SPACE RDT PRIORITIES

2020

THE INCREMENTAL ROADMAP OF TECHNOLOGY RESEARCH AND DEVELOPMENT ACTIVITIES FOR SPACE

ASD-EUROSPACE

CONTENTS

INTRODUCTION

The Space RDT Priorities are a proactive initiative of Eurospace to raise awareness on key needs and expectations of the European space industry with regard to research development and technology (RDT). The initiative supports the establishment of a consolidated consensual technology development roadmap, supported by European space industry stakeholders.

The Eurospace consolidated roadmap of activities is not a complete technology plan, it is an incremental roadmap of development proposals and activities: activities and developments already well covered in current technology programmes are not included.

The database of activities is updated annually to include emerging needs and opportunities and remove obsolete activities.

EUROSPACE RDT PRIORITIES: A CONSOLIDATED INCREMENTAL ROADMAP OF TECHNOLOGY ACTIVITIES

Initiated in 2004 the Eurospace R&T Priorities is a multifaceted tool whose heart lies in a technology requirements database. The requirements database process is supported by annual soft updates and by a major re-haul every 4 years.

The requirements database is fed by a bottom up process in which all entities in the Technology Harmonisation Panel can contribute granular technology development requirements. The requirements are organized, consolidated and submitted to a consensus-based approval process. Once approved, they are available under the name Eurospace RDT Priorities.

RDT priorities process, key points:

- The bottom-up process is industry-owned and fully transparent
- All technology suppliers can join in, from small to large companies and including research entities, it is a voluntary process
- There are no entry barriers to the process and there is no heavy cost associated to the participation: all is done electronically
- The consolidation process ensures that all technology requirements support the development of a capability not yet available in Europe

The Eurospace R&T Priorities are organized in consistent development roadmaps and are associated to a variety of descriptors (mission, technology domain, dependence level, readiness level, etc.) that allow to filter, sort and extract the requirements to support any given request in a very short timeframe. They also support the identification of key trends and challenges, as well as risk factors and policy drivers of technology developments.

For an activity to be considered in the Eurospace RDT priorities list it must fulfil the following conditions:

1. The activity must generate consensus with European technology stakeholders, it must be recognised as useful for the sector
2. The activity must not duplicate an existing capacity in Europe
3. The activity must not be covered by an existing (funded) technology plan

SPACE APPLICATIONS REQUIRE MATURE AND PROVEN TECHNOLOGY

The space sector is strongly technology oriented. Space systems seek to optimise technological choices balancing safety and reliability aspects (maturity and predictability), with maximum performance (state of the art and innovation):

- Space sector is a demanding technology integrator (uses innovation and research concepts developed for other sectors)
- Space sector is also an innovation 'driver' (drives technology development for unique uses, pushes the limits of technology and novel concepts).

For technology integration the space sector takes technology with proven/promising concepts (TRL 2 to 4) and needs to produce incremental developments to bring it to TRL 6-9 for use in space programmes.

- E.g. CCDs, memories, FPGAs, DSPs, solar cells, batteries, MEMS/MOEMS (actuators and sensors), materials (composites, shape memory alloys) etc.

This incremental development is usually done in two stages:

- TRL 2-3 to TRL 4-5: component/breadboard validation
  - this stage of development is currently pursued by ESA in its CTP, TRP and GSTP programmes (addressing TRL1 to 5 globally). It is also pursued by the EU within its Framework Programmes, addressing TRL 2-4 and 4-6 developments.
- TRL4-5 to TRL 6-9 (depending on qualification requirements): from breadboard to flight model and prototype/system qualification in space (or on ground).
  - There is no coordinated approach to support technology maturity and qualification at European level. This final stage of qualification is often performed on-board the actual mission (with a risk for the mission).

With a growing number of space applications (meteorology, telecoms/broadcast, navigation, environment/resources monitoring) the requirement for technology reliability (and maturity) is progressively imposing itself, as more users learned to rely on space systems for actual services provision.

To support the continuity and development of space applications, technology strategies need to give the appropriate attention to technology maturity aspects, to ensure that technical advances and consolidations are translated into products and services.

AN EFFECTIVE AND COORDINATED SPACE TECHNOLOGY POLICY IN EUROPE

Space programmes have long lead time, the long time constant require the establishment of long term comprehensive roadmaps until market introduction is possible.

Combined Innovation in Systems and Enabling/baseline Technologies is necessary to develop products with leading edge performance to meet customer expectations. Innovation is mandatory to keep European Space Industry competitive worldwide.

The RDT Policy is a key enabler to European Space programmes, it is the stepping-stone giving shape to industrial capabilities and providing the foundations for space to remain accessible to Europe. **The RDT policy shall support the key objectives for ensuring European access to space to all missions and programmes, and maintaining an efficient, competitive and non-dependent industrial base.**

Today, after decades of consistent public investment, European industry has achieved enviable positions on the global market. Space is one of the areas of European technological excellence. But the global space paradigm is changing, and European positions on the global space arena need to be preserved. The growing competition from China, and the new space business models pioneered in the USA require specific attention.

The European Space industry is competitive, but competitiveness needs to be permanently re-assessed with respect to the achievements of the competition. Support to industry competitiveness is a concern shared by all institutions in the space sector, and it is a core driver for technology policies and strategies. Eurospace promotes the setting up of a consistent and coordinated dialogue between institutions and industry to ensure the fulfillment of core needs in the frame of coordinated European space governance for Research and development.

Eurospace proposes a complete roadmap of technology developments, highlighting critical needs not yet addressed by the European technology plans. The sector aims at achieving unrestricted access to the state of the art in all technology domains to serve institutional and global costumers. Technology readiness for risk mitigation remains a core concern, whereas bringing technology to the appropriate maturity levels is a mandatory requirement. Notwithstanding, programmes aiming at higher TRL (6 and above), including in-orbit validation opportunities, are still very scarce.

In technology programmes time is of the essence, to bring products to the market in line with global competition. This requires a careful selection of priorities and the effective rollout of appropriate processes and tools. Today these are still not sufficiently addressed in technology programmes.

European space RDT policy shall take stock of European space sector needs. It shall ensure the good alignment of budgets and priorities, through permanent exchange with industry and users, ensuring that technologies are brought to the appropriate maturity level for their good adoption by users and the creation of added value.

A Europe wide technology policy shall consistently aim at the proper coordination of national, ESA, and EU development programmes, avoiding unnecessary duplication and ensuring that critical objectives are met: readiness, time-to-market, maturity, non dependence, and efficiency.

SUMMARY OF RECOMMENDATIONS

Earth Observation

Improve resolution, timeliness, data processing, reactivity and system optimisation for observation systems competitiveness and efficiency - including readiness for constellation systems.

Support short revisit time, accessibility, reactivity requirements and improved data update at system level.

Telecommunications

The telecommunication roadmap aims at reducing the cost of available technologies and systems, and pursuing performance increase to maintain competitiveness.

Navigation

Address European GNSS systems overall performance: improve life cycle costs, enhance clocks and signal stability. Optimise system and architecture. Improve accuracy and service availability on all areas of the globe.

Ground systems

Support the key requirements of future missions and systems for increased data rate, flexibility, efficiency, ergonomics and the implementation of cloud-based solutions and data dissemination.

Support the development and take up of European design models and tools for system and architecture development and optimisation: engineering, system virtualisation, simulation, and modelling.

Protection of space assets

Europe shall establish capabilities for independent assessment of the orbital environment (debris and objects tracking, and trajectory prediction) and support technological readiness for debris mitigation and prevention.

Science

Improve system performance and payload capabilities, promote European readiness for state of the art instrument technologies, including large and very large structures (ultra-stable, deployable, thermal properties).

Human and robotic exploration

For Exploration: address long duration travel issues, increase readiness level for planetary activities.

For human exploration: investigate and develop synergies between crew and robotics, improve European readiness level on habitats.

Launcher

Improve launch service/system end-to-end competitiveness, from development and manufacturing aspects, to cost reduction strategies at all system and subsystems levels.

Support full life cycle cost assessment, minimise environmental impact.

Develop re-usability aspects and modelling/engineering tools.

Materials and processes

Materials and processes are providing the foundations of industry competitiveness. Eurospace recommends the continued investigation, assessment and development of materials, and advanced manufacturing techniques. New concepts, new designs, new processes, new tools will open new possibilities for space system design. REACH, cleanspace, dependence, eco-consciousness issues drive some developments.

(in-space) Propulsion

Support the development of innovative, high performance electrical and chemical propulsion systems:

- Compliant to environmental regulations.
- Address performance and versatility, test and tools, new systems.

It is critical to organise the synergies between the power roadmaps and the Electric propulsion roadmaps.

Power and Avionic systems

Power generation is a key roadmap for European systems future competitiveness. Eurospace recommends to supporting innovative solutions for power generation, storage and distribution with a view of addressing efficiently the challenges of high power and high voltage as well as cost effective, competitive, solutions for lower power in the context of smaller spacecraft (and constellations).

For Avionics, Eurospace recommends to addressing the requirements for high stability associated to high, and very high resolution systems, as well as the needs of high data rate in telecommunications, particularly with optical communications systems.

In all areas of Avionics, Eurospace supports the SAVOIR1[1] initiative roadmaps and positions.

EEE components readiness

Ensure the availability of critical EEE components and building blocks through sustainable European supply chains.

Support readiness, maturity and evolution of the DSM functional chain.

Organise the take up of COTS components in space programmes.

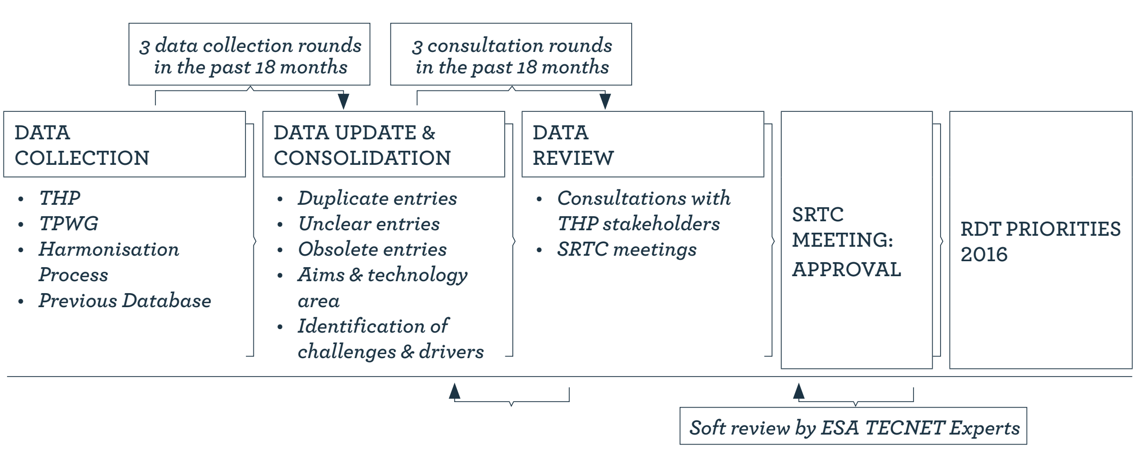
THE EUROSPACE RDT PRIORITIES PROCESS

BACKGROUND

The Eurospace RDT process is a full scale high value-added technology requirements survey undertaken annually with the key technology stakeholders in the European space sector. It is supported by Eurospace Space Research and Technology Committee (SRTC), a very large group of technology experts which is composed of Eurospace members and non member companies. The mailing list used to collect, consolidate and validate the contents of the RDT requirements database involved more than 1200 contacts. All were given the same opportunity to contribute new items to the database of requirements and modify existing activities. It is, at European level, the most extensive technology survey ever performed with a stable and recurrent framework.

Since the seminal exercise in 2004, Eurospace has thrived on maintaining and updating a complete technology requirements database with soft annual updates. Full reports and a complete structured technology roadmap are published every four years (2004, 2008, 2012).

THE 2016 UPDATE PROCESS



1] Space AVionics Open Interface aRchitecture. The SAVOIR initiative brings together users and suppliers of avionics systems to jointly optimise avionics architecture and technologies.

In 2014-2015 Eurospace organised a full revisit of the 2012 RT priorities list in preparation of the publication of the 2016 report. The data collection and update started in 2014 and was carried out throughout the years 2014 and 2015, involving all members of the THP. Three data collection rounds were organised and three feedback loops, giving visibility to all of new additions/modifications proposed, were undertaken.

On September 17th 2015 a complete review of the DRAFT consolidated priorities was organised with ESA TECNET experts, where further comments were gathered and activities were better refined. The event confirmed the importance of the exercise for the space industrial community, a well as the relevance of Eurospace consolidated proposals.

The final step of the RDT process was the organisation of a dedicated workshop to expose the larger space institutional sector to the RT&D priorities of Eurospace. This event took place in Lausanne (Switzerland) on April 26-27. It featured the presentation of technology priorities and round tables on space industrial and technical policy matters.

HIGHLIGHTS FROM THE 2016 RDT WORKSHOP OF LAUSANNE

Eurospace presented the industry vision for key technology areas and actions to support a competitive European space sector.

This vision was shared and discussed by industrial and institutional stakeholders, highlighting the many points of convergence in the sector.

The discussion on key RDT trends comes at a turning point of the evolution of European space policy, with the ESA ministerial Council at the end of the year together with the preparation of EU's H2020 roadmap to 2020 and the definition of the new Space strategy for the Union.

Member of Parliament, Mr Marinescu, reaffirmed his commitment to work towards more extensive and better use of space. Space programmes and space research shall be a key topic for inclusion in the upcoming discussions on the new MFF in the European Parliament.

European Commission highlighted its unfailing commitment to space programmes, with a view to further such essential initiatives as Galileo and Copernicus, and aiming at supporting technology development in key areas within H2020. European Commission also highlighted the importance of supporting service development and efficient exploitation of Space infrastructures for the creation of added value from space programmes.

