Innovative Small Launcher

Arnaud van Kleef, B.A. Oving (Netherlands Aerospace Centre NLR)
C.J. Verberne, B. Haemmerli (Nammo Raufoss AS)
M. Kuhn, I. Müller, I. Petkov (German Aerospace Center DLR)
Introduction

- The market for small satellites is expected to increase substantially in the coming years, but there is little capacity to launch them dedicatedly and affordably.
- Based on market analyses the range up to 50 kg payload capacity can be considered the “sweet spot” for a small satellites launcher.
- Need for Affordable and dedicated launcher for small satellites.
- Launch costs of less than €50,000 per kg of payload are required in order to compete with piggy-back ride shares.
Introduction

• Competition under way (not operational yet)
  – USA (SuperStrypi, Aerojet Rocketdyne; LauncherOne, Firefly, Virgin Galactic; Lynx, XCOR; ALASA, DARPA),
  – New Zealand (Electron, Rocket Lab Ltd.)
  – India (Reusable Launch Vehicle, ISRO)
  – Europe: UK (Skylon, Reaction Engines Ltd.), Switzerland (SOAR, S3), France (Eole, CNES), Spain (Arion, PLD Space), Norway (North Star, Nammo/Andøya Space Centre)

• Focus competition is on payload launch ranges 1-10 kg or 100kg+
• No focus on the range up to 50 kg payload capacity
Introduction

• Aiming for commercial launch prices of less than 50,000 €/kg for a payload capacity of up to 50 kg, the total maximum cost for a launch shall be below 2.5 M€. This target cost drives the design, construction, and operation of the launcher

• Major challenge requires a cost effective design approach
SMILE

- SMall Innovative Launcher for Europe” SMILE project
- Horizon 2020 work programme for three years
- Grant Agreement preparation phase with European Commission
Objectives SMILE:

- To design a concept for an innovative, cost-effective European launcher for small satellites
- To design a Europe-based ground facility for small launcher, based on the evolution of the existent sounding rocket launch site at Andøya Space Center
- To increase the Technology Readiness Level (TRL) of critical technologies for low-cost European launchers
- To develop prototypes of components, demonstrating this critical technology
- To create a roadmap defining the development plan for the small satellites launcher system from a technical, operational and economical perspective
SMILE

• SMILE will enhance innovative technologies:
  – Hybrid engine technology
  – Liquid engine technology with transpiration cooling
  – Advanced low-mass and low-cost materials
  – Series production of low-cost composite structures
  – Printing technology for low-cost metal components
  – Advanced, reliable COTS technology for miniaturised, low-power avionics
  – Europe-based launch facility

• Focus on novel hybrid and liquid rocket engine technologies in this presentation
SMILE

• Focus on novel hybrid and liquid rocket engine technologies in this presentation
• SMILE objectives for critical engine technology development:
  – To perform a trade-off between two propulsion technologies
  – To design the architecture of the launcher’s propulsion modules based on the requirements
  – To generate the detailed design of the propulsion modules
  – To select technology for low-cost advanced engine parts
  – To produce prototypes of the selected engine parts
  – To conduct firing tests of the liquid engine
Hybrid Engine Technology

- Unitary Motor UM design by Nammo Raufoss AS:
  - Oxidizer: Hydrogen Peroxide (H2O2)
  - Fuel: Hydroxyl-Terminated Polybutadiene (HTPB) rubber

- 2 phases for UM development and test
  - 1. Heavy-Wall Unitary Motor HWUM (Completed fall of 2014)
  - 2. Flight Weight Unitary Motor FWUM (November 2015)

<table>
<thead>
<tr>
<th>Property</th>
<th>HWUM</th>
<th>FWUM</th>
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<tbody>
<tr>
<td>Total impulse</td>
<td>750 kNs</td>
<td>980 kNs</td>
</tr>
<tr>
<td>Outer diameter</td>
<td>305 mm (12 in.)</td>
<td>356 mm (14 in.)</td>
</tr>
<tr>
<td>Burn duration</td>
<td>25 s</td>
<td>35 s</td>
</tr>
<tr>
<td>Dry mass (without consumed fuel)</td>
<td>&gt;280 kg</td>
<td>&lt;100 kg</td>
</tr>
<tr>
<td>Consumed fuel mass</td>
<td>&lt;50 kg</td>
<td>&gt;60 kg</td>
</tr>
<tr>
<td>Consumed oxidizer mass</td>
<td>~270 kg</td>
<td>~380 kg</td>
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Hybrid Engine Technology

