Satellite and Terrestrial Network for 5G

D6.7
Exploitation Activity Report

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MPQUIC  Multipath Quick UDP Internet Connection
MPTCP  MultiPath Transmission Control Protocol
MSS  Mobile Satellite Services
MVNE  Mobile Virtual Network Enabler
MVNO  Mobile Virtual Network Operator
Naas  Network as a Service
NEO  Network Operation
NF  Network Function
NFV  Network Functions Virtualisation
NFVI  Network Function Virtualisation Infrastructure
NG2  5G Control Plane Interface
NG3  5G User Plane Interface
NGMN  Next Generation Mobile Networks
NIS  Network Infrastructure and Security
NMS  Network Management System
NPV  Net Present Value
NR  New Radio
NS  Network Service
NSSF  Network Slice Selection Function
NTN  Non Terrestrial Network
ODL  OpenDayLight
ONAP  Open Networking Automation Platform
OPEX  Operation Expenditure
OSM  Open-Source MANO
OSS  Operation Support System
OTA  Over The Air
OTM/P  On The Move/Pause
OTT  Over The Top
PCF  Policy Control Function
PEP  Performance Enhancement Proxy
PFCP  Packet Forwarding Control Plane
PIMT  Propagation Impairments Mitigation Techniques
PNF  Physical Network Function
POI  Point Of Interest
POP  Point Of Presence
PPP  Public Private Partnership
PSTN  Public Switched Telephone Network
QoE  Quality of Experience
QoS  Quality of Service
QUIC  Quick UDP Internet Connection
R&D  Research & Development
RAN  Radio Access Network
RAN1  (3GPP) Radio Access Network – WG1 (Radio Layer 1 specification)
RDSS  Radio Determination Satellite Service
RIFE  architectuRe for an Internet For Everyone
RNIS  Radio Network Information Service
RoI  Return on Investment
RP  Research Pillar
RRC  Radio Resource Control
RRU  Remote Radio Unit
Rx  Receive
SA  Service and System Aspects
SA1  (3GPP) Service and System Aspects – WG1 (Services)
SANSAS  Shared Access Terrestrial-Satellite Backhaul Network enabled by Smart Antennas
Sat5G  Satellite and Terrestrial Network for 5G
Sat5G  Satellite and Terrestrial Network for 5G
SatCom  Satellite Communications
SATis5  Demonstrator for Satellite-Terrestrial Integration in the 5G Context
SatNaaS  Satellite Network as a Service
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCN</td>
<td>Satellite Communication and Navigation</td>
</tr>
<tr>
<td>SDN</td>
<td>Software Defined Network</td>
</tr>
<tr>
<td>SDO</td>
<td>Standardisation Organisation</td>
</tr>
<tr>
<td>SDR</td>
<td>Software Defined Radio</td>
</tr>
<tr>
<td>SES</td>
<td>Satellite Earth Stations and Systems (ETSI TC)</td>
</tr>
<tr>
<td>SLA</td>
<td>Service Level Agreement</td>
</tr>
<tr>
<td>SMARTER</td>
<td>Services and Markets Technology Enablers (3GPP)</td>
</tr>
<tr>
<td>SMB</td>
<td>Server Message Block</td>
</tr>
<tr>
<td>SME</td>
<td>Small Medium Enterprise</td>
</tr>
<tr>
<td>SMF</td>
<td>Session Management Function</td>
</tr>
<tr>
<td>SNO</td>
<td>Satellite Network Operator</td>
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<tr>
<td>SOHO</td>
<td>Small Office/Home Office</td>
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<tr>
<td>SON</td>
<td>Self-Optimizing Network</td>
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<tr>
<td>SOTA</td>
<td>Software Over-the-Air</td>
</tr>
<tr>
<td>SPECSCI</td>
<td>Strategic Positioning of the European and Canadian SatCom Industry</td>
</tr>
<tr>
<td>SSPA</td>
<td>Solid-State Power Amplifier</td>
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<tr>
<td>STB</td>
<td>Set-Top-Box</td>
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<tr>
<td>SUC</td>
<td>Satellite Use Case</td>
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<td>SUCC</td>
<td>Satellite Use Case Category</td>
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<td>SVNO</td>
<td>Satellite Virtual Network Operator</td>
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<td>SWP</td>
<td>Sub-Work Package</td>
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<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
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<td>TC</td>
<td>Technical Committee</td>
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<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
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<tr>
<td>TESS</td>
<td>Techno-Economic Software Suite</td>
</tr>
<tr>
<td>TM</td>
<td>Technical Module</td>
</tr>
<tr>
<td>TN</td>
<td>Transport Network</td>
</tr>
<tr>
<td>TR</td>
<td>Technical Report</td>
</tr>
<tr>
<td>TS</td>
<td>Technical Specification</td>
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<td>TSG</td>
<td>Technical Specification Group</td>
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<td>TV</td>
<td>TeleVision</td>
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<tr>
<td>Tx</td>
<td>Transmit</td>
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<td>UAS</td>
<td>Unmanned Aircraft System</td>
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<tr>
<td>UC</td>
<td>Use Case</td>
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<tr>
<td>UDM</td>
<td>User Data Management</td>
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<td>UE</td>
<td>User Equipment</td>
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<td>UHD</td>
<td>Ultra High Definition</td>
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<td>UHDTV</td>
<td>Ultra High Definition TV</td>
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<tr>
<td>UPF</td>
<td>User Plane Function</td>
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<tr>
<td>URLLC</td>
<td>Ultra-Reliable Low-Latency Communications</td>
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<td>UTRAN</td>
<td>Universal Terrestrial Radio Access Network</td>
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<td>VHTS</td>
<td>Very High Throughput Satellite</td>
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<tr>
<td>VIM</td>
<td>Virtualised Infrastructure Manager</td>
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<tr>
<td>VNF</td>
<td>Virtualised Network Function</td>
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<td>VNI</td>
<td>Visual Networking Index</td>
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<td>VoD</td>
<td>Video on Demand</td>
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<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>VSAT</td>
<td>Very Small Aperture Terminal</td>
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<td>WCE</td>
<td>Wireless Communication Engineering</td>
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<td>WG</td>
<td>Working Group</td>
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<td>WP(L)</td>
<td>Work Package (Leader)</td>
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<td>WRC</td>
<td>World Radiocommunication Conference</td>
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<td>WSN</td>
<td>Wireless Sensors Network</td>
</tr>
<tr>
<td>ZDS</td>
<td>Zodiac Data Systems</td>
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<tr>
<td>ZII</td>
<td>Zodiac Inflight Innovations</td>
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</tbody>
</table>
Executive Summary

This deliverable document corresponds to second of the two outputs of SaT5G WP6.4 “Exploitation Plan”, and defines the exploitation activities and plans of the research & innovation results and findings from the project. In particular, the present deliverable document D6.7 “Exploitation Activity Report” describes the exploitation activities and outcomes within the SaT5G project, as well as recommendations for future work supporting the integration of satellite and 5G.

This deliverable document describes the SaT5G exploitation activities on both a thematic and partner specific basis, based on the strategic plan developed in D6.6 “Exploitation Plan”.

Thematically four broad areas are considered in terms of SaT5G exploitation elements: Products, Services, R&D, and Standards.

The individual exploitation activity reports for each SaT5G consortium partner have been independently developed by each party based on its business strategies; however, some of the exploitable opportunities are developed in conjunction by a subset of the project partners towards and after the completion of the project. Every partner has provided the identification of the exploitable knowledge they have developed so far in the project as well as defined opportunities for exploitation coming out from such knowledge.

In addition a number of joint exploitation activities have advanced sufficiently to provide some details.

Finally recommendations for further work looking at products, service development, R&D and standardisation have been made.
1 Introduction

1.1 Scope of SaT5G

SaT5G is a European Commission H2020 5G PPP Phase 2 project, kicked-off in June 2017 with 33-month duration, whose vision has been to develop cost effective “plug and play” SatCom (Satellite Communication) solutions for 5G to enable telecom operators and service providers to accelerate 5G deployment in all geographies and at the same time create new and growing market opportunities for SatCom industry stakeholders. SaT5G focuses primarily on backhaul via satellite and on enhanced mobile broadband (eMBB) use cases for 5G.

SaT5G aimed to deliver the seamless integration of satellite into 5G networks to ensure ubiquitous 5G access everywhere. The six principal SaT5G project objectives were to:

- Leverage relevant ongoing 5G and satellite research activities to assess and define solutions integrating satellite into the 5G network architecture;
- Develop the commercial value propositions for satellite-based network solutions for 5G;
- Define and develop key technical enablers for the identified research challenges;
- Validate key technical enablers in a lab test environment;
- Demonstrate selected features and use cases with in-orbit GEO and MEO HTS satellites;
- Contribute to the standardisation at ETSI and 3GPP of the features enabling the integration of SatCom solutions in 5G.

1.2 Document Context

This deliverable document corresponds to one of the two outputs of SaT5G Work Package (WP) #6.4 titled “Exploitation Activity Report”, which defines herein the plans for exploitation of the research & innovation results and findings from the project. The WP6.4 activities undertaken are summarized as follows:

- Definition of a strategic plan for the commercial exploitation of the SaT5G concept and project results at national, European and international level.
- Consolidation of individual and joint exploitation plans in line with the common SaT5G roadmap defined.
- Identification of potential joint exploitation of project results by project partners.
- Identification and definition of future roles and responsibilities of all project partners targeting a successful commercial exploitation of the project results.

Deliverable document D6.6 defines the strategic plan for SaT5G project results exploitation.

The present deliverable document D6.7 builds on this by documenting all of the exploitation activities undertaken, and defines plans for future exploitation.

As an output document of WP6.4, this deliverable document D6.7 is fed with inputs from all WPs and sub-WPs. As an illustration, WP6.4, as well as WP6 in general, fits in with the surrounding activities as depicted in the figure below.
1.3 **Document Organisation**

This document is organized as follows:

- Chapter 1 introduces the document, defines its context, and its organisation.
- Chapter 2 provides a report on the exploitation activities undertaken and outcomes achieved within the SaT5G project, as well as planned future activities. Sixteen sub-Chapters are included, one for each SaT5G consortium partner, where individual business exploitation activities are presented.
- Chapter 3 provides a description of and outcomes related to joint exploitation activities involving multiple SaT5G partners.
- Chapter 4 develops recommendations on future exploitation work in thematic areas. These recommendations focus on required activities to promote satellite communications in 5G and beyond.
- Chapter 5 summarizes the main exploitation outcomes and recommendations for future work of the SaT5G project.
- Chapter 6 lists the various references used throughout this document.

This document is best read in conjunction with D6.6 “Exploitation Plan” where the business strategies and exploitation plans are developed in detail, both thematically and by partner.
2 Exploitation Activity Reports

2.1 AVANTI COMMUNICATIONS (AVA)

Avanti connects people wherever they are - in their homes, businesses, in government and on mobiles. Through the HYLAS satellite fleet and more than 150 partners in 118 countries, the network provides ubiquitous internet service to 27 per cent of the world’s population. Avanti delivers the level of quality and flexibility that the most demanding telecoms customers in the world seek.

Avanti is the first mover in high throughput satellite data communications in EMEA. It has rights to orbital slots and Ka-band spectrum that cover an end market of over 1.5bn people. The Group has invested $1.2bn in a network that incorporates satellites, ground stations, datacentres and a fibre ring. Avanti has a unique Cloud based flexible customer interface that is protected by patented technology.

Avanti’s capacity expansion is focused over Africa; with 3 satellites servicing the continent we are biggest provider of Ka-band High-Throughput Satellite (HTS) services to the continent.

Avanti is UK based, listed on the London Stock Exchange and headquartered in London, with operations in Cornwall, Cyprus, Turkey, Germany, Kenya, Tanzania, Nigeria and South Africa. The company employs over 200 highly skilled staff coming from many different nationalities.

HYLAS Satellite Fleet and Infrastructure

Avanti has four satellites currently in orbit (HYLAS 1, 2, 3, and 4). The HYLAS fleet provides significant advantages to customers:

- **Full coverage**: Avanti delivers 100% national coverage of primary countries with overlapping beam patterns (no in-country coverage gaps) so that service providers can offer a truly national service with consistent quality
- **High spectral density**: Service providers can use the smallest possible terminals providing a cheaper, attractive and more efficient way of delivering bandwidth to customers
- **Smart beam clustering**: Avanti’s beam clusters land in a single Gateway in the relevant country or region.
- **Diverse networks deliver resilience**: Avanti’s ground network is protected from atmospheric events with redundant gateway offering market beating Service Level Agreements.

Avanti has redundant Gateway Earth Stations (“GES”) in the UK, Cyprus, Germany, Turkey, Nigeria and South Africa. Avanti’s network is designed to offer the levels of quality and flexibility that the most demanding telecoms customers seek:

- 99.99% uptime due to redundancy and no single points of failure
- Cloud based interface (operational support system) allows customers to become virtual network operators with minimal investment
- Direct connections into major network peering centres and internet exchanges in London, Amsterdam, Frankfurt, and Istanbul

Figure 2-1: Avanti coverage
Products and Customers

Avanti provides products and services in four market facing verticals Consumer, Enterprise, Carrier and Government.

Avanti sells on a wholesale business-to-business basis. Customers choose from a range of products:

- **Pure**: Service Providers have exclusive use of a defined number of MHz in specific beams.
- **Adapt**: Fully flexible bandwidth. Service Providers have exclusive use of a defined number of Mbps in specific beams via a Virtual Network Operator access model.
- **Connect**: Packaged broadband. Service Providers buy individual broadband internet services from an Avanti defined list of standard tariffs.
- **Serve**: Managed services for focused service delivery.

The customer base is evolving from a core of regional ISPs and specialist providers to include organisations with potentially very large demand requirements, including national carriers, global telecoms operators, global internet and media companies and government customers.

Avanti has prided itself as being a leader in innovative satellite services for mobile networks and carriers.

The solution model outlined below has resulted in significant projects – including carrier grade backhaul to ~1000 sites for the BT/EE 4G network in the UK to support delivery of the Emergency Services Network (ESN) system.

### 2.1.1 Exploitation Activities within SaT5G

Avanti has made the following progress within the SaT5G project:

- Converged satellite 5G business and operational modelling is identifying new routes to markets and the commercial & operational constraints that will exist in the future.
- We have leveraged interim work on satellite integration into 5G testbeds to support proposals for 5G demonstrations and trials at multiple testbeds and for multiple market verticals. Demonstration of pre-5G satellite-terrestrial services will support operational roll out of satellite 5G post 2020.
- Support definition of standards based approaches for satellite network platform virtualisation, multi-vendor interoperability and management/orchestration in 3GPP and ETSI – laying the groundwork for future procurements and OSS development.
- Building relationships with vendors (including iDirect, Gilat, TAS, i2Cat etc.) that will help deployment of satellite backhaul 5G services starting with future trials and pilots.
- Support for the Limassol testbed of the EC H2020 project 5GENESIS [1].
2.1.2 Exploitation Outcomes from SaT5G

Table 2-1: Exploitation Outcomes for partner AVA

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Business and operational models for converged satellite-terrestrial 5G service delivery</td>
<td>Adapt and Serve products addressing Enterprise, Carrier Services</td>
<td>2020 onwards</td>
<td>Publications, Know-how, relationships</td>
</tr>
<tr>
<td>2</td>
<td>Satellite 5G reference Architecture and Standards</td>
<td>Adapt and Serve products addressing Carrier Services</td>
<td>2020 onwards</td>
<td>Publications, Know-how, relationships</td>
</tr>
<tr>
<td>3</td>
<td>Pre-5G Satellite Platforms integrated Avanti Network Environment</td>
<td>Adapt and Serve products addressing Enterprise, Carrier Services</td>
<td>2020 onwards</td>
<td>Know-how, relationships</td>
</tr>
<tr>
<td>4</td>
<td>Satellite 5G Edge Caching &amp; Multicast Approaches</td>
<td>Adapt and Serve products addressing Media &amp; Entertainment, Content Distribution</td>
<td>2020 onwards</td>
<td>Publications, Know-how, relationships</td>
</tr>
</tbody>
</table>

2.1.3 Planned Future Activities

Leveraging Avanti satellite network in 5GIC testbed

The 5GIC testbed facility in University of Surrey utilising Avanti satellite capacity as part of the project demonstration positions Avanti at the fore-front for 5G and satellite pilot deployments going forward. As a founding member of Horizon 5G, we also leverage the testbed for trials, pilots and demonstration activities. The testbed will also be used in pre-positioning Avanti as UK 5G and satellite test network following a new project proposal, “Satin5G” which we working with ESA (see also section 3.2). Avanti also works on the EC project 5GENESIS [1].

