Critical Space Technologies

for

European Strategic Non-Dependence

Actions for 2021-2023

18/02/2020

European Commission esa EUROPEAN DEFENCE AGENCY

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1 OBJECTIVES

In 2019, The Commission-ESA-EDA Joint Task Force (JTF) ran another round of the non-dependence process to prepare a list of actions for Critical Space Technologies for European Non Dependence for the time-frame of 2021-2023.

A consultation of European stakeholders allowed to gather feed-back from Member States, Industry and SMEs. The JTF reviewed and consolidated the collected inputs.

This document reflects the consensus on the Critical Space Technologies for European Strategic Non-Dependence – Actions for 2021-2023 which was reached with the delegates of the Commission, ESA and EDA during the European Non-Dependence Final Meeting held on 25 November 2019 in Noordwijk

2 DISTRIBUTION OF THE DOCUMENT

This document is made available to all three participating institutions, their member states, represented in the respective committees (COM SPEG-T, ESA IPC/THAG, EDA CapTech National Coordinators (CNC)), relevant Industry and SMEs.

3 EUROPEAN NON-DEPENDENCE PROCESS IN 2019

The European Non-Dependence Process in 2019 follows the structure as defined here below:

European Non-Dependence Process in 2019

The process involves the following three main steps:

1. The first stage is the Mapping. This step involves all European actors (COM, ESA, EDA, Research, Industry, ...), to build a complete mapping of critical technologies for European Strategic Non-Dependence. It consists of the following 3 steps:
   I. A *Draft Background Document* was prepared and distributed by the Commission, ESA and EDA to all actors in the process (the Member States of EU, ESA, EDA, and Industry representatives), in March 2019.
   II. Industry comments were collected by Eurospace (including SME4Space). In this context, Eurospace involved both Eurospace and non-Eurospace members in its process. Expression of interest to be included in the process by Eurospace and SME4Space was expressed via the 3 organizations (COM, ESA, EDA).
   III. The **Mapping Meeting** was held on the **24 May 2019** in ESTEC to discuss and complement the information in the *Draft Background Document.* Member State (MS) Delegations, Representatives from Industry, EDA, ESA and COM were invited to

contribute at the meeting. The Mapping Meeting was co-organised and co-chaired by COM, ESA and EDA. In particular, contributors were asked to provide information on needs for critical space technologies for European Strategic Non-Dependence, relevant on-going developments in critical technology domains identified and strategic interests.

2. The next stage was the planning of the way ahead in the form of a *European Non-Dependence List of for 2021-2023* including recommendations for their implementation as appropriate);

    I. A first *Draft European Non-Dependence List* for 2021-2023 was prepared by the three organisations, based on the information from the Background Document, and information gathered during the mapping meeting. It can include in addition recommendations on priorities and for implementation strategies. The first *Draft European Non-Dependence List for 2021-2023* was delivered for review and comments to MS Delegations and Industry Representatives through Eurospace and SME4Space.

    II. Industry (via Eurospace/SME4Space) was invited to present comments to the first *Draft European Non-Dependence List for 2021-2023* in a dedicated meeting with COM, ESA and EDA on 15 October 2019. The second *Draft European Non-Dependence List for 2021-2023*, including Industry agreed comments, has been distributed to MS Delegations in preparation for the Final Meeting.

    III. At the Final Meeting on the **25 of November 2019** in ESTEC, the proposed final *European Non-Dependence List for 2021-2023* was presented to the MS Delegations; the aim of the meeting is to arrive at an agreed *European Non-Dependence List for 2021-2023,* including implementation recommendations. After the Final meeting, the *European Non-Dependence List for 2021-2023* was updated (as necessary) to reflect the discussions and agreements of the meeting.

    IV. The updated *European Non-Dependence List for 2021-2023* was then sent to the MS Delegations for final review and comments. After implementing received comments the *European Non-Dependence List for 2021-2023* was finalised in February 2020.

    V. The final *European Non-Dependence List for 2021-2023* is distributed to all European stakeholders.

3. The *European Non-Dependence List for 2021-2023* with implementation recommendations will then be implemented in National and European Programmes. Tracking of the status of implementation will be performed yearly by COM, EDA, ESA.

3.1 Definition of dependence

In the context of this document, it is important to recall the definitions of “Independence” and of “Non-Dependence”, namely:

- “Independence” would imply that all needed space technologies are developed in Europe.

- “Non-dependence” refers to the possibility for Europe to have free, unrestricted access to any required space technology.

The aim of this action being undertaken by COM, ESA and EDA is to contribute to ensuring European non-dependence.

In particular, the criteria used to evaluate if a technology can be included in the final list of actions will be:

1. Items shall be of low integration level, i.e. building blocks and components (System/sub-system assembly are not included)
2. Items shall have a clearly identified function and performance target
3. Items shall be multi use and/or applications (i.e. not an enabling technology for a one shot use)
4. Items shall be not available from a European source and for which the unrestricted availability from non-European suppliers cannot be assured
5. Critical items for which no adequate or sufficient action is on going

3.2 Labels for Actions

- Title
- Item Description and Needed Action
- Estimated Initial TRL
- Target TRL
- Applicable Mission Class(es)*
- Industrial Non-Dependence Concern
- Delegations/Agencies voicing non-dependence concern
- Reference(s): In case this item was developed / is related to a specific process e.g. Technology Harmonisation Dossier/Roadmap Reference, ESCC or other consultation process
- Remarks / Justifications
- Date of Entry of Item / Last Date of Change

*Mission Classes: Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Unmanned Aircraft Systems (UAS), Defence Applications.

4 GROUP 1: HIGH URGENCY ACTIONS ADDRESSING CURRENT TECHNOLOGY DEPENDENCY ISSUES AND NEEDING IMPLEMENTATION OF NEW ACTIVITIES IN THE 2021-2023 TIMEFRAME

4.1 Microelectronics and On-board Data Systems

4.1.1 [JTF-2021/23-1] - ASICS FOR MIXED SIGNAL PROCESSING

Description and needed Action	• Need to qualify export restriction free rad-hard mixed signal technologies • implemented in 65nm or smaller nodes (deep sub-micron technologies)Establish development, verification and validation standards for derived mixed-signal IP cores • Establish an independent ASIC source in Europe based on a commercial (sustainable) process and radiation-hard-by-design libraries • Qualification of full supply chain (including assembling and test house, …) including organic and ceramic packaging. • Support European packaging of naked complex multi-pad dies and mixed ASIC testing capabilities • Ensure fair and non-discriminatory access to the IP for European companies. • NVRAM integration due to current limited access or even no European capability
Estimated Initial TRL:	4
Target TRL	7
Applicable Mission Class(es)	Earth Observation, Science Mission, Telecommunications, Navigation, Robotic Exploration, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Microelectronics: ASIC and FPGA, 2016 Technology Harmonisation Dossier
Remarks / Justifications	• Increased demand for mixed signal ASICS in Telecommunications and scientific satellites. • Special market and interest in medium and high voltage applications. Increased interest for mega-constellations. • High priority: still missing NVRAM integration • There are mixed signal ASICS platform in 180nm and 150nm already available in Europe

Date of Entry / Last Date of Change	December 2019

4.1.2 [JTF-2021/23-2] - HIGH CAPACITY FPGAS AND SOFTWARE ECOSYSTEM

Description and needed Action	Validation of a high capacity Rad Hard Reprogrammable Field-Programmable Gate Array (FPGA) of European source ("BRAVE FPGA family") and development and validation of software tools. The family of BRAVE FPGAs contains: 1. BRAVE FPGA NG-MEDIUM (0.5Mgates, 65nm) 2. BRAVE FPGA NG-LARGE (2Mgates, 65nm) 3. BRAVE FPGA NG-ULTRA (>10Mgates, 28nm) Further developments are foreseen for: 4. BRAVE FPGA NG-ULTRA+ (>25Mgates, UDSM) Different tasks are necessary, focusing on BRAVE ULTRA and ULTRA+: • Development and qualification of BRAVE ULTRA and its variants • BRAVE tools ecosystem: complement BRAVE FPGA tools with capability to use higher abstraction-level design descriptions languages above RTL, extensions to recognise specialised macros, optimised place and route for timing/power/area, tools supporting embedded SoC inside ULTRA • Consolidation of qualified assembly and packaging supply chain for BRAVE FPGAs using Flip-Chip in all its packaging variants (ceramic and organic, hermetic and non-hermetic) • BRAVE FPGA first use cases and reference designs, benchmarks (space IP Cores and full space systems, including on-board reprogrammable and Software Defined Radio). In order to promote component use and get valuable feedback for optimisation of running developments of tools, FPGA HW internal design and packaging, and even PCB assembly and thermal dissipation aspects ECSS qualification of BRAVE FPGA-ULTRA and its derivatives (ultra150, ultraRF) The following requirements are needed: • The FPGA shall be radiation hardened. • The FPGA devices shall become available in space-qualified suitable packages.

	• The FPGA product shall include the software tools that execute the typical digital microelectronics flow starting from a Register Transfer Level (RTL) description and system constraints (e.g. timing, capacitive loading) to ultimately generate the bit-stream necessary to program the FPGA with the desired functions. • In order to meet the FPGA capacity and performance requirements, the FPGA shall be implemented in a technology node (minimum feature size of the transistors) of 28 nm or smaller. • The FPGA shall be a European sourced free of non-European export control regulation product
Estimated Initial TRL:	3-4
Target TRL	7-8
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Microelectronics: ASIC and FPGA. 2016 Technology Harmonisation Dossier
Remarks / Justifications	The requirements and characteristics mentioned above are derived after discussions in the framework of CTB / ESCC and other fora with Industry (customers), Vendors (technology suppliers, private funding) and Public Space Institutions, Organizations and Agencies (institutional funding). There is also the need for rad-tolerant low power, high capacity, low cost solution in Europe. In order to establish a commercially attractive product, an organic substrate (“Plastic”) Package in addition to a classic ceramic package shall be made available. BRAVE ULTRA FPGA useful variants that can be developed can have a combination of the following: high or low speed ADC and DAC, NVRAM (see N53), short range die-to-die interconnects, new version (ULTRA+) based on ultra-deep submicron (smaller than 28 nm) with 25 Gbps SerDes, etc.
Date of Entry / Last Date of Change	December 2019

4.1.3 [JTF-2021/23-3] - HIGH SPEED DAC-ADC BASED ON EUROPEAN TECHNOLOGY

Description and needed Action	Future ADC and DAC developments should support direct conversion for multi-band capability in order to contribute mitigating the scarce availability of frequencies with software controlled and dynamically optimized frequency plans. Future developments should also anticipate and be compatible with a distributed ADC and DAC implementation away from the signal processing chip and physically positioned on the antenna element tiles or other remote units, using a digital harness on fiber instead of classic RF harnesses. This calls for associated innovations in photonics and on-fiber communication for data and ultra-low phase noise clock distribution over the optical harnesses. • Qualification of "current generation" of High speed, and high accuracy Analogue to Digital and Digital to Analogue BiCMOS converters • Development of "next generation" direct sampling solution at Ka-Band (30/20) and Q/V (50/40 GHz) • Need for ADC/DAC 60 GHz as stand-alone devices
Estimated Initial TRL:	2 (for next generation), >5 for current generation
Target TRL	5/6 (for next generation), 7 for current generation
Applicable Mission Class(es)	Navigation, Earth Observation, Telecommunications, Science Mission, Human Spaceflight, Space Transportation, Robotic Exploration, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Microelectronics: ASIC and FPGA, 2016 Technology Harmonisation Dossier
Remarks / Justifications	
Date of Entry / Last Date of Change	October 2019

