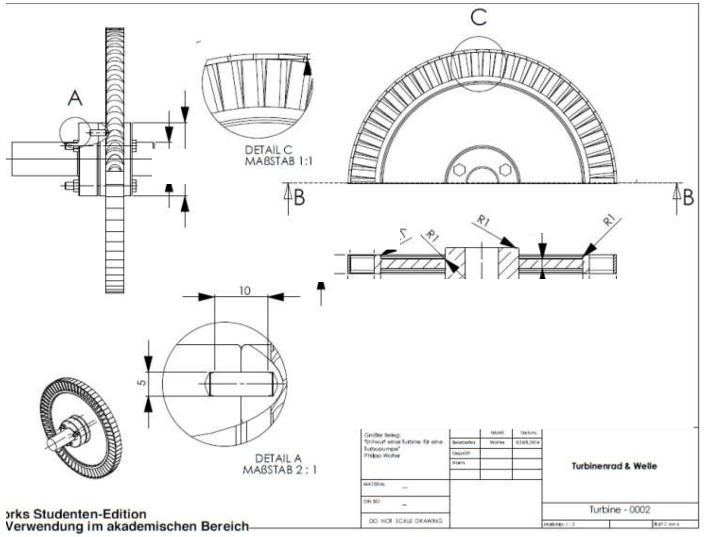
- Weight: max. 25 kg (incl. gas generator + control unit)

- Arrangement: turbine – fuel – oxidizer

5.1 Development of Turbo Pump Unit – overview

- Turbine
  - single or double axial stage, impulse type
  - partial admission of drive gas
  - inlet temperature: < 850 K
- Pump
  - single radial stage
- Seals
  - dynamic type (majority)
- Bearings
  - ceramic material based
    - journal type – transpirational lubrication

      (collaboration with DLR and TU Kaiserslautern (Prof. Böhle))
- <u>Status</u>
  - First spinning tests of TPU to commence in Q3 2016 (electric drive)



credit: Wolter / Zetschke
(TU-Dresden 2014)

