TEMA
TRUSTED
EXTREMELY PRECISE
MAPPING AND PREDICTION
FOR EMERGENCY
MANAGEMENT

Deliverable D2.2: Report on TEMA platform design, data models and architecture

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D2.2 – Report on TEMA platform design, data models and architecture	
Executive Summary:	**This document focuses on strategies and technology choices to identify the best technology approach in this field. The TEMA Platform was designed based on use case scenarios to determine the necessary technologies and functionalities. The aim of TEMA's reference architecture is to support interoperability among devices, AI tools, and software solutions. A Data Catalogue template was distributed to collect datasets from pilot projects, which will be continuously updated. The preliminary Business Missions were defined.**
WP:	**2**
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Disclaimer

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List of Terms and Abbreviations

Abbreviation	Description
TEMA	Trusted extremely precise mapping and prediction for emergency management
AI	Artificial Intelligence
NDM	Natural Disaster Management
WPx	Work Package x
XR	Extended Reality
UCS	Use Case Scenario
NDVI	Normalized Difference Vegetation Index
DWD	Deutscher Wetterdienst
AOI	Area of Interest
CFD	Centro Funzionale Decentrato
SOUP	Sala Operativa Unificata Permanente
OGC	Open Geospatial Consortium
STAC	SpatioTemporal Asset Catalogs
NRT	Near Real Time
WFS	Web Feature Service
GDACS	Global Disaster Alert and Coordination System
DNN	Deep Neural Network
XR	eXtended Reality

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Executive Summary

The executive summary below provides a brief overview of key findings and recommendations on the TEMA architecture for natural disaster management. The full document examines the architectural approach, starting with use cases and focusing on strategies, and technology choices to identify the best technology approach in natural disaster management.

To design the TEMA Platform, the Use Case Scenarios describe what the pilots need during an emergency situation and what technologies they would like to use. The functional and non-functional requirements of the technical platform were extracted from the latter, and the technical specifications were defined. The functional requirement's purpose, originated from the Use Case Scenario, is to discover the essential technologies and functionalities required for the successful development of the TEMA Platform, ensuring that it aligns seamlessly with the requirements outlined by the pilots.

Starting from technical specifications, TEMA's ambition is to establish a reference architecture that is as flexible as possible with the main objective of supporting interoperability among devices, AI tools and software solutions. The aim is to establish minimum interoperability requirements and optimise their integration in a continuum cloud and edge data and processing space. The TEMA logical architecture is intended to be simple and flexible to meet the needs of various Pilots and in general to be able to be adopted in different contexts, where heterogeneous data sources and field devices of all types are used. Before going any further, a premise is needed.

Within the architectural framework of the TEMA platform, the aim is to ensure the seamless integration of datasets provided by pilot projects. For this reason, a Data Catalogue template was distributed in order to collect data sets owned by each pilot. TEMA Data Catalogue is a live catalogue that will be updated during the project lifespan. The TEMA architecture contains many components that exchange data in a variety of formats. Some of these are images and videos in different standard formats. Others are structured data sometimes adhering to recognized standards such as GeoTIFF, Shapefiles, OGC WMS, etc., or in some cases proprietary formats that need to be adapted and transformed.

Finally, to address the specific needs of end-users and utilize the technologies provided by technical partners, a set of initial business missions has been developed. These business missions represent the main TEMA platform functionalities.

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1. Introduction

Climate change is leading countries in Europe to experience increasingly frequent and damaging adverse climatic events, such as large fires and flooding. The impact of severe weather events is expected to make Europe increasingly vulnerable due to the magnitude and frequency with which they will occur in the coming years.

According to the Emergency Events Database (EM-DAT), natural hazards have cost about **3 trillion dollars** of economic destruction and **1.3 million casualties** with more than **4.4 billion people injured** between 1998 and 2017 [5]. In Europe, between 1980 and 2020, disasters affected nearly **50 million people** and caused economic losses of roughly **€12 billion per year**.

Natural Disaster Management (NDM) is crucial to prevent these events from becoming life-threatening. In light of such urgency, and under the advancements in science and technology that have been achieved in recent years, the TEMA research project will develop **beyond-state-of-the-art** methods and technologies to facilitate disaster management procedures, in particular by developing automated means for precise semantic area mapping and phenomenon evolution predictions for Natural Disaster Management in (near-)real-time. This will be achieved by **AI systems** that receive multiple heterogeneous data modalities, like geosocial media, topographical, or official meteorological data as input. Using AI technologies and multiple data sources, TEMA will provide a map-based emergency decision support system able to make an accurate assessment of an evolving crisis situation while also giving automated response recommendations.

TEMA has 3 main goals:

1. Improve Natural Disaster Management using **new digital technologies** and **extreme data analytics.**
2. Improve and accelerate extreme data analytics, by increasing **trustworthiness**, **accuracy** and **responsiveness** of extreme data analysis algorithms.
3. Improve and accelerate emergency phenomenon **modelling**, evolution **predictions**, simulation and **interactive visualization.**

The solution provided by TEMA project, both technological and methodological ones, will be experimented in four pilots across the Europe.

1. Central-European Regional **Flash Floods Pilot** site: **Bavaria** (Germany). Central Europe, due to presence of big rivers, can experience heavy persistent rains that cause regional floods. In this pilot, the objective of TEMA is to provide information to be used to warn the responsible authorities, population and public protection, and provide information about the accessibility of the affected region leading to improved NDM.

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2. Mediterranean Flash **Floods Pilot** site: **Municipality of Mantoudi-Limni-Agia Anna** (Greece).In the Greek pilot, a flood model will be set up for the area and calibrated based on information retrieved from historic flood events as well as near-real-time information coming from the observations of streamflow gauges.
3. Mediterranean **Forest Fires** Pilot site: **Montiferru** (Sardinia, Italy). The forest fire scenario will be played out with available data about the area vegetation, geomorphological data, damage details and safety procedures that have been adopted, output of meteorological models, forecast fire danger bulletins, satellite images, videos from drones filming the burnt area. The TEMA platform will also be used for examining the conditions of post-event territory, with particular regard to the implications for geomorphological risk.
4. Finnish Forest **Fires Pilot** site: **Kainuu** area (Finland).The pilot will provide a study case on forest fire management operations through the aggregation of environmental data sources, both existing and collected during the project. These datasets will be enriched with earlier reports on prevention strategies. It will be possible to examine and improve procedures for managing disasters and for decision making.

TEMA aims to have a significant impact on a) scaling-up European capacity for extreme data analytics, b) producing explainable, robust and humanly verifiable analytics, c) providing fast and precise phenomenon prediction and response planning, d) reducing the emergency response times during Natural Disaster Management, e) improving the decision making during Natural Disaster Management, f) boosting the EU policy agenda in the Data Spaces domain, as well as in the adoption of Decision Support Systems for emergency management, g) opening up a new market segment via the envisioned Extreme-Analytics-as-a-Service, which makes select TEMA methods available to external users via the cloud and standardized interfaces.

1.1 About this deliverable

The remainder of this deliverable is structured as follows. Section 2 outlines the foundation the TEMA Solution was built on, that is the functional and non-functional requirements and the Use Case Scenarios the pilots would like to test. Starting from this foundation, Section 3 defines the TEMA Logical and Computational Architecture, focusing on the integration of components and their interaction. The exact specifications of each single component will be integrated into future deliverables. Section 4 describes all the data the partners are able to collect and provide during the development of the project, building the TEMA Data Catalogue that will be the base of TEMA experiments. Section 5 preliminary defines the Business Missions that are an application of TEMA platform following the Use Case Scenarios defined. Finally, Section 6 concludes this deliverable.

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In Appendix I: TEMA Interaction Diagrams, the reader can satisfy his/her curiosity related on how the TEMA platform components interact with one another. Towards this end, an Interaction Diagram is developed for each single component, briefly describing its functionalities and presenting the information flow and all the interactions with other platform components. In Appendix II: End-User requirements as Defined in D2.1, the reader can find the end user requirements defined in D2.1.

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2. TEMA Platform Requirements and Technical Specifications

To build the TEMA Platform we started by asking the TEMA end users to define specific Use Case Scenarios (UCS) that explicitly describe what are their needs during an emergency and what technologies they would like to use to fulfil these needs. Then, from the defined UCS, the functional and non-functional requirements of the TEMA platform were extracted and the technical specifications of the TEMA Platform, in terms of logical and computational architecture, were defined.

2.1 Use Case Scenarios

This section presents five different, UCS as designed by the TEMA end users. This task was carried out during Task T2.2 starting from the information collected during Task T2.1, which are presented here in more detail to enhance the understanding of the TEMA end user requirements. In this direction, a UCS template was disseminated among the end users to establish a common framework for collecting information in the form of narratives. Each end user delineated, by completing the UCS definition, the distinct domain needs, aimed at focusing on the services that the TEMA platform should offer to bolster their activities. Finally, the end-user requirements that were defined in D2.1 and presented in Appendix II, are associated with the UCS.

2.1.1 BRK Floods

ID	UCS 1.1
Title	Historical Flood in Arthal Region in Summer 2021
Description	In July 2021 there was a historical rainfall over multiple days, with more than 200 litres of water per square metre. Consequently, there was flooding in Western Europe. The dramatic event was a flash flood in the region of the river Ahr (Western Germany). More than 180 persons died, there was substantial damage to the infrastructure: bridges, roads, hospitals, fire stations and rescue stations. The civil protection units from all PPDR as well as BRK were involved with special assessment teams, medical task force, and housing.

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Primary Actors	● Control room in BABZ (Bundesakademie für Bevölkerungsschutz und Zivile Verteidigung) in Ahrweiler
	● Command post (Control room)
	● Commanders from:
	    ○ Firefighters
	    ○ Rescue service
	    ○ Civil protection units
	    ○ Police
	    ○ German army
	    ○ THW- Federal Agency for technical relief
	    ○ LEMA staff (Local emergency management agency)
	    ○ Experts from the critical infrastructure (electricity, energy provider)
	    ○ Red Cross (sheltering, sanitation, water purification, food)

Pre-conditions	● Heavy rain (more than 200L per m2) ● Dried-out soil ● Bad weather zone in Western Europe ● Issued warnings were not understood by the general population
Post-conditions	● water purification is set up and is operational ● search and rescue operations are ongoing ● filed kitchens and sheltering are set up (provided) ● communication network is reconstructed and operational ● improvised bridges are under construction ● energy supplies only partially operational ● temporary fire and rescue stations are set up ● fire and rescue units outside of the affected area support the Ahrtal

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	• logistical need in the field is provided for (equipment, pumpers, generator, tents, water tanks) • sewage treatment plants are not operational • field hospitals are taking care of the persons in medical need
Main Success Scenario	For the pilot trial, we will use real historical data covering the period from mid to late July 2021. A warning was issued on the 12th by DWD (Deutscher Wetterdienst – Germany's National Meteorological Service). The flood starts at 15th July 2021 in the night. THE SET-UP OF THE TRIAL: BRK will set up the simulated operations room (laboratory) with stable internet access and number of working stations and separate rooms to test TEMA solutions. The staff from the operations room are first responders, experienced in command and control systems of disaster management (focus on flooding scenarios). The TEMA solution will be tested by the first responders (trained and experienced in leadership and command in emergency operations, command and control system), based on German regulation DV100. The focus in this system is S2 (Information Gathering / Assessment) and S3 (Operations). This both positions will be set up as a minimum 2 persons / sector to test the TEMA solution. The rest 4 chapters of DV100 (S1, S4, S5, S6) will be simulated if needed. The data input will be via helicopter, drones, satellite imaginary, social media, weather forecast, radio, television, newspapers. In the river Ahr valley, heavy rain produces a flash flood. As the first alarm is raised by the DWD (historical alert) the control room (S2) receives a decision proposal, e.g. as an e-mail, which states when satellite data products are expected to become available to the operator at which time(s) for the Area of Interest (AOI), and which commercial satellite data acquisition options are available for the next few hours and days, pre-prepared using the **Decision Support Service for Remote Sensing** (fictional product as historic satellite data acquisition options cannot be reproduced by the data provider). An integrated network of **ground-based sensors**, installed near the AOI, exhibits a fast increase of the water level and relays the information to S2. The civil protection team promptly activates first responder rescue teams which are in standby until more situational information is gained.

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	The civil protection team assesses the situation-based upon the available information, to determine the extent and intensity of the flash flood. They utilise images and data from **aerial drones**, cameras, weather stations, topography, and the presence of nearby vulnerable areas, such as residential communities or critical infrastructure. **Satellite-based flood detection and assessment, flood/background segmentation, novel semantic visual analysis through concept-based explanations, concept-based explanations and remote sensing AI algorithms** produce processed results which are integrated by the **Digital Enabler**, combined by **Information Fusion** and visualised in dashboards, the **smart desk** and the **XR-based interactive visualisation system** (S2) for the team to gain comprehensive real-time situation awareness and take informed decisions. A first printed situational awareness map is generated after hours followed by more and more accurate versions once additional remote sensing data is acquired over time. This process accumulates in the creation of an accurate **Digital Twin**, which combines the various data elements into one 3D map of the area. Through human-comprehensible presentation of concept-based explanations, the team is able to assess which information they are facing is trustworthy. Starting from this information. Drones will survey the area taking images for their processing and segmentation. By using the information fusion, images from drones will be georeferenced. Also, an AI-based system exploits a flood propagation model to elaborate predictions on the mode of advancement of the flood. Using also the data from the proximity of residential areas, vital infrastructure, and historical buildings within the flooded zone, civil protection can decide if it is necessary to evacuate certain zones and establish immediate protective measures, including activating first responder rescue resources to safeguard vulnerable structures. After some time, high-resolution satellite (this is only available if the operators have requested commercial satellite data acquisition based on the decision proposal above – or if available for historic event) and drone images are used to **detect objects** of interest such as vehicles, damaged buildings and bridges and **affected persons** to verify the phenomenon and search for people in danger. Also, **video analysis tools** detect people and the actions they are performing. The Detection and Segmentation models of objects and persons will be enhanced with the addition of **Synthetic Generated Data**. The **geo-social media analysis** including sentiment analysis in short texts (e.g., tweets) is used to gain a better understanding of the natural disaster extent, affected

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	people, and for cross validating the results of detection and segmentation technologies. Situation during the trial: ● more than 1300 persons missing ● major damage to the infrastructure (roads, bridges, logistics, food, water) ● major damage to the critical infrastructure (affected hospitals, fire and rescue stations, sewage plants) ● energy infrastructure damaged and non-operational ● thousands of persons need to leave their home ● national and international alarm plans activated ● ongoing search and rescue operations
Related End User Requirements as defined in D2.1	● ***Non-Functional***: EU-RQ-NF-01, EU-RQ-NF-03, EU-RQ-NF-04, EU-RQ-NF-05, EU-RQ-NF-06, EU-RQ-NF-08 ● ***Functional***: EU-RQ-FUNC-01 – EU-RQ-FUNC-04, EU-RQ-FUNC-07, EU-RQ-FUNC-12 – EU-RQ-FUNC-15

2.1.2 RAS Forest Fire and Flood

ID	UCS 2.1
Title	Forest wildfire in Sardinia
Description	A forest fire starts in a countryside of Mediterranean bush and wood of cork oak and holm oak but also in Mediterranean pine wood. The lookout system of the Sardinia region detects the smoke a few minutes after it starts, also thanks to the support of the fire and smoke detection system. All the first responders were activated to fight and put out the fire, while securing population and sensitive buildings.
Primary Actors	● Civil Protection (CFD centre and SOUP room): CFD: decentralised functional centre (i.e. hazard and risk forecasting centre: meteorological sector and ground effects sector), that delivers daily fire hazard bulletins by using, above all, meteorological

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	forecasts, sensor measurements and vegetation data; SOUP: unified operative room (i.e. emergency management room – wildfire), comprised mainly of: ● Forest Ranger (Corpo Forestale e di vigilanza Ambientale – CFVA); ● Fire fighters (vigili del fuoco – VVFF); ● Forestas Agency, that organizes the sighting activity with human lookouts ● Civil protection Volunteers, that support the process of extinguish wildfires.
Pre-conditions	● temperature is over 37- 40°C ● humidity < 30% ● wind > 30km/h ● dry vegetation ● drones or human lookouts notice a beginning of fire
Post-conditions	● Buildings were safeguarded and population were rescued ● Conducted successful evacuations ● Safeguarded human lives, animals and as much as possible infrastructures and buildings
Main Success Scenario	The CFD forecasts very high temperatures, strong winds and low air humidity for the following day. In addition to this, through satellite images, vegetation is seen to be very dry (Normalized Difference Vegetation Index (NDVI) index method). Fire propagation for the following day is estimated by means of meteorological forecasts, fire danger prediction models and also by a forest fire simulator. CFD predicts extreme fire hazard for the day after in a particular sub-region of Sardinia, therefore it alerts institutions (regional authorities, municipalities, agencies etc.), citizens and issues a fire hazard bulletin: this information is sent out by IT platforms, official websites, email, certified email, sometimes also by TV news etc. The SOUP room, by using also the information within the CFD bulletin, takes all precautionary measures to prepare for the following day (e.g.,

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	helicopters, resources, look out personnel are increased, especially where the highest hazard has been forecasted). The following day, due to extreme meteorological conditions a large wildfire spreads quickly around the countryside located in the predicted area. Thanks to lookout tower personnel and also through drone image and video acquisition and analysis and geosocial media analysis the fire is detected and its location is correctly identified. First responders, mainly CFVA, arrive on the site of the wildfire. They make use of drones for scouting and taking some photos and video footage of the event. This information is used locally by teams on the, but when/if possible, the data is sent to the cloud, so that CFD and especially SOUP operators can consult it and take decisions accordingly. Some others first responders try to limit the spread of fires. Photo and video footage is continuously sent to SOUP and CFD by CFVA, Forestas and volunteers by means of a smartphone application, in order to share information from the field. In addition to this, semantic segmentation and background segmentation techniques are used continuously to better understand the behaviour of the fire and infer which areas are being affected the most, this is useful in order to act as quickly as possible on those areas, by sending teams on the ground or helicopters etc. As soon as available, satellite burnt area analysis products are consulted by the CFD and SOUP and statistical and geographical mapping instruments are used to understand how big the area is involved is. Geo-social media analysis arrives in SORI and CFD. Images and footage are georeferenced, hot spots are identified. CFD gets information regarding meteorological condition provided by models and weather stations and make them available for SOUP. In SOUP, also thanks to updated meteorological information, techniques to reconstruct how wildfire could spread depending on local condition of wind, temperature, humidity, etc. are adopted. A fire simulation software will provide wildfire behaviour outputs like arrival time in municipalities, rate of spread, fireline intensity, flame length or fire paths exportable in GeoTIFF, KMZ or Shapefile formats.

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	CFD and SOUP uses XR based visualization techniques to break down and rearrange data to clearly understand visualizable parts. SOUP specialists use the Smartdesk to support the exchange of information between operations rooms and teams in the field. The civil protection team assesses the situation, collecting all the data available from heterogeneous sources, to determine the extent and intensity of the fire. Civil Protection decide if it is necessary to evacuate certain zone and establish immediate protective measures, including deploying firefighting resources to safeguard vulnerable structures. The civil protection authorities establish an incident command centre, which serves as the central hub for coordinating firefighting efforts. Incident commanders (CFVA or VVFF) analyse the collected data and formulate a comprehensive strategy to combat the forest fire. They divide the affected area into sectors and assign Forest Ranger teams to specific regions based on their expertise, availability, and available resources.
Related End User Requirements as defined in D2.1	• ***Non-Functional***: EU-RQ-NF-01, EU-RQ-NF-03, EU-RQ-NF-04, EU-RQ-NF-05, EU-RQ-NF-08 • ***Functional***: EU-RQ-FUNC-01 – EU-RQ-FUNC-11, EU-RQ-FUNC-13 – EU-RQ-FUNC-15

ID	UCS 2.2
Title	Flood in Sardinia
Description	The CFD forecasts very high rainfall and potential floods in a certain alert area of Sardinia. An alert notice for hydrogeological and hydraulic risk is issued and sent to Institution, authorities and agencies of the territory involved. Heavy rains start in the forecasted zone. Floods start in the countryside and also within the municipality area
Primary Actors	• Civil Protection (CFD centre and SORI room): CFD: decentralised functional centre (i.e. hazard and risk forecasting

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	centre: meteorological sector and ground effects sector) that delivers daily meteorological, hydrogeological and hydraulic risk bulletins. SORI: regional integrated operative room (i.e. emergency management room – floods), comprised mainly of: ● Forest Ranger (Corpo Forestale e di vigilanza Ambientale – CFVA); ● Firefighters (vigili del fuoco – VVFF), that deliver interventions and support even in case of hydrological risk; ● Forestas Agency, that provides equipment and personnel support in case of critical issues in an area. ● Civil protection Volunteers, that support the process of safeguarding population.
Pre-conditions	● forecasted Rain cumulate : 200 mm/24 h ● floods of local rivers ● widespread landslides ● drones and satellite to support reconnaissance flights of area flooded
Post-conditions	● Building were safeguarded and population were rescued ● Conducted successful evacuations ● Safeguarded human lives, animals and as much as possible infrastructures and buildings
Main Success Scenario	The CFD meteorological forecasts very high rainfall and CFD hydro through the Water modelling in continuous mode predicts potential floods in a certain alert area of Sardinia. Institutions (regional authorities, municipalities, agencies etc.) and citizens are alerted for meteorological conditions and hydrogeological risk: a specific alert is emitted by the CFD; this information is sent out by IT platforms, official websites, email, certified email, sometimes also by TV news etc. The SORI room, by using also the information within the CFD bulletin/alert, Takes all precautionary measures to prepare for the following day/days (e.g., prepares means and resources; especially where the highest risk has been forecasted).

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	Due to the intense rains, many municipalities have large flooded areas with isolated agro-pastoral farms and isolated people to be saved. Difficulties in reaching isolated areas. First responders send drones on survey to assess the flooded areas and the precise position of the people to be rescued. Social media provides images, footage and hotspots analysis of the affected areas to the CFD and SORI. As soon as it is available, satellite flood analysis products are used to assess the affected area and to direct rescue teams. Photo and video footage is continuously sent to SORI and CFD by CFVA, Forestas and volunteers by means of a smartphone application, in order to share information from the field. The CFD continuously monitors the event and provides continuous updates of expected rainfall and foreseeable ground effects for the next few hours. XR based visualisation techniques are used to break down and rearrange data to clearly understand visualizable parts. Specialist in the SORI use the Smartdesk applications to support the exchange of information between operations rooms and rescue teams in the field. The civil protection team assesses the situation, collecting all the available data from heterogeneous sources, to determine the extent of the area flooded, in order to label and identify the phenomenon correctly. Civil Protection can decide if it is necessary to evacuate certain zone and establish immediate protective measures. The Civil protection authorities establish a CCS (field rescue coordination centre), which serves as central hub for coordinating rescue teams, assist the population and restore conditions pre-event. The rescue teams are divided by intervention area and tasks. They are supported by survey drones.
Related End User Requirements as defined in D2.1	• ***Non-Functional***: EU-RQ-NF-01, EU-RQ-NF-03, EU-RQ-NF-04, EU-RQ-NF-05, EU-RQ-NF-06, EU-RQ-NF-08 • ***Functional***: EU-RQ-FUNC-01 – EU-RQ-FUNC-04, EU-RQ-FUNC-06, EU-RQ-FUNC-07, EU-RQ-FUNC-12 – EU-RQ-FUNC-15

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2.1.3 D. MALIAN Floods

ID	UCS 3.1
Title	Flash Flood after Fire
Description	A mega fire of August 2021 took place at the municipality of Mantoudi – Limni – Agia Anna in Greece. The geomorphology, the land cover and the hydrometeorological regime of the area contribute to extreme flash floods events.
Primary Actors	• Firefighters • Civil protection units • Police • Volunteers • Municipality
Pre-conditions	• Heavy rain (more than 200L per m2) • Burned soil • Warnings were late and fail to alarm the population"
Post-conditions	• Population was rescued • Conducting successful evacuations • Safeguarding both human lives and buildings • Map the flood area • Map the mud area
Main Success Scenario	Two days prior to the event a high-risk alert was raised by meteorologists about the occurrence of an extreme flood in the area. Before the event started a **flood model** was set up based on information retrieved from the historic fires. **Digital Enabler** collected data coming from **devices (in situ sensors)** installed near the area, analyse and visualise them. During the event the meteorological data provide a **warning alert** for an imminent flood. The D.MALLIAN civil protection centre continuously collects information from

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	the incident site and the surrounding area through **drones** and **remote sensing** for the presence of nearby vulnerable areas, such as residential communities, flooded areas and people in danger. Through **drone images,** detected flood is localised on the constructed **digital twin** or **geo-visual map**. Video analysis tools detect people, re-identify them and detect the actions they are performing. A **first situational awareness map** is generated after hours followed by more and more accurate versions once additional **remote sensing data** is acquired over time. The analysis of **social media texts** is used as an additional source of information to gain a better understanding of the natural disaster extent, and for cross validating the results of detection and segmentation technologies. The **information fusion module** will integrate results of processing of drone images, satellite images, contextual information, and in-situ sensors to obtain the georeferenced status of the flood. After the event, the drones survey the affected area **searching for people** and providing the **size of the affected** and **mud area.**
Related End User requirements as defined in D2.1	• ***Non-functional***: EU-RQ-NF-01 – EU-RQ-NF-04, EU-RQ-NF-06, EU-RQ-NF-08 ***Functional***: EU-RQ-FUNC-01 – EU-RQ-FUNC-04, EU-RQ-FUNC-07, EU-RQ-FUNC-12, EU-RQ-FUNC-13, EU-RQ-FUNC-14

2.1.4 KAHY Forest Fire

ID	UCS 4.1
Title	Kainuu forest fire
Description	A forest fire starts in Kainuu region. Firefighters from across the Kainuu region participate in the extinguishing efforts. The large scale of the fire threatens to cause significant damage to forest property, and also to nearby settlements and infrastructure.
Primary Actors	• Firefighters (field units, command centre)

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	● Police ● Municipalities/cities ● Social welfare
Pre-conditions	Forest fire index: ● temperature is over 20°C ● humidity < 50% ● wind > 25m/s ● citizens notice the beginning of a fire”
Post-conditions	● Fire is extinguished ● Property owners are informed ● Responsibility of the area surveillance is transferred to property owners”
Main Success Scenario	In the picturesque countryside, a devastating forest fire starts in a densely wooded area. The first alarm is raised by citizens that notice a fire. KAHY receives a decision proposal, e.g. as an e-mail, which states when satellite data products are expected to become available to the operator at which time(s) for the AOI, and which commercial satellite data acquisition options are available for the next few hours and days, pre-prepared using the **Decision Support Service for Remote Sensing** (fictional product as historic satellite data acquisition options cannot be reproduced by the data provider). KAHY confirms the fire incident through **drones**. KAHY promptly dispatches the appropriate response units equipped with XR glasses providing **interactive visualisation** of the scene. KAHY established an incident command centre, which serves as the central hub for coordinating firefighting efforts. The KAHY command centre continuously collects information from the incident site and the surrounding area through **drones** and **remote sensing devices** such as **smoke and wind patterns**, **satellite based forest fire detection**, topography, infrastructure, **civilians** , and the presence of nearby vulnerable areas, such as residential communities, wildlife habitats, or important infrastructure. Based on the collected information, KAHY utilizes the **Digital enabler** to examine data, and disseminates to the rest of the

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	operatives in the command centre through the Smartdesk, and in the field to XR devices to plan their approach. Starting from this information, KAHY uses the **fire propagation model** to elaborate predictions on the mode of advancement of the fire front. Using also the **data from geographical areas of interest** of residential areas, vital infrastructure, and historical buildings within the fire zone, KAHY can decide if it28ecessaryy to evacuate certain areas and establish immediate protective measures, including deploying firefighting resources to safeguard vulnerable structures.
Related End User requirements as defined in D2.1	• ***Non-functional***: EU-RQ-NF-01 – EU-RQ-NF-04, EU-RQ-NF-06, EU-RQ-NF-08 • ***Functional***: EU-RQ-FUNC-01 – EU-RQ-FUNC-05, EU-RQ-FUNC-07 – EU-RQ-FUNC-10, EU-RQ-FUNC-13, EU-RQ-FUNC-14

2.2 TEMA Technical Requirements

The requirements originate from the Use Case Scenario definitions contributed by pilots. The primary purpose of this analysis is to define the essential technologies and functionalities required for the successful development of the TEMA Platform, ensuring that it aligns seamlessly with the requirements outlined by the pilots. Moreover, these specifications have been categorized, distinguishing between hardware and software components, in order to ensure a comprehensive alignment with the diverse array of pilot needs.