Our role in the Standardisation Fora

Avanti is an active participant in standardisation bodies. As a thought leader, our goal is to continue exposing the satellite industry into the wider 5G communities, to reduce barriers and enhance common understanding on the proposition of satellite for 5G networks. Avanti is a member in the following bodies: ETSI SES CN, ESA Standards Special Interest Group, ESOA Standards Working Group and Networld 2020 Satellite Experts Group. In 3GPP, Avanti supports activities such as preparing and supporting inputs in the RAN1, RAN3, SA2, SA3 and SA5 working groups.

Integration with MNOs for Converged 5G Service Delivery

From 2020 onwards, Avanti will seek to structure its carrier offerings such that there will be transparent interworking or integration between Telco, MNO and Satellite operators in the user, control and management planes. This will be key to support efficient carrier grade backhaul and trunking in 5G service in particular by supporting fast, seamless end-to-end service creation and management. Key items include:

- Interoperability of satellite network solutions with the 5G network management system allowing a third party to manage and configure virtualised satellite network resources. This also includes virtualisation of satellite communication elements as non-conventional;
- Integration of the satellite communications system into the 5G core network to provide secure end-to-end 5G services to and from satellite terminals;
- Multi-vendor interoperability between elements (e.g., terminals, radio access networks) of satellite network solutions for 5G.
SaT5G work on requirements, future architecture, use-cases and standards definition for converged 5G delivery (as well as lessons learnt from the integration of live satellite networks into 5G testbeds) will catapult Avanti a head-start in leading the 5G and satellite industry network converged operational and delivery systems. Discussions with MNOs regarding the roles for GEO SatComs in their plans are underway and thought leadership presentations are being made in various contexts.

**Future service platform developments**

In order to realise the potential of a next generation OSS it is necessary that the satellite community adopt the technology paradigms and standards of the 5G community to transparently support end-to-end hybrid service delivery to the Verticals; and drive interoperability & economies of scale in satellite networks.

For Avanti a key output of SaT5G is the development of satellite network platforms that are priced effectively (by leveraging economies of scale from standardisation including at 3GPP) and that meet 5G requirements for converged service delivery. SaT5G provides a forum in which to work with satellite network platform developers (such as iDirect, Gilat, TAS) and other platforms for Avanti to shape and better understand future satellite network platform capabilities (including by use of prototype capability in testbeds). This know-how will feed through directly into future satellite hub platform procurements.

Further, the Avanti Cloud Operational Support System is developed in house. The OSS is fundamental to successful and scalable service delivery. To allow Avanti to readily work with 5G MNOs and service providers it is necessary to adopt an industry standard driven interface rather than a partially Avanti driven interface. SaT5G is developing an open source based approach to integrated network management and orchestration systems for 5G satellite systems. This work will be used to inform the development of the Avanti OSS.

The work in SaT5G and the knowledge gained by Avanti will be leveraged in future conversations with operators as it seeks to grow its carrier market in Africa, the Middle-East and Europe.

### 2.2 THALES ALENIA SPACE FRANCE (TAS)

Thales Alenia Space, TAS, is a key European player in space telecommunications, navigation, Earth observation, exploration and orbital infrastructures. In particular, it is one of the world’s leading manufacturers of communications satellites, platforms and payloads, which account for 50% of its business. The company offers a complete range of solutions, from high-performance components to turnkey systems.

TAS is engaged in the development of the necessary technologies at both space and ground segments to develop future satellite systems to be fully integrated in the 5G system.

#### 2.2.1 Exploitation Activities within SaT5G

During the project, TAS has been driving the standardisation effort (Rapporteur of all relevant study/work items) in both 3GPP and ETSI since mid-2016 to ensure a role for SatCom solutions in 5G system by

- Providing guidance to the definition of future SatCom solutions for full integration with the 5G network
- Easing the accommodation of legacy SatComs in 5G network.

This effort exploiting work carried out mostly in WP3.5 and WP4.4 has successfully involved cellular and satellite stakeholders which is the world premiere. Thanks to this effort, it is widely recognised now that satellite has a role to play in 5G.

In addition, TAS has led in ETSI, the comparison of the complexity of the different architecture scenarios related to mid and long term approached (See ETSI TR 103 611 “Integration of satellite and/or HAPS (High Altitude Platform Station systems into 5G and related architecture options”, provided within the deliverable document of WP3.5) involving a wide number of key SatCom stakeholders beyond SAT5G project (such as HNS, Echostar).
2.2.2 Exploitation Outcomes from SaT5G

Table 2-2: Exploitation Outcomes for partner TAS

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5G Satellite transport solution (DVB based)</td>
<td>Backhaul</td>
<td>Short/mid term</td>
<td>Design</td>
</tr>
<tr>
<td>6</td>
<td>5G Satellite access solutions (NR/NG-RAN based)</td>
<td>Mobile voice and broadband services, Indirect Access and Backhaul</td>
<td>Mid/long term</td>
<td>Design</td>
</tr>
</tbody>
</table>

2.2.3 Planned Future Activities

The reference architectures options that are selected amongst others, for N3, N2, N1 reference points impacts analysis are described in the D3.5 and D4.4 deliverables:

- Direct UE 3GPP access (scenario A1), both for User Plane and Control Plane, with the highest priority
- Indirect UE 3GPP access (scenario A2), both for User Plane and Control Plane, with lower priority

These architecture options share the same high layers such as NAS and NGAP, than other UE Non-3GPP access based architectures. Hence, the impact analysis on high layers should be relevant to several architecture options. Note that the impact analysis for the direct UE 3GPP access architecture is relevant to the Indirect UE 3GPP access, when applied to the NTN Relay UE, acting as UE with direct 3GPP access.

Beyond SaT5G, TAS will work on:

- The Xn interface (3GPP TS 38.420) and the F1 interface (3GPP TS 38.470) impacts analysis could be studied, in a cellular and NTN multi-connectivity context.
- The impacts analysis on the above protocols (table ) could also be studied in a context of regenerative NTN payload, embedding gNB functions.
- Studies related to Non-Terrestrial Network architectures for 5G and impacts analysis will be defined as part of the 3GPP Release 17.

For information, the selected architectures options for the protocols impacts analysis, are depicted below. It is excerpt from WP3.5 delivery.

The scenario A1 architecture option (Direct UE 3GPP access), for the User Plane, is depicted below.

Figure 2-3: Scenario A1 – End-to-end transport of NTN NT UE layers, for Direct 3GPP access, with bent-pipe payload
The scenario A1 architecture option (Direct UE 3GPP access), for the Control Plane, is depicted below.

![Diagram of scenario A1](image)

**Figure 2-4: Scenario A1 – End-to-end transport of NTN NT UE CP layers for Direct 3GPP access, with bent-pipe payload**

The scenario A2 architecture option (Indirect UE 3GPP access), for the User Plane, is depicted below.

![Diagram of scenario A2](image)

**Figure 2-5: Scenario A2 – End-to-end transport of UE UP layers, for Indirect 3GPP access, with bent-pipe payload**

The scenario A2 architecture option (Indirect UE 3GPP access), for the Control Plane, is depicted below.
2.3 UNIVERSITY OF SURREY (UoS)

2.3.1 Exploitation Activities within SaT5G

The University of Surrey is a research based organization with a mission to extend knowledge and to exploit the knowledge in collaboration with industry and to its teaching programmes. Knowledge gained from research is intellectual property that we exploit as background in bidding for additional research contracts. We also exploit the knowledge in collaboration with industrial partners or directly via spin off activities. The University has an experienced team of enterprise staff to help discover and exploit the IPR. New knowledge is also incorporated in our teaching programmes at post and undergraduate level in order to enhance our attractiveness to students. As UK universities are assessed on a five yearly period the research output in terms of published papers in good quality journals is an important KPI in our activities.

We see opportunities provided by work in SaT5G to extend the functionality of the 5GIC testbed by incorporating a satellite element and engaging in further vertical trials which involve a satellite element. The 5GIC 5G testbed is one of the most advanced in implementing and validating 3GPP Rel 15 standards. It has already been connected to other 5G projects both within the UK and abroad. Its development as an industry facing standard testbed makes it attractive to industrial sectors wishing to trial real applications.

Our exploitation activities will also include the incorporation of knowledge gained into post graduate and CPD courses on 5G. In addition the outcomes will give us the opportunity to bid for further R&D contracts in the area.

There is also an opportunity to spin off some of the software knowledge and developments in connection with 5G into a separate company which could also include the marketing of the ‘testbed as a service’ to customers.
2.3.2 Exploitation Outcomes from SaT5G

Table 2-3: Exploitation Outcomes for partner UoS

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
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<td>Know how</td>
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<tr>
<td>2</td>
<td>5G core network</td>
<td>5G user trials</td>
<td>2018-2020</td>
<td>Know how</td>
</tr>
<tr>
<td>3</td>
<td>5G Core and RAN</td>
<td>5G User trials</td>
<td>2019-23</td>
<td>Know how</td>
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<tr>
<td>4</td>
<td>Satellite enabled 5G test facility</td>
<td>R&amp;D contracts</td>
<td>2019 23</td>
<td>Know how</td>
</tr>
</tbody>
</table>

2.3.3 Planned Future Activities

UoS plan to add a business layer to the 5G testbed which will enable simpler integration with 5G user trials. We plan to bid for new R&D contracts using this facility. We will continue to flow the knowledge gained into our post-graduate and CPD courses on 5G which will be made available to industries. We will continue to investigate the possibility of our software services as a spin out company.

2.4 SES S.A. (SES)

2.4.1 Exploitation Activities within SaT5G

In the frame of SaT5G, SES partnered with SaT5G consortium members - iDR, BPK, i2CAT and UoS – for the first-of-its-kind over-the-air live demo at EuCNC 2018 in Ljubljana (18-21 June 2018). The purpose was to demonstrate key benefits of satellite integration with an SDN/NFV/MEC-enabled pre-5G construction testbed, with its in-orbit geostationary satellite system ASTRA 2F as a proof-of-concept for integration of those features into a full 5G network.

In addition, SES has been collaborating with the SaT5G partners ZII, GLT, QUO, i2CAT and BPK in the SaT5G 5G aero backhauling demo, which will take place towards the end of the project. The main aim here is to address the O3b MEO satellite integration into 5G for aero backhauling towards broadband connectivity to airplanes for Next Generation In-Flight Entertainment Connectivity (NextGen IFEC).

The gained experiences and interim results of these demos as well as the related R&D work conducted within SaT5G is being exploited to drive the SES’ 5G productisation and commercialization strategy for multiple market verticals, such as Fixed Data, Aero, Maritime, Energy, Government, Cloud, and Video. Moreover, it enables SES to support 5G demonstrations and trials at multiple testbeds and for multiple market verticals. Furthermore, this collaboration has helped SES to build strong relationships with key players in the integration of satellites into 5G networks, and especially with the vendors participating in the SaT5G project that will help deployment of satellite backhaul 5G services.

But demo tests alone are not enough to advance satellite integration into 5G. At the same time, there is need to further standardize the way satellite fits the overall 5G architecture. In particular, together with SaT5G consortium partners, SES has been actively participating in 3GPP SA/RAN, ETSI TC-SES SCN, ITU-R WP4B and CEPT FM44 standardisation activities to promote the satellite role into the 5G ecosystem. Advancements on this front and ecosystem developments mean that satellite will open new avenues for commercial products and services, enabling MNOs to avail of the emerging business opportunities.

Hence, participation in SaT5G project coupled with other SES’ relevant initiatives enables SES to realise its vision towards a software-defined, automated, cloud-scale platform as shown in Figure 2-7. In addition, it allows SES to contribute to the roll out of a truly global next-generation data network that can serve key areas such as cellular backhauling and IoT, and enables SES to open new, not yet identified or accessible to satellite markets.
2.4.2 Exploitation Outcomes from SaT5G

Based on its global GEO-MEO fleet (over 50 GEO satellites and 20 MEO satellites), SES is strategically positioned as the unique satellite operator to offer combined GEO-MEO service capabilities for the future 5G infrastructure globally. The combination of GEO’s high-powered global coverage and MEO’s low latency capabilities will accelerate the 5G deployment. In addition, SES is active proponent of integration of satellite into 5G and key driver of innovation in building a cloud-scale, automated, “virtual fibre” network of the future. SES is well-positioned to add value to the 5G opportunity by collaborating closely with key public and industrial stakeholders.

The exploitation outcomes from SaT5G for SES are summarized in the following table.

As can be deduced, there is good ground to believe that the first commercial applications for satellite integration into 5G will be available already in 2020 for various verticals.

Table 2-4: Exploitation Outcomes for partner SES

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Integrated satellite-terrestrial 5G reference architectures, requirements and standards</td>
<td>Global Managed Data Services</td>
<td>2020 onwards</td>
<td>Know-how</td>
</tr>
<tr>
<td>2</td>
<td>Business and operational models for converged satellite-terrestrial 5G service delivery</td>
<td>Global Managed Data Services</td>
<td>2020 onwards</td>
<td>Know-how</td>
</tr>
<tr>
<td>3</td>
<td>Next generation 5G-enabled virtualised ground segment infrastructure for network slicing</td>
<td>Global Managed Data Services</td>
<td>2020 onwards</td>
<td>Know-how</td>
</tr>
<tr>
<td>4</td>
<td>Next generation MEC-enabled edge network delivery</td>
<td>Global Managed Data Services</td>
<td>2020 onwards</td>
<td>Know-how</td>
</tr>
</tbody>
</table>
Furthermore, the knowledge gained within SaT5G project has already helped SES to bid and acquire new R&D and innovation projects to further promote the satellite integration into 5G. As an illustration, SES has successfully kicked-off the following relevant projects:

- **EdgeSAT**: Edge Network Computing Capabilities for Satellite Remote Terminals (ESA ARTES)
  - Aim: To explore the applicability and implementation of edge networking concepts in satellite networks in order to identify and characterise the resulting opportunities for Satellite Network/Service providers as well as Satellite terminals manufacturers, and to specify and validate a SatCom enabled edge node.
  - Project Website: https://artes.esa.int/projects/edgesat

- **5G-VINNI**: 5G Verticals INNovation Infrastructure (EU H2020 5G PPP Phase 3)
  - Aim: To accelerate the uptake of 5G in Europe by providing an end-to-end facility that validates the performance of new 5G technologies by operating trials of advanced vertical sector services
  - Project Website: https://www.5g-vinni.eu/

- **SATis5**: Demonstrator for Satellite-Terrestrial Integration in the 5G Context (ESA ARTES)
  - Aim: To build a large-scale real-time live end-to-end 5G integrated satellite terrestrial network proof-of-concept (PoC) testbed that enables the satellite terrestrial convergence into the 5G context, with focus on 5G use cases towards enhanced mobile broadband (eMBB) and massive machine type communications (mMTC)
  - Project Website: https://artes.esa.int/projects/satis5-0

### 2.4.3 Planned Future Activities

From the SES’ perspective, the path to innovation for 5G can be summarized as follows:

- Satellite helps mobile operators respond to strong demand for data from consumers and businesses, driven primarily by video, and overcome geographic and cost constrains
- Satellite’s ubiquitous availability helps accelerate global 5G deployment on the ground, at sea and in the air
- Next-generation satellite equipment and networks are leveraging key 5G technologies, standards and capabilities in order to ensure seamless integration and enable significant cost reductions
- The satellite industry is investing massively in new satellite and ground infrastructure to support those new capabilities and needs

As such, 5G enables new business models also for the satellite industry – to the benefit of affordable connectivity worldwide

Recognizing that 5G represents a key satellite services opportunity, SES has been following a three-pronged approach which is illustrated in the following figure.
To support the 5G roll-out, SES and the satellite industry in general are investing massively in new satellite and ground infrastructure to support those new capabilities and requirements. The SES’ roadmap to build the satellite infrastructure to support the 5G roll-out is illustrated in the following figure.

In particular, the SES’ planned future activities beyond SaT5G can be outlined as follows:

**O3b mPOWER**

O3b mPOWER (see Figure 2-10) corresponds to the next generation of O3b MEO satellite system, where SES has been massively investing and is to be launched in 2021. A system unlike any other, O3b mPOWER includes step change technology advancements, including a new constellation of advanced MEO satellites, ground infrastructure innovation and convergence, and new software intelligence. The result is cloud-scale connectivity for low-latency, application-aware services virtually anywhere in the world. O3b mPOWER introduces a new concept in network endpoints: Customer Edge Terminals. Bringing together application-specific antennas, storage, compute and routing resources, virtualised network functions and network intelligence in a small device that is fast and simple to install, O3b mPOWER puts high-performance data services in reach for more kinds of customers and in more places than ever before. Moreover, SDN capabilities enable O3b mPOWER to deliver services that are automated, agile and assured.
Integration with MNOs and mobile industry ecosystem for converged 5G service delivery: Making satellite seamless

Increased RAN density requirements and the need for rapid deployment put pressure on MNOs to reconsider infrastructure plans—including urban infill, small towns and truly rural areas—in order to remain competitive. Satellite backhaul solutions can provide the required velocity and flexibility to accelerate time to market. In addition, MNOs can leverage the access to capacity to tap into new segments driven by surge and seasonal requirements. By partnering with satellite operators, MNOs can expand their footprint into regions that are difficult or impossible to serve via their terrestrial assets. Satellite represents a path for MNOs to expand their footprint and thus deliver on the promise of seamless, universal 5G coverage and services.

