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Abstract	This deliverable focuses on the implementation plan for the iNGENIOUS use cases deployment and validation. It includes a list of required resources

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	to be used for a proper testbeds' setup as well as a list of development and integration activities to be carried out during the project lifetime. A common methodology to keep track of system requirements verification per use case is also provided. In this deliverable use cases' implementation risks are also considered.
Keywords	Implementation, Planning, Demonstration, Integration, Validation, PoCs, Demos, Testbeds, Test Cases, RTM, Risks.

Document Revision History

Version	Date	Description of change	List of contributor(s)
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Disclaimer

This iNGENIOUS D6.1 deliverable is not yet approved nor rejected, neither financially nor content-wise by the European Commission. The approval/rejection decision of work and resources will take place at the Mid-Term Review Meeting planned in June 2022, after the monitoring process involving experts has come to an end.

The information, documentation and figures available in this deliverable are written by the "Next-Generation IoT solutions for the universal supply chain" (iNGENIOUS) project's consortium under EC grant agreement 957216 and do not necessarily reflect the views of the European Commission.

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Dissemination Level		
PU	Public, fully open, e.g. web	
CL	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to iNGENIOUS project and Commission Services	✓

** R: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

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Executive Summary

The main aim of this deliverable is to provide and describe the initial implementation plan for all use cases of the iNGENIOUS project in order to identify all the required activities to be carried out for their proper deployment and validation.

A planning of the required resources, facilities, connectivity and logistics for the set-up of each test-bed is presented and discussed.

Based on these data, appropriate components of the iNGENIOUS PoCs and the technological infrastructure of the test-beds are listed, describing the actions required and the time plan for setting up the PoCs and the use cases, from the beginning of the project, until they become ready for testing and demonstrations.

The planning includes a methodology and checklist for addressing the specified requirements, that results in a common set of concise test specifications. This ensures that all PoCs and use cases will be on time, reliable and easy to compare.

The identified implementation plan per use case, will be then used as a basis for the integration and final evaluation activities foreseen by the WP6 during the lifetime of the iNGENIOUS project (e.g T6.2 and T6.3).

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Abbreviations

3GPP	3rd Generation Partnership Project
A2A	Authority to Authority
ACK	Acknowledge
AES	Advanced Encryption Standard
AI	Artificial Intelligence
AIDA	Automazione Integrata Dogane Accise (Integrated Automation Customs Excise)
AIS	Automatic Identification System
AGV	Automatic Guided Vehicle
API	Application Programming Interface
B2A	Business to Authority
B2B	Business to Business
BBU	Baseband Unit
BT	Bluetooth
BTC	Bitcoin Native Token
CIoT	Consumer Internet of Things
CPU	Central Processing Unit
CSE	Common Service Entity
CSV	Comma Separated Values
DL	Downlink
DLT	Distributed Ledger Technology
DVL	Data Virtualization Layer
E2E	End to End
ECDSA	Elliptic Curve Digital Signature Algorithm
EDA	Exploratory Data Analysis
ETA	Expected Time of Arrival
ETD	Expected Time of Departure
ETSI	European Telecommunications Standards Institute
FER	Frame Error Rate
FMEDA	Failure Modes, Effects and Diagnostics Analysis
FPGA	Field Programmable Gate Array
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSMA	Global System for Mobile Communications
GUI	Graphic User Interface
GW	Gateway
HTTP	HyperText Transfer Protocol
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organization for Standardization
IT	Information Technology
LAN	Local Area Network
LO-LO	Lift On – Lift Off
LoRa	Long Range
LTE	Long Term Evolution
M2M	Machine to Machine
MAC	Media Access Control
MEC	Mobile Edge Computing
ML	Machine Learning
MR	Mixed Reality
NDA	Non Disclosure Agreement
NEF	Network Exposure Function
NFV	Network Function Virtualization

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NSA	Non Standalone
NSD	Network Service Descriptor
NWDAF	Network Data Analytics Function
ODU	Outdoor Unit
OS	Operating System
PC	Personal Computer
PCS	Port Community System
PMIS	Port Management Information System
PoC	Proof of Concept
PSU	Power Supply Unit
QoS	Quality of Service
R&D	Research and Development
RAN	Radio Access Network
RF	Radio Frequency
RO-RO	Roll On – Roll Off
ROS	Robot Operating System
RoT	Root of Trust
RPI	Raspberry Pi
RRH	Remote Radio Head
SA	Standalone
SCADA	Supervisory Control And Data Acquisition
SDR	Software Defined Radio
SHA	Secure Hash Algorithm
SOAP	Simple Objects Access Protocol
SR	System Requirement
TC	Test Case
TCP	Transmission Control Protocol
TLS	Transport Layer Security
ToD	Tele-operated Driving
TPCS	Tuscan Port Community System
TTT	Truck Turnaround Time
UC	Use Case
UDP	User Data Protocol
UE	User Equipment
UL	Uplink
UPF	User Plane Function
UR	User Requirement
URLLC	Ultra-Reliable Low-Latency Communications
USRP	Universal Software Radio Peripheral
VPN	Virtual Private Network
VSAT	Very Small Aperture Terminal
VSMF	Vertical Service Management Function
WAN	Wide Area Network
WiFi	Wireless Fidelity
WP	Work Package

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1 Introduction

In this chapter, the deliverable's objective, structure and the relation with iNGENIOUS project are briefly presented and discussed.

1.1 Objective of the Document

The main objective of this deliverable is to provide a preliminary version of the implementation plan per use case to be used for the overall duration of the project in order to make sure that PoCs and Demos are properly deployed, integrated and validated during the WP6 duration.

The deliverable includes a list of preliminary configuration and setup activities to be carried out to allow use case deployment as well as further integration and development activities towards the innovation goals of the project. Moreover, a checklist for addressing the requirements, that results in a common set of concise test specifications is also presented according to the adopted methodology.

This deliverable will be the main basis for the integration and final validation activities expected to be carried out by T6.2 and T6.3 during the next period of the iNGENIOUS project.

1.2 Structure of the Document

The deliverable follows the structure described below:

- *Section 2, iNGENIOUS Testbeds*: This section focuses on the description of different iNGENIOUS testbeds (namely ASTI factory, COSCO ship, Valencia Port and Livorno Port) that are expected to be used for the PoC and/or demo deployment and validation; the testbeds description takes some aspects into account that are relevant for the use cases' implementation in terms of ICT infrastructures, available connectivity, premises and facilities as well as digital platforms;

- *Section 3-8, PoCs and Demos Description*: These sections refer to the identification of different activities to be carried out during the lifetime of the iNGENIOUS project in relation to all use cases. More specifically, setup and configuration activities are identified in order to define a proper environment to be used for the implementation activities. Development and integration activities are also identified according to the functionalities of each use case. Finally, a set of test cases per use case are defined in order to make sure that system requirements are going to be properly covered.

- *Section 9, Initial Planning for PoCs and Demos*: In this section, the main implementation plan per use case is provided and briefly discussed according to the activities previously identified and defined in Sections 3-8. Moreover, a Requirements Traceability Matrix (RTM) section describes the

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main approach used to keep track of the User requirements, System Requirements and Test Cases.

1.3 WP6 Scope in iNGENIOUS

The goal of WP6 is to coordinate all activities related to the implementation of PoCs, demonstrations and validations driven by the use cases deployed in the different realistic testbeds. It uses the outcomes of the technical work packages (WP2, WP3, WP4 and WP5) and provides at the same time the iNGENIOUS test methodology in order to evaluate NG-IoT solutions for the universal supply chain. The test results and data collected will be used by WP7 for dissemination, standardisation, exploitation, and innovation actions according to a defined implementation plan per use case. Moreover, the trials in WP6 will provide meaningful insights into the potential benefits of the solutions adopted in the project.

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2 iNGENIOUS Testbeds

This section includes a general and brief testbeds description, highlighting aspects relevant for the iNGENIOUS use cases implementation (e.g. operational context, use cases involved, expected scenarios, etc.). The following testbeds are considered: ASTI Factory, COSCO Ship, Valencia Port and Livorno Port.

2.1 ASTI Factory

The objective of the ASTI testbed is to interconnect varieties of sensors and actuators to a centralised controller running on the edge. The demo will be carried out using a robotic arm equipped with a 3D sensor camera to perform an inspection operation over an AGV. The robotic arm is a Yaskawa GP25 and the AGV is an Easybot AGV. The robotic arm and the AGV will be synchronized thanks to the 5G network. Both devices will be controlled by applications that run in the MEC.

Figure 1: Use case testbed

The Easybot AGVs are specially designed for the automotive sector. They are characterized by their simplicity of use, the flexibility of implementation and usefulness in assembly line automation and internal transport of materials.

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Figure 2: AGV for the use case

They are equipped with different sensors that provide guiding and/or localization: magnetic sensors, optical sensors, lidars, etc. Guiding information is related to the deviation from a predefined trajectory in the ground. On the other hand, localization information indicates the absolute coordinates and the orientation in a plane. In this AGV, the guiding and the localization are uncoupled. The guiding is provided by a magnetic sensor that returns the distance between the centre of the sensor and the middle of a magnetic tape placed on the floor. While the localization is provided by an RFID reader which identifies tags placed on the floor.

2.2 COSCO Ship

The objective of COSCO testbed is to assess IoT tracking technologies that contribute optimizing end-to-end supply chain service, real-time data exchange and customer satisfaction. The demo will be carried out using a 20 feet empty container equipped with the IoT sensors and transported both on the maritime and inland leg. For maritime transport, the container will be loaded on a ship at the Port of Valencia and unloaded at the Port of Piraeus, where it is stored until its next loading to Valencia. The terrestrial transport is carried out by truck from the port of Valencia to the hinterland and vice versa. The IoT tracking sensors installed in the container will monitor the following data:

- Real-time location of the cargo;
- Cargo conditions in terms of temperature, humidity;
- Safety conditions (e.g. container opening and bump detection, etc.).

To support the development of the demonstrator the following information is shared:

- COSCO service lines between the Mediterranean region and Asia or the Black Sea region for developing an inter-modal asset tracking between Valencia and Piraeus ports. Container shipment is arranged to follow the route with pre-defined time schedules for its loading and unloading.

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- Inland transport management and data to move the container from inland to Valencia port and vice versa. The container will follow pre-defined inland movements and transport documents will be managed.

2.3 Valencia Port

Testbed Background

The port of Valencia is the sixth largest port in Europe in terms of traffic volume, being the second port in the Mediterranean region in import, export and transhipment operations. With a multipurpose operative, the port is equipped with infrastructures and equipment suited for different types of traffic such as containers, roll-on/roll-off (RO-RO), solid and liquid bulk, cruises and ferries. As a consequence, the flows of information in and around the port are highly complex and involve numerous different players. Within one year, around 2 million trucks, 3 million containers, 3 thousand trains and almost 8 thousand vessels enter and exit the port area. The port is managed by the Port Authority of Valencia, the public body responsible for running and managing two other state-owned ports along an 80km stretch of the Mediterranean coast in Eastern Spain: Sagunto and Gandía. Around the Port Authority, there is a wide range of stakeholders such as terminal operators, maritime agencies, freight and ship forwarders, carriers, third-party logistics providers and other institutional bodies that constitute the Port Community ecosystem.

Within the Port Community, Fundación Valenciaport was created as the Research and Innovation centre of the Port of Valencia with the aim of transferring the technology and knowledge created in research projects to enhance the operative of real-life applications in the sector whilst gathering and covering the new needs of the port community stakeholders. Fundación Valenciaport, which is located at the premises of the Port Authority of Valencia, has at its disposal its laboratory infrastructures and the global facilities of the Port of Valencia, including IT facilities (local data centre and servers), systems and platforms.

Technology Perspective

The ICT infrastructure of the port of Valencia is composed of different systems and platforms that are continuously evolving towards Service Oriented Solutions architecture through the development and exploitation of Edge and Cloud Computing techniques, Application Programming Interfaces (APIs) and distributed data centres. Within the ICT infrastructure, the most relevant IT systems of the port of Valencia are: the Port Communty System (ValenciaportPCS), the Automatic Identification System (AIS) and PI OSIsoft system. Valenciaport PCS is an open and neutral electronic platform based on web services that allow a safe and smart information exchange between public and private agents. ValenciaportPCS offers more than 20 transactional and informative services to more than 600 companies and public entities through the integration of different modules focused on different stakeholders and agents importers, exporters, freight forwarders, customs agents, carriers, shipping agents, port authorities and other bodies, customs, inspection bodies, hauliers, rail operators, container terminals and depots. Automatic Identification System (AIS) is an automatic tracking system used for geopositioning vessels at the maritime segment. The information provided by the AIS includes a unique identification for the vessel, position, course and speed. The Port of Valencia manages their own AIS system. PI OSIsoft system is an M2M

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platform used to store, structure, process and analyse big amounts of data generated by IoT systems, devices and sensors of the Port of Valencia. The main sources of data ingested by the PI system are related to: (i) terrestrial accesses through the connection with SCADA and (ii) environmental sensors. In a short term, the PI system will interact with Valenciaport PCS and the AIS for sharing information related to terrestrial accesses and environmental domains. In terms of connectivity, the Port of Valencia offers an ultra high- speed fibre optics network that acts as the backbone node for providing wired access connectivity and exchanging data between the different IoT devices and IT systems deployed at the port facilities. Additionally, in the wireless domain, the Port of Valencia also offers full LTE and NB-IoT coverage thanks to the deployment of the commercial network by different network operators. Within the port area, the different container terminals also have private LTE networks deployed for optimizing their internal operative.

Relation with iNGENIOUS Project

As part of the iNGENIOUS project, the Port of Valencia will be the scenario for the demonstration of four different use cases (*Improve Drivers' Safety with MR and Haptic Solutions*, *Inter-modal Asset Tracking via IoT and Satellite*, *Situational Understanding in Smart Logistics Scenarios and Supply Chain Ecosystem Integration*). For the demonstration of the drivers' safety use case, Nokia will deploy a small 5G private network for providing mmWave connectivity at the Port of Valencia in order to control ASTI's AGV remotely by means of mixed reality and haptic solutions. For the deployment of the 5G node, both non-standalone and stand-alone configurations will be explored according to the current technology readiness levels, i.e. first focusing on NSA and then on SA. The port area to be covered with the gNodeB (base station) is depicted in Figure 3:

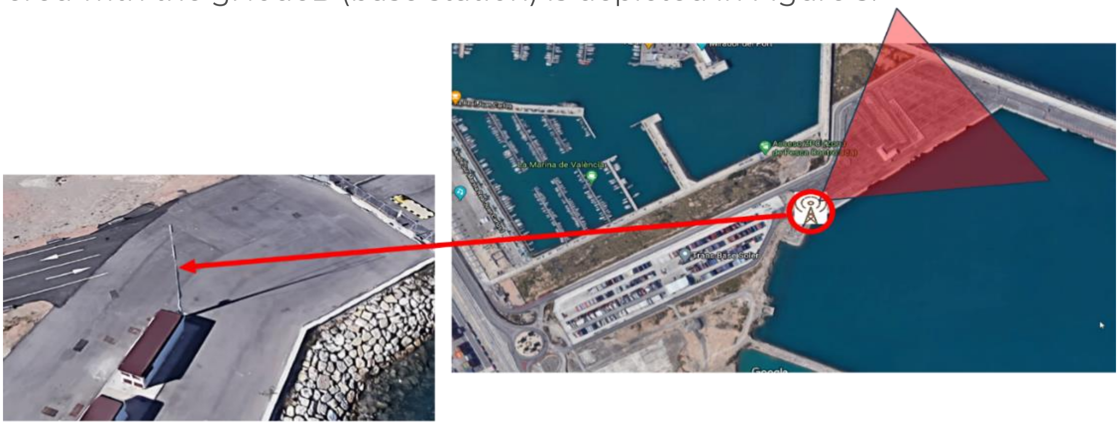

Figure 3: gNB location at the Port of Valencia

Regarding the inter-modal asset tracking use case, FV will ease access to the physical infrastructure of the Port of Valencia, where COSCO ship will load and discharge the iNGENIOUS container for its transportation in both maritime and terrestrial segments. On the other hand, for the demonstration of the situational-understanding use case, FV will grant access to the physical infrastructure of the Port of Valencia for tracking trucks inside the port facilities as well as enable the ingestion of data from Valenciaport PCS and PI System OSIsoft (Valencia Port M2M platform). The tracking of trucks and the integration of the data will contribute to validate the situational understanding models developed in the use case. The ingestion of data will be linked to the arrival and departure of vessels in all terminals as well as to the arrival and departure of trucks at the different accesses of the port

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of Valencia. The list of accesses and berthing areas for all terminals at the Port of Valencia is shown in Figure 4.

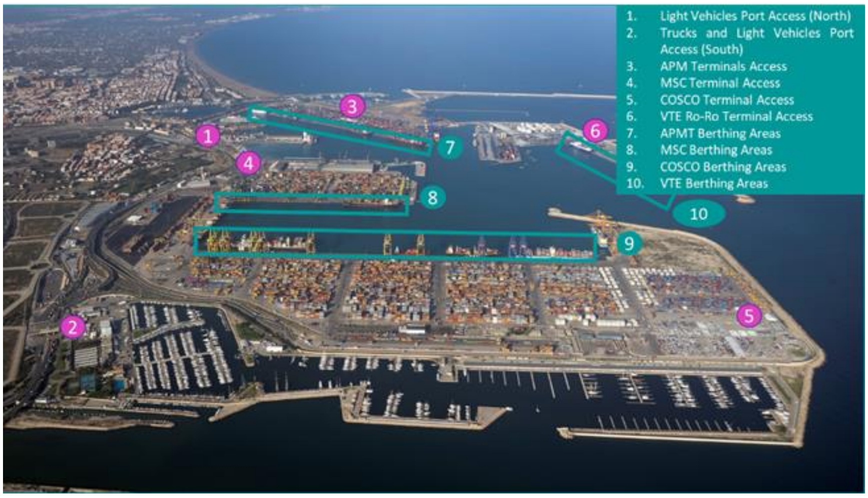

Figure 4: Accesses and berthing areas at the Port of Valencia

Finally, for the demonstration of the use case for the Supply Chain Ecosystem Integration, FV will leverage their available computational resources for enabling the integration of PI OSIsoft system with the iNGENIOUS Data Virtualization Layer and the deployment of a local Hyperledger Fabric network able to exchange gate access data events with the Cross-DLT layer solution leveraged in iNGENIOUS, i.e. TRUST-OS.

2.4 Livorno Port

Testbed Background

The port of Livorno (AdSPMTS) is classified as a Big Regional (first level port) along the Tyrrhenian corridor, by the Freight Leaders Club, and is a multipurpose port, namely it is equipped with infrastructures and equipment that can berth any vessel and handle any type of goods traffic (LO-LO, RO-RO, bulk solids and liquids, new cars, cruises, ferries, timber and timber derivatives, machinery etc.). The port of Livorno includes a wide range of actors/stakeholders, building up the port of Livorno ecosystem: *Terminal Operators, Maritime Agencies, Freight Forwarders, Ship Forwarders, Institutional Bodies, Carriers, Third-party Logistics Providers and Technology providers.* As ICT innovation is considered the key enabler for Industry 4.0 processes and pave the ground to sustainable growth, the Port Network Authority of the North Tyrrhenian Sea has started a strategic collaboration (founding the Joint Lab - http://jlab-ports.cnit.it) with the Italian National Inter-university Consortium of Telecommunications (CNIT) to define and implement a "Digital Agenda" for the port network. Joint Lab operates within the maritime/transportation field. On one hand, the port infrastructure can be used by CNIT for R&D purposes, on the other hand the port communities (both industries and institutions) will be offered a roadmap for innovating their equipment, functions and processes.

Technology Perspective

The information systems of the port of Livorno are currently undergoing a deep digital transformation. To respond to new port requirements, an approach based

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on the usage of monolithic and technological solutions difficult to scale, has been descoped. The current ICT stack has been redesigned by means of Service Oriented Architectures (with Enterprise Service Bus and Data Virtualization Layer components) based on cloud solutions. The most relevant IT infrastructures are: Tuscan Port Community System (TPCS) and Monitoring and Control Application (MonI.C.A). TPCS is a specialized IT system, based on cloud technologies and open via web services to the users, that acts as the Administration-to-Administration (A2A), Business-to-Administration (B2A) and Business-to-Business (B2B) one-stop-shop for facilitating port operators and port community stakeholders/members in their daily. TPCS allows communication with the Integrated Automation Customs Excise (AIDA). MonI.C.A is a real-time monitoring and control platform characterized by a multi-level architecture capable of integrating, aggregating and elaborating information coming from a multiplicity of information sources (including PMIS, the Italian National Single Window), operating at distinct information levels and belonging to distinct functional contexts (on-the-field sensors, embedded sensors, IoT, Middleware HW/SW systems, specialized IT systems, etc.). In Figure 5, the Port of Livorno ICT stack is presented:

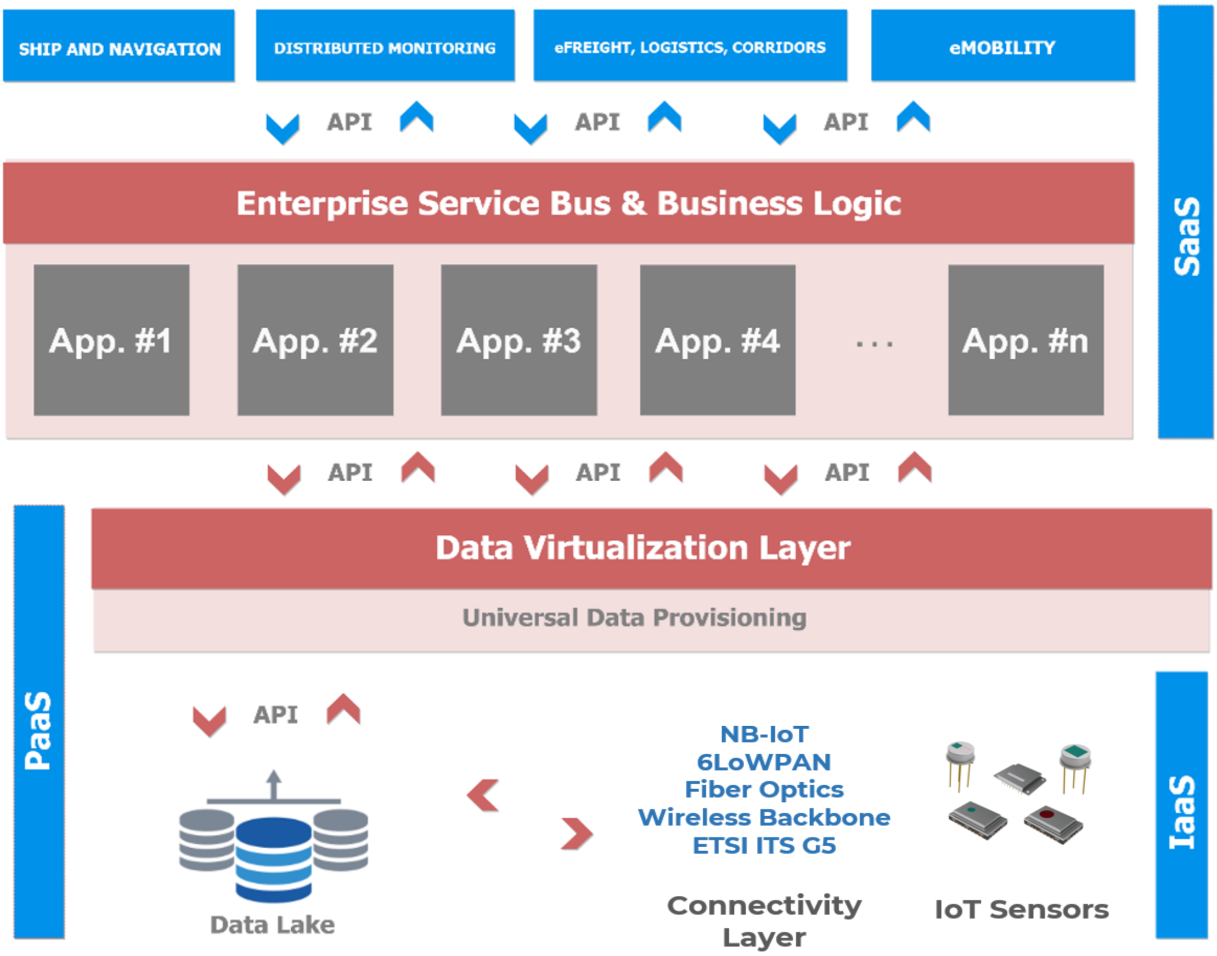

Figure 5: Port of Livorno ICT stack

From the connectivity perspective, the Port of Livorno offers a full 4G/NB-IoT coverage of its area as well as wired connectivity based on fiber optics acting as a backbone both for the interconnection with physical IoT devices and for the interconnection with different IT systems.

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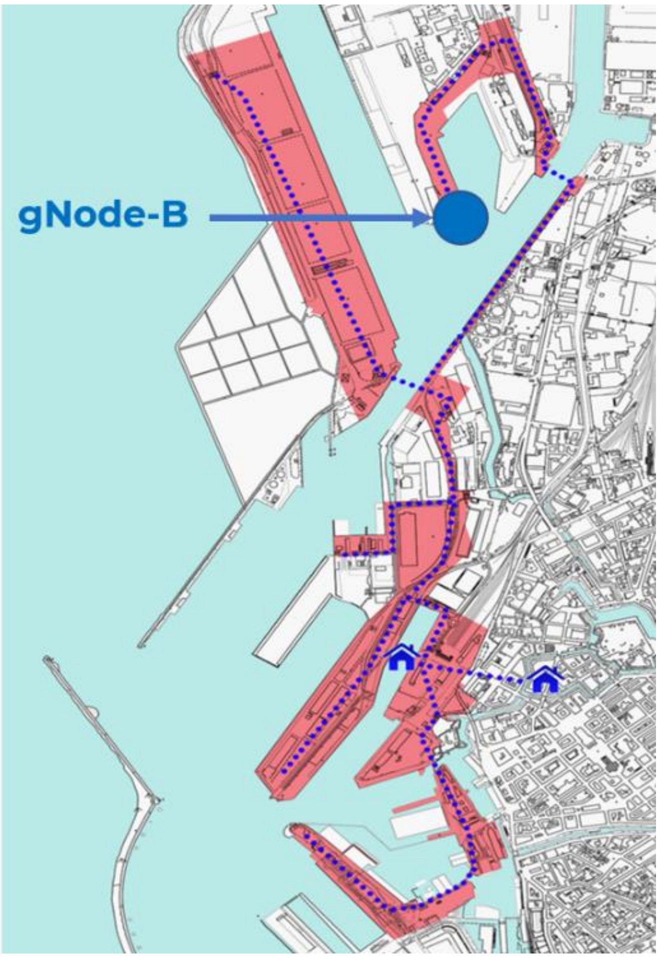

Figure 6: Fiber optics backbone and 5G equipment

By means of this physical backbone, data generated by in-field devices/sensors and IT systems can be gathered and processed in the Joint Lab facility so that innovative services can be tested in a real environment. Moreover, a 5G connectivity based on a private network (NSA configuration) could also be exploited during use cases demonstrations and validations (this will be further investigated during the project life-time). Currently, the gNode-B is installed close to one of the two major Container Terminals from the seaport, as depicted in Figure 6.

Relation with iNGENIOUS Project

As depicted in the figure below, the port of Livorno includes different type of terminals (e.g. RO-RO, general cargo, passengers, containers, etc.). Considering that within iNGENIOUS project, the Port of Livorno is involved in the demonstration of three different use cases (transportation platforms monitoring, situational-understanding and supply chain integration), two major container terminals have been considered for this purpose: green area, orange area and purple area as it can be seen in Figure 7.

During the demonstration of the situational-understanding use case, trucks flows will be considered for both terminals and predictive models for the TTT estimation within the Port of Livorno will be applied accordingly. This will allow the identification of factors that could potentially affect the trucks' turn around time (TTT) while the truck is within the seaport area. For the supply chain integration use case instead, the demonstration and validation will take place in the Joint Lab, according to available computational resources. In this case, the primary goal will

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be the instantiation (in terms of hosting) of the architectural components such as OneM2M platform, IOTA private network and Data Virtualization Layer, although further assets are expected to be deployed in the staging environment (e.g. other M2M platforms used in the project and eventually part of MANO framework).

Figure 7: areas under test for the use case demonstration

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3 PoC - Automated Robots with Heterogeneous Networks

This chapter includes details as far as the overall use case implementation plan is concerned.

In this use case, we focus on automatic robot control as a scenario of industrial automation. Robot arms are widely used in automated manufacturing, and they can also be used in other operations of the supply chain, such as waste elimination and inventory control. In addition, robotics can be exploited in the distribution phase, in shipping, packaging and retail. Smart robots are equipped with sensing and computation power, which allows them to be context-aware. Several fixed and mobile robots operate cooperatively to perform complicated tasks. Moreover, collaborative robots are robots that interact with humans in close proximity. Given these points, the realization and testing of Tactile Internet and integration with a robot/IoT network is critical. Therefore, the experimental routines for the PoCs are here defined.

3.1 ASTI Factory & TUD Testbed

In this chapter setup, development and integration activities are listed and discussed. TUD's testbed will be used for demonstrating the flexible radio access network (RAN) integrated with the 5G core network and MANO slice manager. By contrast, the demonstration planned to be shown in ASTI's facilities will employ in the RAN a full 5G compatible modem, the remaining components and setup are identical. The network core that will be used in both testbeds is fully based on the 5G standard. The Vodafone Chair for Mobile Communication Systems at TU Dresden focuses not only on the theoretical development and analysis of concepts and algorithms, but also on implementation and evaluation of mobile communication technology. The main task of TUD's testbed is to create a real-time capable test environment, which enables the fast and easy demonstration and the testing of prototypes of wireless communication systems on real devices and under real conditions. TUD's testbed consists of outdoor base stations on the institute roof and indoor access points in the building, as well as facilities in laboratory. A central technical room for the cloud computing servers and the core switches is located in a dedicated laboratory area. All stations are connected via optical fibers. Together with the extensive infrastructure, the testbed allows real communication conditions to be mapped experimentally in a holistic system context. The presence of permanently installed base stations and access points allows remote-controlled experiments for reference and test purposes, especially before hardware is transferred from project partners to Dresden for joint research projects. The flexible architecture can also be easily expanded with additional devices as needed and allows experiments with both "standard" mobile radio solutions and special systems such as Massive-MIMO and mmWave. The TU Dresden has a license from the Federal Network Agency to use experimental radio from 3.7 to 3.8 GHz with up to 5 watts of

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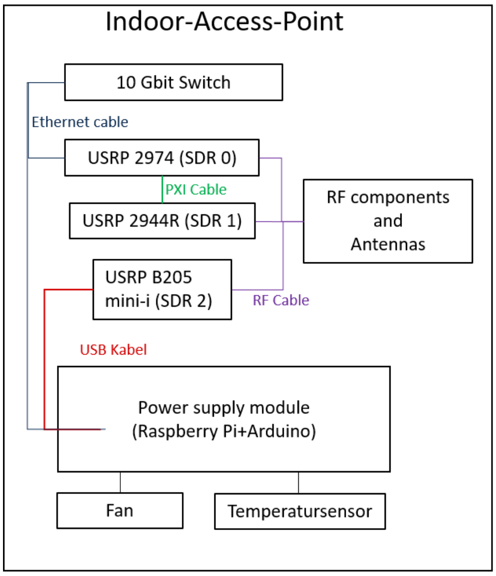
effective radiated power in the campus area. The indoor access points of the testbed will be a part of the demo for iNGENIOUS. There are six indoor access points mounted in the hallway of the chair. An indoor access point is a remotely controllable and flexibly configurable radio access point, which consists of three software-defined radio (SDR) devices, RF components, a 10Gbit network switch, power supply units and a control board. All components in an Indoor Access Point are shown in Figure 8.



RF Capabilities:

- Frequency range: 10 MHz to 6 GHz
- Bandwidth: 160 MHz
- Output power: 0.5 W
- Antenna: 4x4 MIMO

Processing Capabilities:

- CPU: Intel i7, 16 GB RAM, 256 GB SSD
- FPGA: 2 x Xilinx Kintex 7-410T

Figure 8: Components of the indoor access point

The three SDR devices are an USRP 2974 (SDR0), USRP 2944 RIO (SDR1), and USRP B205 mini-I (SDR2). The USRP 2974 from the manufacturer National Instruments contains an integrated computer (CPU) and programmable RF with FPGA. It can map a wide variety of radio applications, including a base station or a terminal from a mobile communication system such as WiFi and LTE. The second radio USRP 2944 RIO is connected to the USRP 2974 via a PCIe interface. It can emulate a smartphone or user terminal and also enables dual-connectivity experiments, which are especially important for high reliability applications. Each transmitter port of the USRPs is connected to a 0.5-Watt amplifier in order to guarantee sufficient output power for long-range radio transmission. In each access point there is 4x4 MIMO antenna connected for transmission and reception. The maximum gain of the broadband antenna is 6 dBi. A 10 Gbps fiber optic switch is also used in each indoor access point. The selected network switch obtains synchronization information, such as precision time protocol (PTP), from the network and forwards the corresponding synchronization signal to the SDR devices. All the six indoor access points were mounted in the corridor of the institute building to allow for a realistic test scenario (see Figure 9). Figure 10 shows the network structure of TUD'S testbed. The USRPs in each Access Point is connected via 1 Gbps ethernet to a fiber optic switch. The optical switches are routed via optic fibers to a first main switch 1 (Cisco c9500-48y4c). The main switch 1 is directly connected to the second identical main switch 2 via a 100 Gbps optic link. The second Cisco switch was installed in a separate server room, which can provide a cooling and an uninterruptible power supply.

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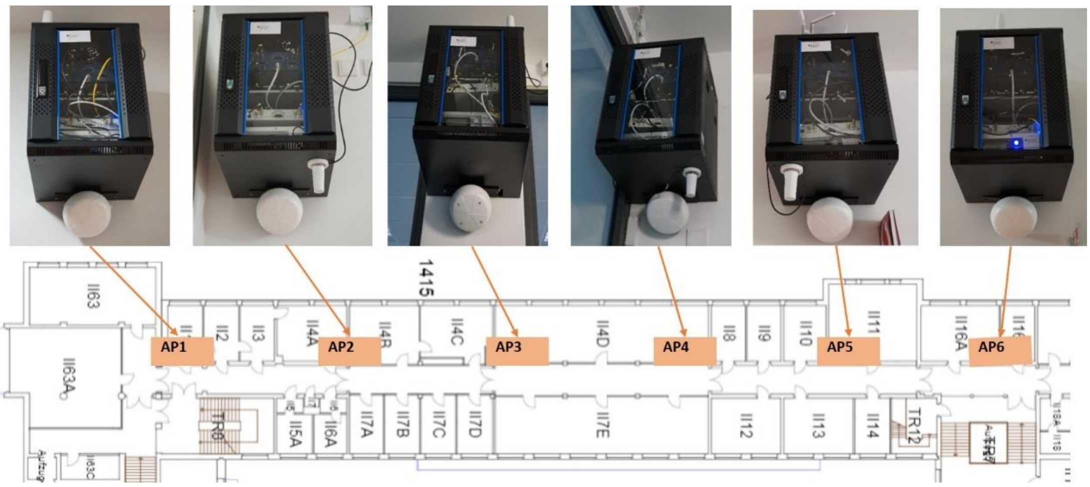

Figure 9: Overview of the indoor access points in the corridor

All the switches in the testbed are managed, to make sure that the users from different groups can work in separated virtual LANs. A Main server was connected to the main switch 2 via a 100 Gbps directly attached copper cable. The high-performance server provides virtual machines as experiment controllers, and functions as a gateway server to enable access to the Internet and to provide remote desktop access for the users.

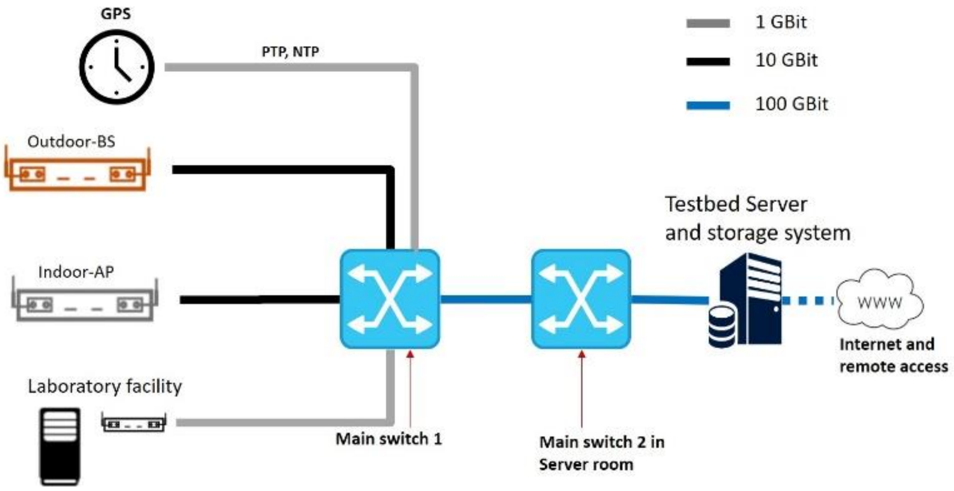

Figure 10: Network infrastructure

The controller of the access points has Microsoft Windows 10 as the operating system. The development tool NI LabVIEW NXG 5.1 is also available in the testbed. The Linux operating systems such as Ubuntu 20.4 can be also installed on the PCs in the testbed if required. The other open-source development tools like GNU Radio, are compatible with our testbed platform.

3.1.1 EXISTING COMPONENTS SETUP

In this chapter, planning of the required resources, facilities, connectivity and logistics for the setup of the testbed is performed, and it will support the use case deployment. The main activities that have been identified, are listed below:

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Test Bed	Resource Type	Resource Description	Required Setup Activities	Responsible Partner	Start Date (Planned)	Due Date (Planned)	Ready to be used?
ASTI	Asset	Acquire Frequency license 3.5 GHz	ASTI_UC1_setup_01	ASTI	15/09/2021	20/09/2021	No
ASTI	Infrastructure	Installation of gNB RRH with 220v to power up RRH PSU. RRH installation on wall with coverage of area under test	ASTI_UC1_setup_02	ASTI	15/09/2021	20/09/2021	No
ASTI	Infrastructure	Allocation of power and small cabinet for installing Supermicro server and gNB BBU unit.	ASTI_UC1_setup_03	ASTI	15/09/2021	20/09/2021	No
ASTI	Infrastructure	Installation of GPS cabling from BBU to outside for GPS signal acquisition	ASTI_UC1_setup_04	ASTI	15/09/2021	20/09/2021	No
ASTI	Infrastructure	Configuration of gNB and 5GC SA	ASTI_UC1_setup_05	CUMUCORE	20/09/2021	25/09/2021	No
ASTI	Infrastructure	Access Point with Fujitsu Esprimo Q956 and NI USRP 2974, 2944R. Integration of device I/O with flexible connectivity (application, link-layer, PHY/MAC, and RF) Test at TUD	ASTI_UC1_setup_06	TUD	01/09/2021	31/10/2021	No
ASTI	Infrastructure	User Equipment (Type 1) including Laptop Thinkpad x230 + NI USRP RIO for communication with access point over the air. Test at TUD	ASTI_UC1_setup_07	TUD	N/A	N/A	Yes
ASTI	Infrastructure	User Equipment (Type 2) including Fujisu mini PCs + sensors and USRP 205i mini for implementation of IoT sensor. Test at TUD	ASTI_UC1_setup_08	TUD	N/A	N/A	Yes
ASTI	Infrastructure	Wireless Gateway with Laptop Thinkpad x230 + NI USRP 2944R for implementation of Gateway interfaces. Test at TUD	ASTI_UC1_setup_09	TUD	N/A	N/A	Yes
ASTI	Infrastructure	RAN Controller and Edge Computing for integration of core network functions and MANO	ASTI_UC1_setup_10	TUD	01/07/2022	30/11/2022	No

Table 1: Use case - setup activities

3.1.2 INGENIOUS CHECKLIST

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In this chapter development and integration activities are listed and discussed.

