

**European Space Agency**  
**ARTES 4.0 Strategic Programme Line**  
**“Space Systems for Safety and Security” (4S)**

**Work Plan 2025**

## **1. Introduction**

Our society and economy are increasingly dependent on secure telecommunications networks. These networks are required for the secure operation of critical infrastructures, governmental services or in transport. They may constitute a systemic point of failure with major safety and security threats, particularly during disruptions caused by natural or human-made disasters or by cyberattacks. Satellite communications can provide a secure space component as a self-standing element or in complement to the terrestrial telecommunications system.

In 2019, ESA Member States decided to focus their efforts on this domain by the creation of a Strategic Programme Line named “[Space Systems for Safety and Security \(4S\)](#)” under the [ESA ARTES](#) (Advanced Research in Telecommunications Systems) programme. The 4S Strategic Programme Line objective is to support the development of Next Generation Satcom Systems aimed at providing secure, safe, and sovereign communications for governmental/institutional and public regulated services and ensuring resilience to society’s critical digital infrastructures.

As part of the 4S strategic action, the Work Plan aims to support the development of critical technologies deemed essential to support the future implementation of safety and security satcom systems.

In September 2024, a further 12 Work Plan activities were approved for 2025. 6 Additional activities have been approved in February 2025 as additions to the Work Plan. The full list of activities can be found in Annex I and described in Annex II.

## **2. Implementation**

The implementation of the 4S Work Plan activities under the 4S SPL 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 4S Programme Office via the contact email address: [artes-4S@esa.int](mailto:artes-4S@esa.int).

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 4S WORK PLAN 2025

Activity Ref.	Activity Title	Cost (k€)	Classification	Cost (k€) (Classification B)	Cost (k€) (Classification R)	Proc. Policy
<b>1. SYSTEM/ NETWORK / PROTOCOLS</b>						
<b>1.1 System, Networking and Management</b>						
3A.207	Resilience-by-design of satcom systems and services study	500	B	500	0	C
3A.221	Space-Based RF Interference Geolocation leveraging existing in-orbit assets	1,500	B	1,500	0	C
3A.222	Exploiting the synergy between ground- and space-based RF monitoring systems	1,000	B	1,000	0	C
3A.223	Optimisation of the spectrum utilisation leveraging existing space- and ground-based RF monitoring systems	1,000	B	1,000	0	C
3A.225	European VDES reference architecture and related standardisation, interoperability and regulatory activities	500	B	500	0	C
3A.226	Towards an infrastructure supporting the hyper-connected vessel	900	B	900	0	C
3A.227	Towards an infrastructure supporting the hyper-connected aircraft	900	B	900	0	C
3E.030	Over-the-air demonstration of VHF Data Exchange (VDE) overlay broadcasting and ship-to-ship communication via satellite	2,800	R	0	2,800	C
<b>Subtotal</b>				<b>6,300</b>	<b>2,800</b>	
<b>1.2 Coding, Modulation and Access</b>						
3C.051	Space-Based ADS-B Phase Overlay Receiver	650	R	0	650	C
<b>Subtotal</b>				<b>0</b>	<b>650</b>	
<b>1.3 Security and Cryptography</b>						
3D.034	Secure Software Defined Networking Module for Space Networks	800	B	800	0	C
3D.035	Security Module for high-speed inter-satellite link data rate	1,500	B	1,500	0	C
3D.033	Mobile Network Security Assessment Equipment for 5G Non-Terrestrial Networks (NTNs)	1,750	B	1,750	0	C



3E.031	In-Orbit Secure Telecom Laboratory	8,500	B	8,500	0	C
<b>Subtotal</b>				<b>12,550</b>	<b>0</b>	
<b>2. SPACE SEGMENT - PAYLOAD</b>						
<b>2.1 RF Repeater and Signal Processing</b>						
5C.533	Multi-octave wide band receiver to geo-locate interference sources	1,200	R	1,200	0	C1
5C.534	Interference mitigation analog engine for Ku/Ka Phased Array Antenna	700	R	700	0	C
<b>Subtotal</b>				<b>1,900</b>	<b>0</b>	
<b>3. GROUND SEGMENT</b>						
<b>3.1 TT&amp;C/Satellite Ground Equipment and Support</b>						
6A.096	Secure segregated payload operations ground segment services	1,500	B	1,500	0	C
<b>Subtotal</b>				<b>1,500</b>	<b>0</b>	
<b>4. USER TERMINALS</b>						
<b>4.1 Professional User Terminals</b>						
7A.082	Integrated Satellite/Coastal terminal for small Maritime Uncrewed Surface Vehicles used in maritime safety applications	900	B	900	0	C
<b>Subtotal</b>				<b>900</b>	<b>0</b>	
<b>4.2 Consumer User Terminals</b>						
7B.088	AI-enhanced adaptive antenna array for Satcom terminals for automatic interference detection and Mitigation	1,000	B	1,000	0	C
<b>Subtotal</b>				<b>1,000</b>	<b>0</b>	
<b>TOTAL (k€)</b>				<b>24,150</b>	<b>3.450</b>	



