



SMILE - Small Innovative Launcher for Europe

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

SMILE – The Demand



Satellite Manufacturing & Launch



Projections based on as many as 3,000 nano

7m
Global Small Satellite Market Worth USD 5.32 Billion by 2021

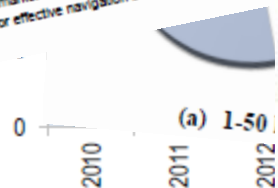
Press Release From: Research and Markets (<http://www.researchandmarkets.com/>)
Posted: Friday, May 6, 2016

Research and Markets has announced the addition of the "Small Satellite Market by Type (Nano, Mini, & Microsatellite), by Application (Earth Observation & Meteorology, Science Research & Exploration, Surveillance & Security, and Others), by End-User, by Geographic Region, and Global Forecast to 2021" report to their offering.

The small satellite market is expected to grow from USD 2.22 billion in 2016 to USD 5.32 billion by 2021, at a CAGR of 19.14% from 2016 to 2021.

The microsatellite segment is projected to be the fastest-growing segment in the small satellite market. These satellites are useful for high precision and complex space applications such as remote-sensing and navigation, maritime and transport management, earth observation, disasters management, military intelligence, telecommunication among other academic purpose.

The segment comprising mapping and navigation is projected to be the fastest growing segment in the small satellite market as it helps the Global Navigational Satellite System (GNSS) to generate signals for effective navigation and accurate global positioning during the forecast period.



1,400 satellites with launch mass over 50 kg will be launched on average each year over the decade for governments & commercial companies.

The increase in number of satellites would be significantly higher if two mega-constellation projects for small communications satellites were included in the forecast. The 1,400 satellite count over the decade already includes 350 satellites to be deployed by ten commercial constellations into low or medium Earth orbits for communication or Earth observation.

Governments in 60 countries will be responsible for 75% of the \$255 billion in revenues expected from the manufacturing and launch of these 1,400 satellites over the next decade. Nearly 90% of the government market will remain concentrated in the ten countries with an established space industry.

In the commercial space sector, Euroconsult anticipates a total of 550 satellites to be launched over the decade by 40 companies. The ten commercial constellations to be launched into non-geostationary orbits for

2015 SpaceWorks Nano/Microsatellite Market Assessment

Press Release From: SpaceWorks Enterprises, Inc. (<http://www.sei.aero>)
Posted: Thursday, January 29, 2015

SpaceWorks Enterprises, Inc. (SEI) released the annual update to its nanosatellite and microsatellite market assessment. The assessment presents the latest observations and trends for the nano/microsatellite market. The study summary is available in presentation format for a free download on the website, <http://www.spaceworkforecast.com>.

SEI has actively monitored global satellite activities to provide its clients with valuable insight into this growing market. For example, SpaceWorks is currently tracking the 2015-2017 nano/microsatellites with masses between 1 kilogram and 10 kilograms in various stages of planning or development. Historical launches and publicly available information on the quantity of satellites that will launch between 2015 and 2020. Data from these launches is sourced from public announcements by small satellite launch providers, government agencies, and other industry sources, as well as additional market research.

The satellite market continues to flourish, bolstered by increased commercial activity. The small satellite sector remains highly interested in using small satellites to provide valuable imagery and data services for a wide variety of applications," stated John Chen, Director of SpaceWorks' Engineering Economics Group. "We offer our market presentation as a resource for the community and for those interested in understanding this dynamic market."

SEI maintains a broad Launch Demand Database (LDD) to track satellite launches in all size classes. Detailed analyses and custom assessments of the nano/microsatellite market and larger satellite classes are available to interested parties.



source: SpaceWorks Enterprises Inc (SEI)