4.1.4 [JTF-2021/23-4] - VERY HIGH PERFORMANCE MICROPROCESSORS AND SOFTWARE ECOSYSTEM

Description and needed Action	New generation rad-hard high performance microprocessors: • implemented in ≤ 28nm deep sub-micron technologies • performance improvements of factor 5-10 over existing microprocessors and SOC's implemented in existing European technologies

	Adding functionalities that are today missing in current space state-of-the-art general-purpose microprocessors: e.g. DDR i/f, SerDes, clusters of multi-cores, dynamic scheduling of processor execution on the thread level, support for sub-word integer arithmetic (SWAR – SIMD within a register), runtime extensions of the instruction set, hypervisor HW and SW support. • development, validation, qualification of flight models of such performance and their application in space missions • Consolidation of SW ecosystem to exploit in an optimal way (processing speed, power consumption, and fault-tolerance) the SoC multi-core nature of these processor devices. Extension of the existing SW ecosystem to support programming models for MIMD execution in multi-core systems with built-in HW support for resource and task allocation. • architectural design investigations for different CPU open source architecture
Estimated Initial TRL:	4
Target TRL	> 7
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Microelectronics: ASIC and FPGA, 2016 Technology Harmonisation Dossier
Remarks / Justifications	Europe is leading in the development of the next generation high performance microprocessor, the GR740 based on four LEON4 cores, for which qualified FM parts are expected for Q4-2019, and in parallel a quad-ARM solution that will be embedded in BRAVE NG-ULTRA FPGA, prototypes expected for Q2-2020. Large and fast memory components are also needed to reach high performances with new microprocessors.
Date of Entry / Last Date of Change	December 2019

4.1.5 [JTF-2021/23-5] - HIGH DATA RATE (12.5 TO 28 GBPS OR HIGHER 56 GBPS), LOW CONSUMPTION, SHORT RANGE LINKS

Description and needed Action	Develop IP for high data rate, low consumption, short range links that could connect future BRAVE FPGA and Optical transceivers.

	Cross-strapping of Gbps links. Component needs for cross-strapping for redundant systems and interface protection: for 12.5 Gbps and above, protocol agnostic, with MUX/DEMUX function.
Estimated Initial TRL:	3
Target TRL	7
Applicable Mission Class(es)	Earth Observation, Science Mission, Telecommunications, Defense applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	On Board Payload Data Processing, 2016 Technology Harmonisation Dossier
Remarks / Justifications	Such a component does not exist in Europe but is critical for the implementation of redundancy concepts, for achieving good signal integrity, and for the protection of ASICs/FGPAs.
Date of Entry / Last Date of Change	October 2019

4.1.6 [JTF-2021/23-6] - ULTRA DEEP SUBMICRON TECHNOLOGY FOR NEXT GENERATION SPACE INTEGRATED CIRCUITS: ASICS, FPGA AND MICROPROCESSORS

Description and needed Action	• Evaluation and development of next generation space ASIC/FPGA/Microprocessor technology building blocks to accomplish higher integration and performance levels, using Ultra Deep Submicron (UDSM) node. • The new UDSM technology of interest for space applications identified with highest priority by Space Agencies, and European industry stakeholders in the frame of the UDSM WG is 16/12 nm FinFET. • 28 nm and 22 nm FDSOI processes are already used for space FPGA and ASIC developments with financial support from Agencies and EU, however, complementary developments on these technologies or their future evolution would also be interesting. • Development and characterization of radiation hardened basic European IP building blocks (e.g. basic logic cell libraries) and design kit for space users. • Development and characterization of radiation hardened high complexity European IP building blocks (e.g. PLL, high speed serial links (HSSL), ADC and DAC, DDR, die-to-die interconnect IP).

	• Evaluation and development of assembly and packaging technology suitable for UDSM complex devices (ASIC, FPGA and Microprocessors), including technology for SiP, multi dice systems in one package.
Estimated Initial TRL:	3
Target TRL	6
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defense applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	• Microelectronics: ASIC and FPGA, 2016 Technology Harmonisation Dossier • ESCC CTB roadmaps
Remarks / Justifications	• UDSM processes require a high degree of focus on long term reliability and SEE process capability. Radiation and SEE hardened cells and libraries are required since SEE is affecting the overall performance reliability to a non-negligible extent. • A generic space digital ASIC platform will help with the development of other general use integrated circuits manufactured with the same Silicon process: BRAVE-Ultra FPGA, microprocessors.
Date of Entry / Last Date of Change	October 2019

4.1.7 [JTF-2021/23-7] - QUALIFICATION OF MICROCONTROLLER FOR SPACE APPLICATION

Description and needed Action	Need to ESCC qualify an export-restricted-free rad-hard single-core microcontroller for space applications.
Estimated Initial TRL	5
Target TRL	7
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Unmanned Aircraft Systems (UAS), Defence Applications.
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)

Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	Data Systems and On-Board Computer, 2016 Technology Harmonisation Dossier
Remarks / Justifications	• Software based data acquisition/processing and simple control applications are widely used in many spacecraft subsystems. They allow implementing software based control architectures that provide a higher flexibility and autonomous capability versus hardware implementations. For these types of applications, where limited performances are requested to the processor, general-purpose microprocessors are usually considered not compatible due to high power consumption, high pin count packages, need of external memories and peripherals. • Low-end microcontrollers are considered more attractive in many applications such as: propulsion system control, sensor bus control, robotics applications control, simple motor control, mechanism control, power control, particle detector instrumentation, radiation environment monitoring, thermal control, antenna pointing control, AOCS/GNC (Gyro, IMU, and MTM), RTU control • For future microcontroller evolutions, include a simple but robust floating point control unit co-processor to allow fast control loop implementation for mechanisms and other power control applications (e.g. cryo-coolers control) and NVM.
Date of Entry	December 2019

4.2 Space System Control

4.2.1 [JTF-2021/23-8] - HIGH PERFORMANCE GYRO BASED SENSORS

Description and needed Action	Ensure long term availability of a European cost effective high performance Gyro Unit (GU) and IMU (Inertial Measurement Unit with accelerometers). This activity targets the full range of GU and IMUs aiming at dependence and cost reduction. The introduction of COTS components is considered as a possible way to achieve the goal. Adaptation of this IMU to gyro-only or vice-versa solutions will be defined as well in order to guarantee market sustainability. Target specifications:

	Landers	Scientific Satellites (L2)	Earth Observation, Navigation	Unit
Gyro Input Range	400	1 - 3 for full performance	20	deg/s
Accelerometer Input Range	25	0.01	N/A	g
Angular Random Walk	0.01	0.0001	0.001	deg/√ hr
Gyro Bias Stability (3σ)	0.2	0.005	0.005	deg/h
Accelerometer Bias Stability (3σ)	100	1	N/A	µg
Accelerometer Scale Factor Stability (3σ)	500	2000	N/A	ppm
Mass	3	5	3	kg

The origin of the inertial core shall be fully European (European IPR) to guarantee no future export restriction.

Estimated Initial TRL:	4
Target TRL	≥ 6
Applicable Mission Class(es)	Navigation, Science Missions, Earth Observation, Human Spaceflight, Robotic Exploration, potential Telecommunications, Launcher, UAS, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	AOCS Sensors and Actuators, 2015 Technology Harmonisation Dossier
Remarks / Justifications	The target TRL of 6 implies at least the adaptation of an IMU Engineering Model. The gyro technology in Europe currently fulfilling the requirements (in terms of performance, heritage, non-dependence and maturity) is the Fiber Optical Gyro technology or Coriolis Gyros.
Date of Entry / Last Date of Change	December 2019

4.3 *Power*

4.3.1 [JTF-2021/23-9] - HIGH PERFORMANCE, COST EFFECTIVE MULTI - JUNCTION SOLAR CELLS AND SOLAR GENERATOR ELEMENTS FOR SPACE APPLICATIONS

<table>
<tr>
<td>Description and needed Action</td>
<td>The action is split in two sub-actions as follows:

A - High performance, cost effective multi - junction solar cells for space applications

The EOL efficiency of 28.5% has been reached in 2019 with BOL efficiencies well above 31%. Although increasing efficiency will still be the main objective in space solar cell R&D, mission needs in the future might require dedicated solar cells for different type of missions. More specifically, there will be missions where low cost, low mass of flexible solar cells might be more important than highest efficiency. On the other hand, there will be missions that strongly exceed radiation doses typically linked to “EOL” conditions. This asks for a more diversified portfolio of solar cell types to be made available by solar cell manufacturers in order to satisfy customer needs.
Main driver in solar cell R&D will remain efficiency increase. Qualification of a 28.5% EOL quadruple cell will be achieved in 2020. At development level, for the near term a “30% EOL class” cell is targeted (with EOL efficiency in the order of/greater than 30%, and BOL efficiencies in the order of/greater than 33-35%) to be available in 2021 and qualified in 2022. As a next step, EOL efficiencies of 33% are targeted and initial R&D is started in 2019.
The main cell concepts under investigation are lattice matched quadruple-quintuple cells (LM), upright lattice mismatched quadruple-sextuple cells also called upright metamorphic (UMM), inversely grown quadruple-sextuple solar cells including Inverted Metamorphic (IMM) and quadruple solar cells realized by semiconductor bonding technology (SBT). While the efficiencies are the key parameters, it is equally important to target cost effective designs that have high potential to become a product.
At the same time existing solar cell structures shall be modified to derive variants optimised in terms of;

BOL efficiency (potentially at the expense of EOL performance)
EOL efficiency at very high radiation dose