There is also a lot of room for the expression of national interests in technology policies, with national space strategies being elaborated with the support of complex political and technological toolboxes paving the way to the consolidation of various stakeholder's views. National strategies need to strike the appropriate balance between the focused development of national capabilities, and the achievement of a competitive industry within a European and global environment.

Participants acknowledged how much technology is a driving force for the space sector; technology policies and programmes shall ensure readiness for the right technologies, at the right moment. It is critical to bridge not only the maturity gap, but also the gap to the final users in order to ensure availability of the right technologies, at the right time for the right application supporting a product or a service.

THE TECHNOLOGY CHALLENGES AND THE DRIVERS

To provide qualitative analysis capabilities to the Eurospace roadmap of technology developments, we have identified the drivers and challenges acting as the driving forces promoting and/or justifying technology developments. Drivers and challenges are organised in three separate groups: those associated to core competitiveness, those associated to identified risk factors, and those where policy and regulation are the driving forces.

Competitiveness drivers

Competitiveness drivers are essential forces for technology developments. They are supported by emerging technology evolutions and anticipate market and customer expectations with a view of improving the overall competitiveness of the sector, with impact at system, equipment, and component levels, and also involving industry processes and manufacturing.

IC

Innovation Challenge

Activities that provide breakthrough solutions or open new horizons for space systems and missions. They include low TRL research, new missions concepts ground-breaking innovations in development and manufacturing techniques, models improvements etc.

PC

Propulsion challenges

Propulsion challenges aggregate activities that provide solutions to the current Chemical and Electric propulsion challenges.

They are influenced by environmental legislations (e.g. REACH), by new enhanced propulsion for launchers and by innovative mission profiles relying on full electric propulsion satellites.

Developments proposed are not limited to propulsion systems, but also involve new materials, new propellant formulations, models, ground test facilities. Regarding electric propulsion, developments will also include power generation and thermal aspects driven by EP systems requirements.

ME

Mission enablers

Mission enablers bring together activities supporting next generation or future missions, in satellite applications, science, exploration and robotics. This roadmap aims at keeping European systems and products at the state of the art, to stay abreast with competition in all application areas.

This roadmap includes activities aiming at e.g. improved resolution in EO, higher throughput in TLC or better signal precision in NAV.

In this group are found typically activities with low to medium TRL start (up to 4-5) and medium to high maturity targets. Also includes mission enablers in science, such as instrument technologies, and in exploration and human flight, such as habitats, long distance flight, landing and surface activities, robotics etc. Mission enablers complement the mission specific development promoted in support to European programmes organised in the European frame of ESA and national agencies initiatives.

C/MR

Cost/mass reduction

In space the reduction of mass at launch has always a positive impact on cost, in addition, specific cost reduction strategies will be implemented to improve system competitiveness. This roadmap includes all activities aiming at reducing the cost and/or mass of systems. These include incremental efforts over existing technologies but also radical innovations.

D&M

Design and manufacturing

In the past decade the space sector has been exposed to a growing array of new concepts and solutions in the area of processes, materials and manufacturing. This challenge brings together activities aiming at improving the design and/or manufacturing of space systems and parts, such as the adoption of new materials, the use of additive manufacturing or improvements in design and simulation tools. These drivers have potential a strong impact on industry processes and system design.

DC

Data Challenge

The amount of data handled and/or generated in space is growing with the combined action of many technology and mission trends. This results in increased requirements for all aspects of data handling on board and for higher data rates for data links from orbit to ground and ground to orbit. There are also growing requirements for orbit-to-orbit data transfers (such as data relay missions) and high speed data links with mobile terminals (LEO to UAV e.g.).

The sector shall thus address the data challenge, and key activities are brought together in this roadmap: activities that support increased data handling requirements, such as big data aspects, secure data transfer, long distance data transfers, high data rates and all processing/storage issues. These developments are transversal in nature and may support missions in Earth Observation, Science, Telecommunications, and Navigation. The data challenge is not only about rate and throughput; it also includes the problematic of data security and integrity.

Risk factors & challenges

Some technology developments are associated to risk factors, that can be associated to current risk factors (such as technological dependence), anticipated risk factors associated to high gains (such as using critical materials) or to a critical path for development (urgent developments to keep abreast with competition). Every risk factor is identified separately in Eurospace roadmap of activities, noting that for each risk there is an opportunity to catch.

EU CM

EU Critical materials

In 2014 the EU published[2] the «REPORT ON CRITICAL RAW MATERIALS FOR THE EU» where materials that are crucial to Europe's economy and essential to maintaining and improving our quality of life have been identified. These materials all provide high added value to the European economy, but are usually not available from European sources. It is an objective of the EU to secure reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe. The Eurospace roadmap has identified all areas where critical materials are used, this roadmap brings them together. The critical materials concerned are Indium, Silicium, Beryllium, Chromium, Gallium, Germanium.

CD

Critical Dependence

There are situation where the European space sector is unable to supply the appropriate technologies/products required for a given mission. This is due to low level of readiness of European solutions. In some cases the recourse to non-European space technologies/products is associated to restrictive conditions (such as re-export restrictions, administrative delays to access the products, limitations on product technical information etc.). In some situations these dependence situations are characterised as critical, in particular when the product/technology plays an essential role in the overall system. Since 2009 European institutions (ESA; EC, EDA) have decided to address the critical dependence situations from a political perspective aiming at reducing critical dependence situations. In the Eurospace RDT roadmap the dependence situation is systematically assessed, and all activities associated to a current critical dependence level are brought together in the critical dependence roadmap.

CP

Critical path

Some activities in the Eurospace roadmap are associated to a relatively urgent need (due to the fact that they have already been rolled out by the competition) and require a significant and urgent effort to be developed, due to a relatively high TRL gap. A specific algorithm was designed to identify all such activities that are brought together in this specific sub-roadmap. Activities in this roadmap combine a high TRL gap and a relatively short time to readiness, setting a short timeframe for development with potentially high costs and higher development risks.

Policy and regulation drivers

Some developments are required due to the emergence of specific policies and/or regulations. In most cases space programmes promoted by public entities have planned the required technology developments, this is typically the case for ESA and National agencies programmes. But this is not always the case, particularly with EU initiatives in the areas of Earth observation, Next Generation (post EGEP) GNSS and Space surveillance and tracking. Environmental regulations in the areas of debris mitigation and environmental and health protection also support the emergence of new requirements in space systems and technologies. And last, the EU has identified key enabling technologies for Europe, with high potential for innovation and growth. All these will act as additional drivers for technology development and have been identified accordingly in the Eurospace roadmap.

EU I

EU Initiatives

All activities that provide enabling solutions to EU initiatives, i.e. Copernicus, Galileo and Space surveillance and tracking have been identified here. They are all mission/ application driven.

2] http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm

EU KETs

EU Key Enabling Technologies (KETs)

KETs have been identified by an EU action in 2009[3] and recognised as critical for Europe in 2012[4]. KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts. All activities that support the take up of EU-defined KETs (advanced manufacturing, advanced materials, micro-nano electronics, nanotechnology, photonics) have been identified specifically for further action. KETs for space are highly relevant to the adoption of new and smart materials, new manufacturing processes (and particularly additive manufacturing) and, to a lesser extent, micro/nano technologies and photonics.

CS

Clean Space

Clean Space is the ESA initiative that aims at achieving, at all levels of its action, a cleaner space sector. This approach has impact on the early stages of system development and all manufacturing steps, and has relevance to the full life cycle of space systems, including the end of life and the requirements for de/re-orbiting and appropriate demise. In Eurospace roadmap of activities there are many developments motivated by the compliance to EU's REACH and RoSH regulations, as well as developments addressing debris mitigation strategies, including monitoring aspects and end of life solutions.

POLICY DRIVERS

- *EU Initiatives*
- *EU Legislation*
- *Key Enabling Technologies*

RISK FACTORS

- *Critical materials*
- *Critical Dependence*
- *Critical Path*

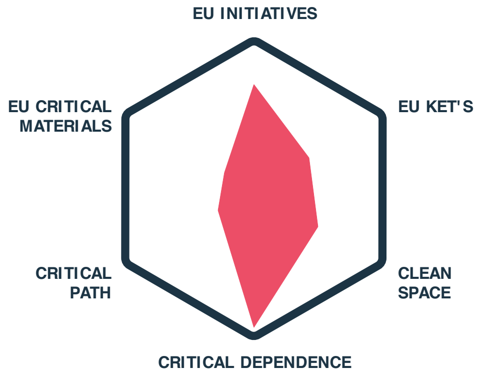
TECHNOLOGY TRENDS

COMPETITIVENESS & MARKETS

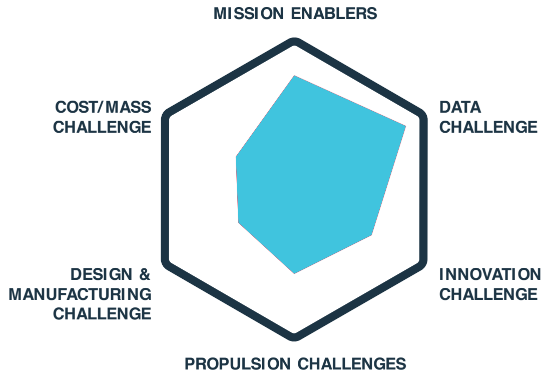
- *Propulsion challenges*
- *Mission enablers*
- *Cost/Mass*
- *Design & Manufacturing*
- *Data Challenge*
- *Innovation Challenge*

OVERALL ASSESSMENT OF DRIVERS AND RISK FACTORS

Policy drivers and risk factors



Competitiveness drivers



3] *Current situation of key enabling technologies in Europe, SEC(2009) 1257*
4] *COM(2012) 341 final - A European strategy for Key Enabling Technologies – A bridge to growth and jobs.*

THE TECHNOLOGY READINESS LEVELS SCALE

(Source: The TRL handbook)

The ability to make good decisions concerning the inclusion or exclusion of new technologies and novel concepts, and to do so in the absence of perfect information, is essential to the success of many space programs. Accurate and timely 'technology readiness assessments' (TRAs) are very important for the cost-effective management of advanced technology R&D portfolios, whether at the program manager level, the prime contactor level or the supplier level. Numerous approaches have been developed to assist in meeting this management challenge, including the use of a variety of decision support tools. A critical step in all such methodologies, however, is the consistent assessment of maturity of various advanced technologies prior to their incorporation in new system development projects.

The Technology Readiness Levels have been defined to provide a common metric by means of which knowledge of new technology's maturity might be communicated among program executives, system developers and technology researchers, and among individuals from different organizations. The TRL are therefore not linked to a specific technical discipline. In addition, the use of TRLs can provide a needed foundation for developing and communicating insight into the risks involved in advancing a new system and its constituent new technology components.

TRLs are a set of management metrics that enable the assessment of the maturity of a particular technology and the consistent comparison of maturity between different types of technology – all in the context of a specific system, application and operational environment.

The table below provides a high-level illustration of the TRL scale in the context of the progression from basic research to system operations.

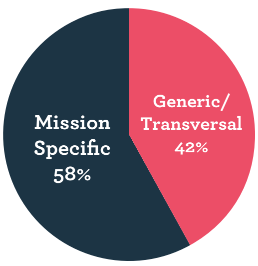
Readiness Level	Definition	Explanation
TRL 1	*Basic principles observed and reported*	*Lowest level of technology readiness. Scientific research begins to be translated into applied research and development.*
TRL 2	*Technology concept and/or application formulated*	*Once basic principles are observed, practical applications can be invented and R&D started. Applications are speculative and may be unproven.*
TRL 3	*Analytical and experimental critical function and/or characteristic proof-of-concept*	*Active research and development is initiated, including analytical / laboratory studies to validate predictions regarding the technology.*
TRL 4	*Component and/or breadboard validation in laboratory environment*	*Basic technological components are integrated to establish that they will work together.*
TRL 5	*Component and/or breadboard validation in relevant environment*	*The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.*
TRL 6	*System/subsystem model or prototype demonstration in a relevant environment (ground or space)*	*A representative model or prototype system is tested in a relevant environment.*
TRL 7	*System prototype demonstration in a space environment*	*A prototype system that is near, or at, the planned operational system.*
TRL 8	*Actual system completed and "flight qualified" through test and demonstration (ground or space)*	*In an actual system, the technology has been proven to work in its final form and under expected conditions.*
TRL 9	*Actual system "flight proven" through successful mission operations*	*The system incorporating the new technology in its final form has been used under actual mission conditions.*

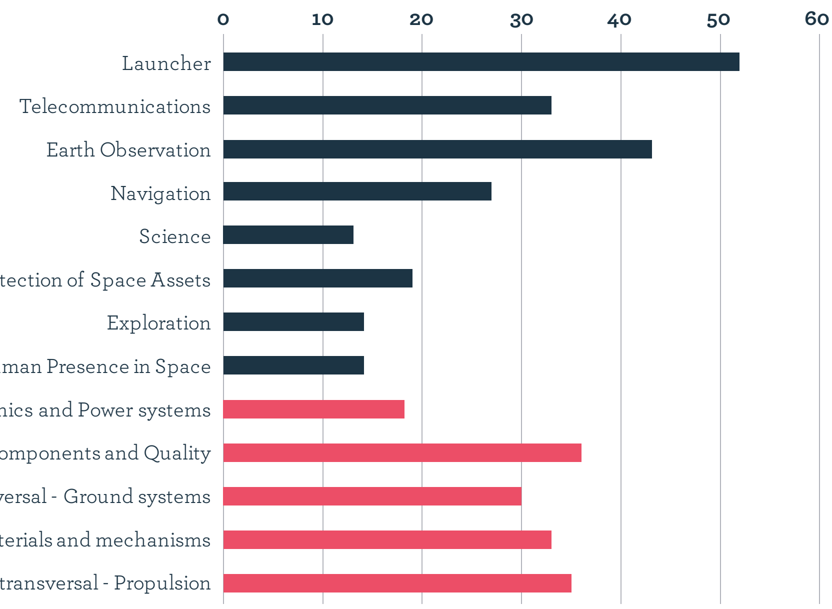
RDT PRIORITIES 2020 OVERVIEW

THE PRIORITIES BY SERVICE DOMAINS

The Eurospace typology allows separating activities that are relevant to specific applications from activities that are addressing lower level components and generic technologies, including aspects specific to the spacecraft platform.

