Miniaturisation Technology Development for Disruptive Spacecraft

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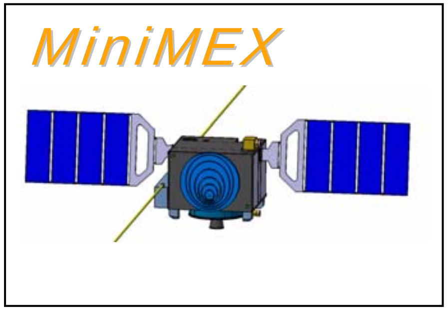
ESA/ESTEC

7th ESA Round-Table on MNT for Space Applications
13-16th September 2010

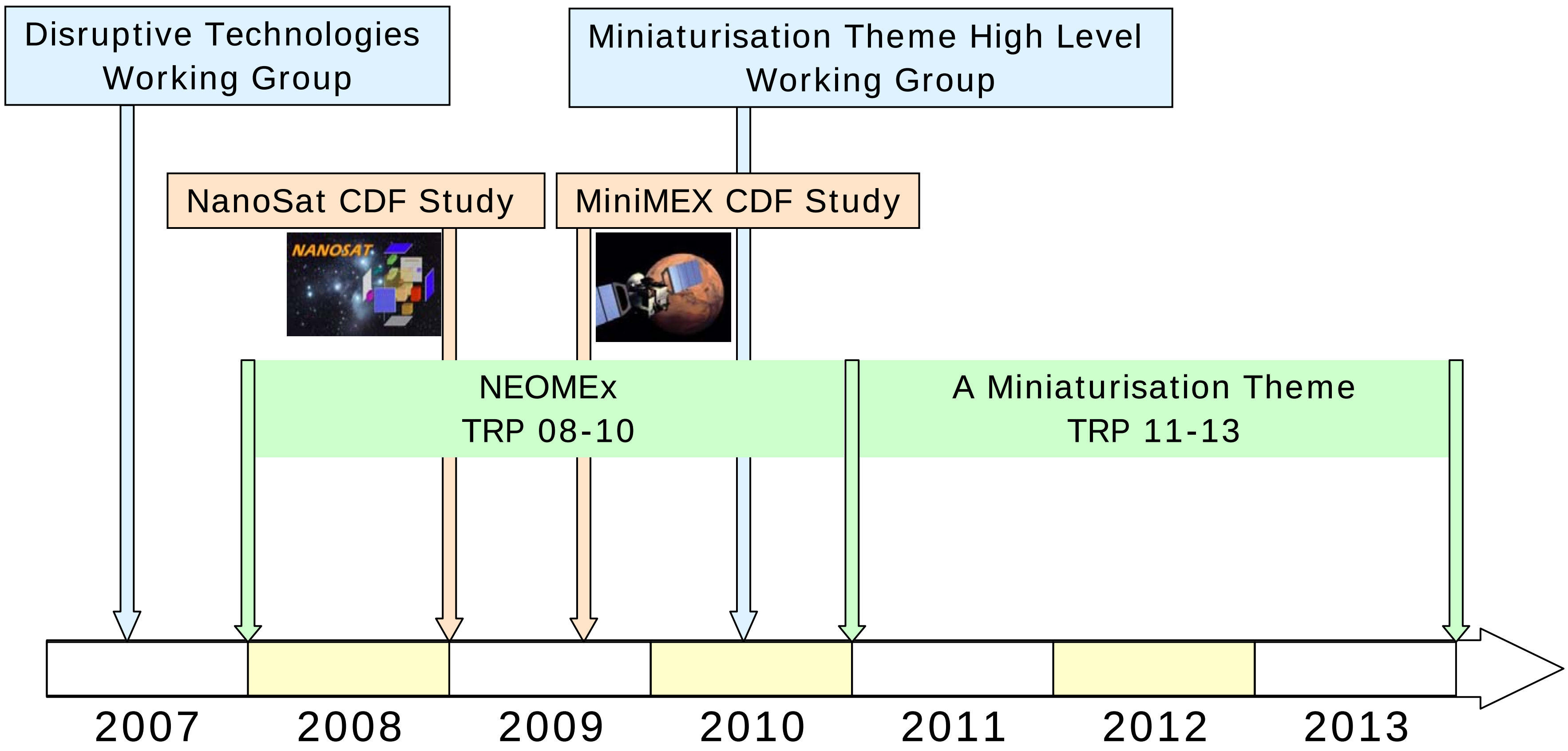
Microsystem-based spacecraft

One current and a future technology development theme and two internal concurrent design study

- NEOMEx theme in Basic Technology Research Programme (TRP) 2008-2010.
- NanoSat CDF study
- MiniMEX CDF study
- Future Miniaturisation Theme (TRP 2011-2013)



Contents in context



The NEOMEx Strawman

NEOMEx: Near Earth Object Micro   plorer

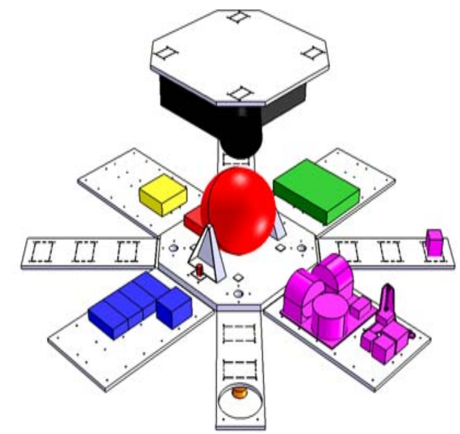
- To provide a focus application for a microsystem-based spacecraft concept
  - *Design driver for consolidated microsystems and miniaturisation developments*
  - *Modular microsystem-based design*