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	o Cost • Light-weight, flexible solar cells are mission enabling for specific cases. Therefore, dedicated lift-off processes are needed to allow the manufacturing of ultra-thin, flexible solar cells with very high yield and low cost.. This process may also be used for the manufacturing of some solar cell concepts, e.g. IMM and SBT • Cost-effective high quality Ge - substrates are required for present and next generation multi-junction solar cells in space. Requirements: • For next generation solar cells: • Efficiency target for BOL and EOL (1MeV electrons,1E15cm^{-2}) per each solar cell concept: o UMM 4 junctions: 33% BOL, 30% EOL o UMM 5 junctions: 36% BOL, 33% EOL o IMM 4 junctions: 34% BOL, 30% EOL o IMM 5 junctions: 36% BOL, 31% EOL o LM 4 junctions: 35% BOL, 31% EOL o SBT 4 junctions: 35% BOL, 31% EOL o SBT 5 junctions: 36% BOL, 33% EOL • • Diversification of solar cell portfolio to answer back to specific mission requirements • Development of Lift-off process (or substrate removal process) for flexible, light-weight solar cells and for cost reduction potential of IMM and SBT solar cell types • Development of epi and device processing for 8" wafer for any potential solar cell type (e.g. SBT- wafer bonding, IMM, UMM, LM) • Space qualification covering environmental testing and reliability aspects • For Ge substrates: o Reduction of production costs at guaranteed high product quality o High yield 8" wafer process with optimized substrate o In view of environmental impact requirements, reduction of the amount of Germanium, used only as

	a support layer, by appropriate lift-off processes and/or by an effective recycling approach. o Adopt a proper life cycle assessment (LCA) approach for Germanium. **B - High performance, cost effective solar generator elements for space applications** • Concerning solar generators, the improvement of their performance metrics is essential, because it impacts directly on the performance metrics of platforms, while creating additional value at satellite level. • Future exploration missions, new and large platforms with electrical propulsion for orbit raising, as well as multiple satellite launches, will require significant increases in the following performance parameters: o power per unit area (W/m2) o power per unit volume when stowed (kW/m3) o power to weight (W/kg) These will require new configurations of solar arrays, based on innovative elements (e.g. new panel substrates/flexible blankets, interface with innovative mechanisms, advanced photovoltaic assembly technologies and processes). For solar generators, develop innovative elements (e.g. new panel substrates/flexible blankets, interface with innovative mechanisms, advanced photovoltaic assembly technologies and processes) for new concepts of solar generators to permit: • power/mass ratio of around 200 W/kg • power/volume ratio of 60 kW/m3 • generation capacity of around 150 kW • ultra lightweight module for specific near space application (1500W/kg)
Estimated Initial TRL:	2 (A - High performance, cost effective multi - junction solar cells for space applications) 4 (B - High performance, cost effective solar generator elements for space applications)
Target TRL	5 (A - High performance, cost effective multi - junction solar cells for space applications)

	7 (B - High performance, cost effective solar generator elements for space applications)
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Telecommunications, Navigation, Space Security, Exploration, HAPS
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Solar Generators and Solar Cells, 2015 Technology Harmonisation Dossier
Remarks / Justifications	For the time being the work horse solar cell for almost all European and many international satellite projects is the lattice-matched triple cell technology. This technology has reached the end of its evolution with the 3G30 and the CTJ30 solar cell whose qualifications are finalized. As of 2019, 4G32 solar cell family will be introduced in the market. For the development, qualification and product introduction of the next generation multi-junction solar cell a strong effort in a very competitive US-European market environment is needed, an effort comparable to the transition from silicon single junction solar cells to triple GaAs solar cells. Very significant investments are made in the US. Future exploration missions, new and large platforms with electrical propulsion for orbit raising, as well as multiple satellite launches, will require innovative solar generators, comprising new panel substrates/flexible blankets, interface with innovative mechanisms, advanced photovoltaic assembly technologies and processes. US players are very active in this domain. It is of high importance to develop in complement to the solar cells new array architectures/concepts, where US competitors are clearly more advanced and where there is also more room for increasing the relevant figures of merit.
Date of Entry / Last Date of Change	January 2020

4.4 *RF Payload System*

4.4.1 [JTF-2021/23-10] - RF COMPONENTS

Description and needed Action	In any space mission high sophisticated semiconductor components such as frequency converters, PLLs, prescalers, power and low noise amplifiers are vital for reliable communication. Although there are very promising attempts in R&D for such components in Europe, a lot of components are ordered from overseas. European industry and research facilities have the technological know-how and potential to supply the space community with components having equivalent or even better performance in comparison to its "overseas competitors" but still need R&D to come to market readiness of space qualified components. Activities will include RF components such as integer/fractional-N PLLs, voltage-controlled oscillators (i.e. VPAs), and high performance MMIC Power Amplifiers, MMIC LNAs and their monolithic integration. Other examples are: • more Si-based MMICs : RF CMOS, FD SOI, SiGe, … • plastic-packaged MMIC (III-V or Si-based) and other non-hermetic packaging options for RF components • very high frequency MMIC (Q/V bands, W bands and higher, III-V or Si-based). In particular, it is necessary to pursue the following: • the development of EU PLL outsmarting the US devices in terms of operating frequencies and radiation hardness; • the development of MMICs for multiconstellation telecom payloads, like integrated TX/RX miniaturized units; • the development of specialized RF components for Synthetic Aperture Radars and electronically steerable antennas in general; • the development of complete MMIC frequency generators in the 2-20GHz range, with state of the art spectral purity.
Estimated Initial TRL	4
Target TRL	7
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	

Reference(s)	Critical RF Technologies (GaN & SiGe), 2014 Technology Harmonisation Dossier
Remarks / Justifications	For practical implementation reasons, it is recommended to split this item into separate comprehensive activities/projects. RF and Microwave RF components such as frequency converters, PLLs, power and low noise amplifiers, and their monolithic integration, are definitively needed as today only available from US with EAR Export license required. A qualified and European controlled source is vital for space end users. New components are needed so that the future high-throughput Terabyte satellites become a reality: components at Ka-band and higher in particular for multi-constellation low-cost aspects and non-hermetic operation should be emphasised.
Date of Entry / Last Date of Change	December 2019

4.4.2 [JTF-2021/23-11] - SPACE QUALIFIED RF GAN COMPONENTS AND DEMONSTRATORS

Description and needed Action	Develop, improve efficiency, qualify and demonstrate qualified GaN Technology: • Stimulate and establish a space qualifiable European source of high operating frequency GaN power transistors • Extend the operating frequency capability of European GaN processes to Q, V, W bands • Higher frequency GaN HEMT technology for improvement of Noise performance and robust receiver operation and robust switches • RF front-ends and SSPAs based on GaN technology • Robust GaN MMIC process • Improve thermal management at semiconductor level to increase RF power density • Maintain and grow European capability in high performance GaN epitaxy • Promote and stimulate European GaN into future space missions • GaN-MMIC for non-hermetic operation • Monitor the availability and quality of semi-insulating SiC substrates, establish a second source capability that is not subject to export control restrictions / end user licence restrictions.
Estimated Initial TRL:	4 for GaN MMICs, 5 for discrete GaN components
Target TRL	7

Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Critical Active RF Technologies, 2014 Technology Harmonisation Dossier
Remarks / Justifications	
Date of Entry / Last Date of Change	December 2019

4.4.3 [JTF-2021/23-12] - POWER AMPLIFICATION: TRAVELLING WAVE TUBE (TWT) MATERIALS

Description and needed Action	Ensure unrestricted access to materials for TWT production: • High voltage cable • Metal alloys such as MoCu and MgAl3Zn for the manufacturing of critical TWT parts. Ensure alternatives to Lead (in REACH list), in particular suitable for brazing processes in TWTs.
Estimated Initial TRL:	Depending on material 3-5
Target TRL	≥ 6
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence applications.
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	
Remarks / Justifications	
Date of Entry / Last Date of Change	December 2019

4.5 EEE Components

4.5.1 [JTF-2021/23-13] - PASSIVE & RF PASSIVE COMPONENTS

Description and needed Action	European Space industry is still very reliant in most cases on single source suppliers and/or suppliers from outside of Europe (e.g. USA and Japan), There is a need to increase the number of freely accessible space qualified passive and RF passive components, this includes developing and qualifying new technologies in Europe. Components that are needed include: Capacitors: • Wet tantalum with high capacitance (> 1 mF) • Polymer Aluminium capacitors • High Voltage capacitor miniaturisation (ceramic and mica film) (>0.5kV) • Decoupling capacitor for next generations of FPGA Supercapacitors (SC): • SC with higher reliability and SC based on innovative technologies with high specific Energy densities (>10Wh/Kg) Inductors and transforms: • High current small size inductors for point of load applications • High power planar transformers (>5KW) Relays and Switches: • Development and qualification of high voltage (>2kV) for propulsion applications and robust to high mechanical stress relays (e.g. pyro 3000g) Thermal parts: • Development of smart heaters and thermoelectric coolers Connectors: • Development and qualification of Modular and solderless connectors (e.g. press-fit) • Qualification of high data rate (>50 Gbps) connectors including backplanes solutions with low insertion losses Cable assemblies: • Qualification of cable assemblies for High data rate and for high voltage applications (electric propulsions applications) RF Cables assemblies: • Development and qualification for RF cables assemblies for high frequencies (Q, V and W band) and/or for high power applications • Development of RF phase stable cable assemblies for phase sensitive payload instruments (≤10 ppm/°C) RF Passive components including and not limited to circulators, isolators, couplers, power dividers, loads, attenuators and switches: • Miniaturisation of RF components with the help of game changer technologies (SMT, SIW, SoC, etc.) for high frequencies Q, V and W bands • Development of Higher power RF components for RF frequencies: P, L, S, C, Ka/Ku, Q, V and W bands

	Where applicable, activities should follow the recommendations with regard to highest priority items from European Space Components Co-ordination (ESCC) via CTB.
Estimated Initial TRL	3-4(usually)
Target TRL:	7
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Number of Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	
Remarks / Justifications	Passive components requires continuous support and investment to expand the current portfolio available within Europe, as most passives for space cannot be replaced by terrestrial devices.
Date of Entry / Last Date of Change	October 2019

4.5.2 [JTF-2021/23-14] - ACTIVE COMPONENTS FOR POWER APPLICATIONS

Description and needed Action	Development and qualification (including reliability evaluations) of active components (like diodes) assuring unrestricted availability of space qualified high reliability components in Europe. This action is split in two sub actions as follows: **A: Discrete power devices** • Wide catalogue of MOSFET transistors (from 30V to 600V) • non-RF GaN and SiC diodes and transistors for voltages up to 600V or higher **B: Integrated circuits for power applications** • Functions for power control and conversion: POL, PWM, ICL, drivers (especially for GaN) , other ICs (Low Voltage High current POL • small FPGAs with integrated ADC for power converters • digital isolators • Monolithic integration on WBG (Wide Band-Gap) The recommendations from European Space Components Coordination (ESCC) via CTB will be taken into account.

