

**European Space Agency**  
**ARTES 4.0 Core Competitiveness Element**  
**Programme Component “A” Advanced Technology**

**Work Plan 2025**

## **1. Introduction**

A key role of ESA within the satellite telecommunications sector is to promote high levels of Research and Development activity within Participating State industry to help ensure both their preparedness and competitiveness in both the short and long terms.

ARTES Core Competitiveness Element Programme Component “A” Advanced Technology (ARTES AT) is concerned with the early development stages of new systems and the exploitation of new and promising technologies for satellite communications. In some instances ARTES AT activities are a continuation of activities such as ARTES Future Preparations (ARTES FP) and the Technology Development Element (TDE).

Through ARTES AT, ESA supports the introduction of new technologies into equipment designs so that in the long-term, industry will be able to introduce state-of-the-art equipment and (sub)systems at competitive prices to the commercial marketplace. ARTES AT encompasses activities related to the development of both (sub)systems and equipment for satellite communications.

ARTES AT is the Agency’s main programme for preparatory development of satellite communications technology. ARTES AT involves long-term R&D activities inherently incorporating a significant level of technical risk, and is therefore fully funded by the Agency.

The Work Plan for 2025 specifically addresses technology and equipment activities in support of the priorities defined in the Telecommunications Long Term Plan. The Work Plan for 2025 has been coordinated with other ESA technology programmes. The activities are organised per application area and grouped as Ground Segment, System, or Space segment (Payload, Platform) related.

In September 2024, a further 35 Work Plan activities were approved for 2025. The full list of activities can be found in Annex I and described in Annex II.

## **2. Implementation**

The implementation of the ARTES AT Work Plan activities will follow the Specific Implementing Rules for the ARTES 4.0 Generic Programme Line “Core Competitiveness”, Component A “Advanced Technology”.

The following implementation will be followed:

**Phasing:** phasing of the contractual activities may be considered depending on the risks associated with the development, the maturity of the technologies, and potential early market perspectives.

**Parallel contracts:** in accordance with the ARTES 4.0 Specific Implementing Rules for the Generic Programme Line “Core Competitiveness”, proposals that have not ranked first in the Tender evaluation, may be re-considered for award of a parallel contract under the following conditions:

- The proposal is ranked at least “good” (60)
- The proposed technology is innovative and technically mature
- The starting TRL is lower than 4.
- The delegations concerned reconfirm their support for the proposal.

**Procurement Policy:** the following procurement policies are foreseen for the proposed activities:

- C: Activities in open competition without any further restrictions.
- C1: Activities in open competition limited to non-Large System Integrators (LSIs) as prime. LSIs are allowed to participate as sub-contractors.
- C2: Activities are in open competition, where a significant participation of non-LSIs is requested.
- C3: Activities restricted to SMEs & R&D organisations, preferably in cooperation.
- C4: Activities in open competition, subject to the SME subcontracting clause.

For the full definition of these procurement policies, please refer to document ESA/IPC(2005)87, rev.4.

**Implementation Category:** The activities comprising this work plan are designated as either B (Baseline) or R (at the Request of Delegates). The assignment of activities into these implementation categories is not a declaration of technological, commercial, or programmatic priority. Instead, it simply indicates whether an activity requires a prior request from a Delegation for the ITT to be generated and released. This categorisation could, for example, be related to a limited industrial landscape for the proposed activity.

Activities identified as B will be issued according to the schedule published (and regularly updated) on the ESA-STAR website and ESA ARTES web site: [ARTES 4.0 planned activities](#)

[Summary table \(AT, ScyLight, 4S and 5G\) | ESA CSC](#). B activities for which industry and Participating States declare an interest will be given precedence when preparing Invitations to Tender (ITT). Such interest can be notified directly to the ARTES AT Programme Office.

Activities designated Implementation Category R will only be initiated either:

- On the explicit request of at least one delegation; or
- On the initiative of the Executive following consultation of the JCB.

## Annex I: SUMMARY TABLE FOR THE ARTES AT WORK PLAN 2025

| Activity Ref.                                 | Activity Title   | Cost (k€) | Classification | Cost (k€)<br>(Classification B) | Cost (k€)<br>(Classification R) | Proc. Policy |
|---|--|-----------|----------------|---------------------------------|---------------------------------|--------------|
| <b>1. SYSTEM/ NETWORK / PROTOCOLS</b>         |  |           |                |                                 |                                 |              |
| <b>1.1 System, Networking and Management</b>  |  |           |                |                                 |                                 |              |
| 3A.213  | Swarm satellite system architecture  | 800       | B              | 800                             | 0                               | C            |
| <b>Subtotal</b>                               |  |           |                | <b>800</b>                      | <b>0</b>                        |              |
| <b>1.2 Small Satellites</b>                   |  |           |                |                                 |                                 |              |
| 3E.027  | Returnable testbed for in-orbit manufacturing processes for large structures of telecom satellites               | 7,000     | B              | 7,000                           | 0                               | C            |
| 3E.028  | In-orbit test of prototype re-fuelling technologies for green propellants  | 6,525     | R              | 0                               | 6,525                           | C            |
| <b>Subtotal</b>                               |  |           |                | <b>7,000</b>                    | <b>6,525</b>                    |              |
| <b>2. SPACE SEGMENT - PLATFORM</b>            |  |           |                |                                 |                                 |              |
| <b>2.1 Platform - System and Architecture</b> |  |           |                |                                 |                                 |              |
| 4A.104  | Space debris compliant microsatellite platform for large satcom constellations                                   | 3,000     | B              | 3,000                           | 0                               | C            |
| 4A.106  | High aspect ratio satellite architectural model for large volume manufacturing, assembly, testing and deployment | 3,500     | R              | 0                               | 3,500                           | C            |
| <b>Subtotal</b>                               |  |           |                | <b>3,000</b>                    | <b>3,500</b>                    |              |
| <b>2.2 Propulsion System</b>                  |  |           |                |                                 |                                 |              |
| 4B.188  | Digital twin supported design and manufacturing of thrusters for constellations.                                 | 800       | B              | 800                             | 0                               | C2           |
| 4B.189  | High-power, high-density propellant based thruster   | 1,000     | B              | 1,000                           | 0                               | C1           |
| <b>Subtotal</b>                               |  |           |                | <b>1,800</b>                    | <b>0</b>                        |              |
| <b>2.3 AOCS</b>                               |  |           |                |                                 |                                 |              |
| 4C.072  | Attitude and Orbit Control System for high aspect ratio satcom satellites  | 1,800     | R              | 0                               | 1,800                           | C            |
| <b>Subtotal</b>                               |  |           |                | <b>0</b>                        | <b>1,800</b>                    |              |
| <b>2.4 Thermal System</b>                     |  |           |                |                                 |                                 |              |
| 4D.087  | Direct cooling system for high performance, high power (300W class) telecom signal processing components         | 700       | B              | 700                             | 0                               | C            |
| <b>Subtotal</b>                               |  |           |                | <b>700</b>                      | <b>0</b>                        |              |
| <b>2.5 Mechanical System</b>                  |  |           |                |                                 |                                 |              |
| 4E.098  | Slip ring less solar array drive mechanism for constellations  | 800       | B              | 800                             | 0                               | C            |
| 4E.099  | Separation system for stacked high aspect ratio satcom satellites  | 1,000     | R              | 0                               | 1,000                           | C            |



|  |  |       | Subtotal        | 800          | 1,000    |    |
|--|--|-------|-----------------|--------------|----------|----|
| <b>2.6 Power System</b>                      |  |       |                 |              |          |    |
| 4F.173                                       | High-energy solid-state battery cell for satcom application  | 700   | B               | 700          | 0        | C2 |
| 4F.174                                       | High specific power photovoltaic assembly components and modules   | 1,000 | B               | 1,000        | 0        | C  |
| 4F.175                                       | Spin-in development of terrestrial solar cell technology for constellation applications                            | 1,000 | B               | 1,000        | 0        | C1 |
| 4F.176                                       | Power bus isolation device to achieve reliable electrical passivation  | 700   | B               | 700          | 0        | C  |
| 4F.177                                       | Lithium free batteries for low earth orbit satcom constellations   | 700   | B               | 700          | 0        | C  |
|  |  |       | <b>Subtotal</b> | <b>4,100</b> | <b>0</b> |    |
| <b>3. SPACE SEGMENT - PAYLOAD</b>            |  |       |                 |              |          |    |
| <b>3.1 Antenna</b>                           |  |       |                 |              |          |    |
| 5B.247                                       | Large modular antenna with reduced grating lobes   | 2,200 | B               | 2,200        | 0        | C  |
| 5B.248                                       | Transmit and receive dual polarisation active antenna based on scalable tile assembly for geostationary satellites | 1,400 | B               | 1,400        | 0        | C  |
| 5B.249                                       | Q-band transmit active antenna for combined user and feeder link on low earth orbit satellites                     | 1,300 | B               | 1,300        | 0        | C  |
| 5B.250                                       | Fast, wideband and scalable antenna measurement system for large active antennas                                   | 700   | B               | 700          | 0        | C  |
| 5B.251                                       | Ka-band single polarisation transmit and receive active antenna for low earth orbit satellites                     | 1,200 | B               | 1,200        | 0        | C  |
|  |  |       | <b>Subtotal</b> | <b>6,800</b> | <b>0</b> |    |
| <b>3.2 RF Repeater and Signal Processing</b> |  |       |                 |              |          |    |
| 5C.525                                       | Low power Ka-band direct conversion receiver module  | 1,500 | B               | 1,500        | 0        | C  |
| 5C.526                                       | Scalable processor array for digital beamforming   | 1,500 | B               | 1,500        | 0        | C  |
| 5C.527                                       | Power-efficient and linearised solid-state high-power amplifier for active antenna                                 | 900   | B               | 900          | 0        | C  |
| 5C.528                                       | Dual band Ku- and Ka-band low noise amplifier for future flexible payloads   | 700   | B               | 700          | 0        | C  |
| 5C.529                                       | Dual-band Ku- and Ka-band filters for future flexible payloads   | 700   | B               | 700          | 0        | C  |
| 5C.530                                       | Intelligent signal monitoring unit for payload equipment autonomy, health monitoring, and reconfiguration          | 1,200 | B               | 1,200        | 0        | C  |
| 5C.531                                       | Toxic free joining of RF passive assemblies  | 800   | B               | 800          | 0        | C  |
| 5C.535                                       | High-linearity W-band GaN Low-Noise Amplifier for intense radio-frequency interference environment                 | 800   | B               | 800          | 0        | C  |
|  |  |       | <b>Subtotal</b> | <b>8,100</b> | <b>0</b> |    |
| <b>3.3 TT&amp;C and Data Handling</b>        |  |       |                 |              |          |    |
| 5D.041                                       | High throughput reprogrammable dataplanes for on-board satellite communication protocol implementations            | 800   | B               | 800          | 0        | C  |
|  |  |       | <b>Subtotal</b> | <b>800</b>   | <b>0</b> |    |
| <b>5. USER TERMINALS</b>                     |  |       |                 |              |          |    |
| <b>5.1 Professional User Terminals</b>       |  |       |                 |              |          |    |
| 7A.079                                       | Q/V band phased array antenna for aeronautical applications  | 1,100 | B               | 1,100        | 0        | C  |



