



ARTES 4.0 Strategic Programme Line
“Space for 5G/6G and Sustainable Connectivity”

Work Plan 2024

Introduction

The 5G/6G Work Plan covers the high-level set of activities required to maximise the integration of satellite in 5G and support its commercial success. This document proposes the 5G/6G Work Plan for 2024.

2. 5G/6G Work Plan: 5G/6G Essential

The 5G/6G Essential element, i.e. the 5G/6G Work Plan, is designed to support industry in advanced technology developments that are key for the integration of satellite with terrestrial networks. These are considered essential technology developments that require ESA’s intervention to get industry started to develop these urgent 5G/6G-related satcom elements.

The validation of the developments, later referred as ‘5G Hub Over-the-Air Validation’, is also supported with testing over either existing space infrastructure or a new one. In the latter case, new space infrastructure will be developed as part of the 5G/6G Essential element.

Within this element, several categories that require ESA intervention have been identified. Each category corresponds to one or more activities to be placed with industry, as follows.

5G.01 - Standardisation/Licensing/Regulatory Support

Standardisation is a strategic step that will be supported to ensure future compatibility and interoperability of technologies. Great efforts have already been made over the past years, allowing the recognition of 5G New Radio (NR) Non-Terrestrial Network (NTN) within 3GPP. Additional efforts to support the standardisation of satellite 5G/6G component are foreseen, which will be implemented as part of ARTES Future Preparation activities.

5G.02 - 5G System Infrastructure Study

All technologies and system architectural options that may be the basis for European and global next-generation 5G infrastructure will be identified. That analysis will be used to determine technology readiness levels and to identify gaps that industry needs to address. The study will focus on three key areas: the overall system, the space segment and the ground segment.

5G.03 - 5G New Radio - Radio Access Network (NR-RAN) Developments

The development of Radio Access Network (RAN) techniques and protocols compliant with the recently-released 5G/6G standard is crucial and will be supported to enable the direct access via satellite to the terrestrial communication networks and therefore provide full integration and compatibility.

5G.04 - 5G Core Network Developments

The interoperability of satellite networks with terrestrial 5G/6G core networks is of paramount importance to guarantee full network convergence and a set of development activities are envisaged here.

In parallel, to enable inter-operability with other satellite non 5G/6G networks, the development of Non-3GPP Interworking Functions will also be initiated to demonstrate additional integration with 5G/6G core networks.

5G.05 - 5G Testbed Infrastructure

Adequate infrastructure is required to test the future new 5G/6G network functions, protocols and security for 5G/6G satellite nodes. Additional effort shall be initiated with regards to solutions for potential security vulnerabilities introduced by the adoption of 5G/6G NTN features.

5G.06 - 5G Universal Satellite-Terrestrial User Equipment (UE)

This category aims at supporting industry in developing universal (i.e. satellite-terrestrial), efficient and cost-effective user terminals. To achieve the required economies of scale, it is important to equip industry with essential user equipment building blocks compliant with the standards.

Activities within this category will focus on developing engineering breadboards, a reference protocol stack and implementing required modification to existing user equipment to enable 5G/6G satellite connectivity.

5G.07 - 5G Hub for Over-the-Air Validations

There is a degree of scepticism regarding the integration of satellite with terrestrial network especially based on historical challenges with Mobile Network Operators (MNO).

Promotion and validation are fundamental to overcome such perceptions. As explained above, the 5G/6G SPL introduces a development to validation approach. It aims at validating over-the-air the developments undertaken through the categories previously described in realistic conditions, namely, using existing space infrastructure and therefore foster the adoption of 5G/6G satellite technologies.

As part of the promotion of validation activities, ESA has built a 5G/6G Hub in ECSAT. The 5G/6G Hub enables stakeholders from different sectors to collaborate, develop and test new 5G and future 6G solutions. It acts as a catalyst for the proliferation of communities working on 5G/6G activities across the ESA Member States, facilitating their engagement and collaboration with one another.

5G.08 - 5G/6G Satellite Proof-of-Concept Missions

Complementary to the 5G/6G Hub over-the-air validations block, which utilises existing space infrastructure for validations, a set of 5G/6G satellite proof of concepts missions will be proposed to develop and validate new functionality requiring new space infrastructure. This is the case, for example, to demonstrate the functionalities of a 5G gNodeB in space as well as a direct 5G broadband access from LEO to very small aperture mobile terminals (proposed in the 5G/6G SPL Work Plan 2021), and the 6G Satellite Precursor proposed in this 5G/6G Work Plan 2023.

5G.09 - Beyond 5G (B5G) and 6G

The 5G and Beyond roadmap is rapidly evolving alongside the 3GPP standardisation process, with Beyond 5G (B5G) to be specified in the next releases (rel.18 to 20) and 6G after that (rel. 21 upwards). With the establishment of satellite firmly part of rel. 17 and beyond, it is important to start identifying essential building blocks to support and align to subsequent 3GPP releases B5G and 6G. For this reason, this new

category has been added to the 5G/6G Work Plan classification to prepare next stages of development and identify early building blocks required.

Implementation

All the presented categories aim at fostering the integration of satellite with terrestrial networks and are considered essential technology developments to stimulate and support industry. The Executive proposes the implementation of the 5G/6G Essential activities (i.e. the 5G/6G Work Plan) under the 5G/6G SPL, following the Specific Implementing Rules for the ARTES 4.0 Generic Programme Line “Core Competitiveness”, Component A “Advanced Technology”.

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

Parallel Contracts: In accordance with the ARTES 4.0 Specific Implementing Rules for the Generic Programme Line “Core Competitiveness”, Component A “Advanced Technology”, 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 in open competition, where a significant participation of non-LSIs is requested.
- C3: Activity 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 the draft 5G/6G Work Plan for 2024 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.

An ITT for activities designated Implementation Category B will automatically be generated by the Executive. Implementation Category B activities for which industry and/or a delegation declares an interest will be implemented as a priority. Such interest can be notified directly to the AT Programme Office.

An ITT for 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.

The Executive will inform the JCB of any request it receives for the initiation of an Implementation Category R activity.

The approved 5G/6G Work Plan, including the Implementation Category definition, will be published on esa-star. The activities of the approved 5G/6G Work Plan will be included in the AT Planned Activities Summary Table (<https://artes.esa.int/artes-planned-activities-summary-table>). That table will include the intended week of issue for each activity.