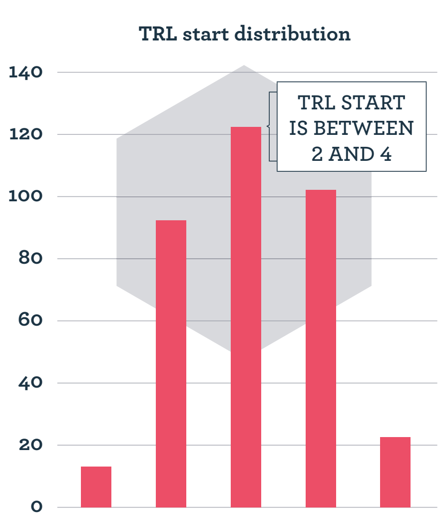
In the current 2016 set of RDT priorities 58% of requirements are applicable to one service domain, and 42% are generic.

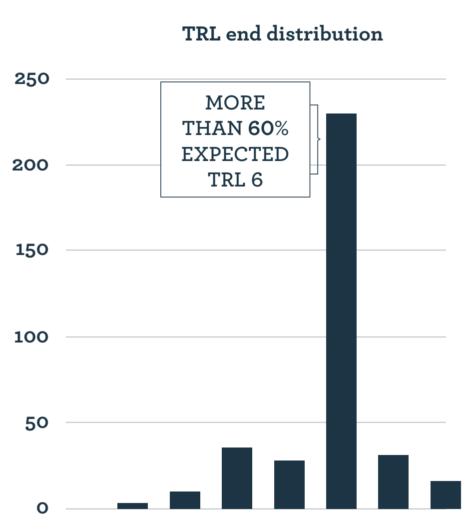




THE PRIORITIES BY MATURITY LEVEL

The RDT priorities database identifies the current maturity level of the technology in Europe (TRL Start) and sets the target maturity level (TRL End) for development activities. In most cases the End TRL is set to 6 («A representative model or prototype system is tested in a relevant environment.») because this is the typical minimum risk mitigation step before a technology can be used in a mission. Some customers, that are particularly risk averse, will require that a maturity level of 7 to 9 (that includes a validation in orbit) is attained before adopting a new technology.





SPACE RDT PRIORITIES

2020 OVERVIEW

THE PRIORITIES BY SERVICE DOMAINS

ME DC EU I CD

EARTH OBSERVATION

Drivers & challenges

BACKGROUND

This domain is driven largely by three synergetic market segments:

- Programmes supporting European policies towards increased environmental awareness and readiness: Climate change, carbon monitoring, meteorology, etc.
- Programmes supporting European policies towards increased global population security: Border control, vessels monitoring, travel security, power distribution systems, ...
- Programmes supporting the enforcement of European policies: Vegetation/crop monitoring & control, fishing activity, sea pollution, etc.

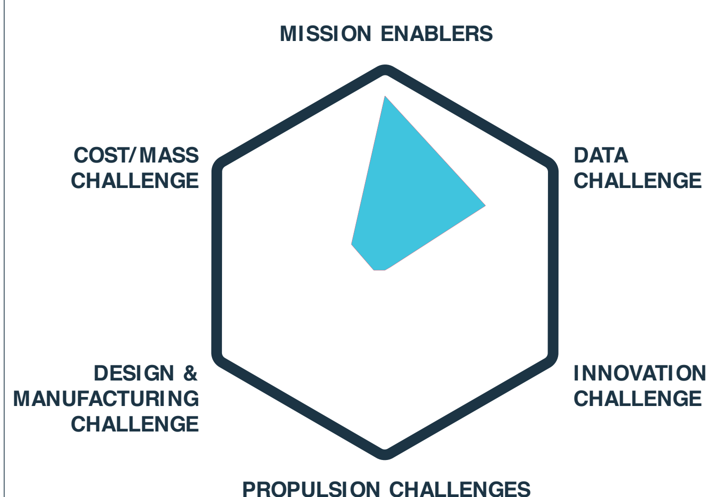
This domain is also driven by the need for European competitiveness to address Export and commercial markets.

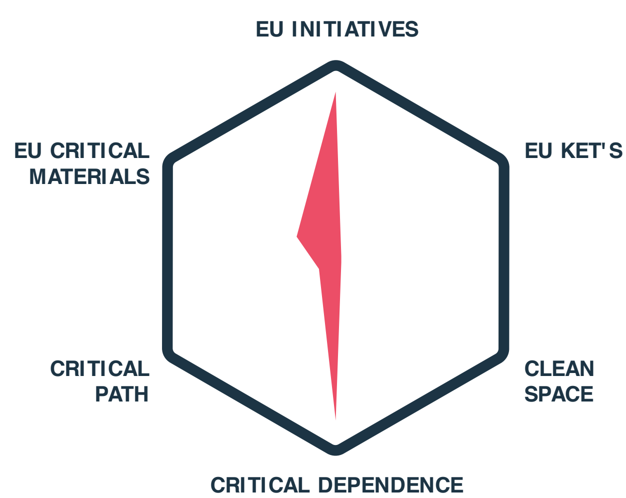
ACTIVITIES PROPOSED

In this service domain the Eurospace proposal is focusing mostly on payload needs. From a functional and mission point of view data chain activities will also be required. They are addressed in the dedicated section for generic technologies in the data chain, that covers activity with synergy across service domains in the data handling and transmission areas. However, some EO-specific data chain requirements addressed here.

KEY TECHNOLOGY DRIVERS

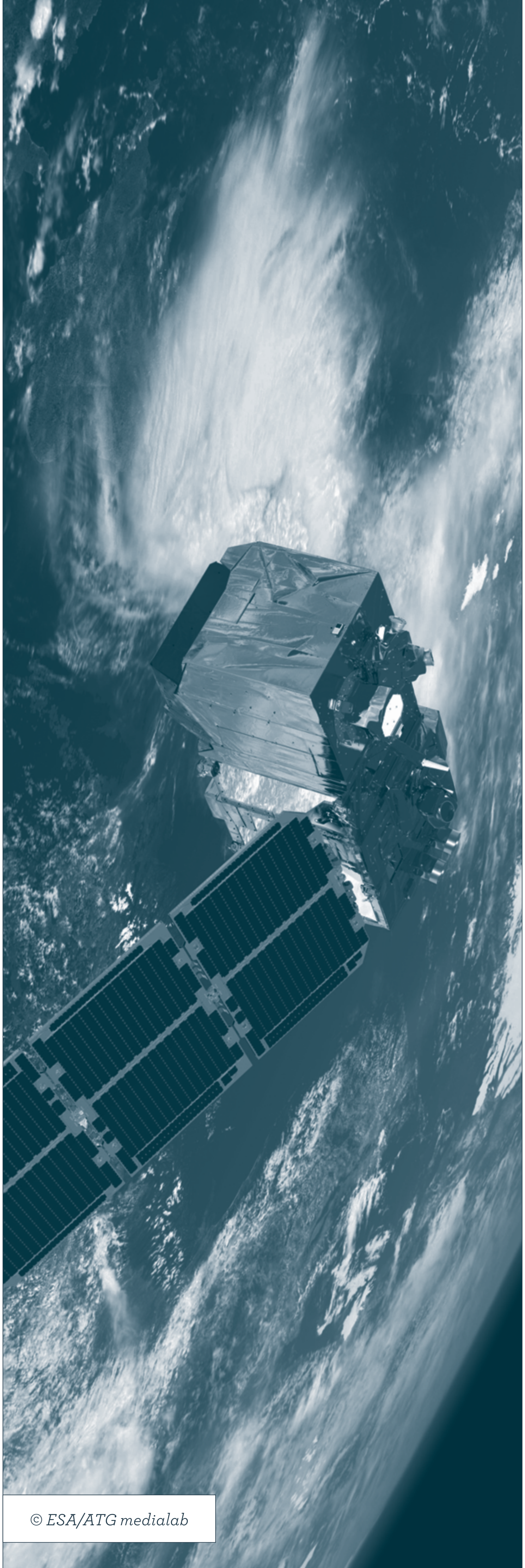
COMPETITIVENESS	POLICY AND RISK
• Mission enablers • Data chain aspects	• EU initiatives • Dependence reduction





RECOMMENDATIONS

IMPROVE RESOLUTION, TIMELINESS, DATA PROCESSING, REACTIVITY AND SYSTEM OPTIMISATION FOR OBSERVATION SYSTEMS COMPETITIVENESS AND EFFICIENCY - INCLUDING READINESS FOR CONSTELLATION SYSTEMS.
SUPPORT SHORT REVISIT TIME, ACCESSIBILITY, REACTIVITY REQUIREMENTS AND IMPROVED DATA UPDATE AT SYSTEM LEVEL.



KEY AREAS FOR ACTION

Support for increased resolution (market driven)

- High resolution (HR) to Very High resolution (VHR) imaging (in optical and radar) - achieve less than 30 cm for LEO and a few meters for GEO
- Large size telescopes
- Large focal plane (incl. infrared & cooling solutions)
- Multi/Hyper-spectral imagers
- Synthetic Aperture Radar: wide swath and high resolution

High performance data chain processing for system performance and frequent observation update

- The data capability shall support coverage of the Earth with frequent revisit (and persistent observation): thousands of square km per day.
- Data processing capabilities improvement.

Data links to ground

- Data rate: from 2 Gbps today to few tens Gbps.
- Address downlink critical issues: processing, encryption, security & integrity.

System optimisation activities

- Onboard signal & image processing, compression, optimisation and calibration.
- Active disturbance management (e.g. thermal and mechanical environment, micro-vibrations, ...).
- Ground systems performance - need to acquire, process and distribute the data.
- Prepare the future for large/distributed instruments (and formation flying).

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TELECOMMUNICATIONS

ME DC C/MR EU CM CP CD

Drivers & challenges

KEY TRENDS IN TELECOMMUNICATIONS

Two important trends are driving the Telecommunications roadmap. The evolution of the large geostationary systems towards higher performance and improved life cycle cost management, and the emergence of low Earth orbit constellations for telecommunications services (including the so called 'mega-constellations').

It is particularly worth noting the gradual shift towards full Electric Propulsion (EP) systems in telecommunications. This has consequences at system level, particularly in terms of system radiation hardening (the long transfer to orbit phase exposes spacecraft to higher radiation doses) and added constraints on the power and thermal system. These aspects are addressed specifically in the related generic and transversal roadmaps.

Telecommunications systems represent two thirds of European space industry exports, they are a key area for sector competitiveness, hence the critical requirements for dependence reduction and control.

High performance in GEO, optimise total in-orbit acquisition and operational costs:

- Drive down cost of Mbps at system level
- Support the development of the Terabit satellite
- Improve high and very high throughput satellites (HTS/VHTS, up to 1Tbps), focus on flexibility/processing & power
- Lifetime extension solutions (up to 18 years)
- Shorter lead time (from contract to operations)
- Secure systems and architectures
- EP transfer: radiation hardening issues
- Low cost and performance in LEO constellations
- Manufacturing challenges, COTS implementation, cost-driven solutions
- Dependence reduction
- EEE components, materials, thermal control

KEY TECHNOLOGY AREAS

Antennas, active and reconfigurable

Advanced RF equipment

Optical communications technologies

- Data relay
- Inter-satellite links
- Feeder links
- Direct to Earth communications

Photonics based payloads

Q/V band technologies

Data systems: from board to ground, higher data rates and processing power

- Digitalised networks and processors

Interference and network management

E2E system and architecture development for constellation

ACTIVITIES PROPOSED

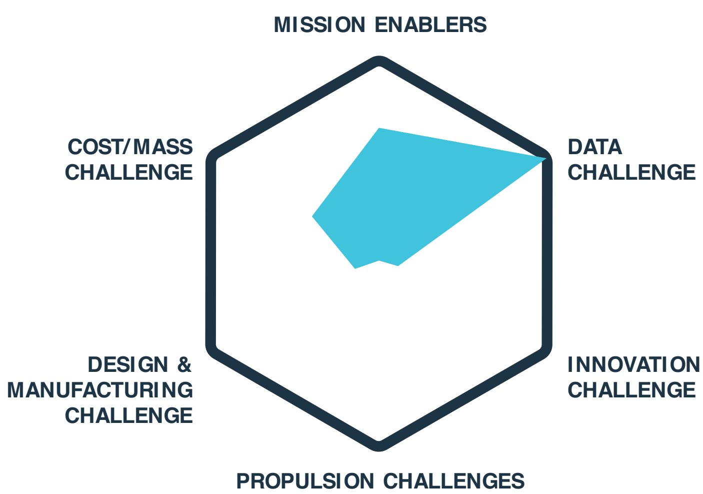
The Eurospace telecommunications roadmap focuses (by construction) on payload technologies mainly in the RF and electromagnetic domain, and in the emerging optical technologies area. Architecture aspects, as well as matching ground segment capabilities need to be considered.