## Annex II: DETAILED DESCRIPTION OF NEW ESA-INITIATED ACTIVITIES PROPOSED FOR THE 4S WORK PLAN

### System/Network/Protocols

#### 1.1 System, Network and Management

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3A.207	Resilience-by-design of satcom systems and services study	500	B
<b>Objective:</b>	The objective of this activity is to perform an analysis of the applicability of the resilience-by-design concept for the design of future satellite communication systems, to identify innovative system design and operations concepts, methodologies and technical solutions, and deliver a technology development roadmap. This will drive the definition of a set of intelligent system design optimisation tools for which a parametric optimisation model will be developed as a first step.		
<b>Targeted Improvements:</b>	Enabling the development of resilient satcom systems and services to offer continuous services under the harshest conditions, adopting a resilience by design approach.		
<b>Description:</b>	<p>In the last decade, the global community has moved away from a peaceful world, where efforts were centralised on expanding reliability, coverage, and performance of space systems and services, to a world where disasters and hybrid threats in quasi-peaceful environment became common, and where an increased number of attacks and impactful disruptions of our critical infrastructures are foreseen, calling for a proper protection thereof. In this context, it is crucial to explore new approaches to enhance the resilience of the next generation of satellite communications systems. It is proposed to study resilience by design as a novel approach to ensure that future satcom assets and services are developed to be foundationally resilient. The objective is to offer uninterrupted communication services under harshest conditions possible (e.g. deprivation of launch capabilities and orbital access during deployment, loss of more than a third of space segment assets and/or ground control assets due to catastrophic events), all while enhancing the competitiveness and readiness of ESA Member States industry. This activity will follow the approach described below:</p> <p>In a first step, the activity will identify and assess current and future threats and risks on next generation of commercial / governmental satcom systems, considering pertinent use cases in need of a robust / uninterrupted satcom service, listing threats (e.g. space debris and weather, kinetic/non-kinetic attacks, non-physical / electronic attacks) by categories and assessing their likelihood of occurrence over the time horizon and their impact and consequences, and deriving related risks. Those threats would be ranked by assessing at a high-level their economical and societal consequence for ESA Member States. For high priority threats and risks, the activity will identify current and future mitigation concept / techniques and protection measures and their associated future technology developments. A framework shall be proposed, able to numerically assess their effectiveness in terms of resilience measure.</p> <p>The activity will in parallel focus on the development of a parametric optimisation model that aims to deliver a formalised framework towards a full system resilience architecture optimisation, targeting system cost, system resilience measure, and overall performances. As a minimum, a baseline use case example will be implemented within the model, addressing relevant multi-mission multi-service system operating in multiple-threat scenarios. The parametric optimisation model shall be capable to assess dynamically and flexibly: 1) The multidimensional, value-driven resilience optimisation trade space related to resilient satcom system / services design, and related key system design and cost drivers. 2) The limitations of mitigation technologies and protection measures on the overall system architecture level. 3) The cost of technology implementation to counter identified threats, and the financial and/or societal consequences of losing the service/system. 4). The low-hanging fruit in terms of concept or technologies that will greatly improve the robustness at a low cost.</p> <p>A development roadmap shall be proposed to evolve the parametric optimisation model concept into a full-scale resilience-by-design intelligent optimisation tool. The applicability of multi-layered deep learning (DL) development and deployment approach for the next development step shall be assessed. Using the parametric optimisation model, the activity shall perform a high-level technology gap assessment and identify the technological delta between current and future design concepts and methodologies, techniques and countermeasures to mitigate identified risks. A technology development roadmap addressing a timespan of up to 10 to 15 years shall be proposed, to provide recommendations on future, low TRL technologies and development activities for the next generation of satcom systems addressing both commercial and regulated sectors, and governmental</p>		



	services and to identify new approaches for their implementation. For the identified protection measures, technologies and/or concepts, high-level requirements will be defined, and development costs and timeline will be estimated.
<b>Deliverables:</b>	Summary report, threat and risk assessment, technological gap analysis, technology roadmap, high-level parametric optimisation model.
<b>Estimated current TRL:</b>	2
<b>Target TRL:</b>	3
<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
3A.221	Space-Based RF Interference Geolocation leveraging existing in-orbit assets	1,500	B
<b>Objective:</b>	<p>The objective of the activity is to identify and develop several use cases to demonstrate the added value of space-based monitoring to geolocate interferences with respect to existing ground-based monitoring capabilities.</p> <p>The objective of the activity is to demonstrate the added value of space-based monitoring to geolocate interferences with respect to existing ground-based monitoring capabilities, serving several use cases, translating them into technical requirements up to a demonstration in an operational environment.</p>		
<b>Targeted Improvements:</b>	Enabling European space-based monitoring capabilities to geolocate interferences as required by relevant regulatory bodies, not addressable by ground-based monitoring capabilities.		
<b>Description:</b>	<p>Except for GNSS (Global Navigation Satellite System) interference geolocation, there are limited European capabilities of space-based monitoring for geolocating telecommunication signal interferences. While some technological advancements have been made, they remain limited in scope, and there has yet to be significant, widespread adoption of these methods as a basis for operational commercial services. Notably, practical use cases as identified by CEPT and National Regulatory Authorities have not been thoroughly explored or addressed.</p> <p>New signal processing methods and spectrum monitoring concepts will need to be developed to answer to these use cases. This will address a gap in validating the potential benefits of space-based solutions with respect to current ground-based monitoring capabilities for ensuring spectrum integrity and managing interference issues. In addition, it is expected that existing ground-based geolocation methods which are using transparent satellites need to be enhanced in scope of this activity, using new techniques.</p> <p>Raw data from existing in-orbit assets shall be used to validate several key use cases that demonstrate the advantages of space-based interference geolocation over current ground-based monitoring capabilities</p> <p>For that purpose, in coordination with Frequency Regulators, and involving end users, the activity aims to formulate and develop, on the basis of use case geolocation problems, a set of requirements and develop and validate related technology developments, demonstrate them in an operational environment, establish operational concepts for geolocation, including those with multiple independent service providers, as well as the identification of further capability gaps, security aspects and identify future developments.</p>		
<b>Deliverables:</b>	Summary report, CONOPS, geolocation algorithms software prototype for selected use cases		
<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>	6 - RF Systems, Payloads and Technologies		





Activity Ref.	Activity Title	Budget (kEuro)	Classification
3A.222	Exploiting the synergy between ground- and space-based RF monitoring systems	1,000	B
<b>Objective:</b>	The objective of the activity is to define, implement, and verify key scenarios that demonstrate the added value of a system integrating both ground- and space-based RF monitoring capabilities.		
<b>Targeted Improvements:</b>	The following figures intend to depict the targeted improvement of a joint ground- and space-based system with respect to an individual ground- or space-based system: Increased detection accuracy of at least 20%. Enhanced geolocation precision of at least 15%. Expanded geographical coverage of at least 40%. Reduced response time of at least 30%.		
<b>Description:</b>	<p>While advancements in space-based monitoring technologies have been made, their integration with ground-based systems has not yet been fully realised. Previous efforts have concentrated primarily on enhancing the individual capabilities of either ground or space monitoring, often overlooking the potential benefits that can arise from a collaborative approach.</p> <p>Within Europe, there is an industrial base which offers ground-based interference detection solutions. This activity aims to support this industrial base by developing and validating the techniques to integrate space- and ground-based RF monitoring solutions. The maturity of solutions exploiting space- and ground-monitoring is currently low in Europe. It is foreseen that the activity will be supported by existing ground-based infrastructure provided by private parties or national regulators.</p> <p>This activity focuses on the definition, implementation, and demonstration of key scenarios to exploit the potential synergies of ground-based and existing space-based RF monitoring capabilities. These scenarios shall cover various domains, including but not limited to spectrum occupancy, geolocation accuracy, and interference detection, which shall be developed and verified in a representative environment. This involves the reproduction of RF interference conditions to demonstrate the added value of a joint ground and space RF monitoring system and using existing ground- and space-based RF monitoring systems. Additionally, the activity aims to establish operational concepts, including the definition of protocols and security aspects for data sharing, operational workflows, and collaborative methodologies that enable the two systems to complement one another effectively.</p>		
<b>Deliverables:</b>	Summary report, CONOPS, ground- and space-based RF monitoring system test bed		
<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>	6 - RF Systems, Payloads and Technologies		