3.1.2.1 Development Activities List and Planning

According to the main list of required resources and facilities, the following development activities have been defined for this use case:

Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
ASTI	Software	Cross-layer MANO: basic lifecycle management of 5G Core Network Functions (packaging, instantiation)	ASTI_UC1_development_01	N/A	NXW	01/05/2021	30/10/2021
ASTI	Software, API, Data Source	Cross-layer MANO: data collection and processing from NWDAF	ASTI_UC1_development_02	ASTI_UC1_development_01	NXW	01/07/2021	31/11/2021
ASTI	Software	Cross-layer MANO: manual scaling of 5G Core Network Function(s)	ASTI_UC1_development_03	ASTI_UC1_development_01	NXW	01/10/2021	31/12/2021
ASTI	Software	Cross-layer MANO: automated management of edge applications and functions	ASTI_UC1_development_04	ASTI_UC1_development_01	NXW	01/11/2021	31/03/2021
ASTI	Software, Data Source	Cross-layer MANO: automated slice configuration through 5G Core NSM	ASTI_UC1_development_05	ASTI_UC1_development_01	NXW	01/12/2021	31/03/2022
ASTI	Software, Data Source	Cross-layer MANO: basic AI/ML slice optimization algorithms (automated scaling)	ASTI_UC1_development_06	ASTI_UC1_development_01 ASTI_UC1_development_02	NXW	01/02/2022	31/05/2022
ASTI	Hardware	Fivecomm 5G Modem (F5GM) development	ASTI_UC1_development_07		5CMM	01/10/2020	30/09/2021
ASTI	Hardware	Fivecomm 5G Modem (F5GM) enhancements	ASTI_UC1_development_08	ASTI_UC1_development_07	5CMM	01/10/2021	15/01/2022 (tentative)
ASTI	Hardware	Nokia AWQE gNB indoors 3.5Ghz	ASTI_UC1_development_09	N/A	CMC	15/09/2021	20/09/2021
ASTI	Hardware	Supermicro server for 5GC	ASTI_UC1_development_10	N/A	CMC	15/09/2021	20/09/2021
ASTI	Software	5GC network functions	ASTI_UC1_development_11	N/A	CMC	20/09/2021	25/09/2021

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ASTI	Communications, interface	Baseband-Radio frontend interface	ASTI_UC1_development_12	N/A	TUD	01/05/2021	30/08/2021
ASTI	Device, Communications	Type-1 device: FPAG implementation of device side PHY/MAC framework	ASTI_UC1_development_13	N/A	TUD	01/06/2021	31/10/2021
ASTI	Device, Communications	Type-2 device: software implementation of device side PHY/MAC framework	ASTI_UC1_development_14	N/A	TUD	01/07/2021	31/10/2021
ASTI	Device, application interface, software	I/O device-application interface	ASTI_UC1_development_15	N/A	TUD	01/07/2021	31/10/2021
ASTI	Communications, interface	Data-link – MAC interface	ASTI_UC1_development_16	ASTI_UC1_development_13, ASTI_UC1_development_14	TUD	01/09/2021	31/12/2021
ASTI	Network	Flexible-IoT gateway: Type-2 and Type-1 PHY/MAC translation	ASTI_UC1_development_17	ASTI_UC1_development_13, ASTI_UC1_development_14	TUD	01/11/2021	31/03/2022
ASTI	Network	Access-point with type-1 PHY/MAC and multiuser support	ASTI_UC1_development_18	ASTI_UC1_development_13	TUD	01/11/2021	31/03/2022
ASTI	Communications, interface	Network-Data-link interface	ASTI_UC1_development_19	ASTI _UC1_development_18	TUD	01/02/2022	30/04/2022
ASTI	Communications, interface	Application-Network interface	ASTI_UC1_development_20	N/A	TUD	01/01/2022	30/04/2022

Table 2: Use case - development activities

3.1.2.2 Integration Activities List and Planning

According to the main list of required resources, facilities and development activities expected to be performed for the use case implementation, the following integration activities have been identified in order to support the use case deployment and validation:

Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
ASTI	Software, Infrastructure	Automated deployment and management (basic + scaling) of 5G Network Functions as VNFs through MANO	ASTI_UC1_integration_01	N/A	NXW, CMC	01/10/2021	28/02/2022
ASTI	Software, API	Interaction between cross-layer MANO and NWDAF	ASTI_UC1_integration_02	ASTI_UC1_integration_01	NXW, CMC	01/11/2021	31/1/2022

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ASTI	Software, Infrastructure	Automated deployment of edge applications and functions through MANO	ASTI_UC1_integration_03	ASTI_UC1_integration_01	NXW, ??	01/02/2022	31/04/2022
ASTI	Software, API	Interaction between cross-layer MANO and 5G Core NSM	ASTI_UC1_integration_04	ASTI_UC1_integration_01	NXW, CMC	01/03/2022	31/05/2022
ASTI	Hardware	Fivecomm 5G modem pre-trials in CMC laboratory to integrate with their core	ASTI_UC1_integration_05	N/A	5CMM, CMC?	01/10/2021	30/11/2021
ASTI	Hardware	Fivecomm 5G modem integration with ASTI AGVs for trials	ASTI_UC1_integration_06	ASTI_UC1_integration_05	5CMM, ASTI?	15/01/2022 (tentative)	???
ASTI	Device, communications	Integration of device I/O with flexible connectivity (application, link-layer, PHY/MAC, and RF)	ASTI_UC1_integration_07	N/A	TUD	01/09/2021	31/10/2021
ASTI	Network	Integration of IoT-gateway with Type-2 devices	ASTI_UC1_integration_08	ASTI_UC1_integration_07	TUD	01/03/2022	30/04/2022
ASTI	Network	Integration of access point with Type-1 devices and IoT-gateway	ASTI_UC1_integration_09	ASTI_UC1_integration_08	TUD	01/03/2022	30/04/2022
ASTI	Network	RAN setup with multiple access points	ASTI_UC1_integration_10	ASTI_UC1_integration_09	TUD	01/05/2022	30/06/2022
ASTI	Network	Integration of core network functions	ASTI_UC1_integration_11	ASTI_UC1_integration_10	TUD	01/07/2022	31/08/2022
ASTI	Network	Integration of MANO	ASTI_UC1_integration_12	ASTI_UC1_integration_11	TUD	01/09/2022	30/11/2022

Table 3: Use case - integration activities

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3.2 Test Cases Definition

In this chapter, a list of test cases to be performed during the lifetime of the project are presented for proper use case validation. According to a common template, the test cases are listed below:

Test Case Id	UC1_TC_01
Responsible Partner	TUD
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Hardware and software implementation
Prerequisites	• Availability of hardware in TUD's testbed • Availability of spectrum license
Type of test	Performance evaluation with respect to FER, E2E latency, and run-time reconfiguration of the SDR implementation
Reference standards used	N/A
Test Environment	Test will be conducted in a laboratory environment
Input to the system	N/A
Output of the system	FER, E2E latency measurements
Data involved in the test	Random data generated for testing connectivity and performing measurements
System requirements covered	UC1_SR_08
Related KPIs	Data rate for IoT sensors, data rate per camera, data rate per robot, E2E latency for environmental sensors, E2E latency for remote control, E2E latency for human-in -loop control, E2E control-in-loop control,
Are UC's users involved in the test?	No
Who will perform the test?	TUD
Test Steps	• Setup transmitter and receiver nodes • Select PHY parameters • Perform tests and evaluate if the selected parameters suffice the requirements
Risks	Selected PHY parameters meet the requirements only partially
Mitigation	Search parameters that attend all requirements within the possible performance that can be delivered by the SDR modules
Expected result	• E2E latency for remote control: 10-50 ms • E2E latency for control/human-in -loop control: 1-5 ms • Data rate per robot: 10 Mbps • Data rate for IoT sensors: 0.1 Mbps
Actual result	to be determined
Passed/Failed	to be determined

Table 4: Use case - UC1_TC_01

Test Case Id	UC1_TC_02
Responsible Partner	TUD
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Core network integration testing
Prerequisites	• Flexible RAN up and running (passed in test case #1) • Availability of spectrum license • Access to Testbed network in TUD premises integrated with core network (provided by CUMUCORE)
Type of test	Compatibility of integration with core network.
Reference standards used	N/A
Test Environment	Laboratory
Input to the system	N/A
Output of the system	E2E latency measurement, connectivity between devices within the network
Data involved in the test	Test data for latency measurements
System requirements covered	UC1_SR_08
Related KPIs	Data rate for IoT sensors, Data rate per robot, E2E latency
Are UC's users involved in the test?	No

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Who will perform the test?	TUD, CUMUCORE
Test Steps	• Application unit and function test • Interface testing • Core network integration testing
Risks	Incompatible integration with core network
Mitigation	N/A
Expected result	• E2E latency for remote control: 10-50 ms • E2E latency for control/human-in -loop control: 1-5 ms • Data rate per robot: 10 Mbps • Data rate for IoT sensors: 0.1 Mbps
Actual result	to be determined
Passed/Failed	to be determined

Table 5: Use case - UC1_TC_02

Test Case Id	UC1_TC_03
Responsible Partner	TUD
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Gateway test
Prerequisites	• Flexible RAN up and running (passed in test case #1) • Implementation of different RAN standards in SDR up and running • Availability of spectrum license
Type of test	Testing the gateway that will do the translation between different RAN standards
Reference standards used	N/A
Test Environment	The test is planned to be executed in two different environments: • Local laboratory environment • TUD testbed
Input to the system	Test data for checking the translation
Output of the system	N/A
Data involved in the test	Random data generated for testing connectivity and perform measurements
System requirements covered	UC1_SR_08
Related KPIs	Data rate for IoT sensors
Are UC's users involved in the test?	No
Who will perform the test?	TUD
Test Steps	• Setup transmitter and receiver nodes with different RAN standards • Perform tests and evaluate if the selected RANs are able to receive and forward the sensor information correctly
Risks	Increase latency to levels beyond the necessary KPI
Mitigation	N/A
Expected result	Successful data transmission with different RAN standards
Actual result	to be determined
Passed/Failed	to be determined

Table 6: Use case - UC1_TC_03

Test Case Id	UC1_TC_04
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Onboard industrial IoT network slice templates and NF descriptors
Prerequisites	• Cross-layer MANO components up and running • Vertical Service and Network slice template are available 5G Core NF descriptors (VNFD) are available
Type of test	Functional test
Reference standards used	• 3GPP 5G Network Resource Model (28.540) • GSMA Generic Network Slice Template (NG.116) • ETSI NFV SOL006
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed

	• ASTI testbed
Input to the system	Network Slice Templates and related 5G Core Network Service and VNF Descriptors to be uploaded through cross-layer MANO Graphical User Interfaces (GUIs)
Output of the system	Network Slice Templates and related 5G Core Network Service and VNF Descriptors to be uploaded through cross-layer MANO Graphical User Interfaces (GUIs)
Data involved in the test	Descriptors and templates of network slices and related resources in json format, packaged as software archives
System requirements covered	UC1_SR_06
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW
Test Steps	• The 5G Core NF descriptors (VNFDs) are onboarded in the cross-layer MANO NFV&MEC Resource Orchestrator through its GUI • The 5G Core Network Service descriptor (NSD) is onboarded in the cross-layer MANO NFV&MEC Resource Orchestrator through its GUI • Network Slice templates are onboarded in the cross-layer MANO NSMF through its GUI • Vertical Slice blueprints and descriptors are onboarded In the cross-layer MANO VSMF through Its GUI • All of the templates and descriptors are available in the cross-layer MANO (i.e. they can be queried and visualized through the GUI) and are ready to be used for instantiating new vertical services and network slices
Risks	No risks foreseen
Mitigation	N/A
Expected result	The onboarded network slice templates and related descriptors are successfully maintained by the cross-layer MANO to create new vertical services and network slices instances
Actual result	to be determined
Passed/Failed	to be determined

Table 7: Use case - UC1_TC_04

Test Case Id	**UC1_TC_05**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Automated deployment of industrial IoT network slice instance
Prerequisites	UC1_TC_04 successfully executed Cross-layer MANO has access to the virtualized infrastructure where to deploy the slice NFs
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Management and Orchestration (3GPP TS 28.530) • ETSI NFV SOL005
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Interaction with the cross-layer MANO GUI to trigger the creation of a new network slice based on an existing template or descriptor
Output of the system	Network slice and 5G Core NF are automatically created and instantiated by the cross-layer MANO (and visible in the GUI), and ready to be used
Data involved in the test	None
System requirements covered	UC1_SR_03, UC1_SR_07, UC1_SR_08
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW

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Test Steps	• An available Vertical Service Descriptor or Network Slice Template is selected to be used as reference for the creation of the new slice instance • A new vertical service or network slice instance is requested through the cross-layer MANO GUI, providing all of the additional attributes and constraints required that may be required for the specific slice (QoS, number of devices, location, etc) • The cross-layer MANO automatically process the request and translate it into a set of automated operations to deploy/allocate the required slice resources, including the 5G Core virtualized NFs • For this, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to allocate and configure the required slice resources
Risks	No risks foreseen
Mitigation	N/A
Expected result	A new network slice instance is created, all the related network and computing resources have been allocated and the 5G Core NFs are up and running and ready to be configured. Moreover, the cross-layer MANO maintains the information related to the network slices instance and the NFs information related.
Actual result	to be determined
Passed/Failed	to be determined

Table 8: Use case - UC1_TC_05

Test Case Id	**UC1_TC_06**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Automated termination of industrial IoT network slice instance
Prerequisites	UC1_TC_05 successfully executed
Type of test	Functional test Integration test
Reference standards used	3GPP 5G Management and Orchestration (3GPP TS 28.530) ETSI NFV SOL005
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Interaction with the cross-layer MANO GUI to trigger the termination/deletion of an existing network slice instance
Output of the system	Resources used for the network slice instance are deallocated and network slice is deleted (and no more visible in the GUI)
Data involved in the test	None
System requirements covered	UC1_SR_03, UC1_SR_07, UC1_SR_08
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW
Test Steps	• An existing vertical service or network slice instance is requested to be terminated from the cross-layer MANO GUI • The cross-layer MANO automatically process the request and translate it into a set of automated operations to release and de-allocate all of the involved network and compute resources, including the 5G Core virtualized NFs • For this, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to release the related slice resources
Risks	No risks foreseen
Mitigation	N/A
Expected result	The network slice instance is terminated, all the related network and computing resources have been de-allocated and

	the 5G Core virtualized NFs are terminated and the related virtual resources freed. Moreover, the cross-layer MANO still maintains the information of the network slice instance terminated.
Actual result	to be determined
Passed/Failed	to be determined

Table 9: Use case - UC1_TC_06

Test Case Id	**UC1_TC_07**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Manual scaling of an industrial IoT network slice instance
Prerequisites	UC1_TC_05 successfully executed
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Network Resource Model (28.541) • 3GPP 5G Management and Orchestration (28.530) • GSMA Generic Network Slice Template (NG.116) • ETSI NFV SOL006
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Interaction with the cross-layer MANO GUI to trigger the scaling of an existing network slice instance
Output of the system	Resources used for the network slice instance are correctly scaled accordingly to the given input. The GUI shows the updates on the slices manually scaled terms of resource.
Data involved in the test	None
System requirements covered	UC1_SR_07
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, TUD, ASTI
Test Steps	• An existing vertical service or network slice instance is requested to be scaled from the cross-layer MANO GUI • The cross-layer MANO automatically processes the request and translates it into a set of automated operations to either resize the involved network and compute resources or creating new 5GC NF instances (e.g. UPF) • For this reason, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to resize the related slice resources (if needed to execute new NF(s))
Risks	No risks foreseen
Mitigation	N/A
Expected result	The network slice instance is modified, all the related network and the 5G Core virtualized NFs are modified (or new ones are created) and the related virtual resources as well
Actual result	to be determined
Passed/Failed	to be determined

Table 10: Use case - UC1_TC_07

Test Case Id	**UC1_TC_08**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Automatic slice configuration through 5GC NSM
Prerequisites	UC1_TC_05 successfully executed
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Network Resource Model (28.541)

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	• 3GPP 5G Management and Orchestration (28.530)
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Automated interaction of cross-layer MANO with the 5GC NSM NF to trigger the slice configuration
Output of the system	The network slice is automatically configured by the NSM NF
Data involved in the test	None
System requirements covered	UC1_SR_07
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, CMC
Test Steps	• After the creation of the network slice instance (TC_05) the cross-layer MANO automatically requests to configure a network slice through the 5GC NSM NF according to the network slice template requirements (e.g. QoS, etc) • The 5GC NSM applies all the actions to perform all the required configurations • The 5GC NSM notifies the cross-layer MANO about the slice configuration updates
Risks	No risks foreseen
Mitigation	N/A
Expected result	The network slice is correctly configured by the NSM NF as requested.
Actual result	to be determined
Passed/Failed	to be determined

Table 11: Use case - UC1_TC_08

Test Case Id	**UC1_TC_09**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Automated deployment of industrial IoT network slice instance and of an edge robot control application as part of network slice instance
Prerequisites	UC1_TC_04 successfully executed
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Network Resource Model (28.541) • 3GPP 5G Management and Orchestration (28.530) • ETSI NFV SOL006
Test Environment	The test is planned to be executed in three different environments: • Local lab environment; • TUD testbed; • ASTI testbed.
Input to the system	Interaction with the cross-layer MANO GUI to trigger the creation of a new network slice based on an existing template or descriptor that includes robot control edge application as part of the slice.
Output of the system	Network slice and 5G Core NFs are automatically created and instantiated by the cross-layer MANO (and visible in the GUI), and ready to be used. As part of the network slice instance, resources used for the deployment of the edge robot control application are correctly allocated to the edge compute location.
Data involved in the test	None
System requirements covered	UC1_SR_04
Related KPIs	N/A
Are UC's users involved in the test?	No

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Who will perform the test?	NXW, TUD, ASTI
Test Steps	• An available Vertical Service Descriptor or Network Slice Template is selected to be used as reference for the creation of the new slice instance and the deployment of a control robot application • A new vertical service or network slice instance is requested through the cross-layer MANO GUI, providing all of the additional attributes and constraints required that may be required for the specific slice (QoS, number of devices, location, etc) and for the robot control application • The cross-layer MANO automatically processes the request and translate it into a set of automated operations to deploy/allocate the required slice resources, including the 5G Core virtualized NFs. Moreover, the cross-layer MANO component interacts with the edge controllers to allocate and deploy the required computing resources at the edge.
Risks	No risks foreseen
Mitigation	N/A
Expected result	A new network slice instance is created, all the related network and computing resources have been allocated and the 5G Core NFs are up and running and ready to be configured. As part of network slice instance, a robot control application is deployed at the edge and the related computing resources have been correctly allocated. Moreover, the cross-layer MANO maintains the information related to the network slices instance and the related NFs information.
Actual result	to be determined
Passed/Failed	to be determined

Table 12: Use case - UC1_TC_09

Test Case Id	**UC1_TC_10**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Automated termination of industrial IoT network slice instance and of edge robot control application as part of network slice instance
Prerequisites	UC1_TC_09 successfully executed
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Network Resource Model (28.541) • 3GPP 5G Management and Orchestration (28.530) • ETSI NFV SOL006
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Interaction with the cross-layer MANO GUI to trigger the termination/deletion of an existing network slice instance and the termination of a running control robot application as part of network slice instance
Output of the system	Resources used for the network slice instance are deallocated and network slice is deleted (and no more visible in the GUI). As part of network slice instance, resources used for the deployment of the edge robot control application are correctly deallocated\removed from the edge of the network as well
Data involved in the test	None
System requirements covered	UC1_SR_04
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, TUD, ASTI
Test Steps	• An existing vertical service or network slice instance is requested to be terminated from the cross-layer MANO GUI.

	• The cross-layer MANO automatically processes the request and translates it into a set of automated operations to release and de-allocate all of the involved network and compute resources, including the 5G Core virtualized NFs and the control robot application computing resources at the edge. • For this, the cross-layer MANO components interact with the network and compute infrastructure and edge controllers and managers to release the related slice resources.
Risks	No risks foreseen
Mitigation	N/A
Expected result	The network slice instance is terminated, all the related network and computing resources have been de-allocated and the 5G Core virtualized NFs are terminated and the related virtual resources freed. As part of network slice instance, also the computing resources at the edge are de-allocated. Moreover, the cross-layer MANO still maintains the information of the network slice instance terminated.
Actual result	to be determined
Passed/Failed	to be determined

Table 13: Use case - UC1_TC_10

Test Case Id	**UC1_TC_11**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Subscription to either Network Data Analytics Function (NWDAF) or Network Exposure Function (NEF) for collecting monitoring and analytics information related to the network slices, NFs and UEs.
Prerequisites	UC1_TC_05 successfully executed NEF/NWDAF up and running
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Network Data Analytics Services (29.520) • 3GPP 5G Network Exposure Function Northbound APIs (29.522)
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Subscription to network slice(s) and/or NF(s) and/or UE(s) monitoring or analytics information from the NWDAF\NEF
Output of the system	Reception from NWDAF\NEF of either periodic or event-based notifications based on the subscription(s) performed. The received data is then stored as part of the cross-layer MANO monitoring facility
Data involved in the test	None
System requirements covered	UC1_SR_03, UC1_SR_05, UC1_SR_07, UC1_SR_08
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, CMC
Test Steps	• The cross-layer MANO automatically sends a subscription request to the NWDAF\NEF, specifying the subscription type and optional filters based on the monitoring requirements expressed in the Network Slice Template • As response, the NEF\NWDAF confirms the subscription to the cross-layer MANO • Then, the NEF\NWDAF sends, depending on subscription type and filters, either periodically or on an event basis notification to the cross-layer MANO
Risks	No risks foreseen

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Mitigation	N/A
Expected result	The cross-layer MANO is able to receive the notifications it is subscribed to.
Actual result	to be determined
Passed/Failed	to be determined

Table 14: Use case - UC1_TC_11

Test Case Id	**UC1_TC_12**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Deletion of either Network Data Analytics Function (NWDAF) or Network Exposure Function (NEF) active subscription.
Prerequisites	UC1_TC_11 successfully executed 5G Core NEF/NWDAF up and running
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Network Data Analytics Services (29.520) • 3GPP 5G Network Exposure Function Northbound APIs (29.522)
Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Unsubscription to network slice(s) and/or NF(s) and/or UE(s) monitoring or analytics information from the NWDAF\NEF
Output of the system	Stop of reception of notifications of an existing subscription
Data involved in the test	None
System requirements covered	UC1_SR_03, UC1_SR_05, UC1_SR_07, UC1_SR_08
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, CMC
Test Steps	• the cross-layer MANO automatically sends a unsubscription request to the NWDAF\NEF, specifying the subscription identifier (e.g. as part of the network slice instance termination procedure) • As response, the NEF\NWDAF confirms the subscription removal to the cross-layer MANO • Then, the NEF\NWDAF stops to send notification related to such subscription to the cross-layer MANO.
Risks	No risks foreseen
Mitigation	N/A
Expected result	The cross-layer MANO is no longer able to receive the notifications related to the just removed subscription
Actual result	to be determined
Passed/Failed	to be determined

Table 15: Use case - UC1_TC_12

Test Case Id	**UC1_TC_13**
Responsible Partner	NXW
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Automated slice scaling triggered by AI\ML platform using NWDAF data.
Prerequisites	UC1_TC_05 successfully executed UC1_TC_11 successfully executed
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Network Data Analytics Services (29.520) • 3GPP 5G Network Exposure Function Northbound APIs (29.522)

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Test Environment	The test is planned to be executed in three different environments: • Local lab environment • TUD testbed • ASTI testbed
Input to the system	Data collected from the NWDAF\NEF subscriptions and ML slice optimization algorithm output
Output of the system	Resources used for the network slice instance are correctly scaled accordingly to the given input. The GUI shows the updates on the slices automatically scaled terms of resource.
Data involved in the test	None
System requirements covered	UC1_SR_07, UC1_SR_11
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, CMC
Test Steps	• AI\ML platform collects data related to the network slice instances, network functions and UEs. • The slice optimization ML algorithm detects the needs of scaling the network slice instance identifying affected critical network instance attributes (e.g. maximum number of UEs in a network slice instance, QoS requirements, NFs instances, etc) • The cross-layer MANO, based on the identified critical attributes by ML algorithm, automatically processes the request and translates it into a set of automated operations to either resize the involved network and compute resources or creating new 5GC NF instances (e.g. UPF) • For this reason, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to resize the related slice resources (if needed to execute new NF(s))
Risks	No risks foreseen
Mitigation	N/A
Expected result	The cross-layer MANO correctly and automatically scales with the support of the AI\ML platform the network slice instance.
Actual result	to be determined
Passed/Failed	to be determined

Table 16: Use case - UC1_TC_13

Test Case Id	**UC1_TC_14**
Responsible Partner	ASTI
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Robot interface connectivity
Prerequisites	N/A
Type of test	Functional test
Reference standards used	• Ethernet
Test Environment	The test is planned to be executed in two different environments: • Local lab environment • ASTI testbed
Input to the system	N/A
Output of the system	N/A
Data involved in the test	None
System requirements covered	UC1_SR_01
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	ASTI
Test Steps	• Test connectivity between robot arms, AGVs, camera and sensor using a standard Ethernet connection to the 5G modem

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Risks	No risks foreseen
Mitigation	N/A
Expected result	The devices in the robot can utilize standard Ethernet RJ45 ports to connect to 5G communication module and connect to 5G network.
Actual result	to be determined
Passed/Failed	to be determined

Table 17: Use case - UC1_TC_14

Test Case Id	**UC1_TC_15**
Responsible Partner	ASTI
Use Case	UC1 - Automated robots with heterogeneous networks (Industrial IoT)
Test case description	Test of API for application development
Prerequisites	N/A
Type of test	Functional test
Reference standards used	N/A
Test Environment	The test is planned to be executed in two different environments: • Local lab environment • ASTI testbed
Input to the system	list of the available devices and functions to interact with the devices, GUI tools for devices visualization, monitoring and controlling
Output of the system	N/A
Data involved in the test	None
System requirements covered	UC1_SR_10
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	ASTI, TUD
Test Steps	• Applications development should be run via APIs that abstract the underlying network resources and operations. • APIs provide tools to reserve resources and specify the application requirements. • Testing functions that enable interacting with end-user interface
Risks	No risks foreseen
Mitigation	N/A
Expected result	Simple application implemented using the available devices and the connectivity among them should be demonstrated
Actual result	to be determined
Passed/Failed	to be determined

Table 18: Use case - UC1_TC_15

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4 Demo - Improved Drivers' Safety with MR and Haptic Solutions

This chapter includes details as far as the overall use case implementation plan is concerned.

In this use case we focus on an ASTI AGV driving teleoperation with virtual reality and haptics solutions. Automated Guided Vehicles are widely used in industrial scenarios in which they are a key part on the supply chain. Within technologies such as virtual reality and haptic devices we can implement a teleoperation in which a pilot, making use of a cockpit, a haptic glove and virtual reality glasses, can drive an AGV from a remote place. This teleoperation allows a safe driving performance in which potentially hazardous situations given on industrial environment can be avoided.

4.1 Valencia Port Testbed

For the implementation of the tests defined in the following sections of this document, two phases have been identified.

The first phase takes place in Madrid, at the Nokia headquarters where the ToD and the immersive cockpit will be developed. To implement tests at the laboratory, a small AGV is needed. The Summit XL, from Robotnik, is a modular and highly customizable mobile robot platform, ideal for research and development applications (see Figure 11):

Figure 11: Summit XL mobile robot

The second phase takes place at Valencia Port, where the ToD is performed with an industrial AGV, TriBOT, manufactured by ASTI.

This AGV belongs to their tractor line, it can work around traffic, transporting several trolleys at the same time.

Figure 12: TriBOT AGV

In order to elaborate the demonstration of the Tele-operated Driving (ToD) in Valencia Port, three main points are taken in account as the main challenges of the use case:

- The deployment 5G millimetre wave Antenna at Valencia Port: to accomplish with the KPIs described in D2.1 from WP2 a deployment of a 5G mmW antenna is needed. With this configuration we ensure the system requirements in terms of levels of coverage for the AGV operating in the area.

- Immersive cockpit implementation: in accordance with T3.3 from WP3 an immersive cockpit must be designed and implemented in order to accomplish with the requirements of the testbed. The immersive remote indoor cockpit provides telepresence and controls the AGV wirelessly, by an operator fully equipped with forehead Virtual Reality glasses (for the 3D view & dashboard of the real scene), haptic gloves,

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along with a steering wheel and pedals. Through the haptic gloves, tactile sensations are felt by the operator during the mission and in the event of immediate risks. The immersive remote indoor cockpit is additionally in charge for the translation of these sensations to a far-edge MEC via fixed fibre (IP access) and/or 5G Hotspot (FastMile 5G Gateway: mmW modems) wirelessly. Haptic gloves will also capture hand-arm displacement during the remote driving and register biometric signals that provide information about driver's psychological and physical status.

- ASTI AGV integration: automated routes are defined for the transport of goods in the industrial area. AGV follows this close loop programmed route with stopovers for the loading/unloading of assigned bays. The AGV is equipped with 4 cameras with a field of view of 120° each. By placing them in a position forming a squared structure, a 360° view can be formed. In addition, the AGV also integrates proximity sensors to monitor its route and automatically detect objects. Furthermore, it is equipped with a 5G millimetre wave modem for uplink and downlink communication to a private mmW next generation NodeB base station. Those devices permit sending real-time positioning and status updates to the network infrastructure.

4.1.1 EXISTING COMPONENTS SETUP

In this chapter planning of the required resources, facilities, connectivity and logistics for the setup of the testbed is performed, supporting the use case deployment. The main activities that have been identified, are listed in the table below:

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Test Bed	Resource Type	Resource Description	Required Setup Activities	Responsible Partner	Start Date (Planned)	Due Date (Planned)	Ready to be used?
VALENCIA	Infrastructure	Port facilities	VALENCIA_UC2_setup_01	FV	N/A	N/A	Yes
VALENCIA	Infrastructure/Network	ICT Infrastructure	VALENCIA_UC2_setup_02	FV	N/A	N/A	Yes
VALENCIA	Infrastructure/Network	Commercial LTE coverage	VALENCIA_UC2_setup_03	NOK	N/A	N/A	Yes
VALENCIA	Infrastructure	5G mm Wave Antenna (will be tested in Madrid)	VALENCIA_UC2_setup_04	NOK	N/A	N/A	Yes
VALENCIA	Equipment	5G mm Wave Modem (will be tested in Madrid)	VALENCIA_UC2_setup_05	NOK	N/A	N/A	Yes
VALENCIA	Equipment	Prototype AGV (will be tested in Madrid)	VALENCIA_UC2_setup_06	NOK	N/A	N/A	Yes
VALENCIA	Equipment	Virtual Reality Glasses - OCULUS QUEST. (will be tested in Madrid)	VALENCIA_UC2_setup_07	NOK	N/A	N/A	Yes
VALENCIA	Equipment	Cockpit hardware device (will be tested in Madrid)	VALENCIA_UC2_setup_08	NOK	N/A	N/A	Yes

Table 10: Use case - setup activities

4.1.2 INGENIOUS CHECKLIST

In this chapter development and integration activities are listed and discussed.

4.1.2.1 Development Activities List and Planning

According to the main list of required resources and facilities, the following development activities have been identified for this use case:

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Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
VALENCIA	Software	Haptic gloves gesture recognition	VALENCIA_UC2_development_01	N/A	5CMM,UPV	01/05/2021	30/06/2021
VALENCIA	Software	Remote driving with gesture recognition for Robotnik AGVs	VALENCIA_UC2_development_02	VALENCIA_UC2_development_01	5CMM,UPV	01/05/2021	30/06/2021
VALENCIA	Software	Remote driving with gesture recognition for ASTI AGVs	VALENCIA_UC2_development_03	VALENCIA_UC2_development_01	5CMM,UPV	01/09/2021	31/01/2022
VALENCIA	Software	Development of generic interface to send feedback from the cockpit to the haptic gloves	VALENCIA_UC2_development_04	N/A	5CMM	01/05/2021	30/09/2021
VALENCIA	Software	Development of interface for feedback transmission from Robotnik AGVs to the cockpit	VALENCIA_UC2_development_05	VALENCIA_UC2_development_04	5CMM	01/05/2021	30/09/2021
VALENCIA	Software	Development of interface for feedback transmission from ASTI AGVs to the cockpit	VALENCIA_UC2_development_06	VALENCIA_UC2_development_04	5CMM	01/09/2021	31/03/2022
VALENCIA	Hardware	Fivecomm 5G Modem (F5GM) development	VALENCIA_UC2_development_07	N/A	5CMM	01/10/2020	30/09/2021
VALENCIA	Hardware	Fivecomm 5G Modem (F5GM) enhancements	VALENCIA_UC2_development_08	VALENCIA_UC1_development_07	5CMM	01/10/2021	15/01/2022 (tentative)
VALENCIA	Hardware	5G AGV connectivity via Askey Modem (testbed in Madrid)	VALENCIA_UC2_development_10	N/A	NOK	01/05/2021	30/05/2021
VALENCIA	Software	Code implementation of teleoperation driving (will be tested in Madrid)	VALENCIA_UC2_development_12	N/A	NOK	01/05/2021	30/05/2021
VALENCIA	Software	Code implementation of Obstacle Avoidance through Depth Camera (will be tested in Madrid)	VALENCIA_UC2_development_13	N/A	NOK	01/06/2021	30/09/2021

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VALENCIA	Hardware	3D design attaches for devices on Robotnik AGV (will be tested in Madrid)	VALENCIA_UC2_development_14	N/A	NOK	01/05/2021	30/09/2021
VALENCIA	Software	Design immersive APP (will be tested in Madrid)	VALENCIA_UC2_development_15	N/A	NOK	01/05/2021	30/06/2021
VALENCIA	Software	Communication video streaming Robotnik AGV-APP (will be tested in Madrid)	VALENCIA_UC2_development_16	VALENCIA_UC2_development_15	NOK	01/06/2021	30/09/2021
VALENCIA	Software	Communication video streaming ASTI AGV-APP (will be tested in Madrid)	VALENCIA_UC2_development_17	VALENCIA_UC2_development_15	NOK	01/07/2021	30/09/2021

Table 11: Use case - development activities

4.1.2.2 Integration Activities List and Planning

According to the main list of required resources, facilities and development activities expected to be performed for the use case implementation, the following integration activities have been identified in order to support the use case deployment and validation:

Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
VALENCIA	Data Sources	Assess the availability of fiber optic connectivity for the core network deployed at the Port of Valencia.	VALENCIA_UC2_integration_01	N/A	FV	01/07/2021	31/08/2021
VALENCIA	Data Sources	Supervise the installation and deployment of equipment at the Port of Valencia.	VALENCIA_UC2_integration_02	N/A	FV	01/07/2021	01/11/2021
VALENCIA	Hardware	Area definition for deployment in Valencia Port	VALENCIA_UC2_integration_03	N/A	NOK	01/03/2021	1/04/2021

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VALENCIA	Hardware	Definition of radio antenna location at Valencia Port	VALENCIA_UC2_integration_04	VALENCIA_UC2_integration_03	NOK	01/03/2021	1/04/2021
VALENCIA	Hardware	Authorization to use 5 MHz in the 2600 MHz band in Valencia Port area for experimentation	VALENCIA_UC2_integration_05	VALENCIA_UC2_integration_04	NOK	01/03/2021	1/05/2021
VALENCIA	Hardware	Antenna equipment selection and ordered for Valencia Port	VALENCIA_UC2_integration_06	VALENCIA_UC2_integration_05	NOK	01/04/2021	1/05/2021
VALENCIA	Hardware	Antenna equipment integration at Valencia Port	VALENCIA_UC2_integration_07	VALENCIA_UC2_integration_06	NOK	01/09/2021	1/11/2021
VALENCIA	Software	Antenna equipment configuration at Valencia Port	VALENCIA_UC2_integration_08	VALENCIA_UC2_integration_07	NOK	01/09/2021	1/11/2021
VALENCIA	Software	Haptics integration with Robotnik AGV teleoperation (will be tested in Madrid)	VALENCIA_UC2_integration_09	N/A	NOK	01/05/2021	10/09/2021
VALENCIA	Software	Teleoperation integration with ASTI AGV	VALENCIA_UC2_integration_10	N/A	NOK, ASTI	01/09/2021	1/11/2021
VALENCIA	Software	Haptics integration with ASTI AGV teleoperation	VALENCIA _UC2_integration_11	VALENCIA _UC2_integration_10	NOK, ASTI	01/09/2021	1/11/2021

Table 12: Use case - integration activities.

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4.2 Test Cases Definition

In this chapter, a list of test cases to be performed during the lifetime of the project are presented for a proper use case validation. According to a common template, the test cases are listed below:

Test Case Id	UC2_TC_01
Responsible Partner	NOKIA
Use Case	Improve Drivers' Safety with MR and Haptic Solutions
Test case description	Perform measurements of 5G millimeter wave coverage in Segovia
Prerequisites	Deployment of 5G mmW antenna simulation of throughput in UL and DL for TCP and UDP traffic in Segovia
Type of test	Software implementation and hardware deployment. Performance testing
Reference standards used	N/A
Test Environment	5G millimeter wave antenna deployment at open area. Device connectivity through the antenna.
Input to the system	UL data
Output of the system	DL data
Data involved in the test	Time measurement of UL and DL latency
System requirements covered	UC2_SR_03, UC2_SR_11
Related KPIs	Coverage, end-to-end latency
Are UC's users involved in the test?	No. It is a previous integration test of the 5G millimeter antenna
Who will perform the test?	NOKIA
Test Steps	• 5G millimeter antenna deployment • Connected device test • Device 5G connectivity through the antenna • UL data request • DL data request • Latency measurement
Risks	• Inadequate selected equipment • Electricity power connection damaged • Electricity power cut • 5G antenna pole damaged • 5G antenna stolen
Mitigation	• Inadequate selected equipment: good definition of the test requirements and iterative design process. Experience in 5G and telecommunication technologies; • Electricity power connection damaged: proper installation of the underground structure; • Electricity power cut: proper selection of the area environment; • 5G antenna pole damaged: consider a wide range of different atmospheric conditions such as wind or rain. • 5G antenna stolen: secured area.
Expected result	Low latency measurements.
Actual result	to be determined
Passed/Failed	to be determined

Table 13: Use case - UC2_TC_01

Test Case Id	UC2_TC_02
Responsible Partner	NOKIA
Use Case	Improve Drivers' Safety with MR and Haptic Solutions
Test case description	AGV teleoperation via 5G millimeter wave in Segovia
Prerequisites	Test case UC2_TC_01 AGV
Type of test	Software implementation. Performance testing.