Below the list of functional requirements, divided in software and hardware.

The information requested in the tables to fill in the requirements is the following, according to the Volere Methodology [4]:

- **Name**: title of the requirement.

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- **Requirement Type**: whether it is a functional or non-functional requirement and in case of non-functional requirements the specific type of requirement according to the Volere notation.
- **Description**: a requirement must say exactly what is required.
- **Rationale**: a justification of the requirement
- **Fit Criterion**: measurable if it is possible, once the system has been constructed, to verify that this requirement has been met. In other words, this means the tests which must be performed in order to satisfy the requirement.
- **Priority**: the requirement is ranked according to the customer value (Scale from 1=low priority to 5=highest priority).
- **Difficulty**: level of difficulty for requirement implementation (estimation). (Scale from 1=low difficulty to 5=extreme difficulty).
- **Related Technologies**: the technologies that can satisfy this requirement, described in the Appendix I.
- **Author**: name of the partner who wrote this requirement.

2.2.1 Functional Software

ID	FS #1
Name	Simulation of forest fire behaviour
Requirement Type	Functional
Description	The fire simulation software shall be able to operationally simulate forest fire behaviour and generate fire simulation outputs.
Rationale	The simulator shall be able to run forest fire simulations and generate fire behaviour outputs such as arrival time, rate of spread, flame length, fire line intensity and fire paths.
Fit Criterion	The simulator produces the expected fire behaviour outputs.
Priority	5
Difficulty	2
Related Technologies	Forest Fire Simulation (PDM-tech-01)

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Author	TSYL

ID	FS #2
Name	Provide flooded areas, permanent water and secondary products as well as detected objects (e.g. vehicles, buildings)
Requirement Type	Functional
Description	The flood processor must provide: ● for Copernicus Sentinel-1 and -2 satellite sensors flooded areas, permanent water and secondary products. ● for on-demand satellite VHR optical, as well as on-demand aerial VHR optical such as drone images detected objects (e.g. vehicles, buildings).
Rationale	Satellite-based data products support disaster response teams and decision-makers to assess the extent and severity of the event, the chronological event evolution and damages, plan response efforts, and allocate resources.
Fit Criterion	● Flooded areas, permanent water and secondary products are provided over OGC WMS and STAC or any other channel as cloud-optimized GeoTIFF. ● Detected objects are sent via e-mail or any other channel in GeoJSON format.
Priority	5
Difficulty	4
Related Technologies	Satellite-based flood detection and assessment (TFA-tech-08)
Author	DLR-DFD

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ID	FS #3
Name	Provide burnt areas (NRT) (OGC WFS and GPKG)
Requirement Type	Functional
Description	The processor provides burnt areas (NRT) in OGC WFS and GPKG, based on satellite imagery of the sensors Sentinel-3 OLCI, Aqua/Terra MODIS, Sentinel-2 MSI. Aerial VHR optical and drones' images are possible additionally.
Rationale	Satellite-based data products support disaster response teams and decision-makers to assess the extent and severity of the event, the chronological event evolution and damages, plan response efforts, and allocate resources.
Fit Criterion	Burnt areas (NRT) can be requested over OGC WFS and GPKG.
Priority	5
Difficulty	4
Related Technologies	Satellite-based Forest fire detection and assessment (TFA-tech-09)
Author	DLR-DFD

ID	FS #4
Name	Provide, based on public alerts and/or on disaster simulations, decision proposals on when and which remote sensing data will be available for a crisis region.
Requirement Type	Functional

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Description	The decision support service must provide an interface for the following input data: ● public disaster alerts (available via REST APIs, e.g., by GDACS) ● disaster simulations (available from TEMA partners TSYL and NS) ● satellite acquisition data (available from DLR-DFD via gRPC) Based on a spatiotemporal fusion of the input data the decision support service must generate the following output data: ● human-readable decision proposals (via e-mail in a text-based format) ● machine-readable decision proposals (via GraphQL)
Rationale	The decision support service provides end users with information on upcoming satellite data acquisitions for a defined area of interest (from end-user perspective). This can reduce the latency between an early warning, e.g., provided by GDACS or hydrometeorological services, and the delivery of crisis-related Earth observation products. Workload from manual retrieval of satellite positions and acquisition data is reduced though the automatization of previously manual operations in the satellite-based rapid mapping process.
Fit Criterion	Decision proposals can be requested over an API or are sent by the service via e-mail in a text-based format.
Priority	5
Difficulty	4
Related Technologies	Data-fusion-based decision support and process triggering (PDM-tech-06)
Author	DLR-DFD

ID	FS #5
Name	Interoperability with external and legacy systems

This project has received funding from the European Union – European Commission under grant agreement No 101093003

Requirement Type	Functional
Description	It has to be possible to connect the TEMA platform with the existing legacy systems (e.g., databases, web services). Secure and reliable communication with the existing information systems must be provided without requiring changes in these systems.
Rationale	Existent services are based on different and probably legacy technologies. Some parts of these services will continue to be fully functional because they are related to critical functionalities that cannot be easily changed or outsourced.
Fit Criterion	The platform is able to provide connectors towards the legacy systems to enable the interoperability.
Priority	5
Difficulty	3
Related Technologies	Digital Enabler (SV-tech-02)
Author	ENG

ID	FS #6
Name	Secure Storage
Requirement Type	Functional
Description	TEMA architecture has to provide secure storage functionalities in order to record data needed for their execution.
Rationale	It will be useful to have storage functionalities available in the TEMA platform to manage and save in a secure way the information from data sources involved in NDM.
Fit Criterion	All TEMA components have implemented proven expedients to secure the data they store and manage.

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Priority	5
Difficulty	5
Related Technologies	Digital Enabler (SV-tech-02)
Author	ENG

ID	FS #7
Name	Context Information Management
Requirement Type	Functional
Description	TEMA architecture shall provide a compliant context information management. The developed architecture must allow the integration with the NGSI API.
Rationale	To enhance its adoption after project completion.
Fit Criterion	NGSI API implemented in the TEMA architecture.
Priority	5
Difficulty	3
Related Technologies	Digital Enabler (SV-tech-02)
Author	ENG

ID	FS #8
Name	Edge Computing Storage

This project has received funding from the European Union – European Commission under grant agreement No 101093003

Requirement Type	Functional
Description	The developed Edge Computing solutions must allow local data storage.
Rationale	so that allows autonomous operation and no data is lost in case it is disconnected from the network.
Fit Criterion	Local storage solution is available.
Priority	5
Difficulty	3
Related Technologies	Digital Enabler (SV-tech-02)
Author	ENG

ID	FS #9
Name	Deep neural networks explanations
Requirement Type	Functional
Description	Human-comprehensible presentation of concept-based explanations of deep neural networks.
Rationale	In natural disaster management, the necessity for human-comprehensible explanations of deep neural networks is critical due to the high-stakes nature of decision-making in this field. These complex AI systems, employed for tasks like forecasting disasters, coordinating responses, and assessing damages, must be transparent for effective and trustworthy application. Emergency responders and planners rely on clear, understandable AI-generated insights for making timely and life-saving decisions.

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Fit Criterion	Fit criterion: compatibility of explainability methods with the deep neural networks employed in TEMA platform.
Priority	5
Difficulty	3
Related Technologies	Human-comprehensible presentation of concept-based explanations (TFA-tech-02)
Author	FHHI

ID	FS #10
Name	Detection of smoke, fire, persons and cars on images captured by drones
Requirement Type	Functional
Description	Methods based on Deep Neural Networks (DNN) for detecting and recognizing fire, smoke, persons, and vehicles (including their localization in images and videos) followed by projection of each detection on the real world coordinate system.
Rationale	These advanced DNN-based techniques enable rapid and accurate identification of critical elements like fire outbreaks and smoke spread, which is essential for timely intervention and mitigation. Additionally, they facilitate the locating and tracking of individuals and vehicles, which is vital for evacuation and rescue operations. The ability to process and analyse visual data from various sources in real-time greatly enhances situational awareness, enabling emergency responders to make informed decisions and effectively allocate resources during natural disasters.
Fit Criterion	Real time analysis
Priority	5
Difficulty	1

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Related Technologies	Fire/smoke/person detection (TFA-tech-05)
Author	AUTH

ID	FS #11
Name	Fire, smoke, flood, and background semantic segmentation
Requirement Type	Functional
Description	Semantic segmentation for creating masks for fire, smoke, flood, and their backgrounds on images captured by drones.
Rationale	By accurately distinguishing between affected and unaffected areas, semantic segmentation aids in the precise mapping of disaster extents, such as the spread of a fire or the reach of floodwaters. This level of detail is crucial for directing emergency response efforts to the most impacted regions. Furthermore, by isolating the background, responders can better understand the context of the disaster, helping in planning evacuations, relief operations, and assessing the potential impact on nearby structures and populations. In essence, semantic segmentation enhances the efficiency and effectiveness of disaster response by providing clear, detailed visual data.
Fit Criterion	Real time analysis
Priority	5
Difficulty	1
Related Technologies	Fire/flood/background segmentation (TFA-tech-06)
Author	AUTH

This project has received funding from the European Union – European Commission under grant agreement No 101093003

ID	FS #12
Name	Processing of social media posts
Requirement Type	Functional
Description	The system must process text snippets (from e.g., tweets) to predict sentiments (e.g., anger, fear).
Rationale	The system's ability to process brief text snippets, such as those from tweets, for sentiment prediction (identifying emotions like anger or fear) is highly valuable in the context of natural disaster management. In times of crises, such as floods or wildfires, real-time public sentiment analysis can be a critical tool for emergency responders and disaster management teams. By evaluating the emotions expressed in social media posts, this system can provide immediate insights into the affected population's needs, fears, and perceptions. This understanding can guide the deployment of resources, tailor communication strategies to address public concerns, and enhance overall crisis response effectiveness. Essentially, this sentiment analysis serves as a pulse check on the affected communities, enabling more empathetic and responsive disaster management.
Fit Criterion	Real time analysis
Priority	5
Difficulty	1
Related Technologies	Sentiment analysis for short texts (TFA-tech-12)
Author	AUTH

ID	FS #13
Name	Privacy preservation during visual analysis

This project has received funding from the European Union – European Commission under grant agreement No 101093003

Requirement Type	Functional
Description	Images, bounding boxes, segmentation maps from detection and segmentation technologies should be provided for generating gender-neutral image samples and replacing any detected identity identifiers.
Rationale	Privacy preservation in the context of visual analysis is a critical aspect in natural disaster management. Ensuring the privacy and confidentiality of individuals during image and video analysis for disaster response is paramount. This involves anonymizing identifiable features in visual data, like faces or license plates, while still gathering essential information for effective disaster response, such as the extent of damage or the number of people in an area. By maintaining privacy, emergency response teams can utilize visual data to coordinate efforts, assess damages, and plan rescues without compromising individual rights. This approach balances the need for urgent and informed action in disaster situations with the ethical imperative to respect and protect personal privacy.
Fit Criterion	Real-time anonymization of identifiable information.
Priority	5
Difficulty	1
Related Technologies	Privacy preservation during visual analysis (TFA-tech-10)
Author	AUTH

ID	FS #14
Name	Smoke and Wind modelling engine
Requirement Type	Functional
Description	A numerical engine for processing of the collected smoke and wind measurements.

This project has received funding from the European Union – European Commission under grant agreement No 101093003

Rationale	The modelling engine is required to compute the 3D models of the wind and smoke concentration in space and time.
Fit Criterion	Given measured smoke and wind samples the 3D models are computed in real time.
Priority	5
Difficulty	5
Related Technologies	Realistic 3D smoke modelling and fire detection (PDM-tech-03)
Author	DLR-KN

ID	FS #15
Name	Autonomous drone trajectory planning
Requirement Type	Functional
Description	An algorithm for optimal selection of the drone routes and trajectories for data collection.
Rationale	Since physical phenomena such as forest and floods are space-time varying processes, autonomous data collection has to account for this. Human operators cannot perform optimal planning in this case as the used sensors are non-visual and large amounts of data need to be processed. Thus, autonomous path planning and optimal sampling points for the swarm have to be identified. Planning will make use of an automated planning engine for optimal multi-UAV task allocation and multi-UAV planning. It uses as input: Information on status of UAVs and desired measurements and generates as output: UAVs optimal trajectories that can be considered as recommendations to the drone operators. Planning can consider different aspects for optimization including: mission duration, energy consumed by drones, inter-drone communication distance, explicit capacity of drones, among others.

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	Planning should be efficient to consider dynamic obstacles.
Fit Criterion	Safety (distance to obstacles) of obtained trajectories.
Priority	5
Difficulty	5
Related Technologies	Drone planning (PDM-tech-04)
Author	USE

ID	FS #16
Name	Information fusion
Requirement Type	Functional
Description	An engine that fuses the heterogeneous sources of information to keep updated track of the phenomenon status.
Rationale	The measurements and sources of information in phenomenon monitoring are widely diverse (in terms of modality, temporal and spatial resolutions, among others). This module abstracts the received measurements and results of intermediate processing using statistical descriptions and fuses them to offer the updated phenomenon status. Combination of different sources of information (information from the processing of drone and satellite images, in-situ sensors, sentiment analysis) to obtain an accurate online georeferenced monitoring of a forest fire or flood. It will provide georeferenced estimates of the phenomenon status (location, speed, phenomenon dimensions, among others). It will be based on a georeferenced recursive Bayesian estimation engine.
Fit Criterion	Quantification in the reduction in uncertainty resulting from the fused information w.r.t. the input measurements.
Priority	5

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Difficulty	5
Related Technologies	Information fusion (PDM-tech-05)
Author	USE

ID	FS #17
Name	Hydrodynamic flood modelling (simulation)
Requirement Type	Functional
Description	3Di hydrodynamic software shall be able to operationally simulate flooding behaviour and generate flood extents, water depths, flow velocities and flooding outputs.
Rationale	3Di hydrodynamic software shall be able to run flood scenarios and generate flooding behaviour outputs such as arrival times, flow velocities, flood extents, water depths and flowlines.
Fit Criterion	If the flood scenarios produce the expected flood extents, arrival times, corresponding to real-time monitoring by satellites or in-situ stations.
Priority	5
Difficulty	2
Related Technologies	3Di Hydrodynamic simulation (PDM-tech-02)
Author	NS

ID	FS #18
Name	Geo-social Media Analysis

This project has received funding from the European Union – European Commission under grant agreement No 101093003

Requirement Type	Functional
Description	The geo-social media analysis component aims to 1.) identify semantic topics that are related to a disaster, 2.) extract posts that are relevant to disaster management, 3.) identify hotspots of affected areas, 4.) extract sentiments to provide information about how severely people and geographic areas are affected by a disaster.
Rationale	Data from social media platforms supports disaster response teams and decision-makers to assess the course, spatial extent, and severity of an event. Most importantly, this information can be provided in a timely manner.
Fit Criterion	- Provision of relevant social media posts - Provision of spatial hot spot maps - Data quality assessment through relevance classification
Priority	4
Difficulty	3
Related Technologies	Geo-social media analysis (TFA-tech-11)
Author	PLUS

ID	FS #19
Name	Smartdesk software
Requirement Type	Functional
Description	Smartdesk software's purpose is to visualise the current situation in a field.

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Rationale	Bring the collected data together and visualize where flood, forest fire, etc. is happening. Firefighters' positions, weather data, drone footage, simulations, predictions etc. Working alongside other software.
Fit Criterion	Data from TEMA components is visualised
Priority	5
Difficulty	4
Related Technologies	Smartdesk Application (SV-tech-07)
Author	KAMK

ID	FS #20
Name	Photogrammetry data
Requirement Type	Functional
Description	Photogrammetry data for the computation of the Digital Twin.
Rationale	Images needed for image processing.
Fit Criterion	Visual output of afflicted areas.
Priority	5
Difficulty	1
Related Technologies	3D computer vision (SfM)/Photogrammetry (SV-tech-03)
Author	ND

This project has received funding from the European Union – European Commission under grant agreement No 101093003

ID	FS #21
Name	API to the Digital Enabler
Requirement Type	Functional
Description	API to provide the data that is supposed to be visualised.
Rationale	API to Digital Enabler needed to receive data for visualisation. Without data there is no visualisation.
Fit Criterion	The visualisation is working and correct.
Priority	4
Difficulty	3
Related Technologies	Extended Reality-based interactive visualisation system (SV-tech-06)
Author	ND

ID	FS #22
Name	Integration of heterogenous data sources in several formats
Requirement Type	Functional
Description	TEMA platform needs to read, manipulate, and integrate geospatial data in several format, also legacy (e.g., csv).
Rationale	Integration of heterogenous data sources in several formats enable the join of produced analysis data with other data sources like demographic data, environmental data providing a more comprehensive understanding of the phenomenon.

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Fit Criterion	The platform is able to manipulate geospatial data in several format.
Priority	4.
Difficulty	3.
Related Technologies	Geovisual Analytics (SV-tech-04)
Author	LAT40

ID	FS #23
Name	Detection and Reidentification of persons on images
Requirement Type	Functional
Description	Detects and tracks persons on video frames in real time on the edge, each person detected is assigned a unique ID and given the bounding box of the detection on the current image. In further video frames if the person reappears, the system keeps the ID and determines the new bounding box on the frame.
Rationale	The detection and reidentification of persons on the natural disasters such as floods and fires, allows to keep the status of individuals aiding the tasks of search and rescue, and helps to locate the survivors of such disasters.
Fit Criterion	Real Time Analysis.
Priority	5
Difficulty	1
Related Technologies	Person re-identification (TFA-tech-07)
Author	ATOS

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ID	FS #24
Name	Contrastive image-language models
Requirement Type	Functional
Description	Analyse an image, then generates a brief text with a description of the image through contrastive image-language-models. Then proceeds to calculate the similarity between the input text and the description generated.
Rationale	Data from social media often contains images, this technology allows to extract a description of an image to evaluate its importance regarding the natural disaster, and to compare the similarity between the text coming from social media and the corresponding image.
Fit Criterion	Real Time Analysis.
Priority	5
Difficulty	1
Related Technologies	Contrastive image-language models (TFA-tech-13)
Author	ATOS

2.2.2 Functional Hardware

ID	FH #1
Name	Drone fleet
Requirement Type	Functional

This project has received funding from the European Union – European Commission under grant agreement No 101093003

Description	A fleet of three drones, equipped with the following capabilities: safe GNSS-RTK autonomous navigation, communication equipment, on-board processing, and onboard sensors (visual & infrared cameras, other sensors). The drones should weigh below 25 Kg (to avoid complex permit procedures). The drone fleet also includes a Ground Base Station that links the drones to the TEMA architecture.
Rationale	They are needed to collect images and other data, log the data and transmit it to the Ground Base Station.
Fit Criterion	Capacity of drones to position accurately and collect images and data at the specified locations. Positioning accuracy.
Priority	5
Difficulty	5
Related Technologies	Drone-based image and data acquisition (SV-tech-01)
Author	USE

ID	FH #2
Name	In-Situ sensors
Requirement Type	Functional
Description	A network of sensors, both ground-based and optionally on drones, equipped with the following capabilities: ● Peer-to-peer communication equipment ● GNSS-RTK based positioning ● On-board processing (e.g., Intel NUC PC)

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	● Onboard sensor pack consisting of non-visual (and optionally visual) sensors
Rationale	The in-situ sensors should provide information from the field in real-time to be fed into the other TEMA components and technologies. A special focus is placed on environmental parameters, such as wind, temperature, pressure and humidity. Also smoke concentration data are collected processed in real-time to generate the corresponding numerical models.
Fit Criterion	The ground network is “alive”, the data is transmitted to the TEMA components. The information flows from to the network. Sensors report measurement values.
Priority	5
Difficulty	4
Related Technologies	Realistic 3D smoke modelling and fire detection (PDM-tech-03)
Author	DLR-KN

ID	FH #3
Name	Ground station
Requirement Type	Functional
Description	The ground station with a portable computer and a Starlink terminal.
Rationale	The ground station should provide an access point to the in-situ sensors and drones, while at the same time acting as a relay of information to and from other TEMA subcomponents.

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Fit Criterion	The internet through Starlink terminal is available at the location. There is connectivity to the swarm.
Priority	5
Difficulty	2
Related Technologies	Realistic 3D smoke modelling and fire detection (PDM-tech-03)
Author	DLR-KN

ID	FH #4
Name	Smartdesk hardware
Requirement Type	Functional
Description	Smartdesk device
Rationale	Physical device with smartdesk software which is developed in the TEAM project.
Fit Criterion	Physical device to run Smartdesk software is deployed.
Priority	5
Difficulty	2
Related Technologies	Smartdesk Application (SV-tech-07)
Author	KAMK

2.2.3 Non-Functional Requirements

Below the list of non-functional software requirements

This project has received funding from the European Union – European Commission under grant agreement No 101093003

ID	NFR #1
Name	Privacy and Data Protection
Requirement Type	Non-Functional (Security)
Description	TEMA platform has to be compliant with the EU legislation regarding privacy and data protection. It should adopt all the necessary technologies, standards and methods to protect privacy of the users of the platform services and to secure stored information that could be considered private.
Rationale	Despite the fact that the platform should not permanently store any sensitive data, the services that will run on it could handle private data. For this reason, it is necessary that the TEMA platform provides functionalities to protect personal information in line with the current legislation.
Fit Criterion	The platform is compliant with Data Privacy and Data Protection EU regulations.
Priority	5
Difficulty	4
Related Technologies	All
Author	ENG

ID	NFR #2
Name	Increased simulation accuracy
Requirement Type	Non-Functional
Description	The simulator shall be able to improve the accuracy of the fire behaviour simulation within situ real time data.

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Rationale	The simulator shall be able to adapt wind speed and direction and rate of spread (ROS) from in-situ sensors weather data and firefront position in real time.
Fit Criterion	Simulations are better matched to the actual fire perimeter using real-time data versus simulations using only weather forecast service.
Priority	4
Difficulty	3
Related Technologies	Forest Fire Simulation (PDM-tech-01)
Author	TSYL

ID	NFR #3
Name	Open API access
Requirement Type	Non-Functional (Operational and Environmental)
Description	Data and services available in the TEMA platform must be accessible via a set of APIs using standardised approaches (e.g., RESTful API).
Rationale	The TEMA platform should provide tools, data and services to several actors. For this reason, it is necessary that all the necessary platform functionalities have to be accessible through standard and well documented open APIs.
Fit Criterion	All TEMA platform components provide a set of Open API to interact with them. All Open APIs of the TEMA platform are documented in a standard and uniform way.
Priority	4
Difficulty	3

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Related Technologies	All
Author	ENG

ID	NFR #4
Name	Improve weather forecast data
Requirement Type	Non-Functional
Description	The simulator must be able to calibrate the weather forecast data with real time data from in-field sensors.
Rationale	The simulator must be able to improve weather forecast data by extrapolation models using data obtained in real time.
Fit Criterion	Weather forecast data more closely match actual weather data measured in the field after adjustment with data from field sensors.
Priority	4
Difficulty	4
Related Technologies	Forest Fire Simulation¸ 3Di Hydrodynamic simulation (PDM-tech-01/02)
Author	TSYL

ID	NFR #5
Name	Cloud-Edge Continuum Architecture
Requirement Type	Non-Functional
Description	A novel architecture is required to (i) perform computation among mobile (e.g., drones) and stationary (e.g., base station, data

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	center).device and (ii) allow offloading through the cloud-edge layers when resources (e.g., CPU, memory, network, energy) is not available.
Rationale	To allow all AI algorithms to run on mobile and stationary devices.
Fit Criterion	At least one mobile device and a stationary device can perform and offload computation.
Priority	5
Difficulty	4
Related Technologies	All
Author	UNIME

ID	NFR #6
Name	Algorithms for Distributed Intelligence
Requirement Type	Non-Functional
Description	Computation running on multiple mobile and stationary devices need tools and algorithms for distributing the intelligence. Federated Learning (FL) is a novel technique for running local training on decentralized clients and building a unique global model on a centralized server.
Rationale	To improve the quality of AI algorithms running on geographically distributed mobile and stationary devices.
Fit Criterion	At least two clients and a server must perform Federated Learning tasks.
Priority	3
Difficulty	3
Related Technologies	All

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Author	UNIME

ID	NFR #7
Name	Use of Container-based technology
Requirement Type	Non-Functional
Description	The architecture must be designed to leverage containerization technology to provide a highly scalable, portable, and efficient environment for deploying and managing applications.
Rationale	To enable easy creation, deployment, and management of containers. It should support features and functionalities such as container image creation, container orchestration, network management, and resource utilization monitoring.
Fit Criterion	All TEMA components must be deployed into a container.
Priority	3
Difficulty	3
Related Technologies	All
Author	ENG

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3. TEMA Platform Architecture

Disaster management is a complex challenge and requires the coordination of many resources and skills. Digital technologies can contribute in various ways to improve the effectiveness of management activities and can play an increasingly important role in natural disaster management. TEMA's ambition is to establish a reference architecture that is as flexible as possible with the main objective of supporting interoperability among devices, AI tools and software solutions by establishing minimum interoperability requirements and optimizing their integration in a continuum cloud and edge data and processing space.

The TEMA platform, designed to address the complexities of disaster prevention, management, and response, is inherently positioned to handle the immense challenges of big data in the context of extreme events like floods and forest fires. This platform is tailored to meet the essential requirements of collecting and integrating a vast array of data from heterogeneous sources such as satellite imagery, drone-captured data, smart sensors, and geosocial media. TEMA's advanced data collection mechanisms are equipped to manage the sheer volume and variety of unstructured data, exemplified by the significant storage needs of high-resolution drone videos and satellite images. Furthermore, the platform incorporates scalable storage and processing capabilities, crucial for handling the high velocity and variability of data generated during such catastrophic events. This includes efficient data compression techniques and high-performance computing infrastructures. Beyond mere data aggregation, TEMA ensures the cleansing, normalization, and standardization of data to maintain consistency and veracity, thereby facilitating comprehensive and meaningful analysis. The deployment of advanced analytical techniques, including machine learning and artificial intelligence, within TEMA, underscores its capability to derive actionable insights crucial for predicting disaster spread, identifying at-risk areas, optimizing resource allocation, and supporting prompt decision-making. In essence, TEMA is not just equipped to deal with big data; it is meticulously engineered to harness and analyse this data effectively, making it an indispensable tool in the realm of disaster management and mitigation.

The next sections describe the high-level logical architecture that will show which components participate in data collection, integration, and processing, followed by an architectural view to describe the mechanisms used to enable the cloud-edge continuum. The detail of each component, belonging to the TEMA Architecture, will be described in the related WPs (WP3, WP4, WP5) and the implementation of the TEMA platform will be addressed in the WP6.

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3.1 Logical Architecture

The TEMA logical architecture (Figure 1) is aimed to be straightforward and adaptable to accommodate the diverse requirements of various Pilots and, more broadly, to be suitable for various scenarios where heterogeneous data sources and various types of field sensors are utilized. Before going any further, a premise is needed. The logical components will be described without taking into account the deployment modality, which can be in the cloud or in the edge and will be dynamically managed with the mechanisms we will explain in the next subsection. The followed approach is made up of four layers as depicted in Figure 1.

3.1.1 Data

The Data layer contains all possible data sources useful for disaster management such as open data repositories, structured data acquired from external services or legacy systems, and in general digital object sources. We call **TEMA Digital Object** any data of interest, for example satellite images, videos and streams acquired from cameras, drones or field operators' information, etc.