Activity Ref.	Activity Title	Budget (kEuro)	Classification
3A.223	Optimisation of the spectrum utilisation leveraging existing space- and ground-based RF monitoring systems	1,000	B
<b>Objective:</b>	The objective of this activity is to identify, develop, and demonstrate at least five use cases where the active use of RF monitoring improves spectrum utilisation.		
<b>Targeted Improvements:</b>	Spectrum utilisation efficiency increase of at least 20%. Enhanced spectrum sharing of at least 10%.		
<b>Description:</b>	<p>Despite advancements in RF spectrum monitoring technologies, there is a notable lack of practical examples demonstrating how such monitoring systems can be effectively used to optimise spectrum usage and sharing. While the technology has progressed, particularly in terms of monitoring capabilities and data collection, hardly any real-world examples showcase how these systems can be leveraged to actively improve spectrum efficiency.</p> <p>This activity aims to identify, develop and demonstrate, in collaboration with both space- and ground-based RF monitoring providers, several use cases in which the active use of RF spectrum monitoring can significantly improve spectrum utilisation. This activity will leverage upon several dynamic spectrum sharing activities which have been completed, but put them into a realistic context, using actual RF measurements instead of simulations.</p> <p>These scenarios will focus on how leveraging measurements obtained from RF monitoring systems can result in optimised spectrum utilisation. This involves the development of a representative environment where existing space- and ground-based RF spectrum monitoring systems and the optimisation of spectrum usage scenarios are demonstrated. As part of the demonstration, the bidder shall derive the improvement factor achieved due to the active use of RF spectrum monitoring systems. The findings shall be derived into a set of guidelines for the optimisation of spectrum utilisation using RF monitoring systems, to address issues like dynamic spectrum sharing, interference management and cross-border spectrum coordination, as well as the identification of capability gaps and future developments.</p>		
<b>Deliverables:</b>	Summary report, spectrum utilisation optimisation test bed		
<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>	6 -RF Systems, Payloads and Technologies		



Activity Ref.	Activity Title	Budget (kEuro)	Classification
3A.225	European VDES reference architecture and related standardisation, interoperability and regulatory activities	500	B
<b>Objective:</b>	The objective of this activity is to support the collaborative efforts of maritime stakeholders in ESA Member States aimed at defining VDES reference architecture, technologies and interfaces enabling the federation of multi-operator systems and at reaching accordingly an appropriate level of service standardisation and system interoperability between European initiatives. This will be complemented by supporting European efforts in regulatory bodies at international level i.e. IMO, ITU, in view of overall enabling the delivery to European maritime communities and beyond, of timely, higher-scale and competitive maritime European solutions and services.		
<b>Targeted Improvements:</b>	<ul style="list-style-type: none"> <li>- Interoperable solutions and network sharing among systems from multiple European actors (and beyond)</li> <li>- Improved effectiveness of the standardisation and regulatory efforts by European actors towards VDES and associated technologies</li> <li>- Viable business models</li> </ul>		
<b>Description:</b>	<p>The WRC 2019 allocated maritime VHF frequencies for two-way VHF Data Exchange System via satellites, making space communication an integrated component of the VDES (VDE-SAT). This has created opportunities for broadcasting messages from satellite to vessels and for communications from ship-to-shore, shore-to-ship and ship-to-ship via satellite. Although having reached critical technical milestones, the wide scale deployment and adoption by user communities of VDES solutions is facing a number of perceived roadblocks caused by persisting regulatory obstacles, the lack of standardisation, business aspects and technical complexity.</p> <p>There are currently several initiatives in Europe (and outside Europe) aiming at developing operational VDE-SAT systems and services, however the VDES ecosystem is today highly fragmented. The proposed activity aims at strengthening common interests among VDES actors in ESA Member States to join efforts, collectively identify actual challenges, foster definition of shared reference architecture, technologies and interfaces (as needed) to allow system interoperability and network sharing, support overall standardisation and regulatory efforts and develop related business potential. The activity will require to gather most of European VDES (SAT &amp; TER) stakeholders at all stages around a common roadmap based on the existing VDES guidelines from IALA.</p> <p>The first work stream will address the concept of federating multi-operator systems in view of delivering enhanced services to users. In coordination with European VDES actors, this activity will assess gaps and benefits of such a concept, and identify and define a shared reference architecture, with needed technical solutions (including security elements) and interfaces, and related business models. This shall lead to the mutual beneficial alignment of the different initiatives at technical level (i.e. enabling interoperability, user roaming and network sharing), and business level (e.g. service monetisation agreement). Contributions towards standardisation (e.g. IALA, IEC) will be accordingly prepared. A plan of actions will be also proposed that shall leverage existing/planned infrastructures for developing and demonstrating systems interoperability and federation (including, if possible, international cooperation).</p> <p>The second work stream will support regulatory efforts of the VDES ecosystem. It shall coordinate actual contributions to various regulatory bodies (e.g. IMO, ITU), assess regulatory gaps and prepare contribution to future amendments related to VDES and associated technologies for e.g. GMDSS (Global Maritime Distress and Safety System), primary channel allocation, VDES-R, e-navigation strategy. The goal is to unify and strengthen European VDES stakeholders' voice, engaging also with international stakeholders where relevant, to support European interests.</p> <p>The third work stream will focus on unleashing VDES business potential opportunities, by performing a realistic assessment of the various business models both for VDES-based maritime regulated safety and other commercial applications in view of identifying the most viable and scalable models. A particular emphasis will be put on revenue generation scheme and impact of other satcom systems emergence on VDES market potential. This task will be complemented with the definition of a plan of actions, including regarding raising user and stakeholders' awareness on VDES-based solutions to support future commercialisation. This will lead to recommendations towards the VDES actors and Member States.</p>		
<b>Deliverables:</b>	Summary report, reference architecture, technologies and interfaces definition for interoperability and network sharing, standardisation & regulatory contributions		
<b>Estimated current TRL:</b>	N/A		
<b>Target TRL:</b>	N/A		
<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>	6 - RF Systems, Payloads and Technologies		



