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space technology
harmonisation

esa

→ HARMONISATION OF EUROPEAN SPACE TECHNOLOGY

A FUNDAMENTAL ROLE ENHANCING EUROPEAN INDUSTRY WORLDWIDE COMPETITIVENESS

European Space Agency

2001
1st Harmonisation Roadmap agreed and released: AOCS

2002
ESTMP first issued

2006
Creation of the IPC-THAG

2009
European Commission-ESA-EDA Non dependence process defined based on Harmonisation

2013
100th Harmonisation Roadmap agreed and released: Pyrotechnic Devices

2014
1st European Space Technology Harmonisation Conference - ESA/ESTEC

2015
Public release of the ESTMP 12th Edition during an ESA press conference at Le Bourget of former DG, Jean-Jacques Dordain, in presence of ESA DG, Johann-Dietrich Woerner

→ HARMONISATION OF EUROPEAN SPACE TECHNOLOGY

“Harmonisation produces joint Roadmaps with the aim of optimizing public funding and guiding developments to ensure the right technology is at the right maturity at the right time”

The Technology R&D Harmonisation provides to all European actors the framework and the key instruments to coordinate Space Technology at European level by agreeing on European Space Technology Roadmaps.

Harmonisation is a voluntary process, based on transparency and exchange of information. The continuous support from all participants, including Delegations, Industry, Research Institutes, etc, is key to the success of this European initiative.

Objectives

The European Space Technology Harmonisation main objectives are:

- “Fill strategic gaps” and “Minimize unnecessary duplications”
- Consolidate European Strategic capabilities
- Achieve a coordinated and committed European Space Technology Policy and Planning
- Contribute to continuity and coherence between Technology and Industrial Policies

ESA Technology Harmonisation team

The Technology Harmonisation team resides within the Directorate of Technical and Quality Management (TEC). The section manages the complete European Space Technology Harmonisation Process in close collaboration with all the stakeholders and relies heavily on the inputs from the ESA Technical Officers and colleagues.

In addition to taking care of the Technology Harmonisation, THAG matters and associated databases, the Technology Harmonisation team:

- Provides the secretariat of the Technology Advisory Working Group (TA-WG)
- Establishes the European Space Technology Master Plan (ESTMP)
- Interfaces with the EU on technology matters
- Coordinates the European Commission-ESA-EDA Critical Space Technologies for European Non-Dependence initiative
- And maintains the end-to-end process for management of technology development within ESA

ESA channels around 8% of its budget into direct technology research and development.

THAG: Technology Harmonisation Advisory Group

The Technology Harmonisation Advisory Group (THAG) is an ESA delegate body, established in 2006 to advise the ESA Industrial Policy Committee (IPC) on Technology Harmonisation matters.

In particular, THAG advises the IPC and makes recommendations on the following matters:

- Selection of topics for Technology Harmonisation
- Mapping of European capabilities with respect to the needs of the institutional and commercial markets
- Technology Roadmaps and Conclusions
- Implementation within ESA programmes of agreed Roadmaps and Conclusions, and identification of national and European level funding
- Harmonisation measures to be applied in institutional programmes and by industry.

THAG monitors the implementation of the harmonised Technology Roadmaps and Conclusions.

It is composed of a maximum of two delegates for each ESA Member State and Canada, who may be accompanied by experts for some specific issues.

The THAG may advise the IPC, at its request, on technology related matters, such as technology strategy, technology plans, technology non-dependence and worldwide technology watch.

Participants of the harmonisation

The community involved in the Harmonisation has progressively increased and now includes:

- ESA Member States
- The European Cooperating States (ECS)
- The European Commission
- The European Defence Agency (EDA)
- Eurospace
- SME4Space
- Industry and research organisations

The Technology Harmonisation team manages the complete Harmonisation Process in close collaboration with all relevant stakeholders.

