D5.2 High-Level Service design

Version 1.3

Work Package 5 – Platform Techno/Economic specifications

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Abbreviations (Example)

AIKP	AI Knowledge Pack
API	Application Programming Interface
ARD	Analysis Ready Data
AWS	Amazon Web Service
CLI	Command Line Interface
COG	Cloud-Optimized GeoTIFF
CRM	Critical Raw Materials
DB	Database.
DIAS	Data and Information Access Services
ENVI	Environment for Visualizing Images, a file format commonly used in remote sensing
EO	Earth Observation
GDPR	General Data Protection Regulation
G-RAM	GoldenRAM - EO Platform Supporting Critical Raw Materials Industry in Europe
GUI	Graphical User Interface
HDF	Hierarchical Data Format
HPC	High-Performance Computing
IaaS	Infrastructure as a service
IPR	Intellectual Property Rights
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
LLM	Large Language Model
MFA	Multi-Factor Authentication
OCLI	Optoss Command Line Interface

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OGC	Open Geospatial Consortium
PaaS	Platform as a service
RBAC	Role-based Access Control
SAFE	Standard Archive Format for Europe
VM	Virtual machine
WMS	Web Map Service

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1. Executive Summary

1.1. Subject of the Deliverable

Deliverable 5.2 presents the high-level design of the GoldenRAM platform "as a service" within the scope of this project, a groundbreaking initiative aimed at transforming exchange of accurate information in the Critical Raw Materials (CRM) industry in Europe. GoldenRAM project integrates Earth Observation (EO) data, Artificial Intelligence (AI) and large-scale cloud technologies to offer in one platform comprehensive and seamless solutions for CRM exploration, environmental monitoring and sustainability compliance. The deliverable defines the platform's core components, architectural principles and service delivery mechanisms, serving as a conceptual design framework for further development and implementation of the platform in following WP7 and WP8 which fits in the scope of the project. The deliverable explicitly excludes out of the project scope matters, such as possibility of commercial or non-commercial exploitation of the deliverables in alternative IT service providers. For avoidance of doubt, it is **important to underline that this deliverable does not serve as a mere "example", but relates exactly to "the GoldenRAM platform" being designed and delivered in this project.**

The GoldenRAM platform is a response to Europe's growing need for sustainable resource management, particularly in the context of the European Green Deal and the CRM strategy. By leveraging cutting-edge technologies, the platform aims to reduce dependency on non-EU sources of raw materials, promote environmentally sustainable practices and foster international collaboration in resource-rich regions on the European continent.

1.2. Summary of Work Carried Out

Deliverable 5.2 stems from the work completed under Tasks 9.2, 11.2, 13.2 (cooperation between OPT/NET and applications developers from BGR, VTT, GTK) and WP1 where EFTAS and Evenflow conducted a set of interviews to define the needs of diverse stakeholders, including mining companies, regulatory authorities and research institutions. Recent discussions and agreements between OPT/NET and CloudFerro (CF) regarding the setup of the platform in the CF environment have played a pivotal role in shaping the platform's deployment strategy and ensuring a secure and compliant cloud infrastructure.

Key achievements covered in this deliverable include:

- **Architectural Design**: high level design for development of a modular, scalable architecture that integrates EO data, AI-driven analytics and

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scalable cloud infrastructure to ensure reliability, adaptability, low cost and high performance.

- **Core Services**: Definition of services tailored to CRM stakeholders, such as predictive analytics, environmental monitoring and automated ESG compliance reporting.
- **Data Integration Strategy**: Integration of multiple multimodal and heterogeneous data sources, including Copernicus satellite data, ground-based sensors and proprietary datasets, to create a unified ecosystem for CRM insights.
- **Stakeholder Collaboration**: Frameworks for collaboration among the platform' stakeholders such as mining companies, regulators and researchers, enabling shared access to data and tools that drive informed decision-making.
- **Field Trials**: Planning and initiation of field trials across identified locations in Europe and Ukraine to validate the platform's capabilities in real-world scenarios, such as mineral prospectivity mapping and environmental risk assessment.

1.3. Main Conclusions

GoldenRAM is a transformative platform that has to become an effective and flexible solution which offers a unique value proposition to the CRM industry by addressing critical challenges in exploration, safety and sustainability of mining sites. Key conclusions include:

- **Enhanced Data Utilization**: By integrating existing data with remote sensing EO data and advanced AI driven applications (i.e. AI Knowledge Packs (AI KPs) which were pioneered in the predecessor Horizon projects), the platform combines more accurate CRM exploration and resource assessment with ease of use, powered by natural human language interface (Gen AI and LLM).
- **Sustainability Impact**: GoldenRAM will supports compliance with Environmental, Social and Governance (ESG) standards, helping mining companies meet regulatory requirements and enhance their social license to operate by making these processes easy to implement at lower cost.
- **Operational Efficiency**: The platform's AI-driven AIKPs streamline data acquisition and processing workflows, reduce operational risks and will improve resource efficiency across the mining lifecycle.
- **Stakeholder Empowerment**: Lowering entry barriers for adoption of advanced technologies (e.g. Big Data in the cloud and AI) by fostering collaboration and providing actionable insights, GoldenRAM enhances the

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ability of stakeholders to address pressing challenges in resource management.

These conclusions underscore the platform's alignment with Europe's green and digital transitions, as well as its potential to redefine CRM exploration and sustainability practices.

1.4. Purpose of the Deliverable

The purpose of this deliverable is to provide condensed multidomain multifaceted platform overview for its further development and implementation in Year two of the project.

It serves as:

1. **A Conceptual Framework**: Providing a clear and strategic overview of the GoldenRAM platform's design, highlighting how its architectural principles and service delivery mechanisms meet the unmet needs of the CRM industry.
2. **A Strategic Guide**: Outlining the long-term vision for the platform, including all components, functions and processes that will be completed and iteratively updated in the next WPs during the implementation of the platform.
3. **A Stakeholder Resource**: To offer technical and non-technical description of the platform's value proposition for the stakeholders. Explains usability of the solution and elaborate its positive impact on critical challenges in resource exploration and management.

This deliverable is a critical step in the GoldenRAM project, setting overall direction and laying the foundation for further technical development, stakeholder engagement and commercial deployment. It emphasizes the importance of leveraging modern state-of-the-art technology to achieve sustainable resource management and secure Europe's raw materials supply.

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2. Platform Objectives and Vision

2.1. Platform Vision

The "**GoldenRAM platform**" is envisioned as a transformative IT solution for the Critical Raw Materials (CRM) industry in Europe, supporting the entire mining lifecycle—from early exploration to post-closure environmental monitoring. By integrating remote sensing Earth Observation (EO) data, advanced Artificial Intelligence (AI) platform and scalable cloud technologies, **GoldenRAM** aims to deliver cutting-edge applications, tools and insights that will help industry stakeholders achieve operational excellence, sustainability and regulatory compliance at the reduced cost.

At the core of **GoldenRAM's** vision is the drive to support responsible mining practices, ensuring the sustainability and social acceptance of CRM extraction which are essential ingredients for securing the raw materials supply necessary for EU green deal and digital transition. The platform is designed to empower a wide range of stakeholders, from mining companies and regulatory bodies to research institutions and investment firms, by offering easy access to high-quality data, advanced analytics and automated workflows.

GoldenRAM seeks to become a cornerstone cloud-based IT platform in Europe's raw materials supply chain, helping the region reduce reliance on external sources and reinforcing the European Green Deal's goals of sustainability and resource efficiency. The platform will offer access to mineral prospectivity data, operational activity monitoring data, predictive analytics and environmental impact assessments, enabling stakeholders to better understand and optimise operations, ensure compliance and enhance decision-making and governance processes across the CRM value chain.

2.2. Key Objectives

1. Enhance CRM Exploration and Production
   GoldenRAM will improve the efficiency and accuracy of CRM exploration by leveraging digitised historical survey data, current and past multispectral and hyperspectral satellite and aerial survey data, AI-based mineral prospectivity mapping and advanced geological analysis implemented as easy-to-use AI KPs. For example, the platform will help mining companies and geological institutions identify potential of raw material deposits and optimize resource extraction processes, from site selection to production.
2. Support Environmental and Social Governance (ESG) Compliance
   The platform will play a critical role in supporting ESG compliance for mining companies by offering tools for effective monitoring of environmental impacts such as deforestation, air and water quality and tailings

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management. Through automated ESG report preparation, stakeholders can ensure they meet the stringent environmental and social standards set by European regulators and improve the social acceptance of mining activities.

3. Foster Sustainable Mining Practices
   By integrating data from satellites, airborne and in-situ proximal sensors, **GoldenRAM** will enable monitoring of mining operations to mitigate environmental risks, such as tailings dam failures or hazardous waste leakage. The platform will also provide early warning systems for natural hazards, ensuring the safety of workers and local communities near mining sites.

4. Facilitate International Collaboration and Data Sharing
   GoldenRAM will promote cross-border collaboration between EU member states and resource-rich partner countries such as Ukraine. The platform will offer an open data-sharing environment, allowing stakeholders to access Analysis Ready Data (ARD), AI-driven insights and CRM datasets, ensuring more efficient collaboration along the raw materials value chain.

5. Drive Innovation in Raw Materials Research and Technology
   The platform will support research and development (R&D) in the CRM sector by offering AI Knowledge Packs (AIKPs), enabling researchers to build, validate and share AI models and applications for raw materials analysis. This will encourage innovation in CRM exploration technologies and support the development of new, more efficient mining techniques.

6. Ensure a Sustainable Raw Materials Supply for Europe
   GoldenRAM's ultimate goal is to ensure that Europe can meet its critical raw materials needs in a sustainable and responsible manner. By improving access to the large volumes of new high-quality data and streamlining exploration and production processes, this IT platform will help Europe reduce its dependence on imported raw materials, strengthen its supply chains and secure the resources necessary for the green transition.

2.3. Key Success Metrics

To ensure that **GoldenRAM** delivers on its vision and objectives, the platform will be measured against the following key success metrics:

- Platform Adoption Rate: The number of active users of the platform, including mining companies, regulatory authorities and research institutions, regularly visiting and using the platform to access data and insights.

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- Field Trial Successes: The successful demonstration of **GoldenRAM's** capabilities in six field trials across Europe, with measurable improvements in KPIs for CRM exploration, production efficiency and environmental monitoring.
- Stakeholder Engagement: The breadth and depth of engagement with diverse stakeholders, including partnerships with at least five different types of stakeholders (e.g., mining companies, governmental authorities, research institutions).
- Data and Insights Delivery: The volume and quality of Analysis Ready Data (ARD) and AI-driven insights provided to stakeholders through the platform, with a target of publishing over 10 knowledge products (AI KPs) for CRM applications.
- Sustainability Impact: Demonstrable improvements in environmental monitoring and ESG compliance, with measurable reductions in environmental impacts such as water contamination and tailings dam failures.
- Partnership Expansion: Establishment of strategic partnerships with key stakeholders from CRM-rich countries and international organizations, including the European Space Agency (ESA), Copernicus programme and resource-rich non-EU countries (Ukraine, Kazakhstan).

By achieving these metrics, **GoldenRAM** will not only improve operational efficiencies and sustainability in the mining industry but also position itself as a leading cloud-based IT platform for EO data-driven solutions in Europe's critical raw materials sector.

2.4. Advancement of G-RAM Platform Service Design Compared to the Predecessor GoldenEye

The GoldenRAM platform represents a pivotal evolution in IT architectural design, building upon the foundation laid by precursor GoldenEye (colloquially referred to as "GoldenAI") project[1]. These advancements reflect significant strides in improvement of scalability, functionality, modularity, standartisation, interoperability and include better alignment with leading providers of the modern cloud-native technologies in Europe (CREODIAS, CodeDE, Wekeo, ESA Datacube facility, etc.). This chapter details the architectural innovations

[1] https://cordis.europa.eu/project/id/869398

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introduced in GoldenRAM, emphasizing their impact on improving platform efficiency, usability and future-proofing.