For SES, this strategy represents a natural extension of its existing synergistic relationships with MNOs. Its cellular backhaul solution has long been used by MNOs to expand the reach of their mobile offerings, allowing them to meet customer demands and generate new revenue streams without the capex associated with network builds and expansions. The diversity of SES’ multi-orbit, multi-band satellite fleet allows us to tailor backhaul solutions for MNOs’ specific requirements, optimizing connectivity based on one or more key service attributes, including cost, capacity, latency, coverage and reliability.

A key part of SES’ value proposition to MNOs is making it simple and seamless to interconnect to satellite-based networks, integrate into the SES operational environment and deliver innovative networking solutions anywhere with minimal risk. By making it simpler to integrate into our network, we enable MNOs to address new subscriber growth opportunities faster and at lower cost.

Making satellite seamless is the primary goal of SES’ network modernization strategy. SES’ vision integrates satellite-based connectivity services with the capabilities and advanced services of 5G network and cloud platforms. To this end, SES is developing an automated, virtualized network service platform that allows our customers and technology partners to onboard new applications and launch new, satellite-based managed services in an orchestrated, standards-based environment.

SES is testing and integrating SD-WAN, MEC, vEPC, and many other technology solutions into its network service platform, enabling MNOs and other service provider customers to offer intelligent, application-aware managed network services. Supporting points:

- SES is the first and only satellite-enabled service provider to earn MEF Carrier Ethernet 2.0 certification, enabling MNOs to integrate into our satellite networks easily and in a standards-driven environment. Adopting our MEO-based services, MNO customers can take advantage of industry-standard, end-to-end SLAs for latency, jitter and throughput.
- SES is adopting the Linux Foundation’s Open Networking Automation Platform (ONAP) and the MEF Lifecycle Services Orchestration (LSO) reference architecture to drive fulfilment and
assurance of network services in an agile, automated operational environment ideally suited to cloud-based applications.

- SES is leading and investing in a wide variety of 5G standards initiatives to demonstrate the viability of 5G use cases in a satellite-enabled network environment.
- SES is working with MNOs to ensure that mobile subscribers are able to continue to use their connected devices in the air, enabling operators to extend their services onto aircraft and provide a consistent and seamless broadband experience to their customers.

Satellite players must “plug into” the MNO ecosystem and become a true enabler of value-based outcomes. This is the approach adopted by SES, which is enabled by participation to the SaT5G project among other SES initiatives. If satellite players are a fully integrated part of the mobile industry ecosystem, MNOs don’t need to incur extra costs by adjusting their systems and operations to tap into satellite capacity. Put simply, the cost and complexity of bespoke engineering for traditional satellite capacity is removed by SES, offering standard managed end-to-end IP and Ethernet services seamlessly across its fleet towards converged 5G service delivery.

**Partnership with mobile and satellite industry in standardisation to promote satellite integration in 5G ecosystem**

SES sees 5G as an opportunity to integrate satellite more deeply into the mobile industry ecosystem, but one key ingredient remains missing – open standards. Satellite companies have been targeting the mobile sector for years with services like cellular backhaul. But it’s generally been a niche play for a variety of reasons, not least of which the fact that satellite doesn’t integrate seamlessly with 3G and 4G networks. 5G will be different because this time, satellite players have been directly involved with standardisation bodies, such as 3GPP and ETSI. Together with SaT5G project partners, SES has been trying to get a lot more integrated with the bodies that are responsible for defining the standards so that they understand more about satellite, they understand more about the future of satellite, and that 5G is going to be a network of networks embracing every technology, including satellite.

However, one of the key challenges for satellite is that satellite technology systems are still mainly closed, proprietary systems – which flies in the face of the rest of the telecoms sector’s march (albeit not quite enthusiastically) towards open standards and open source software. To this end, participation in SaT5G project enables SES to encourage further satellite equipment vendors to move away from their proprietary systems and move more into standards based systems. The interfaces used in satellite need to be interfaces that are seamless in 5G networks going forward.

The starting point for 3GPP to work on a standard about the use of satellites in the 5G network has been established through key satellite initiatives, such as SaT5G. SES in collaboration with other SaT5G project partners has contributed to several 3GPP Technical Reports addressing the satellite integration into the 5G ecosystem. Apart from 3GPP, SES has also been an active member of ETSI, CEPT and ITU-R relevant standardisation groups promoting the integration of satellite into 5G.

SES’ other relevant activities which demonstrate its commitment to the advancement of 5G and the development of 5G standards for the satellite industry include its certification activity with the MEF (Metro Ethernet Forum) and SES’ participation with the Linux Foundation’s open source networking activities.

As such, SaT5G enables SES to continue partnership with terrestrial mobile and satellite industry in standardisation in order to further promote satellite role in 5G ecosystem. The standardisation of the underlying network and device technologies will help in the development and commercialisation of satellite ground segment systems with new capabilities, which in turn will enable SES to provide improved and cost-effective service offerings to its customers. This constitutes an important opportunity for SES.
Next generation 5G-enabled virtualised ground segment platforms for integrated satellite-terrestrial MANO and network slicing

Based on the standardisation efforts above, SES expects that the use of satellite ground segment systems enabled with SDN/NFV technologies will be offered commercially in reasonable short-medium timeframe by the industry stakeholders and suppliers. The implementation of these technologies will allow operational integration of satellite into 5G and will provide SES with the benefit to be in a position to provide further improved cellular backhaul and broadband services to unserved and underserved areas, as well as to mobile platforms, such as airplanes and vessels. Such next generation 5G-enabled virtualised satellite hub platforms will allow the application of network slicing over integrated satellite-terrestrial networks, which will in turn allow SES to obtain flexible bandwidth allocation, where and when it is needed, in an entirely automated way. In this context, the collaboration with SaT5G industrial partners, and particularly the ground segment equipment vendors and MNOs, provides an important opportunity towards this direction.

By adopting industry standard Ethernet service constructs and orchestration, it is possible for a satellite-based backhaul solution to plug seamlessly into an MNO’s backhaul landscape — in the same manner as any terrestrial solution does. Leveraging upon the relevant R&D work within SaT5G towards an integrated satellite-terrestrial Management and Orchestration (MANO) system, and coupled with the inter-carrier visibility and control of an Open Network Automation Platform (ONAP) based automation solution, as well as with the use of MEF compliant lifecycle service orchestration (LSO), it is possible for an MNO to turn every bit transported over satellite into a productive bit with no stranded capacity. Satellite players must “plug into” the MNO ecosystem and become a true enabler of value-based outcomes. This is the approach adopted by SES, which is enabled by participation to SaT5G project among other SES’ initiatives.

Moreover, with the help of SDN and LSO, MNOs can have clear visibility on satellite-network resources, as well as the tools to leverage and manage them in a very flexible manner. There are other advantages. In much the same way as MNOs can use SDN technologies to run their networks “hotter”, they will be able to do the same with capacity delivered within the framework advocated by SES. Flexible bandwidth allocation to match network demand with available satellite capacity improves network efficiency in the process. This capability better matches their business-model needs. Going forward, MNOs will be less tied to buying dedicated bandwidth links, which are likely to be under-used most of the time.
SES is focused on providing aggregated pools of capacity to be allocated, where and when it’s needed, in an entirely automated way. Think of it as on-demand bandwidth coupled with easy-to-use management tools. Data services enabled over satellite remain an under-utilised mechanism for unlocking new markets for MNOs quickly and cost-effectively. By using satellite-based Ethernet links for end-to-end mobile backhaul connectivity, MNOs can reach remote areas to unlock demand and provide new applications to users faster than with terrestrial alternatives. To connect new or underserved subscribers, an MNO’s time to market is as fast as it takes to ship equipment, rather than the weeks or months it takes to deploy fibre.

Network slicing technologies investigated within SaT5G will enable SES to pursue its vision towards an application-aware intelligent routing concept for multi-orbit support. That is, the “plug and play” integration of satellite networks in the sliced and virtualised 5G network for the support of backhaul services will allow an intelligent routing that sends the right data to the right user over the best path, be it terrestrial or satellite, allowing so even seamless multi-orbit support over GEO/MEO.

With a roadmap to deliver standards-based automation, orchestration and related APIs, SES is working with industry stakeholders and MNOs to extend networks seamlessly into new markets, improving visibility and management of critical services. And SaT5G provides an important opportunity towards this direction.

**ONAP: A platform for cloud-based network automation, service orchestration and network slicing**

Based on the aforementioned concept of automated orchestration, where the SaT5G plays an important role, SES is the first satellite network solutions provider to adopt ONAP, an open software platform designed for orchestrating the creation and delivery of new services in an automated operational environment. Particularly, in August 2019 SES announced [2] that it is implementing ONAP with Amdocs on Microsoft Azure, the industry’s scalable and flexible cloud services platform supported by Microsoft’s expansive global network. With ONAP operating on Microsoft Azure, SES can extend network services and activate virtualised network functions quickly and at scale, accelerating time-to-market and improving service agility for customers anywhere on the globe.

SES envisions ONAP as the “Master Orchestrator” to automate and control all aspects of service delivery in a 5G environment:

![ONAP Diagram](image)

**Figure 2-12: ONAP as Master Orchestrator in a 5G environment [3]**

Key points to note include:

- A Heterogeneous Connectivity Fabric interconnects a Distributed Cloud/Compute fabric upon which virtualized 5G network functions are instantiated. This Connectivity fabric can be comprised of several network segments, including wireline, wireless/cellular and satellite. SES believes the satellite segment will be an important modality for ubiquitous reach to land, sea, and air endpoints.
• 5G Cloud Native Architectures will allow RAN functionality to increasingly be centralized – important for control plane functions – as well as mobile core functions to be increasingly be distributed – important for performance and local context.

• ONAP serves as the “Master Orchestrator” to manage key functions across multiple domains: Network Topology (the Connectivity Fabric), Cloud Resources (The Compute Fabric), Mobile Core Functions, Distributed RAN functions, and End User/End Application devices, people and things.

• End User devices include the “5G box” concept. Thanks to ONAP, it will be possible to use a generic purpose device, with smart software, interconnected (and therefore, visible) to the network. This visibility would allow the configuration, management, maintenance of the “5G box”, and the ability to push new services and/or content

SES believes the combination of ONAP for 5G Service Orchestration applied to the MEF LSO framework presents the best solution for enabling Mobile Network Operators (MNOs) and Satellite Operators to interface in delivering end to end 5G services.

New Bids and Contracts

Last but not least, knowledge gained from conducted R&D work within the SaT5G project is intellectual property that SES will exploit as background knowledge in bidding for and acquiring additional innovation related contracts. Moreover, participation in SaT5G project allows SES to acquire the necessary skills and know-how to proceed to potential future investments as necessary.

As an illustration, building upon the SaT5G background experience, SES has been bidding in response to the Call for 5G Pilot Projects 2019 issued by the Luxembourg Government - Department of Media, Telecommunications and Digital Policy (SMC).

2.5 AIRBUS DEFENCE AND SPACE SAS (ADS)

Airbus Defence and Space (ADS) has a total capability in all fields of space systems design, engineering and manufacturing. This encompasses all facets of the space industry and includes telecommunications, earth observation, launchers, manned flight and scientific missions together with their associated ground segment hardware and software. The Airbus DS heritage in space spans over more than 50 years of successful programmes and involvement in the space industry. Across the Airbus DS sites a comprehensive capability has been established in spacecraft throughout all areas of design, manufacture, integration, project engineering and test/services.

The Space Systems Business Division of ADS is dedicated to providing civil and defence space systems as well as satellite based services in civil and military bands of frequencies, including space capacity, satellite communication engineering expertise, anchoring and backhauling services. Airbus Defence and Space is a world leader in communications satellites. Providing its customers, including the world’s top operators, with tailored solutions for the full range of capabilities and missions, Airbus Defence and Space is a global player in the design and manufacture of exceptionally reliable, high performance telecommunications satellites and is delighted to provide 5G ready satellite systems.

2.5.1 Exploitation Activities within SaT5G

ADS has taken part or led several analysis, definition and design for the 5G satellite and terrestrial integration. The main outcomes are:

• The support to the definition of the SaT5G use cases and scenarios and the lead for the definition of two scenarios for Use case 4, mobile platform backhaul; The two scenarios has driven the architecture design for the moving platform backhaul and has paved the way for the future Airbus solution for in flight connectivity;

• The definition of a generic satellite and terrestrial backhaul architecture which enables the four identified use cases and highlights the requirement for genericity and flexibility as different level of terrestrial and satellite network in order to allow such integration;
• The definition of detailed backhaul architectures and associated functionalities; it has led to the identification of the challenges that need to be faced either at the interface between the network of within the satellite network. Thanks to this work, Airbus consider different opportunities to address some challenges: gNB mobility management, backhaul multilink management, SDN/NFV applied to SatCom etc.;

• The contribution to the 5GPPP Architecture whitepaper;

• Base on the outcomes of different analysis in SaT5G, Airbus has supported the initiatives of satellite community in 5G standardisation organisation (mainly 3GPP and ETSI) and is co-signer and author of several contributions accepted in the 5G standardisation.

2.5.2 Exploitation Outcomes from SaT5G

Table 2-5: Exploitation Outcomes for partner ADS

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SDN and NFV applied to SatCom</td>
<td>Satellite communication and Telecommunication</td>
<td>3 years</td>
<td>On-going studies, Know-how, whitepaper</td>
</tr>
<tr>
<td></td>
<td>Enhanced 5G Backhaul</td>
<td>Satellite communication and Telecommunication</td>
<td>2 years</td>
<td>Publications, Know-how, whitepaper</td>
</tr>
<tr>
<td></td>
<td>Edge delivery</td>
<td>Telecommunication</td>
<td>3 years</td>
<td>Know-how</td>
</tr>
<tr>
<td></td>
<td>Aero-connectivity</td>
<td>Aviation, Maritime, Telecommunication</td>
<td>3 years</td>
<td>Publications, Know-how</td>
</tr>
</tbody>
</table>

2.5.3 Planned Future Activities

Following the work done in the frame of SaT5G project, Airbus has launched or is about to launch several initiatives to progress on the study, analysis, design and development of the technological modules identified as key enablers for the satellite and terrestrial integration.

SUPER-G project

The project goal is to design a platform with virtualized SatCom functions improving the flexibility of SatCom network, and supporting 5 requirements, in particular network slicing and resource on demand. The project has been launched in 2019 in the frame of a French research institute (IRT Saint Exupery in Toulouse) and in partnership with Thales Alenia Space, Viveris Technology, QoS Design and other companies to join.

Standardisation:

Airbus is an active participant in standardisation bodies. As the leader of the architecture work, we plan to continue to participate to 3GPP working groups, in particular the WG SA2 and SA5. Also as a satellite manufacturer, we plan to further participate to the study on adoption of 5G NR for non-terrestrial network. Airbus also plan to further participate in the 3GPP CT group to ensure that the constraints related to the satellite network are well considered for the selection of 5G core network protocol.

Other projects:

Airbus is also following different initiatives related to edge delivery and aero-connectivity.
2.6 EKINOPS SA (OA)

2.6.1 Exploitation Activities within SaT5G

EKINOPS is a leading provider of open and fully interoperable layer 1, 2 and 3 solutions to service providers around the world. Its product portfolio consists of two highly complementary product sets. One, marketed under the EKINOPS 360 brand name, provides a single, fully integrated platform for Metro, Regional, and Long-Haul applications up to 400G. The other, marketed under the OneAccess brand name, provides a wide choice of physical and virtualized deployment options for enterprise services requiring layer 2 and layer 3 network functions. EKINOPS provides solutions focused on the needs of service providers, including communication service providers (CSPs), Over-the-Top (OTT)/Managed Service Providers, cable MSOs, data centre providers and mobile service providers.

2.6.2 Exploitation Outcomes from SaT5G

The research and developments performed during the SaT5G project do enhance significantly the multi-link technology issued from the BATS and VITAL projects to transition it towards software-defined networking and virtualized delivery of network services.

This technology is ambitioned to be a strong feature of the company's SD-WAN solution. This integration will open more market segments to the company where resilience, smart link management and Quality of Experience are paramount.