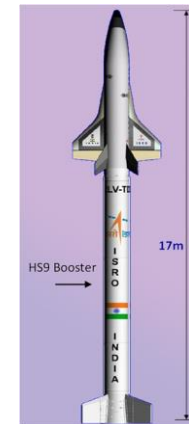


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SMILE – The Competition



- 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/>



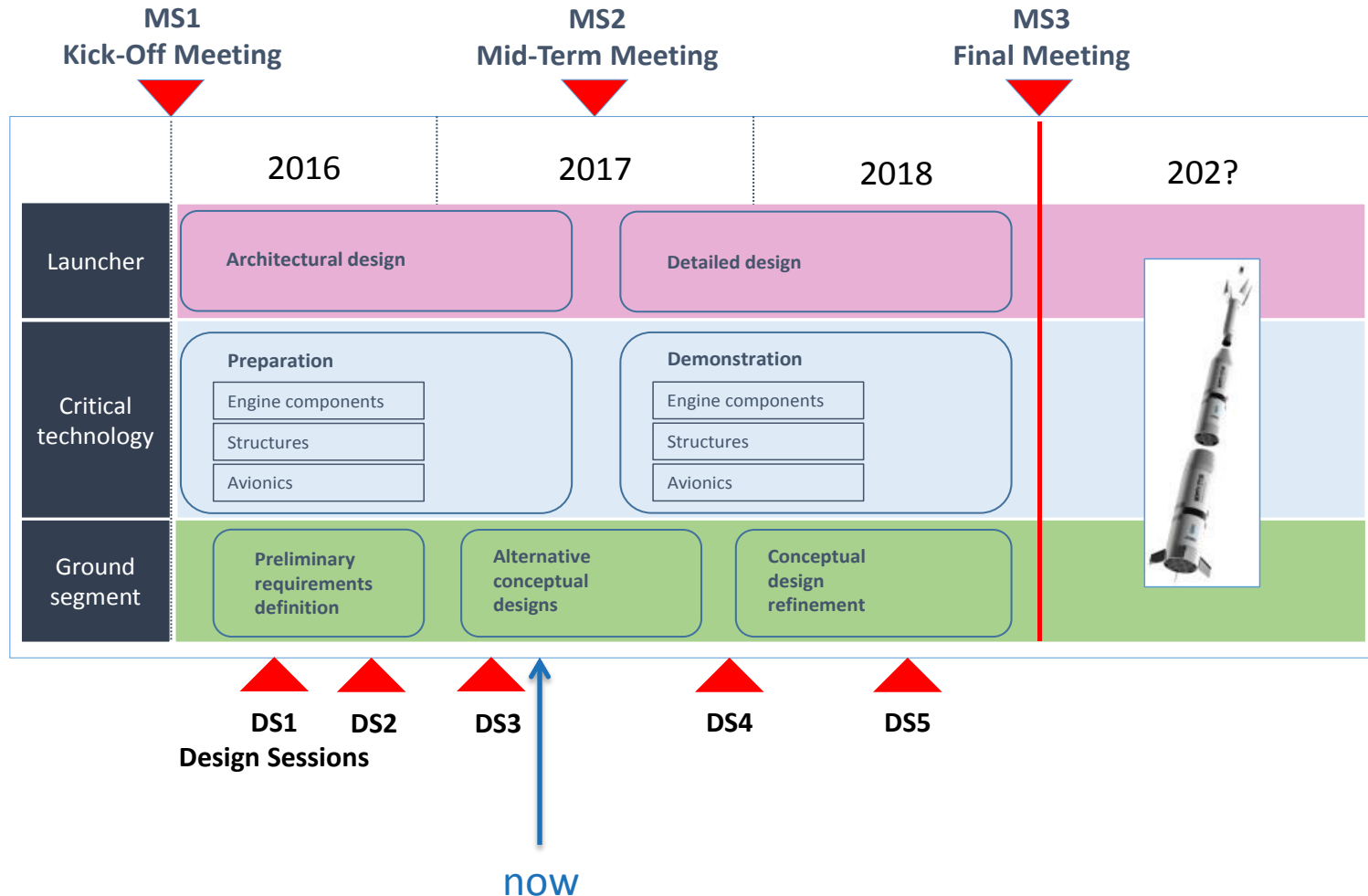
SMILE – The Consortium



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 ₂ O ₂
3D Systems	3D printing of metal parts



SMILE – The Planning



SMILE – The Challenge



- Smaller launcher -> lower payload fraction -> less benefit -> difficult to achieve ROI
- Focus on **cost-effectiveness**:
 - hybrid HTPB/H₂O₂ *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



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

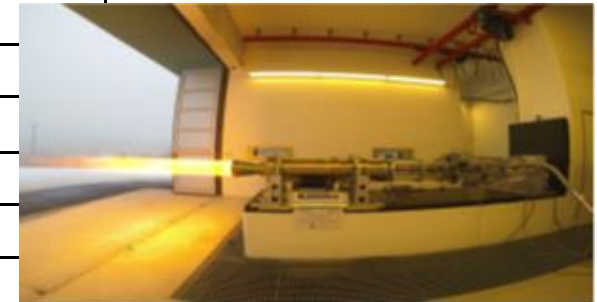


SMILE – The Hybrid Engine



- 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



SMILE – The Hybrid Engine



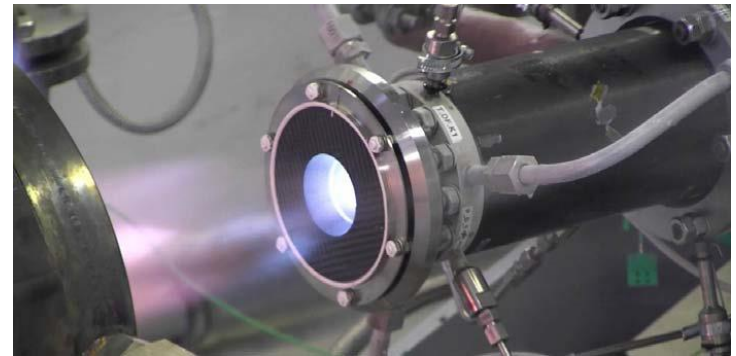
- Self-ignition increases engine start reliability and enables unlimited restart capability
- Wide-range throttling with limited performance loss
- Green life cycle and exhaust properties
- Solid inert fuel and high-density green storable oxidizer
- High combustion efficiency, performance, and stability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



