



NOSTRADAMUS

NOSTRADAMUS - Open Call #1

Annex 1.1

Technical Specification_V1.0



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1. Introduction and Project Context

Under the Nostradamus project, two Open Calls will be launched to support the design, development, and delivery of **open-source digital applications** that enhance sustainable and efficient agricultural production systems, with a specific focus on cereal-based systems and food security. All applications must **build upon the Nostradamus** data infrastructure, make use of the project's architecture, tools, and services, and contribute to the expected outcomes of the Horizon Europe call by improving the sustainability performance, competitiveness, and digital transformation of the agricultural sector.

There will be two Open Calls (OC):

- **OC#1 - Decision-Making Applications:** targeting farmers, cooperatives, farm advisors, and agri-industrial actors. Applications should deliver (near)-real-time, data-informed recommendations to enhance farm management, productivity, and resilience.
- **OC#2 - Policy-Shaping Applications:** targeting policymakers, public administrations, and strategy planners. Applications should provide evidence-based analytics and indicators to guide agricultural and food security policies, sustainability monitoring, and EU strategic alignment.

The current OC#1 aims at attracting and funding system actors and innovators – such as SMEs, start-ups, and agricultural research institutes – to develop, test, and validate multi-functional, open-source digital applications for farm decision-making and agribusiness. By leveraging the Nostradamus Data Cubes, Earth Observation data, and IoT streams, these solutions will enable farmers to optimize critical agricultural inputs (including water, fertilizers, and pesticides), improve energy balance, and enhance production resilience under changing climate and soil conditions.

OC#2 for policy-shaping applications will launch in 2027.

1.1. The NOSTRADAMUS Vision:

Overview of the "Data SILO" concept for EU Food Security and cereal-based systems.

Nostradamus is built around a structured, aggregated, and easily accessible pool of agricultural data designed to safeguard EU Food Security and support EU independence in agricultural inputs. Technically, this silo is implemented as the Data Cube Ecosystem, comprising five interoperable Data Cubes (one per demonstration country: Cyprus, Serbia, Slovenia, Switzerland, and Germany), each acting as a multi-dimensional, one-stop-shop for agricultural data at national and cross-border level. The silo consolidates four categories of data pipelines: (i) Earth Observation (EO) data, (ii) IoT-derived, in-situ sensor data from the project's demonstration sites, (iii) existing databases (e.g. soil, vegetation, agricultural management practice data), and (iv) agricultural market and socio-economic data. By harvesting, harmonising, and structuring this data in near real time, the silo removes the fragmentation, redundancy, and inconsistency that currently hinder the development of reliable, data-driven agricultural applications. Within this silo, Nostradamus develops four core modules directly relevant to cereal-based systems and Food Security: drought monitoring, crop suitability and yield estimation, soil fertility and crop nutritional management, and sustainable pest management. These modules draw specifically on the cereal-supply-chain dimension of the project,



given that the five demonstration sites were selected in part for their cereal productivity, agrochemical consumption profiles, and diversity of biogeographical and socio-economic conditions. For Open Call applicants, the Data Infrastructure is the foundation on which Third-Party digital applications are built. Rather than sourcing and cleaning agricultural data independently, funded Third Parties will access a ready-to-use, quality-assured data layer. This allows applicants to focus their effort on developing multi-functional, farm- and policy-oriented decision-support tools, rather than on data engineering, while ensuring their applications remain interoperable with the wider AgData partnership and EU Strategy for Data.

1.2. OC#1 Objective

Designing data-driven Decision-Making Applications for farmers, advisors, and agri-industrial actors.

Nostradamus treats decision-making as a data problem before it is a software problem. Farmers, advisors, and agri-industrial actors currently rely on fragmented, uneven-quality sources (weather, soil, yield, market, and socio-economic data), so Nostradamus first identifies the data gap, in terms of accessibility and quality, and unites these sources within the Data Cube Ecosystem to produce structured, comparable, decision-ready information. This enables three tiers of data-driven decisions: operational/agronomic (irrigation, pest management, input levels, crop suitability), advisory/business (risk exposure, business models, investment timing), and strategic/industrial (market and demand intelligence and socio-economic indicators). Nostradamus translates this data into practical decision support through multi-functional, open-source digital applications, developed by Third Parties funded under Open Call #1 (Digital Applications for Farm Decision Making and Agribusiness). These applications serve three interconnected user groups: land managers and farmers' associations, agricultural and investment advisors, and agri-industrial actors (agri-tech companies, IT solution providers, precision-agriculture and agrichemical/agrimachinery businesses). The design process follows a needs-driven workflow approach: functional requirements are elicited directly from these target groups, ensuring applications address real operational bottlenecks, such as evidence-based crop management, input optimisation, and market/policy responsiveness, rather than generic digital tooling. Validated applications are demonstrated at NOSTRADAMUS' five pilot sites and packaged as EIP-AGRI-format "practice abstracts," ensuring that farmers, advisors, and agri-industrial actors receive not just software, but documented, replicable, evidence-based decision-making tools that remain interoperable with the wider Data Cube Ecosystem.