ANNEX I

Summary of Activities Proposed for the 5G/6G Work Plan 2024

Activity Ref.	Activity Title	Cost (k€)	Classification	Cost (k€) (Classification B)	Cost (k€) (Classification R)	Proc. Policy
Standardisation/Licensing/Regulatory Support						
3F.011	5G New Radio (NR) non-terrestrial network Release 18 protocol stack enhancements	1,200	B	1200	0	C
	Subtotal			1,200	0	
5G System Infrastructure Study						
3E.023	In-orbit demonstration of a Narrow Band Internet of Things (NB-IoT) Inter-Satellite Data Relay	800	B	800	0	C2
4E.093	Multifunctional hinge for large on-board direct satellite-to-device active antenna arrays	750	B	750	0	C
	Subtotal			1,550	0	
5G New Radio - Radio Access Network (NR-RAN) Developments						
3F.022	5G non-terrestrial network secure two-way ranging for LEO satellites	600	B	600	0	C
	Subtotal			600	0	
5G Core Network Developments						
3F.012	Network embedded hybrid connectivity over terrestrial and satellite 5G access	1,800	B	1,800	0	C
	Subtotal			1,800	0	
5G Testbed Infrastructure						
3F.015	Handover engine and testbed for satellite-based 5G non-terrestrial network	500	B	500	0	C
3F.017	Assessment of 5G non-terrestrial networks with sub-6GHz Time Division Duplexing (TDD) communications	600	B	600	0	C
3F.018	Future Railway Mobile Communication System (FRMCS) satellite system simulator for low frequency spectrum	650	B	650	0	C
3F.024	Protocol for 5G integrated networks to enhance reliable positioning	650	B	650	0	C
3F.023	Predictive Quality of Service (QoS) protocol for non-terrestrial networks in support of automotive services	3,000	B	3,000	0	C
	Subtotal			5,400	0	
5G Universal Satellite-Terrestrial User Equipment (UE)						
7C.093	Ka-band Satellite Terminal Prototyping for Future Railway Mobile Communication System (FRMCS)	900	B	900	0	C
7B.078	DVB/3GPP hybrid terminal for broadband applications	1500	B	1,500	0	C2
7C.094	Invisible phased array antenna to provide broadband connectivity on board cars	2000	B	2,000	0	C1
7A.076	On-chip active reconfigurable filters for 5G phased Array Antennas	2500	B	2,500	0	C1
3F.010	5G automotive makerspace	4000	B	4,000	0	C
	Subtotal			10,900	0	

5G Hub for Over the Air Validations						
3F.013	Protocol stack enabling voice-call using non-terrestrial IoT waveform	600	B	600	0	C
3F.020	Improvements to 5G throughput and efficiency using UE equipped with Galileo High Accuracy Service (HAS)	800	B	800	0	C
3F.014	Cloud-based signal processing in ground segment for use of standard 3GPP air interface	500	B	500	0	C
Subtotal				1,900	0	
5G/6G Satellite Proof-of-Concept Missions						
Beyond 5G (B5G) and 6G						
3F.019	Very low earth orbit system simulator for direct satellite-to-device 5G/6G communications	700	B	700	0	C
3F.016	Power efficient user plane functions for B5G small satellite platforms	2,000	B	2,000	0	C
3F.021	5G/6G enabled multi-cooperative systems	2,000	B	2,000	0	C
5A.088	Processor technology for direct satellite-to-device 5G/6G communications	4,000	B	4,000	0	C
Subtotal				8,700	0	
TOTAL (k€)				32,050	0	