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



SMILE – The Liquid Engine



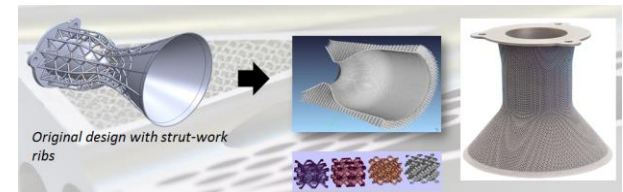
- Reusability advantage for
 - Ceramic matrix composites (CMC) to improve engine life when thermally cycled without degradation
 - Transpiration cooling (selected by P&W to fulfil NASA req. of 100-time engine reusability in the 1960s)
- Reduction in engine's structural weight by use of
 - Low cost 3D 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



SMILE – The Automation



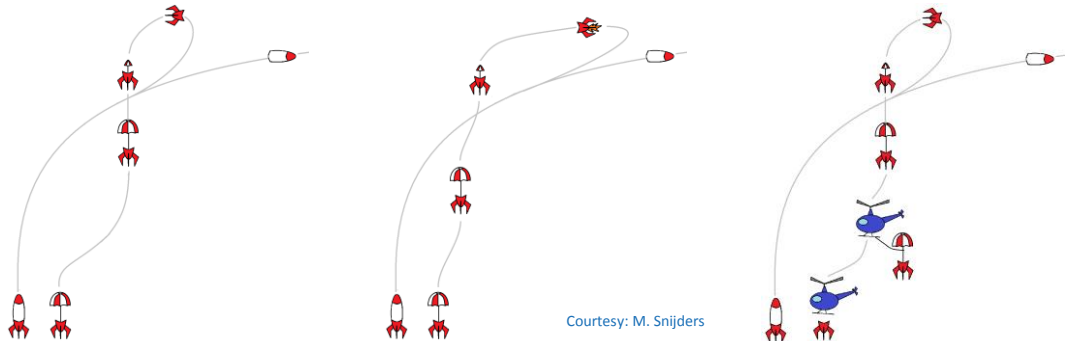
- Automated lay-up of composites
 - Filament winding
 - Automated tape laying
 - Automated fibre placement
 - Robotic pick & place
 - Braiding
- 3D printed metal parts
 - both hybrid and liquid engines
 - structural inserts



SMILE – The Reuse



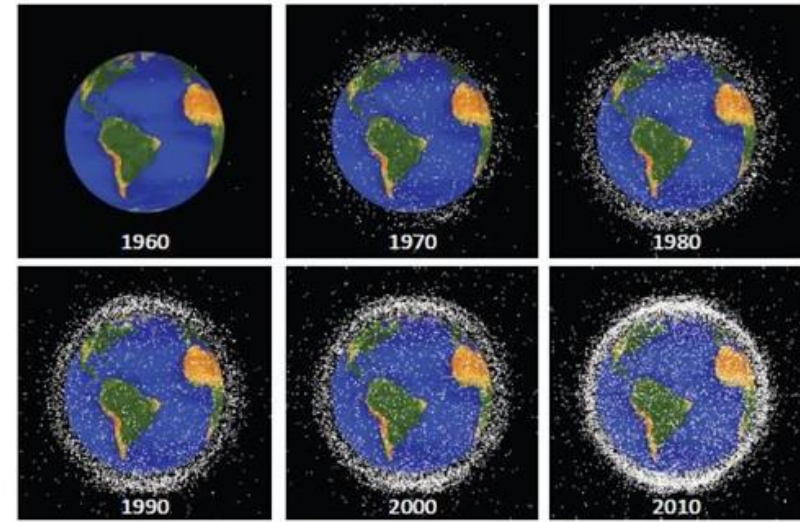
- Significant cost reduction through reuse of first stage
- Recovery implies some extra cost
 - Extra mass for recovery system (propellants, parachutes)
 - Retrieval and transport to launch site
 - Inspection



SMILE – The Regulatory



- Many launches, many small satellites
- Orbital debris *is* a problem
 - Even though each pixel is 1000 km³
 - 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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