Estimated Initial TRL	4
Target TRL:	7
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Number of Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	• Power Management and Distribution, 2019 Technology Harmonisation Dossier • ESSC/ CTB Roadmap
Remarks / Justifications	Note that at present there is no European rad-hard GaN-FET or SiC on the market. About the need of Low Voltage High current POL: new FPGAs and microprocessors are becoming very demanding in terms of voltage and current. These devices need an input voltage between 1.2 V and 0.9 V and the current level is reaching 50 A. This is very demanding specification for a DC/DC converter and needs specific topologies, components and control systems. This is needed in demanding signal processing applications. At the moment, only one American converter can fulfil these needs and there is no European alternative. Given the fact that this advanced digital devices are becoming more and more used, it will be an interesting commercial opportunity. ESCC evaluation and qualification of 650V MOSFET is on-going. Expected completion Q3 2020.
Date of Entry / Last Date of Change	December 2019

4.5.3 [JTF-2021/23-15] - HIGH CHALLENGES FOR PCBS AND SMT (SURFACE MOUNT TECHNOLOGIES)

Description and needed Action	The following major action items may be listed:
	• Secure a European pool of PCB manufacturers and critical PCB base material suppliers for strategic dual-use applications.
	• High Density Interconnection PCB technology (HDI) PCB and assembly process.
	    ○ RF PCBs and RF SMT
	    ○ Thermal Management issues in PCB and SMT
	    ○ Flexible PCB

	○ Embedded components into PCB ○ Transition to Pb free assembly • Transition to organic package assembly
Estimated Initial TRL:	4
Target TRL	7
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	
Remarks / Justifications	It is recommended to promote European coordination between civil and military industrial end-users. Qualification of a European assembly process and PCB technology for HDI components is required. The use of high density products (ASICs and FPGAs) allows increasing the competitiveness (higher integration, increased performance, new functionalities).
Date of Entry / Last Date of Change	October 2019

4.5.4 [JTF-2021/23-16] - HIGH TEMPERATURE PACKAGING

Description and needed Action	Thermal management of high power semiconductors and very advanced components to ensure performance and reliability. • Specifically thermal management in space components where the efficient cooling of semiconductors is a key issue in order to be able to minimize volume and weight of electronics • A low junction temperature by an efficient dissipation of heat in order to ensure a long life and reliability of components. • Specific problematic are GaN RF and Power and SiC discrete components but other technologies may also be covered under this new element Actions needed include: • Development of advanced space and REACH compatible assembly materials replacing AuSn alloy, die attachment with thermal conductivity>200W/mk and techniques,

	• Enhanced thermal dissipation materials to be used as package baseplate or substrates like for example graphite material or AlN, -Diamond composites, with thermal conductivity>600W/mK
	• Space qualification of a family of high dissipative hermetic packages (e.g. metal micro package, SMD, …) for:
	  o RF applications for different ranges of dissipated power and frequency up to Q-Band
	  o Power applications for different ranges of dissipated power and frequency up to 2MHz

Estimated Initial TRL	4
Target TRL	7
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	
Remarks / Justifications	Components based on GaN start to be commercially available but with assembly and packaging techniques that are not always demonstrated as being suitable for space applications. SiC components are already used in ESA project with specific requirements, but it is urgent to improve high temperature materials and packaging techniques if we want to make optimum use of these new technologies. Improved high thermal conductivity / heat dissipating packages are required. There have been several European developments using Cu/Diamond/AlN, etc. The key issue is the commercial viability of the solutions. A European source of packages has to be competitive with Japan or USA. Today, commercial materials/packages are available from Japan or US only and European R&D. Concerning Japan, packages/materials have no strong restriction so far. Thermal management of GaN space components is critical to optimise the electrical performance of GaN Power Amplifiers. Enhanced thermal dissipation materials are needed.
Date of Entry	October 2019

4.6 *Space Environment and Effects*

4.6.1 [JTF-2021/23-17] - VERY HIGH ENERGY ION ACCELERATORS FOR COMPONENT, SHIELDING AND RADIOBIOLOGY CHARACTERIZATION

Description and needed Action	Support the development of very high energy (>100MeV/nucleon, up to several GeV/nucleon) ion facilities in Europe for the tests of EEE components, shielding and radiobiology, to experimentally simulate the cosmic rays environment for space applications Facilitate the access to users: industry, agencies; for assessment and qualification tests in accordance with European quality standards
Estimated Initial TRL	*3*
Target TRL	*6-7*
Applicable Mission Class(es)*	All
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	
Remarks / Justifications	European accelerator facilities are routinely used for testing electronic component susceptibility to single event effects, investigating radiobiological effects, and validating shielding methods. Some aspects are specific to human spaceflight, but in general all space missions, Telecom, Science, Navigation, Earth Observation, are affected. However, in Europe the facility energy limits makes them not completely representative and as a result it is necessary to go to the US or Japan. For example, when high energy is needed for complex components, European industry is routinely performing tests at TAMU (College Station, US). Facility upgrades in Europe are needed to avoid this dependence. ESA has frame contracts with three facilities (UCL Belgium, PSI Switzerland, RADEF Finland). However the energy is limited (10-15 MeV/nucleon for heavy ions, 200 MeV for protons). These facilities are accessible to users, within reasonable delays and competitive commercial conditions. However they do not address the very high energy range needed to test complex components, COTS multi-chip modules, and for shielding and radiobiology characterisation.

	Other European facilities (KVI Netherlands, GANIL France) are accessible, but limited to 100 MeV/nucleon and with a limited number of ion species and test time possibilities. GSI-FAIR (Darmstadt, Germany), and occasionally CERN, addresses the GeV/nucleon range, however with very limited accessibility to external users for routine tests. The beam time cost for routine industrial tests is not addressed. The difficult access to very energy ion accelerators was noted in the Harmonisation dossier "Radiation Environment and Effects" as a coming issue, especially with the increasing number of complex components, artificial intelligence and big data treatment on-board satellites, but without significant supporting activities. The need for radiobiology was beyond the scope of this dossier, but it will be increasing with the lunar and mars manned Exploration roadmap. The need would be to coordinate at European level with users (industry, agencies), to cover the energy range above 15 MeV/nucleon with a properly supported network of facilities, accessible to users, including in particular KVI, GANIL and GSI FAIR. The access to high energy accelerators would be within short delays, a large combination of ion species, and at reasonable cost. This would imply the development of a generic test station, with sample positioning and connections, accurate dosimetry at the sample position, and user interface. The targeted applications are to experimentally simulate the cosmic rays environment for space applications: • tests of EEE components, including COTS and complex ICs, multi-chip modules, thick packaging, test at board level, • shielding against cosmic rays, radiobiology, for human spaceflight and exploration Clear interest for EEE tests
Date of Entry	October 2019

4.6.2 [JTF-2021/23-18] - RADIATION BELT GLOBAL MODELLING

Description and needed Action	Develop European models of the Earth radiation belts. The software tools, models and data should be accessible to the European space agencies, industry, and research organisations, working on the design and development of spacecraft. Support radiation environment monitoring aboard spacecraft on different orbits (LEO, MEO, GEO, GTO including electric propulsion orbit raising through the radiation belts) and coordinate the acquisition of in-flight data as a key requirement of the modelling.

	The aim should be to develop a global Earth radiation belt model covering all orbits.
Estimated Initial TRL	n/a
Target TRL	n/a
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	Some past European developments targeting specific orbital regions, particle species or energy ranges of the Earth's radiation belts are: • TREND-4: http://trend.aeronomie.be/trend4/sum/intro.shtml • MEO-V2: https://arc.aiaa.org/doi/abs/10.2514/6.IAC-06-D5.2.04 • IGEE-2006: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2007SW000368 • Slot region model: https://ieeexplore.ieee.org/document/6937415 • BAS-RBM: https://www.bas.ac.uk/science/research-models/bas-radiation-belt-model-bas-rbm/ Radiation Environments and Effects (AIM A), 2015 Technology Harmonisation Dossier

Remarks / Justifications	Radiation belt models are a critical part of the radiation hardness assurance process for space systems development. Presently Europe is obliged to use US models based on US data. What is crucial is to have an independent technological development of models based on European data in order to verify the accuracy of US models, and possibly be used to lead to consensus international standard models. Past ESA activities have included the development of a range of models targeting specific orbital regions or particle species, and the preliminary validation of the US-led AP9/AE9-IRENE ("International Radiation Environment Near Earth") activity. Current ESA activities include contributions to the AP9/AE9-IRENE activities, generation of a Low Altitude proton model, and the development of a dedicated model for Electric Orbit Raising missions. There are also significant European national developments in the domain. CNES and ONERA have for several decades developed radiation belt models, radiation monitoring instruments and radiation measurement data bases, and the development of the global radiation belt model GREEN, which could represent an alternative to US models, has recently been initiated. The British Antarctic Survey (BAS) has also developed a dedicated model for the electron radiation belts. Related to the above, various activities are also ongoing for the collection and processing of European radiation environment monitor data for modelling and model validation activities (e.g. from the SREM, ICARE, XMM/RM, EPT, Giove-A/Merlin, NGRM instruments). But there is no comprehensive programme in Europe to coordinate in-flight data and modelling activities as new data becomes available. It is worthwhile to consider this new item given the need for radiation environment monitoring of different orbits (LEO, MEO, GEO, GTO including electric propulsion orbit raising through the radiation belts, upcoming constellations, and the related impact on COTS). Proposed development approach focusing on coordinating and merging the different, dedicated ongoing developments.
Date of Entry	December 2019

4.7 *Mechanisms*

4.7.1 [JTF-2021/23-19] - LOW SHOCK NON-EXPLOSIVE ACTUATORS (NEA) FOR SMALLSATS

Description and needed Action	Space qualification for non-explosive hold down and release actuators. This action principally refers to a hold down and release actuator for small sat applications (sat mass up to around 50Kg) Typical range of release actuator preload range is in the order of 100N - 2kN The qualification of Hold Down & Release devices should not only concern the load capabilities of the unit, but also the unit price, resetability (preferable by customer); exported shock; temperature range; power consumption; the electrical interface(i.e. input voltage, current) and also the actuation time. .
Estimated Initial TRL:	3/4
Target TRL	7
Applicable Mission Class(es)	Target Application: Small sat especially for: Telecom constellation, Science, Exploration and Navigation
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Technologies for Hold Down and Release Mechanisms and Deployment Mechanisms, 2015 Technology Harmonisation Dossier
Remarks / Justifications	
Date of Entry / Last Date of Change	December 2019

4.8 *Materials and Processes*

4.8.1 [JTF-2021/23-20] - SPACE QUALIFIED CARBON FIBRE PRE-IMPREGNATED MATERIAL SOURCES FOR LAUNCHER AND SATELLITE SUBSYSTEMS

Description and needed Action	Enhance European capability for manufacturing innovate C-fibre C-fibres and pre-pregs technologies. Today, high performance carbon fibre materials are required in almost all space relevant applications, appearing in components in launchers (typically high strength applications) and satellites (typically high stiffness applications).. Polymer matrices include thermoset systems such as epoxy, cyanate ester, phenolic, and BMI resins as well as thermoplastic systems

	such as PEEK and PEK. Novel prepreg formulations should target cryogenic, or high temperature applications, low-temperature curing systems, extended out-time, and functional improvement such as thermal and electrical conductivity, and EMI shielding. With new prepreg technologies, suitable sizing to ensure carbon-fibre /matrix interface performance must be considered. In addition innovative prepreg technologies should be introduced to replace UHM or HM fibres by benefiting of commonalities with other large-scale industrial sectors to improve lead-time and market security.
Estimated Initial TRL:	4-5
Target TRL	>7
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Launcher vehicles
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Composite Materials, 2019 Technology Harmonisation Dossier With the FP7 and the H2020 activities, EUCARBON and SpaceCarbon a European production capability for high modulus fibres is expected which should be followed by dedicated development strategies to enhance European capability with the aim to support the establishment of a competitive industry and innovative supply chain, and, if economically viable, providing access to regular and non-monopolized manufacturing slots.
Remarks / Justifications	In 2019 a European Harmonisation on this topic was concluded, where the European needs and needed actions were identified and agreed on.
Date of Entry / Last Date of Change	Decembre 2019