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Reference standards used	N/A
Test Environment	5G millimeter antenna deployment in Segovia open area. Cockpit installation at NOKIA laboratory. MEC simulation at NOKIA laboratory. AGV provided with ROS middleware connected via 5G thought the antenna. Common VPN connectivity of the cockpit, the simulated MEC and the AGV, to allow communication between them.
Input to the system	Teleoperation commands from the cockpit (speed, twist)
Output of the system	AGV desired trajectory and ACK messages.
Data involved in the test	Analysis of the message flow performance in terms of latency and lost packages.
System requirements covered	UC2_SR_02, UC2_SR_04, UC2_SR_06, UC2_SR_09
Related KPIs	Availability, coverage, data rate, end-to end latency, mobility, reliability
Are UC's users involved in the test?	Yes, the teleoperation pilot.
Who will perform the test?	NOKIA
Test Steps	• Pilot at NOKIA laboratory driving AGV through the cockpit. • AGV operating at Segovia area. • Analysis of command messages and ACK messages during the performance.
Risks	Risks due to Test Case UC2_TC_01 AGV crash
Mitigation	Risks due to Test Case UC2_TC_01: Test Case UC2_TC_01 mitigation section. AGV crash: slow driving and supervision of the AGV during the whole performance.
Expected result	Low latency. Proper AGV teleoperation
Actual result	to be determined
Passed/Failed	to be determined

Table 14: Use case - UC2_TC_02

Test Case Id	**UC2_TC_03**
Responsible Partner	NOKIA
Use Case	Improve Drivers' Safety with MR and Haptic Solutions
Test case description	Immersive cockpit
Prerequisites	Camara installation on AGV Cockpit (wheel, gearbox, pedals) Virtual reality glasses
Type of test	Software implementation. Performance testing
Reference standards used	N/A
Test Environment	Teleoperation of the AGV
Input to the system	Video streaming from the AGV Telemetry data from the AGV Hardware interaction pilot-cockpit (pedals and wheel movement)
Output of the system	Visualization of the video in VR Visualization of the driving parameters in VR Software commands from the cockpit
Data involved in the test	All the data related with the driving interaction. There are two different branches. Video: UDP video messages from camara to VR App. Driving commands: UPD messages from cockpit to AGV.
System requirements covered	UC2_SR_07, UC2_SR_08, UC2_SR_12
Related KPIs	Availability, reliability
Are UC's users involved in the test?	Yes, the teleoperation pilot.
Who will perform the test?	NOKIA
Test Steps	• Installation of the cockpit hardware. • Software caption of the hardware interaction with the cockpit. • Virtual reality app implementation to visualize the video and different driving parameters. • Set-up the communication MEC-virtual reality glasses, via VPN. • Set-up the communication cockpit-MEC, via VPN.
Risks	Cockpit or virtual reality glasses damaged

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	Virtual reality app hanged
Mitigation	Cockpit or virtual reality glasses damaged: adequate use of the hardware. Correct packaging of the different parts. Virtual reality app hanged: iterative code development.
Expected result	Good performance of the visualization of the AGV environment through virtual reality glasses. Good software capture of the hardware interaction of the cockpit.
Actual result	to be determined
Passed/Failed	to be determined

Table 15: Use case - UC2_TC_03

Test Case Id	**UC2_TC_04**
Responsible Partner	Fivecomm
Use Case	Improve Drivers' Safety with MR and Haptic Solutions
Test case description	Fivecomm's cockpit integration for AGV teleoperation
Prerequisites	-
Type of test	Software implementation, integration, and performance testing.
Reference standards used	N/A
Test Environment	The tests will be carried out in Fivecomm's headquarters at UPV campus, and in the port of Valencia
Input to the system	The user will send the commands to the AGV from the cockpit using the haptic gloves and VR glasses
Output of the system	The commands received will be translated to AGV movements. There will also be communication in the other direction to control the haptic gloves and to send the video so the user can see in a VR interface the virtual gloves and the real video sent from the AGV.
Data involved in the test	Information captured by the gloves (3D position) and the glasses and sent by the cockpit, processed orders to the AGV, and video coming from the AGV back to the cockpit.
System requirements covered	UC2_SR_02, UC2_SR_03, UC2_SR_04, UC2_SR_07, UC2_SR_09
Related KPIs	Availability, data rate, end-to end latency, mobility, reliability
Are UC's users involved in the test?	Yes, the pilot in the cockpit wears the glasses and gloves.
Who will perform the test?	Fivecomm and UPV
Test Steps	• Integration of the haptic gloves and VR glasses in Fivecomm's cockpit (local). • Creation of commands and connection with the server. • AGV configuration and connection to the server. • AGV command creation and transmission. • Video configuration back to the cockpit.
Risks	AGV crash, cockpit or virtual reality glasses damaged.
Mitigation	AGV sensors used to detect objects in the sourroundings. Stop commands with easy and quick access. Drive with caution and in wide spaces.
Expected result	Successful teleoperation with fully integrated VR glasses and haptics gloves. Haptic feedback from the AGV. Future integration with Nokia.
Actual result	to be determined
Passed/Failed	to be determined

Table 16: Use case - UC2_TC_04

Test Case Id	**UC2_TC_05**
Responsible Partner	NOKIA
Use Case	Improve Drivers' Safety with MR and Haptic Solutions
Test case description	Perform measurements of 5G millimeter wave coverage in Valencia Port
Prerequisites	Deployment of 5G mmW antenna simulation of throughput in UL and DL for TCP and UDP traffic in Valencia Port
Type of test	Software implementation and hardware deployment. Performance testing
Reference standards used	N/A
Test Environment	5G millimeter wave antenna deployment at open area. Device connectivity through the antenna

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Input to the system	UL data
Output of the system	DL data
Data involved in the test	Time measurement of UL and DL latency
System requirements covered	UC2_SR_03, UC2_SR_11
Related KPIs	Coverage, end-to-end latency
Are UC's users involved in the test?	Yes
Who will perform the test?	NOKIA
Test Steps	• Connected device test • Device 5G connectivity through the antenna • UL data request • DL data request • Latency measurement
Risks	• Inadequate selected equipment • Electricity power connection damaged • Electricity power cut • 5G antenna pole damaged • 5G antenna stolen
Mitigation	• Inadequate selected equipment: good definition of the test requirements and iterative design process. Experience in 5G and telecommunication technologies • Electricity power connection damaged: proper installation of the underground structure • Electricity power cut: proper selection of the area environment • 5G antenna pole damaged: consider a wide range of different atmospheric conditions such as wind or rain. • 5G antenna stolen: secured area
Expected result	Low latency measurements.
Actual result	to be determined
Passed/Failed	to be determined

Table 17: Use case - UC2_TC_05

Test Case Id	**UC2_TC_06**
Responsible Partner	NOKIA
Use Case	Improve Drivers' Safety with MR and Haptic Solutions
Test case description	ASTI AGV teleoperation via 5G millimeter wave in Burgos
Prerequisites	Test case UC2_TC_02 Test case UC2_TC_03 ASTI AGV
Type of test	Software implementation. Performance testing.
Reference standards used	N/A
Test Environment	5G millimeter antenna Cockpit installation at ASTI laboratory MEC simulation at ASTI laboratory ASTI AGV 5G connectivity through the mmWave antenna Common VPN connectivity of the cockpit, the simulated MEC and the AGV, to allow communication between them.
Input to the system	Teleoperation commands from the cockpit (speed, twist)
Output of the system	AGV desired trajectory and ACK messages
Data involved in the test	Analysis of the message flow performance in terms of latency and lost packages.
System requirements covered	UC2_SR_02, UC2_SR_04, UC2_SR_06, UC2_SR_09
Related KPIs	Availability, coverage, data rate, end-to end latency, mobility, reliability
Are UC's users involved in the test?	Yes, the teleoperation pilot
Who will perform the test?	NOKIA, ASTI
Test Steps	• AGV 5G connectivity through mmW antenna. • Teleoperation test.

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	• Pilot at ASTI laboratory driving AGV through the cockpit. • AGV operating at ASTI area. • Analysis of command messages and ACK messages during the performance.
Risks	AGV crash
Mitigation	AGV crash: slow driving and supervision of the AGV during the whole performance.
Expected result	Low latency. Proper AGV teleoperation
Actual result	to be determined
Passed/Failed	to be determined

Table 18: Use case - UC2_TC_06

Test Case Id	**UC2_TC_07**
Responsible Partner	NOKIA
Use Case	Improve Drivers' Safety with MR and Haptic Solutions
Test case description	ASTI AGV teleoperation via 5G millimeter wave in Valencia Port
Prerequisites	Test case UC2_TC_03 Test case UC2_TC_05 Test case UC2_TC_06
Type of test	Software implementation. Performance testing.
Reference standards used	N/A
Test Environment	5G millimeter antenna Cockpit installation at Valencia Port MEC configuration at Valencia Port ASTI AGV 5G connectivity through the mmWave antenna Common VPN connectivity of the cockpit, the simulated MEC and the AGV, to allow communication between them.
Input to the system	Teleoperation commands from the cockpit (speed, twist)
Output of the system	AGV desired trajectory and ACK messages
Data involved in the test	Analysis of the message flow performance in terms of latency and lost packages.
System requirements covered	UC2_SR_02, UC2_SR_04, UC2_SR_06, UC2_SR_09
Related KPIs	Availability, coverage, data rate, end-to end latency, mobility, reliability
Are UC's users involved in the test?	Yes, the teleoperation pilot
Who will perform the test?	NOKIA, ASTI
Test Steps	• Remote Pilot driving AGV through the cockpit. • AGV operating at Valencia Port defined area. • Analysis of command messages and ACK messages during the performance.
Risks	AGV crash
Mitigation	AGV crash: slow driving and supervision of the AGV during the whole performance.
Expected result	Low latency. Proper AGV teleoperation
Actual result	to be determined
Passed/Failed	to be determined

Table 19: Use case - UC2_TC_07

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5 PoC - Transportation Platforms Health Monitoring

The transportation platform UC has the objective of showing that asset health tracking can lead to low operational costs and high asset availability. It uses new data-based services provided by low-power edge distributed networks and intelligent sensor modules installed in the transportation platforms. Specifically, this UC will enable the monitoring of health for transportation platforms with a particular focus on railway transportation. The monitoring of health conditions will reside in the design of neuromorphic sensors able to gather and process data on the edge of the network while bringing low cost and power and high life expectancy. For enabling the exchange of data between smart edge sensors and platforms, near continuous connectivity to the edge will be enabled by exploiting terrestrial and non-terrestrial access networks. All this will take place in a secure infrastructure that allows remote attestation of edge devices, securely updating them as well as protected information exchange between the on-board sensors and the control centre.

5.1 Livorno Port Testbed

A demonstration of "Rail-Health" is challenging in "Real-Life" conditions because rail defects are not casual occurrences, nor easily generated. Testing with real defects has been done on certified test tracks, and the results will be presented. The testbed demonstration will show "Lab-Like" simulated fault situations. The demonstration will consist of various system sub-components, specifically Network Security, Payload Encryption, and IP Signal Transmission via Satellite Connectivity. For the demonstration setup with BI, all these components will be present on an FPGA board. The sensor will be connected to the FPGA and a static railway component simulation produces senor input. For this first demonstration, the data transmission from the sensor device to the control centre (i.e., a Linux application running on a separate machine) will be carried out over wired ethernet. However, in a later project stage, the integration of the BI sensor with e.g., 5G or satellite modems might be considered to demonstrate a real global-scale communication stack. At Livorno, a representative demonstrator to illustrate "Rail-Health" components and workings will be presented.

In the following sections the existing components as well as development and integration activities for the implementation of the PoC are listed and discussed.

5.1.1 EXISTING COMPONENTS SETUP

In this section, we discuss the setup/configuration activities of the PoC. Particularly, the table below includes a list and planning of required resources, facilities, connectivity and logistics for a proper set-up of the UC3 PoC.

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At the core of the transportation use case, there is the IoT gateway server provided by NCG. This gateway has to be set up to support communication with edge sensors and provide connectivity via terrestrial and non-terrestrial communication channels. To this end, integration with the platform provided by BI is planned. On the operating system side, a micro-kernel-based OS called M^3 already exists. It will provide encryption and authentication services. It currently runs in a lab at BI using a synthesized, FPGA-based hardware board.

For implementing the non-terrestrial communication in a later project stage, SES provides one of their satellites, including the necessary ground station. In the domain of satellite communication there also already exists a light weight, compact, transportable terminal which enables broadband connectivity almost anywhere on earth. Conceptually, this portable satellite terminal is envisioned to be connected to the sensor edge, potentially using a mesh network. For simulating the central control centre that evaluates the sensor data sent by the edge sensors, iDR provides for demonstration a set of standard rack-mounted servers. These machines will run Linux on them. The use case foresees that, on the edge device side, components like modem and IoT gateway are combined to send the railway health data received from the sensor to the central control centre. The edge device runs M^3 as an operating system and encrypts all payload sent to the data centre which uses a Linux-hosted monitoring framework. Depending on the radio coverage in the area in that the respective transportation assets are being moved, information will be transmitted either via NB-IoT, 5G, or with satellites. However, a fully integrated demo will not be built within the project, as it would require rail-infrastructure and defect rail carriages. But multiple sets of components will be demonstrated separately in labs. In the local testbed at BI, a wired ethernet connection will be used. Note however, that this does not limit the implementation of the remote attestation and encryption stack as switching to a different transmission technology only requires the integration of the respective gateways and modems into the edge device platform.

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Test Bed	Resource Type	Resource Description	Required Setup Activities	Responsible Partner	Start Date (Planned)	Due Date (Planned)	Ready to be used?
LIVORNO	Device	IoT Gateway Server (Edge Sensor Connectivity Cloud Connectivity Data Logging Data Context Fusion)	LIVORNO_UC3_setup_01	NCG	N/A	N/A	Yes
LIVORNO	Hardware, Software	BI's tile-based computing platform with M3 microkernel-based operating system running on FPGA: M3 is running on the synthesized hardware architecture on the FPGA, but some platform enablement for network support is still being worked on	LIVORNO_UC3_setup_02	BI	03/02/2021	31/08/2021	No
LIVORNO	Asset	ASTRA 2F – Geostationary Satellite	LIVORNO_UC3_setup_03	SES	N/A	N/A	Yes
LIVORNO	Asset	Satellite RF Uplink Ground Station	LIVORNO_UC3_setup_04	SES	N/A	N/A	Yes
LIVORNO	Asset	Satellite RF Downlink Ground Station	LIVORNO_UC3_setup_05	SES	N/A	N/A	Yes
LIVORNO	Asset	SatCube Ku-band transportable terminal with embedded ST Engineering iDirect's iQ200 modem	LIVORNO_UC3_setup_06	SES	N/A	N/A	Yes
LIVORNO	Hardware/Device/Equipment	Satellite Hub (in iDR testbed/lab)	LIVORNO_UC3_setup_07	iDR	N/A	N/A	Yes
LIVORNO	Asset	1.2m Ku-band Tx/Rx Ku-band Antenna ODU System (in iDR testbed/lab)	LIVORNO_UC3_setup_08	iDR	N/A	N/A	Yes
LIVORNO	Hardware/Device/Equipment	VSAT modem (in iDR testbed/lab)	LIVORNO_UC3_setup_09	iDR	01/08/2021	01/08/2021	Yes
LIVORNO	Hardware/Device/Equipment	Smart IoT Gateway (in iDR testbed/lab)	LIVORNO_UC3_setup_10	iDR	01/06/2021	30/04/2022	No
LIVORNO	Hardware/Device/Equipment	IoT Sensors	LIVORNO_UC3_setup_11	iDR	01/06/2021	30/04/2022	No

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		(in iDR testbed/lab)					
LIVORNO	Hardware/Device/Equipment	COTS Rackmount Linux Servers x2 (in iDR testbed/lab)	LIVORNO_UC3_setup_12	iDR	N/A	N/A	Yes
LIVORNO	Hardware/Device/Equipment	Either: VPN between iDirect Testbed and Partner IoT Sensors, Or: Partner-Sourced IoT Sensors (in iDR testbed/lab)	LIVORNO_UC3_setup_13	iDR, NCG	01/07/2021	01/10/2021	No

Table 20: Use case - setup activities

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5.1.2 INGENIOUS CHECKLIST

In order to make the demonstration of the rail-health use case work, we can not only rely on connecting existing components, but instead we will design and implement several new parts. First, NCG is in charge of creating a rail health signal generator. This is a neuromorphic sensor that monitors the state of vital parts of railway carriages such as trailing wheels or axles. The sensor converts analogue measurement data into some digitized form that can be further handled by BI's FPGA connected to the sensor. The FPGA board is programmed to provide the tiled hardware architecture required by M^3. The railway health sensor is contained in a single tile, so from the point of view of the OS, it acts like a normal device that is accessible by other applications or services running on the M^3 instance. Since the sensor data has to be transmitted to the control centre via some network, there also needs to be a component that generates IP packets from the measurement data obtained. The payload of these packets should be encrypted and the sensor sending reports should be securely identifiable, so the operating system will also need to implement services for authentication and data encryption. For production use, the sensor and data processing platform will have to be integrated into a single platform like the one provided by the BI, but in the form of a system-on-chip. This hardware appliance could be mounted on real-life railway assets, but this level of integration cannot be shown in the project. In the domain of data transmission via satellites, iDR is in charge of newly creating a mechanism that allows for transmission of IoT traffic via extra-terrestrial communication paths. Such a backhaul channel for sensor data is important to guarantee coverage even in areas that may not be covered by standard cellular phone networks. In this way, proper reporting of technical failures is guaranteed throughout the whole journey of a carriage.

5.1.2.1 Development Activities List and Planning

This section describes the development activities which are still to be completed the demonstration of this use case in more detail.

The base sensor that keeps track of the railway carriage health data will consist of a vibration sensor that monitors the state of vital components like carriage axles. It is accompanied by a data logger that records supplemental data that describe the operating conditions of the carriage such as speed and acceleration of the monitored parts. Such auxiliary data may help identifying operational conditions that lead to an increase of failure rate. Together with a trigger and time stamping mechanism, these parts form the hardware of the battery-driven core sensor for monitoring transportation assets. Development of these parts has already finished in spring 2021. Of course, the hardware itself does not suffice for detecting abnormal conditions. Hence, there is a need for AI-based algorithms that indicate an error of the monitored component. NCG contributed a real-time capable classification algorithm to the project which allows for distinguishing sane operational states from those that indicate an existing or imminent failure of transportation equipment. In contrast to common classification algorithms, the classification mechanism used in this

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use case is also able to learn about new states instead of just labelling measured data with one member of a set of pre-defined classes.

The sensor must be enabled to transmit its data to a remote-control site in some secure fashion. Hence, it has to be connected with a more complex embedded system that enables reliable and secure communication over various carrier technologies. This is where M^3, the tile-based operating system of the BI, comes into play. There already is a synthesized RISC-V system running with M^3 on top of an FPGA. Currently, the BI is working on finalizing the integration of a network stack into M^3. For the rail-health monitoring demonstration, the neuromorphic processing, the root-of-trust and encryption facilities as well as the network components needed for transmitting the sensor data to the control station will be run as applications on top of M^3.

BI will develop the remote attestation and encryption framework. For authenticating edge sensor services, the scenario relies on a root of trust (RoT). This is a special hardware module that contains a secret that can be used for proving the identity of a sensor edge device to the central monitoring service. For instance, a root of trust could be a private key that is used for signing messages in a PKI-style infrastructure. With the help of the RoT hardware module, a remote attestation service is built which is used for guaranteeing that only trustworthy components can report data to the data centre. An edge sensor device is considered trustworthy if all of its components work correctly (i.e., they successfully pass their self-tests) and its identity matches an entry in the list of installed sensors (i.e., unknown devices must not be able to communicate with the railway health service).
Since the communication between edge devices and the control centre should not be public, a TLS-encrypted networking stack will be implemented to protect data sent by the edge devices. In this way, the payload of the sensor data packages is shielded from unauthorized access by third parties.

BI will also develop M^3 services that enable communication with the remote-control facility. For the demonstration at BI labs, the transmission technology will be wired ethernet. However, we envision integrating 5G and satellite modems during later project phases. The required knowledge to do so is provided by CMC and iDR.

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Test Bed	Component Type	Component Description	Development Activities	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
LIVORNO	Hardware	Vibro-Acoustic Rail Health Data Collection System: Development of Batterie Powered Recording Platform with optimized Sensor Path and vibration characteristics (Field Tests)	LIVORNO_UC3 development_01	N/A	NCG	01/10/2020	30/11/2020
LIVORNO	Hardware	Context Data Logger: Development of Batterie Powered Context Data Logger (Speed, Acceleration, Position) (in NCG lab)	LIVORNO_UC3 development_02	N/A	NCG	01/10/2020	30/11/2020
LIVORNO	Hardware	Remote Trigger: Trigger and Time Stamp for distributed Measurement System (in Field Tests)	LIVORNO_UC3 development_03	N/A	NCG	01/10/2020	30/11/2020
LIVORNO	Testing	Measurements System: Design of Experiment Testing (in NCG lab)	LIVORNO_UC3 development_04	N/A	NCG	01/12/2020	31/12/2020
LIVORNO	Data Engineering	Data Preparation: Data Labeling, Visualization, Validation (in NCG lab)	LIVORNO_UC3 development_05	LIVORNO_UC3 development_04	NCG	01/01/2021	31/04/2021
LIVORNO	Data Science	Edge Algorithm: Signal Pre-Processing Feature Engineering	LIVORNO_UC3 development_06	LIVORNO_UC3 development_05	NCG	01/03/2021	31/06/2021

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		Feature Vectors Generation Feature Vector Classification (in NCG lab)					
LIVORNO	Embedded Software	Real-Time Engine: Embedded Algorithm (in NCG lab)	LIVORNO_UC3 development_07	LIVORNO_UC3 development_05	NCG	01/07/2021	31/08/2021
LIVORNO	hardware	User Requirements: Gateway Sensor Design (in NCG lab)	LIVORNO_UC3 development_08	LIVORNO_UC3 development_07	NCG	01/05/2021	31/10/2021
LIVORNO	Data Engineering/ Science	Cluster Engine: Feature Space Mapping System Performance Validation (in NCG lab)	LIVORNO_UC3 development_09	LIVORNO_UC3 development_08	NCG	01/11/2021	31/12/021
LIVORNO	Testing	Measurements System: Data Diversity Analysis (in NCG lab)	LIVORNO_UC3 development_10	LIVORNO_UC3 development_09	NCG	01/01/2022	31/03/2022
LIVORNO	Communication	Meta Data Connectivity: Communication (in NCG lab)	LIVORNO_UC3 development_11	User Test Requirements	NCG	01/04/2022	31/12/2022
LIVORNO	Hardware	Platform enablement: the M3 microkernel-based OS is running on the synthesized hardware architecture on the FPGA, add missing platform support for network	LIVORNO_UC3 development_12	LIVORNO _UC3 setup_02	BI	01/04/2021	30/08/2021
LIVORNO	Hardware	BI platform minimal hardware root-of-trust	LIVORNO_UC3 development_13	NONE	BI	01/04/2021	30/11/2021

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LIVORNO	Software	OS integration of minimal hardware root-of-trust	LIVORNO_UC3 development_14	LIVORNO_UC3 development_13	BI	01/09/2021	28/02/2022
LIVORNO	Software	OS support for authenticated boot and remote attestation of BI's platform based on minimal hardware root-of-trust	LIVORNO_UC3 development_15	LIVORNO_UC3 development_14	BI	01/06/2021	28/02/2022
LIVORNO	Software	Integration of Transport Layer Security (TLS) with remote attestation	LIVORNO_UC3 development_16	LIVORNO_UC3 development_15	BI	01/01/2022	30/06/2022
LIVORNO	Software	OS support for software updates and integration with root-of-trust, authenticated boot, and remote attestation	LIVORNO_UC3 development_17	LIVORNO_UC3 development_16	BI	01/04/2022	30/09/2022
LIVORNO	Infrastructure / communications	Enable satellite backhaul communication for IoT traffic (at iDR testbed/lab)	LIVORNO_UC3 development_18	LIVORNO _UC3 setup_03, development_05	iDR	01/01/21	31/03/22

Table 21: Use case - development activities

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5.1.2.2 Integration Activities List and Planning

For completing the demonstration setup at BI (sensor and M^3 FPGA with data transmission over wired Ethernet), the neuromorphic sensor hardware provided by NCG has to be integrated into the FPGA infrastructure that is already present at BI. In order for this step to be successful, NCG develops the interface of the neuromorphic processor according to the specifications provided within the BI development plan. They also provide a software implementation for processing the data provided by the NCG sensor. Once the hardware integration is completed successfully, the software integration will start. This is mainly the development of systems software needed for making the device accessible in the M^3 operating system.

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Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
LIVORNO	Hardware	Rail Health Signal Generator Demonstrator Design & Testing (in NCG lab)	LIVORNO_UC3_integration_01	LIVORNO_UC3 development_07	NCG, BI	01/09/2021	30/11/2021
LIVORNO	Hardware	Life IP Data (in NCG lab) and Integration with CMC Development Environment	LIVORNO_UC3_integration_02	LIVORNO_UC3 development_11	NCG, CMC	01/06/2022	31/12/2022
LIVORNO	Hardware	Integration of NCG signal generator and pre-processing software into BI's FPGA platform (in BI lab)	LIVORNO_UC3_integration_03	LIVORNO_UC3 development_18	BI, NCG	01/062021	31/12/2021
LIVORNO	Infrastructure/ Communications/ Software	Provide satellite backhaul communication for IoT traffic (at iDR testbed/lab)	LIVORNO_UC3_integration_04	LIVORNO _UC3_setup_02	iDR	01/01/2021	31/05/2022

Table 22: Use case - integration activities

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5.2 Test Cases Definition

In this chapter, a list of test cases to be performed during the lifetime of the project are presented for proper use case validation. According to a common template, the test cases are listed below:

Test Case Id	UC3_TC_01
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Lifetime Operation - Battery Life Load Cycles
Prerequisites	Battery Spec
Type of test	Simulation
Reference standards used	N/A
Test Environment	Target Platform Architecture (Key Component BOM)
Input to the system	Processing & Communication Frequency, Battery Degradation
Output of the system	Lifetime Energy Usage
Data involved in the test	Quiescent Currents, Peak Currents, Operation Currents, Leakage
System requirements covered	UC3_SR_01
Related KPIs	KPI_01 (Autonomous Operation Duration – 12 Yrs)
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Build Simulation Model & Assumptions. 2) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Lifetime Operation Value
Actual result	to be determined
Passed/Failed	to be determined

Table 23: Use case - UC3_TC_01

Test Case Id	UC3_TC_02
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Connectivity Frequency
Prerequisites	Minimum Communication Content and Frequency Requirements
Type of test	Simulation
Reference standards used	N/A
Test Environment	Target Platform Architecture (Key Component BOM)
Input to the system	Processing & Communication Frequency, Battery Degradation
Output of the system	Lifetime Energy Usage
Data involved in the test	Quiescent Currents, Peak Currents, Operation Currents, Leakage
System requirements covered	UC3_SR_02
Related KPIs	KPI_02 (Defect Detection)
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Build Simulation Model & Assumptions. 2) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Communication Frequency and Fault Latency for Bearing & Critical Flat Spot detection.
Actual result	to be determined
Passed/Failed	to be determined

Table 24: Use case - UC3_TC_02

Test Case Id	UC3_TC_03
Responsible Partner	iDR, SEQ
Use Case	Rail Health
Test case description	Connectivity Coverage
Prerequisites	Area of Usage Assumptions
Type of test	Connectivity Database Analysis

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Reference standards used	N/A
Test Environment	Simulation
Input to the system	Connectivity Database
Output of the system	Overall Connectivity Coverage + Extended (Rail Blank Spots / per Region)
Data involved in the test	Connectivity Database
System requirements covered	UC3_SR_03
Related KPIs	Connectivity Coverage
Are UC's users involved in the test?	CMC, SEQ
Who will perform the test?	CMC, SEQ
Test Steps	1) Define Region of Interest 2) Load COM Coverage Database 3) Limit to Rail-Network 4) Analyze Blank Spots and Coverage
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Communication Frequency and Fault Latency for Bearing & Critical Flat Spot detection.
Actual result	to be determined
Passed/Failed	to be determined

Table 25: Use case - UC3_TC_03

Test Case Id	**UC3_TC_04**
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Edge Storage
Prerequisites	TC3 Connectivity Coverage
Type of test	Requirements Estimation
Reference standards used	N/A
Test Environment	Simulation
Input to the system	Processing & Communication Frequency
Output of the system	Memory Requirements
Data involved in the test	Monitoring Resolution
System requirements covered	UC3_SR_04
Related KPIs	Critical Event Monitoring
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Build Simulation Model & Assumptions 2) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Memory Requirements and Strategy for Data Reduction/Compression
Actual result	to be determined
Passed/Failed	to be determined

Table 26: Use case - UC3_TC_04

Test Case Id	**UC3_TC_05**
Responsible Partner	NCG, SES
Use Case	Rail Health
Test case description	Multimodal Connectivity
Prerequisites	Functional Safety Requirements, Connectivity Frequency, Connectivity Coverage
Type of test	Estimation
Reference standards used	N/A
Test Environment	Simulation
Input to the system	Connectivity Coverage, Public Data Connectivity Map
Output of the system	Connectivity Map – GSM, Backfall, Multimodal Connectivity Opportunities
Data involved in the test	Public Data
System requirements covered	UC3_SR_05
Related KPIs	Connectivity Coverage
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Data Collection 2) Build Simulation Model & Assumptions 3) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Multimodal Connectivity Opportunities
Actual result	to be determined

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Passed/Failed	to be determined

Table 27: Use case - UC3_TC_05

Test Case Id	UC3_TC_06
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Monitoring Resolution
Prerequisites	Functional Safety Requirements, Customer Requirements
Type of test	Estimation
Reference standards used	N/A
Test Environment	PC
Input to the system	Functional Safety Requirements, Customer Requirements
Output of the system	Monitoring Resolution
Data involved in the test	Functional Safety Requirements, Customer Requirements
System requirements covered	UC3_SR_06
Related KPIs	Critical Event Monitoring
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Requirements Elicitation 2) Build Simulation Model & Assumptions 3) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Monitoring Resolution
Actual result	to be determined
Passed/Failed	to be determined

Table 28: Use case - UC3_TC_06

Test Case Id	UC3_TC_07
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Monitoring Capability
Prerequisites	Functional Safety Requirements, Customer Requirements, Energy Resources, Application Results
Type of test	Simulation
Reference standards used	N/A
Test Environment	PC
Input to the system	Functional Safety Requirements, Customer Requirements, Energy Resources, Application Results
Output of the system	Monitoring Capability (Defect Detection Capability)
Data involved in the test	Application Results + Assumptions
System requirements covered	UC3_SR_07
Related KPIs	Autonomous Lifetime Operation, Critical Event Monitoring
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Requirements Elicitation 2) Build Simulation Model & Assumptions 3) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Monitoring Capability
Actual result	to be determined
Passed/Failed	to be determined

Table 29: Use case - UC3_TC_07

Test Case Id	UC3_TC_08
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Cloud Defect Validation
Prerequisites	Edge Classification & Edge Pre-Processing Capabilities & Results
Type of test	Simulation
Reference standards used	N/A (Machine Learning)
Test Environment	PC
Input to the system	Edge Classification & Edge Pre-Processing Capabilities & Results
Output of the system	Defect Validation via alternative analysis and statistical trend analysis

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Data involved in the test	Rail Health Raw & Meta Data
System requirements covered	UC3_SR_08
Related KPIs	Critical Event Monitoring
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Build Simulation Model & Assumptions 2) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Cloud Defect Validation Capability
Actual result	to be determined
Passed/Failed	to be determined

Table 30: Use case - UC3_TC_08

Test Case Id	UC3_TC_09
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Gateway Defect Validation
Prerequisites	Edge Classification & Edge Pre-Processing Capabilities & Results
Type of test	Simulation
Reference standards used	N/A (Machine Learning)
Test Environment	PC
Input to the system	Edge Classification & Edge Pre-Processing Capabilities & Results
Output of the system	Defect Validation via alternative analysis and statistical trend analysis
Data involved in the test	Rail Health Raw & Meta Data
System requirements covered	UC3_SR_09
Related KPIs	Critical Event Monitoring, Autonomous Operability
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	1) Build Simulation Model & Assumptions 2) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Gateway Defect Validation Capability
Actual result	to be determined
Passed/Failed	to be determined

Table 31: Use case - UC3_TC_09

Test Case Id	UC3_TC_10
Responsible Partner	NCG, BI
Use Case	Rail Health
Test case description	Security (Phishing)
Prerequisites	System Architectural Design and Communication Architecture
Type of test	Theoretical
Reference standards used	State-of-the-art Transport Layer Security (TLS)
Test Environment	N/A
Input to the system	System Architectural Design and Communication Architecture
Output of the system	Robustness Features
Data involved in the test	TLS Security Capabilities
System requirements covered	UC3_SR_10
Related KPIs	Security Attack Robustness
Are UC's users involved in the test?	NCG, BI
Who will perform the test?	NCG, BI
Test Steps	Literature Search
Risks	N/A
Mitigation	Out-of-Organization Expertise
Expected result	Confidentiality and integrity of connection via TLS
Actual result	to be determined
Passed/Failed	to be determined

Table 32: Use case - UC3_TC_10

Test Case Id	UC3_TC_11
Responsible Partner	BI
Use Case	Rail Health
Test case description	Security (Listening)

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Prerequisites	Hardware Root of Trust (RoT) integrated into BI FPGA platform
Type of test	Functional test
Reference standards used	State-of-the-art Transport Layer Security (TLS) will be used, but integrated with remote attestation
Test Environment	BI Lab
Input to the system	Connection request from sensor endpoint to cloud endpoint
Output of the system	Sensor data delivered to cloud endpoint
Data involved in the test	Sensor data (obtained via vibration generator)
System requirements covered	UC3_SR_11
Related KPIs	Security Attack Robustness
Are UC's users involved in the test?	BI
Who will perform the test?	BI
Test Steps	Connection between cloud sensor endpoint and server is established
Risks	Hardware Root of Trust (RoT) needed for remote attestation in BI FPGA platform not integrated/functional on time
Mitigation	Hardware simulator used to demonstrate software needed for remote attestation of sensor endpoint, integration of remote attestation with TLS on simulated platform
Expected result	Confidentiality and integrity of connection between sensor endpoint and cloud server protected via TLS
Actual result	to be determined
Passed/Failed	to be determined

Table 33: Use case - UC3_TC_11

Test Case Id	**UC3_TC_12**
Responsible Partner	NCG, BI
Use Case	Rail Health
Test case description	Security (Flash)
Prerequisites	Hardware Root of Trust (RoT) integrated into BI FPGA platform
Type of test	Functional test
Reference standards used	N/A
Test Environment	BI Lab, NCG Lab
Input to the system	N/A
Output of the system	N/A
Data involved in the test	N/A
System requirements covered	UC3_SR_12
Related KPIs	Security Attack Robustness
Are UC's users involved in the test?	NCG, BI
Who will perform the test?	NCG, BI
Test Steps	Measured startup of M3 operating system and checking of code signatures before execution of applications and service programs
Risks	Hardware Root of Trust (RoT) and ROM-based boot loader in BI FPGA platform not integrated/functional on time
Mitigation	Hardware simulator used to demonstrate secure startup of M3 operating system on the BI platform
Expected result	Only cryptographically signed M3 operating system and applications can start on BI platform
Actual result	to be determined
Passed/Failed	to be determined

Table 34: Use case - UC3_TC_12

Test Case Id	**UC3_TC_13**
Responsible Partner	BI
Use Case	Rail Health
Test case description	Security (Commanding)
Prerequisites	Hardware Root of Trust (RoT) integrated into BI FPGA platform
Type of test	Functional test
Reference standards used	N/A
Test Environment	BI Lab
Input to the system	Connection request from sensor endpoint to cloud endpoint
Output of the system	Sensor data delivered to cloud endpoint
Data involved in the test	Sensor data (obtained via vibration generator)
System requirements covered	UC3_SR_13
Related KPIs	Security Attack Robustness
Are UC's users involved in the test?	BI

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Who will perform the test?	BI
Test Steps	Connection between cloud sensor endpoint and server is established
Risks	Hardware Root of Trust (RoT) needed for remote attestation in BI FPGA platform not integrated/functional on time
Mitigation	Hardware simulator used to demonstrate software needed for remote attestation of sensor endpoint
Expected result	Connection only established, if remote attestation of sensor endpoint passed; connection refused, if the sensor endpoint does not pass remote attestation
Actual result	to be determined
Passed/Failed	to be determined

Table 35: Use case - UC3_TC_13

Test Case Id	**UC3_TC_14**
Responsible Partner	BI, PJATK
Use Case	Rail Health
Test case description	Data Encryption
Prerequisites	Hardware Root of Trust (RoT) integrated into BI FPGA platform
Type of test	Functional test
Reference standards used	State-of-the-art encryption, digital signature, and padding algorithms (e.g., AES, ECDSA, SHA3, ...)
Test Environment	BI Lab
Input to the system	Sensor data (obtained via vibration generator)
Output of the system	Encrypted and integrity-protected sensor data
Data involved in the test	Sensor data (obtained via vibration generator)
System requirements covered	UC3_SR_14
Related KPIs	Security Attack Robustness
Are UC's users involved in the test?	BI
Who will perform the test?	BI
Test Steps	Data provided by the sensor is encrypted offline and stored in local memory/storage of the BI FPGA platform for later transmission to sensor endpoint
Risks	Hardware Root of Trust (RoT) needed for securing receiver public key and signing of data in BI FPGA platform not integrated/functional on time
Mitigation	Hardware simulator used to demonstrate local encryption and signing of sensor data
Expected result	Sensor data is encrypted and digitally signed, cloud server can decrypt and verify signature.
Actual result	to be determined
Passed/Failed	to be determined

Table 36: Use case - UC3_TC_14

Test Case Id	**UC3_TC_15**
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Functional Safety
Prerequisites	Rail Health Functional Safety Requirements, Customer Requirements
Type of test	Fault Detection Mechanisms (Diagnostics Coverage)
Reference standards used	IEC 51608
Test Environment	N/A (PC)
Input to the system	Rail Health Functional Safety Requirements, Customer Requirements, System Architecture
Output of the system	Fault Detection Diagnostics Coverage
Data involved in the test	Reviews
System requirements covered	UC3_SR_15
Related KPIs	Functional Safety
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	Design Review (FMEDA)
Risks	Methodological Capability
Mitigation	Methodological Experience + System Experts
Expected result	Fault Detection Diagnostics Coverage

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Actual result	to be determined
Passed/Failed	to be determined

Table 37: Use case - UC3_TC_15

Test Case Id	UC3_TC_16
Responsible Partner	NCG
Use Case	Rail Health
Test case description	Fire/Explosion Safety
Prerequisites	Explosion Safety Requirements, Customer Requirements
Type of test	N/A (PC)
Reference standards used	ATEX
Test Environment	N/A (PC)
Input to the system	Explosion Safety Requirements, Customer Requirements, ATEX
Output of the system	ATEX Compliance Gaps
Data involved in the test	System Design
System requirements covered	UC3_SR_16
Related KPIs	Fire and Explosion Safety
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG
Test Steps	Design Review
Risks	Methodological Capability
Mitigation	Methodological Experience + System Experts
Expected result	ATEX Compliance Gaps
Actual result	to be determined
Passed/Failed	to be determined

Table 38: Use case - UC3_TC_16

Test Case Id	UC3_TC_17
Responsible Partner	CMC
Use Case	Rail Health
Test case description	The radio access should be able to run local application processing when user selects low latency for selected applications
Prerequisites	Device has been assigned to URLLC network slice and RAN includes MEC server
Type of test	The device during registration process to the mobile core request low latency slice and the mobile core will allocate User Plane Function (UPF) closer to the device for local data processing to reduce latency
Reference standards used	3GPP Rel 16 (Network slicing), ETSI MEC
Test Environment	Device with slice support, 5G Core with Network Slice Management Service and MEC
Input to the system	Data to be processed close to the device
Output of the system	Data processed with minimum delay
Data involved in the test	Network slice info,
System requirements covered	UC3_SR_17
Related KPIs	Low end-to-end delay
Are UC's users involved in the test?	CMC
Who will perform the test?	CMC
Test Steps	1. Device profile added to the 5G Core to be added to low latency slice 2. Application for device data processing installed in UPF close to the device 3. Device connected to the network request low latency slice and is assigned the UPF with the application for data processing Data is processed in UPF close to the device and return to the device with minimum delay
Risks	Device supporting network slice Device data processing application can be installed in UPF (i.e. support for Linux Ubuntu OS)
Mitigation	If device does not support network slice, the device profile can be pre-configured to assign the low latency.
Expected result	The data received from the device will be processed as closer as possible to the device and returned with lower delay than processing the data in another UPF in the cloud.
Actual result	to be determined

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Passed/Failed	to be determined