ANNEX 2

Detailed Description of New Activities Proposed for the 5G/6G Work Plan 2024

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.011	5G New Radio (NR) Non-Terrestrial Networks Release 18 protocol stack enhancements	1,200	B
Objective:	The objective of this activity is to develop the software protocol stack for Release 18 enhancements related to 5G New for Radio (NR) for Non-Terrestrial Networks. The software protocol stack development shall be based on a testbed considering both the User Equipment (UE) and g-NodeB (gNB) features and operational procedures.		
Targeted Improvements:	Enable 5G NR NTN system performance simulations with the latest Release 18 modifications.		
Description:	The 5th generation of wireless broadband networks (5G) promised a new paradigm in communications, offering higher transmission rates, more Internet of Things (IoT) and internet application connections, high reliability, very low latency, and connectivity for remote areas. The 5G New Radio (NR) adaptations for Non-Terrestrial Networks (NTNs) have been introduced for the first time in the 3GPP Release 17 specifications, to support network offloading, coverage enhancements, connectivity resilience and service continuation in remote areas. With the support of the ARTES 5G Workplan, open-source software protocol stack versions have been implemented for NTN Release 17, starting from the Open-Air Interface (OAI) and from the SRS library. Based on the current 3GPP work item description, the new Release 18 will introduce further features related to the support and the enhancements of 5G NR services in satellite networks. Among the new features, it is recalled that NTN Release 18 will support downlink/uplink coverage enhancement techniques, network verified UE location capabilities, NTN-TN mobility enhancements for service continuity, and the support of above 10 GHz satellite frequency bands. The proposed activity shall thus foresee the following steps: a) Review the latest 3GPP specifications for the NTN scenario (i.e., Release 17) and identify the missing models and capabilities of the selected library to be enhanced with features of Release 18; b) Identify key features planned for Release 19 to be added to the library; c) Software design and development of the new functions in the protocol stack of both UE and gNB to support bi-directional communication links for both GEO and NGSO satellite networks; d) Thorough laboratory validation of the new software library capabilities. This activity should target publicly available licensing model (i.e., GPL licensing).		
Deliverables:	Summary report, Software		
Estimated current TRL:	3		
Target TRL:	4		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	ESA Software Community Licence		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3E.023	In-orbit demonstration of a Narrow Band Internet of Things (NB-IoT) Inter-Satellite Data Relay	800	B
Objective:	The objective of this activity is to proof that a standardised existing solution such as NB-IOT can be used for satellite-to-satellite low data rate communications.		
Targeted Improvements:	Introduce world's first standardised intersatellite data relay solution based on 3GPP NTN standards, opening up a new market for new companies and telecom operators to provide data solutions to Earth Observation missions via intersatellite data relay.		
Description:	This activity will take as a baseline the various NB-IoT NTN developments in industry and implement a data relay solution (LEO-GEO, LEO-MEO or higher LEO-lower LEO) based on these standards. The intention is to exploit the already existing GEO based NB IoT service providers (e.g., Inmarsat, Skylo, Echostar), that provide services to ground services, and use them to provide a connection to a LEO embarked NB-IoT user terminal. The activity will include an initial assessment of the system architecture and different trade-off between regulatory constraints, frequencies, data relay use cases and variations to the standardised air interfaces shall be made. A prototype of the NB-IoT NTN data relay user terminal modem shall be implemented and embarked on a small satellite, which would use a GEO based relay to interface with the corresponding eNB on ground.		
Deliverables:	Summary report, Prototype NB-IoT NTN UE for embarkation on small satellite, and ground-based NTN eNB		
Estimated current TRL:	3		
Target TRL:	6		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
4E.093	Multifunctional hinge for large on-board direct satellite-to-device active antenna arrays	750	B
Objective:	The objective of the activity is to develop and test a multifunctional hinge technology to accommodate a large multi panel active antenna array on a spacecraft platform, with integrated sensing to avoid adverse local deflections due to spacecraft dynamics.		
Targeted Improvements:	Enabling technology for very large active antennas with disperse panels to be accommodated on a spacecraft platform for future 5G/6G (direct to handheld) satellites		
Description:	Particularly for large active antennas, unique hinge solutions are necessary to accommodate many panels in a launcher. Conventional hinge solutions (e.g., fixed axis without integrated harness), are not considered feasible for very high numbers of active antenna panels. The proposed activity would develop a hinge compatible with the needs for large active spacecraft 5G/6G antenna arrays, for direct to handheld. The activity will take a multifunctional approach to address the problem areas including how to stow/deploy the necessary panels on the S/C, how to transfer the electrical power and signals, how to optimise the stiffness / thermal stability and monitor the position to maintain the necessary array flatness. Thus, a multifunctional hinge concept able to provide the necessary deployment, whilst also integrating electrical transfer and the ability to sense deformations at array level is considered an enabling technology in this domain. This activity encompasses the following task outline: - Perform literature review to elaborate large active array system needs - Perform system analysis to generate refine hinge level requirements - Preliminary design of Multifunctional Hinge, ending with trade-off to down select a baseline and backup - Detailed design of Multifunctional Hinge Development Models - Manufacturing of Multifunctional Hinge Development Models - Test campaign of Multifunctional Hinge Development Models (including mechanical and electrical) - Summary of verified performance and future development plan		
Deliverables:	Summary report and multifunctional hinge breadboard		
Estimated current TRL:	4		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.022	5G non-terrestrial network secure two-way ranging for LEO satellites	600	B
Objective:	Study, design and validate a secure two-way ranging protocol relying on 5G Non-Terrestrial Network (NTN) in LEO.		
Targeted Improvements:	Enable secure two-way ranging via future LEO 5G satcom services for target applications such as IoT sensors.		
Description:	All GNSS systems are principally based on one-way ranging and as such they are fundamentally vulnerable to spoofing and/or meaconing attacks, even in the presence of GNSS security mechanisms such as navigation message authentication or signal authentication. Over the last decade, secure two-way ranging techniques at physical layer have matured for short-distance terrestrial applications, including standardisation and commercial deployments based on rigorous security analysis. More recent work has proposed the utilisation of 5G New Radio (NR) waveforms to implement such secure two-way ranging techniques on the basis of 5G 3GPP terrestrial networks. Such techniques when periodically applied could assist GNSS receivers in eliminating even the most complex spoofing/meaconing attacks such as ab-initio (a.k.a. cold-start) spoofing but are today preconditioned to the existence of terrestrial 5G NR connectivity. For applications such as IoT in remote locations without terrestrial 5G connectivity, LEO satellite based 5G networks could offer an alternative solution. This activity shall analyse different 5G LEO satellite scenarios (transparent payload, regenerative payload or direct access to mobile) to determine whether the 5G NR waveforms which are considered for these NTN communication use cases could additionally support secure 2-way ranging. The study shall also demonstrate secure 2-way ranging in a testbed by implementing such 5G NR waveforms.		
Deliverables:	Summary report, two-way ranging protocol and testbed		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.012	Network embedded hybrid connectivity over terrestrial and satellite 5G access	1,800	B
Objective:	The objective of this activity is to design, develop and test a 5G system to support upper layer Access Traffic Switching, Steering and Splitting (ATSSS) mechanisms relating a User Equipment (UE) data session across dual terrestrial and satellite 5G access, as well as over dual 5G satellite access.		
Targeted Improvements:	- Enable dual 3GPP access. - Significant part reduction - Network and device centric system. - Enable 5G Core Network with an embedded application function (AF) for traffic related policy deduction. - Optimisation of multipath transmission protocols.		