4.8.2 [JTF-2021/23-21] - NON DEPENDENCE OF MATERIALS AND PROCESSES

Description and needed Action	The activity should aim to identify and qualify critical European materials and processes affected by export control or non-European single source. Specific actions are required, at least, to ensure unrestricted access to the following categories:

	• **A** - European alternative of low outgassing medium E-modulus epoxy resins, essential e.g. for optical applications. This includes ultra-low outgassing, room temperature curing, high peel and shear strength, preferably dark/black to avoid straylight, medium modulus paste adhesives, and low/intermediate Tg adhesives for cryogenic applications.
	• **B** - New coatings (e.g. thermal, tribological and protection function). High Thermal IR high emissivity coating for accurate absolute temperature calibration. Black coatings for thermal control at extreme temperature and for straylight mitigation.
	• **C** - Thermal control materials including polymer films which enhanced radiation and promoting electro-static charge dissipation, flexible solar reflectors.
	• **D** - European primers and advanced surface treatment processes for long-term stability prior bonding and structural bonding applications.
	• **E** - Oil and greases for long-term and high-temperature applications for space mechanisms
	• **F** – Solvents: Replacement of solvent-based processes such as surface pre-treatments with solvent-less processes
	• **G** - Radiation-hard materials, parts and processes for atomic clocks:
	  o Low diffusion cells for lamps and bulbs
	  o Devices for the generation, control and sustainability of plasma dissociator
	  o Quartz material for oscillator
	• **H** – High purity quartz crystals such as for frequency generators and converters, modulators, digital processors, TT&C transponders
	• **I**- Advanced metal matrix composites offer material options beyond existing space qualified systems in Europe. capabilities for manufacturing MMC especially using continuous fibre for high performance materials need to be developed. Aluminium reinforced materials can address the demisability requirements in the context of Clean Space.
	• **J** -High-tensile-strength, high-temperature textiles, including 3D-woven and metal/carbon-reinforced fabrics to keep structural resistance in high-temperature conditions
	
	Space environment qualification of the associated processes is needed including endurance of material properties in case of Long Term Storage applications.

Estimated Initial TRL	3-4
Target TRL	7
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	
Remarks / Justifications	
Date of Entry / Last Date of Change	December 2019

4.8.3 [JTF-2021/23-22] - OBSOLESCENCE OF MATERIALS AND PROCESS

Description and needed Action	The activity aims towards green and sustainable long-term replacement solutions for substances that are facing regulatory (e.g. REACH, RoHS) or commercial obsolescence risks and where only remaining suppliers are in non-European countries.
	
	Specific actions are required, at least, to ensure unrestricted access to the following categories:
	• **A -** Applications of hexavalent chromium: Whereas alternatives for surface treatments, primers and paints for corrosion protection are largely available in Europe, speciality applications and critical performance drivers can lead to dependece on non-European sources.
	• **B** - Aprotic polar solvents such as N-Methyl-2-pyrrolidone (NMP) that cause already loss of available products in Europe.
	• **C** - Isocyanate chemisty, particulary when used in manufacturing polyurethane foams
	• **D** - Widespread applications of metallic lead (Pb):
	  ○ electronic assembly processes (SnPb solder),
	  ○ EEE parts manufacturing in internal solder joints and external terminations,

	○ radiation shielding of components ○ copper and brass alloys, ○ solid lubrication in bearings and other applications Space relevant validation of the associated processes is needed.
Estimated Initial TRL	N.A.
Target TRL	7
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	
Remarks / Justifications	In the context of REACH, an obsolescence risk in the space industry can be defined as any possibility of impairment of quality and reliability or even loss of critical technologies for qualified materials and processes, caused by a chemical's unavailability or substitution. REACH poses two major forms of obsolescence risks that could for some items be transformed in dependence issue for space activities: The regulatory obsolescence risk, mainly caused by the legal consequences of regulations The commercial obsolescence risk, for example when suppliers change or discontinue products used by the space sector in favour of alternatives for other customers but that are not fit for purpose for space applications. For the European space industry as a small volume user and thus typical niche customer for the chemicals industry, the market realities may lead to significant commercial obsolescence risks over and above the REACH regulatory demands Bibliography available on qualified materials and processes is becoming obsolete. It is deemed as limiting factor for space applications. The identification of an alternative materials Cr+ is not a dependence issue, the problem is the low TRL and the lack of manufacturing equipment for such special alternative process e.g. sol gel based coatings.

Date of Entry / Last Date of Change	December 2019

4.9 *Optics and Optoelectronics*

4.9.1 [JTF-2021/23-23] - POWER LASER SOURCES IN THE EYE-SAFE REGION

Description and needed Action	Develop power laser sources for application in the eye-safe region. Eye safe laser sources allow for use of laser beams in atmosphere with reduced risks for human beings. Critical key points: optical pumping, active material, power sources, etc. High power / high pulse energy laser instruments in the eye-safe spectral range are relevant for the monitoring of atmospheric trace gases such as carbon dioxide and methane by differential absorption lidar (DIAL). In particular the spectral bands around 1.6 microns and 2.0 - 2.4 microns are of interest. ESA is pursuing the development of pulsed laser systems that are either based on the direct generation of the required wavelength from a suitable solid state laser source or wavelength conversion of a Nd:YAG laser. Important parameters (of such a DIAL system that are driving current developments) are an extraordinary wavelength stability and tunability. Resonnant optical amplifiers (notably 1,5 microns) also need to be developed.
Estimated Initial TRL	3-4
Target TRL	≥ 6
Applicable Mission Class(es)*	Science Mission, Human Spaceflight, Space Transportation, Space Security, Robotic Exploration, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	
Remarks / Justifications	No source for laser materials in Europe for high power applications in the eye-safe region.

	For laser cooling applications, high power source at 1020nm is missing and the only one known is currently manufactured in the US.
Date of Entry	October 2019

4.9.2 [JTF-2021/23-24] - ENHANCED PERFORMANCE AND SPACE QUALIFIED DETECTORS

Description and needed Action	High-performance image sensors continue to be a requirement for future Earth Observation, Science and Astronomy missions with sensitivity from UV to VLWIR. Those high end image sensors should meet not only requirements of high performance e.g. high quantum efficiency, low read out noise, fast read-out, high dynamic range, but also combine design features like large format e.g. 2D arrays up to 2kx2k with stitching and butting capabilities enabling even larger size of focal plane arrays. This action is encompassing various building blocks in the design, manufacturing and testing chain of an image sensor e.g. wafer processing and backside thinning, (cryogenic) ROIC design, hybridization, deposition of optical filters/coatings/lenses, front end electronics and ASICS, packaging/butting, space qualification etc. The action is split in two sub-actions as follows: **A - Enhanced performance and space qualified detectors – IR range** In the infrared, a good base of European manufacturers is available and recent developments in NIR, SWIR and LWIR continue to improve the range of technologies on offer. However, it is clear that further progress is both necessary and possible in terms of improved performances and exploitation of different material systems. Large format arrays in the NIR and SWIR are essential for future missions as are longer wavelength detectors with lower dark currents. While IR detectors are more and more critical technology for most of optical Earth Observation and Science payloads, the gap between US and Europ for both IR detection materials and cryogenic readout circuits is increasing (e.g.: very large format detection array, very low readout noise ROIC , very high dynamic ROIC , cryogenic ROIC with very fast digital outputs, and cryogenic electrical interfaces. European capability in term of high performances optical coatings is far behind US capabilities notably in SWIR and TIR spectral ranges. European independence require to enhance these

	technologies for instance High Power safe coatings ,high power safe rejection filters (optical comms) ,TIR pass band filters (Earth observation) and High Spectral Resolution Lidar filtering optics with widened field of view (Lidar application) **B - Enhanced performance and space qualified detectors – visible range** In the visible waveband (UV is also included here), CCDs continue to dominate due to their higher electro-optical performances. While this remains the case, it is not possible to fully exploit the inherent advantages on offer from CMOS Image Sensors (CIS) likelower power, faster readout, enhanced radiation tolerance, ease of interfacing… and it is a high priority goal to meet this challenge. Two approaches are possible: 1. European design house coupled with non-European foundry non affected by export restrictions 2. European design house coupled to European foundry Option 1 is likely to provide the best performance in the shorter term, but is only partial non-dependence and consequently subject to more external influences. Option 2 implies full European non-dependence and potentially better control over the processes. However, the European foundry landscape is currently changing and developments need to be targeted and controlled. This said, it is still considered a high priority to develop and support a stable, European CIS supply chain.
Estimated Initial TRL:	2-5
Target TRL	8
Applicable Mission Class(es)	Earth Observation, Science Mission, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Optical Sensors, Visible Range, 2015 Technology Harmonisation Dossier
Remarks / Justifications	High-performance image sensors (and not just in the infrared) are state-of-the-art for high-end applications and consequently subject to export control. U18b: Several design houses exist in Europe, thus the funding should focus on developing a truly European foundry.
Date of Entry / Last Date of Change	December 2019

4.10 Propulsion

4.10.1 [JTF-2021/23-25] - ALTERNATIVE TO HYDRAZINE IN EUROPE

Description and needed Action	Taking full account of on-going relevant European activities, ensure the availability of a less toxic alternative to Hydrazine for a long term replacement. To address this issue, it is important to act: • to identify , with the support of ECHA, the proper acceptable CMR and SVHC levels of the non-hydrazine propellants, • to invest in non-hydrazine propellants , with the aim of replacing, at least, the hydrazine performances, • to invest in technologies, including the qualification of appropriate thrust chamber and catalyst combinations, and all other parts coming into contact with the fuel, as tank and its PMD / diaphragm / bladder, piping, valves, etc. • to invest in technologies, including the qualification of appropriate flight and ground systems components
Initial Estimated TRL:	4
Target TRL	8
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence applications.
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Chemical Propulsion – Components, 2018 Technology Harmonisation Dossier
Remarks / Justifications	The text refers to hydrazine availability as a potential future issue. The propellant may remain available from current sources (e.g. US, Russia and China) even if REACH prohibits use in Europe. The real issue is potential prohibition or restriction of hydrazine use in Europe. Costs vary considerably depending on the programmatic decision taken, especially with respect to hydrazine-derived propellants. For development of alternatives to Hydrazine on spacecraft costs can be in range from 5 – 10 million€ per thruster class per propellant (depending also on necessity to qualify the alternative propellant itself). On the other hand costs for replacement of hydrazine-derived launcher stages can easily reach the order of several hundred million Euro.