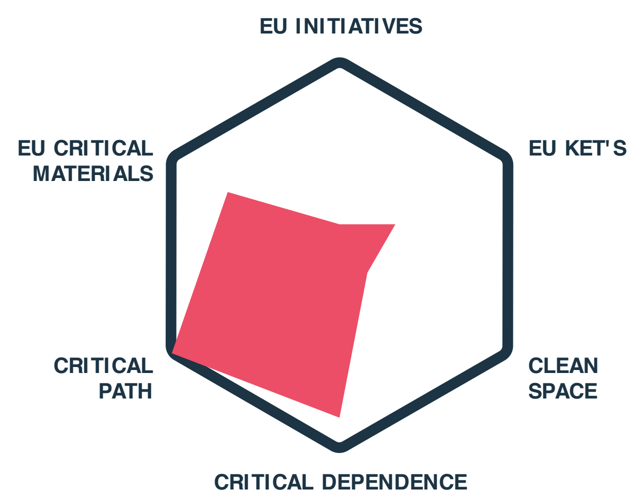
Key aims

- Data rate and throughput
- Flexibility, reconfigurability and power
- » *Note that the Propulsion Roadmap has high relevance to TLC missions*

KEY TECHNOLOGY DRIVERS

COMPETITIVENESS	POLICY AND RISK
• Data challenge • Mission enablers • Cost and mass reduction	• Critical path (time to market, match competition) • Dependence reduction





RECOMMENDATION

THE TELECOMMUNICATION ROADMAP AIMS AT REDUCING THE LIFE-CYCLE AND OPERATIONS COST OF AVAILABLE TECHNOLOGIES AND SYSTEMS, AND PURSUING PERFORMANCE INCREASE TO MAINTAIN COMPETITIVENESS.

KEY TECHNOLOGY TRENDS

- Payload: spectrum, power and flexibility
- Broadband
- High data rate/High throughput
- Large antenna building blocks
- Hybrid space/ground communication networks
- Narrowband
- Security applications
- System optimisation
- Programmatic/ Methodologies

KEY AREAS FOR ACTION

Large antennas and large reflectors, deployable, mesh etc.

- Large antennas building blocks
- Very large reflectors, models, designs, verifications and solutions (5 to 7m for higher frequencies and up to 15m for lower frequencies)
- Active antennas for spectrum management: flexibility, reconfigurability, power

RF & photonics based equipment

- Higher frequency bands
- Flexibility and integrated functions

Conversion chain

- High throughput, high data rates

Processing

- Payload data (transparent and regenerative, digital BFN)
- Feeders (from RF to optical, for VHTS)

Data transmission

- Secure links
- Inter-satellite links
- Links to airborne systems

Ground segment matching requirements

- High data rate/High throughput (up to 1Tbps and more): Optical feeders (incl. cloud mitigation aspects)
- Hybridised with Space/Cloud communication networks
- Security applications

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NAVIGATION

Drivers & Challenges

BACKGROUND

The context of the navigation roadmap is the European GNSS next generations of space segment (called block 2 and block 3) and the preparation of future system improvements. The Navigation roadmap has also a ground segment component (addressed in Ground segment).

ACTIVITIES PROPOSED

Activities proposed in the Eurospace roadmap are mostly focusing on payload subsystem technologies, with an important focus on time and signal generation. System aspects have also their own importance in the roadmap, together with overall architecture aspects and the matching requirements of ground segment and solutions.

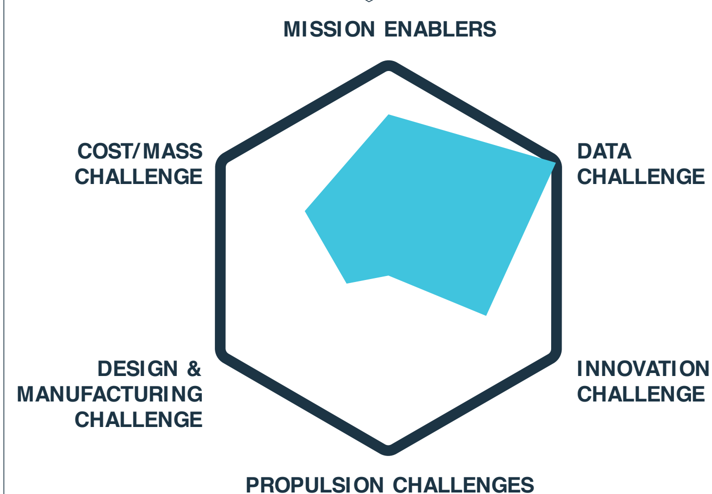
Key aims

- Overall system performance improvement
- Signal precision/integrity

KEY TECHNOLOGY DRIVERS

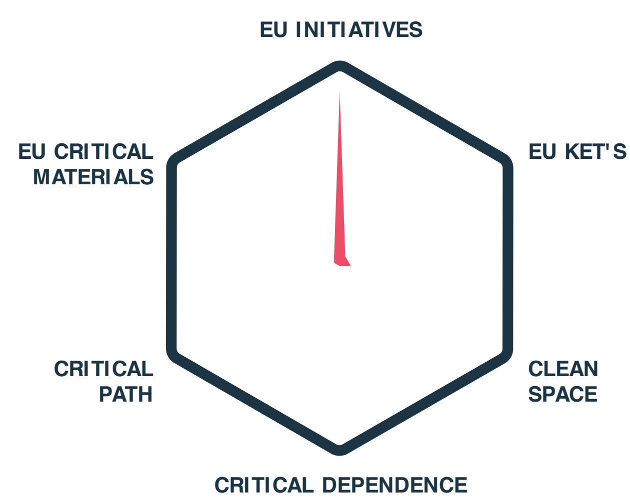
COMPETITIVENESS

- Mission enabling technologies (clocks)
- Data Challenge (processing)



POLICY AND RISK

- EU initiatives are driving the Navigation roadmap



RECOMMENDATION

ADDRESS EUROPEAN GNSS SYSTEMS OVERALL PERFORMANCE: IMPROVE LIFE CYCLE COSTS, ENHANCE CLOCKS AND SIGNAL STABILITY. OPTIMISE SYSTEM AND ARCHITECTURE. IMPROVE ACCURACY AND SERVICE AVAILABILITY ON ALL AREAS OF THE GLOBE.

KEY AREAS FOR ACTION: CLOCKS AND SIGNAL GENERATION

Enhance signal precision

- Stable clocks, stable feed, low inter-calibration needs, ISL

Compact PHM atomic clocks (block 2)

- Improved performance
- Frequency stability
- Low power consumption
- Low mass/volume budgets (Gain 30 to 70%)
- Increased robustness, reduce environmental sensibility

Next generation clocks (block 3)

- Ion trap, Cesium, TFT, Maser Optical-pumped…
- Consider IOD/IOV for most promising solutions

KEY AREAS FOR ACTION: SYSTEM & ARCHITECTURE

Ground/Space segment synergies to improve:

- System performance
- Cost efficiency
- System validation
- Signal integrity

Reduce GNSS Vulnerability

PRS requirements

- Robustness, anti-jamming/spoofing

Enable SBAS services in low and high latitude regions

Next generation Integrated system

D&M DC CP CD

GROUND SYSTEMS

Drivers & Challenges

BACKGROUND

Ground systems are integral part of the space infrastructure. In the early phases of the programme, ground systems support spacecraft and launchers development and production processes (tools, models and GSE). During programme operations ground systems provide the capacity to interface with the space segment for mission control (telemetry and command) and for mission operations (data downlink and uplink).

ACTIVITIES PROPOSED

The ground systems roadmap embraces three main areas of activity:

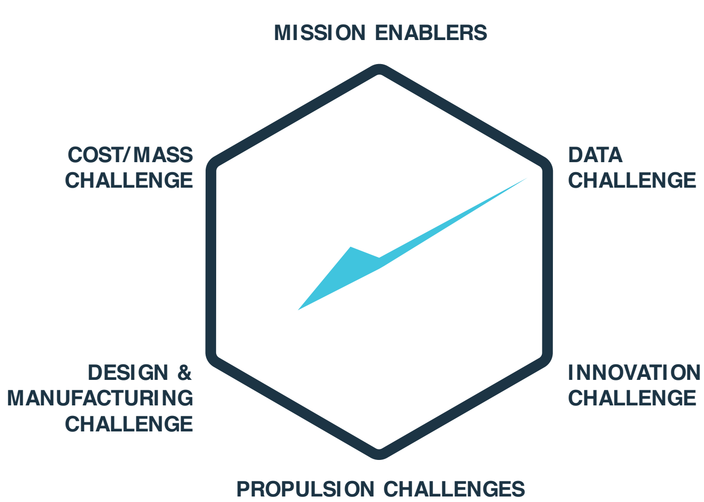
- Simulation and design tools
- User/Mission Ground segment
- Spacecraft control and operations

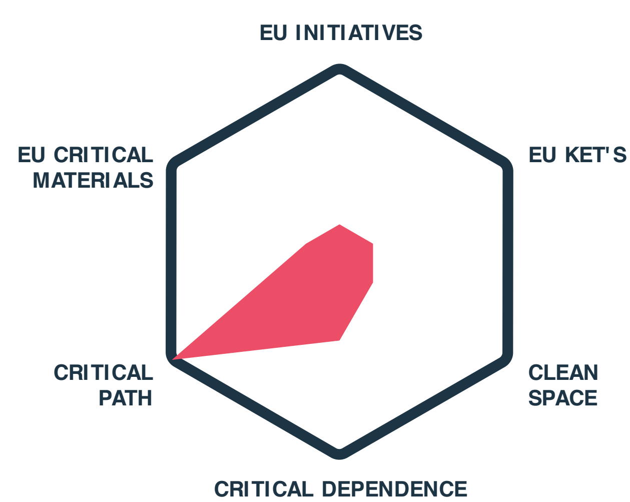
Key aims

- System optimisation, rapid tasking, security, mega-constellations
- End to End simulation, optimisation, mission planning
- Data processing, data handling, network solutions

KEY TECHNOLOGY DRIVERS

COMPETITIVENESS	POLICY AND RISK
• Data Challenge: big data, multi sensor data, high throughput	• Dependence situations • Critical path: support competitive solutions take-up in Europe - Rationalise Ground Segment architecture





RECOMMENDATION: MISSION AND USER GROUND SEGMENT

SUPPORT THE KEY REQUIREMENTS OF FUTURE MISSIONS AND SYSTEMS FOR INCREASED DATA RATE, FLEXIBILITY, EFFICIENCY, ERGONOMICS AND THE IMPLEMENTATION OF CLOUD-BASED SOLUTIONS AND DATA DISSEMINATION.

KEY AREAS FOR ACTION FOR MISSION AND USER GROUND SEGMENT

Standardisation:
- Configuration life cycle management
- EGS-CC, stable architectures
- Inter-operability of ground sub-systems

Maintenance costs reduction, automated functions
- E2E monitoring and control
- Efficient exploitation and computing infrastructure
- User-interface simplification

Data handling & optimisation
- New algorithms (e.g. Big Data, Data analytics, deep learning…)
- Scalable Processing power
- Massive parallel processing, data management & long term archiving

Near real time processing and delivery of satellite data and products
- Mission planning/optimisation

Security critical solutions

Smart constellation tasking

RECOMMENDATIONS: DESIGN MODELS AND TOOLS

SUPPORT THE DEVELOPMENT AND TAKE UP OF EUROPEAN DESIGN MODELS AND TOOLS FOR SYSTEM AND ARCHITECTURE DEVELOPMENT AND OPTIMISATION: ENGINEERING, SYSTEM VIRTUALISATION, SIMULATION, AND MODELLING.

KEY AREAS FOR ACTION FOR EUROPEAN TOOLS FOR SATELLITE DESIGN, SIMULATION, ENGINEERING

Simulation, virtualisation, performance modelling
- Optimise designs, identify & reduce over-margins (from system level to E2E operations)
- Optimise the trade offs between ground and space segment
- Standardisation of approaches: Cross-platform solutions, unified approaches

ME DC IC D&M EU I CS

PROTECTION OF SPACE ASSETS, SPACE SURVEILLANCE AND ASSESSMENT (INCL. SST)

Drivers & Challenges

BACKGROUND

The context of this roadmap is provided by the growing relevance of satellites services to European citizens and policies, driving requirements for service continuity. The protection of space assets is a four-dimensional issue where space weather, situation monitoring, debris avoidance/mitigation aspects and prevention inter-play. It is also appreciated in the context of space debris and space environmental protection regulations at European (ESA) and national levels.

ACTIVITIES PROPOSED

This roadmaps has three main areas of implementation: the improvement of European readiness regarding space weather, the development of European systems and solutions for orbital objects and debris monitoring and tracking, and the development of appropriate end-of-life solutions.

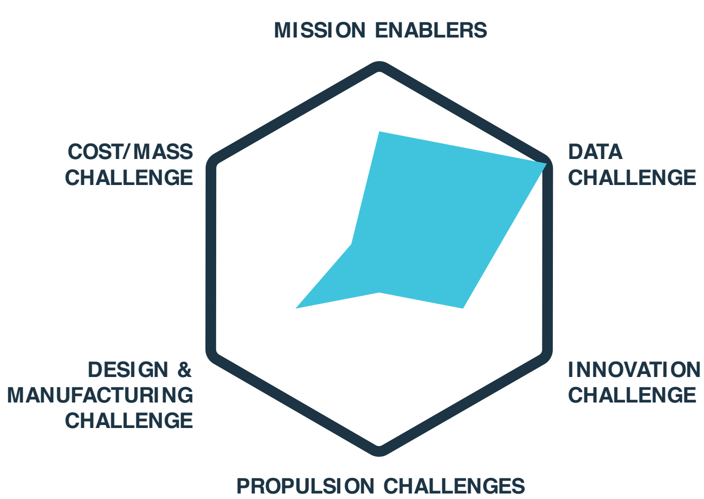
Activities in this roadmap are mostly relevant to space segment (i.e. in orbit techniques), but ground segment solutions are proposed as well, in complement and synergy with space segment approaches with a global architecture approach. The overarching aims are to support the development and take up of critical end of life (EOL) solutions for debris reduction strategies and the improvement of European debris monitoring and mitigation solutions.

