



ARTES Advanced Technology

Workplan 2016

Introduction

A key role of ESA in telecommunications is to promote a significant level of R&D activities to ensure the readiness and competitiveness of European industry in the short and long term.

ARTES Advanced Technology (formerly named ARTES Element 5 sub-element 5.1), short ARTES AT, is the Agency's main programme for preparatory development of satellite communications, and it covers the long-term R&D activities. ARTES AT activities contain significant amount of industrial research and technical risk and are therefore fully funded.

ARTES AT is concerned with the early stages of development of systems and exploitation of new and promising technologies for satellite communications. In several cases the ARTES AT activities are a continuation of a TRP activity. Within the TRP the components are developed and basic feasibility is demonstrated, while within ARTES AT the equipment are developed to breadboard or engineering model level. The further development to a space qualified or industrialised product is supported within the co-funded ARTES Growth and Competitiveness (formerly called ARTES 3-4) element.

Through ARTES AT, ESA supports the exploitation of new technologies into equipment such that in the long-term the industry will be able to offer state-of-the-art equipment and systems at competitive prices. It encompasses activities related to the development of subsystems and equipment for satellite communications.

The Work Plan for 2016 specifically addresses technology and equipment activities in support of the priorities defined in the Telecommunications Long Term Plan. The Work Plan for 2016 has been coordinated with other ESA technology programmes. The activities are organised per application area and grouped as Ground Segment, System, or Space segment (Payload, Platform) related.

The complete Workplan 2016 is presented in Annex 1 in tabular form and in detailed form in Annex 2.

Implementation

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

Parallel contracts: In accordance with the ARTES Advanced Technology Implementing Rules, parallel contracts will not be awarded in ARTES AT.

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: Activity restricted to SMEs & R&D organisations, preferably in cooperation.

Priority: The ARTES Advanced Technology Work Plan for 2016 consists of a number of activities assigned Priority 1 (P1) and a number assigned Priority 2 (P2).

Activities identified as P1 will be issued according to the schedule published (and regularly updated) on the ESA ARTES web site: <https://artes.esa.int/funding>

P1 activities for which industry and Participating States declare an interest will be given precedence when preparing Invitations To Tender (ITT). Such interest can be notified directly to the ARTES AT Programme Office via the contact details on the ESA ARTES web site: <https://artes.esa.int/advanced-technology>.

P2 activities will only be initiated either:

1. on the explicit request of at least one delegation; or
2. on the initiative of the Agency following consultation with national delegations.

The P2 activities which have been requested to be initiated will be identified on the ESA ARTES web site: <https://artes.esa.int/funding>.

ANNEX 1: SUMMARY TABLE FOR ARTES ADVANCED TECHNOLOGY ACTIVITIES IN THE WORKPLAN 2016

Activity Ref.	Title	Cost	Priority	Cost (K€) (priority 1)	Cost (K€) (priority 2)	Proc. Policy
SYSTEM/ NETWORK / PROTOCOLS						
System, Networking and Management						
3A.062	Prototype for a command and control data link for UAV's in the 5 GHz band (**)	500	P1	500	0	C
3A.066	Test-bed for Cost-efficient M2M Systems (**)	400	P2	0	400	C
3A.069	Network Coding Protocols for Satellite Terminals with Multiple Logical Paths (**)	500	P1	500	0	C
3A.070	Verification campaign of the DVB Carrier-ID detection and demodulation (re-issue) (**)	600	P1	600	0	C1
3A.071	Demonstrator of light-weight application and transport protocols for future M2M applications (*) (**)	400	P1	400	0	C1
3A.073	High Throughput Digital Broadcasting Satellite Systems (**)	500	P1	500	0	C
3A.074	Security and content rights management in satellite-assisted in-network caching systems (**)	600	P1	600	0	C
3A.075	Demonstrator for Satellite Terrestrial integration in the 5G context	1,500	P1	1,500	0	C1
3A.076	Carrier Aggregation in Satellite Communication Networks	450	P1	450	0	C1
3A.077	Demonstrator of License Assisted Spectrum Access Satellite Networks	600	P1	600	0	C
3A.078	Live Satellite Demonstration of Advanced Interference Management Techniques	1,300	P2	0	1,300	C
3A.079	Demonstrator for Extremely High Frequency (EHF) Broadband Links	400	P2	0	400	C
3A.080	Satellite M2M Technologies Demonstration	500	P2	0	500	C
	subtotal	8,250		5,650	2,600	
Propagation						
3B.033	Cubesat-based W-band channel measurements (re-issue) (**)	3,000	P1	3,000	0	C
	subtotal	3,000		3,000	0	
Coding, Modulation and Access						
3C.012	DTH Transmit and Receive Demonstrator using Variable/Scalable Coding and Modulation	520	P2	0	520	C
	subtotal	520		0	520	
SPACE SEGMENT - PLATFORM						
Platform - System and Architecture						
4A.057	Low cost GNSS Receiver for Geostationary Telecom Satellites (re-issue) (**)	500	P1	500	0	C
4A.060	Fault-Tolerant and Commercial Off The Shelf-based On Board Computer	500	P1	500	0	C
4A.061	Multifunctional Structure Elements	500	P2	0	500	C
4A.063	Industrial Radiation Shielding Analysis Methods for Telecom Satellites	450	P2	0	450	C
4A.064	Pointing Error Engineering for Telecommunication Missions	400	P2	0	400	C
	subtotal	2,350		1,000	1,350	

Activity Ref.	Title	Cost	Priority	Cost (K€) (priority 1)	Cost (K€) (priority 2)	Proc. Policy
Propulsion System						
4B.108	High flow rate pressure regulator for all electric telecom satellite applications (**)	600	P2	0	600	C
4B.120	Alternative Titanium Tank Hemisphere Manufacturing Techniques	500	P2	0	500	C
4B.121	Long-Life and High Performance Thruster	700	P1	700	0	C
	subtotal	1,800		700	1,100	
AOCS						
4C.035	Star Tracker based on Faint Star predevelopment for Telecoms (**)	500	P1	500	0	C1
4C.041	Improved Torque Stability of Reaction Wheels via Embedded Digital Wheel Speed Control	500	P1	500	0	C
4C.042	On-board Guidance Optimisation for Electric Propulsion Orbit Raising	450	P1	450	0	C
	subtotal	1,450		1,450	0	
Thermal System						
4D.044	3D Thermal Interface for High Power Unit using Additive Layer Manufacturing	400	P1	400	0	C
4D.045	Development of Wireless Passive Sensors for Temperature Measurement	300	P2	0	300	C1
4D.046	Heat Pump System Compressor	600	P2	0	600	C1
	subtotal	1,300		400	900	
Mechanical System						
4E.059	Design margin optimisation for mechanisms on board telecommunication spacecrafts (re-issue) (**)	500	P1	500	0	C
	subtotal	500		500	0	
Power System						
4F.084	Aluminium wire application in telecommunication platforms (**)	400	P2	0	400	C
4F.099	Power Processing Unit Switch-On strategy after Spacecraft Separation	400	P1	400	0	C
4F.100	Alternative European Micro-Point of Load Design	500	P2	0	500	C1
4F.101	Development and Optimisation of a new Slip-Ring for High Power Density Applications	500	P2	0	500	C1
4F.102	Enhanced Coating Technologies for Next Generation Solar Cells	500	P2	0	500	C
4F.103	Solar Array Drive Mechanism Slip-Ring Sensitivity Against Standard Pollution Types and Levels	600	P2	0	600	C
4F.104	Alternative Components for Medium to High Power Solar Array Drive Mechanisms	700	P2	0	700	C
	subtotal	3,600		400	3,200	
Command and Data Handling						
4G.013	Low-cost multi-channel transceiver for hosted payloads (**)	700	P1	700	0	C
4G.015	Development of a Hosted Payload Interface Unit	400	P1	400	0	C
4G.016	Corona-Free S-band Diplexers for Tracking Telemetry & Command	400	P2	0	400	C
	subtotal	1,500		1,100	400	

Activity Ref.	Title	Cost	Priority	Cost (K€) (priority 1)	Cost (K€) (priority 2)	Proc. Policy
SPACE SEGMENT - PAYLOAD						
Payload - system and architecture						
5A.037	On-board Interference Geo-Location System (**) (*)	600	P1	600	0	C
5A.051	Performance Enhancement of Transparent Digital Processors	400	P1	400	0	C
5A.052	Risley Prism Beam Steering Device	800	P1	800	0	C1
5A.053	Wavelength Division Multiplexing (WDM) on Optical Communication Terminals	800	P2	0	800	C1
5A.054	C-band Inter-Satellite Link	650	P2	0	650	C
5A.055	Accurate Pressure Predictions in Critical High Power RF Hardware	400	P2	0	400	C
	subtotal	3,650		1,800	1,850	
Antenna						
5B.162	Measurement Methodology for Fast Antenna Testing	600	P1	600	0	C
5B.163	Antenna Deployment Arm with Integrated Elastic Hinges	400	P1	400	0	C
5B.164	Design for Manufacture Approach for Large Frequency Selective Surfaces for Telecom Applications	500	P1	500	0	C1
5B.165	Cost-Effective High-Gain CubeSat Antennas	350	P2	0	350	C2
	subtotal	1,850		1,500	350	
Repeater Equipment						
5C.266	Gallium Nitride output stage for converter (re-issue) (**)	750	P1	750	0	C
5C.269	Miniaturised Ka-Band Beamforming Network Using Additive Manufacturing Techniques (**)	500	P2	0	500	C
5C.270	Miniaturised Dplexers for L-Band Mobile Missions (re-issue) (**)	600	P1	600	0	C1
5C.275	High Voltage Cable for Q-Band Traveling Wave Tube Amplifiers (re-issue) (**)	600	P1	600	0	C1
5C.276	Waveguide Flanges with enhanced passive intermodulation performance (**)	300	P1	300	0	C
5C.300	Cost Competitive and Reliable Converters	1,000	P1	1,000	0	C
5C.301	Miniature Bulk Acoustic Wave Filters	500	P1	500	0	C1
5C.302	High Linearity Gallium Nitride (GaN) Mixer	500	P1	500	0	C1
5C.303	Fully Adaptive RF Lineariser for High Power Amplifiers	850	P1	850	0	C
5C.304	Next Generation Temperature Compensated OMUX Channel Filters	650	P1	650	0	C
5C.305	Adaptable MODEMs for Inter-Satellite Links	900	P2	0	900	C1
5C.306	Transparent Optical Transponder Demonstrator	750	P2	0	750	C
5C.307	Q-Band Output Multiplexer	500	P2	0	500	C
5C.308	Development of Nonlinear Broadband Models of TWTs for Highly Optimised Linearisers	700	P2	0	700	C
5C.309	Low Loss Flexible Waveguide Interconnections	350	P2	0	350	C1
5C.310	Novel Class of Isolators	600	P2	0	600	C1
5C.311	Demonstration of GaN HPA with Improved Radiation Robustness for Future Telecom Missions	600	P2	0	600	C
5C.312	Channel Amplifier Integrating SiGe Technology	500	P2	0	500	C
5C.313	W-Band Waveguide Switch	400	P2	0	400	C1
	subtotal	11,550		5,750	5,800	

Activity Ref.	Title	Cost	Priority	Cost (K€) (priority 1)	Cost (K€) (priority 2)	Proc. Policy
Small Sat Payload Equipment						
5E.002	C-band transceiver for small satellites (**)	500	P1	500	0	C
5E.005	Deployable antenna structures for small satellites (re-issue) (**)	500	P1	500	0	C
5E.006	Network and link layer solutions for inter-satellite links between small satellites (**)	350	P1	350	0	C
5E.009	Space Based VDE Transceiver (*)	900	P1	900	0	C2
5E.010	Development of a Light-weight Optical Terminal for Small Satellites	1,000	P2	0	1,000	C2
	subtotal	3,250		2,250	1,000	
GROUND SEGMENT						
TT&C/Ground Support Equipment						
6A.054	Implementation of Virtualised Network Function (VNF) for Broadband Satellite Networks	750	P1	750	0	C
6A.055	Integrated Bi-Directional Amplifier for Remotely Piloted Vehicle Applications	500	P1	500	0	C1
	subtotal	1,250		1,250	0	
Ground Network Operation Control and Gateway						
6B.030	Satellite Gateway Development for Massive Uncoordinated Access Networks	700	P1	700	0	C
6B.031	Critical Building Blocks for Next-Generation Q-/V- and W-Band ground HPAs	1,500	P2	0	1,500	C2
6B.032	Innovative Feeder Link Antenna Array for Future Wide Band Communications in Ka- and Q/V-Band	300	P2	0	300	C
	subtotal	2,500		700	1,800	
USER TERMINALS						
7-.038	Embedded Antenna Arrays in small UAV Wing Structures (re-issue) (*) (**)	500	P1	500	0	C1
	subtotal	500		500	0	
Professional User Terminals						
7A.036	Ka-band Transceiver Power devices	1,000	P2	0	1,000	C2
7A.038	10 Gbps Modem for Telecom Point-to-Point Applications	1,400	P2	0	1,400	C1
7A.039	Terrestrial Interference Resilient Terminal Prototype	600	P2	0	600	C1
	subtotal	3,000		0	3,000	
Consumer User Terminals						
7B.031	M2M 'Makerspace' for Satellite Communications	500	P2	0	500	C3
7B.032	Broadband SiGe IQ-modulator	350	P1	350	0	C1
	subtotal	850		350	500	
User Terminal Mobile						
7C.039	Ka-band Receive Only Active Antenna for the Consumer Market (**)	1,500	P2	0	1,500	C1
7C.042	SatCom Module for Smartphones (re-issue) (**)	550	P1	550	0	C1
	subtotal	2,050		550	1,500	
TOTAL (k€)		54,720		28,850	25,870	

(*) P2 activity for which a request for initiation has been received.

(**) Carried forward from previous workplan

ANNEX 2

ARTES ADVANCED TECHNOLOGY WORKPLAN 2016

The activities are grouped into the following categories:

1. SYSTEM/NETWORK/PROTOCOLS
 - 1.1 System, Networking and Management
 - 1.2 Propagation
 - 1.3 Coding, Modulation and Access

2. PLATFORM
 - 2.1 Platform - System and Architecture
 - 2.2 Propulsion System
 - 2.3 AOCS
 - 2.4 Thermal System
 - 2.5 Mechanical System
 - 2.6 Power System
 - 2.7 Command and Data Handling

3. PAYLOAD
 - 3.1 Payload - System and Architecture
 - 3.2 Antenna
 - 3.3 Repeater Equipment
 - 3.4 Small Sat Payload Equipment