Date of Entry / Last Date of Change	December 2019

4.10.2 [JTF-2021/23-26] - ALTERNATIVE TO MMH AND UDMH

Description and needed Action	Hydrazine, N2H4, is widely used as monopropellant in space crafts and missiles. Hydrazine is however currently on the REACH list of chemicals of very high concern and might be banned in the future. This might adversely influence the European propulsion industry. Alternatives to monopropellant hydrazine are thus of interest and this is covered by action point U5: Alternative to hydrazine in Europe. Monomethylhydrazine, MMH, and unsymmetrical dimethylhydrazine (UDMH) are used in bipropellant engines. MMH is proposed for harmonised classification carcinogenic 1B. Although currently not added in Annex XIV, such classification makes MMH/UDMH a Substance of Very High Concern (SVHC). It is thus of importance for the European propulsion community to be proactive and prepare for what might come by developing alternatives to MMH and UDMH. It is therefore proposed to include a new action point concerning alternatives to MMH and UDMH.
Estimated Initial TRL	2
Target TRL	5
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	Chemical Propulsion – Components, 2018 Technology Harmonisation Dossier
Remarks / Justifications	
Date of Entry / Last Date of Change	October 2019

4.11 *Structures and Thermal*

4.11.1 [JTF-2021/23-27] - ADVANCED PASSIVE THERMAL CONTROL SYSTEMS

Description and needed Action	Further improve the performance and optimise current advanced passive thermal control systems to provide current and future missions with enhanced heat transport, heat storage and heat rejection or heat switching capabilities. Technologies cover in particular capillary-driven two-phase heat transport technologies, such as heat pipes,Pulsating Heat Pipes, and Phase Change materials and advanced heat rejection techniques. Applications are targeted at spacecraft level as well as for electronic units cooling. In-orbit demonstrations of such advanced passive thermal control systems need to be identified and funded to enable improved thermal performance in European satellite platforms and payloads.
Estimated Initial TRL:	5
Target TRL	8
Applicable Mission Class(es)	Target Application: High power / heat rejection mission, and other thermally challenging missions especially: Telecom and dual use, Defence applications. CubeSats and planetary landers
Industrial Non Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Two-Phase Heat Transport Equipment, 2017 Technology Harmonisation Dossier
Remarks / Justifications	In addition an in-orbit demonstration of a complete deployable radiator is urgently needed to increase maturity and acceptance level for potential users. With the advancement in additive layer manufacturing, several activities have been initiated, as 3D thermal interface, Heat pipe widen sections, 3D printed Loop heat pipe as well as electronic units with integrated two phase channels, which aim to reduce the temperature difference between the electronic components and the radiator. Other capillary pumped loop equipment has been developed specifically for electronic box cooling. Development activities currently on-going for embedding Pulsating heat pipes in CFRP panel. Due to the large CTE mismatch of extruded aluminium profiles, Pulsating Heat Pipe

	using material as Titanium could be easily embedded. This development goal is to increase substantially the in-plane thermal conductivity of CFRP panels. Advance thermal management for electronic units is an area that requires further development, implementation as well as qualification since the power density of units is increasing. In addition, active antennas are being used more and more on telecommunication satellite due to their re-configurable capability as well as multiple steerable spot beams. However, the power dissipation of such antennas can be significant which requires advance thermal control technologies.
Date of Entry / Last Date of Change	December 2019

4.11.2 [JTF-2021/23-28] – DEVELOPMENT OF DEPLOYABLE REFLECTOR ANTENNAS TECHNOLOGIES

Description and needed Action	It is expected that, as a minimum, the yearly worldwide large reflector sales remain at 4 to 5 large reflectors launched per year in the 5 coming years for the already established markets. This conservative forecast may strongly increase in case the high throughput satellite telecommunications systems requiring larger apertures emerge. Considering the high price of large reflector, this figure may generate a substantial revenue. In addition, it is observed that more and more Earth Observation missions consider the use of large reflector based solutions. Furthermore, the market forecasts do not include large reflectors for small satellites - in a relative sense -, where 10's to 100's antennas are needed per non-geo synchronous satellite constellation. Past and on-going R&D actions enabled to mature technologies at components and sub-system levels. It will be necessary to perform flight demonstration due to the complexity of such large structures, in particular the deployment and on orbit dynamics. Other technologies related to these antennas include deployable reflective surface (mesh net or other), deployment booms and mechanisms, hold-down and pointing mechanisms, RF and mechanical design methodologies, together with appropriate ground test facilities are of strategic interest and shall also be addressed. Next key activity is to make an in-orbit demonstration of current European solutions covering reflector antennas in the range of 5-6m,

	and develop larger diameter FM antennas up to 20m and frequency range up to Ka-Band. Current mission needs for Earth Observations and Telecoms applications foresee antenna reflectors with diameters 8-12m (with a potential of further diameter increase) and with improved surface accuracy suitable for Ka-Band operation, exceeding LEA development parameters: X-band and 5m diameter. In parallel, these larger diameter antennas will require larger deployment booms and related mechanical deployment and pointing mechanisms.
Estimated Initial TRL:	5/6
Target TRL	8
Applicable Mission Class(es)*	Telecommunications, Earth Observation, Science mission, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	• Reflector Antennas, 2016 Technology Harmonisation Dossier • Deployable Booms and Inflatable Structures, 2018 Technology Harmonisation Dossier • Technologies for Hold Down and Release Mechanisms and Deployment Mechanisms, 2015 Technology Harmonisation Dossier
Remarks / Justifications	The US has a quasi-monopoly in this field. Development of a 12 m aperture EQM can be estimated for about 15 MEuro Development of a 12 m aperture EQM and a 12 m PFM with deployable arm can be estimated for about 25 MEuro. Large deployable structures for Radar antenna could also be considered.
Date of Entry / Last Date of Change	December 2019

4.11.3 [JTF-2021/23-29] - THERMAL INSULATION SYSTEMS BASED ON AEROGELS FOR SPACE

Description and needed Action	To further develop and qualify aerogels based thermal insulation systems for safety use in Space environments e.g. the ones with atmosphere. Although Aerogel is a promising material, more development work is needed to solve the particle shedding problems by e.g. packaging so as to meet the material cleanliness levels required for space qualification.
Estimated Initial TRL	4-5
Target TRL	7

Applicable Mission Class(es)	Science Mission, Human Spaceflight, Unmanned Aircraft Systems (UAS), Space Transportation
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	
Remarks / Justifications	Considering the strategic nature of this product for future space exploration missions, and the need for non-dependence of Europe in the production of Aerogels with a potential spin-off for non-space applications, actions are deemed necessary to complement the past European studies on aerogels already performed.
Date of Entry / Last Date of Change	October 2019

4.11.4 [JTF-2021/23-30] - POLYIMIDE THIN FILMS

Description and needed Action	High temperature MLI is made of thin internal layers of Polyimide (7.5µm to 12µm) in order to withstand the high temperature. External MLI layer are usually required to be electrically conductive, which is generally achieved with a carbon fibre filled polyimide (e.g. Black Kapton XC type) or with with an external deposited coating (e.g. Indium Tin Oxide, Germanium or StaMet -a metallic alloy based on silicium). The inner side is generally Vacuum Deposited Aluminium (VDA) coated with a thickness of 1000 Å, which is needed to block the sun light and Infra-Red radiation. For the internal MLI layers, there are two alternatives currently on the market, KAPTON and UPILEX, with VDA coating on both side. However, recently, UBE, Japanese company, discontinued the production of the ultra-thin UPILEX which is currently used in high temperature MLI. The ultra-thin KAPTON has been reported to be on the ITAR list as well as some thicknesses of the carbon loaded KAPTON. Polyimide film are also used in electronic PCB, Heaters as well as Solar Panels. There is also the need for RF transparent Polyimide (usually achieved with germanium or StaMet deposited coating) but opaque to sun intrusion. Therefore, securing a European manufacturer of Polyimide able to produce film with thickness of 7.5µm, 12.5µm, 25µm, 51µm, 76.2µm and 127µm with a width of 1.22m and length of 33m as well as the ability to perform vapour deposition coatings such as aluminium, gold, germanium and StaMet, would be an important step in securing the product for future missions
Estimated Initial TRL	2

Target TRL	8
Applicable Mission Class(es)	Earth Observation Missions, Science Missions, Human Spaceflight, Telecommunications, Navigation, Space Security, Robotic Exploration
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	
Remarks / Justifications	High temperature MLI is made of thin layers of Polyimide in order to withstand the high temperature. There are two alternatives currently on the market, KAPTON and UPILEX. However, recently, UBE, Japanese company, is discontinuing the production of the ultra-thin UPILEX which is currently used in high temperature MLI. The ultra-thin KAPTON has been reported to be on the ITAR list as well as some thicknesses of the carbon loaded KAPTON. Polyimide film are also used in electronic PCB, Heaters as well as Solar Panels. There is also the need for RF transparent Polyimide but opaque to sun intrusion. Therefore, securing a European manufacturer of Polyimide with also the vapour deposition coating capability would be an important step in securing the product for future missions
Date of Entry	December 2019

4.11.5 [JTF-2021/23-31] - ADVANCED ACTIVE THERMAL CONTROL SYSTEMS

Description and needed Action	Further improve the performance and optimise current advanced active thermal control systems to provide current and future missions with enhanced heat transport and heat rejection capabilities as well as applications with stringent temperature control requirements. Technologies cover in particular mechanically-driven two-phase heat transport technologies, with Mechanically Pumped Two-Phase Loop, Electro-Hydrodynamic (EHD) Pumps, Mechanically assisted Two-Phase loop e.g. Hybrid Loop Heat Pipe with Mechanical Pump, all components needed for such systems. Heat pumps are also to be addressed. Applications are targeted at spacecraft level as well as for electronic units cooling. Mechanically pump system can also be coupled with deployable radiatiors in order to increase the radiating surfaces, hence increasing the overall heat rejection capability. Furthermore, EHD or Mechanical pump system may

	be used as an active heat switching device which can be use in Planetary surface missions. In addition, advanced or smart heater technology developments in certain applications could be essential in achieving the stringent temperature control. In-orbit demonstrations of such advanced active thermal control systems need to be identified and funded to enable improved thermal performance in European satellite platforms and payloads.
Estimated Initial TRL	3
Target TRL	8
Applicable Mission Class(es)*	Target Application: High power / heat rejection mission, and other thermally challenging missions especially: Telecom and dual use, Defence applications, Cubesat and Planetary Landers
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	Two-phase Heat Transportation Equipment, 2017 Technology Harmonisation Dossier
Remarks / Justifications	No European solution exists
Date of Entry	October 2019

5 GROUP 2: MEDIUM URGENCY ACTIONS FOR WHICH ACTIVITIES ARE EITHER ON-GOING OR PLANNED

5.1 Microelectronics and On-board Data Systems

5.1.1 [JTF-2021/23-32] - GBIT HIGH SPEED SERIAL LINK NETWORKS ROUTER

Description and needed Action	Development of a router device for High Speed Serial Link networks in the Gbps range. Suitable for routing SpaceFibre links, in full compliance with SpaceFibre ECSS standard "ECSS-E-ST-50-11C – SpaceFibre – Very high-speed serial link"
Estimated Initial TRL	2
Target TRL	4
Applicable Mission Class(es)*	Telecommunications (incl. Constellations) and internet based services

Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	On-Board Payload Data Processing, 2016 Technology Harmonisation Dossier
Remarks / Justifications	• An open standard for very high speed serial interfaces (SpaceFibre) has been standardized through ECSS in 2019. • SpaceFibre IP cores for end nodes are available. • Network node devices are planned (SpaceFibre Network Terminal Chip). • The missing unit for a complete network is the router device, which connects the different nodes of the network. • The router must be able to support end-to-end deterministic communication and QoS rules to separate different data streams.
Date of Entry	December 2019

5.1.2 [JTF-2021/23-33] - DESIGN AND PROTOTYPE OF NVRAM FOR SPACE WITH SERIAL INTERFACE ((QUAD)-SPI)

Description and needed Action	Use of microcontrollers and FPGA in peripheral systems push for the availability of low-footprint, small size, high resilience and reliable NVRAMs. Availability of small-footprint NVRAM is already a problem for several MCU-based designs. • Design, manufacture and evaluate NVRAM stand-alone memory (using ferroelectric or phase-change technology) • Design, manufacture and evaluate NVRAM embedded technology.
Estimated Initial TRL	3
Target TRL	5
Applicable Mission Class(es)*	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Unmanned Aircraft Systems (UAS), Defence Applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)

Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	Data Systems and On-Board Computer, 2016 Technology Harmonisation Dossier
Remarks / Justifications	• Flexible storage for boot code, program code, vital preference data or logged data • Industry-standard SPI interface reduces pin count and simplifies routing • Easy migration and modularity: devices are all pin compatible and require only 4/5 pins to connect to MCU/FPGA for different sizes and with minor design changes. • Uniform block erase architecture simplifies wear levelling design and is ideal for embedded code and data storage • Embedded NVRAM with the clear target for embedding in FPGAs or ASICs, therefore compatibility with these processes required
Date of Entry	December 2019

5.1.3 [JTF-2021/23-34] - VERY HIGH SPEED DIFFERENTIAL CROSSBAR SWITCH FOR SERIAL LINKS

Description and needed Action	Development/Industrialisation of an European differential crossbar switch for high speed serial links with a throughput of >= 12,5 Gbps.
Estimated Initial TRL:	3
Target TRL	7
Applicable Mission Class(es)	Earth Observation, Science Mission, Telecommunications, Defense applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	On Board Payload Data Processing, 2016 Technology Harmonisation Dossier
Remarks / Justifications	Such a component does not exist in Europe but is critical for the implementation of redundancy concepts, for achieving good signal integrity, and for the protection of ASICs/FGPAs.
Date of Entry / Last Date of Change	December 2019

5.2 Space System Control

n/a

5.3 Power

n/a

5.4 RF Payload System

5.5 EEE Components

n/a

5.6 Software

5.6.1 [JTF-2021/23-35] - SW TOOL: AUTOMATIC GENERATION OF CODE

Description and needed Action	Develop a European solution of Software Tool suite (including environment tool: model editor, simulator, model verification tool) for "Automatic Generation of Code" from existing non-European mathematical and simulation tools "MathWorks - Matlab and Simulink", and if possible in addition compatible with the European tool.
Estimated Initial TRL:	4
Target TRL	6/7 for an operational certified tool
Applicable Mission Class(es)	Earth Observations, Space Science, Exploration, Telecom, Navigation, Human Space Flight, Launchers and Operations
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	
Remarks / Justifications	Two qualities are important for automatic code generation of critical embedded software: • the knowledge of how the code is generated, and therefore the visibility within the code generator • the possibility to qualify the code generator to save the cost of validation of the generated code. These qualities are more difficult to achieve with non-European commercial tools than e.g. open source European tools. As an example, previous European projects have allowed the development of a prototype open source code generator (QGen) that needs to be

	pushed to a qualified product that would support significantly the autonomy of European stakeholders industry and agencies. It would allow European companies to establish themselves at the centre of a new ecosystem created around a new generation of tools called "model compilers", which are essential elements to the more and more expanding model based engineering.
Date of Entry / Last Date of Change	October 2019

5.7 Space Environment and Effects

5.7.1 [JTF-2021/23-36] - SPACECRAFT CHARGING SIMULATION TOOL

Description and needed Action	Ensure long term availability of a European state-of-the-art validated software for the simulation of the spacecraft charging. This tool should cover, at least the following aspects: • External and internal charging • Charging by the space environment • Simulation of instrument behaviour • Interaction with electric thruster • Charged dust interactions with probes.
Estimated Initial TRL:	5
Target TRL	6
Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defence applications.
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Spacecraft Plasma Interaction System SPIS: http://dev.spis.org/projects/spine/home/spis
Remarks / Justifications	
Date of Entry / Last Date of Change	October 2019

5.8 Mechanisms

n/a

5.9 Materials and Processes

n/a

5.10 *Optics and Optoelectronics*

5.10.1 [JTF-2021/23-37] - ADVANCED LASER CRYSTALS FOR HIGH POWER SPACE APPLICATIONS

Description and needed Action	Presently space laser missions for Earth Observation, such as ADM or Earth Care, as well as for Space Science, such as LISA (future L1 mission, to follow-up Lisa Pathfinder) or Planetary exploration and Navigation, are based on Nd:YAG laser technology. This technology can meet both high power/energy and low power/energy applications needs (for high power, high energy applications. Nd:YAG laser technology, operating in the infrared @ about 1 micron, suffers from low electrical efficiency, which require complex cooling systems and adequate high power laser-diode pumping to achieve the required output energies at the specific operating wavelengths. Emerging laser technology such as that based on Alexandrite crystal is very promising alternative and is presently being investigated at ESA as potential YAG replacement in view of the intrinsic higher efficiency, superior thermo- mechanical properties, shorter operating wavelengths, tunability and overall superior performance. ESA is pioneering the use of this technology and a number of activities have been or are presently running in the various technology programmes. To ensure adequate technology readiness and independence from the US market in this critical emerging area, this proposal is brought forward to develop this technology for space. The establishment of a European source for high-quality, custom-tailored laser crystals is of interest in the context of on-going developments of laser instruments for various space applications. Priority should be given to the advancement of laser materials such as Ho:YLF and alexandrite, which are being considered for active sensing missions targeting the measurement of atmospheric CO_2 at 2 microns and vegetation monitoring at around 750 nm, respectively. The laser crystal development should go along with the enhancement of high damage threshold coatings for the crystal optical surfaces.
Estimated Initial TRL	4
Target TRL	6-7
Applicable Mission Class(es)*	Earth Observations, Space Science, Telecom, Navigation
Industrial Non-Dependence Concern	To avoid export restriction issues and ensure long term availability of this technology, it is proposed to introduce an

	activity item to cover a fully European development of high quality, high power Alexandrite crystals for space applications.
Delegations/Agencies voicing non-dependence concern on the item	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Reference(s)	
Remarks / Justifications	Basic laser crystal technology is mainly controlled by US and Chinese manufacturers.
Date of Entry	December 2019

5.10.2 [JTF-2021/23-38] - PHOTONICS COMPONENTS

Description and needed Action	**A: Components for all photonic payloads** Photonics components needed for future photonic telecom payloads optical communication terminals as well for RF Earth Observation photonic functions like: Frequency Generation, up/down Frequency Conversion, Local Oscillator Distribution, Optical Switching, programmable photonic processors, Optical Beam Forming/Steering, Photonic RF filtering, Optical Modulators, Optical Fiber Amplifiers, Optical Switch (of low and high port count), Optical Wavelength Division MUX/DEMUX, High dynamic range - High frequency detectors for optical RF links. Development and qualification of high data rate, high density optical links for future space missions to take advantage of the mass and AIT advantages that optical fibers and optical communications offer such as 25Gbps (up to 56 Gbps as target goal) optical emitter/receiver. The challenge for developing these components for space remain: • Radiation hard driver electronics • Hermetic fiber feed through technology for parallel optic modules (12 fibers/module) • Space qualified optical cables and connector assemblies for multifiber cables (12 channels). The cable assemblies include; optical fiber, jacket, connectors and mating adapter assemblies. Different approaches required for inside and outside equipment boxes. • Space Qualified Laser sources for direct and external modulation and high-power • Quantum cascade laser (note: higher level bullet) • Optical Frequency comb • high linearity detectors up to V band, high bandwidth detectors

	In addition, a "photonic sampler" which can be used as part of an Electro-Photonic ADC can be used to down-convert an RF signal to baseband (similar to frequency converter of Microwave Payloads) Micro-photonic integration (in the form of Photonic Integrated Circuits –PIC of active and passive components) for compact low phase noise RF frequency generation and conversion in the optical domain as well as beam-forming are already pursued. Furthermore, such PICs should be considered for use in scientific instrumentation for both earth science and space science. European independence requires to enhance these technologies for instance new generation telescope to opens a path for extremely lightweight optical instruments, allowing for more hosted payloads or smaller spacecraft (Planar Imaging Detector, planar spectrometers such as integrated Fourier transform spectrometers, micro frequency combs for calibration of spectrometers). **B - MOEMS** MOEMS are considered for Photonics Routers in Telecom Microwave Photonic Payloads, Optical Communication terminals and Scientific Instruments. European independence require to enhance the MOEMS technologies for instance fine pointing mechanisms, deformable mirrors for adaptive optics, and optical multiplexers for Optical Communication terminals and for space observation payloads.
Estimated Initial TRL	4
Target TRL:	7
Applicable Mission Class(es)	Telecommunications, Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Navigation, , Robotic Exploration, Defence applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	
Remarks / Justifications	High speed digital optical links are a high priority across all missions. The first commercial Digital Payload with optical interconnects is to be launched in 2019 and more are under manufacturing or secured orders. Demonstrators with Photonic LO distribution and Photonic Frequency Converters are already In Orbit and more are upcoming There is a high interest to fly an IOD of a Microwave Payload including photonic routers by around 2022.