Cloud-Native Design and Scalability:

1. **GoldenAI** project was built with a focus on a medium scale hybrid architecture that primarily supported basic Earth Observation (EO) data processing and visualization for single-tenant on traditional dedicated on-premise and/or virtual machine (VM) based cloud systems.
2. **G-RAM**, by contrast, adopts a **cloud-native architecture** leveraging the elastic technologies such as Kubernetes and Dockers deployed in CREODIAS infrastructure. This design enables the platform to handle:
    - Large-scale data ingestion and processing from multiple heterogeneous sources.
    - Horizontal and vertical scalability to accommodate growing user demand and diverse use cases.
    - Multi-tenant environments that support isolated, scalable deployments for distinct customer organizations.
    - Cost effective and elastic resource utilisation and flexible billing on “pay per-use” basis.
    - Unhindered hyper-scalability of the platform.

Data Flow and Processing Improvements:

1. In **GoldenAI**, the backend was limited to a limited set of specific data pipelines for processing EO datasets which included mostly open sources of EO data or required custom integration with commercial datasets.
2. **GoldenRAM** introduces a new **highly modular data flow architecture**, integrating:
    - **data ingestion** from EO satellites, ground sensors and historical repositories.
    - AI-powered **data fusion and new AIKP pipelines** optimized for CRM-specific tasks such as mineral prospectivity mapping, volume change and tailings dam monitoring.
    - **Automated workflows** for ESG compliance and predictive analytics, minimizing manual analyst work.

Enhanced Modular Architecture:

1. **GoldenAI’s** backend was tailored for pre-defined procedural workflows, limiting its flexibility and scalability.
2. **G-RAM** will become a modular software project and will consist of Open Source and Proprietary modules.

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- Open Source module will be available for researchers and AIKP developers, which will improve the attractiveness of the platform for the new knowledge creators. It will be published in GitHub under GPL 3.0[2] license under public access.
- Proprietary modules of the platform will assure commercial viability of the platform by offering enterprise set of features which improve performance and reliability of the service and offer premium services and advanced professional expertise via AIKPs authored by the experts of the industry.

3. **G-RAM** adopts a **microservices-based architecture**, which:
   - Allows independent deployment, scaling and updating of components by developers (e.g. AI Knowledge Packs (AIKPs), reporting modules).
   - Supports seamless integration of third-party services via standardized APIs in new AIKPs.

Security and Multi-Tenant Management:

1. **GoldenAI** provided a single-instance architecture with basic user access controls.
2. **G-RAM** incorporates **Keycloak (or alternative OAuth 2.0[3] based solution) of the Service Provider for identity and access management** and a robust **multi-tenant use model** using OpenStack for service orchestration. Each tenant operates in a dedicated, secure environment with isolated data and resources, ensuring:
   - Strong separation for data privacy purposes for multiple stakeholders (e.g., mining operators, regulators, research institutions).
   - Simplified resource allocation, monitoring and billing at the service operator level

[2] https://www.gnu.org/licenses/gpl-3.0.en.html
[3] https://oauth.net/2/

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3. Stakeholder Overview

GoldenRAM is designed to serve a broad range of stakeholders (Figure 1) within the Critical Raw Materials (CRM) industry, each with specific roles and expectations from the platform. This chapter provides an overview of the key stakeholders (actors) who will interact with the platform, focusing on how **GoldenRAM** will address their needs and enhance their operations.

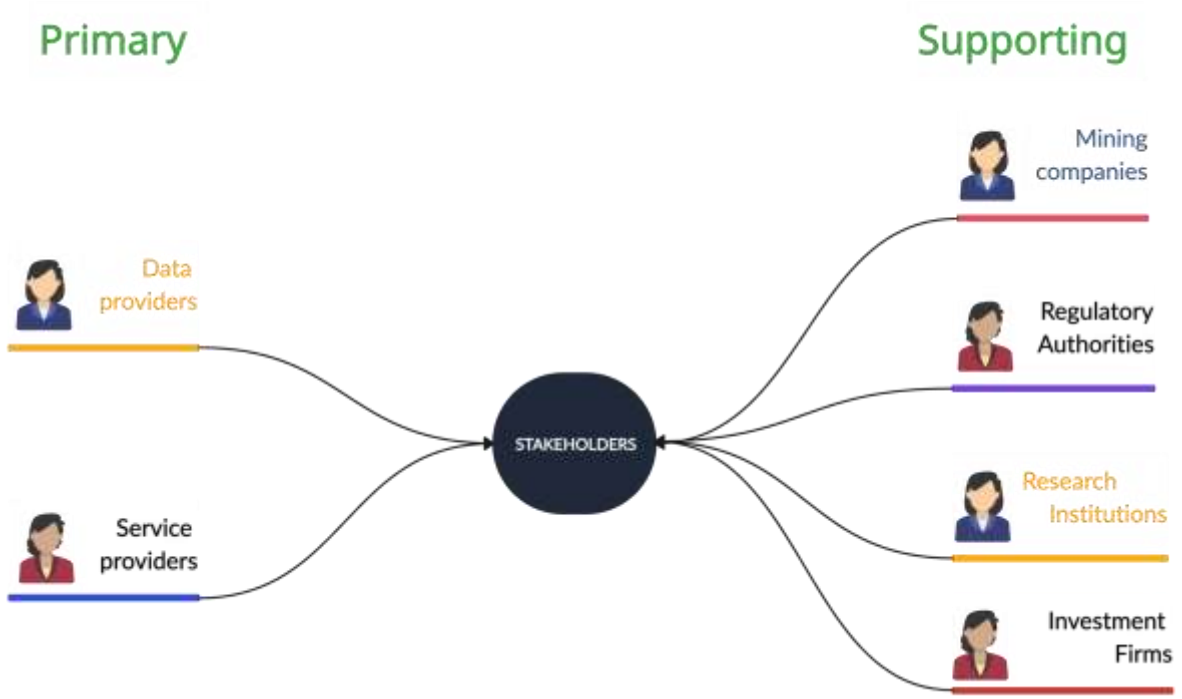

Figure 1. Stakeholder Overview

3.1. Primary Stakeholders

1. Data Providers
    - Role: Data providers supply the platform with Earth Observation (EO) data, ground sensors, in-situ data and proprietary datasets essential for CRM exploration, environmental monitoring and AI model development.
    - Needs: Data providers seek a platform where their datasets can be integrated, processed and shared with a broad audience of users, including mining companies, regulatory bodies and researchers.

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- Platform Benefits: **GoldenRAM** will serve as a central hub for EO data, allowing providers to share data through standardised APIs and collaborate with a wide range of industry and government stakeholders. This will create new opportunities for data monetization and cross-industry partnerships.

2. Service Providers
    - Role: Service providers include cloud infrastructure providers, AI algorithm developers and consultants who deliver support services to enhance platform functionality.
    - Needs: These stakeholders require an open and flexible platform that allows for seamless integration of their services and tools into the **GoldenRAM** ecosystem.
    - Platform Benefits: **GoldenRAM** will provide service providers with access to a broad range of industry stakeholders, enabling them to offer cloud-based solutions, AI-driven analytics and consulting services. The platform's modular architecture allows for the easy integration of third-party services, creating new business opportunities.

3.2. Supporting Stakeholders

1. Mining Companies
    - Role: Mining companies are the primary users of the GoldenRAM platform, leveraging it for CRM exploration, extraction, environmental monitoring and operational efficiency and duty to periodic reports to the national authorities and mining law.
    - Needs: These companies require access to advanced tools for insights into raw material availability, predictive analytics for resource extraction and environmental monitoring to ensure compliance with regulations. They also need AI-driven tools to automate workflows and optimise mining operations from exploration to closure.
    - Platform Benefits: GoldenRAM will provide mining companies with tools for mineral prospectivity mapping, tailings dam stability monitoring and environmental impact assessment, helping them reduce operational risks, increase efficiency and meet sustainability targets.
2. Regulatory Authorities
    - Role: Regulatory bodies oversee compliance with environmental, safety and governance standards. They are responsible for ensuring that mining companies adhere to regulations and sustainability requirements.

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- Needs: These authorities need accurate and timely data on mining activities, environmental impacts and CRM extraction practices. They require tools for monitoring mining operations remotely and verifying compliance with regulatory frameworks such as the EU's Critical Raw Materials Act and Environmental, Social and Governance (ESG) reporting.
- Platform Benefits: **GoldenRAM** will provide regulatory bodies with data on mining sites, automated ESG reporting and early warning systems for potential environmental hazards. This will help regulators enforce compliance, assess environmental risks and ensure sustainable resource management.

3. Research Institutions
   - Role: Research institutions use **GoldenRAM** for scientific studies and innovation in CRM exploration and environmental sustainability. They contribute to the advancement of geospatial and AI technologies for the mining industry.
   - Needs: Researchers require access to high-quality Earth Observation (EO) data, AI models and historical datasets to conduct their studies on resource management, environmental impacts and advanced mining technologies.
   - Platform Benefits: **GoldenRAM** will provide these institutions with AI Knowledge Packs (AIKPs), geospatial data and analysis-ready datasets, enabling them to develop new AI-driven methodologies for mineral exploration and environmental research. This will accelerate scientific innovation and foster collaboration between academia and industry.
4. Investment Firms
   - Role: Investors use the platform to assess the financial viability of mining projects and make informed investment decisions in CRM-related industries.
   - Needs: Investment firms require access to reliable data on CRM deposits, operational safety, environmental sustainability and regulatory compliance. They need tools for assessing the long-term profitability and risk associated with mining investments.
   - Platform Benefits: **GoldenRAM** will provide insights into CRM exploration and extraction processes, safety assessments and ESG compliance. This will enable investors to evaluate potential risks and returns, supporting informed decision-making in financing mining projects.

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3.3. Stakeholders' Inter-relationship and Collaboration

GoldenRAM is designed to foster collaboration across all stakeholder groups (Figure 2), ensuring that data, insights and best practices flow seamlessly between mining companies, regulators, researchers and service providers. By centralising access to data and analysis tools, the platform enables:

- Data Sharing: Stakeholders can collaborate by sharing data and insights, improving the overall quality of CRM exploration and environmental monitoring efforts.
- Knowledge Exchange: Researchers, industry experts and regulators can collaborate to improve sustainability standards, develop new AI tools and optimise mining processes.
- Market Development: Investors, mining companies and service providers can work together to develop and commercialise new technologies that improve operational efficiency and environmental impact assessments.

GoldenRAM aims to create an interconnected ecosystem where all stakeholders benefit from shared data, tools and insights, resulting in better decision-making and more sustainable resource management across the CRM value chain.