Description:	Convergence of multiple radio access technologies such as terrestrial 5G and satellite bearers, is one of the key enablers in providing a diverse set of features to 5G and Beyond 5G (B5G) network users. Multi access (MA) connectivity can offer network resilience, seamless connectivity, traffic offloading, and bonding thus improving user experience and service reliability, essential features for critical, emergency response and vehicular communications. Currently, MA connectivity is mainly achieved through intelligent routing devices; that is proprietary Software Defined Wide Area Network (SD-WAN) developments, built on top of proprietary hardware platforms and deployed in addition to the existing end user devices and Core network infrastructure. This implies an additional layer of complexity on the hybrid connectivity fabric, which currently makes it impractical and costly. The introduction of MA-PDU (Multi access Protocol Data Unit) by 3GPP (Third Generation Partnership Project) in Release 16, and its enhancement as part of Release 17, challenges this issue, by enabling the so-called Access Traffic Steering-Switching-Splitting (ATSSS) feature, in which both 3GPP access (e.g., 5G access) and non-3GPP radio access technologies (RATs) can be used simultaneously. In the current studies, the satellite element is considered as a non 3GPP RAT. However, the integration of satellite access into 3GPP release 17 specifications dictates the development of novel ATSSS solutions where both terrestrial and satellite bearers, implement 5G (3GPP compliant) Access Therefore, the proposed activity will develop and test a novel 5G system to support upper layer ATSSS mechanisms relating a UE data session across two or more 3GPP RATs, namely dual terrestrial and satellite 5G access or dual 5G satellite access over LEO and GEO links. The main tasks to be delivered are the following: 1) Architectural adaptations to 5G Core Network and 5G User Equipment to support ATSSS enabled 5G terrestrial-satellite access; 2) Implement the Performance Measurement Function (PMF), both at UE and core network side; 3) Develop a 5G Core Application Function (AF) to deduce ATSSS decision policies; 4) Compare and optimise upper- and lower-layer multipath transmission protocols (ATSSS-LL, MPTCP, MPDCCP). The results and lessons learnt of this work, will provide inputs to the 3GPP relative standardisation working groups that are currently scoping the subject as part of System Architecture (SA), services and requirements working group – (SA1). The activity will seek synergies with ARTES SPL 5G deliverables and testbeds related to the subject.		
Deliverables:	Summary Report; Software/hardware deliverables (modified UE and 5G CN)		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.015	Handover engine and testbed for satellite-based 5G non-terrestrial networks (NTNs)	500	B
Objective:	The objective of this activity is to develop a machine learning (ML) engine that optimises handover between two different 5G networks, where at least one of them is a satellite-based non-terrestrial network (NTN). The activity will also provide the testbed to assess the handover key performance indicators in a laboratory environment.		
Targeted Improvements:	Identify and avoid higher risk handovers improving thus the handover success rate to reach at least 95%.		
Description:	The coverage extension promised by the integration of terrestrial and non-terrestrial 5G networks comes with technical challenges. Ubiquitous network access requires 5G user equipment capable to connect to both terrestrial and non-terrestrial networks directly. Handheld devices with omni-directional antennas operating in lower frequency bands is expected to support dual connectivity. Such devices will need to handover 5G connections between terrestrial and non-terrestrial networks. The number of handovers between gNBs and the success rate is important for the network as it influences the service unavailability. In low earth orbit (LEO) NTN deployments with satellites bearing regenerative payloads, the source gNBs can be implemented on-board while the target gNBs on ground. To initiate the handover process, the source gNB will send a request to the target gNB. In practise, a handover can be triggered by signal strength measurements, location information and other parameters such as Timing Advance (TA) values or doppler values exceeding a predefined threshold. Moreover, the handover rate may depend on the inclination orbit of the satellites, the antenna features, but also on the connection interval. Often, the network needs to take handover decisions while dealing with partial information, uncertainty, time constraints, and rapidly changing communication environment. The targeted machine learning solution shall assist the 5G NTN in developing the required cognition to improve the handover success rate to over 95%, decreasing thus the handover signalling load and the service interruption time to a minimum. This activity shall develop and test a machine learning (ML) engine capable to optimise the decision to handover connections between two different 5G networks, where at least one of them is a satellite-based non-terrestrial network (NTN). The associated development shall be of a modular architecture to allow future enhancement and shall be independent of the selected hardware and software implementation platform. The activity shall provide the testbed and means to validate the ML-based handover engine and verify its performance in a laboratory environment using commercially available computer platforms.		
Deliverables:	Summary report, machine learning based software for handover and testbed		
Estimated current TRL:	3		
Target TRL:	4		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.017	Assessment of 5G Non-Terrestrial Networks (NTN) with sub-6GHz Time Division Duplexing (TDD) communications	600	B
Objective:	The objective is to carry out an assessment of the NTN deployment of the 5G NR air interface in TDD mode and identification of technology gaps and constraints. Develop a software testbed implementing and testing the scenario.		
Targeted Improvements:	Improve the overall spectrum utilisation by up to 50% when using Time Division Duplex communication as per 3GPP standard.		
Description:	The 3GPP has specified for Non-Terrestrial Networks (NTN) the n255 and n256 bands, both operating in Frequency Division Duplex (FDD) mode and allocated at L- and S-band. Enabling Time Division Duplex (TDD) communications could further improve the overall spectrum utilisation in Frequency Range 1 (FR1). In addition, this could support the prospective of a unified NTN-TN scenario where the satellite components may dynamically assist terrestrial stations (e.g., in TDD communications with handheld operating at C-band). To pursue this objective, the NTN capability to support the TDD operations of the 5G NR needs to be assessed in detail, this shall include: - a coexistence study of MSS/FSS services and 5G TDD transmissions from space in FR1; - the assessment of the round-trip time and mobility (doppler, variable delay) effects on the radio interface efficiency, evaluating whether LEO and/or MEO based accesses in FR1 TDD can be employed (new solutions to support TDD NTN on the 5G PHY and MAC layer may be required); -the technological constraints coming from the space segment (e.g., digital processor, active antenna) limiting the actual performances of such system scenario. This activity is a system-level assessment of the 5G NTN operating in TDD mode providing a feasibility and performance analysis; PHY and MAC improvements on the 5G NTN stack shall be proposed. In addition, a software simulator implementing and testing the scenario shall be developed.		
Deliverables:	Summary report and software simulator		
Estimated current TRL:	3		
Target TRL:	4		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.018	Future Railway Mobile Communication System (FRMCS) satellite system simulator for low frequency spectrum	650	B
Objective:	The objective of this activity is to design a satellite system for FRMCS which is operating in the same frequency bands as the terrestrial counterpart (i.e., 900 MHz and 1.9 GHz), with the purpose to exclusively service the coverage gaps of the terrestrial network while avoiding interference. The performance of such system will be evaluated with the development of a system simulator.		
Targeted Improvements:	- Reduce by 80% the cost of the satellite system for FRMCS. - Reduce by 50% the cost of on-board railway terminals, by allowing a single terminal solution for terrestrial and satellite FRMCS connectivity.		
Description:	The Future Railway Mobile Communication System (FRMCS), being a successor of the GSM-R system, is planned to be operational before GSM-R's predicted saturation in 2030. Through standardisation work, satcom is established as a component of the future system, while it is found that the satellite integration into FRMCS is simplified when satcom is employing the 5G NR, which is the selected air interface for the terrestrial FRMCS access. However, the frequency bands for such a service via satellite and the design of the satellite system are yet to be concluded. The advantages of an innovative approach, where the satellite offers connectivity exclusively to the coverage gaps of such terrestrial network, have been recently reported. In fact, such a satellite system targeting only the terrestrial coverage gaps while ignoring the areas serviced by the terrestrial network, will have a lower complexity and overall cost, as fewer satellites of less capacity will be required. In addition, such a satellite system will be able to operate in the same frequency bands as the terrestrial network (i.e., 900 MHz and 1.9 GHz), as each network (terrestrial or satellite) will not be available in the same area where the other network operates and therefore they will not interfere with each other. This usage of the same frequency from the satellite and the terrestrial network not only facilitates the integration of the two networks into FRMCS, but also potentially allow the usage of the same terminal for both networks, a solution that is very favourable for railway operators. This activity will therefore investigate the design of a 5G NR based satellite system for FRMCS which exclusively targets the terrestrial network gaps of communication and operates in the same frequency bands as the terrestrial FRMCS network. The activity will include a traffic characterisation and capacity analysis for the terrestrial network gaps which will then feed the system design and the element sizing of the ground and space components. The impact of the railway-satellite channel for the 900 MHz and the 1900 GHz will also be thoroughly investigated. The best numerologies and 5G NR configurations will also be identified for such a satellite system. The work will be supported by the development of a system simulator which will investigate the FRMCS 5G NR satellite link performance and achieved C/I ratios under a variety of different orbits, system architectures, frequency bands, channel conditions and air interface configurations. The activity will also investigate and conclude on the feasibility of having a single modem and a single antenna equipped on board the trains, which offer connectivity both to the satellite and the terrestrial network at different time instances.		