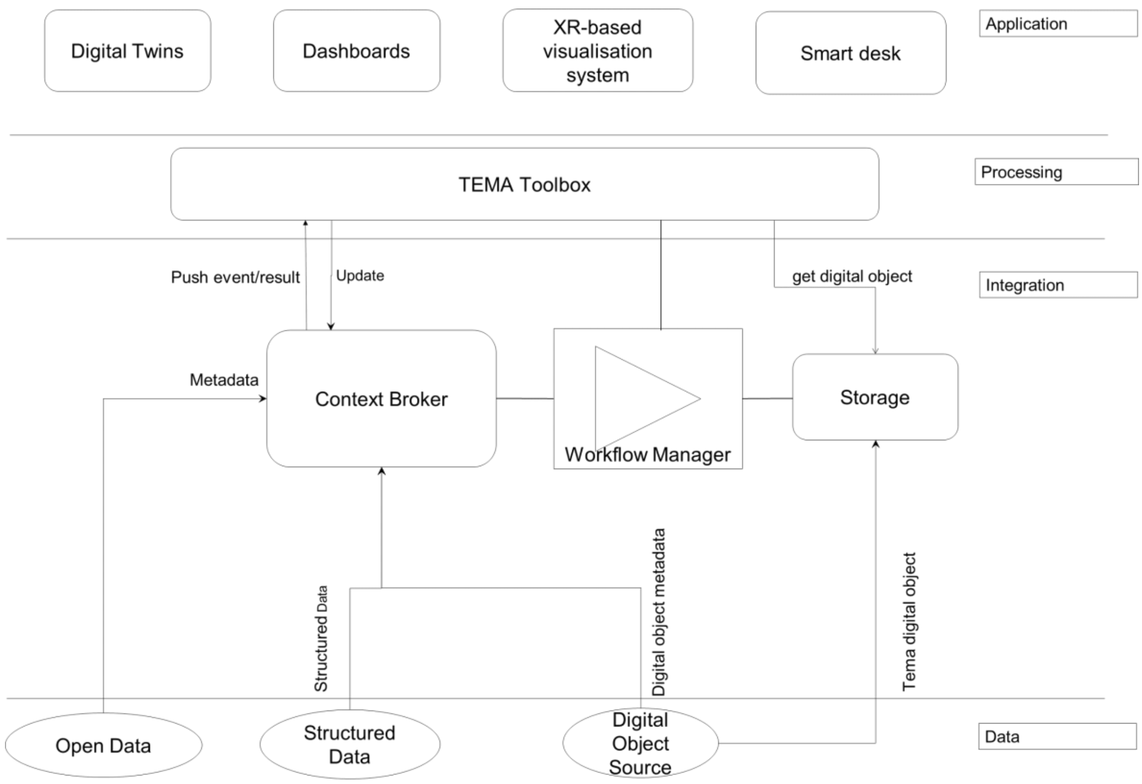

Figure 1 - TEMA Logical Architecture

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In order to connect heterogeneous devices, sensors, and data sources, the FIWARE ecosystem provides various adaptor agents (Figure 2) that are very useful for adapting specific formats and protocols to NGSI APIs[3]. This way, the Data layer will be able to feed the integration layer seamlessly, when possible.

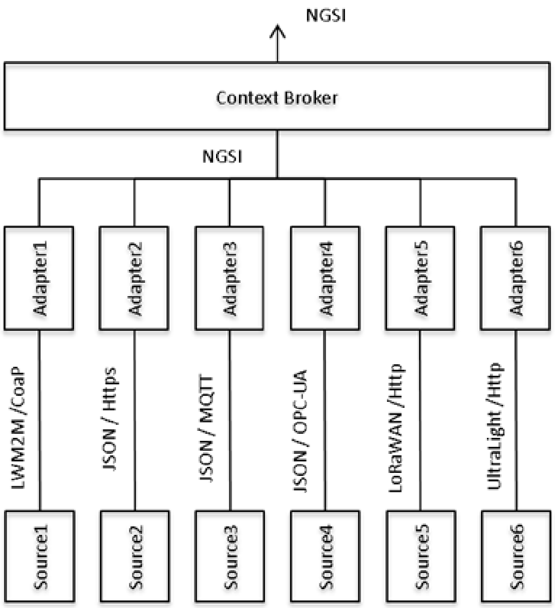

Figure 2 - FIWARE adaptor agents

3.1.2 Integration

The Integration layer is in charge of:

1. collecting and unifying data from the various sources,
2. storing data resulting from the processing performed by the TEMA tools,
3. providing a publish/subscribe mechanism for the purpose of triggering different tools in a processing chain,
4. and workflow management and scheduled execution of tool/services.

The main component of this layer is the **Context Broker**, which leverages on JSON-LD [1] (a JSON-based serialization format for Linked Data) to manage context information in a uniform manner and provides the publish/subscribe mechanism via its API based on the NGSI-LD ETSI standard [2].

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As illustrated in the reference architecture (Figure 1), the Context Broker is a tool that can be used in different ways depending on the specific conditions and constraints, taking advantage of its ability to collect data and its publish-subscribe mechanism:

a) as a metadata register, containing integration information to facilitate the retrieval and invocation of (data/processing) services or to hold configuration information useful for dynamic instantiation of devices,
b) as a real data repository, using NGSI-LD to facilitate the integration of components using different formats,
c) and as a publish/subscribe information broker.

The concrete architecture must be very flexible and adapt to the needs of the end users. It is not a mandatory constraint to go through the broker to integrate different tools, but it is certainly suggested, in order to maximize the possibility of integrating and reusing solutions in multiple contexts. TEMA Tools can interact and communicate each other without using the Context Broker. The only constrain is to previously define a data-model to interact.

Below we provide a small example (Figure 3) of the NGSI-LD JSON-LD format. For a more detailed description, please refer to the official documentation [3].