Activity Ref.	Activity Title	Budget (kEuro)	Classification
3A.226	Towards an infrastructure supporting the hyper-connected vessel	900	B
<b>Objective:</b>	The objective of this activity is to study and define effective and competitive infrastructure architectures of a system of satcom systems for hyper-connected vessels addressing European regulated and commercial maritime connectivity needs (e.g. low data rate / IoT and broadband) and maritime domain awareness (e.g. AIS and RF signals detection and characterisation) in the mid-term (2030+) and long term (2040+).		
<b>Targeted Improvements:</b>	Enabling a European system of satcom systems for hyper-connected vessels		
<b>Description:</b>	<p>As 80% of global trade by volume, and over 70% by value, is carried by ships and handled by ports worldwide, the maritime industry (shipping, fishery, tourism...) is of paramount importance and constitutes a huge commercial opportunity for satcoms. The Maritime sector needs satcom solutions for current and future critical services, both safety-related or commercially oriented (e.g. AIS, GMDSS, Surveillance, IP Connectivity, Autonomous Ships). As of today, no individual space system can answer all the needs. A new and uncertain Maritime satcom landscape is emerging, transitioning from legacy L-Band, AIS and GEO VSAT systems to a more complex technological environment with broadband NGSO constellations, VDES, Direct-to-Device (D2D) and RF signals detection and monitoring systems.</p> <p>This system study shall define a competitive infrastructure architecture of a system of satellite systems for hyper-connected vessels addressing European regulated and commercial maritime connectivity needs. The activity will study how dedicated systems operating on regulated/safety of life bands and new LEO Broadband constellations may effectively complement each other to respond both to regulated needs (critical communications and surveillance for traffic management and safety of life) and commercial needs (company operations, services to the passenger and to the crew).</p> <p>This activity will first consolidate user needs and requirements, addressing institutional and commercial, national and European maritime actors, and actual and future services. Relevance of current and emerging satcom Systems including VDES, D2D, multi-band multi-orbit constellations, IoT, RF signal detection systems to address these needs will be then reviewed. A system of systems architecture and implementation options will be studied, and synergies assessed. Market and regulatory analysis will also be carried out to ensure a coherent prospective solution. Considering technical feasibility and performance, business opportunity, competition, future regulations, service costs, and criticality of the services for ESA MS safety and resilience, trade-offs shall be made between identified technical scenarios in order to derive the scenarios with the highest potential in terms of economic sustainability and/or in contributing to Europe's independence. For the most promising architectures and scenarios, a technical and programmatic roadmap for their development, validation and deployment will be defined. Outputs will be available to European authorities, and European authorities will be invited to participate to ensure coordination.</p>		
<b>Deliverables:</b>	Summary report, system of satellite systems architecture for hyper-connected vessel and maritime domain awareness, market analysis, roadmap		
<b>Estimated current TRL:</b>	N/A		
<b>Target TRL:</b>	N/A (system study)		
<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>	6 - RF Systems, Payloads and Technologies		



Activity Ref.	Activity Title:	Budget (kEuro)	Classification
3A.227	Towards an infrastructure supporting the hyper-connected aircraft	900	B
<b>Objective:</b>	The objective of this activity is to study and define effective and competitive infrastructure architectures of a system of satcom systems based on multilink (i.e. combination of satcom and terrestrial datalinks) and multi-band/multi-orbit satellite constellations for addressing future aviation communication ('hyperconnected' aircraft) and surveillance needs in the mid-term (2030+) and long term (2040+).		
<b>Targeted Improvements:</b>	Enabling a European system of satcom systems for hyper-connected aircraft		
<b>Description:</b>	<p>Aviation traffic is growing fast. By 2050 it is expected to have 50% traffic increase with respect to 2024. Air Traffic Management must evolve to cope with this traffic growth, with the evolution of the user needs (i.e. by Airlines and ANSPs) and with new regulatory requirements for safety and security (e.g., standardisation bodies and EASA).</p> <p>Multi-systems (e.g. a combination of satellite and terrestrial links operating in a hot-redundancy multilink approach) have the potential to meet the performances required in the future. This activity will explore and identify new systems and architectures based on multilink (i.e., combination of satcom and terrestrial datalinks) and multi-band/multi-orbit satellite constellations for addressing future aviation communication and surveillance needs, and define the individual satcom systems. The activity will study how dedicated systems operating on regulated/safety of life bands and new LEO Broadband constellations may effectively complement each other to respond both to regulated needs (critical communications and surveillance for traffic management and safety of life) and commercial needs (airline operations, services to passengers).</p> <p>The activity will first identify and assess current and future user needs and requirements (taking assumptions on forecasted ones for ~2030+), addressing institutional and commercial, national and European aviation actors (e.g., Airlines, ANSPs, consumers and standardisation bodies), and actual and future communication and surveillance services. Relevance of current and emerging Satcom systems and technologies (e.g. ADS-B, multi-band multi-orbit infrastructure, Direct-to-Device, GNSS-free surveillance) to address these needs will then be reviewed. A system of systems architecture and implementation options will be studied and synergies assessed. Technical gap analysis will be performed with respect to current systems available or under deployment in Europe. Market and regulatory analysis will be furthermore carried out to ensure a coherent prospective solution.</p> <p>Considering technical feasibility and performance, business opportunity, competition, future regulations, service costs, and criticality of the services for ESA Member States' safety and resilience, trade-offs will be made to derive the scenarios with the highest potential in terms of economic sustainability and/or in contributing to Europe's independence.</p> <p>For the most promising architectures and scenarios, a roadmap for their development, validation and deployment will be defined. Outputs will be available to European authorities, and European authorities will be invited to participate to ensure coordination.</p>		
<b>Deliverables:</b>	Summary report, system of satellite systems architecture for hyper-connected aircraft, market analysis with cost-benefits assessments, roadmap		
<b>Estimated current TRL:</b>	N/A		
<b>Target TRL:</b>	N/A (system study)		
<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>	6 - RF Systems, Payloads and Technologies		



Activity Ref.	Activity Title	Budget (kEuro)	Classification
3E.030	Over-the-air demonstration of VHF Data Exchange (VDE) overlay broadcasting and ship-to-ship communication via satellite	2,800	R
<b>Objective:</b>	The objective of this activity is to complement existing receive-only satellite capabilities operating in the VHF maritime band by developing and demonstrating a space-based solution for maritime data broadcasting according to VDES Satellite Component (VDE-SAT) air interface. The objective is also to use the broadcasting capabilities of VDE-SAT for ship-to-ship communications via satellite in VHF maritime bands		
<b>Targeted Improvements:</b>	Increase the VDES downlink capacity up to two folds by using VDES broadcasting as an overlay service (distinct VHF transmitting satellite) and enabling ship-to-ship communications in VHF bands.		
<b>Description:</b>	<p>The WRC 2019 allocated maritime VHF frequencies for two-way VHF Data Exchange System via satellites, making space communication an integrated component of the VDES. The allocation of frequency in WRC2019, rectified uncertainties and potential regulatory risks in the deployment of VDES for two-way communications, to and from vessels via satellite. This has created opportunities for broadcasting messages from satellite to vessels and collect information from vessels. While there are already numerous satellites with the capability to receive VHF maritime messages (AIS, ASM or VDE-SAT uplink) deploying Software Defined Radio technology, the design and demonstration of VDE-SAT downlink is limited to a small number of demonstration missions that share resources with other experiments.</p> <p>The concept of distinct VDES transmitting satellite can complement the existing VDES receiving satellites and pave the way to new service offerings such as maritime safety, aid to navigation and time synchronisation. The VDES broadcast overlay will allow data dissemination to vessels to deliver search and rescue services, Maritime Safety Information (MSI) services, environmental information services, etc. The VDES broadcast overlay satellite can also be used to provide control and signalling information as required by VDES protocol. Ship-to-ship services can also be realised by collecting messages from vessels using receiving satellites and route the traffic to a transmitting satellite for broadcasting to other ships. Possible architectures could entail one-hop satellite with or without store and forward or a two-hop satellite link with a ground gateway, as well as involving inter-satellite links. Ship-to-ship data exchange via satellite using maritime VHF would improve communications for instance in distress and safety relevant situations, esp. in offshore areas not covered by terrestrial stations. Ships could also report real-time environmental information services and navigational route exchange data to other ships in the area.</p> <p>This activity will setup an in-orbit experiment (implemented by a dedicated or hosted payload) to demonstrate the VDES broadcasting via satellite as an overlay service to complement existing receive only satellites. The VDE-SAT transmitter may require the development of innovative solutions, particularly for antenna solution to allow for wider coverage suitable for broadcasting services.</p> <p>The activity will be implemented in two phases. The first phase of the activity will develop, manufacture, and test the VDES transmitter hardware and software. The design shall be compatible with accommodation on industries selected satellite platform. The second phase will build, qualify, launch and operate in-orbit the VDES transmitter. Communication experiments will be carried out in maritime challenging environments to characterise the reception performance of the VDES broadcasting satellite. An experimental phase of up to 12 months will be performed.</p>		
<b>Deliverables:</b>	Summary report, VDES functional hardware and software engineering models, in-flight performance data		
<b>Estimated current TRL:</b>	4		
<b>Target TRL:</b>	6		
<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		



