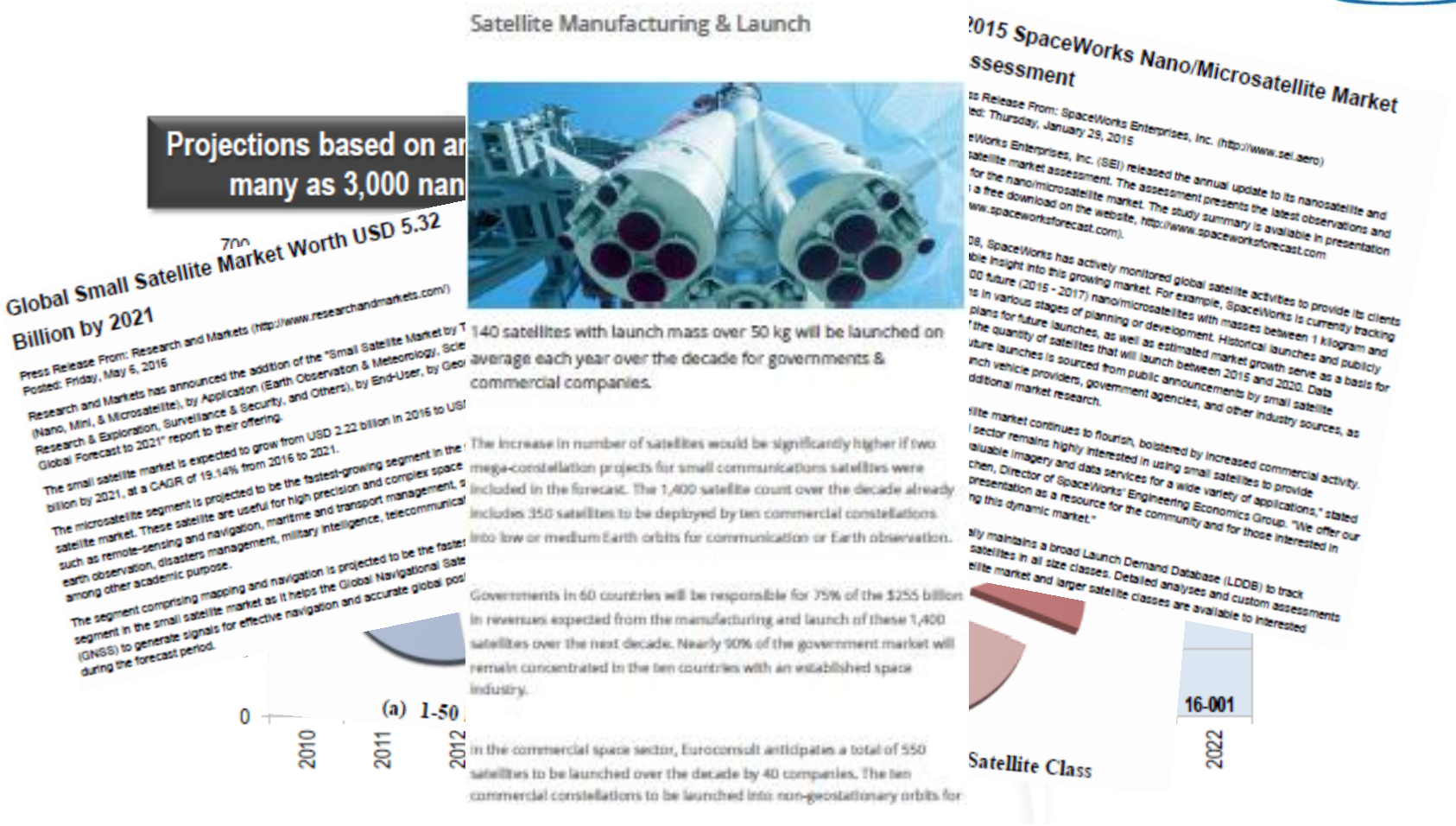
SMILE - Small Innovative Launcher for Europe

Bertil Oving, Netherlands Aerospace Centre (NLR)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 687242.