- Explorer mission applications as first target.
  - *Possible mission enabler*
  - *Mass saver*

- **Objective:** To perform close-up scientific investigations on several sites on a Near Earth Object.
- **Constraints:** Extreme mass-limitation, 5 kg platform, 2-4 kg payload of 10-15 W
- **Challenge:** use microsystems integrated in a system to gain performance with respect to mass.

ESA Don Quixote Mission Concept

NanoSat CDF study

- Nanospacecraft (20 kg wet mass, launch 2018): assess technologies and units/modules within 5 years of development
- Highly modular multipurpose platform.
- Application of disruptive miniaturisation to all subsystems.
- Low recurring cost, readily configurable platform to serve large range of potential missions and payloads.



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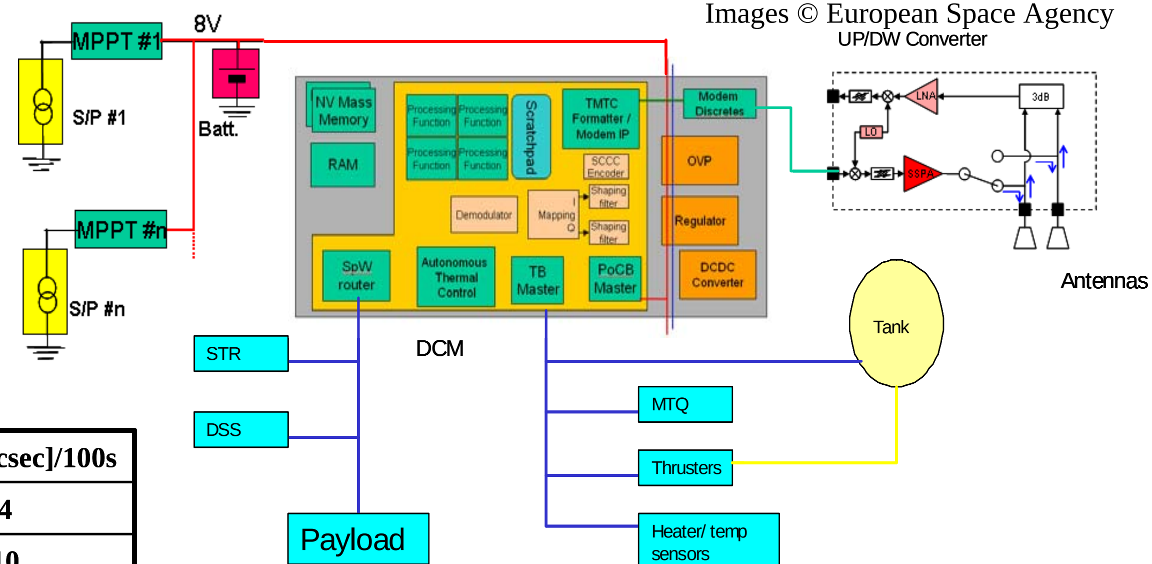
<u>Example performance</u>