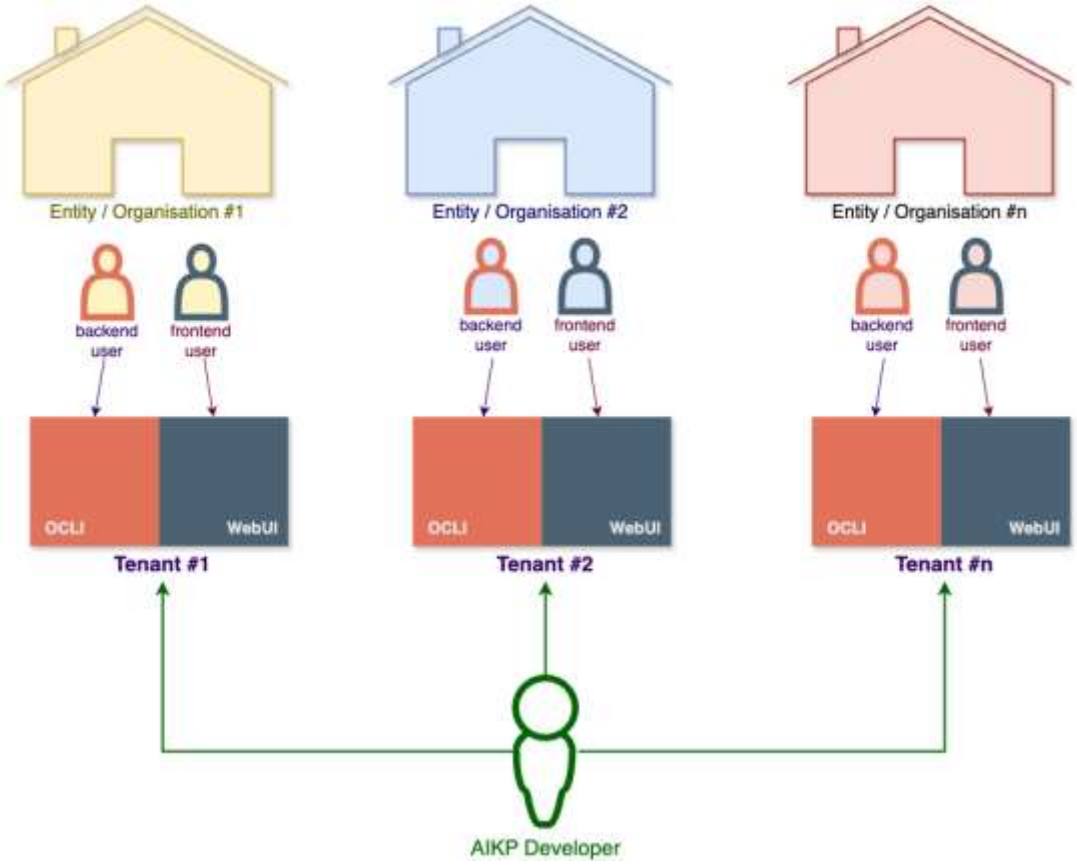

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Figure 2. Stakeholders' Inter-relationship

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4. High-Level Platform Architecture

The architecture of the **GoldenRAM** platform is designed in accordance to the user requirements as identified in D 5.1 Service solution specifications in order to provide a robust, scalable and modular infrastructure capable of supporting the diverse needs of the Critical Raw Materials (CRM) industry. The platform integrates Earth Observation (EO) data, AI-based analytics and cloud computing (with associated security, access and billing mechanists) to deliver AI driven insights and advanced analytical tools for CRM exploration, environmental monitoring and operational safety. This chapter outlines the key components and architectural principles that define the high-level design of the platform.

4.1. System Overview

GoldenRAM's architecture is built on a cloud-native foundation, leveraging scalable cloud infrastructure to support data integration and processing, AI workflows and web-based simple to use visualisation tools. The platform consists of several core components that interact seamlessly to provide stakeholders with actionable insights, predictive analytics and environmental monitoring capabilities.

The system's modular design allows for easy integration of new services, such as additional AI Knowledge Packs (AIKPs) and ensures that the platform can scale both horizontally and vertically to meet the growing data and user demands of the CRM sector. The platform's cloud-based infrastructure also facilitates the deployment of services across different geographic regions, enabling cross-border collaboration between EU countries and CRM-rich partners like Ukraine.

4.2. Core Components

1. Frontend (User Interface)
   The **GoldenRAM** frontend provides a user-friendly web-based interface for accessing the platform's tools, data and analytics. Designed with simplicity in mind, it enables users – ranging from mining companies to regulatory authorities – to complete complex tasks via natural human language (English or local) and interact with the platform effortlessly, regardless of technical expertise.
   Key Features:

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- Data Visualization: Interactive workspace to display EO data, AI-generated insights and predictive analytics with web-based access.
- Reporting Tools: Easy-to-use tools for reviewing ESG reports and downloading, safety assessments and compliance documentation as produced by AIKPs.

2. Backend (Data and Processing Engine)
The backend is the heart of the **GoldenRAM** platform, responsible for large scale data ingestion, processing and analysis. It integrates multiple heterogeneous data sources, including satellite or aerial imagery, ground sensors and historical mining data, 2D and 3D maps with specialised visualisations methods and processes them using AI algorithms to generate actionable insights.

   Key Functions:

   - Data Ingestion: Seamless collection of EO data from Copernicus and other proprietary sources.
   - Customizable Workflows: Users can set up personalised workflows for CRM exploration, ESG compliance monitoring and environmental impact assessments.
   - AI-Driven Analytics: AI and machine learning algorithms process data to deliver insights on CRM availability, mining safety and environmental conditions.
   - Data Storage and Management: Secure storage and management of large datasets using cloud infrastructure, ensuring fast retrieval and processing.

3. AI Knowledge Packs (AIKPs)
AIKPs are a key feature of **GoldenRAM**, enabling intelligent automation of complex data workflows and providing stakeholders with tailored insights based on advanced AI models and algorithms. These packs consist of pre-trained AI models, parametrisation, pre- and post-processing algorithms, data fusion algorithms, metadata and database. AIKPs are ready to be applied to specific use cases, e.g. mineral prospectivity mapping and tailings dam stability monitoring with DevOps methodology based on CI/CD principles.
   Key Capabilities:

   - Automated Workflows: Pre-built AI enabled applications that automate data acquisition, pre-processing and analysis for CRM exploration and environmental monitoring.

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- Custom AI Development: Developers of the platform can develop and deploy custom AI models for specific CRM-related applications.
- Continuous Learning: AIKPs improve over time through machine learning, ensuring that the platform's insights become more accurate with increasing usage.

4.3. Data Flow and Integration

GoldenRAM integrates data from multiple sources and processes it to provide stakeholders with insights and predictive analytics. The platform's architecture is designed for seamless data flow between external sources (Figure 3), the processing engine and the frontend interface.

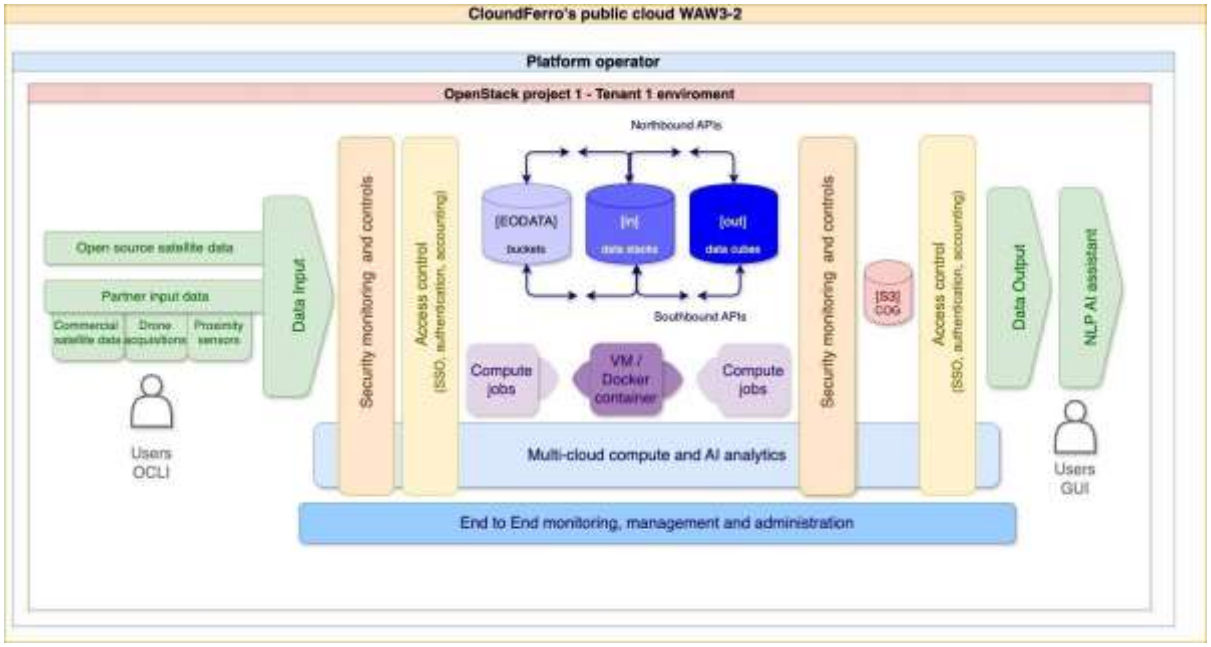

Figure 3. Data flow diagram for single Tenant pod.

1. Data Collection
   The platform would be able to ingest data from a variety of external sources, including:
   - Copernicus EO data: Satellite imagery for CRM exploration and environmental monitoring.
   - Airborne sensors: UAV multi- and hyperspectral imaging, LIDAR scans, other raster and vector based data.
   - Ground Sensors: Data from on-site sensors monitoring factors like water quality, ground stability and weather conditions, etc.

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- Historical Data: Proprietary datasets, geological reports and regulatory information for historical context and analysis.

2. Data Processing
Once data is ingested, the backend processing engine applies pre-processing, data fusion and various AI algorithms (as defined in a particular AIKP) to analyse the data and generate required insights. This includes tasks such as:
    - Mineral exploration: EO Mineral Mapping, Mineral prospectivity Mapping, Drill core mapping, Mapping of secondary CRM deposits
    - Tailings Dam Stability Monitoring: Analysing satellite data to assess the structural integrity of tailings dams and prevent potential failures.
    - Volume Change and Activity monitoring
    - Environmental Impact Assessments: Monitoring the impact on the environment by monitoring surrounding vegetation, soil and water bodies to document compliance with environmental regulations.
3. Data Visualization and Delivery
Processed data is delivered to users through the GoldenRAM web-based frontend. Stakeholders can interact with data via:
    - Natural human language interface (English is primary language, but national EU languages may also be supported depending on the LLM provider which should be interchangeable and configurable in the platform).
    - Processed or raw data: platform visualise 2D, 3D and vector data according to user requiems
    - Reports: Automated generation of regulatory reports, ESG compliance documents and safety audits.
    - Alerts and Notifications: Early warning systems to notify stakeholders of potential environmental risks or safety concerns.

4.4. Integration with External Systems

GoldenRAM is designed to be a data agnostic platform with discretional access which may range from “public” to “authorised users only” that would be deployed in CloudFerro environment, allowing for easy integration with external data sources and systems (e.g. CREODIAS, CODE, Wekeo). This ensures that stakeholders can leverage additional datasets and tools to enhance their analysis.

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1. Copernicus Integration
   The platform is closely integrated with Copernicus satellite data, providing stakeholders with access to open Earth Observation (EO) imagery and Copernicus services and products (e.g. Copernicus Contributing Missions Data, Copernicus Land Service) for CRM exploration and monitoring. **GoldenRAM** uses open and commercial satellite data for a variety of applications, including mineral mapping, environmental impact assessments, operations and safety monitoring.

2. CREODIAS Cloud Platform
   GoldenRAM will run on the CREODIAS[4] cloud infrastructure, (Figure 4), a scalable, cloud-native platform that supports large-scale EO data access and processing. This allows **GoldenRAM** to handle vast amounts of data efficiently, ensuring fast data retrieval and processing without costly and lengthy data transfers and duplication.