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```json
{
	"id": "urn:ngsi-ld:AirQualityObserved:RZ:Obsv4567",
	"type": "AirQualityObserved",
	"dateObserved": {
	"type": "Property",
	"value": {
		"@type": "DateTime",
		"@value": "2018-08-07T12:00:00Z"
	}
	},
	"NO2": {
	"type": "Property",
	"value": 22,
	"unitCode": "GP"
	},
	"refPointOfInterest": {
	"type": "Relationship",
	"object": "urn:ngsi-ld:PointOfInterest:RZ:MainSquare"
	},
	"@context": [
	"https://schema.lab.fiware.org/ld/context",
	"https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld"
	]
}
```

Figure 3 - NGSI-LD JSON-LD example

Note that it is basically a JSON object, where we must provide a context and follow some rules to convert old NGSI v2 instantiations to NGSI-LD:

- NGSI v2 entity id attributes have to be converted to URIs, preferably using the NGSI-LD URN.

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- Regular entity attributes have to be converted to JSON-LD nodes of type Property.
- ref attributes (pointing to other entities) have to be converted to JSON-LD nodes of type Relationship.
- The timestamp metadata item has to be mapped to the observedAt member of a Property node.
- The unitCode metadata item has to be mapped to the unitCode member of a Property node.
- The NGSI v2 DateTime type has to be properly encoded as per the JSON-LD rules.
- The NGSI v2 geo:json type has to be renamed to GeoProperty.

The **Storage component** will group all the necessary storage tools: NoSql databases, Object Storage to hold media and large files, Relational Databases, etc. There are several connectors that can connect the Context Broker to storage units for the purpose of historicizing context data sets as they change over time.

The **Workflow management** allows:

- the definition of workflows, which can be complex and may involve a series of steps, known as "tasks," each of which performs a specific action or calculation. Dependencies can be established between tasks so that they are executed in a specific order. For example, a task B can be configured to execute only after task A has been successfully completed.
- the execution of workflows to be monitored in real time. It must be possible to check task status, timings and any exceptions.workflows to be scheduled for execution based on specific times, regular intervals or triggering events.
- a scheduling system that can automatically schedule the execution of workflows and tasks. You can define the frequencies at which workflows or tasks are to be executed, such as daily, hourly, or according to a custom schedule. supporting the retry of tasks in case of errors or failures. The number of retries, delays between retries, and actions to be taken in case of failure can be configured.

These features enable the composition of tasks performed by different TEMA tools for the purpose of satisfying a broader use case (Figure 4).

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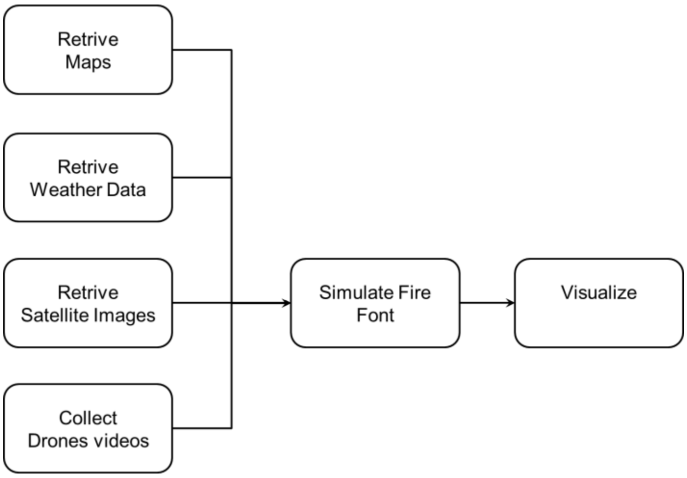

Figure 4 - Simple workflow example

3.1.3 Processing

The Processing layer is implemented through the TEMA Toolbox that supports the end user services that will be provided by the TEMA architecture. The data analysis toolbox contains both generic big data tools and specific analytical tools for disaster management based on AI models. The toolbox has to provide the possibility to process data in batch and near real-time manner.

TEMA Toolbox should also allow distributed implementation of the different parts of the data analytics tools (Figure 5) at different levels of the architecture (i.e. at the edge and on cloud/premise). In this way, the tools make efficient use of the available storage and processing capability.

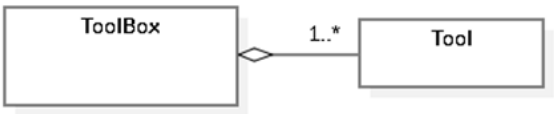

Figure 5 - TEMA ToolBox interaction

To be part of the TEMA Toolbox, a software component must meet few constraints; no matter what language or technology it is defined in, it must have an accessible and open API interface, and it must support and be possible to deploy it in a container (e.g., Docker container). To meet TEMA requirements, a container-based design approach is proposed. A container is a standardised

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executable software unit that includes the source code and all its dependencies and the correspondent packages.

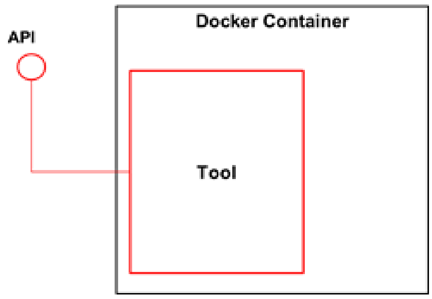

Figure 6 - An example of container (Docker)

The containerized software is isolated from its environment. Hence, a container (Figure 6) is easy to ship and deploy into different environments, even if these are different from that one used during development and thus also on different cloud- or edge-side infrastructures as long as they support containerization technology.

3.1.4 Application

The Application layer consists of all the high-level services that end-users will use in disaster management scenarios. These services will be available to operators in the field and decision-makers managing emergencies from operations centres.

Dashboards will be created to aggregate useful information to keep track of the evolution of emergency situations and significant events; for example, it would be useful to have the map (in a single/integrated view) with the real-time evolution of a fire in which the buildings at risk and the predicted evolution of the fire front are also highlighted.

Digital Twins can be created to represent a specific geographical area and integrate data from different sources, such as sensors, satellites and mobile devices. This data can be used to continuously monitor environmental conditions and detect early warning signals for potential natural disasters, such as earthquakes, floods, forest fires and storms.

The XR-based system collects and presents all the data obtained by TEMA in a simplified manner to the operator. It combines the geospatial data from the Digital Twin with a geovisual map to create a comprehensive and detailed 3D TEMA map in an XR environment or desktop application.

Smartdesk is a useful tool to visualize the current situation on the field. Purpose of Smartdesk software is to be the dashboard to give easy access to the necessary data that is needed and bring everything together for visualization purposes.

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3.2 Cloud-Edge continuum Architecture

The relationship between cloud and edge is a co-operation that aims to capitalize on the centralized resources of the cloud and the distributed processing of the edge to provide computing solutions that are more efficient, scalable and suitable for a variety of use cases. The choice of which approach to use will depend on the specific needs of the application and system conditions. In the TEMA architecture some components will be bound to the cloud side (Context Broker), others belong naturally to field operations and thus to the edge (Drones, Sensors, Base Stations, etc.).

Other components have dual deployment (Storage, Processing). The computational architecture in Figure 7 represents how the intelligent processing is distributed over the continuum. In this regard, the figure uses some keywords that are explained in the following. The continuum scenario in which the operations are carried on is composed of two edge layers and one cloud layer. From the bottom, the first edge layer is composed of autonomous and/or mobile devices (e.g., autonomous unmanned vehicles, data stations). Even if this could be considered an Internet of Things layer, the devices are more powerful (e.g., NVIDIA Jetson Orin) and able to make autonomous computations. The second edge layer is composed of one or more base stations. This is, therefore, the computation area that supports the devices on the field, placed side by side with the first responder's mobile stations. For example, this could be a powerful computer or a small rack. The cloud layer facilitates the remote support (e.g., control room) and provides extreme powerful resources for huge computation requirements. While the cloud to edge communication is fully promoted for the injection of communication or top-down order, the vice versa should be limited for supporting response times as close as real-time. Computation is provided by a *computation unit*, which is a resource-constrained or a powerful computer able to process jobs. A *job* is the small components executed by the computation units. The computation offloading follows the edge-to-edge-to-cloud (and vice versa) rule, avoiding any interaction between the first edge level and the cloud. The rule's goal is gradually moving the jobs among the computation units, encouraging the use of units i) closest to the field, and ii) less expensive from the energy point of view. Moreover, another important component is the agent. While Figure 7 highlights the agent from the computational point of view by showing how the scheduler interacts with the other components, a more detailed presentation can be seen in Figure 8.

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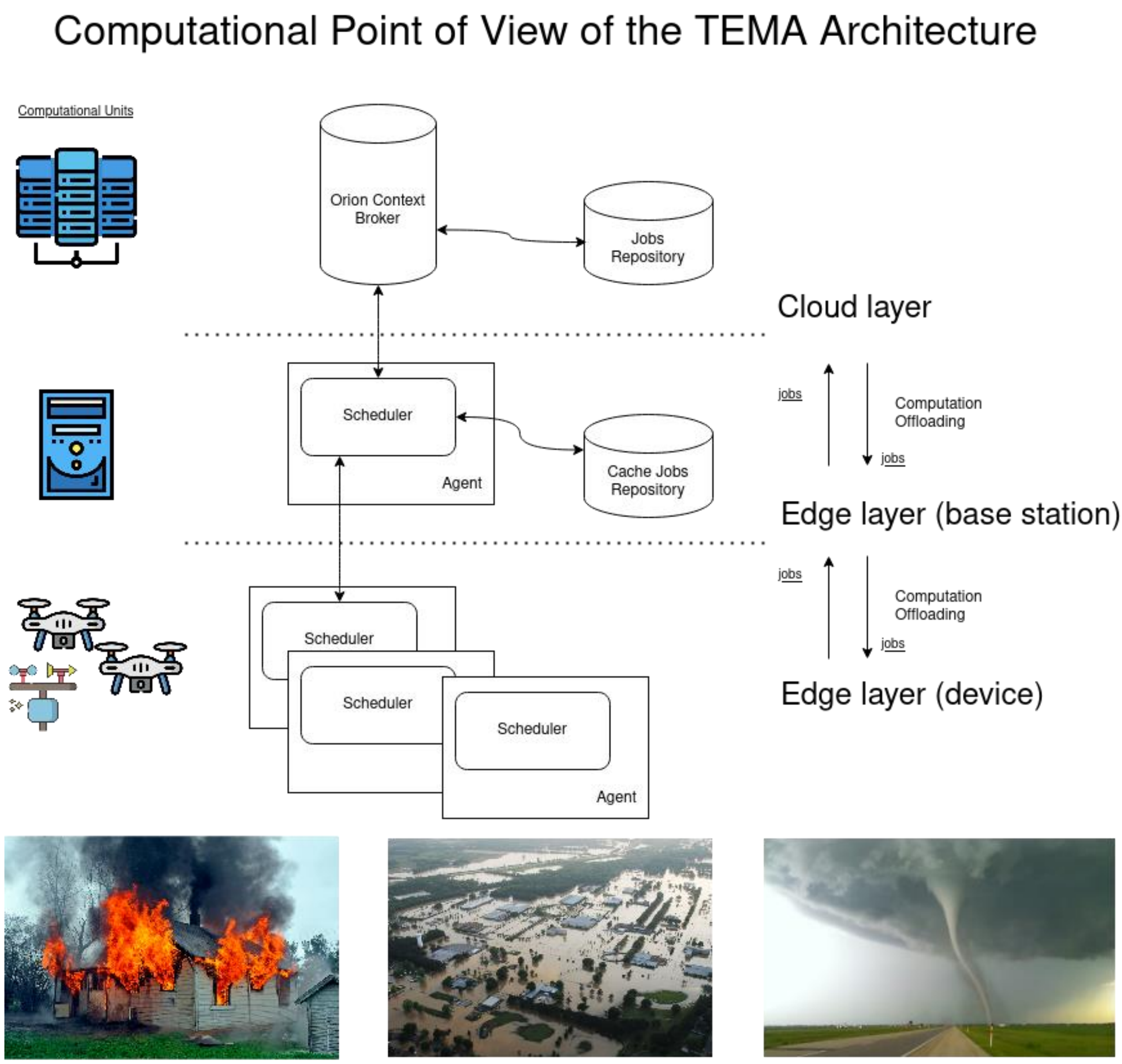

Figure 7 - Cloud-Edge continuum (computational) architecture

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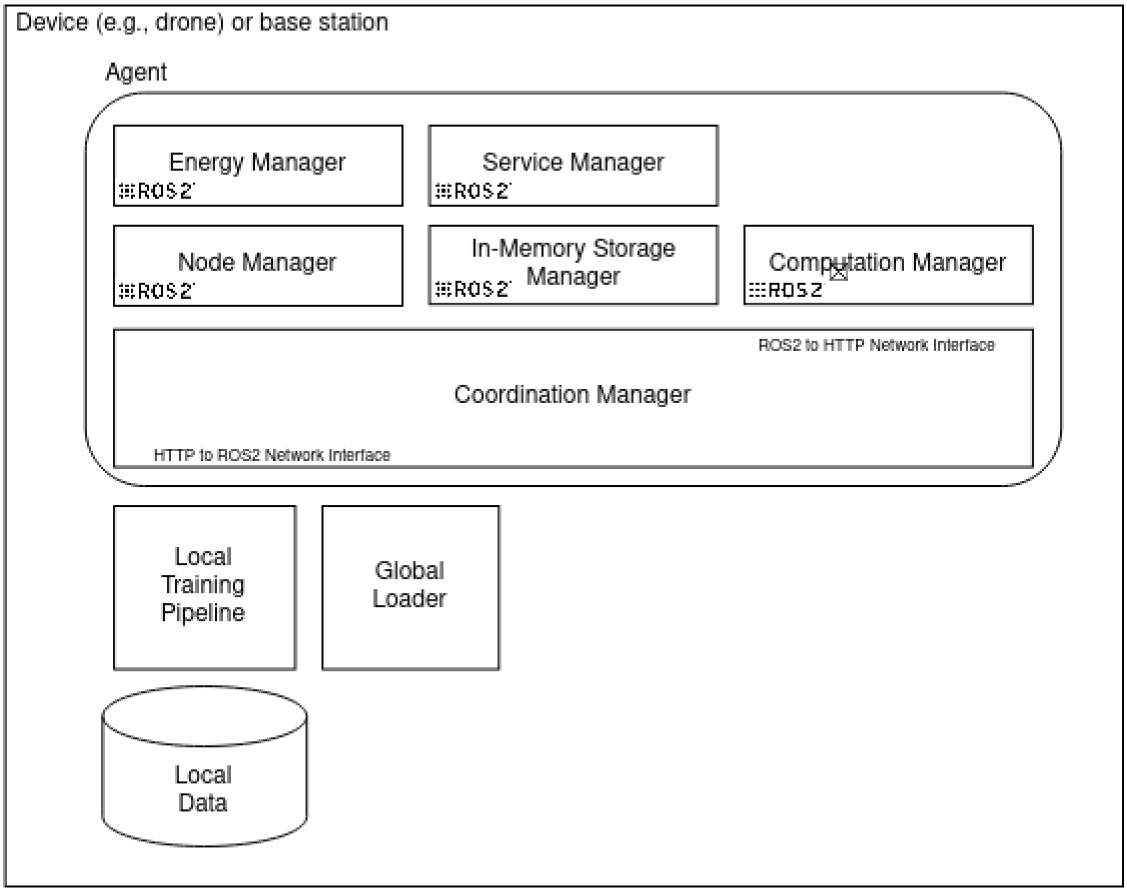

Figure 8 - Agent component

The devices are the only components included in the first edge layer. They are heterogeneous by design and represent mobile (e.g., drones, autonomous vehicles, robots) and stationary (e.g., weather stations) devices involved in the field. The devices are resource-constrained and, typically, battery powered. These are managed by the first responder and perform following a centralised or decentralised approach (e.g., client-server or peer-to-peer model). Moreover, the devices are organised in heterogeneous fleets, where subgroups of them can be involved in specific tasks by defining a dedicated network overlay. When initialized, the devices are clean of jobs. The only component installed is the agent represented in Figure 8, which allows the baseline operations (e.g., self-management, networking, energy saving). The agent's service manager is in charge of reading the configuration file pushed by the Cloud Core Task Manager. Such file uses a human- and machine-readable markup language, such as JSON or YAML. The file includes the services selected by a maintained list and identifies the processing targets of the device. The service manager queries a repository and starts a pulling process to set up the device. The computation manager is, therefore, involved for running jobs as instances of the services. From that moment on, the device performs the selected tasks and operates on the field. In the meantime, the node manager monitors the used resources (CPU, memory, inbound/outbound network, energy). Indeed, a resource-constrained device is limited both in computational power and energy. In this regard, jobs could not have enough

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resources to run or complete the processing. Therefore, the computation manager executes an offloading algorithm for moving the jobs to the upper edge layer, where the base station may continue the computation.

3.3 TEMA Architectural Components and their interactions

TEMA's architecture contains many technologies that contribute to the high-level services available to actors involved in natural disaster management scenarios.

The entry point for using these services and for managing all the tools of the platform will be a web application that we will call TEMA webAPP.

The TEMA webAPP will be the unique point of access to manage the TEMA Solution and the related services it provides. Through the TEMA webAPP, the users can mainly

- configure the environment,
- launch a Business Mission,
- visualise the results of the Big Data Analysis through the dashboards and the tool provided by the Application layer (Figure 1).

This webAPP will trigger the services and tools so as to better manage field operations, receive information from operators, firefighters, and all stakeholders, and provide decision support and information to operations coordinators. For example, when a flooded area monitoring service is requested in the coordination centre, several TEMA tools will have to coordinate to process the necessary information: acquire images from drones, process them to locate people and vehicles in flooded areas, simulate the flooding pattern, etc.

We will have two ways to start the process:

1. The user will start the process by clicking on the button of a specific Business Mission.
2. The Business Mission will be triggered when a specific event will take place (e.g. a satellite image will be stored).

The first option will be experimented in the first piloting phase, while the second one will be tested in the second piloting phase.

In these kinds of scenarios, the interactions and information flows between different tools is very complex and difficult to render in a few all-inclusive diagrams, so we preferred to draw many interaction diagrams from the perspective of the individual technologies and tools that are part of the TEMA architecture. To improve the readability of this document, we have included all the interaction diagrams in Appendix I, at the end of this document.

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3.4 Deployment Architecture

As the number of connected devices has increased, edge computing has begun to gain momentum in recent years. This is due to the rapid growth of data and the increasing unsustainability of cloud-only models. The TEMA architecture is flexible from a deployment perspective, will be based on containerization of its modules, and will run its services on the edge whenever possible, reshaping the deployment to the cloud when circumstances require it.

Edge computing moves data processing and storage as close as possible to the original source in order to address these challenges. Therefore, edge computing is used to create content delivery networks that decentralize the delivery of data and services, bringing them closer to end users. The edge computing capabilities offered by the TEMA platform will enable distributed processing, storage, and control at the edge. This approach aims to solve the latency problem, reduce the required network bandwidth, and reduce power consumption.

As mentioned above, sometimes it is necessary to move to the cloud for disparate reasons, for example: need for high computational capacity, devices with low battery power that cannot waste energy to ensure on-site processing of information, etc.

To ensure that sufficient resources are available to instantiate services in a scalable manner in all cases, in addition to the available edge-side resources, TEMA will offer a highly scalable cloud infrastructure with storage and processing capabilities. Therefore, the generic dynamic deployment scheme on the TEMA platform will be the following.

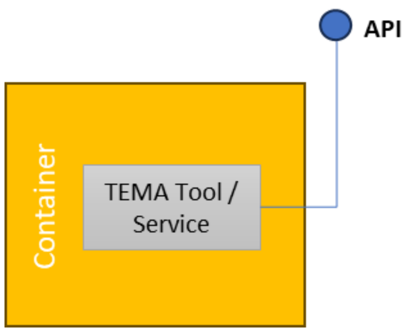

Figure 9 – Deployment container

Thanks to containerization technology, starting with a container based on the configured and ready-to-run image of a TEMA tool (or speaking more generally TEMA service) with its API interface (Figure 9), we can instantiate that tool on a device or base station running a container management service.