- LEO SSO 6o km alt.
- 3-axis stabilised nadir-pointing
- 1 DoF control, 62.5 m/s Δv
- Payload: 8 l, 6.5 kg, 5 W cont.
- Data rate: 2 Mbps
- Downlink: 4.5 Gb/day
- Mass: 11.3 kg platform
  6.7 kg payload
  2.0 kg propellant

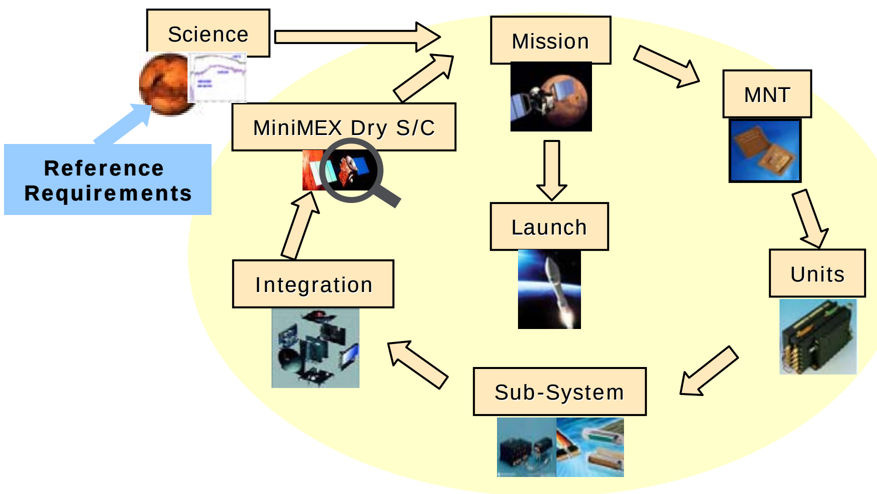


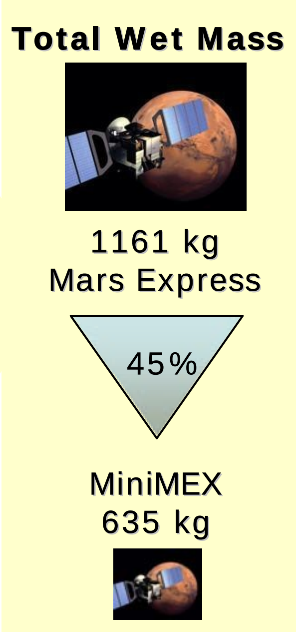
AOCS Performance	APE [arcmin]	RPE [arcsec]/100s
Determination	0.4	4
Pointing	1	10
Slewing	90 deg in < 100 sec	