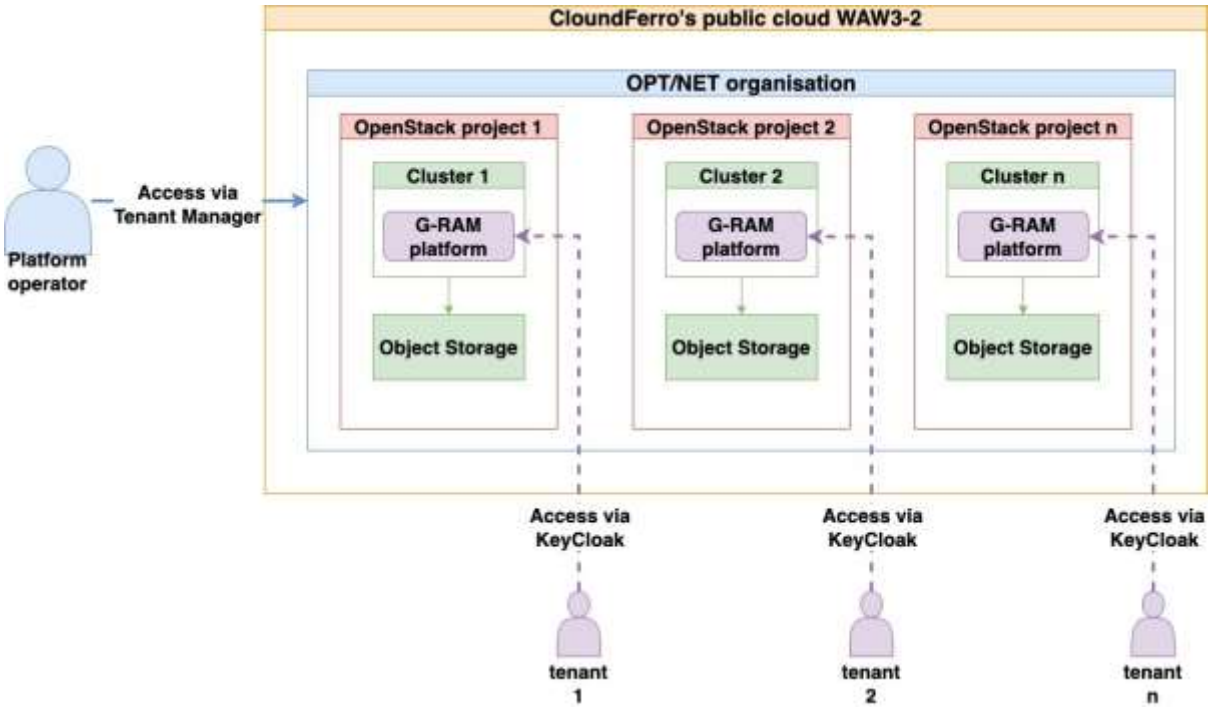

Figure 4. GoldenRAM integration with CREODIAS solutions

To integrate the platform with the CloudFerro environment, a set of interviews was conducted during the functional and non-functional requirements scoping phase leading to the following architecture (Figure 4).

Tenant Manager (TM) is CloudFerro's service management tool, used for managing organizations and OpenStack's projects. It also includes a component for resource

[4] https://creodias.eu/cloud/cloudferro-cloud/

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usage billing. For OPT/NET a dedicated organization (in OpenStack: domain) shall be created in TM. Within the organisation (domain), multiple projects (tenants) and logins for the users can be created.

From the TM level, the operator has access to provisioning (creating) OpenStack projects and managing already created projects. CloudFerro recommends creating all projects in one domain (in one cloud datacenter) during the GoldenRAM project. This way, during planned maintenance, all projects will experience downtime simultaneously, ensuring consistency and simplified operational procedures during the project duration. However, this limitation will be lifted after the completion of the project, as dependent on the commercial traction of the project, where the regional demand will determine the proposition.

From the TM perspective, OPT/NET would be a master tenant managing organizations and projects in OpenStack. From the platform perspective, there can be multiple sub-tenants/platform users. To ensure tenant separation on the platform, OPT/NET should create separate environments (a separate project in OpenStack) for each tenant. Within each project, dedicated K8S (kubernetes) clusters and Object Storage[5] buckets and Docker containers can be created.

Users will access the platform through the Keycloak IAM solution of CloudFerro. The Tenant Manager and OpenStack layers are not visible to them.

The platform operator role during the project will be performed by (OPT/NET). It can view infrastructure resource usage in TM, which can be divided per OpenStack project (so also per platform's tenant).

3. APIs and Data Sharing
   GoldenRAM uses open APIs to facilitate integration with external platforms and tools. This allows stakeholders to access data programmatically, integrate their own datasets and share data with other users via GoldenRAM frontend. The platform's adherence to OGC standards ensures compatibility with other geospatial data platforms. The exact list of the APIs and standards will be covered in subsequent deliverables of the GoldenRAM project after implementation of the platform will be complete in year two of the project.

4.5. High-Level Data Flow Diagram

Figure 5. describes a simplified description of the high-level data flow:

1. Data Acquisition: Data from satellite imagery, ground sensors and historical datasets are collected and sent to the backend.

[5] https://en.wikipedia.org/wiki/Object_storage

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2. Data Processing (Fusion & AI): AI and machine learning algorithms process the data, generating actionable insights for users.
3. Data Storage: The processed data is stored securely in the cloud for future retrieval and analysis.
4. Data Visualization: Stakeholders access insights, dashboards and reports via the frontend interface.

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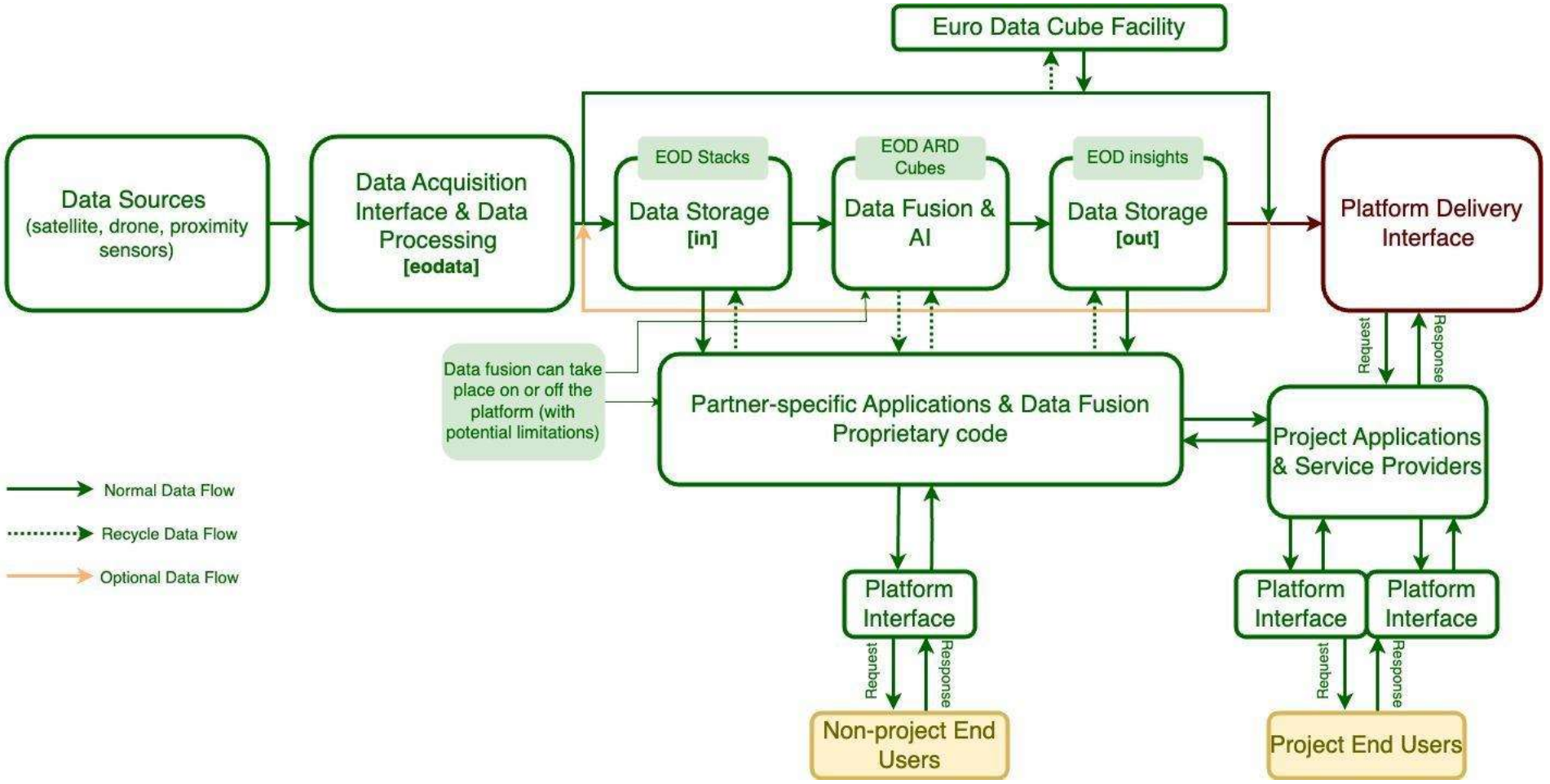

Figure 5. High-Level Data Flow Diagram

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5. Service Delivery Architecture

GoldenRAM's service delivery framework is designed to provide a suite of high-value services, applications, tools and capabilities to identified earlier stakeholders across the Critical Raw Materials (CRM) industry. The platform enables mining companies, regulators and research institutions to access data, derive AI-driven insights and invoke intelligent automated workflows, which support the entire mining lifecycle from exploration to environmental monitoring and post-closure activities.

This chapter outlines the key use cases and core services delivered by the **GoldenRAM** platform.

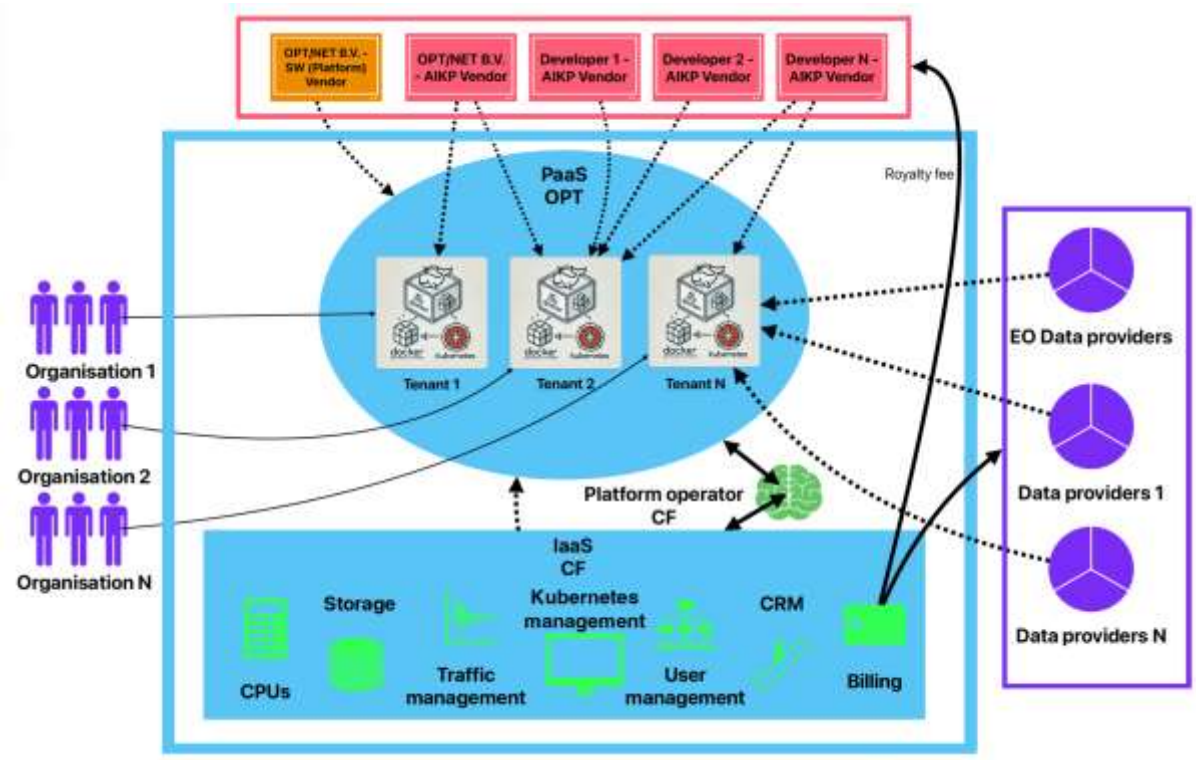

Figure 6. GoldenRAM Service Delivery Architecture

Figure 6. **Service Delivery Architecture** illustrates the architecture for deployment of the GoldenRAM solution as a Platform-as-a-Service (PaaS) operated by OPT/NET. The main actors and components with which actors will interact include:

1. **Platform and AIKP Vendors**:
    - OPT/NET B.V. serves as both the Platform Vendor and an AIKP (Artificial Intelligence Knowledge Pack) Vendor.