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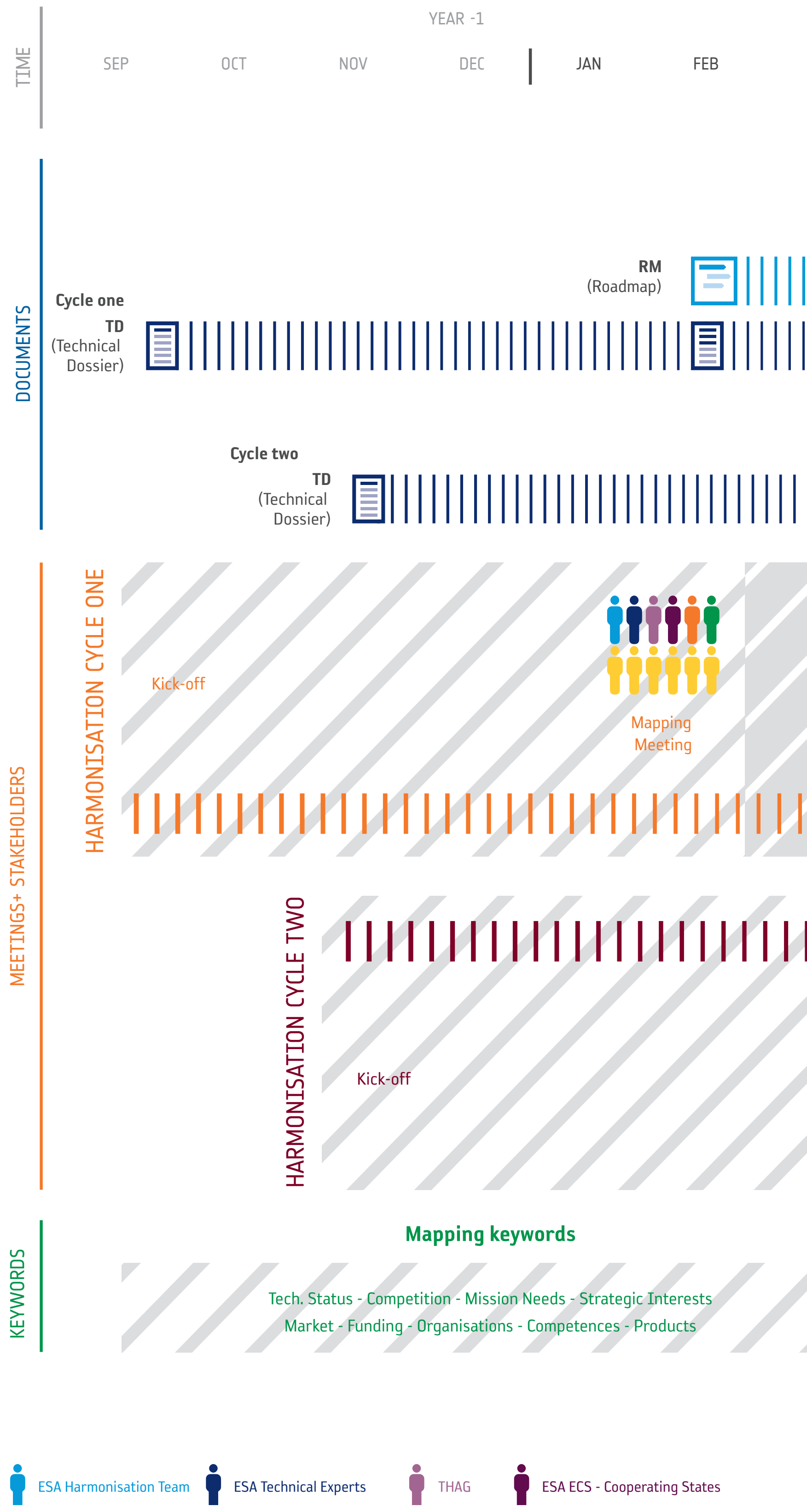
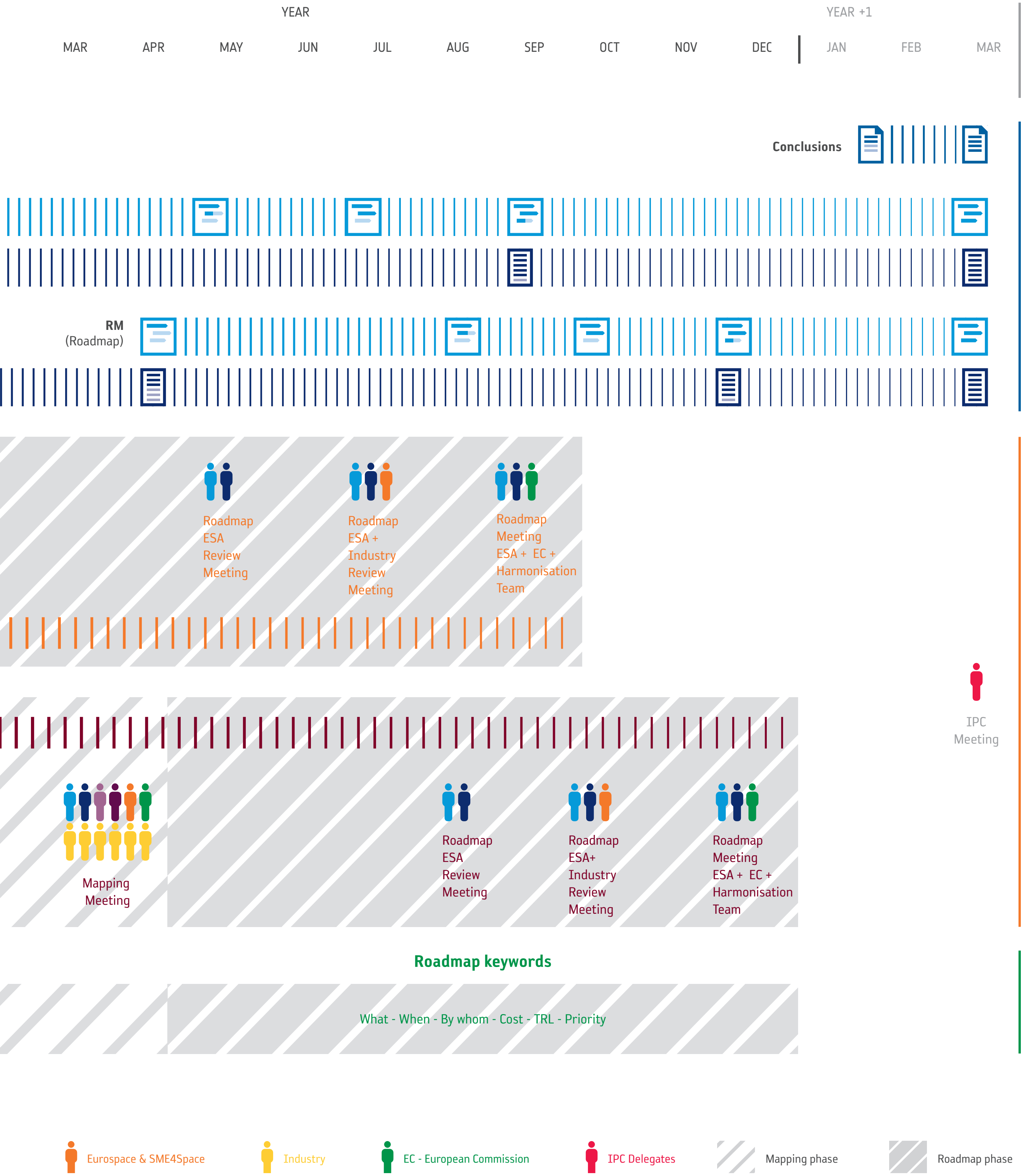
THE HARMONISATION PROCESS

An effective coordination of the European Space Technology R&D activities.

The “European Space Technology Harmonisation” process takes into account the various European needs, developments, capabilities and budgets to enhance the complementary roles of the various partners in meeting common objectives and agreeing on European space technology Roadmaps.

The roadmaps include relevant on-going, funded and new proposed activities prioritised and broken down in the different steps required to achieve defined objectives.

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Conclusions
RM
(Roadmap)
Roadmap ESA Review Meeting
Roadmap ESA + Industry Review Meeting
Roadmap Meeting ESA + EC + Harmonisation Team
IPC Meeting
Mapping Meeting
Roadmap ESA Review Meeting
Roadmap ESA+ Industry Review Meeting
Roadmap Meeting ESA + EC + Harmonisation Team
Roadmap keywords
What - When - By whom - Cost - TRL - Priority
Eurospace & SME4Space
Industry
EC - European Commission
IPC Delegates
Mapping phase
Roadmap phase

HTS

Harmonisation Tracking System

One of the Key Performance Indicators (KPI 5) of the Agency is the percentage of harmonised roadmap activities implemented versus all activities in the roadmap.

To assess the level of implementation of the Roadmaps, ESA experts and THAG Delegations are regularly consulted on the status of technology activities related to each harmonised roadmap.

The information is introduced in the HTS (Harmonisation Tracking System).