Table 39: Use case - UC3_TC_17

Test Case Id	UC3_TC_18
Responsible Partner	iDR
Use Case	Rail Health
Test case description	IP connectivity. Validate confidentiality of satellite backhauled sensor data.
Prerequisites	Live satellite capacity is available End to end network from sensors to data centre/cloud is configured, satellite backhaul configured
Type of test	Verify traffic between the sensor gateway and the cloud is encrypted over the satellite communications network
Reference standards used	N/A
Test Environment	iDirect Testbed
Input to the system	Data produced by sensors and gathered by the sensor gateway and delivered via IP to Satellite terminal for backhaul
Output of the system	Backhauled sensor data to cloud endpoint
Data involved in the test	Sensor measurement data
System requirements covered	UC3_SR_18, UC3_SR_21
Related KPIs	Security Attack Robustness
Are UC's users involved in the test?	iDR, SES, others TBD
Who will perform the test?	iDR
Test Steps	Setup – Data path establishment between Sensor Gateway and Data centre using satellite backhaul. Capture sensor data in transit, at point between Sensor Gateway and Teleport IP egress point. Analyse captured sensor data to verify encrypted status.
Risks	Sensor data provided to satellite backhaul unencrypted
Mitigation	Consider additional further encryption steps (e.g. between Sensor Gateway to Teleport)
Expected result	Captured sensor data is undecipherable between Sensor Gateway and teleport IP egress point
Actual result	to be determined
Passed/Failed	to be determined

Table 40: Use case - UC3_TC_18

Test Case Id	UC3_TC_19
Responsible Partner	CMC
Use Case	Rail Health
Test case description	Communication Load Optimization The platform shall be able to use the most appropriate radio technology depending on network access and communication demands.
Prerequisites	Customer Requirements, State-of-the-Science
Type of test	Concept
Reference standards used	N/A (Machine Learning)
Test Environment	Concept
Input to the system	Communication Load Requirements (Normal Operation/Novelty Detection)
Output of the system	Edge Storage + Hybrid Communication Strategy
Data involved in the test	Communication Load Requirements (Normal Operation/Novelty Detection)
System requirements covered	UC3_SR_19
Related KPIs	Low End-to-end delay
Are UC's users involved in the test?	CMC
Who will perform the test?	CMC
Test Steps	1) Build Simulation Model & Assumptions 2) Simulation
Risks	Wrong assumptions or incomplete simulation model
Mitigation	Peer Review
Expected result	Communication Load Optimization
Actual result	to be determined
Passed/Failed	to be determined

Table 41: Use case - UC3_TC_19

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Test Case Id	UC3_TC_20
Responsible Partner	BI, NCG
Use Case	Rail Health
Test case description	OTA upgradeability
Prerequisites	Hardware Root of Trust (RoT) integrated into BI FPGA platform
Type of test	Functional test
Reference standards used	N/A
Test Environment	BI Lab, NCG Lab
Input to the system	Software update
Output of the system	N/A
Data involved in the test	N/A
System requirements covered	UC3_SR_20
Related KPIs	Critical Event Monitoring
Are UC's users involved in the test?	NCG
Who will perform the test?	NCG, BI
Test Steps	A digitally signed software update is downloaded, its signature checked, and started in A/B configuration with the currently running software (A) kept as a fallback in case the new version (B) fails to start
Risks	Hardware Root of Trust (RoT) needed for securing public key needed to check update integrity in BI FPGA platform not integrated/functional on time
Mitigation	Hardware simulator used to demonstrate signature checking of software update
Expected result	After reboot in A/B configuration, the signature-checked software update is B is running; A is started if signature checks failed on B
Actual result	to be determined
Passed/Failed	to be determined

Table 42: Use case - UC3_TC_20

Test Case Id	UC3_TC_21
Responsible Partner	iDR
Use Case	UC3 on Transportation Platform Health Monitoring
Test case description	Extended Satellite Coverage Satellite Multi-Protocol Support Validate confidentiality of satellite backhauled sensor data
Prerequisites	Live satellite capacity is available End to end network from sensors to data centre/cloud is configured, satellite backhaul configured
Type of test	Verify traffic between the sensor gateway and the cloud is encrypted over the satellite communications network
Reference standards used	N/A
Test Environment	iDirect Testbed
Input to the system	Data produced by sensors and gathered by the sensor gateway and delivered via IP to Satellite terminal for backhaul
Output of the system	Backhauled sensor data to cloud endpoint
Data involved in the test	Sensor measurement data
System requirements covered	UC3_SR_21
Related KPIs	Security Attack Robustness
Are UC's users involved in the test?	iDR, SES
Who will perform the test?	iDR
Test Steps	Setup – Data path establishment between Sensor Gateway and Data centre using satellite backhaul. Capture sensor data in transit, at point between Sensor Gateway and Teleport IP egress point. Analyse captured sensor data to verify encrypted status.
Risks	Sensor data provided to satellite backhaul unencrypted
Mitigation	Consider additional further encryption steps (e.g. between Sensor Gateway to Teleport)
Expected result	Captured sensor data is undecipherable between Sensor Gateway and teleport IP egress point
Actual result	to be determined
Passed/Failed	to be determined

Table 43: Use case - UC3_TC_21

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Test Case Id	UC3_TC_22
Responsible Partner	iDR
Use Case	UC3 on Transportation Platform Health Monitoring
Test case description	Extended Satellite Coverage Satellite enables the guarantee of a Fault Communication Time within 30-minute intervals
Prerequisites	Live satellite capacity is available End to end network from sensors to data centre/cloud is configured, satellite backhaul configured
Type of test	A test to prove that the gateway can establish IP connectivity with the cloud via Satellite.
Reference standards used	N/A
Test Environment	iDirect Testbed
Input to the system	Data produced by sensors and gathered by the sensor gateway and delivered via IP to Satellite terminal for backhaul
Output of the system	Backhauled sensor data to cloud endpoint
Data involved in the test	Sensor measurement data
System requirements covered	UC3_SR_21, UC3_SR_22
Related KPIs	Connectivity Coverage
Are UC's users involved in the test?	iDR, SES, others TBD
Who will perform the test?	iDR
Test Steps	Setup – Data path establishment between Sensor and Data centre using satellite backhaul Publish sensor data from device to data centre/cloud Verify successful receipt of sensor data
Risks	Availability of satellite capacity
Mitigation	Test using a lab environment
Expected result	Sensor data is received successfully at data centre/cloud
Actual result	to be determined
Passed/Failed	to be determined

Table 44: Use case - UC3_TC_22

Test Case Id	UC3_TC_23
Responsible Partner	iDR
Use Case	UC3 on Transportation Platform Health Monitoring
Test case description	Extended Satellite Coverage Verify uplink and downlink Satellite backhaul latency
Prerequisites	Live satellite capacity is available End to end network from sensors to data centre/cloud is configured, satellite backhaul configured
Type of test	Verify Satellite latency is within required KPI limits for Use Case
Reference standards used	N/A
Test Environment	iDirect Testbed
Input to the system	UDP and TCP test data for latency measurement
Output of the system	UDP and TCP test data for latency measurement, with corresponding latency statistics
Data involved in the test	UDP and TCP test data
System requirements covered	UC3_SR_21, UC3_SR23
Related KPIs	Low End-to-End Delay (satellite)
Are UC's users involved in the test?	iDR, SES, others TBD
Who will perform the test?	iDR
Test Steps	Setup – Data path establishment between Sensor and Data centre using satellite backhaul. Send test TCP/UDP data uplink and downlink between sensors at/co-located with satellite terminal and teleport egress point, to measure latency observed over satellite segment of backhaul.
Risks	Possible risk of connectivity issues
Mitigation	Perform enough tests and preparation to ensure sources of connectivity issues are known and resolved
Expected result	Latency should be within the limits specified for the use case
Actual result	to be determined
Passed/Failed	to be determined

Table 45: Use case - UC3_TC_23

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6 Demo - Intermodal Asset Tracking via IoT and Satellite

This use case aims at providing E2E asset tracking via satellite backhaul from the IoT RAN to the corresponding data/control centre, enabling real-time/periodic monitoring of predetermined parameters (temperature, humidity, accelerometer, etc.) of shipping containers when they are sailing on the sea, while terrestrial IoT connectivity is provided when the ship approaches at the port. To enable ubiquitous coverage, IoT tracking devices will be installed on the shipping containers transported by ships and trucks on both segments. The end-to-end intermodal asset tracking would allow shipment information to be ubiquitously available across all connected platforms and interested parties in real-time. The following section includes information regarding the use case implementation.

6.1 COSCO Ship and Valencia Port Testbed

Regarding the installation of a satellite terminal on a ship, we should highlight that the cost is very high as well as that it is a very complicated process and needs the authorization of the owner of the ship and the captain. The physical installation may not take a lot of time, but a huge amount of considerations (safety regulations, site survey to decide where to accommodate the satellite terminal, opening holes and passing cables in the ship, etc.) should be taken into account in order to get the approval. For this reason, we decided that the satellite terminal will be installed at the port of Valencia. Therefore, the workflow of the use case is described below, while the architecture of the use case to be demonstrated is depicted in Figure 13:

- A 20 feet shipping container will be equipped with a certain number of heterogeneous IoT devices able to monitor the internal environment of the container (accelerometer, temperature, humidity) as well as to detect critical events (physical shocks, door opening);
- The shipping container will be loaded on a truck and will be transported from the inland to Valencia port;
- During the trip, the heterogeneous IoT devices send a regular status updates, the Smart IoT GW on the truck gathers and processes the data and the connectivity with the IoT cloud/Data centre is obtained through a terrestrial access network;
- Then, the shipping container will be discharged from the truck and it will be loaded on a ship;
- Subsequently, the shipping container will be transported from the port of Valencia to the port of Piraeus and vice versa. During the trip, depending on the service level required by the owner of the container and the supply chain associated, the heterogeneous IoT devices send regular status updates;
- The messages from the heterogeneous IoT devices will be aggregated and stored by a Smart IoT Gateway installed on the bridge or IT room of the ship;
- When the ship returns to the port of Valencia, the data will be sent to the IoT cloud/Data centre through satellite backhaul (a satellite terminal will be installed on the port of Valencia). The baseline space

segment to be used corresponds to the SES's GEO satellite fleet which will provide seamless connectivity between the satellite terminal on the port of Valencia and the innovative 3GPP compliant hub platform located at the SES' teleport in Betzdorf, Luxembourg;

- Then, the shipping container will be discharged from the ship and it will be loaded on a truck;
- The truck will leave from the port of Valencia and it will transport the shipping container to inland. During the trip, the heterogeneous IoT devices send a regular status update, the Smart IoT GW on the truck gathers and processes the data and the connectivity with the IoT cloud/Data centre is obtained through a terrestrial access network.

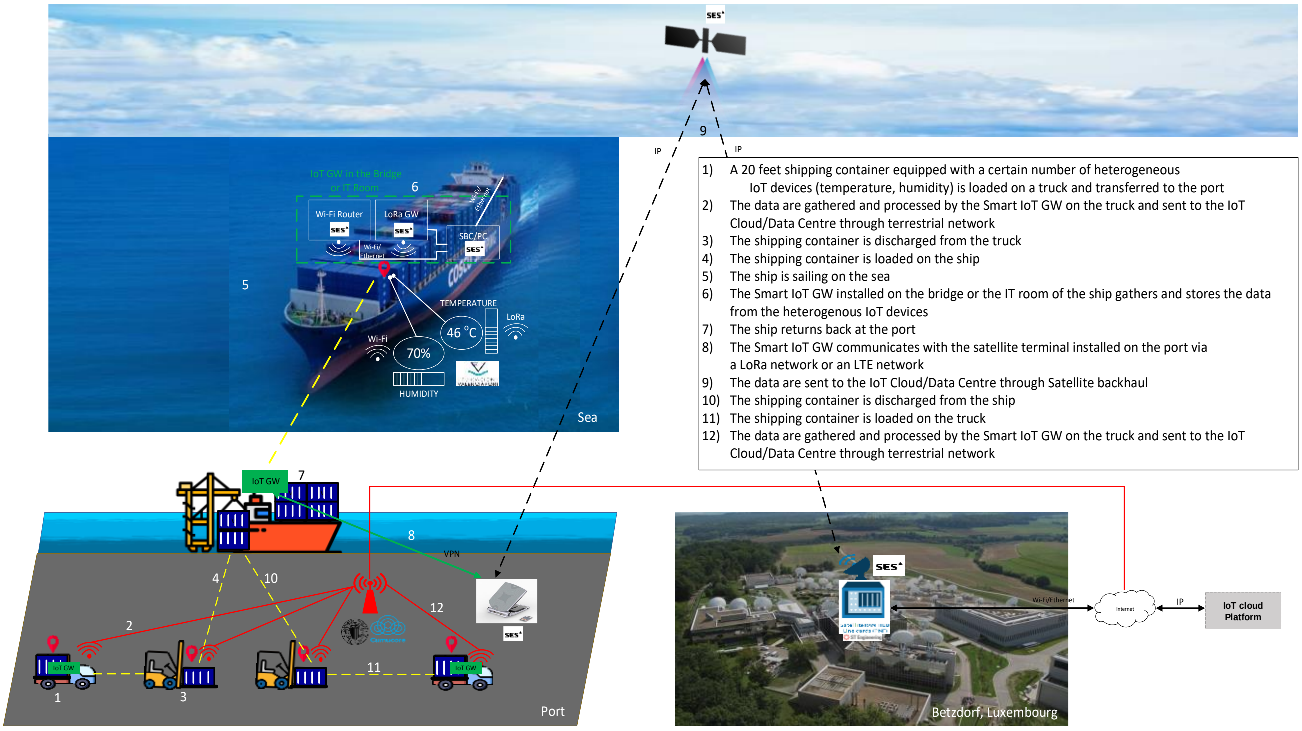

Figure 13: Scenario of the use case to be demonstrated

Here, we need to note that in addition to the COSCO Ship and Valencia Port testbed, iDirect will provision an additional testbed (the iDirect Lab Testbed) to facilitate additional validation of the use case. In most aspects, the testbed will mirror the live testbed; it will include, for example, satellite ground equipment, sensor notes and Smart IoT Gateway. The lab testbed will also include shared access to a simulated satellite network using satellite channel emulators with similar ground equipment to the live configuration. In this way additional simulation and validation can take place without the need for live satellite capacity, although it will still also be possible to connect via the SES live satellite network when capacity is available. In the following sections the existing components as well as the development and integration activities for the implementation of the use case testbed (COSCO ship, Valencia port and iDirect Lab) are listed and discussed.

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6.1.1 EXISTING COMPONENTS SETUP

In this chapter planning of the required resources, facilities, connectivity and logistics for the setup of the testbed is performed, and it will support the use case deployment. The main activities that have been identified, are listed below:

Test Bed	Resource Type	Resource Description	Required Setup Activities	Responsible Partner	Start Date (Planned)	Due Date (Planned)	Ready to be used?
COSCO, VALENCIA	Asset	ASTRA 2F – Geostationary Satellite	COSCO_VALENCIA _UC4_setup_01	SES	N/A	N/A	Yes
COSCO, VALENCIA	Asset	Satellite RF Uplink Ground Station	COSCO_VALENCIA _UC4_setup_02 (Luxembourg)	SES	N/A	N/A	Yes
COSCO, VALENCIA	Asset	Satellite RF Downlink Ground Station	COSCO_VALENCIA _UC4_setup_03 (Luxembourg)	SES	N/A	N/A	Yes
VALENCIA	Asset	SatCube Ku-band transportable terminal with embedded ST Engineering iDirect's iQ200 modem	VALENCIA_UC4_setup_04	SES	N/A	N/A	Yes
VALENCIA	Asset	1.2m Ku-band Tx/Rx Ku-band Antenna ODU System	VALENCIA_UC4_setup_05	iDR	N/A	N/A	Yes
COSCO, VALENCIA	Hardware/Device/Equipment	Satellite Hub Platform	COSCO_VALENCIA _UC4_setup_06 (Luxembourg)	iDR	N/A	N/A	No
VALENCIA	Infrastructure	Port Facilities	Valencia_UC4_setup_07	FV	N/A	N/A	Yes
VALENCIA	Infrastructure/Network	Commercial LTE Coverage	VALENCIA_UC4_setup_08	FV	N/A	N/A	Yes
COSCO, VALENCIA	Hardware/Device/Equipment	IoT Sensors for measuring temperature, humidity, movement, vibration, etc.	COSCO_VALENCIA _UC4_setup_09	FV	01/05/2021	30/04/2022	No
COSCO, VALENCIA	Hardware/Device/Equipment	LoRa Gateway	COSCO_VALENCIA _UC4_setup_10	SES	N/A	N/A	Yes
COSCO, VALENCIA	Hardware/Device/Equipment	Smart IoT Gateway	COSCO_VALENCIA _UC4_setup_11	SES	01/04/2021	31/03/2022	No
COSCO, VALENCIA	Asset	iNGENIOUS shipping container	COSCO_VALENCIA _UC4_setup_12	FV	01/12/2021	31/05/2022	No

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COSCO, VALENCIA	Asset	Container 42	COSCO_VALENCIA _UC4_setup_13	FV	01/04/2021	**TBD**	No
COSCO	Asset	Ship with AIS for navigation data exchange and VHF radio connection for exchange when the ship is approaching the port	COSCO_UC4_setup_14	COSSP	01/12/2021	31/10/2022	No
VALENCIA	Asset	Truck for inland transport	VALENCIA_UC4_setup_15	COSSP	01/12/2021	31/10/2022	No
VALENCIA	Hardware/Device/Equipment	MEC Server (Supermicro or RPI tbd)	VALENCIA_UC4_setup_16	iDR	01/07/2021	31/03/2022	No
iDirect Lab	Hardware/Device/Equipment	Satellite Hub	iDR_UC4_setup_17	iDR	N/A	N/A	Yes
iDirect Lab	Asset	1.2m Ku-band Tx/Rx Ku-band Antenna ODU System	iDR_UC4_setup_18	iDR	N/A	N/A	Yes
iDirect Lab	Hardware/Device/Equipment	iQ Desktop VSAT modem	iDR_UC4_setup_19	iDR	N/A	N/A	Yes
iDirect Lab	Hardware/Device/Equipment	9350 VSAT Modem	iDR_UC4_setup_20	iDR	N/A	N/A	Yes
iDirect Lab	Hardware/Device/Equipment	iQ 200 VSAT Modem	iDR_UC4_setup_21	iDR	01/08/2021	01/08/2021	No
iDirect Lab	Hardware/Device/Equipment	Satellite Channel Emulator x2	iDR_UC4_setup_22	iDR	N/A	N/A	Yes
iDirect Lab	Hardware/Device/Equipment	LoRa Gateway	iDR_UC4_setup_23	iDR	01/06/2021	30/04/2022	No
iDIrect Lab	Hardware/Device/Equipment	Smart IoT Gateway	iDR_UC4_setup_24	iDR	01/06/2021	30/04/2022	No
iDIrect Lab	Hardware/Device/Equipment	IoT Sensors	iDR_UC4_setup_25	iDR	01/06/2021	30/04/2022	No
iDIrect Lab	Hardware/Device/Equipment	COTS Rackmount Linux Servers x2	iDR_UC4_setup_26	iDR	N/A	N/A	Yes
iDirect Lab	Hardware/Device/Equipment	iQ LTE Modem	STE_UC4_setup_27	STE	01/08/2021	01/08/2021	No

Table 46: Use case - setup activities

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Satellite backhaul

The hardware/asset/software items of the transport network (satellite backhaul) of the use case testbed are the following:

- Space Segment corresponding to SES's ASTRA 2F geostationary satellite operated at the orbital location 28.2°E;
- Satellite RF Uplink/Downlink facilities located at the SES's teleport premises in Betzdorf, Luxembourg;
- Satellite Hub Platform (or else referred to as Virtualized Satellite Gateway) located at the SES's teleport premises in Betzdorf, Luxembourg;
- Fixed Edge Node located at this moment in Killarney, Ireland, while maybe during the demo will be deployed in the port of Valencia, Spain;
- Nomadic Edge Node corresponding to the SatCube Ku-band small-factor lightweight transportable terminal located at this moment in Betzdorf, Luxembourg, while during it will be deployed in the Port of Valencia, Spain.

These are described in the tables below.

Satellite	ASTRA 2F
Orbital Type	Geostationary
Orbital Location	28.2° East
Orbital Control	+/- 0.1° relative to nominal OL
Satellite Type	EADS Astrium, Eurostar E3000 platform, 3-axis stabilized
Launch Vehicle	Ariane 5 ECA
Launch Date	28 September 2012
Design Lifetime	15 years
Payload Transponders	64 Ku-Band (TWTA and LTWTA, FSS: 26 and 36 MHz, BSS: 33 MHz) and 3 Ka-Band (LTWTA, 480 and 580 MHz)
Coverage Beams	Ku-Band: PE [Europe] (see Figure 14), UK [United Kingdom], WA [West Africa] Ka-Band: KaBB [France], steerable over the visible Earth
Further info:	https://www.ses.com/our-coverage/satellites/344

Table 47: ASTRA 2F Satellite - Orbital Location 28.2°E

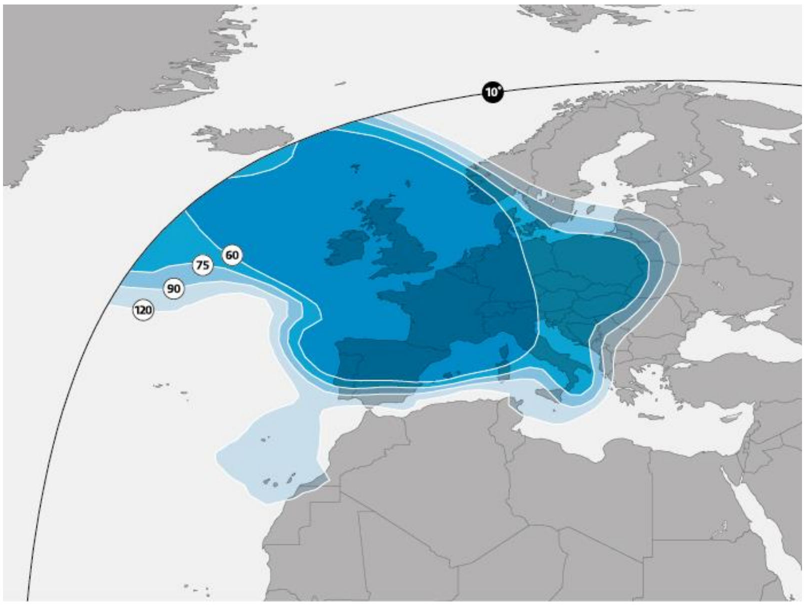

Figure 14: ASTRA 2F Europe Ku-Band coverage beam

Item	Quantity	Data sheet / Specification	Vendor
RF Uplink Ground Station	1	ATF #33 Antenna, Diameter: 9 m, Vertex, Tx/Rx, Ku-band (see Figure 16)	SES
RF Downlink Ground Station	1	MBA Antenna, Diameter: 4.5 m, Multi-Beam Antenna, Rx only, Ku-band (see Figure 17)	SES

Table 48: Satellite RF specifications

Figure 15: SES's Teleport in Betzdorf, Luxembourg

Figure 16: RF Uplink ground station

Figure 17: RF Downlink ground station

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Item	Quantity	Data sheet / Specification	Vendor
 **HUB Chassis - MODEL 15152, 5IF,GIGE,PAY-AS-YOU-GROW,220VAC,RCM-PPS**	1	Info: https://www.idirect.net/products/series-15100-universal-satellite-hub-5if-20-slot/	ST Engineering iDirect

Table 49: Satellite Hub Platform hardware specifications

Item	*Quantity*	*Data sheet / Specification*	*Vendor*
 **iQ Desktop Modem**	1	Datasheet: https://www.idirect.net/wp-content/uploads/2019/01/iDirect-Spec-Sheet-iQ-Desktop-1018.pdf	ST Engineering iDirect


1.2m Ku-band Tx/Rx Ku Band Antenna ODU System
	1	ODU system includes:
		• 1.2m Type 123 Class II Ku Band Transmit/Receive:
		  ○ Antenna with Linear Polarised Cross Pol Feed and Az/El Mount (SES Compliant):
		  ○ Transmit Frequency: 13.75 - 14.50 GHz
		  ○ Receive Frequency: 10.70 - 12.75 GHz
		  ○ Includes 30 dB Cross Pol OMT and TRF
		• 4W Universal Ku-Band Block Up Converter:
		  ○ RF Output Frequency: 13.75 - 14.5 GHz
		  ○ Local oscillator frequency 12.80 GHz
		  ○ IF Frequency 950 to 1,700 MHz
		  ○ Output Interface: WR75 Waveguide with Groove
		  ○ Output Power 4W (+36 dBm min.)
		  ○ Input Connector: F-type
		• Universal Ku-Band 2LO PLL LNB:
		  ○ RF Frequency: 10.70-11.70 GHz / 11.70-12.75 GHz
		  ○ Local Frequency: 9.75 GHz / 10.60 GHz
		  ○ Local Stability: +/- 10 ppm
		  ○ IF Connector: F-type
		  ○ Local Frequency Selected by 22kHz Tone
			ST Engineering iDirect

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		• 30m Pre Terminated Tx/Rx Shotgun Cable with F Type Connectors (75 Ohm).	
 **MEC Server** **SuperServer 5019A-FTN4**	1	Info: https://www.supermicro.com/en/products/system/1U/5019/SYS-5019A-FTN4.cfm	ST Engineering iDirect

Table 50: Fixed Edge Node hardware specifications

Item	Quantity	Data sheet / Specification	Vendor
 **SatCube Ku-band small-factor lightweight transportable terminal with embedded ST Engineering iDirect's iQ200 modem**	1	Info: http://www.satcube.com/satellite-terminal/ Datasheet: http://www.satcube.com/wp-content/uploads/2019/09/satcube_ku_2018_IBC_20190906-web.pdf	SatCube

Table 51: SatCube transportable terminal

The hardware items of the Smart IoT GW are described in the table below:

Item	Quantity	Data sheet / Specification	Vendor
 **Raspberry Pi 4 Model B - 8GB**	4	Info: Raspberry Pi 4 Model B - 8GB (antratek.com)	SES
 **PG1301 LORAWAN CONCENTRATOR FOR RASPBERRY PI**	2	Info: https://www.antratek.com/10-channels-lorawan-gps-concentrator-for-raspberry-pi	SES

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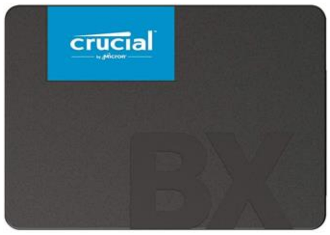
 **RE_COMPUTER CASE FOR ODYSSEY, RASPBERRY PI, BEAGLEBONE AND JETSON NANO**	4	Info: re_computer case for ODYSSEY, Raspberry Pi, BeagleBone and Jetson Nano (antratek.com)	SES
 **120 GB Internal SSD**	4	Info: Crucial BX500 CT120BX500SSD1 120GB Internal SSD: Amazon.de: Computers & Accessories	SES

Table 52: Smart IoT GW hardware specifications

6.1.2 INGENIOUS CHECKLIST

In this section, the development and integration activities of the use case testbed are listed and discussed.

6.1.2.1 Development Activities List and Planning

In this sub section, we discuss the development activities of the use case testbed. Particularly, the following table presents a summary of the required development activities and the time plan for their completion.

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Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
COSCO, VALENCIA	Hardware/Device/ Equipment	Procurement of IoT Sensors for Measuring Temperature, Humidity, Movement, Vibration, etc.	COSCO_VALENCIA_UC4_ development _01	COSCO_VALENCIA _UC4_ setup _09	FV	01/06/2021	31/08/2021
COSCO, VALENCIA	Asset	Procurement of iNGENIOUS shipping container	COSCO_VALENCIA _UC4_ development _02	COSCO_VALENCIA _UC4_ setup _12	FV	01/12/2021	28/02/2022
COSCO, VALENCIA	Asset	Collaboration with Container 42 for Using it at UC4 Demo	COSCO_VALENCIA _UC4_ development _03	COSCO_VALENCIA _UC4_ setup _13	FV	01/04/2021	30/03/2022
COSCO, VALENCIA	Smart IoT GW	IoT GW Interfaces (M2M Interfaces and Sensor Network Interfaces)	COSCO_VALENCIA _UC4_development_04	COSCO_VALENCIA _UC4_setup_11	SES	01/04/2021	30/09/2021
COSCO, VALENCIA	Smart IoT GW	IoT GW Data Storage	COSCO_VALENCIA _UC4_development_05	COSCO_VALENCIA _UC4_setup_11	SES	01/05/2021	30/06/2021
COSCO, VALENCIA	Smart IoT GW	IoT GW Data Transformation and Routing	COSCO_VALENCIA _UC4_development_06	COSCO_VALENCIA _UC4_setup_11	SES	10/04/2021	30/09/2021
COSCO, VALENCIA	Smart IoT GW	IoT GW Management Service	COSCO_VALENCIA _UC4_development_07	COSCO_VALENCIA _UC4_setup_11	SES	01/04/2021	20/06/2021
COSCO, VALENCIA	Smart IoT GW/Visualization	IoT GW HMI & API (Grafana, Node Red Dashboards)	COSCO_VALENCIA _UC4_development_08	COSCO_VALENCIA _UC4_setup_11	SES	20/06/2021	10/08/2021
COSCO	Asset	Ensuring that a COSCO's ship will be used for the Site Survey and also for the UC4 Demo	COSCO_UC4_development_09	COSCO_UC4_setup_14	COSSP	01/12/2021	31/05/2022
VALENCIA	Asset	Ensuring that a truck will be used for the UC4 Demo	VALENCIA_UC4_development _10	VALENCIA_UC4_setup_15	COSSP	01/12/2021	31/05/2022
COSCO	Site Survey	Site Survey for the Installation the Satellite Terminal and the IoT GW on the Ship	COSCO_UC4_development_11	COSCO_UC4_development_09	SES, iDR, FV, COSSP	01/04/2021	30/11/2021

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COSCO, VALENCIA	Infrastructure / communications	Development work to enable SatCube Integration	COSCO_UC4_development_12	VALENCIA _UC4_setup_04	iDR	01/04/2021	30/09/2021
COSCO, VALENCIA	Infrastructure / communications	End to End Satellite communications data path	COSCO_UC4_development_13	COSCO_ VALENCIA _UC4_setup_01 COSCO_ VALENCIA _UC4_setup_02 COSCO_ VALENCIA _UC4_setup_03 COSCO_ VALENCIA _UC4_setup_06 COSCO_ VALENCIA _UC4_setup_16 VALENCIA _UC4_setup_04	iDR	01/04/2021	31/12/2021
iDirect Lab	Infrastructure / communications	Lab demonstrator development	iDR_UC4_development_14	iDR_UC4_setup_17 iDR_UC4_setup_18 iDR_UC4_setup_19 iDR_UC4_setup_20 iDR_UC4_setup_21 iDR_UC4_setup_22 iDR_UC4_setup_23 iDR_UC4_setup_24 iDR_UC4_setup_25 iDR_UC4_setup_26 iDR_UC4_setup_27	iDR	01/01/2021	31/12/2021
VALENCIA	Procedure	Ensuring transport procedure and documentation for container vessel trip.	Valencia_UC4_development_15	COSCO_Valencia _UC4_setup_12 COSCO_UC4_setup_14	COSSP	01/12/2021	31/10/2022
VALENCIA	Procedure	Ensuring transport procedure and documentation for container inland transport by truck	Valencia_UC4_development_16	COSCO_Valencia _UC4_setup_12 Valencia_UC4_setup_15	COSSP	01/12/2021	31/10/2022

Table 53: Use case - development activities

6.1.2.2 Integration Activities List and Planning

According to the main list of required resources, facilities and development activities expected to be performed for the use case implementation, the following integration activities have been identified in order to support the use case deployment and validation:

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Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
COSCO, VALENCIA	Hardware/Device/Equipment	Sensors Integration with Main Board	COSCO_VALENCIA_UC4_integration_01	N/A	FV	01/09/2021	31/12/2021
COSCO, VALENCIA	Hardware/Device/Equipment	Integration of Main Board with LoRa and Wi-Fi Communication Modules	COSCO_VALENCIA_UC4_integration_02	COSCO_VALENCIA _UC4_integration_01	FV, SES	01/09/2021	15/11/2021
COSCO, VALENCIA	Hardware/Device/Equipment	Integration of Main Board with CIoT Communication Modules	COSCO_VALENCIA_UC4_integration_03	COSCO_Valencia _UC4_integration_02	FV, SEQ	01/09/2021	31/12/2021
COSCO, VALENCIA	Communication	Sensors Communication with the Smart IoT GW	COSCO_VALENCIA_UC4_integration_04	COSCO_VALENCIA _UC4_ development _04 COSCO_VALENCIA _UC4_integration_02 COSCO_VALENCIA _UC4_integration_03	FV, SES	01/01/2022	28/02/2022
COSCO, VALENCIA	Hardware/Device/Equipment	Sensors Installation in the Container	COSCO_VALENCIA_UC4_integration_05	COSCO_VALENCIA _UC4_ development _02 COSCO_VALENCIA _UC4_integration_02 COSCO_VALENCIA _UC4_integration_03 COSCO_VALENCIA _UC4_integration_04	FV	01/03/2022	30/04/2022
COSCO	Hardware/Device/Equipment	Installation of the Smart IoT GW on the Ship	COSCO_UC4_integration_06	COSCO_UC4_ development _09 COSCO_UC4_ development _11	SES, COSSP	01/03/2022	31/05/2022
VALENCIA	Hardware/Device/Equipment	Installation of the Satellite	VALENCIA_UC4_integration_07	N/A	SES, FV, iDR	01/03/2022	31/05/2022

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		Terminal on the port of Valencia					
COSCO, VALENCIA	Communication	Communication of the Smart IoT GW with the VSAT terminal via i) Ethernet, or ii) LTE, or iii) Wi-Fi	COSCO_VALENCIA_UC4_integration_08	COSCO_VALENCIA _UC4_ development _04 COSCO_UC4_integration_06 VALENCIA_UC4_integration_07	SES, iDR	01/03/2022	31/05/2022
VALENCIA	Hardware/Device/Equipment	Installation of the Smart IoT GW on the truck	VALENCIA_UC4_integration_09	VALENCIA_UC4_ development _10	COSSP, SES	01/03/2022	31/05/2022
VALENCIA	Communication	Communication of the Smart IoT GW with the terrestrial connectivity	VALENCIA_UC4_integration_10	COSCO_VALENCIA _UC4_ development _04	SES, FV, COSSP	01/03/2022	31/05/2022
iDirect Lab	Infrastructure / Communications/ Software	Integration of Smart IoT GW within Killarney lab	iDR_UC4_integration_11	COSCO_VALENCIA _UC4_development_08	iDR	01/07/2021	31/01/2022
iDirect Lab	Infrastructure / Communications/ Software	Lab Simulator/ Demonstrator	iDR_UC4_integration_12	iDR_UC4_development_14	iDR	01/01/2021	31/05/2022

Table 54: Use case - integration activities

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6.2 Test Cases Definition

In this chapter, a list of test cases to be performed during the lifetime of the project are presented for proper use case validation. According to a common template, the test cases are listed below:

Test Case Id	UC4_TC_01
Responsible Partner	FV
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Integration and installation of sensors and communication modules on iNGENIOUS container
Prerequisites	Procurement of sensors and iNGENIOUS containers
Type of test	Hardware tests for integrating all sensors in a single board. After integrating all sensors, the main board module should be installed by performing usability and stress tests
Reference standards used	N/A
Test Environment	Sensors will be integrated in a laboratory environment. The module will be installed on the container at the container terminal.
Input to the system	Temperature, humidity, bump, gate opening and tracking sensors
Output of the system	Module with all sensors installed on iNGENIOUS container
Data involved in the test	Temperature, humidity, bump, gate opening and tracking data sets
System requirements covered	UC4_SR_25, UC4_SR_27
Related KPIs	Battery life, typical message size, maximum message size, typical frequency, positioning accuracy
Are UC's users involved in the test?	FV, COSSP
Who will perform the test?	FV (Subcontracted)
Test Steps	1. Integration of sensors in main board 2. Integration of communication modules in main board 3. Installation of main board module on iNGENIOUS container
Risks	Incompatibility between sensors, the communication modules and the main board. Problems related to the installation of the main board on the container
Mitigation	Consider compatibility between sensors and communication modules during the sensor procurement. Ensure that the battery life of sensors is long enough to provide periodic measurements
Expected result	Module with all sensors installed on iNGENIOUS container
Actual result	to be determined
Passed/Failed	to be determined

Table 55: Use case - UC4_TC_01

Test Case Id	UC4_TC_02
Responsible Partner	FV
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Over-the-air tests for evaluating LoRa and LTE connectivity at the container in maritime and terrestrial scenarios at the Port of Valencia
Prerequisites	Integration of sensors in the main board and installation on the container
Type of test	Hardware and system tests including integration, connectivity and security testing
Reference standards used	To be verified
Test Environment	Connectivity first to be checked in laboratory environment and then with over-the-air demonstration in shipping container terminal and COSCO vessel
Input to the system	Main board with communication modules integrated
Output of the system	LoRa and LTE connectivity ensured with the container at the terrestrial and maritime segments
Data involved in the test	Transmission of data measured by the different sensors

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System requirements covered	UC4_SR_27, UC4_SR_28
Related KPIs	Availability, reliability, coverage, typical frequency (messages per day) connectivity of heterogeneous, IoT devices, latency, mobility
Are UC's users involved in the test?	FV, Sequans, COSSP, SES
Who will perform the test?	FV (Subcontracted)
Test Steps	1. LoRa connectivity tests at the laboratory 2. LoRa connectivity tests in the maritime segment (when the container is on the vessel) 3. LTE connectivity tests at the laboratory 4. LTE connectivity tests in the terrestrial segment (when the container is on the truck)
Risks	Connectivity issues (interferences, bad coverage) when the container is loaded on the vessel/truck
Mitigation	Identify a suitable position for the container inside the vessel. Identify the LTE coverage in the port area
Expected result	LoRa and LTE connectivity ensured with the container at the terrestrial and maritime segments
Actual result	to be determined
Passed/Failed	to be determined

Table 56: Use case - UC4_TC_02

Test Case Id	**UC4_TC_03**
Responsible Partner	FV
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Develop a web service-based application where data gathered by IoT sensors and actuators is stored and visualized
Prerequisites	Receive the data gathered by the Smart IoT GW or the LTE network
Type of test	Software and system tests including integration, interface and reliability testing
Reference standards used	To be verified
Test Environment	Tests will be performed in a laboratory environment
Input to the system	Data produced by sensors and gathered by the Smart IoT GW and/or the LTE network
Output of the system	Web-service based application able to represent and give access to the data
Data involved in the test	Data measured by the different sensors
System requirements covered	UC4_SR_04
Related KPIs	Availability, Confidentiality and integrity protection of sensitive data
Are UC's users involved in the test?	FV, SES, COSSP
Who will perform the test?	FV (Subcontracted)
Test Steps	1. Structuring and storage of data in a database 2. Development of back-end for a web service-based application 3. Development of front-end for a web service-based application
Risks	Problems for accessing the data coming from IoT sensors
Mitigation	Find database/server where data could be stored
Expected result	Web service-based application where data gathered by IoT sensors and actuators is stored and visualized
Actual result	to be determined
Passed/Failed	to be determined

Table 57: Use case - UC4_TC_03

Test Case Id	**UC4_TC_04**
Responsible Partner	COSSP
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Container transport from the Port of Valencia to the Port of Piraeus, including storage at the Port of Piraeus until next loading
Prerequisites	Integration and installation of sensors and communication modules on iNGENIOUS container
Type of test	Usability test to monitor cargo and safety conditions and real-time location of the container
Reference standards used	DCSA