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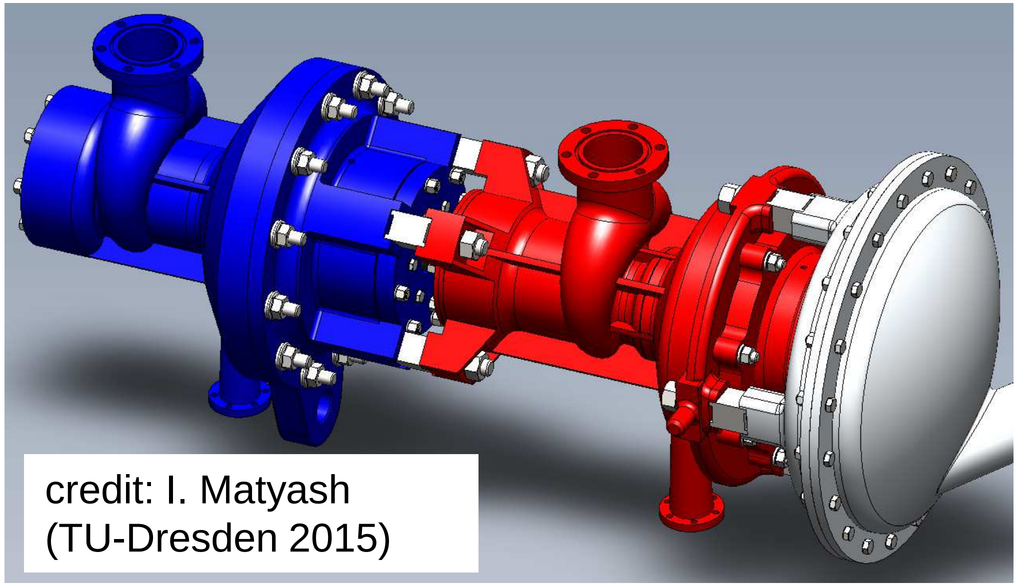
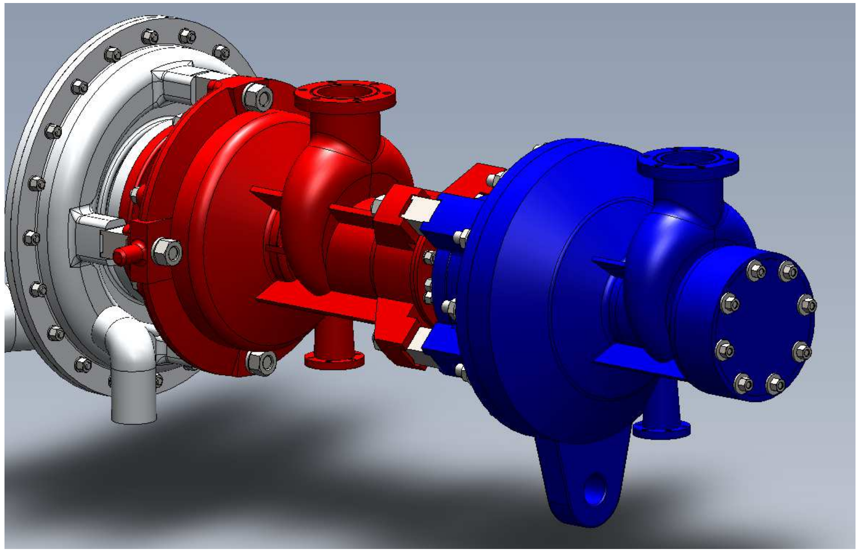
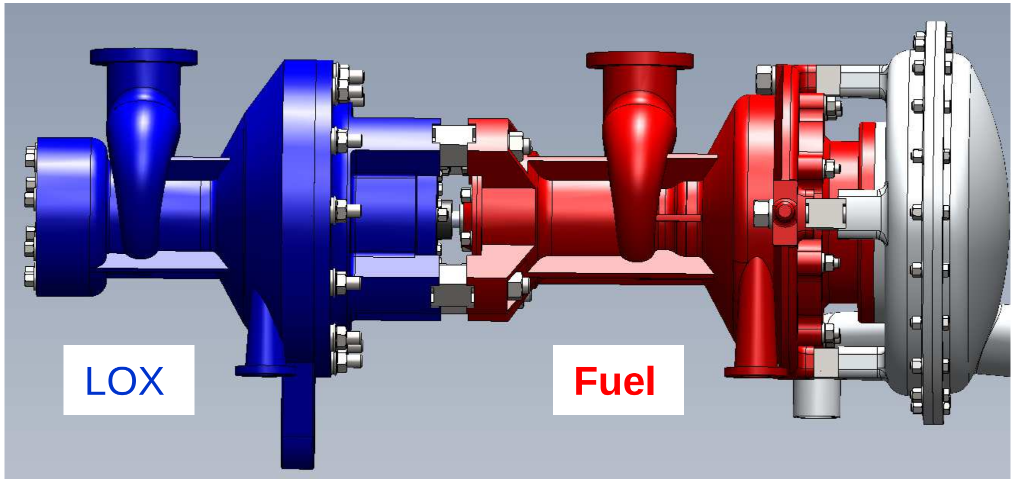
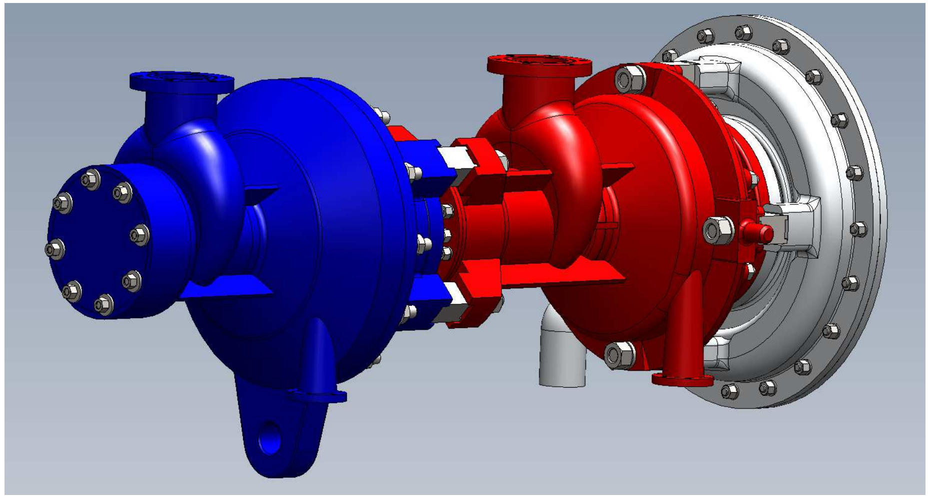
5.2 Development of Turbo Pump Unit – overview