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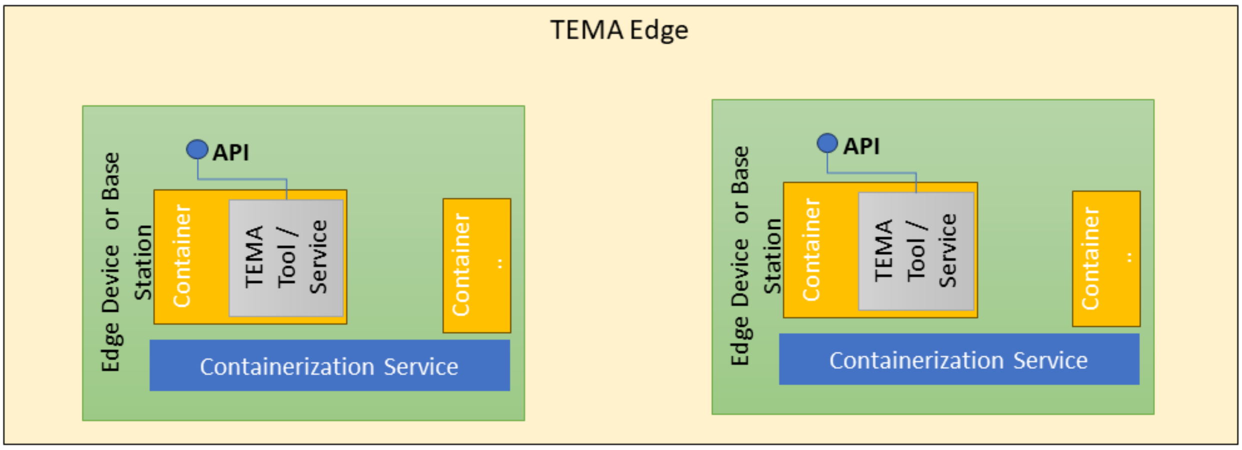

Figure 10 – TEMA Edge containers

The containerization technology fully abstracts an execution environment. In this way, we can use the same image above mentioned of a TEMA tool or service to create an instance of it on the cloud when needed. TEMA will provide an infrastructure based on a virtualised cluster in which depending on computational capacity requirements, multiple nodes called workers will be created. A containerization service will run into each worker node as well as containers, based on images of TEMA tools or services, can be instantiated in the worker nodes

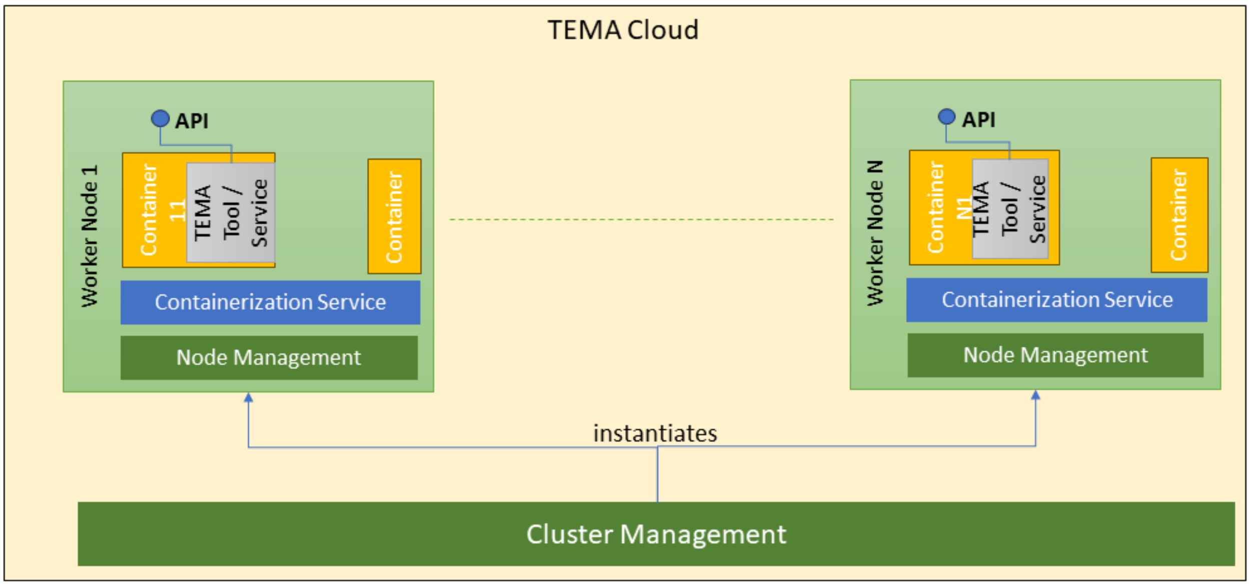

Figure 11 - TEMA Cloud containers

By leveraging the virtualization capability of an execution environment (including state) that containerization provides us with, it is also possible to move during execution a particular processing from the edge (Figure 10) to the cloud (Figure 11).

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It is important to point out that this is a first draft of a possible deployment solution. During the implementation phase and in the activities performed in the WP6, this architecture will be better defined to set-up & running the TEMA platform to be tested in the Pilots.

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4. TEMA Data Catalogue

In the context of the TEMA project, data assumes relevance. Indeed, within the architectural framework of the TEMA platform, the aim is to ensure the seamless integration of datasets provided by pilot projects. For this reason, a Data Catalogue template was distributed in order to collect data sets owned by each end user. By establishing a structured data repository and constructing coherent data models, the TEMA platform will be able to respond swiftly and efficiently to the unique needs of each pilot. This will facilitate proactive disaster management and effective emergency responses based on the available and shared real data.

This section contains documentation provided by partners (in particular pilots) regarding their datasets. This activity allows us to better understand how to collect, share and integrate data in the TEMA platform architecture. TEMA Data Catalogue is a live catalogue that will be updated during the project lifespan.

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Table 1 - Preliminary Datasets in the TEMA Data Catalogue

DATASET	AVAILABLE FROM	ACCESSIBLE VIA	STRUCTURE	LICENSE	HOW DO YOU WANT TO USE THIS DATA?	DATASET follows METADATA
Drone footage	KAHY	Drones	.MOV video files		Train/evaluate semantic image segmentation methods	NO
Weather data	Finnish Metereological Institute	API/PORTAL		Creative Commons Attribution 4.0 International license	Monitoring weather changes and how it can influence fire behaviour	NO
Terrain maps (property owner)	National land survey					NO
Forest vegetation	Finnish Forestry Centre					NO
Meteo network temperature	RAS	API/PORTAL	CSV, SQL	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	NO
Meteo network wind direction	RAS	API/PORTAL	CSV, SQL	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	NO
Meteo network wind intensity	RAS	API/PORTAL	CSV, SQL	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	NO

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Meteo network relative humidity	RAS	API/PORTAL	CSV, SQL	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	NO
Meteo network rain	RAS	API/PORTAL	CSV, SQL	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	NO
Meteo network hydrometers	RAS	API/PORTAL	CSV, SQL	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	NO
Forecast data global model emcwf (main meteo variables)	EUROPEAN CENTRE	API/PORTAL	GRIB	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Radar data (arpas and composite, real time and storic)	ARPAS/NATIONAL CIVIL PROTECTION	ARPAS AND DPC PORTAL	HDF5, GRIB, BUFR, RASTER	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Satellite meteo data (sentinel-copernicus)	E.U	COPERNICUS PORTAL	RASTER	TO BE DEFINED	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Satellite data (nasa-modis)	NASA	EARTH EXPLORER PORTAL	RASTER	TO BE DEFINED	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Dynamic informations (event damages surveys)	RAS	PORTAL	GEOJSON, CSV, RASTER	NO	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers: administrative boundaries (common, province)	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES

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Static layers : strategic public buildings (e.g hospitals, police stations, municipality sites, etc)	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers : relevant buildings (e.g schools, religious buildings, sport facilitiies, prisons)	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers: cultural heritage (e.g libraries, museums)	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers: productive activities (e.g farms, animal shelters, shopping centers)	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers: potenzial envinromental hazard structures (e.g factories, oil refinery)	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers: mobility and service infrastructures (e.g factories, oil refinery)	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers: historical districts	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES

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Static layers: protected natural areas	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Static layers: dams and other hydraulic structures	RAS	API/PORTAL	SHP	FREE FOR RAS	INPUT FOR AI MODEL/MACHINE LEARNING	YES
Geo-social media data (text, url to pictures/videos)	PLUS	API	GPKG / CSV	Free for research purposes	"- Early detection of floods and forest fires	YES
Satellite data (sentinel-1 / -2)	ESA	API	GeoTIFF	Free for research purposes	- Creation of hot spot maps (areas affected by a disaster)	YES
Satellite data (sentinel-3, aqua/terra modis)	ESA, NASA	API	GeoTIFF	Free for research purposes	- Understand people's needs (sentiment analysis)"	YES
Aerial images (drone, helicopter, plane)	DLR	Direct download	GeoTIFF	Free for research purposes	INPUT FOR MODEL/MACHINE LEARNING (FLOOD MAPPING)	NO
Digital terrain maps (copernicus dem)	ESA	API	GeoTIFF	Free for research purposes	INPUT FOR MODEL/MACHINE LEARNING (BURNT AREA MAPPING)	NO
Nasa firms	NASA	Direct download	CSV	Free	INPUT FOR MODEL/MACHINE LEARNING (OBJECT DETECTION)	YES
Esa worldcover	ESA	Direct download	GeoTIFF	Free	INPUT FOR MODEL/MACHINE LEARNING (FLOOD MAPPING)	YES

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Alerts (international; floods, wildfires and others)	Global Disaster Alert and Coordination System (GDACS) GDACS is a cooperation framework	Direct download	XML	Free	AUXILIARY DATA FOR MODEL/MACHINE LEARNING (BURNT AREA MAPPING)	NO
Alerts (national [germany]; floods)	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK)	API	JSON	Free	AUXILIARY DATA FOR MODEL/MACHINE LEARNING (BURNT AREA MAPPING)	NO
Alerts (national [finland]; wildfires)	Finnish Metereological Institute?				Input data for decision support	?
Alerts (national [germany]; weather)	Deutscher Wetterdienst (DWD)	API	GeoJSON and other formats	Free	Input data for decision support	NO
Aerial images (drone)	BRK			Free for research purposes	Input data for decision support	
Images (, onsite images)	BRK		jpg, png, pdf	Free for research purposes	Input data for decision support	

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AERIAL FOOTAGE & IMAGES (DRONE)	KEMEA			Free for research purposes	Input data for decision support/ INPUT FOR AI MODEL/MACHINE LEARNING	
Meteorological Data	D. MALLIAN	National Authorities		Free for research purposes	Input data for decision support	
Meteorological Data	D. MALLIAN	In situ Sensor		Free	Input data for decision support/ INPUT FOR AI MODEL/MACHINE LEARNING	

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5. Preliminary Business Missions

In response to specific end-user requirements and leveraging the technologies offered by technical partners, a series of preliminary business missions have been crafted. These are strategic statements that define the core purpose and objectives of TEMA initiative, tailored to meet the specific needs and challenges of the end users while ensuring alignment with innovation goals. The business missions encompass comprehensive assessments for pre-event planning, real-time management during the event, and post-event analysis and assessment. These missions are designed with a high degree of flexibility, primarily focusing on enhancing interoperability among various devices, AI tools, and software solutions. This objective is achieved by setting minimum interoperability standards and optimizing the integration of these elements within a seamless cloud and edge data and processing environment. Such a strategy ensures a harmonious and efficient workflow across different platforms and technologies. Importantly, these business missions are not set in stone; they are adaptable and subject to modification based on evolving end-user needs and insights gained from the initial trial phase. This approach allows for continual refinement and optimization of the missions to better align with real-world applications, ensuring that the missions remain relevant and effective in achieving their intended outcomes. The final versions of Business Missions are expected to be defined on deliverable D6.1.

Pre-event Mission

In response to public alerts and meteorological warnings, the administrator, well-trained in TEMA's technical solutions, utilizes the TEMA Admin GUI running either on SmartDesk or on a regular computer, to manually plan the drone flight mission. This is carried out to capture images necessary for creating a Digital Twin for the area of interest. In situations involving flood-related alerts, 3D hydrodynamic modelling software can be used to simulate the transition from a warning stage to an actual emergency scenario.

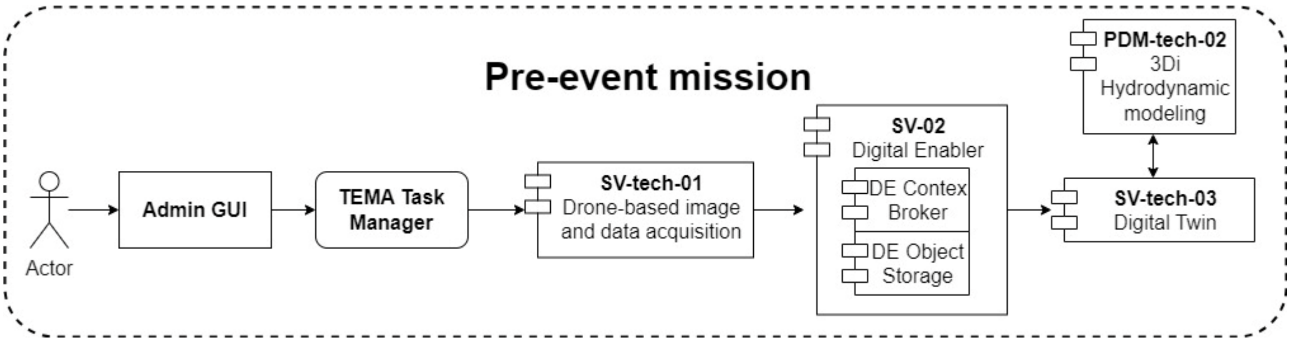

Figure 12 - Pre-event mission

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Event Monitoring Mission

TEMA Platform Initialization

Upon confirmation that the anticipated emergency is underway, the administrator, being at the control room, activates the TEMA platform using the TEMA Admin GUI. Depending on the type of emergency, two specific services are available: 1) Fire Monitoring, and 2) Flood Monitoring. Once a particular event monitoring mission is initiated, the TEMA task manager (the core component of TEMA architecture) launches the necessary technologies, distributing them across the edge or cloud layers of the TEMA platform.

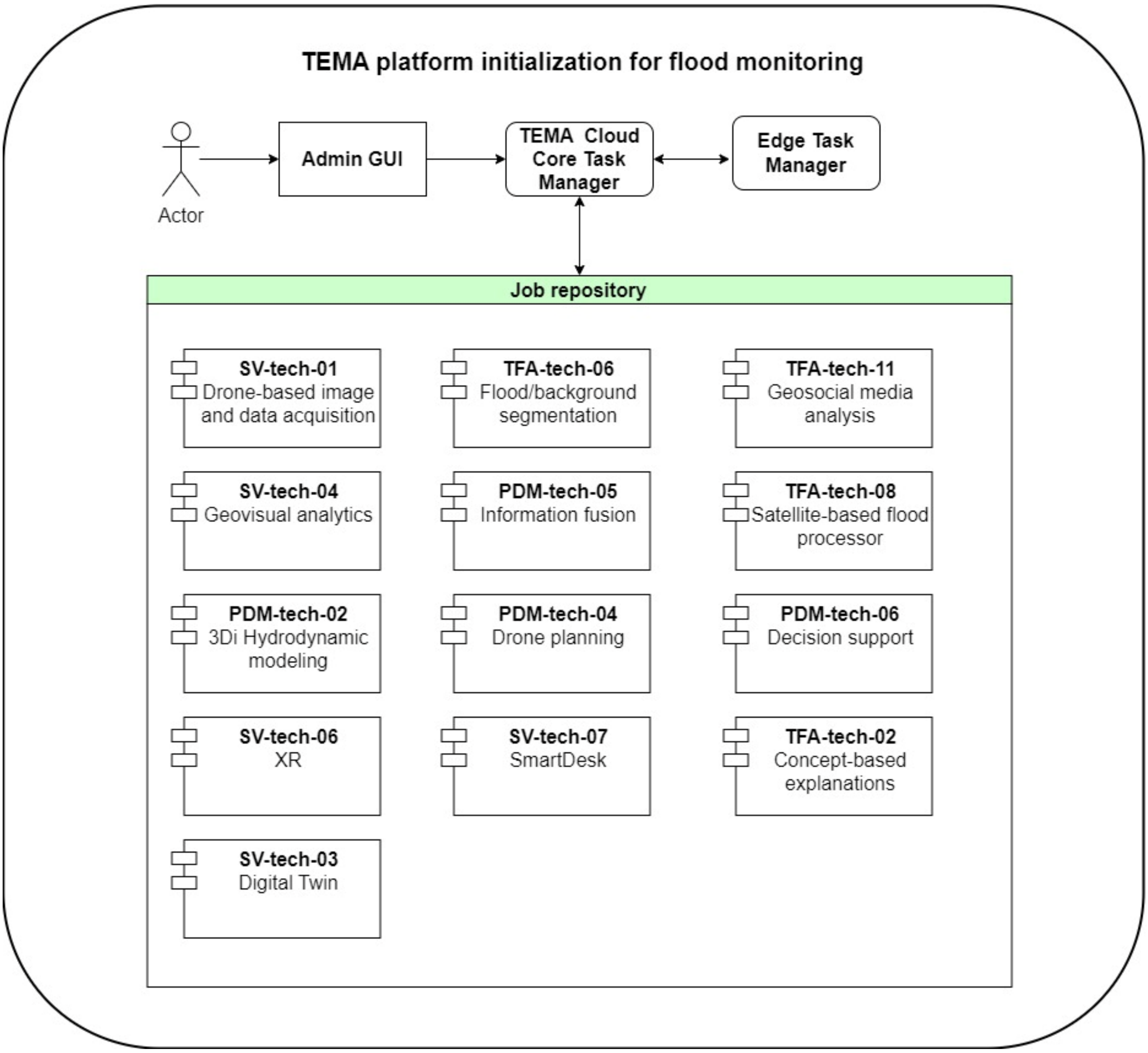

Figure 13 - TEMA platform initialization for flood monitoring

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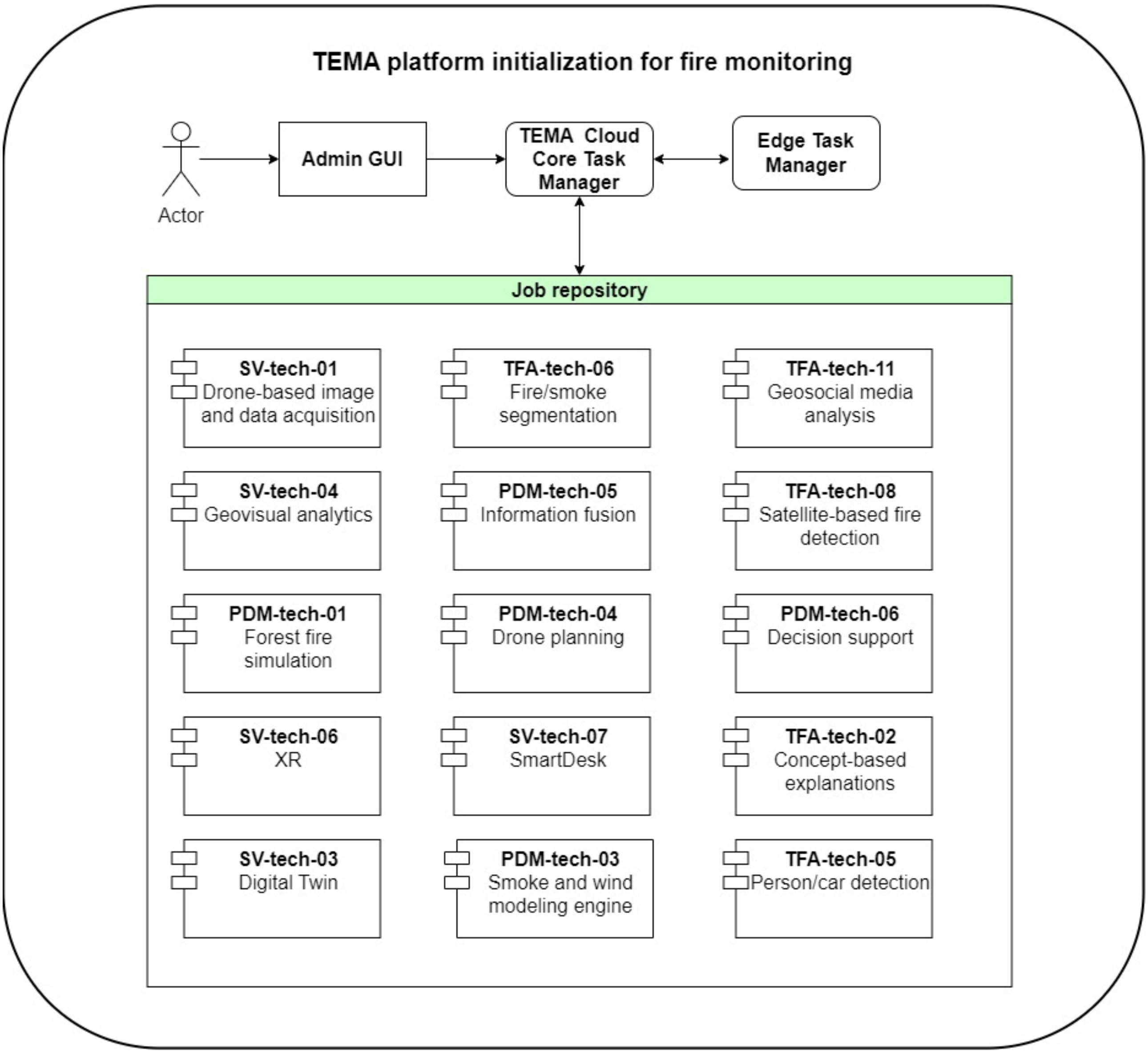

Figure 14 - TEMA platform initialization for fire monitoring

Control Room

End users in the control room can monitor emergency situations in real-time using a specialized web app either on the SmartDesk or on a regular computer. This app features a 3D situational awareness map, which is based on the constructed Digital Twin and is continuously updated. The map includes multiple layers of information:

- Current Phenomena Layer: Displays ongoing emergencies like fires or floods, analysed from drone and satellite imagery.
- Vulnerable Entities Layer: Shows the locations of vulnerable individuals and vehicles.

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- Predictive Simulation Layer: Uses simulation technologies to forecast the progression of the emergency event.
- Alerts and Evacuation Layer: Provides warnings and evacuation notices for specific areas as needed.

Potentially end users can select a specific area where an object is detected and view the detection results overlaid on the raw image captured by the drone. This functionality also includes explanations for the neural-based object detector's predictions, enhancing understanding and decision-making processes in emergency management.

Drone planning

After the first drone flight mission, the TEMA platform autonomously generates the drone's flight trajectory for the next mission based on the processed data. The proposed trajectory is shown on a dedicated section of the TEMA web app on the SmartDesk. However, it's the administrator's responsibility to verify this trajectory before each mission iteration. This crucial step ensures that the planned path aligns with operational requirements and safety protocols, leveraging the platform's processing capabilities while maintaining human oversight for optimal mission execution.

XR Headset

End users operating on the field are able to utilize an XR headset to access the 3D situational awareness map. This immersive technology allows them to view a comprehensive 3D map in real-time, enhancing their spatial understanding and situational awareness. Also, it ensures that field operators are constantly informed with up-to-date information, aiding in efficient and effective response to dynamic emergency scenarios.

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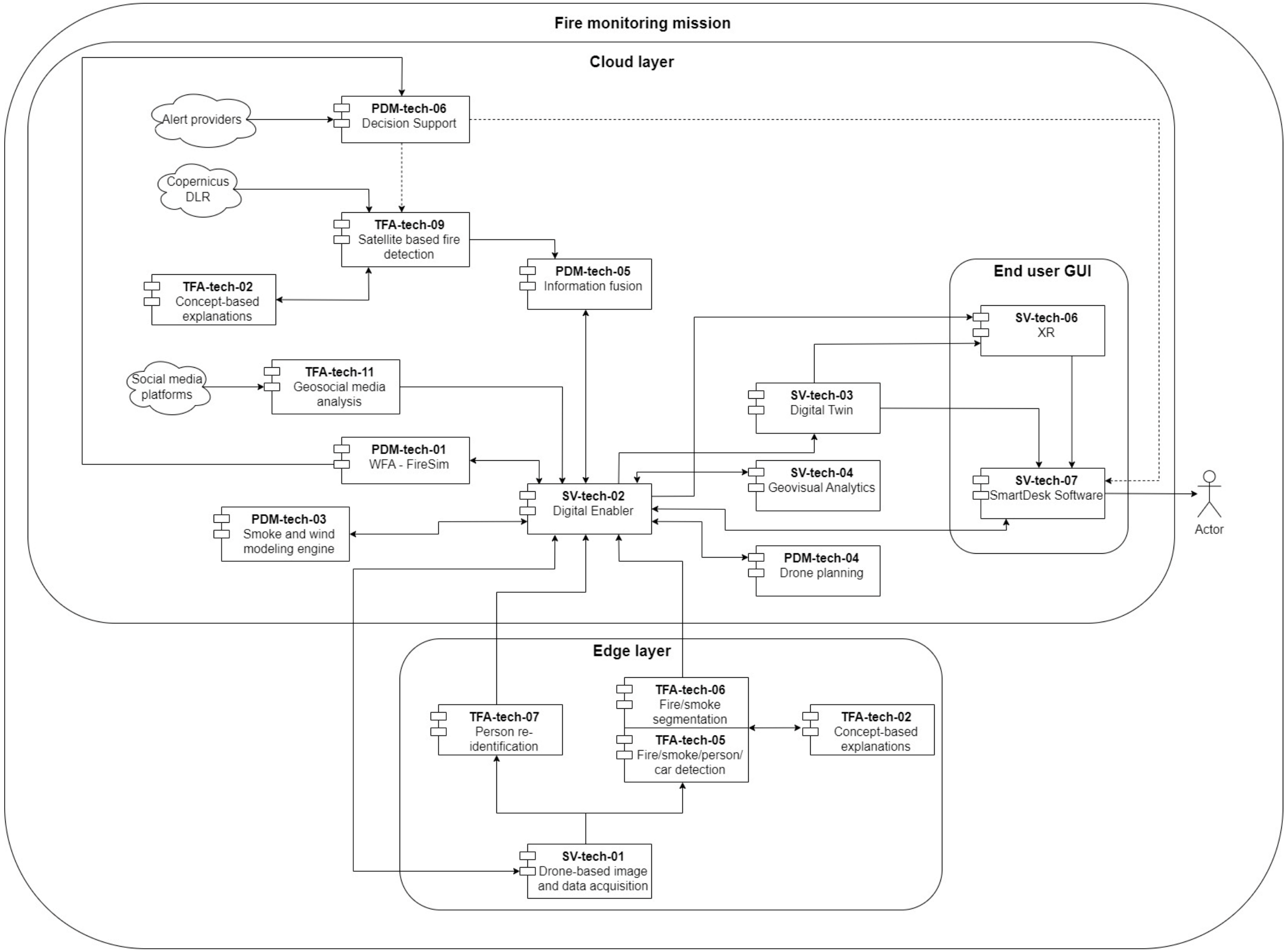

Figure 15 - Computational flow of TEMA platform during fire monitoring mission

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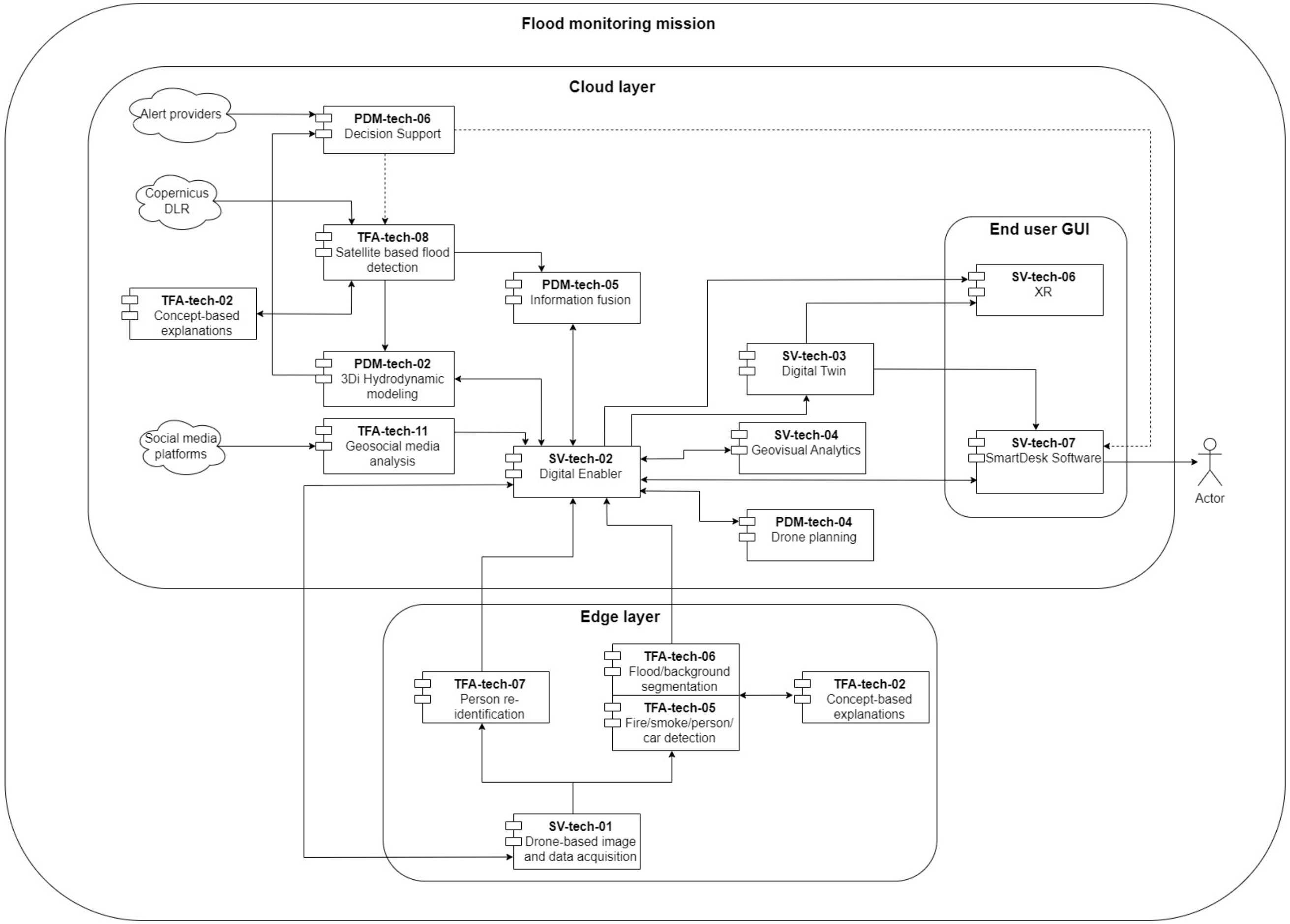

Figure 16 - Computational flow of TEMA platform during flood monitoring

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Post event fire assessment

End users can utilize the 3D situational awareness map TEMA web-app either on the SmartDesk or on a regular computer to assess the damages occurred during the emergency. Towards this end the 3D map includes the following layers of information:

- Damage Assessment Layer: It provides the detection of the damage caused by emergencies like fires or floods, utilizing data processed from drone and satellite imagery.
- Vulnerable Entities Layer: This layer highlights the locations of vulnerable individuals and vehicles.

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6. Conclusions

The origin of this deliverable stemmed from the needs and challenges faced by the end users during natural disasters. By taking into account the Use Case Scenarios provided by the end users, valuable information about each specific domain was collected, which help us to identify the TEMA Platform requirements and categorize them into functional and non-functional (software and hardware) groups.

This deliverable presents the initial version of TEMA's requirements, which were developed through an iterative process involving active participation from each end user. Both common and specific functionalities, services, and data requirements were identified. Additionally, with the involvement of WP2 partners, a preliminary set of logical components was established based on an initial conceptual architecture. Each component was described in terms of its functionalities and interactions with other logical components, and technical aspects were further elaborated, primarily focusing on the suggested technological solution. Finally, these components were distributed among partners to be included in the Platform for implementing the identified functionalities.