## 1.2 Coding, Modulation and Access

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3C.051	Space-Based ADS-B Phase Overlay receiver	650	R
<b>Objective:</b>	The objective of the activity is to design, develop and test techniques for ADS-B phase overlay receivers for satellite-based air traffic surveillance at 1090 MHz, in order to reach a higher transmission efficiency for that frequency band, already very crowded and overloaded by current standard transmissions. The main tasks will foresee the breadboarding and performance verification of the identified techniques, and tests will be carried out to demonstrate reliable space-based reception of the original ADS-B signal as well as the 8-PSK modulation overlay signal.		
<b>Targeted Improvements:</b>	Increase the ADS-B transmission efficiency (estimated by a factor of 4). Enhance the capability of space-based ADS-B detection and decoding for broad range of applications including air traffic surveillance and situation awareness.		
<b>Description:</b>	<p>The World Radiocommunication Conference (WRC) in 2015 made a primary allocation of frequency band 1087.7 to 1092.3 MHz for satellite reception of Secondary Surveillance Radar (SSR) messages transmitted by the aircraft. The usage of these frequencies has increased significantly due to the increasing air traffic. A higher spectral efficiency for the transmissions would be key to offload the channel. The recent revision of ADS-B and Mode-S transponders (version 3) supports a new feature known as phase overlay that consists in a phase modulation (8PSK) message coexisting with the original Pulse Position Modulation (PPM) of the ADS-B signal. The phase overlay allows for increasing the information content of squitter messages from the original 54 bits (PPM) to 204 bits (PPM and 8-PSK overlay). The increase in the data content is intended to carry more information in each telegram message or conversely reduce the repetition rate of messages hence reducing the spectrum congestion. Considering the potential future use of the phase overlay in the near future, it is essential to devise space-based receiver techniques to decode the overlay signal along with the original PPM signal. The new information content could in particular be used for cybersecurity as well as situation awareness such as sharing weather conditions. This would allow Air Traffic Control authorities to know more about the situation and decide better routes for the aircraft.</p> <p>This activity aims to design and develop the critical technologies that are needed to implement a space-based receiver suitable for small platforms while meeting the technical requirements for the RF baseband processing. This activity will design, manufacture and test techniques for an ADS-B Phase Overlay reception. The receiver algorithms will be implemented in a representative software defined radio platform. This will also require the software implementation of the ADS-B phase overlay transmitter and aircraft-satellite channel model. The receiver breadboard will be used to test and evaluate the performance in the presence of multiple messages with low Signal to Noise Ratio (SNR). Introduction of encryption for a safer end-to-end communication may be considered as part of the activity.</p>		
<b>Deliverables:</b>	Summary report, breadboard of the ADS-B phase overlay receiver and software implementation of the ADS-B phase overlay transmitter		
<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		



### 1.3 Security and Cryptography

Activity Ref.	Activity Title	Budget (kEuro)	Classification
3D.034	Secure software defined networking module for space networks	800	B
<b>Objective:</b>	The objective of the activity is to develop and test a software prototype of an on-board Software Defined Networking (SDN) module that includes security aspects such as secure interface following a 'defence-in-depth' approach, network segmentation, traffic segregation and resource isolation between services with different security requirements.		
<b>Targeted Improvements:</b>	Enabling secure SDN onboard infrastructure sharing between governmental and commercial services, adding the following security features to on-board SDN technology: secure interface, network segmentation, traffic segregation, resource isolation between services and network slicing.		
<b>Description:</b>	<p>The current Software Defined Networking (SDN) on-board technology available in ESA Member States allows to be programmed from ground and can provide simple prioritisation between different services based on flags encoded in data packets. Nevertheless, traffic belonging to services with different security requirements flows through the on-board switch with no specific segregation and using the same resource pool. This poses potential security issues when the satellite needs to serve users with different security requirements and different levels of Quality of Service. In addition, the current SDN technology secures its interface based on the security checks done at payload level, not providing a defence-in-depth approach.</p> <p>The proposed activity will investigate the required security improvements to on-board SDN technology, to provide the following features: secure independent interface ('defence-in-depth' approach), network segmentation, traffic logical isolation between different services, resource isolation between different services, network slicing capabilities. The activity will consolidate the requirements of the secure SDN onboard software module focussing on the security features (i.e. traffic/resources segregation, slicing, network segmentation) and on the security aspects of the interface with ground-based Software Defined Networking controllers (i.e. having standalone security controls for the module itself). In addition, security requirements will be analysed and consolidated based on a technical analysis on the possible vulnerabilities and attacks on the on-board software module. The activity will trade-off different solutions for the on-board software module as well as consider the tailoring of already existing solutions for all the different interfaces leading to the module. The designed on-board software module and any additional tools needed for functional verification will be designed and implemented, producing a breadboard representative of an on-board hardware to be tested in laboratory. Performance evaluation of the on-board software module will be made, including relevant demonstrations and security tests.</p>		
<b>Deliverables:</b>	Summary report, secure software defined network module breadboard including software		
<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>	06 - RF Subsystems, Payloads and Technologies		