The results of this annual exercise are reported in the HTS report, which is issued each year, and made available on the HDMS.

ICM

Industry Capability Mapping

The Industry Capability Mapping (ICM) Database maps the Capabilities of the European Space Industry and Research Institutes of which it provides a repository for the Technology Competencies and Products.

The ICMdb is being gradually updated through the Harmonisation Process and being used to support the process itself.

It is accessible not only to ESA and THAG Delegates but also to European Industry, upon request.

For more information, or to request access, please contact *harmo@esa.int*.

HDMS

Harmonisation Document Management System

All Harmonisation documentation, including the final Roadmaps and Technical Dossiers, are available on the Harmonisation Document Management System. It can be accessed at the URL *https://harmostrat.esa.int*.

The HDMS allows searching for Harmonisation documents using a variety of parameters (e.g. Technology Title, Cycle, Document Class, etc.).

Login details can be requested by sending an e-mail to *harmo@esa.int* (providing business affiliation and position in the company).

ESTMP

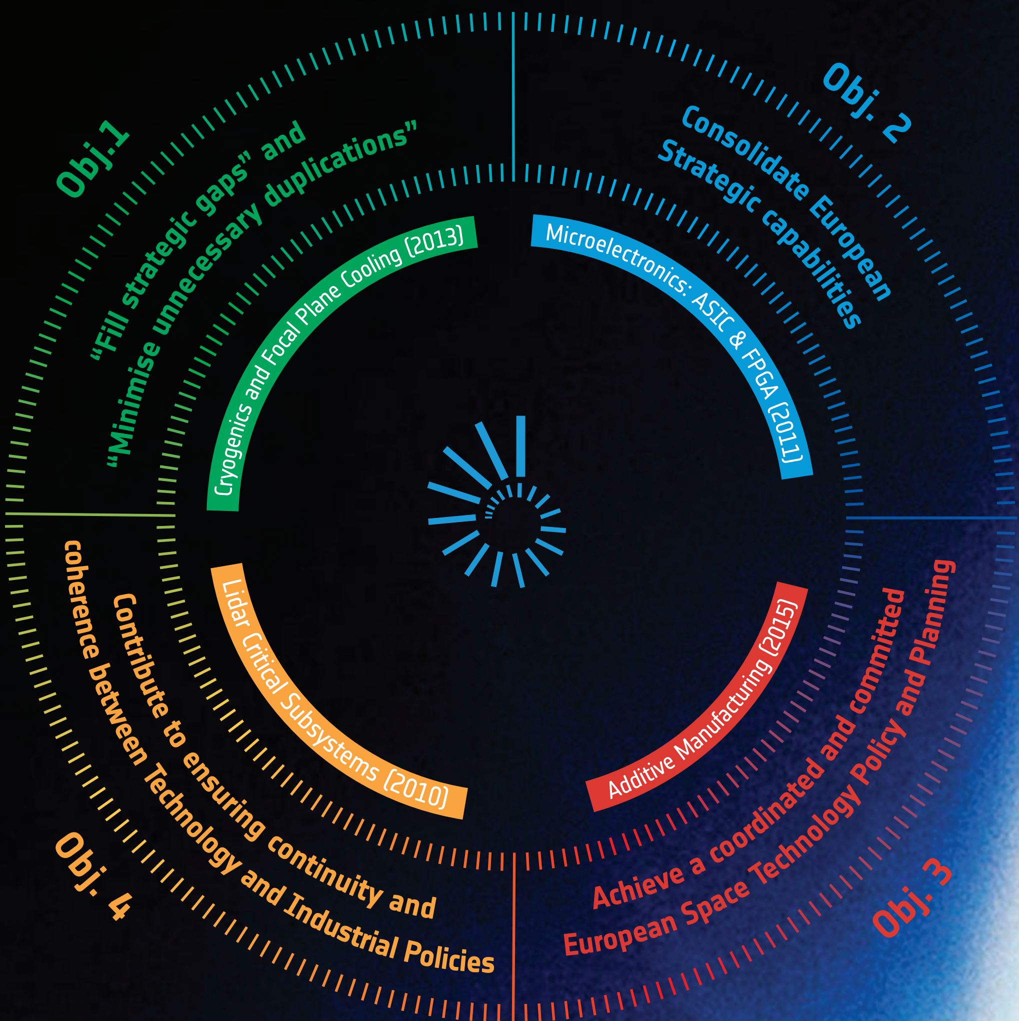
The European Space Technology Master Plan

- Updated annually by ESA together with key stakeholders and widely distributed every year, the ESTMP constitutes a comprehensive overview of technology in Europe, including European harmonised roadmaps.
- The ESTMP is an instrument to support decision makers and stakeholders in the implementation of the European Technology medium and long-term strategy, and the definition and consolidation of a European Space Policy on Space Technology.

A printed copy can be requested by sending an email to *harmo@esa.int*.

The e-ESTMP can also be found on the HDMS: *https://harmostrat.esa.int*.

→ HARMONISATION OBJECTIVES AND EXAMPLES



Currently active roadmaps

49

active harmonisation roadmaps

2100 harmonisation roadmap activities for a total budget of 1.5 B€ of which 65% has been approved (KPI 5)

Since 2001

121

harmonisation roadmaps

6000 harmonisation roadmap activities for a total budget of 4 B€

See HTS Report 2016 on the HDMS: *https://harmostrat.esa.int.*

2016

- Optical Detectors, Visible Range(2015.1)
- Power RF Measurements and Modelling (2015.1)
- Solar Generators and Solar Cells (2015.1)
- Additive Manufacturing (2015.2)
- AOCS Sensors and Actuators II (2015.2)
- Electrical Motors and Rotary Actuators (2015.2)
- Ground Station Technology (2015.2)
- Radiation Environments & Effects (2015.2)
- Technologies for Hold Down and Release Mechanisms and Deployment Mechanisms (HDRM&DM) (2015.2)

2015

- Electrochemical Energy Storage (2014.1)
- Solar Array Drive Mechanisms (2014.1)
- Composite Materials (2014.2)
- Functional Verification and Mission Operations Systems (2014.2)
- Micro and Nano Technologies: RF MEMS, MOEMS AND MEMS PRESSURE SENSORS (2014.2)
- On-Board Software (2014.2)
- System Data Repository (2014.2)