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Test Environment	Maritime transport: Port of Valencia, COSCO ship and Port of Piraeus
Input to the system	Vessel - vessel schedule
Output of the system	Temperature, humidity, bump, gate opening and tracking data obtained from the different IoT sensors
Data involved in the test	Vessel - vessel schedule - Temperature, humidity, bump, gate opening and tracking sensors
System requirements covered	UC4_SR_01, UC4_SR_03
Related KPIs	Availability, reliability, connectivity of heterogeneous devices, mobility, positioning accuracy, typical frequency
Are UC's users involved in the test?	COSSP, FV, SES, iDR
Who will perform the test?	COSSP
Test Steps	Transport from Valencia port to Piraeus port: 1. Container loading to the ship at the Port of Valencia 2. Transport to the Port of Piraeus by vessel 3. Container unloading at the Port of Piraeus 4. Storage at the Port of Piraeus
Risks	No risk identified
Mitigation	N/A
Expected result	Real-time tracking and monitoring of cargo and safety conditions of the container
Actual result	to be determined
Passed/Failed	to be determined

Table 58: Use case - UC4_TC_04

Test Case Id	**UC4_TC_05**
Responsible Partner	COSSP
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Container transport from the Port of Piraeus to the Port of Valencia
Prerequisites	Integration and installation of sensors and communication modules on iNGENIOUS container
Type of test	Usability test to monitor cargo and safety conditions and real-time location of the container
Reference standards used	DCSA
Test Environment	Maritime transport: Port of Valencia, COSCO ship and Port of Piraeus
Input to the system	Vessel - vessel schedule; Shipping container
Output of the system	Temperature, humidity, bump, gate opening and tracking data obtained from the different IoT sensors
Data involved in the test	Vessel - vessel schedule - Temperature, humidity, bump, gate opening and tracking sensors
System requirements covered	UC4_SR_01, UC4_SR_03
Related KPIs	Availability, reliability, connectivity of heterogeneous devices, mobility, positioning accuracy, typical frequency
Are UC's users involved in the test?	COSSP, FV, SES, iDR
Who will perform the test?	COSSP
Test Steps	Transport from the Port of Piraeus to the Port of Valencia 1. Container loading to the ship at the Port of Piraeus 2. Transport to the port of Valencia by vessel 3. Container unloading at the Port of Valencia 4. Storage at the Port of Valencia
Risks	No risk identified
Mitigation	N/A
Expected result	Real-time tracking and monitoring of cargo and safety conditions of the container
Actual result	to be determined
Passed/Failed	to be determined

Table 59: Use case - UC4_TC_05

Test Case Id	**UC4_TC_06**
Responsible Partner	COSSP
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Terrestrial transport by truck from Port of Valencia to hinterland and vice versa
Prerequisites	Integration and installation of sensors and communication modules on iNGENIOUS container

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Type of test	Usability test to monitor cargo and safety conditions and real-time location of the container
Reference standards used	3GPP
Test Environment	Inland transport: Port of Valencia
Input to the system	Truck - Transport orders; Shipping Container
Output of the system	Temperature, humidity, bump, gate opening and tracking data obtained from the different IoT sensors
Data involved in the test	Truck - Transport orders - Temperature, humidity, bump, gate opening and tracking sensors
System requirements covered	UC4_SR_01, UC4_SR_03, UC4_SR_23, UC4_SR_27
Related KPIs	Availability, reliability, connectivity of heterogeneous devices, mobility, positioning accuracy, typical frequency
Are UC's users involved in the test?	COSSP, FV, SEQ
Who will perform the test?	COSSP
Test Steps	Inland segment from the Port of Valencia to Madrid area and vice versa: 1. Container loading on the truck 2. Inland transport by truck 3. Container unloading
Risks	No risk identified
Mitigation	N/A
Expected result	Real-time tracking and monitoring of cargo and safety conditions of the container
Actual result	to be determined
Passed/Failed	to be determined

Table 60: Use case - UC4_TC_06

Test Case Id	**UC4_TC_07**
Responsible Partner	COSSP
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Site Survey for exploring the practical viability of accommodating and installing the Smart IoT Gateway aboard, as well for exploring the theoretical viability of installing VSAT antenna on the vessel
Prerequisites	Authorisation of the captain and the owner of the ship to carry out the site survey, list of activities to be performed aboard as part of the survey execution
Type of test	Inspection test aboard the ship when docked at the port
Reference standards used	N/A
Test Environment	Maritime transport: COSCO Ship, Port of Valencia
Input to the system	List of activities to be performed aboard as part of the survey execution
Output of the system	Assessment and validation of power supply requirements, environment and physical dimensions required, electromagnetic compatibility, LoRa, Wi-Fi and BT coverage, accessibility, and deployment constraints for installing the Smart IoT GW on board. Theoretical assessment of a potential installation of the VSAT antenna onboard
Data involved in the test	Power supply requirements, environment and physical dimensions required, electromagnetic compatibility, LoRa, Wi-Fi and BT coverage, accessibility, and deployment constraints
System requirements covered	UC4_SR_01, UC4_SR_08, UC4_SR_12, UC4_SR_13, UC4_SR_15
Related KPIs	Availability, reliability, coverage, connectivity of heterogeneous devices, positioning accuracy, typical frequency
Are UC's users involved in the test?	COSSP, FV, SES, iDR
Who will perform the test?	COSSP, SES
Test Steps	1. Drafting of list of activities for performing the site survey 2. Validation with COSCO, the captain and the owner of the ship 3. Execution of the site survey 4. Drafting of document summarizing the main outcomes of the survey
Risks	Problems related with permission for the Site Survey before starting the test
Mitigation	Preparing a list of activities to be shared the captain and owner of the ship to get the approval
Expected result	Assessment and validation of power supply requirements, environment and physical dimensions required,

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	electromagnetic compatibility, LoRa, Wi-Fi and BT coverage, accessibility, and deployment constraints for installing the Smart IoT GW on board. Theoretical assessment of a potential installation of the VSAT antenna onboard
Actual result	to be determined
Passed/Failed	to be determined

Table 61: Use case - UC4_TC_07

Test Case Id	**UC4_TC_08**
Responsible Partner	iDR
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Validate proposed satellite backhaul infrastructure A number of iterations of testing will take place as satellite capacity is made available, in order to guarantee that the infrastructure will meet the KPI requirements of the live demonstration
Prerequisites	Live satellite capacity is available VSAT (including SatCube) terminal availability. Necessary remote access infrastructure to facilitate management and testing
Type of test	Connectivity
Reference standards used	N/A
Test Environment	iDirect Testbed & SES Betzdorf live network
Input to the system	Test IP traffic between Satellite terminals, and Teleport
Output of the system	Measurement data
Data involved in the test	IP traffic measurement data
System requirements covered	UC4_SR_01, UC4_SR_18, UC4_SR_29
Related KPIs	Availability, Reliability, Coverage
Are UC's users involved in the test?	SES
Who will perform the test?	iDR, SES
Test Steps	1. Setup – SatCube terminal connectivity to SES live network 2. Send measurement data from device co-located with SatCube via satellite to host at teleport side (and vice-versa) 3. Verify receipt of test data in both directions
Risks	Possible risk of connectivity issues
Mitigation	Advance preparation and test and testing to ensure sources of connectivity issues are identified and resolved
Expected result	Test data exchanged successfully over satellite between terminal and teleport. Achieved bandwidth and latency results should indicate sufficient performance to meet use case requirements
Actual result	First iteration of testing was completed successfully with SatCube and Fixed VSAT terminals. Detailed results will be provided in a separate document
Passed/Failed	First iteration took place 25/05/21 – 31/05/21, and was successful

Table 62: Use case - UC4_TC_08

Test Case Id	**UC4_TC_09**
Responsible Partner	iDR
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Validate end to end connectivity using Satellite backhaul
Prerequisites	Live satellite capacity is available End to end network from sensors to data centre/cloud via Smart IoT Gateway is configured, satellite backhaul configured
Type of test	Connectivity
Reference standards used	N/A
Test Environment	Valencia Port Live testbed / iDirect Testbed
Input to the system	Data produced by sensors and gathered by the Smart IoT GW and/or the LTE network and delivered via IP to Satellite terminal for backhaul
Output of the system	Backhauled sensor data received by cloud endpoint
Data involved in the test	Sensor measurement data
System requirements covered	UC4_SR_01, UC4_SR_18, UC4_SR_24, UC4_SR_26, UC4_SR_29
Related KPIs	Availability, Reliability, Coverage
Are UC's users involved in the test?	SES (+ use case partners requiring sensor data backhaul)

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Who will perform the test?	iDR
Test Steps	1. Setup – Data path establishment between Sensor and Data centre using satellite backhaul 2. Publish sensor data from device to data centre/cloud 3. Verify successful receipt of sensor data
Risks	Availability of partner sensors
Mitigation	Validation using iDR / SES supplied sensors to test cloud destination
Expected result	Sensor data is received successfully at data centre/cloud
Actual result	to be determined
Passed/Failed	to be determined

Table 63: Use case - UC4_TC_09

Test Case Id	**UC4_TC_10**
Responsible Partner	iDR
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Verify uplink and downlink Satellite backhaul capacity meets Use Case KPI requirements
Prerequisites	Live satellite capacity is available End to end network from sensors to data centre/cloud via Smart IoT Gateway is configured, satellite backhaul configured
Type of test	Backhaul Capacity (verify downlink and uplink capacity meets UC KPI requirements)
Reference standards used	N/A
Test Environment	Valencia Port Live testbed / iDirect Testbed
Input to the system	iperf generated test data between endpoints at (or co-located with) Smart IoT Gateway, and Satellite Teleport site
Output of the system	iperf received data at same locations as input
Data involved in the test	iperf test data
System requirements covered	UC4_SR_01, UC4_SR_05, UC4_SR_07, UC4_SR_08, UC4_SR_18
Related KPIs	Typical message size, Maximum message size, Typical frequency (messages per day)
Are UC's users involved in the test?	SES
Who will perform the test?	iDR
Test Steps	1. Setup – Data path establishment between Sensor and Data centre using satellite backhaul 2. Using iperf or similar utilities, measure UDP and TCP downlink bandwidth between Satellite Terminal location and Betzdorf egress point 3. Using iperf or similar utilities, measure UDP and TCP downlink bandwidth between Satellite Terminal location and Betzdorf egress point
Risks	Allocated downlink or uplink bandwidth is insufficient to cater for required capacity
Mitigation	Review capacity allocations during iterations of pre-trial validation tests (see UC4_TC_05)
Expected result	Uplink and downlink capacity should exceed the minimum requirements defined in Use Case KPIs
Actual result	to be determined
Passed/Failed	to be determined

Table 64: Use case - UC4_TC_10

Test Case Id	**UC4_TC_11**
Responsible Partner	iDR
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Verify uplink and downlink Satellite backhaul latency
Prerequisites	Live satellite capacity is available End to end network from sensors to data centre/cloud via Smart IoT Gateway is configured, satellite backhaul configured
Type of test	Verify Satellite latency is within required KPI limits for Use Case
Reference standards used	N/A
Test Environment	Valencia Port Live testbed / iDirect Testbed
Input to the system	UDP and TCP test data for latency measurement
Output of the system	UDP and TCP test data for latency measurement, with corresponding latency statistics
Data involved in the test	UDP and TCP test data

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System requirements covered	UC4_SR_01, UC4_SR_05, UC4_SR_07, UC4_SR_08, UC4_SR_18
Related KPIs	Latency
Are UC's users involved in the test?	SES
Who will perform the test?	iDR
Test Steps	1. Setup – Data path establishment between Sensor and Data centre using satellite backhaul 2. Send test TCP/UDP data uplink and downlink between host at/co-located with satellite terminal and Betzdorf teleport egress point, to measure latency observed over satellite segment of backhaul
Risks	N/A
Mitigation	N/A
Expected result	Latency should be within the limits specified for the use case
Actual result	to be determined
Passed/Failed	to be determined

Table 65: Use case - UC4_TC_11

Test Case Id	**UC4_TC_12**
Responsible Partner	iDR
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Validate confidentiality of satellite backhauled sensor data
Prerequisites	Sensor data must be encrypted before being passed vi IP to satellite backhaul
Type of test	Security
Reference standards used	N/A
Test Environment	Valencia Port Live testbed / iDirect Testbed
Input to the system	Data produced by sensors and gathered by the Smart IoT GW and/or the LTE network and delivered via IP to Satellite terminal for backhaul
Output of the system	Backhauled sensor data to cloud endpoint
Data involved in the test	Sensor measurement data
System requirements covered	UC4_SR_01, UC4_SR_05, UC4_SR_07, UC4_SR_18, UC4_SR_21
Related KPIs	Confidentiality and integrity protection of sensitive data
Are UC's users involved in the test?	SES (+ use case partners requiring sensor data backhaul)
Who will perform the test?	SES, FV
Test Steps	1. Setup – Data path establishment between Sensor and Data centre using satellite backhaul. 2. Capture sensor data in transit, at point between Smart IoT Gateway and Teleport IP egress point. 3. Analyse captured sensor data to verify encrypted status.
Risks	Sensors data provided to satellite backhaul unencrypted
Mitigation	Consider additional further encryption steps (e.g. between IoT Gateway to Teleport)
Expected result	Captured sensor data is undecipherable between IoT Gateway and teleport egress point
Actual result	to be determined
Passed/Failed	to be determined

Table 66: Use case - UC4_TC_12

Test Case Id	**UC4_TC_13**
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Connectivity with sensors
Prerequisites	Smart IoT GW deployed and running. Sensor network operative and in range
Type of test	Messages are received from the sensors and the Smart IoT GW can communicate with the sensors (i.e. status and ACK)
Reference standards used	LoRa, Bluetooth and/or Wi-Fi
Test Environment	Tests will be performed in: • a laboratory environment • a vessel: GW deployed in the planned location and sensors in the container
Input to the system	Sensor data (regardless of the meaning)
Output of the system	Processed sensor data stored in the GW
Data involved in the test	Any data from sensors
System requirements covered	UC4_SR_03, UC4_SR_06

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Related KPIs	Coverage, availability, reliability
Are UC's users involved in the test?	SES, FV, COSSP
Who will perform the test?	SES, FV
Test Steps	1. Configure GW and sensors (IDs, security...) 2. Sensors start transmitting meaningful data 3. GW receives the messages 4. GW processes the messages 5. GW stores the messages
Risks	No radio coverage on the sensor network. Sensor radio link too weak or broken by interferences. Misconfiguration between sensors and GW
Mitigation	Measure radio link quality in advance. Simulate coverage
Expected result	GW and sensors can communicate and exchange data
Actual result	to be determined
Passed/Failed	to be determined

Table 67: Use case - UC4_TC_13

Test Case Id	UC4_TC_14
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Connectivity with M2M space (direct)
Prerequisites	Smart IoT GW deployed and running. Test CSE accessible
Type of test	Connectivity with M2M systems via satellite
Reference standards used	To be verified (TCP/IP?)
Test Environment	Tests will be performed in UC4 Live testbed and in a laboratory environment. Network can be wired or wireless. An oneM2M CSE accessible through the satellite link
Input to the system	Dummy data stored or generated in the Smart IoT GW
Output of the system	Validate oneM2M data
Data involved in the test	Transmission of data measured by the different sensors
System requirements covered	UC4_SR_01, UC4_SR_02
Related KPIs	Availability, reliability, connectivity, mobility
Are UC's users involved in the test?	SES
Who will perform the test?	SES
Test Steps	1. Configure oneM2M CSE 2. Trigger messages on the IoT GW that needs to be routed directly
Risks	Connectivity issues, misconfiguration. Satellite communication not available
Mitigation	Verify satellite terminal network configuration
Expected result	Messages are correctly routed to the oneM2M CSE
Actual result	to be determined
Passed/Failed	to be determined

Table 68: Use case - UC4_TC_14

Test Case Id	UC4_TC_15
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Connectivity with M2M space (VSAT)
Prerequisites	Smart IoT GW deployed and running. VSAT terminal running and tested. Satellite capacity available
Type of test	Connectivity with M2M systems via satellite
Reference standards used	To be verified (TCP/IP?)
Test Environment	Tests will be performed in UC4 Live testbed and also in Betzdorf (Luxembourg). Smart IoT GW connected in the same network as the VSAT terminal. This network can be wired or wireless. An oneM2M CSE accessible through the satellite link
Input to the system	Dummy data stored or generated in the Smart IoT GW
Output of the system	Valid oneM2M data
Data involved in the test	Transmission of data measured by the different sensors
System requirements covered	UC4_SR_01, UC4_SR_11, UC4_SR_16, UC4_SR_17, UC4_SR_19, UC4_SR_23
Related KPIs	Availability, reliability, connectivity, mobility
Are UC's users involved in the test?	SES
Who will perform the test?	SES, iDR
Test Steps	1. Configure VSAT termina 2. Configure oneM2M CSE

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	3. Trigger messages on the IoT GW that needs to be route via satellite 4. Send M2M messages through the VSAT
Risks	Connectivity issues, misconfiguration. Satellite communication not available
Mitigation	Verify satellite terminal network configuration. Run direct M2M connectivity tests in advance
Expected result	Messages are correctly routed via satellite
Actual result	to be determined
Passed/Failed	to be determined

Table 69: Use case - UC4_TC_15

Test Case Id	**UC4_TC_16**
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Smart IoT GW will receive and process sensor data
Prerequisites	Smart IoT GW deployed. Sensor network deployed. Sensor coverage checked
Type of test	Software and system tests including integration, interface and reliability testing
Reference standards used	To be verified
Test Environment	Tests will be performed in UC4 Live testbed and in a laboratory environment. Several endpoints are simulated. Real sensor network with multiple devices sending data simultaneously
Input to the system	Real sensor data, including humidity, temperature, position transmitted wired or wirelessly
Output of the system	Transformed messages in the appropriate format and routed to the appropriate destination
Data involved in the test	Data measured by the different sensors
System requirements covered	UC4_SR_07, UC4_SR_08, UC4_SR_10, UC4_SR_11, UC4_SR_16, UC4_SR_17, UC4_SR_19, UC4_SR_23
Related KPIs	Availability, reliability, coverage, typical frequency (messages per day) connectivity of heterogeneous, IoT devices, latency, mobility.
Are UC's users involved in the test?	SES
Who will perform the test?	SES
Test Steps	1. Trigger message generation for a specific route type 2. Change message parameters (type, priority, payload...) 3. Repeat step 2 for the supported message types
Risks	Invalid configuration, connectivity issues
Mitigation	Verify lab environment
Expected result	Correctly formatted messages are routed to the appropriate destination
Actual result	to be determined
Passed/Failed	to be determined

Table 70: Use case - UC4_TC_16

Test Case Id	**UC4_TC_17**
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Smart IoT GW configuration via remote management
Prerequisites	Smart IoT GW deployed
Type of test	Software and system tests including integration, interface and reliability testing
Reference standards used	To be verified
Test Environment	Tests will be performed in UC4 Live testbed and in a laboratory environment
Input to the system	Login information, configuration data
Output of the system	Smart IoT configuration
Data involved in the test	Configuration
System requirements covered	UC4_SR_09, UC4_SR_12, UC4_SR_20
Related KPIs	Monitoring and configuration
Are UC's users involved in the test?	SES
Who will perform the test?	SES
Test Steps	1. Log in to Smart IoT GW management endpoint 2. Send configuration parameters 3. Retrieve status and configuration data

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	4. Sensors send alert/warning messages 5. Verify that the Smart IoT GW sends the appropriate alerts
Risks	Invalid configuration, connectivity issues
Mitigation	Verify lab environment
Expected result	The Smart IoT GW changes configuration and shows status
Actual result	to be determined
Passed/Failed	to be determined

Table 71: Use case - UC4_TC_17

Test Case Id	**UC4_TC_18**
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Smart IoT GW will receive and process sensor data during outages
Prerequisites	Smart IoT GW deployed. Sensor network deployed. Sensor coverage checked
Type of test	Software and system tests including integration, interface and reliability testing
Reference standards used	To be verified
Test Environment	Tests will be performed in a laboratory environment. Several endpoints are simulated. Real sensor network with multiple devices sending data simultaneously. Endpoints should be able to connect and disconnect on request
Input to the system	Real sensor data, including humidity, temperature, position transmitted wired or wirelessly
Output of the system	Transformed messages in the appropriate format and routed to the appropriate destination
Data involved in the test	Data measured by the different sensors
System requirements covered	UC4_SR_12, UC4_SR_13, UC4_SR_14, UC4_SR_15, UC4_SR_16
Related KPIs	Availability, reliability, coverage, typical frequency (messages per day) connectivity of heterogeneous, IoT devices, latency, mobility.
Are UC's users involved in the test?	SES
Who will perform the test?	SES
Test Steps	1. Trigger message generation for a specific route type 2. Change message parameters (type, priority, payload...) 3. Verify that messages are being routed 4. Disconnect destination endpoint 5. Verify that messages are being stored 6. Connect back the destination 7. Verify that the stored messages are (re)sent again
Risks	Invalid configuration, connectivity issues
Mitigation	Verify lab environment
Expected result	During the outages, the messages are held and sent again when the destination network is available
Actual result	to be determined
Passed/Failed	to be determined

Table 72: Use case - UC4_TC_18

Test Case Id	**UC4_TC_19**
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Smart IoT GW Security
Prerequisites	Smart IoT GW deployed
Type of test	Software and system tests for security
Reference standards used	To be verified
Test Environment	Tests will be performed in UC4 Live testbed and in a laboratory environment
Input to the system	Data produced by sensors and gathered by the Smart IoT GW
Output of the system	Sensor data to be delivered to cloud satellite or terrestrial connectivity
Data involved in the test	Sensor measurement data
System requirements covered	UC4_SR_21
Related KPIs	Security
Are UC's users involved in the test?	SES (+ use case partners requiring sensor data)
Who will perform the test?	SES, FV

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Test Steps	1. The Smart IoT GW captures and processes sensor data 2. Analyse captured sensor data to verify encrypted status
Risks	Sensors data provided to cloud unencrypted
Mitigation	Consider additional further encryption steps
Expected result	Captured sensor data are sent to cloud with high level of security
Actual result	to be determined
Passed/Failed	to be determined

Table 73: Use case - UC4_TC_19

Test Case Id	**UC4_TC_20**
Responsible Partner	SES
Use Case	UC4 on Inter-modal Asset Tracking via IoT and Satellite
Test case description	Smart IoT GW Integration with other systems
Prerequisites	Smart IoT GW deployed
Type of test	Software and system tests for integration with other systems
Reference standards used	To be verified
Test Environment	Tests will be performed in UC4 Live testbed and in laboratory environment
Input to the system	Data produced by sensors and gathered by the Smart IoT GW and/or the LTE network and delivered via IP to Satellite terminal for backhaul
Output of the system	Backhauled sensor data received by cloud endpoint
Data involved in the test	Sensor measurement data
System requirements covered	UC4_SR_22
Related KPIs	Availability, reliability, Connectivity of heterogeneous IoT devices.
Are UC's users involved in the test?	SES, FV, iDR
Who will perform the test?	SES, FV, SYE
Test Steps	1. Communication of the Smart IoT GW with the sensors 2. Communication of the Smart IoT GW with the satellite terminal or the LTE network
Risks	Incompatibility between sensors, the communication modules, the Smart IoT GW and the satellite terminal or LTE network
Mitigation	Consider compatibility between sensors, communication modules, Smart IoT GW and satellite terminal
Expected result	Sensor data is received successfully at data centre/cloud
Actual result	to be determined
Passed/Failed	to be determined

Table 74: Use case - UC4_TC_20

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7 Demo - Situational Understanding in Smart Logistics Scenario

This use case focuses on enhancing the situational understanding of events in maritime ports and terminals by means of collecting and aggregating data processing. To do so, the development of analytical and predictive models to estimate and optimize trucks turnaround times in ports is targeted through the aggregated ingestion of the different port and terminal data sources. Analysis and predictions of TTT will be performed by exploiting ML techniques that will allow to identify the TT times across the different phases (terminal TT, gate TT, idling times) of the port operative. Analytical and predictive services will be deployed at iNGENIOUS platform by exploiting REST API architecture. The outcome of the analysis and predictions will be visualized in a graphical interface composed of dashboards and maps.

Additionally, for enhancing the accuracy of situational understanding and predictive models, the use case will install real-time IoT tracking sensors on trucks as a new data source able to help estimating TTT. Tracking sensors will be integrated into the system architecture by considering wireless IoT technologies like LoRa, LTE-M or 5G. Network resources required for tracking trucks will be ensured by integrating a MANO component.

7.1 Valencia and Livorno Ports - Testbed

In this chapter setup, development and integration activities are listed and discussed.

7.1.1 EXISTING COMPONENTS SETUP

In this chapter planning of the required resources, facilities, connectivity and logistics for the setup of the testbed is performed, and it will support the use case deployment. The main activities that have been identified, are listed below:

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Test Bed	Resource Type	Resource Description	Required Setup Activities	Responsible Partner	Start Date (Planned)	Due Date (Planned)	Ready to be used?
VALENCIA	Infrastructure	Port facilities	VALENCIA_UC5_setup_00	FV	N/A	N/A	Yes
VALENCIA	Infrastructure/Network	Commercial LTE coverage	VALENCIA_UC5_setup_01	FV	N/A	N/A	Yes
VALENCIA	Data Source	Gate access data	VALENCIA_UC5_setup_02	FV	N/A	N/A	Yes
VALENCIA	Data Source	Meteorological data	VALENCIA_UC5_setup_03	FV	N/A	N/A	Yes
VALENCIA	Data Source	ValenciaPCS data	VALENCIA_UC5_setup_04	FV	N/A	N/A	Yes
VALENCIA	Data Source	AIS data	VALENCIA_UC5_setup_05	FV	N/A	N/A	Yes

Table 75: Use case - setup activities

7.1.2 INGENIOUS CHECKLIST

In this chapter development and integration activities are listed and discussed.

7.1.2.1 Development Activities List and Planning

According to the main list of required resources and facilities, the following development activities have been identified for this use case:

Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
VALENCIA, LIVORNO	Data Sources, Software	Data preparation and exploratory analysis	VALENCIA_LIVORNO_UC5_development_01	VALENCIA_LIVORNO_UC5_integration_01	AWA, FV	01/04/2021	31/10/2021
VALENCIA, LIVORNO	Software	Prediction model development	VALENCIA_LIVORNO_UC5_development_02	VALENCIA_LIVORNO_UC5_development_01	AWA, FV	01/11/2021	28/02/2022

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VALENCIA, LIVORNO	Software	Optimization model development	VALENCIA_LIVORNO_UC5_development_03	VALENCIA_LIVORNO_UC5_development_02	AWA, FV	01/01/2022	30/04/2022
VALENCIA, LIVORNO	Software	Basic port configurations	VALENCIA_LIVORNO_UC5_development_04	VALENCIA_LIVORNO_UC5_integration_02	AWA, FV	01/03/2022	30/04/2022
VALENCIA, LIVORNO	Software	Visualizing hinterland traffic, TT and cargo movements	VALENCIA_LIVORNO_UC5_development_05	VALENCIA_LIVORNO_UC5_development_04	AWA, FV	01/05/2022	30/06/2022
VALENCIA, LIVORNO	Software	Deployment of prediction and optimization models	VALENCIA_LIVORNO_UC5_development_06	VALENCIA_LIVORNO_UC5_development_05	AWA, FV	01/05/2022	31/07/2022
VALENCIA, LIVORNO	Application, Software, Platform	API Programming	VALENCIA_LIVORNO_UC5_development_07	VALENCIA_LIVORNO_UC5_integration_03	UPV, AWA, FV	01/03/2022	31/07/2022
VALENCIA, LIVORNO	Visualization, Platform, Software	Dashboard Implementation	VALENCIA_LIVORNO_UC5_development_08	VALENCIA_LIVORNO_UC5_development_07	UPV, AWA, FV	01/03/2021	31/07/2022
VALENCIA, LIVORNO	Software	Cross-layer MANO lifecycle management of 5G network functions and slices (5G experimental network or alternatively emulated 5G network)	VALENCIA_LIVORNO_UC5_development_09	N/A	NXW	01/10/2021	28/02/2021
VALENCIA, LIVORNO	Software	Cross-layer MANO collection and processing of DVL data	VALENCIA_LIVORNO_UC5_development_10	LIVORNO_UC5_development_09	NXW	01/01/2022	31/03/2022
VALENCIA, LIVORNO	Software	Cross-layer MANO optimization algorithm based on DVL data	VALENCIA_LIVORNO_UC5_development_11	LIVORNO_UC5_development_09 LIVORNO_UC5_development_10	NXW	01/02/2022	31/06/2022

Table 76: Use case - development activities

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7.1.2.2 Integration Activities List and Planning

According to the main list of required resources, facilities and development activities expected to be performed for the use case implementation, the following integration activities have been identified in order to support the use case deployment and validation:

Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
VALENCIA, LIVORNO	Data Sources	Collection of historical data sets	VALENCIA_LIVORNO_UC5_integration_01	N/A	FV, CNIT, AdSPMTS	01/01/2021	31/07/2021
VALENCIA, LIVORNO	Data Sources	Data source integration	VALENCIA_LIVORNO_UC5_integration_02	None	AWA, FV, CNIT	01/11/2021	28/02/2022
VALENCIA, LIVORNO	Data Sources, Software	Data ingestion for visualization	VALENCIA_LIVORNO_UC5_integration_03	VALENCIA_UC5_integration_01, VALENCIA_UC5_integration_02	UPV, AWA, FV	01/03/2022	30/08/2022
LIVORNO	Data Source, Software	DVL data collection in cross-layer MANO	LIVORNO_UC5_integration_04	N/A	NXW	01/03/2022	31/05/2022
LIVORNO	Data Source, Software	cross-layer MANO and 5G experimental network (if available/possible, otherwise 5G network will be emulated)	LIVORNO_UC5_integration_05	N/A	NXW	01/02/2022	30/06/2022

Table 77: Use case - integration activities

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7.2 Test Cases Definition

In this chapter, a list of test cases to be performed during the lifetime of the project are presented for proper use case validation. According to a common template, the test cases are listed below:

Test Case Id	UC5_TC_01
Responsible Partner	FV
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Test the quality of historical datasets for the development of predictive and simulation models.
Prerequisites	There should be available sufficient historical data from the data sources that will be available when the models will be online.
Type of test	This is mainly a software test based on a data exploratory analysis (EDA) of the data to check the quality of datasets (e.g. missing values, inconsistences, etc.) and confirm the pre assumed correlation between the different features extracted from the data.
Reference standards used	Could be based on ISO/IEC 25012
Test Environment	Jupiter Notebook executed in a local server or laptop with relevant Python libraries to analyze and manipulate data. A non-exhaustive list of libraries are: Pandas, Seaborn, MatplotLib, Numpy and Scikit-Learn.
Input to the system	Historical data sets from text files (e.g. CSV), databases or similar.
Output of the system	Data quality indicators in form of percentages, statistics and charts.
Data involved in the test	Datasets about: • History of port calls at the port • History of cargo flows at the port • History of trucks' entry/exit events • History of meteorological data • AIS data • History of vessels that arrived at the port and their characteristics
System requirements covered	UC5_SR_04
Related KPIs	Data Source Sufficiency, Data Quality
Are UC's users involved in the test?	Yes: FV and Port of Livorno
Who will perform the test?	FV and AWAKE
Test Steps	1. Identification of variables and data types. 2. Analysis of basic metrics. 3. Non-Graphical Univariate Analysis. 4. Graphical Univariate Analysis. 5. Bivariate Analysis. 6. Variable transformations. 7. Analysis of missing values. 8. Analysis of outliers.
Risks	Data is not sufficient and in bad quality.
Mitigation	If data is not sufficient, the dataset will be enhanced with more years of historical data. Data will be collected after the integration so that recent data will be gathered.
Expected result	Historical data is sufficient in size and in quality for the development of the predictive and simulation models with the expected accuracy.
Actual result	to be determined
Passed/Failed	to be determined

Table 78: Use case - UC5_TC_01

Test Case Id	UC5_TC_02
Responsible Partner	FV
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios

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Test case description	Integration of different data sources.
Prerequisites	All data sources are up and running. An agreement (e.g. NDA) exists between data owner and the partners involved in the usage of data.
Type of test	Software test to ensure that all data sources feed predictive models with the necessary data. It may include unit tests with data endpoints and some integration testing.
Reference standards used	N/A
Test Environment	Postman or SOAP UI tools will be used for unit tests of accessibility to data sources endpoints. For the end-to-end testing, a comparison of junks of data at the origin and at the destination will be done.
Input to the system	Sample requests to data sources' endpoints for unit tests. Portion of data gathered manually from data sources for integration tests.
Output of the system	Returned data by data sources endpoints. Datasets at the cloud platform.
Data involved in the test	The preliminary data involved is the following: • Port call data • Cargo flows data • Trucks' entry/exit events • Meteorological data • Vessels characteristics • AIS data
System requirements covered	UC5_SR_04, UC5_SR_06
Related KPIs	Data Availability, Data Source sufficiency
Are UC's users involved in the test?	Yes. FV and Port of Livorno
Who will perform the test?	FV and AWAKE
Test Steps	1. Data source accessibility tests with request/response queries to the endpoints for the following data: a. Port calls data b. Cargo flows data c. Trucks' entry/exit events d. Meteorological data e. Vessels characteristics f. AIS data 2. Data source is queried from data destination platform (cloud) and compared with the data at the origin: a. Port calls data b. Cargo flows data c. Trucks' entry/exit events d. Meteorological data e. Vessels characteristics f. AIS data
Risks	Incompatibility between data sources and the destination platform
Mitigation	Data translation mechanisms will be applied in these cases
Expected result	Requested data in all test steps are returned from data sources and available in the destination platform with the format required. All data is consistent with the values present in the origin. All targeted data sources are integrated with cloud platform (DVL and/or AWAKE).
Actual result	to be determined
Passed/Failed	to be determined

Table 79: Use case - UC5_TC_02

Test Case Id	**UC5_TC_03**
Responsible Partner	FV
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Evaluate prediction model accuracy analysis as part of training process
Prerequisites	Clean datasets for testing the models are available Models are trained and ready to be tested
Type of test	This is mainly a software test to check the performance of predictions made by the models (models' output data).
Reference standards used	N/A
Test Environment	Jupiter Notebook executed in a local server or laptop with relevant Python libraries to analyze and manipulate data. A

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	non-exhaustive list of libraries are: Pandas, Seaborn, MatplotLib, Numpy and Scikit-Learn.
Input to the system	Historical data sets from text files (e.g. CSV), databases or similar.
Output of the system	Accuracy indicators in form of percentages, error rates, statistics and charts.
Data involved in the test	Truck turnaround time idling time, cargo flow levels, trucks' traffic and ETA/ETD
System requirements covered	UC5_SR_01, UC5_SR_02
Related KPIs	Truck Turnaround Times Idling Times, Time Prediction Accuracy
Are UC's users involved in the test?	Yes, FV.
Who will perform the test?	FV and AWAKE
Test Steps	1. Models are run with input variables of the entire test dataset 2. Models' output set is saved 3. Models' output and expected output from test dataset is compared by calculating some of these indicators: a. Mean Absolute Error (MAE) b. Root Mean Squared Error (RMSE) c. R-Squared d. Adjusted R-Squared 4. Optionally some charts can be plotted to visually see the performance of the models (e.g. scatter plots, box plots, etc.)
Risks	Models' performance are poor.
Mitigation	Training dataset will be reviewed and enhanced if necessary. Models' selection process will be reviewed to select other methods.
Expected result	Accuracy expected by models fulfill the targeted KPIs
Actual result	to be determined
Passed/Failed	to be determined

Table 80: Use case - UC5_TC_03

Test Case Id	**UC5_TC_04**
Responsible Partner	FV
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Performance evaluation of models deployed in production
Prerequisites	Models are deployed and running in production
Type of test	This is mainly a software test to check the performance of predictions made by the models in production (models' output data).
Reference standards used	N/A
Test Environment	Jupiter Notebook is executed in a local server or laptop with relevant Python libraries to analyze and manipulate data. A non-exhaustive list of libraries are: Pandas, Seaborn, MatplotLib, Numpy and Scikit-Learn.
Input to the system	History of predictions made by the deployed models and stored in a database
Output of the system	Accuracy indicators in form of percentages, error rates, statistics and charts.
Data involved in the test	Truck turnaround time idling time, cargo flow levels, trucks' traffic and ETA/ETD
System requirements covered	UC5_SR_01, UC5_SR_02, UC5_SR_03, UC5_SR_10
Related KPIs	Truck Turnaround Times Idling Times, Time Prediction Accuracy
Are UC's users involved in the test?	Yes, FV.
Who will perform the test?	FV and AWAKE
Test Steps	1. Models' output is retrieved from the database in production 2. True values from M2M platform about target variables are extracted 3. Models' output and expected output are compared by calculating some of these indicators: a. Mean Absolute Error (MAE) b. Root Mean Squared Error (RMSE) c. R-Squared d. Adjusted R-Squared

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	4. Optionally some charts can be plotted to visually see the performance of the models (e.g. scatter plots, box plots, etc.)
Risks	Models' performance is poor.
Mitigation	A larger training dataset (with more recent data) will be used to train models. Models' selection process will be reviewed to select other methods if necessary. Models could be fine-tuned as well.
Expected result	Accuracy expected by models fulfill the targeted KPIs
Actual result	to be determined
Passed/Failed	to be determined

Table 81: Use case - UC5_TC_04

Test Case Id	**UC5_TC_05**
Responsible Partner	FV
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Validate the reception of trucks' geoposition data in the M2M platform
Prerequisites	Sensors are installed on trucks with sufficient coverage to transmit data
Type of test	Software based unit tests to query geoposition data to the M2M platform, first at the laboratory and later on the field
Reference standards used	N/A
Test Environment	Tools such as Postman, Soap UI or similar
Input to the system	HTTP REST request with the necessary parameters
Output of the system	Geoposition data from the devices being queried
Data involved in the test	GPS coordinates, Id of sensor, Battery, Timestamp
System requirements covered	UC5_SR_07, UC5_SR_19
Related KPIs	Positioning Accuracy
Are UC's users involved in the test?	Yes, FV.
Who will perform the test?	FV, UPV.
Test Steps	5. Geoposition data is sent to a local server at the laboratory in good coverage conditions 6. Geoposition data is sent to the M2M platform at the laboratory in good coverage conditions. The data is queried by the user from the M2M API or checked at the event logs of the M2M platform. Sensors are installed on the trucks and user checks the reception of geoposition data at the M2M platform from the API or reading the logs.
Risks	Connectivity is lost in some areas.
Mitigation	Data is saved and sent as soon as connectivity gets recovered.
Expected result	All data provided by the sensor is returned by the M2M platform in near real-time.
Actual result	to be determined
Passed/Failed	to be determined

Table 82: Use case - UC5_TC_05

Test Case Id	**UC5_TC _06**
Responsible Partner	NXW
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Onboard supply chain network slice templates and NF descriptors
Prerequisites	• Cross-layer MANO components up and running • Vertical Service and Network slice template available 5G Core NF descriptors (VNFD) available
Type of test	Functional test
Reference standards used	• 3GPP 5G Network Resource Model (28.541) • GSMA Generic Network Slice Template (NG.116) • ETSI NFV SOL006
Test Environment	The test is planned to be executed in these two environments: • Local lab environment • Port of Livorno testbed

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Input to the system	Network Slice Templates and related 5G Core Network Service and VNF Descriptors to be uploaded through cross-layer MANO Graphical User Interfaces (GUIs)
Output of the system	Network slice and 5G Core NF correctly available in the cross-layer MANO (and visible from the GUI) for their automated instantiation
Data involved in the test	Descriptors and templates of network slices and related resources in json format, packaged as software archives
System requirements covered	UC5_SR_13
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW
Test Steps	• The 5G Core NF descriptors (VNFDs) are onboarded in the cross-layer MANO NFV&MEC Resource Orchestrator through its GUI • The 5G Core Network Service descriptor (NSD) is onboarded in the cross-layer MANO NFV&MEC Resource Orchestrator through its GUI • Network Slice templates are onboarded in the cross-layer MANO NSMF through its GUI • Vertical Slice blueprints and descriptors are onboarded in the cross-layer MANO VSMF through Its GUI • All of the templates and descriptors are available in the cross-layer MANO (i.e. they can be queried and visualized through the GUI) and are ready to be used for instantiating new vertical services and network slices
Risks	No risks foreseen
Mitigation	N/A
Expected result	The onboarded network slice templates and related descriptors are successfully maintained by the cross-layer MANO to create new vertical services and network slices instances
Actual result	to be determined
Passed/Failed	to be determined