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- Multiple AIKP Vendors (including OPT/NET and VTT, BGR, GTK) provide AI-based data processing and analysis expertise (encapsulated and packaged as AIKPs) services on the platform.

2. **PaaS and IaaS Infrastructure**:
   The platform is built on an elastic cloud infrastructure with essential services managed by the platform operator. These include CPU resources, storage, traffic management, Kubernetes service orchestration, tenant and user management, CRM (Customer Relationship Management) and billing.
3. **Tenant Structure**:
   Each tenant (Tenant 1, Tenant 2, Tenant N) represents a customer organisation utilising containerized elastic compute environments via Docker and Kubernetes/OpenStack orchestration technologies, ensuring isolated and scalable on-demand deployments.
4. **Data Providers**:
   The platform integrates with multiple data providers, including EO and other data providers. The open data is accessible to and/or commercial data is fed into tenants' environments for processing and analysis, with fees paid to data providers (if applicable).
5. **Users and Organisations**:
   Various organisations (Organization 1, Organization 2, Organization N) can access and utilise the platform's services, benefiting from the AI-based data processing and analysis solutions provided by the AIKP vendors.
6. **Platform Operator**:
   The platform operator oversees the management of services and infrastructure, handling core functions like billing, CRM and Kubernetes management to support seamless service delivery to the tenants.

This structure highlights a multi-tenant, modular approach, with the primary platform operator enabling collaboration with external data providers and AI developers to deliver AI-driven solutions to multiple client organisations.

5.1. Service Use Cases

GoldenRAM is tailored to meet the diverse needs of stakeholders in the CRM sector, offering solutions that address critical challenges in exploration, safety and sustainability. Below are the primary use cases that demonstrate the platform's value:

1. **CRM Exploration and Prospectivity Mapping**
   GoldenRAM uses AI-driven mineral prospectivity mapping to assess the likelihood of CRM deposits in unexplored regions. This service helps mining companies make upfront data-driven decisions about where to invest in exploration, improving both the efficiency and success rates of their

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operations. As a result, the exploration step of sending geologists into the exploration area can be managed more efficiently and costs can be saved.
Key Features:

- AI-powered analysis of multispectral and hyperspectral satellite imagery.
- Geological insights to identify potential CRM deposits.
- Tools for selecting optimal locations for further exploration.

2. **Tailings Dam Stability Monitoring**
Tailings dam failures pose significant risks to mining operations, surrounding communities and the natural environment. **GoldenRAM** provides tailings dam stability monitoring through satellite data, offering early warning alerts to help prevent potential disasters. In addition, ground-based sensors can be integrated into the analysis and training of the system.
Key Features:

   - Monitoring of dam deformations, ground deformation and structural integrity using InSAR data.
   - AI models to predict potential dam failures.
   - Alerts for rapid response to detected risks.

3. **Environmental Monitoring and Impact Assessment**
To comply with strict environmental regulations, mining companies must continuously monitor the impact of their operations. **GoldenRAM's** environmental monitoring tools provide insights into water quality, vegetation health and soil conditions and can help ensure that companies meet Environmental, Social and Governance (ESG) standards.
Key Features:

   - Monitoring of water quality and land cover changes.
   - Automated ESG compliance reporting tools.
   - Tools for assessing the ecological impact of mining operations.

4. **Safety and Risk Management**
Mining companies face numerous safety challenges, including ground instability and hazardous environmental conditions. **GoldenRAM** offers predictive analytics to help mitigate these risks by providing data on safety hazards and potential risks.
Key Features:

   - Predictive analytics for safety assessments.

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- Early warning systems for environmental hazards (e.g., landslides, water seepage) with the option of integrating ground-based sensors into the analysis..
- Customizable workflows for generating safety reports.

5. **Post-Closure Monitoring**
   After mining sites have been decommissioned, companies are required to monitor environmental recovery and ensure compliance with reclamation agreements. **GoldenRAM** provides tools to track post-closure environmental conditions, ensuring long-term compliance and sustainability.
   Key Features:
   - Time-series analysis of post-closure sites to track ecological recovery.
   - Monitoring of vegetation regrowth, water quality and soil conditions.
   - Compliance reporting tools for regulatory bodies.

5.2. Core Services

GoldenRAM's core services are designed to provide stakeholders with the tools and insights they need to make informed decisions, improve operational efficiency and meet regulatory requirements. Below is an overview of the platform's key service offerings:

1. **Earth Observation (EO) data and Insights**
   GoldenRAM provides access to Earth Observation (EO) data and AI-driven insights, allowing stakeholders to monitor mining operations and environmental conditions continuously. This data is presented through interactive dashboards that visualise key metrics and trends.
   Key Capabilities:
   - Data feeds from Copernicus satellites and ground sensors.
   - AI-powered insights for CRM prospectivity, environmental monitoring and safety.

2. **Predictive Analytics for CRM Exploration and Mining Operations**
   Using machine learning models and historical datasets, **GoldenRAM** delivers predictive analytics that help stakeholders anticipate risks and opportunities related to CRM exploration, mining safety and environmental compliance. These analytics enable mining companies to optimize their operations, reduce operational risks and save costs.
   Key Capabilities:

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- AI-driven predictions for mineral deposit locations.
- Risk assessments for tailings dams, ground stability and environmental hazards.
- Predictive tools for optimising exploration investments.

3. **Automated Workflow Execution**
GoldenRAM streamlines complex data workflows through automated AI Knowledge Packs (**AIKPs**), allowing stakeholders to run data analyses with minimal manual intervention. These AIKPs are tailored to specific use cases, such as CRM exploration, ESG compliance and safety monitoring.
Key Capabilities:
   - Pre-built AI models that automate data analysis for CRM and environmental monitoring.
   - Customizable workflows that adapt to the specific needs of users.
   - Integration with external data sources and platforms for seamless data processing.
4. **ESG Compliance Monitoring and Reporting**
Compliance with Environmental, Social and Governance (ESG) standards is critical for mining companies operating in the EU. **GoldenRAM** offers tools for automated ESG reporting, documenting that companies meet regulatory requirements and demonstrate their commitment to sustainability.
Key Capabilities:
   - Automated generation of ESG compliance reports.
   - Monitoring of environmental impacts, including water, vegetation and soil.
   - Alerts and notifications for potential ESG violations.
5. **Custom Reporting Tools**
GoldenRAM provides stakeholders with custom reporting tools that generate detailed reports on mining operations, environmental monitoring, safety assessments and regulatory compliance. These reports can be tailored to meet the specific needs of mining companies, regulators and investors.
Key Capabilities:
   - Customizable reports for environmental, safety and compliance data.
   - Automated generation of regulatory and financial reports.
   - Export options for sharing reports with internal and external stakeholders.

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5.3. Service Delivery Infrastructure

GoldenRAM's services are delivered via a cloud-native platform, leveraging the scalable and robust infrastructure of the CREODIAS cloud. This ensures that services are available 24/7, with minimal downtime and high data processing capacity. The platform's modular design allows for the seamless integration of new tools and datasets, ensuring that stakeholders can continuously benefit from the latest advances in AI and EO data processing.

- Scalability: The platform is designed to scale both horizontally and vertically, allowing it to handle increasing data volumes and user demands.
- Security: Strong data security measures are in place, including role-based access control (RBAC), data encryption and GDPR compliance to protect sensitive mining and environmental data.
- User Support: **GoldenRAM** provides comprehensive user support, including tutorials, helpdesk services and a knowledge base to ensure users can take full advantage of the platform's features.

5.4. User Journeys/Workflow Descriptions

While service use cases have been described above, the document further includes more detailed **user journeys** (Figure 7. User Journeys) or **workflow descriptions** that highlight the interaction between users and the platform in various scenarios.

Clearer Focus on Service Components: The document further emphasises how each architectural component translates into **service delivery**. For example, linking how specific services (like predictive analytics or ESG reporting) are built into the modular and scalable architecture.

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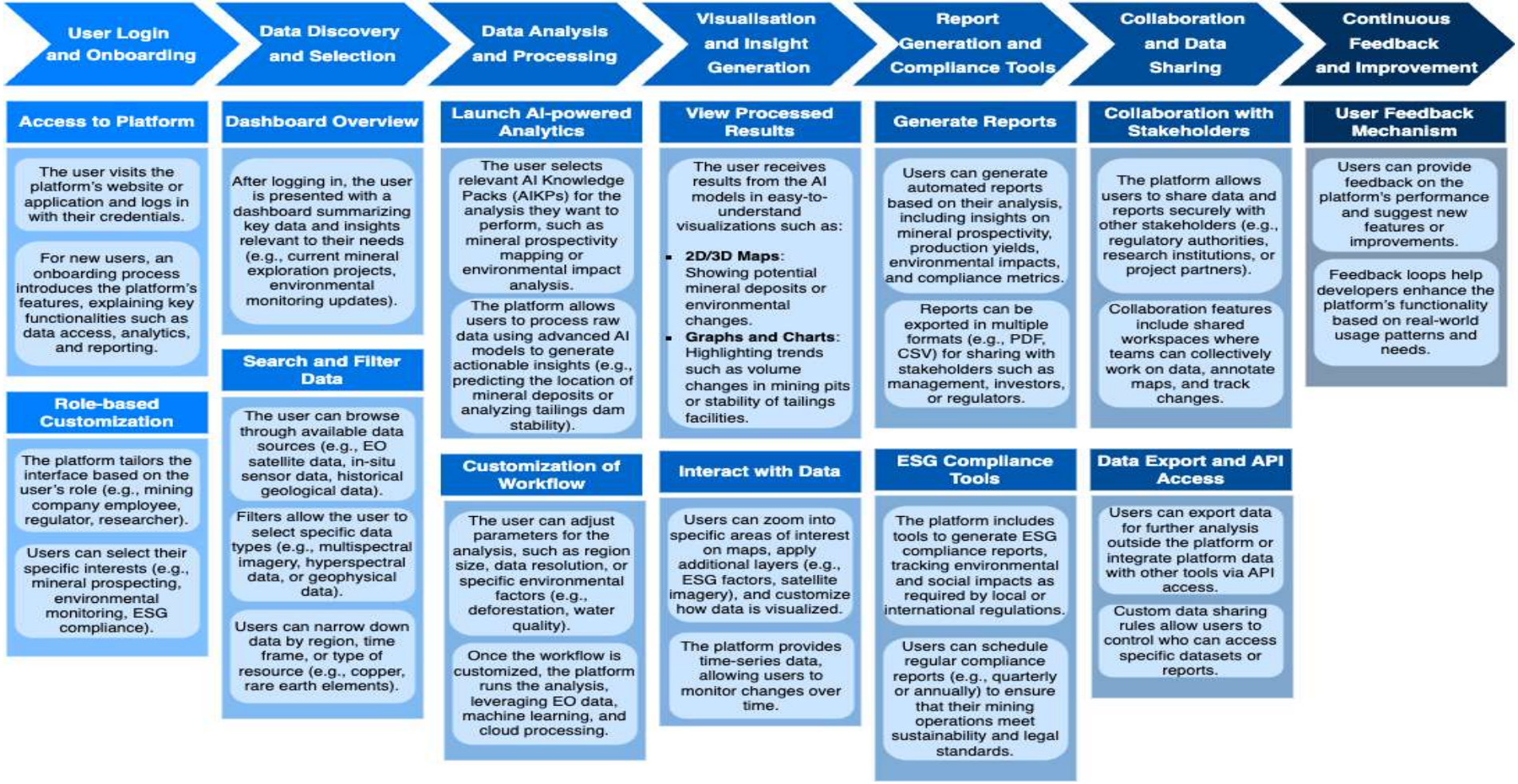

Figure 7. User Journeys

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6. Key Architectural Principles

The design of the **GoldenRAM** platform is guided by several key IT architectural principles that ensure its scalability, flexibility, security and alignment with the needs of the Critical Raw Materials (CRM) industry. These principles and best practices form the foundation upon which the platform is built, allowing it to adapt to evolving stakeholder requirements while delivering high-performance services for mining, environmental monitoring and regulatory compliance.