2014

- AOCS Sensors and Actuators I (2013.1)
- Pyrotechnic Devices (2013.1)
- Technologies for Optical Passive Instruments (Mirrors) (2013.1)
- Technologies for Optical Passive Instruments (Stable & Lightweight Structures) (2013.1)
- Cryogenics and Focal Plane Cooling (2013.2)
- Frequency and Time Generation and Distribution - Space (2013.2)
- On-Board Radio Navigation Receivers (2013.2)
- Power Management and Distribution (2013.2)
- Critical Active RF Technologies (2013.2)

2013

- Automation and Robotics (2012.1)
- Chemical Propulsion - Green Propulsion (2012.1)
- System Modelling and Simulation Tools (2012.1)
- Chemical propulsion - Components (including Tanks) (2012.2)
- Fluid Mechanic and Aerothermodynamics Tools (2012.2)
- Optical Communication for Space (2012.2)
- TT&C Transponders and Payload Data Transmitters (2012.2)

2012

- Frequency and Time Generation and Distribution - Ground (2011.1)
- Array Antennas (2011.2)
- Chemical Propulsion - Micro Propulsion and Related Technologies (2011.2)
- Data Systems and On Board Computers (2011.2)
- Microelectronics - ASIC & FPGA (2011.2)
- On-Board Payload Data Processing (2011.2)

2011

- Avionics Embedded Systems (2010.1)
- Lidar Critical Subsystems (2010.1)
- Deployable Booms & Inflatable Structures (2010.2)
- Technologies for Passive Millimetre & Submillimetre Wave Instruments (2010.2)

2010

- Position Sensors (2009.1)
- Two-Phase Heat Transport Systems (2009.1)
- Electric Propulsion Pointing Mechanisms (EPPMs) (2009.2)
- Electric Propulsion Technologies (2009.2)
- Telecommunications Reflector Antennas (2009.2)

2009

- Formation Flying - Optical Metrology (2008.1)
- Formation Flying - RF Metrology (2008.1)

2008

→ CRYOGENICS AND FOCAL PLANE COOLING

Active version: 2013

Previous versions: 2007, 2001.

Roadmap agreement in 2013:

- 76 activities (incl. 53 ESA activities)
- agreed budget of 33 M€ (incl. ESA budget of 28 M€)

Roadmap implementation status in 2016*:

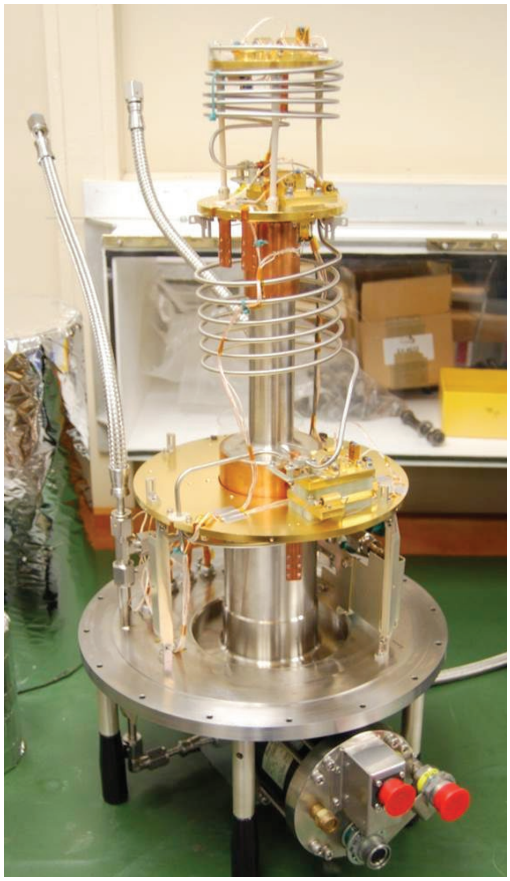
- 55% activities funded or partially funded
- 53% of the roadmap budget funded

** only activities with a planned start date before 31/12/2015*

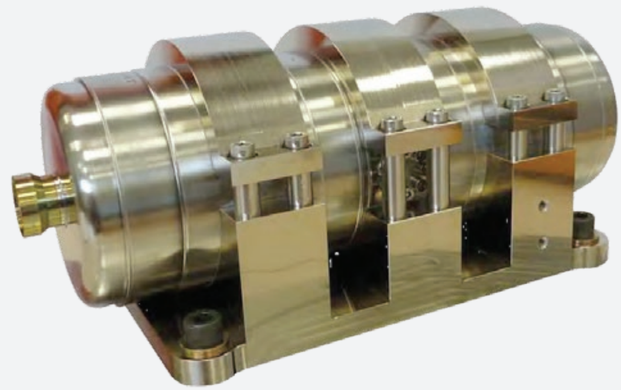
Cryogenics in general is the domain of thermal science dedicated to the study and the production of temperature below 200K. Applied to the Space Sector, this term describes the different types of technologies that permit to reach such temperatures.

The need of Cryogenics Temperature range for Space can be motivated by different needs (conservation of samples, boil-off reduction etc.) but the main application lies in the cooling of Focal Planes which requires temperatures covering the whole range from Ambient to SubKelvin.

In addition to the absolute temperature requirements, other mission dependant challenges drive the choice of cooling technologies: e.g. microvibration, accommodation, reliability. One of the purpose of the Harmonisation is to identify the mismatch between the European catalogue of technologies and the upcoming driving constraints in order to fill the gap.

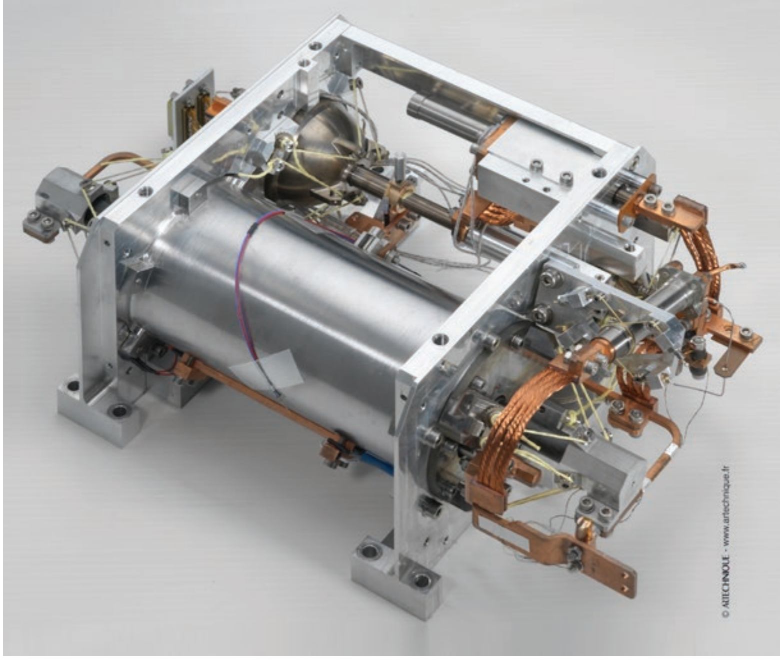


Heat Exchanger of the Advanced 2K Cooler (courtesy of RAL)