Table 2-6: Exploitation Outcomes for partner OA

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SD-WAN solution</td>
<td>EuCNC and 5GIC demonstration Service Providers Enterprises</td>
<td>2019 2020</td>
<td>patent no 1454645</td>
</tr>
<tr>
<td>2</td>
<td>3GPP AT3S</td>
<td>5G networks</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>QUIC protocol</td>
<td>Heterogeneous networks</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Multi-link</td>
<td>5GENESIS project Limassol testbed</td>
<td>2020</td>
<td></td>
</tr>
</tbody>
</table>

2.6.3 Planned Future Activities

The technology is a critical part of the future EKINOPS SD-WAN solution and will need therefore to be industrialized and integrated as physical and virtual components into a mainstream commercial solution for the Service Provider and System Integrator market.

2.7 NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO (TNO)

2.7.1 Exploitation Activities within SaT5G

TNO is a not-for-profit research organisation with approximately 3500 staff whose mission is to support industry and society in general in transforming knowledge into products, processes and policies of economic and societal value. In the innovation ecosystem, TNO acts as an intermediary between science and market. TNO’s customers value its broad knowledge base and independent position.
Within TNO, the Information Society theme focuses on the gains that ICT can bring to society, and the mission of the Networks department is to bring innovation in network and communication protocols and network deployment for the benefit of the users of networks. Its focus is on the telecom market (fixed and mobile broadband Internet), the defence market and the intelligent transportation market. Activities range from research into new network technology concepts and protocols, via promoting the adoption of such newly developed concepts and protocols in worldwide standards, lab, up to field tests and network pilots.

Knowledge and results of SaT5G are used by TNO to actively contribute to 3GPP SA1 (requirements), SA2 (architecture), SA3 (security), SA4 (content delivery) and SA5 (virtualisation and management). In the CDN area, TNO has been contributor to a series of IETF standards (RFC 6770, RFC 6707, RFC 7337, RFC 6983, and RFC 7336) on Content Delivery Network Interconnection (CDNI) that enables network operators to provide standardised access to operator-based CDN.

Further, SaT5G has resulted in better contacts with partners from satellite domain (vendors, operators) and led to number of projects for ESA on topics of integration and application of 5G and satellites for verticals.

In addition to this, TNO has started organizing 5G SatCom seminar, as a platform where satellite operators and vendors can exchange opinions and visions of integration of 5G and satellites with their terrestrial counterparts.

### 2.7.2 Exploitation Outcomes from SaT5G

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How to integrate non-3GPP networks with 5G core network for seamless performance</td>
<td>Telecom sector (operators, vendors, standardisation)</td>
<td>continuous</td>
<td>Know-how</td>
</tr>
<tr>
<td>2</td>
<td>5G testbed</td>
<td>Telecom sector (operators, vendors, standardisation), regulator, satellite sector (operators, vendors)</td>
<td>continuous</td>
<td>Know-how</td>
</tr>
<tr>
<td>3</td>
<td>Content delivery across different transport and access networks (including non-3GPP)</td>
<td>Telecom sector (operators, vendors, standardisation)</td>
<td>continuous</td>
<td>Know-how</td>
</tr>
</tbody>
</table>

### 2.7.3 Planned Future Activities

In its role, TNO will use developed knowledge and testbed to start new projects, and to transfer knowledge to SMEs via joint projects. That will be done in H2020 (Horizon Europe) context, in ESA tenders, and finally on commercial (contract research) basis.

TNO will finish working on its 5G SatCom testbed, and use it as basis for further knowledge development whose focus is providing improvements and new features to existing 5G standards (in 3GPP and 5G-PPP contexts).
2.8 BRITISH TELECOMMUNICATIONS (BT)

2.8.1 Exploitation Activities within SaT5G

As a very large operator with many millions of retail customers in the UK as well as business customers all over the world, BT is very interested in any technology which will extend connectivity, or provide connectivity at lower cost. With our large customer base, even incremental efficiency gains can have a large payoff. As a result, we are following, and contributing to the SaT5G outputs closely, both in the technologies and business modelling, in order to identify any exploitable results. At the moment we see two specific use-cases as shown in the following table. We await the final business modelling outputs to check whether these will become economic propositions in the near future. We would hope that some version of these technologies become adopted into standards, rather than being rendered more costly to use because of patent protection.

2.8.2 Exploitation Outcomes from SaT5G

Table 2-8: Exploitation Outcomes for partner BT

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rural backhaul via satellite</td>
<td>Consumer broadband</td>
<td>3 years</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Railway and aircraft connectivity</td>
<td>Mobile voice and broadband</td>
<td>5 years</td>
<td></td>
</tr>
</tbody>
</table>

2.8.3 Planned Future Activities

BT is planning to be partners in several 5G-related collaborative projects, which are now in the planning stage. Of particular interest are massive MIMO and other antenna technologies for improving capacity. It remains to be seen whether these can be combined with satellite backhaul.

2.9 ZODIAC IN-FLIGHT INNOVATIONS (ZII)

Zodiac Aerospace, a world leader in aerospace equipment and systems on-board aircrafts, develops and manufactures solutions to improve inflight comfort and living conditions, as well as high-technology systems that boost aircraft performance and enhance flight safety. The Zodiac Inflight Innovations (ZII) business unit is part of the Zodiac Aerospace group and is mainly involved in the development of innovative, intuitive and trusted IFEC (Inflight Entertainment and Connectivity) systems such as the RAVE™ currently used by more than 50 leading airlines and aircraft manufacturers worldwide. The ZII-Germany unit, previously known as TriaGnoSys GmbH, is a world-leading technology provider for satellite backhauling of mobile/remote wireless systems and mobile/wireless passenger communication solutions on-board aircrafts, and has a long track record in R&D, successfully integrating prototypes, test-beds and demonstrators for various aeronautical applications. With the know-how and the results gathered from SaT5G, ZII-Germany targets the internal roadmap and R&D activities that will enhance visibility within the customer-facing departments in the business unit, accelerating the potential adoption of technologies developed/presented through the project. The SaT5G testbed, integrated into the cabin mock-up test environment, is planned to remain available for internal/external customer showcases.

2.9.1 Exploitation Activities within SaT5G

The current report of exploitation activities is the follow up of the initial inputs provided in SaT5G D6.6, and thus information initially delivered are reused, otherwise amended when needed.
ZII, as a world technology leader for commercial aircrafts, puts significant emphasis on research and development strategy, both internally and externally. The ZII-Germany unit is involved in an ample range of projects to scout and test cutting-edge technology solutions that can be the basis for new and upgraded products offer. Particularly, ZII-Germany has a significant tradition of involvement in large EU projects and German co-funded ones that complement internal product-oriented research and development activities. At EU level, ZII is currently involved in two H2020 5G PPP Phase 2 projects (i.e. 5G ESSENCE besides SaT5G). To provide example of the involvement in German technology programmes, ZII is currently involved in the LuFO-V2 programme through the project ConCabinO.

By means of this strategy, ZII targets to pave the way that shall lead to a new range of IFEC products. In addition, ZII targets to bring the market of civil aviation inside the verticals’ portfolio supported by 5G technology. The virtualised platform wherein satellite and mobile network services are currently being deployed stands for the incubator of a converged satellite-terrestrial system under the overarching umbrella of 5G. Alongside with ZII, the planned demonstration of airplane connectivity whereby the SES leased O3b satellite capacity and the Gilat SkyEdge II-c virtualised satellite segment harness some major players for providing airplane connectivity.

Not limited to that, the experimentation activities inside SaT5G stands as the trial of one extremely innovative system that raises passengers’ on-board connectivity to the next level of evolution through heterogeneous mobile network and Wi-Fi connectivity. The video demonstration planned for EuCNC 2019 is just one occasion to increase visibility of the developed system. This is illustrative of the path that will be pursued by ZII after SaT5G completion.

2.9.2 Exploitation Outcomes from SaT5G

ZII has contributed to technical work packages, laying specific focus on the virtualisation technology pursued by SaT5G both in satellite and terrestrial networks. This was motivated by the exploitation potentials of virtualisation in the next generation of IFEC products. In addition, ZII contributed to develop mobility management procedures tackling the airplane moving platform integrated in the 5G satellite-terrestrial network. Although the exploitation of SaT5G outcomes is still in progress, ZII has set in place already concrete actions in this regard.

ZII has set in place a virtualised platform managed by OSM and OpenStack, as well as a test LTE network to connect personal devices of passengers, besides the Wi-Fi connectivity provided by means of aeronautical certified Wi-Fi access points designed by ZII. ZII has also restructured its aircraft cabin mock-up infrastructure to be part of the SaT5G test-bed and set forth the action of establishing a dedicated VPN connection to the point-of-presence of the satellite operator SES in Unterföhring (Munich – Germany). The latter action is done in support of splitting the virtualised satellite system of Gilat. The action previously announced in D6.6 regarding the integration of an antenna prototype with aero form factor supplied by Zodiac Data System had to be postponed since it does not meet the timeframe of the SaT5G project but has given rise to newer collaboration opportunities between different Zodiac business units beyond SaT5G. The ZII test-bed has also created the playground for a wide range of activities of the test-bed’ partners: the satellite equipment vendor Gilat is deploying its virtualised SkyEdge II-c system in the platform managed by OSM/Openstack, Broadpeak its CDN solution in an aeronautical environment, whereas QUO Multi-access Edge Computing solutions for the mobile core split on-board aircrafts.

As test-bed leader, ZII’s focus during the remaining time of the project will be on completing the test-bed to be used in the SaT5G project demonstration of "5G Moving Platform Validation" toward the final demonstration in November 2019. ZII will also contribute to the elaboration of business models to appropriately identify the technology maturation and commercialisation potentials of SaT5G technology that can accelerate the adoption of 5G technology in inflight communications.

Beyond SaT5G, ZII is extremely experienced in the process that leads to new aeronautically certified products that can be deployed on aircrafts. This includes the mandatory re-design of hardware and software elements to pass the extremely tight aeronautical certification procedure. Hence, beyond SaT5G, ZII will focus on the planning activities towards successful aeronautical certification.
Table 2-9: Exploitation Outcomes for partner ZII

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Virtualised SatCom</td>
<td>R&amp;T/Product certification</td>
<td>Beyond 2022</td>
<td>Aircraft backhaul</td>
</tr>
<tr>
<td>2</td>
<td>O3b demonstration</td>
<td>R&amp;T/Business development</td>
<td>Beyond 2020</td>
<td>Aircraft backhaul</td>
</tr>
<tr>
<td>3</td>
<td>Heterogeneous radio access platform</td>
<td>R&amp;T/Product development</td>
<td>Beyond 2022</td>
<td>Know-how/HW development</td>
</tr>
<tr>
<td>4</td>
<td>Virtualised mobile core for passengers’ connectivity</td>
<td>R&amp;T/Product development</td>
<td>Beyond 2022</td>
<td>Know-how/SW development</td>
</tr>
<tr>
<td>5</td>
<td>Business models</td>
<td>R&amp;T/Business development</td>
<td>Beyond 2020</td>
<td>Know-how</td>
</tr>
</tbody>
</table>

### 2.9.3 Planned Future Activities

ZII plans in future to leverage on the know-how and infrastructure developed inside SaT5G are manifold. Since the test-bed to demonstrate the SaT5G use case four is managed by ZII, this gives rise to the opportunity to reuse it as part of the wider R&T activities carried out inside the company. At first, the current test-bed set-up and services will be shown to the ZII management team as a proof of concept of the next generation of technology for aircraft connectivity. This is scoped toward enlarging the existing product offer and service portfolio of ZII to airlines and aircraft manufacturers, while engaging also other ZII business units as potential customers.

Second, ZII will reuse the infrastructure developed inside SaT5G for testing aeronautically certified devices in a virtualized infrastructure in order to create the basis for future products design that leverages on 5G technologies. In addition, ZII will reuse the existing infrastructure inside the new upcoming R&T projects, in which it will be further upgraded. To make concrete example projects; German funded (LuFO programme) and Bayern funded projects will leverage on the ZII hosted SaT5G test-bed. Whilst not explicitly stated in chapter 3 this may well involve work with other SaT5% partners.

### 2.10 BROADPEAK (BPK)

Broadpeak designs and manufactures video delivery components for Content Providers and Network Service Providers deploying IPTV, Cable, Satellite, OTT and mobile services. Its portfolio of solutions and technologies powers the delivery of movies, television programming and other content over managed networks and the internet for viewing on any type of device. The company’s systems and services help operators increase market share and improve subscriber loyalty with superior quality of experience.

### 2.10.1 Exploitation Activities within SaT5G

Broadpeak has developed a technology to optimize the delivery of live Adaptive Bitrate Video in HTTP formats (HLS & DASH) leveraging networks multicast capabilities. Within the framework of Sat5G, this technology has been tested to answer the use cases combining satellite and the 5G domains, by enabling the optimization of video delivery through local caching.

In pre-5G networks, video streaming is still very much centralized, emanating from one single cluster of servers. The bandwidth capacity increase that comes with 5G will lead to a tremendous growth in video consumption over mobile devices on the go, together with higher expectations concerning the quality of service. A centralized architecture will not be sufficient to sustain the streaming requirements anymore, for both live and VOD content.
Within SaT5G, Broadpeak has participated in an economical study to analyse the conditions under which operators can deploy satellite based contribution to local caches located in the 5G network, closer to the base stations and end-users.

It has contributed to the design of the workflows that allow to provision live and VOD content in ABR formats to local streamers and to handle the hand-over between several sources of streaming.

It has tested its developments of the transcaster (unicast to multicast encapsulator) and its nanoCDN agent (multicast to unicast de-encapsulator) in a satellite context through a prototype implementation.

### 2.10.2 Exploitation Outcomes from SaT5G

The exploitation of SaT5G outcomes concerns several products:

- The BkE200 unicast to multicast transcaster that pushes the content to a modulator fit for satellite delivery;
- The nanoCDN agent (multicast to unicast) that is embedded in a reception server;
- The BkS400, the virtualized streaming server that embed the nanoCDN agent and streams the cached content;
- The BkM100, the mediator that configures and monitors the video delivery system, defines the content popularity and its spreading;
- The BkA100 analytics server that provides information about content consumption.

### Table 2-10: Exploitation Outcomes for partner BPK

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BkE200 transcaster</td>
<td>Live &amp; VOD delivery in multicast</td>
<td>2020</td>
<td>Patent</td>
</tr>
<tr>
<td>2</td>
<td>nanoCDN agent</td>
<td>Live &amp; VOD delivery in multicast</td>
<td>2020</td>
<td>Patent</td>
</tr>
<tr>
<td>3</td>
<td>BkS400 caching server</td>
<td>Live &amp; VOD delivery in multicast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>BkM100</td>
<td>Live &amp; VOD delivery in multicast</td>
<td>2020</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>BkA100</td>
<td>Analytics</td>
<td>2020</td>
<td></td>
</tr>
</tbody>
</table>

### 2.10.3 Planned Future Activities

After the prototyping and the confirmation of the workflows, Broadpeak plans to promote its solution with mobile operators who have a 5G ambition.

The solution will be delivered as a proof of concept in a first phase, in order to tweak the elements related to the specificities of the operator’s network, before leading to a deployment phase.
2.11 GILAT SATELLITE NETWORKS LTD (GLT)

Gilat Satellite Networks Ltd. is a leading global provider of satellite-based broadband communications. With 30 years of experience, we design and manufacture cutting-edge ground segment equipment, and provide comprehensive solutions and end-to-end services, powered by our innovative technology. Delivering high value competitive solutions, our portfolio comprises of a cloud based VSAT network platform, high-speed modems, high performance on-the-move antennas and high efficiency, high power Solid State Amplifiers (SSPAs) and Block Upconverters (BUCs). Gilat’s comprehensive solutions support multiple applications with a full portfolio of products to address key applications including broadband access, cellular backhaul, enterprise, in-flight connectivity, maritime, trains, defence and public safety, all while meeting the most stringent service level requirements.

Gilat is looking to continue to deliver competitive and innovative satellite communication solutions and extend its role in providing satellite backhaul solutions over all satellite constellations GEO, MEO and LEO for all the different markets and with this in mind is also focusing on expanding its role into the next generation 5G backhauling market. At the same time Gilat is researching SDN/NFV solutions to provide more flexible and cost-saving solutions for its customers.

2.11.1 Exploitation Activities within SaT5G

Within the Sat5G project Gilat is supplying two Satellite backhaul access systems, the first over a High-Fly MEO Satellite link and the second over a Low-Fly simulated GEO Satellite link. By providing the two satellite type links, Gilat is allowing the testbed partners to show a “live” comparison of the user experience that can be obtained via the two technologies.

Gilat partnered with SES, Zodiac, Quortus, Broadpeak and i2cat to develop an Inflight Entertainment and Connectivity (IFEC) testbed that is connected to both MEO satellites and 5G network to showcase a 5G enabled IFEC service. The first phase was a demo to set-up and pave the way towards the over-the-air live satellite connectivity demo by the end of the project.