4. GROUND SEGMENT
 - 4.1 TT&C/Ground Support Equipment
 - 4.2 Ground Network Operation Control and Gateway

5. USER TERMINALS
 - 5.1 Professional User Terminals
 - 5.2 Consumer User Terminals
 - 5.3 User Terminal Mobile

1. SYSTEM/NETWORKS/PROTOCOLS

1.1 System, Networking and Management

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.062	Prototype for a command and control data link for UAV's in the 5 GHz band	500	1	24
Objective:	Full design and validation of a 5 GHz BLOS (Beyond Line of Sight) and LOS (Line of Sight) air interface for command and control of UAVs.			
Targeted Improvements:	Open new markets for satellite operators and terminal manufacturers by enabling future integration and operation of UAVs in manned airspace by means of a satellite Command & Control and non-Payload Communications link in the 5 GHz band.			
Description:	<p>UAV commercial operations are a potential business that Industry will transfer from the military to the civil world provided that regulatory hurdles (i.e integration into civil airspace) are solved and the right data link technology is available. Key stakeholders (ICAO, aviation agencies, ITU and Industry) are already working on both fronts. The FAA has the US Congress mandate to integrate UAVs in civil airspace by 2015 and NASA has received rather large funds to carry out studies, including the development and certification of a command and control (C2) link radio prototype for commercial UAV operations.</p> <p>Although the World Radio Conference 2012 has allocated spectrum for UAV C2, so far no European UAV C2 civil data links have been proposed for these frequency bands (5030-5091 MHz). While civil aviation authorities will not allow UAV operations without certified links and terminals, regulatory authorities expect that Industry will propose standardised data links for certification.</p> <p>Given the fast evolution in the domain of civil UAV operations, it is key to promote a European C2 datalink proposal that enables European space industry to access this market. In this context it is also mandatory to pave the way for the inclusion of a satellite component in the C2 operational definition to show the added value that satcoms can bring. It is also important that any satellite datalink solution shall interwork with the terrestrial datalink solutions.</p> <p>On this very topic, ESA has supported the inclusion of a work item in the relevant EUROCAE working groups, such that proposed activity will be implemented in the right context and with proper access to the datalink requirements which are currently being formulated.</p> <p>In order to promote a European datalink solution, a prototype shall be developed which shall demonstrate that the stringent requirements can be achieved. Furthermore, the prototype shall prove that synergies can be obtained by combining LOS and BLOS communications in the same avionics. The activity shall contribute to European discussions regarding the 5 GHz band planning in Europe.</p> <p>The proposed activity shall:</p> <ul style="list-style-type: none"> - Revisit the ARTES 1 “ESPRIT” study according to the latest ICAO/FAA/EUROCAE/RTCA Conops and Minimum Performance Standards documents. - Propose a sharing mechanism of the 5030-5091MHz band between the terrestrial and satellite links that guarantees the necessary resources for competitive satellite links. - Design and validation of the prototype supporting an air interface that exploits synergies between terrestrial and satellite data links. - Establish a representative test environment. - Implement and test of a radio prototype covering both terrestrial and satellite datalinks. 			
Deliverables:	Preliminary Air Interface prototype with design and test documentation			
Follow-up of a previous activity:	This activity will build upon the results of a previous ARTES 1 study (“ESPRIT”), in which the system aspects of satellite communication solutions for UAVs command and control were studied.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.066	Test-bed for Cost-efficient M2M Systems	400	2	18
Objective:	Demonstrating in laboratory the performance of a cost-efficient M2M system based on advanced techniques and technologies.			
Targeted Improvements:	Minimize the service provision costs (e.g. achieve ~2 dB reduction of transmit power at terminal level while lowering the terminal cost).			
Description:	<p>Some market segments tend to be more satellite affine than others such as transportation, logistics and supply chain, SCADA and energy. The major reasons for selecting satellite to connect devices are coverage, lack of alternatives, and high reliability requirements. On the other hand, the reported major disadvantages of satellite communication are costs, both for the service and the terminal hardware.</p> <p>This activity shall demonstrate within physical layer and system simulators the performance of an advanced M2M network, exploiting state-of-the-art air interface techniques as well as an optimised space segment. To this end, the activity will derive the major figures of merit at system level (e.g. efficiency, achievable throughput, availability, network size, and scalability) based on the user traffic profiles of the selected M2M services. The overall goal is to minimize the service provision cost also taking into account the terminal complexity impact. Other aspects like security and integration with terrestrial networks will be addressed.</p>			
Deliverables:	Study report, breadboard			
Follow-up of a previous activity:	ARTES 1: SAMOS and ARTES 5.1:Frequency Flexible M2M Modem			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.069	Network Coding Protocols for Satellite Terminals with Multiple Logical Paths	500	1	18
Objective:	To design and validate Network Coding mechanisms that can exploit modern satellite networks with multiple logical paths from the satellite terminals towards their Corresponding Nodes. Also, to provide a reference implementation for Network Coding mechanisms in a representative satellite network scenario.			
Targeted Improvements:	Improved user perceived quality of service (QoS). Preliminary results of network coding applied in satellite networks with multiple logical paths indicate up to 50% improvement in throughput for a subset of terminals.			
Description:	<p>There are numerous emerging satellite network scenarios where the logical path between the information source and the destination is not unique. Such logical paths can be realised with satellite user terminals that support multiple frequency bands, multiple air interfaces, or that can access to multiple beams and gateways. Recent studies have shown the merit of applying network coding to jointly use multiple logical paths in offering more flexibility, diverse service portfolios, seamless handovers, and improved QoS.</p> <p>Despite the potential gains of multiple logical paths, there are currently no commonly-adopted methods that integrate such network coding into the OSI-layered network architecture.</p> <p>The activity first aims to consolidate different deployment strategies for network coding in pertinent satellite system scenarios with multiple logical paths. It shall be ensured that the proposed solutions shall not interfere with the operation of other protocols including – at least – IPv4/IPv6 security, mobility, network discovery, and multicast routing protocols, IETF header compression techniques, performance enhancing proxies and data compressors at transport and application layers, Ethernet bridges, virtual LANs, and ARQ at link layer according to the following work logic:</p> <ul style="list-style-type: none"> • Review and consolidation of satellite network scenarios that can exploit multiple logical paths between source and destination; • Investigation of possible network coding mechanisms that can improve the QoS and network efficiency in the aforementioned scenarios; • Design and validation of protocols that can support such mechanisms; • Dissemination of the outcomes to standardization bodies. <p>The protocol and its interactions with other network elements shall be validated in a real-time packet-level testbed that shall incorporate commercial off-the-shelf (COTS) network equipment.</p>			
Deliverables:	Study report, and testbed software			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.070	Verification campaign of the DVB Carrier-ID detection and demodulation	600	1	12
Objective:	To develop and demonstrate in the field a receiver terminal implementing the newly defined DVB Carrier-ID standard (DVB-CID) for the detection and demodulation of multiple transmitting carriers.			
Targeted Improvements:	The proposed activity will demonstrate in a realistic satellite environment the effectiveness of the DVB-CID technologies for the detection of unintentional jammers. This activity will be instrumental for generating new market opportunities for European modem manufacturers.			
Description:	<p>The DVB-CID technology has been recently standardized (May 2013) with the purpose of detecting the presence of unintentional sources of interference coming from DSNG (Digital Satellite News Gathering) or others. In fact, one of the main sources of service interruptions in broadcasting or professional communication links is the presence of unintentional interferers which are accidentally transmitting towards another transponder (e.g., erroneous dish pointing, broken BUC –block upconverter- sweeping in frequency).</p> <p>The DVB-CID consists in a mandatory spread-spectrum signal to be transmitted by all new satellite modulator equipments in order to allow their identification.</p> <p>The purpose of this activity will be to implement the required receiver technologies to detect multiple DVB-CID signals, and verify the effectiveness of current technologies in realistic interference scenario. The activity will be instrumental to enhance and improve the capability for detecting the presence of unwanted transmitter signatures. Concerning the generation of DVB-CID signals, the available products in the market will be used to set up the test-bed for the end-to-end validation campaign.</p> <p>The activity shall define the typical scenarios of disrupted broadcasting channels. These scenarios will be instrumental to determine the requirements of the DVB-CID demodulators. The successive step will be the hardware implementation of the spread spectrum techniques for the correct and robust detection of the different transmitted signals. Finally, the activity shall include a field demonstration of the effectiveness of the developed technologies in the DVB-CID receiver to meet the challenges of typical satellite scenarios with unintentional jammers.</p>			
Deliverables:	Study report, and testbed			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.071	Demonstrator of light-weight application and transport protocols for future M2M applications	400	1	15
Objective:	To critically review, propose improvements for, and to assess in a satellite network testbed or simulator, the recent light-weight application and transport protocols proposed for M2M communications.			
Targeted Improvements:	Performance improvement of M2M application and transport protocols in satellite networks by 50%. Increase market share of European satellite industry in M2M applications. Cost reduction in general.			
Description:	<p>Device heterogeneity, low power and memory, and the need to operate unattended for extended intervals on limited battery lifetimes are typical characteristics of M2M (machine-to-machine) communications. Hence, there is an increasing drive among developers, equipment manufacturers, and users towards open and interoperable light-weight yet efficient M2M protocols. There is a need to assess the suitability of these protocols in satellite networks, and propose to relevant standardisation fora appropriate improvements to increase the share of satellite communications in the M2M market.</p> <p>This activity will undertake a critical review of light-weight application and transport protocols for M2M devices. Furthermore, the activity will design and develop optimisations for these protocols for satellite networks. A verification and quantitative assessment of proposed optimisations will be performed following that. The results will be actively reported back to relevant standardisation fora.</p>			
Deliverables:	Study report and testbed			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.073	High Throughput Digital Broadcasting Satellite Systems	500	1	12
Objective:	To demonstrate the feasibility of techniques and technologies that can significantly reduce the total cost of video content delivery via satellite to the end users while improving flexibility, service quality, and the user’s experience in a real time platform, representing realistic system scenarios.			
Targeted Improvements:	The target gain is to demonstrate and quantify the performance gain of payload, system and ground component techniques that can together enable significant improvements (more than twofold) in the content delivery capacity of digital broadcasting satellites, in comparison to conventional state-of-the-art solutions. The goal is to demonstrate a combination of such techniques working together in a real-time platform (preferably taking advantage of the existing space assets), to deliver a higher capacity under a set of system constraints (such as available power and/or bandwidth).			
Description:	<p>Starting from the outcome of previous ARTES studies, this activity aims to demonstrate measurable enhancements in quality, performance and flexibility offered by innovative techniques and technologies both at the ground segment and system level. It also aims to assess the feasibility of proposed techniques in a representative system set-up.</p> <p>The goal is to provide convincing evidence to the stakeholders of the benefits which would allow to significantly improve the competitive advantage of direct broadcasting satellites. This activity is meant to improve the maturity and the technology readiness level of promising solutions that are identified in other previous or on-going TRP and ARTES projects.</p> <p>The first part of this activity will focus on selecting relevant techniques (inputs from other activities) that have reached a level of maturity to be included in an end-to-end system demonstrator platform. Consolidating the results of previous activities and complementing them with relevant technologies and techniques to demonstrate how to achieve the above objectives.</p> <p>The end-to-end demonstrator shall combine several techniques such as: Exploitation of regional/linguistic beams/multi-beam in the conventional Ku-band frequency and higher (Ka-band broadcasting); Increased frequency/polarization reuse; Reduction of orbital spacing for coordinated fleets by implementing interference mitigation techniques; A Higher EIRP Density/higher order modulations for broadcasting; Seamless reduction of video quality in case of fading to reduce the static link margin using VCM or Hierarchical Modulation (and SVC); Higher efficiency video encoder (HEVC) Adaptive link margin control based on return channel feedback; Minimum SNR maximization techniques at the transmitter of a multi-beam broadcasting systems; Enhanced multiplexing and transport protocols such as GSE-Lite; Exploitation of residual capacity for terminals in more favorite position.</p> <p>The benefits shall be quantified according to pre-selected figures of merit in comparison to a benchmark conventional system. The activity shall establish a set of representative scenarios and consolidate the results for the identified technology showcases for presentation and demonstration to key players in satellite broadcasting segment.</p>			
Deliverables:	Study report, Demonstrator			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.074	Security and content rights management in satellite-assisted in-network caching systems	600	1	24
Objective:	The project aims to study and develop an end-to-end secure infrastructure for delivery of collaborative multimedia services over integrated satellite terrestrial networks. The project envisages an expedient combination of broadcast and unicast technologies where typically the main component is satellite broadcast/multicast assisting in-network caching telecommunication systems.			
Targeted Improvements:	Collaborative services delivery over heterogeneous integrated satellite terrestrial networks creates new business opportunities for satellite networks enabling satellite service providers to enhance their services line up. Users can benefit from an enhanced service experience, i.e. service resilience and security and improved Quality of Experience.			
Description:	<p>The activity shall analyse integrated networks deployment scenarios where the satellite acts as the interconnection link between in-network caches and/or feeds edge-network caches at micro-centre locations. Video packet or chunk based caching techniques shall be analysed. Cache access control, content integrity, provenance, confidentiality and authentication as well as privacy and caches security and availability are of outmost importance.</p> <p>Once the security requirements are established, the activity shall focus on the security solutions proposed for distributed in-network caches in terrestrial networks, and examine how these solutions compare to traditional IP-based security solutions, what are the benefits they bring and how they could be adapted to match satellite network requirements.</p> <p>The new security solution space shall include advanced solutions against privacy infringement attacks, enhancements of access control and the establishment of security custodian as a new trustful entity, and use of homomorphic encryption.</p> <p>The activity shall analyze carefully the complexity of proposed security solutions and minimize the signalling exchanges over satellite links. The activity shall then extend the integrated satellite terrestrial networks architecture with selected security mechanisms, validating the security-enhanced architecture performance. The activity shall analyze also how the value chain configurations are impacted by the introduction of security and content rights management enablers, identify potential conflicts between actors and propose solutions. The activity shall build upon the results of the ARTES 5.1 activity on ‘The role of satellite in adaptive bitrate streaming services’ by using and enhancing the developed Proof-of-Concept with security and content rights management solutions.</p>			
Deliverables:	Study report and testbed			
Follow-up of a previous activity:	The role of satellite in collaborative adaptive bitrate streaming services			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.075	Demonstrator for Satellite-Terrestrial Integration in the 5G context	1500	1	24
Objective:	<p>To design and build a large-scale real-time live 5G integrated satellite-terrestrial network Proof-of-Concept that enables the satellite terrestrial convergence into the 5G context.</p> <p>Also to :</p> <ul style="list-style-type: none"> – provide reference implementation for Software Defined Network (SDN) and Virtualized Network Functions (VNF) technology enablers in a representative satellite network operational environment covering high bandwidth video and narrow band M2M services; – enable virtual satellite networks operation in the 5G environment; – assess end-to-end integrated system performance and provide coherent integrated network management. 			
Targeted Improvements:	<ul style="list-style-type: none"> – Lower cost per satellite service and make satellite networks more cost efficient and accessible for numerous service providers and customers; – CAPEX reduction to more than 50% , OPEX reduction to more than 20% respect to current status of art (percentages extrapolated from terrestrial implementations); – Satellite service creation reduction to 40 min instead of 90 hours which is the current status if all customised H/W devices are deployed; – Cross sectorial use of the same satellite network infrastructure (i.e. high bandwidth video and narrowband M2M services with different Quality of Service (QoS) and dynamic Service Level Agreements (SLA)). 			
Description:	<p>The 5th generation of mobile communications technology (5G) is positioned to address the demands and business contexts of 2020 and beyond,. To materialize the vision, 5G needs to support and exploit the integration of heterogeneous networks such as terrestrial and satellite.</p> <p>The main vehicle for providing customized 5G network infrastructures for specific applications and services is the cloud computing technology extended to include the network infrastructure (cloud networking). The most promising architecture and implementation comes from Software Defined Networking (SDN) where networks can be dynamically programmed through centralized control points and from Network Function Virtualization (NFV) enabling the cost-efficient deployment and runtime of network functions as software only. Through this the specific services can be highly customized, enabling the seamless integration of different heterogeneous networks such as satellite networks. In an integrated 5G ecosystem, satellite networks are providing a highly dependable and global coverage type of communication. Satellite is well positioned to target high data rate broadcast/multicast services, M2M narrowband services, congestion offload of terrestrial networks (i.e., for signaling and/or video) as well as highly distributed and customized enterprise networks (i.e. critical infrastructures, dedicated M2M, industrial communication).</p> <p>The advent of different satellite networks based on GSO/NGSO satellites and constellations as well as new technologies used in High Throughput Satellites (HTS) facilitate the emergence of new players i.e. Satellite Virtual Network Operators and Service Providers, in the launch of satellite services market and allow the satellite industry to improve its value proposition in the 5G ecosystem. These developments are opening up and expanding market opportunities particularly in M2M/IoT, edge networking (for low latency localized communication and reduced backhaul data traffic), dynamic backhaul, and IP multimedia distribution, which are seeing explosive demand on the back of high growth rates in 4G.</p> <p>The role of satellite needs to be practically demonstrated, especially in the area of comprehensive network integration with 5G terrestrial networks, including integration at physical and virtualized infrastructure levels, as well as for providing a coherent end-to-end runtime environment for highly distributed applications. Currently, satellite networks are missed within the 5G large-scale experiments. Its core relevance needs to be addressed, especially because of the need to scale highly customized network infrastructures for the different services with different delay, Quality of Service (QoS), Service Level Agreements (SLA), security and reliability requirements through a common integrated multi-tenant infrastructure.</p> <p>The activity proposes to build a large-scale real-time live end-to-end 5G integrated satellite terrestrial network Proof-of-Concept that enables the satellite terrestrial convergence into the 5G context. It shall include the infrastructure test-bed considering both physical and network functions virtualisation in order to enable the establishment of the end-to-end virtual integrated satellite terrestrial network following the Infrastructure as a Service (IaaS) principle. A prototype of the integrated networks and services management and orchestration shall be implemented to provide coherent</p>			

	<p>overall management. Generic functional enablers shall be implemented at both the gateway and remote terminals, such as IP multicast, small messages aggregation and caching, addressing different communications domains i.e. video and M2M/IoT (Platform as a Service PaaS). These shall be executed transparently to the specific service under test. Finally, selected usage cases for IP-enabled video and M2M/IoT services shall be demonstrated over the air.</p> <p>The activity shall:</p> <ol style="list-style-type: none"> 1. demonstrate SDN-enabled satellite network performance enhancements, 2. prototype SDN-enabled elements in support of the next generation satellite ground and space segment, 3. interoperability of the satellite and terrestrial component within the 5G integrated networks, 4. establish key parameters for satellite networks so as to achieve their optimal operation considering both technical (required capacity, tolerable latency) and economical (cost) factors, 5. provide inputs to the on-going standardisation groups such as ETSI NFV, ETSI MEC, 3GPP and IETF SFC with satellite specific requirements , and <p>The activity shall take advantage of a large set of Proof-of-Concepts test beds developed for the terrestrial area as baseline for the proposed development. Only satellite specific delivery components developments and customisation of management, orchestration, measurement and monitoring tools are accounted in the proposed activity.</p>
Deliverables:	Study reports, test bed/demonstrator software
Follow-up of a previous activity:	ARTES1 ‘Service Delivery over integrated terrestrial networks’, ‘The role of satellite in Future Internet Services’, ‘Scenarios for integration of satellite components in future networks’, ‘Next Generation of satellite networks for video distribution and content delivery’.

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.076	Carrier Aggregation in Satellite Communication Networks	450	1	18
Objective:	<p>The objective of the activity is to demonstrate the potential of Carrier Aggregation (CA) technology for various satellite communications networks (MSS, FSS) operating in various frequency bands (C-, Ku, Ka- and Q/V-bands). Carrier aggregation needs to be addressed at different levels of the communication stack:</p> <ul style="list-style-type: none"> – Physical layer (e.g. multi-carrier transmit/receive, non-linear satellite channel, guard band setting); – RF (e.g antenna bandwidth, Max output power, spectrum emission mask, adjacent channel leakage ratio, spurious emissions); – Payload (e.g. impact on the payload channel size and filling rate) and onboard receiver architecture; – MAC (e.g. Resource allocation approach/flexibility, transponder traffic fillings, beam handover control, complexity of processing). 			
Targeted Improvements:	<ol style="list-style-type: none"> 1. Increased practical & peak data rates. 2. Leverage all spectrum assets by allowing to fill unused gaps in transponders. 3. Simplifies multi-band traffic management over non-contiguous spectrum allocations. 4. Improves latency (and QoS in general) through load balancing as the traffic can be accommodated by multiple smaller resource blocks instead of a single larger one. 5. Enables interference management with intelligent allocations of resources as the assignment of multiple carriers to each user creates an additional axis in the resource allocation. 			
Description:	<p>Carrier Aggregation (CA), that is the association of multiple carriers to/from a single user, is a key enabling technology in terrestrial radio communications networks (e.g. LTE) with the first CA chipset already available in the terrestrial market.</p> <p>As satellite spectrum is a finite resource and user expectations for interactive data services are becoming increasingly sophisticated, intelligent allocation of resources and the optimum use of transponders is mandatory. Carrier aggregation (CA) enables the optimal exploitation of spectrum resources and transponders and leads to higher peak and average data rates for user terminals (e.g. in hot spots).</p> <p>CA can be of high interest in scenarios where a single terminal can satisfy its aggregate leased capacity demand from multiple carriers occupying spectrum in different transponders. This approach could minimize gaps in the satellite transponders that cannot be utilized for other services. It can also lead to a substantial increase in the delivered data rate, up to levels not possible when only a single carrier is employed.</p> <p>The benefits of CA come at the cost of complexity in the satellite terminal (at various levels) that need to be traded-off. For example, the proposed study shall identify and analyse which elements of the transmit and receive chain (e.g. tuner, SSPA) need to be augmented, as well as identify what processing is required at the physical and MAC layer. Additionally, the layer of re-combining data from multiple carriers (e.g. at GSE level) shall also be an area of study.</p> <p>The activity shall:</p> <ol style="list-style-type: none"> 1. Define the operational scenarios, system architectures, type of terminals, and physical layer techniques that are more relevant to CA. 2. Assess the impact on the user terminal and onboard receiver architecture. 3. Develop the ‘Carrier Aggregation Demonstrator’ carrying out emulations of carrier aggregation at the physical, RF and MAC layer over multiple loaded satellite transponders. 4. Test the ‘Carrier Aggregation Demonstrator’ and obtain relevant performance metrics. 			
Deliverables:	Study report, S/W demonstrator			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.077	Demonstrator for License Assisted Spectrum Access Satellite Networks	600	1	24
Objective:	To design and build a License-assisted Spectrum Access (LSA) demonstrator that can exploit frequency sharing scenarios between satellite and other networks and radio services. To provide and trade off reference implementations of centralised versus distributed database-enabled LSA architectures in representative satellite operating environments.			
Targeted Improvements:	<ul style="list-style-type: none"> • Provide cost efficient and technically effective spectrum sharing between satellite and other network and radio services in case of primary/secondary, co-primary and GSO/NGSO sharing scenarios. • Enable satellite networks to access non-dedicated spectrum resources for future expansion opportunities. • Potential traffic increase up to 3 times respect to current traffic as extrapolated from current LSA implementation in 2.3GHz mobile terrestrial broadband networks. 			
Description:	<p>Satcom and terrestrial wireless networks today are designed for and operate in dedicated licensed spectrum. At the same time there are other spectrum usage authorization models, such as unlicensed spectrum access, or, as widely discussed currently but not yet implemented in practice, various forms of licensed shared spectrum. Hence, wireless technology as of today can only operate in a subset of the spectrum that is in principle available. Future satellite systems may benefit from the ability to access spectrum opportunities other than dedicated licensed spectrum. For example, in High Throughput Satellite (HTS) networks, the use case of Ka band shared between fixed terrestrial and satellite as well as between GSO/NGSO networks and the use of higher frequency bands such as Q/V/W as e.g., co-primary users, are important usage cases. Similarly, shared spectrum access can be considered for hierarchically organised satellite networks, constellations, smallsats, etc. Although some additional ways of authorizing spectrum usage have been identified and deemed to become relevant in the future, i.e. Licence-assisted Spectrum Access (LSA), it remains important to analyze the resulting technical requirements and representative demonstrators.</p> <p>Recent ARTES1 studies, i.e. Frequency Sharing techniques with other networks and radio services (FREESTONE), have looked at the sharing possibilities in S band, C band, and Ka band for HTS and between GSO/NGSO. Both technical and cost impacts have been assessed and critical issues identified for the bands mentioned. Scenarios of LSA techniques have been described. Other projects such as TRP ASPIM (Antennas and Signal Processing techniques for Interference Mitigation in next generation Ka band high throughput satellites) have proposed interference mitigation techniques applied at the terminal antenna that can be used alternatively or in combination with the licence-assisted techniques as proposed by Freestone. Satellite band sharing has been studied at EU level as well, i.e. FP7 CoRaSat (COgnitive RADio for SATellite Communications) project that focused exclusively on Ka band. CoRaSat however, did not focus on LSA techniques.</p> <p>The present activity proposes the technology development and demonstration of LSA technique for future satellite communication networks. The activity proposes as a first step the database assisted implementation of LSA Proof of Concept (PoC) enabling the demonstration of various sharing scenarios. The proposed PoC shall consist of an integrated satellite terrestrial test bed and the implementation and the demonstration of LSA generic technology concept in combination with geo-location, satellite and terrestrial/satellite Carrier IDentifier (DVB-CID). As a second step, the activity shall propose selected usage areas (e.g. sharing scenarios in Ka-band, Q/V/W band) and the applied vertical use cases implementation and demonstration – only the satellite components shall be considered/accounted in this activity.</p> <p>The activity shall detail the necessary procedures for the collaboration models between the frequency sharing networks trading-off i.e. centralised vs distributed coordination entity, etc, that could be used to address the sharing scenarios, both horizontal (between primary users) and vertical (between primary and secondary users). The activity shall trade-off also centralised vs distributed database implementations. The prototype shall validate the procedures and assess performance in terms of Key Performance Indicators such as satellite network supported traffic increase, database reactivity time to minimise system outage.</p>			
Deliverables:	Study reports, Proof of Concept Software			
Follow-up of a previous activity:	ARTES1 ACROSS (2011-2012), FREESTONE (2013-2015).			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.078	Live Satellite Demonstration of Advanced Interference Management Techniques	1300	2	18
Objective:	To develop firmware/hardware and demonstrate over an existing satellite multi-beam network the potential of advanced interference management techniques applied at the transmitter (pre-coding) or/and at the receiver (multi-user detection). The activity shall also demonstrate terminal synchronization, estimation and feedback algorithms in support of these techniques.			
Targeted Improvements:	<p>Improve the confidence on advanced interference management/mitigation techniques applied at the transmitter (precoding) or/and at the receiver (multi-user detection) through a satellite live demonstration.</p> <p>Depending on the system assumptions, these techniques can increase the capacity of High Throughput Satellites (HTS) between 30% up to 100% under the same on board burden in terms of mass and power with a conventional satellite, leading to a substantial cost benefit over the existing generation of HTS and mobile satellite systems.</p>			
Description:	<p>Advanced interference management/mitigation techniques – such as precoding and multi-user detection – have shown a great potential for improving the system capacity of high frequency re-use multiple spot beam interactive satellite networks. Results from recent ESA feasibility studies demonstrated that the gains are solid even under practical system, payload and terminal assumptions/ impairments. Interference management/mitigation techniques can also provide flexibility in terms of moving traffic among multiple spot beams without requiring additional on board flexible equipment.</p> <p>The starting point for this activity are the following ARTES and internal activities: (a) Internal work for on “Next Generation HTS Systems”, ARTES 1: “Next Generation Waveform for Improved Spectral Efficiency”, ARTES 5.1: “System Demonstrator for Advanced Interference Mitigation Techniques in Satellite Networks” and “Precoding Demonstrator for Broadband System Forward Links”.</p> <p>To reach the necessary Technology Readiness Level (TRL) so that the satellite industry may take advanced interference management /mitigation techniques with minimum risk, a prototyping of the required firmware/hardware as well as a satellite live demonstration are needed. Toward this, ‘soft’ firmware prototypes (such as Software Defined Radio (SDR)) shall be developed to emulate the gateway and terminal functionalities that are required to realize interference management/mitigation and are beyond the capabilities of currently available hardware. These functionalities are mostly focused on acquiring synchronization, performing channel estimation and cancelling the interference at the terminal and on calculating the precoding matrix, selecting the modulation and coding and scheduling the users at the gateway. For the purpose of the demonstration, also a return channel needs to be implemented in order to feed back the terminal channel estimates.</p> <p>The work logic is as follows:</p> <ol style="list-style-type: none"> 1. Define the operational scenarios, system architectures, type of terminals and gateway, and physical layer techniques of which the satellite live demonstration is representative. The system may be operating in any frequency band providing fixed or nomadic user services. 2. Develop the necessary transmitter and receiver prototyping that emulate the functionalities at the gateway and terminal side when advanced interference management techniques are applied. 3. Test the advanced interference management transmitter and receivers over a satellite network. The network may be operating in any frequency band. The only pre-condition shall be the presence of at least two co-channel beams in the network. Preferably, to fully demonstrate the potential of interference management, existing satellite that can achieve full frequency re-use should be used. 			
Deliverables:	Study report, prototype			
Follow-up of a previous activity:	ARTES 5.1: System Demonstrator for Advanced Interference Mitigation Techniques in Satellite Networks” and “Precoding Demonstrator for Broadband System Forward Links”.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.079	Demonstrator for Extremely High Frequency (EHF) Broadband Links	400	2	18
Objective:	<p>To explore the feasibility of usage cases for EHF frequencies amongst which aeronautical broadband services that constitute an area for growth for future broadband satcom systems.</p> <p>To demonstrate, through the development of an appropriate system emulator, that with EHF bands the performance would be so to justify the development of new space assets.</p> <p>To provide supporting arguments for efficient and effective spectrum usage of satcom services for the 5G and beyond era and propose detailed technology developments roadmaps and strategic recommendations for the MS Industry.</p>			
Targeted Improvements:	<p>All allocated RF spectrum are now under scrutiny as large portions of spectrum is going to be reserved for the needs of future 5G deployment (i.e., in WRC15 new Action Items are established in this direction for the WRC19). Projected terrestrial 5G deployments are based on the development of new systems and services that have already begun. EHF spectrum is already proposed to be used in co-primary sharing with terrestrial networks. The satcom community needs to proactively demonstrate the potential for EHF frequencies and highlight the contribution of satellite in order to ensure usage of these allocations.</p> <p>Usage of EHF is expected to double the max throughput compared to existing satcom modems, reduce terminal antenna size, and prove the viability of such services.</p>			
Description:	<p>The exploitation of Q/V bands for broadband services has the potential to significantly increase customer throughput thanks to the larger RF bandwidth available, the (relatively) interference free environment, as well as reducing the aeronautical terminal antenna size. The propagation channel effects (when flying below clouds) can be compensated thanks to the exploitation of the new DVB-S2X Very Low SNR (VLSNR) Modulation–Coding (MODCODs) combinations and thus successfully close the link during most adverse weather conditions.</p> <p>The proposed activity will first analyse the requirements of future broadband access and derive the specifications of next generation high throughput terminals using a Q/V band link. A high level terminal antenna design will also be carried out. The relevant regulatory constraints shall also be analysed in detail. Then, an architectural design of the system will follow taking realistic assumptions for space segment performance. The performance of the system shall then be characterized by means of analysis and computer simulations. An extrapolation exercise to evaluate operation in W-band shall also be carried out.</p> <p>A system demonstrator shall be designed and developed with the target of demonstrating the high-speed service during the different channel propagation conditions encountered on a typical flight route. Atmospheric propagation effects shall be included together with the impacts of typical plane manoeuvres and multi-beam hand-overs.</p> <p>The activity shall:</p> <ul style="list-style-type: none"> • Propose and analyse the feasibility of usage areas for EHF frequencies amongst which broadband aeronautical services • Develop system demonstrator • Assess performance of selected services • Propose detailed technology development roadmaps • Propose strategic recommendations for the benefit of MS Industry 			
Deliverables:	Study report, test bed			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3A.080	Satellite M2M Technology Demonstration	500	2	15
Objective:	<p>To demonstrate Machine-to Machine (M2M) services in two representative scenarios based on existing space assets (one in GEO and one in LEO orbit) utilizing existing satellite ground segment technologies developed for cost-effective and bandwidth efficient uncoordinated satellite access networks.</p> <p>Additionally, to analyse and study the applicability of existing and emerging air interfaces, as currently developed and used in the terrestrial sector; to study and implement the necessary modifications/adaptations in the demonstrator for a trial over satellite. The goal is to reuse existing hardware and air interfaces, hopefully enabling satcom solutions that are highly cost effective and present an opportunity for new product and service generation based on compact, low profile, and power efficient user terminals with low maintenance and low installation costs.</p>			
Targeted Improvements:	<p>The targeted improvement are to take the level of maturity of satellite M2M technologies from laboratory to live demonstration over satellite and provide consolidated end-to-end solutions targeting a variety of M2M services. The activity will provide proof of concepts to the key players in the M2M market by demonstrating the feasibility of M2M services via satellite and the cost-effectiveness of global satellite access networks for M2M applications.</p>			
Description:	<p>In recent years there has been a steady progress in developing techniques and technologies (as proprietary or open standards) that allow for uncoordinated system access of a large number of user terminals by taking advantage of contention resolution capabilities at the receiver. Such techniques rely on signal processing techniques such as successive interference cancellation at the gateway that can achieve 2-3 order of magnitudes improvement in throughput at low packet loss ratio compared to conventional ALOHA solutions.</p> <p>Among many solutions, the Enhanced Spread-Spectrum ALOHA (E-SSA) is considered a promising solution in terms of performance (throughput, power/energy efficiency, flexibility etc.) and is adopted as an open standard (S-MIM and its evolutions to other frequency bands). There are also proprietary solutions that are currently adopted for terrestrial wireless M2M applications that may be applicable also to satellite systems.</p> <p>Existing validation platforms will be complemented for live satellite tests. A representative user terminal prototype will be selected or developed for the test campaign. Two complementary space assets, one in GEO orbit and one in LEO, will be identified for the test. In order to assess the effectiveness of the proposed techniques, in addition to a small number of representative user terminals, additional background traffic will be generated and transmitted using a terminal population emulator.</p> <p>The end-to-end test will include representative M2M traffic (e.g. modelling smart metering applications, financial transactions, etc). The performance of each test scenario will be compared against laboratory test results according to a set of predefined figures of merit (e.g. link dimensioning validation, throughput, delay, packet reception success rate).</p> <p>The activity will provide a realistic assessment of the M2M technologies (and different types of air interfaces) that have been available for some time in a pre-operational state. It also allow to show the use of existing space assets to deliver realistic M2M services.</p> <p>The activity shall:</p> <ol style="list-style-type: none"> 1. Define operational scenarios, system architectures, and representative use cases for M2M satellite services for the live demonstrations. Identify the space assets, ground segment components and validation plan. 2. Carry out modifications, delta developments of the M2M terminal prototypes to be used for the validation campaign. Identify methods to represent population of terminals (background traffic). 3. Carry out test campaigns, comparative performance analyses and demonstration of the M2M services using the end-to-end systems 4. Record the validation results, disseminate project findings and promote commercial deployments by planning pilot services 			
Deliverables:	Engineering Model			