Compressor of the 15K Pulse Tube Cooler (courtesy of ALAT/TCBV)

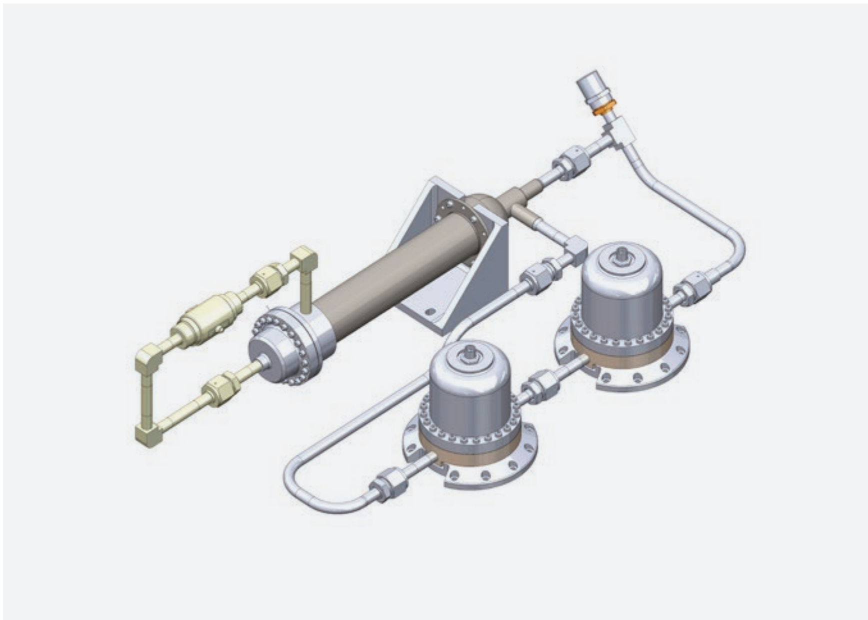
In 2009, the launch of Planck was not only a tremendous technical success for the Cryogenic community but was also a brilliant demonstration of a worldwide collaboration that permitted to put together a cryogenic chain from ambient to 0.1K. One of the link of this chain was the Hydrogen Sorption Cooler provided by the Jet



Hybrid Sorption-ADR Cooler in TRP version (courtesy of CEA)

Propulsion Laboratory in order to obtain the 15K stage which was not available in Europe. For future Scientific missions, the harmonisation process highlighted the need to have a full European Cryochain. In the last 6 years, the European Space Agency organised the developments of multiple coolers (e.g. Advanced 2K coolers from the Rutherford Appleton Laboratory, the 15K Pulse Tube cooler from Air Liquide, the Hybrid Sorption-ADR cooler from CEA) that will now be used in the upcoming class L Science mission Athena: the detector of the X-IFU instrument will reach the temperature of 50mK thanks to a cascade of coolers, fully European.

Another example of how the Harmonisation process can be used to help fill strategic technology gaps: the mapping meeting in 2013 highlighted the urgent need to find a cooling solution compatible with the stringent microvibrations requirements of Earth Observation missions. Three years after, the promising 40-80K Reverse Turbo Brayton technology for Space is being developed in Europe and could revolutionize the architecture and performances of Earth Observation and also Science missions.



CAD representation of the 40-80K Reverse Turbo Brayton Cooler (courtesy of Absolut System)

Recuperator of the Breadboard Model of the RTB (Courtesy of Absolut System)

MICROELECTRONICS: ASIC AND FPGA

DEEP SUBMICRON CHIPS: ON-BOARD INTELLIGENCE

Active version: 2011

Revisited version: 2016 *(on-going)*

Previous versions: 2007, 2002.

Roadmap agreement in 2011:

- 79 activities (incl. 49 ESA activities)
- agreed budget of 53 M€ (incl. ESA budget of 30 M€)

Roadmap implementation status in 2016*:

- 67% activities funded or partially funded
- 73% of the roadmap budget funded

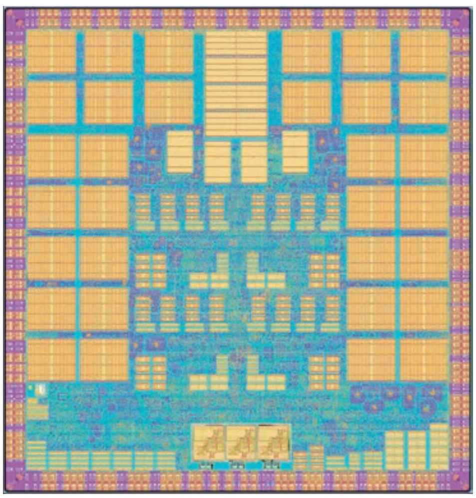
** only activities with a planned start date before 31/12/2015*

Complex integrated circuits act as the brains that process all the incoming and outgoing data in the spacecraft.

Satellites use up to hundreds of these microchips to control their navigation in space, and to be able to convert the signals measured by all the instruments on board into useful information. Sophisticated circuit design tools and commercial manufacturing technologies used to produce microchips for terrestrial applications (inside home computers, mobile phones, etc.) have been adapted for their use in space applications. The main obstacle that these chips must survive in space is radiation. In addition, their good behaviour must be also guaranteed at extreme temperatures and often for long mission durations, where no on-board parts repair or replacement is an option.

ESA and European industry have been defining and implementing together multiple technology development activities to ensure that advance and reliable space microchip technology is available. The focus has been put on Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) and Microprocessors. ASICs can provide the best compromise in performance, power consumption and miniaturisation. FPGAs can provide enough “brain power” in many cases, at normally lower costs and shorter development times, and introducing more flexibility for changes with the “re-programmable” variant of FPGA technology. Microprocessors bring great processing power and flexibility to modify the on-board functions by changing the software that instructs the microprocessor what to do.