Deliverables:	Summary report and system simulator		
Estimated current TRL:	3		
Target TRL:	4		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.024	Protocol for 5G integrated networks to enhance reliable positioning	650	B
Objective:	The objective of this activity is to design and develop a simulation testbed for secure delivery of assistance data with 5G satellite networks to enhance positioning.		
Targeted Improvements:	Foster the use of 5G satellite networks to enhance positioning with ubiquitous, reliable, and secure delivery of assistance data. Enable secure time and frequency synchronisation in existing or future telecommunication infrastructure.		
Description:	Various positioning use cases, such as high-accuracy or integrity, rely on receiving assistance data to enhance the positioning performance beyond what can be obtained by using messages broadcast by the global navigation satellite system (GNSS). Currently, the 5th generation (5G) terrestrial networks provide a native mechanism to delivery assistance data through the 3GPP LTE positioning protocol (LPP), enhancing the performance of mobile users within the coverage of the network in terms of time to first fix, position accuracy, and/or integrity. Important benefits of 5G terrestrial networks in this context include the intrinsic reliability and security of communication channels. The expansion of 5G to direct-to-device satellite networks in low-Earth orbit (LEO) will enable new use cases and enhance the existing ones, by providing continuous and ubiquitous connectivity across the globe. In terms of enhanced positioning, 5G satellite networks could adapt protocols and solutions of terrestrial networks to allow for secure delivery of the assistance data also to remote areas or to ensure no service interruption, enabling use cases such as autonomous shipping or GEO referencing sensor data. To achieve this, the protocols and solutions currently available in terrestrial networks need to be adapted and simulated for the satellite networks. Enhancing positioning with assistance data delivered through secure channels will also serve telecommunication infrastructure. It will bring the trust in time and frequency synchronisation, currently achieved by using unprotected GNSS messages. The activity will: 1) Review the relevant standards and study/identify network architectures providing assistance data to enhance positioning with 5G satellite networks. 2) Consolidate use cases and performance targets benefiting from secure delivery of assistance data, targeting worst-case positioning users requiring high-accuracy and integrity in relevant scenarios, such as in remote areas, denied environments, or during network congestion. 3) Design and develop a representative end-to-end testbed capable of simulating network architectures and modelling high-fidelity user environments considering the identified use cases. 4) Assess the performance of the assistance data dissemination with 5G satellite networks considering the consolidated use cases using the developed testbed.		
Deliverables:	Summary report, Simulation Testbed, Protocol		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.023	Predictive Quality of Service (QoS) protocol for non-terrestrial networks in support of automotive services	3,000	B
Objective:	This objective of this activity is to develop and test an extended protocol to address the support of predictive Quality of Service (QoS) in Non-Terrestrial Networks (NTNs). The activity will also undertake the necessary investigation and selection of data-driven algorithms to automate predictive QoS in NTN.		
Targeted Improvements:	Features enhancement to align NTN solutions in an integrated NTN/TN ecosystem in support to automotive services. This is a critical technology element to enable support of important automotive use cases.		
Description:	The 5G Automotive Association (5GAA) has developed the concept of predictive Quality of Service (QoS), now part of 3GPP standards for Terrestrial Networks (TN). This method allows to adjust application behaviour before the predicted QoS change takes effect, which is important in certain automotive use cases, such as remote and autonomous driving. QoS is measured in an objective way in 5G 3GPP for Terrestrial Networks (TN), this is done via a set of 5G QoS attributes [3GPP TS 23.501 cl. 5.7], e.g., packed delay budget and error rate. However, an equivalent or similar method is not available for NTN. The proposed activity will therefore investigate, trade-off, select and validate the following aspects: 1) model for services adaptation over NTN (e.g., LEO and/or multilayer NTN), time requirements, exchanging info in cars and network components (e.g., edge computer in car); 2) develop the architecture and the interfaces for integrated NTN/TN; 3) consider different deployment options of QoS provision in single/multiple operator domain and multiple MEC deployments typical in automotive i.e. roadside/car/onboard satellite; 4) develop prototype solutions and validate through testbed; 5) perform over-the-air demonstrations		
Deliverables:	Summary report, predictive QoS protocol and testbed		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	12 - Ground Station Systems and Networks		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
7C.093	Ka-band Satellite Terminal Prototyping for Future Railway Mobile Communication System (FRMCS)	900	B
Objective:	The objective of this activity is to design, develop and validate in a lab environment a Ka-band satellite terminal prototype (i.e., modem and antenna) allowing to offer 5G NR FRMCS services via satellite while equipped on trains.		
Targeted Improvements:	Ensure by 2030 the 100% coverage of railway lines by FRMCS and the consistency of passenger safety among the whole line.		
Description:	The Future Railway Mobile Communication System (FRMCS), being a successor of the GSM-R system, is planned to be operational before GSM-R's predicted saturation in 2030. satcom is already established as a component of the future system and extensive work already took place to trade-off the best candidate satellite scenarios for the FRMCS servicing. Among the various options considered in terms of frequency bands, satellite orbit and air interface, the work concluded that one of the most promising and mature scenarios for immediate service is a 5G NR transparent GEO system in the Ka-band. Nevertheless, specific 5G NR terminals that mitigate the particularities of the railway environment for such satellite system are currently not available. This activity will therefore pave the way for such a terminal, by designing and developing a HW-based, Ka-band satellite terminal prototype for future usage on board of trains and 5G NR FRMCS communication connectivity via satellite. The HW-based terminal prototype will include both a 5G NR FRMCS modem and a satellite antenna integrated [FDP1] as necessary to form a complete solution. The activity will be supported by existing literature and on-going ESA activities, which highlight the best 5G NR configurations (e.g., numerologies, multiplex scheme), the best antenna solutions (e.g., parabolic vs. flat panel) and the best train installation options (e.g., single vs. dual antenna) for the mitigation of the channel impairments. These technical conclusions will be incorporated into the HW-based modem and antenna solutions to form a state-of-the-art integrated terminal prototype. The integrated prototype shall use and/or upgrade COTS components (e.g., 5G modem parts, railway broadband antennas, RF front ends), and integrate them as necessary to adapt to the particularities of the satellite scenario. In addition, it shall be able to offer connectivity with existing transparent GEO satellites of today, without requiring modifications to the space segment and the feeder ground network component. The integrated solution however shall be able to achieve the demanding performance requirements of FRMCS despite the challenging railway-to- -satellite channel. The performance of the developed terminal prototype shall be validated in a laboratory environment with extensive testing under various realistic channel conditions.		
Deliverables:	Summary report and FRMCS terminal prototype		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
7B.078	DVB/3GPP hybrid terminal for broadband applications	1,500	B
Objective:	The objective of this activity is to design, develop and test a user terminal integrating DVB and 3GPP functions to enable seamless utilisation of satellite DVB-based systems, satellite 3GPP based systems and terrestrial 3GPP based systems in a single terminal.		
Targeted Improvements:	Foster the integration of conventional satellite interfaces with 3GPP satellite and terrestrial systems.		
Description:	The 5th generation of wireless broadband networks (5G) promised a new paradigm in communications, offering higher transmission rates, higher reliability, very low latency, and connectivity to remote areas. When the 3GPP included NTN (Non-Terrestrial Network) features in release 17 of its specification, satellite officially entered the 5G world. As of today, most of satellite broadband systems use the DVB-Sx standard, however as satellite players are starting to experiment with 5G NTN implementations, it is expected that future satellite systems will adhere to this air interface. It is anticipated that both interfaces will co-exist for a long period (considering the life cycle of satellite systems), opening the door to hybrid user terminals that could equally exploit both interfaces. Furthermore, as 5G keeps deploying in the terrestrial infrastructure, such hybrid terminals might combine satellite and terrestrial connectivity as well. This could introduce a variety of advantages in terms of availability (i.e., more systems available for diversity), connectivity resilience (hot link redundancy) and security (i.e. simultaneous data transmission through multiple paths, reducing the risk of data lost and interception).		