1.2 Propagation

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3B.033	Cubesat-based W-band channel measurements	3000	1	40
Objective:	Perform channel measurements at W-bands by means of a beacon designed, developed and launched on a Cubesat platform.			
Targeted Improvements:	Augment ITU-R models for W-band with specific measurements such as i) Tropospheric scintillation at W-band including spectral properties & dependence on elevation angles, ii) combination of cloud and attenuation effects, iii) frequency scaling of rain attenuation, iv) depolarization due to ice (fast XPD without concurrent attenuation).			
Description:	<p>For large broadband satellite networks, the number of gateways may be such that the cost of the ground segment exceeds the cost of the satellite, even when using Q/V band in the gateway feeder link. The use of W-band as a feeder link frequency band in future HTS system could significantly reduce the cost of the ground segment.</p> <p>The usage of the spectrum available in W-band (70/80 GHz) for satellite communications will significantly reduce the number of gateways and consequently the overall cost of the ground segment. However, the channel models available from ITU are known to be accurate only until 30~40 GHz. Therefore new measurement campaigns are needed to characterize the channel propagation at W-band.</p> <p>In this activity a Cubesat shall be used to embark a beacon in W-band in order to perform channel measurement experimentation. The LEO orbit of the Cubesat, although different from the geostationary orbit of future operational satellites exploiting W-band, will allow to characterize fairly well all the major satellite channel impairments. In addition, supporting tools will be used to cope with the short contact times available for the measurements. In particular, an atmospheric channel simulator will be used to bridge the gap between the relatively short LEO measurements and the statistical reliability needed for GEO propagation measurements. The collected Cubesat channel measurements will be used to tune the atmospheric channel simulator. Satellite movement effects will be de-convolved from measurements in order to extrapolate the equivalent GEO propagation channel.</p> <p>The activity shall design and develop the W-band beacon together with the propagation terminal and the Cubesat platform which will host the beacon. Second, the beacon will be tested, integrated in the platform launched using the first flying opportunity. A measurement campaign of at least two years duration shall follow.</p>			
Deliverables:	Study report, in-orbit Cubesat, and updated channel models for W-band			

1.3 Coding, Modulation and Access

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
3C.012	DTH Transmit and Receive Demonstrator using Variable/Scalable Coding and Modulation	520	2	18
Objective:	Develop a DTH demonstrator with Ultra High Definition TV (UHDTV), Scalable High Efficiency Video Coding (S-HEVC) and Variable Coding Modulation (VCM)			
Targeted Improvements:	The combined use of SHVC and VCM could provide between 20% to 30% bandwidth usage efficiencies.			
Description:	<p>The definitions of the HEVC video codec and its scalable extension S-HEVC have now been standardized. They enable a progressive increase video quality by sending only delta information on top of an existing base video signal. S-HEVC is backwardly compatible with MPEG-4 AVC video codecs which are currently in wide spread use. Combined with VCM, S-HEVC would allow to optimise satellite bandwidth usage while maintaining high service availability.</p> <p>The activity could be an enabler for UHDTV broadcast, augmenting HDTV, making an efficient use of the available satellite capacity.</p> <p>The activity shall study, design and build a demonstrator, showing in particular backward compatibility on top of an existing service. Conditional Access System / Digital Right Management aspects shall also be addressed.</p>			
Deliverables:	Prototype			

2. SPACE SEGMENT - PLATFORM

2.1 Platform - System and Architecture

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4A.057	Low cost GNSS Receiver for Geostationary Telecom Satellites	500	1	24
Objective:	To design, manufacture and test a low cost GNSS navigation receiver for Geo satellites, with special emphasis on the RF front-end.			
Targeted Improvements:	Drastic cost reduction as compared to currently available GNSS receivers (200 kEur target). Easier and cheaper ground operations.			
Description:	<p>Current GNSS receivers suffer from a high cost, which impedes their deployment on-board geostationary telecom satellites even though this would significantly help in the determination of the actual position of the satellites. This is mostly due to the fact that space GNSS receivers come from an instrument background rather than a telecom equipment development.</p> <p>Several studies have identified the benefits of having a GNSS receiver as part of the orbit control system for GEO/GTO satellites operations. The main improvements are in terms of operations, autonomy and cost. Indeed the GNSS receiver can determine the orbit thus giving autonomy to the AOCs, and hence simplifying the ground operations and reducing their cost.</p> <p>A currently running Artes 5.1 activity is studying design trade-offs for the integration of a space qualified GNSS chip set (AGGA-4) into the on-board computer. This is one area of cost reduction which is being explored.</p> <p>The proposed activity aims at revisiting current navigation receiver implementations by assessing the different cost contributors, carrying an extensive trade-off analysis as to define an architecture and physical implementation compatible with the typical cost of standard telecom equipment. Special effort shall be made for a compact and cost-efficient complete RF front-end. The re-use of existing building blocks is possible providing that this remains compatible with the cost target.</p> <p>An Elegant Breadboard (EBB) of the GNSS receiver including the newly designed complete RF front-end shall be manufactured and fully tested. The EBB may rely on existing hardware like demonstrator board for the processor, TM/TC and power supply functions.</p> <p>Work Logic:</p> <ul style="list-style-type: none"> - Review of current implementation and GNSS receiver requirements. - GNSS Receiver RF front-end architecture trade-off. - Design, manufacture and test of the GNSS receiver EBB. - Conclusions and way forward. 			
Deliverables:	Study Report and Elegant Breadboard.			
Follow-up of a previous activity:	4C.025 AGGA-4 in OBC (contract 4000108120)			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4A.060	Fault-Tolerant and Commercial Off The Shelf-based On Board Computer	500	1	21
Objective:	Design, development, and prototyping of a fault tolerant and low cost On Board Computer (OBC) with integrated Mass Memory (MM) for LEO and GEO applications			
Targeted Improvements:	Cost reduction and reduced development and production flow for the OBC and MM. The target is a recurrent cost of less than 10% of the current cost of components for a System Monitoring Unit. Possible performance improvements (e.g. mass, power, or volume reduction) from the use of Commercial Of The Shelf (COTS) parts are the expected secondary benefits.			
Description:	<p>LEO orbits have less stringent requirements in term of radiation compared to those of GEO orbits meaning the use of radiation tolerant components instead of radiation hardened parts can be considered. Reduced radiation hardness requirements allow innovative low cost solutions to be considered for the OBC and MM, whilst still providing reliable and fault tolerant on-board avionics. The aim of the proposed activity is to explore new technologies, processes, and packages targeting a cost, mass, and volume reduction compared to processors currently used within telecommunication missions. Whilst the solutions investigated may initially be most attractive for small, low-cost, non-GSO missions, the applicability to the conventional GSO market will be considered.</p> <p>An architecture for OBC and MM for telecom applications shall be studied and detailed. The use of new technologies and packaging solutions (e.g. plastic instead of ceramics) for non-volatile memory, interfaces, FPGAs and processors shall be investigated. The use of COTS parts with a minimum but effective screening shall be explored. A breadboard/prototype of a Fault-tolerant and COTS-based OBC for low-cost applications shall be produced and tested.</p> <p>The proposed activity should consider the results of previous ESA studies on COTS elements (processors, memories, interfaces): e.g. the GSTP activities on High Reliability, High Availability, and High Performance Processors.</p> <p>The proposed Work logic is the following:</p> <ul style="list-style-type: none"> - Requirement definition and trade-off with available technologies and solutions for a low cost fault tolerant OBC+MM. - Architectural definition of a OBC + MM. - Detailed design of a OBC+MM (prototype) . - AIT of OBC+MM prototype. 			
Deliverables:	Breadboard-Prototype			
Follow-up of a previous activity:	GSTP activities: “High Available Computer (Hi-V)”, “High Reliable Computer (Hi-R)“, and “ High Performance Computer (Hi-P)”			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4A.061	Multifunctional Structure Elements	500	2	24
Objective:	The objective of this activity is to use the satellite structure as a storage area.			
Targeted Improvements:	The benefit would be to reduce or remove the need for tanks on board leading to significant mass savings			
Description:	<p>A multi-functional structure can lead to a significant mass savings. By merging other sub-system elements into the satellite structure, and using the inherent strength of these parts, the satellite structure mass can be reduced.</p> <p>In a previous ESA study, “Multifunctional Structure For Hydrogen Storage” (ARTES 5 contract n° 17436,2004) investigating regenerative fuel cell systems and hydrogen storage for large satellites, the use of tanks as structural elements was identified as a promising way to significantly decrease the mass of the platform. Such a concept could also be applied to other sub-systems. The most promising candidate combinations for multifunctional structures which act as mechanical support and reactant storage will be identified and studied. The mechanical properties will be derived from testing the best combinations.</p> <p>The proposed Work logic is the following:</p> <p>Reactant/Carrier Analysis:</p> <ul style="list-style-type: none"> * Review of applications in the propulsion and power supply areas that make use of liquid or gaseous reactants (Fuel, Oxygen, Helium, Xenon, etc.); * Investigation of storage methods (cavities, chemical storage, etc.); * Analyse which of the reactants can be stored using which storage methods within which structural elements, <p>Testing of Material Properties:</p> <ul style="list-style-type: none"> * Define generic structural elements (rods, plates, etc.) * Identify the most relevant reactant/carrier combinations * Define and run tests to find the relevant mechanical properties of these candidate combinations inside such structural elements. 			
Deliverables:	Multifunctional structure analysis report, test plan, test report			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4A.063	Industrial Radiation Shielding Analysis Methods for Telecom Satellites	450	2	24
Objective:	The objectives of the activity are to develop an operational tool to reduce errors in shielding analyses and associated data exchanges, and quantify design margins more accurately.			
Targeted Improvements:	Improving the accuracy of radiation shielding analysis will release a source of hidden design margins; if more accurate tools are available, computed radiation levels will be lower, allowing a relaxation of procurement radiation hardness requirements, reducing costs. An accurate transfer of radiation shielding and dose environment information between spacecraft and unit manufacturers will have similar benefits.			
Description:	<p>Recent years have seen significant improvements in the accuracy of radiation tools for the analysis of radiation effects at spacecraft, equipment, and parts level. Despite past efforts, deficiencies still persist in the link between system configuration and the design of radiation countermeasures, significantly limiting the accuracy and the efficiency of the industrial process.</p> <p>Traditional radiation shielding analyses performed during the radiation hardness assurance (RHA) process are assumed to be conservative. However, these methods assume radiation travels in straight lines, ignoring the physics of interactions of the main hazard to telecommunications missions - electrons - that scatter greatly and create secondary radiation in random directions. While it is appreciated that errors are probable, this is thought to be compensated by underestimation of spacecraft mass distribution, and the application of techniques such as assuming perpendicular propagation through walls. In addition, methods to specify spacecraft effective shielding and doses at unit level (“6-faces”) are similarly questionable, as highlighted by an ESA TRP activity.</p> <p>These factors particularly affect the commercial space sector, where confidentiality of the geometry models excludes detailed the transfer of design information. Also, the fast turn-around of analyses in telecom programmes has made the use of detailed but slower analysis tools (based on Monte Carlo transport techniques) impractical (at least until very recently), therefore limiting the benefit that could come from the recent improvements in accuracy for in-flight prediction of both Ionising and Non-Ionising dose.</p> <p>This activity will build upon the exploratory TRP work to develop a fully operational industrial toolkit with shielding analysis and data exchange capabilities. The proposed work logic is the following:</p> <ul style="list-style-type: none"> • Analyses of techniques for Ionising and Non-Ionising Dose calculation and information exchange (ray-tracing, 6-faces, 3-D Monte Carlo), in order to verify accuracy and quantify the conservatism in current industrial procedures. (This is essential for establishing margins in the RHA process). • Development of a new shielding information exchange method ,based on/combined with Monte Carlo calculation at spacecraft level, including support for the HDF5 format. • Detailed analysis of the accuracy of current industrial sectorial analysis of radiation effects with respect to detailed 3-D Monte Carlo techniques. This is to address the risk from potential under-prediction, and has implication for ECSS standards (E-ST-10-12). 			
Deliverables:	Analysis tools and data exchange tools for deployment in industry/customers			
Follow-up of a previous activity:	TRP: "GEO Telecoms Radiation Tools Efficiency Improvement with Methods and Geometry Exchanges for Industrial Tools", Contract No. 4000111684/14/NL/AK			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4A.064	Pointing Error Engineering for Telecommunication Missions	400	2	12
Objective:	The objective is to develop software based on existing methodologies to improve pointing error control			
Targeted Improvements:	<ul style="list-style-type: none"> – The expected benefits are a significant in the duration of the pointing error engineering process within the AOCS design and development cycles, as well as the improvement in the process of the robustness and reliability of the calculations. This also includes the exchange of information between the various entities during the design and development process of the AOCS system. – Improved performance of AOCS subsystems. 			
Description:	<p>Pointing error engineering for new telecommunication missions with high demands has become a complex and time consuming task: specifying performance and pointing knowledge requirements or identifying and characterising the different error contributors is critical to the success of the mission.</p> <p>ESA has developed a successful prototype tool for pointing error engineering called PEET (Pointing Error Engineering Tool). The tool implements the step-by-step process elaborated in the ESA Pointing Error Engineering Handbook ESSB-HB-E-003, Issue 1, 19 July 2011. PEET is necessary to process complex calculations for high accuracy pointing, to support frequency domain techniques introduced in the handbook, and to provide a common platform for exchange of information between the various entities during the design and development process of the AOCS system.</p> <p>The proposed work logic is the following:</p> <ul style="list-style-type: none"> – Review of lessons learnt from use of the PEET prototype and feedback from users for telecommunication missions. – Update of the software framework requirements for the new telecommunication missions. – Extension of modules to support high precision missions (e.g. EDRS, NEOSAT, IAP, ELECTRA). – Based on the existing sensitivity analysis feature, implementation of a specific functionality for pointing requirement allocation (apportionment) for telecommunication missions. – Extension of the reporting functionality according to suggestions by future users. – Issuing online manual, tutorial and setting up a forum. 			
Deliverables:	Software tool and technical documentation			

2.2 Propulsion System

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4B.108	High flow rate pressure regulator for all electric telecom satellite applications	600	2	18
Objective:	Develop a new all European high flow rate pressure regulator to satisfy the needs of electric propulsion and auxiliary propulsion systems on the new generation of electric propulsion platforms.			
Targeted Improvements:	20% cost reduction cf. US components. 50% market share increase for European valve supplier.			
Description:	<p>Application of mechanical pressure regulators on European telecommunication satellites has a strong reliance on the use of US solenoid valve components (eg. Alphasat, Eurostar, Spacebus). These US mechanical pressure regulators are subject to ITAR restrictions which prevent visibility of the regulator design, and consequently the regulator performance limits are not well known. In addition, the recent developments of all electric platforms requires high flow rate to be supplied by the regulator for the auxiliary propulsion system. These high flow rates can cause significant problems for regulator operation due to Joules-Thomson cooling effects, and it is not clear that currently available regulators will be able to overcome these problems by simple addition of external thermal controls.</p> <p>The activity aims to develop a European, ITAR free, pressure regulator capable to provide flow rates over a wide range covering all foreseeable electric propulsion and cold gas applications. The activity will build on existing competences in European suppliers, with the aim to develop a cost effective, high performance, high pressure pressure regulator to Engineering model status.</p> <p><u>Work logic</u></p> <ol style="list-style-type: none"> 1. Requirements definition. 2. Concept definition and breadboarding. 3. Engineering model design, manufacture and test. 4. Roadmapping to valve commercialisation. 			
Deliverables:	Study report, Breadboard, Engineering Model.			
Follow-up of a previous activity:	ARTES-8 Xenon Pressure Regulator			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4B.120	Alternative Titanium Tank Hemisphere Manufacturing Techniques	500	2	18
Objective:	The objective is to manufacture titanium hemispheres for spacecrafts tanks at lower cost, by using new manufacturing techniques			
Targeted Improvements:	Reduce tank manufacturing cost by > 25%, while preserving the tank performance.			
Description:	<p>The majority of chemical propellant tanks and gas pressure vessels used in European telecommunication spacecraft are based on Titanium shells. The hemisphere sections of these tanks are typically manufactured from forged blanks. The supply of the raw materials and the forging process are limited to a small number of key suppliers and are very expensive, currently accounting for more than 50% of the overall tank manufacturing costs. Particularly for large diameter tanks the availability of materials and the forging process can become prohibitively expensive.</p> <p>In order to reduce the overall cost of the tank , it is proposed to investigate alternative methods for manufacturing the tank hemispheres, like: additive manufacture, spinning, fabrication, and pressing.</p> <p>Since these parts are safety and fracture critical (pressurised) items, the design and non-destructive inspection of the parts must complement the different manufacturing method to ensure the correct safety margins are applied.</p> <p>The proposed work logic is the following:</p> <ul style="list-style-type: none"> - Assessment of requirements and potential manufacturing techniques, - Definition of manufacturing processes and design of breadboard hemisphere, - Manufacture of breadboard hemispheres, - Testing and analysis of suitability of produced breadboards, - Development and qualification roadmap of Ti hemispheres tank manufacturing with selected alternatives techniques. 			
Deliverables:	Breadboard hardware, Design and Manufacturing Documentation, Test Plan, Test Report, Roadmap			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4B.121	Long-Life and High Performance Thruster	700	1	18
Objective:	The objective of the activity is to design and evaluate an improved thruster in order to significantly improve performance and lifetime characteristics.			
Targeted Improvements:	<ul style="list-style-type: none"> – Improved thruster key performance by 10%. – Increase lifetime by 25%. 			
Description:	<p>The evolution of GEO telecom satellites has resulted in a considerable increase in available electrical power to satisfy payload needs, an increase in platform size to accommodate larger payloads, and longer mission durations of typically 15 years. In addition, Electric Orbit Raising has been widely adopted for Geostationary telecommunications missions over the last few years, generating a need for thruster designs to simultaneously meet the diverse needs of orbit raising (high thrust) and station-keeping (high reliability and specific impulse).</p> <p>Hall Effect thrusters have been successfully deployed onboard geostationary satellite missions to fulfil these dual functions, although given evolving mission requirements, current designs are far from optimal. Current Hall effect thrusters are life limited due to erosion of the ceramic discharge chamber and performance is also limited by the relatively high divergence of the plasma beam. Improving the magnetic topology and ceramic discharge chamber design may significantly improve both performance and lifetime.</p> <p>Whilst the Hall Effect Thruster is presently the most viable technology for current mission needs, the activity should commence by actively considering alternatives and selecting the most promising technology for further development considering future requirements. The proposed work logic (assuming a Hall Effect solution is adopted) is the following:</p> <ol style="list-style-type: none"> 1. Trade-off of most promising technologies for combined orbit raising and station keeping applications, selection of most promising technology to be evaluated 2. Understanding and Modelling of the couplings between the ceramic discharge channel geometry, the magnetic topology, and the ceramic erosion patterns, 3. Design of an optimised channel geometry and magnetic circuit with the aim to substantially lower erosion rates, 4. Test of the new design with a sufficient diagnostics and duration to characterise the performance and the stability of the erosion rate and estimate the overall lifetime capability, 5. Development / qualification roadmap. 			
Deliverables:	EM of critical elements, Design and manufacturing documentation, Test Plan, Test Report, Roadmap			