The purpose of this deliverable is to describe and share the identified requirements with all end users, ensuring a proper understanding of their needs in fulfilling the TEMA Platform. Moreover, this document also provides a list of tools and technologies to pave the way for establishing the TEMA infrastructure.

The final deployment architecture and the final version of the TEMA Platform and its technical components will be described in the next upcoming WP3-6 deliverables. TEMA Solution will be tested in the pilots, and it will be upgraded after the end users' feedback, accordingly.

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Appendix I: TEMA Interaction Diagrams

As pointed out in Section 3, the interactions and information flows between different tools are very complex and difficult to render in a few all-encompassing diagrams. Some of TEMA's technologies and tools are not included in these diagrams because they operate behind the scenes and/or were developed for research purposes only.

In this annex, we have described and drawn different interaction diagrams from the perspective of the individual technologies and tools that are part of the TEMA architecture. The interaction diagrams are provisional and are subject to potential changes. The final versions of interaction diagrams and the detail of each component, belonging to the TEMA Architecture, will be described in the related WPs (WP3, WP4, WP5).

Human-comprehensible presentation of concept-based explanations (TFA-tech-02)

Component TFA-tech-02 (Human-comprehensible presentation of concept-based explanations) is responsible for providing concept-based explanations for the outputs of various DNN-based TEMA models. These models include TFA-tech-05 (Fire/smoke/flood/person detection), TFA-tech-06 (Fire/flood/background segmentation), TFA-tech-08 (Satellite-based flood detection and assessment), and TFA-tech-09 (Satellite-based Forest fire detection and assessment).

Concept-based explanations are based on a meaningful decomposition of the latent space of the DNN model. Component TFA-tech-01 (Concept discovery for latent space interpretability of deep neural networks) will compute such a decomposition and construct a Virtual Concept Layer that could be plugged into the DNN components (TFA-tech-05, TFA-tech-06, TFA-tech-08 TFA-tech-09). This Virtual Concept Layer performs an identity loop through the interpretable concept decomposition and does not change the model effectively. This is the [0]th step and should be framed as a research element in the sense that it is done prior to employment of the TEMA platform.

Concept-based explanations consist of multiple relevance heatmaps that highlight the importance of each concept toward model's prediction. Compared to a traditional single heatmap, the concept-based explanation offers a more comprehensive understanding of the model's decision, but it may take longer for humans to comprehend due to the increased amount of information they need to process. For this reason, the level of detail in the explanation is determined by the model's output (step [1]), and in component TFA-tech-02 triggers the computation (step [2]) of the corresponding relevance values by performing a modified backward pass through the DNN model. Finally, the DNN

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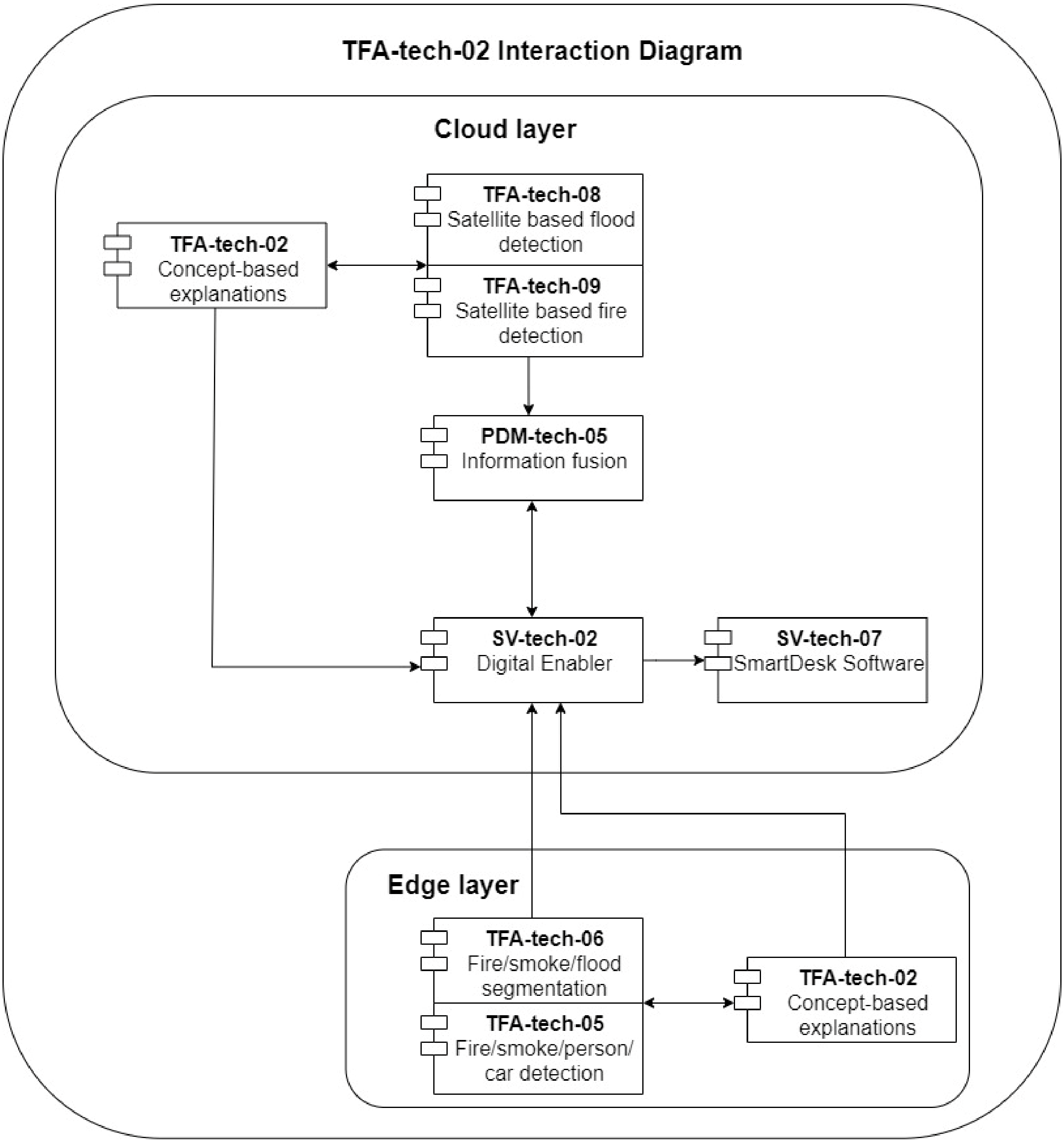
component sends back the relevance values to TFA-tech-02 (step [3]). Finally, the latter constructs the visualization for the final explanation. This final explanation will be sent to SV-tech-07 via SV-tech-02 to be displayed.



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Fire/smoke/person detection (TFA-tech-05)

Running on the edge:

- SV-tech-01 captures video frames in real time and pushes them (in any format) to TFA-tech-05.
- TFA-tech-05 accepts as input:
  - Video frames: A sequence of video frames (any format).
- TFA-tech-05 detects objects (e.g., fire sources, smoke, persons, cars etc.) on video frames in real time on the edge, assigning each detected object of a frame with a given frame ID, a unique object ID. For each video frame n objects can be detected. Each of the detected instances is represented by a unique ID, a string label indicating the type of detected object ("fire", "smoke", “person”, “car”, etc.) and a tuple representing the pixel coordinates (x, y, h, w) of the bounding box around the detected object. x and y are the pixel coordinates of the top-left corner of the bounding box, and h and w are the height and width of the bounding box, respectively. The results, along with optional drone location, camera, and gimbal parameters, are returned as a JSON object for interoperability with other technologies.
- TFA-tech-05 forwards to SV-tech-02 a JSON object containing a dictionary containing the processed video frames’ metadata and the detected objects on each video frame.

Path for the visualization on georeferenced map:

- SV-tech-02 pushes the outputs of TFA-tech-05 to PDM-tech-05 in order to be georeferenced and fused with the outputs of relative technologies processing different types of data (e.g., satellite images, wind sensors etc.)
- The fused information is forwarded to SV-tech–04 for the retrieval of geospatial information (e.g., proximity of fire to residential areas).
- SV-tech-06 merges the geospatial information retrieved by SV-tech-04, the georeferenced information extracted by PDM-tech-05 and the 3D model generated by SV-tech-03 to produce an XR-based visualization system.
- The output of SV-tech-06 is forwarded to SV-tech-07 for interactive visualization.

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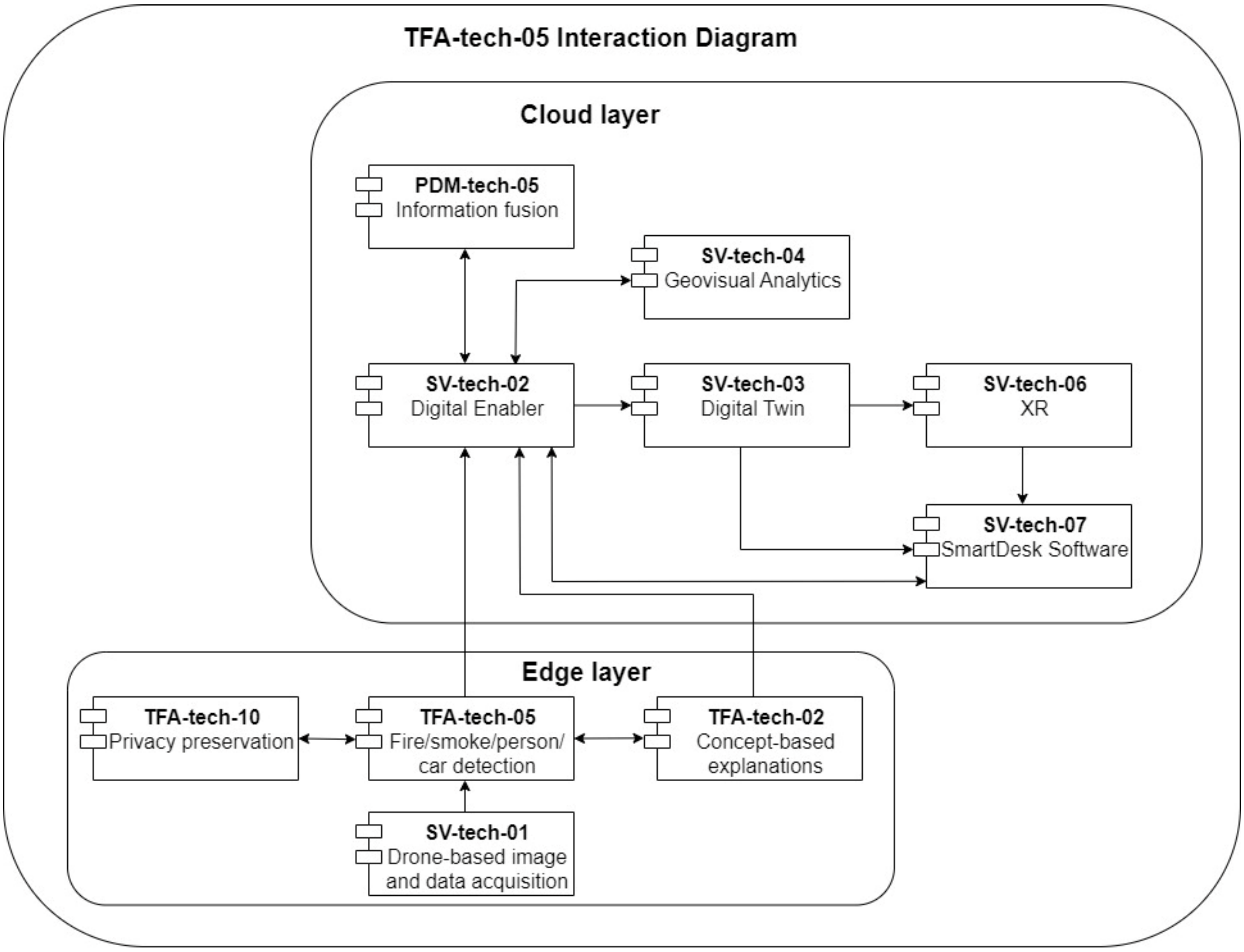

Fire/flood/background segmentation (TFA-tech-06)

Running on the edge:

- SV-tech-01 captures video frames in real time and pushes them (in any format) to TFA-tech-06.
- TFA-tech-06 accepts as input: Video frames, A sequence of video frames (any format).
- TFA-tech-06 segments image regions based on semantics. The results are either returned as image (any format), or as polygon pixel coordinates in .json file.
- TFA-tech-06 forwards the image and/or the .json file to SV-tech-02.

Path for the visualization on georeferenced map:

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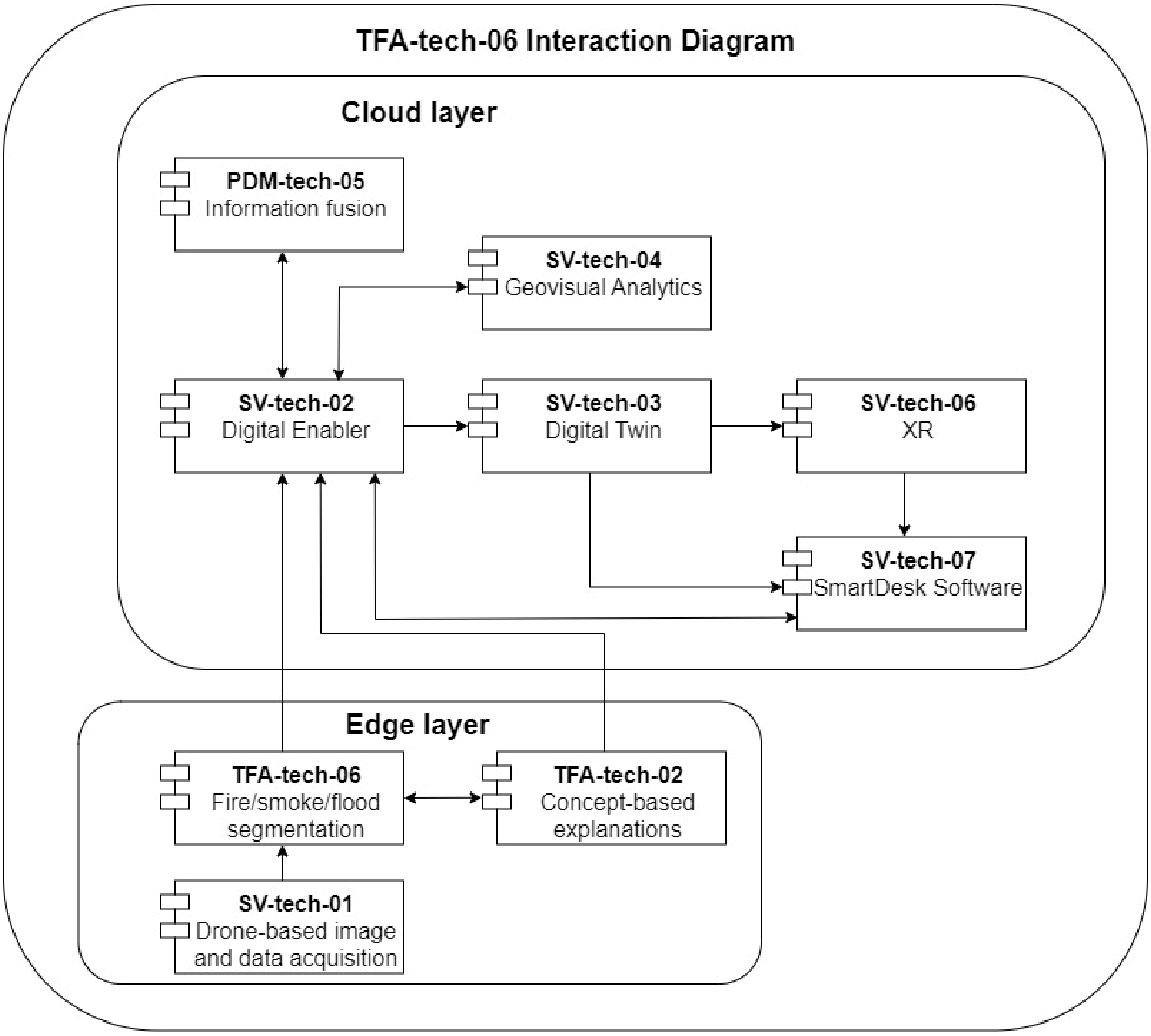
- SV-tech-02 pushes the outputs of TFA-tech-06 to PDM-tech-05 in order to be georeferenced and be fused with the outputs of relative technologies processing different types of data (e.g. satellite images,wind sensors etc.)
- The fused information is forwarded to SV-tech–04 for the retrieval of relative geospatial information such as the proximity of residential areas.
- SV-tech-06 merges the georeferenced map generated by SV-tech-04 and the 3D model generated by SV-tech-03 to produce an XR-based visualization system.
- The output of SV-tech-06 is forwarded to SV-tech-07 for interactive visualization.



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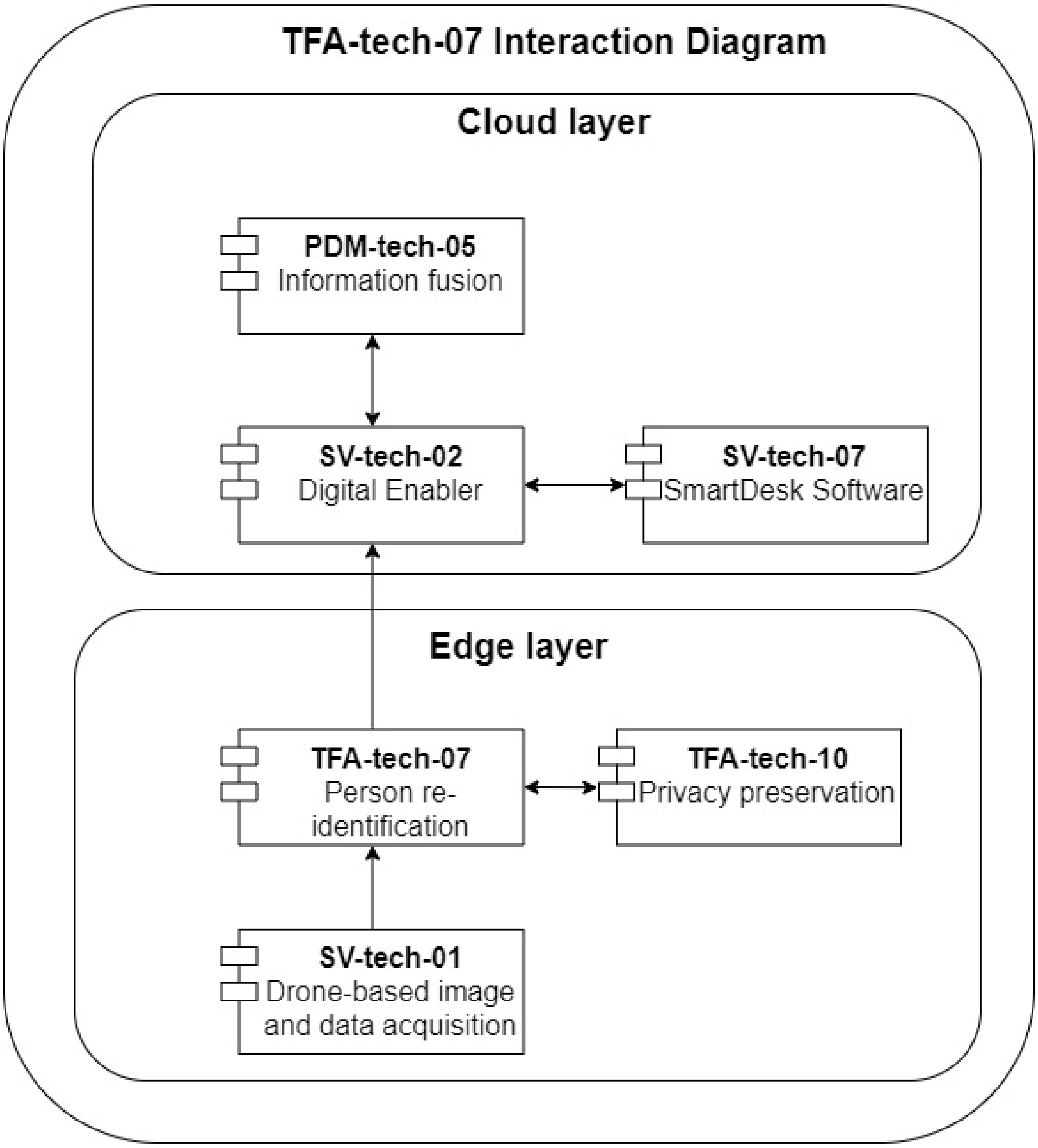
Person re-identification (TFA-tech-07

Running on the edge:

TFA-TECH-07 receives as an input a video stream through SV-TECH-01.

TFA-TECH-07 will detect and track persons on the video while generating the bounding boxes, Ids, and tracks of every detection on the scene. This information will be the output of TFA-TECH-07 sent to TFA-TECH-10 to anonymize any personal information. Afterwards, through SV-TECH-02 it will be sent to PDM-TECH-05 for information fusion and to SV-TECH-07 for visualization.



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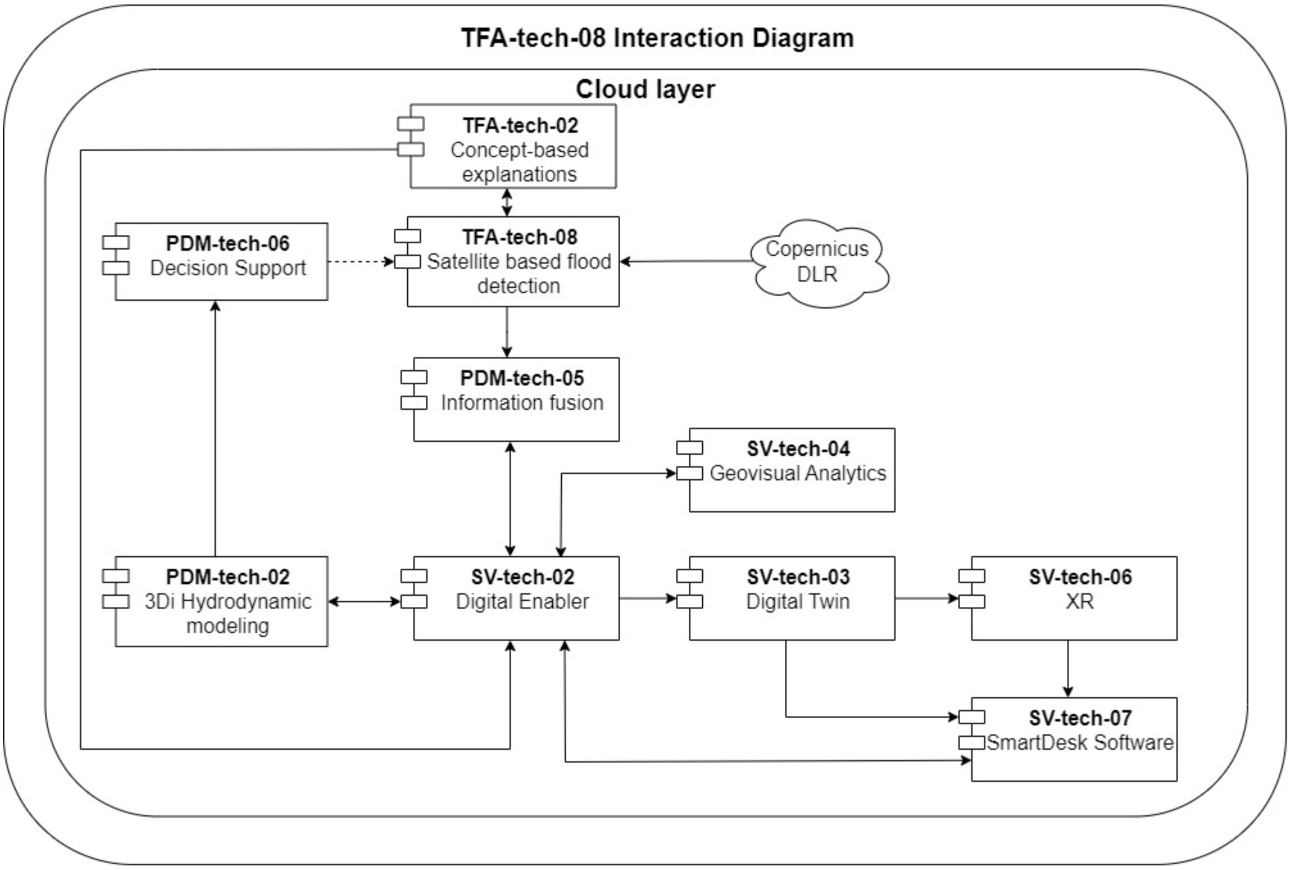
Flood Processor (TFA-tech-08)

Component TFA-tech-08 (Flood Processor) is responsible for analysing satellite images provided through the Copernicus Data Space Ecosystem (CDSE) and the DLR receiving station using direct broadcast mode as well as aerial images from drones provided through component SV-tech-02 (Digital Enabler). Components PDM-tech-02 (Hydrodynamic Modelling/ Flood Simulation) and PDM-tech-05 (Information Fusion) retrieve from the Flood Processor over its API flooded areas, permanent water and secondary products. Detected objects (e.g., vehicles, buildings) are provided as GeoJSON. Components SV-tech-06 (XR Visualization) and SV-tech-07 (Smart Desk) visualize the results of the Flood Processor. PDM-tech-06 (Decision Support) may trigger the flood processing for a specific AOI. TFA-tech-02 (Concept-based explanations) will be integrated with the model used by the Flood Processor (way of integration TBD).



Input:

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- Sentinel-1 (SAR) and Sentinel-2 (multi-spectral) satellite images (from Copernicus and/or DLR)
- On-demand aerial VHR optical data such as drone images (from SV-tech-02)
- Tasking request (from PDM-tech-06)

Output:

- Flood extents (GeoTIFF)
- Permanent water (GeoTIFF)
- Flood duration and frequency (GeoTIFF)
- Detected objects (vehicles and buildings) (GeoJSON)

Procedure:

1. The Flood Processor acquires from Copernicus/DLR satellite imagery of the sensors Sentinel-1 Ground Range Detected (GRD) and Sentinel-2 MSI
2. The Digital Enabler sends to the Flood Processor on-demand aerial VHR optical data such as drone images
3. The Flood Simulation, Information Fusion, XR Visualization and Smartdesk components retrieve from the Flood Processor flooded areas, permanent water and secondary products in GeoTIFF format through OGC Web Map Service (WMS) and STAC. Detected objects (vehicles and buildings) are provided in GeoJSON format.

Recipients:

The output is provided through OGC Web Map Service (WMS) and a STAC API and/or is sent directly to a receiver:

- PDM-tech-02 (Flood Simulation)
- PDM-tech-05 (Information Fusion)
- SV-tech-06 (XR Visualization)
- SV-tech-07 (Smartdesk)

End User Functional Requirements (D2.1):

- EU-RQ-NF-01 (The technology used in cases of ND needs to be clean and simple to use)
- EU-RQ-NF-03 (Information provision as soon as possible)
- EU-RQ-FUNC-01 (Information to define event area and extent)

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- EU-RQ-FUNC-03 (Monitor the development, the size of the affected area)
- EU-RQ-FUNC-11 (Available water extinguishing resources from nearby swamps, ponds etc.)

Burnt Area Processor (TFA-tech-09)

Component TFA-tech-09 (Burnt Area Processor) is responsible for analysing satellite images provided through the Copernicus Data Space Ecosystem (CDSE) and the DLR receiving station using direct broadcast mode as well as aerial images provided through component SV-tech-02 (Digital Enabler). Component PDM-tech-05 (Information Fusion) retrieves from the Burnt Area Processor component burnt areas and burn severity and fuses them with other TEMA data products. Components SV-tech-06 (XR Visualization) and SV-tech-07 (Smart Desk) visualize the results of the Burnt Area Processor. PDM-tech-06 (Decision Support) may trigger the burnt area processing for a specific AOI (TBD). TFA-tech-02 (Concept-based explanations) will be integrated with the model used by the Burnt Area Processor (way of integration TBD).

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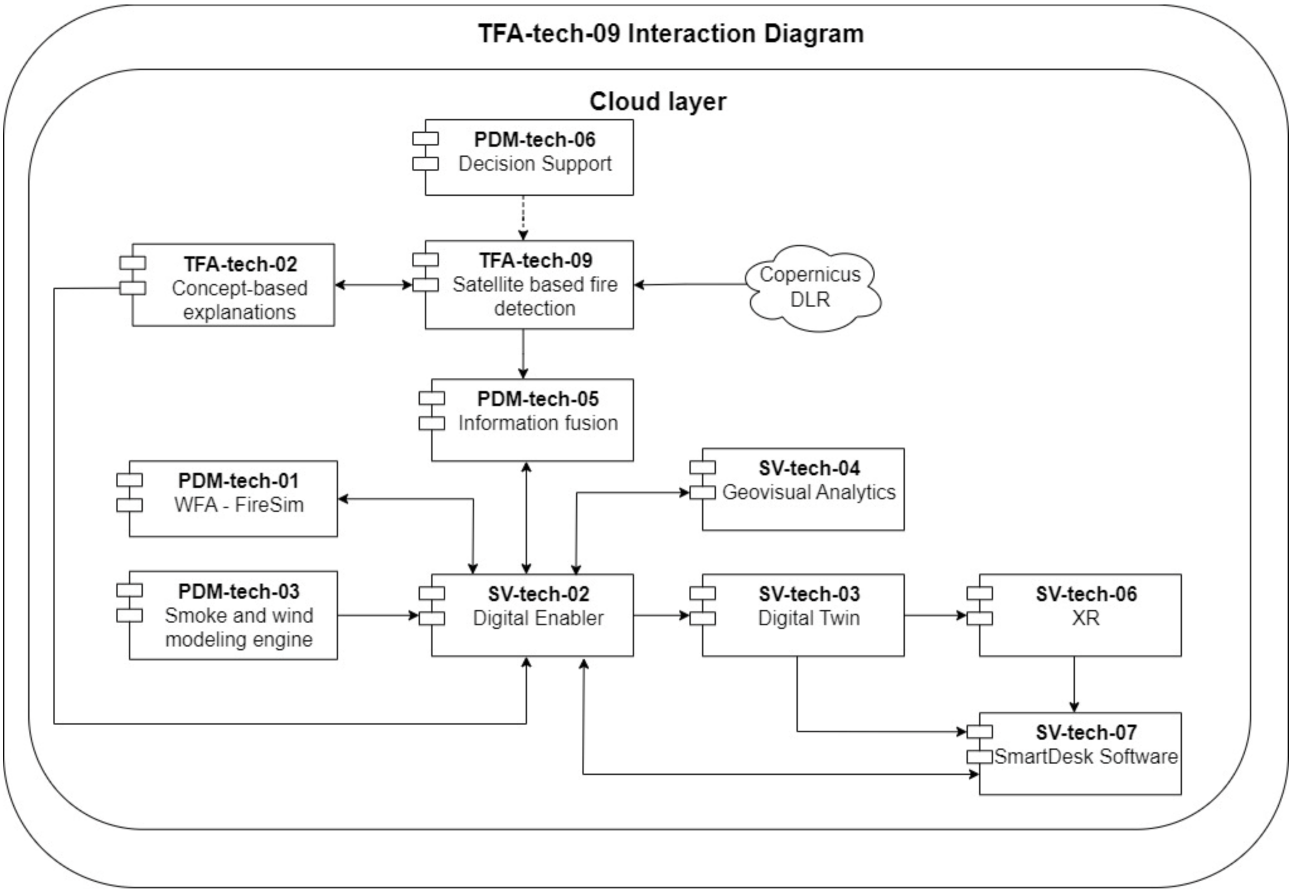

Input:

- Aqua/Terra MODIS, Sentinel-3 OLCI and Sentinel-2 MSI (multi-spectral) satellite images (from Copernicus and/or DLR)
- On-demand aerial optical data (from SV-tech-02)
- Tasking request (from PDM-tech-06)

Output:

- Burnt area extents, subdivided into regions with fire severity information (GPKG)

Procedure:

1. The Burnt Area Processor acquires satellite imagery of Sentinel-3 OLCI and Sentinel-2 MSI sensors through Copernicus Data Space Ecosystem and of Aqua/Terra MODIS sensors through DLR receiving stations.

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2. The Digital Enabler sends on-demand aerial VHR optical data such as drone images to the Burnt Area Processor

3. The Information Fusion, XR Visualization and Smartdesk components retrieve burnt areas and burn severity from the Burnt Area Processor through OGC WFS and GPKG interfaces.

Recipients:

The output is provided through OGC Web Map Service (WMS) and a STAC API and/or is sent directly to a receiver:

- PDM-tech-05 (Information Fusion)
- SV-tech-06 (XR Visualization)
- SV-tech-07 (Smartdesk)

End User Functional Requirements (D2.1):

- EU-RQ-NF-01 (The technology used in cases of ND needs to be clean and simple to use)
- EU-RQ-NF-03 (Information provision as soon as possible)
- EU-RQ-FUNC-01 (Information to define event area and extent)
- EU-RQ-FUNC-03 (Monitor the development, the size of the affected area)

Privacy preservation during visual analysis (TFA-tech-10)

Privacy preservation for deep neural networks, especially concerning visual data, primarily revolves around the use of blurring and masking techniques. These methods are employed to obscure sensitive elements in images or videos, such as faces, license plates, and other personally identifiable information. Blurring applies a filter to reduce the clarity of specific regions in the visual data, making identification of individuals or specific objects difficult. Masking, on the other hand, involves overlaying a portion of the image with a shape or pattern, effectively hiding the underlying details. These techniques are critical in scenarios where drones or surveillance cameras capture real-time visuals of disaster-affected areas. The altered visual data ensures that while the neural networks can analyze and learn from the situation for improved disaster response and management, the privacy of individuals within the captured data is maintained, preventing potential misuse or violation of personal privacy rights.

Running on the edge:

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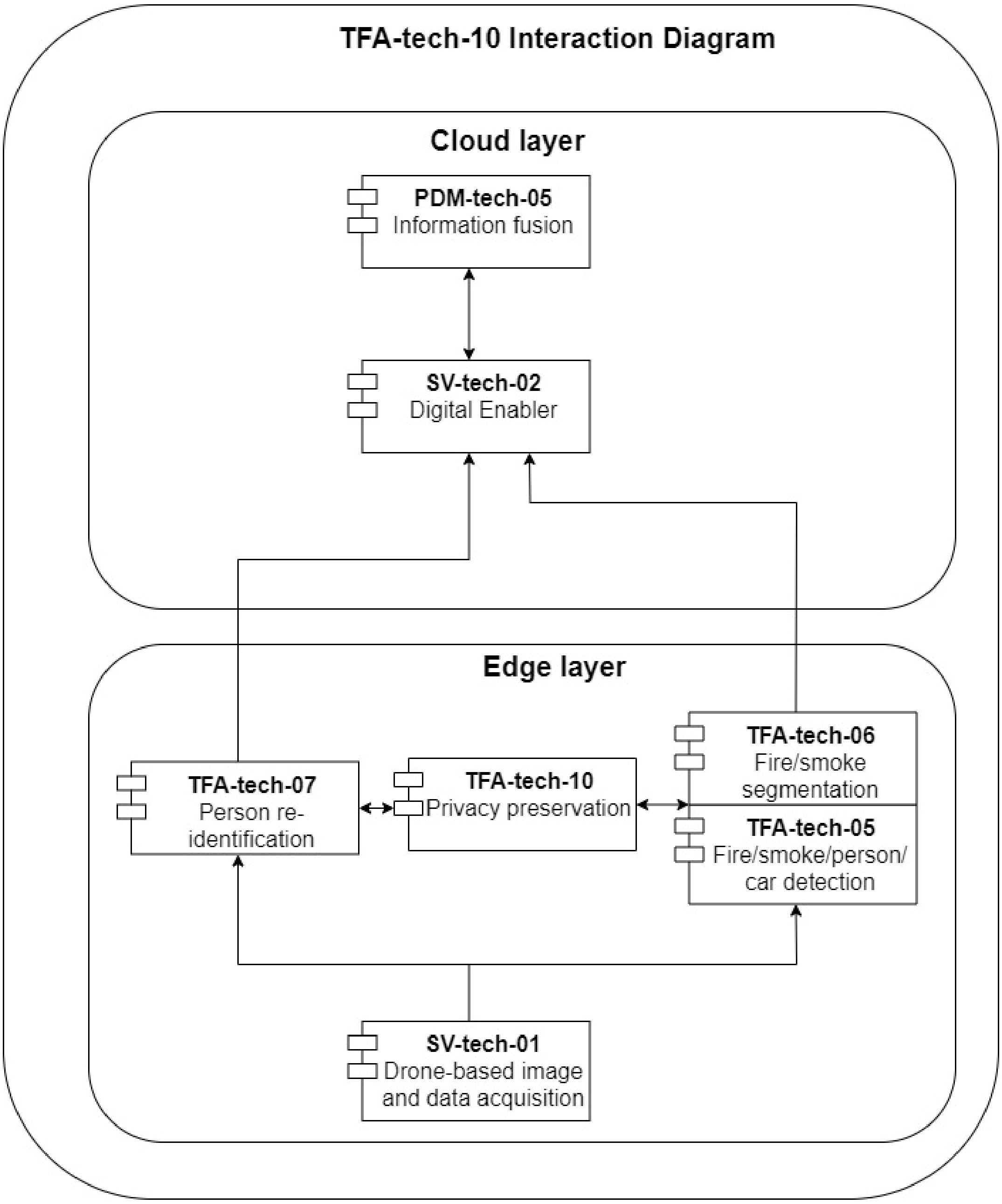
- TFA-tech-10 accepts as input the drone images captured by SV-tech-01 and the detected objects exported from TFA-tech-05 and TFA-tech-07.
- TFA-tech-10 generates blurring masks on faces, car plates etc. to ensure privacy.
- TFA-tech-10 forwards its results to SV-tech-02.



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Geo-social media analysis (TFA-tech-11)

Social media platforms can provide manifold information in different modalities (text, imagery, location) in near-real time. Most importantly, TEMA uses georeferenced social media posts, i.e., posts with a geographic position (e.g., GPS) attached, which adds information about the geographic context of a post.

For use in disaster management, this huge pool of data has to be filtered. This is done by 1.) identifying semantic topics that are related to a disaster, and 2.) by multi-dimensional relevance classification, i.e., taking spatial, temporal and semantic relevance into account.

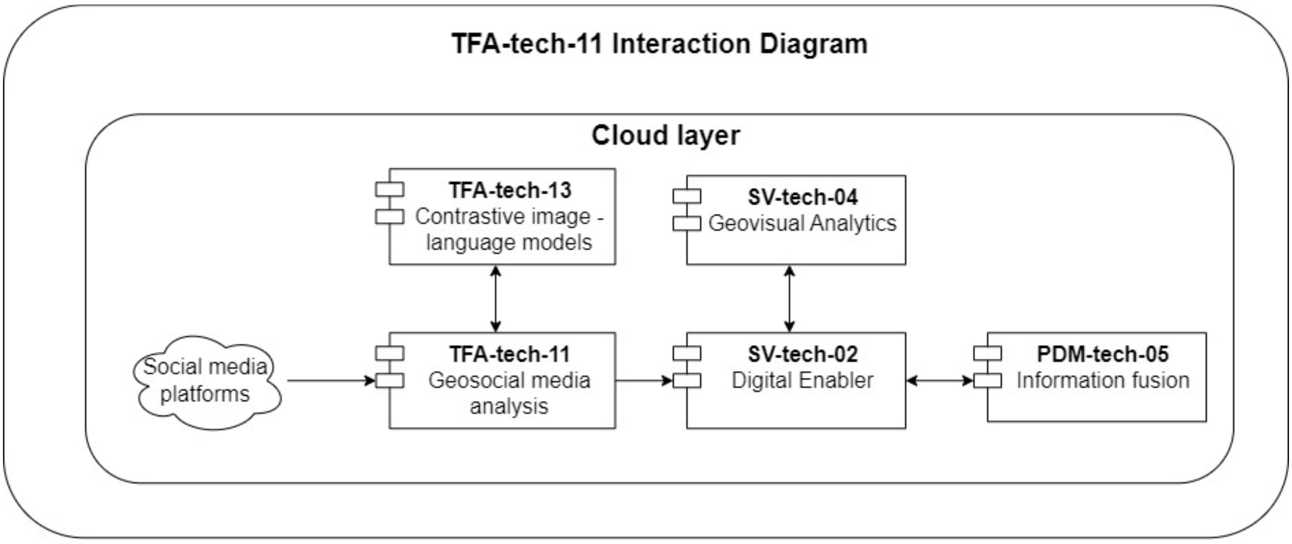
Based on the textual content, hotspots of affected areas can then be detected, using state-of-the-art machine learning and geostatistical methods.

Furthermore, sentiment analysis algorithms provide information about how severely people and geographic areas are affected by a disaster and how people feel in the disaster area (desperate, contained, hopeful, etc.).

The system will use the outputs of these analyses, which can be provided as diverse geodata formats (e.g. GeoJSON, WFS). Data from a PostgreSQL / PostGIS database is envisaged as input.