Layout of GR740 Quad-Core LEON4 microprocessor, designed by Cobham Gaisler using C65SPACE of STMicroelectronics (Copyright: Cobham Gaisler/ STMicroelectronics)

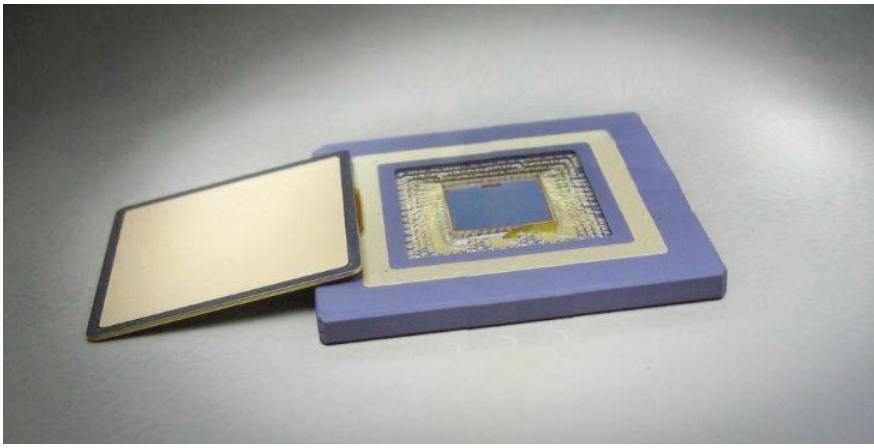


More than 12 test chips were designed, manufactured and tested since 2008 to develop STMicroelectronics rad-hard 65nm ASIC technology known as C65SPACE (Copyright: STMicroelectronics)

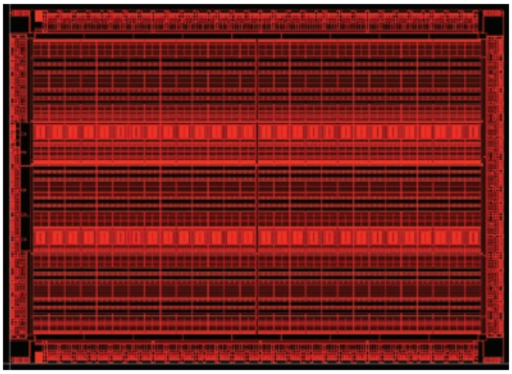
Space ASIC technology and reusable off-the-shelf chips using a feature size of 180 nanometers (ATC18RHA and DARE180) were promoted in the 2006 Harmonisation Microelectronics roadmaps. Tens of different ASICs were designed and manufactured between 2003 and 2015, covering specialised functions as Telecom payload processors, SpaceWire networks, star-tracker control, GPS and Galileo signal processors or on-board image compression. The successful LEON general purpose SPARC microprocessor was manufactured and qualified, and is today extensively used in most ESA missions, as either a stand- alone chip, or existing as an embedded function inside a larger microchip (System-on-Chip). The Harmonisation exercise of 2007 was already reflecting the first steps towards the development of a next generation deep submicron technology, based on transistors of minimum feature sizes of just 65 nanometers. In 2015 the first microchips using this technology (C65SPACE) were manufactured: the most complex ever European space Telecom ASIC, the ambitious quad-LEON4 next generation microprocessor and the new European reprogrammable space FPGA, called BRAVE, have been manufactured in June 2016 using also this 65nm technology.

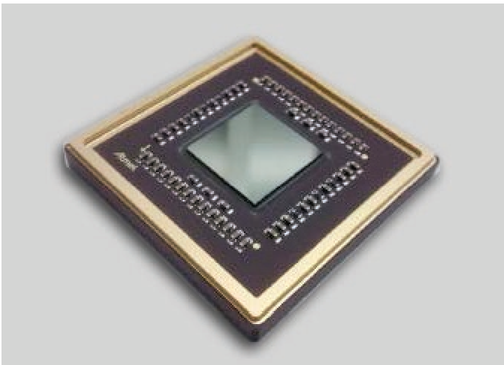
The Microelectronics: ASIC and FPGA roadmaps are undergoing a third harmonisation cycle in 2016. The challenges now are to qualify the first microchips made with this technology, the GR740 microprocessor, and the first BRAVE-MEDIUM FPGA. In addition, larger capacity BRAVE FPGAs are in the roadmap, as well as the first steps to do the next jump in miniaturisation in space microchip technology: 28 nanometers or below, but also coming microprocessor generations and the integration of microprocessor and FPGA on a single chip.

GR740 Microprocessor with the package lid open exposing the silicon die and its 625 wire-bonds (Copyright: Cobham Gaisler)



Layout of BRAVE-MEDIUM FPGA a full-custom design by NanoXplore manufactured with STMicroelectronics 65nm technology in July 2016 (Copyright: NanoXplore/ STMicroelectronics)





VT65 telecom application specific integrated circuit (ASIC) designed by Thales and manufactured with STMicroelectronics C65SPACE technology (Copyright: Thales Alenia Space)

→ ADDITIVE MANUFACTURING

Active version: 2015

Revisited version: 2017 *(on-going)*

Roadmap agreement in 2015:

- 68 activities (incl. 55 ESA activities)
- agreed budget of 40 M€ (incl. ESA budget of 29 M€)

Roadmap implementation status in 2016*:

- 31% activities funded or partially funded
- 22% of the roadmap budget funded

** only activities with a planned start date before 31/12/2015*

The landscape of manufacturing technologies has evolved during the last decade and additive manufacturing technologies are considered as important contributors to an industrial revolution for space.

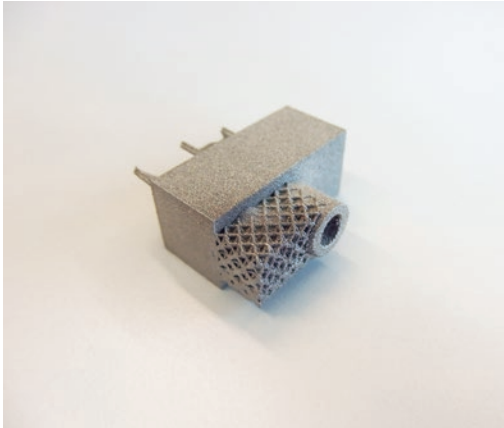
Those technologies do not, per se, improve already designed hardware. However, they allow improving the performances of many space equipment and permit complexity and multi-functionality at no cost. The whole European Space community worked together to put in perspective the developments required to mature those technologies.