2.3 AOCS

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4C.035	Star Tracker based on Faint Star predevelopment for Telecoms	500	1	18
Objective:	The objective of the activity is to derive an optimised star tracker design for telecoms based on the Faint Star detector with the main development focus on the optimisation of the use of the Faint Star on-chip functions and the star tracker (STR) software so as to provide a low impact, easy hosting of the s/w in the On-Board Computer (OBC).			
Targeted Improvements:	The objective is to reduce both a) power dissipation (up to -75% in case of active cooling removal), to ease the accommodation on the platform, and b) the recurring cost of one optical head, shrinking down the number of components per head.			
Description:	<p><u>Background:</u> Improvements of platform competitiveness requires innovative changes at system level as well as unit level price reductions. For the STR, the development of the Faint Star detector is intended to lead to the possibility to design and manufacture a low cost intelligent optical head consisting mainly of only a detector chip, the optics, and the support structure. What enables Faint Star to do this is the integration on chip of a wide array of initial image processing functions and a pixel array controller that enable to remove the need for a support ASIC/FPGA. Optimum use of such functions should enable the remainder of the software functions of the STR to be simplified to the point where a compact, but still robust, STR software may be produced and hosted in the central computer, thus saving the recurring cost of the processor and memories in the STR. To maximise the cost savings, the Thermo Electrical Cooler (TEC) should also be removed. The low noise, high sensitivity of the Faint Star detector, together with enhanced software is expected to make this possible.</p> <p><u>Activity description:</u> To prepare for such an implementation on a telecoms mission, the feasibility of the above outlined approach needs to be demonstrated. In particular this will require the optimisation of the use of Faint Star and its on-chip functions (including the comparison of these against full s/w implementations), the reassessment of the STR software processing and processing flow - including improvements needed to aid in the removal of the TEC, the optimisation of the STR software for being hosted in an OBC and the demonstration of the correct function and feasibility with a breadboard level series of tests to demonstrate the correctness of the control and functioning of the detector element (with commercial optics) and the ability of the s/w to be hosted in an OBC. It is expected that time and space partitioning (TSP) and auto-coding are likely to be beneficial to these endeavours.</p> <p><u>Starting point:</u> The starting point is the availability of Faint Star detector prototypes (mid 2014, GSTP G601-69EC),</p> <p><u>Work logic:</u></p> <ul style="list-style-type: none"> ○ Overall trade-offs, such as needs in terms of surrounding electronics, Telecom mission EOL expected performance, possibility to avoid the need of active cooling. ○ Breadboard design, assessment of on chip functionality, capabilities in terms of SW simplification (in both acquisition and tracking mode) keeping extreme robustness requirements vs solar flares. ○ Test of the Breadboard using commercial optics. ○ Development plan preparation for follow on activity (with REC and NREC cost estimation) 			
Deliverables:	Study report, breadboard.			
Follow-up of a previous activity:	Complementary to G601-69EC (Faint Star Development = Second generation APS improvements for flexible low cost and mass sensors LCMS2) - GSTP			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4C.041	Improved Torque Stability of Reaction Wheels via Embedded Digital Wheel Speed Control	500	1	18
Objective:	The objective of this activity is to improve reaction wheel torque stability and repeatability via the application of an internal wheel speed control loop, and to demonstrate the feasibility and effectiveness by test at Breadboard level. A secondary objective is to assess the possibility of achieving a cost reduction for the electronics via the wholesale migration towards a digital wheel drive electronics.			
Targeted Improvements:	Improved pointing performances, lower mass and lower overall cost solution at spacecraft level. The reaction wheel electronics cost, mass and volume is targetted to be reduced by 25%. A reaction wheel digital signal interface is expected to further reduce costs at system level.			
Description:	<p>All conventional reaction wheels have to face bearing & lubrication related phenomena that result in torque instabilities. These, together with any variation/deviation in the reaction torque realisation profile, have an impact on S/C pointing performance. Currently, all reaction wheels for GEO telecom applications are based on heritage designs relying on analogue discrete wheel drive electronics. These are bulky and costly to assemble and test. Further, they impact significantly the system AIT process and are not readily interchangeable with similar wheels from other manufacturers creating potential supply chain issues. The choice of analogue interfaces is driven by current equipment availability and potential re-use.</p> <p>Digital motor controllers and embedded motor speed control are used extensively in other applications and have also been demonstrated on some small wheels. Such approaches have the potential to react quickly to (erratic) changes in the friction torque by rapid local detection of wheel speed changes while simultaneously allowing the integration of several functions in a single component and shrinking the overall electronics. Such an implementation naturally leads itself also to digital interfaces, which open the way for more exchangeability between units. Other approaches also exist (e.g. external to the reaction wheel equipment), but these are likely to lead to higher cost and mass than current products and so are not considered here. The increasing demand for high pointing stability, for e.g. multi-spot missions and optical inter-satellite links, shows a clear need for improving the reaction wheel torque stability. And the digital speed control embedded in the wheel is the most promising way to improve torque stability without large scale bearing technology changes, and potentially leads to important system budget savings at satellite attitude control level.</p> <p>The proposed work logic is the following:</p> <ul style="list-style-type: none"> - Define & gather requirements (including interface, commanding, mass, cost and performance requirements) - in close collaboration with primes & operators covering 20 to 100Nms wheels. - Propose and study wheel speed control loop algorithms, for the full wheel speed range, enabling the improvement of the performances (in particular torque stability and torque realisation repeatability) as well as the required wheel speed measurement techniques needed to ensure sufficient accuracy over the full wheel speed range. This study shall consider both compatibility with existing Reaction Wheel Assembly (RWA) designs and their wheel speed measurement hardware as well as produce proposals for improved wheel speed measurement solutions. It is expected that different techniques are required for different wheel speed ranges in order to ensure the maximum performance. The algorithms shall also ensure that they are designed such as to not have any adverse reactions with AOCS measurement and control loops (e.g. shall be sufficiently high bandwidth as to fall well outside of the AOCS measurement and control domain). - Propose a new electrical design embedding not only the wheel speed loop, but also as many of the required wheel drive electronic functions (motor controller, external interface, housekeeping etc.) in a single component (i.e. FPGA or ASIC) with the goal of reaching a new WDE design with reduced footprint, assembly/test effort and cost. - Design, build & test this solution at breadboard level and demonstrate the performances achievable with an existing RWA hardware and from there extrapolate what could be achieved with updated RWA hardware and also to determine how much degradation bearing/lubrication or other (e.g. cogging torque) induced torque instabilities could be potentially removed by such methods. - Propose a roadmap (with associated cost) to reach a recurring fully qualified product based on the concepts demonstrated. 			
Deliverables:	EM of critical functions: digital wheel drive electronics with embedded wheel speed loop tested together with existing reaction wheel, Design and Manufacturing documentation, Test Plan, Test Report, Roadmap.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4C.042	On-board Guidance Optimisation for Electric Propulsion Orbit Raising	450	1	18
Objective:	Development of efficient on-board guidance algorithms for autonomous electric propulsion (EP) transfer and validation on a representative Processor In the Loop (PIL).			
Targeted Improvements:	When existing on-board hardware resources can be used to establish the guidance function on-board, then this will allow to reduce the need for ground station availability and control centre support to compute the attitude guidance thereby reducing related financial cost (for renting of stations and provision of staff) by at least 80%. Flexibility is also improved opening towards future platform autonomy. In addition it supports collocation.			
Description:	<p>Typical scenarios for electric propulsion transfer of telecom satellites are based on a period of 3-6 months until the satellite arrives in GEO. During the early and late part of the transfer, the satellite is almost continuously in contact with a ground control centre. Ground-based guidance is justified, because of the navigation function being based on ranging measurements and because of the complex algorithms for generating the transfer guidance. It results in extensive costs for ground station time and control centre availability.</p> <p>This activity proposes to overcome the need for extensive ground-based support for transfer guidance generation by moving the guidance function on-board.</p> <p>An on-board guidance algorithm would exploit the available GNSS measurements for navigation and run elaborate, robust and high-performing algorithms on the on-board computer to generate the attitude guidance, establishing the optimum EP thrust direction, solar array pointing and any further attitude constraints required to be addressed in the guidance. The AOCS software will then control the attitude during transfer, removing the need for routine ground-intervention.</p> <p>In order to make the on-board guidance robust and reliable, new algorithms need to be developed and verified for which the limited computing power on-board is sufficient. Hybridization of analytic methods with limited numerical optimization appears to have such potential.</p> <p>The proposed work logic is the following:</p> <ul style="list-style-type: none"> – Initial trade-off of guidance methods – Review of available analytic and semi-analytic methods to compute EP transfer guidance. – Elaboration and testing of algorithm – Implementation of algorithm in software for full verification on a flight-representative processor – Extensive testing to demonstrate full functionality 			
Deliverables:	On-board software, simulation tool with processor (e.g. laptop) in the loop and technical documentation			

2.4 Mechanical System

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4E.059	Design margin optimisation for mechanisms on board telecommunication spacecrafts	500	1	24
Objective:	The objective is to extend the operational range of known mechanisms with flight heritage.			
Targeted Improvements:	The activity will define the type of requirements at mechanism level (mechanical, thermal, lifetime, motorisation margins, etc.) and at system level (mechanical, thermal, lifetime) that could be waived under certain conditions in relation with operators' specifications. This would improve the performance of a mechanism and extend its application range in satcoms.			
Description:	<p>The difficulties to understand the failures mechanics of space mechanisms lead to systematically oversize the functional architecture since these devices are usually single point failure. The development risks and recurring cost resulting from the objective of achieving compliance to these margins hampers the competitiveness of new products, thereby limiting the competition faced by incumbent technologies.</p> <p>Within telecommunication spacecraft business, often, the combination of price, mass and volume constraints in combination with ECSS margins leads to a non-compatible mechanism design: either too big and/or too heavy and too costly, or with too low margins. Telecommunication spacecraft often use flight proven mechanisms from the US, but in many cases these US based mechanisms do not comply to the ECSS margins, especially at actuator level. This creates an unfair disadvantage to European mechanism manufacturers. Effectively, US mechanisms with flight heritage are allowed lower margins. This activity aims at margin optimisation of flight proven European mechanisms, which would create a larger application range for these mechanisms, and thereby improve competitiveness.</p> <p><u>Justification:</u> The identification of a process to optimize the functional design of flight-proven mechanisms used on telecommunication satellites would give European products a guideline towards increased market share.</p> <p><u>Work logic:</u> Identify a flight proven recurring mechanism qualified for telecom mission with applicable and quantified functional margins. Based on the existing design (FMECA,...), the final customer requirements (operators) and the bidders knowledge of the product, generate a design with reduced functional margins (typically 1.1). Manufacture an EM. Perform a test campaign in representative conditions and document the results. Compare EM test results with the available reference data from the existing flight design, quantify the improvement in performance, mass, volume, and in cost. Identification of candidate mechanism(s) for further development Generate a guideline for optimising mechanism designs for public reference.</p>			
Deliverables:	EM			

2.5 Thermal System

Activity Ref.	Activity Title	Procurement Policy	Budget (kEuro)	Priority	Estimated duration (months)
4D.044	3D Thermal Interface for High Power Units using Additive Layer Manufacturing	C	400	1	24
Objective:	The objective is to design, manufacture and test a 3D thermal interface for high power units using Additive Layer Manufacturing (ALM) to decrease the operational temperature of High power units, Power Conditioning and Distribution Units, Plasmic Propulsion Units, or Travelling Wave Tube Amplifiers.				
Targeted Improvements:	Decrease the temperature of the unit and increase the reliability.				
Description:	<p>The standard method of mounting equipment to a Heat Pipe network is to mount on to a flat 2D interface. The equipment provider designs the electronic box so that the heat is conducted to the base plate. An on-going ALM activity aims to widen the Heat pipe area in order to increase the contact surface, hence increasing the amount of power dumped into the heat pipes. In addition, increases to the thermal conductivity of electronic boxes, using heat pipes or loop heat pipes to transport the power to the base plate, can be realised. All of these applications are however restricted to the 2D base plate surface area. By increasing the contact surface area, using a 3D concept, this would allow to increase the amount of power injected into the heat pipe without increasing the temperature of the equipment.</p> <p>The proposed activity may use ALM to create a 3D interface by increasing the horizontal thermal contact area, and by adding a third dimension in height, which could interface directly with the side walls of an electronic unit. The internal capillary structure would be such that it could also work in a 1g environment. In a horizontal configuration, the third dimension of the two phase structure will be able to transport the full power of the unit without compromising on-ground testing at spacecraft level. In essence, this would look like a cradle for an electronic unit which would be directly connected to standard axial groove heat pipes network.</p> <p>Follow-on activities could see an embedded two-phase structure inside an electronic box which could be directly connected to heat pipe network. By removing the thermal interfaces, this would allow to decrease the thermal gradient between an electronic components on a PCB to the radiator.</p> <p>The proposed work logic is the following:</p> <ul style="list-style-type: none"> • Technical trade-off to establish performance requirements • Design and build a breadboard • Testing of the breadboard 				
Deliverables:	Breadboard, Design and manufacturing documentation, Test Plan, Test Report				

Activity Ref.	Activity Title	Procurement Policy	Budget (kEuro)	Priority	Estimated duration (months)
4D.045	Development of Wireless Passive Sensors for Temperature Measurement	C1	300	2	12
Objective:	To optimise the packaging of wireless passive sensor and associated antennas, including the interrogation antenna and reader firmware, starting from existing commercial systems.				
Targeted Improvements:	The primary advantages are the elimination of wires and reduction in harnesses complexity, leading to shorter integration times and overall payload mass, along with flexibility in modifying installed configurations with respect to traditional wired solutions. About 15% cost reduction is expected in terms of temperature sensing installation along with 10% relevant mass reduction.				
Description:	<p>Wireless instrumentation for measurement of physical parameters (e.g. temperature) on board the spacecraft as a replacement of traditional wired solutions, e.g. thermocouples, is recognized as a potential improvement for space systems. Here, the technology of wireless passive sensors based on Surface Acoustic Wave (SAW) devices is proposed for remote measurement of temperature. These types of sensor are interrogated by a radio frequency (RF) signal and do not contain batteries or active circuits, being simple piezoelectric components. They do not require maintenance and feature robustness and high reliability.</p> <p>A demonstrator based on wireless SAW sensor technology was successfully designed, implemented and tested in a TRP ITI activity.</p> <p>Using results from this TRP ITI short study, the proposed activity shall focus on a new design of the SAW sensor package and antennas to facilitate integration and installation within the satellite platform. Design drivers shall include miniaturization and the thermal and electrical contact with the mounting surfaces.</p> <p>The proposed work logic is the following:</p> <ol style="list-style-type: none"> 1. Review of the system design based on the conclusions from previous TRP activity; 2. Starting from existing commercial SAW devices, outline design of the SAW sensors including the antenna; 3. Design of the interrogating antenna; 4. Review of the firmware and algorithm of the interrogation technique. 5. EM (critical functions) manufacturing and testing 				
Deliverables:	Study report, EM of critical functions, Design and Manufacturing report, Test Plan, Test report				
Follow-up of a previous activity:	“Wireless Passive Sensors for Temperature Monitoring system”, Contract No. 4000107410/12/NL/CO, Funding source: TRP				

Activity Ref.	Activity Title	Procurement Policy	Budget (kEuro)	Priority	Estimated duration (months)
4D.046	Heat Pump System Compressor	C1	600	2	24
Objective:	The objective is to develop and test a Heat Pump System (HPS) compressor				
Targeted Improvements:	A Heat Pump System-based thermal bus design will allow the realisation of a 20kW telecom spacecraft at lower cost compared to existing platform technologies.				
Description:	<p>Because of the increasing power demand of telecommunication payloads and high-density accommodation, the cooling requirements for these platforms is steadily increasing up to the point that conventional heat transfer technologies are no longer sufficient to cope with the requested heat rejection. In order to remain competitive in the current and future high-power commercial satellite market, it is essential to improve the efficiency of the thermal subsystem. In order to pursue this effort, it is proposed to develop and test (in a representative environment) a breadboard model of a compressor, a key component of a Heat Pump System.</p> <p>Heat Pump Systems are devices based on the so called ‘reversed cycle’ and are commonly used in the heating and refrigeration industry. The vapor compression heat pump system includes an evaporator, a compressor, and an expansion valve coupled in a closed-loop manner to a radiator-condenser. State-of-the art of the terrestrial compressor technology provides good performance but needs to be adapted to space telecom missions requirements. Flexibility (variable compression ratio to allow scalability of the system) and optimization of the power consumption are also important.</p> <p>At equivalent radiative surface area, the isentropic compression of an HPS based thermal bus permits higher temperature of the working fluid and leads to a higher rejection capability, suitable to meet the projected need of telecom satellites. The system allows also a higher flexibility in term of payload accommodation and possible coupling of the radiators.</p> <p>The following work logic is foreseen:</p> <ul style="list-style-type: none"> – Technical requirements definition. – Preliminary and detailed design of the compressor technology envisaged. – Test plan definition (functional, environmental). – Design and manufacturing of a test loop. – Manufacturing and tests with functional tests of the compressor in the dedicated test loop. – Functional and performance test of the compressor. 				
Deliverables:	Breadboard, Design and Manufacturing documentation, Test Plan, Test Report				
Follow-up of a previous activity:	TRP: “Heat pump conceptual study and design” (concluded in 2014)				

2.6 Power System

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4F.084	Aluminium wire application in telecommunication satellites	400	2	18
Objective:	To know under which conditions the aluminium wires can be used for telecommunication satcoms.			
Targeted Improvements:	Mass saving of 30%.			
Description:	<p><u>Background information and activity justification:</u> In telecommunication spacecraft, harnesses are mainly composed of copper wires, and aluminium wires are seldom used. On one hand copper wires present the advantages of large heritage, known and stable manufacturing process with several ESCC qualified sources and established good practices for assembly and integration activities. On the other hand, due to the lower density of aluminium wires compared to copper wires, aluminium wires represent a very interesting way for mass reduction. But some open questions and known issues, such as assembly process (crimping, soldering), derating rules, integration activities wrt curvature radius and mechanical strength, will be analysed to provide accurate recommendations for use.</p> <p><u>Work logic:</u> Perform trade-off aluminium versus copper to identify which part(s) of the cable harness would benefit the most from changing to aluminium. Samples, compliant with space application requirements, will be manufactured according to a Process Identification PID and will be submitted to an evaluation test sequence, including crimping or soldering ability tests.</p> <p>Results will be presented in a procurement specification.</p>			
Deliverables:	Samples and procurement specification			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4F.099	Power Processing Unit Switch-On strategy after Spacecraft Separation	400	1	24
Objective:	The objective of the activity is to allow Power Processing Unit (PPU) switch on as quickly as possible after spacecraft separation.			
Targeted Improvements:	To avoid long drifts during mission phases (days).			
Description:	<p>High power units like PPUs have the risk of Corona at first start-up if the pressure is too high. Traditionally, such units are therefore only switched on after several days of depressurisation and outgassing. With full electric orbit raising, there is a need to start PPUs within a few hours after separation, in order to start the electric orbit raising as early as possible. The days of depressurisation and outgassing lead to a decay of the spacecraft's orbit while waiting for the operational requirements to be met for switching on the plasmic propulsion.</p> <p>After choosing a EOR missions profile and a PPU existing design, it is proposed to define the conditions (temperature, pressure, etc.) required to switch-on the PPU as early as possible after separation, without Corona.</p> <p>The proposed work logic is:</p> <ul style="list-style-type: none"> – Selection of a reference PPU design & reference EOR mission profile; – Define the pressure profile using materials outgassing rate and any other parameters driving pressure decay (manufacturing, temperature, etc.) – Definition of max pressure allowed to ensure no risk of Corona - analytically, or by test; – Issue of some recommended methods for a safe start-up after separation without design change - possibly by measuring temperature, pressure, time, etc. – Validation of this method by test; – recommend design changes if necessary. 			
Deliverables:	Test Plan, Test Report; validated conditions for early start-up of PPUs			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4F.100	Alternative European Micro-Point of Load Converter Design	500	2	18
Objective:	To develop a simple and very low cost circuit to control a micro-Point Of Load (POL) based DC/DC converter.			
Targeted Improvements:	<ul style="list-style-type: none"> - low cost design - Efficiency is estimated to be higher than 95%, mass lower than 30 grs 			
Description:	<p>As the number of ASICs, FPGAs and complex electronic components is increasing, the need for secondary voltage generation and distribution has been identified. A micro POL converter could be used to generate low voltages for those applications. For the supply of digital electronics, there is a general trend to implement distributed power architectures (Point of Load conversion) where the power conversion is performed in a two-step approach: a first converter converts the input source voltage to an intermediate low voltage, and small, miniaturised converters are then used in cascade to provide individual loads with very low regulated voltages according to the digital power needs (FPGAs, memories, processors, etc).</p> <p>The work logic proposed is the following:</p> <ul style="list-style-type: none"> - Specification including trade off - EM design (critical functions), manufacture, and testing 			
Deliverables:	EM of critical functions, Design and Manufacturing documents, Test Plan, Test Report			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4F.101	Development and Optimisation of a new Slip-Ring for High Power Density Applications	500	2	24
Objective:	Design and test High Power Slip-Ring with minimised internal power dissipation.			
Targeted Improvements:	<ul style="list-style-type: none"> - Volume decrease by a factor 2 (slip ring). - Secondary effect to SADM volume. - Reduced operational temperature . 			
Description:	<p>Solar Array Drive Mechanisms (SADM) for future high power missions, e.g. full electric platforms, will have to transfer more power without increasing their physical volume. Therefore, the ratio of power to mass will have to increase further such that more power can be transferred per unit volume. Since slip rings dissipate a small portion of the power they transfer, this means also that their operational temperature may increase. Consequently, it is important to develop a new design and/or identify new sliding contact materials that can operate under higher temperatures and/or dissipate less power per unit of transferred power.</p> <p>SADM slip-ring technologies suffer from ageing and creep effect during their lifetime. Being temperature dependant, these effects can be reduced if the design of the slip-ring and the SADM is made such that the power dissipation inside the SADM is reduced. The proposed activity will deal with the development of a more robust and long life SADM for high power telecom applications.</p> <p>The work logic proposed is the following:</p> <ul style="list-style-type: none"> - Review of slip ring technologies and selection of most promising technology for high power telecomms missions - Design of a slip ring for high power telecom applications - Manufacture and Testing of an EM representing critical functions 			
Deliverables:	EM of critical functions, Design and Manufacturing Documentation, Test Plan, Test Report			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4F.102	Enhanced Coating Technologies for Next Generation Solar Cells	500	2	18
Objective:	The objective of the activity is to investigate sputtering techniques and evaluate their benefits compared to state-of-the-art e-beam evaporation techniques in uses such as the application of the antireflective coating (ARC), and front and backside metallisation and passivation layers (which become more important as cell designs become thinner).			
Targeted Improvements:	Performance increase for next generation solar cells, reliability improvement (especially during storage), potential cost reduction due to cheaper process. Overall efficiency increased by 0.5%.			
Description:	<p>The production process of III/V-solar cells includes the deposition of dielectric films for antireflection coatings and the coating with metal layers for front- and backside contacts. At present, these layer systems are fabricated using e-beam evaporation techniques. However, to meet the future requirements which can be anticipated for next generation solar cells, it is interesting to investigate other deposition techniques such as sputtering or Plasma-Enhanced Chemical Vapour Deposition (PECVD), which are not currently used in the current production processes.</p> <p>In the field of ARC, future cell concepts make it necessary not only to reduce the reflection in the wavelength range from 250 to 900nm, but up to 1800nm. To obtain such a broadband ARC, dielectric materials with special demands on refractive index and transmission need to be deposited. Candidate materials (e.g. high refractive TiO_x, SiC and SiN), can be deposited by using sputter techniques or PECVD, but not by conventional e-beam evaporation techniques.</p> <p>Comparing sputtering with evaporation methods, the kinetic energy of the layer forming particles in a sputter process is much higher. This could have an effect on metal layer properties such as adhesion of the metal fingers and their conductivity. Furthermore, as for dielectric materials, new deposition approaches may also offer a variety of alternative metallisation solutions.</p> <p>The following work logic is foreseen:</p> <ul style="list-style-type: none"> – Review of deposition techniques, e.g sputtering and PECVD – Selection of ARC deposition techniques – Design and manufacturing of a flight representative coupon – Coupon Test plan definition (functional, environmental) – Coupon testing 			
Deliverables:	Scaled Engineering Model, test report			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4F.103	Solar Array Drive Mechanism Slip-Ring Sensitivity Against Standard Pollution Types and Levels	600	2	18
Objective:	To determine the pollution levels detrimental to Solar Array Drive Mechanism (SADM) performance and to issue recommendations for cleaning process improvement.			
Targeted Improvements:	Decrease the noise level in slip-rings, and to increase reliability of the slip ring.			
Description:	<p>In the last years, slip-rings have suffered from noise problems, often due to contamination. In slip-rings, gold/gold technology is now the most standard contact technology used for the middle to high power range of SADM. Nevertheless this technology has showed, in some cases, to be noise sensitive to very low level of pollution and this problem needs to be better understood.</p> <p>The acceptable electrical noise level is specified by Prime contractors and satellite operators as a result of satellite EMC considerations. The impact of these signals could lead to monitoring (telemetry) errors, interference on the main power supply, and/or operational constraints or communications performance issues. In recent years, there have been several instances of SADM's not conforming to these requirements, resulting in lengthy investigations and additional test costs. Identifying reliable and repeatable test methods and the problems caused by pollutants will potentially avoid costly Non Conformance processing at spacecraft and equipment level and potentially lead to more reliable hardware.</p> <p>It is known that Silicon is one of the pollution sources that may increase the electrical noise produced by slip rings. The goal of the proposed activity is to identify which other pollution sources are detrimental to electrical performances of slip-ring and define which levels are needed to start affecting performances. The activity will help to establish cleaning procedures, such that dangerous materials at spacecraft level are avoided within the vicinity of the SADM.</p> <p>The work logic foreseen is the following:</p> <ol style="list-style-type: none"> 1. Identify potential pollution sources for slip-ring. 2. Test their effect and define the minimum level needed to start affecting the electrical performances of the slip-ring. 3. Define clear success criteria for cleaning processes. 			
Deliverables:	List of contaminant levels, Test Plan, Test Report, and cleaning procedures			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4F.104	Alternative Components for Medium to High Power Solar Array Drive Mechanisms	700	2	18
Objective:	To decrease the cost of Solar Array Drive Mechanisms (SADM) for high power applications (between 10 and 20 kW) by using a building block approach for SADM products			
Targeted Improvements:	<ul style="list-style-type: none"> - cost reduction by 20%. - increased use of EU-sourced components. 			
Description:	<p>The standardisation of SADM component parts will allow to optimise the industrial process. The proposed activity’s goal is to improve the design of an essential satellite element via a revisit of the chosen architecture and the introduction of new technologies. Specific themes would be to identify (alternative) lower recurring-cost components and to seek to standardise component interfaces. By rationalising the design, e.g. adopting a building blocks approach, standardising the interfaces; and rationalising the testing of medium to high power SADMs and their sub-assemblies, it will be possible also to reduce costs. The development of new tooling or manufacturing techniques may also contribute to reduced overall costs and integration effort.</p> <p>An overall trade-off is needed to select the most promising components. Some bread boarding will be defined on a case by case basis and a full EM design will be requested in order to be manufactured and tested. The work logic foreseen is the following:</p> <ul style="list-style-type: none"> - Review of available technologies and selection of the most promising ones - Breadboard of key elements - Design and Manufacturing of an EM - Testing of the produced EM 			
Deliverables:	EM			