Deliverables:	Summary report and user terminal prototype		
Estimated current TRL:	3		
Target TRL:	6		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	12 - Ground Station Systems and Networks		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
7C.094	Invisible phased array antenna to provide broadband connectivity on board cars	2,000	B
Objective:	The objective is to develop and test a Ku or Ka band transparent phased array antenna to provide broadband connectivity on board cars.		
Targeted Improvements:	Develop a new class of phased array antennas for cars able to guarantee a seamless broadband connectivity with LEO satellites.		
Description:	There is today a significant interest to provide broadband connectivity to cars. This request is associated to the need to guarantee emergency services (such as police, firefighters, paramedics), environmental protections, healthcare (telemedicine), urban services, entertainment and autonomous driving. Next generation cars will be designed with large panoramic, transparent roofs. Therefore, broadband connectivity can be only enabled by developing large transparent antennas in Ka-band integrated in the car glasses (windows, panoramic roof, windshield, etc). Connections with Low Earth Orbit (LEO) satellites, as compared with connection with GEO satellites, offer a significant advantage in terms of link budget but poses additional challenges in terms of antenna pointing angles and extension of the angular field of view. The antenna is expected to be able to point a beam everywhere inside a conical region with a minimum angle of 30 degrees elevation as compared to the horizon. Exploiting higher frequency, Ku or Ka-band, guarantees some advantages in terms of link budget. However, an antenna with reduced thickness on the top roof of the car cannot provide an acceptable gain level unless a significant portion of the roof is used. In this activity a transparent phased array antenna able to provide a broadband connectivity with LEO satellites shall be developed. A Ku or Ka band operational frequency shall be considered. Antennas with limited dimensions integrated on glasses have been already developed for other applications and this type of placement guarantees an almost invisible antenna with a negligible impact on the car aesthetics. These antennas could be considered as a starting point for the design of a reconfigurable array. In the first part, a phased array antenna shall be developed. In the second part, a scaled fully representative demonstrator of the antenna shall be manufactured and experimental testing shall include usable bandwidth, sidelobe levels, cross-polarisation and grating lobe levels.		
Deliverables:	Summary report and scaled fully representative demonstrator		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	07 - Electromagnetic Technologies and Techniques		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
7A.076	On-chip active reconfigurable filters for 5G phased Array Antennas	2,500	B
Objective:	The objective of the activity is to design, build and test reconfigurable Radio Frequency Integrated Circuit (RFIC) filters, and demonstrate their benefits on a C-Band antenna array demonstrator for 5G.		
Targeted Improvements:	Enabling a variety of terrestrial/satcom 5G use-cases currently not feasible at C-Band.		
Description:	Phased array antennas provide an efficient way to steer and direct the radiated RF energy in terrestrial 5G applications such as base stations and fixed wireless access (FWA) terminals. However, the performance and benefits of the phased array can be limited by trade-offs within the constituent RF chains, particularly when considering interference from terrestrial and satellite networks co-existing at C-Band. The ability to reconfigure the bandwidth of a RF chain to control the effects of emissions and interference is therefore a desirable capability in future mid-band 5G services. As an example of the advantages of the proposed concept, a wideband and dynamically programmable array operating over C-Band (e.g., 3.3 to 7.0 GHz), could achieve a combination of passband system noise figure and rejection of out-of-band interference by optimising the filter's transfer function for various operating and interference conditions. Such a flexible array architecture would in fact enable a variety of 5G use-cases currently limited by interference (e.g., Connected Car, Aeronautical and 5G FWA terrestrial/satellite dual-connectivity). It could also support use-cases requiring high 5G data rates on both uplinks and downlinks simultaneously from a single node. This activity aims at developing a new class of reconfigurable filters, suitable for integration in intermediate RF stages, where very compact size is required but relatively high losses are acceptable. A review of RFIC-based filter technologies and techniques shall be carried out, including silicon, PIN diode, MEMS as well as switchable filter banks. The activity will trade off, design, and manufacture the required RFICs to cover a variety of C-Band application scenarios requiring hybrid terrestrial/satellite connectivity. A small 16x16 C-Band array demonstrator, representative of the identified C-Band scenarios, shall be designed, manufactured, and tested to validate the benefits of the new RFICs (COTS could be used for other RF/Antenna components). Key performance such as linearity, tuning time, tuning range, power consumption and size of the specific RFICs shall be analysed at both device and system levels. To assist the antenna designer in optimising the benefit of these degrees of freedom, a software tool comprising an accurate behavioural filter model shall also be developed.		
Deliverables:	Summary report; RFIC filter prototypes; 16x16 antenna array (reduced scale prototype).		
Estimated current TRL:	4		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.010	5G automotive makerspace	4,000	B
Objective:	The objective of this activity is to design, develop and test automotive prototypes following 5GAA workplans and increase the number of companies working on automotive satellite communications by 30%.		
Targeted Improvements:	Novel hand-over methods between satellite and terrestrial networks supporting use cases as formulated by 5GAA and miniaturised automotive terminal baseband units.		
Description:	The 5G Automotive Association (5GAA) workplans highlight various architectures and technologies that need to be developed to enable automotive satellite communications. These range from antenna integration, protocol development, 5G NTN prototypes with specific automotive characteristics and predictive terrestrial-satellite handover for 5G automotive connectivity. This activity will support the evolving 5GAA workplans and carry out up to about twenty five prototyping activities. This will include novel automotive antenna integration concepts, novel handover schemes and 5G air interface robustness tests. As the 5GAA workplan is continuously evolving, subsequent further prototyping activities will be defined by ESA during the activity, in accord with the prime contractor. This will allow initiating small prototyping activities in line with work-areas defined in the 5GAA workplan. The activity will engage with the community of start-up companies, university spin-offs, very small companies which often implement projects in the spirit of open-source hardware and full sharing of intellectual property, and normally do not engage with ESA. A prime contractor will be responsible managing separate individual development contracts defined by ESA and placed with suitable sub-contractors. The prime contractor will be a single interface to ESA.		
Deliverables:	Summary report, 25 relevant prototypes that address at least 25 techniques or technologies that are proposed in the 5G AA Workplans.		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.013	Protocol stack enabling Voice-call using Non-Terrestrial IoT waveform	600	B
Objective:	The activity aims at the development of new functions in the protocol stack, in support of voice calls using the latest NTN NB-IoT waveform. The activity shall select the most promising voice encoder/decoder technology and shall demonstrate its fixability over a NB-IoT communication link via satellite.		
Targeted Improvements:	Enrich the portfolio of satellite services supported with the NB-IoT technology.		
Description:	With the endorsement of the Release 17 NTN NB-IoT specifications from the 3GPP community, new satellite services are recently announced based on this M2M/IoT technology. Currently, these services are intended only for short messaging and positioning information in the context of Machine-to-Machine (M2M) applications. On the other hand, relatively broadband type of services supported by the 5G NR standard is difficult to be initiated at the satellite L-/S- band, due to the limited capabilities of the current legacy systems and the need for dedicated non-geostationary satellite constellations. Looking at Voice-over-IP (VoIP) services, the latest AMR (Adaptive Multi-Rate) codec works with variable bit rates ranging from 4.75 to 12.2kbps, and with 20ms data arriving interval among the data packets. Consequently, it is of interest to evaluate the adoption of the NB-IoT standard to support voice calls in satellite networks. The activity shall therefore undertake the following steps: a) Review the latest 3GPP specifications for the NTN scenario (i.e., Release 18) and the identified solutions for satellite coverage enhancements; b) Given the current state-of-the-art AMR codec, design and develop the new functions in the protocol stack of both UE and gNB to support VoIP services for NGSO satellite networks; c) Thorough laboratory validation.		
Deliverables:	Summary report, software		
Estimated current TRL:	3		
Target TRL:	4		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