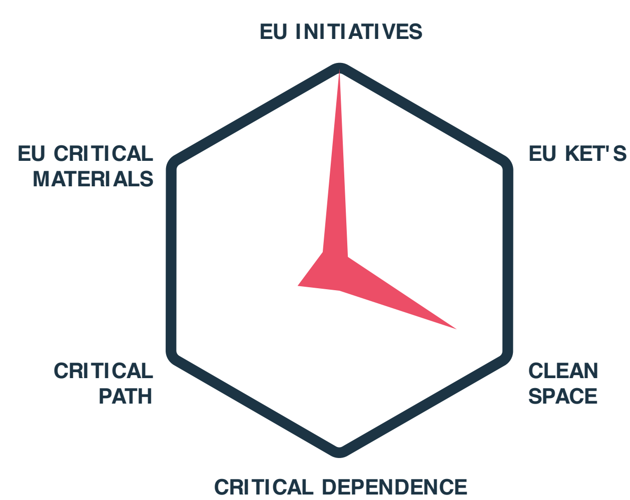
Key aims

- Debris mitigation and reduction, EOL solutions, abide to EOL regulations, debris prevention
- Monitoring solutions (space & ground based) for debris and object tracking, mitigation and impact avoidance

KEY TECHNOLOGY DRIVERS

COMPETITIVENESS	POLICY AND RISK
• Data challenge	• EU initiatives • Cleanspace





RECOMMENDATIONS

EUROPE SHALL ESTABLISH CAPABILITIES FOR INDEPENDENT ASSESSMENT OF THE ORBITAL ENVIRONMENT (DEBRIS AND OBJECTS TRACKING, AND TRAJECTORY PREDICTION) AND SUPPORT TECHNOLOGICAL READINESS FOR DEBRIS MITIGATION AND PREVENTION.

KEY AREAS FOR ACTION FOR SPACE WEATHER AND SURVEILLANCE CAPABILITIES

- Tools and models (prediction/mitigation)
- Surveillance tracking networks: detection, correlation, scheduling - On-Board and Ground aspects

KEY AREAS FOR ACTION FOR DEBRIS IDENTIFICATION, TRACKING, REDUCTION & AVOIDANCE SOLUTIONS - GROUND

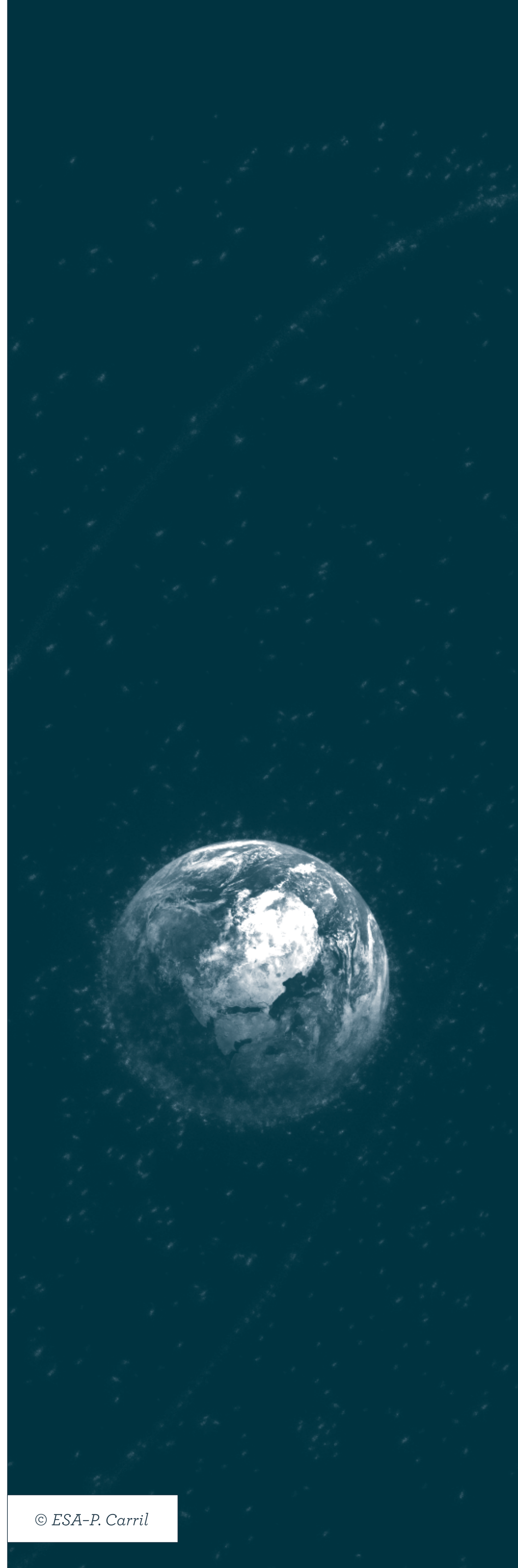
- Tracking system: Radar & optical/laser solutions – very small (<10 cm in LEO, few tens cm in GEO) debris identification
- Reduction solutions: Laser removal
- Ground segment: data fusion, processing, service tooling

KEY AREAS FOR ACTION FOR DEBRIS IDENTIFICATION, TRACKING, REDUCTION & AVOIDANCE SOLUTIONS - SPACE

- Tracking: In orbit sensors
- Reduction: Active debris removal
- Protection: shielding, prediction, autonomous collision avoidance systems

KEY AREAS FOR END-OF-LIFE SOLUTIONS FOR SPACECRAFT (AND UPPER STAGES)

- Building blocks and technologies
- System and architecture
- Tools and model, design for demise: controlled fragmentation/re-entry/drag
- Advanced concepts: tugs, refuelling



ME CD

SCIENCE

Drivers & Challenges

BACKGROUND

This service domain is driven largely by ESA programmes developed and designed in partnership with the European (and global) scientific communities. Programmes and scientific targets are the main drivers for all technology developments. Technology preparation activities are usually well organised in the frame of the programmes themselves, hence the Eurospace roadmap focuses on those activities with critical impact on missions or that would open up new opportunities for scientific missions.

Current missions on the European agenda are:

- S-Class missions (Cheops)
- M-Class missions (M3/Plato and M4/TBD)
- L-class missions (Juice, Athena, eLisa)

Scientific missions often pose unique technology challenges, Scientific instruments are growingly complex, and they often drive the system architecture and design. There are thus links between the science roadmap and the platform/system constraint, in areas such as power, communication systems, data handling, system stability (mechanical and thermal), radiation hardening etc.

Critical functions/system constraints are driving future developments.

- High stability, pointing accuracy
- EMC & radiation requirements
- Temperature challenges

ACTIVITIES PROPOSED

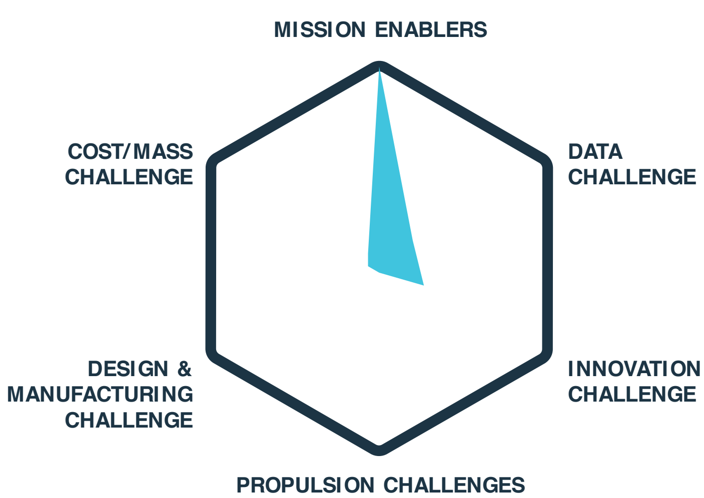
The core of the roadmap is focusing on payload and instrument technologies. It is important to note that there are often synergies between the remote sensing roadmap and the scientific systems roadmap. These synergies have relevance to the detection chain, thermal constraints for very low temperature operations, and high performance materials supporting the development of very large instruments and structures. Science programmes also exhibit potential synergies with the time generation roadmap (navigation).

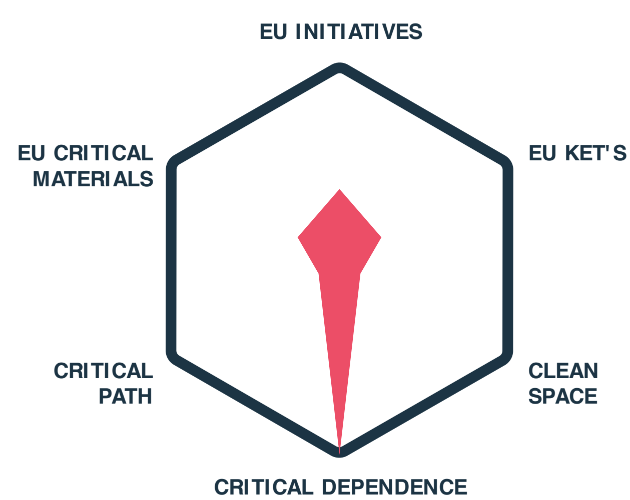
Key aim is to improve instruments capabilities

- Detection chain
- Infra-red/Low-temperature
- Synergies with the Materials roadmap e.g. for stable and large structures

KEY TECHNOLOGY DRIVERS

COMPETITIVENESS	POLICY AND RISK
• Mission enablers • Innovation	• Dependence reduction • EU initiatives





RECOMMENDATIONS

IMPROVE SYSTEM PERFORMANCE AND PAYLOAD CAPABILITIES, PROMOTE EUROPEAN READINESS FOR STATE OF THE ART INSTRUMENT TECHNOLOGIES, INCLUDING LARGE AND VARY LARGE STRUCTURES (ULTRA-STABLE, DEPLOYABLE, THERMAL PROPERTIES).

KEY AREAS FOR ACTION

State of the art Instruments:

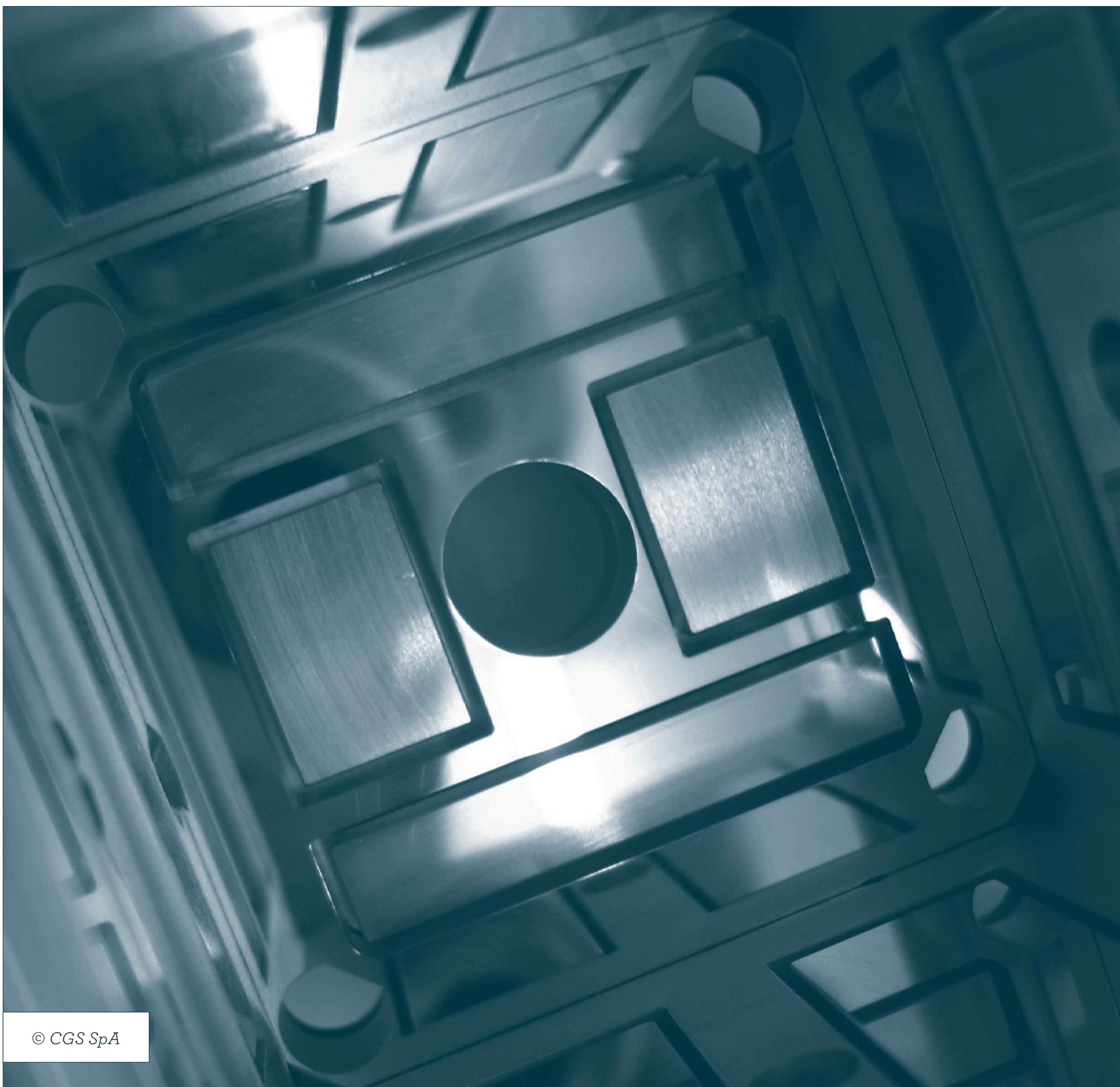
- Large Telescopes
- Detection chain improvement
- Infra-Red/far Infra-Red, mm-wave technologies
- Low temperature/cryogenic temperature operations
- Radiation environment (check if relevant)
- Time measurement

Structures, large & distributed instruments:

- Wide field of view (FoV), large/deployable/ultra-stable structures

Data handling:

- Long distance communications, high data rate/high throughput, ka/ku/optical solutions



HUMAN PRESENCE & EXPLORATION

ME IC CP CD CS

Drivers & challenges

BACKGROUND

Robotic exploration missions open new horizons for planetary knowledge, and will also act as precursors for human exploration missions.