2.7 Command and Data Handling

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4G.015	Development of a Hosted Payload Interface Unit	400	1	15
Objective:	To design, manufacture, and test a breadboard of a low-cost multi-channel Hosted Payload Interface Unit (HPIU).			
Targeted Improvements:	<ul style="list-style-type: none"> - To enable segregated, cost-effective, command and data handling for hosted payloads by developing a low-cost multi-channel Hosted Payload Interface Unit. - Simplify the incorporation of hosted payloads 			
Description:	<p>The concept of hosted payloads on GEO telecom satellites is gaining significant interest within both government and industry, in the US and in Europe. An important aspect to be considered in hosted payload accommodation and management is the command and telemetry function.</p> <p>Satcom operators often prefer a separate TM/TC chain for hosted payloads on board of their satellites and hosted payload operators may also want dedicated access to their payload. The activity will develop a low-cost multi-channel transceiver in order to facilitate segregated command and telemetry functions for hosted payloads. In order to make full segregation possible, a separate Hosted Payload Interface Unit is also needed. The HPIU will interface directly with the multi-channel transceiver and payload equipment and have a link with the On Board Computer (OBC).</p> <p>The recently completed ARTES 5.1 study 4000108340/13/NL/NR showed that an HPIU is needed when full segregation between hosted payload and spacecraft data is required, when multiple hosted payloads are embarked, or when the tele-command data rate of the hosted payload exceeds the available OBC capability.</p> <p>Such an interface will increase the attractiveness of GEO satcom to hosted payloads by developing one of the building blocks needed if full segregation is requested or multiple hosted payloads are embarked on a single spacecraft. The foreseen work logic is the following:</p> <ul style="list-style-type: none"> - Establish the requirements baseline for the HPIU, - Design breadboard of HPIU module(s), - Breadboard manufacturing and test. 			
Deliverables:	Study report, breadboard, test plan & test report			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
4G.016	Corona-Free S-band Diplexers for Tracking Telemetry & Command	400	2	24
Objective:	Development of a compact corona-free S-band diplexer at EM level.			
Targeted Improvements:	Corona-free diplexer with a 50% footprint, 30% mass reduction and lower insertion losses.			
Description:	<p>S-band TT&C systems are commonly used in telecommunication satellites for the RF link between the spacecraft and ground stations during flight and lift off until the arrival of the satellite in its nominal orbit. TT&C systems commonly include a diplexer which separates Rx and Tx paths.</p> <p>Corona phenomena can appear due to the RF power (in the range of 10 Watt) and environmental conditions in the early stage of the launch where vacuum conditions (considered around 10E-5 Pa) are not yet reached.</p> <p>Commonly used coaxial resonator technology in the design of the diplexers leads to bulky solutions with an associated risk of Corona discharge due to the geometry/field distribution. Dielectric material has been used extensively to achieve compactness for low power filters and, lately even for medium/high power applications. New dielectric materials can provide a good Q-factor and hence, good insertion losses.</p> <p>Dielectric material can be used as resonators (for instance, TM dielectric resonators or dielectric combine filters) or to fill the critical regions in structures such as metallic coaxial cavities.</p> <p>In order to achieve the required near band rejection, the insertion of transmission zeros is commonly needed. By using more complex transfer functions, it is possible to increase the number of transmission zeros while keeping a low number of resonators. This can lead to an improvement in the insertion losses and a reduction of the footprint for the diplexer while providing a good near-band rejection.</p> <p>The foreseen work logic is the following:</p> <ul style="list-style-type: none"> - Review of current state of the art. - Detailed evaluation of dielectric resonators material properties. - Design of two different concepts (Breadboards) based on dielectric technology. - Selection of the preferred solution. - EM design, manufacturing, assembling and high power testing of the EM unit. 			
Deliverables:	Engineering Model, test plan, test report			

3. SPACE SEGMENT - PAYLOAD

3.1 Payload - System and Architecture

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5A.051	Performance Enhancement of Transparent Digital Processors	400	1	12
Objective:	Identify and develop the architectural and algorithmic improvements necessary to enhance the performance of Digital Transparent Processors in terms of signal dynamic range, low noise, port bandwidth flexibility, robustness to interference, power consumption, etc.			
Targeted Improvements:	Improvement in dynamic range, noise level, robustness to interference and overall processor performance (power consumption and suitability for narrowband and asymmetric payloads).			
Description:	<p>Recent developments of European transparent on-board digital processors have been focusing on increased bandwidth per input/output port and channelization/routing flexibility. The current generation of processors is particularly well suited for symmetric input/output ports (both in terms of number of ports and bandwidth per port).</p> <p>Notwithstanding the remarkable performance achieved, improvements are necessary to maintain competitiveness in the area of narrow-band processors (e.g. MSS), to render transparent processors attractive for payload architectures where the number or the bandwidth of inputs/outputs is not symmetric (e.g. channelized payloads, multi-star payloads, MSS, etc.), to improve signal quality performance (e.g. signal dynamic range, low noise, robustness to interference, etc.)</p> <p>Focusing on narrowband and asymmetric port/bandwidth processors, the activity shall aim at identifying, defining and trading-off techniques and architectures in order to obtain the needed performance enhancement.</p> <p>In particular the following aspects shall be addressed:</p> <ul style="list-style-type: none"> - Analyse contributions to signal quality and the changes necessary to improve end-to-end noise figure, dynamic range and robustness to interference (e.g. increased number of bits, improved LO phase noise for reduced aperture uncertainty at higher Nyquist zones, improved channelization algorithms, anti-clipping based processing techniques, narrow bandwidth/ high sampling rate converters, etc.). - Identify architectural/algorithmic upgrades to offer output port signals of variable bandwidth (to maximise the signal to beam allocation) allowing the optimisation of the DSP to reduce the power consumption and RF payload architecture complexity. <p>The study will demonstrate the key changes/developments via simulation and via a prototype board including EM-level for critical functions.</p>			
Deliverables:	EM of critical functions			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5A.052	Risley Prism Beam Steering Device	800	1	24
Objective:	European alternative for the United States based Risley beam steering device.			
Targeted Improvements:	Compared to classical gimbal based beam steering devices, the Risley prism beam steering systems are smaller, use less power and weigh less, making them more immune to vibration and thus able to achieve higher response times and beam steering rates.			
Description:	<p>European alternative for the United States based Risley beam steering device.</p> <p>To design and evaluate a Risley prism beam steering device together with the advantages such a system may provide over a gimbal based device. In particular the expected improvements in response time and pointing error shall be investigated</p> <p>The activity is divided into the following steps:</p> <ol style="list-style-type: none"> 1) Design of Risley prism based beam steering device for 1064 nm/ 1550nm operation. Perform a beam pointing error analysis taking into account any prism manufacturing tolerances. The design shall be able to withstand the vibration environment encountered during launch and be able to operate under micro-vibration excitation. Establish the steering algorithms. 2) Develop and test a Risley prism beam steering device with associated driver electronics and characterise its performance in terms of throughput, field of view and pointing error and to validate the steering algorithms in random step and stare mode. 3) Result evaluation and define steps needed to reach EQM. 			
Deliverables:	Engineering Model of critical functions			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5A.053	Wavelength Division Multiplexing (WDM) on Optical Communication Terminals	800	2	24
Objective:	Implement wavelength division multiplexing (WDM) at 1064 nm wavelength to significantly increase the data rate of the current generation of laser communication terminals			
Targeted Improvements:	Enable next generation Laser Communication Terminals to provide data rates in excess of 20 Gbps.			
Description:	<p>The goal of this activity is to demonstrate wavelength division multiplexing (WDM) within the broad amplification window of fibre amplifiers in the 1064 nm wavelength range. This shall enable next generation Laser Communication Terminals to provide data rates in excess of 20 Gbps.</p> <p>Despite the fact that wavelength division multiplexing (WDM) is mostly associated with operation in the 1550 nm wavelength band, fibre amplifiers operating at 1064 nm are also sufficiently wideband to allow WDM. To implement WDM, the currently used single non-planar ring oscillator laser will need to be replaced with a Bragg grating stabilised single frequency laser diode (laser line-width:<100KHz, output power:> 20 mW). The laser diodes shall support operation in an optical phased locked loop and shall be tuneable to compensate for the doppler shifts encountered using optical inter-satellite links. The laser product family may cover the amplification range of Ytterbium doped amplifiers (e.g. 1064nm - 1083nm).</p> <p>In addition the WDM system shall be able to utilise incoherent modulation formats such as On/Off-Keying (OOK) or Pulse Position Modulation (PPM) to simplify communication through atmospheric turbulence with an optical ground station. In this way the 3dB advantage of 1064 nm over 1550 nm technology is maintained. The 1064 nm amplifier technology also benefits from increased efficiency and alower radiation sensitivity when compared to 1550 nm solutions.</p> <p>The activity shall develop a breadboard demonstrating communication via (as a minimum) 3 wavelengths separated by 0.1 nm (TBC) within the spectral range of a fibre amplifier of >1 Watt power. The receiver chain shall provide sufficient attenuation to simulate a LEO-GEO link and shall investigate the channel separation, intermodulation sensitivity and the channel quality with a data rate of (minimum) three times 1 Gbps.</p>			
Deliverables:	Breadboard			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5A.054	C-band Inter-Satellite Link	650	2	12
Objective:	Develop a low-cost C-band inter-satellite link terminal for use between LEO and GEO satellites.			
Targeted Improvements:	Proposed activity shall lead to a low cost inter-satellite link solution for satellite missions. The solution may benefit from existing - globally available - C-band GEO infrastructure.			
Description:	<p>The use of FSS C-band satellites for providing a low-data rate inter-satellite link between LEO to GEO has been considered by industry in ESA member states.</p> <p>The advantage of such an approach is the global availability of C-band, at moderate costs compared to e.g. L-band. Typically, rates of 10-20 kbps can be reached with limited RF power, for example using spread spectrum solutions. The required transceivers for such an application can be implemented using off -the-shelf software defined components, which are regularly used in smaller satellites.</p> <p>The starting point for this development is the preliminary requirements for such a service as already considered by European industry. Regulatory wise, the concept is similar to the usage of L-band on LEO satellites.</p> <p>The activity shall consolidate requirements and operational concepts, specify the overall architecture, and develop and test the C-band terminal.</p> <p>The activity shall actively seek embarkation opportunities on future missions.</p>			
Deliverables:	Terminal EM (critical functions)			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5A.055	Accurate Pressure Predictions in Critical High Power RF Hardware	400	2	24
Objective:	Objective of this activity is the development and verification of software algorithms that allows accurate prediction of the pressure profile inside intricate high power RF hardware.			
Targeted Improvements:	Today there is no software available to predict the pressure profile of intricate hardware with multiple cavities and multiple materials as encountered in high power switches, ferrites and RF filters. The estimations currently used are often not reliable and constitute a significant development and schedule risk factor.			
Description:	<p>For high power RF hardware the accurate prediction of the pressure profile inside the hardware is often critical to (a) determine the time before it is safe to switch on the hardware in orbit and (b) to determine the pumping time needed before the equipment is safe to operate for the verification/qualification campaign. In both cases if power is applied too early, destructive plasma discharge can occur.</p> <p>Hence in this activity novel software algorithms shall be developed. The software algorithms shall allow the accurate prediction of the internal pressure profile in intricate high power RF hardware. Thermal conditions shall be considered and material data shall be directly linked to a public material database. Recent advances in the predictions of contamination inside of space hardware shall be taken into account.</p> <p>At least 3 different types of multi-cavity, multi material samples shall be manufactured and tested to verify the software algorithms.</p>			
Deliverables:	Study report, Software Algorithms			
Follow-up of a previous activity:	TRP 'Fast contamination modelling Tool'			

3.2 Antenna

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5B.162	Measurement Methodology for Fast Antenna Testing	600	1	18
Objective:	The objective of the activity is to consolidate a working approach to reduce antenna RF testing time. This can be achieved by either using multi-probe measurement approaches or by means of interpolation-extrapolation of near field measured data. A combination with simulations of the overall response in the measured environment is expected to be required to achieve a competitive performance.			
Targeted Improvements:	The major benefit expected from the activity is schedule and cost reduction of antenna testing whilst maintaining the accuracy of the measurements. Time reduction relates directly to the reduction in the number of measurement points required. The exact improvement will be dependent on the antenna to be tested and the hardware/software solution selected (e.g. the selection of the set of basic functions used for the interpolation) and the required accuracy. However, a reduction of a factor of 4 should be within reach.			
Description:	<p>The methodology shall target existing measurement instrumentation and systems without being specifically bound to a particular one. However the complementary exploration of further potential improvements offered by alternative viable solutions, eventually requiring infrastructure changes, should also be identified.</p> <p>Antenna measurements and electromagnetic antenna modelling tools are well established in their respective fields and ideas have been generated to best combine them to reduce testing cost to a minimum. At the same time efforts have been made to remove some of the major obstacles in RF antenna testing on integrated satellites, using new testing approaches.</p> <p>The aim of the activity is to demonstrate a solution that is able to measure complex antennas for telecom applications by reducing RF testing time and cost. Major benefits are expected in terms of test time for multiple-beam multiple band antennas and reconfigurable antennas. Currently in all the cases identified, the large number of radiation patterns needing to be acquired result in long test durations.</p> <p>More specifically the activity will look into special hardware solutions and/or software techniques to achieve a reduction in measurement time. Ways to determine the final accuracy of the data obtained shall also be investigated and included in the methodology to ensure its applicability as part of a quality-controlled industrial process, such that the community may accept it.</p> <p>The methodology shall be demonstrated on a suitable satellite model equipped with an antenna subsystem of a suitable complexity including at least one multiple-beam antenna.</p>			
Deliverables:	Measurement methodology (software and documentation)			
Follow-up of a previous activity:	TRP and ARTES activities. In particular: "Innovative RF testing ...", TRP, 4000102461 and "Portable antenna measurement system...", ARTES 3-4, 4000101551			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5B.163	Antenna Deployment Arm with Integrated Elastic Hinges	400	1	24
Objective:	The objective is to develop the concept, the mathematical model, and develop the materials and processes for building ultra light and lower-cost composite arms for deployable antennas.			
Targeted Improvements:	<p>This activity streamlines one of the recurring elements of telecom satellites virtually eliminating the mass and cost of the deployment mechanisms. For some configurations of antenna deployment arms this will result in a reduction of cost and mass by a factor of 2.</p> <p>The currently used motorized hinges could be avoided along with their large number of parts and associated assembly and integration cost and time. Also, the need for harnesses may be significantly reduced and the overall appendage becomes more stable.</p>			
Description:	<p>Deployable antenna arms are a recurrent component of telecommunication satellites payloads. Presently deployable arms are implemented by articulating one or multiple limbs through mechanical hinges. These have a large number of parts, are far from optimal in terms of mass and require a lengthy process for assembly and integration. Alternatively, patterned slots can be directly integrated in composite booms creating the localized flexible regions required for compact stowage with much simpler and lighter configurations. The challenge resides in defining the slot geometry and selecting the right materials that allow for a short radius of curvature in the stowed configuration, while producing smooth deployment and latching to provide a stable stiff state in the deployed configuration. However, an accurate understanding of the stress distribution around the slot under very large deformations is paramount for avoiding damage during the folding, storage and launch processes.</p> <p>Deployable antennas with slotted hinges have been successfully manufactured in the US and deployed on-orbit, however Europe and Canada are lagging behind.</p> <p>This activity aims at providing ESA Member States industry with this capability and promoting enhancements in terms of :</p> <ul style="list-style-type: none"> - Configuration of the deployable arm; - High stiffness and strength and stable materials; - Micromechanical modelling for accurate prediction of stresses; - Slot design for compact and damage-free stowage ; - Manufacturing processes. <p>In the activity, an antenna deployable arm with slotted integrated hinges shall be designed which replicates the functions of a conventional design using mechanical hinges. This design shall be supported by testing at sample level. Finally, a demonstrator with integrated slotted hinges shall be manufactured and tested for deployment, thermal cycling and vibrations and the performances compared to those of the conventional technology.</p>			
Deliverables:	Breadboard			
Follow-up of a previous activity:	Spin off of CFRP blades study (ARTES5.1)			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5B.164	Design for Manufacture Approach for Large Frequency Selective Surfaces for Telecom Applications	500	1	24
Objective:	The main objective of this activity is to develop and test a frequency selective surface enabling antenna architectures capable of producing a transmit/receive multiple beam coverage with only one main reflector aperture.			
Targeted Improvements:	Reduced number of antenna apertures required for given telecommunications mission/Enable more complex and flexible antenna beam generation			
Description:	<p>There is a general trend towards the use of multibeam coverage to increase the satellite systems capacity. State-of-the-art multibeam payloads at Ka-band are based on single-feed-per-beam reflector antennas using three or four apertures to produce all the beams. Multibeam payloads are also being considered down to Ku and C-band. Satellite accommodation restrictions for secondary missions at Ka-band or primary missions at lower frequency bands bring the need for antenna configurations capable of producing all the beams of a multibeam coverage, but with a reduced number of apertures.</p> <p>A possible approach is to use a multiple-feed-per-beam (MFB) system that generates the full coverage with two apertures, one operating in transmit and the other one in receive. Recent works on Frequency Selective Surfaces (FSS) have demonstrated the possibility to significantly reduce the ratio between transmitted and reflected bands. This activity shall investigate the combination of Multiple Feed per Beam (MFB) feed systems and an FSS to produce a multibeam coverage with only a single reflector antenna. This activity shall include a trade-off on the antenna geometry as well as on the FSS technology with a design for manufacturing approach so as to provide RF performance in line with mission needs. Besides more conventional manufacturing techniques, additive manufacturing, pressing and inkjet printing shall also be considered in the trade-offs.</p> <p>Particular attention shall be given to the mechanical design and manufacturability of the FSS, as well as power handling and space environment constraints. The possibility to combine the degrees of freedom of both the FSS and the MFB feed systems shall be investigated as means to mitigate beam degradation with pointing angle. An EM of the proposed FSS shall be manufactured and tested. Performance at antenna level shall be derived from those measurements. The applicability of the selected design and technology to other frequency bands, such as C- and Ku-band, shall also be discussed.</p>			
Deliverables:	EM of critical functions			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5B.165	Cost-Effective High-Gain CubeSat Antennas	350	2	15
Objective:	The objective of this activity is to develop cost-effective high gain antennas for inter-satellite links between cubesats.			
Targeted Improvements:	<p>1. Increased gain compared to the already proposed Bulls Eye Medium Gain antenna (>10 dB)</p> <p>2. Increased compactness compared to other 60 GHz high gain antennas (HGA)</p> <p>Using the described manufacturing technologies a mass reduction of 50% can be expected. It should be noted that for 60 GHz ISLs, there is a limited choice of high gain antennas compatible with CubeSat building blocks and this is a new development.</p>			
Description:	<p>One of the important capabilities, which could enhance the attractiveness and would enable telecommunication applications for smaller satellites, is inter-satellite links (ISLs). To save costs, it is proposed to take advantage of interesting developments that have occurred in the terrestrial world around the IEEE 802.11ad Wireless Gigabit standard and use these as building blocks for inter-satellite links at 60 GHz.</p> <p>For ISLs high gain antennas are needed. Cubesats consist of 100x100x100mm building blocks and the antenna design shall be compliant to this volume. Since the antenna is not the only component that has to fit inside this cube, a low profile design is preferred. Possible solutions are compact metallised plastic dual-reflector antennas or flat lens antennas using IR filter technology.</p> <p>The developments are needed because existing antenna designs (e.g. Bull's Eye antenna) do not have sufficient antenna gain for the ISL. Furthermore, focus shall be on cost, mass and volume reductions.</p> <p>The activity will start with a review of the requirements including frequency, pointing accuracy, field of view, followed by a trade-off and then a selection of the most suitable HGA concept. A demonstrator shall be built and tested at the frequency of interest.</p>			
Deliverables:	Study report, breadboard			