The diagram below illustrates the interactions with the other components.

Broad view:



Detailed view:

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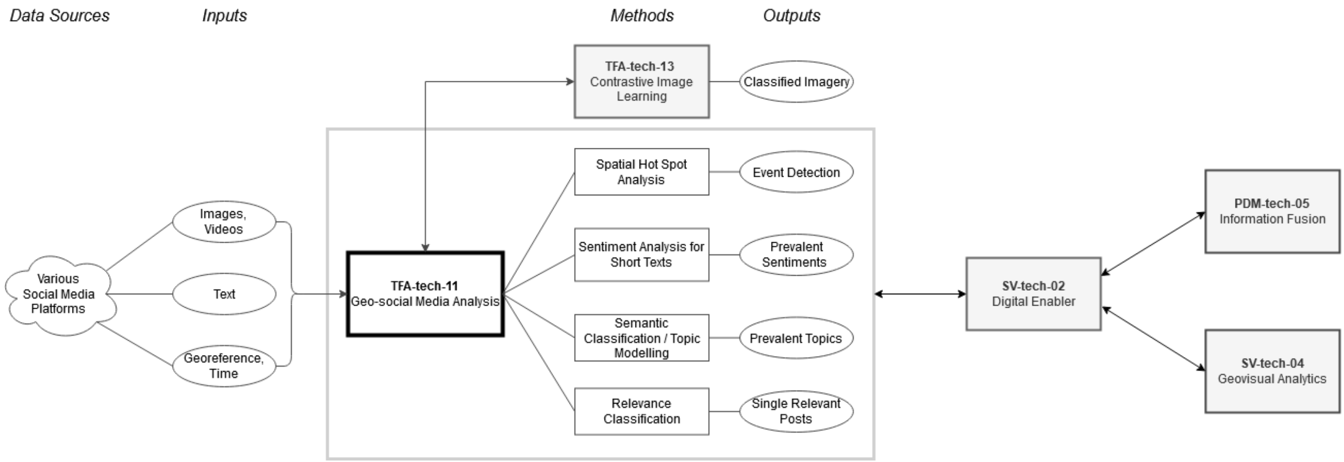

- The outputs of TFA-tech-11 will be fed to contrastive image learning (TFA-tech-13).
- The output of the respective analyses acts as input to information fusion (PDM-tech-05) and data-fusion-based decision support and process triggering (PDM-tech-06). The outputs can also be fed in SV-tech-04 (Geovisual Analytics) and visualised in SV-tech-07 (Smart desk).

Contrastive image-language models (TFA-tech-13)

Running on the cloud:

- TFA-TECH-13 receives as an input an Image to be analyzed from TFA-TECH-11 and the corresponding text.
- Through contrastive image-language models TFA-TECH-13 generates an automatic text description of the image. Then proceeds to calculate the similarity from the input text and the description generated. Both the description and the similarity results are sent to TFA-TECH-11 for further analysis.

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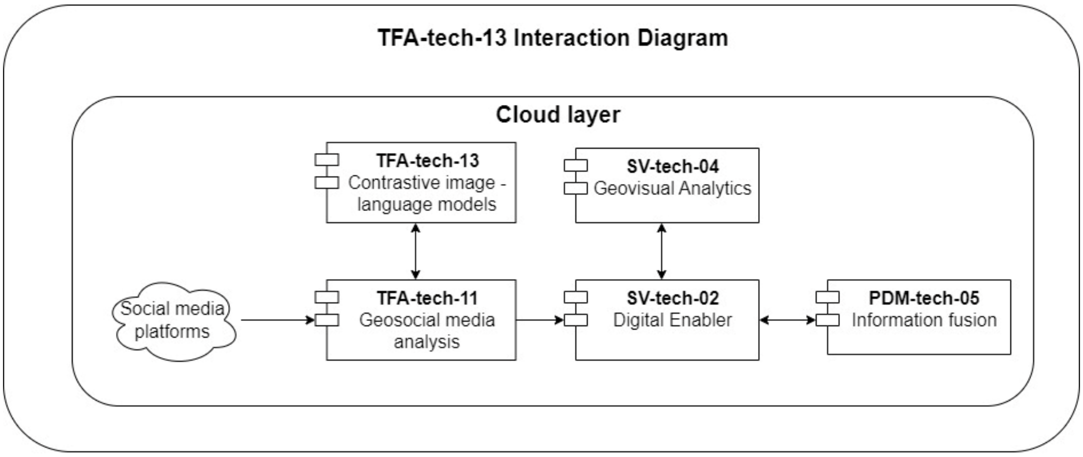

WildFire Analyst - Forest Fire Simulation (PDM-tech-01)

Components interaction overview:

The external sensor sends information to the Digital Enabler. This component interacts with the Context Broker when new information is received, so the Context Broker notifies WildFire Analyst - FireSim about the availability of new information (fire location, in-situ weather). WildFire Analyst - FireSim obtains the new data to run new simulations (new simulations or reruns with updated data). Finally, the new simulation outputs are sent to the display and analysis platforms.

Components with which the technology interacts

- TFA-tech-05: Fire/smoke/flood/person detection
- TFA-tech-06: Fire/flood/background segmentation
- TFA-tech-09: Satellite-based Forest fire detection and assessment
- PDM-tech-03: Realistic 3D smoke modelling and fire detection
- SV-tech-01: Drone-based image and data acquisition. Responsible for acquiring images and other data from the drones

The aforementioned technologies are responsible for detecting fire locations. Useful for setting initial ignition geometries (point(s)/line(s)) or fire fronts to update ignition geometries in updated simulations.

- SV-tech-02: Digital Enabler. Responsible for transforming all the data sources into meaningful information accessible through user interface and standard APIs
- SV-tech-04: Geovisual Analytics. Responsible for rapid retrieval of large-scale geospatial data using in-memory technologies to perform spatial data processing

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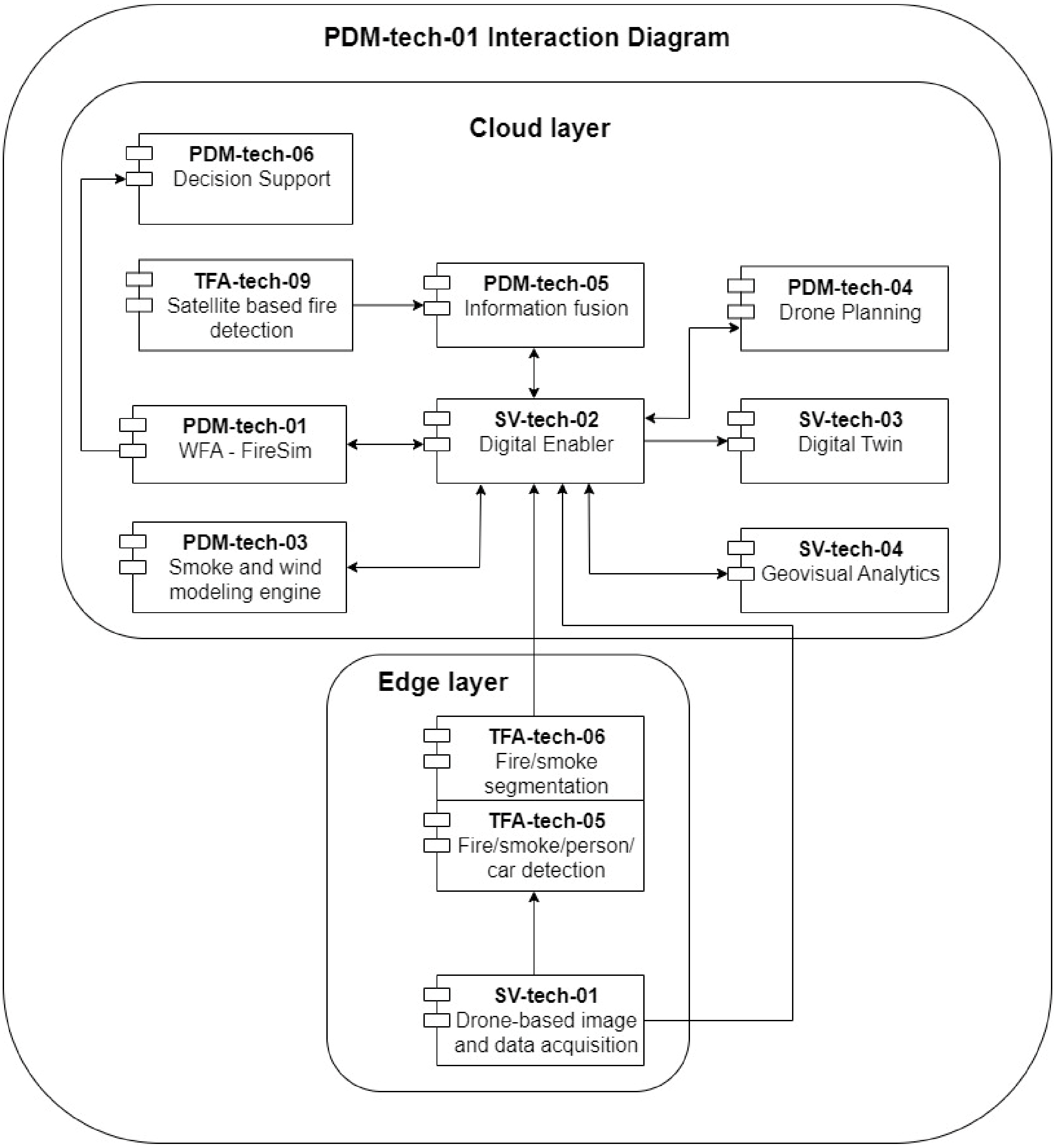
- SV-tech-06: Extended Reality-based interactive visualization system. Responsible for gathering and displaying simulation results data.
- SV-tech-07: Smart desk. Responsible for creating a user-friendly interface with touch controls.
- PDM-tech-04: Drone planning. Uses the simulation results to update the flying plan.
- PDM-tech-05: Information fusion. Combines all types of information, including fire simulation results, to produce useful maps for operational purposes.
- PDM-tech-06: Data-fusion-based decision support and process triggering

The main interactions between components are shown in the diagram below:



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Information flow:

1. Remote sensing, fire detection/ segmentation and in-situ weather data from drone and other sensors is sent to the Digital Enabler component.
2. The Context Broker identifies the availability of new data.
3. The Context Broker notifies WFA-FireSim API about the availability of new data.
4. WFA - FireSim API obtains the new ignitions/fire fronts position and in-situ weather data available from the Digital Enabler.

If the Digital Enabler needs to work on demand, periodical requests for new data could be sent from WFA-FireSim API.

5. WFA-FireSim API calculates the new fire simulations and sends the results to the selected display and analysis platforms.

Flood Simulation - 3Di Hydrodynamic (PDM-tech-02)

TFA tech-05 is responsible for retrieving drone-based images or videos and flood bounding boxes and class labels of floods.

TFA tech-06 translates drone-based images to segmentation maps for flood extents.

TFA tech-08 monitors floods continuously, detects objects and flood extents in very high resolution on an ad-hoc basis.

PDM tech-02 is the 3Di flood simulation software, which can make predictions about the progress of the flood extents, the water depths by processing data coming from A, B and C. It also uses weather station data to set up the models and a real-time scenario.

PDM tech-04 uses flood simulation data to pinpoint areas of interest that need to be covered by real-time images of drones. As such, they plan or propose trajectories for the drones in the affected areas. Processed through the DE (SV tech-02).

PDM tech-05 combines flood simulation data with different sources of information to obtain an accurate monitoring of floods. We receive ground-truth map data (blocked roads, damaged bridges, houses etc.) back from Digital Enabler (SV tech-02) which has the processed results from SV tech-01 (drones based acquisition).

PDM tech-06 processes flood simulation data and integrates the data with other data in a data-fusion product that supports decisions about early remote sensing data acquisition.

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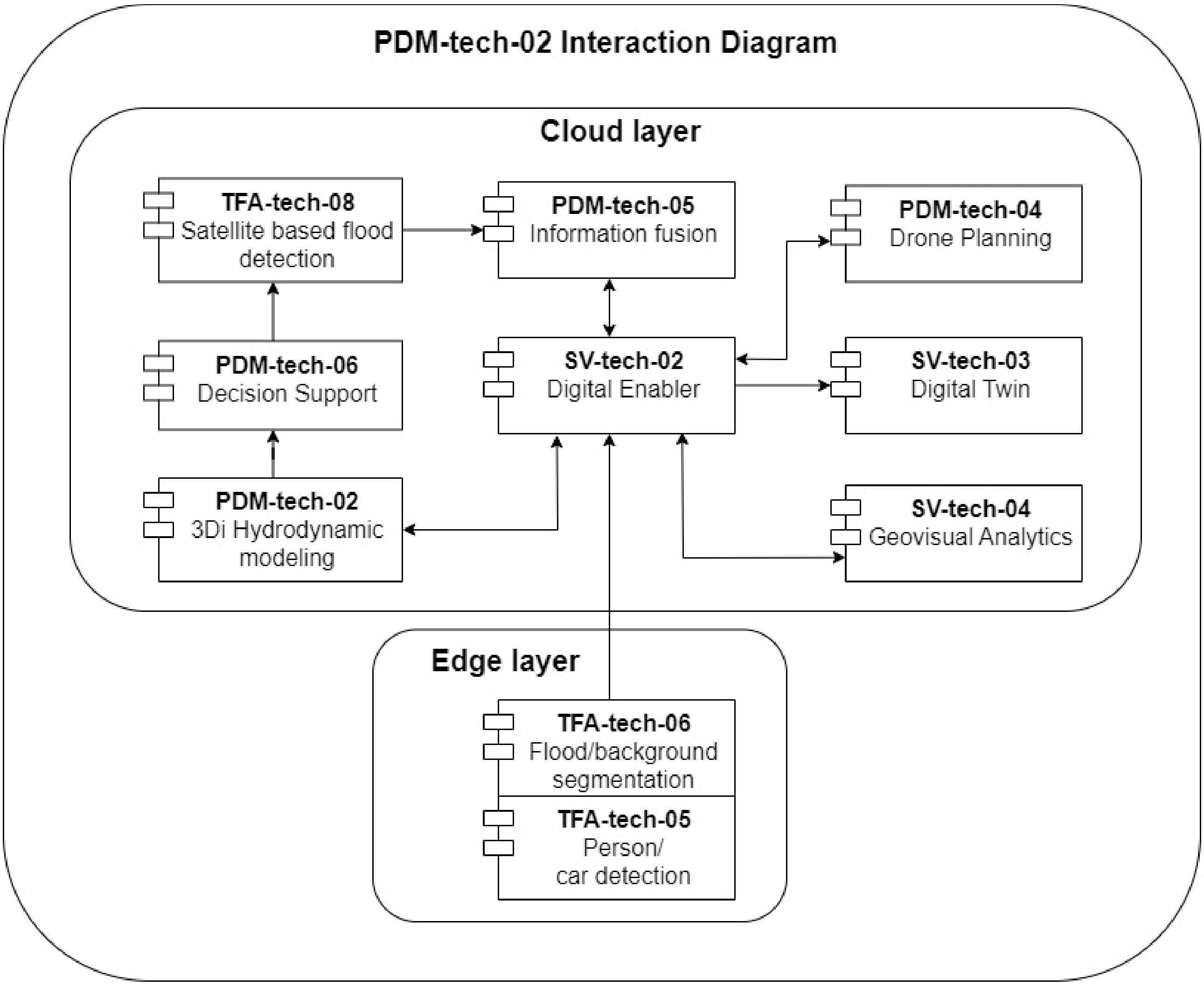
SV tech-02 is the digital enabler that receives flood simulation data and processes the data to generate a harmonized data output.

SV tech-04 integrates geospatial flood simulation data to perform spatial data processing. Processed through the DE (SV tech-02) SV tech-06 merges flood simulation data in an intuitive and easy-to-understand XR-based application with complementary desktop GUI.

Processed through the DE (SV tech-02) and digital twin (SV-tech-03). SV tech-07 visualizes flood maps in SmartDesk (through DE - SV tech-02) and digital twin (SV-tech-03).



1) TFA tech-08 via PDM-tech-05 (information fusion) sends to PDM tech-02 flood extents and area of interest in GeoTIFF format as well as detected objects (vehicles, buildings etc.) in GeoJSON format through OGC WMS web services.
2) TFA tech-05 sends via SV tech-02 the bounding boxes of flood extents in JSON format (text

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files) to PDM tech-02.

3) TFA tech-06 sends via SV tech-02 the segmentation background maps in image files to PDM-tech-02.
4) PDM tech-02 sends flooding simulation map results (water depths, flood extents etc.) in GeoTIFF format and/or vector data (flowlines, velocities etc.) as polyline GeoJSON files to PDM tech-06.
5) PDM tech-02 sends flooding simulation map results (water depths, flood extents etc.) in GeoTIFF format and/or vector data (flowlines, velocities etc.) as polyline GeoJSON files via SV tech-02 to PDM tech-04.
6) PDM tech-02 sends flooding simulation map results (water depths, flood extents etc.) in GeoTIFF format and/or vector data (flowlines, velocities etc.) as polyline GeoJSON files via SV tech-02 to SV tech-04.
7) PDM tech-02 sends flooding simulation map results (water depths, flood extents etc.) in GeoTIFF format and/or vector data (flowlines, velocities etc.) as polyline GeoJSON files via SV tech-02 and SV-tech-03 to SV tech-06.
8) PDM tech-02 sends flooding simulation map results (water depths, flood extents etc.) in GeoTIFF format and/or vector data (flowlines, velocities etc.) as polyline GeoJSON files via SV tech-02 and SV-tech-03 to SV tech-07.

3D smoke modelling and fire detection (PDM-tech-03)

Component PDM-tech-03 (Realistic 3D smoke modelling and fire detection) addresses aspects relevant to modelling of smoke propagation and identification of possible fire hotspots based on the detections of smoke in the air. The modelling engine utilizes a model-based approach that represents phenomenon of interest – wind and smoke in the air – using mathematical models based on partial differential equations. The data collected by the drones (in visual and non-visual domains), along with selected prior information, is used in a numerical optimization framework to compute a numerical representation of the 3D smoke and wind dynamics. The diagram below illustrates the described interactions in more details.

The very nature of the underlying inverse estimation problem implies ill-posedness. The corresponding numerical solution would typically require regularization or additional constraints that would guarantee a solution. These constraints can often be provided through prior information that would restrict the set of solutions. For this purpose, PDM-tech-03 relies on input from several components. Specifically, SV-tech-03 provides accurate area digital elevation information that can be used for constraining air and smoke flow in 3D through; essentially, it provides boundary conditions for the numerical solver.

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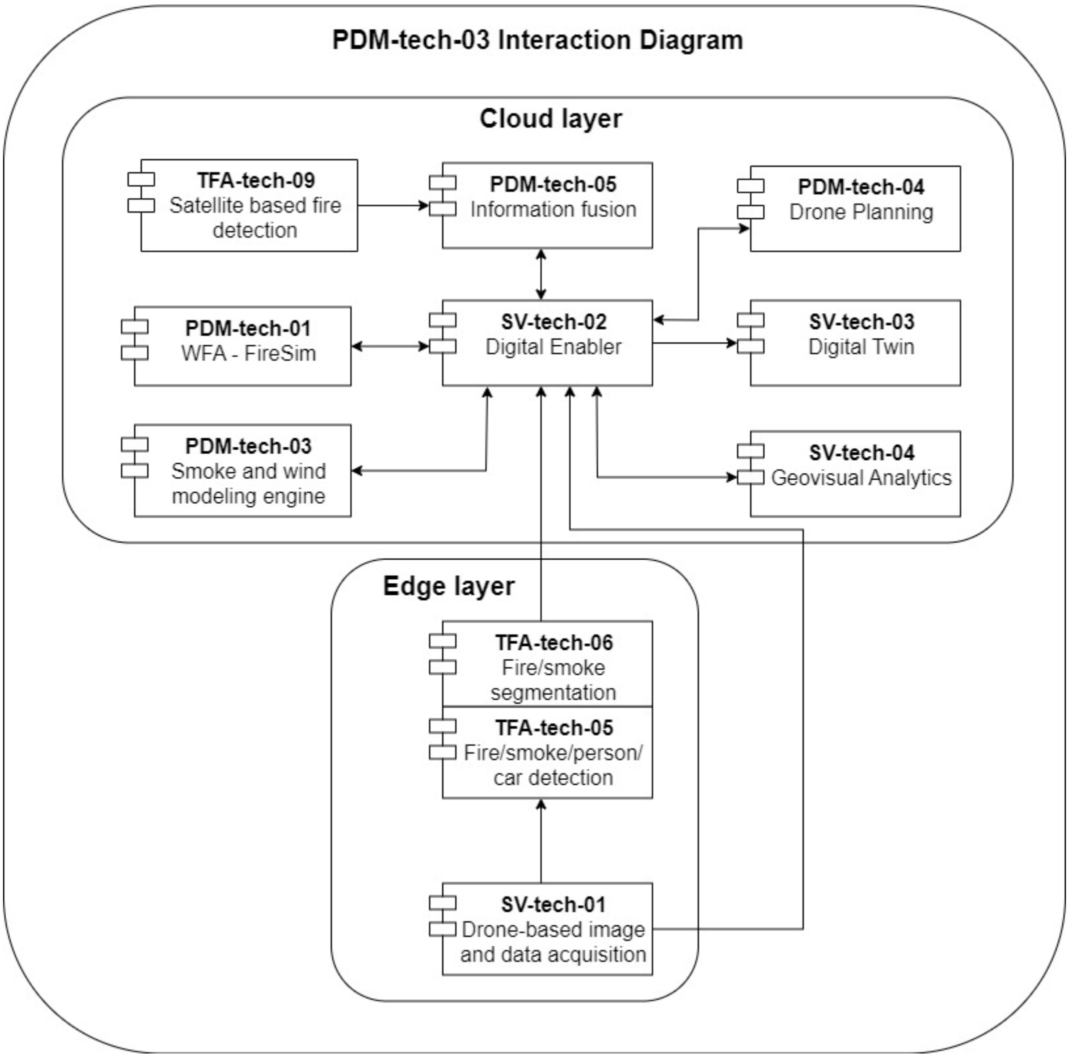

Technologies TFA-tech-05 and TFA-tech-06 both use KI methods for detection of the smoke and segmentation of fire and background using information from the visual domain. These data again can be used to equip a solver with possible locations of the fire or fire hotspots, or extent of the smoke, which again can be used as boundary or initial conditions for the solver. Finally, PDM-tech-01 supplies predictions or fire intensities directions, which can be used to identify possible fire spread directions and further optimize discretization of the area of interest, resulting in higher accuracy in areas where fire is potentially more probable under current weather conditions.

The results of the numerical evaluations, and specifically digital 3D voxel maps of the smoke concentration, as well as 3D wind directions, subject to the above identified constraints, are then numerically computed on the edge using computing resources of several drones. The online computation is needed to generate optimal sampling points, which is the further input into PDM-tech-04. This should allow capturing smoke dynamics more efficiently. The role of PDM-tech-04 is to produce trajectories and get a confirmation from the end user/operator to execute them. The decision is then forwarded to PDM-tech-03 for execution through digital enabler. The resulting

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numerical models are then visualized through digital twin of the event in SV-tech-06 or SmartDesk PDM-tech-07 or fused with other sources of information in PDM-tech-05. Furthermore, it is also used to adjust the fire simulator and thus as an input in PDM-tech-01. Detections of the fire nests based on the sensed smoke can also be used to trigger actions through PDM-tech-06.

Flow of the information:

Note that the information exchange between our PDM-tech-03 and other components is realized exclusively through the Digital Enabler SV-tech-02.

1. The PDM-tech-03 acquires from input of the prior information and/ or input from operator concerning area of interest for search.

2. By collecting the data using on-board sensors, several actions can take place:

    2.1 wind models are computed based on information from drones and ground stations.

3. If smoke has been already detected, then numerical models of wind and smoke models are evaluated. These models can then be sent over the corresponding interface (digital Enabler SV-tech-02) to SV-tech-06, PDM-tech-05, PDM-tech-01)

    3.1 using the numerical models new optimal sampling points are identified, which are then provided to PDM-tech-04 and executed by the drones.

Drone Planning (PDM-tech-04)

This technology is running on the cloud, and it is responsible for optimally planning the trajectories of drones. Drone planning needs flight maps (external) and inputs maps from: forest fire simulation (PDM-tech-01), flood simulation (PDM-tech-02), smoke simulation (PDM-tech-03), and phenomenon current status from information fusion (PDM-tech-05). Drone planning outputs optimal drone plans that will be shown to human on smart desk (SV-tech-07) and XR visualization system (SV-tech-06). The planning is started by the Smart Desk (SV-tech-07), which can also send requests to Drone Planning.

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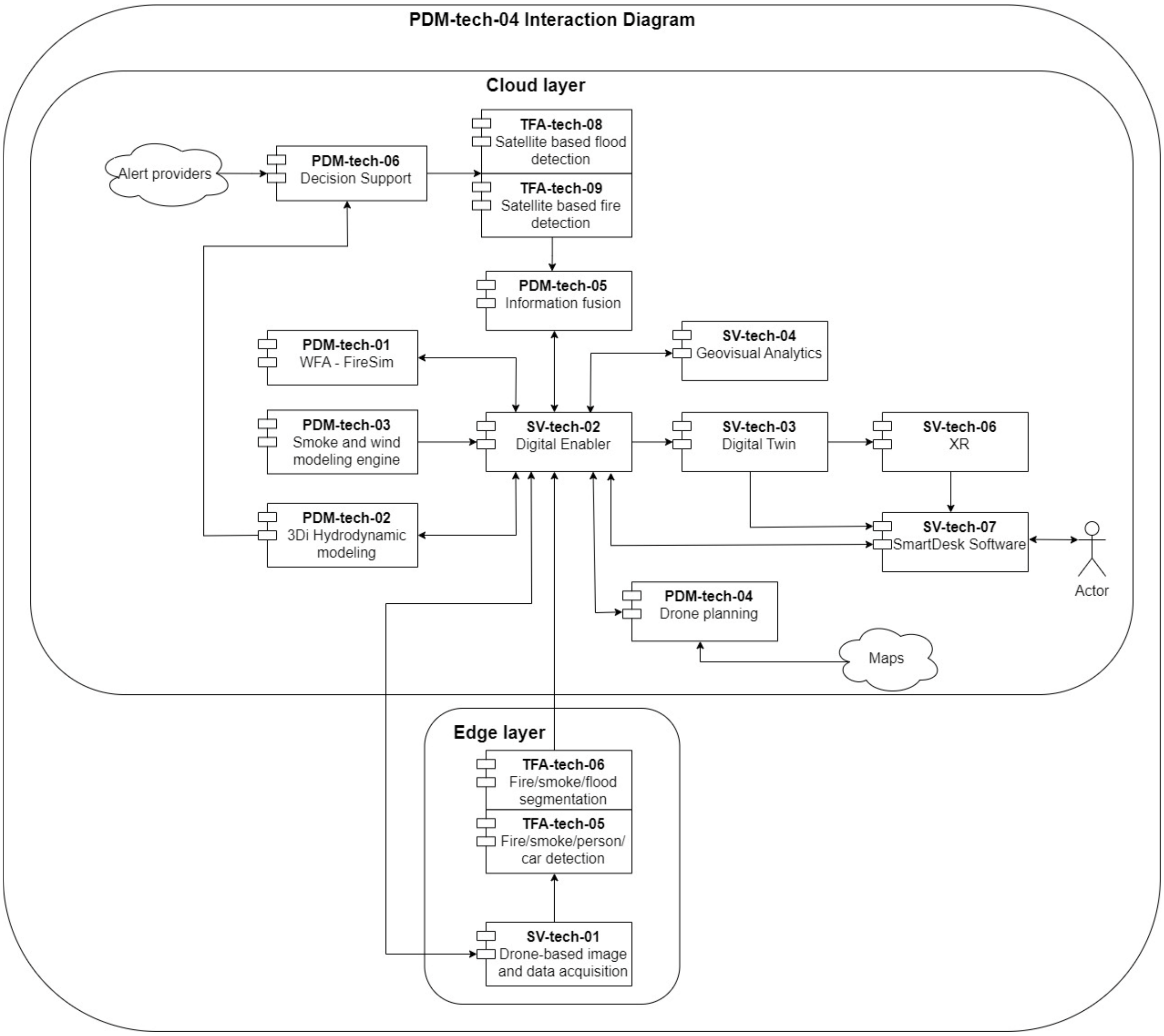

Sequence of interactions:

· Drone planning acquires flight maps (external).

· Smart Desk (SV-tech-07) requests to compute the drone plans.

· Drone planning receives maps with the forest fire simulation (PDM-tech-01), flood simulation (PDM-tech-02), smoke simulation (PDM-tech-03), and phenomenon current status (PDM-tech-05) through the Digital Enabler (SV-tech-02)

· Drone planning computes drone trajectories and sends them to Smart Desk (SV-tech-07) through the Digital Enabler (SV-tech-02)

· Smart Desk (SV-tech-07) shows the trajectories to human, which confirms them or not.

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· Smart Desk (SV-tech-07) sends the confirmed trajectories to the Drone-based image and data acquisition (SV-tech-01) for execution.

Information fusion (PDM-tech-05)

Information fusion combines different data sources to obtain an accurate monitoring of the forest fire or flood.

Information fusion uses as input -through the Digital Enabler (SV-tech-02)- the result of the processing of the different data sources:

- result of drone-collected image processing: Fire/smoke/flood/person detection (TFA-tech-05), Fire/smoke/background segmentation (TFA-tech-06), Person re-identification (TFA-tech-07).

- result of processing of satellite images: Satellite-based flood detection and assessment (TFA-tech-08) and Satellite-based Forest fire detection and assessment (TFA-tech-09),

- result of Sentiment analysis for short texts (TFA-tech-12) and Geo-social analysis (TFA-tech-11)

- result of realistic smoke modelling and fire detection (PDM-tech-03),

Information fusion outputs -through the Digital Enabler (SV-tech-02)- the phenomenon status (map) is sent to Drone Planning (PDM-tech-04), to the Wildfire simulator (PDM-tech-01) and flood simulator (PDM-tech-02) to enable refinement of simulation results, and also for visualization in the Extended Reality-based interactive visualization system (SV-tech-06) and the Smart Desk (SV-tech-07).

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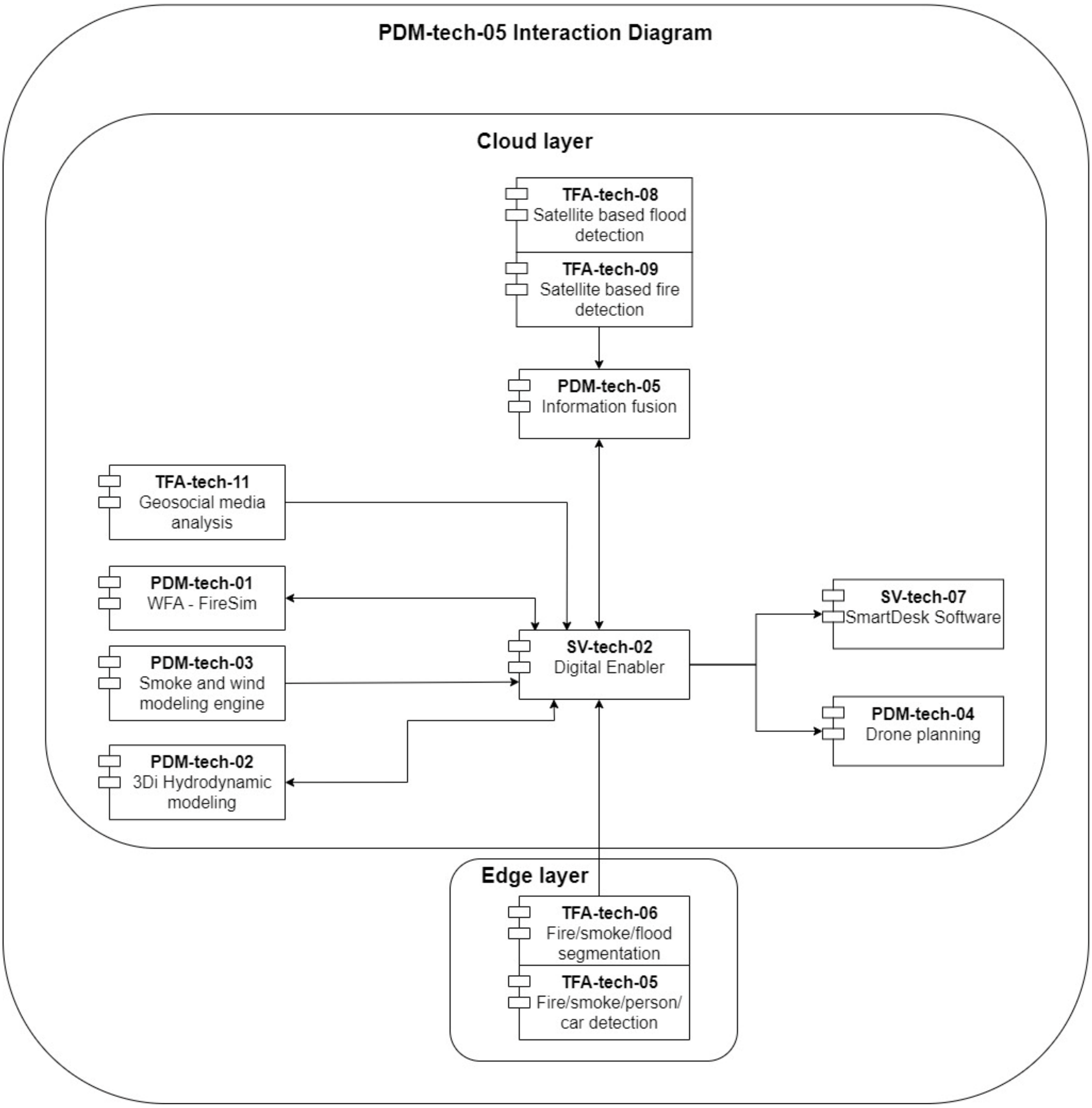

Sequence of interactions:

- Information fusion collects through the Digital Enabler (SV-tech-02) the result of the processing of the different data sources:

- result of drone-collected image processing: Fire/smoke/flood/person detection (TFA-tech-05), Fire/smoke/background segmentation (TFA-tech-06), and Person re-identification (TFA-tech-07).

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- result of processing of satellite images: Satellite-based flood detection and assessment (TFA-tech-08) and Satellite-based Forest fire detection and assessment (TFA-tech-09),

- result of Sentiment analysis for short texts (TFA-tech-12) and Geo-social analysis (TFA-tech-11)

- result of realistic smoke modelling and fire detection (PDM-tech-03),