2.11.2 Exploitation Outcomes from SaT5G

Table 2-11: Exploitation Outcomes for partner GLT

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orchestration of Satellite communication equipment</td>
<td>Satellite communication services.</td>
<td>Immediate</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>2</td>
<td>Deployment of Satellite Communication software modules in Opensource VM and cloud environments</td>
<td>Next Generation Satellite Communication Networks.</td>
<td>Immediate</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>3</td>
<td>Comparison of GEO and MEO based satellite communications</td>
<td>Next Generation Satellite Communication Networks.</td>
<td>2019 onwards</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>4</td>
<td>Flexible and Resilient Satellite Networks</td>
<td>Satellite communication services</td>
<td>2019 onwards</td>
<td>Prototype &amp; Know-how</td>
</tr>
</tbody>
</table>
2.11.3 Planned Future Activities
Gilat plans to continue to design and develop its next generation cutting-edge products based on the flexibility and agility of open-source virtual satellite communication modules that can be deployed and removed from service in real time, according to current and predicted traffic demand and based on SDN/NFV and cloud technologies.
In addition, Gilat will take an active role in defining the standards for non-3GPP satellite component that will be able to interact directly with the 5G EPC and support 5G slices for various applications and provide the required BW where the 5G network is unable to reach.

2.12 ST Engineering iDirect (Ireland) Limited (iDR)
iDirect, a subsidiary of ST Engineering, is a global leader in IP-based satellite communications providing technology that enables our 350+partners to optimize their networks, differentiate and profitably expand their businesses. The iDirect Intelligent Platform™ allows our partners to run their entire business operations more efficiently via a single, unified IP-based satellite architecture, whether it's providing core IP applications to the enterprise or specialized services to any number of diverse vertical markets. iDirect is the number one name in global satellite communications in key industries including maritime, military/government, and oil and gas, with a 62% hub market share and more than a quarter million remotes installed worldwide. In 2007, iDirect Government Technologies (iGT) was formed to drive adoption of its IP-based solutions in the U.S. government market. In 2008, iDirect Asia Pte Ltd was established in Singapore to enhance its value-add and responsiveness to customers in the Asia Pacific region. For more information please visit www.idirect.net.
VT iDirect Solutions Ltd. (Ireland) was established in 2015 as a research and development organisation, initially specialising in optimising satellite backhaul for cellular communications protocols and the development of 3GPP standards-based networking solutions within Satellite.

2.12.1 Exploitation Activities within SaT5G
Within the SaT5G project VT iDirect have successfully built and delivered two state-of-the-art testbeds using live over the air (OTA) satellite capacity from SES and Avanti using Astra-2F and Hylas-4 satellites respectively. This was a huge undertaking from iDirect which underpinned many of the successful prototypes, demonstrations and analysis performed during the project.
Firstly, iDirect partnered with SaT5G consortium members SES, BPK, i2CAT and UoS for the first-of-its-kind over-the-air live demo at EuCNC 2018 in Ljubljana (18-21 June 2018). The system demonstrated the initial 3GPP core network integration into satellite network and key benefits of satellite integration with an SDN/NFV/MEC-enabled pre-5G construction testbed. This used SES’ in-orbit geostationary satellite system Astra-2F as a proof-of-concept for initial integration and laid the foundation for the rest of the project.
This testbed went on to become an integral part of the ongoing ESA ARTES SATis5 project.
iDirect also partnered with SaT5G consortium members AVA and UoS to construct the satellite component of the 5GIC testbed. The 5GIC 5G testbed is one of the most advanced in implementing and validating 3GPP Rel-15 standards so it was a fitting place for iDirect to integrate and test iDirect's 5G-enabled satellite communications network. This implementation provides end to end satellite connectivity to the 5GIC testbed using a combination of Avanti's HYLAS-4 satellite and VT iDirect’s system installed at Avanti’s Hub site in Goonhilly.
The 5GIC testbed, and especially the satellite component delivered by iDirect, provided the platform for successful end to end testing and, critically, 5G use-case demonstrations. This was initially demonstrated at EuCNC 2019 and subsequently throughout the latter phases of the project in tests carried out using the 5GIC testbed and demonstrations at the Industry day at the end of the project.
Both testbeds provided iDirect with knowledge on varying levels of integration between satellite and mobile networks. For example, iDirect considered 5GIC as a Mobile Network Operator who have specific requirements on integrating satellite and 5G in their network which is analogous to what might be expected in the industry when future satellite and 5G networks can be managed and operated as one ubiquitous network.
As satellite ground infrastructure vendors, the experience gained from building the testbeds, delivering end to end demos as well as the related R&D work conducted within SaT5G is being used to guide the next generation of iDirect products. The project has helped iDirect build strong relationships with key players in the integration of satellites into 5G networks, and especially with the satellite network operators participating in the SaT5G project whom we worked closely with to build and deliver the testbeds. This will no doubt help in shaping iDirect’s future products.

While building and delivering the testbeds was a major effort it was not the only exploitation activity undertaken by iDirect in SaT5G.

Another major item worked on was the data modelling activity. This allowed iDirect and other partners, including other vendors, gain insight and clarity on how the satellite and mobile network operators envisage the new relationships between them and the services they can provide using technologies like network slicing.

Along with partners in SaT5G, iDirect have also participated in standardization activities including 3GPP SA/RAN and ETSI TC-SES SCN, to promote the satellite role into the 5G ecosystem. iDirect believe standardization is a key area to ensure satellite and 3GPP industry become more aligned. In order to engage fully with the 3GPP eco system, the standards effort is paramount as this is where all the 3GPP community come together.

Participation in the SaT5G project has been a huge benefit to iDirect from a technical and collaborative perspective. Technically, the knowledge and experience gained from working with new technologies and implementing fully operational systems with live satellite network operators has been invaluable. The relationships fostered with other project partners have also been hugely beneficial in understanding the full eco system requirements and will encourage further collaborations in this area.

### 2.12.2 Exploitation Outcomes from SaT5G

The table below summarises the exploitation outcomes from iDirect

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Integration of Satellite communications into standard 3GPP architecture.</td>
<td>Satellite communications and Telecommunications</td>
<td>Immediate</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>2</td>
<td>Adoption of SDN and NFV technologies and management systems</td>
<td>Satellite communications</td>
<td>Immediate</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>3</td>
<td>Satellite and Terrestrial network and service convergence</td>
<td>Satellite communications and Telecommunications</td>
<td>Immediate</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>4</td>
<td>Definition of data model for satellite interoperability</td>
<td>Satellite communications</td>
<td>2019 onwards</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>5</td>
<td>Next generation 5G-enabled virtualized satellite hub platforms</td>
<td>Satellite communications and Telecommunications</td>
<td>2019 onwards</td>
<td>Prototype &amp; Know-how</td>
</tr>
<tr>
<td>6</td>
<td>Support for Network Function distribution and MEC-enabled Edge Network</td>
<td>Satellite communications and Telecommunications</td>
<td>2019 onwards</td>
<td>Prototype &amp; Know-how</td>
</tr>
</tbody>
</table>
The experience and industry partnerships gained in the SaT5G project has already helped iDirect to join the ongoing SATis5 project and successfully bid for the EdgeSAT project along with SES who are also involved in SaT5G. Both projects promote the satellite integration into 5G and both are complimentary to SaT5G. A short overview of the two project is given here:

- **EdgeSAT**: Edge Network Computing Capabilities for Satellite Remote Terminals (ESA ARTES);  
  o Aim: To explore the applicability and implementation of edge networking concepts in satellite networks in order to identify and characterize the resulting opportunities for Satellite Network/Service providers as well as Satellite terminals manufacturers, and to specify and validate a SatCom enabled edge node.

- **SATis5**: Demonstrator for Satellite-Terrestrial Integration in the 5G Context (ESA ARTES)  
  o Aim: To build a large-scale real-time live end-to-end 5G integrated satellite terrestrial network proof-of-concept (PoC) testbed that enables the satellite terrestrial convergence into the 5G context, with focus on 5G use cases towards enhanced mobile broadband (eMBB) and massive machine type communications (mMTC);  
  o Project Website: [https://artes.esa.int/projects/satis5-0](https://artes.esa.int/projects/satis5-0).

### 2.12.3 Planned Future Activities

The SaT5G project provided the opportunity to demonstrate that satellite functions, including virtualised functions, can be integrated seamlessly in a 5G network and that the satellite industry can work with 3GPP to define standardised approaches for those functions and interfaces which are unique to satellite.

This will be achieved by firstly integrating satellite communication into a standard 3GPP telecommunications network architecture and secondly, evolving to the 5G architecture once the specifications mature and solutions become available throughout and beyond the project.

Taking a standards approach to satellite network architecture design will allow satellite network operators to leverage the many years of seamless multiparty integration and interoperability which has seen the telecommunications industry flourish.

Working together with the telecommunications industry will create closer integration between satellite and mobile network operators, making the delivery of services over satellite as flexible and as efficient as over other transmission media.

iDirect understands the importance of the standards activities to the seamless integration of satellite and 5G and we plan to support satellite activities in 3GPP SA and RAN working groups along with other related SDOs.

SaT5G has provided a very good foundation for the integration of satellite and 5G and we plan to continue exploring this architecture for future generations of our products.
2.13 INTERUNIVERSITAIR MICROELECTRONICA CENTRUM (IMEC)

Inter-university Microelectronics Center (IMEC) is a world-leading independent research centre in nanoelectronics and digital technology. IMEC is headquartered in Leuven, Belgium, and also has distributed R&D groups at a number of Flemish universities, in the Netherlands, Taiwan, USA, China, and offices in India and Japan. IMEC staffs more than 3500 people including over 600 industrial residents and guest researchers. IMEC’s uniqueness relies in the combination of a widely acclaimed leadership in microchip technology and a profound software and ICT expertise.

IMEC leverages its world-class infrastructure and local and global ecosystem of partners across a multitude of industries to create innovation in application domains such as healthcare, smart cities, logistics and manufacturing, and energy. IMEC's research bridges the gap between fundamental research at universities and technological development in industry.

One of IMEC's ICT-focused departments is IDLab. IDLab performs fundamental and applied research on internet technologies and data science. IDLab collaborates with many universities and research centres worldwide and jointly develops advanced technologies with industry (R&D centres from international companies, Flanders' top innovating large companies and SMEs, as well as numerous high-tech start-ups). IDLab is a core research group of IMEC and a large part of IDLab's research activities are embedded in Ghent University. In the SaT5G project, IMEC is represented by the IDLab group related to Ghent University. Within SaT5G, the techno-economic research unit within IDLab is responsible for the business modelling work.

2.13.1 Exploitation Activities within SaT5G

There are three important routes towards exploitation of the results. The first is focusing on exploiting outcome and methodologies developed in SaT5G in future research projects, the second will exploit SaT5G in education, and the third focuses on spreading gained insights through academic publications and white papers.

With respect to the first part, IMEC can use the expertise gained in SaT5G to in future research projects with ICT and telecom companies, but also with public authorities. The techno-economic software library can be used to assist decision makers by translating technological innovation into business opportunities and challenges, and this library is expanded and further optimised in all research projects IMEC is involved.

Secondly, as IMEC’s research is fully embedded in the different Flemish universities, this allows a very efficient exploitation of knowledge by embedding this in the more advanced master courses in engineering and related high-quality PhD programs. The research group IDLab is part of Ghent University. Specifically, the business case of satellite integration into 5G networks can be used as a use case in one of the techno-economic courses.

Finally, new methodologies (e.g. for a cost allocation model for network slicing) will be published in academic publications and white papers.

2.13.2 Exploitation Outcomes from SaT5G

Exploitable knowledge developed by IMEC in the framework of the SaT5G project is summarised in Table 2-13. Please note that both our software library and our methodology are not fully developed within the SaT5G project, but – as in each research project – we extend both based on insights learned and cases studied. For the specific case of SaT5G, we extended our techno-economic methodology (and related software implementation) with a:

- Total Cost of Ownership model for integrated networks;
- Cost allocation model for network slicing;
- Multi-actor analysis model to allow for evaluating different business models for operating integrated networks (e.g. the brokerage model).
Table 2-13: Exploitation Outcomes for partner IMEC

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TESS and BEMES software library</td>
<td>Multiple application domains</td>
<td>Continuous</td>
<td>Software library under license</td>
</tr>
<tr>
<td>2</td>
<td>Techno-economic cost modelling methodology</td>
<td>Multiple application domains</td>
<td>Continuous</td>
<td>Know-how</td>
</tr>
</tbody>
</table>

2.13.3 Planned Future Activities

Apart from further developing the techno-economic methodology and related software library in general, both to be used in future research and future collaboration projects, we will develop the methodologies started in SaT5G further. The slicing allocation model will be extended, such that it can be generically applied to different types of networks. The multi-actor analysis model can be further applied to evaluate different types of business models in different network settings.

2.14 FUNDACIO PRIVADA I2CAT - INTERNET I INNOVACIO DIGITAL A CATALUNYA (I2CAT)

2.14.1 Exploitation Activities within SaT5G

I2CAT is a non-profit technology centre that promotes R&D and innovation activities in the field of information and communication technologies and future internet. It is a key research centre in the European community with demonstrable knowledge and prototype around SDN/NFV for virtualized 5G networks, focusing on the development of the management and orchestration frameworks required.

I2CAT has an extensive experience in European and national research and innovation projects, leading the implementation of future internet technologies in the main economic sectors such as telecommunications, industry and health in order to improve productivity and competitiveness in companies and the well-being in society.

I2CAT contributes to the SaT5G project to merging 3GPP next generation architecture with ETSI MANO framework to cover both satellite and terrestrial communication technologies. We targeted to tackle this challenge by introducing a holistic management and orchestration system able to coordinate all terrestrial and satellite elements. Such a solution support an open source available MANO implementation, in particular OSM and will provide Northbound Interface (NBI) with both terrestrial and satellite operators. To do so, we design, deploy and develop a software for management and orchestration of satellite and terrestrial networks. This software is a coordination solution, which can support end-to-end services composed of satellite, radio access, cloud and mobile edge computing resources. Our solution can provide a single and easy to use point of integration for all stakeholders involved in the ecosystem, i.e. terrestrial and satellite operators as well as different 5G verticals.

Moreover, i2CAT contributed on many scientific societies by publishing articles in prestigious and international recognized journals, conferences and book and the new methodologies and results will be published on upcoming academic publication events.
2.14.2 Exploitation Outcomes from SaT5G

Table 2-14: Exploitation Outcomes for partner I2CAT

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Terrestrial and Satellite Resource Coordinator (TALENT)</td>
<td>5G verticals, and terrestrial and satellite operators</td>
<td>Continuous</td>
<td>TBD</td>
</tr>
<tr>
<td>2</td>
<td>Northbound Interface</td>
<td>Multiple domains</td>
<td>Continuous</td>
<td>TBD</td>
</tr>
</tbody>
</table>

2.14.3 Planned Future Activities

I2CAT is working on the detailed design, specifications and implementations of the satellite and terrestrial coordination software (TALENT) to be used by multiple operators and verticals, as well as future projects. Furthermore, this coordination model will be extended to include authentication and authorization module in order to enable users with different privilege perform various operation through the system. In addition, in near future it can support resource slicing manager and smart Service Level Agreement (SLA) manager for both terrestrial and satellite domains, and users.

2.15 UNIVERSITY OF OULU (UOULU)

The Centre for Wireless Communications (CWC) is a research unit of 180 people inside the University Of Oulu (UOULU) involved in saT5G. Its strategy is to provide high class education and research. It has been in frontlines when 3G, 4G and 5G mobile radio technologies have been developed. It also looks forward towards 6G, the connectivity technology at 2030s. This future vision has started by organising the first 6G Summit at Levi, FI, March 24-26, 2019 along with 300 participants from academia and industry who envisaged what 6G could and should be. The 6G research in Finland is under the 6G Flagship program lead by the unit.

2.15.1 Exploitation Activities within SaT5G

UOULU’s main tasks where evaluation of 5G NR suitability to satellite systems at PHY and MAC levels and build a demonstrator for that on top of 5GTN. In the research part, the outcomes are publications (journal and conference papers, presentations) and, as important, feeds to SaT5G industry partners (mainly TAS) for their standardization activities where integration of 5G and SATCOM are studied. Therefore, we have both direct and indirect results. Furthermore, the testbed results were demonstrated in various events.

2.15.2 Exploitation Outcomes from SaT5G

SaT5G project has significantly increase our partial understanding of satellite systems. This is thanks to fruitful discussions and explanations in project meetings as well as in the documents and publications, and due to our research efforts in SaT5G.

This increased know-how about SATCOM can be used in education and research. The SaT5G demonstrator block in 5GTN forms a solid base for its future development.