3.3 Repeater Equipment

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.266	Gallium Nitride output stage for converter	750	1	30
Objective:	To design, manufacture and test an output amplifier based on European GaN MMIC technology.			
Targeted Improvements:	The GaN implementation of the output stage could be very attractive since the technology can provide high linearity together with high efficiency i.e. high figure of merit (IP3/P_DC). An improvement of 5 dB is expected. Moreover, the inherent property of GaN impedance level of GaN v.s. that of GaAs brings easier matching and wider bandwidth.			
Description:	<p>Frequency converters are today based on GaAs technology. Fulfilling the new linearity requirements simultaneously with a low power consumption is very challenging as evidenced by several converter developments (C, Ku, K). Indeed, the GaAs technology has been pushed to its limits in this respect, and even in the best case, there is no design margin left and non-compliances are frequent. The starting point for activity is the existing GaAs output amplifier designs. These can be used as baselines for the GaN amplifier. The GaN amplifier is expected to improve the equipment competitiveness due to the increased linearity and design margin. In addition, the linearity requirement should be achieved with one GaN power amplifiers, contrary to the current GaAs design imposing 2 parallel power amplifiers.</p> <p>The activity shall commence with consolidation of the converter output stage requirements for linearity, consumption, figure of merit, and thermal environment for C or Ku-band converters. Next, the trade-off and consolidation of the output amplifier architecture shall be carried out. Finally the detailed design, manufacturing and test of the MMIC and its variants shall carried out, based on European GaN technology. A test in an EM representative RF line-up converter configuration over temperature shall be included.</p>			
Deliverables:	EM (Engineering Model), MMIC samples and reports.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.269	Miniaturised Ka-Band Beamforming Network Using Additive Manufacturing Techniques	500	2	24
Objective:	The objective is the design, manufacturing and testing of a BB of a miniaturised Ka-Band multilayer BFN.			
Targeted Improvements:	Monolithic beam forming network (BFN) presenting a high level of integration leading to size reduction and a 50% loss reduction.			
Description:	<p>Future telecommunication satellites will aim at achieving higher throughput and flexibility with respect to current satellite systems with consequential unit cost reduction (cost/Gb). This goal may be fulfilled by implementing a high number of user beams within the target coverage (e.g., >200 beams for European coverage and >30 for national coverage).</p> <p>For instance, in the case of a DRA antenna, in order to generate a given number of beams a high number of individual radiating elements are required. A very complex structure for splitting and routing the signal (BFN) is then needed between the repeaters and the individual radiating elements.</p> <p>Current BFN architectures are typically implemented by cascading several hybrid couplers heavily interconnected. The resulting structures are often bulky, with negative impacts on the payload mass and footprint as well as presenting considerable RF losses.</p> <p>Manufacturing technologies based on the local deposition of materials (additive manufacturing) have been successfully used in a number of applications such as microwave filters and RF harnesses. The application of these additive manufacturing technologies to BFNs can provide an increased integration level leading to size reduction and, potentially mass reduction while even improving RF performances. Additionally, due to the monolithic design approach, the AIT complexity is reduced.</p> <p>This activity consists in the design, manufacturing and test of miniaturised multilayer BFNs to be used in telecom multibeam missions based on additive manufacturing technologies.</p> <p>The work-logic of this activity may be summarised as follows:</p> <ul style="list-style-type: none"> - Survey of available technologies for multilayer applications; - Preliminary design of a miniaturized multilayer BFN at Ka-band; - BB manufacturing and test. 			
Deliverables:	Breadboard			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.270	Miniaturised Diplexers for L-Band Mobile Missions	600	1	24
Objective:	To design, manufacture and test one EM of a Tx-Rx diplexer for L-Band applications.			
Targeted Improvements:	<ul style="list-style-type: none"> - 30% mass and size reduction - 100% RF power handling increase 			
Description:	<p>Coaxial resonators are currently the standard technologies for L-band filters and multiplexers, however this technology is inherently bulky and often leads to significant size and mass overruns. Moreover, current solutions are only suited for low and medium power operation up to 50 Watt.</p> <p>One important application that benefits from both miniaturisation and/or power handling increase, is that of Mobile missions where a large number of Tx-Rx diplexers (typically more than 100 units) are integrated on-board of large GEO multibeam satellites.</p> <p>In this activity a new class of compact diplexers for 100 W RF power operation shall be developed based on dielectric technology, used either as a main resonator concept or as a filling feature for the filter critical gaps. Preliminary work at filter level has shown that a footprint reduction up to 30% can be achieved compared with coaxial technology, whilst maintaining similar in-band and out-of-band performance. However, this results needs to be extended at diplexer level, with a detailed trade-off between in-line and cross-coupled filters for complex transfer functions. Other major challenges exist in terms of increased temperature range and higher RF power handling (average, multipactor and PIM) which shall be addressed simultaneously.</p> <ul style="list-style-type: none"> - The first step of the proposed activity shall be the review of current state of the art addressing both single-mode and dual-mode operation, including detailed evaluation of dielectric resonators properties, miniaturization and mounting techniques for high power L-Band applications. - In the second step, two different design concepts based on dielectric technology shall be studied and developed into two diplexer BB units. One concept shall be selected for the design of one EM. - The final step shall be the manufacturing, assembling and high power testing of the EM unit. 			
Deliverables:	Study Report, Engineering Model.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.275	High Voltage Cable for Q-Band Traveling Wave Tube Amplifiers	600	1	24
Objective:	Development and evaluation of a slim and flexible High Voltage Cable for future Q/V band repeater units as electrical interface between the amplifier Tube (TWT) and Electric Power Conditioner (EPC).			
Targeted Improvements:	No existing solution.			
Description:	<p>One of the major applications for high-voltage cables in telecom platforms is as electrical interface between the traveling wave tube (TWT) and its driving High-Voltage electronics (EPC). Although the current technologies are highly reliable with a great level of heritage, they are not suitable for Q-Band applications due to the increased operating voltage and different tube and EPC interface. At the same time there is a need for a slim, lightweight and flexible design to be compatible with the mechanically small dimension of the Q-band TWT.</p> <p>No high voltage cables for Q-band high power TWT are currently available in Europe for space applications but the development of Q-band tubes is ongoing.</p> <p>State of the art high voltage cables for TWT/EPC interfaces provide lack the mechanical flexibility and compatibility with regards to the potting material for Q-Band application. However, a possible solution could be based on high voltage cables for commercial industrial terrestrial use. Hence in this activity the following work logic shall be adopted:</p> <ol style="list-style-type: none"> 1. Assessment, evaluation and up-screening of existing cable for terrestrial application is foreseen as the starting point including review of requirements. 2. Prototype characterisation and process/design trade-off. 3. Evaluation at system level (EPC+cable+TWT, including assembly techniques) and cable level (ESCC 3901/3902). 			
Deliverables:	Study Report, Breadboard Cable.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.276	Waveguide Flanges with enhanced passive intermodulation performance	300	1	24
Objective:	The objective of this activity is to develop waveguide flanges with ultra-low PIM performance for space applications.			
Targeted Improvements:	The new flange intends to become new state-of-the-art with improvement of the PIM performance from typically -140 dBc to -210 dBc (3rd order PIM).			
Description:	<p>With the advent of high power channel communication satellites, Passive Intermodulation (PIM), has arisen as a spacecraft performance of considerable importance. PIM is of great concern due to the risk of polluting very weak receive signals. Waveguide flanges have been identified as major source of Intermodulation Products in telecommunications satellites. Actual satellite requirements push technology to achieve levels of PIM above 200 dBc. The design of low PIM flanges usually leads to solutions with a quite significant contribution to the overall harness mass. Reducing the mass of the flanges would have a direct benefit on the satellite cost.</p> <p>The activity shall concentrate in the development of a novel waveguide flange based on techniques involving not only the pressure distribution between two flanges but selecting the right materials and coating to achieve smooth contact between surfaces. Alternatively, the design should also look into the possibility to use different heat expansion coefficients (flanges vs bolts) to increase the contact. The development will be limited to standard RF cross-sections.</p> <p>The design shall consider as a minimum:</p> <ul style="list-style-type: none"> - Novel flange geometry for forces distribution and optimum electrical contact. - Suitable materials with Young Module suitable for best metal contact. - Fasten bolts distribution and geometries. - Thickness of the flange. - Flange alignment. - Metal surface coating, polishing and finishing (grooves). <p>The activity includes the following tasks and work logic:</p> <ol style="list-style-type: none"> 1. Trade-off and preliminary analysis of the low PIM flange geometries. 2. Trade-off of material and processes. 3. Proof of concept design, manufacturing and test of the flanges. 4. Design, manufacturing and RF testing of EMs. <p>A number of waveguide EMs with novel flanges will be designed, manufactured and tested. The selection of the frequency band will be accordingly to the available PIM test benches.</p>			
Deliverables:	Study report prototype, Engineering Models.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.300	Cost Competitive and Reliable Converters	1000	1	24
Objective:	The objective of the activity is to assess the flexible converters requirements for geostationary applications, evaluate the potential requirements relaxation and build and test an associated engineering model.			
Targeted Improvements:	Reduced costs (20%).			
Description:	<p>The pressure to reduce prices and delivery times of geostationary commercial telecommunications satellites is always increasing, at satellite, payload and equipment levels. This is particularly true for highly recurrent units such as converters, low-noise amplifiers and channel amplifiers where the competition is fierce. Non-European countries are currently flying equipment following different quality approaches, for instance non hermetic hybrids, reduced screened parts, off-the-shelf commercial components. Those companies are commercially successful in providing cheap equipment, which remains the number one market driver.</p> <p>This development will provide a completely new and innovative approach, enabling the production of converters with reduced cost and lead-time, whilst meeting the needs of the satellite manufacturers and having a commercial advantage against worldwide manufacturers.</p> <p>In particular, the following domains shall be investigated:</p> <ol style="list-style-type: none"> 1. A detailed breakdown of the recurring and non-recurring costs, including procurement, engineering, manufacturing, test and documentation shall be performed. The main converter performances cost drivers shall be identified and quantified. 2. A review of the quality requirements for GEO flight part and equipment screening, reliability and assessment of real requirements needs. Associated cost shall be quantified. 3. Analysis and comparison of quality standards (space, military, automotive for instance) shall be performed. Potential highlighted major saving axis shall be evaluated. A new quality plan shall be defined to meet target cost savings on the equipment. 4. Preliminary reliability studies and tests shall be performed to demonstrate feasibility of the new quality plan. 5. A new converter shall be designed to cost according to the new quality plan. An engineering model of the selected configuration shall be built and tested, and associated reliability demonstrated. 6. The cost analysis taking into account the new quality plan shall also be made for other highly recurring RF equipment, e.g. Channel amplifiers. 			
Deliverables:	Engineering Model			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.301	Miniature Bulk Acoustic Wave Filters	500	1	24
Objective:	The objective of this activity is to study, manufacture and test filters based on Thin Film Bulk Acoustic Resonator (FBAR) technology at frequencies up to C-band.			
Targeted Improvements:	Considerable footprint (up to 50%-70%) and mass reduction when compared to current filter technology, enabling the next level of miniaturised microwave modules.			
Description:	<p>Surface Acoustic Wave (SAW) filter technology has proven to be very successful in many telecom applications both in space and on ground. This type of technology offers very small devices with high performances. However, the frequency range is limited to around 2 GHz due to process limitations which together with a power loss that may be very high, is preventing a more widespread usage.</p> <p>Film Bulk Acoustic Resonator (FBAR) technology has potential for application at higher frequencies, lower power losses and wider bandwidths. It is the result of the combination of microelectronics techniques with the well-known technique of bulk acoustic wave filters. The small size of the device and new material have shown in a C band demonstration filter.</p> <p>This technology is a key technology for miniaturization of microwave modules with a significant improvement in terms of integration density.</p> <p>Hence the activity aims at assessing filters based on thin Film Bulk Acoustic Resonator (FBAR) technology at frequencies up to C-band for telecom applications. This shall include evaluation of concepts for implementing multiple transmission zeros and accurate simulation techniques.</p> <p>The work logic is as follows:</p> <p>In a first Phase, the existing technologies shall be reviewed and a manufacturing concept shall be validated through the fabrication of simple demonstrators. Preliminary designs of the demonstrators shall conclude this Phase.</p> <p>In a second Phase, FBAR filters shall be designed, fabricated and measured against agreed specifications.</p>			
Deliverables:	Study reports, Breadboards			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.302	High Linearity Gallium Nitride (GaN) Mixer	500	1	24
Objective:	This activity is to demonstrate a high linearity GaN mixer device, which can be used for up- and down-converters.			
Targeted Improvements:	Improved Linearity, Bandwidth, and Noise Figure of Frequency Converters operating in Ka-Bands			
Description:	<p>Mixers are a common sub-circuit utilized in the frequency converters of telecom payloads. High Throughput Satellites require a large number of frequency converters (>200 for future mission designs) and hence a large number of mixers are needed. Today, high linearity mixers are made in GaAs (Gallium Arsenide) which are approaching their limits in terms of wideband operation, which precludes specific frequency tuning.</p> <p>The major benefit of using GaN devices is the high linearity performance due to the material wide band gap. (Frequency converter design is always a compromise between linearity and noise figure). Additionally a high breakdown voltage is obtained with GaN technology, therefore enabling more robust devices for space application. The activity will therefore be to investigate the suitability, and to demonstrate, the improved performance that may be possible using a GaN mixer via the design and development of an Engineering Model frequency converter stage.</p> <p>The current state of art mixers used within 30/20 GHz down-converters have an input IP3 limited to +20 dBm, a maximum bandwidth of 6 GHz, and will be discontinued soon. Whereas the achievable targets for the GaN mixer are +25dBm on input IP3, minimum of 8 GHz of bandwidth, and ACPR = - 77dBc.</p>			
Deliverables:	Study report, Scaled Engineering Model			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.303	Fully Adaptive RF Lineariser for High Power Amplifiers	850	1	30
Objective:	Design, manufacture and test an RF pre-distorter based on a single-chip, for High Power Amplifiers, that is able to linearize in a closed-loop operation telecommunication multi-carrier signals			
Targeted Improvements:	<ul style="list-style-type: none"> – New market opportunities for the MSS / FSS / BSS market. – Fully adaptive and flexible pre-distortion capabilities for different traffic scenarios and for signals with bandwidths >36 MHz. – Reduced RF output back off level in High Power Amplifiers (HPAs) for a given Noise to Power Ratio (NPR). – Increased efficiency of the High Power Amplifier (HPA). – Reduced power consumption compared to existing technologies. 			
Description:	<p>The DC-to-RF efficiency of High Power Amplifiers (HPAs) is currently the main contributor to the power consumption of a spacecraft. This equipment is responsible for consuming > 70% of the overall DC power available in bent-pipe architectures for broadcasting satellites.</p> <p>To improve the scenario, analogue pre-distortion techniques are currently used in order to linearize the HPA. This analogue linearisation allows for an increase of the overall DC-to-RF efficiency since the HPA can be operated closer to saturation.</p> <p>Nevertheless, the linearisation function is tuned for one single configuration of the HPA and for static conditions (i.e. temperature, RF output power, etc.). In addition, the capability of linearising HPAs presenting memory effects or with non-uniform traffic demands, is very limited when using analogue linearisers.</p> <p>Closed-loop RF pre-distortion techniques are more suitable for this variable scenario, where the lineariser uses the HPA output signal to determine the nonlinear characteristics of the HPA and adapts the linearisation technique as a function of the conditions and signal to be transmitted (i.e. modulation scheme, temperature of the HPA, level of back-off, bias point, etc.). This technique allows a dynamically optimised transfer function and enhance the overall HPA efficiency.</p> <p>The US has a commercial product (Maxim SC 1894) already available while no product yet exists in Europe.</p> <p>The work logic shall be as follows:</p> <ol style="list-style-type: none"> 1. Literature and market survey. 2. Trade-off analysis on analogue and digital pre-distortion techniques. 3. Design a flexible and adaptive single chip pre-distorter. 4. Manufacture and test the single chip device for different telecom scenarios. 5. Final reporting, conclusions and roadmaps towards higher TRLs. 			
Deliverables:	Scaled Engineering Model			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.304	Next Generation Temperature Compensated OMUX Channel Filters	650	1	24
Objective:	Objective of this activity is the development and evaluation of novel concepts for temperature compensated Output Multiplexer Channel Filters making use of advanced materials.			
Targeted Improvements:	Cost reduction of output multiplexers of between 30-50%.			
Description:	<p>Output multiplexers are core payload elements in 80% of today's commercial telecom satellites. High power channel filters are key elements of the OMUX. The ohmic losses of the materials contribute to increase the temperature in the device. Thermal issues related with these losses in high power operation dictate the complexity of the design, which, in turn, impacts the overall mass and ultimately complicates the spacecraft design. Classical materials are INVAR for low to medium power level and aluminium (in configurations with complex and delicate thermal compensation mechanisms) for medium to high power channel filters.</p> <p>The need for a temperature compensation mechanism to achieve the required frequency stability for high power levels (> 100W) leads to very challenging mechanical designs, complex assemblies and difficult tuning procedures.</p> <p>Over the past 10 years there has been a shift from hardware built in INVAR to those in aluminium, to allow for the increase in power handling requirements but also taking advantage of the reduced mass and footprint.</p> <p>Novel materials with very a low coefficient of thermal expansion and high thermal conductivity, like those based on advanced alloys (e.g. RSA-473, RSA-483) or metal-matrix composites, offer the possibility to overcome current limitations and eliminate the need for complex temperature compensation mechanisms.</p> <p>In this activity, self-compensated OMUX channels based on novel materials shall be studied, developed to EM level, manufactured and tested.</p> <p>The following work logic is foreseen:</p> <ul style="list-style-type: none"> - Study of the available advanced materials. - Study of resonators types, topologies, thermal compensation solutions and materials for the realization of OMUX channel filters at Ku-band. - Validation of the concept (over temperature and power) with representative samples. - Design, manufacturing and testing including mechanical, thermal and high power validation. 			
Deliverables:	Study report, Channel filter EM			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.305	Adaptable MODEMs for Inter-Satellite Links	900	2	24
Objective:	To develop power efficient and high throughput physical layer and access protocols for multi-point to multi-point inter-satellite links, taking advantage of the current transceiver designs while improving the throughput and power efficiency.			
Targeted Improvements:	To use adaptive modulation and coding together with full-duplex communications to enhance the power/ bandwidth efficiency of ISL MODEMS (LEO-LEO and LEO-GEO Solutions in S-Band and higher frequency bands while maintaining a high link availability). The developed solution can serve as a reference design for small satellite initiative improving the State-of-art solutions by reducing DC power requirements.			
Description:	<p>The target is to demonstrate the improvements compare to the state-of-the art in a representative demonstration platform. There are number of satellite missions to demonstrate distributed small-satellite networks for different applications. The inter-satellite link is a crucial element in all these missions. (CanX, EDSN, S-NET). Many missions rely on S-band frequencies for inter-satellite communications. Although there are other frequency bands (e.g. Ka, Q/V) available for inter-satellite link, the maturity, the technology and number of existing services make the S-band transceivers a convenient choice as starting point for an adaptable MODEM design. Despite the number of well-established protocols and product design for ISL, many advances in physical layer and access layer techniques that have reached a high level of maturity for ground segment equipment have not been used for ISL. Examples include, adaptive coding and modulation, constant envelop modulation to allow for efficient use of on-board power amplifiers as well as random access scheme that allows more efficient use of the spectrum in multi-point to multi-point communication links and the possibility of hosting full duplex communications to improve the spectral efficiency.</p> <p>Work logic:</p> <ol style="list-style-type: none"> 1) Pre-select physical layer and access schemes that are more relevant to defined scenarios. 2) Develop simulation tools to carry out emulations at the physical, MAC layer and system level to evaluate the performance taking into account different mission concepts (orbits, number of satellite, ground segment etc.). 3) Iteration on the design and simulation as necessary. 4) Design breadboard and carry out tests to demonstrate performance improvements compared to the state of the art. 			
Deliverables:	Study report, breadboard			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.306	Transparent Optical Transponder Demonstrator	750	2	30
Objective:	To study potential technical solutions for the implementation of a non-regenerative optical transponder to operate on a geostationary telecommunication spacecraft.			
Targeted Improvements:	Demonstration of a disruptive technology with the potential to achieve cost and performance improvement by an order of magnitude.			
Description:	<p>Optical communication technologies can in principle provide virtually unlimited and license free bandwidth, but the current generation optical terminals, such as those flown on Alphasat and EDRS, demodulate the optical signal and re-modulate the signal onto an RF carrier for the purpose of transmitting it to the ground. At high data rates this is extremely power consuming and does not support new modulation and coding schemes that may be implemented during the lifetime of the transponder. Furthermore because the modulation scheme and coding scheme are fixed at launch and due to the lack of common standards are specific to the terminal, this results in a closed ecosystem, which is unlikely to be inter-operable with other systems.</p> <p>Pure Optical communication systems do not support point to multi-point communication, However some combination of optical links and RF links can overcome these limitations while retaining the advantages of optical links in key segments of the end-to-end link such as avoiding potential interference, eavesdropping or jamming and the significant license free bandwidth availability.</p> <p>A non-regenerative optical system could utilise either RF over free-space optics or a pure end-to-end optical system depending on the application. However both will require a number of common building blocks, such as source modulators, optical amplifiers, and low noise optical amplifiers.</p> <p>For an optical bent pipe system to work, all required operations (amplification, filtering) have to be performed in the optical domain, which does not support signal re-generation. This activity shall investigate the feasibility and noise performance of an all-optical bent pipe transponder.</p> <p>The reference scenario for this study is an optical relay, where a LEO spacecraft transmits an RF signal modulated onto an optical carrier, this is then transmitted to a GEO spacecraft. The signal is then amplified and then passed to a second spacecraft, where it is converted to RF and transmitted to the ground.</p> <p>The activity shall result in a breadboard of the end-to-end link.</p> <p>The following work-logic is foreseen:</p> <ol style="list-style-type: none"> 1) Mission and technology review. 2) Optical repeater preliminary design. 3) Critical subsystem verification. 4) Optical repeater detailed design. 5) Manufacturing and Testing. 			
Deliverables:	Study Report; Transparent Optical Transponder Demonstrator Breadboard			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.307	Q-Band Output Multiplexer	500	2	24
Objective:	The objective is to design, build, and test a high power Q-band output multiplexer EM for future high throughput telecommunication satellite payloads.			
Targeted Improvements:	Enabling product for Q/V band systems			
Description:	<p>Next generation high throughput telecommunication satellite systems are expected to use Q/V-Band for the gateway feeder links reducing the number of gateways required to support the system capacity and enabling full use of the Ka-band for user links.</p> <p>High power multiplexers are needed for the implementation of a Q-band payload output section. For this equipment two main issues must be considered. On the one hand, the multiplexer shall withstand the required transmitted power (100W class) and losses shall be minimized in order to facilitate high system EIRP. Large quality factor, high order resonance mode cavities developed for lower frequencies might overcome these stringent requirements. Manufacturing and assembly features need to be carefully addressed because of the high sensitivity of the RF performance to manufacturing tolerances.</p> <p>The activity shall cover the design, development and test of an output multiplexer with three channels supporting different bandwidths: 2 GHz, 1GHz and 500MHz. Power handling, multipaction and Passive Intermodulation shall be evaluated.</p> <p>The following work logic is foreseen:</p> <ol style="list-style-type: none"> 1) Study of filter topologies, resonator concepts, multiplexing techniques and manufacturing methods. 2) Development of channel filter BBs. 3) Design, manufacturing and testing of a Q-band Multiplexer EM. 			
Deliverables:	Study Reports; Engineering Model			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.308	Development of Nonlinear Broadband Models of TWTs for Highly Optimised Linearisers	700	2	24
Objective:	Development of TWT model based on X-parameters and design of breadboard lineariser			
Targeted Improvements:	<ul style="list-style-type: none"> - To provide nonlinear broadband models for TWT compared to present day AM-AM/AM-PM measurements at 2-3 frequencies. - To be able to predict very accurately nonlinear behaviour, memory effects etc. over >3 GHz BW. - To be able to produce a highly optimised lineariser which matches tube nonlinear performance accurately over a wide operating band. - To reduce time to market by automation of manual efforts. - Applicable to both ground and space. 			
Description:	<p>There is a need to introduce wideband modelling methods for TWTs as presently there are no reliable equivalent circuit or empirical data based models. Such models are used in SSPA design with a very high accuracy to predict performance. At present linearisers are designed using AM-AM/AM-PM characteristics measured across 3-5 frequencies. These measurements do not allow the designer to accurately predict nonlinear performance and therefore trade-off between nonlinear characteristics and efficiency over a wide bandwidth. As a result of this, the lineariser design process is cumbersome. The problem has been accentuated by increasing demand for Ka and Ku band TWTA with an operating BW >3 GHz.</p> <p>Due to recent advances in the field of X-parameters and related test equipment, X parameters are widely used in the modelling and design of SSPA.</p> <p>The purpose of this activity is to adapt large signal nonlinear modelling and design practices from the SSPA world and use them for accurate TWT modelling and enable wideband nonlinear models for TWT. These models can then be used for designing linearisers and accurately predict nonlinear performance of TWTA during the design stage. A detailed optimisation of the lineariser will be possible because X-parameters are a super set of small signal and large signal S parameters, over a large number of frequencies within the required frequency band.</p> <p>This will allow the TWT models to use a single standard design platform for design and optimisation leading to increased competitiveness in the market due to highly optimised design flow for MPMs and LTWTAs and reduced time to market. It may lead to less effort in TWT tuning for a given project thus increasing the saving on delivery time to market.</p> <p>Work logic:</p> <p>Phase 1</p> <ol style="list-style-type: none"> 1) Study of various X parameters, modelling methods and feasibility of measurements on TWT 2) Define Modelling Plan, Construct appropriate test bench and carry out modelling of TWT <p>Phase 2</p> <ol style="list-style-type: none"> 3) Demonstrate accuracy of prediction of performance using existing designs of lineariser and TWT 4) Define improved design flow, design and implement an improved breadboard lineariser. 			
Deliverables:	Study report, breadboard			
Follow-up of a previous activity:	ARTES 5.1 Broadband Linearisers for High Capacity Ka-Band Multibeam Payloads			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.309	Low Loss Flexible Waveguide Interconnections	350	2	24
Objective:	To develop and demonstrate a concept for low loss flexible waveguide interconnections.			
Targeted Improvements:	Reduced dissipation losses of flexible waveguide interconnections sections; reduced AIT; reduced schedule risk.			
Description:	<p>Today, waveguide routing between sub-systems inside the payload and routing connecting the payload and the antennas are considered critical paths. RF requirements such as very low PIM and low losses are essential.</p> <p>Flexible waveguide routing is used at all stages of the payload assembly and allows for mechanical tolerances, last minute layout changes etc. caused during the assembly or manufacturing process.</p> <p>Traditional designs allow mechanical flexibility at the expense of significant power losses. Therefore today, flexible waveguide technology is only used for short sections where no other reasonable solution is available or an assembly time constraint is imposed.</p> <p>In this activity alternative flexible waveguide solutions shall be developed and evaluated based on the use of plastic materials. Suitable materials providing the flexibility required and able to sustain specific space and/or general mission related environment shall be identified and evaluated. The activity shall include the implementation of a suitable metallic coating on the plastics with an acceptable electrical conductivity.</p> <p>An end-to-end manufacturing process shall be developed. Breadboard demonstrators shall be designed, built and tested to fully evaluate the novel concepts.</p> <p>The following tasks are foreseen:</p> <ol style="list-style-type: none"> 1) Review and evaluation of available manufacturing approaches, materials and surface coatings. 2) Manufacturing of representative samples as proof of concept. 3) Breadboard design, manufacturing and test. 			
Deliverables:	Study reports; Breadboards of Ka or Ku-band waveguide flexible interconnections			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.310	Novel Class of Isolators	600	2	24
Objective:	Objective of this activity is the development and evaluation of a novel class of compact isolators suitable for integration into RF cables.			
Targeted Improvements:	-20-30% time and cost reduction during AIT of satellite input section.			
Description:	<p>Today’s Ku- and Ka-band commercial telecommunication satellites require the assembly and integration of many assemblies, sub-assemblies and equipment. A standard task is the installation of the RF interconnections, balancing of the path losses of the input section along with isolator, attenuator and RF cable procurement management. In particular for large Ka-band mission this consumes a significant time due to the high number of interfaces and thus the high number of verification tests needed but also due to the significant effort of the parts procurement management of cables, isolators and attenuators.</p> <p>In order to reduce the assembly and verification effort, but also the parts procurement management, in this activity a novel class of coaxial isolators shall be breadboarded based for example on non-reciprocal coaxial phase shifter concepts suitable to be directly integrated with the cable interface. The integration of attenuators shall also be evaluated and breadboarded.</p> <p>The activity is divided into the following steps</p> <ol style="list-style-type: none"> 1) Review of processes and possible design approaches 2) Breadboarding; 3) Manufacturing and Testing. 			
Deliverables:	Breadboard			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.311	Demonstration of GaN HPA with Improved Radiation Robustness for Future Telecom Missions	600	2	24
Objective:	To study the reliability of an HPA under telecom mission representative radiation, temperature and RF operating conditions in order to define the safe operating area limits of European GaN technology.			
Targeted Improvements:	<ul style="list-style-type: none"> – Improved understanding and definition of the safe operating area for Telecom GaN HPA under mission representative radiation and temperature environment. – Complete characterisation of radiation related operating anomalies of HPA over temperature and extreme RF operating conditions (>10dB gain compression, multicarrier modulation schemes). – Radiation robustness improvement demonstrated against GaAs. – Clear definition of telecom HPA safe operating area for European GaN technologies. 			
Description:	<p>Extensive radiation tests were undertaken within GREAT2 (GaN Reliability and Technology Transfer Initiative), however these radiation tests were only performed for small transistors, under CW operation and at ambient temperature. This is not representative for realising >60W telecom HPA's. Also, current de-rating practices in the presence of heavy ion irradiation do not always guarantee safe operation and several anomalies have been observed. For example, from the GREAT2 project an unexpected reduction in SEB burnout voltage was identified as device size increases, which requires additional testing to determine the cause and anomalies with GaAs HPA's that have been observed on existing programs with failures attributed to heavy ion radiation, even though GaAs is supposed to be a rad-hard technology. Furthermore, in recently developed GaN SSPAs, the operating conditions (e.g. RF voltage excursion, power density) are far more extreme compared to GaAs amplifiers. For large GaN power transistors operating under these extreme conditions there is no comprehensive radiation test data available, especially for heavy ion irradiation.</p> <p>These issues indicate that the present methodology for radiation qualification of telecom HPA's may not be sufficiently robust and that more work is required to determine the radiation robustness of large periphery power transistors. This is the major objective of this work. Also, it is proposed for the first time, to perform heavy ion SEE tests over a range of temperatures.</p> <p>In summary, this activity intends to define the safe operating area (SOA) for GaN HPA transistors that will experience high peak RF voltages, high levels of RF compression and will be exposed to high energy radiation (SEE) over a range of operating temperatures. After quantifying the SOA of individual transistors, radiation robustness for a representative telecom HPA stage will be demonstrated. The HPA breadboard will be realised using hermetically packaged power transistors that are planned to be qualified under ECI funding. This approach will help to stimulate acceptance of space qualified European GaN technology for future telecom applications.</p> <p>Work logic:</p> <ol style="list-style-type: none"> 1) SOA tests on individual transistors. 2) Determine SOA and determine if SEB burnout is correlated with wafer batch-to-batch DC breakdown variations. 3) Design, fabrication and Test of HPA EM (critical functions). 4) Demonstrate improved radiation robustness for the HPA. 			
Deliverables:	Study report, EM (of critical functions)			
Follow-up of a previous activity:	ARTES 5.1 SSPA with European GAN devices ARTES 5.1 SSPA with reduced Footprint GREAT2: GaN Reliability and Technology Transfer Initiative			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.312	Channel Amplifier Integrating SiGe Technology	500	2	18
Objective:	The objective of the activity is to design, and test an engineering model of the RF line-up including associated analogue circuit of a channel amplifier			
Targeted Improvements:	20% cost savings for a channel amplifier			
Description:	<p>The pressure to reduce prices and delivery times of commercial telecommunications satellites is always increasing, at satellite, payload and equipment levels. This is particularly true for highly recurrent units such as converters, low-noise amplifiers and channel amplifiers where the competition is fierce. New Silicon Germanium (SiGe) process allows the integration of analog and digital technologies. New technologies enable a decrease in the price of the equipment, such as flip chip or plastic packaging.</p> <p>In particular, the following domains shall be investigated:</p> <ol style="list-style-type: none"> 1) SiGe implementation for space equipment 2) Associated cost reduction evaluation linked to multifunction implementation. <p>An engineering model of the selected RF chain configuration (including analogue biasing circuits) shall be built and tested, and associated reliability demonstrated.</p>			
Deliverables:	Scaled Engineering Model			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5C.313	W-Band Waveguide Switch	400	2	24
Objective:	Objective of the activity is to design, manufacture and test a W-band waveguide switch for advanced communication payloads.			
Targeted Improvements:	This technology development is targeted to enable future W-band communication payloads where redundancy is needed.			
Description:	<p>The usage of the spectrum available in W-band for satellite communications will significantly reduce the number of gateways and consequently the overall cost of the ground segment. Already studies related to the propagation characterization and systems for W-band have been kicked-off.</p> <p>W-band waveguide switches are required to implement redundancy, flexibility and change in polarization but are not available. Key developments are needed to arrive at a suitable actuator. Critical aspects of the RF, mechanical and thermal design include the small waveguide size and the relatively high power requirement resulting in the associated design challenges to achieve low losses, sufficient multipactor threshold and to manage the heat dissipation.</p> <p>Hence the activity shall cover the development of all critical switch technologies. A W-band switch engineering model shall be designed, manufactured and tested to fully evaluate the concepts and technologies for space application.</p> <p>The activity shall be organised as follows:</p> <ul style="list-style-type: none"> - Analysis and identification of critical techniques and technologies; - Preliminary design of a BB; - Manufacturing and testing; - Design of an EM W-band switch; - Manufacturing and testing. 			
Deliverables:	Study report, EM			