Activity Ref.	Activity Title	Budget (kEuro)	Classification
3D.035	Security module for high-speed inter-satellite link data rate	1,500	B
<b>Objective:</b>	The objective of the activity is to design, develop and test an IP core for an onboard security module able to achieve data rate of 100Gbit/s full duplex, to support inter satellite link communication.		
<b>Targeted Improvements:</b>	Enabling a high-speed (up to 100Gbits/s) security module able to protect state-of-the-art inter-satellite communication links.		
<b>Description:</b>	<p>The availability of high-speed protection capabilities for satellite constellations is nowadays a challenge. Current solutions may not be readily available or suitable for to follow the very fast pace of development and improvement of the optical communication technologies, particularly those requiring data rates up to 100Gbits/s. This technology would be applicable to satellite constellations requiring secure inter-satellite links (ISLs) using optical links and RF links, but could also be used for satellite requiring a secure high-speed feeder link. The ability to encrypt/decrypt/protect data at high speeds could enable more secure communications, reducing the risk of data interception and improving overall system security. Even though optical communications use narrower beam widths than radio frequency systems, improving security by drastically reducing the geographic area where a communications link can be intercepted/received, it may be required to protect optical links of missions with stringent security requirements. An intellectual property core (IP Core) is a reusable unit of logic, that could be integrated later in a multitude of products, from FPGA to ASICS depending on the project need. In the context of this activity the result will be demonstrated on an FPGA. The development of such IP core would provide several benefits, including enhanced security through high-speed, on-board encryption/decryption/protection, flexibility in supporting different modes (authentication or authenticated/encryption), improved system performance with key rotation and synchronisation features, and independence from external equipment for key management. It could furthermore support multiple key management schemes, from symmetric preplaced keys, to externally provided, dynamically negotiated one. Compliance to ECSS standards will be in addition considered in order to enable future re-use.</p> <p>Existing products able to protect such intersatellite links for medium rate data communication provide proof of a starting TRL3. With this activity, the objective is to reach a TRL5 for a high-speed solution, with a breadboard able to demonstrate the targeted functions.</p> <p>The activity will start with the IP Core high level description and the key management concepts definition. The IP core requirements will be also refined, and a blueprint of the IP core architecture will be developed. In a second step, the IP core module will be developed on a representative space grade platform and tested. A demonstration simulating end-to-end communications between two security modules will then be performed.</p>		
<b>Deliverables:</b>	Summary report, two security modules breadboard and associated testbed		
<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>	06 - RF Subsystems, Payloads and Technologies		



Activity Ref.	Activity Title	Budget (kEuro)	Classification
3D.033	Mobile network security assessment equipment for 5G Non-Terrestrial Networks (NTNs)	1,750	B
<b>Objective:</b>	The objective of this activity is to develop a breadboard mobile network security assessment equipment to enable 5G NTN providers/integrators to assess, in-field and in support of simulations, the security of their networks (via RF, covering at least network manipulation, extraction of sensitive information, e.g. user metadata, and jamming and spoofing). The activity will encompass the development of a testbed integrating the Mobile Security Assessment Equipment, capable of supporting the evaluation of specific security related technologies such as authentication protocols, encryption mechanisms, anomaly detection systems.		
<b>Targeted Improvements:</b>	50% improvement in time and effort needed to test and verify the security of 5G NTN networks		
<b>Description:</b>	<p>5G non-terrestrial networks (NTN), like any satellite communication systems, will be exposed to wireless threats including signal interception, jamming and spoofing. 5G Non-Terrestrial Networks (NTN) providers/integrators' security professionals will need tools capable of testing and identifying vulnerabilities, in particular a dedicated RF based product that enables more pervasive security testing of 5G (NTN) originating from the physical layer (OSI layer 1), either in-field or via simulations, allowing to fully address certain aspects such as: interception/eavesdropping techniques which cannot be detected at OSI layer 3, jamming/spoofing attacks which (even if detected at layer 3) would manifest as connectivity issues, jamming/spoofing attacks specific to NTN but not TN, e.g. attacks on feeder links, spoofing/replay attacks which are not observable at layer 3, aspects linked to layer 1 authentication which can only be seen via RF properties, side-channel attacks which are not guaranteed to be observed at layer 3. This activity will develop a mobile network security assessment equipment and a supporting test bed.</p> <p>The proposed activity will be implemented in two phases.</p> <p>In the first phase, following an analysis of the gaps in the current security testing frameworks applicable to 5G NTN, and the definition of the appropriate test scenarios applicable to 5G NTN(s) (including RF attacks/techniques aimed at the radio access network (RAN), core network (CN) and feeder links), the technical baseline of a mobile network security assessment equipment will be elaborated and proof of concepts for the primary RF attacks/techniques applicable to 5G NTN(s) will be developed. The first phase will also include the pre-development of a supporting testbed for the identified primary RF attacks/techniques as well as for the evaluation of 5G security related technologies linked to authentication protocols, encryption mechanisms, anomaly detection systems, etc.</p> <p>In the second phase a mobile network security assessment equipment breadboard able to exercise the test scenarios, and the complete supporting testbed (integrating the mobile network security assessment equipment) will be developed. Using the testbed, security assessments will be performed to identify required mitigations. Identified mitigations will be implemented and tested.</p>		
<b>Deliverables:</b>	Summary report, mobile security assessment equipment and user manuals		
<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>	06 - RF Subsystems, Payloads and Technologies		