SMILE – The Demand



source: SpaceWorks Enterprises Inc (SEI)

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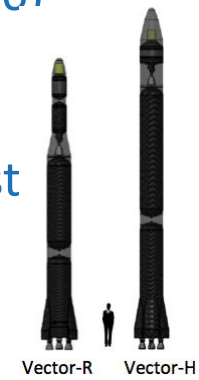
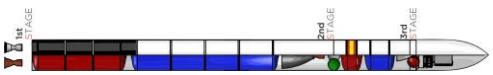
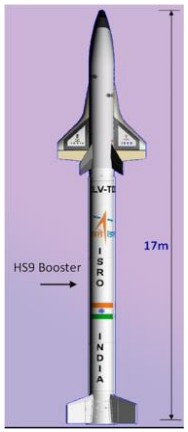
SMILE – The Competition

- Electron (NZ) – qualification & acceptance test of first stage booster (December 2016)
- Vector (US) – test of first stage engine (December 2016)
- Eole/Altair (Fr) – autonomous winged first stage (H2020 project)
- Arion (Sp) – secured funding (6.7M€) for sounding rocket Arion-1
- LauncherOne (US) – first flight expected in 2017
- Skylon (UK) – secured funding (10M€) for SABRE engine
- Reusable Launch Vehicle (India) – RLV-TD successful flight re-entry test (May 2016)
- Intrepid-1 (US) – hybrid engines
- GO Launcher 2 (US) – air launch







SMILE – The Programme

- SMall Innovative Launcher for Europe – SMILE in EU Horizon 2020 framework programme
- 14 companies & institutes from 8 European countries, 4 M€ grant, Jan 2016 – Dec 2018
- Objectives
  1. business development
  2. launcher & ground segment design
  3. demonstration of critical technology
- http://www.small-launcher.eu/

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SMILE – The Consortium

Airborne Composites Automation	production methods, structures
Andøya Space Centre (ASC)	ground segment, market analysis
BoesAdvies	business development
German Aerospace Centre (DLR)	launcher, liquid engines, cost analysis
Heron Engineering	structural analysis
INCAS	launcher, aerodynamics, trajectory
ISIS - Innovative Solutions In Space	business development, market analysis, payload deployment system
Nammo Raufoss AS	launcher, hybrid engines, cost analysis
Netherlands Aerospace Centre (NLR)	launcher, structures, avionics, EGSE, cost analysis, project coordinator
PLD Space	liquid engine testing
Tecnalia	advanced low-weight materials
Terma	avionics, EGSE
WEPA-Technologies	turbopumps: LOX/kerosene, H_2O_2
3D Systems	3D printing of metal parts

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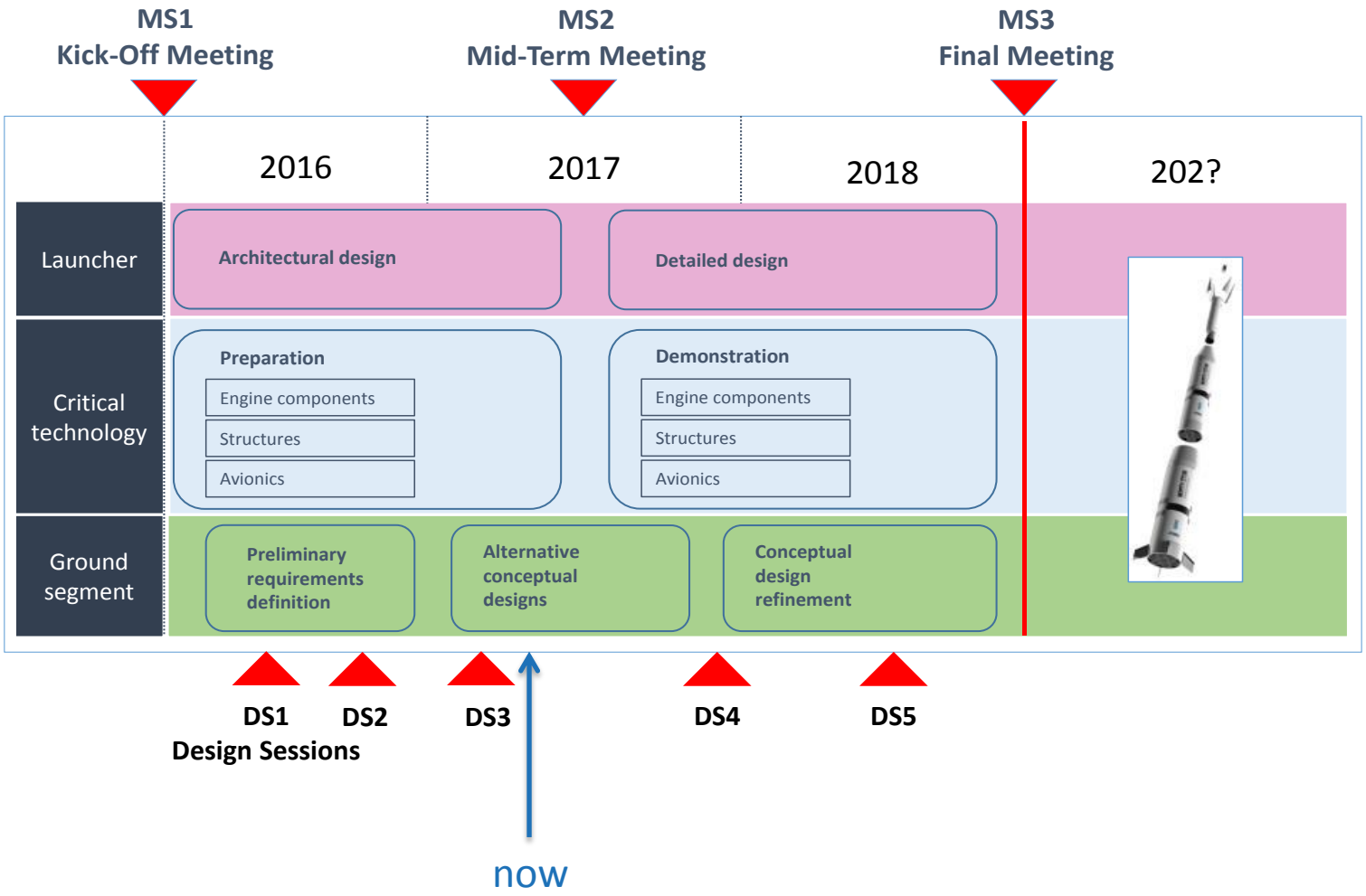
SMILE – The Planning