6.1. Modularity and Service Life-Cycle

Modularity and service Life-Cycle management are core principles in **GoldenRAM's** architecture, ensuring that the platform can easily accommodate new features, services and data sources as they become available. The modular design allows different components of the platform—such as the **AI Knowledge Packs (AIKPs)**, data ingestion modules and visualisation tools—to function independently and be updated or replaced without disrupting the overall system.

Key Benefits:

- **Future-Proof Design**: As new technologies, AI models, or data sources emerge, they can be integrated seamlessly into the platform.
- **Customizability**: Stakeholders can tailor the platform to their specific needs by enabling or disabling certain modules or adding custom features.
- **Ease of Maintenance**: Modular components can be updated or replaced independently, minimising system downtime during maintenance or upgrades.

6.2. Scalability and Elasticity

GoldenRAM is designed to be highly scalable, capable of handling growing data volumes and increasing numbers of users as the platform expands. By leveraging the CREODIAS cloud infrastructure, the platform can scale both vertically (increasing computational power) and horizontally (adding more servers and storage) to meet the needs of stakeholders in the CRM industry.

Key Benefits:

- **Elastic Resource Allocation:** The platform can automatically allocate additional computing resources as needed, ensuring optimal performance during periods of high demand.

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- **Support for Large Datasets: GoldenRAM** can process and analyse large datasets from satellite imagery, ground sensors and historical mining data without performance degradation.
- **Global Reach:** The cloud-native design allows the platform to be accessed from multiple geographic locations, enabling cross-border collaboration between EU countries and resource-rich partner nations.

6.3. Interoperability and Standards

Interoperability is essential for **GoldenRAM** to function effectively within the larger ecosystem of CRM exploration, mining operations and regulatory frameworks. The platform is built to integrate seamlessly with a wide variety of external systems, datasets and tools through the use of open standards and **application programming interfaces (APIs)**.

Key Benefits:

- **Integration with External Data Sources: GoldenRAM** supports the integration of data from Copernicus, proprietary satellite imagery, ground sensors and third-party databases.
- **Compatibility with External Platforms:** The platform adheres to Open Geospatial Consortium (OGC) standards, ensuring that it can exchange data with other geospatial information systems used in the mining and environmental sectors.

6.4. Security and Compliance

Given the sensitive nature of the data processed by **GoldenRAM**—ranging from proprietary mining data to environmental monitoring information—security and compliance are critical priorities in the platform's architecture. The platform adheres to the **General Data Protection Regulation (GDPR)** and incorporates advanced security measures to protect data integrity and ensure compliance with industry regulations.

Key Security Features:

- **Role-Based Access Control (RBAC):** Access to data and services is restricted based on user roles, ensuring that only authorised personnel can access sensitive information.
- **Audit Logs:** The platform maintains detailed logs of all user interactions and data access, providing a comprehensive audit trail for compliance and security reviews.

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- **Two-Factor Authentication (2FA):** The integration of Keycloak enables the activation of 2FA for users, adding an extra layer of security to user authentication processes.

Compliance Features:

- **GDPR Compliance: GoldenRAM** ensures that all personal data is processed in accordance with European data protection laws.
- **ESG Reporting Compliance:** The platform is designed to support Environmental, Social and Governance (ESG) compliance by providing tools for tracking and reporting on environmental impacts, social responsibility and governance standards.

Cloud Hosting and Certifications

The platform will be hosted on CloudFerro's public cloud infrastructure. CloudFerro is a reputable cloud service provider with comprehensive certifications, including:

- **ISO 27001**: International standard for information security management systems (ISMS).
- **BSI 200-1**: Certification that ensures compliance with information security standards.
- **BSI-C5**: A cloud-specific standard that addresses security requirements for cloud computing.

These certifications ensure that the cloud environment maintains a high standard of security, availability, and data protection. Hosting the platform on a certified cloud provider like CloudFerro reinforces GoldenRAM's commitment to security and regulatory compliance.

6.5. Flexibility and Modularity

GoldenRAM's architecture is built with flexibility in mind, allowing the platform to adapt to the unique needs of different stakeholders within the CRM ecosystem. Whether users are mining companies, regulatory bodies, or research institutions, the platform can be customised to deliver tailored services and insights.

Key Benefits:

- **Customizable Workflows:** Stakeholders can configure the platform's workflows to meet their specific requirements, whether it's for CRM exploration, environmental monitoring, or regulatory compliance.
- **Adaptable AI Models:** The platform's AI Knowledge Packs (AIKPs) can be customised or extended to address unique data processing needs and use cases.

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- **Multiple User Profiles:** Different user roles (e.g. mining engineers, environmental scientists, regulators) can be assigned different levels of access and functionality, ensuring that each stakeholder receives the tools they need.

6.6. High Availability and Reliability

The platform's cloud infrastructure includes failover mechanisms, backup systems and redundancy features to ensure continuous service even in the event of hardware or network failures.

Key Features:

- **Automatic Failover:** In the event of a server failure, the platform automatically redirects traffic to backup servers, minimising downtime.
- **Data Backup and Recovery:** Regular backups of critical data ensure that information is never lost and recovery systems allow for rapid restoration in the event of data corruption or loss.
- **Service-Level Agreement (SLA):** GoldenRAM operates under a high-availability SLA, ensuring a minimum uptime of 99.9%.

6.7. Data Privacy and Ownership

Data privacy is a key concern for many stakeholders in the CRM industry, particularly when it comes to proprietary data related to exploration sites, mineral resources and operational performance. **GoldenRAM's** architecture ensures that data privacy and ownership are fully respected, allowing stakeholders to maintain control over their data.

Key Features:

- **Data Ownership:** Stakeholders retain full ownership of their data, with **GoldenRAM** acting only as the processor. Users can control how their data is shared, accessed and utilised.
- **Data Anonymization:** Sensitive personal or operational data can be anonymized to protect the privacy of individuals and companies while still allowing for meaningful analysis.
- **Data Access Controls:** Advanced access controls allow data owners to define who can access, modify, or share their data, ensuring that proprietary information remains secure.

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6.8. CI/CD and Agile Development Practices

The design and implementation of the **GoldenRAM** platform are built on Continuous Integration and Continuous Delivery (CI/CD) principles. These principles were established and agreed upon by all project stakeholders during periodic meetings and Design Review Meetings (DRM). This approach ensures that the platform evolves continuously, responding efficiently to stakeholder needs while maintaining high standards of quality and performance. The following key elements define this design approach:

- Lean IT Processes: The platform design prioritises lean methodologies, focusing on rapid iterations and delivering incremental value. This Agile approach allows for quick adjustments to changes in stakeholder requirements, thus accelerating delivery without compromising quality.
- Software-Defined Life Cycles: The platform's lifecycle is defined by tools and workflows that emphasise automation. From code deployment to monitoring, the CI/CD pipeline automates the integration, testing and delivery of new features, ensuring faster and more reliable updates.
- DevOps Culture: Emphasising collaboration and communication between development and operations teams, the platform adopts a DevOps model. This ensures a culture of responsiveness and accountability, allowing for rapid deployment, quick issue resolution and continuous improvement.

This approach aligns with ITILv4 and other industry best practices, ensuring the GoldenRAM platform remains adaptable, scalable and resilient throughout its development and operational phases.

6.9. Detailed Mapping of Existing and Missing Specifications

This section provides a comprehensive mapping of the existing and missing specifications for the **GoldenRAM** solution, based on the requirements and needs expressed across various sites. The specifications are categorised into three main areas: technical, performance and economic requirements. This analysis will ensure that the **GoldenRAM** platform meets the necessary standards for effective operation while highlighting areas requiring further development.

6.9.1. Technical Requirements

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The technical requirements focus on the system architecture, integration of various data sources (EO, in-situ, drone data), scalability and security.

Category	Existing Specifications	Missing Specifications	Comments
Data Integration	EO, drone and in-situ data from multiple sites available	Harmonisation of geospatial formats for multisite data integration (Sokli)	Cross-site data integration and fusion is needed
Data Processing	Use of AIKP for Sentinel-1 and Sentinel-2 data for mineral and environmental mapping	Expanded AIKP for handling hyperspectral data for mineral mapping and secondary raw materials	Hyperspectral data handling needs enhancement for high-resolution
System Architecture	Cloud-based infrastructure for data storage and processing	Elastic compute service, on-demand execution	Necessary for tasks like open-pit monitoring
Security	GDPR-compliant access controls in place, using role-based access	ISO 27000, AI regulation and GDPR regulations compliance	Security measures need to cover all data flows

Table 1. Specification mapping

The platform requirements include a variety of platform and service specifications that focus on data processing, visualisation and integration of EO data and in-situ data. Here are the main backend-related requirements, based on user requirements gathered during set of interviews and presented in the documents:

- T9.2 Specifications of mineral exploration AIKPs
- T11.2 Specifications of the production, operations and safety AIKPs
- T13.2 Specifications of the environmental applications AIKPs

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	UR-TABLES_GIUA_UKRAINIANSHIELD	**UR-TABLES_CUPRUMIN_ABRUD**	**UR-TABLES_SOKLI_SOKLI SITE**	**UR-TABLES_SAVANNAH_ BARROSO**
Platform Requirements	The platform must enable data retrieval of precomputed information, offer step-by-step wizards for users to select and run analyses, and support secured connections.	The backend must handle DEM (Digital Elevation Models) processing, 2D/3D map visualisation, and integrate Sentinel-1 Persistent Scatterer Interferometry (PSI) data.		Backend must handle DEM Difference Stack, Time Series AIKPs, RGB composites, and data visualisation for 3D geological mapping.
Front end Requirements	The user interface is expected to support data visualisation and download options, including maps and geospatial information	The platform also requires functionalities for visualising velocity maps and time series analysis	The platform needs to support time series analysis and visualisation.	The platform needs to support remote access to geospatial data through secure connections and data downloads

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AIKP Requirements			Should include GOLDENEYE AIKP with functionalities like Principal Component Analysis, RGB composites, and unsupervised clustering for satellite data	
Service Inputs	Data inputs include satellite data sources (Sentinel-1, Sentinel-2, ASTER, Landsat-8), multispectral, hyperspectral, and SAR data. EOD is integrated with geological parameters for investment-related evaluations	The backend must support multiple satellite data sources (Sentinel-1, Sentinel-2, ASTER), drone campaigns, in-situ data collection, and processing for environmental monitoring	Inputs include drone and satellite data (multispectral, hyperspectral, SAR), along with ground-based data for correlating surface measurements and drill core samples	EOD from satellites and drones, alongside in-situ data, are required for hyperspectral mineral mapping and monitoring soil moisture

Table 2. Technical Requirement

Each document specifies a need for secure, data-intensive backend systems capable of integrating satellite data, processing DEMs and visualizing results in both 2D and 3D formats. The platforms must support environmental monitoring, mining evaluations and geospatial analysis.

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6.9.2. Performance Requirements

This section evaluates the platform's performance-related requirements, including data accuracy, system responsiveness and scalability.