Activity Ref.	Activity Title	Budget (kEuro)	Classification
3E.031	In-Orbit Secure Telecom Laboratory	8,500	B
<b>Objective:</b>	The objective of the activity is to develop and deploy an advanced in-orbit laboratory infrastructure based on a LEO cubesat to test, assess and demonstrate in real space conditions innovative secure communications and security technologies needed to increase resilience and robustness of novel satellite telecommunication systems, as well as to measure the impact of space environment on them.		
<b>Targeted Improvements:</b>	Enabling new security capabilities and technologies for future secure satellite communications, including novel, quantum resistant cryptographic technologies for networking protocols suitable for satellite communications, through in-orbit demonstration capabilities.		
<b>Description:</b>	<p>Due to the transition of current satcom systems to LEO and a resulting proliferation of large satellite constellations, the reliance of the satellite sector on COTS components to reduce cost will grow. Secure communications should be viewed as an essential and integral part of such systems, particularly due to the European legislation and regulations regarding anonymity and protection of communications. A provision of secure telecommunications in space requires a chain of security mechanisms, namely: security protocols, cryptographic mechanisms, protection of RF or optical links, security at the spacecraft level, preventive measures on board to stop compromise or other impact of non-trusted user traffic processed in the spacecraft, mechanisms addressing challenges like on board patching in a secure way, log collection and many more. While well-established solutions do exist for terrestrial networks, their suitability, performance, and effectiveness in space specific conditions have not been tested in a representative environment yet, particularly with respect to natural noise and electromagnetic environment. New threats such as the quantum threat to cryptography must be addressed by new solutions that not only are more complex (e.g. PQC) but are also more susceptible to natural noise. In addition, techniques such as selective filtering applications for security reasons based on geolocation can only reliably be tested and assessed in orbit.</p> <p>Therefore, this activity will establish an in-orbit laboratory open to industrial and academic stakeholders for the purpose of assessment, evaluation and end-to-end testing of secure telecom technologies, techniques and products addressing domains such as:</p> <ul style="list-style-type: none"> <li>– Novel crypto mechanisms</li> <li>– Secure network protocols and routing techniques for LEO and multi orbit constellations</li> <li>– Near real time log collection traffic from the spacecraft</li> <li>– Protection of RF links using secure Software Defined Radio (SDR) implementations for Satellite communications</li> <li>– On-board secure updates of software defined payloads and secure SDR reconfiguration</li> </ul> <p>In addition, the activity aims to provide inputs to standardisation bodies (IETF, CCSDS, ECSS, ETSI) and to European post quantum crypto adoption roadmap for space through the appropriate bodies (e.g. INFOSEC panel).</p> <p>The activity will be implemented in two phases. The first phase of the activity will develop, manufacture, and test the Secure telecom lab testbed. The design of the test bed shall be compatible with accommodation on industries selected satellite platform. The second phase will build, qualify, launch and operate in-orbit the secure telecoms lab spacecraft, and relevant experiments of innovative security techniques and solutions will be performed for a minimum of 12 months after commissioning phase (with possibility to support execution of experiments provided by other companies at no cost) using the ground and in-orbit laboratories.</p>		
<b>Deliverables:</b>	Summary report, experimental flight model of the secure telecom laboratory testbed, ground segment, in orbit data		
<b>Estimated current TRL:</b>	3		
<b>Target TRL:</b>	6		
<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		



## Space Segment – Payload

### 2.1 RF Repeater and Signal Processing

Activity Ref.	Activity Title	Budget (kEuro)	Classification
5C.533	Multi-octave wide band receiver to geo-locate interference sources	1,200	R
<b>Objective:</b>	The objective of this activity is to design, manufacture and test a breadboard model of a wide band receiver capable of determining the direction of arrival and geo-locating the source of RF interference covering the spectrum from 0.6 to 40 GHz.		
<b>Targeted Improvements:</b>	Enabling new instruments exploiting both RF properties and signal processing techniques and able to monitor RF interference signals in a very large frequency spectrum (from 0.6 GHz to 40 GHz).		
<b>Description:</b>	<p>There is a growing interest to observe RF spectrum from space to geo-locate sources of interference from both ground and space. This application could play a key role in spectrum management and deployment of supplementary coverage from space without interfering with the terrestrial assets. Initiatives such as CleanWaves and European Spectrum Monitoring Systems are working towards geo-locating sources of RF interferences at very high spatial accuracy.</p> <p>In-order to enable such initiatives, there is a need to develop an onboard antenna system including a signal processing backend capable of identifying RF interference sources covering a large spectrum bandwidth from 0.6 to 40 GHz. The goal of the wide band receiver will not be to decode the source of interferences but use some advance signal processing methods such as MUSIC algorithms or super resolution techniques to identify the direction of arrival and geo-locate the source at a high special accuracy. In this activity, a breadboard of a wide-band receiver that cover the spectrum from 0.6 GHz to 40 GHz will be developed and signal processing algorithms will be tested and compared to identify the most suited algorithm to achieve the best spatial accuracy.</p>		
<b>Deliverables:</b>	Summary report, demonstration testbed using breadboard models.		
<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
5C.534	Interference mitigation analog engine for Ku/Ka Phased Array Antenna	700	R
<b>Objective:</b>	The objective of the activity is to design, assemble and test an interference mitigation demonstrator based on analog techniques derived from multi-antenna theory (e.g. monopulse, beams reuse, etc).		
<b>Targeted Improvements:</b>	Estimation of the interference source angle of arrival within +/- 1 degree and suppression of the interference by at least 30dB within 1 second.		
<b>Description:</b>	<p>This activity will address the challenge of interference detection and mitigation in satellite payloads, particularly when analog-to-digital converters (ADCs) are saturated by strong interferers. Existing methodologies for interference detection and mitigation in satellite payloads rely primarily on digital techniques implemented within the on-board processor (OBP). These methods involve a sequence of steps: firstly, detecting interference, followed by geolocating it (i.e., computing the angle/direction of arrival), and adjusting the radiation pattern (i.e. beamforming weights) in phased array systems to mitigate the interference. However, these techniques are contingent upon the assumption that the Analog to Digital Converters (ADCs) are not saturated. In the event of ADC saturation due to a strong interferer, the algorithm will be blind, and the only option is for the digital processor to resort to blind adjustments of beamforming weights. This may render the payload non-operational for a significant period.</p> <p>To address these challenges, the proposed approach is to investigate analogue techniques rooted in multi-antenna theory. Analog methods offer the potential to estimate the angle of arrival of interference signals without relying on digital processing, which can be compromised by ADC saturation. The envisioned interference mitigation analog engine would serve as a complementary solution to existing digital interference detection methods, providing an additional layer of defence against interferers. By utilising analogue techniques to estimate the angle of arrival of interferers, this engine can provide crucial information to the OBP to adapt the radiation pattern and mitigate interference without necessitating the full sequence of digital interference detection steps. Additionally, a secondary goal is to conduct a trade-off analysis by suggesting optimal alternative versions of the architecture proposed in the first objective across different beamforming topologies, including hybrid, and analogue. The main outcome anticipated from this initiative is a more resilient interference mitigation system for satellite payloads, ensuring continuous operational performance even in the presence of strong interference sources. Suitability of the solution for the user segment may also addressed during the activity. The deliverables of this activity shall include a breadboard consisting of a combined hardware and software payload phased array demonstrator.</p>		
<b>Deliverables:</b>	Summary Report, Interference mitigation analog engine 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		