Adaptation of technology demonstrator to requirements in H2020 / SMILE- project in progress (**S**mall **I**nnovative **L**auncher for **E**urope)

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H_2O_2-Concentration Technology

6. Supply of H_2O_2 (88 - 98 %): Motivation

- Advantages of H_2O_2-based propulsion systems
  - Storability / no evaporative losses during pre-operation time
  - Simplified, non cryogenic feed system (turbo pump and pressure feeding)
  - No chill down of system prior to ignition required
  - Reliable, “hypergolic” ignition process (catalytic decomposition)
  - Multiple burns possible
  - No safety / toxicity issues compared to N_2O_4 / UDMH
  - Reduced system complexity => increased operational reliability !

- Use in many different propulsion systems possible
  - launchers, upper stages, sounding rockets, space planes, RCS

- Very high strength H_2O_2 required for high performance systems
  - H_2O_2 (95 %) / Kerosene does show comparable overall system performance with respect to LOX / Kerosene (=> higher density impulse of H_2O_2 system)

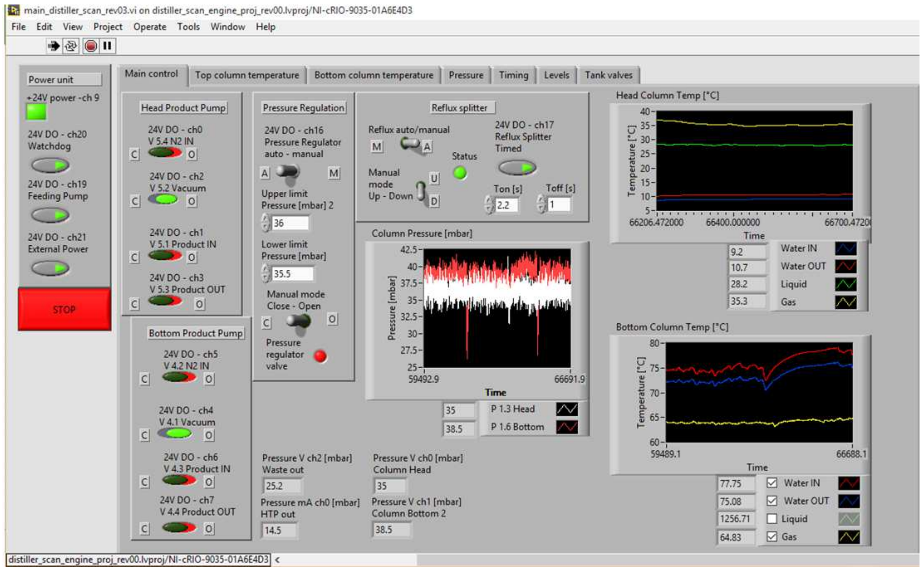
- Limited commercial availability / high costs, even though one large company entered pilot production of 98 % - grade in late 2015