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SMILE – The Challenge

- Smaller launcher -> lower payload fraction -> less benefit -> difficult to achieve ROI
- Focus on **cost-effectiveness**:
  - hybrid HTPB/H_2O_2 *low cost, unitary* hybrid engines
  - liquid LOX/kerosene *reusable, unitary* engines
  - *low cost* turbopumps
  - *automated* production of composite structures
  - *automated* 3D printing
  - *low-cost* avionics using COTS
  - *efficient* ground segment, handling and operations

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SMILE – The Launcher

- Payload at least 70 kg into 600 km SSO
- Launch from Andøya Space Centre (Norway)
- Competitive price (less than 50k€ per kg)
- Various configurations using combination of hybrid and liquid engines
  - Three-stage hybrid
  - Two-stage liquid
  - Three-stage liquid
  - Three-stage liquid/hybrid
  - Turbopumps for first and second stages
- Family of launchers with more capacity

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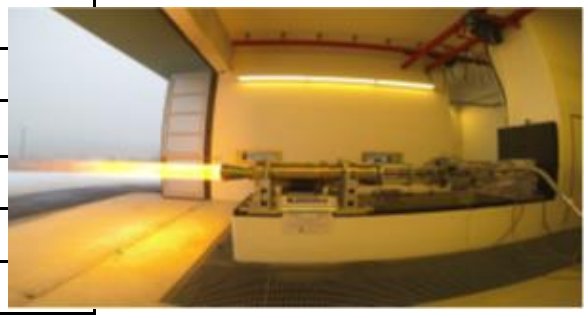
SMILE – The Hybrid Engine

- Unitary Motor (UM) by Nammo Raufoss AS:
  - Oxidizer: Hydrogen Peroxide (H_2O_2)
  - Fuel: Hydroxyl-Terminated Polybutadiene (HTPB)
- Two phases for UM development and test
  1. Heavy-Wall Unitary Motor HWUM (fall 2014)
  2. Flight Weight Unitary Motor FWUM (fall 2015)
- Further mass reduction using composite casing
- Design of H_2O_2 turbopump (with WEPA)

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



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SMILE – The Hybrid Engine

- Self-ignition increases engine start reliability and enables unlimited restart capability
- Wide-range throttling with limited performance loss
- Green life cycle and exhaust properties
- Solid inert fuel and high-density green storable oxidizer
- High combustion efficiency, performance, and stability
- Simplicity of a single circular port and single feedline configuration
- Low development and operational costs with potential for automated production

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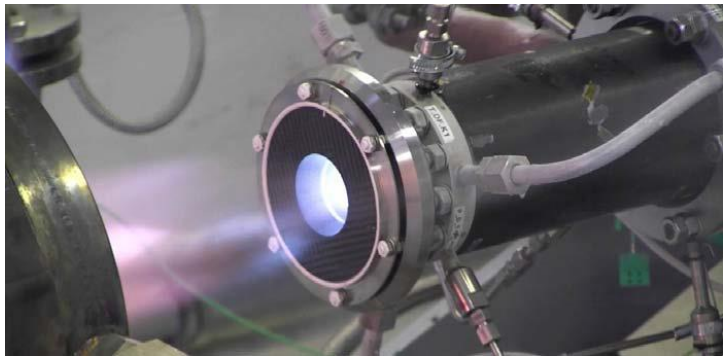
SMILE – The Liquid Engine

- High performance, reliable technology, variable thrust-levels and easily re-ignited
- Liquid engine design by DLR (LOX/LH2 heritage)
- Design of LOX/kerosene turbopump (with WEPA)
- Combination of LOX and kerosene:
  - High-density
  - Low cost
  - World wide available
  - Easy storage and refuelling
  - Green propellants