Last Date of Change	December 2019

5.11 *Propulsion*

5.11.1 [JTF-2021/23-39] - PROPELLANT FLOW AND DISTRIBUTION COMPONENTS FOR CHEMICAL PROPULSION

Description and needed Action	Development and qualification of European alternatives for access restricted flow and distribution components, especially the pressure regulators including electronic pressure regulator systems as standalone systems, the mass flow controller and the isolation valve (latch valves, flow control valves and pyro valve replacement valve technology) including miniaturization and, eventually, integration of two or more components.
Estimated Initial TRL:	4
Target TRL	7
Applicable Mission Class(es)	All missions, especially Telecom and Science
Industrial Non Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Chemical Propulsion - Components, 2018 Technology Harmonisation Dossier
Remarks / Justifications	
Date of Entry / Last Date of Change	October 2019

5.11.2 [JTF-2021/23-40] - ADVANCED MATERIALS AND MATERIAL TECHNOLOGY FOR COMBUSTION CHAMBERS

Description and needed Action	• Availability of export licence free materials and coatings for space engines (TRL 7). Mature process for Pt/Rh nozzle processes. • Ceramic chamber materials for advanced bi-propellant spacecraft engines (TRL 4) • Extend functional grading activities to cover also combustion chamber transition joints • Ceramic chamber for electric propulsion • Ceramic and ceramic/metal composite chamber materials for high temperature applications
Estimated Initial TRL:	2
Target TRL	4-7

Applicable Mission Class(es)	Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Defense applications
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s):	Chemical Propulsion - Components, 2018 Technology Harmonisation Dossier Electric Propulsion Technologies, 2017 Technology Harmonisation Dossier
Remarks / Justifications	As far as chemical propulsion is concerned, this activity is to address the current and next generation of spacecraft engine combustion chambers (i.e. MON/MMH) engines.
Date of Entry / Last Date of Change	December 2019

5.11.3 [JTF-2021/23-41] - 20KW ELECTRIC PROPULSION THRUSTER

Description and needed Action	Development of a long lifetime and 20 kW Electric Propulsion Thruster.
Estimated Initial TRL	5
Target TRL	8
Applicable Mission Class(es)*	Space Transportation, Debris Removal, Exploration. Future space transportation vehicles e.g. space tugs will require these systems with high lifetime that could allow space tugs to survive for a long period of time increasing the revenues of the missions. Space tugs should be used for orbit transfer (LEO-GEO, GTO-GEO, Interplanetary, Clean Space, etc.).
Industrial Non-Dependence Concern	Industry consensus confirmed at the JTF Industry Review meeting (15 October 2019)
Delegations/Agencies voicing non-dependence concern on the item	
Reference(s)	Electric Propulsion Technologies, 2017 Technology Harmonisation Dossier
Remarks / Justifications	Today USA is leading on high power (15-20 kW) HET developments. If Europe loses this race, it will depend most probably on a single American source for these engines. The EU addresses electric propulsion with a dedicated H2020 SRC.
Date of Entry	October 2019

5.12 Structures and Thermal

n/a

6 APPENDIX A: TABLE OF ACRONYMS AND ABBREVIATIONS

AD	Analogue-to-digital
ADC	Analogue Digital Converter
AIT	Assembly, Integration & Test
AOCS	Altitude Orbit Control System
ARM	Asteroid Removal Mission
ARTES	ESA Advanced Research In Telecommunication Systems Programme
ARW	Angle Random Walk
ASIC	Application Specific Integrated Circuit
BiCMOS	Combination of Bipolar and CMOS technology
BOL	Beginning Of Life
CCD	Change-coupled Device
CIS	CMOS imaging sensor
CMOS	Complementary Metal Oxide Semiconductor
CMR	Carcinogenic, Mutagenic or toxic to Reproduction
CNC	CapTech National Coordinators (CNC)
CS	Compressive Sensing
CTB	ESCC Components Technology Board
DA	Digital-to-analogue
DAC	Digital Analogue Converter
DC	Direct Current
DIAL	Differential Absorption Lidar
DPR	Deployable Radiators
DSM	Deep Sub-Micron
DSP	Digital Signal Processor
EAR	Export Administration Regulations
ECSEL	Electronics Components and Systems for European Leadership
ECSS	European Cooperation for Space Standardization
ECHA	European Chemicals Agency
EDA	European Defence Agency
EOL	End Of Life
EQM	Engineering Qualification Model
ESA	European Space Agency
ESCC	European Space Components Coordination
FLPP	ESA Future Launchers Preparatory Programme
FOG	Fiber Optic Gyro
FPGA	Field Programmable Gate Array
GaAs	Gallium Arsenide
GaN	Gallium Nitride
GEO	Geostationary Orbit
GFLOPS	Giga Floating Operations Per Second
GNC	Guidance, Navigation & Control
GPP	General Purpose Processor
GPU	Graphic Processor Unit
Gsps	Giga samples per second
GSTP	ESA General Support Technology Programme
GTO	Geostationary Transfer Orbit
HEMT	High-Electron-Mobility Transistor
HET	Hall Effect Thruster
HSSL	High Speed Serial Link
HV	High Voltage
ICL	Integrated Current Limiter
I/F	Interface
I/O	Input/Output
IMU	Inertial Measurement Unit
IOD	In Obit Demonstration
IP	Internet Protocol
IPC	ESA Industry Policy Committee
IR	Infrared
ITAR	International Traffic in Arms Regulation

ITI	Innovation Triangle Initiative
JTF	Joint-Task-Force
JU	Joint Undertaking
LCA	Life Cycle Assessment
LEO	Low Earth Orbit
LNA	Low Noise Amplifier
LH2	Liquid Hydrogen
LNA	Low Noise Amplifier
LO	Local Oscillator
LOX	Liquid Oxygen
LUT	Look-up Table
LWIR	Long-Wave Infrared
MCU	Microcontroller Unit
MISHFET	Metal Insulator Semiconductor Heterostructure Field Effect Transistor
MMH	Monomethylhydrazine
MMIC	Monolithic Microwave Integrated Circuit
MON	Mixed Oxides of Nitrogen
MOS	Metal-Oxide-Semiconductor
MOSFET	Metal-Oxide-Semiconductor Field Effect Transistor
MS	Member States
MTM	Magnetometer
Nd:YAG	Neodymium-doped Yttrium Aluminium Garnet
NEA	Non-Explosive Actuator
NIR	Near Infrared
NoC	Network on Chip
NRZ, NRTZ	Non-return-to-zero
NVRAM	Non-Volatile Random-Access Memory
PCB	Printed Circuit Board
PFM	Proto-Flight Model
PLL	Phase-Lock-Loop
PMD	Propellant Management Device
POL	Point-of-load
PWM	Pulse-width modulator

R&D	Research and Development
RAD hard	Radiation hard
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RF	Radio-Frequency
RTL	Regional Transfer Level
RTU	Remote Terminal Unit
SEE	Single-Event Effects
SEFI	Single Event Failure Interrupts
SERDES	Serializer/Deserializer
SEU	Single Event Upset
SiC	Silicon Carbide
SiGe	Silicon Germanium
SMA	Shape Memory Alloy
SME	Small and Medium-sized enterprise
SOC	System on Chip
SPI	Serial Peripheral Interface
SpW	Space Wire
S-PwL	Space-PowerLink
SVHC	Substance of Very High Concern
SW	Software
SWIR	Short Wavelength Infrared
TEC	Thermoelectric Cooler
THAG	ESA Technology Harmonisation Advisory Group
TID	Total Ionising Dose
TRL	Technology Readiness Level
TRP	ESA Basic Technology Research Programme Research Programme
TWT	Travelling Wave Tube
UAS	Unmanned Aircraft Systems
UDMH	Unsymmetrical dimethylhydrazine
UV	Ultraviolet
VMD	Vacuum Microelectronics Device
VLWIR	Very Long Wavelength Infrared

7 APPENDIX B: TRACEABILITY MATRIX

	Group	JTF ID	Action title	Draft list ID	New
Microelectronics and On-board Data Systems	1	[JTF-2021/23-1]	ASICS for mixed signal processing	U11	
	1	[JTF-2021/23-2]	High Capacity FPGAs and software ecosystem	U12	
	1	[JTF-2021/23-3]	High speed DAC-ADC based on European Technology	U19	
	1	[JTF-2021/23-4]	Very high performance microprocessors and software ecosystem	U20	
	1	[JTF-2021/23-5]	High data rate (12.5 to 28 Gbps or higher 56 Gbps), low consumption, short range links	V30	x
	1	[JTF-2021/23-6]	Ultra Deep Submicron technology for next generation space integrated circuits: ASICS, FPGA and microprocessors	U22b	
	1	[JTF-2021/23-7]	Qualification of Microcontroller for Space application	N52	
	2	[JTF-2021/23-32]	Gbit High speed serial link networks router	N51	
	2	[JTF-2021/23-33]	Design and prototype of nvRAM for space with Serial interface ((quad)-SPI)	N53	
	2	[JTF-2021/23-34]	Very high speed Differential crossbar switch for serial links	U21	
Space System Control	1	[JTF-2021/23-8]	High performance Gyro based sensors	U6	

Power	1	[JTF-2021/23-9]	High performance, cost effective multi - junction solar cells and solar generator elements for space applications	U9	
RF Payload System	1	[JTF-2021/23-10]	RF components	N27	
	1	[JTF-2021/23-11]	Space qualified RF GaN components and demonstrators	U16	
	1	[JTF-2021/23-12]	Power amplification: Travelling Wave Tube (TWT) materials	U7	
EEE Components	1	[JTF-2021/23-13]	Passive & RF Passive components	U13	
	1	[JTF-2021/23-14]	Active components for power applications	U14	
	1	[JTF-2021/23-15]	High challenges for PCBs and SMT (Surface Mount Technologies)	U17	
	1	[JTF-2021/23-16]	High Temperature Packaging	N49	
Software	2	[JTF-2021/23-35]	SW tool: Automatic Generation of code	N64	
Space Environment and Effects	1	[JTF-2021/23-17]	Very high energy ion accelerators for component, shielding and radiobiology characterization	V4	x
	1	[JTF-2021/23-18]	Radiation belt global modelling	V5	x
	2	[JTF-2021/23-36]	Spacecraft charging simulation tool	U8	
Mechanisms	1	[JTF-2021/23-19]	Low shock Non-Explosive Actuators (NEA) for smallsats	U1	
Materials and Processes	1	[JTF-2021/23-20]	Space qualified carbon fibre pre-impregnated material sources for launcher and satellite subsystems	U26	

	1	[JTF-2021/23-21]	Non Dependence of materials and processes	N28	
	1	[JTF-2021/23-22]	Obsolescence of materials and process	V1	x
Optics and Optoelectronics	1	[JTF-2021/23-23]	Power laser sources in the eye-safe region	N62	
	1	[JTF-2021/23-24]	Enhanced performance and space qualified detectors	U18	
	2	[JTF-2021/23-37]	Advanced Laser Crystals for High Power Space applications	N63	
	2	[JTF-2021/23-38]	Photonics components	U15	
Propulsion	1	[JTF-2021/23-25]	Alternative to Hydrazine in Europe	U5	
	1	[JTF-2021/23-26]	Alternative to MMH and UDMH	N37	
	2	[JTF-2021/23-39]	Propellant flow and distribution components for chemical propulsion	U3	
	2	[JTF-2021/23-40]	Advanced materials and material technology for combustion chambers	U4	
	2	[JTF-2021/23-41]	20kW Electric Propulsion Thruster	N59	
Structures and Thermal	1	[JTF-2021/23-27]	Advanced Passive thermal Control Systems	U2	
	1	[JTF-2021/23-28]	Development of Deployable REFLECTOR ANTENNAS technologies	U23	
	1	[JTF-2021/23-29]	Thermal insulation systems based on aerogels for Space	N41	
	1	[JTF-2021/23-30]	Polyimide Thin Films	V2	x

	1	[JTF-2021/23-31]	Advanced Active Thermal Control Systems	V14	x