Category	Existing Specifications	Missing Specifications	Comments
Response Time	2D and 3D visualisation tools for mineral prospectivity maps available	Optimised response time during peak data processing periods	Crucial for big data sets and monitoring applications
Accuracy of Data	Good correctness in EO-based (VHR1 / VHR2) environmental monitoring	Use enhanced models for calculations based especially on multi- and hyperspectral data	Necessary for improving results and predictions
Scalability	Supports current mining sites across various regions	Automatic scaling based on user and data load	Required for handling increased user demand

Table 3. Performance Requirement

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7. Platform Integration Strategy

The integration strategy for the **GoldenRAM** platform is designed to ensure seamless connectivity with external systems, data sources and tools, enhancing its utility for stakeholders across the Critical Raw Materials (CRM) industry. This chapter outlines how **GoldenRAM** integrates with various platforms, data providers and cloud infrastructure to support data ingestion, processing and sharing while maintaining interoperability, flexibility and scalability.

7.1. Integration with External Data Sources

GoldenRAM's architecture allows for the ingestion of a wide variety of external data sources, including Earth Observation (EO) data, proprietary datasets and in-situ sensor data. The platform is designed to handle large, diverse datasets, making it a powerful tool for mining companies, regulatory bodies and research institutions that require access to detailed, up-to-date information.

Key Data Sources:

- **Copernicus Satellite Data**: **GoldenRAM** is closely integrated with the Copernicus Earth Observation Program, utilising satellite data to provide real-time insights into CRM exploration, environmental monitoring and land use changes. This data is critical for mineral prospectivity mapping, tailings dam stability assessments and environmental impact monitoring.
- **Proprietary Data:** Mining companies and research institutions can integrate their proprietary geological and operational data with **GoldenRAM**, allowing them to combine their internal insights with **EO data** and AI-driven analytics for more comprehensive decision-making.
- **Historical Data: GoldenRAM** also integrates with historical **CRM** exploration and mining datasets, enabling long-term analysis of resource availability, extraction trends and environmental impacts over time.

Benefits:

- **Comprehensive Data Fusion: GoldenRAM** enables the fusion of multiple data types, improving the accuracy and granularity of insights delivered to stakeholders.
- **Monitoring**: Seamless integration with satellite and sensor data ensures that users have access to updates on mining operations and environmental conditions.

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- **Custom Data Import:** Stakeholders can upload and integrate their own datasets into the platform, allowing for more tailored analysis and reporting.

7.2. CREODIAS Cloud Infrastructure Integration

GoldenRAM leverages the **CREODIAS** cloud platform, part of the Copernicus Data and Information Access Services (DIAS) initiative, to support large-scale EO data processing and storage. This integration provides **GoldenRAM** with a powerful, scalable infrastructure for handling the vast amounts of data required for **CRM** exploration and monitoring.

Key Features of **CREODIAS** Integration:

- **Scalability**: **CREODIAS's** cloud infrastructure is designed to scale according to data and user demand, allowing **GoldenRAM** to handle increasing data volumes and expanding user bases without performance degradation.
- **Data Processing and Storage**: The platform provides high-performance storage for large EO datasets and enables fast, efficient processing of these datasets using advanced AI algorithms.
- **Secure and Compliant Environment**: **CREODIAS** ensures that all data processing and storage meet European data protection and security standards, including **GDPR** compliance and other relevant regulatory requirements.
- **Availability of Copernicus Data**: By being hosted on **CREODIAS**, **GoldenRAM** has direct access to Copernicus satellite data archives, facilitating seamless data retrieval and reducing latency for stakeholders accessing EO data.

Benefits:

- **High-Performance Data Processing:** The **CREODIAS** platform supports fast, reliable data processing, allowing **GoldenRAM** to deliver real-time insights and reports to its users.
- **Cloud-Native Flexibility:** Integration with a cloud-native infrastructure ensures that **GoldenRAM** can expand or contract its computing resources as needed, optimising operational costs and performance.
- **Data Sovereignty: CREODIAS** operates under EU jurisdiction, ensuring that data sovereignty is maintained, particularly for sensitive mining and environmental data.

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7.3. API Integration and Data Sharing

GoldenRAM is built to facilitate seamless integration with external platforms and services via standardised Application Programming Interfaces (APIs). The platform supports Open Geospatial Consortium (OGC) standards, ensuring interoperability with other geospatial platforms and services in the mining and environmental sectors.

API Capabilities:

- **Programmatic Data Access**: Stakeholders can access **GoldenRAM's** datasets and analytics via APIs, allowing them to integrate the platform's capabilities into their existing workflows and tools. This includes programmatic access to EO data, AI-driven insights and historical datasets.
- **External System Integration:** The platform can connect to external systems used by mining companies, regulatory bodies and research institutions, enabling seamless data flow between **GoldenRAM** and other operational tools.
- **Data Sharing:** APIs allow users to share data with external stakeholders, such as regulators or investors, ensuring that decision-makers have access to the latest insights on **CRM** exploration, environmental monitoring and operational safety.
- **Customization and Extension:** Through APIs, users can develop custom applications or extend the functionality of **GoldenRAM** by building new tools that integrate with the platform's core services.

Benefits:

- **Interoperability:** By adhering to open standards, **GoldenRAM** ensures compatibility with a wide range of external platforms, enabling more efficient collaboration between stakeholders.
- **Custom Integration:** The API-driven architecture allows users to create bespoke solutions tailored to their unique requirements, enhancing the platform's flexibility.
- **Scalable Data Access:** APIs provide scalable access to data and analytics, allowing multiple users or systems to retrieve information simultaneously without performance degradation.

7.4. Integration with Regulatory Systems

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One of **GoldenRAM's** key objectives is to support Environmental, Social and Governance (ESG) compliance for mining operations. To facilitate this, the platform is designed to integrate with regulatory frameworks and reporting systems, ensuring that mining companies can automatically generate and submit reports to the relevant authorities.

Key Integration Points:

- **Automated ESG Reporting:** GoldenRAM can generate automated compliance reports based on environmental monitoring data. These reports can be formatted to meet the requirements of specific regulatory bodies, reducing the administrative burden on mining companies.
- **Cross-Border Collaboration:** GoldenRAM supports international regulatory collaboration by providing shared access to data between EU member states and CRM-rich partner countries. This promotes transparency and cooperation in managing raw materials supply chains.

Benefits:

- **Streamlined Compliance:** Mining companies can automate the generation and submission of regulatory reports, ensuring that they remain compliant with evolving ESG standards.
- **Enhanced Oversight:** Regulators benefit from access to data on mining operations, enabling them to monitor compliance more effectively and intervene in cases of non-compliance.
- **Global Integration:** The platform facilitates the exchange of data and insights across borders, helping to harmonize regulatory standards and improve sustainability in the CRM industry.

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8. Business and Operational Model

The **GoldenRAM platform** operates under a business model designed to ensure long-term sustainability and value creation for its diverse set of stakeholders, including mining companies, regulatory authorities, research institutions and investors. The platform's operational model ensures high-quality service delivery, continuous platform development and a focus on innovation while maintaining operational efficiency. This chapter outlines the commercialization strategy, revenue streams, cost structure and operational model for the platform as it transitions from development to full-scale commercial operation.

8.1. Commercialization Strategy

GoldenRAM's commercialization strategy is centred around delivering value to stakeholders in the **Critical Raw Materials (CRM)** industry through real-time data analytics, predictive insights and compliance tools. The platform is positioned to address critical challenges such as **CRM** exploration efficiency, environmental sustainability and regulatory compliance, making it an indispensable tool for stakeholders across the mining ecosystem.

Key Commercialization Goals:

- **Market Penetration: GoldenRAM** aims to penetrate the CRM market by providing tailored solutions to key industry stakeholders, including mining companies, regulatory bodies and investors. The platform will be marketed as a comprehensive tool for CRM exploration, safety monitoring and environmental impact assessment.
- **Strategic Partnerships: GoldenRAM** will collaborate with strategic partners, such as Copernicus, CREODIAS and mining industry associations, to expand its reach and integrate additional services. These partnerships will allow the platform to grow its data sources and extend its value proposition to a wider audience.
- **Field Trials and Demonstrations: GoldenRAM's** field trials in six European countries and Ukraine serve as a key component of its commercialization strategy, showcasing the platform's capabilities in real-world scenarios. Successful demonstrations will lead to broader adoption across the CRM industry.
- **Scalability and Flexibility:** The platform is designed to scale, allowing it to serve a growing number of stakeholders. **GoldenRAM** will offer modular solutions that can be customised to fit the needs of various users, from small mining firms to large multinational corporations.

Go-To-Market Strategy:

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- **Targeted Marketing: GoldenRAM** will focus on CRM companies and regulators in Europe and CRM-rich regions. The platform's unique selling points— EO data integration, AI-powered insights and ESG compliance tools—will be emphasized in marketing campaigns.
- **Direct Sales and Licensing:** The platform will be made available through direct sales and licensing agreements, where stakeholders can access the full suite of GoldenRAM's services through a subscription model.
- **Early Adopters and Pilot Programs:** Early adopter programs will offer reduced subscription rates and additional support to attract initial users and encourage platform engagement. These pilot programs will provide valuable feedback for further development and optimization.

8.2. Revenue Models

GoldenRAM's business model is built around a variety of revenue streams, ensuring both short-term profitability and long-term financial sustainability. The platform offers value-added services to a wide range of stakeholders, each of which will be monetized through different pricing structures.

Primary Revenue Streams:

1. Subscription-Based Model
   GoldenRAM will primarily operate under a subscription-based model, where stakeholders pay recurring fees to access the platform's services. The subscription tiers will be based on the volume of data accessed, the number of users and the specific services required (e.g., monitoring, predictive analytics, ESG reporting).
   Key Features:
   - Basic Tier: Entry-level access to standard data and analytics features, suitable for smaller mining companies or regulatory bodies with limited data requirements.
   - Premium Tier: Advanced features, including AI-driven insights, monitoring and customization options for large-scale operations or multinational companies.
   - Enterprise Tier: Fully customizable plans for large organisations with complex data needs, offering full access to all GoldenRAM features and dedicated support.
2. Pay-Per-Use Model
   For stakeholders with sporadic data needs, GoldenRAM will offer a pay-per-use model, allowing users to pay for access to specific datasets or analytics on an as-needed basis. This model is ideal for research institutions or

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investors who require occasional access to specific data points for CRM analysis.

3. Data Monetization
GoldenRAM's data services, such as processed Earth Observation (EO) data, mineral prospectivity maps and ESG compliance reports, will be available for sale to third parties. This creates an additional revenue stream, particularly for stakeholders outside the **CRM** sector who may benefit from the platform's environmental monitoring tools.
Key Features:
    - Custom Reports: Tailored ESG and safety compliance reports can be sold to regulators, investors and other interested parties.
    - Analysis Ready Data (ARD): Access to refined EO data that has been processed and analysed by **GoldenRAM's** AI algorithms.
4. Partnership and Licensing Agreements
GoldenRAM will enter into licensing agreements with third-party service providers, allowing them to integrate **GoldenRAM's** data and analytics into their platforms. This will enable a broader range of stakeholders to access the platform's capabilities while generating additional revenue through licensing fees.

8.3. Operational Model

GoldenRAM's operational model is based on a combination of cloud-based services, user support and continuous innovation to ensure a high level of service for its stakeholders. The platform's cloud-native architecture ensures that it can scale quickly and efficiently, while the modular design allows for continuous improvement and the addition of new services.

Key Elements of the Operational Model:

1. **Cloud-Based Service Delivery**
All services are delivered through the cloud, ensuring high availability and minimal downtime. The use of cloud infrastructure allows **GoldenRAM** to scale its operations in response to user demand without the need for significant upfront investment in physical infrastructure.
2. **User-Centric Approach**
GoldenRAM's services are designed with user needs in mind, ensuring that the platform remains flexible and customizable. Users can choose the specific services and data they need, while customer support provides assistance to optimise their use of the platform.
3. **Continuous Platform Development**
GoldenRAM is committed to ongoing innovation, with a dedicated team

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working on the development of new AI models, data integrations and user features. This ensures that the platform remains relevant and continues to provide cutting-edge solutions for the CRM industry.