- Information fuses the inputs and generates a map with the current phenomenon status.

Information fusion outputs -through the Digital Enabler (SV-tech-02)- the phenomenon status (map) is sent to Drone Planning (PDM-tech-04), to the Wildfire simulator (PDM-tech-01) and flood simulator (PDM-tech-02) to enable refinement of simulation results, and also for visualization in the Extended Reality-based interactive visualization system (SV-tech-06) and the Smart Desk (SV-tech-07).

Decision Support for Remote Sensing (PDM-tech-06)

Component PDM-tech-06 (Decision Support Service) is responsible for the detection of (potential) disaster areas of interest (AOIs) and event times from public disaster alerts provided by the Global Disaster Alert and Coordination System GDACS and others as well as simulated flood and forest fire extents provided by PDM-tech-01 (Fire Simulator) and PDM-tech-02 (Flood Simulator). Optionally, affected areas detected from geo-social media by TFA-tech-11, smoke alarms issued by PDM-tech-03 may be evaluated as an input. Based on fully automatic retrieval of satellite position and acquisition data provided by DLR the Decision Support Service generates decision proposals with information on when and which remote sensing data will be available for a crisis region. An Operator receives from the Decision Support Service human-readable decision proposals. Component SV-tech-07 (Smart Desk) optionally visualizes the machine-readable geospatial data fusion product retrieved via the API of the Decision Support Service. Optionally, the Decision Support Service may trigger processes of TFA-tech-08 and TFA-tech-09.Remarks:

- Decision support service requires access to current warnings provided by a data provider such as GDACS and the Finnish Meteorological Institute (=> real-time data).
- Decision support service requires access to disaster simulations provided by TEMA partners TSYL and NS over a web-based API.
- Decision support service needs access to current overflight passes of the satellites (=> real-time data) via DLR-internal system over gRPC.
- The decision support service entirely relies on real-time data. Thus, it is not available for historical use cases.

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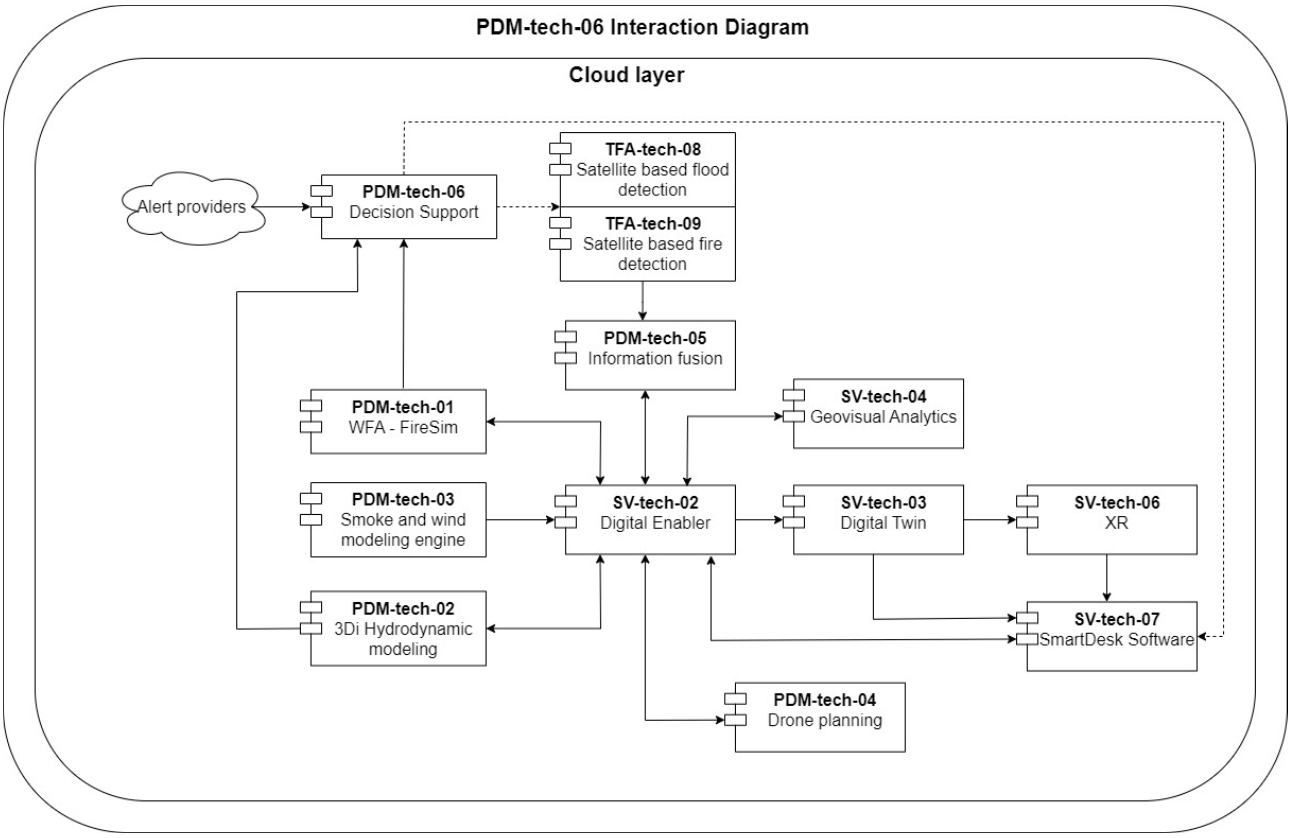

Input:
- Public alerts in XML (RSS or CAP)
- Flood extents in GeoTIFF and/or csv (from NS: PDM-tech-02)
- Fire extents in GeoTIFF, Shapefile and/or KMZ (from TSYL: PDM-tech-01)
- Optional: Geo-social-media Hotspots (e.g. GPKG; TFA-tech-11)
- Optional: Smoke Detection Alerts from DLR-KN (e.g. JSON; PDM-tech-03 via SV-tech-02)

Output:
- Decision proposal text (e.g. JSON, HTML, etc.)
- Geospatial information fusion product (GraphQL)

Procedure:
1. The Decision Support Service acquires from GDACS and others public disaster alerts provided over REST APIs.
2. The Decision Support Service acquires from the Flood Simulator simulation results such as flood extents as GeoTIFF or vector data.
3. The Decision Support Service acquires from the Fire Simulator simulation results such as arrival time and fire paths in GeoTIFF, Shapefile or KMZ formats.
4. It is to be evaluated whether affected areas from geo-social media and smoke detection can be used as an input.
5. The Decision Support Service acquires satellite acquisition data provided by DLR over gRPC.
6. An Operator receives from the Decision Support Service human-readable decision proposals via e-mail or other text-based channels.

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7. Smartdesk optionally retrieves from the Decision Support Service a machine-readable geospatial data fusion product via GraphQL.
8. The Decision Support Service may trigger the Flood and Burnt Area Processor (TBD).

Recipients:
The output is provided over the Decision Support Service's API and/or is sent to a text receiver such as the operator:
- Operator
- TFA-tech-08 (TBD)
- TFA-tech-09 (TBD)
- SV-tech-07 (TBD)

End User Functional Requirements (D2.1):
- EU-RQ-NF-01
- EU-RQ-NF-03
- EU-RQ-NF-08
- EU-RQ-FUNC-01 (Information to define event area and extent)
- EU-RQ-FUNC-02 (Geo-Social Media Information)
- EU-RQ-FUNC-05 (Reveal fires as they start)

Drone-based image and data acquisition (SV-tech-01)

This technology is responsible for acquiring images and other data from drones. The technology is executed at the Edge Layer, which is comprised by the drones and the Base Station, which will be used as a link to the TEMA system.

The drone-based image and data acquisition receives plans after confirmation from the operator from the Smart Desk (SV-tech-07) through the Digital Enabler (SV-tech-02).

Drone-based image and data acquisition captures the images and data from the drones and sends them to: Fire/smoke/flood/person detection (TFA-tech-05), Fire/smoke/flood/person background segmentation (TFA-tech-06) and Person re-identification (TFA-tech-07).

Drone-based image and data acquisition sends the images through the Digital Enabler (SV-tech-02) to: 3D computer vision/Photogrammetry (SV-tech-03), and smart desk (SV-tech-07).

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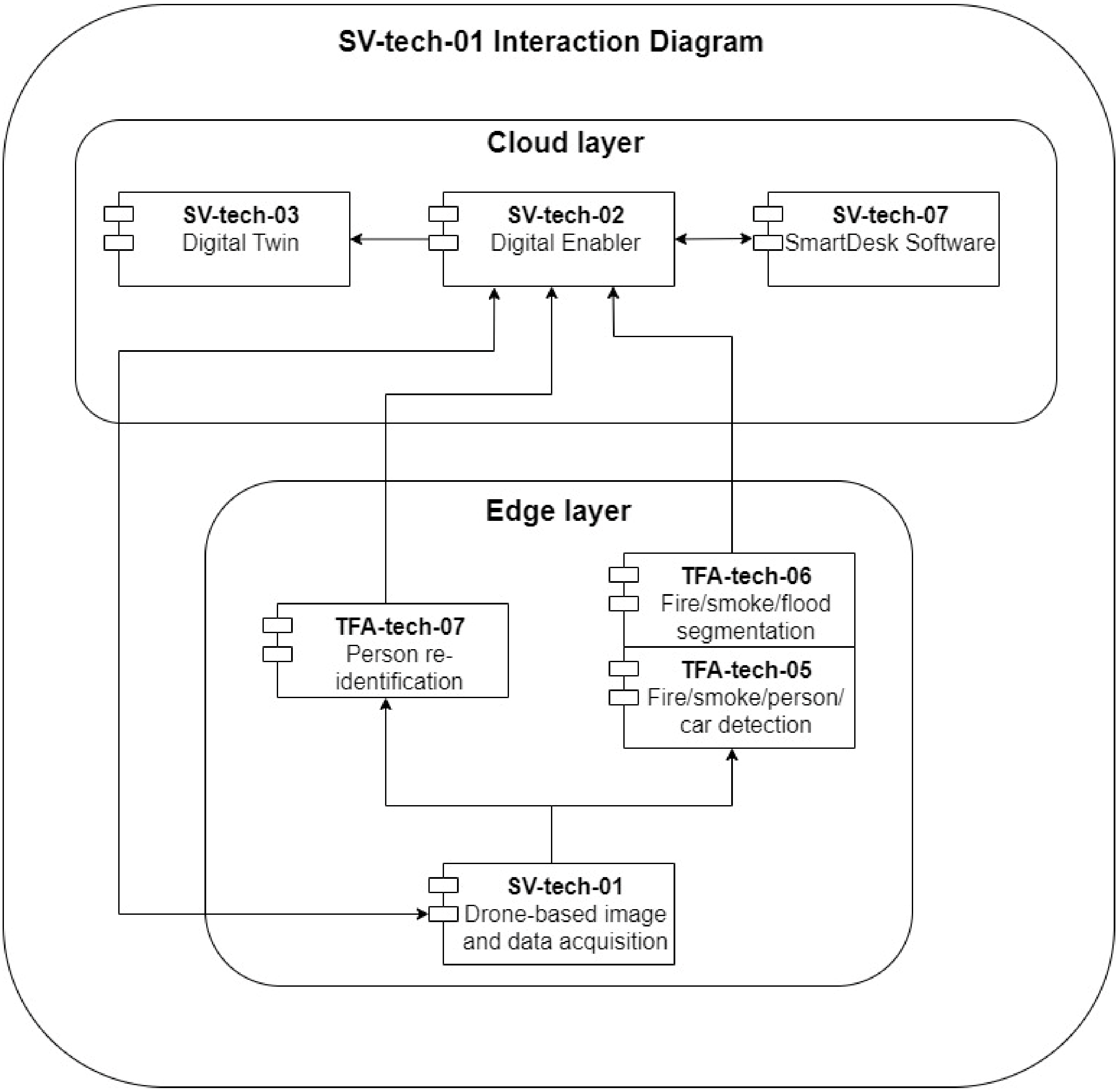

Sequence of interactions:

- The Drone-based image and data acquisition receives plans from the Smart Desk (SV-tech-07) after confirmation from the human.
- The Drone-based image and data acquisition gathers from drones: RGB images and IR images, smoke measurements, and telemetry.
- The Drone-based image and data acquisition sends images RGB and IR images to: Fire/smoke/flood/person detection (TFA-tech-05), Fire/smoke/flood/person background segmentation (TFA-tech-06), Person re-identification (TFA-tech-07) and Privacy preservation

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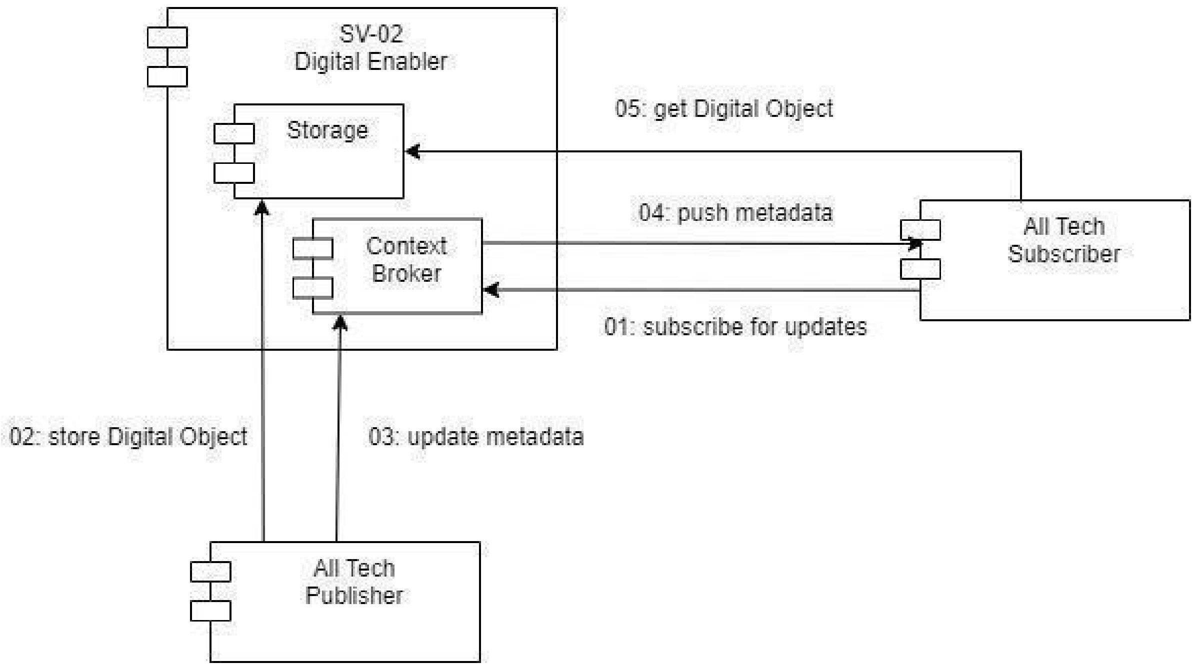
during visual analysis (TFA-tech-10). These technologies are performed on the Edge (Base Station).

- Drone-based image and data acquisition sends the images through the Digital Enabler (SV-tech-02) to Realistic 3D smoke modeling and fire detection (PDM-tech-03), 3D computer vision/Photogrammetry (SV-tech-03), Extended Reality-based interactive visualization system (SV-tech-06), and smart desk (SV-tech-07). These technologies are performed on the Cloud.

Digital Enabler (SV-tech-02)

Component DE (SV-tech-02 Digital Enabler**)** is responsible for storage and metadata management with its cloud-side publish subscribe mechanism. This ID shows the interaction among the DE, a generic publisher, and a subscriber.

Publisher and subscriber can be any TEMA technology (processing, visualization, etc.) that wants to take advantage of the storage and context information management capabilities of the DE.



01: subscriber component subscribes to updates to a particular entity containing the metadata it is interested in.

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02: the publisher uploads a Digital Object (Image, video, text, structured data, etc.) to the DE (Storage).

03: the publisher updates the metadata of the Digital Object on the DE (Context Broker)

04: DE notifies the subscriber by sending updated data to the endpoint that was specified at the time of subscription.

3D computer vision (SfM) - Photogrammetry (SV-tech-03) and XR interactive visualization system (SV-tech-06)

Component SV-tech-06 (XR interactive visualization system) is responsible for merging of the geospatially referenced Digital Twin from SV-tech-03 (Digital Twin) with additional data feeds from PDM-tech-01 (Forest Fire Simulation), PDM-tech-02 (3Di Hydrodynamic simulation), PDM-tech-03 (Realistic 3D smoke and fire), PDM-tech-04 (Drone planning), PDM-tech-05 (Information fusion), and PDM-tech-06 (Data-fusion-based) into a common, detailed semantic 3D TEMA map.

The diagram below illustrates the described interactions.

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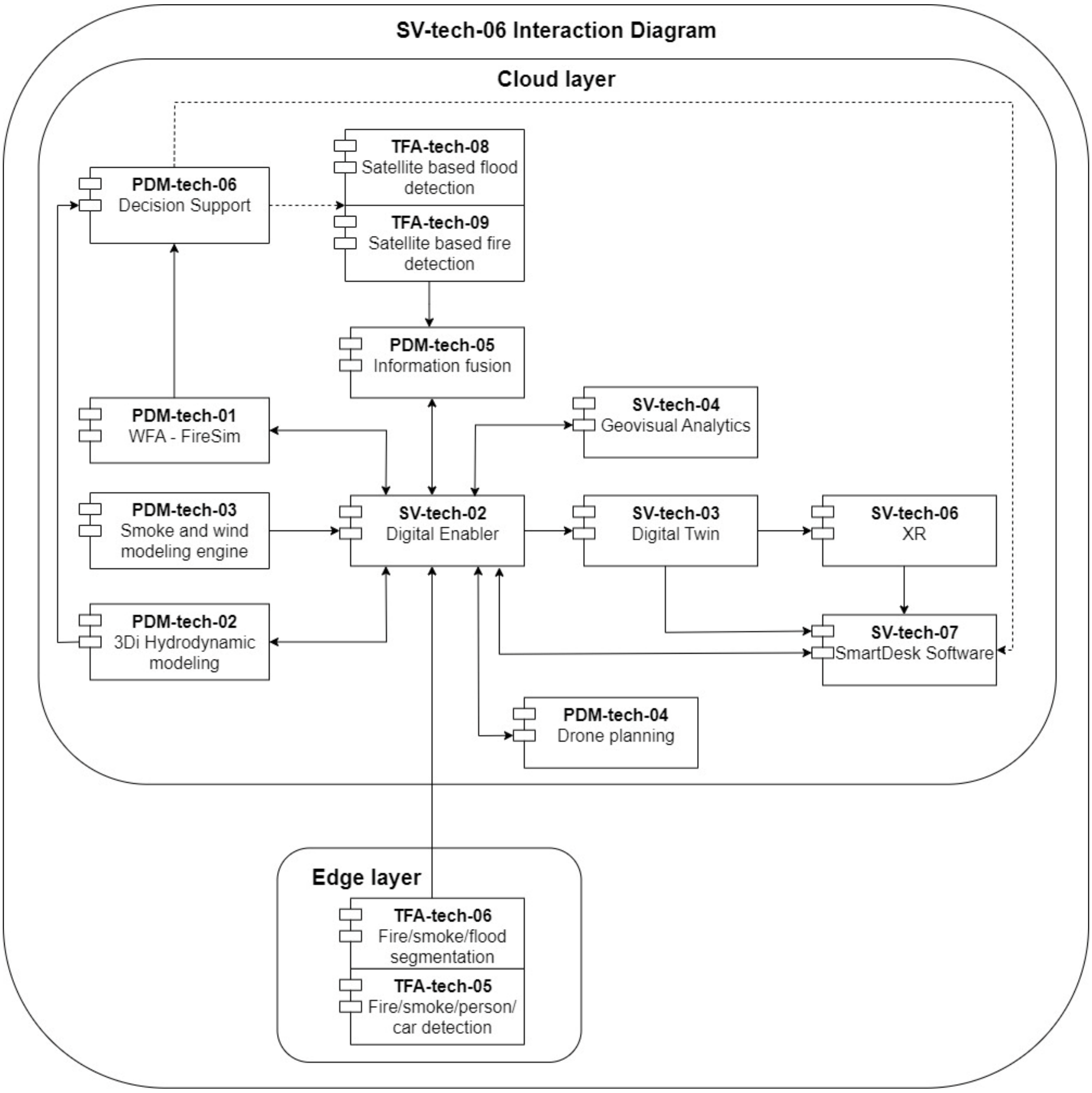

1. The **c**omponent SV-tech-06 (XR interactive visualization system) requires reliable and normalized data from the following systems to create a comprehensive and interactive XR visualization:

- SV-tech-03 (Digital Twin)
- PDM-tech-01 (Forest Fire Simulation)
- PDM-tech-02 (3Di Hydrodynamic simulation)
- PDM-tech-03 (Realistic 3D smoke and fire)
- PDM-tech-04 (Drone planning)
- PDM-tech-05 (Information fusion)
- PDM-tech-06 (Data-fusion-based)

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Geovisual Analytics (SV-tech-04)

Component SV-tech-04 (Geovisual Analytics) is responsible for rapid retrieval of large-scale geospatial data using in-memory technologies to perform spatial data processing and map visualization.

The component require data from the following components for result analysis and/or visualization:

- PDM-tech-01 (Forest Fire Simulation)
- PDM-tech-02 (3Di Hydrodynamic simulation)
- TFA-tech-10 (Privacy preservation during visual analysis)
- TFA-tech-12 (Sentiment analysis for short texts)

Data from and to the above modules are provided via SV-tech-02 (Digital Enabler).

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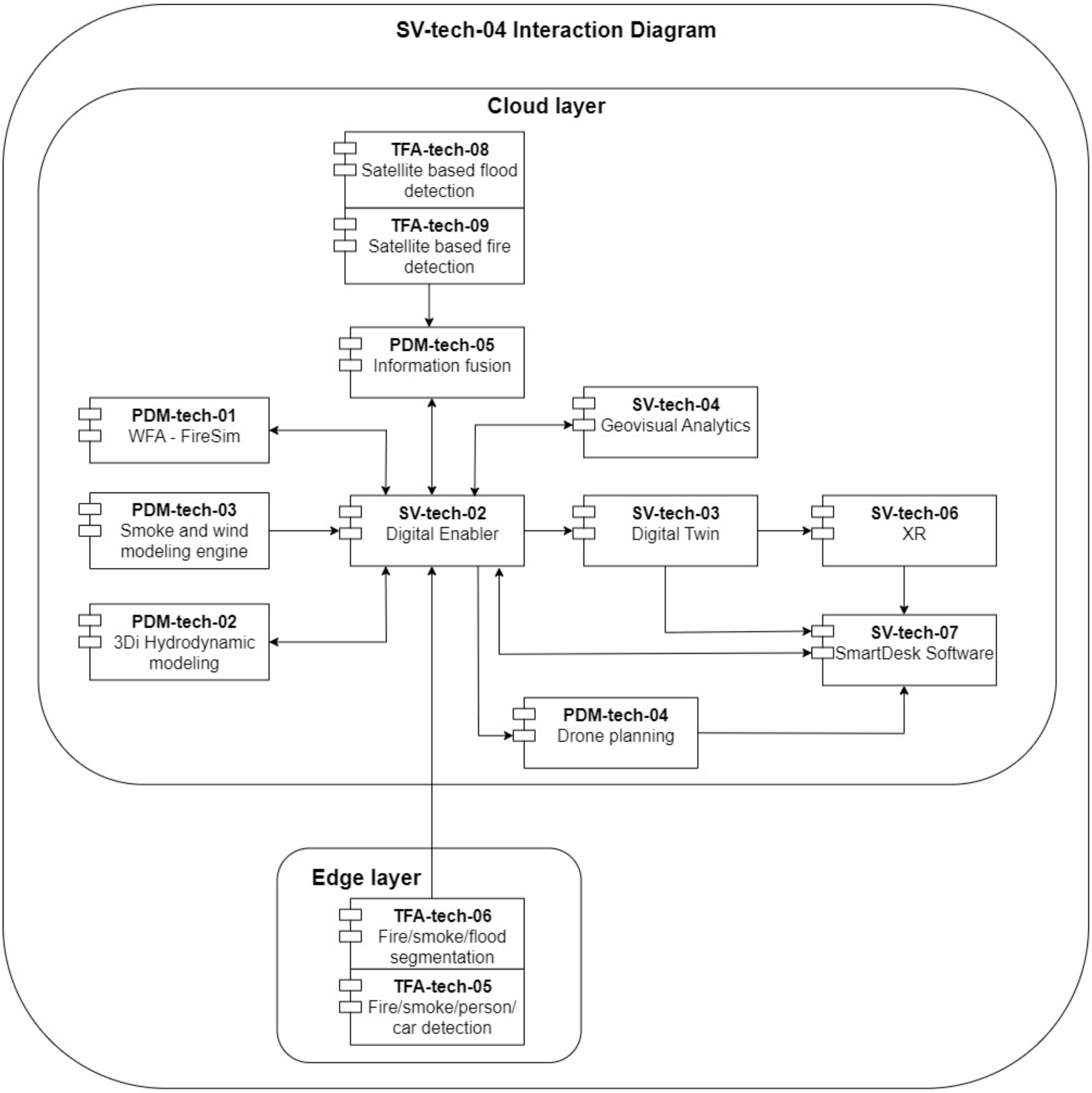

Smartdesk Application (SV-tech-07)

Component SV-tech-07 (Smartdesk) is responsible for quick visualization of situation on map with data feeds gained from PDM-tech-01 (Forest Fire Simulation), PDM-tech-04 (Drone planning), PDM-tech-05 (Information fusion), PDM-tech-06 (Data-fusion-based) combining with situation information gained from SV-tech-01 (Drone-based image and data), SV-tech-02 (Digital Enabler), SV-tech-04 (Geovisual Analytics) and SV-tech-05 (Geospatial information) through SV-tech-02 digital enabler or straight from the data source.

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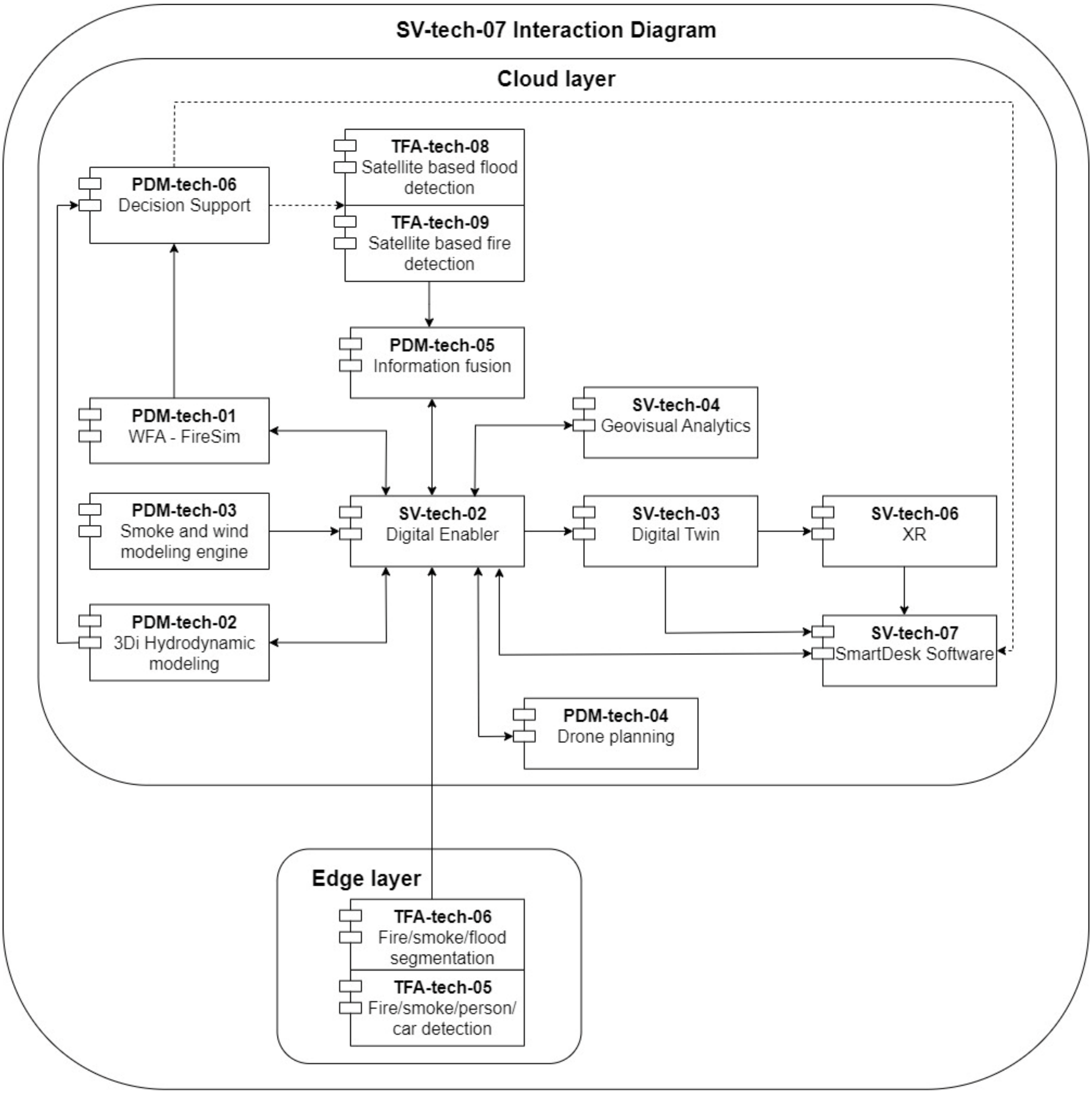
The diagram below illustrates the described interactions.



1. The component SV-tech-07 (Smartdesk) requires reliable and normalized data from the following systems to create an interactive situation map:

- SV-tech-01 (Drone-based image and data)
- SV-tech-02 (Digital Enabler)
- SV-tech-04 (Geovisual Analytics)
- SV-tech-05 (Geospatial information)
- PDM-tech-01 (Forest Fire Simulation)
- PDM-tech-04 (Drone planning)

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- PDM-tech-05 (Information fusion)
- PDM-tech-06 (Data-fusion-based)

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Appendix II: End-User Requirements as Defined in D2.1

Category	Req ID	Requirement	Description
Non-Functional Requirements	EU-RQ-NF-01	The technology used in cases of ND needs to be clean and simple to use	A person who is in rescue hasn't got the time to learn about the new technology or to try what are the options that this (new) warning system provides.
	EU-RQ-NF-02	Privacy, Ethics and Data Policy protection	The tools that the responders use need to be compliant with ethics, privacy, and data policy policies. The data is available only to those who are related to performing the emergency.
	EU-RQ-NF-03	Information provision as soon as possible	It is crucial during the Natural Disaster event the FND Managers have information about the area as soon as possible.
	EU-RQ-NF-04	Sharing information and data regarding ND	Sharing information and data regarding fire (how it is developing, etc.) during ND events
	EU-RQ-NF-05	Coordination between authorities during reconnaissance activities	It would be useful to create real-time maps for data sharing for public authorities
	EU-RQ-NF-06	Ability to operate in rescue activities at night or in heavy rains	Need for clearer satellite images in difficult circumstances
	EU-RQ-NF-07	Solution of the absence of communication means	During a Natural Disaster event, there is the possibility of affecting the electricity and the base stations, the collapsed radio antennas.
	EU-RQ-NF-08	Valid warnings	Sensors are essential for detecting and measuring environmental conditions

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Category	Req ID	Requirement	Description
Functional Requirements	EU-RQ-FUNC-01	Information (footage, images, maps etc.) from the site of the disaster to define event area and extent	Information (footage, images, maps etc) in the control room that could be acquired by the teams on the ground to understand the extent of the event and how it is developing.
	EU-RQ-FUNC-02	Geo-Social Media Information	Social Media will contribute to a NDM due to its awareness, immediate response and geolocation characteristics.
	EU-RQ-FUNC-03	Monitor the development, the size of the affected area	It would be beneficial if there are information regarding the size of the affected area (flood/fire, preferably a map)
	EU-RQ-FUNC-04	Local information about weather variables/data (early warning)	Weather data is crucial for predicting the likelihood and severity of extreme weather events
	EU-RQ-FUNC-05	Reveal fires as they start	Tools- instruments technologies to reveal fires as they start (as soon as possible, to have quick information)
	EU-RQ-FUNC-06	Teams involved	The information regarding the teams that are involved in a ND event and in what tasks are assigned is very important.
	EU-RQ-FUNC-07	Geolocation of people who are in danger of life	It would be useful a system for text messaging to citizens to direct them on the actions to take in order to save themselves and warn of the closure of public facilities in order to prevent people from dangerous roads in case of heavy rain events
	EU-RQ-FUNC-08	Model of fire propagation	It can be useful to use a model of fire propagation in SOUP room during a big fire
	EU-RQ-FUNC-09	Monitor the area of interest for fire revival	The initial fire that seemed to be extinguished, restarted the day after.
	EU-RQ-FUNC-10	Response planning for extinguishing fires	Detailed information regarding the available as well as the already deployed fire fighting forces in the field.
	EU-RQ-FUNC-11	Available water extinguishing resources from nearby swamps, ponds etc..	extinguishing water source e.g., swamps, ponds... (if accessible by heavy trucks, amount of water)
	EU-RQ-FUNC-12	Flood propagation modelling	It would be useful to know how the flood will propagate

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	EU-RQ-FUNC-13	Estimation of the damages	It would be beneficial if there are informations regarding the extension of a flood/fire (preferably a map) and the damages
	EU-RQ-FUNC-14	Scarcity of information about the accessibility to settlements (roads, bridges, etc.) in an affected area and relevant resources.	Map with available infrastructure, the condition of roads, terrain etc. during or after an event of Natural Disaster.
	EU-RQ-FUNC-15	Resource planning	When support is requested, more information is required from the additional responders. A means to plan and prepare tasks for the additional support and to oversee planned tasks.

References

[1] https://json-ld.org/, last visited 29 August 2023

[2] https://www.etsi.org/deliver/etsi_gs/CIM/001_099/009/01.01.01_60/gs_CIM009v010101p.pdf, , last visited 29 August 2023

[3] https://fiware-datamodels.readthedocs.io/en/stable/ngsi-ld_howto/, , last visited 29 August 2023

[4] Robertson, S. &. (2012). Mastering the requirements process: Getting requirements right. Addison-wesley .

[5] https://www.emdat.be/, last visited 28 November 2023

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