Table 83: Use case - UC5_TC_06

Test Case Id	**UC5_TC _07**
Responsible Partner	NXW
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Automated deployment of supply chain network slice instance
Prerequisites	• TC_UC5_06 successfully executed • The cross-layer MANO has access to the virtualized infrastructure where to deploy the slice NFs
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Management and Orchestration (3GPP TS 28.530) • 3GPP 5G Network Resource Model (28.541) • ETSI NFV SOL005
Test Environment	The test is planned to be executed in two different environments: • Local lab environment • Port of Livorno environment
Input to the system	Interaction with the cross-layer MANO GUI to trigger the creation of a new network slice based on an existing template or descriptor
Output of the system	Network slice and 5G Core NFs are automatically created and instantiated by the cross-layer MANO (and visible in the GUI), and ready to be used
Data involved in the test	None
System requirements covered	UC5_SR_14, UC5_SR_15
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, AdSPMTS
Test Steps	• An available Vertical Service Descriptor or Network Slice Template is selected to be used as reference for the creation of the new slice instance

	• A new vertical service or network slice instance is requested through the cross-layer MANO GUI, providing all of the additional attributes and constraints required that may be required for the specific slice (QoS, number of devices, location, etc) • The cross-layer MANO automatically processes the request and translates it into a set of automated operations to deploy/allocate the required slice resources, including the 5G Core virtualized NFs • For this, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to allocate and configure the required slice resources
Risks	The 5G network could not be available in the port of Livorno.
Mitigation	In case 5G network is not available the tests can be performed using a 5G emulated network.
Expected result	A new network slice instance is created, all the related network and computing resources have been allocated and the 5G Core NFs are up and running and ready to be configured.
Actual result	to be determined
Passed/Failed	to be determined

Table 84: Use case - UC5_TC_07

Test Case Id	**UC5_TC_08**
Responsible Partner	NXW
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Automated termination of supply chain network slice instance
Prerequisites	TC_UC5_07 successfully executed
Type of test	Functional test Integration test
Reference standards used	· 3GPP 5G Management and Orchestration (3GPP TS 28.530) · 3GPP 5G Network Resource Model (28.541) · ETSI NFV SOL005
Test Environment	The test is planned to be executed in two different environments: • Local lab environment • Port of Livorno environment
Input to the system	Interaction with the cross-layer MANO GUI to trigger the termination of a new network slice based on an existing template or descriptor
Output of the system	Resources used for the network slice instance are deallocated and network slice is deleted (and no more visible in the GUI)
Data involved in the test	None
System requirements covered	UC5_SR_14, UC5_SR_15
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, AdSPMTS
Test Steps	• An available Vertical Service Descriptor or Network Slice Template is selected to be used as reference for the creation of the new slice instance • An existing vertical service or network slice instance is requested to be terminated from the cross-layer MANO GUI • The cross-layer MANO automatically process the request and translate it into a set of automated operations to release and de-allocate all of the involved network and compute resources, including the 5G Core virtualized NFs • For this, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to release the related slice resources
Risks	The 5G network could not be available in the port of Livorno.
Mitigation	In case 5G network is not available the tests can be performed using a 5G emulated network.
Expected result	A new network slice instance is created, all the related network and computing resources have been allocated and the 5G Core NFs are up and running and ready to be configured.
Actual result	to be determined

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Passed/Failed	to be determined

Table 85: Use case - UC5_TC_08

Test Case Id	**UC5_TC_09**
Responsible Partner	NXW
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Manual scaling of a running supply chain network slice instance
Prerequisites	TC_UC5_07 successfully executed
Type of test	Functional test Integration test
Reference standards used	• 3GPP 5G Management and Orchestration (3GPP TS 28.530) • ETSI NFV SOL005
Test Environment	The test is planned to be executed in two different environments: • Local lab environment • Port of Livorno environment
Input to the system	Interaction with the cross-layer MANO GUI to trigger the scaling of an existing network slice instance
Output of the system	Resources used for the network slice instance are correctly scaled accordingly to the given input. The GUI shows the updates on the slices manually scaled terms of resource.
Data involved in the test	None
System requirements covered	UC5_SR_14, UC5_SR_15
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, AdSPMTS
Test Steps	• An existing vertical service or network slice instance is requested to be scaled from the cross-layer MANO GUI • The cross-layer MANO automatically processes the request and translate it into a set of automated operations to either scale the involved network and compute resources, including the 5G Core virtualized NFs • For this, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to release the related slice resources
Risks	The 5G network could not be available in the port of Livorno.
Mitigation	In case 5G network is not available the tests can be performed using a 5G emulated network.
Expected result	The network slice instance is manually modified, all the related network and computing resources have been scaled and the 5G Core resources accordingly.
Actual result	to be determined
Passed/Failed	to be determined

Table 86: Use case - UC5_TC_09

Test Case Id	**UC5_TC_10**
Responsible Partner	NXW
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Interaction with the Data Virtualization Layer (DVL) to start collecting IoT application data from deployed M2M platforms
Prerequisites	The DVL is running and reachable from the cross-layer MANO
Type of test	Functional test Integration test
Reference standards used	None
Test Environment	The test is planned to be executed in two different environments: • Local testbed • Livorno testbed
Input to the system	Supply chain network slice instantiation request
Output of the system	Start of collection of DVL data
Data involved in the test	None
System requirements covered	UC5_SR_12

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Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, CNIT
Test Steps	• As part of the supply chain network slice instantiation, the cross-layer MANO detects that DVL related data (i.e. as specified in the related Vertical Service Descriptor) is required to be collected as monitoring data • The cross-layer MANO starts a monitoring job to interact with DVL and starts collecting (e.g., with periodic requests) data based on the monitoring requirements expressed in the Vertical Service Descriptor • The data is correctly provided by the DVL.
Risks	No risks foreseen
Mitigation	N/A
Expected result	The cross-layer MANO is able to collect data from DVL
Actual result	to be determined
Passed/Failed	to be determined

Table 87: Use case - UC5_TC_10

Test Case Id	UC5_TC_11
Responsible Partner	NXW
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Interaction with the Data Virtualization Layer (DVL) to stop collecting IoT application data from deployed M2M platforms
Prerequisites	TC_UC5_010 successfully executed The DVL is running and reachable from the cross-layer MANO
Type of test	Functional test, Integration test
Reference standards used	None
Test Environment	The test is planned to be executed in two different environments: • Local testbed • Livorno testbed
Input to the system	Supply chain network slice instantiation request
Output of the system	Stop of collection of DVL data
Data involved in the test	None
System requirements covered	UC5_SR_12
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, CNIT
Test Steps	• As part of the supply chain network slice termination, the cross-layer MANO detects that DVL related data monitoring job is active • The cross-layer MANO stop the monitoring job to interrupt the collection of the related DVL data • The monitoring job is correctly terminated
Risks	No risks foreseen
Mitigation	N/A
Expected result	The cross-layer MANO does not collect DVL data anymore
Actual result	to be determined
Passed/Failed	to be determined

Table 88: Use case - UC5_TC_11

Test Case Id	UC5_TC_12
Responsible Partner	NXW
Use Case	Situational Understanding and Predictive Models in Smart Logistics Scenarios
Test case description	Automated slice scaling triggered by AI\ML platform using data application collected from DVL
Prerequisites	TC_UC5_07 and TC_UC5_10 successfully executed
Type of test	Functional test Integration test
Reference standards used	None
Test Environment	The test is planned to be executed in two different environments: • Local testbed • Livorno testbed

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Input to the system	Data collected from the DVL subscriptions and ML slice optimization algorithm output
Output of the system	Resources used for the network slice instance are correctly scaled accordingly to the given input. The GUI shows the updates on the slices automatically scaled terms of resource.
Data involved in the test	None
System requirements covered	UC5_SR_12, UC5_SR_14, UC5_SR_15, UC5_SR_16
Related KPIs	N/A
Are UC's users involved in the test?	No
Who will perform the test?	NXW, AdSPMTS
Test Steps	• AI\ML platform collects application data from DVL. • The slice optimization ML algorithm detects the needs of scaling the network slice instance identifying affected critical network instance attributes (e.g. maximum number of UEs in a network slice instance, QoS requirements, NFs instances, etc) • The cross-layer MANO, based on the identified critical attributes by ML algorithm, automatically processes the request and translates it into a set of automated operations to either resize the involved network and compute resources or creating new 5GC NF instances (e.g. UPF) • For this reason, the cross-layer MANO components interact with the network and compute infrastructure controllers and managers to resize the related slice resources (if needed to execute new NF(s))
Risks	The 5G network could not be available in the port of Livorno.
Mitigation	In case 5G network is not available the tests can be performed using a 5G emulated network.
Expected result	The cross-layer MANO correctly scales the network slice instance.
Actual result	to be determined
Passed/Failed	to be determined

Table 89: Use case - UC5_TC_12

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8 PoC - Supply Chain Ecosystem Integration

The Supply Chain Ecosystem Integration use case aims at developing an interoperable layer in order to abstract the complexity of the underlying data sources such as M2M platforms (e.g. OneM2M, OM2M, PISystem and Symphony) as well as to federate the most common distributed ledger technologies (e.g. Bitcoin, IOTA, Hyperledger Fabric and Ethereum). The implementation of this use case is going to take place both in Port of Livorno and Port of Valencia even though the PoC validation will be performed by means of intermodal asset tracking and situational understanding use cases of the iNGENIOUS project. More specifically, both use cases will be used to feed the interoperable layer with relevant data according to identified events in the maritime domain so that the PoC can be demonstrated and validated accordingly. Further details about this use case are available in *D2.1 – Use Cases, KPIs and Requirements*, and they will not be discussed in the following sections.

8.1 Valencia and Livorno Port - Testbed

In this chapter, the setup activities of the existing resources and facilities, development and integration activities are listed and discussed in order to guarantee the PoC is going to be properly deployed, demonstrated and validated.

8.1.1 EXISTING COMPONENTS SETUP

As a preliminary step, the existing resources and facilities to support the further development and integration activities of the use case, have been identified and listed. Unlike other use cases of the project, this one is mainly focused on software components instantiation and communication interfaces development. For this reason, in terms of existing resources to be allocated for the use case implementation, computational resources have been identified in order to support the preliminary instantiation of the architectural components (proper hosting capabilities and computational resources allocation). These components include: different instances of the considered DLTs and M2M platforms, the MANO platform for network usage monitoring, an instance of Data Virtualization Layer and Cross-DLT layer based on Trust-OS. The following table reports the main setup activities that have been identified as mandatory to support the integration and development activities of this use case accordingly:

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Test Bed	Resource Type	Resource Description	Required Setup Activities	Responsible Partner	Start Date (Planned)	Due Date (Planned)	Ready to be used?
LIVORNO	Software/Hardware	Computational and hosting resources allocation for the instantiation of different architectural components such as DVL, IOTA private network, OneM2M, Symphony M2M platform and other required assets.	N/A	CNIT	N/A	N/A	Yes
LIVORNO	Software	DVL local instance that needs to be properly configurated in a staging environment. The configuration includes a dedicated VM instantiation with allocated computational resources.	LIVORNO_UC6_setup_01	CNIT	01/04/2021	31/07/2021	No
LIVORNO	Software	OneM2M instance that needs to be configurated for development and integration activities within INGENIOUS project. The instance will run in a staging environment at the Port of Livorno.	LIVORNO_UC6_setup_02	CNIT	01/04/2021	31/07/2021	No
LIVORNO	Software	Symphony M2M platform instance that needs to be configurated for development and integration activities within INGENIOUS project. The instance will run in a staging environment at the Port of Livorno.	LIVORNO_UC6_setup_03	CNIT/NXW	01/05/2021	30/09/2021	No
LIVORNO	Software	IOTA private network that needs to be deployed in a staging environment at the Port of Livorno.	LIVORNO_UC6_setup_04	CNIT	01/06/2021	30/09/2021	No
VALENCIA	Software	PI System OSIsoft – M2M Platform available and ready for use at the Port of Valencia.	N/A	FV	N/A	N/A	Yes
VALENCIA	Software	Hyperledger Fabric network that needs to be deployed in a staging environment at the Port of Valencia.	VALENCIA_UC6_setup_05	FV	01/06/2021	30/09/2021	No
VALENCIA, LIVORNO	Software/Hardware	Computational and hosting resources allocation for the instantiation of Bitcoin public network node and other related assets (PJATK Lab).	N/A	PJATK	N/A	N/A	Yes
VALENCIA, LIVORNO	Software/Hardware	Local instance of software and hardware to support nodes of public and private DLTs (i.e. Bitcoin, Ethereum and potentially IOTA).	LIVORNO_VALENCIA_UC6_setup_06	PJATK	01/04/2021	31/07/2021	No
VALENCIA, LIVORNO	Software	TrustOS platform deployed in a cloud environment and connected with both Hyperledger Fabric and Ethereum networks.	N/A	TID	N/A	N/A	Yes

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VALENCIA, LIVORNO	Software	Ethereum network connector for TrustOS deployed in a private cloud.	N/A	TID	N/A	N/A	Yes
VALENCIA, LIVORNO	Software	Eclipse OM2M instance deployment in SES premises.	LIVORNO_VALENCIA_UC6_setup_07	SES	01/05/2021	30/09/2021	No

Table 90: Use case - setup activities

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8.1.2 INGENIOUS CHECKLIST

In this chapter development and integration activities are identified, listed and discussed for the use case implementation and demonstration.

8.1.2.1 Development Activities List and Planning

In this subchapter the main development activities to be carried out during the lifetime of the project are listed and considered. According to the main requirements for this use case, the development activities are mainly related to the specific functionalities implementation of the core components of this use case: Data Virtualization Layer and Cross-DLT layer based on Trust-OS. In order to support the interaction with the underlying M2M platforms as well as with external data sources and/or systems, different translators (wrappers) are expected to be implemented at Data Virtualization Layer. Additionally, a pseudonymization function will be developed and implemented at DVL level in order to identify any personal data with respect to GDPR regulation. The DVL will aggregate available data according to a given data model. A preliminary activity for proper data sources identification will be conducted. In order to guarantee the communication between the DVL and Cross-DLT layer, a proper interface will be developed. Once data are available at Cross-DLT layer, a unified interface is going to be developed to allow the communication with available DLTs according to their capabilities so that secure data storage and management can be performed. The following table lists all the identified activities:

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Test Bed	Component Type	Component Description	Development Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
VALENCIA, LIVORNO	Data Model	Data Model definition for supported events (GateIn, GateOut, Vessel Arrival and Vessel Departure) to be used for data aggregation at DVL level. This also includes the identification of required attributes and related data sources both for the Port of Livorno and Port of Valencia.	VALENCIA_LIVORNO_UC6_development_01	N/A	CNIT/FV	01/05/2021	31/07/2021
LIVORNO	Translator	Translator implementation for the communication with OneM2M platform through DVL for meteorological data retrieval.	LIVORNO_UC6_development_02	N/A	CNIT	01/05/2021	30/09/2021
LIVORNO	Translator	Translator implementation for the communication with Symphony M2M platform through DVL for sensors data retrieval.	LIVORNO_UC6_development_03	N/A	CNIT/NXW	01/07/2021	31/10/2021
VALENCIA	Translator	Translator implementation for the communication with PISoft M2M platform through DVL for gate access data retrieval.	VALENCIA_UC6_development_04	VALENCIA_LIVORNO_UC6_development_01	CNIT/FV	01/07/2021	31/10/2021
LIVORNO, COSCO	Translator	Translator implementation for the communication with Eclipse OM2M platform through DVL for container42 smart sensor data retrieval.	LIVORNO_COSCO_UC6_development_05	N/A	CNIT/SES	01/07/2021	31/10/2021
LIVORNO	API	Communication interface to be used by Trust-OS for the interaction with IOTA private network by providing writing and reading capabilities across distributed ledgers.	LIVORNO_UC6_development_06	VALENCIA_LIVORNO_UC6_development_01	CNIT/TID	01/07/2021	31/12/2021
VALENCIA, LIVORNO	API	Communication Interface between DVL and Trust-OS. This interface allows events data exchange between two platforms.	VALENCIA_LIVORNO_UC6_development_07	VALENCIA_LIVORNO_UC6_development_01, VALENCIA_UC6_development_08, LIVORNO_UC6_development_06,	CNIT/TID/FV/PJATK	01/09/2021	28/02/2022

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				VALENCIA_LIVORNO_UC6_development_10			
VALENCIA	API	Development of API allowing Trust-OS to interact with Hyperledger Fabric.	VALENCIA_UC6_development_08	VALENCIA_LIVORNO_UC6_development_01	FV/TID	01/10/2021	31/12/2021
VALENCIA, LIVORNO	Data Model	Transaction model on Bitcoin DLT (PJATK Lab).	VALENCIA_LIVORNO_UC6_development_09	VALENCIA_LIVORNO_UC6_development_01	PJATK	15/06/2021	31/07/2021
VALENCIA, LIVORNO	API	Communication interfaces to be used by Trust-OS for the interaction with Bitcoin DLT by providing writing and reading capabilities across ledgers (PJATK Lab).	VALENCIA_LIVORNO_UC6_development_10	VALENCIA_LIVORNO_UC6_development_09	PJATK/CNIT/TID	01/05/2021	31/12/2021
VALENCIA, LIVORNO	API	Search methods for Bitcoin transactions related to the data received from Trust-OS (PJATK Lab).	VALENCIA_LIVORNO_UC6_development_11	VALENCIA_LIVORNO_UC6_development_10	PJATK/TID	10/06/2021	31/10/2021
VALENCIA, LIVORNO	Security	Bitcoin wallet support for handling transactions fees on Bitcoin DLT (PJATK Lab).	VALENCIA_LIVORNO_UC6_development_12	VALENCIA_LIVORNO_UC6_development_09, VALENCIA_LIVORNO_UC6_development_10	PJATK	01/09/2021	28/02/2022
VALENCIA, LIVORNO	Security	Accounting data handling for Bitcoin DLT native token-BTC (PJATK Lab).	VALENCIA_LIVORNO_UC6_development_13	VALENCIA_LIVORNO_UC6_development_12	PJATK	01/09/2021	31/12/2021
VALENCIA, LIVORNO	Security	Security for assets on Bitcoin DLT (PJATK Lab).	VALENCIA_LIVORNO_UC6_development_14	VALENCIA_LIVORNO_UC6_development_12, VALENCIA_LIVORNO_UC6_development_13	PJATK	01/09/2021	28/02/2022
VALENCIA, LIVORNO	Security	Backup capabilities for the metadata of the information retrieved from Trust-OS (PJATK Lab).	VALENCIA_LIVORNO_UC6_development_15	VALENCIA_LIVORNO_UC6_development_12, VALENCIA_LIVORNO_UC6_development_13, VALENCIA_LIVORNO_UC6_development_14	PJATK	01/01/2022	31/03/2022
VALENCIA	API	Development of API allowing Hyperledger Fabric to interact with Trust-OS.	VALENCIA_UC6_development_16	VALENCIA_UC6_setup_05	FV/TID	01/10/2021	31/12/2021
VALENCIA, LIVORNO	API	Definition of the abstract interface for accessing DLTs.	VALENCIA_LIVORNO_UC6_development_17	N/A	TID	01/05/2021	31/07/2021

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VALENCIA, LIVORNO	API	Adapt the development of Ethereum connector and SmartContract for interacting with TrustOS.	VALENCIA_LIVORNO_UC6_development_18	N/A	TID	01/10/2021	31/12/2021
VALENCIA, LIVORNO	Data Model/Software	Definition and development of TrustPoints within TrustOS Platform.	VALENCIA_LIVORNO_UC6_development_19	N/A	TID	01/07/2021	30/09/2021
VALENCIA, LIVORNO	API	Integration between TrustOS and the different DLTs connectors developed by the partners for the CrossDLT layer interoperability.	VALENCIA_LIVORNO_UC6_development_20	N/A	TID	31/12/2021	28/02/2022
VALENCIA, LIVORNO	API, Software	Development of the pseudonimization function interface	VALENCIA_LIVORNO_UC6_development_21	VALENCIA_LIVORNO_UC6_development_07	TEI	01/12/2021	31/05/2022

Table 91: Use case - development activities

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8.1.2.2 Integration Activities List and Planning

In this subchapter the main integration activities with external data sources and systems, to be carried out during the lifetime of the project, are considered. As already mentioned, from the integration perspective, this use case foresees the interaction and communications with external data sources and systems for proper data retrieval according to the identified data model for maritime events. This integration is expected to be performed at Data Virtualization Layer. More specifically, the DVL is expected to be able to interact with the following external systems:

- MANO platform in order to provide network usage data by means of a subscription mechanism instead of specific interface;
- Awake.AI platform in order to provide historical data for predictive algorithms training by means of an API exposed by DVL;
- Port Community System from the Livorno Port (Tuscan Port Community System) in order to retrieve data needed for the consistent definition of the maritime events (e.g. transport equipment ID, carrier booking number, bill of lading number, transportation phase, vehicle ID, vehicle name, terminal, etc.). For the case of Valencia Port, the possibility to interact with the Port Community System will be also exploited.

The following table lists the main integration activities to be performed that have been identified so far:

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Test Bed	Component Type	Component Description	Integration Activities Required	Dependency	Responsible Partner	Start Date (Planned)	Due Date (Planned)
LIVORNO, VALENCIA	Software, API	Communication interface between MANO and DVL, including data retrieval logic (MANO side).	LIVORNO_VALENCIA_UC6_integration_01	N/A	NXW/CNIT	01/01/2022	31/03/2022
VALENCIA, LIVORNO	API	Communication interface to be used by Awake.AI Platform for historical data retrieval from DVL.	LIVORNO_VALENCIA_UC6_integration_02	N/A	Awake/CNIT	01/11/2021	28/02/2022
LIVORNO	API	Integration between Tuscan Port Community System (TPCS) and DVL in order to retrieve data for the maritime events definition.	LIVORNO_UC6_integration_03	N/A	CNIT/AdSPMTS	01/09/2021	31/12/2021

Table 92: Use case - integration activities

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8.2 Test Cases Definition

In this chapter, a list of test cases to be performed during the lifetime of the project are presented for a proper use case validation. According to a common template, the test cases are listed below:

Test Case Id	UC6_TC_01
Responsible Partner	CNIT
Use Case	Supply Chain Ecosystem Integration
Test case description	Interaction between OneM2M platform and Data Virtualization Layer. The test should demonstrate the interaction is working properly according to defined system requirements.
Prerequisites	OneM2M and DVL instances properly configured in a staging environment.
Type of test	Non-Functional testing (integration test).
Reference standards used	N/A
Test Environment	The test is expected to be executed in a laboratory environment (Joint Lab staging farm).
Input to the system	Meteorological data from OneM2M platform.
Output of the system	Virtual view of extracted meteorological data at DVL level.
Data involved in the test	Meteorological data from OneM2M platform.
System requirements covered	UC6_SR_01, UC6_SR_02
Related KPIs	Data Virtualization Layer Scalability
Are UC's users involved in the test?	No
Who will perform the test?	CNIT
Test Steps	1. By using a custom framework written in C# or Java, HTTP request to the OneM2M platform will be performed. 2. By using a custom framework written in C# or Java, HTTP request to DVL will be performed (note that at this stage the translator for the communication with OneM2M is implemented and unit tests are performed correctly). 3. The results of both requests are compared in order to make sure data are correctly structured.
Risks	No risks are foreseen.
Mitigation	N/A
Expected result	Correct meteorological data retrieval from OneM2M platform. Correct data processing and its availability at DVL layer.
Actual result	to be determined
Passed/Failed	to be determined

Table 93: Use case - UC6_TC_01

Test Case Id	UC6_TC_02
Responsible Partner	CNIT
Use Case	Supply Chain Ecosystem Integration
Test case description	Interaction between OM2M platform and Data Virtualization Layer. The test should demonstrate the interaction is working properly according to defined system requirements.
Prerequisites	OM2M and DVL instances properly configured in a staging environment.
Type of test	Non-Functional testing (integration test).
Reference standards used	N/A
Test Environment	The test is expected to be executed in a laboratory environment (Joint Lab staging farm).
Input to the system	Sensor data from OM2M platform.
Output of the system	Virtual view of extracted sensor data at DVL level.
Data involved in the test	Sensor data from OM2M platform.
System requirements covered	UC6_SR_01, UC6_SR_02
Related KPIs	Data Virtualization Layer Scalability
Are UC's users involved in the test?	No
Who will perform the test?	CNIT

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Test Steps	1. By using a custom framework written in C# or Java, HTTP request to the OM2M platform will be performed. 2. By using a custom framework written in C# or Java, HTTP request to DVL will be performed (note that at this stage the translator for the communication with OM2M is implemented and unit tests are performed correctly). 3. The results of both requests are compared in order to make sure data are correctly structured.
Risks	No risks are foreseen.
Mitigation	N/A
Expected result	Correct sensor data retrieval from OM2M platform. Correct data processing and its availability at DVL layer.
Actual result	to be determined
Passed/Failed	to be determined

Table 94: Use case - UC6_TC_02

Test Case Id	UC6_TC_03
Responsible Partner	CNIT
Use Case	Supply Chain Ecosystem Integration
Test case description	Interaction between PISystem platform and Data Virtualization Layer. The test should demonstrate the interaction is working properly according to defined system requirements.
Prerequisites	PISystem and DVL instances properly configured in a staging environment and/or in a local facility.
Type of test	Non-Functional testing (integration test).
Reference standards used	N/A
Test Environment	The test is expected to be executed in a laboratory environment (Joint Lab staging farm).
Input to the system	GateIn/GateOut data from PISystem platform.
Output of the system	Virtual view of extracted gate-in/gate-out data at DVL level.
Data involved in the test	GateIn/GateOut data from PISystem platform.
System requirements covered	UC6_SR_01, UC6_SR_02
Related KPIs	Data Virtualization Layer Scalability.
Are UC's users involved in the test?	No
Who will perform the test?	CNIT
Test Steps	1. By using a custom framework written in C# or Java, http request to the PISystem platform will be performed. 2. By using a custom framework written in C# or Java, http request to DVL will be performed (note that at this stage the translator for the communication with PISystem is implemented and unit tests are performed correctly). 3. The results of both requests are compared in order to make sure data are correctly structured.
Risks	No risks are foreseen.
Mitigation	N/A
Expected result	Correct gate-in/gate-out data retrieval from PISystem platform. Correct data processing and its availability at DVL layer.
Actual result	to be determined
Passed/Failed	to be determined

Table 95: Use case - UC6_TC_03

Test Case Id	UC6_TC_04
Responsible Partner	TID
Use Case	Supply Chain Ecosystem Integration
Test case description	Interaction between TrustOS and the set of DLTs
Prerequisites	DLTs APIs available
Type of test	Software testing by making request to the different APIs and directly to TrustOS, storing information in different DLTs.
Reference standards used	N/A.
Test Environment	Test is expected to be executed on multi cloud environment
Input to the system	Data coming from the DVL
Output of the system	Transaction where the information is stored.
Data involved in the test	Data related to maritime events: GateIn, GateOut, Vessel Arrival and Vessel Departure.

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System requirements covered	UC6_SR_05, UC6_SR_08, UC6_SR_10, UC6_SR_11, UC6_SR_12, UC6_SR_13, UC6_SR_15
Related KPIs	Cross-DLT layer access control, Cross-DLT layer scalability, Availability of the DLT connectivity layer, Data processing time in DLTs, Cross-DLT concurrent requests.
Are UC's users involved in the test?	No
Who will perform the test?	TID
Test Steps	1. Integrate all the APIs within TrustOS platform 2. Store information in different DLTs through TrustOS 3 Results checked in the DLTs browser
Risks	No
Mitigation	N/A
Expected result	Correct storing of the data on the different DLTs
Actual result	to be determined
Passed/Failed	to be determined

Table 96: Use case - UC6_TC_04

Test Case Id	UC6_TC_05
Responsible Partner	CNIT
Use Case	Supply Chain Ecosystem Integration
Test case description	Mapping of the access roles for Data Virtualization Layer consumers (e.g: TrustOS, Awake.AI and MANO Platform): RBAC – Role-Based Access Control.
Prerequisites	Preconfigured local instance of Data Virtualization Layer is available.
Type of test	Functional test (Unit Test).
Reference standards used	N/A
Test Environment	Staging environment with local instance of Data Virtualization Layer running in a dedicated Virtual Machine.
Input to the system	List of permissions set for a given consumer.
Output of the system	The consumer
Data involved in the test	Testing data set.
System requirements covered	UC6_SR_03
Related KPIs	Data Virtualization Layer access control.
Are UC's users involved in the test?	No
Who will perform the test?	CNIT
Test Steps	• Sets of available permissions (according to CRUD – Create, Read, Update and Delete) will be first defined in a Virtual Database file (.xml). • A given data consumer will be then identified in a form of resource path within Virtual database. For the considered consumer, only READ permissions will be assigned for a specific schema (eventually table and/or columns). • A dummy schema will be created and a testing application will act as a consumer in order to verify assigned roles are properly working. This will include two different scenarios that will be tested: i) the consumer attempts to invoke a specific operation he is not authorized for and ii) the consumer attempts to invoke a specific operation he is authorized to, according to a given virtual schema.
Risks	No risks are foreseen.
Mitigation	N/A
Expected result	The considered Data Virtualization Layer consumer has the permission to perform only assigned operations (CRUD basic operations).
Actual result	to be determined
Passed/Failed	to be determined

Table 97: Use case - UC6_TC_05

Test Case Id	UC6_TC_06
Responsible Partner	TEI
Use Case	Supply Chain Ecosystem Integration
Test case description	All personal data received by Data Virtualization Layer has to be pseudonymized so that, when stored, it is never in cleartext

	format. Note that only personal data previously agreed must be retained. All the remaining ones are ignored. For example, the race of a truck's driver is useless to the scope of iNGENIOUS, so should never been retained.
Prerequisites	Incoming personal data
Type of test	Non-functional test
Reference standards used	N/A.
Test Environment	The test is expected to be executed in a laboratory environment (Joint Lab staging farm).
Input to the system	Sensor data from OneM2M platform or data coming from other data sources, such as Port Community System from Livorno seaport.
Output of the system	Pseudonymized data.
Data involved in the test	Sensor data from OneM2M platform or data coming from other data sources, such as Port Community System.
System requirements covered	UC5_SR_25, UC5_SR_26, UC5_SR_27, UC5_SR_30, UC6_SR_14, UC6_SR_15, UC6_SR_16, UC6_SR_19
Related KPIs	Confidentiality and integrity protection of personal data.
Are UC's users involved in the test?	No
Who will perform the test?	TEI/CNIT
Test Steps	• Pseudonymization function is fed by sensor data; • Personal data are pseudonymized (pseudonym production) and a retention period is associated to it; • Pseudonym and retention period are stored in cross-DLT repository.
Risks	No risks foreseen
Mitigation	N/A
Expected result	• No personal data in cleartext format; • In case a conversion table is needed for the selected pseudonymization function, it is stored in encrypted repository.
Actual result	to be determined
Passed/Failed	to be determined

Table 98: Use case - UC6_TC_06

Test Case Id	**UC6_TC_07**
Responsible Partner	TEI
Use Case	Supply Chain Ecosystem Integration
Test case description	Only authorized entity can access to specific personal data in cleartext format.
Prerequisites	Pseudonym exists in cross-DLT layer.
Type of test	Non-functional test
Reference standards used	N/A.
Test Environment	The test is expected to be executed in a laboratory environment (Joint Lab staging farm).
Input to the system	A request to DVL from cross-DLT with the following data: {pseudonym, pseudonym-type, entity-id}
Output of the system	Personal Data in cleartext format is returned
Data involved in the test	Pseudonym stored in cross-DLT/entity-id (partner-id)
System requirements covered	UC5_SR_28, UC6_SR_17
Related KPIs	Confidentiality and integrity protection of personal data.
Are UC's users involved in the test?	No
Who will perform the test?	TEI/CNIT/TID
Test Steps	• An entity (partner) requests to cross-DLT layer to reverse a pseudonym to cleartext format; • The cross-DLT layer forwards the request to DVL layer; • The DVL ask *Pseudonymization Function* to reverse the pseudonym; • The *Pseudonymization Function* reverse the data and give it back to DVL; • DVL forwards it to cross-DLT; • Cross-DLT forwards to entity (partner). NOTE: it is supposed that AWAKE.AI platform works only with pseudonym, so the pseudonym-reverse requests can arrive only from cross-DLT.
Risks	No risks foreseen
Mitigation	-

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Expected result	Only authorized partners can access personal data in cleartext format.
Actual result	to be determined
Passed/Failed	to be determined

Table 99: Use case - UC6_TC_07

Test Case Id	UC6_TC_08
Responsible Partner	TEI
Use Case	Supply Chain Ecosystem Integration
Test case description	Personal Data cannot be stored forever, when retention period expires personal data has to be cancelled.
Prerequisites	Pseudonym present in cross-DLT layer with proper expiration date.
Type of test	Non-functional test
Reference standards used	N/A.
Test Environment	The test is expected to be executed in a laboratory environment (Joint Lab staging farm).
Input to the system	N/A
Output of the system	All personal data are cancelled after retention period expiration, both in cross-DLT (pseudonym) and in conversion table, if any.
Data involved in the test	Pseudonym stored in cross-DLT, personal data in Conversion Table, if any.
System requirements covered	UC5_SR_29, UC6_SR_18
Related KPIs	Confidentiality and integrity protection of personal data.
Are UC's users involved in the test?	No
Who will perform the test?	TEI/CNIT
Test Steps	Every night a process in the cross-DLT and in DVL (Pseudonymization function) checks if personal data with expired retention period exist. In that case it removes data (pseudonyms in cross-DLT, personal data in conversion table, if any).
Risks	No risks foreseen
Mitigation	N/A
Expected result	No personal data with expired retention period stored in the Interoperable Layer.
Actual result	to be determined
Passed/Failed	to be determined

Table 100: Use case - UC6_TC_08

Test Case Id	UC6_TC_09
Responsible Partner	TEI
Use Case	Supply Chain Ecosystem Integration
Test case description	Data Owner can request to the platform to cancel own personal data.
Prerequisites	Pseudonyms are present in cross-DLT layer with proper expiration date.
Type of test	Non-functional test
Reference standards used	N/A.
Test Environment	The test is expected to be executed in a laboratory environment (Joint Lab staging farm).
Input to the system	N/A
Output of the system	All personal data will be canceled after Data Owner requests for deletion.
Data involved in the test	Pseudonym stored in cross-DLT, personal data in Conversion Table, if any
System requirements covered	UC5_SR_29, UC6_SR_18
Related KPIs	Confidentiality and integrity protection of personal data.
Are UC's users involved in the test?	No
Who will perform the test?	TEI/CNIT
Test Steps	• A Data Owner submits a right-to-be-forgotten request; • The request is processed by pseudonymization function removing data from conversion table, if any and rising a request for cancellation-pseudonym to the cross-DLT; • The Cross-DLT removes ALL the occurrences of the pseudonym from its repository.
Risks	No risks foreseen
Mitigation	N/A

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Expected result	No personal data, requested to be canceled, are stored in the Interoperable Layer.
Actual result	to be determined
Passed/Failed	to be determined

Table 101: Use case - UC6_TC_09

Test Case Id	**UC6_TC_10**
Responsible Partner	CNIT
Use Case	Supply Chain Ecosystem Integration
Test case description	Views and query results caching capability in case underlying data does not change frequently.
Prerequisites	The DVL translators are available for allowing data retrieval from the underlying M2M Platforms.
Type of test	Functional test (Unit Test)
Reference standards used	N/A.
Test Environment	Staging environment with local instance of Data Virtualization Layer running in a dedicated Virtual Machine.
Input to the system	Query execution request from an external test application.
Output of the system	Query results are properly cached.
Data involved in the test	GateIn, GateOut, Vessel Arrival and Vessel Departure data.
System requirements covered	UC6_SR_04
Related KPIs	Data Virtualization Layer data processing.
Are UC's users involved in the test?	No
Who will perform the test?	CNIT
Test Steps	• In order to retrieve and aggregate data at DVL level, a specific query will be implemented and included in a virtual database configuration file; • A test application will invoke the query and the query results will be cached according to virtual database configuration file; • A test application will invoke the same query once again. A manual check will allow to very weather the requested results are taken from the cache or not.
Risks	No risks foreseen
Mitigation	N/A
Expected result	Query results are properly cached and properly retrieved by a test application.
Actual result	to be determined
Passed/Failed	to be determined

Table 102: Use case - UC6_TC_10

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9 Initial Planning for PoCs and Demos

In this chapter the implementation plan per use case is presented and discussed according to the main setup, development and integration activities identified and reported in the previous sections. In addition, a methodology based on Requirements Traceability Matrix (RTM) is presented and described in order to allow to keep track of the system requirements and test cases verification and validation. Finally, for each use case a Risk Registry is provided to catch any potential risk associated with the PoC/demo implementation and development. A mitigation strategy is also defined to make sure that any identified risk is not going to affect the use cases' implementation and development activities.

9.1 PoC - Automated Robots with Heterogeneous Networks

According to the main list of required resources, facilities, development and integration activities presented and discussed in this deliverable, the following implementation plan has been defined for the considered use case in a form of a Gantt chart. A set of macro activities are listed and a preliminary roadmap is provided for the use case implementation.

9.1.1 ASTI FACTORY - IMPLEMENTATION PLAN

The time plan for the use case PoC implementation is provided in the figure below:

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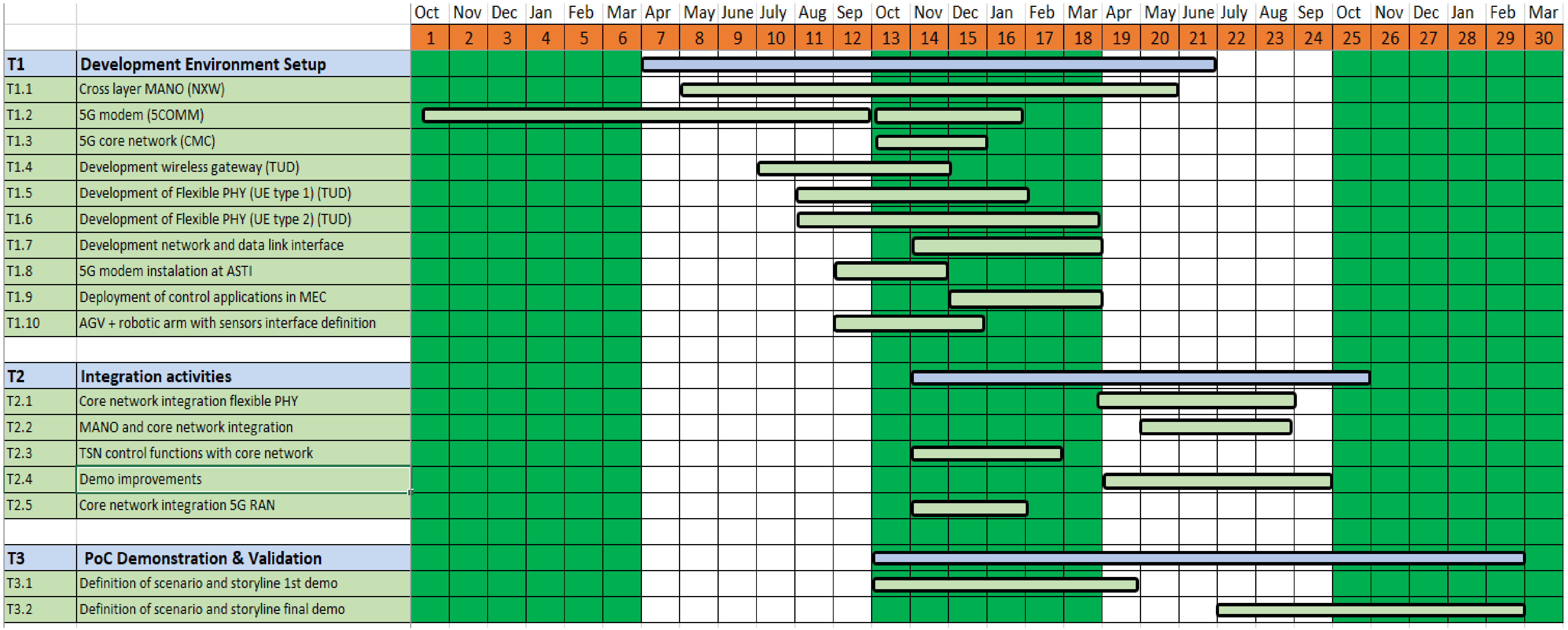

Figure 18: Use case - implementation plan.