1.3. The Multi-Actor Approach (MAA)

The Multi-Actor Approach (MAA) is a central part of NOSTRADAMUS. It ensures that the project's digital solutions are developed together with the people who will use, support, and benefit from them. Stakeholders are therefore not involved only at the end of the development process. They contribute to identifying needs, defining requirements, testing solutions, and providing feedback throughout the project.

The NOSTRADAMUS MAA is based on four main principles:

- **co-creation**, by developing solutions with end users rather than only for them;
- **knowledge sharing**, by combining practical, scientific, technical and policy knowledge;



- **collaborative decision-making**, by considering different stakeholder perspectives when defining priorities and improving solutions; and
- **co-ownership**, by building trust and encouraging the continued use and uptake of project results.

Stakeholder engagement is organised through Multi-Actor Platforms (MAPs) associated with the five NOSTRADAMUS demonstration sites in Cyprus, Germany, Serbia, Slovenia and Switzerland. Each MAP acts as a regional innovation ecosystem where project partners and external stakeholders can exchange knowledge, discuss local challenges, and contribute to the development and testing of digital solutions. The MAPs provide a structured setting for identifying user needs, discussing barriers to digital adoption, reviewing technical developments and validating the usefulness of project applications under different agricultural, environmental and socio-economic conditions. The participation of different actor groups helps ensure that the resulting solutions are demand-driven, practical, understandable, and capable of wider adoption.

The five MAPs are coordinated by the following project partners:

TABLE 1. NOSTRADAMUS PARTNERS COORDINATING THE 5 MAPS

Regional MAP	Lead organisation
Germany	DLG e.V.
Cyprus	Eratosthenes Centre of Excellence (ECoE)
Slovenia	ITC – Innovation Technology Cluster Murska Sobota
Serbia	BioSense Institute
Switzerland	Agroscope

The MAPs bring together stakeholders from across the agricultural knowledge and innovation system. These include farmers and farmers' organisations, agricultural advisors, researchers and universities, technology and IT providers, SMEs and start-ups, agri-food businesses, policymakers, public authorities, civil-society organisations and other actors relevant to the regional agricultural context. The composition of each MAP reflects its local conditions and challenges. Particular attention is also given to the participation of smallholder farmers, rural women, young people and stakeholders located in areas with limited connectivity or lower levels of digital readiness. Their involvement is important to ensure that the developed applications are accessible and relevant to different farm types, regions and levels of technological capacity.

Following the establishment of the regional MAPs, the project moved towards active stakeholder engagement and co-creation. Through consultations, workshops, surveys and relevant sector events, stakeholders have contributed to their needs, challenges and expectations for future digital solutions. Further information on the activities and progress is available in the public deliverables.

Requirements for OC#1 applicants

Applicants are expected to apply the MAA in the design and implementation of their proposed applications. The involvement of end users should be planned from the beginning and continue throughout development, testing, and validation. Applicants are expected to follow a user-oriented



approach by clearly identifying the target users and other relevant stakeholder groups for their proposed application. Proposals should describe how users will be involved throughout the development process, including in the identification of needs, definition of key functionalities, testing and validation of the solution.

Applicants should also explain how stakeholder feedback will be collected, documented and used to improve the application. The proposed engagement activities should help ensure that the final solution is practical, understandable and relevant to real agricultural needs. Consideration should also be given to usability, accessibility, different levels of digital skills and the conditions in which the application is expected to be used. Where appropriate, applicants may include demonstrations, training or user guidance to support the uptake of the developed solution.

Stakeholder engagement should not be limited to a single consultation or to dissemination after the application has already been developed. Applicants should demonstrate a continuous feedback process through which users can influence the proposed solution.