3.5 Small Sat Payload Equipment

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5E.002	C-band transceiver for small satellites	500	1	12
Objective:	Design and develop a C-band transceiver for small satellite TT&C or low-data rate payload operations.			
Targeted Improvements:	Lowering radio regulatory hurdles for small satellite missions. In the future, commercial satellite telecommunications missions based on small satellites will not have access to amateur frequencies anymore. The proposed development will allow the small satellite community to use regular frequencies for TT&C and payload communications.			
Description:	<p>Currently, a number of small satellite missions use frequencies allocated for radio amateur use, but are actually targeting commercial services. The IARU (International Amateur Radio Union) has stated that they will not accept these kind of satellite filings anymore in the future. More and more small satellite missions will therefore need to use regular (non-amateur) frequencies, but equipment is not readily available within ESA member states for the small satellite platforms.</p> <p>A possible solution for future small satellite communication missions is the use of C-band, as this band will become permanently available as a feeder link for non-geostationary MSS applications after WRC-15. Transceivers for this frequency range and which can be accommodated on small platforms shall therefore be developed.</p> <p>The activity shall:</p> <ul style="list-style-type: none"> - possibly starting from existing C-band developments for larger platforms - design, develop and test a miniaturised C-band transceiver for TT&C and possibly payload data use. <p>Requirements shall be validated by candidate missions and the small satellite community of ESA Member States. The activity shall actively seek a flight opportunity to demonstrate the developed hardware in orbit.</p>			
Deliverables:	Prototype model			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5E.005	Deployable antenna structures for small satellites	500	1	15
Objective:	Develop a prototype model of a deployable high-gain antenna for smaller satellite platforms.			
Targeted Improvements:	Improved performance of communication solutions based on smaller satellites by improving the gain of on board antennas. Currently there is no solution for deployable high gain antennas on smaller satellites within ESA Member States.			
Description:	<p>A number of satellite communication missions based on smaller satellites are being considered in industry.</p> <p>As smaller satellite platforms are often power limited for what concerns their telecommunication payloads, deployable high gain antennas could compensate for the lack of power. Such high gain antennas would be required for future missions in various frequency bands (S, VHF, UHF, L and Ka/Ku).</p> <p>In the U.S. a number of deployable antenna's (e.g. 50 cm S-band antenna on 3U Cubesat and reflect-array for Ka-band) have already flown or will be in orbit soon.</p> <p>The activity shall identify requirements for deployable antenna structures for a number of frequency bands based on upcoming missions needs. The requirements shall be identified in collaboration with the small satellite community. The activity shall then design, develop and test a prototype model of the most promising concept.</p> <p>Within the activity, a flight opportunity for the deployable antenna shall be sought.</p>			
Deliverables:	Prototype model.			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5E.006	Network and link layer solutions for inter-satellite links between small satellites	350	1	12
Objective:	Design and develop link and network layer mechanisms to enable the routing of data over inter-satellite links between smaller satellites.			
Targeted Improvements:	Enable or augment communications missions based on small satellites with the capability of light-weight inter-satellite communications between such smaller satellites.			
Description:	<p>Within industry, a number of commercial telecommunication missions are considered that would be enabled by - or benefit from - the capability of inter-satellite link based communications within constellations. based on smaller satellites.</p> <p>It is therefore required to develop medium access, network layer, and routing solutions (based on e.g. channel routing, digital transparent processing, on-board software defined radio) that can be accommodated on small satellite platforms.</p> <p>The activity shall establish requirements for simplified routing mechanisms for candidate small satellite missions. Solutions shall be designed for such routing mechanisms, taking into account target satellite platform, frequency bands, RF characteristics, access methods, link and network layer issues. The activity shall establish a testbed (at breadboard or "FLATSAT" level) in which the most promising solutions can be validated and demonstrated.</p>			
Deliverables:	Breadboard			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5E.009	Space Based VDE Transceiver	900	1	24
Objective:	To enable two-way VHF data exchange according to the emerging VDE standard using LEO Satellites.			
Targeted Improvements:	The outcome of this activity will be an engineering model of a VDE-SAT transceiver, implementing full VDE-SAT (uplink and downlink protocols) as well as spectrum monitoring in real-time that would be essential for traffic load control in VDE system.			
Description:	<p>The proposed activity is aimed to design, develop and validate an engineer model of space-based VDE- transceiver suitable for small satellites. In particular, the uplink reception of the VDE signal via satellite would require particular attention to accommodate different service types already envisaged in VDE-Sat uplink standard, such as random access as well as dedicated access with highly spectral efficient waveform. At the same time, the on-board receiver shall be able to detect and decode the uplink signal in the presence of interference caused by VDE-terrestrial links, other satellite uplink signals as well as external interferences from sources other than VDE. Considering potential mission concepts based on LEO satellites, the aim is to devise an efficient access scheme that allows for efficient use of the satellite link coexisting with all terrestrial services such as AIS and terrestrial VHF data exchange systems. Novel ideas for full-duplex communications for VDE Up/Downlink will also be explored.</p> <p>The work would start with consolidating the physical layer and access control protocols to be implemented as part of the space-based VDE transceiver. The interaction between the uplink and downlink shall be defined and the required on-board resources to perform scheduling and data processing shall be evaluated and accounted for.</p> <p>An engineering model of the on-board VDE transceiver shall be developed along with the required test platform to verify the functionality and performance of the unit. For the uplink it is important that there is a system to emulate loaded conditions in a realistic way. A thorough simulation campaign shall be carried out to establish a quantitative assessment of the overall proposed solution under a realistic channel models. As part of the quantitative assessment, verification of system critical functions should be tested on actual hardware preferably on an end-to-end system including ground components.</p>			
Deliverables:	Scaled Engineering Model			
Follow-up of a previous activity:	ARTES 5.1, VDE SAT downlink Verification, ARTES 1, VDES studies			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
5E.010	Development of a Light-weight Optical Terminal for Small Satellites	1000	2	15
Objective:	To develop an Engineering Model of a miniaturised optical terminal for LEO-LEO and LEO-ground applications.			
Targeted Improvements:	Improved communication rates for small satellites, and increased use of smaller satellites for telecommunication missions by removing radio regulatory hurdles.			
Description:	<p>Optical communications is a technology currently being explored for embarkation on medium sized satellites. Within European industry there is an interest to use ISL for smaller sized satellites in the range of 6 to 16 U (Cubesat), but there are currently no European products available for this application. Various U.S. initiatives, using NASA or DARPA funding, are currently addressing this market, including demonstrations using already in-orbit small satellites. At the moment, related European developments target solutions for the heavier and larger satellites of around 100 kg.</p> <p>The starting point of this development shall be optical technology and products from European suppliers. A number of mission cases shall be investigated, in which mission requirements shall be formulated that would justify optical communications on small satellites.</p> <p>The activity shall perform system level trade-offs with regards to pointing mechanisms, optical technology and link budgets for the various use cases in which optical ISL provide additional benefits.</p> <p>An engineering model terminal shall then be designed, developed and tested and an example accommodation exercise shall be performed with a candidate mission.</p>			
Deliverables:	Scaled Engineering Model			

4. GROUND SEGMENT

4.1 TT&C/Ground Support Equipment

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
6A.054	Implementation of Virtualised Network Functions (VNFs) for Broadband Satellite Networks	750	1	24
Objective:	To design, implement and validate a prototype of a Virtualised Network Functions -Performance Enhancement Proxy (VNF-PEP). To provide a reference implementation for different PEP enhanced algorithms and assess the performance in representative satellite scenarios.			
Targeted Improvements:	<p>VNFaaS (Virtual Network Functions as a Service) has the potential to expose the telecommunications satellite community to VNF market perspectives and contribute to significant growth of the satellite-oriented virtual appliance market. The targeted improvement of satellite broadband ground segment refers to:</p> <ul style="list-style-type: none"> – flexibility in function allocations, – simplification of ground segment deployment, – performance enhancement when/where and for the time this is needed. <p>It means also that there is no need for dedicated H/W for the PEPs leading to cancellation of the HW cost for these elements.</p>			
Description:	<p>Satellite networks make up a low percentage of the total market value of the telecommunication sector. At the same time satellite networks are retailed by service providers whose platforms are interconnected and supported by terrestrial infrastructures.</p> <p>Virtualised Network Functions (VNF) are part of the currently developing solutions in terrestrial networks and infrastructures: it is a new way to roll out distributed networks capabilities that can be dynamically allocated and deliver carrier-grade services, via highly resilient, multi-tenant network infrastructures. One of the prevailing scenarios pursued in terrestrial networks is the VNFaaS (Virtual Network Function as a Service). It targets customers who migrate functionalities from hardware network appliances to their virtualised counterparts and ease green field deployments. The VNFaaS scenario is seen as highly relevant to Satcom broadband networks, since it provides the capability to enhance the satellite network service offering with added-value VNFs, lower the satellite network deployment CAPEX/OPEX, and simplify ground terminals deployment. Practically, VNF functions aim to extend the end nodes of the satellite network with cloud networking capabilities. These nodes give the opportunity for the satellite Virtual Network Operators (VNO) to deploy on demand complete virtual network infrastructures customized to the service requirements. The customization does not include only the delivery of the service to the customers, but also the communication between the different network elements. The VNF orchestration gives the possibility to adapt the overall infrastructure during runtime, as well as to control the sharing of the environment between multiple Virtual Network Operators (VNOs) or between different customized services of the same VNO. The resources of the VNFs are allocated so as to match the requirements/SLA of the customers.</p> <p>In satellite broadband networks, the functions which are the most suitable to be virtualized are the ones which are computational intensive and able to support a high parallelization such as TCP/IP Performance Enhancing Proxies (PEPs). These VNF-PEPs can be instantiated at the satellite hub and at satellite terminals. PEPs are necessary to counteract the satellite links long path delay and enhance the TCP/IP performance. However, due to their non-standardised mechanisms, they introduce a number of challenges as they split the end-to-end TCP connection. These challenges relate mainly to “ossification” of transport mechanisms used over satellite networks, security, mobility, multi-homing support and control plane interactions. Consequently, VNF implementation of new PEPs mechanisms shall enable quicker and lower cost implementation of new congestion control algorithms as necessary for new services and applications that may be disabled, e.g. IPSec VPNs, mobility flows handled by tunnelled Mobile IP. Such issues inhibit the seamless integration of satellite and future terrestrial networks and the efficient support of future network usages.</p> <p>The activity shall develop a prototype implementation of VNF-PEPs in satellite hub and remote terminals offering also enhanced Explicit Rate Notification (ERN) TCP, multi-path TCP (MP-TCP) and Information Content Networking (ICN) support for seamless integration with future</p>			

	<p>terrestrial links. Both fixed and mobile terminals are considered.</p> <p>The prototype implementation shall cover the specific functionalities such as establishment of the virtual network infrastructure and the end-to-end network performance assessment of the VFN-PEPs including the comparative evaluation of the new congestion control algorithms ERN-PEP, MPTCP, ICN. The implemented functionalities shall include also, both the physical and hypervisor functionalities and set of generic enablers addressing mobility and security (IPsec) support. An over the air demonstration shall be performed for selected use cases.</p>
Deliverables:	Prototype
Follow-up of a previous activity:	ARTES1 INSTINCT, Cloudsat