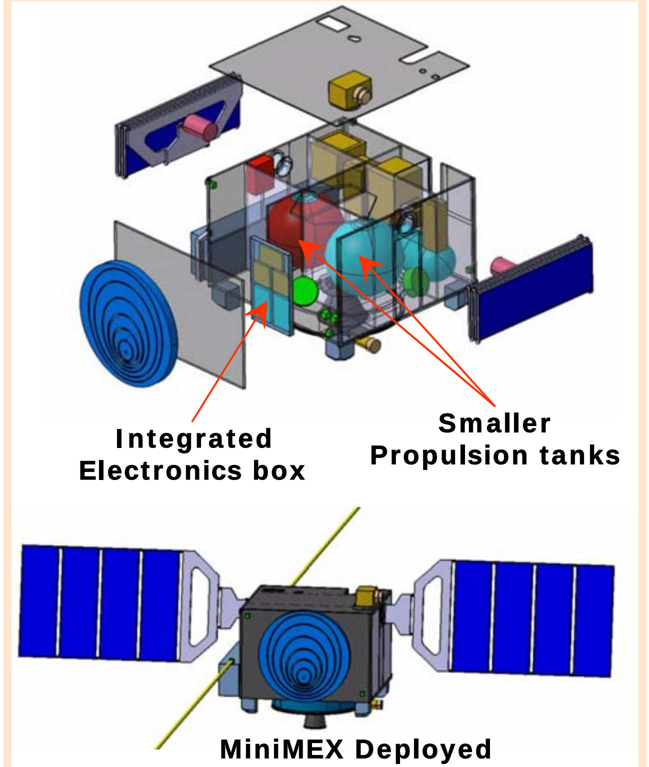
MiniMEX CDF study

- Miniature Mars Express or *"MiniMEX"* is a technology study to investigate the system impact of new technologies, including:
  - Micro Nano Technology
  - Innovative Integration
  - Existing Concepts in the TRP/GSTP/Other

@ Concurrent Design Facility







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	MEX	0: Mod	1: Mini	2: Int
Total Dry	617.4	452.8	304.7	285.4
Reference Proportion (%)	100	73	49	46

MNT systems considered including:
- AOCS Sensors-on-a-chip
- Integrated Data Handling
- RF MEMS switch
- MEMS IMU
- Nano D connector
- Passive reconfigurable thermal control

Future Disruptive Miniaturisation Theme Proposed for TRP 2011-2013

Overall Objective

- Define a coherent set of activities ensuring the development of key technologies to demonstrate advantages of miniaturisation: lighter spacecrafts aiming at lower recurrent costs, easier integration and simplified testing based upon a strawman concept.