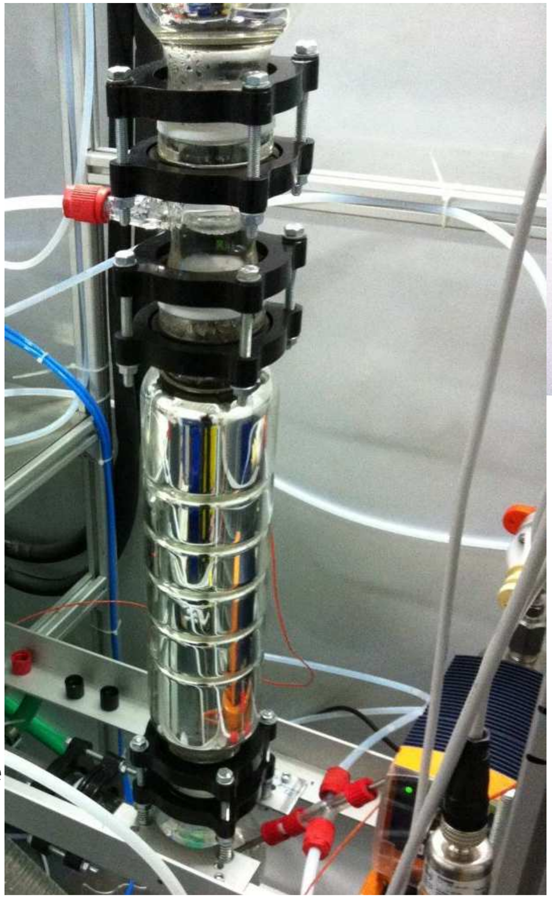
6.1 Supply of H_2O_2 (88 - 98 %)

- H_2O_2 concentration plant developed by WEPA-Technologies (EU-customer / 2015)
  - Capacity: up to ~ 50 kg / d (91 %)
  - Feed: 50 % - 70 % H_2O_2
  - Fully automatic, 24 / 7 operability implementable
  - Working packages supplied by WEPA-Technologies
    - Conceptional process design incl. safety concept
    - Detail engineering (process-, control- and electrical diagrams)
    - Equipment purchase
    - Erection and commissioning
    - Trouble shooting

- Very safe production process up to 98 % concentration available (~ 50 kg / day)
  - Scale-up to 1500 kg H_2O_2 / day possible (set-up in 20 – 40 ft container)

6.2 Supply of H_2O_2 (91 %) : Plant





=> general commercialisation of H_2O_2 supply intended (88 – 98 %)

=> customer requests welcome !

Control by PLC:
LabVIEW RT
(alternative: TWINCAT)

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Summary

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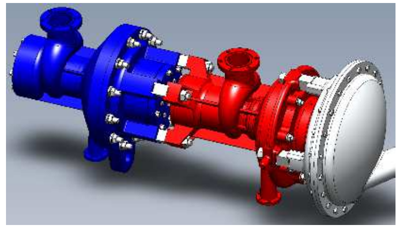
7. Summary: development activities at WEPA-Technologies

- **Liquid propellant rocket engines and turbo pump units**
  - Focus on low cost and potential re-usability
    - => ceramic materials: thrust chamber (transpiration cooling) resp. journal bearings
  - Present: 35 kN LPRE technology demonstrator (LOX / Ethanol and LOX / LCH_4)
  - Spinning tests of TPU (LOX / Ethanol) to commence in Q3 2016 (electric drive)
  - Adaptation of technology demonstrator to requirements of H2020 / SMILE- project in progress (**S**mall **I**nnovative **L**auncher for **E**urope)



- **H_2O_2**
  - Significant facilitation of development and reliable operation of propulsion systems – however: difficult supply situation at concentrations > 70 %
  - On-site concentration unit available to enable flexible project activities
    - Key features
      - Very safe production process up to 98 % concentration available
      - fully automatic, 24 / 7 operability implementable
      - reference plant available : ~ 50 kg / day capacity / 91 % H_2O_2
  - Production technology scalable up to ~ 1500 kg H_2O_2 / day

=> customer requests welcome !