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9.1.2 RISK REGISTRY

In order to make sure that the use case demonstration and validation is going to take place as expected, the following (potential) risks have been identified and a relevant mitigation action is also provided:

WP	Description of Risk	Risk-Mitigation measures	Probability	Impact
6	Incompatible RAN integration with core network.	Functionalities partially implemented.	L	M
6	Spectrum licence unavailable at ASTI factory.	Core and MANO functionalities can be demonstrated without over the air transmission.	M	H

Table 103: Risk Registry for the use case

9.2 Demo - Improved Drivers' Safety with MR and Haptic Solutions

According to the main list of required resources, facilities, development, and integration activities presented and discussed in this deliverable, the following implementation plan has been defined for the considered use case in form of a Gantt chart. A set of macro activities are listed and a preliminary roadmap is provided for the use case implementation.

9.2.1 VALENCIA PORT - IMPLEMENTATION PLAN

The main activities for the implementation of the use case demo are the following (see the Figure 19):

- Deployment of 5G millimetre Wave Antenna at the Test Case scenario;
- Evaluation of the performance of the connectivity through the antenna;
- Immersive cockpit implementation and integration with the required AGV;
- Evaluation of the teleoperation performance in preliminary scenarios (Madrid, Segovia, and Burgos) with the required AGV;
- Real Demo.

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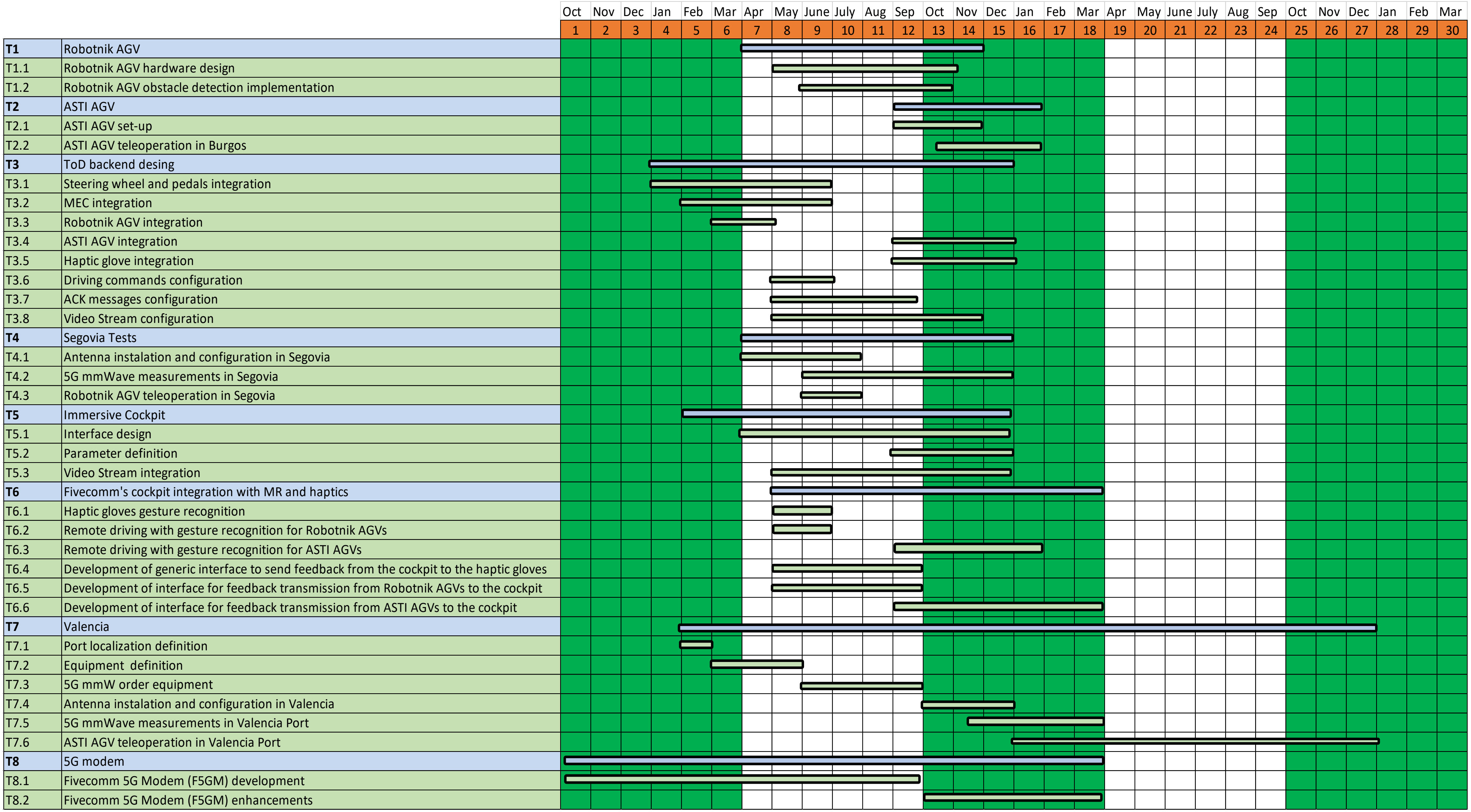

Figure 19: Use case - implementation plan

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9.2.2 RISK REGISTRY

In order to make sure that the use case demonstration and validation is going to take place as expected, the following (potential) risks have been identified and a relevant mitigation action is also provided:

WP	Description of Risk	Risk-Mitigation measures	Probability	Impact
6	Antenna deterioration	Study the antenna localization	L	H
6	AGV crash	Depth sensor to Emergency Stop	M	M
6	AGV coverage loss	Good delimitation of the coverage area	M	H
6	Cockpit disconnection	Robust backend application	L	H

Table 104: Risk Registry for the use case

9.3 PoC - Transportation Platforms Health Monitoring

According to the main list of required resources, facilities, development, and integration activities presented and discussed in this deliverable, the following implementation plan has been defined for the considered use case in a form of a Gantt chart. A set of macro activities are listed and a preliminary roadmap is provided for the use case implementation.

9.3.1 LIVORNO PORT - IMPLEMENTATION PLAN

The time plan for the use case PoC implementation is provided in the figures below (Figure 20 and Figure 21):

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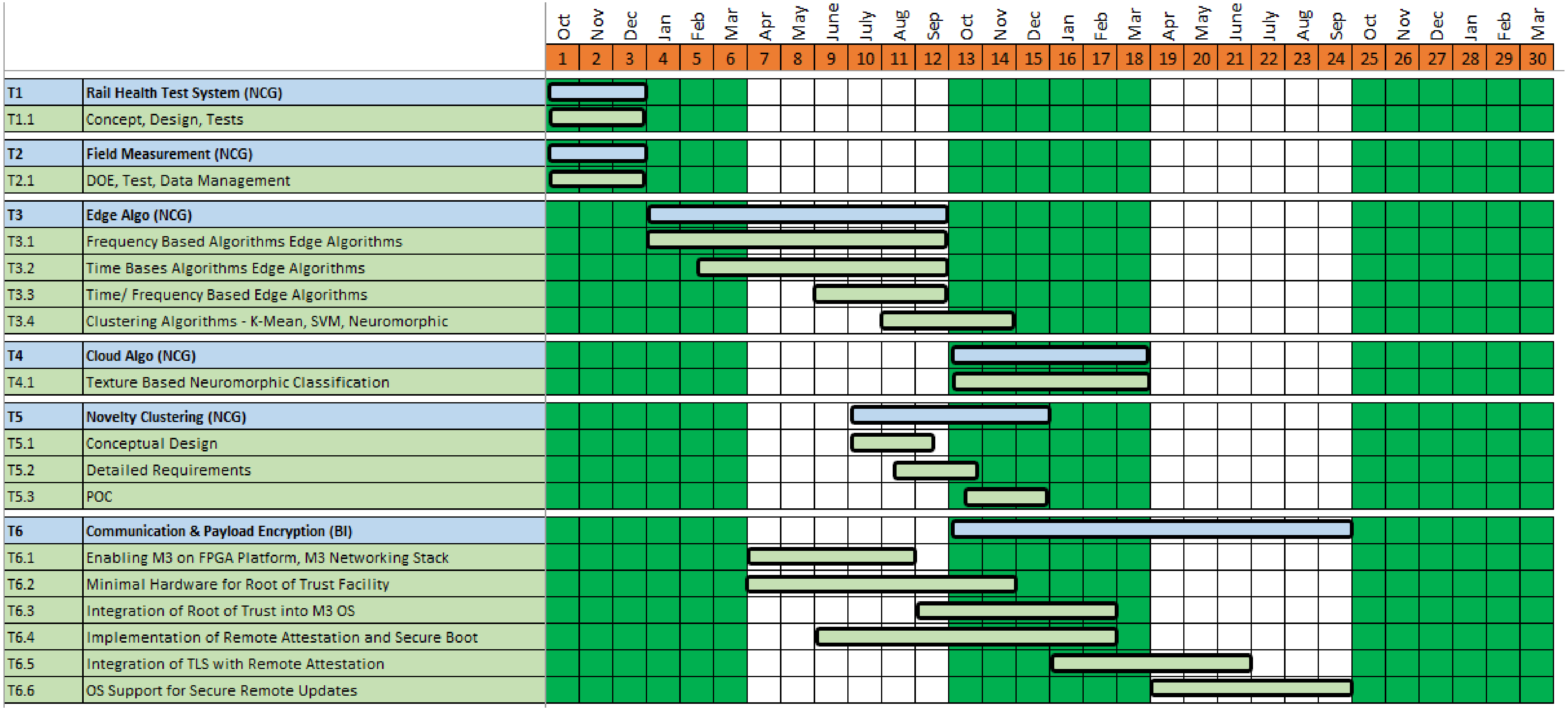

Figure 20: First phase of the implementation plan of the use case

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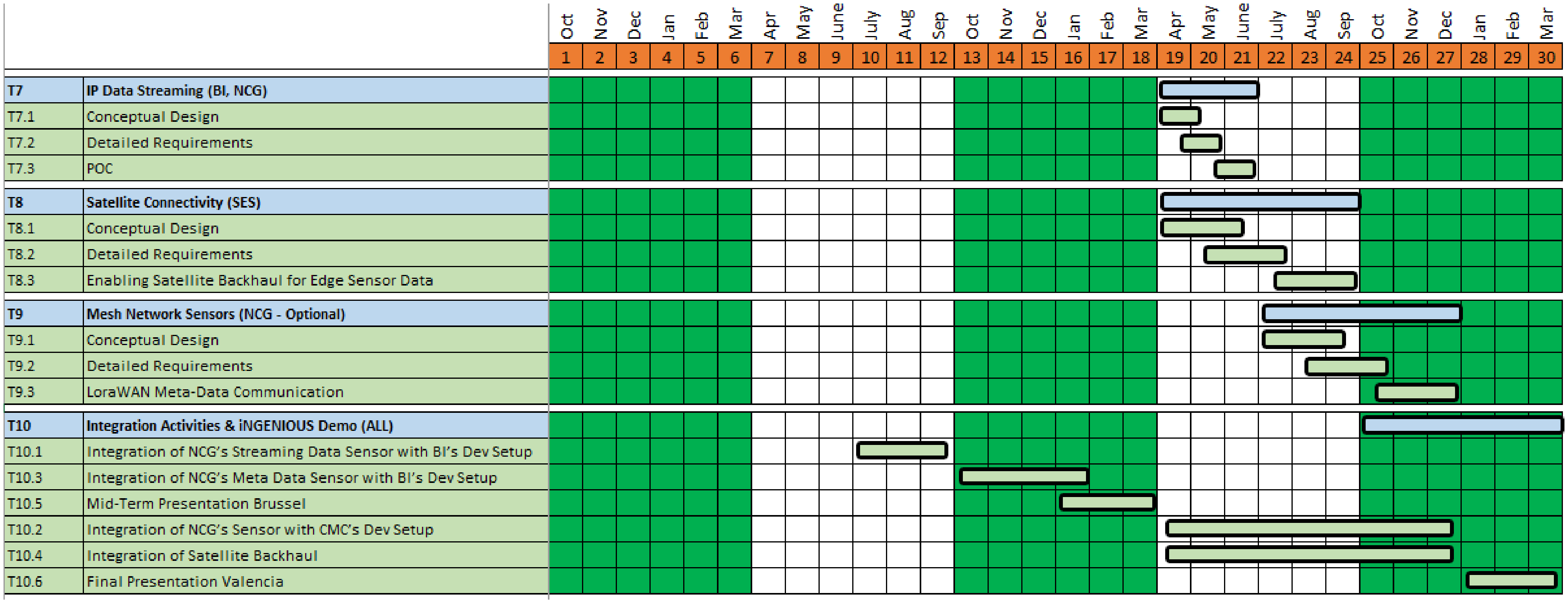

Figure 21: Second phase of the implementation plan of the use case

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9.3.2 RISK REGISTRY

In order to make sure that the use case demonstration and validation is going to take place as expected, the following (potential) risks have been identified and a relevant mitigation action is also provided:

WP	Description of Risk	Risk-Mitigation measures	Probability	Impact
6	Edge Algo (NCG): Low Performance.	Multiple Algorithm Approaches	H	H
6	Cloud Algo (NCG): Too Data Intensive.	Meta Data Compression	H	M
6	Novelty Clustering (NCG): Ineffective Feature Cluster.	Multiple Feature Vectors	M	M
6	Communication & Payload Encryption (BI): too Large Encryption Effort.	Algorithm Iterations	M	M
6	FPGA Platform (BI): Hardware Root-of-Trust not ready on time.	Use Hardware Simulator	M	M
6	IP Data Streaming (BI, NCG): Limited Bandwidth.	Hybrid Connectivity	L	L
6	Satellite Connectivity (SES): Large Latency.	Edge Algo + Cloud Algo	L	L
6	Mesh Network Sensors (NCG - Optional): Insufficient Resources.	Additional Project Sponsors	M	L
6	Integration Activities & iNGENIOUS Demo (ALL): Integration Problems.	Pre-Pilot	L	L
6	Edge Algo (NCG): Low Performance.	Multiple Algorithm Approaches	H	H

Table 105: Risk Registry for the use case

9.4 Demo - Intermodal Asset Tracking via IoT and Satellite

According to the main list of required resources, facilities, development, and integration activities presented and discussed in this deliverable, the following implementation plan has been defined for the considered use case in form of a Gantt chart. A set of macro activities are listed and a preliminary roadmap is provided for the use case implementation.

9.4.1 COSCO SHIP, VALENCIA PORT AND IDIRECT LAB - IMPLEMENTATION PLAN

The main activities for the implementation of the use case are the following:

- Development of the Smart IoT Gateway;
- Evaluation of the performance of the SatCube transportable terminal;
- Sensors procurement, integration with the main board and then with the communication modules and installation in the container;
- Site Survey;

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- Real Demo;
- iDirect Lab Demonstrator/Simulator.

The development of the Smart IoT GW is divided into the following tasks:

- Definition;
- Implementation;
- Integration;
- Validation and Verification.

The time plan for the definition and implementation of the Smart IoT GW is presented in Figure 22, while the time plan for integration and validation of the Smart IoT GW is illustrated in Figure 23:

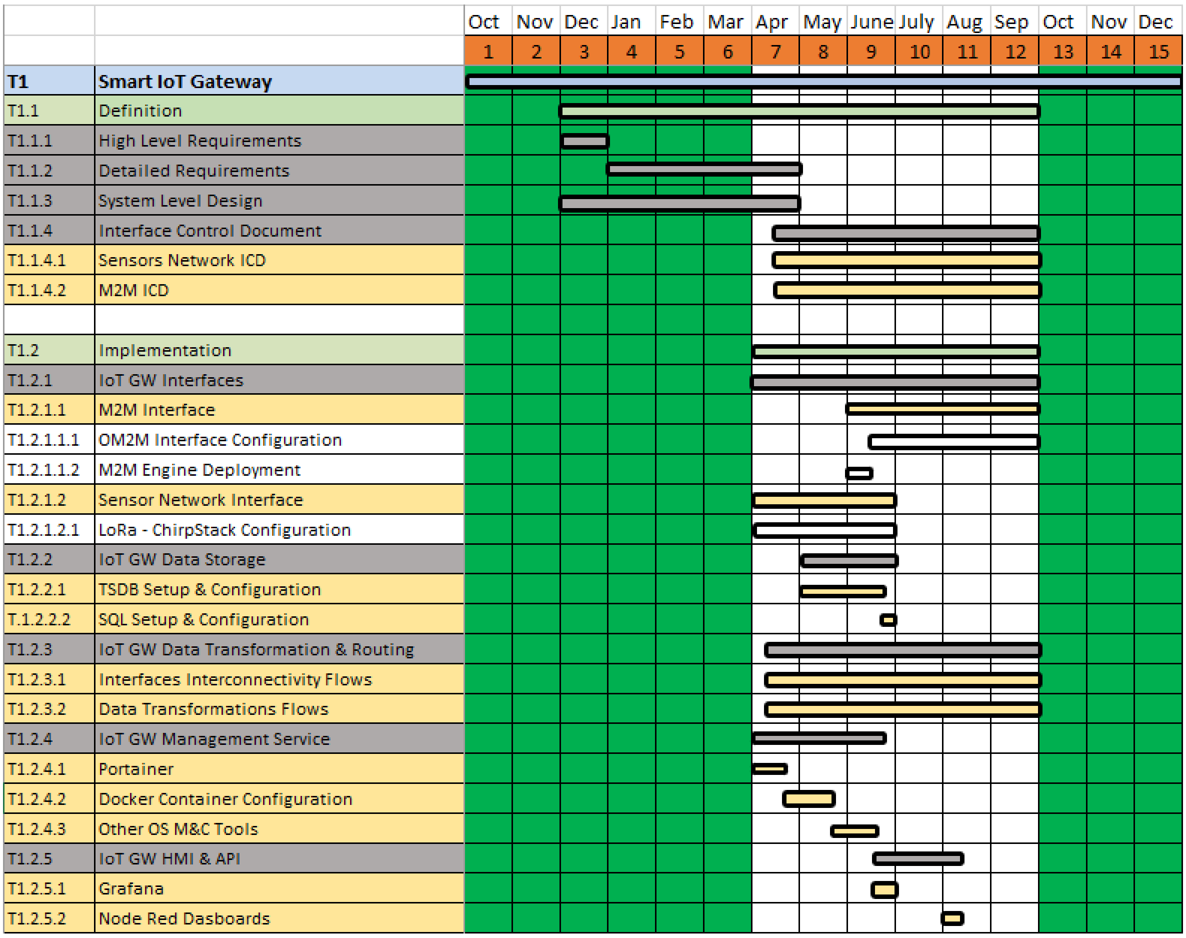

Figure 22: Definition and implementation of the Smart IoT Gateway

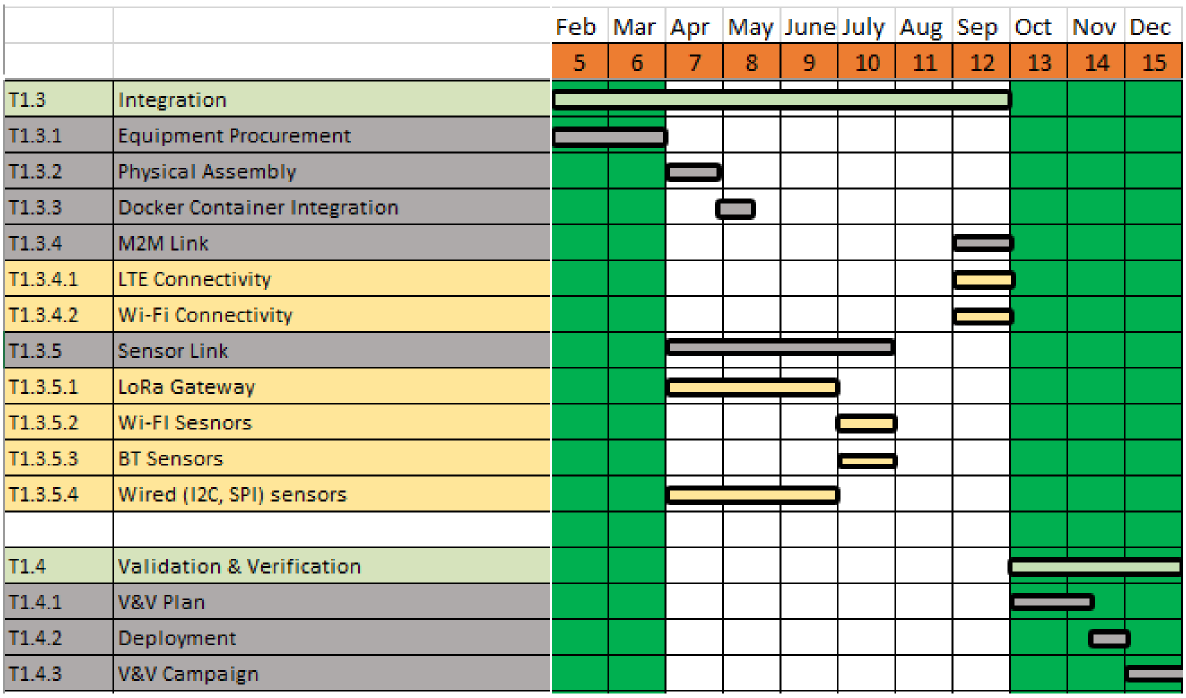

Figure 23: Integration and validation of the Smart IoT Gateway

The performance of the SatCube transportable terminal will be evaluated in two sessions of over-the-air tests using live satellite capacity and the time plan is depicted in Figure 24:

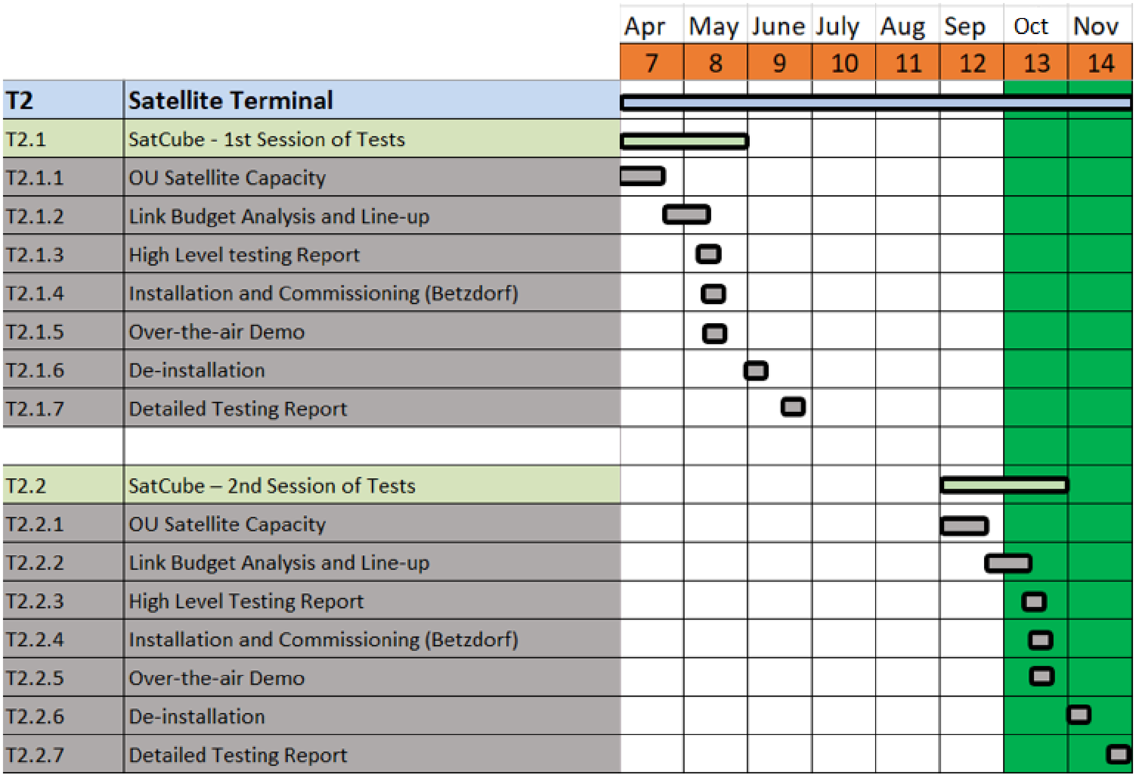

Figure 24: Evaluation of the performance of the SatCube

The tasks related to sensors are the following:

- Procurement of sensors;
- Integration of sensors with the main board;
- Integration of the main board with the communication modules;
- Installation of the sensors in the container.

The time plan for the sensors is presented in Figure 25:

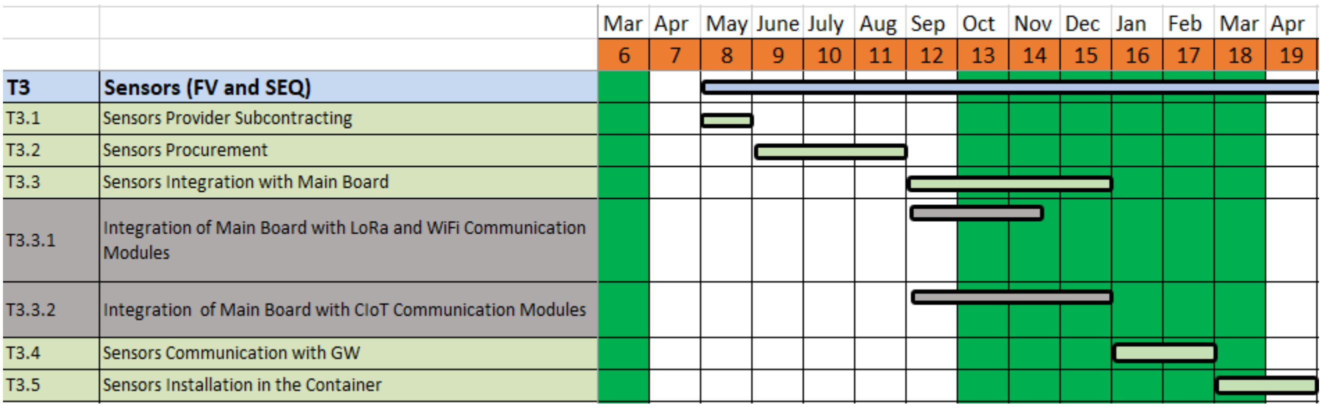

Figure 25: Gantt chart for the sensors deployment

The site survey will focus on:

- exploring the potential locations for the installation of the VSAT antenna system on the ship;
- the installation of the Smart IoT GW on the ship, evaluating the RF conditions on the ship, how the communication between the Smart IoT GW and the container will be obtained, where the Smart IoT GW will be installed (inside the bridge, outside, etc.), etc.

The time plan for the site survey is presented in Figure 26:

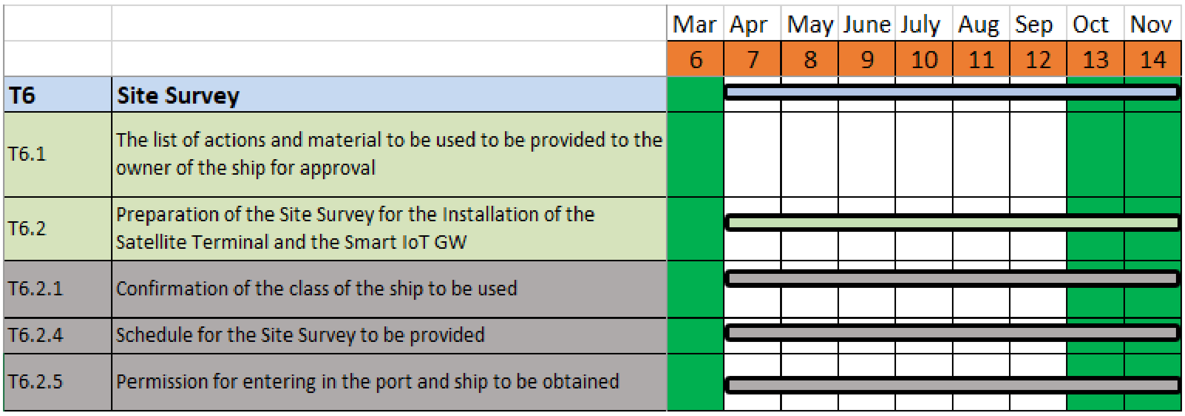

Figure 26: Gantt chart for the site survey

Finally, the time plan for use case real demonstration and for iDirect lab demonstrator/simulator is presented in Figure 27 and Figure 28:

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Figure 27: Real demonstration time plan

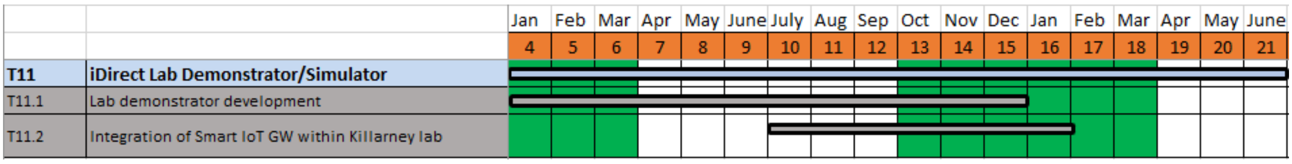

Figure 28: iDirect Lab demonstration and simulator time plan

9.4.2 RISK REGISTRY

In order to make sure that the use case demonstration and validation is going to take place as expected, the following (potential) risks have been identified and a relevant mitigation action is also provided:

WP	Description of Risk	Risk-Mitigation measures	Probability	Impact
6	Installation of the Smart IoT GW on the vessel cannot be realised.	COSCO Spain has got direct links with the COSCO HQ Group for installing additional equipment in container ships. However, equipment installation follows very strict process, all the material should be certified for maritime use, and hence the approval of the captain and the owner of the ship is required. In order to	M	H

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		mitigate this risk a site survey will be carried out. Furthermore, the equipment installation follows very strict time schedules aligned with maintenance periods. If the Valencia – Piraeus – Valencia route vessel will not have any scheduled retrofit/maintenance during the execution of the project, the shipping container equipped with the heterogeneous IoT devices, as well the Smart IoT GW will be installed on the port.		
6	Problems related with permission for the Site Survey before starting the test.	Preparing a list of activities to be shared the captain and owner of the ship to get the approval. Contact with different vessels to have more probability to get the approval. Contact with the different departments involved to collect all possible information in case a simulation has to be done.	M	H
6	Unavailability of in-orbit satellite transponder for the real demo.	SES owns and operates the world's largest commercial telecom satellite fleet with over 70 satellites in two different orbits (GEO/MEO) and in multiple frequency bands (C/X/Ku/Ka). If the baseline satellite transponder identified for the real demo is not available at the given time, an alternative in-orbit satellite transponder will be identified with similar characteristics.	L	H
6	Performance of Satcube system for live trial at Valencia Port. There is a possibility that the Satcube system may not meet the requirements for the live demo in Valencia port due to lack of coverage or reduced bandwidth..	It is planned to run a number of tests using the Satcube system prior to the live demo to ensure this risk will be reduced. Ideally a live test would be performed onsite beforehand but this may not be possible. If the Satcube performance is deemed to be insufficient, an alternative approach would be to install a VSAT antenna and terminal at Valencia Port. The latter is not the preferred solution as it would mean a lot of logistical effort for the short-term live demo and therefore the Satcube solution is much preferred.	L	H

Table 106: Risk Registry for the use case

9.5 Demo - Situational Understanding in Smart Logistics Scenarios

According to the main list of required resources, facilities, development, and integration activities presented and discussed in this deliverable, the following implementation plan has been defined for the considered use case in form of a Gantt chart. A set of macro activities are listed and a preliminary roadmap is provided for the use case implementation.

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9.5.1 VALENCIA AND LIVORNO PORTS - IMPLEMENTATION PLAN

The list of activities for the implementation and development of the use case is the following:

- Data Analysis and Model Development;
- Service and SW Application Development;
- Cross-layer MANO Development and demo;
- IoT Tracking Sensors;
- Visualization Interface;
- Real Demonstration.

The first activity focuses on the execution of the data analysis and model development. For that purpose, four different subtasks are defined (Figure 29):

- Collection of historical data sets;
- Data preparation and exploratory analysis;
- Prediction and model development;
- Optimization model development.

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
T1	**Data Analysis and Model Development (FV, CNIT, AdSPMTS, AWA)**																
T1.1	Collection of historical data sets																
T1.2	Data preparation and exploratory analysis																
T1.3	Prediction model development																
T1.4	Optimization model development																

Figure 29: Gantt Chart for data analysis and model development

The second activity on service and SW application development is split into four different subtasks (see **Figure 30**):

- Data source integration;
- Basic port configurations;
- Visualizing hinterland traffic, TT and cargo movements;
- Deployment of prediction and optimization models.

		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
		13	14	15	16	17	18	19	20	21	22
T2	**Service and application SW development (AWA, FV, CNIT)**										
T2.1	Data source integration										
T2.2	Basic Port Configurations										
T2.3	Visualizing hinterland traffic, TT and cargo movements										
T2.4	Deployment of prediction and optimization models										

Figure 30: Service and SW application development

The third activity on IoT tracking sensors is split into 4 different subtasks (see Figure 31):

- Development of basic slice lifecycle management;
- Development of DVL data collector and processing;
- Development of slice optimization algorithm based on DVL data;

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- Cross-layer MANO demo preparation and execution.

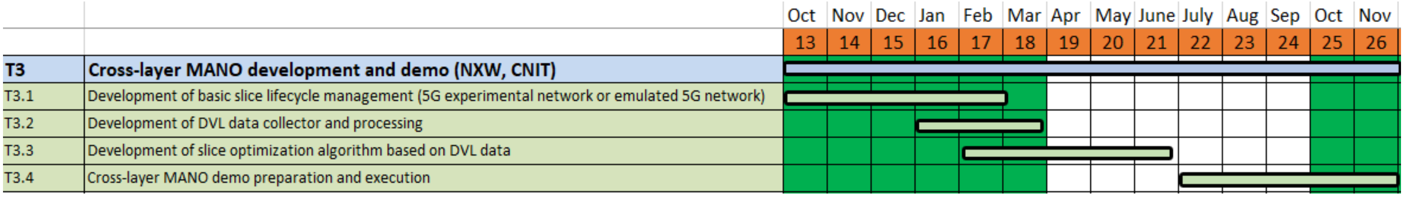

Figure 31: Cross-layer MANO development and demo

The fourth activity on IoT tracking sensors is split into two different subtasks (see Figure 32):

- Sensors Procurement;
- Sensors Installation in the Truck.

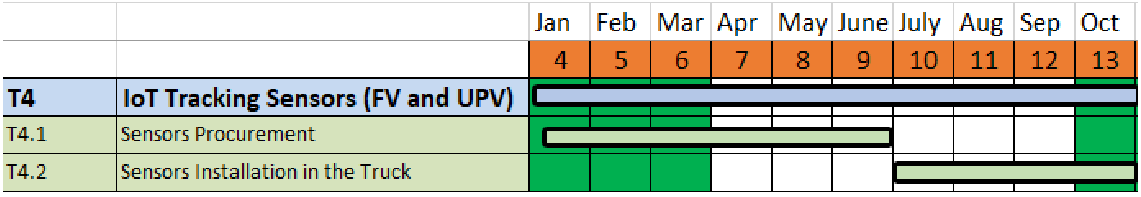

Figure 32: Gantt Chart for IoT tracking sensors

The fifth activity on visualization interface is split into two different subtasks (see Figure 33):

1. Data Ingestion and API Programming;
2. Dashboard Implementation.

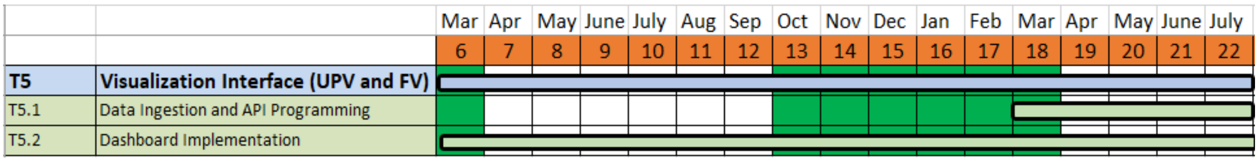

Figure 33: Gantt Chart for visualization interface

Finally, the time plan for the demonstration is presented in the Figure 34:

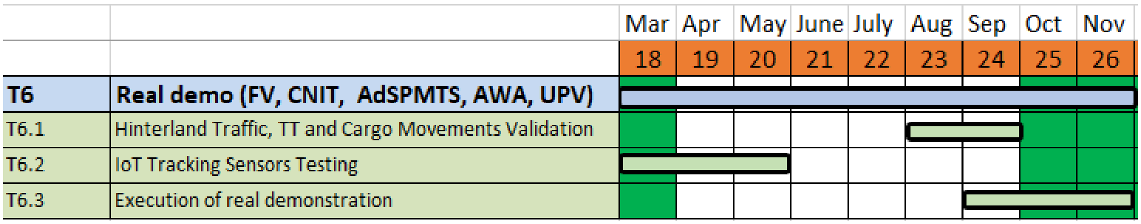

Figure 34: Gantt Chart for real demo

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9.5.2 RISK REGISTRY

In order to make sure that the use case demonstration and validation is going to take place as expected, the following (potential) risks have been identified and a relevant mitigation action is also provided:

WP	Description of Risk	Risk-Mitigation measures	Probability	Impact
6	Lack of trucks to be used for real time tracking and localization within the port of Livorno.	Instead of installing tracking devices on the incoming trucks, the Port of Livorno security vehicles (cars) will be used to simulate the truck's run.	H	L
6	Lack of coverage of commercial LTE/NB-IoT/LTE-M networks in some spots at the port of Valencia for tracking trucks.	Field tests to verify the coverage in different areas within the port. Depending on the test results, the most suitable technology will be selected to track trucks.	M	L
6	Impossibility of accessing to some of the online data sources at the Port of Valencia for performing situational understanding predictions in real-time	Perform offline predictions with historical data sets.	M	M

Table 107: Risk Registry for the use case

9.6 PoC - Supply Chain Ecosystem Integration

In this chapter the implementation plan for the supply *chain Integration use case* is presented according to the main activities identified in the previous sections. The PoC validation will be performed by considering both Livorno Port and Valencia Port as testbeds. Moreover, both ports will be considered as end users for the validation of this use case.

9.6.1 VALENCIA AND LIVRONO PORTS - IMPLEMENTATION PLAN

The implementation plan has been defined by considering the following groups of core activities to be carried out for a proper use case implementation as well as its validation:

- *Environment Setup*: this group of activities is mainly focused on preliminary activities that need to be carried out in order to prepare a proper environment for the deployment of different architectural

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components involved in this use case, such as: Data Virtualization Layer, M2Ms and DLTs testing instances and the cross-DLT layer based on TrustOS solution. This setup procedure is mandatory to allow development and integration activities to be performed according to the main objectives of this use case.