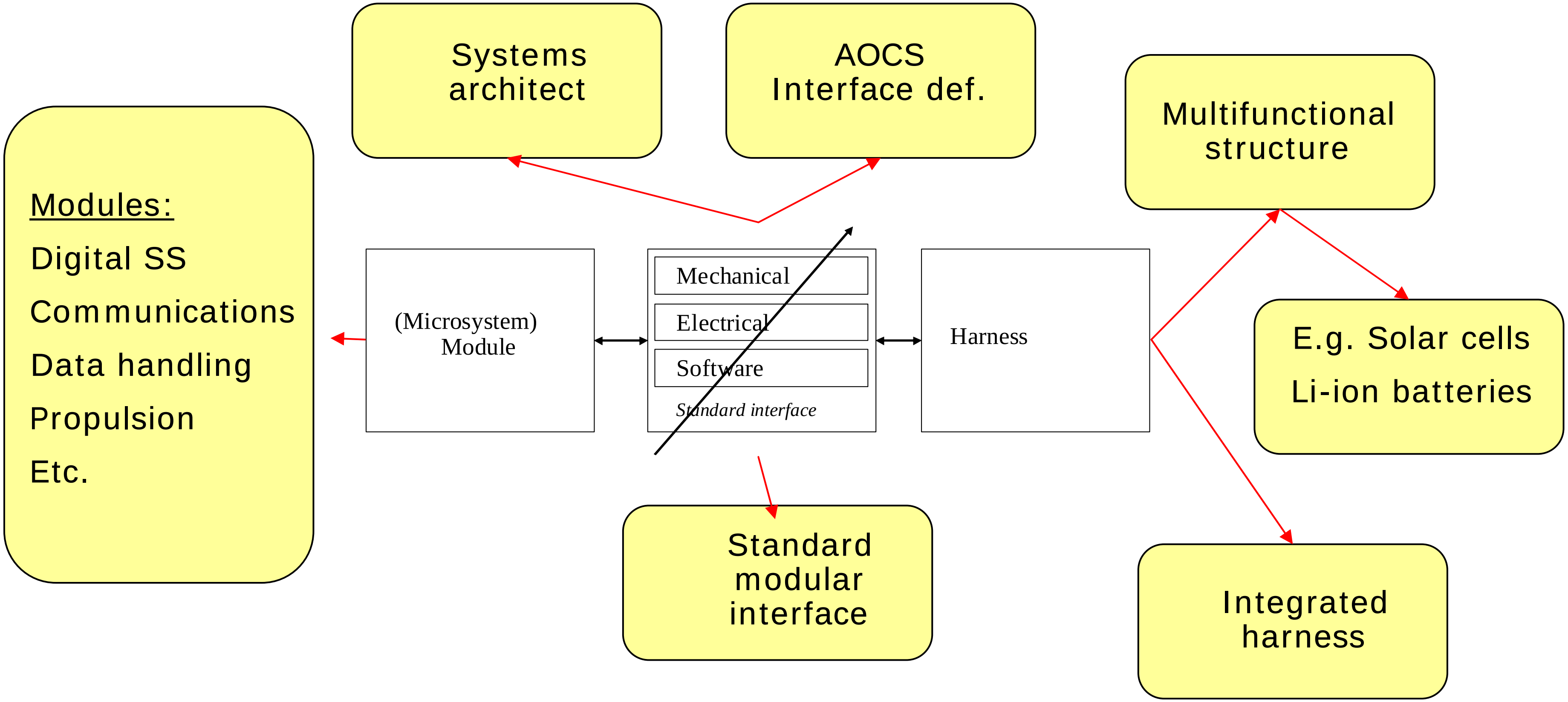
Platform

- The theme was started in the previous 3-year plan around strawman NEOMEX, driven by technology push.
- The approach is complemented with a top-down approach, need to reduce by a factor 2 the mass of the 1000 kg (dry mass) class spacecraft

Targets activities for which TRL 5 can be achieved no later than 2017 and includes:

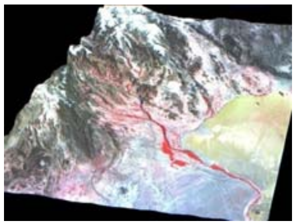
- Breadboards and demonstration of new disruptive concepts
- Space qualification of advanced miniaturisation enabling components, in particular for power applications
- Equipment options that have shown potential based on system studies:
    - Sensors-on-a-chip development
    - Integrated RF
    - Passive reconfigurable thermal control
    - Antennas: smaller, lighter, multi-functional for X-band applications (avionics)

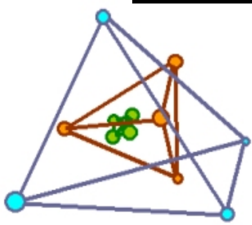
NEOMEx Activities in a System Context

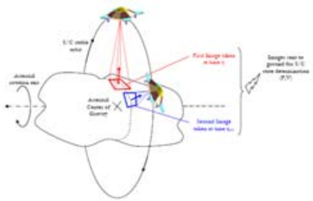


- Plug-and-play capability
- Standard interfaces
- Low recurrent cost
- Reusability of modules