|                                    |   |       |   |               |               |    |
|------------------------------------|---|-------|---|---------------|---------------|----|
| 7A.083                             | Compact linear integrated amplifier for Ku, Ka, Q and V bands with high back-off efficiency     | 750   | B | 750           | 0             | C1 |
| <b>Subtotal</b>                    |   |       |   | <b>1,850</b>  | <b>0</b>      |    |
| <b>5.2 Consumer User Terminals</b> |   |       |   |               |               |    |
| 7B.082                             | Automated phased array factory calibration from radiation pattern using artificial intelligence | 700   | B | 700           | 0             | C  |
| 7B.083                             | Single aperture transmit-receive phased array antenna for Ka band terminals                     | 1,200 | B | 1,200         | 0             | C2 |
| 7B.084                             | Reduced-complexity analogue and hybrid beamforming networks                                     | 1,000 | B | 1,000         | 0             | C  |
| <b>Subtotal</b>                    |   |       |   | <b>2,900</b>  | <b>0</b>      |    |
| <b>TOTAL (k€)</b>                  |   |       |   | <b>38,650</b> | <b>12,825</b> |    |



## Annex II: DETAILED DESCRIPTION OF ESA-INITIATED ACTIVITIES PROPOSED FOR THE ARTES AT WORK PLAN

| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 3A.213                        | Swarm satellite system architecture  | 800            | B              |
| <b>Objective:</b>             | The objective of the activity is to develop a system concept of a satellite swarm (group of satellites orbiting information) enabling direct to device telecom missions in UHF/L/S bands. The developed concepts will be implemented and evaluated in a swarm system simulator.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enable synthetic antenna gain in the range of 40 dBi in low frequency bands (UHF/L/S bands).</li> <li>- Enable communications with unmodified terrestrial devices (e.g. handheld, automotive, IoT) with downlink and uplink data rates in the range of up to several Mbps.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Typically, individual satellites prevent high antenna gains in low-frequency bands (UHF/L/S bands) beyond the 30 dBi range. The implementation of satellite swarms may enable new services and applications (e.g. handheld, automotive, IoT) that can be deployed in a scalable and incremental way and optimising the use of the launcher capacity. The swarm's distributed nature also provides inherent robustness against single-point failures, enhancing the system's reliability.</p> <p>This activity will develop a system concept of satellite swarm for at least one of the use cases (e.g. GEO, LEO, MEO, handheld, automotive, IoT), enabled by the creation of a large gain synthetic antenna aperture thanks to coherent processing of signals from a formation of radiating arrays in space. This requires synthetic beamforming in space with high number of narrow beams, tight synchronisation and position/attitude control, possibly aided by inter satellite links and real time calibration from ground reference stations. The developed concepts will be implemented in a software simulator for constellations for telecom applications and compare to non-swarm satellite systems.</p> <p>The swarm system simulator will model the key system building blocks and their related impairments acting the system performances (e.g. synchronisation, latency/jitter/throughput during signals distribution according to the inter-satellite links architecture, multi-beam, grating lobes, formation flying dynamics, user equipment waveforms). The swarm system simulator will serve as a virtual environment to evaluate the system performance including throughput, system capacity, inter-system interference and co-existence/integration with other satellite/terrestrial systems, availability) for the selected use cases and compare to reference scenario.</p> |                |                |
| <b>Deliverables:</b>          | Summary Report and, swarm system software simulator  |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | N/A  |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | Yes  |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 3E.027                        | Returnable testbed for in-orbit manufacturing processes for large structures o telecom satellites   | 7,000          | B              |
| <b>Objective:</b>             | The objective of the activity is to develop and characterise an additive manufacturing process to enable in-orbit manufacturing of large structural parts for satcom applications (e.g. large reflector, large solar array, large radiator structure). An in-orbit test-bed will be designed, manufactured and operated. Test-samples and complex demonstrators will be produced in order to evaluate the developed end-to-end in-orbit manufacturing process.  |                |                |
| <b>Targeted Improvements:</b> | Enabling large in-orbit manufactured satcom hardware (e.g. large reflector, large solar array, radiator structure) not possible today.  |                |                |
| <b>Description:</b>           | <p>Recent studies have explored the possibility of making large structures in orbit for future satcom applications, revealing new opportunities for applications, services and markets. The use of in-orbit additive manufacturing could eliminate the constraints of the launch vehicle fairings and the complexity of the deployment mechanisms, which are currently required for large deployables (e.g. very large reflectors, radiators and booms) relative to the platform size. However, the effects of microgravity, thermal, vacuum, and radiation on the additive manufacturing process in space are not well known, especially when assessing the structural, thermophysical and thermoelastic properties of the fabricated parts.</p> <p>This activity will characterise, through the production of test samples, the space environmental effects on the additive manufacturing processes required for future in-orbit manufacturing of large structural parts for satcom applications. An onboard testbed, using well established additive manufacturing processes and space qualified materials, will be developed, manufactured and validated. The testbed shall accommodate visual and in situ measurements of the manufacturing process (e.g. temperature, molecular/particulate contamination induced by the process, etc) as well as allowing for the retrieval of the produced specimens for post-analysis on Earth. The testbed will also be used to produce complex demonstrators (e.g. reflectors, booms and radiators or representative parts thereof). All in-orbit produced parts will be returned to Earth for post-analysis.</p> <p>The activity will be implemented in a phased approach. The first phase of the activity will develop, manufacture and achieve flight readiness of the testbed. The testbed performance will be validated on ground with reference test samples being produced and characterised. Phase 1 output will comprise of: Flight ready in-orbit manufacturing testbed, characterised end-to-end manufacturing process and reference test samples. The second phase will launch and operate the test bed to investigate the end-to-end additive manufacturing process in the space environment. Phase 2 will produce test samples in-orbit for process and material characterisation that are collected and returned for on ground analysis and comparison. The test results will be fed into Integrated Computational Materials Engineering (ICME) models to optimise in-orbit manufacturing parameters and processes for the production of the complex demonstrators.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, in-orbit manufacturing testbed, manufacturing process, reference and in-orbit produced demonstrators  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | N/A   |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 24 - Materials and Manufacturing Processes  |                |                |





| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 3E.028                        | In-orbit test of prototype re-fuelling technologies for green propellants   | 6,525          | R              |
| <b>Objective:</b>             | The objective of this activity is to design, manufacture and test in-orbit prototype re-fuelling technologies for green (non-toxic) self-pressurising propellants, enabling the adoption of these technologies in multi-orbit satellite communication constellations.   |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Extension of satellite on-orbit life by &gt; 100%.</li> <li>- Reducing spacecraft propellant mass by &gt;50%.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>One of the challenges for multi-orbit Satcom networks is to find an effective and convenient solution for refuellable propulsion systems. Self-pressurising green propulsion systems (chemical and electrical) and can be refuelled in orbit provide an excellent option. They have many advantages over conventional hydrazine-based chemical propulsion systems, such as being non-toxic, cheaper, highly scalable, and accessible. Developing refuelling technology of these systems will enable spacecraft to be refuelled several times during their lifetime, reducing the propellant load needed at launch, improving in-orbit manoeuvres (collision avoidance, orbit changes, disposal) and prolonging mission life. Refuelling capabilities are expected to be needed first for Medium Earth Orbit (MEO) and Geostationary Earth Orbit (GEO) missions but could also apply to future Low Earth Orbit (LEO) missions. These technologies are already under development outside of ESA Member States and, while some work has been performed (e.g. in-orbit refuelling activities for cryogenics, Xenon, and MON-MMH/hydrazine), this technology is not yet available in ESA Member States.</p> <p>The activity will be implemented in a phased approach. The first phase will design, manufacture and achieve flight readiness of an in-orbit re-fuelling payload for investigating technologies for green (non-toxic) self-pressurising propellants. Phase 1 outputs will comprise of a functioning in-orbit propellant transfer system including the propellant coupling interfaces and the pumping technology needed to make the propellant transfer. Phase 2 will launch and operate the propellant transfer system in orbit, testing in the microgravity environment (up to several hours) allowing for the characterisation of the gravity-dependent effects and their impact on the transfer performance (e.g. proper gas/liquid separation, complex two-phase flow phenomena). Additionally, a fluidic model of the propellant transfer system will be developed. Outputs of Phase 2 will consist of: The results from the in-orbit experiment verifying docking interface (including leak checks before/during/after docking and transfer), evaluating the propellant transfer performance and efficiency (rate and percentage of propellant transferred); as well as improved fluidic modelling for the design of propellant transfer systems.</p> |                |                |
| <b>Deliverables:</b>          | Summary report; In-orbit testbed of propellant interface and transfer systems; Fluidic model for propellant transfer.   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 19 – Propulsion   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 4A.104                        | Space debris compliant microsatellite platform for large satcom constellations   | 3,000          | B              |
| <b>Objective:</b>             | The objective of this activity is to design, develop, manufacture and test a new microsatellite platform suitable for large satcom constellations, in compliance to ESA's space debris mitigation requirements   |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Achieve compliance to evolving space debris mitigation requirements, including in passivation, timely and reliable deorbiting, and sustainable operations.</li> <li>- Reduce the overall system complexity of a constellation implementation by 30% in comparison to using existing nanosatellite designs.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Over the past years, the market has seen a consistent and considerable increase in large nanosatellite constellations for telecommunications. A large amount of these satellites are built to the cubesat standard (or variations of it). This large increase of orbiting space assets has raised concerns on the sustainable use of space and as a result many space organisations and nations have taken a proactive step. In particular, the European Space Agency recently released an update on the Space Debris policy, posing more stringent requirements for the design and operation of satellites, which current nanosatellites were not designed to be compliant with. Additionally, the CubeSat standard was not developed to facilitate mass manufacture, and assembling, integrating and testing CubeSats is often a time consuming, challenging process involving many manual steps.</p> <p>This activity will create a platform design comprising, structure and core avionics compliant to the ESA Space debris mitigation requirements (ESSB-ST-U-007) as well as optimised for cost effective mass production. The platform does not necessarily need to adhere to the existing CubeSat standard; however, compatibility is an advantage. If the platform developed is not compatible with existing cubesat deployers, a complementary deployment system has to be proposed. The development and testing on the breadboard should show the reduction in AIT effort and the estimations on the production time should be calculated to show the potential for mass manufacture. An Engineering Model of the nanosat platform (i.e. structure and core avionics) and its corresponding deployment system will be designed, manufactured and tested in environmental and radiation representative conditions to demonstrate core functionality and required reliability. The activity will also develop a Product Assurance and Quality Assurance plan, a manufacturing plan and an appropriate tailoring to the ECSS that demonstrates future compliance to the functional and space debris mitigation requirements.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, engineering model of satellite platform and breadboard of satellite deployment system.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | N/A  |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 20 - Structures  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4A.106                        | High aspect ratio satellite architectural model for large volume manufacturing, assembly, testing and deployment  | 3500 kEUR      | R              |
| <b>Objective:</b>             | The objective of this activity is to design and develop a high aspect ratio platform for large volume manufacturing, testing and assembly, and constellation deployment and associated satellite digital twin.  |                |                |
| <b>Targeted Improvements:</b> | Increase the rate of deployment and scalability of a large constellation (>300 spacecraft) by a factor of 4.  |                |                |
| <b>Description:</b>           | <p>The trend within the satellite telecommunications industry is to move to large constellations in LEO and MEO orbit. To support these systems, it is necessary to manufacture, test, deploy and bring into use a large number of spacecrafts in a short timescale to meet service and regulatory constraints. This has driven the introduction of new spacecraft configurations, such as High Aspect Ratio satellites, which have been already successfully deployed by non-European companies. High Aspect Ratio satellites offer significant advantages over traditional spacecraft configurations, enhanced stackability to reduce the number of launches needed, reduce atmospheric drag, and more efficient manufacturability, thereby optimising the throughput-to-mass ratio for flexible telecom missions that require a large on-board active array antenna.</p> <p>This activity shall kick start the development of a European high aspect ratio platform for large volume manufacturing, assembly, testing and deployment able to serve as a minimum emerging Direct-to-Device FR1 (D2D) opportunities. The activity will develop a satellite digital twin along with the design, manufacturing and testing of a Structural Thermal Model (STM) of the platform. Architecture flexibility and evolution of the platform beyond D2D applications shall be part of trade-offs. The digital twin model will be continuously improved as designs are updated and test results become available. The activity will employ an iterative design approach to co-engineering with designers, manufacturers and supply chain ecosystem for both platform and payload subsystems utilising the digital twin model, including sub-models of the critical sub-systems. The platform architecture will take into account the need for the spacecraft to evolve over the constellation lifetime, including during the design phase, due to a lean system development approach, required to address the uncertainties, trends and evolution of the market and technology as well as Space Debris Policies.</p> <p>Output of the activity will be a complete first iteration starting at the high level satellite configuration trade-off and ending with a platform design and test of a first STM of the selected platform concept, a detailed analysis of the Design for Manufacturing (DfM), Design-for-Testing (DfT), Design-for-Assembly (DfA), Design-for-Reliability (DfR), and Design-for-Deployment of the constellation for effective implementation of large volume constellations. This will include a detailed analysis of supply chain availability and addressing industrialisation constraints.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, satellite digital twin, structural thermal model breadboard of the high aspect ratio satellite platform   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | Yes   |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 20 – Structures<br>06 - RF Subsystems, Payloads and Technologies  |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 4B.188                        | Digital twin supported design and manufacturing of thrusters for constellations  | 800            | B              |
| <b>Objective:</b>             | The objective of this activity is to develop and test a digital-twin based design and manufacturing methodology for thrusters for LEO satellites, allowing higher accuracy thrust predictions significantly improving the development and verification approach and fuel margin philosophy.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Reduction of electric thruster manufacturing, assembly, integration, test duration and complexity by 25%.</li> <li>- Reduction of satellite propellant level margins by 5%</li> <li>- Increase sustainability of propulsion systems by reducing the propellant and power required for ground testing.</li> </ul>  |                |                |
| <b>Description:</b>           | <p>Thruster performance is very sensitive to small design variations and manufacturing tolerances and often full batch firing testing is required to confirm the thruster performance. This is not acceptable for large electric thruster orders for constellation, which typically require to test one out of ten thrusters to achieve effort and delivery time requirements. Accurate thruster performance prediction is also important to reduce propellant margins at satellite level, needed to compensate for possible underperformances of the untested engines.</p> <p>This activity will develop and test a digital-twin based design and manufacturing methodology to accurately predict the individual thruster performance (e.g. thrust, thrust vector and Isp) with respect to those of the product family of a widely used thruster technology. The sensitivity of thruster performance on the geometric variation and material property variation of the unit will be studied. A digital twin able to predict the thruster performance will be developed. A modular thruster breadboard with adjustable geometry as well as a thruster test bed will be developed, manufactured and characterised. The thruster breadboard will be tested and used to train the digital twin model. The achieved accuracy of the thruster performance prediction when compared to test results will be statistically evaluated and compared to the target of achieving a partial acceptable test philosophy of 1 out of 10 thrusters.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, model algorithm, thruster testbed and thruster breadboard.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | Yes - 2023 - Electric Propulsion   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 19 – Propulsion  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4B.189                        | High-power, high-density propellant based thruster  | 1,000          | B              |
| <b>Objective:</b>             | The objective of this activity is to develop, manufacture and tests a high power (>3kW) high density propellant-based thruster for GEO satcom applications.   |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- 3x improvement of storage density compared to Xenon and 5x compared to Krypton.</li> <li>- Overall more compact platform allowing multiple launches or increased payload volume.</li> </ul>  |                |                |
| <b>Description:</b>           | <p>The structure of GEO platforms is today heavily influenced by the size of the required propellant tanks which reach volume of the order of 1000L for Xenon. A potential reduction in this tank size thanks to the use of High-Density Propellant (HDP) would result in more compact platforms saving dry mass or allowing more space to be dedicated to payload or simplifying the stack of multiple platforms on a single launch. The use of HDP, like iodine for example, can provide several benefits which are mainly higher storage density and more compact systems compared to Xe. However, its applicability to high power thrusters (&gt;3kW) for GEO satcom propulsion is currently limited by the lack of cathodes compatible with these propellants and able to deliver the required current and lifetime. Additionally, the use of HDP will pose additional challenges on the mass flow controller suitable to be operated with high power thrusters, considering not only the propellant material compatibility but also that given the large mass of propellant present in the tank (&gt;1000 kg), the tank temperature cannot be used to modulate the thruster mass flow rate in any way.</p> <p>This activity will conduct a literature review to define the selected HDP material properties and assess compatibility with materials commonly found on the design of high-power thruster, cathode and flow controllers will be performed. Then, the applicability of the HDP to high power (&gt;3kW) thruster for GEO application will be evaluated. Starting from a set of typical requirements of a GEO mission (performance, lifetime, environment etc) and from data relative to the HDP material compatibility, the main technological barriers to the HDP implementation in the thruster system composed by thruster, cathode, flow control unit and PU will be identified and quantified. Finally, a breadboard including the cathode, thruster and flow controller will be designed, manufactured and tested to verify the performances of the system (e.g. Thrust and Isp Thruster and cathode operating temperatures Plume divergence Thruster and cathode electrical characteristics and discharge stability). An endurance test to assess the performances and lifetime capability of the thruster assembly will be part of the test campaign.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and high-power, high-density propellant based thruster breadboard  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | Yes - 2023 - Electric Propulsion  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 19 – Propulsion   |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4C.072                        | Attitude and Orbit Control System for high aspect ratio satcom satellites   | 1,800          | R              |
| <b>Objective:</b>             | The objective of the activity is to design, manufacture and test an Attitude and Orbit Control System (AOCS) architecture for high aspect ratio satellites in Low Earth Orbits (LEO) and Very Low Earth Orbits (VLEO), capable as well to perform controller and propulsion-less de-orbiting operations.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enabling AOCS for high aspect ratio satellites</li> <li>- Enabling high aspect ratio satellite to perform a controlled re-entry manoeuvre</li> </ul>   |                |                |
| <b>Description:</b>           | <p>High aspect ratio (HAR) satellites are of increasing interest for satcom users, due to several advantages at system level over a more traditional design (e.g. easier accommodation in the launcher, possibility to have larger surfaces for a given volume to accommodate solar arrays, antennas, radiators, etc.). However, the AOCS for such satellites takes on additional degrees of complexity both on the hardware architecture and the modelling and control algorithms side, such as limited volume for actuators accommodation such as wheels, or the compensation of increased atmospheric drag in specific attitudes when flying at lower altitudes in VLEO. The controlled re-entry for such satellite class poses additional AOCS technical challenges which require specific attention.</p> <p>This activity will design, manufacture and test an AOCS engineering model for a single High Aspect Ratio (HAR) spacecraft in at least two scenarios; nominal VLEO or LEO operations and a controlled propulsion-less re-entry case from VLEO. Possible AOCS architectures, flight dynamics modelling, on-board algorithms and associated operational concepts will be studied. Currently available sensors (e.g. star trackers, gyros, etc) and actuators (e.g. wheels, magnetorquers, control moment gyros, etc) will be assessed and required adaptation will be identified for the HAR configuration. Breadboarding of AOCS hardware will be carried out and AOCS algorithms developed. An AOCS subsystem scaled engineering model will be developed and implemented into a AOCS testbed. The testbed will be used to evaluate the performance for a nominal mission scenario in VLEO or LEO and a controlled re-entry scenario without the need of propulsion system. The re-entry scenario shall be tested representative environment (e.g. wind tunnel).</p> |                |                |
| <b>Deliverables:</b>          | Summary Report; AOCS algorithms, software and associated testbed; AOCS breadboards; AOCS subsystem scaled engineering model.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | Yes   |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 05 - Space System Control   |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4D.087                        | Direct cooling system for high performance, high power (300W class) telecom signal processing components  | 700            | B              |
| <b>Objective:</b>             | The objective of the activity is to design, develop and test an active two-phase cooling system capable to remove in the order of 300Watts from a single electronic component (e.g. switch/router Integrated Circuit).  |                |                |
| <b>Targeted Improvements:</b> | Increase by at least a factor of 5 the maximum thermal dissipation of signal processing components that can be supported on a spacecraft.   |                |                |
| <b>Description:</b>           | <p>Modern satellite telecommunications systems are moving towards on board regenerative payloads, capable of routing high throughput real time traffic across the system. As a result, satellite technology providers and integrators have started considering powerful digital integrated circuits, often developed for the terrestrial market, with extremely high-power consumption and dissipation (in the range of several hundreds of Watts), creating an unprecedented thermal bottleneck at component level (factor 6 to 10 increase of thermal dissipation with respect to heritage space grade devices). In order to be able to dissipate the large amount of power with a very high heat flux density, new technics such as microchannel cooling, direct spray cooling or jet impingement cooling, already utilised in terrestrial applications, will need to be studied, traded-off and developed. The design of the integrated circuits will need as well to consider thermal aspects (e.g. internal thermal gradients). The availability of a high performing component thermal management solution will as well benefit other highly dissipative elements of the payload and platform, such as Power Field Effect Transistors (FET) commonly used in many equipment and RF amplifiers.</p> <p>This activity will start with a comprehensive state-of-the-art technology survey with corresponding trade-offs to select a preferred technical solution and implementation architectures to support the use of high dissipation components in the next generation of spacecraft platform and payloads. A representative breadboard of the selected technology(ies) will be designed, built and tested to evaluate the performance of the cooling system. Finally, the activity will identify key remaining risks in the technology and the necessary development activities that would be required to generate the corresponding space suitable commercial solution.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and breadboard(s).   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | Yes - 2022 - Heat Transport Equipment and System  |                |                |
| <b>Dependency:</b>            | No  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 21 - Thermal  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4E.098                        | Slip ring less solar array drive mechanism for constellations   | 800            | B              |
| <b>Objective:</b>             | The objective of the activity is to develop a Solar Array Drive Mechanism (SADM) designed for high volume production and short lead time to address current and future constellations needs.  |                |                |
| <b>Targeted Improvements:</b> | Reduction of lead time by a factor of 10, enabling production capacity of around 1 unit per week.   |                |                |
| <b>Description:</b>           | <p>The development and validation of a state-of-the-art SADM using slirings is a constant challenge for European suppliers in particular for modern large constellation markets. The current state of the art, based on slirings, require long and manual processes which create a bottleneck in the production of satellites for large constellations.</p> <p>This activity will focus in identifying and assessing alternative technologies and techniques that could address these challenges, minimising the need of labour intense activities and simplifying verification, validation, and Quality Assurance efforts. For instance, twist capsules, very intensively used in terrestrial applications, could be considered to replace traditional slirings, with a significant simplification of the assembly process, even at expense of compromising the full rotation capability. A Solar Array Drive Mechanism (SADM) scaled Engineering Model optimised for high production rates and short lead times will be designed, manufactured and tested in relevant environmental conditions to confirm performances.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, slip-ring less scaled SADM engineering model.   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | Yes - 2020 - Solar Array Drive Mechanisms   |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 15 – Mechanisms   |                |                |





| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4E.099                        | Separation system for stacked high aspect ratio satcom satellites   | 1,000          | R              |
| <b>Objective:</b>             | The objective of the activity is to develop and verify an Open Standard of a separation system specifically for stacked high aspect ratio satellites (up to 1,200 kg class spacecraft).   |                |                |
| <b>Targeted Improvements:</b> | Enabling technology for launches of stacked high aspect ratio satellites.   |                |                |
| <b>Description:</b>           | <p>High aspect ratio satellites are an established form factor for satcom satellites, already operating and providing global telecommunication services. To maximise launch capacity, it is common to launch large stacks of multiple (10s) of such satellites together. The required separation technologies have to date been bespoke developments by and for each specific constellation. In Europe, there is currently no such system available, nor an off the shelf existing solution.</p> <p>This activity aims to develop an open standard for a European hold down and release system to enable stacked launches of up to 60 high aspect ratio (up to 1200kg class) satellites. This will ensure that development of such systems is coordinated across Europe and allow different providers to be mixed within single launches and across multiple launches and constellations. A separation system by necessity includes: a mechanical load path for the stack, the hold down mechanism, a pre-loading device to ensure that the stack is effectively held down through launch conditions. a release mechanism and a sequencing system to control the ejection of each spacecraft from the stack. The engineering model separation system concept will be developed, and a breadboard will be manufactured and tested in a sufficiently representative scenario to validate critical functions of the system in the different stacking configurations. Then, an engineering model will be manufactured and tested, including a series of deployment tests in different conditions to assess the overall design performance. The final stage of the activity will propose an open standard for separation system for stacked high aspect ratio satcom satellites to promote compatibility of spacecraft design.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, breadboard(s) of a separation system (including actuator) and EM of Stack of the system, draft open standard document.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 15 - Mechanisms   |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4F.173                        | High-energy solid-state battery cell for satcom application   | 700            | B              |
| <b>Objective:</b>             | The objective of the activity is to develop, manufacture and test a high-energy, solid-state battery cell with a specific energy over 300 Wh/kg and a minimum capacity of 4-5 Ah.   |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enabling high energy low volume battery for high ratio aspect satellite.</li> <li>- Increase specific energy at cell level by at least 35%</li> <li>- Increase cell intrinsic safety.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Batteries are a key component of the power sub-system of telecommunication satellites and have a significant impact in the platform design. The size and mass of satellite batteries is driven by the current achievable specific and volumetric energy parameters and operational depth of discharge (DoD). Solid state battery is considered as next generation battery technology due to significant improvement compared to conventional Li ion technology: more energy, more power, increased safety and higher production rates. Other concepts, like a new application of composite materials to create a multi-functional composite panel that can store electrical charge, could also be very relevant for flat satellites applications.</p> <p>This activity will conduct a thorough state-of-the-art assessment on solid state battery technologies in Europe and world-wide. A battery cell breadboard with a capacity of at least 4 Ah, and a specific energy of 300 Wh/kg will be designed, developed, manufactured and tested. The test campaign will include cycling at 100% Depth of Discharge to validate their cyclability, accelerated life tests and safety tests. Finally, a manufacturing upscale assessment will be performed to assess the feasibility for mass production.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, solid state battery cell breadboard.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | Yes - 2019- Electrochemical Energy Storage  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 03 - Space Systems Electrical Power   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 4F.174                        | High specific power photovoltaic assembly components and modules   | 1,000          | B              |
| <b>Objective:</b>             | The objective of this activity is to design, manufacture and test thin solar cells, a photovoltaic assembly (PVA) module of very high specific power (140 W/kg) and develop new processes for solar cell thinning, welding, laydown.   |                |                |
| <b>Targeted Improvements:</b> | Doubling the specific power of the state-of-the-art photovoltaic assembly with standard rigid solar arrays (benchmark 60-70 W/kg)  |                |                |
| <b>Description:</b>           | <p>In recent years, flexible solar arrays have become more popular as they enable lighter and thinner structures and solar cells. However, the current technology for the rest of the photovoltaic assembly, such as protective shielding, diode, cell interconnection and suitable interconnection solutions, compatible with the necessary low mass and flexibility requirements, are not yet available.</p> <p>This activity will design, manufacture and test thin solar cells, a photovoltaic assembly (PVA) breadboard of very high specific power (140 W/kg) and develop new processes for solar cell thinning, welding and lay down. This includes lift-off and handling processes of thinned solar cells as well as solutions for interconnection of solar cells and welding technologies allowing for embedding shielding material into a laminate. Different innovative PVA concepts based on low mass and flexible technologies will be investigated, breadboarded and tested.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, thin solar cell breadboards, photovoltaic assembly breadboard.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | Yes - 2021 - Solar Generators and Solar Cells  |                |                |
| <b>Dependency:</b>            | Yes  |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 03 - Space Systems Electrical Power  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4F.175                        | Spin-in development of terrestrial solar cell technology for constellation applications   | 1,000          | B              |
| <b>Objective:</b>             | The objective is to investigate use of cost-effective solar cells, using materials such as silicon or perovskites, currently available or under development for terrestrial applications, and test their suitability for satcom constellation missions as well as undertake any necessary adaptations.  |                |                |
| <b>Targeted Improvements:</b> | Enabling an European or Canadian source of solar cells for constellation.   |                |                |
| <b>Description:</b>           | <p>Low Earth Orbit (LEO) constellation market is impacting the solar cell requirements, and parameters such as production rates is becoming a priority. Terrestrial solar arrays use predominantly silicon solar cells, but there are multiple variants (inc. homojunction cells, heterojunction cells) that are expected to have degraded performance in space environment mainly due to particle irradiation. Additionally, design features such as contact metallisation and cell interconnection schemes may need to be adapted to survive the thermal cycling environment to take full benefit of terrestrial solar cells for LEO constellation satellites.</p> <p>This activity will survey and test the different existing terrestrial solar cell technologies for space applications in low Earth orbit taking into account the specific space environment requirements (e.g. particle irradiation environment, thermal cycling, etc.). The survey results will be used to identify needed design changes and an engineering model of a terrestrial based solar cell for LEO constellation will be developed and experimentally tested.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, solar cell engineering models.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 6   |                |                |
| <b>Technology harmonised:</b> | Yes - 2021 - Solar Generators and Solar Cells   |                |                |
| <b>Dependency:</b>            | Yes   |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 03 - Space Systems Electrical Power   |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 4F.176                        | Power bus isolation device to achieve reliable electrical passivation   | 700            | B              |
| <b>Objective:</b>             | The objective of this activity is to design, develop, manufacture and test a power bus passivation isolation device providing a physical gap on the power path at the end of mission suitable for telecom satellites.   |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enabling above 95% reliability for permanent electrical passivation</li> <li>- Achieving an operating thermal range of -150 to +120degC.</li> <li>- Reduce the complexity of implementation of electrical passivation by more than 50%.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Due to the increase of human-made objects in Earth orbit, especially with many constellation programmes, it is paramount to reduce the risk of collisions in orbit. Regulations and policies are evolving and include the need of electrical passivation and a probability target for a successful passivation until spacecraft disposal. The current state of the art techniques for electrical passivation typically isolates the battery from its power source via electronic switch or electromechanical devices. These techniques lack a high probability successful passivation isolation when there is no satellite thermal control anymore and continuous exposition to radiation.</p> <p>This activity will develop an electrical isolation technique for satcom missions in all Earth orbits, based on introducing a physical gap on the power path of the spacecraft to prevent for example the charging of batteries after end of mission. The isolation performance shall not be influenced by the thermal environment or by radiation effects. Different potential solutions to achieve the desired passivation isolation performance and reliability will be studied including existing technologies such as a pyro device (e.g. pyro connector). A passivation isolation device scaled engineering model will be designed, manufactured and tested to evaluate its performances.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, passivation device engineering model.   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | N/A   |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 03 - Space Systems Electrical Power   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 4F.177                        | Lithium free batteries for low earth orbit satcom constellations   | 700            | B              |
| <b>Objective:</b>             | The objective of this activity is to develop, manufacture and test batteries from sustainable and ESA Member States sourced materials with high cycle life at high Depth of Discharge (DoD) and a good rate capability for small communication satellites in LEO.  |                |                |
| <b>Targeted Improvements:</b> | Enabling a European or Canadian source of lithium free space battery for LEO satcom constellations.  |                |                |
| <b>Description:</b>           | <p>Currently the state-of-the-art technology for energy storage in satellites are Li-ion batteries, however this technology relies on materials which are not readily available in ESA Member States and have limited lifetime and power density. Consequently, Li-ion batteries Deep of Discharge (DoD) in Low Earth Orbit (LEO) applications is severely limited (typically 20%), further reducing the effective energy densities. Over the past years, manufacturers have reached high power density and promising life cycles with technologies such as Na-ion batteries (up to 5 kW/kg and over 5000 cycles, with an energy density of up to 160 Wh/kg) which could revolutionise energy storage in telecommunication satellites. An inherent advantage of lithium free batteries is also, that they are considerably more sustainable and use ESA Member States available raw materials, such as hard carbon on the anode side and Prussian blue analogues on the cathode side for Na-ion batteries.</p> <p>This activity will improve the effective energy density of batteries for small satellites and secure ESA Member States' independence by using environmentally friendly materials, that are easily accessible. A lithium free battery breadboard made of non-critical materials will be designed, developed, manufactured, and tested to demonstrate both compliance with space requirements and high cycle life at depth of discharge and power relevant to telecommunication satellites in Low Earth Orbit.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and lithium free battery breadboard.  |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | Yes - 2024 - Electrochemical Energy Storage  |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 03 - Space Systems Electrical Power  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5B.247                        | Large modular antenna with reduced grating lobes  | 2,200          | B              |
| <b>Objective:</b>             | The objective of the activity is to develop a large antenna composed of modules or subarrays physically separated by multiple wavelengths in L-/S-Band, Ku- or Ka-band. This includes the development of wideband antenna beamforming and signal processing techniques to control the grating lobes and the necessary interconnectivity architecture to achieve the required phase and time synchronisation.  |                |                |
| <b>Targeted Improvements:</b> | Enabling wideband beamforming for modular large apertures composed of multiple-wavelength-separated arrays.   |                |                |
| <b>Description:</b>           | <p>Large antenna apertures up to tens of meters in diameter could enable many types of services in all orbits, including broadband, Internet of Things, and direct-to-device. However, today's launchers and platform choices often limit the size of the antenna to be deployed. Beamforming for apertures comprising multiple subarrays (modules, tiles) separated by a large electrical distance is possible, at the cost of grating lobes that degrade the performance of the antenna and extra complexity due to the required synchronisation. However, advanced beamforming techniques, such as multi-level beamforming as well as signal processing techniques, have the potential to reduce the interference introduced by grating lobes.</p> <p>This activity will study, develop, and implement wideband beamforming and signal processing techniques to mitigate the effect of the grating lobes and to improve the antenna performance in terms of Carrier-to-Interference ratio (C/I) in L-/S-band, and in Ku- or Ka-band. The developed concepts will be implemented into an antenna breadboard and tested.</p> <p>The activity will be implemented in a phased approach where:</p> <p>Phase 1 will study array synthesis techniques to reduce the grating lobes, and the maximum electrical distance between adjacent subarrays to ensure that the resulting aggregate C/I will be above the threshold required for applications in L-/S-band, and in Ku- or Ka-band. Antenna performance in terms of directivity, grating lobes, sidelobe level, C/I, and Equivalent Isotropic Radiated Power (EIRP) will be evaluated against distance between adjacent arrays. An interconnectivity architecture and critical technologies enabling the antenna beamforming, including interconnectivity and synchronisation, will be investigated and tested by a limited-scale derisking breadboard. Signal processing solutions that do not require a main processor will be studied where the processing is implemented in each module and then combined. Phase 1 output shall comprise a beamforming and signal processing concept supported by analysis and derisking test results as well as a definition of an antenna baseline.</p> <p>The developed concepts shall be further developed in Phase 2 and implemented into an antenna testbed in L-/S-Band, Ku- or Ka-band (to be confirmed in Phase 1) capable to fully evaluate the performance and grating lobe suppression of the modular antenna aperture. The testbed will consist of 5-7 tiles (to be confirmed in Phase 1), each tile representing a co-located array antenna of limited size with several tiles implementing the beamforming network and interconnectivity. The antenna tile beamforming patterns and performance shall be tested as well as the combined beamforming performance of all tiles to evaluate the grating lobe suppression efficiency.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, documented beamforming and signal processing concepts, and large modular antenna testbed in L-/S or Ka- or Ku-band.   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5B.248                        | Transmit and receive dual polarisation active antenna based on scalable tile assembly for geostationary satellites  | 1,400          | B              |
| <b>Objective:</b>             | The objective of this activity is to design, manufacture and test a scalable Ku- or Ka-band tile assembly enabling compact combined transmit and receive active antenna for satellites in geosynchronous orbit. This will include the development of a mechanical and thermal concept.  |                |                |
| <b>Targeted Improvements:</b> | Reduction of the number of antennas at spacecraft level by a factor of 2.   |                |                |
| <b>Description:</b>           | <p>There is a trend for telecommunication satellites in Geostationary Orbits to reduce the size of the platform whilst maintaining capacity of the system. The accommodation of several active antennas in such reduced size platforms is becoming more challenging and the need for integrated transmit and receive phased array antennas is growing. The current feed chain solutions are often based on hollow or ridge waveguide technology which meet performance requirements but result in bulky implementations and therefore they are not compatible for implementing transmit and receive in the same aperture while keeping both orthogonal polarisations. New ways of implementing RF components based on planar technologies have been previously studied but this technology is trading in insertion loss and RF bandwidth performance. New PCB based technology such as Air-Filled Surface Integrated Waveguide (AFSIW), gap-technology and advanced manufacturing techniques have the potential to significantly reduce the volume with respect to the current state of the art, whilst maintaining good RF performance. Metamaterials, which are engineered materials with unique properties, are also a potential solution to reduce the volume of feed chain assemblies.</p> <p>This activity will develop in a concept of a dual polarised combined transmit and receive active antenna in Ku- or Ka-band. Trade-off studies of several antenna topology designs will be performed. Breadboarding of critical components of the feed chain will be carried out including the development of a low loss filtering solution. A breadboard of a tile assembly will be developed and tested. For the breadboard tile assembly off-the shelf high power amplifiers and low noise amplifiers shall be baselined. Thermal and mechanical assessment and experimental tests of the tile-assembly will be carried to evaluate the performance of the developed active antenna.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and transmit and receive Ku- or Ka-band dual polarised antenna tile assembly.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |





| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 5B.249                        | Q-band transmit active antenna for combined user and feeder link on low earth orbit satellites   | 1,300          | B              |
| <b>Objective:</b>             | The objective of this activity is to develop a Q-band transmit, scalable active antenna for the combined user and feeder links for Low-Earth-Orbit (LEO) broadband applications.   |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enabling broadband services in Q-band for LEO satellites.</li> <li>- Eliminating the need for separate user and feeder link antenna.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Satellite telecommunication systems have experienced an increased traffic in Ku and Ka frequency bands and higher frequency bands are targeted to satisfy the increasing required capacity. Currently, Q/V bands are mostly used for feeder links on (Very)-High-Throughput-Satellites (V)HTS Geostationary Earth Orbit (GEO) satellites, and passive antenna solutions already available and active ones under initial development. While feeder link beams are fixed on GEO systems, in Low Earth Orbit (LEO) satellites the feeder beams benefit from repointing of an array antenna solution as it provides more flexibility and reliability and the ability to dynamically assign multiple beams to multiple gateways and users.</p> <p>This activity will design a highly integrated Q-band direct array antenna for LEO satellites allowing multi-beam operations for both user and feeder links. This shall include a mechanical and thermal management concept. An engineering model of an antenna tile (at least 10 cm x 10 cm size) will be developed and tested. The engineering model tile shall contain the most representative passive and active components. Commercial-off-the-shelf (COTS) active components can be considered. The thermal management system shall be designed, and representative components shall be included in the antenna tile engineering model.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and Q-band transmit antenna tile engineering model.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 5  |                |                |
| <b>Technology harmonised:</b> | Yes - 2022 - Array Antennas and Periodic Structures  |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5B.250                        | Fast, wideband and scalable antenna measurement system for large active antennas  | 700            | B              |
| <b>Objective:</b>             | The objective is to develop and test a fast wideband antenna measurement system able to simultaneously measure the radiated power of all apertures of large, phased array antennas. Post-processing algorithms shall be developed and tested to compute multiport transmission coefficients and the far field pattern.  |                |                |
| <b>Targeted Improvements:</b> | Order of magnitude faster measurement acquisition time (seconds instead of hours or even days) to verify the functionality of large arrays.   |                |                |
| <b>Description:</b>           | <p>Large systems to measure the patterns of phased array antennas exist, but they are narrowband and require dedicated and frequency-tailored setups. Measurement time is usually in the order of hours or days, and, hence, testing at antenna tile level or full antenna level is often reduced or limited to basic functional tests at radiating element level without computing all relevant antenna parameters (e.g. radiation pattern, cross polar level). Further, current measurement systems are often limited to spot-beam measurements and contour-beam measurements are challenging.</p> <p>This activity will develop a fast and wideband measurement system prototype covering frequencies from 1GHz up to 50GHz capable to compute transmission and far field patterns. This will include the development of algorithms to compute the multiport transmission coefficients and far field patterns. The measurement system shall be scalable to large phased arrays of at least up to 5m. It shall be possible to assemble, disassemble, and transport the system. The activity will manufacture a scaled size measurement system prototype in the 2m class. Testing shall be carried out using a characterised phased array.</p> |                |                |
| <b>Deliverables:</b>          | Summary report; Fast wideband, and scalable antenna measurement system prototype including post-processing algorithms.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | N/A   |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | Yes   |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 07 - Electromagnetic Technologies and Techniques  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5B.251                        | Ka-band single polarisation transmit and receive active antenna for low earth orbit satellites  | 1,200          | B              |
| <b>Objective:</b>             | The objective of this activity is to design, manufacture and test a Ka-band single polarisation, combined transmit and receive, active antenna for low earth orbit satellites.  |                |                |
| <b>Targeted Improvements:</b> | Reduction by a factor of 2 the numbers of on-board antenna.   |                |                |
| <b>Description:</b>           | <p>Low Earth Orbit (LEO) telecommunication satellites require compact and highly integrated antennas. These antennas require very large fields of view with a typical beam scanning range of up to 60 degrees from the boresight direction. Active direct radiating phased array antennas are attractive solutions for these satellites because they provide better scanning capabilities as compared to phased arrays magnified by reflectors and are simpler in terms of accommodation. Current Ka-band active antennas are designed with separated transmit and receive functionalities as the large frequency band separation between the transmit and receive functions makes difficult to integrate them in the same aperture. In addition, the small pitch required for such wide scan angles makes the accommodation of the radiating elements, associated beamforming network and active components challenging. Multi-layer printed technology represents a promising solution to achieve the integration of combined transmit and receive active antennas. Available now are technologies featuring 3-D integration capabilities with low losses and cross talk capable of realising micro-coax transmission lines or Air-Filled Substrate Integrated Waveguide with integrated active and passive component.</p> <p>This activity will develop a concept of a combined transmit and receive active antenna with wide scanning range for applications in low earth orbit. This includes the developed thermal management and mechanical concept. Wideband beamforming and advanced manufacturing technologies will be investigated. Breadboarding shall be carried out to derisk the most critical components (filtering function, radiating elements). A reduced antenna engineering model with critical functions comprising of at least one tile assembly of at least 10x10 radiating elements will be manufactured and tested.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and scaled engineering model of the Ka-band receive antenna with all critical functions.   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5C.525                        | Low power Ka-band direct conversion receiver module   | 1,500          | B              |
| <b>Objective:</b>             | The objective of the activity is to design, manufacture and test a 12bit direct conversion receiver module covering the full Ka-band with significant reduced power consumption in comparison to current state of the art.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enabling a European source of low power direct conversion Ka-band receivers.</li> <li>- Factor 5 reduction of power consumption compared to the State of the Art.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Today's flexible telecommunication satellites require receivers operating at higher frequencies and over a wider bandwidth than in the past, with a complex RF chain and lossy harnesses. A trend towards highly integrated solutions using direct sampling receivers compatible with Software Defined Radios (SDRs) is one solution, but the power consumption of these direct sampling architectures can be prohibitive for some applications. The available direct conversion receivers in Ku-band and Ka-band have power consumption figures in excess of several Watts and limited conversion accuracy, constraining the application areas where these could be used for space telecommunication applications. A direct conversion receiver system in a single package integrating the Analog to Digital Converter (ADC) in the advanced semiconductor technology and using a time-interleaved ADC architecture can achieve the desired lower power consumption and higher conversion accuracy.</p> <p>This activity will develop a prototype wideband ADC with high-speed track-and-hold circuit, implemented as a System-in-Package (SiP) RF to digital front-end module including digital processing features, operating in upper Ka-band. Available State-of-the-Art low-power wideband ADC will be assessed, and a trade-off analysis performed to determine the optimum RF chain architecture (including the track-and-hold with digital processing engine and high-speed interfaces) suitable for wideband SDRs operating in full Ka-band applications. The breadboard will be designed to meet key performance requirements in terms of power consumption (&lt;500mW per channel), bandwidth, and input frequency. The noise and linearity performance shall be measured to determine suitability for a range of SDR scenarios also considering synchronisation and clock jitter requirements. The breadboard shall be tested in a representative RF chain architecture in a laboratory environment, to demonstrate direct sampling at upper Ka-band frequencies and assess viability for V/W band applications. Additionally, radiation tolerance shall be demonstrated by analysis to assess suitability of the low-power ADC for future applications in space.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and breadboard of a Ka-band direct conversion receiver module.   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 5C.526                        | Scalable processor array for digital beamforming   | 1,500          | B              |
| <b>Objective:</b>             | The objective of the activity is to develop a scalable processor architecture for digital beamforming applications. An elementary processing node of a scalable telecom phased array antenna will be designed and manufactured. Beamforming algorithms will be developed and integrated into a processor array testbed comprising several nodes in order to evaluate the concept.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- 50% power and volume reduction compared state of the art digital beamforming.</li> <li>- 50% improvement in the thermal management system due to the distribution of the processing.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Digital beamforming networks offer the highest level of flexibility to telecommunication payloads but at the same time incur high costs and increased power consumption. This activity will aim at reducing the complexity of such network, with the development of a custom digital processor firmware for state-of-the-art highly integrated processing technologies. Critical functions of this development include the interconnect and networking between the processing nodes of the processor array, the selection and customisation of algorithms for digital beam weighting and aggregation, as well as the accompanying transparent and regenerative digital operations, and how they will be mapped to the processing nodes of the digital processor array or supported by additional hardware for direct sampling up to Ka-Band and to achieve a modular and scalable architecture that enables building of large antenna arrays. Architecture trade-offs to minimise power consumption will be carried out and the thermal and physical constraints of such a processor array will be analysed. In the initial stage of the activity, a range of technology options shall be considered to define the elementary building node of the Scalable Processor Array. As a minimum, the following technology options will be studied: (1) RF System-on-Chip (RF SoC) technology with integrated wideband, high-speed data converters. (2) FPGA technology with external data converters (3) FPGA technology with external Analog to Digital Converters (ADCs) only, while the Digital to Analog Converter (DAC) is implemented inside the digital logic. The third option will allow for the evaluation of an all-digital signal transmission chain, with the support of Multi-Gigabit Transceivers (MGTS) for the DAC. Previous work has shown that FPGA-embedded MGTS can serve as 1-bit RF DACs, acting as the interface between the digital and analogue domains.</p> <p>The activity places priority on overall power consumption, while ensuring no adverse effects on the RF Figures of Merit to enable the definition of an optimal architecture for both phased array payloads and phased array terminals based on the same concept. In cases where external data converters are considered, high-speed interfaces suitable for wideband Software-Defined Radio (SDR) up to Ka-band applications should be chosen. Once elementary building node are identified, the activity will design, manufacture, and test a digital processor array testbed, comprising several processing array nodes and its algorithms for digital beamforming applications to demonstrate the Scalable Processor Array. The processor array shall be scalable to several hundreds of antenna elements. A mathematical model of the processor array architecture will be developed. A testbed, comprising a representative interconnected number of processing nodes shall be developed and used to evaluate the performance.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, mathematical algorithms of the processor array architecture, processor array testbed and associated firmware.  |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 5  |                |                |
| <b>Technology harmonised:</b> | No   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5C.527                        | Power-efficient and linearised solid-state, high-power amplifier for active antenna   | 900            | B              |
| <b>Objective:</b>             | The objective of the activity is to design, manufacture and test an engineering model of a Ku- or Ka-band power-efficient and linearised solid state higher power amplifier for satcom applications.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- At least 10% points of power added efficiency improvement in comparison to state of art at nominal noise power ratio.</li> <li>- Improvement of the nominal output power of at least 3dB.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Telecommunication satellites high power amplifiers typically operate at approximately 3dB output backoff to meet linearity requirements. While it is possible to operate current state of the art RF amplifiers at higher efficiencies, it comes at the cost of increased distortion products, resulting in high in-band and, often more limiting, out-of-band distortion. Therefore, efficiency and output back-off parameters are often traded off leading a significant loss of efficiency and increases the burden on satellite thermal system and DC power system to remove dissipated power.</p> <p>This activity will develop a concept of simultaneously achieving power-efficiency and linear performance which will enable the RF amplifier to operate in saturation while allowing greater efficiency of at least up to 10% and higher output power of at least 3dB compared to state of art. Concepts such as load-modulated linearised amplifier systems and harmonic Injection Doherty power amplifiers etc will be studied. This will allow to operate much closer to saturation, meeting linearity requirements and providing improved power added efficiency. A scaled engineering model of a high-power amplifier in Ku- or Ka-band will be designed, manufactured, and tested over the representative operational temperature ranges.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and scaled engineering model of Ka- or Ku-band power-efficient and linearised high power amplifier.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5C.528                        | Dual band Ku- and Ka-band low noise amplifier for future flexible payloads  | 700            | B              |
| <b>Objective:</b>             | The objective of the activity is to design, manufacture and test an engineering model of a dual band (Ku- and Ka-band) Low Noise Amplifier (LNA) for future flexible payloads.  |                |                |
| <b>Targeted Improvements:</b> | Enabling technology for seamless Ku- and Ka-band flexible payloads.   |                |                |
| <b>Description:</b>           | <p>Current flexible satellites offer flexibility in terms of coverage and in-band frequency reconfigurability (e.g. Ku-band and Ka-band). However, this reconfigurability is frequency band specific and satellites requiring simultaneous operation in both bands, are required to duplicate frequency specific equipment, bringing a high penalty in terms of cost, mass and volume. A European source of state-of-the-art dual band LNAs which can offer both Ku-band and Ka-band capability for in-orbit configuration would provide the payload with enhanced and seamless multi-band flexibility and is an enabling step towards achieving frequency agnostic payloads.</p> <p>This activity will design, build and test a dual band LNA engineering model covering the full Ku- and Ka- telecom bands. The LNA shall have comparable RF performance to existing state-of-the-art single band MMIC devices (noise figure lower than 2dB, with gain greater than 35dB) and lower power consumption compared to existing wideband LNAs, targeting less than 500mW. The engineering model shall be tested for critical functions including performance over temperature.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, dual Ku- and Ka-band LNA Engineering Model.   |                |                |
| <b>Estimated current TRL:</b> | 4   |                |                |
| <b>Target TRL:</b>            | 6   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 5C.529                        | Dual-band Ku- and Ka-band filters for future flexible payloads   | 700            | B              |
| <b>Objective:</b>             | The objective of the activity is to design, manufacture and test compact dual-band Ku- and Ka-band transmit filters for application in Lower Earth Orbit satellites, enabling seamless flexibility and reconfigurability for combined Ku- and Ka-band single aperture active antenna arrays.   |                |                |
| <b>Targeted Improvements:</b> | Enabling technology for seamless Ku- and Ka-band flexible payloads.  |                |                |
| <b>Description:</b>           | <p>Current flexible satellites offer flexibility in terms of coverage and in-band frequency reconfigurability (e.g. Ku-band and Ka-band). This reconfigurability is frequency band specific and satellites requiring simultaneous operation in both bands, are required to duplicate frequency specific equipment, bringing a high penalty in terms of cost, mass and volume. However, frequency agnostic antennas are needed for future satcom systems. Dual band multifrequency single aperture active antennas which can offer both Ku-band and Ka-band capacity in orbit would be a significant advantage as it would address different markets (broadband consumer, mobility, Business-to-Business connectivity, etc.) and extend the capability of LEO constellations operating in Ku- and Ka-bands. A key building block for such systems are dual band filters which can simplify the architecture and reduce the overall volume and mass. Dual band filter implementations based on channel dropping have been studied in the past but lead to high insertion loss. Other solutions based on manifold/coupled structures are attractive but often result in bulky implementations and are often not compatible with the antenna feed spacing. Multimode resonators, dielectric materials and advance manufacturing techniques developed in recent years have the potential to significantly reduce the volume with respect to the current state of the art, whilst maintaining good RF performance.</p> <p>This activity will investigate and develop dual band transmit filter solutions for Ku- and Ka-band active antennas. The activity will also study suitable interfaces that allow easy integration at active antenna level and within the RF chain without compromising the RF performance. The activity shall review the current state of the art, develop dual band breadboards for two different design concepts and produce a filter engineering model to validate the most promising concept.</p> |                |                |
| <b>Deliverables:</b>          | Study report and two dual band Ku- and Ka-band filter breadboards.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | No   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies  |                |                |





| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 5C.530                        | Intelligent signal monitoring unit for payload equipment autonomy, health monitoring, and reconfiguration  | 1,200          | B              |
| <b>Objective:</b>             | The objective of the activity is to design, build and test a monitoring unit and associated testbed capable of executing algorithms, including but not limited to Artificial Intelligence (AI), in real time, to monitor signal and telemetries of RF payloads, trigger autonomous reconfiguration and raise alerts to future autonomous satellites or simply to ground.   |                |                |
| <b>Targeted Improvements:</b> | Enable monitoring of high frequency signals and payload telemetry for autonomous and intelligent anomaly detection in Telecom payloads, which currently rely on manually adjusted thresholds.  |                |                |
| <b>Description:</b>           | <p>The operation of constellations requires efficient management of payload performance, health monitoring and reconfiguration when necessary. Current on-board signal monitoring is limited to low frequency telemetries, like temperature readings, avionics telemetries or health flags, which is not sufficient for autonomous monitoring satellite communication payloads. Closed-loop monitoring of analogue-to-digital converters that interface with antenna calibration channels, beamforming calibration, interference detection, clock monitoring units and other high frequency telemetries is required. These applications are challenging because of the high data rates and the difficulty of processing radio frequency signals. Additionally, these algorithms need to run on-board, because of the number of satellites in constellations and the volume of telemetry data. Advances in monitoring algorithms are becoming more mature, for example adapting beamforming coefficients automatically to improve transmission when interferences or failures occur at module or instrument level and initiating a reconfiguration before equipment breaks down, which demonstrate the viability of the concept and together with the progress in more efficient processors and FPGAs, the execution of such algorithms on-board is possible.</p> <p>This activity will study monitoring algorithms, including convolutional and recurrent neural networks, for broadband payload architectures and develop an intelligent monitoring unit (ISMU) breadboard. The ISMU shall be compatible to the required signal bandwidth and input RF lanes and autonomously trigger mode change or recalibration when a performance drop, health degradation, external interference or failure is detected. Finally, a combined hardware and software testbed will be developed, capable to assess the monitoring and autonomous reconfiguration capabilities, and measure the performance improvements achieved in overall Quality of Service (QoS).</p> |                |                |
| <b>Deliverables:</b>          | Summary Report, Intelligent Signal Monitoring Unit (ISMU) breadboard and associated testbed  |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | N/A  |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies  |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 5C.531                        | Toxic free joining of RF passive assemblies  | 800            | B              |
| <b>Objective:</b>             | The objective of the activity is to develop a sustainable end-to-end joining process for RF passive low and high-power assemblies including waveguides and feed chains. This will include investigation of sustainable brazing and surface coating techniques. The developed end-to-end joining process will be fully evaluated on an RF feed chain and a waveguide assembly.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enable sustainable manufacturing of RF passive assemblies by eliminating toxic elements used in traditional metal-joining techniques.</li> <li>- Reduction of energy consumption of up to 30% when metal-joining techniques are used.</li> </ul>  |                |                |
| <b>Description:</b>           | <p>RF passive assemblies are widely used in telecommunication satellites. This includes waveguides and feed chain assemblies, and in the next decade, large numbers of waveguide components are anticipated to be deployed in Telecom GEO and LEO satellites. These components are mainly made of individual Aluminium alloy parts which are often joined by brazing. Current brazing fillers have melting temperatures which are close to the melting temperature of the alloys that is joined. The high temperature requires the use of flux additives to mitigate corrosion in the joint area. These fluxes can contaminate or corrode the joints and they are toxic. This result in delicate process conditions to ensure the hardware is not affected by the brazing and often leads to a significant number of rejected parts.</p> <p>This activity will investigate and trade-off sustainable, eco-friendly metal-joining technique eliminating the need for toxic flux additives as well as high processing temperature compared to the standard brazing techniques. Selecting the most promising one, an end-to-end sustainable joining process with significantly reduced energy consumption will be developed including internal and external surface treatment. Engineering models of one simple and one complex RF assembly will be manufactured and tested. Testing will include passive intermodulation to fully evaluate the developed end-to-end process.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, one simple and one complex engineering model using the developed sustainable joining process   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 6  |                |                |
| <b>Technology harmonised:</b> | No   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 24 - Materials and Manufacturing Processes   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 5C.535                        | High-linearity W-band GaN Low-Noise Amplifier for intense radio-frequency interference environment   | 800            | B              |
| <b>Objective:</b>             | The objective of this activity is to design, manufacture and test an engineering model of a robust Low-Noise Amplifier (LNA) in W-band, suitable for integration in feed arrays for satellite communications, with a high third-order intercept point and robustness against damage in an intense radio-frequency interference environment. In addition, an assessment of the GaN transistor safe operating area for robust LNA operation shall be made.   |                |                |
| <b>Targeted Improvements:</b> | 10-dB increase in dynamic range and 15-dB increase in radio frequency interference tolerance.  |                |                |
| <b>Description:</b>           | <p>In conventional payloads, the Low-Noise Amplifier (LNA) is located at some distance from the antenna feed, which translates into distribution network losses that degrade the overall noise figure of the receiver, which in turn degrades the system performance (G/T). Additionally, a bandpass filter must be added in front of the LNA to protect it from unwanted out-of-band signals. Thanks to recent advances in Gallium Nitride (GaN) technology, it is now possible to design more robust LNA Monolithic Microwave Integrated Circuits (MMICs) which do not require a bandpass filter at the input, or require a less demanding input bandpass filter, because of the higher third-order intercept point they exhibit, hence improving the third order intercept point (IM3) and noise figure of the receiver. The filtering is then implemented later in the payload chain where it has a limited effect on the noise figure. The use of GaN increases the resilience to strong interference. Additionally, the GaN MMIC can operate over a wider temperature range than current Gallium Arsenide (GaAs) based products. This also helps to place the LNA closer to the antenna feed and thus, reduces the overall noise figure of the receiver.</p> <p>The overdrive due to RF interference can be considered a transient condition and using manufacturer maximum ratings derived from long-duration CW testing at high drain bias will lead to excessive reliability margin. Understanding the limits and safe operating area (SOA) of GaN HEMTs (high electron-mobility transistor) in LNA operations would be beneficial in establishing good design practices for robust LNAs.</p> <p>This activity will study and develop a W-band GaN LNA for use in telecommunication payloads. Test structures shall be implemented in the LNA MMIC wafer run, and experimental tests performed under various LNA bias and RF overdrive (continuous wave and pulsed) conditions to characterise the SOA of GaN LNAs. A scaled Engineering Model containing the following critical functions shall be manufactured and tested:</p> <ul style="list-style-type: none"> <li>-Low noise amplifier chip(s)</li> <li>-Waveguide module, including RF transitions</li> <li>-DC biasing and filtering circuitry</li> </ul> |                |                |
| <b>Deliverables:</b>          | Summary report and LNA scaled engineering model with critical functions.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 5  |                |                |
| <b>Technology harmonised:</b> | No   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 5D.041                        | High throughput reprogrammable dataplanes for on-board satellite communication protocol implementations   | 800            | B              |
| <b>Objective:</b>             | The objective of the activity is to develop high throughput programmable dataplanes on hardware used for space applications. Satcom protocols (e.g. beyond at 3-levels MPLS, Source-Routing, CCSDS USLP, DVB GSE) will be implemented and tested.   |                |                |
| <b>Targeted Improvements:</b> | Improve the throughput of on-board reprogrammable dataplanes of Field Programmable Gate Arrays, Network Processing Units and Central Processing Units by at least a factor of 3.  |                |                |
| <b>Description:</b>           | <p>Packet switching in satellite constellation networks is still not as mature as it is in terrestrial networks. Currently, ASICs, FPGAs, Network Processing Units (NPU), and CPUs are all considered as possible packet processing hardware on board satellites. One common shortcoming of all these approaches is the rigidity of the data plane protocol stack driven by Size, Weight and Power (SWaP) constraints. This makes it very difficult if not impossible to deploy novel data plane protocols, improve the network throughput, update or expand mission objectives, and collect in-network telemetry after launch. Programmable data plane technologies in terrestrial networks allow developing and deploying new packet formats and forwarding functions in operational networks. The same packet processing hardware can be used for different business objectives as the requirements and the techniques evolve. One of the key innovations promised by data plane programmability is the ability to collect new types of user data telemetry from inside the operational network by re-programming the data planes. Other possibilities include Quality of Service (QoS) enforcement and protection against denial-of-service attacks. P4 (Programming Protocol-independent Packet Processors) and POF (Protocol Oblivious Forwarding) are two examples open-source languages that enable network engineers to re-program the network data plane.</p> <p>This activity will investigate the use cases for programmable data planes for satellite constellation networks. FPGAs, NPUs, and CPUs shall be assessed and selected with regards to the availability of supporting compilers and vendor-specific external functions for programmability of their data planes used for space applications. A reference use case (6x6 10Gbps packet switch) and satcom protocol stacks (e.g. beyond at 3-levels MPLS, Source-Routing, CCSDS USLP, DVB GSE) shall be prototyped and tested on the selected packet processing hardware.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, satcom protocol stack software beta version.  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 5   |                |                |
| <b>Technology harmonised:</b> | N/A   |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | Yes   |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 02 - Space System Software  |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 7A.079                        | Q/V band phased array antenna for aeronautical applications  | 1,100          | B              |
| <b>Objective:</b>             | The objective of the activity is to design, manufacture, and test a Q/V band phased array antenna demonstrator for aeronautical applications, including the antenna radiating elements and the main passive components of the beamforming network.   |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- At least twice the number of beams and 3 to 4 times more compact volume compared to Q/V band mechanically scanning antennas.</li> <li>- 2 to 3 times reduced volume compared to Ka band antennas.</li> </ul>  |                |                |
| <b>Description:</b>           | <p>Today, terminal antennas are mainly exploiting Ka and Ku frequency bands. However, a growing number of satellite operators show interest in the emerging Q/V frequency band both for Geostationary Equatorial Orbit (GEO) and for Non-Geostationary Satellite Orbits (NGSOs). This includes new concepts envisaging service links to base stations and backhaul in Ka as well as in Q/V band. Required components and beamforming networks (BFNs) are increasingly becoming available, especially at Q-band, but these neither address the specific requirements of the satcom market nor cover the higher V-band range. For aeronautical applications, in particular, the Q/V band may enable improved performance (in terms of bandwidth, volume), while still maintaining acceptable link budgets with LEO/GEO satellites.</p> <p>In this activity, a Q/V band phased array antenna for aeronautical applications, suitable for GEO or NGSO satellites shall be developed. The demonstrator shall include antenna radiating elements and the main passive components of the BFN. Active commercial off the shelf (COTS) components will be included in the final demonstrator. Innovative solutions like those based on multilayer technology will be considered. A trade-off between two solutions will be performed: one with an antenna aperture combining both transmit and receive functionalities, and one with two separate antenna apertures for the transmission and reception. A single circular polarisation in transmit and a single orthogonal circular polarisation in receive mode can be considered. The antenna demonstrator will be capable of generating two simultaneous beams (minimum target 1 beam). Scanning capabilities between -55 and + 55 degrees in every azimuthal plane shall be guaranteed. A Q/V band demonstrator including 8x8 radiating elements and customised passive BFN to generate two simultaneous beams shall be manufactured (separate Q and V band apertures or a single combined aperture) and tested. Active COTS components will be included in the final demonstrator to guarantee integrability with passive components and to improve the demonstrator representativeness.</p> |                |                |
| <b>Deliverables:</b>          | Summary report; Q/V band antenna partial prototype.  |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | No   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 07 - Electromagnetic Technologies and Techniques   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 7A.083                        | Compact linear integrated amplifier for Ku, Ka, Q and V bands with high back-off efficiency  | 750            | B              |
| <b>Objective:</b>             | The objective of this activity is to design, manufacture and test amplifier topologies in advanced silicon technologies for Ku, Ka, Q and V frequency bands for ground segment user terminals.   |                |                |
| <b>Targeted Improvements:</b> | <p>With respect to state of the art:</p> <ul style="list-style-type: none"> <li>- Improvement of the DC-RF efficiency by 5 percentage point at given linearity.</li> <li>- Reduced silicon area by at least 20 percentage points.</li> <li>- Reduced total power consumption by at least 10 percentage points, in phased arrays antennas for user terminals.</li> </ul>  |                |                |
| <b>Description:</b>           | <p>Phased array antenna solutions in which the beam can be directed to different points in the sky with the speed, accuracy and wide-scanning angle needed for NGSO applications have been enabled thanks to advanced semiconductor and packaging technologies that allow us today efficient integration of the key RF elements. Despite the technology readiness, the key challenge remains unchanged: power consumption management linked to the compromised backoff efficiency of the RF amplifiers. Whereas significant efficiency improvement has been achieved for GaAs and GaN high-power amplifiers, this is not the case for amplifiers in silicon technologies (SiGe BiCMOS, RFCMOS, SOI, etc.) with output power levels below 20 dBm. Even for such low RF power levels, the efficiency of each individual power amplifier (PA) plays a key role in the power consumption of phased arrays for user terminals and needs to be improved.</p> <p>This activity will review existing backoff efficiency enhancement techniques suitable for implementation in silicon, covering aspects such as broadband functionality, DC-RF efficiency, linearity under wideband modulation and circuit complexity/area demands with a focus on user terminals. Semiconductor and packaging technologies will be reviewed, and the most promising concepts will be down-selected for implementation using multi project wafers (MPW) runs. Breadboards that incorporate packaged connectorised silicon amplifiers will be designed and manufactured. Test jigs for each frequency band will be developed and used to experimentally evaluate the performance of the developed amplifiers.</p> |                |                |
| <b>Deliverables:</b>          | Summary report; amplifier prototypes and associated test jigs.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 4  |                |                |
| <b>Technology harmonised:</b> | No   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies  |                |                |



| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 7B.082                        | Automated phased array factory calibration from radiation pattern using artificial intelligence   | 700            | B              |
| <b>Objective:</b>             | The objective of this activity is to develop automated factory calibration of phased arrays to improve the manufacturing process for satellite user terminals in the context of LEO constellations leveraging Artificial Intelligence and Machine Learning techniques.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Enable factory calibration (less than 1 second) from single-shot radiation pattern measurements of phased arrays.</li> <li>- Error between post-factory calibration theoretical should be below 0.5dB.</li> </ul>  |                |                |
| <b>Description:</b>           | <p>Traditionally, satellite manufacturing was focused on producing a limited number of bespoke satellites for GEO orbits. However, the rise of LEO constellations demands a shift towards mass production, requiring efficient assembly and testing processes. This statement extends beyond satellite payloads to LEO user terminals, where phased arrays are becoming ubiquitous for constant asset tracking. With satellite user terminal systems increasingly reliant on phased arrays, precise calibration becomes crucial for optimal performance.</p> <p>Calibration involves ensuring precise alignment and amplitude matching of each element to achieve optimal beamforming, thereby maximising signal strength, and minimising interference. Still, current manual calibration methods are mostly labour-intensive, time-consuming, and prone to errors, presenting a challenge to the efficiency goals of mass-manufacturing. To overcome this, there is a need to develop AI/ML solutions capable of extracting calibration insights from single-scan radiation patterns measurements. Previous research has demonstrated the potential of AI/ML techniques in synthesising radiation patterns, identifying faulty elements and predicting unmeasured phased values speeding up calibration of antenna arrays.</p> <p>Building upon these advancements, this activity will streamline the calibration process of phased arrays using AI/ML techniques. Rather than using brute force or iterative methods, the objective is to achieve fast calibration and accurate in a single shot. Additionally, the AI/ML engine will be capable to cope with process, voltage, and temperature variations inherent to the integrated circuits used in phased arrays, ensuring robust calibration across manufacturing batches. This approach not only addresses the immediate challenge of mass-producing user terminals but also lays the foundation for adaptable testing systems capable of accommodating variations across manufacturing batches. By transitioning from labour-intensive manual methods to streamlined single-shot calibration, manufacturers can achieve greater efficiency and accuracy in production. The developed calibration process will be implemented in a combined software and hardware test-bed that will be developed, and the performance of the developed calibration process will be tested.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and automated calibration algorithm and associated test-bed  |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | Yes   |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |



| Activity Ref.                 | Activity Title   | Budget (kEuro) | Classification |
|-------------------------------|--|----------------|----------------|
| 7B.083                        | Single aperture transmit-receive phased array antenna for Ka band terminals  | 1,200          | B              |
| <b>Objective:</b>             | The objective of this activity is to design, manufacture and test a single aperture transmit-receive flat panel antenna for broadband applications in Ka band.   |                |                |
| <b>Targeted Improvements:</b> | Decrease of antenna surface by up to 40% compared to separate aperture design.   |                |                |
| <b>Description:</b>           | <p>An increasing number of Non-Geostationary Satellite Orbit (NGSO) constellations using Ka band in the user link, have engaged into concrete plans for deployment. A key element of these systems is the user terminal, which needs to offer enhanced flexibility and compactness whilst remaining cost effective. The ability for these terminals to support transmit-receive (Tx/Rx) modes with a single radiating array aperture (as already available in Ku band) would significantly reduce the antenna dimensions compared to a solution utilising separate antennas for Tx and Rx. Combining Tx and Rx is challenging to implement in Ka-band due to the large gap between downlink I (17.2-21.2 GHz) and uplink (27.5-31 GHz) frequencies in contrast to Ku-band where the frequency gap is much smaller. For these reasons, at present, most of Ka-band flat panel user terminals are based on separate Tx and Rx antennas. Promising solutions are emerging to overcome such constraints, for example interlaced array designs and polarisation discrimination between Tx and Rx to achieve improved isolation.</p> <p>This activity will develop a partial prototype of a reduced size Tx/Rx antenna array in Ka band. The partial prototype shall implement the antenna array and the beamforming, either analogue, digital or hybrid, and be of sufficient scale to demonstrate the performance of the overall antenna. A reduced size Tx/Rx phased array hardware prototype of a broadband user terminal antenna will be manufactured, tested and the performance compared to a solution employing 2 separate antennas.</p> |                |                |
| <b>Deliverables:</b>          | Summary report and Ka band antenna phased array partial prototype.   |                |                |
| <b>Estimated current TRL:</b> | 3  |                |                |
| <b>Target TRL:</b>            | 5  |                |                |
| <b>Technology harmonised:</b> | No   |                |                |
| <b>Dependency:</b>            | None   |                |                |
| <b>S/W Clause:</b>            | No   |                |                |
| <b>Service Domain:</b>        | 5  |                |                |
| <b>Technology Domain:</b>     | 07 - Electromagnetic Technologies and Techniques   |                |                |





| Activity Ref.                 | Activity Title  | Budget (kEuro) | Classification |
|-------------------------------|---|----------------|----------------|
| 7B.084                        | Reduced-complexity analogue and hybrid beamforming networks   | 1,000          | B              |
| <b>Objective:</b>             | The objective of the activity is to develop and test a beamforming network with reduced hardware complexity (e.g., number of beamforming ICs or beamforming nodes) for mm-wave phased array antennas for ground terminals.  |                |                |
| <b>Targeted Improvements:</b> | <ul style="list-style-type: none"> <li>- Reduction of the number of beamforming chips by at least 50%.</li> <li>- Reduction of power consumption by at least 50%.</li> <li>- Reduction of silicon area, hence of costs, by at least 50%.</li> <li>- Reduction of digital control complexity by at least 50%.</li> </ul>   |                |                |
| <b>Description:</b>           | <p>Today's phased arrays rely on feeding elements, i.e., every element requires a dedicated channel that applies required beam weights (amplitude, phase steering) generated separately for each element (digitally or in polar/vector modulators). This approach is increasingly complex with the trends towards higher frequencies, where spacing between array elements cannot accommodate the required number of beamforming nodes or chips. Therefore, seeking concepts that reduce hardware complexity is currently among the most important topics in R&amp;D. One of the many approaches to reducing Beamforming Network (BFN) complexity is to seek symmetry in the phased array configuration (e.g., placement of radiating elements w.r.t the centre axis) or in the beams or the beam shapes that are generated. Then, the BFN feeding network can be simplified and symmetrical elements can be fed by a dedicated symmetrical BFN that requires fewer nodes.</p> <p>This activity will develop and test a beamforming network with reduced hardware complexity (e.g., number of beamforming ICs or beamforming nodes) by at least 50% while maintaining performance of array. Existing BFN concepts will be reviewed, covering digital, analogue, and hybrid BFNs. Hardware complexity reduction techniques will be explored, and two most promising concepts will be selected for implementation. Dedicated RFIC design activities are anticipated implementing a novel beamforming IC topology and BFN. A representative scaled version of a mm-wave phased array BFN will be implemented to demonstrate the hardware complexity and power consumption savings.</p> |                |                |
| <b>Deliverables:</b>          | Summary report, beamforming network breadboard.   |                |                |
| <b>Estimated current TRL:</b> | 3   |                |                |
| <b>Target TRL:</b>            | 4   |                |                |
| <b>Technology harmonised:</b> | No  |                |                |
| <b>Dependency:</b>            | None  |                |                |
| <b>S/W Clause:</b>            | No  |                |                |
| <b>Service Domain:</b>        | 5   |                |                |
| <b>Technology Domain:</b>     | 06 - RF Subsystems, Payloads and Technologies   |                |                |