EUROPEAN SPACE AGENCY
Industrial Policy Committee
Procurement Proposal for ARTES 4.0 Strategic Programme Line “Space for 5G/6G and Sustainable Connectivity” for 2024

Procurement Policy
Price type
Weighting

Open Competitive Tender Type: C
Firm Fixed Price
Factor 1

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.020	Improvements to 5G throughput and efficiency using User Equipment (UE) with Galileo High Accuracy Service (HAS)	800	B
Objective:	Improve the timing and positioning accuracy of a 5G User Terminal through the use of Galileo HAS to improve synchronisation and reduce user link offsets and guard times, thus improving latency and throughput.		
Targeted Improvements:	Galileo HAS offers an order of magnitude improvement in positioning accuracy for receivers compared to a standard GNSS signal. All 5G user terminals rely on GNSS for timing and synchronisation, therefore such an improvement in accuracy will enable a corresponding reduction in timing offset and guard times.		
Description:	Future 5G systems will benefit from increased throughput through higher accuracy timing signals. Galileo HAS signals are already on air and a 5G user terminal would benefit using HAS to improve synchronisation and reduce user link offsets and guard times, thus improving latency and throughput. This activity will develop a breadboard prototype of a 5G user terminal implementing Galileo HAS receiver. Testing will include an over the air field test.		
Deliverables:	Summary report, breadboard prototype		
Estimated current TRL:	3		
Target TRL:	6		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	12 - Ground Station Systems and Networks		

EUROPEAN SPACE AGENCY
Industrial Policy Committee
Procurement Proposal for ARTES 4.0 Strategic Programme Line “Space for 5G/6G and Sustainable Connectivity” for 2024