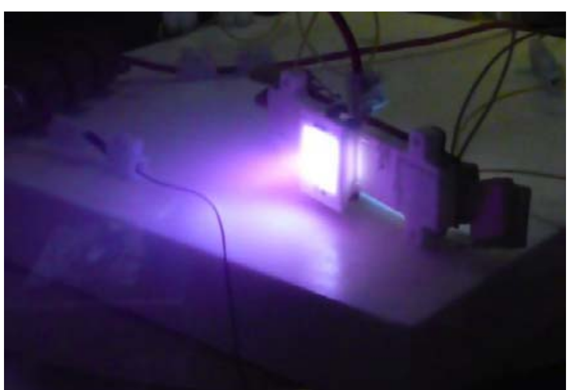
NEOMEx Ongoing Activities I

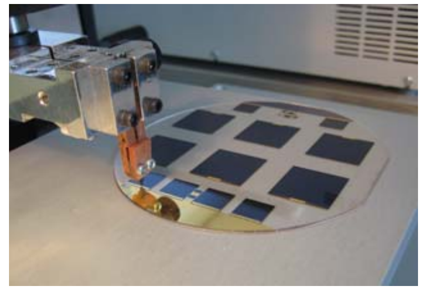




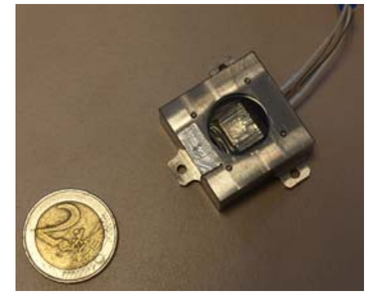


- AOCS definition and sizing
  - SEA



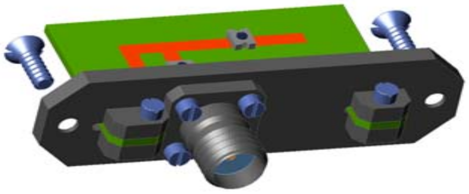


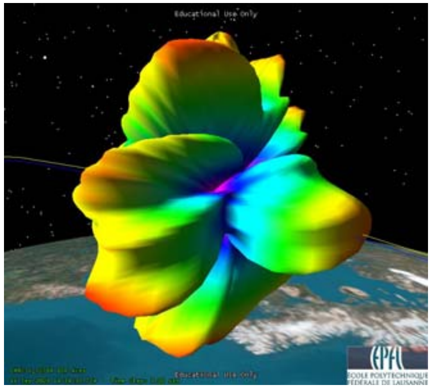
- Ultra-thin multijunction GaAs solar cells
  - Fraunhofer Institute
- Micropropulsion system (μPPT)
  - University of Southampton, ClydeSpace, et al

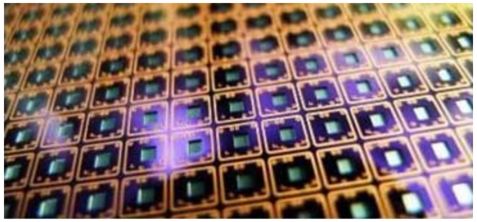


- Digital sunsensor on a chip
  - Selex Galileo

NEOMEx Ongoing Activities II







- Multifunctional antenna systems I
  - IDS
- Multifunctional antenna systems II
  - EPFL
- Standard modular microsystems interface
  - AAC Microtec

NanoSat Modules Development

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
AOCS											
Digital Sun Sensor	3		6	8		9					
Star Tracker		2		3		6		7	9		
Gyro		5	6		8		9				
Earth Sensor	1		3		7						
GNSS Receiver		4	6		8		9				
Magnetometer		4	6	8		9					
Magnetorquer		4	6		8		9				
Reaction Wheel		3	4	6		8		9			
Navigation camera		2		3		6		7	9		
Antennas/Comms											
Lightweight S-band antenna	6		8	9							
Lightweight X-band antenna	2		3		6	8	9				
Multifunctional distributed antenna system	1		2		4		6		8	9	
Electronics for distributed antenna system		1	2		4		6		8	9	
UP/DW converter efficient power amp.	3		6		8	9					
Mobile phone based transponder	2	3		4		6		8	9		
DHS											
Control Distribution Unit	2		4	8		9					
General purpose Interface ASIC		3		5	8						
DCM (SoC ASIC) -System on a chip-											
Power											
Solar Array	2		3		4		5		6		
Battery Pack	2	3	4	5	6	7	8	9			
Power Conditioning		4	5	6	7	8					

