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Innovative Small Launcher

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13th Reinventing Space Conference
11 November 2015, Oxford, UK

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

SMILE

- 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

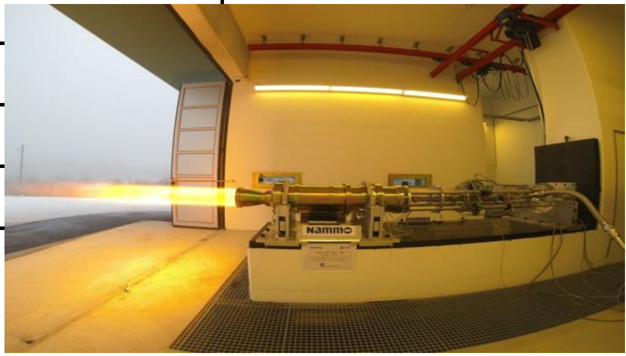
SMILE

- 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)

Property	HWUM	FWUM
Total impulse	750 kNs	980 kNs
Outer diameter	305 mm (12 in.)	356 mm (14 in.)
Burn duration	25 s	35 s
Dry mass (without consumed fuel)	>280 kg	<100 kg
Consumed fuel mass	< 50 kg	> 60 kg
Consumed oxidizer mass	~270 kg	~380 kg



Nammo

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

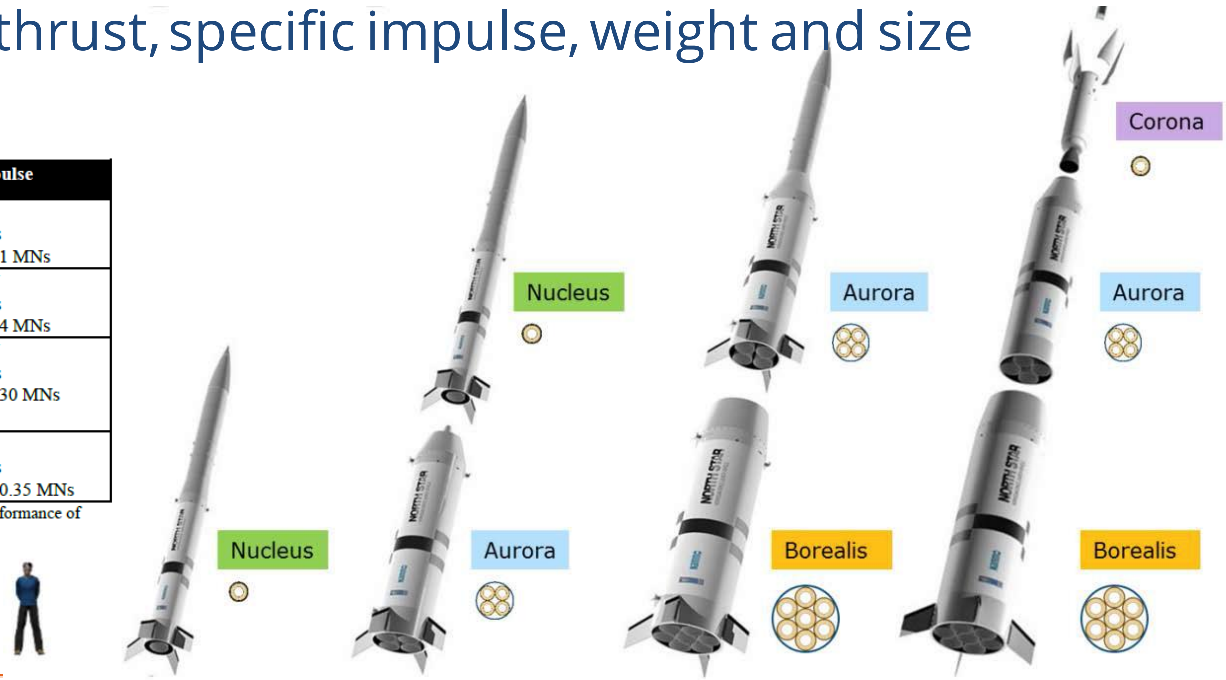
Hybrid Engine Technology

- 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)

Rocket stage	Motorization	Indicative impulse
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.

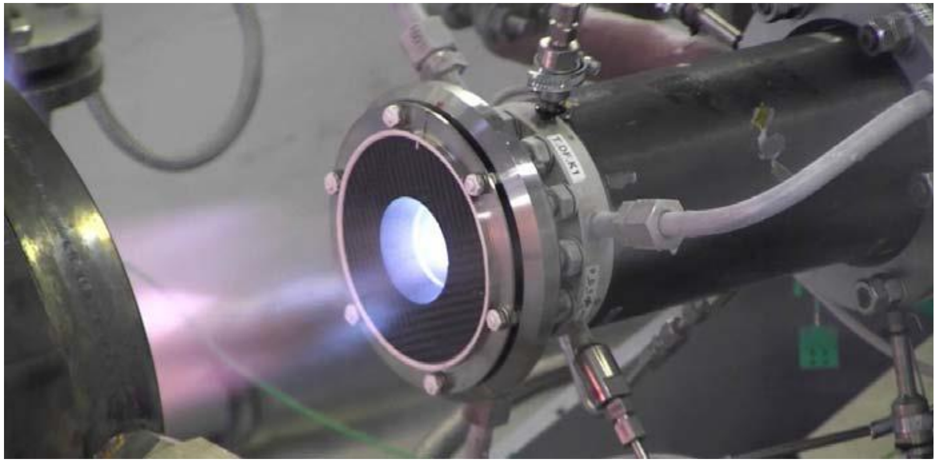
Nammo



North Star Rocket Family

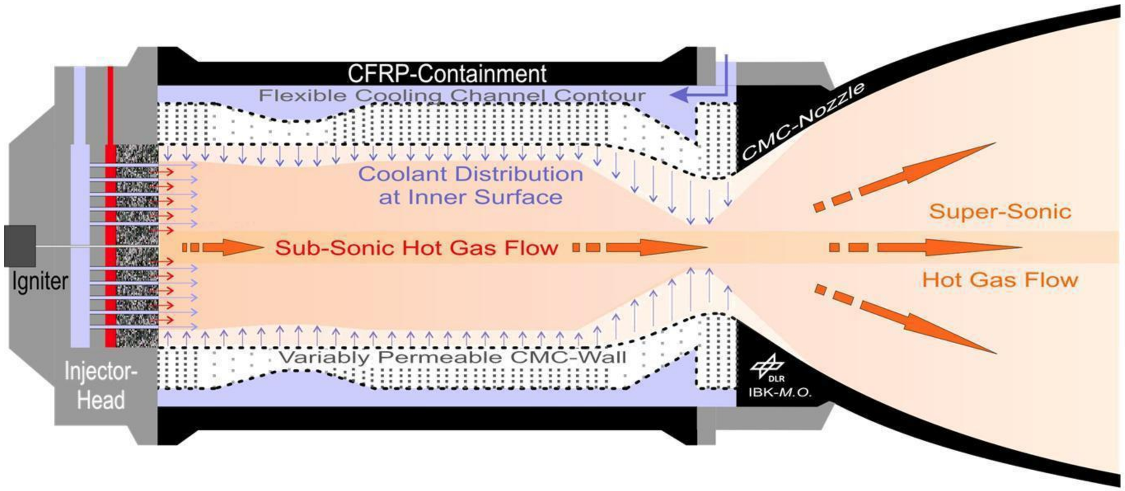
Liquid Engine Technology

- 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

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Thank you for your attention!

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