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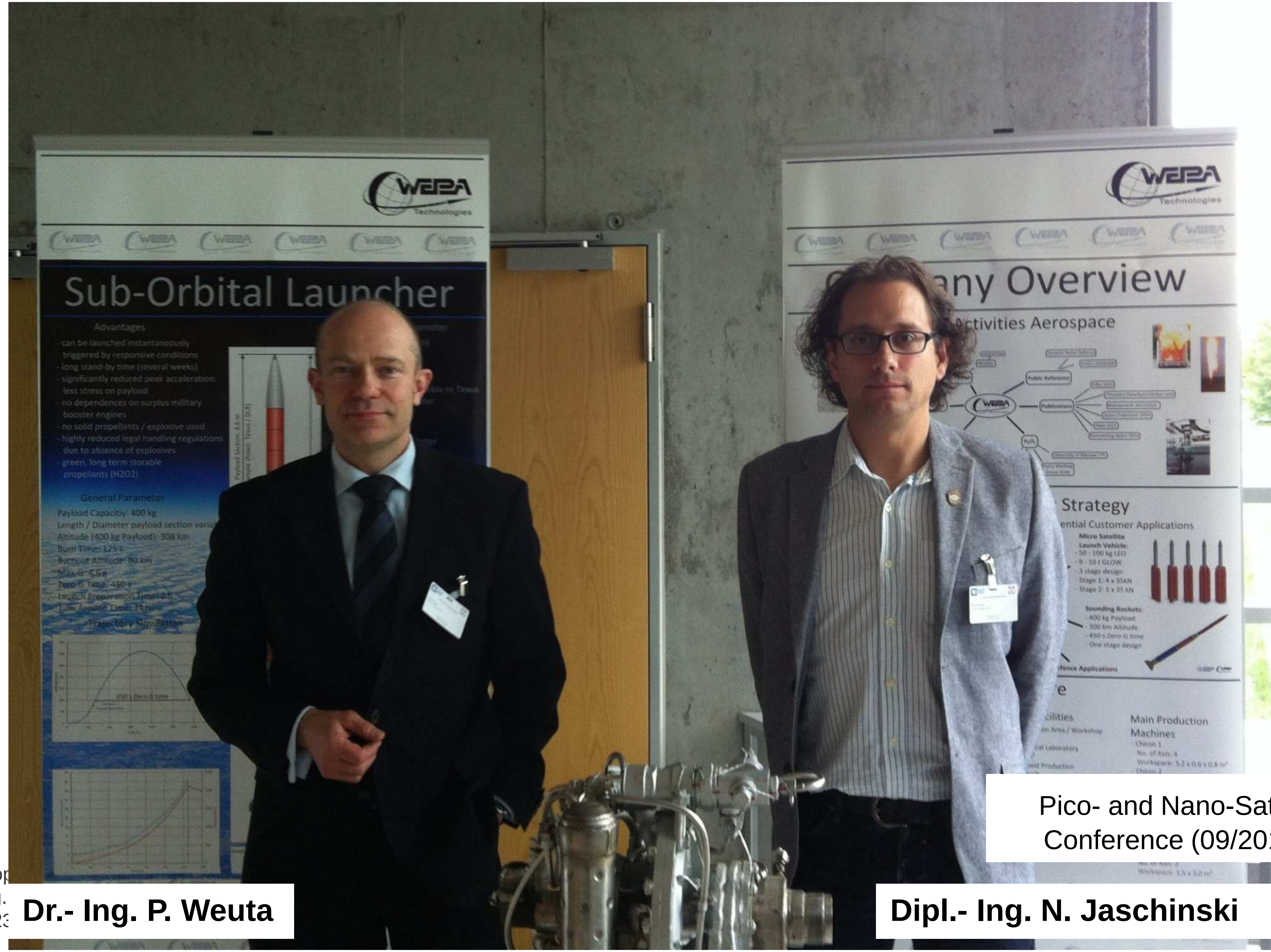
Thank you for your attention !



Pico- and Nano-Satellite Conference (09/2015)

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