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Propulsion											
Propellant Tank Module (A)	5	6	7	7	8						
Cold Gas Generator Module (B)	4	5	6	6	7	8					
Solid Propellant Thruster Module (C)	2	3	3	4	5	5	6	6	7	8	
Single Thruster Monopropellant Module (D)	3	4	5	5	6	6	7	8			
Single Thruster Butane Module (E)	3	4	5	5	6	6	7	8			
Three Thruster Butane Module (F)	3	4	5	5	6	6	7	8			
Four Thruster MEMS Nitrogen Module (G)	3	4	5	5	6	6	7	8			
Structure											
Conventional Structure		7			9						
Innovative Structure		2		3	4	5	6	7	8	9	
Harness based on Nanotubes		1		2		4		5		6	
Conventional Harness		7		9							
Mechanisms											
S/A Deployment Mechanism (SDM)		4	5	6		8					
Deorbit Deployment Mechanism (DDM)		4	5	6		8					
Hold down and Release Mechanism (HDRM)		2			8						
Nano-Terminator Deorbit Module (NTDM)		2			8						
Thermal											
Black paint	8										
MiSER (Miniature Satellite Energy Regulating Radiator)	8										
Thin Plate Heat Switch	8										
Heater line (2 heaters+1 sensor)	8										
Heat pipe	8										
MLI blankets	8										

- The NanoSat mission scenarios provide significant onboard resources, mass and volume to P/L.
- Based on disruptive approach at system level and on an extensive multi-year development programme of significant investments.

NEOMEx – NanoSat - MiniMEX Correspondence I

- System aspects:
  - NEOMEx and NanoSat study correspond closely in terms of requirements, standard interfaces, modularity. MiniMEX is constrained by redundancy requirements.
  - NanoSat as case study for NEOMEx concept, while MiniMEX is a case study for large missions.
- Structure aspects:
  - NEOMEx pursues a more advanced concept including multifunctional structures and integrated harness.
- Mechanisms aspects:
  - No critical mechanisms technologies identified in NEOMEx theme.
  - NanoSat mechanisms are available but requires adaptation. MiniMEX miniaturisation enabled scaled-down requirements for mechanisms.
- Propulsion aspects:
  - NanoSat reaches further defining specific propulsion needs (more kinds of modules).
  - NanoSat is constrained by perceived TRL and therefore limited to chemical propulsion.
  - MiniMEX has a huge delta-v requirement that is the main design driver and a bottleneck for miniaturisation.

NEOMEx – NanoSat - MiniMEX Correspondence I

- Power aspects:
  - Clear gap in NEOMEx on power converter technology and power distribution systems.
  - Candidate technologies outlined in NanoSat and MiniMEX study.
  - Power converter and distribution components are key to MiniMEX integration and architecture.
  - All show a need for improved solar power generators.
- AOCS aspects:
  - Development scope for AOCS corresponds very well between NEOMEx, NanoSat and MiniMEX.
  - Several specific sensors and actuators are not yet covered in NEOMEx.
- Data handling aspects:
  - Approach and architectures correspond well.
- Telecommunications aspects:
  - NEOMEx theme pursues more advanced options on device level.
  - NanoSat addresses integration and modularity to a higher degree.
  - MiniMEX identifies GaN technology as promising.
- Thermal aspects:
  - NEOMEx pursues more advanced thermal control capabilities, but with lower TRL than the NanoSat or MiniMEX baseline.

Conclusions

- The NEOMEx theme pursues advanced miniaturisation as a vehicle of disruption to how spacecraft are built and missions are designed.
- The disruptive miniaturisation theme continues targeting enabling technologies for extreme mass reduction, for applications like NEOMEx, NanoSat, and MiniMEX-like missions.
- NanoSat study can serve as a case study in the NEOMEx concept, while MiniMEX serves a potential new miniaturisation theme for larger spacecraft.
- Efforts to study low-cost manufacture of modules is needed.
- Normal miniaturisation development can feed into a disruptive miniaturisation theme, with some adaptation.