## Ground Segment

### 3.1 TT&C/Satellite Ground Equipment and Support

Activity Ref.	Activity Title	Budget (kEuro)	Classification
6A.096	Secure segregated payload operations ground segment services	1,500	B
<b>Objective:</b>	The objective of this activity is to design, develop and verify end-to-end security services provision for hosted payload and multi-tenant spacecraft operations through extensions to multi-mission ground segment software systems.		
<b>Targeted Improvements:</b>	Enabling a new capability for secure end-to-end payload operations as a service		
<b>Description:</b>	<p>Increasingly, manufacturers and operators are moving towards provision of payload hosting capabilities on their spacecraft, facilitating multi-tenant mission operations concepts. Today the Mission Operations Centre (MOC) typically extracts received payload telemetry packets and forwards it to the payload operator and the payload operator sends their telecommands to the MOC to be processed and uplinked. Currently, whilst Virtual Channels and/or Application Process IDs support a degree of routing capability, there is a lacking support to near-real-time direct payload command and control and to apply end-to-end security services to the communication between the payload operator and the payload, ensuring the confidentiality, authenticity and integrity of payload data and operations. Such a capability on ground is also necessary to support emerging on-board architectures which support segregated and hardware-isolated environments, and future mission platform concepts which foresee protocol tunnelling and routing mechanisms to different (potential multi-operator) payload endpoints.</p> <p>To overcome these limitations, the enabling technologies of interoperable plug-ins and/or extensions to MOC multi-mission ground segment systems are required which implement end-to-end security services including encryption, authentication, management, monitoring and control concepts.</p> <p>This activity shall design, develop and verify a capability for end-to-end secure operations of hosted payloads using the MOC of the host spacecraft. The approach shall account for current and emerging CCSDS and satcom protocols layering, including bundle protocol, as well supporting on-board architectures (e.g. segregated environments, local networked platforms) and future mission operations concepts.</p> <p>The activity shall deliver the necessary interoperable, service-oriented extensions to multi-mission ground segment software systems, verified in a representative test environment (at TRL 6), leveraging and extending existing protocol implementations and simulated or breadboard on-board components.</p>		
<b>Deliverables:</b>	Summary Report, security service extensions to multi-mission ground segment software, representative test environment;		
<b>Estimated current TRL:</b>	4		
<b>Target TRL:</b>	6		
<b>Technology harmonised:</b>	Yes		
<b>Dependency:</b>	None		
<b>S/W Clause:</b>	Yes		
<b>Service Domain:</b>	5		
<b>Technology Domain:</b>	09 - Mission Operation and Ground Data Systems		



## User Terminals

### 4.1 Professional User Terminals

Activity Ref.	Activity Title	Budget (kEuro)	Classification
7A.082	Integrated Satellite/Coastal terminal for small Maritime Uncrewed Surface Vehicles used in maritime safety applications	900	B
<b>Objective:</b>	The objective of the activity is to design, develop, test in a lab environment, and test over representative conditions an integrated NGSO-satellite/coastal terminal for small (<12 meters) Uncrewed Surface Vehicles (USV), including modem and RF front-end that transmits both payload and command and control data.		
<b>Targeted Improvements:</b>	Enabling high-data rate and resilient communications for small Uncrewed Surface Vehicles operating in Beyond Radio Line Of Sight (BRLOS) conditions in maritime environment.		
<b>Description:</b>	<p>The current emergence of Uncrewed Surface Vehicles (USV), also called Maritime Autonomous Surface Ships (MASS), covering both remotely piloted and autonomous vessels, will offer new opportunities in terms of added-value services and applications in the domain of maritime surveillance, maritime domain awareness, environment protection, and transport safety. The availability of high-data rate and resilient communications for operations in Beyond Radio Line Of Sight (BRLOS) conditions will be a key enabler for such applications.</p> <p>The activity shall design and develop an integrated NGSO-satellite/coastal terminal prototype to achieve BRLOS communications comprising both the modem and (multiple) RF front ends in order to communicate both with a coastal receiver as well as an NGSO satellite. The terminal shall provide both narrowband Command &amp; Control (C2) as well as broadband high bandwidth communications (such as video streaming). The high bandwidth communication of the modem shall be asymmetric with emphasis on the return link. A system design shall be carried out for the antenna part, whereas the terminal demonstration shall leverage to the extent possible COTS components. The overall design shall take into account the constraints of small (&lt;12m) and very small (&lt;7m) USVs, especially related to Size Weight and Power (SWAP) and tracking capability under rough seas. The target data rates shall exceed the ones of the state-of-the-art terminals (tens of Mbps), by relying on BRLOS satellite communications. Such an integrated terminal allows for seamless handover and resilience for applications such as Maritime Situational Awareness, Maritime Border Control, etc.</p> <p>The USV prototype sub-systems (antenna, transceivers, modem) shall be tested in a lab environment and optionally showcased on an USV for a live satellite demonstration.</p>		
<b>Deliverables:</b>	Summary report, terminal breadboard prototype		
<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		



## 4.2 Consumer User Terminals

Activity Ref.	Activity Title	Budget (kEuro)	Classification
7B.088	AI-Enhanced adaptive antenna array for Satcom terminals for automatic interference detection and mitigation	1,000	B
<b>Objective:</b>	The objectives of the activity are to develop an AI engine capable of identifying the direction of arrival of interfering signals, as well as to implement an AI algorithm that dynamically reconfigures the antenna array to mitigate interference, while maintaining connectivity. An antenna array demonstrator integrating these new functions will be designed, manufactured, and tested.		
<b>Targeted Improvements:</b>	Improved signal quality and higher security through reducing interference by 30 dB. Real-time interference mitigation with 50% reduction in computation time.		
<b>Description:</b>	<p>Satellite communication systems play a crucial role in providing global connectivity. However, these systems often face challenges due to interference from various sources. A possible solution for interference mitigation is to use an array with beamforming capabilities. Then, once the direction of the interference is known, it is possible to generate a null in such direction and, consequently, to allow continuous reliable connections to the users. This capability is particularly of interest for satcom user terminals in Ku and Ka bands requiring beam steering for connectivity to LEO/MEO constellations or for mobility. Such systems typically use reconfigurable antennas that can benefit from advanced cognitive and adaptive capabilities to automatically detect the direction of arrival (DOA) and the nature of the interfering signals, and to reconfigure the array to generate a radiation null in the interference direction, while maintaining the desired connectivity on the main beam. A promising solution is the use of AI-based algorithms, since they can adapt to new scenarios and do not require knowledge of the number of interfering sources or their positions, which is often not available in practical situations.</p> <p>The AI-enhanced antenna array will operate as follows: 1. Interference Detection and Classification: the AI engine continuously analyses received signals and identifies interference sources based on DOA estimation; then, detected interferences are classified (e.g., narrowband, wideband, pulsed). 2. Dynamic Reconfiguration (when interference is detected): the AI-based reconfiguration algorithm adjusts antenna weights so that nulls are placed in the direction of interference and the main beam is steered toward the desired signal. 3. Learning and Adaptation: the AI engine learns from real-world interference scenarios; thus, it adapts over time to changing interference patterns. The activity will investigate and compare AI-based automatic detection algorithms able to estimate the DOA of the interference for array and beamforming solutions for user terminals in Ku or Ka band. Such algorithms will drive the beamformer with the goal of generating nulls in the interference directions. AI-based solutions for the reconfiguration of the beamformer will also be investigated and assessed. The most adequate AI-enhanced antenna array solution shall be demonstrated through the manufacturing and testing of a breadboard.</p>		
<b>Deliverables:</b>	Summary report, AI software, antenna breadboard.		
<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>	06 - RF Subsystems, Payloads and Technologies		