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
6A.055	Compact Bi-Directional Amplifier for Remotely Piloted Aeronautical Vehicles (RPAS)	500	1	18
Objective:	Development of a low Size, Weight and Power (SWaP) unit integrating SSPA, LNA and diplexer operating in L and S bands. Generic but easily customisable design (e.g. filtering) for specific applications e.g. Inmarsat and Thuraya, and supporting non-constant envelope waveforms. Key parameters are mass of < 200g and power in the order of 5-7W (at the diplexer).			
Targeted Improvements:	<ul style="list-style-type: none"> - Performance improvement (mass reduction, power efficiency, footprint, volume). - Market share increase for EU industry, no product known in this range at the moment. - New market opportunities in relation to the evolution of the RPAS market. 			
Description:	<p>Terminals currently available for Unmanned Vehicles (UAV) are suited to large and medium-size aircrafts. The market is however evolving and several applications are emerging for very small Remotely Piloted Aircrafts (RPAS) with extended range, for which Beyond Line of Sight communications will be required. Current aeronautical terminals are too heavy and too large for these category of aircrafts (mass<25kg. and alt<500ft but with a range of ~100km) therefore not suitable for small RPAS category</p> <p>The activity, starting from the current state of the art, will investigate the most promising technologies (e.g. GaN and ceramic Diplexer) to achieve a low weight (<200g) and power (5-7 W at diplexer) RPAS terminal. Small RPAS requirements and constraints will be taken into account.</p> <p>The technology assessment phase will be followed by the design and development of a representative prototype. The activity will be completed by validation performed in a lab environment</p>			
Deliverables:	Prototype, Design Documentation, Testing Documentation			

4.2 Ground Network Operation Control and Gateway

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
6B.030	Satellite Gateway Development for Massive Uncoordinated Access Networks	700	1	18
Objective:	To design and demonstrate innovative solutions for uncoordinated access networks targeting low duty cycle and low volume traffic (independent of operating frequency bands). This will allow aggressive resource sharing while significantly reducing the power consumption and the cost of the user terminals.			
Targeted Improvements:	The proposed activity aims to design and develop innovative techniques at the satellite network gateways for highly efficient use of satellite resources for the reception of short messages from uncoordinated satellite user terminals. The activity considers different system scenarios, including GEO/LEO satellite, fixed and mobile users. In particular, the impact of the frequency Doppler, fading and power variation will be taken into account.			
Description:	<p>There has been promising development of physical layer and Media Access Control (MAC) layer schemes for asynchronous terminals transmitting short messages. Performance results show between 60% to 90% improvement in the system overall capacity compared to state-of-the-art schemes (and three orders of magnitude improvement with respect to classical ALOHA random access) while maintaining similar complexity of the user terminal baseband processing. The technique investigated in a previous TRP study allows reducing the terminal peak power required to achieve a given throughput.</p> <p>The design of Enhanced Spreading Slotted Aloha (E-SSA) and its evolution as developed under the TRP activity as a software model would be considered as the input. The focus of the development will be on the receiving end (the satellite gateway) where the computation complexity is more demanding.</p> <p>Considering the high interest in systems with massive number of users, with stringent constraints on power consumption at the user terminal, the proposed solution can significantly improve the throughput and system loading while allowing for cost-effective implementation of the user equipment.</p> <p>Work Logic:</p> <ol style="list-style-type: none"> 1) define the operational scenarios, system architectures, applicable physical layer techniques, 2) develop the real-time lower layer satellite gateway sub-systems (mainly Layer 1 and Layer 2), 3) carry out emulations of the new protocol at the physical and MAC layer as well as representative models of the front-end (including the antenna), 4) validation of the access protocol in representative satellite scenarios 			
Deliverables:	<ul style="list-style-type: none"> – Technical Documents (consolidate requirements, scenario definition, design documents, test reports, etc.) – Physical layer and access scheme models in SW/HW – Real-time validation platform (real-time gateway as well as terminal population emulators) 			
Follow-up of a previous activity:	TRP Activity (completed 2015) on Advance Modem Technique for Satellite Networks. Contract No. 4000108548/13/NL/JK			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
6B.031	Critical Building Blocks for Next-Generation Q-/V- and W-Band ground HPAs	1500	2	30
Objective:	Development of critical building blocks (e.g. RF and High Voltage electronics), needed for ground station high power HPAs for Q-/V-band and W-Band feeder links.			
Targeted Improvements:	Develop critical building blocks to support increased RF power up to 1 kW and the related very high voltage levels, Possible creation for the European Satellite Industry of new market opportunities (enabling technology for Q-/V- and W-Band systems).			
Description:	<p>Next generation high throughput telecommunication satellites will be required to utilize Q-/V-Band and possibly W-Band for the feeder link in order to satisfy the capacity demand for the user link. V-band and W-Band HPAs are under development in Europe, but critical building blocks for ground station HPAs will be needed to cover the expected RF power up to 1 kW and the related very high voltage levels.</p> <p>The objective of the activity is the development of such critical building blocks covering RF and High Voltage electronics (EPC), needed for ground station high power HPAs for Q-/V-band and W-Band feeder link.</p> <p>For the RF part, cavity-based circuits represent important building blocks of high-power HPAs, as an alternative to helix interaction structures. Their inherent excellent electrical characteristics and mechanical simplicity offer distinct advantages in those applications requiring both high power, high frequency and large bandwidth operation. This activity shall assess the feasibility of innovative cavity structures for high-frequency HPAs suitable to next generation Q-/V- and W-Band ground stations.</p> <p>For the EPC part, the related high voltage technologies, sub-assemblies and thermal management techniques needed for V-band and W-Band EPCs shall be developed and demonstrated.</p> <p>The activity shall start with a review of the most promising RF interaction structures, performing a detailed trade-off between output power, bandwidth and manufacturing aspects. The selected interaction structures shall be simulated and designed to cover V-Band or W-Band Satcom applications. One design concept - to be selected during the activity - shall be built and tested on a representative prototype. From the prototype RF requirements, a complete high voltage module including transformer and insulation material shall be built and tested to fully validate the technologies developed. All technology-critical aspects shall be verified and limitations identified. A development plan for the full amplifier shall conclude the activity.</p>			
Deliverables:	Study report, 1 interaction structure prototype, 1 EPC prototype			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
6B.032	Innovative Feeder Link Antenna Array for Future Wide Band Communications in Ka- and Q/V-Band	300	2	15
Objective:	To assess the feasibility of using an array of small antennas instead of a single reflector antenna in Ka-Band (LEO and GEO missions) and Q/V-Band (GEO missions), aiming to increase the overall system reliability and to simplify installation.			
Targeted Improvements:	The proposed activity is in line with ESA roadmap defined for the Q/V-Band technology development. It is believed that for the same cost of a large Q/V-Band antenna, an array of small reflector antennas could be deployed thus improving dramatically the system reliability and simplifying installation.			
Description:	<p>Satellite coverage and reliability advantages have been coupled in the last years with a steady decrease in the cost per Mbit/s, as the Ku-Band implementations moved towards broadband Ka-Band, with a considerable increase in projected throughputs. In the near term, Ku-band transponders will continue to dominate the stage, but Ka-band High Throughput Satellite (HTS) have already begun the succession with high capacity increases. Only two channels of 500 MHz are exclusively dedicated to FSS (Fixed Satellite Services), which explains the proposal of a full Ka-Band allocation for user links and moving the feeder link to Q/V-Band. Moreover the use of Q/V band in the feeder link is justified by the fact that there is a stringent band requirement in the satellite-gateway link, increased by the proposed frequency multiplexing of feed signals in GBBF (Ground-Based Beam Forming). A possible idea is to use an array of small reflector antennas for the reception/transmission of high data rate signals needed for future HTS in Q/V-Band. This array will combine/correlate the desired signals over a wide bandwidth. This solution introduces a number of advantages: flexibility to support multiple missions, scalability, higher availability and installation simplification.</p> <p>The proposed solution is based on the heritage from broadband array processing for radio-telescope (CASPER solution). The challenges are: coherent combination of several antennas with wide bandwidth (signal processing design and hardware powerful enough to process the signals) implementing the whole array at the cost of the traditional large antenna solution. Feasibility of such a solution for both the uplink and downlink will be studied.</p> <p>The same concept will also be studied for Ka-Band feeder link stations for GEO applications. In the frame of the study it will also be verified the feasibility of using such a concept for high data rate Ka-Band LEO application.</p> <p>The study would be organized as follows: Requirements Consolidation, System Architecture Analysis, System Design and Synthesis of Results. This activity may enable the development of a wide-band array simulator and breadboard raising further the TRL level.</p>			
Deliverables:	Study report, performance analysis simulator and cost analysis tool			

5. USER TERMINALS

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7-.038	Embedded Antenna Arrays in small UAV Wing Structures	500	1	18
Objective:	The objective of this activity is to assess the viability of the embedded antenna array with real time adaptive beamforming in small UAV wing structures.			
Targeted Improvements	Higher level of integration enabling a high data rate capability for smaller UAVs that are foreseen to be used for civilian applications.			
Description:	<p>The market for satellite communications for backhaul of UAV payload data is expected to grow considerably in the next years. ESA is already funding a number of technical activities in this area. Although the satcom requirement is obvious for larger UAV's, it is expected that the market for middle sized and smaller UAV's will grow the fastest, as there are fewer regulatory hurdles to overcome. However, a recurring obstacle is the accommodation of any satellite antenna into such smaller sized UAV's. Novel concepts shall therefore be explored and validated, also taking into account the compatibility with future systems such as Inmarsat's Ka-band Global Express, or similar multi-spot beam Ka-band systems. An additional requirement is the support of future datalinks (possibly in the 5GHz band) for command & control of UAV's in civilian airspace.</p> <p>Although using antenna arrays in the wings of UAV's has been proposed in literature, few concepts take into account the aerodynamic deformation of the wings. This has been shown to have a significant impact of the overall performance of the antenna in terms of beam pointing, beamwidth and sidelobe level. In order to compensate for this, real-time adaptive beamforming is required. This would also allow for beamsteering. Another challenge is the available volume. In order to optimize the available antenna real estate there is a need to tightly integrate the antenna with the mechanical structure of the UAV or use the structural components as radiating elements.</p> <p>The embedding of phased arrays in fuselage panels has many advantages: lighter weight, no access holes, no mounting hardware, improved RF performance, increased component integration, no aerodynamic drag. ARINC 791 develops new standards for Ku and Ka airborne satcom, which require the placement of advanced electronics (BFN) inside pressurised aircraft structures.</p> <p>In order to optimise performance, some novel antenna concepts would be needed, leading to higher data rates, extended communication range and reduced sensitivity to interference. Furthermore, the weight impact would be minimised.</p> <p>The activity would comprise:</p> <ul style="list-style-type: none"> - Preliminary design - Critical bread boarding - Detailed design. - Manufacture of a prototype - Testing of prototype in realistic environment 			
Deliverables:	Breadboard			

5.1 Professional User Terminals

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7A.036	Ka-band Transceiver Power devices	1000	2	21
Objective:	To design and develop a prototype of a Ka-Band MMIC power device			
Targeted Improvements:	<ul style="list-style-type: none"> - Allow for a European source for procurement. - Allow ITAR free solution. 			
Description:	<p>Ka-band satellite user terminal manufacturing requires the procurement of US-produced RF power devices of up to 5 Watts. With such components representing a non-negligible part of the cost of the complete terminal, the situation is penalizing for Member States Industry. On top of this also come restrictions are present due to ITAR classification, that are very restraining in a mass-consumption oriented market.</p> <p>It is regarded as high importance for ground segment manufacturers to improve the situation, and to see the emergence of new competitive equipment manufacturers in Europe.</p> <p>The study aims to design and develop a prototype of Ka-Band MMIC power device, with the perspective of being competitive towards current products. A reflexion of possible technologies to use shall thus first be done, and architecture trade-offs shall be discussed before the development phase.</p> <p>Work logic :</p> <ol style="list-style-type: none"> 1) Design and architecture of the component. 2) Development of simulation data. 3) Prototyping, testing and validation of an engineering wafer in laboratory environment. 4) Performances assessment and Roadmap towards ‘productisation’. 5) Investigation of power combining techniques to achieve higher RF power levels. 			
Deliverables:	Prototype			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7A.038	10 Gbps Modem for Telecom Point-to-Point Applications	1400	2	24
Objective:	To design, develop and test a very high speed modem (transmitter and receiver) targeting a maximum of 10 Gbps data rate for point-to-point SATCOM applications.			
Targeted Improvements:	Increase the peak throughput of modems by a factor of 5 with respect to state of the art. Allow to work in single carrier per TWTA operations over a large bandwidth.			
Description:	<p>Ever increasing throughput demand is driving a growing interest in the exploitation of larger bandwidths in both Ka and Q/V bands.</p> <p>A total of about 3 GHz of contiguous spectrum is available in Ka-band by combining the exclusive, shared and extended bands as well as in Q/V band. This large amount of bandwidth could be exploited for point-to-point links (backbone, mesh, and professional links) if a single carrier of 2.5 Gbps symbol rate could be transmitted. The benefits would be to increase the peak throughput of point-to-point links by a factor of 5 with respect the state of the art as well as to improve the end-to-end efficiency of the link by allowing to work in a single carrier per HPA configuration.</p> <p>In terms of on-board TWTA technology, >200 W tubes will be shortly available; these devices will also have the capability to amplify more than 2 GHz of bandwidths. In Q/V band a 100 W tube will also be available with similar bandwidth requirements. Thanks to these developments the link budget for the proposed configuration appears feasible.</p> <p>In this activity a DVB-S2x modem (both transmitter and receiver) will be designed to be compliant with the full set of specifications concerning the ‘Professional Profile’ of the standard. This implies the support of a modulation order up to 256 APSK. The target peak throughput shall be set to be around 10 Gbps.</p> <p>Following the design, a development phase will be carried out using fast prototyping platforms and the latest available generation of FPGA technologies. An elegant breadboard will be developed for both the transmitter and the receiver side. A laboratory testing phase will follow to fully characterise the performance of such modem.</p>			
Deliverables:	Study report, prototype			
Follow-up of a previous activity:	TRP MHOMS			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7A.039	Terrestrial Interference Resilient Terminal Prototype	600	2	24
Objective:	Demonstrate terminal interference reduction techniques using reflector antennas in conjunction with auxiliary elements			
Targeted Improvements:	<p>The exploitation of the Ka shared band for uncoordinated ground stations of FSS systems is currently not possible due to the high risk of interference from an FS transmitter.</p> <p>Any technique able to ensure a proper mitigation of interference between the FS and FSS would allow doubling the user link bandwidth available to FSS operators, thus potentially double the satellite capacity. The target of this activity is therefore to enable the use of the Ka "shared" band to uncoordinated ground stations thanks to low cost antenna solutions.</p>			
Description:	<p>The most efficient way for achieving system capacity approaching the terabit/s is to use all the available band in Ka for user links, moving the feeder links to Q/V band. In Europe CEPT is trying to allow FSS services for uncoordinated ground stations to coexist with terrestrial fixed systems in the band 17.7-17.9 GHz referred to as 'Ka shared band'. The use of such a band may be necessary for increasing the capacity of future systems. This opportunity is currently being seriously considered by commercial satellite operators.</p> <p>In 2014 a TRP activity 'Antennas and Signal Processing Techniques for Interference Mitigation' was initiated to look at antenna techniques to minimize the interference power among the two services by adaptively nulling the interferer. Two configurations are being investigated: one based on side lobe suppression through a parabolic reflector and a number of secondary elements and another one based on an Array Fed Reflector with adaptive beam forming implemented digitally. The performance of AFR solution will be demonstrated by a partial prototype.</p> <p>The purpose of the proposed activity is to demonstrate the solution based on the reflector antenna with small auxiliary elements. Such a solution is expected to provide less degrees of freedom for suppressing interference from FS transmitters, but with the benefit of a very limited complexity - and therefore lower cost - compared to the AFR solution.</p> <p>The demonstrator will be a prototype able to reproduce functionally the final antenna product. However the hardware used will be a prototype not necessarily representative of the final engineered product.</p> <p>The project shall follow the following work logic:</p> <ol style="list-style-type: none"> 1) Review of the outcomes of the TRP activity. 2) Design of digital signal processing. 3) Design of the RF front end (ODU). 4) Design of the Antenna. 5) Development. 6) Test. 			
Deliverables:	Prototype			

5.2 Consumer User Terminals

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7B.031	M2M ‘Maker-space’ for Satellite Communications	500	2	15
Objective:	To enable rapid and responsive prototyping of low-cost satellite communications terminal concepts.			
Targeted Improvements:	The activity intends to accelerate the prototyping cycle and exploration of new concepts for satellite communications terminals in the domain of Machine-to-Machine (M2M) and Internet-of-Things (IoT) applications. Such acceleration shall be achieved by applying concepts from the terrestrial network development field, and via addressing a community not normally working on satellite communications. The activity shall specifically address the vibrant "maker" communities throughout Europe that are presently focused on terrestrial and consumer oriented communication projects.			
Description:	<p>In Europe there is a flourishing community of start-up companies and crowd-funded projects, sometimes referred to as the "Maker-space". These are loosely organised groups which implement projects in the spirit of open source hardware and full sharing of intellectual property. This community has generated many innovative hardware products or concepts based on small embedded systems (e.g. Raspberry PI, Arduino), state-of-the-art Software Defined Systems (e.g. HackRF, GNU Radio, URSP), and open source FPGA programming boards. A number of such products or concepts are already used within ARTES projects and some have been placed into orbit.</p> <p>Within this activity it is proposed to conduct 12 small hardware prototyping activities, focussing on developing new technology concepts for satellite communications terminals in the domain of Machine-to-Machine (M2M) and Internet-of-Things (IoT) applications. A prime contractor would be responsible managing separate individual development contracts placed with suitable entities from the ‘Maker-space’. The prime contractor shall coordinate and manage the activities of the group, and will oversee the hardware prototyping activities. The initial four developments will be defined by ESA and included in the activity ITT. These first four hardware prototyping activities shall be dedicated to the prototyping of emerging satellite communication technologies using software defined radio (SDR). Specifically, both terminal and gateway prototypes shall be built using M2M air-interfaces based on narrowband LTE (NB-LTE), the adaptation of current network and application layer M2M protocols over existing space segment shall be prototyped, and the adaptation of low-power terrestrial air interfaces to the satellite environment shall be prototyped and demonstrated. The subsequent eight developments will be defined by ESA, in consultation with the Prime contractor, in the next Phases of the activity.</p>			
Deliverables:	Design reports, Prototypes			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7B.032	Broadband SiGe IQ-modulator	350	1	24
Objective:	The objective of this activity is to develop an IQ-modulator front-end based on SiGe, with very high linearity (large ACPR) and operable over a wide frequency range.			
Targeted Improvements:	GaAs broadband modulators consume large chip area (e.g. 15 sq mm) and only have a moderate yield. With the use of SiGe technology, a more compact design covering a wider frequency range should be feasible. There will be a significant cost reduction due to smaller chip area as the price is set by square area. Additionally power consumption will be reduced drastically due to lower breakdown voltage.			
Description:	<p>IQ-modulators are part of RF frontends. The higher the modulation scheme is (e.g. 1024 QAM), the larger is the demand with respect to linearity. Moreover, a large frequency range can cover different scenarios up to Ka-band frequencies. Today’s IQ-modulators are mainly based on GaAs. These modulators are rather small band (e.g. 1-6 GHz) and show very high ACPR values (e.g. -74 dBc @ 2 GHz). GaAs modulators are limited in maximum frequency due to transistor device sizes in these technologies. With the usage of SiGe, active device size is much smaller. Therefore, these technologies could be a promising candidate for modulators covering a large frequency range. On the other hand side SiGe processes show low breakdown voltage, which may limit the linearity of mixer devices. Mixer device will be the core component of this activity (low noise floor and high linearity).</p> <p>Work Logic: Phase 1: Analysis of existing designs based on GaAs and SiGe. Evaluation of possible SiGe processes, which can be used in order to manufacture a high linear IQ-modulator covering a large frequency range. Phase 2: Design, layout and manufacturing and test if SiGe IQ-modulator. The intention is of this activity the design of a modulator for 1-25 GHz, which shows an ACPR of -74 dBc at low frequencies (comparable to GaAs).</p>			
Deliverables:	Study report, prototype			

5.3 User Terminal Mobile

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7C.039	Ka-band Receive Only Active Antenna for the Consumer Market (Priority 2)	1500	2	24
Objective:	This activity aims at the design, manufacture and test of a consumer compact Ka-band Satcom On the Move (SOTM) receive only active antenna.			
Targeted Improvements:	To demonstrate a solution for a Ka-band receive only active antenna with target price of 200-250 Eur in high volumes.			
Description:	<p>Ka-band High Throughput satellites (HTS) have the potential of cost effective content delivery, allowing novel mobile multimedia receive terminals with small unobtrusive antennas. Many attempts have been made towards the manufacturing of electronically scanned antennas (both receive only and transmit & receive) for user terminals, however none of them has led to a truly cost effective solution. However Ka-band HTS could make this happen due to their lower cost of ownership and higher gain.</p> <p>Silicon technologies are now able to handle microwave signals with reasonable performance up to fairly high frequencies in a very cost effective way in volume production. For a multimedia system, it is foreseen that an electronically scanned antennas will require a size equivalent up to a couple of hundred elements, bringing a low cost solution within reach.</p> <p>The main effort shall be towards the development of a manufacturing tolerant antenna aperture. The activity includes the development and integration of a dedicated custom-made silicon chip with a minimum size and cost.</p> <p>The combination of highly integrated silicon devices with automated pick & place and bonding, globetop technology and Printed Circuit Board (PCB) implementation should lead to a very cost effective antenna.</p> <p>The activity will lead to a complete antenna prototype and is preceded by an ARTES 5.1 system study (finishing 2015) where the antenna requirements are defined.</p> <p>The work logic will cover the following tasks:</p> <ul style="list-style-type: none"> - Preliminary design of antenna based on “design to cost” approach. - Derivation of requirements on sub-elements. - Design, manufacturing and test of the single chip Ka-band front-end. - Assembly and test of a prototype antenna. - Conclusions and way forward. 			
Deliverables:	Study report and antenna prototype.			
Follow-up of a previous activity:	7C.033 ‘Mobile Ka-band Multimedia Receiver for Vehicles’ in Workplan 2014			

Activity Ref.	Activity Title	Budget (kEuro)	Priority	Estimated duration (months)
7C.042	SatCom Module for Smartphones	550	15.1TT.65	12
Objective:	Design and develop SatCom module prototype for modular smartphones such as Google Ara Phone with the following features: - Voice+data services with Software Defined Radio (SDR). - L-band antenna for compatibility with Inmarsat, Thuraya, Iridium and GlobalStar satellite systems.			
Targeted Improvements:	- Satellite module fully integrated in the new Ara phone. - High reduction of terminal cost: below 150 Euro for a Satcom enabled Smartphone. Current satellite phones cost typically more than 500 €. - Compatibility with 4 major mobile operators thanks to SDR. - Such module would be useful also for some M2M applications.			
Description:	<p>In the last years some products like SatSleeve offered by Thuraya have been very successful by adding an external mobile satcom module in L-band to the iPhone and Android smartphones. Google’s project ARA intends to develop a standard interface and a baseline mobile phone, for which new modules will be developed by the telecommunication mobile Industry.</p> <p>Google Ara phone targets 50 \$ as entry price. The satellite module to be developed in this activity would be integrated in the new Ara phone. This will enable the combination of terrestrial and satellite mobile services on smartphone for a low cost (i.e below 150 Euro) thus resulting in a very attractive offer that will foster a wider penetration of satellite services.</p> <p>The work logic will start with the understanding of the environment in which Google’s ARA operates. It will then identify the range of most promising and feasible satcom modules in terms of size, weight, power and frequency bands. Design phase will include trade-off in the hardware options, e.g. FPGA vs. central CPU. It will finally develop and test the module prototype in cooperation with an operator.</p>			
Deliverables:	Study report, prototype.			