Human presence in space and exploration activities are proposed as one integrated roadmap, due to their synergetic nature, from both technology and missions points of views. The proposals of the Human presence and exploration roadmap are made with a view of supporting an adequate level of European readiness within the frame of current programmatic decisions in these areas.

ACTIVITIES PROPOSED

Exploration programmes and Human presence in space programmes are being carried mainly in the ESA frame, but may/will open the way to global endeavours. The current status of European readiness, in view of the breadth of activity in planning is rather consistent, hence the narrow scope of technology proposals put forward by Eurospace in this roadmap. The most of activities are focusing on automation, autonomy and robotics (including crew/robot synergies and crew collaborative robotics, but also automatic docking aspects). Developments of large structures, also considering habitats are also in the roadmap, together with critical aspects related to propulsion and aerothermodynamics.

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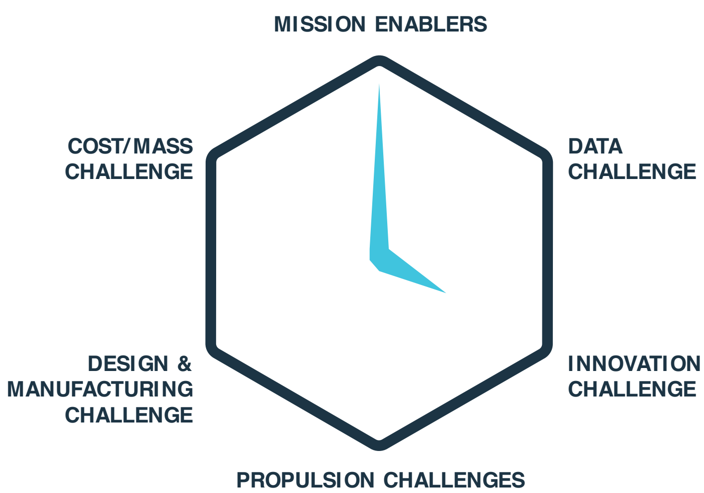
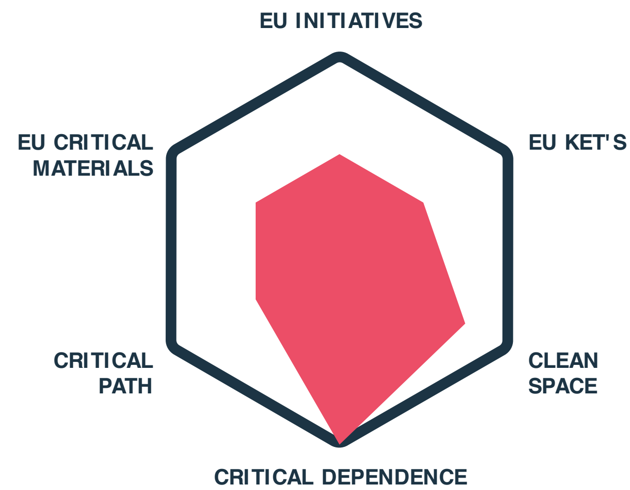
TECHNOLOGY DRIVERS

ALL DEVELOPMENTS ARE STRONGLY MISSION DRIVEN	POLICY AND RISK
	• Exploration is more exposed to dependence situations





RECOMMENDATIONS

FOR ROBOTIC EXPLORATION: ADDRESS LONG DURATION TRAVEL ISSUES, INCREASE READINESS LEVEL FOR PLANETARY ACTIVITIES.
FOR HUMAN EXPLORATION: INVESTIGATE AND DEVELOP SYNERGIES BETWEEN CREW AND ROBOTICS, IMPROVE EUROPEAN READINESS LEVEL ON HABITATS.

KEY AREAS FOR ACTION

Robotics, automation/autonomy, habitats, planetary activities
- End to end automation/autonomy
- Flexible automation/autonomy

Long distance travel
- Propulsion systems (EP and Advanced concepts)
- Fuel and power aspects
- Large assemblies
- Communications
- Breakthrough concepts

Synergy between human and robotics
- Crew collaborative robotics
- Astronaut support

Life support
- ECLS
- Habitats

Safety and protection issues
- Radiation shielding
- Debris/micro-meteoroid/dust

Large structures
- Inflatables: outfitting the interior
- International cooperation

Planetary activities
- Atmospheric entry: Shielding
- Soft/precise landing: Propulsion aspects, mechanical aspects and GNC aspects
- Surface activities: Autonomy, range & mobility and drilling/manipulation requirements
- Planetary protection

Return mission
- Sample handling
- Contamination control

PC IC C/MR D&M EU KETs CS

LAUNCHERS

Drivers & Challenges

BACKGROUND

The launcher roadmap is considered in the context of the European next generation launchers (NGL) development programmatic aims. It addresses a very broad focus of activities, aiming at overcoming the key challenges of launch activities, to preserve the European independent access to space within a highly competitive environment. Overall, European launch services competiveness and reliability are driving factors for this roadmap.

ACTIVITIES PROPOSED

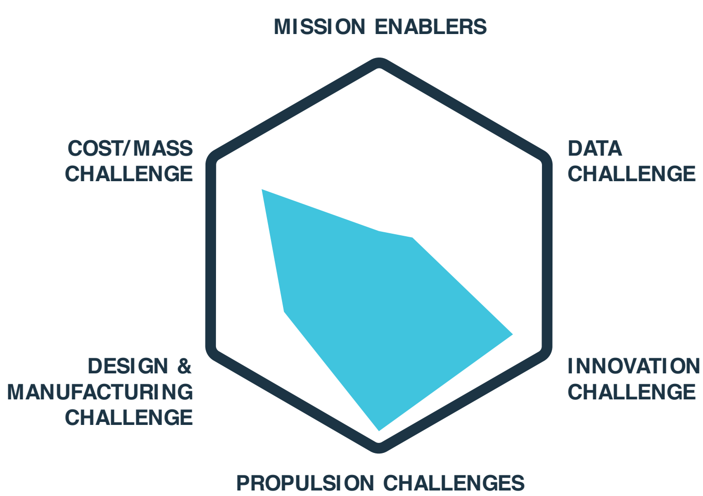
Improvements and evolutions are expected at propulsion level and at architecture level. Some key areas will involve materials at large, including obsolescence and innovative solutions (composites, REACH mitigation etc.), re-usability aspects, the propulsion roadmap and the advances in process and manufacturing at all levels of the supply chain. It is particularly interesting to note that the launcher roadmap has a high relevance and strong synergies with the KETs (Key Enabling Technologies) domains identified by the High level EU experts working group).

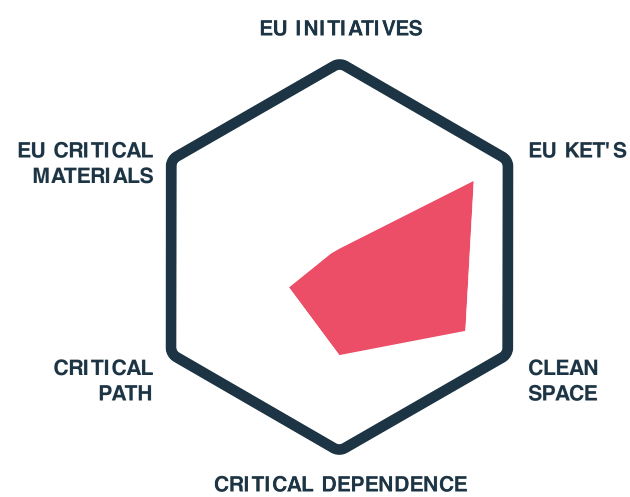
Key aims are:

- Propulsion system competitiveness: Propulsion optimisation and cost/mass reduction activities
- System optimisation: New designs, data system and re-usability
- Process & manufacturing: Composites and Alloys, additive and innovative manufacturing, REACH mitigation activities

KEY TECHNOLOGY DRIVERS

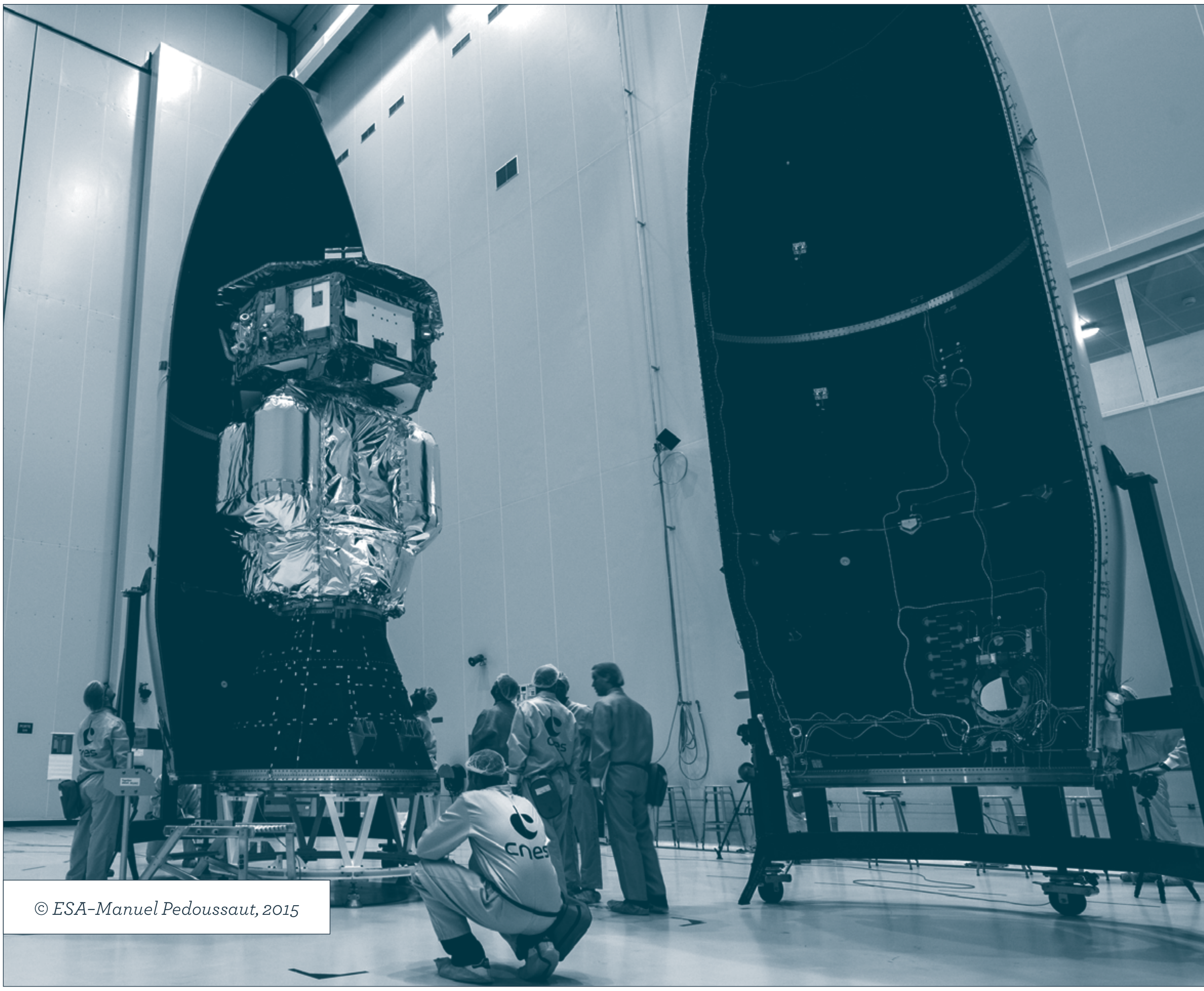
ALL DEVELOPMENTS ARE STRONGLY MISSION DRIVEN	POLICY AND RISK • Exploration is more exposed to dependence situations





RECOMMENDATIONS

IMPROVE LAUNCH SERVICE/SYSTEM END-TO-END COMPETITIVENESS, FROM DEVELOPMENT AND MANUFACTURING ASPECTS, TO COST REDUCTION STRATEGIES AT ALL SYSTEM AND SUBSYSTEMS LEVELS SUPPORT FULL LIFE CYCLE COST ASSESSMENT, MINIMISE ENVIRONMENTAL IMPACT DEVELOP RE-USABILITY ASPECTS AND MODELLING/ENGINEERING TOOLS.



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KEY AREAS FOR ACTION

System level actions (architecture, design, materials)

- Avionics robust long term architecture
- Payload comfort: stay ahead of competition
- Mitigate REACH impact on hydrazine, chromates, resins/glues & solvents
- Health monitoring systems

Propulsion system actions

- Drastic cost reductions on the propulsion system would lead to significant competitiveness improvement of the service,
- Maturity for LOX/Methane main propulsion
- Variable thrust technology for liquid propulsion

Concept evolutions

- Improve versatility, modularity, flexibility, design to operations
- Assess solutions for (partial) re-usability
- Industrial aspects (manufacturing, materials, tools)
- Engineering and simulation toolboxes for system and architecture optimisation
- New manufacturing techniques (eco-design, additive, friction stir welding...)
- Improve functional efficiency of materials, embedded smart sensors, performance driven materials, composite materials, new alloys...