Table 2-15: Exploitation Outcomes for partner UOULU

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Generic know-how on satellite systems</td>
<td>education, research</td>
<td>continuous</td>
<td>no</td>
</tr>
</tbody>
</table>
### 2.15.3 Planned Future Activities

The experiences and know-how from SaT5G will be transformed into education and future research. It is expected that satellite component will be part of 5G in the future (from Release 17?) and that it is an integral part of 6G since the beginning. Consequently, new experts are needed and must be educated in this area. In research, it is good to continue from SaT5G efforts to the next levels. Therefore, SaT5G provides a firm basis to further developments in UOULU. The gained know-how and experience will also be used in future funding applications and discussions with authorities.

UOulu’s 5GTN got a new block during the project. This block can be used as a satellite backhaul or direct UE access and it enlarges our demonstration capabilities. The purpose is to update this block once new 5G capabilities become available and keep it alive in future years since it is foreseen that there will be need for it in future 5G and 6G development. In addition, its capabilities to further evaluations like PHY and NET layers will be developed.

### 2.16 QUORTUS LTD (QUO)

#### 2.16.1 Exploitation Activities within SaT5G

Quortus enables flexible, agile mobile communications networks that provide a foundation for innovative services tailored to a diverse range of end customers. Its award-winning EdgeCentrix (ECX) virtualized mobile core solutions help increase operator margin and ‘stickiness’. They interwork gracefully with existing mobile networks, with small cell and HetNet architectures and with standard IT infrastructure, to create truly integrated communications platforms.

Quortus is increasing its focus on non-traditional market segments IoT, Neutral hosting, Satellite Access and innovative network deployments that are making use of spectrum available 3.5 GHz bands. Quortus is making the best use of its expertise gained in non-typical installation to further gain access and prominence in these areas.

Quortus’ role in the Sat5G project is primarily of supporting testbed with supplying Core Network functional elements and their integration into the whole system with Satellite backhaul access. Our exploitation activities involve inter-working with 3rd party Orchestrating Systems to support SDN based automated deployment of VNFs. These opportunities provided by the Sat5G consortium is helping accelerate R&D in this area. At the same time, it is creating innovative opportunities to create transitional / hybrid networks from 4G to 5G.

Working within the Sat5G consortium is helping us to understand the productisation of Quortus offering and what is useful to the industry. The Sat5G consortium represents sample of the kind of customers/ partners that Quortus may want to work with.

#### 2.16.2 Exploitation Outcomes from SaT5G

Working in the SaT5G consortium has enabled us to understand real requirements of Satellite operators to improve our product strategy and execution. Also, the opportunity to more effectively access markets in the Americas and Far East to promote sales activities in existing vertical sectors such as transportation, industrial IOT and Campus networks.

We have taken the exposure and engagement within the consortium to make our products more competitive and perform better.
Table 2-16: Exploitation Outcomes for partner QUO

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orchestration and integration</td>
<td>Mobile network core as a virtualised service.</td>
<td>2019-2020</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Service based slicing</td>
<td>Mobile CN and MEC</td>
<td>2019</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Key Factors for Success in producing satellite-based 4G/5G terminal equipment</td>
<td>Wherever SatCom as an access technology is deployed - Maritime / aero / rural</td>
<td>2020</td>
<td></td>
</tr>
</tbody>
</table>

2.16.3 Planned Future Activities

Quortus plans to engage with more partners in the consortium to identify opportunities for further exploration. The partners are a good representation of the kind of technologies and partnerships that we want to work with. Our planning includes creating network as a service and also in some cases, testbed as a service kind of commercial engagements.
3 Joint Exploitation Activities

A number of exploitation activities have been developed in conjunction by a subset of the project partners towards and after the completion of the project. This section provides an overview of those joint exploitation activities, their outcomes and planned future work.

3.1 Satellite Integration into 3GPP Core Network Architecture

3.1.1 Partners Involved

iDirect and SES

3.1.2 Exploitation Activities within SaT5G

Within SaT5G

As described above in Sections 2.4.1 and 2.12.1, within the SaT5G project, iDirect and SES successfully delivered a state-of-the-art testbed using iDirect’s 5G-enabled Velocity™ Intelligent Gateway (IGW) solution and live over the air (OTA) satellite capacity from SES on ASTRA-2F GEO Ku-band satellite. An opportunity arose during the SaT5G project to do an early demonstration at the EuCNC 2018 conference. To this end, iDirect and SES partnered with other SaT5G consortium members BPK, i2CAT and UoS for the first-of-its-kind over-the-air live demo at EuCNC 2018 in Ljubljana (18-21 June 2018). The system demonstrated the initial 3GPP core network integration into the satellite network and key benefits of satellite integration with an SDN/NFV/MEC-enabled pre-5G construction testbed. It was used as a proof-of-concept for initial integration and laid the foundation for the rest of the project.

The EuCNC 2018 event was initially not a target for the project but the partners proactively and enthusiastically decided to use this event to kick start the project collaboration. The event proved to be a very successful and the project as a whole benefits greatly from the early demonstration of the research areas. The event also had practical benefits as it allowed the SaT5G partners involved to focus attention onto the basic logistics and configurations that would be needed for the final demonstrations albeit with an early version of the virtualised satellite 5G equipment. The EuCNC 2018 demo setup is illustrated in the figure below.

![Figure 3-1: SaT5G demo setup at EuCNC 2018](image-url)
For the EuCNC 2018 demo, the contributions of the two SaT5G partners, SES and iDirect, were as follows:

- SES: Provided end-to-end managed services, powered the space segment with its existing ASTRA 2F geostationary satellite system, and delivered seamless connectivity between the remote satellite terminals and the hub platform, hosted in the SES’s teleport in Betzdorf, Luxembourg.
- iDirect: Provided the pre-5G enabled satellite hub platform and remote satellite terminals which incorporate SDN/NFV and MEC capabilities and enabled the satellite integration into a 3GPP core network architecture. The satellite HUB was installed at the SES teleport in Betzdorf and the remote was installed onsite in Ljubljana for the EuCNC 2018 event.

Beyond SaT5G

After the successful EuCNC 2018 event, and following agreement between SES and iDirect to explore joint collaboration, the testbed remained in place and went on to become an integral part of several follow-up projects, such as:

- **SATis5**: Demonstrator for Satellite-Terrestrial Integration in the 5G Context (ESA ARTES)
  - Aim: To build a large-scale real-time live end-to-end 5G integrated satellite terrestrial network proof-of-concept (PoC) testbed that enables the satellite terrestrial convergence into the 5G context, with focus on 5G use cases towards enhanced mobile broadband (eMBB) and massive machine type communications (mMTC)
  - Project Website: [https://artes.esa.int/projects/satis5-0](https://artes.esa.int/projects/satis5-0)
- **EdgeSAT**: Edge Network Computing Capabilities for Satellite Remote Terminals (ESA ARTES)
  - Aim: To explore the applicability and implementation of edge networking concepts in satellite networks in order to identify and characterise the resulting opportunities for Satellite Network/Service providers as well as Satellite terminals manufacturers, and to specify and validate a SatCom enabled edge node.
  - Project Website: [https://artes.esa.int/projects/edgesat](https://artes.esa.int/projects/edgesat)
- **5G-VINNI**: 5G Verticals INNovation Infrastructure (EU H2020 5G PPP Phase 3)
  - Aim: To accelerate the uptake of 5G in Europe by providing an end-to-end facility that validates the performance of new 5G technologies by operating trials of advanced vertical sector services
  - Project Website: [https://www.5g-vinni.eu/](https://www.5g-vinni.eu/)

Specifically, the satellite ground segment infrastructure in the projects above (SATis5, EdgeSAT, 5G-VINNI) corresponds to iDirect’s Velocity™ IGW system residing at the SES teleport site in Betzdorf, Luxembourg. The system introduces a standard 3GPP Core Network (SatCore) to the satellite hub platform where functions of the existing satellite network are offloaded to, allowing the SatCore to operate and manage the satellite network like a typical terrestrial 3GPP network. The existing satellite network is modified to behave like a standard RAN, referred to as Satellite RAN (SatRAN), node to the SatCore. In addition, the remote satellite terminal is modified to present itself as a standard UE to the network which allows it to connect to a SatCore in order to access network services.

As part of the innovation in the SATis5 project, the 5G Core Network solution Open5GCore ([https://www.open5gcore.org/](https://www.open5gcore.org/)) was introduced as the SatCore (see Figure 3-2 below). The existing satellite network (SatRAN) has been modified to comply with the standard 3GPP Release 15 compliant 5G Core Network from Open5GCore. The SatRAN presents itself as a standard gNB 5G RAN and the remote satellite terminal presents itself as a standard 5G UE to the network. Adopting the 3GPP architecture enables support for 3GPP services, such as roaming, authentication, billing and policy and charging. This also enables the management of the satellite network by the Mobile Network Operator (MNO) in a seamless way, as a common network management framework can be used.

Also, the SatCore may be operated by the MNO or by Satellite Network Operator (SES), depending on the business model, and there may even be separate 3GPP core networks for the MNO’s cellular and SES’s satellite networks. The satellite network functions are virtualised by transferring their execution environment from a dedicated server to a Virtual Machine (VM) using the OpenStack Pike Virtualised Infrastructure Manager (VIM, [https://www.openstack.org/](https://www.openstack.org/)). Satellite Virtual Network Functions (VNFs) include the SatRAN network function, the satellite 3GPP Core Network function (SatCore), the satellite Network Management System (NMS) as well as additional auxiliary VNFs deployed on the same system using the OpenStack VIM. In terms of Management and Orchestration (MANO), the iDirect Velocity™ IGW system is integrated with the Open Source MANO (OSM, [https://osm.etsi.org/](https://osm.etsi.org/)).
3.1.3 Exploitation Outcomes from SaT5G

Table 3-1: Exploitation Outcomes for Partners from Joint Activity

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
<th>Relevant Partner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5G-enabled virtualized gateway for SATIs5 over-the-air experimentation and prototyping</td>
<td>R&amp;D&amp;I</td>
<td>2018-2020</td>
<td>Know-how</td>
<td>SES, iDR</td>
</tr>
<tr>
<td>2</td>
<td>5G-enabled virtualized gateway for EdgeSAT over-the-air experimentation and prototyping</td>
<td>R&amp;D&amp;I</td>
<td>2019-2021</td>
<td>Know-how</td>
<td>SES, iDR</td>
</tr>
<tr>
<td>3</td>
<td>5G-enabled virtualized gateway for 5G-VINNI over-the-air experimentation and prototyping</td>
<td>R&amp;D&amp;I</td>
<td>2018-2021</td>
<td>Know-how</td>
<td>SES, iDR</td>
</tr>
<tr>
<td>4</td>
<td>Satellite Integration with 3GPP Core Network Architecture for Next Generation Virtualised Ground Segment Infrastructure</td>
<td>Global Managed Data Services</td>
<td>2020 onwards</td>
<td>Know-how</td>
<td>SES, iDR</td>
</tr>
</tbody>
</table>
3.1.4 Planned Future Activities

Based on the successful collaboration between the two partners, iDirect and SES, originated – even though not originally foreseen – in the SaT5G demo at EuCNC 2018 and further built up in the follow-up projects, SATis5, EdgeSAT and 5G-VINNI, there are already ongoing activities.

Participation in SaT5G project allowed SES and iDirect to acquire the necessary skills and know-how to proceed to bid for and acquire additional innovation related contracts as well as to proceed to potential future investments as necessary. As an illustration, building upon the SaT5G background experience, SES in partnership with iDirect have bid in response to the Call for 5G Pilot Projects 2019 issued by the Luxembourg Government - Department of Media, Telecommunications and Digital Policy (SMC).

Finally, iDirect and SES have been discussing on the way forward in terms of 5G commercial requirements, 5G product roadmap, and future potential joint commercial exploitation opportunities. As an illustration, a 2-day F2F workshop between the two partners took place at SES premises in Betzdorf, Luxembourg, on 18-19 September 2019.

3.2 Common Service level API Research

3.2.1 Partners Involved

iDirect, Gilat, I2CAT

3.2.2 Exploitation Activities within SaT5G

One of the areas of research of SaT5G was to define a data model for vendor and platform independent implementations (see WP4.1 description). The initial intention of this research was to agree on a low level data model to allow virtual network functions from different satellite vendors interact in order to provide an end to end satellite communications network or service.

The diagram below (Figure 3-3) illustrates the various levels of interoperability investigated.

![Figure 3-3: Common service API levels](image)

Beginning at level 3, the lowest level shown, the actors involved are satellite network functions from different vendors. This requires very low level interoperability between vendors which the project concluded was too low level for the satellite industry at this time. The satellite industry is in the very early stages of supporting interoperability between vendors and different networks. Also, even in the Telecoms industry (3GPP) there is no agreement at this low level for interoperability i.e. typically wireless network stacks are from one vendor only and not multiple.

At level 2, the network function level, the actors here are a Satellite Network Operator (SNO) OSS or third party service orchestrator and satellite network functions from different vendors. This would result in a common data model for configuring satellite network functions for different satellite vendors. This was also considered to be out of scope mainly because different satellite vendors have different architectures meaning the satellite network functions are not standard across different vendors.
This is similar to the Telecom’s industry (3GPP) where each vendor manages their own radio access network and therefore it is not surprising that this was out of scope for the satellite community. The lack of standards in the satellite industry means this is even less likely in the satellite world.

The next level, level 1 shown, represents service level interoperability and this is where the research concluded would be a good entry point for initial interoperability. The actors here are the SNO OSS or third party service orchestrator and the satellite system from an individual vendor. Engaging at this level allows SNOs or third party service orchestrator to agree at a high level what service is required without having to know low level implementation details of the system and also allows individual satellite network vendors to implement a service in the best way for their system.

Service level integration also meets the high level requirements set out by the SNOs who wish to have a common mechanism for activating and deactivating new services across multiple vendors. The service level integration is discussed in more detail in D4.1.

3.2.3 Exploitation Outcomes from SaT5G

The research completed during the project concluded with agreement from partners that the service level API was a good level to agree on a common data model and API for SNOs to activate and deactivate satellite services.

The interested partners have committed to continue collaboration beyond SaT5G to converge on a common service level data model for the satellite industry and if necessary, contribute the outcome to the appropriate standards development organization (SDO) or agree on a common standard to adopt. Some of the possible SDOs and some potential work items are listed here:

- **3GPP;**
  - Builds on TS 28.500, specifically; (a) figure 6.1.1-1 where the “radio” element is added next to the cloud element to the 3GPP management architecture of virtualized networks, and this can be extended to the satellite element, and (b) Figure 4.7.1: “Example of coordination between 3GPP and TN management systems” that highlights the requirement to coordinate between the 3GPP management system and the transport network (satellite network in backhauling case) management system.
  - TR 28.808, this focuses on "management and orchestration aspects with integrated satellite component in a 5G network";

- **ETSI;**
  - ETSI SCN DTR/SES-00446 “Reference Virtualised Network Functions data model for satellite communication systems”,
  - ETSI SCN DTR/SES-00411 (TR 103 522) TR - Protocol for Resource Management Interface”;

- **MEF;**
  - MEF-55 Presto;

- **IETF;**

<table>
<thead>
<tr>
<th>#</th>
<th>Exploitable Knowledge &amp; Products</th>
<th>Sector(s) of Application</th>
<th>Timeframe</th>
<th>Patents or Other IPR Protection</th>
<th>Relevant Partner</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Common Service level API</td>
<td>Standards</td>
<td>2019-2021</td>
<td>Know-how</td>
<td>iDR, GLT, I2CAT</td>
</tr>
</tbody>
</table>

### Table 3-2: Exploitation Outcomes for partner from Common Service level API Research

3.2.4 Planned Future Activities

There are no definite plans at this time although ongoing conversations and actions can be anticipated.
3.3 **UK 5G Satellite testbed**

### 3.3.1 Partners involved
Avanti, UoS and iDirect.

### 3.3.2 Description
Avanti and UoS are working with iDirect along with some UK organisations to create a UK based 5G satellite testbed building on the systems developed in SaT5G and deployed at the UoS’s 5GIC and Avanti’s Goonhilly satellite gateway. This project is looking for ESA funding within its Space for 5G [4] direction and is hoped that it will be able to go live by Easter 2020.

### 3.3.3 Activities beyond SaT5G
This testbed is intended to allow verticals to run 5G satellite tests and plans a series of four application validation tests looking at four key uses cases are envisaged:

- mMTC service addressing Critical National Infrastructure needs;
- Secure service validated at SIMEX in 2020 and 2021;
- Mobile platform services addressing NHS needs; and
- Media multicast content distribution across satellite and multiple RANs.