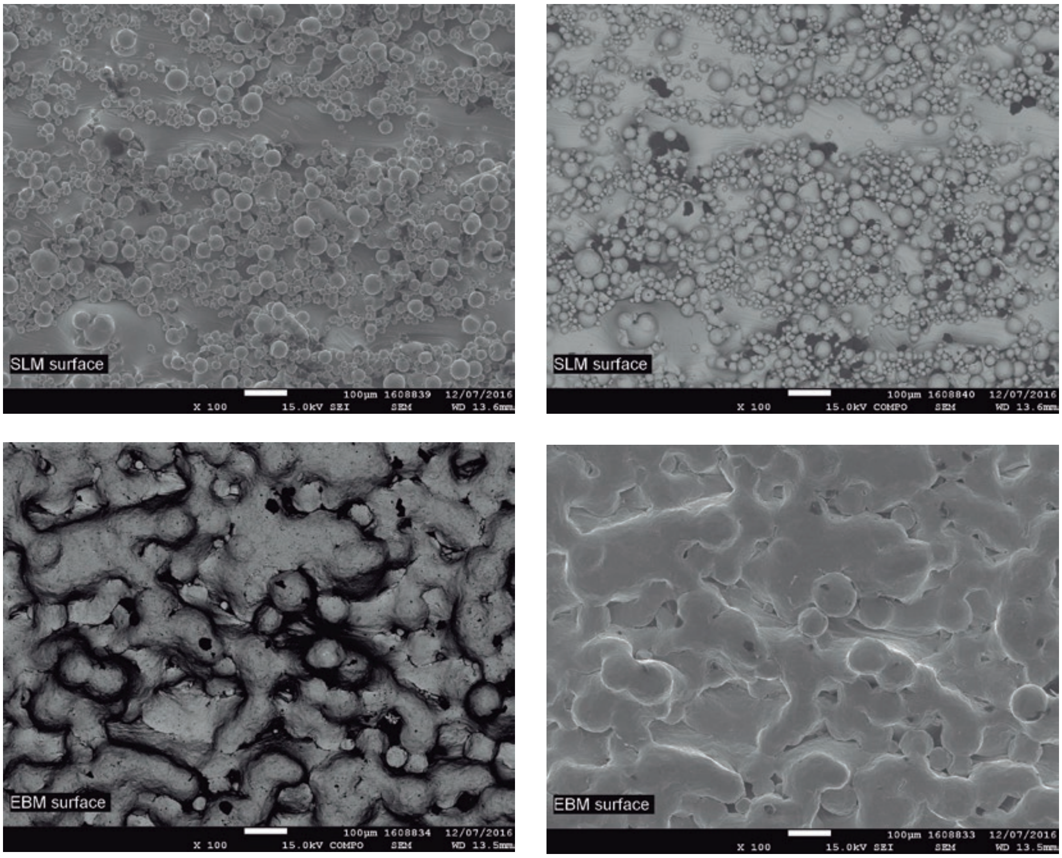
The area covered by this harmonisation round encompasses the complete life cycle of the materials used in additive manufacturing. It provides the elements required by the European Space community to develop the next generation of space hardware for all types of missions. The Additive Manufacturing harmonisation dossier have received an unprecedented attention by Industry and Delegations. During the Mapping meeting in February 2014 , 17 ESA member states have been reporting their specific national capabilities. More than 350 Delegates attended a dedicated preparatory workshop at ESTEC in October 2014. More than 600 experts from 26 countries have been contacted to review the proposed Additive Manufacturing roadmap. The Eurospace database registered 53 new companies from 17 countries during the review of the Additive Manufacturing Roadmap.

3D printing means that much more complex shapes are possible, compared to standard manufacturing. Design is optimized for AM: ~50% mass saving, suppress interfaces, vibration test passed, dimensional control successful. (nov 2015)

The ESA member states not only support the Additive manufacturing technologies as proposed in the AM roadmap but also the development of advanced space hardware manufactured by using these technologies.

One very emblematic activity currently running corresponds to Aim D. It is “Surface Engineering for Parts Made by Additive Manufacturing (Step 1)”. The surface quality obtained by Additive manufacturing is not enough for using the processed part. Therefore, ESA initiated a study aiming at establishing a catalogue of surface finishing techniques for the most commonly used space metallic materials, i.e. aluminium, titanium and stainless steel. The activity has been heavily supported by the ESA member states and several high quality bids have been received allowing the implementation of 3 contracts running in parallel and looking from different perspectives to the surface finishing problem. Impact of AM technology on the surface finish is illustrated in the pictures below. These as-processed surfaces will each require different finishing steps to ensure that no loose particle remains and that the surface is free of contaminant.





Surface of titanium as processed by Additive manufacturing Top) using Selective laser melting, bottom) using Electron beam melting. Left) showing the surface topology Right) contrast highlighting the change in chemical composition; i.e. possible contamination.

→ LIDAR CRITICAL SUBSYSTEMS

Active version: 2010

Revisited version: 2017 *(on-going)*

Previous versions: 2005

Roadmap agreement in 2010:

- 34 activities (incl. 19 ESA activities)
- agreed budget of 34 M€ (incl. ESA budget of 24 M€)

Roadmap implementation status in 2016*:

- 71% activities funded or partially funded
- 89% of the roadmap budget funded or partially funded

** only activities with a planned start date before 31/12/2015*

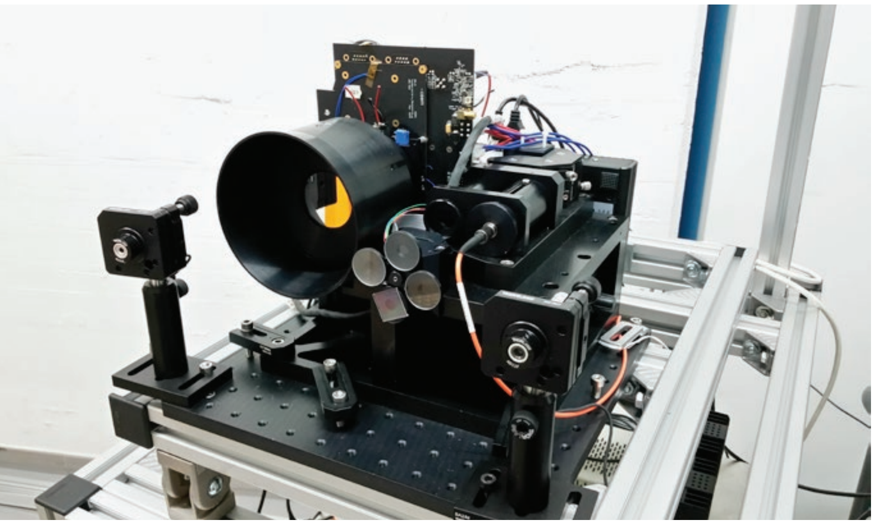
The evolution of Laser related technologies during the last decades opened the road for a new class of optical sensing tools, the LIDARs: LIght Detection And Ranging.