MATERIALS AND PROCESSES

D&M IC EU KETs CD

Drivers & Challenges

BACKGROUND

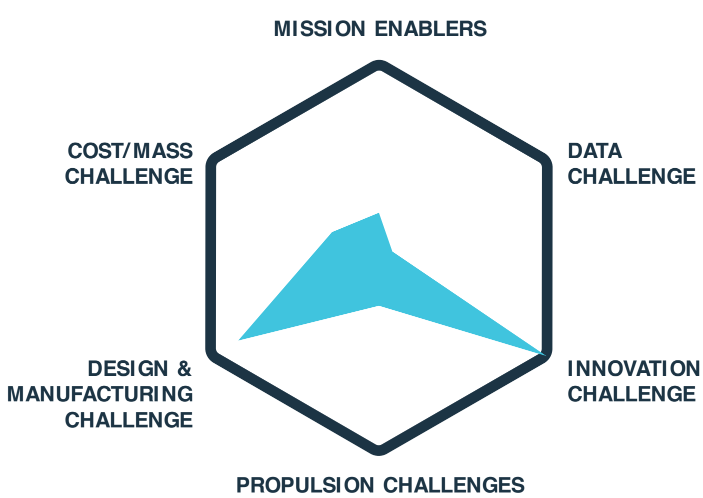
The materials and processes roadmap is proposed within a challenging and exciting technology environment, where opportunities provided by innovations in the materials and manufacturing domains resonate with growing constraints being applied on the development and manufacturing processes. It is also a roadmap where achievements have potentially wide impacts on sector competiveness, and dependence reduction. Materials and manufacturing solutions are also rich with KETs (Key Enabling Technologies).

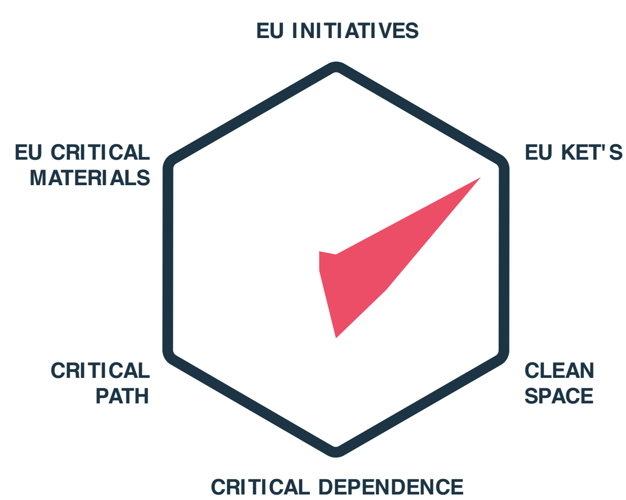
ACTIVITIES PROPOSED

This roadmap includes numerous advanced and smart materials, with specific developments for space applications. The mitigation of REACH impact on the space sector drives many challenges for space applications, from surface treatment, to the use of solvents, glues, resins etc. Some specific functions also provide a breadth of opportunities with the implementation of materials with mechanical and thermal properties. These are areas where dependence situations are frequent. The potential offered by new manufacturing techniques (additive manufacturing e.g.) is very important in space, where the benefits in terms of cost and mass reduction for equipment are very high. New manufacturing techniques may also support the development and adoption of new designs and complete new concepts, with strong potential for innovation. Advanced mechanisms complete this challenging roadmap.

KEY TECHNOLOGY DRIVERS

COMPETITIVENESS	POLICY AND RISK
• Innovation and Industrial processes	• KETs • Critical dependence





RECOMMENDATIONS

MATERIALS AND PROCESSES ARE PROVIDING THE FOUNDATIONS OF INDUSTRY COMPETITIVENESS. EUROSPACE RECOMMENDS THE CONTINUED INVESTIGATION, ASSESSMENT AND DEVELOPMENT OF MATERIALS, AND ADVANCED MANUFACTURING TECHNIQUES. NEW CONCEPTS, NEW DESIGNS, NEW PROCESSES, NEW TOOLS WILL OPEN NEW POSSIBILITIES FOR SPACE SYSTEM DESIGN. REACH, CLEANSPACE, DEPENDENCE, ECO-CONSCIOUSNESS ISSUES DRIVE SOME DEVELOPMENTS

KEY AREAS FOR ACTION

Industrial aspects

- Composite material supply sources
- Additive (3-D) manufacturing: materials characterisation & qualification, design tools for development and qualification.

Materials for enhanced functions and properties

- Mechanical properties: Stability, structures

Thermal protection: Dependence reduction

- Thermally stable materials: High temperature, Cryogenic temperatures, low thermo-elastic distortion.

Smart materials

- Self healing structures
- Embedded sensors
- Shape memory alloys

(IN SPACE) PROPULSION

PC CS CD CP

Drivers & challenges

BACKGROUND

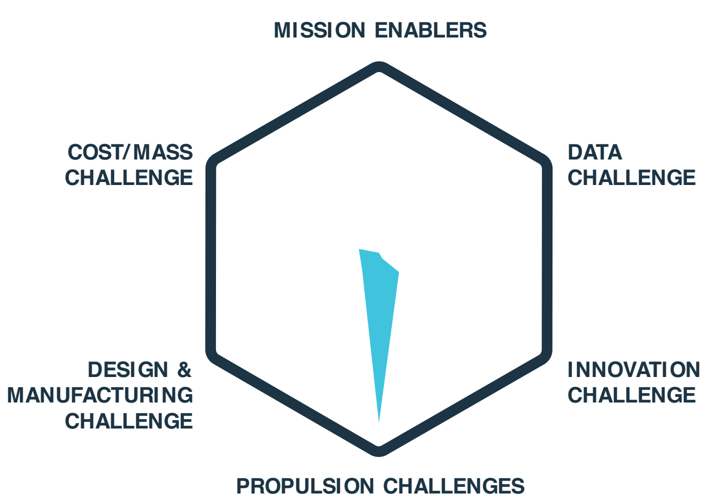
In-space propulsion is a key spacecraft function. It is used for orbit transfer, station keeping and long distance travel in space. It is a determining factor for system efficiency and lifetime. For some specific missions (e.g. exploration) propulsion systems are mission enablers.

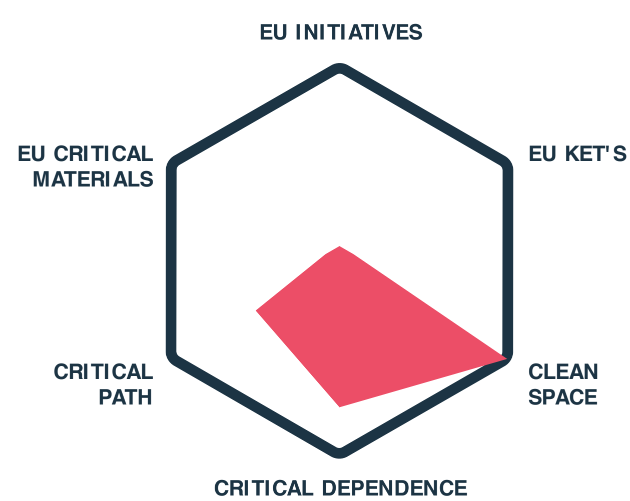
Mission requirements determine the best technology mix, from full chemical, to mixed/hybrid and full electrical solutions.

- Electric propulsion (EP) systems: EP systems have become a growing trend, with widening application domains, from small EP systems for station keeping, to larger EP systems for full spacecraft propulsion functions, including orbit topping and orbital transfer. Electric propulsion systems have strong interactions with the power system (particularly high power) since EP adds requirement to the power generation and storage subsystem. Growing power on the spacecraft may create additional strain on thermal control aspects as well. EP can also be envisaged as a complement for upper stage propulsion in the launcher sector.
- Chemical propulsion systems: Chemical propulsion systems, monopropellant and bi-propellant, offer efficient solutions with long heritage. Monopropellant systems may be challenged by environmental regulations (REACH) since they are using hydrazine. The chemical in-space propulsion roadmap has synergies with launcher propulsion aspects.
- Advanced solutions and concepts may open new horizons and enable new missions

KEY DRIVERS AND CHALLENGES

COMPETITIVENESS	POLICY AND RISK
• Propulsion challenge	• Critical dependence • REACH compliance





RECOMMENDATIONS

SUPPORT THE DEVELOPMENT OF INNOVATIVE, HIGH PERFORMANCE ELECTRICAL AND CHEMICAL PROPULSION SYSTEMS:

- COMPLIANT TO ENVIRONMENTAL REGULATIONS
- ADDRESS PERFORMANCE AND VERSATILITY, TEST AND TOOLS, NEW SYSTEMS

IT IS CRITICAL TO ORGANISE THE SYNERGIES BETWEEN THE POWER ROADMAPS AND THE ELECTRIC PROPULSION ROADMAPS

KEY AREAS FOR ACTION: CHEMICAL PROPULSION (IN SPACE)

Key drivers are environmental regulations and cost reduction:

- Alternative propellants and new designs.

Competitiveness efforts:

- Building blocks cost and mass optimisation,
- Dependence reduction for specific equipment (e.g. valves)

KEY AREAS FOR ACTION: ELECTRIC PROPULSION

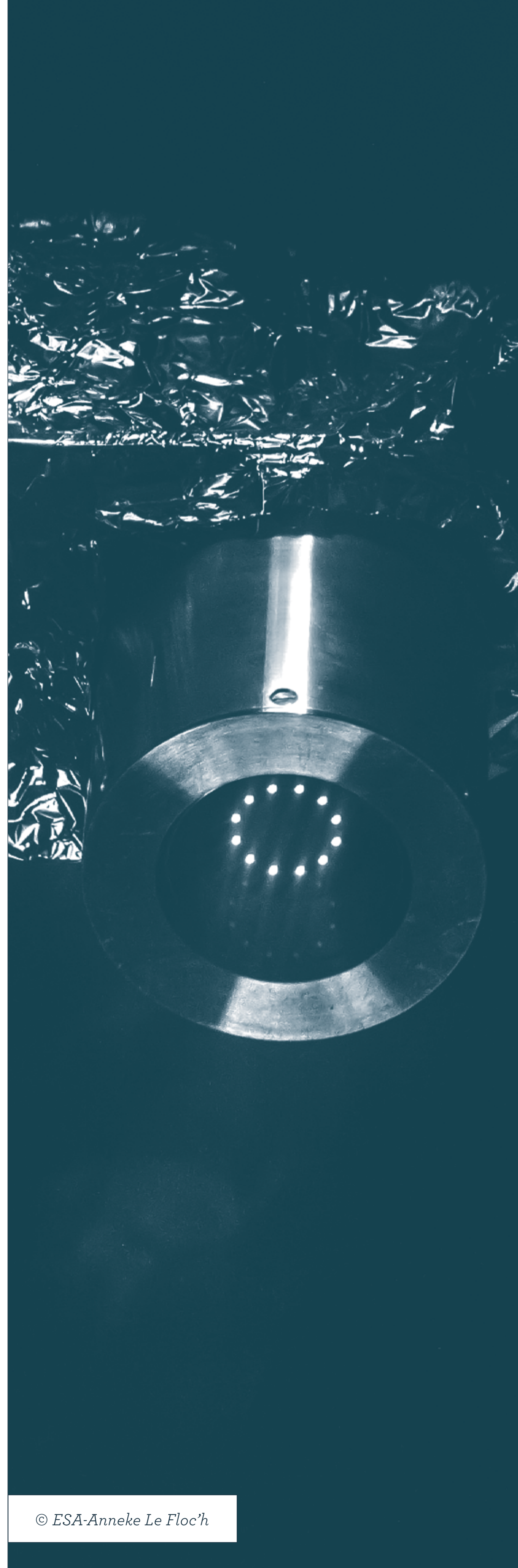
Support the definition of radically new and innovative EP systems: for AOCS and for full electrical platforms

- Low cost solutions for small EP systems
- Dependence issues
- Investigate and assess Xenon alternatives

Performance enhancement

- Optimisation: thrust/power, max thrust, total impulse, cost
- Low cost (mature building-blocks)
- New concepts: thrust vectoring
- Large EP, high power for large platforms
- Small EP for very fine ACS
- Versatility and power for transfer phase and long duration travel
- High Thrust, High power above 1N Power constraints Hybrid solutions Breakthrough solutions

Advanced concepts



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AVIONICS & POWER

Drivers & challenges

BACKGROUND

The power and avionics systems provide key spacecraft bus functions.

The power subsystem provides such critical functions as the power generation, storage, regulation and distribution to all spacecraft subsystems. The power subsystem is a dimensioning factor for spacecraft functions.

The avionics subsystem monitors permanently the spacecraft position and attitude and calculates the corrections required for the spacecraft to remain on its intended orbital path and maintain the appropriate attitude. The avionic subsystem is an enabling factor in many missions where satellite pointing accuracy and/or agility are essential requirements. The avionics and power roadmaps have strong ties with the propulsion systems roadmap

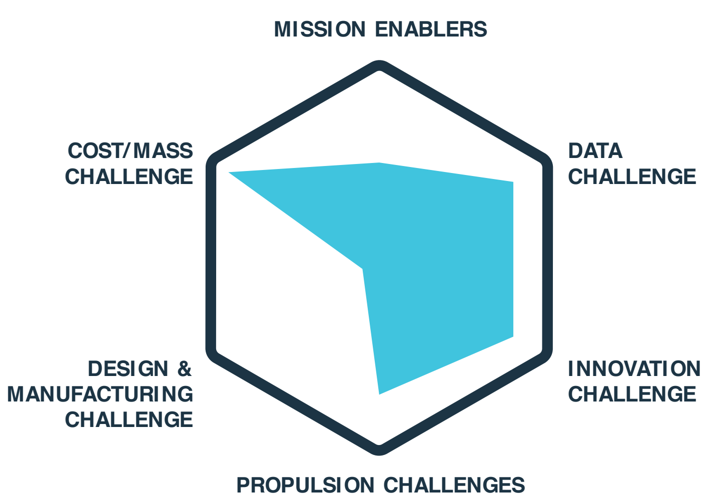
Their evolution and optimisation can be driven by mission requirements, or they can be mission enablers. Both systems are strongly linked to the overall system competitiveness.