Procurement Policy
Price type
Weighting

Open Competitive Tender Type: C
Firm Fixed Price
Factor 1

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.014	Cloud-based signal processing in ground segment for use of standard 3GPP air interface	500	B
Objective:	Development of a cloud-based system for pre- and post-processing of standard 5G NR signals in a satcom environment.		
Targeted Improvements:	Enable signal processing hosted on a cloud service.		
Description:	Multiple start-up operators, often backed by cellular network operators, have proposed direct-to-handheld services using standard terrestrial mobile phone terminals and sophisticated gateway-side signal processing, to allow the use of existing terrestrial protocols over a satellite link and interoperability with terminals in a terrestrial band. For a global system, where traffic demands vary over the course of 24 hours, deployment of expensive compute resource to cover peak demands in each region mean systems will not be fully utilised all of the day. This activity shall analyse traffic demands, building on existing work that has developed models for signal processing of 5G NR in satellite networks. It shall then develop a concept of cloud-based signal processing, sizing the system for peak demand and evaluate the system performance. A testbed shall be developed to carry the testing and evaluation of the selected cloud-based signal processing concept.		
Deliverables:	Summary report, cloud-based signal processing concept and testbed		
Estimated current TRL:	3		
Target TRL:	4		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	05 - Space System Control		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.019	Very low earth orbit system simulator for direct satellite-to-device 5G/6G communications	700	B
Objective:	The objective of the activity is to develop and test a system simulator testbed capable of modelling and assessing the performance of communication satellite constellations operating in Very Low Earth Orbit (VLEO). This includes the assessment of the emerging waveforms (5G NTN, European Protected Waveform).		
Targeted Improvements:	Enable the design and assess the constellation system performance of communication satellites operating in VLEO.		
Description:	Very Low Earth Orbit (VLEO) satellites, operating at altitudes below 300km, offer several communication benefits such as: 1) Improved link budgets enabling new applications (e.g. direct to handheld communications), where the lower distance between satellite and ground implies a lower power requirement on board the satellite; 2) Higher coverage granularity: The closer distance to ground leads to smaller beam footprints for a given antenna size, improving the possibility of reusing spectrum and increasing the overall flexibility and capacity of the system; 3) Use of COTS components: VLEO satellites are subject to a milder radiation environment and enable tight components integration due to the reduced power requirements; 4) Lower Latency: VLEO satellites are positioned closer to the earth's surface than traditional LEO satellites, which results in lower latency communications. However, the use of orbits below 300km introduces new challenges in the satellite systems design, including: • Higher Doppler effects • Shorter pass-times, leading to frequent handovers between satellites. Very high number of satellites to achieve global coverage, increasing the complexity of the interconnections and resource allocation of constellations Unlike conventional LEO constellations, the performance of VLEO has not been thoroughly assessed, especially for what concerns the use of 5G NR waveform. The 5G Air interface is desirable for VLEO systems because it leads to lower power and lower latency, which are crucial for seamlessly integrating the space segment with the terrestrial cellular network. A system simulator will be developed that can model large number of VLEO satellites and is able to evaluate their performance at a system level. This tool would also support the definition of high-level requirements for VLEO payloads in terms of antenna size and required RF power, as well as the development of customised communication payloads within ESA Member States.		
Deliverables:	Summary Report, VLEO constellation combined hardware and software simulator		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	08 - System Design and Verification		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.016	Power efficient user plane functions for B5G small satellite platforms	2,000	B
Objective:	The objective of this activity is to develop and test a power efficient 5G User Plane Function (UPF) prototype, implemented onto space enabled hardware platforms. The development will leverage concrete laboratory results of various RAN splits and compensate for their impact on the 5G protocol stack. Finally, system integration with a ground segment control plane will be tested, over emulated LEO constellations		
Targeted Improvements:	- At least 50 % power consumption reduction when compared to terrestrial 5G user plane deployments. - Reduced user plane latency. - Reduced control plane signalling. - Device to device communications over 5G-enable satellite payloads. - Develop a 5G user plane prototype on space enabled hardware.		
Description:	Amongst all, regenerative payloads could provide delay sensitive communications, neutral hosting services for cross-border service continuation, store and forward operations, and connectivity among two or more 5G User Equipment (UE) devices for emergency response and disaster relief services. Due to their low cost and short production cycles, small satellites are attractive to host 5G enabled payloads. In contrast to terrestrial 5G Radio Access Network (RAN) and Core Network (CN) deployments, on board payloads are bound to stringent power, and mass constraints imposed by the platform. As an example, a typical microsatellite can support an average of 100W power for pure payload operations, whereas a typical 5G terrestrial network, can consume over 2000W assuming high availability within a virtualised network infrastructure. It is apparent that to fit a 5G payload under these rigorous restrictions, a high degree of optimisation is required to current RAN and CN deployments. Currently, there are various options being considered within the NTN community, to shape the on board B5G regenerative payload. However, there are no studies with respect to power consumption, signalling overhead and standardisation impact of these options. This activity will develop a modified 5G RAN protocol stack and user plane functions to reduce the latency and power consumption by 50%. This will include signalling reduction techniques over the N2 and Xn interfaces, between the on-board user plane and ground segment control plane infrastructure as well as traffic influencing to steer non-critical traffic. A UPF prototype will be designed, manufactured. Testing will include device-to-device communication (unicast, multicast and broadcast) over emulated LEO constellations. Outputs of this activity shall be available to standardisation bodies.		
Deliverables:	Summary report, Lightweight UPF prototype; Space enabled RAN and UPF system prototype; System demonstration using emulated LEO constellations		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3F.021	5G/6G enabled multi-cooperative systems	2,000	B
Objective:	The activity shall develop the quadruplets and drones integrated 5G/6G communications system and the full AI-stack to enable the multi-cooperative autonomous operability.		
Targeted Improvements:	Reduce by a factor of 10 the time required for generating large scale, high-fidelity, site mapping.		
Description:	It is understood that hybrid terrestrial-satellite networks could enable multi-collaborative scouting robots and drones for a variety of applications. Mobile robots operating collaboratively will necessitate very large bandwidth and expeditious data transfer rates, which can be attained through 5G or even with a higher degree of impact, through 6G networks. The 5G satcom connectivity will allow the quadrupeds and the drones to communicate in real time, providing resilient, ubiquitous and seamless connectivity. Thereby this will furnish them with the capacity to coordinate their response promptly and accurately. Moreover, 6G could provide ultra-low-latency connections to allow the robots and drones to react quickly to alterations in their environment as well as instantly respond to telecommand in case human control is required as a back-up option. Furthermore, 6G could offer the robots and drones access to powerful AI capabilities, permitting them to make intricate decisions and respond quickly to varying conditions. Finally, 6G could provide the essential security measures to protect the data shared between the robots and drones, guaranteeing it is not compromised. One area of particular interest is the implementation of 5G/6G-enabled multi-collaborative scouting robots and drones interconnected by Artificial Intelligence (AI) and advanced computer vision, enabling autonomous collaborative site mapping. A team of mobile robots (quadrupeds and drones) equipped with this technology can autonomously determine where to explore and interact with the environment. With the support of satellite communications, this concept can be used for various applications, including security site mapping and disaster recovery on Earth. Additionally, similar concepts could also be applied to deep space planetary scouting in areas that fall beyond the reach of traditional wheeled rovers. Processing the data collected in a centralised manner would lead to excessive delay, which is not suitable for applications that require extremely rapid response times, such as disaster recovery. Therefore, one of the key factors to assess in this activity is the use of the advanced edge AI technology.		
Deliverables:	Summary report, set of 4 quadrupeds and one drone, AI-stack development and 5G/6G interfaces		
Estimated current TRL:	3		
Target TRL:	6		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	Yes (standard IPR regime applies)		
Service Domain:	5		
Technology Domain:	12 - Ground Station Systems and Networks		

Activity Ref.	Activity Title	Budget (kEuro)	Classification
5A.088	Processor technology for direct satellite-to-device 5G/6G communications	4,000	B
Objective:	The objective of this activity is to design, develop and validate through testing a scaled demonstrator of a regenerative digital processor supporting NTN 5G/6G waveforms for direct satellite-to-device communications, being highly power efficient, manufacturable efficiently in large quantities, using COTS elements and suitable for the deployment in V/LEO space environments.		
Targeted Improvements:	- 25% improvement in link budget. - 50% reduction in power consumption and size. - Enabling direct satellite-to-device 5G/6G communications through Non-Terrestrial Networks (NTN), currently not available.		
Description:	Current developments for regenerative payload processors are in progress however further advancements are required. in view of direct satellite-to-device 5G/6G communications, the development of a bespoke 5G/6G regenerative processor is essential, to achieve high power-efficiency, compact, low-cost, volume production, supporting of high data throughputs, scalable, future-proof for the next generation of 5G/6G waveforms The advent of low and very low earth orbit constellations (V/LEO) coupled with the recent developments in 5G/6G satellite technologies create an opportunity for such regenerative processors. It is anticipated that the integration of terrestrial 5G New Radio access with non-terrestrial-networks (NTN) satellite access enables ubiquitous connectivity to handheld and non-hand-held 5G/6G devices, including IoT devices, which can switch seamlessly between terrestrial and satellite networks. To achieve a high level of integration, innovative satellite payload concepts are required such as V/LEO satellite architectures utilising active antennas and onboard regenerative digital processors to support reconfigurability, flexibility, frequency hopping and dynamic frequency and power allocations on a per-beam basis, together with alignment to future NTN radio access technologies, in particular future 3GPP releases. Network resilience is another important key factor, as well as the realisation of economies of scale. This activity will design, develop and test a scaled demonstrator of a regenerative digital processor for 5G/6G. The activity shall encompass the consolidation of requirements, the design of a bespoke 5G/6G NTN regenerative processor reference architecture that supports the objectives of low power-consumption, volume production, economies of scale, high data throughputs, scalability, 3GPP NTN compatibility and network resilience as required for the usage in V/LEO satellite constellations targeting 5G/6G communications needs. The demonstrator shall validate critical elements of the regenerative processor technology. The demonstrator shall be verified against functional requirements on regenerative payload operations and the processor configuration. Finally, the technology shall be demonstrated in a test configuration, simulating a typical use-case set-up, compatible with the latest satellite NTN 3GPP release.		
Deliverables:	Summary report and a scaled demonstrator analysing the uplink and downlink signals, compatible with the latest release of 3GPP.		
Estimated current TRL:	3		
Target TRL:	5		
Technology harmonised:	No		
Dependency:	None		
S/W Clause:	No		
Service Domain:	5		
Technology Domain:	06 - RF Systems, Payloads and Technologies		