With a large variety of applications in scientific, military, environmental and commercial domains, these new instruments achieve performances that are typically orders of magnitude larger than the traditional passive sensors used from space.

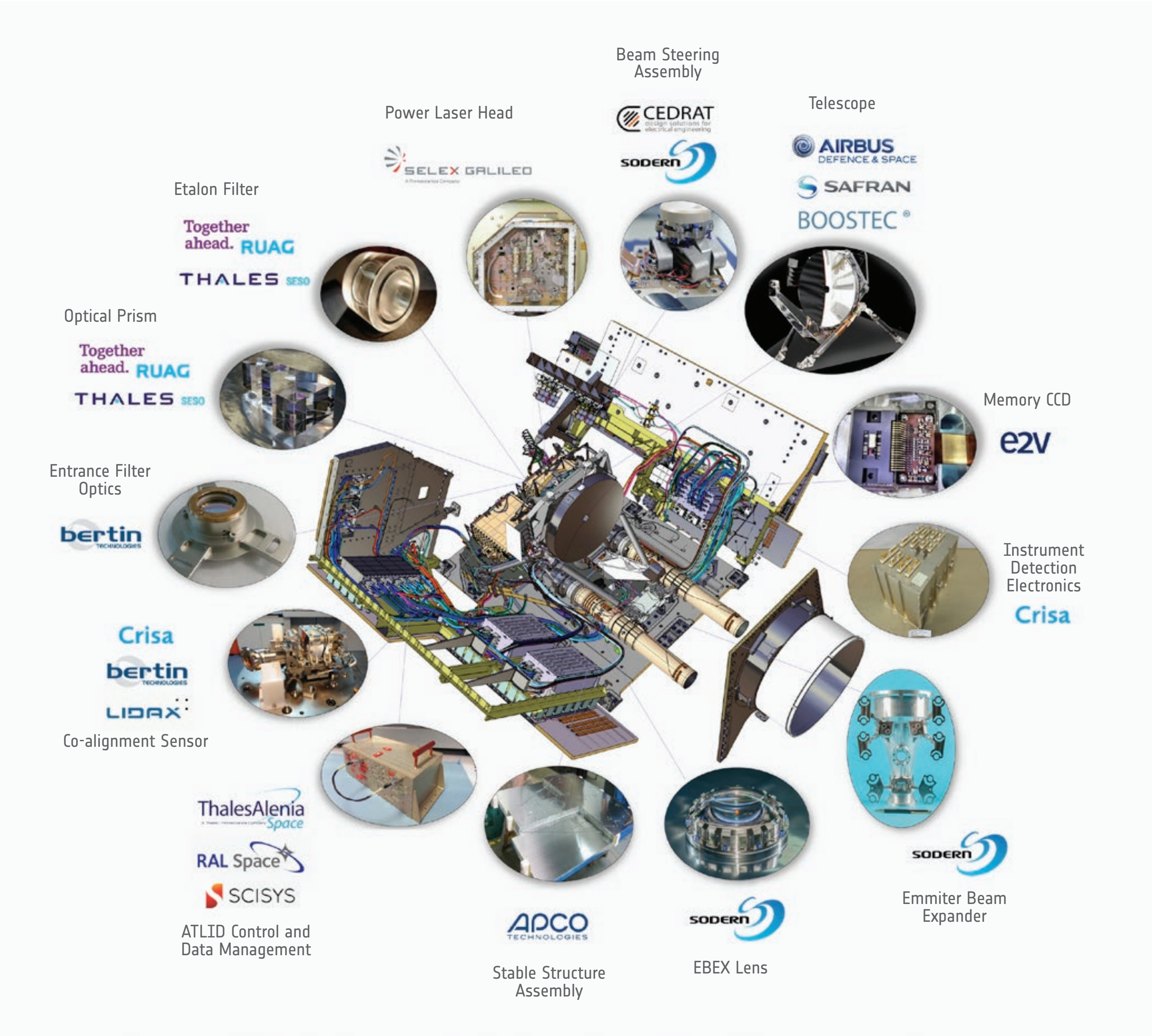
Despite the enormous interest in this type of versatile sensing tools, the technology required to meet the measurements requirements and the reliability issues are not trivial and necessitate a major development effort proportionally to the specifications to be met. In addition to that, the space environment constraints and qualification issues add orders of magnitude in complexity, development effort and cost.

ESA at the moment has three lidar missions in Phase C/D: ADM Aeolus, the Atmospheric Dynamic Mission, a single instrument mission which uses a Doppler Wind Lidar (Aladin) for high-spatial resolution, and high accuracy tropospheric wind measurements expected to be launched within 2017; EarthCare which uses a backscattering lidar (ATLID) for cloud and aerosols measurements, expected to be launched in 2018; and Bepi Colombo that operates BELA a laser altimeter that provides absolute topographic height and position with respect to a Mercury centred co-ordinate system, expected to be launched also in 2018.

The roadmap agreed in 2010 for the Lidar Critical Subsystems, was another example of how valuable the Harmonisation process is for Europe to maintain the strategic lead in critical space domains and technologies. The original roadmap identified 3 high criticality/urgent aims, as well as 30 short/medium and long term technology requirements. Out of the total 34 objectives, currently (Q3 2016) 24 have been pursued, indicating the early and proper identification of the technological needs like the development of non-linear laser crystals for frequency conversion or the development of the MILA (Miniaturized Imaging Laser Altimeter) a compact imaging altimeter for the future ESA mission providing a support for the global navigation system in the approach and landing of flying spacecrafts.



Elegant breadboard of multifunctional Miniaturized Imaging Laser Altimeter (CSEM, Switzerland)



Breakdown of Atlid lidar system from EarthCARE mission (Joao Pereira Do Carmo, ESA)

This new roadmap for the domain of Optoelectronics is currently under development due in 2017. The main objectives of this roadmap remain unchanged and focus on three axis: maintenance the European competences in domains where previous investment provided leading position (ex. high power laser diode stucks); reduction of dependence to non European/Canadian sources and provide viable alternatives from ESA member states entities; last but not least, enhance competition inside ESA member state entities, in line with ESA convention article IIV.

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