It is also anticipated that this legacy can be built on to allow further 5G trials and service pilots can be hosted. It may also link with similar testbeds across Europe such as those in the EC projects 5G-VINNI [5] and 5Genesis [1] along with other similar projects from ESA and nationally driven.
4 Recommendations on Future Work

The SaT5G project has been focussed on developing enablers that support the integration of satellite communication systems into the 5G environment, developing satellite solutions for 5G to enable telecom operators and service providers to accelerate 5G deployment in all geographies and at the same time create new and growing market opportunities for SatCom industry stakeholders.

The SaT5G deliverable D6.6 previously developed four broad thematic areas supporting this goal that will be reviewed in this D6.7 deliverable, specifically:

- Satellite 5G products;
- Services;
- R&D regarding Satellite integration in to 5G; and
- Related standardisation work.

This chapter provides recommendations for future work, building on that undertaken in SaT5G, which will support the further integration of SatCom into the 5G ecosystem, as well as future generations of mobile communication networks. The product and service related recommendations are also addressed in the project roadmap detailed in the SaT5G deliverable D6.1.

4.1 Future Product Development for SatCom 5G & Beyond

4.1.1 Next Generation Virtualized Satellite Hub and User Terminals

SaT5G provided a unique opportunity to mutually discuss and define how future satellite systems are expected to interface and interwork with 5G end-to-end service delivery systems. It is acknowledged that additional work will be required to further enhance initial proof of concept ideas and tests that were defined and standardized by SaT5G project. The SaT5G partners would like to leverage this work in the future to further define the satellite interoperability requirements as well as supporting 5G systems to leverage satellite advantages. The partners and industry will continue the progress made during the project to improve the interoperability and auto provisioning of end-to-end services by further simplifying the interfaces between different network architectures and support different satellite vendors.

Next generation Satellite communications networks are expected to contain some or all of the following concepts:

- Standard 3GPP core network used to manage and operate the satellite communications network in the same way it does in the terrestrial mobile networks;
- Satellite GW functions which will become distributed and virtualized to lower as much as possible the overall cost of maintaining and building multiple GW sites. This will be done by utilizing COTS equipment in each GW site and dynamically allocating resources based on current needs for the satellite system;
- Remote satellite terminals presenting as User Equipment (UE) terminals to the satellite core network;
- Remote sites which will include virtualization capabilities to facilitate VSAT (satellite modem interface) or any additional 5G NF that will be required to complete the end to end service delivery to the users, these NF will be dynamically allocated as needed based on each service delivery definition;
- Management system which will orchestrate the entire satellite delivery segment with tight correlation and integration with a higher-level orchestration system. Management integration will ensure an end to end service delivery while maintaining interoperability between terrestrial and none terrestrial infrastructures.

The satellite industry is poised to take advantage of the next-generation technologies that are available to the terrestrial world and face the same challenges to ensure seamless adoption, integration and migration. As technologies like SDN, NFV and MEC mature, the satellite industry will adopt and it’s in the best interest of the satellite industry to align with the terrestrial industry so it can provide a seamless end to end network and leverage the 3GPP eco-system.
4.1.2 Next Generation Satellite-Terrestrial Integrated MANO

Convergence of various telecommunication technologies is a key enabler to deliver 5G promises such as ubiquitous solution featuring aspect like extraordinary high speeds and capacity. TALENT is introducing to enable seamless integration of satellite communication into 5G networks at the orchestration layer, aiming to manage the end to end services provisioning, lifecycle management and launching of complex services.

TALENT is a coordination solution which supports end to end services composed of satellite, radio access, cloud and Mobile Edge Computing (MEC) resources. It is a management layer sit on top of the MANO frameworks with comprehensive view over all available resources and services. TALENT features important aspects are:

- TALENT is not vendor-locked and can support satellite and radio elements of different vendors;
- TALENT is NFVO (e.g. OSM and ONAP) and VIM (e.g. OpenStack) agnostic;
- TALENT covers end-to-end service management over cloud and edge computational resources;
- TALENT provides a single and easy to use point of interaction for all stakeholders involved in the ecosystem, e.g. terrestrial and satellite operators as well as different 5G verticals;
- TALENT is completely in line with 3GPP and ETSI definition, extending them towards satellite systems.

The original idea of TALENT is based on the definition of hierarchical and distributed orchestration, where an overarching orchestrator is able to manage and coordinate several independent domains. (Satellite, Radio and Cloud). We assume at each domain, there is a domain manager (DM) able to work with resources of the domain – Figure 4-1. In this sense TALENT becomes a light, scalable and efficient solution agnostic to elements of domains coming from various vendors.

Having these objectives in mind and based on the framework suggested by ETSI MANO [6] and 3GPP SA5 [7], we propose an extension towards satellite integration at the management and orchestration level, to build a multi-tier orchestration stack over a heterogeneous environment. The first release of TALENT supports satellite and cloud/edge domains, interworking with each other to deliver end to end services.

![Figure 4-1: Proposed Integrated Terrestrial Satellite Framework.](image)

The proposed architecture provides a user-friendly single point of interaction for all stakeholders in the ecosystem, i.e. terrestrial and satellite operators as well as 5G vertical providers, where they can lunch and manage end to end 5G services. The system allows easy integration of multiple applications (e.g. virtual 5G core, virtual caching, etc.) as well as solutions provided by radio and satellite vendors (e.g. satellite gateway, small cells, etc.).
## 4.1.3 Next Generation MEC-enabled Edge Network Delivery

The SaT5G project has been a great opportunity for Broadpeak to test and validate a number of concepts as well as test and develop solutions related to satellite and 5G networks integration, in the field of television and video assets content delivery.

Edge caching, multicast transmission and HTTP-based ABR technology has been confirmed to be a very powerful combination to deliver TV and video services over a combined cellular and satellite infrastructure.

The studies and product developments performed by Broadpeak for the SaT5G project lay the foundation for further technical improvements – that first commercial deployments will also nourish – and provides food for thoughts on new business models and opportunities.

As next steps, Broadpeak considers the following work items in the domain of satellite communications in 5G:

**Mobility management** – The architecture envisioned in SaT5G and relying on ETSI MEC (see D3.2) does not address the issue of mobility at the application level: if the MEC application is state-full, it is up to the latter to manage the application’s state mobility. In the context of edge video caching, there are several aspects to deal with, like:

- Session continuity (from the monitoring perspective it is very useful to track which server serves which terminal at what time).
- How to deal with the absence of an edge cache at destination when the mobile user moves from one area to another. Recently, ETSI MEC started to work on a mechanism to ensure mobility of the context that is certainly an effort to rely on.

**Caching efficiency leveraging MEC APIs** – The use of MEC as the edge platform to host the distributed 5G core network and caching functions brings a lot of benefits that could be exploited further. MEC offers a number of services and applications through internal APIs that mutually benefit to the various functions it hosts, and that could be used to improve the efficiency and security of video content delivery over the integrated 5G-satellite communication network, like:

- Analytics (with potential use of AI) to monitor/predict the load and channel/link variability of the various transmission segments (5G Radio and distributed Core – Satellite – Centralised Mobile Core functions) and adapt in real time the caching and streaming behaviour.
- Security: MEC hosts security services and applications (accessible via ad hoc APIs) allowing to prevent DDOS and cyber-attacks and moves the security perimeter closer to the source.

**Network slicing** – SaT5G partners like i2cat have started to look at the integration of 5G and satellite communication network for network slicing, from a network and service orchestration standpoint. Further work is needed to better test the integration of the caching functions to the end-to-end slice (3GPP mobile network – satellite network – caching/computing functions), in terms of definition (slice templates), provisioning, operation (including scale in / scale out) and slice release.

**Standardization** – Multicast ABR via satellite is one of the pillars of the solution that Broadpeak has specified and developed for the two main SaT5G use cases it has contributed to (live assets delivery to the 5G mobile network edge and prefetching of VoD assets to a moving aircraft). Multicast ABR is still not standardized in DVB (DVB’s TM-IPI group). Broadpeak will continue to contribute with others to the definition and finalization of this important part of the DVB standards.

**New business models** – As we know, deploying caches at the edge of the satellite network brings a lot of benefits to the end user like a reduced latency and subsequently an increased quality of experience (QoE). This edge layer, that can be located at various places of the integrated 5G-satellite communication network, is a key asset for the operators. The further studies and collaborations should define sustainable business models where this edge layer is made available to application and video content providers and better monetized by the mobile network operators (MNO) and satellite carriers.

Finally, the deployment of satellite contribution in commercial Pre-5G and 5G networks, in various situations and use cases, will certainly provide ideas for a number of improvement areas. The expected deployment cases to be closely looked at are:

- Connectivity to base stations located in low-density, rural areas, remote and hard-to-reach areas;
• Connectivity to moving platform (planes, vessels, trains) where a local pico/femto mobile network is in place.

Contribution links when the MNO have insufficient or no terrestrial transmission networks, or when they are leasing their terrestrial transport links.

### 4.1.4 Next Generation Multi-link and Heterogeneous Transport

For the many reasons motivating this project, Satellite Communication is an interesting complement to increase 5G’s reach, capacity and reliability. In this project, EKINOPS focused on the transport layer support of 5G traffic over a hybrid backhaul. To deliver on the promise of ubiquitous/sub millisecond service, 5G’s requirements in terms of backhaul performances are very strict. In this context, optimally transporting any traffic, i.e. both interactive and download, represents a major challenge for a satellite link, GEO, MEO or LEO with a significant latency. Within SaT5G, the combination of a high throughput and latency satellite link with a low throughput and latency terrestrial link to provide a hybrid 5G backbone was studied.

The results obtained when implementing MP-TCP and MPQUIC multipath protocols associated with a traffic-aware/link-aware Path Selection Algorithm, obtained in a simulated environment as well as on the 3GIC testbed built on a real architecture, demonstrate that the user Quality of Experience (QoE) achieved qualifies the hybrid approach.

In this context, the project follow-up and next step for future development is to productize it as a packaged commercial solution. The hybrid backhaul technology would be is an extra tool for Service Providers to deploy, further and faster their 5G footprint. The solution is essentially software and must be deploy, as VNF or else, and easy to use with self-adjusting dynamic parameters as well as support RAN encryption constraints – a point not addressed with MPTCP for example.

Field test are required with a broad range of actors to challenge and tune the solution. The 5GENESIS project where EKINOPS is a participant comes with the goal of validating 5G KPIs for various 5G use cases, in both controlled set-ups and large-scale events, this is illustrated in the following figure.

![Figure 4-2: 5GENESIS End-to-End Facility](image_url)

5GENESIS will be achieved by realising an integrated End-to-end 5G Facility, built on five diverse in terms of capabilities –yet fully interoperable- experimentation platforms distributed across Europe and interconnected with each other. The platforms will emerge as the evolution of existing testbeds, already owned and operated by the 5GENESIS partners, suitable for large-scale field experimentation.
The 5GENESIS facility, as a whole, will:

- Implement and verify all evolutions of the 5G standard, via an iterative integration and testing procedure;
- Engage a wide diversity of technologies and chain innovations that span over all domains, achieving full-stack coverage of the 5G landscape;
- Unify heterogeneous physical and virtual network elements under a common coordination and openness framework exposed to experimenters from the vertical industries and enabling end-to-end slicing and experiment automation; and
- Support further experimentation projects, in particular those focused on vertical markets.

The Limassol testbed in particular builds a multi-link network with near-shore vessels. As such, 5GENESIS and upcoming H2020 projects are the right place for EKINOPS to continue contributing telecommunications, including 4G, 5G and 5G-PPP and satellite communications.

4.1.5 Next Generation 3GPP/Non-3GPP Satellite Access

The future Satellite access is expected to provide benefits and support main services as described below.

3GPP Satellite Access Network

The 3GPP Satellite access networks and their elements to develop are expected to support:

- Coordinated Radio Resource Allocation, between a 3GPP cellular RAN and a 3GPP based satellite RAN, in a spectrum sharing context;
- RRM (Radio Resource Management) real-time coordination between cellular systems and satellite systems;
- Cellular and satellite Multi-connectivity can be provided to UE;
- Support of three main 5G services enablers, that are key to access the 5G markets;
  - eMBB (1) services. For use cases such as Backhaul for underserved, isolated areas (also vessels and aircrafts),
  - mMTC (2) and uMTC (3) services. For use cases such as Local Radio Access within a given service area or between neighboured service areas, Exchanges between UE of remote / worldwide areas, Tracking Services support, Worldwide Navigation (GNSS) support, Worldwide roaming support, Operational Theatre deployment in response to crisis or disaster;
- Interoperability with the 3GPP standard, selected by the mobile network community;
- While security mechanisms between the UE and the Core Network are restricted to Authorization, an optional Ciphering, it is desirable to avoid IPSEC tunnels, as the Satellite access network is considered as trusted by any MNO.

Non-3GPP Satellite Access Network

The next Non-3GPP Satellite access networks and their elements to develop are expected to support:

- Coordination of Radio Resource Plans, between 3GPP cellular RANs and 3GPP based satellite RANs, in the management plane, in a spectrum sharing context;
- Support of some 5G services enablers, via a VSAT (acting as an Access Node, which may not be recognized neither managed as UE by the mobile network);
  - eMBB (1) services. For use cases such as 5G local RAN Backhaul for underserved, isolated areas (also vessels and aircrafts). A 5G local RAN may serve several 5G UE and includes a serving gNB.
  - uMTC (3) services. For use cases such as Local Radio Access within the local 5G RAN, Tracking Services support (4), Worldwide Navigation (GNSS) support, Worldwide roaming support (4), Theatre of operations deployment, in response to crisis or disaster;
- Security mechanisms, such as IPSEC tunnelling between the CN and the UE, which are re-enforced, whenever the Non-3GPP satellite access network is considered as Non-trusted, by the Mobile Network Operators (unlike a 3GPP Satellite Access Network);
  - This mechanism could be simplified and performances could be enhanced, by implementing IPSEC tunnels only between the local serving VSAT and the Core Network, providing the local RAN is 3GPP NR-Based and therefore, considered as trusted by any MNO,
Keeping the funds of the satellite operators that have invested in On-The-Shelf transmission technologies such as DVB-S2 and related equipment, for the space segment, and moreover, expansive Ground segment infrastructures, which include Mission Centre and Gateways.

Notes:

(1) **eMBB**: Enhanced Mobile Broadband. Main features: *Up to 1 Gbps/user indoor and >50 Mbps in rural areas.*

(2) **mMTC**: massive Machine Type Communications. Main Features: *>1 million devices/km², >10 years battery life time.*

(3) **uMTC**: Ultra reliable Machine Type Communications. Main features: *> 99.99% reliability.*

This is a subset of uRLLC services group (Ultra Reliable and Low Latency machine type Communications). The uRLLC service group which provides the additional feature: “<5 ms end to end latency”, which is out of the target of any satellite system, unlike the efficient reliability.

(4) Based on information (tracking area, subscription profile) related to the serving VSAT whenever it is managed / served as UE by a gNB and a Core Network. Otherwise, based on UE location service information.

### 4.1.6 Next Generation 5G Security for Satellite Networks

During the course of SaT5G, number of topics regarding security measures in both 3GPP (mobile networks) and satellites domains have been opened. Initial expectation of the work package (WP4.5) working on security was that latency introduced by satellites is one of potential problems, and that it might lead to timeout (of timers) connected to security mechanisms. This assumption has been tested by TNO in its lab and subsequently found not to be an actual problem.

Integration of existing satellite and 5G architectures has proven to be feasible, but solutions have opened new issues that have impact on security.

The main one identified is the impact of PEP\(^1\) (Performance Enhancement Proxy) on security. In satellite network, it is used to enhance the performance of TCP connections by ‘cutting connection into two parts and introducing a proxy which controls the transmissions of the TCP segments in both directions, by ‘ack filtering’ and reconstruction in the existing connection. To avoid timeout and possible TCP protocol intervention, proxy is splitting one (longer latency) link into two, thereby giving server and client perception that latency is lower.

Another potential research topic is security in context of shared network resources, where protocol like mcTLS (Multi-context TLS, which is a secure communication protocol that extends TLS to allow endpoints to incorporate trusted middle-boxes into secure sessions) or similar could be needed.

Towards the end of the study period (summer 2019) the 3GPP TS23.501 was updated in SA2 to include the concept of a trusted Non-3GPP Gateway function (TNGF) in Figure 4.2.8.2.1-2 “Non-roaming architecture for 5G Core Network with trusted non-3GPP access”. The implications of the use and implementation of a TNGF for satcom backhauls merits further study.

In coming period TNO’s work will be in field of deployment of 5G networks with integrated satellite components. That deployment will present significant challenges for parties that will provide or orchestrate connectivity across domains – including security. That includes research into locations of MEC nodes for content, security impact (and minimization of impact) of PEP and PEP-like protocols, and efficient use and management of resources in integrated network.