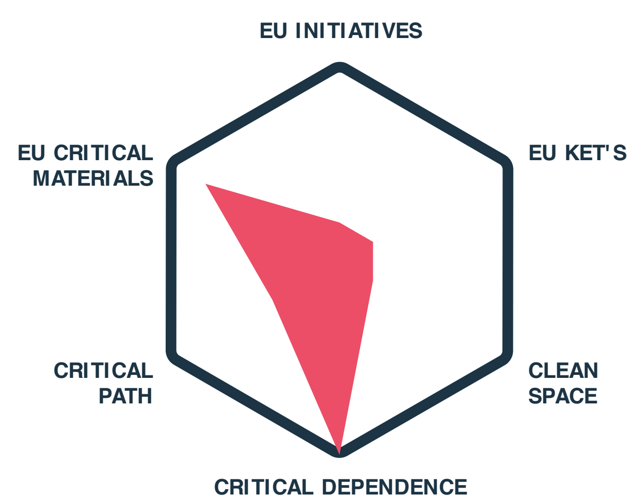
Key aims

- Power subsystem: performance and cost
- Avionics subsystems: on board computing, stability

KEY TECHNOLOGY DRIVERS

COMPETITIVENESS	POLICY AND RISK
• Power: Propulsion, cost and innovation, address challenges of high power and high voltage • Avionics: On board data needs	• Power: Critical materials & KETs • Avionics: Dependence & critical path





POWER SYSTEM: RECOMMENDATIONS

POWER GENERATION IS A KEY ROADMAP FOR EUROPEAN SYSTEMS FUTURE COMPETITIVENESS. EUROSPACE RECOMMENDS TO SUPPORTING INNOVATIVE SOLUTIONS FOR POWER GENERATION, STORAGE AND DISTRIBUTION WITH A VIEW OF ADDRESSING EFFICIENTLY THE CHALLENGES OF HIGH POWER AND HIGH VOLTAGE AND COST EFFECTIVE, COMPETITIVE, SOLUTIONS FOR LOWER POWER IN THE CONTEXT OF SMALLER SPACECRAFT (AND CONSTELLATIONS).

AVIONICS: RECOMMENDATION

EUROSPACE RECOMMENDS TO ADDRESSING THE REQUIREMENTS FOR HIGH STABILITY ASSOCIATED TO HIGH, AND VERY HIGH RESOLUTION SYSTEMS, AS WELL AS THE NEEDS OF HIGH DATA RATE IN TELECOMMUNICATIONS, PARTICULARLY WITH OPTICAL COMMUNICATIONS SYSTEMS.

IN ALL AREAS OF AVIONICS, EUROSPACE SUPPORTS THE SAVOIR[5] **INITIATIVE ROADMAPS AND POSITIONS.**

5] Space AVionics Open Interface aRchitecture. The SAVOIR initiative brings together users and suppliers of avionics systems to jointly optimise avionics architecture and technologies.

POWER SYSTEM: KEY AREAS FOR ACTION

Support power requirements of full electrical satellites

Efficient solar panels

- High efficiency cells
- Panel cost reduction
- New panels designs
- Radiation sensitivity

High voltage: a critical competitiveness issue

- Harnesses, shielding etc.

High efficiency energy storage

Potential game changer concept: wireless power transmission

- Within a system (spacecraft or launcher)
- Between systems (spacecraft)

AVIONICS: KEY AREAS FOR ACTION

New optical technologies

- Fiber optics links/gyros/sensing

Line-of Sight control

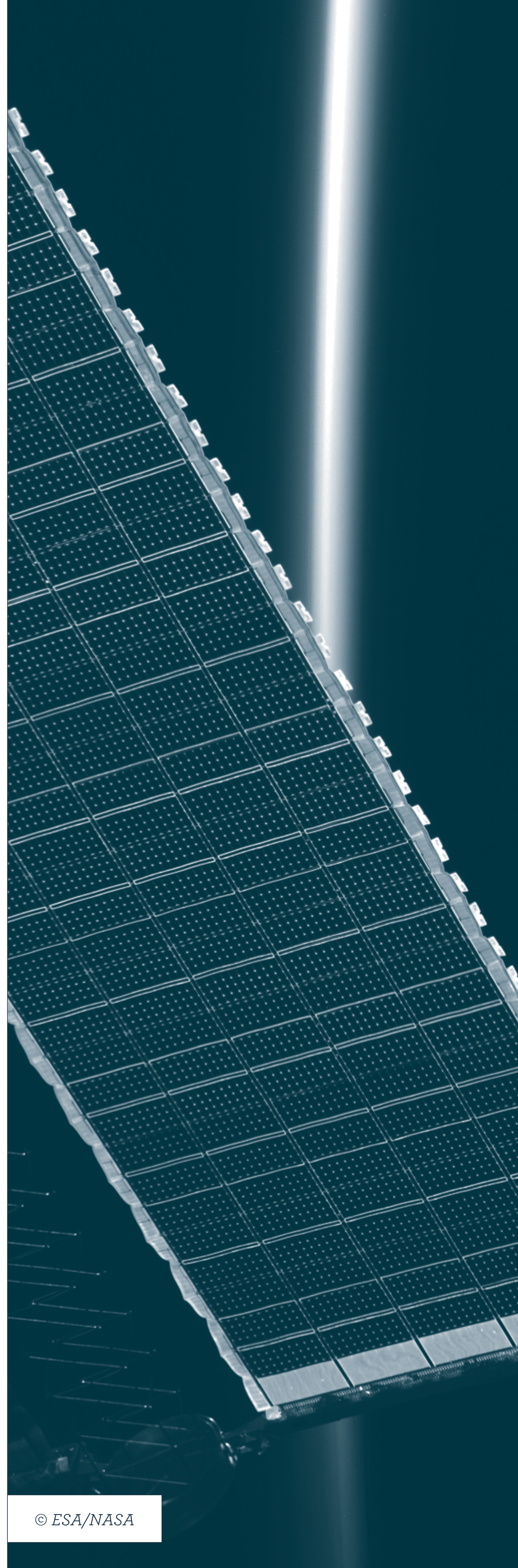
- Stability & pointing accuracy
- Support instrument accuracy

Cost reduction, improve mass and power budget of sensors and actuators

- Miniaturisation of sensors & building blocks
- GNSS receivers
- Functions hybridisation
- Integration of communication systems
- COTS based components

On-board software

- Monitored by SAVOIR



DC CD EU CM

EEE COMPONENTS & ELECTRONICS BUILDING BLOCKS

Drivers & Challenges

BACKGROUND

The EEE roadmap is proposed in a complex programmatic and political context.

EEE components are an area where widespread technological dependence provides programme uncertainties.

EEE components are key elements in the competitiveness of European Space Industry. EEE components are found in most space equipment. This means the equipment overall is significantly driven by EEE components with high impact on cost, reliability and timely availability. Recognizing this strategic role, the user industry, agencies and components manufacturers agreed, in the early 2000's, to a coherent collaboration system, the ESCC*, with the objective of harmonising their efforts concerning the various aspects of EEE space components. In all areas of EEE components Eurospace supports ESCC processes and technology roadmaps.

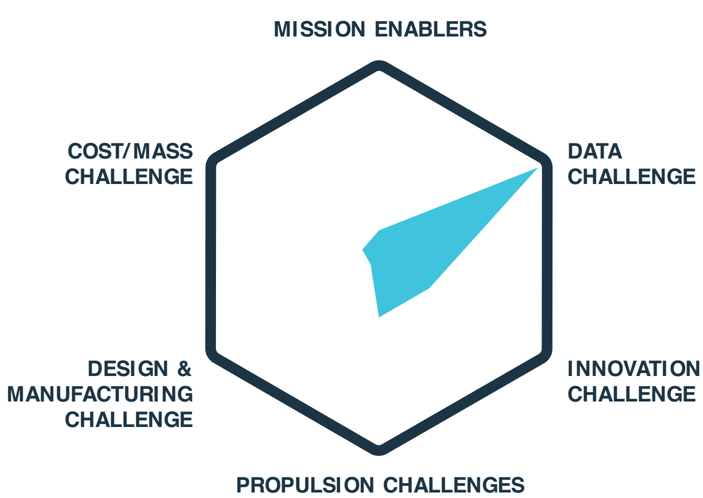
The readiness of European solutions for EEE components is still an issue, despite the significant efforts already pursued in the past decade, and the results achieved so far to reduce the recourse to non-European components for European programmes.

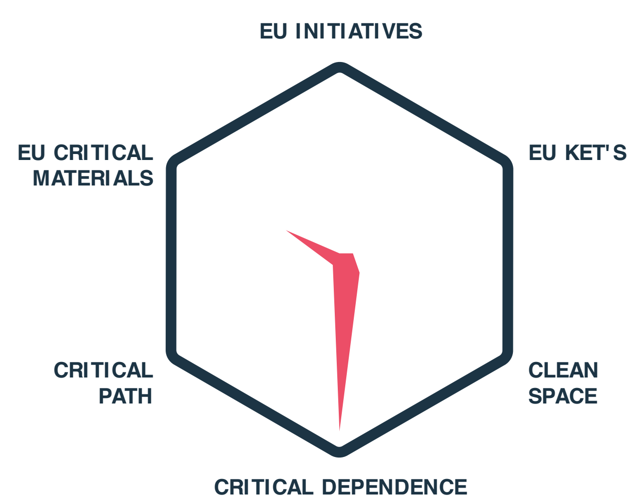
The good alignment of all component related initiatives, programmatic actions and efforts would support the emergence of a sustainable European supply chain.

In complement to high performance, radiation hardened components for demanding applications, developments aiming at introducing COTS components in space systems should be considered as well.

KEY DRIVERS

DATA CHALLENGE	POLICY AND RISK
• High performance • High temperature • Sustainability and supply chain	• Critical dependence reduction





RECOMMENDATIONS

ENSURE THE AVAILABILITY OF CRITICAL EEE COMPONENTS AND BUILDING BLOCKS THROUGH SUSTAINABLE EUROPEAN SUPPLY CHAINS.
SUPPORT READINESS, MATURITY AND EVOLUTION OF THE DSM FUNCTIONAL CHAIN.
ORGANISE THE TAKE UP OF COTS COMPONENTS IN SPACE PROGRAMMES.

**ESCC: European Space Components Coordination*

KEY AREAS FOR ACTION

High speed processing for intensive image and data processing
- Qualify new DSPs
- Co-processing, multi-core processors

DSM (Deep Sub-Micron)
- Qualify the whole high speed chain at 65 nm (IP blocks, interfaces, memories, chips and assemblies)
- Prepare new generations at 28 nm (and below)
- Supply chain: ensure product sustainability
- Affordable mixed signal ASICS

FPGA (Field Programmable Gate Array)
- Develop high performance capacity FPGA by 65 nm (and 28nm at medium term)
- New architecture

Digital information conversion & distribution
- ADC and DAC: high speed (> 3GSamples/s), high resolution (14 bit), multi-channel
- High Speed Serial Links: few Gsamples/s to 6 Gbps (medium term target: 10 Gbps and above)
- Support for TLC and Radar missions

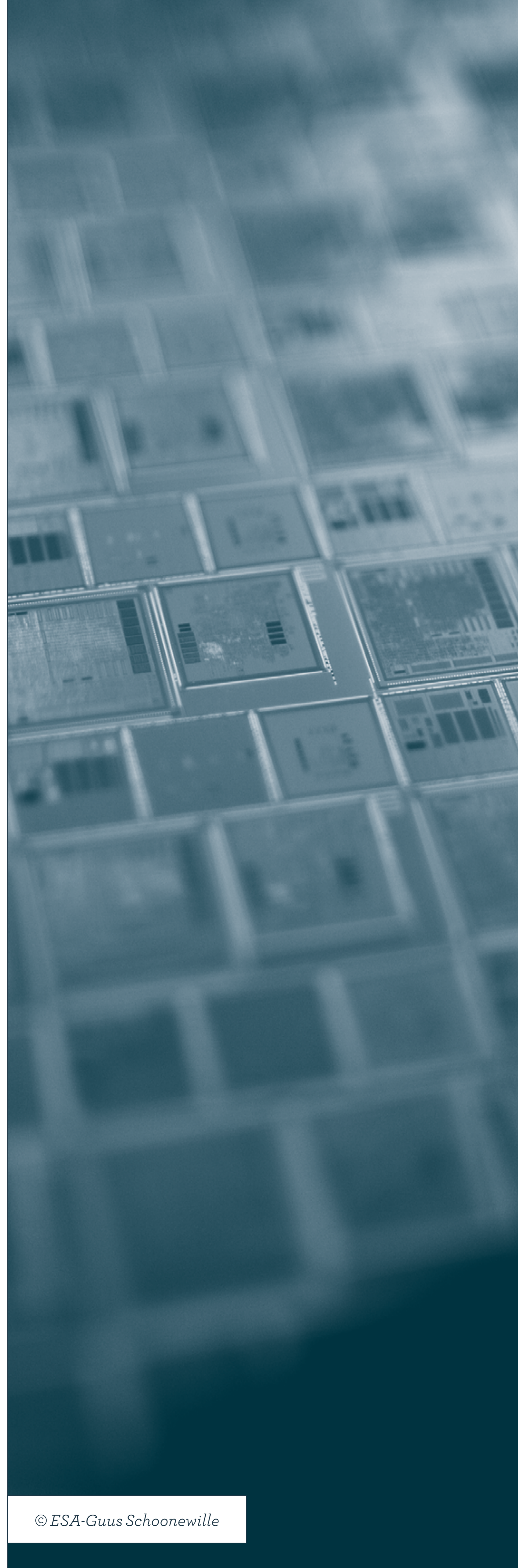
Analog components

Power
- Prepare GaN technology

RF components
- Consolidate GaN technology
- Qualify SiGe technology
- Support for high power
- High temperature operations

Photonics and optoelectronics
- Support for RF digital interconnect
- Optical components for photonic payloads and optical communications

Packaging
- Lead-free packaging & assemblies (RoHS compliance)
- High level integration packaging for DSM (e.g. high pin count)
- Reliable solutions for RF components packaging
- Maturity for non hermetic solutions



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