• Demonstration launch of single FWUM is planned for the fall 2016 onboard prototype Nucleus sounding rocket (>100 km altitude) from Andøya Space Center

• Attractive properties for a small launcher:
  – Self-ignition increasing engine start reliability and enabling an unlimited restart capability
  – Wide range throttling with limited performance losses
  – Green life cycle and exhaust properties
  – Solid inert fuel and high-density green storable oxidizer
  – High engine combustion efficiency, performance and stability
  – Simplicity of a single circular port and single feedline configuration
  – Low development and operational costs
Hybrid Engine Technology

- Similar approach (clustering of UM) in SMILE:
  - Cost reduction by volume production
  - Higher reliability by automated production

- Design and sizing of:
  - Fluid feeding system
  - Performances (thrust, specific impulse, weight and size envelope)

<table>
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<tr>
<th>Rocket stage</th>
<th>Motorization</th>
<th>Indicative impulse</th>
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| Nucleus      | 1x Unitary Motor 1 | Thrust: 28 kN
Burn time: 35 s
Total impulse: 1 MNs |
| Aurora       | 4x Unitary Motor 1 | Thrust: 114 kN
Burn time: 35 s
Total impulse: 4 MNs |
| Borealis*    | 7x Unitary Motor 2 | Thrust: 450 kN
Burn time: 64 s
Total impulse: 30 MNs |
| Corona*      | 1x High Performance Hybrid Motor | Thrust: 5 kN
Burn time: 70 s
Total impulse: 0.35 MNs |

*The characteristics of the stages Borealis and Corona will depend on the flight performance of the Nucleus and later on, the Aurora stages.*

North Star Rocket Family
Liquid Engine Technology

• High performance, reliable technology, variable thrust-levels and easily re-ignited
• Liquid engine design by DLR (LOX/LH2 heritage)
• In SMILE combination of LOX/kerosene propellants is considered favourable:
  – High-density
  – Low cost
  – World wide available
  – Easy storage and refuelling
  – Green propellants
Liquid Engine Technology

• LOX/LH2 design approaches could be transferred to LOX/kerosene operation considering a clustered design with multiple sub-scaled engines

• Engine development focusses on
  – Ceramic design instead of ITAR-controlled metal alloys for combustion chamber
  – Transpiration cooling
Liquid Engine Technology

• Reusability advantage for
  – Ceramic matrix composites (CMC) over metallic alternatives when thermally cycled without degradation → improved engine life
  – Transpiration cooling (selected by P&W to fulfil NASA req. of 100-time engine reusability in the 60s)

• Reduction in engine’s structural weight by use of
  – Low cost 3-D printed components
  – Carbon-Fiber-Reinforced Plastic (CFRP) housing structures
  – Application of SLM techniques (hollow sections)

• In SMILE: Hot firing tests of LOX/kerosene at PLD Space (Spain) → TRL target: 5/6
Conclusions

• Need for small launcher
• Challenge to become cost efficient
• SMILE project will take up this challenge using a cost-effective design approach

• For hybrid rocket engine development:
  • Low life-cycle cost of the hybrid technology
    – simple architecture
    – non-toxicity, inertness and the availability of the propellants
    – overall low development and operational costs
  • Clustering of unitary propulsion elements (Unitary Motor)
    – higher volume production for each component
    – automated production leading to a better reliability of the product
Conclusions

• For liquid rocket engine development:
  • Potential for reuse (engine is expensive part)
    – ceramic materials
    – transpiration cooling technique
  • Reduced engine weight
    – reliable low cost 3-D printed components
    – potential use of CFRP housing structures
    – application of SLM techniques (hollow sections)

• Combination of hybrid and liquid propulsion technology will allow the use of the right technology at the right place to offer the required performance at the lowest price possible → Trade-off between performance, launch objectives and cost for selection
Thank you for your attention!

Arnaud van Kleef
Arnaud.van.kleef@nlr.nl
http://www.nlr.nl