### 4.1.7 Next Generation Space Segment for Integration within 5G

The integration of the space segment within 5G systems is expected to follow two axes:

\(^1\) [https://en.wikipedia.org/wiki/Performance-enhancing_proxy](https://en.wikipedia.org/wiki/Performance-enhancing_proxy)
- Develop and standardise satellite solutions for a seamless integration in 5G systems
- Implement 5G technologies and architecture design in Space Gateway and Space Vehicle payloads and in Non-GEO satellites constellation

This is also applicable to HAPS.

The seamless integration could use:

- AI (Artificial Intelligence) technics to help operator to achieve an acceptable trade-off for radio resource allocation in a context of resource sharing context, between different geographical service area and between network slices;
- Interference mitigation schemes between cellular systems and satellite systems, in a spectrum sharing context. Analysis of ITU-R and 3GPP activities confirms that the spectrum sharing with cellular systems will have deep impact on the satellite systems;
- Any mechanism that helps the satellite system to be self-organised and any mechanism that help cellular and systems to interwork automatically, in an efficient way. It covers, in particular;
  - Any framework and interface provided to an orchestrator (in the management plan) to manage hybrid networks, made of cellular and satellite access networks. All FCAPS functions could help to achieve such as self-organization & interworking: Fault, Configuration, Authorization, Performance and Security. While in the control plane, it covers any mechanism that could optimize in Real Time (with a short response time), functions such as AT3SF (Access Traffic Switching, Splitting and ), packet scheduling, frame scheduling, adaptive modulation and coding, at radio interface and resource allocation to traffic (bandwidth on-demand vs. planned allocation);
  - Any framework and interface that could integrate both Space Mission Infrastructure and Mobile Network Management system, giving efficient inter-working between the systems.

The architecture of Non-GEO satellite constellations are described in 3GPP TR 23.737 “Study on architecture aspects for using satellite access in 5G” (Release 16). This study is an on-going activity at 3GPP. In this technical report, some satellite access network architectures are foreseen, as depicted below for two of them.

Figure 4-3: 5G System integrating regenerative satellite enabled NR-RAN and distributed gNB

In this architecture, the satellite is regenerative. The satellite payload implements a gNB-DU (Distributed Unit) as part of a satellite enabled NR-RAN. Some of the protocols of the NR are processed by the satellite. A Satellite Radio Interface (SRI) transports the F1 protocol between the on-ground CU (Central Unit) and the on-board DU. This SRI may be NR based or not.
In this configuration, each regenerative satellite embarks a gNB supporting:

- Satellite enabled NR-RANs; and
- 5G CN's accessing these gNB's, as described in the above figure, where specific (or not) satellite radio interfaces are used to handle control and user planes.

The exchanges between two neighboured, embedded gNBs is implemented by an Xn over IS interface.

### 4.2 Future Service Development for SatCom 5G & Beyond

#### 4.2.1 Next Generation Edge Content Delivery

Within the project lifetime, the team has investigated various use cases and scenarios on edge content delivery, including both offline content caching through multicasting over satellite-backhauled 5G core network, as well as real-time content delivery applications such as 4K/4K+ video on demand (VoD) and live streaming end-to-end. Multipath-based video content has also been investigated for the sake of enhanced network efficiency and user experiences.

Looking forward, the project team will expand from the current scope to explore additional applications, scenarios and use cases. First, the UoS team will consider the emerging type of media content – holographic-based applications which demand much higher data rate (minimum at the order of X100Mbps as compared to X10Mbps for MPEG 4K videos). This includes both the edge delivery of pre-created holograms as well as live streaming of 3D models of teleported live objects. Synchronised delivery of different objects in such applications is essential in order to be played back based on the accurate composition of streamed objects (either pre-cached or live teleported).

The second direction for future service development is to use SatCom based 5G (and beyond) to support interactive content applications. The vast majority of the application scenarios that have been addressed in SAT5G are non-interactive, meaning that the content traffic delivery is one-way only. The distinct challenge here is the long end-to-end latency introduced by the GEO satellite links which directly affects user experiences during the conversation. We would like to investigate whether (if yes) and how edge computing techniques can play a role in future network environments to expand the applicability of satellite backhaul link to include such application scenarios.
Last but not least, in SaT5G we have mainly considered the content delivery scenario where the GEO satellite links are used as 5G backhaul. Beyond the project lifetime we will consider the scenario of direct UE access to the satellite for content delivery. Such a scenario is applicable to both GEO and LEO satellite networks. In this case the satellites can be considered as base stations in space for content access.

4.2.2 Next Generation Fixed Cellular Backhauling

Both Avanti and SES as market leading providers of fixed cellular backhauling services for 2G, 3G and 4G will look to leverage the work performed in SaT5G in their respective markets. The initial market for 5G fixed cellular backhaul services is likely to be based around supporting future demos, trials and pilots as the MNOs start their 5G deployment in well-connected urban locations. These may be part funded by EC, ESA or national investments such as those by DCMS in the UK; or they may be funded by other routes. The market for next generation fixed cellular backhauling by satellite will emerge over time as the MNOs extend their coverage aware from the urban locations and look to deliver the ubiquitous coverage 5G target KPI.

Work is needed on how best to interwork between MNO and SNO covering areas such as security and trust domains, billing and end-end MANO. Additional work on how to support a mix of 3G, 4G and 5G services may well be beneficial as will building a multi-tenancy solution for isolated locations. Further analysis on business models outside of western-Europe are needed – for example Avanti will need to understand how best to offer these services in sub-Saharan Africa.

Looking further ahead, two additional areas may need to be addressed:

- Differentiation between the optimum roles for GEO, MEO, LEO and mixed orbit solutions;
- Extending this to include other NTN such as HAPs;
- Development and integration of edge delivery services (see section 4.2.1 above) to provide a mixed service solution.

Of note there are discussions between two relevant groups representing satellite and terrestrial operators to discuss extreme rural coverage, the long term outcome of this probably will be a variety of different direct access models however it is hoped this dialogue can lead to increased opportunities for backhaul services. The two groups being ESOA (EMEA Satellite Operators Association) and NGMN (Next generation Mobile Networks).

4.2.3 Next Generation Broadband to Premises

BT, through its wholesale subsidiary BT Openreach, is Britain's largest supplier of broadband services to home and commercial customers. Other operators lease capacity from Openreach, meaning that improvements are shared by a customer base in the size of tens of millions. The regulator Ofcom applies a Universal Service Obligation, with the result that BT is constantly and actively researching new solutions for hard-to-reach premises. Fibre-to-the-premises is still a minority solution, and although copper speeds continue to improve through developments in DSL technology, we are probably reaching the limits of this approach. Thus BT is tracking the SaT5G outputs closely, especially those relevant to use-cases 2 and 3. Copies of SaT5G deliverables will be sent to Openreach researchers. The business models from WP2 will be of great value in evaluating the economic viability of these solutions. And already new research projects focusing on satellites are being planned, which will build on SaT5G work.

4.2.4 Next Generation Moving Platform Backhauling

The inflight connectivity (IFC) market has exploded over the last few years, with a growing number of commercial aircraft providing airline passengers with access to the applications, services, and entertainment they’re able to enjoy on the ground. This trend will continue to intensify over the next decade, with 68% of aircraft expected to be connected by 2026 [8]. Passengers want to be able to access high-speed Wi-Fi, stream video entertainment, and catch up on email and social media while on board, with 78% of global travellers stating they want inflight internet, and 30% specifically looking for that feature when booking their flight [9].
ZII, as a worldwide supplier of aircrafts connectivity solutions will capitalise on the experience and
demonstrations arising from SaT5G beyond the time span of the project. ZII is already focusing on the
next generation of products for connectivity inside airplanes, as well as to/from them. Considering that
the primary customers of Zodiac Inflight Innovations are airlines, ZII is already engaged in the design
of connectivity solutions that embrace virtualisation, not only limiting to virtual machines but considering
also lighter weight implementations such as containers. Moreover, ZII is looking at products that,
through increased level of softwarisation, can cater the advantage to be hardware agnostic, thus
offering a higher degree of flexibility and reconfigurability. It is worth pointing out that all the activities
that can lead to products will require some years, from design to aeronautical certification completion.

In the first place, the R&T group inside Zodiac Inflight Innovations will target as customers other
business units in the group and will leverage on the synergies that were spurred through SaT5G,
including the cooperation between ZII and Zodiac Data Systems. Internal demonstrations are already
planned to take place during 2019 in order to show the potentials of the technology, raise internal
awareness of 5G and increase attention to new R&T/product development activities. Moreover, the
dedicated VPN connection that has been deployed between the ZII office in Weßling (Germany) and
the SES point-of presence in Unterföhring (Munich) will remain active for some months beyond the
duration of SaT5G and can be conveniently exploited by ZII and SES to provide joint demonstrations
to a larger audience of stakeholders, including customers of the respective companies.

SES works closely with all the leading IFC service providers, incl. with ZII through the SaT5G project,
to meet the ever increasing and evolving IFC demands of global airlines and passengers. In fact, SES
is tailoring much of its global fleet of satellites to meet this demand. The SES-12 and SES-14 Ku-band
HTS satellites, launched in 2018, will enable IFC service providers to increase throughputs by a factor
of 5 to 10 in their coverage areas.

The SES-17 Ka-band HTS satellite, scheduled for launch in 2021, will be used by leading IFC providers,
to provide high throughput services in the Americas and over the Atlantic crossing to Europe.
Furthermore, by 2021, SES’s O3b mPOWER satellites will also offer exponentially more power,
performance and flexibility to allow SES to meet the evolving connectivity needs of the airline industry,
with beams that can be adjusted in real-time to meet changing bandwidth needs and enable this door-
to-door solution. The next-generation MEO satellite constellation will enable virtual gaming, chat, and
other live streaming applications for airline passengers.

Furthermore, towards the same direction to improve the communication services inside the airplane,
SES collaborates with key ecosystem partners in order to obtain the satellite integration into 5G. The
use of satellite backhaul integrated to 5G in the airplane will open the door to a new generation of
solutions that can deliver eMBB and mMTC services to airplanes enhancing the passenger experience
and crew operations through reliable, efficient and customisable inflight entertainment systems.

Figure 4-5: Future Aero Services
4.3 Future R&D for SatCom 5G & Beyond

SaT5G has implemented two satellite integration architectures for indirect connection of the satellite and 5G core network and demonstrated four use cases. The connection between the SNO and the MNO has been a very basic one. Within the project we have also researched various business models which between the stakeholders from the simple one demonstrated to a more complex one in which the MNO has overall control. Future research can build upon this and implement a deeper integration of the satellite elements into the core network and investigate more network slicing implementations that represent various business models. 3GPP standards as far as Rel 15 have been implemented in an integrated virtualised system but more work needs to be done to optimise such structure and to follow updates of the 3GPP standards as they progress. Moving on from a basic infrastructure demonstration to wider user trials which is the natural follow on from this project we will need to implement a business or service layer on top of the current structure to enable actual users to more easily interface with the network architecture.

From a business modelling perspective, we have evaluated the role of network slicing in an integrated network. We developed an allocation model to fairly distribute the network resources across multiple slices. This model should be developed further in the future, such that is becomes applicable to multiple type of networks. Furthermore, the different brokerage models have also been described from a qualitative perspective, quantitative evaluation can later follow based on concrete cases.

In some quarters 6G is now being discussed as 5G plus satellites and so it is important to consider further how satellite can extend coverage. In SaT5G we have only considered eMMB but there are applications of IoT and mMTC that can benefit from satellites and thus we need to extend the work to include these as well. Although SaT5G has demonstrated some content delivery applications this is now becoming an important area as more people move from broadcast to the internet for video consumption. Using satellite to integrate more with the MNO distribution of video is a logical extension of the project.

In SaT5G we have not been able to demonstrate live backhauling to moving platforms and this application is very relevant and will need follow up in detail. Most of the demonstrations in SaT5G have used GEO satellites but current proposals for large MEO/LEO systems indicate that there is need to have 5G integration with these systems. Looking further ahead to higher power satellites we can look at putting some of the 5G functionality on board the satellite and investigating the advantages that this could bring to some application areas.

In SaT5G we considered also signal level integration and results were delivered to 3GPP 5G NR work items. 5G signals family could include the satellite element from the beginning and obviously efforts are needed for developing this signal. There is need for satellite signals for several application ranging from eMMB services to IoT for transferring (e.g., environmental) sensor information, as well as to transport sector (especially maritime) and for safety-and-rescue and other authorities’ needs. Therefore, the signals should offer high and low data rates, be reliable and at the same time be energy efficient and economically feasible to implement.

One driving force for this integration is cost reduction since the same chipsets and system solutions could be used. Recent progress in mass production of satellites (e.g., One Web) is also a cost reduction factor. Reduced cost per bit is one important element for success of satellite systems in the future. In addition to services in rich and densely populated areas, internet connections are needed in pooper and remote areas to close the digital divide. However, this requires that connections are affordable and have a sufficient data rate (QoS). By developing low cost solutions the satellite sector could contribute to this together with the terrestrial sector.

Environmental issues have to be taken more seriously in the future and this means further research for corresponding solutions. Example topics include more easily recyclable devices, energy efficient ground segments and the use of sustainable materials instead of rare ones. Another such area of research could be to consider the embedded carbon costs of deploying SatComs widely to help stream popular content. Recent articles are suggesting that the consumption of OTT video streaming content is adding significantly to our greenhouse gas emissions (such as [10] suggests around 300Mt emitted and 1% of the total).
4.4 Future Standardisation Activity for SatCom 5G & Beyond

TAS, SES and many other partners will be involved in the future 3GPP activity.

The objectives are to continue 3GPP NTN study items that have been initiated and also contribute to new ones:

- Initial Potential requirements have been identified on the 5G system to integrate satellite networks and have been approved as Specifications in TS 22.261 during activities led in WG SA1 (Stage 1 of Release 16). Stage 2 activities have been kicked-off on this basis: in WG SA2 to address the potential modifications on the 5G System Architecture (when considering mobility management & backhauling during a 1st phase of the FS_5GSAT_ARCH study). Further, a new study has been initiated in WG SA5 addressing business models, orchestration and management for a 5G system integrating satellite components. Additional activities will therefore be needed to continue the activity in WG SA2 (2nd phase of the study, and normalisation phase), in WG SA5 (to terminate the study, to go to normalisation, and to engage Stage 3), to consolidate any needs to engage with SA3 - security, and to engage with Stage 3 in TSG CT.
- Development in 3GPP of a global standard for future satellite communications based on NR/NG-RAN is foreseen in Release 17 of 3GPP.

The following tables summarize the 3GPP standardization plan on satellite:

- One table for completed contributions (for information);
- Another table for on-going contributions.

In the following:

- “SI” stands for “3GPP Study Item”;
- “TBD” stands for “To Be Defined”.

Table 4-1: Completed contributions to standardization on satellite

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<td>Seamless integration of satellite and/or HAPS (High Altitude Platform Station) systems into 5G system</td>
<td>ETSI TR 103 611</td>
<td>Final version to be reviewed by ETSI partners.</td>
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<td>Edge delivery in 5G through satellite multicast</td>
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<td>TBD</td>
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<tr>
<td>WI DTR/SES-00446</td>
<td>ETSI TC-SES</td>
<td>Reference data model for satellite network</td>
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<tr>
<td>FG-NET2030</td>
<td>ITU-T SG 13</td>
<td>ITU-T Focus Group for 2030 on future network scenarios beyond 5G</td>
<td>TBD</td>
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5 Conclusions

In this deliverable each of the sixteen organisations has identified their exploitation activities within the SaT5G project along with the related outcomes. In addition the known and planned future activities of each of these organisations has been reviewed.

Table 5-1: Exploitation areas

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Knowledge</th>
<th>Relationships</th>
<th>Service</th>
<th>Product</th>
<th>Research</th>
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<tr>
<td>QUO</td>
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</table>

Two joint exploitation activities have been identified (see section 3) that are looking at creating two integrated 5G and satellite testbeds with satellite capacity being provided by the satellite operators Avanti and SES using ESA funding; as well as a common service level API research element led by iDR.

Finally recommendations for future work have been identified (see section 4) looking at future products and services, along with future R&D and standards activities. The future product development work that has been identified includes addressing the following:

1. Greater virtualisation of the hubs and remote terminals and the management thereof;
2. Development of the integrated MANO of terrestrial and satellite network functions;
3. More work on MEC enabled edge caches systems;
4. Progress the implementation of multi-link transport solutions over heterogeneous connections such as satellite and terrestrial links;
5. Considering a 3GPP standards based approach to deploying and managing satellite access;
6. Building a security and trust model to allow MNOs and SNOs to interwork more easily; and

Future R&D work will look to extend the SaT5G work that has been looking at primarily eMBB to understand the implications for the mMTC and where feasible URLLC use cases. Complementing the initial work defining the next generation – 6G – the SatCom research sector may well need to focus on the environmental impacts. Standardisation development and support will be needed to build on the work done so far and extend this in to Release 17 Study and Work Items.
6 References


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