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SMILE – The Liquid Engine

- Reusability advantage for
  - Ceramic matrix composites (CMC) to improve engine life when thermally cycled without degradation
  - Transpiration cooling (selected by P&W to fulfil NASA req. of 100-time engine reusability in the 1960s)
- Reduction in engine's structural weight by use of
  - Low cost 3D printed components
  - Carbon-Fiber-Reinforced Plastic (CFRP) housing structures
  - Application of SLM techniques (hollow sections)
- Hot firing tests of LOX/kerosene at PLD Space (Spain) TRL target: 5/6

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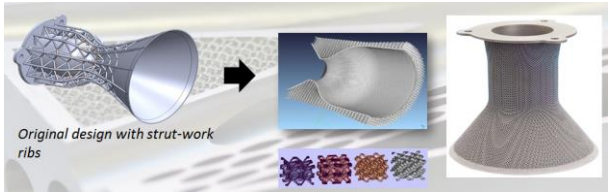
SMILE – The Automation

- Automated lay-up of composites
  - Filament winding
  - Automated tape laying
  - Automated fibre placement
  - Robotic pick & place
  - Braiding
- 3D printed metal parts
  - both hybrid and liquid engines
  - structural inserts



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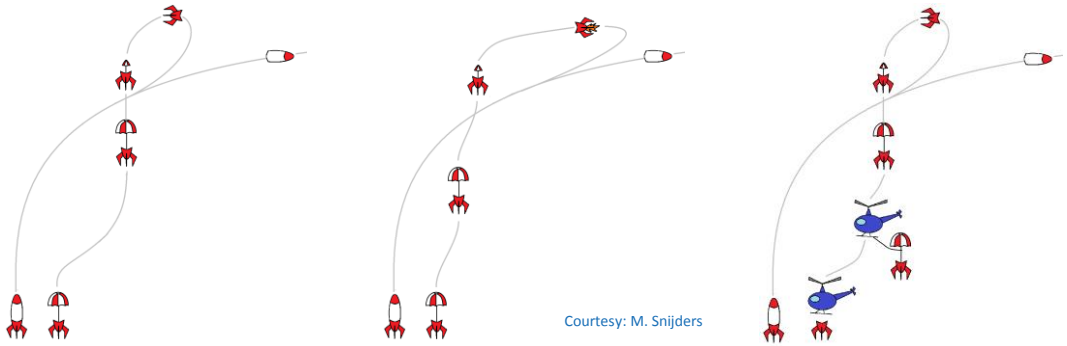
SMILE – The Reuse

- Significant cost reduction through reuse of first stage
- Recovery implies some extra cost
  - Extra mass for recovery system (propellants, parachutes)
  - Retrieval and transport to launch site
  - Inspection



Courtesy: M. Snijders

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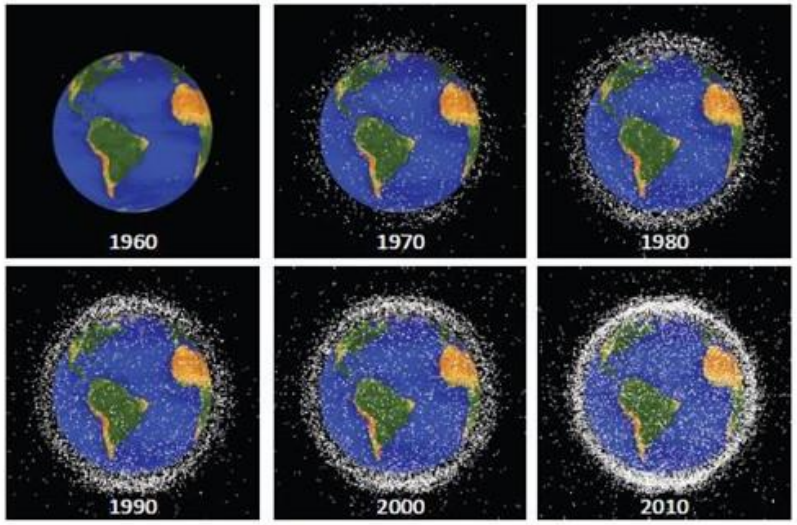
SMILE – The Regulatory

- Many launches, many small satellites
- Orbital debris *is* a problem
  - Even though each pixel is 1000 km^3
  - Difficult to track & trace
  - Many orbital crossings
  - Domino-effect after collision
- Possible mitigations to be discussed
  - De-orbit of upper stages (requirement for SMILE)
  - More limits to orbital lifetime, depending on application (currently only a 25-year limit)



Satellites and debris in low Earth orbit, 1960-2010. Courtesy NASA.

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INCAS
National Institute for Aerospace Research "Elie Carafoli"

Airborne

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