- *M2M & DLT Platforms Integration*: this group of activities is focused on the integration between different M2M platforms and Data Virtualization Layer as well as on the integration between available DLTs and cross-DLT layer based on TrustOS. This mainly includes the development of specific translators to be used by DVL for the interaction with M2M platforms and the development of APIs in order to allow TrustOS to communicate with available DLTs, according to the maritime events data model.

- *DVL and External Systems Integration*: this group of activities takes care of integration activities between Data Virtualization Layer and external platforms such as MANO, TPCS and Awake.AI, according to the main objectives of the predictive models and supply chain integration use cases.

- *PoC Demonstration & Validation*: finally, this group of activities includes the main time plan for providing the alpha version and the final version of the proposed solution. Measurement campaigns are expected to take place for the final validation of this use case and PoC.

The overall implementation plan is provided in the figure below (Figure 35):

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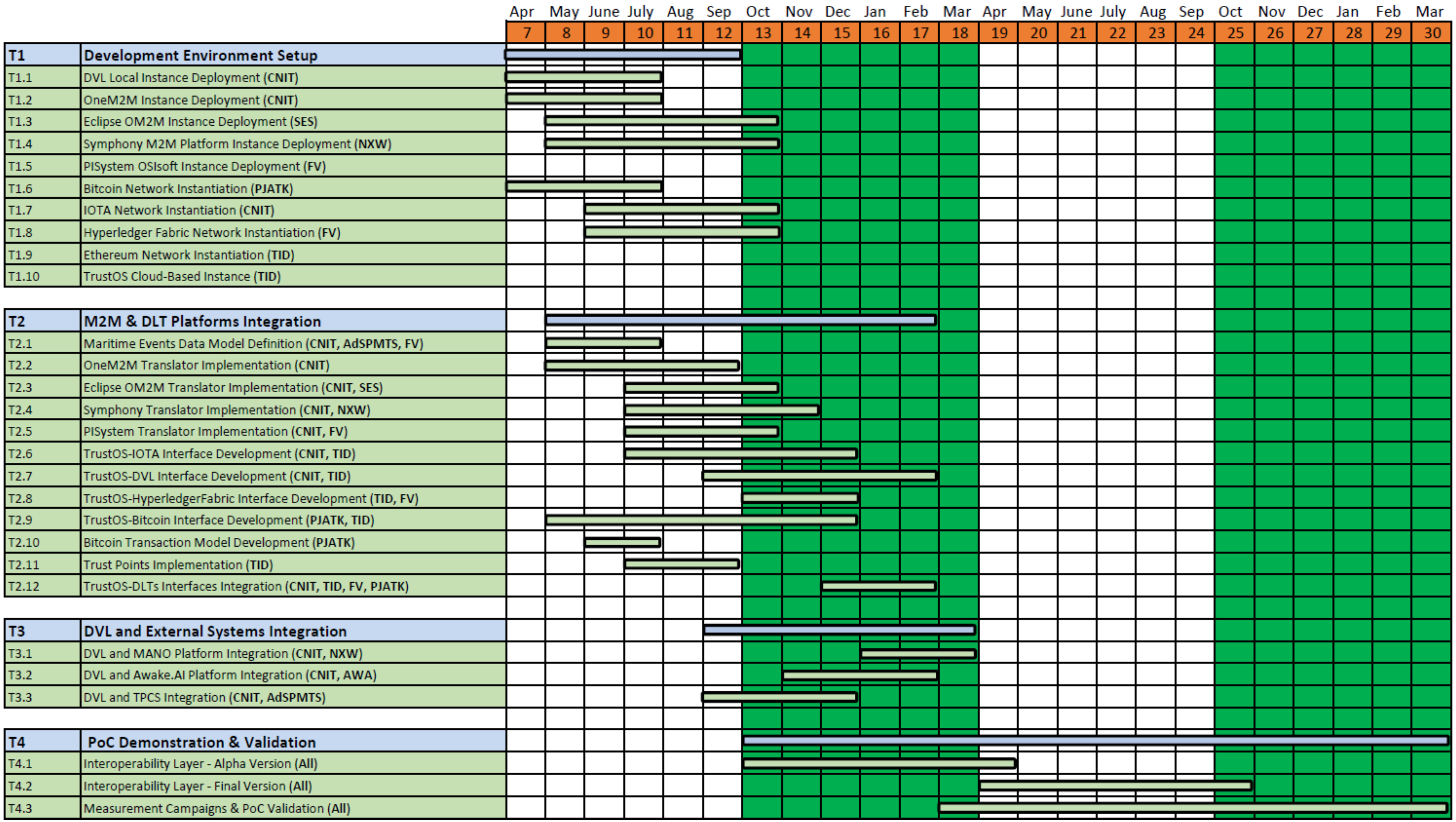

Figure 35: Use case - PoC demonstration & validation time plan

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9.6.2 RISK REGISTRY

In order to make sure that the use case demonstration and validation is going to take place as expected, the following (potential) risks have been identified and a relevant mitigation action is also provided:

WP	Description of Risk	Risk-Mitigation measures	Probability	Impact
6	Delays with building proof-of-concept prototypes as novel technological solutions.	The consortium has industrial partners with proven experience developing high-tech prototypes. Since the project scope is aligned to their business plans, their demonstration capabilities will be improved when the project starts, minimizing this risk. Also, some time has been allocated to allow some delays in the development.	H	L

Table 108: Risk Registry for the use case

9.7 REQUIREMENTS TRACEABILITY MATRIX

The Requirement Traceability Matrix (RTM) gives an overview of all user and system requirements, linking them to test cases and helping in ensuring their coverage. Although a lot of commercial tools for requirements traceability management exist, in this project we relied on a custom sheet-based approach.

In order to monitor test cases execution and the system requirements coverage, a custom template of the RTM has been defined in a form of a live document to be updated during the project lifetime. The form includes the following fields described below:

- *Testbed*: the name of the linked testbed;
- *Use Case*: the name of the linked Use Case;
- *Demonstration Type*: PoC or Real Demo;
- *User Requirement ID*: unique identifier for the linked user requirement;
- *User Requirement Priority*: the priority of the linked user requirement (e.g. MUST, SHOULD, COULD, etc.)
- *System Requirement ID*: unique system requirement identifier;
- *System Requirement Priority*: system requirement priority (e.g. MUST, SHOULD, COULD, etc.);
- *Test Case ID*: unique test case identifier;
- *Responsible Partner*: partner in charge of test case execution;
- *Status*: test case outcome (PENDING in case the test case is not performed yet).

Moreover, for the completeness of the information, a light version of the above-mentioned RTM is also included as part of the deliverable's *Appendix A* and the reader is invited to check it out in order to find out the link between test cases described in this document and system requirements, as well as user requirements, defined in D2.1 - Use Cases, KPIs and Requirements.

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10 Conclusions

According to the outcomes of WP2, WP3, WP4 and WP5, this document has described all the activities related to the implementation of PoCs and real demos by considering the iNGENIOUS use cases to be deployed in the different realistic testbeds.

Planning of the required resources, facilities, connectivity, and logistics for the set-up of each testbed has been conducted. Based on these data, appropriate components of the iNGENIOUS PoCs and the technological infrastructure of the testbeds are listed, describing the actions required and the time plan for setting up the PoCs and the use cases, from the beginning of the project, until they become ready for testing and demonstrations.

According to that, a preliminary implementation plan for development, integration, and validation of the use cases has been identified and it will be subject to further changes depending on the use cases' improvements.

Finally, a tracking methodology of tests case and system requirements for the validation and verification of the use cases, has been defined and introduced and it will represent a baseline for the T6.2 – PoCs development, platform and testbed integration execution according to WP6 roadmap.

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Appendix A

User Requirement	System Requirement	System Requirement Description	Test Case
UC1_UR_01	UC1_SR_01	The devices in the robot do not need to be updated and can utilize standard Ethernet RJ45 ports to connect to 5G communication module and connect to 5G network.	UC1_TC_14
	UC1_SR_02	The 5G system incudes management console where the operator can register new devices and visualize when they are connected and what their status is.	UC1_TC_05
	UC1_SR_04	The AI/ML assisted MANO shall be able to deploy and orchestrate the robot control application as part of the industrial IoT slice provisioning and select a proper edge/MEC location to fulfil the latency requirements.	UC1_TC_13
	UC1_SR_09	To connect devices, form different 3GPP and non-3GPP standards (e.g., Bluetooth, WIFI, LoRA, etc.) to the IoT core network, the RAN should be equipped with gateways that provide multiple radio interfaces. The gateway can be managed by the 5G core control plane or directly connected to the data plane.	UC1_TC_03
	UC1_SR_10	Applications development should be simplified by means of APIs that abstract the underlying network resources and operations. These APIs provide developers with tools to reserve resources and specify the application requirements. It also includes functions and libraries for accessing the devices I/O and implement the control loops on MEC. Furthermore, it enables interacting with end-user interface for acquiring status information and sending remote commands.	UC1_TC_07
UC1_UR_02	UC1_SR_10	Applications development should be simplified by means of APIs that abstract the underlying network resources and operations. These APIs provide developers with tools to reserve resources and specify the application requirements. It also includes functions and libraries for accessing the devices I/O and implement the control loops on MEC. Furthermore, it enables interacting with end-user interface for acquiring status information and sending remote commands.	UC1_TC_15
UC1_UR_03	UC1_SR_10	Applications development should be simplified by means of APIs that abstract the underlying network resources and operations. These APIs provide developers with tools to reserve resources and specify the application requirements. It also includes functions and libraries for accessing the devices I/O and implement the control loops on MEC. Furthermore, it enables interacting with end-user interface for acquiring status information and sending remote commands.	UC1_TC_15
	UC1_SR_03	The MANO shall be able to deploy and orchestrate the 5G network functions including the resources for running TSN translator in the 5G network that allow the communication between mobile devices and TSN devices connected to the fixed infrastructure.	UC1_TC_07
	UC1_SR_11	The AI/ML assisted MANO shall provide ML-based automated mechanisms and procedures for proactively adjusting and adapting the	UC1_TC_12

		provisioned industrial IoT network slices at runtime to optimize their performance profile, network and control functions size and location, network resources usage and configuration.	
UC1_UR_04	**UC1_SR_10**	Applications development should be simplified by means of APIs that abstract the underlying network resources and operations. These APIs provide developers with tools to reserve resources and specify the application requirements. It also includes functions and libraries for accessing the devices I/O and implement the control loops on MEC. Furthermore, it enables interacting with end-user interface for acquiring status information and sending remote commands.	**UC1_TC_07**
UC1_UR_05	**UC1_SR_02**	The 5G system incudes a management console where the operator can register new devices and visualize when they are connected and what their status is.	**UC1_TC_05**

Table 109: Light version of the requirements traceability matrix

User Requirement	System Requirement	System Requirement Description	Test Case
UC2_UR_01	**UC2_SR_01**	The RAN and network should support the network to be managed from the 5GC management console to allocate devices to different slices and define the parts of the fixed LAN that each device can access.	**UC2_TC_01**
	UC2_SR_03	The 5G network shall provide sufficiently low latency to ensure an immersive experience when controlling the AGVs.	
	UC2_SR_04	The 5G network should ensure enough system capacity in terms of throughput to send the data in real-time from AGVs to the VR devices. This also includes control data.	
UC2_UR_01	**UC2_SR_03**	The 5G network shall provide sufficiently low latency to ensure an immersive experience when controlling the AGVs.	**UC2_TC_02**
	UC2_SR_04	The 5G network should ensure enough system capacity in terms of throughput to send the data in real-time from AGVs to the VR devices. This also includes control data.	
UC2_UR_04	**UC2_SR_06**	A 5G sub-6GHz Modem or a 5G mmW Modem should be installed in the AGV for enabling up- and down-link communication to a Public 5G sub6GHz and/or Private mmW gNB.	
	UC2_SR_08	The cockpit should wirelessly deliver communication to far-edge MEC via fixed fibre (IP access) and/or 5G Hotspot.	
UC2_UR_05	**UC2_SR_09**	AGVs should incorporate the necessary security to avoid collisions and accidents in case of no 5G connectivity or human errors. This may be implemented using sensors or restricted locations.	
UC2_UR_01	**UC2_SR_05**	Telepresence should be supported by 4 x 120o low-latency video cameras and other proximity sensors installed in AGVs.	**UC2_TC_03**
	UC2_SR_07	The cockpit should be fully equipped with forehead Augmented Reality glasses (for the 3D view & dashboard of the real scene) + a	

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		sensor trackband and haptic gloves + steering wheel and pedals.	
UC2_UR_05	UC2_SR_08	The cockpit should wirelessly deliver communication to far-edge MEC via fixed fibre (IP access) and/or 5G Hotspot.	
	UC2_SR_12	An Internet of Things devices to be used to connect a devised cockpit to the backhaul.	
UC2_UR_01	UC2_SR_05	Telepresence should be supported by 4 x 120o low-latency video cameras and other proximity sensors installed in AGVs.	UC2_TC_04
	UC2_SR_07	The cockpit should be fully equipped with forehead Augmented Reality glasses (for the 3D view & dashboard of the real scene) + a sensor trackband and haptic gloves + steering wheel and pedals.	
UC2_UR_05	UC2_SR_08	The cockpit should wirelessly deliver communication to far-edge MEC via fixed fibre (IP access) and/or 5G Hotspot.	
	UC2_SR_12	An Internet of Things devices to be used to connect a devised cockpit to the backhaul.	
UC2_UR_01	UC2_SR_01	The RAN and network should support network to be managed from the 5GC management console to allocate devices to different slices and define the parts of the fixed LAN that each device can access.	UC2_TC_05
	UC2_SR_03	The 5G network shall provide sufficiently low latency to ensure an immersive experience when controlling the AGVs.	
	UC2_SR_04	The 5G network should ensure enough system capacity in terms of throughput to send the data in real-time from AGVs to the VR devices. This also includes control data.	
	UC2_SR_10	Adapt current port's infrastructure to the 5G equipment installation maximizing the reuse of existing resources.	
	UC2_SR_11	Satisfy end-to-end wireless communication with good reasonable throughput at its lowest latency.	
UC2_UR_01	UC2_SR_05	Telepresence should be supported by 4 x 120o low-latency video cameras and other proximity sensors installed in AGVs.	UC2_TC_06
UC2_UR_04	UC2_SR_06	A 5G sub-6GHz Modem or a 5G mmW Modem should be installed in the AGV for enabling up- and down-link communication to a Public 5G sub6GHz and/or Private mmW gNB.	
UC2_UR_05	UC2_SR_09	AGVs should incorporate the necessary security to avoid collisions and accidents in case of no 5G connectivity or human errors. This may be implemented using sensors or restricted locations.	
UC2_UR_01	UC2_SR_02	All data transmitted and received for the remote control of AGVs should be secured avoiding security threats.	UC2_TC_07
	UC2_SR_03	The 5G network shall provide sufficiently low latency to ensure an immersive experience when controlling the AGVs.	
UC2_UR_02	UC2_SR_04	The 5G network should ensure enough system capacity in terms of throughput to send the data in real-time from AGVs to the VR devices. This also includes control data.	

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	UC2_SR_05	Telepresence should be supported by 4 x 120o low-latency video cameras and other proximity sensors installed in AGVs.	
UC2_UR_03	UC2_SR_06	A 5G sub-6GHz Modem or a 5G mmW Modem should be installed in the AGV for enabling up- and down-link communication to a Public 5G sub6GHz and/or Private mmW gNB.	
	UC2_SR_07	The cockpit should be fully equipped with forehead Augmented Reality glasses (for the 3D view & dashboard of the real scene) + a sensor trackband and haptic gloves + steering wheel and pedals.	
UC2_UR_04	UC2_SR_08	The cockpit should wirelessly deliver communication to far-edge MEC via fixed fibre (IP access) and/or 5G Hotspot.	
	UC2_SR_09	AGVs should incorporate the necessary security to avoid collisions and accidents in case of no 5G connectivity or human errors. This may be implemented using sensors or restricted locations.	
UC2_UR_05	UC2_SR_11	Satisfy end-to-end wireless communication with good reasonable throughput at its lowest latency.	

Table 110: Light version of the requirements traceability matrix

User Requirement	System Requirement	System Requirement Description	Test Case
UC3_UR_01	UC3_SR_01	The sensor should be able to monitor defect-free axles for 12yrs without maintenance (i.e., no battery replacement).	UC3_TC_01
	UC3_SR_04	In case of lost connectivity, sensors and gateways shall store relevant data until communication connectivity is restored.	UC3_TC_04
	UC3_SR_05	The Gateway shall scan for alternative connectivity modes in case the primary connectivity mode is lost or is not stable. See SR3.	UC3_TC_05
	UC3_SR_06	The sensor shall monitor relevant motion event at least once every 120 minutes.	UC3_TC_06
	UC3_SR_07	The sensor shall differentiate between Flat-Spots, Flat-Spot Width, and Bearing Defects.	UC3_TC_07
	UC3_SR_15	Bearing fault detection shall be Safety Integrity Level 2 compliant.	UC3_TC_15
	UC3_SR_16	The gateway/sensor electronic shall be ATEX certifiable.	UC3_TC_16
UC3_UR_02	UC3_SR_03	The gateway connectivity should be omni-present to guarantee a Fault Communication Time within 30-minute intervals. This shall be achieved, if necessary, with alternative or redundant connectivity methods between Gateway and IP connectivity. (e.g. NB-IOT, LTE-M, Wi-Fi, TE-M, 5G, Satellite, etc.).	UC3_TC_03
UC3_UR_03	UC3_SR_10	The gateway/sensor system shall be robust against security attacks.	UC3_TC_10
	UC3_SR_11	The gateway/sensor/cloud communication shall have end-to-end security encryption.	UC3_TC_11
	UC3_SR_12	The gateway/sensor firmware updates shall be robust against security attacks.	UC3_TC_12

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	UC3_SR_13	In addition to protecting confidentiality and integrity of the communication channel between Platform and Control-centre, the identity of both endpoints should be validated using Remote Attestation. To ensure confidentiality, integrity, and availability of sensor data, it must be ensured that only correctly functioning (i.e., no fake or compromised) sensors are connected to the right and securely operated, cloud-hosted control centre / middle ware and vice versa. Remote Attestation solves this problem, as it provides a cryptographic link between a device identity anchored in a Root of Trust (in hardware).	**UC3_TC_13**
	UC3_SR_14	For asynchronous communications, the payload (e.g., metadata, raw data) shall be encrypted and cryptographically authenticated (e.g., signed) such that it can be stored securely when not in transmission (either locally on the Platform, or in Control-centre).	**UC3_TC_14**
	UC3_SR_20	The platform shall support secure software updates and deployment (i.e., only updates from an authorized party are installed to ensure security and availability). To close previously unknown security vulnerabilities in the deployed device software, a valid new version must be able to be installed, but no fake/compromised update. Also, function updates are desirable to add new features or to adapt to new regulations/requirements.	**UC3_TC_20**
UC3_UR_04	**UC3_SR_08**	The sensor shall record highly probable defect data for cloud confirmation.	**UC3_TC_08**
	UC3_SR_09	The gateway/sensor system shall enable defect confirmation via crosstalk evaluation.	**UC3_TC_09**
UC3_UR_05	**UC3_SR_02**	The gateway should be able to operate up to 30 edge sensors and maintain cloud connectivity every 30 minutes for 12 years without maintenance (i.e., energy optimized Sensor-Gateway Protocol and COM Strategy, energy optimized Gateway-Cloud connectivity.	**UC3_TC_02**
UC3_UR_06	**UC3_SR_17**	The operator has visibility of the devices that will connect to the network and which of those devices require low latency if they have to be controlled remotely. The operator through some platform console should be able to select the devices that will be connected to applications that have to be running closer to the radio access. The operator will select those devices and the required computing resources.	**UC3_TC_17**
	UC3_SR_18	The platform should be able to include multiple radio technologies that can be managed from a common packet core. All those technologies should be connected to the core through IP connection; thus, the core will include the required protocols for each radio access technology.	**UC3_TC_18**
	UC3_SR_19	The platform will integrate different radio technologies depending on the end device and the distance to the application or service that will process the data from the device. Thus, the depending on the device the platform should be able to utilize different radio technologies.	**UC3_TC_19**
	UC3_SR_21	The satellite link that connects the 4G base-station, 5G base-station, LoRa gateway, or mobile edge gateway to the Internet must be capable of backhauling the data.	**UC3_TC_21 – 23**

Table 111: Light version of the requirements traceability matrix

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User Requirement ID	System Requirement ID	System Requirement Description	Test Cases ID
UC4_UR_01	UC4_SR_25	The sensors will include nano-SIM or similar for authentication with the 5GC.	UC4_TC_01
UC4_UR_01	UC4_SR_27	Sensors and actuators should integrate a module for enabling cellular IoT connectivity in static and mobility conditions.	
UC4_UR_01	UC4_SR_27	Sensors and actuators should integrate a module for enabling cellular IoT connectivity in static and mobility conditions.	UC4_TC_02
UC4_UR_01	UC4_SR_28	Sensors should be able to communicate at low power from within the container to communicate with the IoT Gateway.	
UC4_UR_04	UC4_SR_04	Battery-powered IoT device(s)/sensors should be able to operate for the entire lifetime of the tracked container without large capacity battery packs and without being replaced during this period of time.	UC4_TC_03
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_04
UC4_UR_01 UC4_UR_03 UC4_UR_05	UC4_SR_03	Containers should include sensors to monitor environmental variables, such as temperature, pressure, humidity, sudden movement, breach, location.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_05
UC4_UR_01 UC4_UR_03 UC4_UR_05	UC4_SR_03	Containers should include sensors to monitor environmental variables, such as temperature, pressure, humidity, sudden movement, breach, location.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_06
UC4_UR_01 UC4_UR_03 UC4_UR_05	UC4_SR_03	Containers should include sensors to monitor environmental variables, such as temperature, pressure, humidity, sudden movement, breach, location.	
UC4_UR_10	UC4_SR_23	There will be a mechanism for a container to handover between the ship IoT Gateway and the onshore IoT Gateway.	
UC4_UR_01	UC4_SR_27	Sensors and actuators should integrate a module for enabling cellular IoT connectivity in static and mobility conditions.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_07
UC4_UR_06 UC4_UR_07	UC4_SR_08	The IoT GW should be able to receive and process multiple data streams coming simultaneously from multiple containers loaded on the ship and forward them to a data centre or cloud platform.	
UC4_UR_06	UC4_SR_12	The IoT Gateway should be able to report its status via an API and through its management dashboard.	
UC4_UR_07	UC4_SR_13	The IoT Gateway should be resilient to connectivity outages.	
UC4_UR_07	UC4_SR_15		

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UC4_UR_10		The IoT GW should forward (buffered) stored data as soon as possible when backhaul connectivity becomes available.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_08
UC4_UR_10	UC4_SR_18	When the ship is out of range of terrestrial connectivity, the satellite network selected must meet the minimum connectivity requirements.	
UC4_UR_01	UC4_SR_29	Satellite communication should not interfere with existing radio communication systems in the vicinity and should be tolerant of their presence.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_09
UC4_UR_10	UC4_SR_18	When the ship is out of range of terrestrial connectivity, the satellite network selected must meet the minimum connectivity requirements.	
UC4_UR_10	UC4_SR_24	There is an IP connection between the radio access and the mobile core for signalling from base stations and data from sensors.	
UC4_UR_01	UC4_SR_26	The IoT sensor information may be transferred over the satellite network without the need to establish a dedicated data path over the satellite network.	
UC4_UR_01	UC4_SR_29	Satellite communication should not interfere with existing radio communication systems in the vicinity and should be tolerant of their presence.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_10
UC4_UR_05	UC4_SR_05	IoT sensors will send periodic status updates at a frequency that has been tuned for efficient use of bandwidth, and for providing up to date.	
UC4_UR_06 UC4_UR_07	UC4_SR_07	The IoT Gateway will backhaul data in a format and at a frequency that has been tuned for efficient use of bandwidth, and for providing up-to-date information.	
UC4_UR_06 UC4_UR_07	UC4_SR_08	The IoT GW should be able to receive and process multiple data streams coming simultaneously from multiple containers loaded on the ship and forward them to a data centre or cloud platform.	
UC4_UR_10	UC4_SR_18	When the ship is out of range of terrestrial connectivity, the satellite network selected must meet the minimum connectivity requirements.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_11
UC4_UR_05	UC4_SR_05	IoT sensors will send periodic status updates at a frequency that has been tuned for efficient use of bandwidth, and for providing up to date.	
UC4_UR_06 UC4_UR_07	UC4_SR_07	The IoT Gateway will backhaul data in a format and at a frequency that has been tuned for efficient use of bandwidth, and for providing up-to-date information.	

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UC4_UR_10	UC4_SR_18	When the ship is out of range of terrestrial connectivity, the satellite network selected must meet the minimum connectivity requirements.	
UC4_UR_10	UC4_SR_21	The IoT Gateway should be able to provide security for communication through its interfaces.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_12
UC4_UR_05	UC4_SR_05	IoT sensors will send periodic status updates at a frequency that has been tuned for efficient use of bandwidth, and for providing up to date.	
UC4_UR_06 UC4_UR_07	UC4_SR_07	The IoT Gateway will backhaul data in a format and at a frequency that has been tuned for efficient use of bandwidth, and for providing up-to-date information.	
UC4_UR_10	UC4_SR_18	When the ship is out of range of terrestrial connectivity, the satellite network selected must meet the minimum connectivity requirements.	
UC4_UR_09	UC4_SR_21	The IoT Gateway should be able to provide security for the communication through its interfaces.	
UC4_UR_01 UC4_UR_03 UC4_UR_05	UC4_SR_03	Containers should include sensors to monitor environmental variables, such as temperature, pressure, humidity, sudden movement, breach, location.	UC4_TC_13
UC4_UR_09	UC4_SR_06	The creation of a secure and resilient centralized repository for sensor information is required.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_14
UC4_UR_01 UC4_UR_05	UC4_SR_02	Data centre/cloud should have the ability to perform data analytics on collected data and should be able to analyse data on arrival to react as quickly as possible to events. To assist with analytics, the data centre / cloud may offload some of the analytics processing at the IoT Gateway, or edge cloud appliance, located on the ship or truck.	
UC4_UR_01 UC4_UR_02 UC4_UR_05 UC4_UR_06 UC4_UR_07	UC4_SR_01	Network connectivity both on maritime and inland segments is required. Hence, the data center/cloud should be able to have real-time visibility and track the shipping containers reliably and accurately for the whole trip.	UC4_TC_15
UC4_UR_07	UC4_SR_11	The IoT Gateway should be able to optimize the traffic for satellite communications.	
UC4_UR_10	UC4_SR_16	The IoT Gateway, or a co-located appliance, should be able to detect, monitor, and report on the availability of backhaul connectivity.	
UC4_UR_10	UC4_SR_17	The IoT Gateway, or a co-located appliance, must be configurable to allow the operator to configure the connectivity decision process, e.g., choice of terrestrial or NTN connectivity.	
UC4_UR_01	UC4_SR_19	The IoT Gateway should be able to route messages between its interfaces.	
UC4_UR_10	UC4_SR_23	There will be a mechanism for a container to handover between the ship IoT Gateway and the onshore IoT Gateway.	
UC4_UR_06 UC4_UR_07	UC4_SR_07	The IoT Gateway will backhaul data in a format and at a frequency that has been tuned for efficient use of bandwidth, and for providing up-to-date information.	UC4_TC_16
UC4_UR_06 UC4_UR_07	UC4_SR_08	The IoT GW should be able to receive and process multiple data streams coming	

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		simultaneously from multiple containers loaded on the ship and forward them to a data centre or cloud platform.	
UC4_UR_01	**UC4_SR_10**	The IoT Gateway should be able to provide independent interfaces for different IoT protocols.	
UC4_UR_07	**UC4_SR_11**	The IoT Gateway should be able to optimize the traffic for satellite communications.	
UC4_UR_10	**UC4_SR_16**	The IoT Gateway, or a co-located appliance, should be able to detect, monitor, and report on the availability of backhaul connectivity.	
UC4_UR_10	**UC4_SR_17**	The IoT Gateway, or a co-located appliance, must be configurable to allow the operator to configure the connectivity decision process, e.g., choice of terrestrial or NTN connectivity	
UC4_UR_01	**UC4_SR_19**	The IoT Gateway should be able to route messages between its interfaces.	
UC4_UR_10	**UC4_SR_23**	There will be a mechanism for a container to handover between the ship IoT Gateway and the onshore IoT Gateway.	
UC4_UR_06	**UC4_SR_09**	The IoT Gateway should be able to provide a remote management endpoint.	**UC4_TC_17**
UC4_UR_06	**UC4_SR_12**	The IoT Gateway should be able to report its status via an API and through its management dashboard.	
UC4_UR_05 **UC4_UR_06** **UC4_UR_08**	**UC4_SR_20**	The IoT Gateway should be able to publish status, warnings and alert messages to external parties.	
UC4_UR_06	**UC4_SR_12**	The IoT Gateway should be able to report its status via an API and through its management dashboard.	**UC4_TC_18**
UC4_UR_07	**UC4_SR_13**	The IoT Gateway should be resilient to connectivity outages.	
UC4_UR_07	**UC4_SR_14**	The IoT Gateway should be able to provide a configurable limited storage to buffer the data.	
UC4_UR_07 **UC4_UR_10**	**UC4_SR_15**	The IoT GW should forward (buffered) stored data as soon as possible when backhaul connectivity becomes available.	
UC4_UR_10	**UC4_SR_16**	The IoT Gateway, or a co-located appliance, should be able to detect, monitor, and report on the availability of backhaul connectivity.	
UC4_UR_09	**UC4_SR_21**	The IoT Gateway should be able to provide security for communication through its interfaces.	**UC4_TC_19**
UC4_UR_01	**UC4_SR_22**	The IoT Gateway should expose interfaces to allow the integration with other systems.	**UC4_TC_20**

Table 112: Light version of the requirements traceability matrix

User Requirement	System Requirement	System Requirement Description	Test Case
UC5_UR_02 **UC5_UR_03**	**UC5_SR_04**	Data source sufficiency should be ensured to estimate and predict TTT.	**UC5_TC_01**
UC5_UR_01	**UC5_SR_04**	Data source sufficiency should be ensured to estimate and predict TTT.	**UC5_TC_02**
UC5_UR_03	**UC5_SR_06**	Common database to ensure optimum data accessibility.	
UC5_UR_05	**UC5_SR_01**	Truck Turnaround Time prediction should be performed by exploiting online and offline data ingestion services.	**UC5_TC_03**
	UC5_SR_02	Truck Turnaround Time estimation mean error should be reduced.	

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UC5_UR_01	UC5_SR_01	Truck Turnaround Time prediction should be performed by exploiting online and offline data ingestion services.	UC5_TC_04
	UC5_SR_02	Truck Turnaround Time estimation mean error should be reduced.	
UC5_UR_05	UC5_SR_03	Truck Turnaround Time prediction should lead to an increase the port and terminal performance.	
	UC5_SR_10	Continuous (automatic) training capability of the situational understanding and predictive models.	
UC5_UR_03	UC5_SR_07	Real-time tracking of trucks inside the port and terminal facilities.	UC5_TC_05
	UC5_SR_19	Identification and measurement of idle waiting times for current truck turnarounds.	
UC5_UR_01	UC5_SR_13	Supply chain network slice on boarding.	UC5_TC_06
	UC5_SR_14	Lifecycle management of supply chain network slice	UC5_TC_07
	UC5_SR_15	AI/ML assisted MANO interaction with network and computing infrastructures.	
	UC5_SR_14	Lifecycle management of supply chain network slice	UC5_TC_08
	UC5_SR_15	AI/ML assisted MANO interaction with network and computing infrastructures.	
	UC5_SR_14	Lifecycle management of supply chain network slice	UC5_TC_09
	UC5_SR_15	AI/ML assisted MANO interaction with network and computing infrastructures.	
UC5_UR_01 UC5_UR_04	UC5_SR_12	AI/ML module assisting MANO stores the data retrieved from DVL.	UC5_TC_10
UC5_UR_01 UC5_UR_04	UC5_SR_12	AI/ML module assisting MANO stores the data retrieved from DVL.	UC5_TC_11
UC5_UR_01	UC5_SR_12	AI/ML module assisting MANO stores the data retrieved from DVL.	UC5_TC_12
	UC5_SR_14	Lifecycle management of supply chain network slice	
UC5_UR_04	UC5_SR_15	AI/ML assisted MANO interaction with network and computing infrastructures.	
	UC5_SR_16	AI/ML assisted network slice optimization.	
UC5_UR_02	UC5_SR_17	Time event information on the vessel, container, and truck movements.	UC5_TC_13
UC5_UR_02	UC5_SR_18	Unique IDs for connecting vessel, container, and truck events.	UC5_TC_14
UC5_UR_05	UC5_SR_20	Vessel arrival schedule prediction to estimate future traffic levels at the port.	UC5_TC_15
UC5_UR_03	UC5_SR_08		UC5_TC_16

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UC5_UR_05		Web-service based application for visualizing Truck Turnaround Time estimation and prediction outcomes.	
UC5_UR_03	**UC5_SR_09**	Capability to generate alerts of near future TTT peaks.	**UC5_TC_17**
UC5_UR_02	**UC5_SR_24**	User's log-in operation.	**UC5_TC_18**
UC5_UR_03			
UC5_UR_01	**UC5_SR_21**	Data retrieval from M2M platforms by means of DVL.	**UC5_TC_19**
UC5_UR_04	**UC5_SR_22**	Integration between DVL and Port Community Systems.	
UC5_UR_01	**UC5_SR_23**	Integration between AI-based platform and DVL.	**UC5_TC_20**
UC5_UR_01	**UC5_SR_07**	Real-time tracking of trucks inside the port and terminal facilities.	**UC5_TC_21**
UC5_UR_02	**UC5_SR_08**	Web-service based application for visualizing Truck Turnaround Time estimation and prediction outcomes.	
UC5_UR_03	**UC5_SR_11**	End-to-end integration of IoT tracking devices and visualization framework.	
UC5_UR_05	**UC5_SR_17**	Time event information on the vessel, container, and truck movements.	

Note: SR_05 and SR25 – SR31 are addressed as part of UC6 test cases since they focus on UC5 and UC6 interoperability.

Table 113: Light version of the requirements traceability matrix

User Requirement	System Requirement	System Requirement Description	Test Case
UC6_UR_01	**UC6_SR_01**	DVL must be able to retrieve data coming from different M2M platforms, supporting different communication protocols as well as different data formats.	**UC6_TC_01**
	UC6_SR_02	Data Virtualization Layer should be able to virtually aggregate data coming from different M2M platforms accordingly to a given data-model for supported events. Collected data must be sufficient for the gate-in, gate-out, vessel arrival and vessel departure events definition.	
	UC6_SR_01	DVL must be able to retrieve data coming from different M2M platforms, supporting different communication protocols as well as different data formats.	**UC6_TC_02**
	UC6_SR_02	Data Virtualization Layer should be able to virtually aggregate data coming from different M2M platforms accordingly to a given data-model for supported events. Collected data must be sufficient for the gate-in, gate-out, vessel arrival and vessel departure events definition.	
	UC6_SR_01	DVL must be able to retrieve data coming from different M2M platforms, supporting different	**UC6_TC_03**

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		communication protocols as well as different data formats.	
	UC6_SR_02	Data Virtualization Layer should be able to virtually aggregate data coming from different M2M platforms accordingly to a given data-model for supported events. Collected data must be sufficient for the gate-in, gate-out, vessel arrival and vessel departure events definition.	
UC6_UR_03 UC6_UR_04	UC6_SR_05	DVL must allow cross-DLT layer to consume aggregated data by means of an interface so that data can be stored and managed according to DLTs' capabilities.	UC6_TC_04
UC6_UR_02 UC6_UR_03	UC6_SR_08	Cross-DLT layer should be able to generate a hash associated to the received data from the Data Virtualization Layer. This way, the data can be stored securely and anonymously in a public blockchain network using a limited amount of data (ideal for blockchains networks like Bitcoin).	
UC6_UR_02 UC6_UR_03	UC6_SR_09	Cross-DLT layer should allocate a DBMS where data and generated hashes could be stored accordingly to a given data-model, including any other needed information (e.g list of DLTs and stored hash address).	
UC6_UR_01 UC6_UR_02	UC6_SR_10	Cross-DLT layer should be able to distribute hashes and/or data within different DLTs by means of WRITE APIs (writing operation). A positive/negative response should be received from different DLTs and managed by Cross-DLT layer, updating the DBMS accordingly.	
UC6_UR_01 UC6_UR_02	UC6_SR_11	Cross-DLT should integrate an API for exposing data and events to supply chain users, end users and applications in order to allow reading/writing operations. The proof-of-existence should be validated (data integrity and data immutability).	
UC6_UR_02 UC6_UR_04	UC6_SR_12	Cross-DLT layer should expect an authentication mechanism in order to manage and control users' access. This control is expected to affect users from upper layers and interactions with the Data Virtualization Layer, so identity is really important when storing data in DLTs.	
UC6_UR_01 UC6_UR_02 UC6_UR_03	UC6_SR_13	Different DLTs should use a proper setup, according to their own capabilities, for hash and/or data storage across ledgers/network. Hash storage across different DLTs should be guaranteed as a minimum requirement. Cross-DLT layer will store events generated by DVL. As far as DLTs' is concerned, hash storage will be guaranteed for each available DLT as a minimum requirement. In some cases it will be also possible to store data events (e.g IOTA).	
UC6_UR_01 UC6_UR_03	UC6_SR_15	Personal data is any information related to an identified or identifiable living individual. Different pieces of information, which are collected together can lead to the identification of a particular person, also represents a personal	

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		data. According to GDPR, Personal Data can be pseudonymized to protect individual identity.	
UC6_UR_04	**UC6_SR_03**	Data Virtualization Layer should provide data access by following a role-based policy. Roles should include data access privileges (based on writing, reading, deleting and updating capabilities).	**UC6_TC_05**
UC6_UR_04	**UC6_SR_06**	Data Virtualization Layer must allow the ML-based module of MANO to retrieve pseudo-anonymised data related to application and network usage by means of subscription mechanism.	
UC6_UR_04	**UC6_SR_07**	The AI/ML assisted MANO must be able to collect data from the DVL and store them to properly train slice optimization AI/ML algorithms.	
UC6_UR_01 **UC6_UR_03**	**UC6_SR_14**	Personal Data should be anonymized as soon as possible avoiding being exposed in clear text. As DVL is the closest point to M2M platforms (data generator from an Interoperable Layer point of view) it must also act as a Pseudonymization Entity.	**UC6_TC_06**
UC6_UR_01 **UC6_UR_03**	**UC6_SR_15**	Personal data is any information related to an identified or identifiable living individual. Different pieces of information, which are collected together can lead to the identification of a particular person, also represents personal data. According to GDPR, Personal Data can be pseudonymized to protect individual identity.	
UC6_UR_01 **UC6_UR_03**	**UC6_SR_16**	Pseudonymization is a reversible process. To do it "additional information" (e.g. encryption keys, conversion tables, etc.) are necessary. This information has to be protected.	
UC6_UR_01 **UC6_UR_03**	**UC6_SR_19**	Personal data are retained only if strictly necessary.	
UC6_UR_01 **UC6_UR_03**	**UC6_SR_17**	Personal Data has to be accessible in clear format only by the authorized entity.	**UC6_TC_07**
UC6_UR_01 **UC6_UR_03**	**UC6_SR_18**	Personal Data are not forever, they have to be deleted according to data owner's agreements. Furthermore, the data owner has the right to request the deletion of his persona.	**UC6_TC_08** **UC6_TC_09**
UC6_UR_01	**UC6_SR_04**	Data Virtualization Layer should provide a caching mechanism in order to store specific calls to queries and/or virtual procedures. This will yield significant performance gains if the same queries or the same procedures are submitted often.	**UC6_TC_10**

Table 114: Light version of the requirements traceability matrix