4. **Feedback-Driven Improvement**
   User feedback from early adopters and field trials will be critical in shaping the platform's future development. By incorporating feedback into its development process, **GoldenRAM** will ensure that its services evolve to meet the changing needs of the CRM industry.

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9. Roadmap and Future Outlook

GoldenRAM is a forward-looking platform that not only addresses the current needs of the **Critical Raw Materials (CRM) industry** but also aims to anticipate and adapt to future developments. The platform's development roadmap outlines key milestones for its technical and commercial progression, while the future outlook highlights the long-term vision for its expansion, adoption and impact on the CRM and environmental sectors.

9.1. Development Roadmap

GoldenRAM's development is structured in phases, each focusing on expanding its capabilities, improving its technology and scaling its services to more users and use cases. The roadmap below outlines the key milestones from the platform's current stage to its full-scale deployment and commercialization.

Phase 1: Initial Development and Proof of Concept

- Platform Development: Initial development of the core platform architecture, including the backend data processing engine, frontend user interface and integration with the CREODIAS cloud infrastructure.
- AI Knowledge Packs (AIKPs): Development of the first set of AIKPs tailored to CRM exploration, tailings dam stability and environmental monitoring.
- Pilot Testing and Early Field Trials: Pilot field trials in some CRM sites across Europe, focusing on validating the platform's data processing capabilities, AI models and integration with external data sources like Copernicus and ground-based sensors.
- Stakeholder Engagement: Initial outreach to mining companies, regulatory bodies and research institutions to gather early feedback on platform usability and feature relevance.

Phase 2: Expanded Field Trials and Feature Enhancement

- Expanded Field Trials: Conduct full-scale field trials across all CRM sites in Finland, Sweden, Romania, Portugal and Ukraine, demonstrating the platform's use cases in mineral prospectivity mapping, ESG compliance and environmental monitoring.
- Feature Expansion: Incorporation of additional AIKPs to address new use cases, such as safety monitoring and post-closure environmental assessments.

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- User Feedback Integration: Continuous feedback from stakeholders will be incorporated into platform improvements, especially focusing on user experience, data visualisation and reporting tools.
- Enhanced API Integration: Expansion of API capabilities to allow for greater interoperability with external systems, improving data sharing and integration.

Phase 3: Commercial Rollout and Full-Scale Operation

- Commercial Launch: Official commercial launch of the **GoldenRAM** platform, offering subscription-based access to all stakeholders in the **CRM** industry.
- Strategic Partnerships: Establish formal partnerships with mining companies, regulators and investors to scale adoption and secure long-term contracts for platform services.
- Data Marketplace Introduction: Launch of a data marketplace feature, allowing third parties to buy and sell processed data and insights generated by **GoldenRAM's** AI and EO data processing capabilities.
- Regulatory Integration: Strengthen integration with regulatory systems, enabling automated compliance reporting for environmental and safety regulations, particularly for ESG metrics.

Phase 4: Global Expansion and Continued Innovation

- Global Expansion: Expand the platform's user base beyond Europe to include CRM-rich countries in other regions, including Africa, South America and Asia, fostering international collaboration in responsible mining practices.
- AI Model Expansion: Develop new AI models and AIKPs for advanced use cases such as predictive maintenance, enhanced environmental restoration monitoring and geospatial analysis for new mining frontiers.
- Cross-Sectoral Expansion: Explore potential applications of the platform in other industries, such as agriculture, forestry and energy, where EO data and AI-driven environmental monitoring can offer value.
- Sustainability Initiatives: Drive the development of features that further support sustainable resource management, climate change mitigation and circular economy practices in CRM exploration and extraction.

9.2. Future Enhancements

GoldenRAM is positioned as a dynamic and evolving platform that will continuously innovate to meet the changing demands of the **CRM** industry and its

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stakeholders. Below are some key future enhancements that will drive the platform's long-term growth and impact:

1. **Advanced AI and Machine Learning Models**
   As the platform evolves, the focus will be on developing more sophisticated AI models capable of performing complex geospatial analysis, predictive maintenance for mining equipment and anomaly detection in environmental monitoring.
   Planned Features:
   - Enhanced mineral prospectivity models that leverage multi-sensor data fusion.
   - AI models for sustainability assessments, predicting long-term environmental impacts based on historical and data.
   - Integration of natural language processing (NLP) models for automated report generation and regulatory submissions.
2. **AI Knowledge Pack (AIKP) Marketplace**
   A marketplace for AI Knowledge Packs (AIKPs) will be developed, allowing third-party developers to create and sell their AI models on the platform. This will promote innovation and enable stakeholders to access a wider range of AI solutions tailored to specific mining and environmental challenges.
3. **Deeper Integration with Financial and Investment Tools**
   The platform will expand its suite of tools to offer financial risk assessments, helping investors better evaluate the long-term viability of mining projects. This will include integration with financial models and analytics platforms that provide deeper insights into the economics of CRM extraction.
4. **Enhanced Sustainability and ESG Reporting Features**
   As ESG compliance becomes increasingly important, **GoldenRAM** will develop more advanced tools for sustainability reporting. The platform will offer automated solutions that provide real-time ESG tracking, ensuring mining companies can meet stringent regulatory standards and improve their environmental and social governance practices.
5. **International Collaboration for Raw Materials Security**
   GoldenRAM will continue to foster cross-border collaboration, supporting international initiatives to secure access to raw materials in a sustainable and transparent manner. This includes partnerships with global mining associations, governmental bodies and multilateral organisations to promote responsible resource management practices globally.

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9.3. Long-Term Impact on the CRM Industry

GoldenRAM's long-term vision is to become the leading digital platform for sustainable CRM exploration and environmental monitoring, playing a central role in securing Europe's access to critical raw materials while promoting responsible mining practices. The platform will be a driving force in transforming the **CRM** industry by enabling stakeholders to adopt more efficient, safe and environmentally conscious operations.

Key Areas of Long-Term Impact:

- Resource Efficiency: **GoldenRAM** will help optimise **CRM** exploration and extraction processes, reducing waste and improving resource efficiency through data-driven decision-making.
- Sustainability Leadership: The platform's tools for ESG compliance and environmental monitoring will position **GoldenRAM** as a leader in promoting sustainability and accountability within the CRM industry.
- Supply Chain Security: By improving access to high-quality data and predictive insights, **GoldenRAM** will contribute to securing Europe's supply of critical raw materials, reducing dependency on external sources and enhancing supply chain resilience.
- Innovation in AI and EO Technologies: **GoldenRAM** will continue to innovate in the application of artificial intelligence and Earth Observation data to solve complex challenges in the mining and environmental sectors, establishing itself as a cutting-edge platform for digital transformation in the **CRM** industry.

10. Open Source and other matters

This chapter was added after the Mid-Term Project review and its purposes are:

- to address the feedback received from the Expert Evaluator,
- and to provide clarifications and additional information as applicable.

It is very clear to the consortium that GoldenRAM platform will be appealing to the large groups of users and researchers if made publicly available. However, it is also clear that the operational costs and legal provisions surrounding of the use of such platform require thorough study, understanding, and elaborate preparation.

However, it is important to stress that this deliverable describes the exact high-level design pertinent to the **GoldenRAM (G-RAM) platform**, as envisioned in GoldenRAM proposal, and in accordance to the provisions of the Grant Agreement. The HLA document does not describe directly the potential applications of the

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developed software and AIKPs outside of the project scope, and which goes beyond the funding provided by the EC for the GoldenRAM project.

This PUBLIC deliverable 5.2 is only expected to describe a high-level design of the envisioned instance of the **"GoldenRAM platform"** "as a service" to potential outside users interested in the subject matter, but this deliverable is not supposed to provide the designs, code, or any platform data under any usage licenses. The possibility that the platform's services may be designed and provided by entities from outside the consortium is not mentioned deliberately. This is because the platform code and data contain confidential data and know-how which is critical to the successful valorisation of this Innovation Project's outputs. In addition, such advanced AI based GIS data platform exhibited a clear dual-use potential and use in military targeting applications. This summarises the point that very careful approach is warranted when out-of-scope dissemination of non-public material of the GoldenRAM project is discussed.

This is why there are separate and specialised exploitation and valorization activities planned in the second half of the project, where further technical details, business models, legal, IP Licensing, export compliance, and other relevant topics will be studied in sufficient details.

Examples of the future public technical deliverables:

D6.1 –API Manual [G-RAM platform and service Application Programming Interface (API) Manual]

D7.1–User Manual, v1 [G-RAM platform and service User Manual, v1]

The Licensing Agreements and Data/code sharing policies will also be derived which will be compliant with the EU laws and regulations. There are dedicated sensitive deliverables devoted to this subject which are led by experienced law firm, which also cover: Innovation, IPR and legal matters, exploitation strategy, data and code repositories and management plans, etc.

Nevertheless, **it is important to stress that the consortium pledges adherence to the promise of supporting open science initiatives of EC and will make some AIKPs available free of charge for the authorised users under controlled open licenses.** It is important to mention that on this stage of the work on the project, several of the developed AI KPs had already been classified as "open-source code" and provided under the controlled open license to the participants of the consortium and other authorised and associated parties. For example, we already have collaboration with scientists who conduct derivative software development on the basis of the open-source AI KPs originally sourced from OPT/NET.

In addition, the GoldenRAM platform may be hosted by external entities, for example Copernicus DIAS providers, assuming that they have commitment, technical ability and qualifications, underwent required training, and accepted legal terms & conditions, IP and data licensing provisions and are compliant with other requirements which are in-line with Grant Agreement.

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11. Conclusions

This deliverable presents the high-level design of the **GoldenRAM (G-RAM)** platform, a transformative tool aimed at addressing critical challenges in the Critical Raw Materials (CRM) industry. The design aligns strategically with the project's goals, offering innovative solutions to enhance CRM exploration, improve sustainability and foster collaboration among key stakeholders. The main conclusions are as follows:

1. **Strategic High-Level Design**:

   The **GoldenRAM** platform incorporates a modular, scalable and cloud-native architecture. This design ensures flexibility, interoperability and ease of integration with diverse data sources and systems, addressing the varied needs of CRM stakeholders.

2. **Alignment with Project Goals**:

   GoldenRAM directly supports the European Union's CRM strategy and the European Green Deal by reducing dependency on external raw materials, promoting sustainable mining practices and advancing environmental, social and governance (ESG) compliance.

3. **Advanced Data Utilization**:

   By integrating multimodal data sources, such as EO satellite imagery, ground sensors and proprietary datasets, with AI-driven analytics, the platform delivers precise insights for CRM exploration, environmental monitoring and risk management.

4. **Empowering Stakeholder Collaboration**:

   The platform fosters an interconnected ecosystem where mining companies, regulatory bodies, research institutions and investors collaborate. Shared data and insights enhance decision-making, optimize operations and drive innovation in resource management.

5. **Potential Impact on the CRM Industry**:

   GoldenRAM is poised to revolutionize CRM exploration and sustainability practices by introducing predictive analytics, automated ESG compliance tools and advanced environmental monitoring. These capabilities significantly lower operational risks and costs while enhancing efficiency and regulatory adherence.

6. **Future-Proof and Scalable**:

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The platform's modular design ensures adaptability to emerging technologies, new data sources and evolving industry needs. This forward-looking approach guarantees relevance and scalability for long-term industry transformation.

7. **Driving Sustainability and Resource Security**:

   By promoting sustainable mining practices and resource efficiency, **GoldenRAM** contributes to securing Europe's raw material supply and strengthening the CRM industry's alignment with global sustainability goals.

These conclusions highlight the transformative potential of the **GoldenRAM** platform. Its innovative design not only addresses the immediate challenges of the CRM sector but also establishes a collaborative foundation for long-term sustainability and growth. Through continued stakeholder engagement and iterative development, **GoldenRAM** is set to become a cornerstone solution for responsible resource management.

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