Further details on the NOSTRADAMUS Multi-Actor Approach and the structure of the MAPs are provided in [Deliverable D1.1 – MAA Strategic Plan](#) and Deliverable D1.2 – Updated MAA Strategic Plan¹.

1.4. Thematic Alignment

The Open Call is structured in **5 (five)** pre-defined **topics** that are representing different thematic domains according to the project focus and priorities. The applications must **directly address** one of the designated technical topics/domains.

Therefore, the applicants are required to **select one of the topics** presented in TABLE 2.

TABLE 2. TOPICS OF THE NOSTRADAMUS OPEN CALL #1

TOPIC NAME (thematic domain)	
T1	Sustainable crop production and optimisation of cereal-based systems under changing climate and soil conditions.
T2	Nutrient and soil health management, integrating soil fertility indicators, organic matter dynamics, and precision fertilisation models
T3	Water resource efficiency and drought resilience, using the Early Warning System outputs and IoT-based soil moisture monitoring.
T4	Smart and predictive pest and disease management to support the EU objective of reducing pesticide dependency and enhancing sustainability.
T5	Open topic: Integrated, cross-domain decision-support applications combining multiple topics (<i>an open proposal from the applicants for an application that combines at least 2 of the previous topics T1-T4</i>)

¹ Currently under EC review. To be provided to the selected Third Parties after contracting (and after approval by the EC reviewers).



Find more details in Section 3 of this document.

1.5. Alignment with the Project Destination Expected Impact

Beyond ensuring direct alignment with their chosen Open Call topic, applicants must demonstrate strategic alignment with the broader **NOSTRADAMUS Destination Expected Impacts**. Proposed digital applications should explicitly show how their outputs and implementation methodologies will contribute to realizing these overarching objectives, as derived from the NOSTRADAMUS Grant Agreement:

- **Destination Expected Impact#1 (I1):** Innovative governance models enabling sustainability and resilience notably to achieve better informed decision-making processes, societal engagement and innovation.
- **Destination Expected Impact#2 (I2):** Areas related to the European Green Deal benefit from further deployment and exploitation of environmental observation data, products and “green” solutions.
- **Destination Expected Impact#3 (I3):** A strengthened Global Earth Observation System of Systems (GEOSS).
- **Destination Expected Impact#4 (I4):** Sustainability performance and competitiveness in the areas covered by Cluster 6 are improved through further deployment of digital and data technologies as key enablers.
- **Destination Expected Impact#5 (I5):** Stakeholders and end users including primary producers and consumers are better informed and engaged thanks to effective platforms such as AKIS.
- **Destination Expected Impact#6 (I6):** Strengthened EU and international science-policy interfaces to achieve the Sustainable Development Goals.
- **Destination Expected Impact#7 (I7):** (i) “Climate change mitigation and adaptation”; (ii) “Clean and healthy air/ water/soil”; (iii) “Enhancing ecosystems and biodiversity on land/water”; (iv) “Sustainable food systems from farm to fork on land/sea”; (v) “High quality digital services for all” and (vi) “Competitive and secure data-economy”.
- **Expected Impact#8 (I8):** Digital transformation of agricultural sector for guarding EU Food Security and achieving EU independence in agrochemical imports.

2. The NOSTRADAMUS Technology Stack

Each third-party beneficiary will **design, develop, and deliver a data-driven application** that builds upon the Nostradamus data infrastructure, making use of the project’s architecture, tools, and data services, including:

- The Generation Engine for Digital Applications (Task 2.4, D2.5 Application Generation Engine), which supports the synthesis, integration, and visualization of analytical results.
- Integrated existing databases for agricultural management practices (Task 3.1, D3.1 Pipeline for existing databases, agricultural market and socio-economic data), ensuring consistency and comparability across diverse agro-ecosystems.
- The IoT Observatory (Task 3.2, D3.1 Pipeline for existing databases, agricultural market and socio-economic data), which provides real-time, in-situ, and remote sensing data streams.

- Agricultural market and socio-economic data and models (Task 3.3, D3.1 Pipeline for existing databases, agricultural market and socio-economic data), supporting integrated analysis of production systems, markets, and resilience factors.
- Tools for Earth Observation (EO) data ingestion, algorithm integration, and packaging (Task 3.5, D3.3 Data Hub operation platform), enabling the incorporation and operational use of EO-based analytics.
- The overall architecture for cloud, edge, and mixed digital solutions (Task 2.3, D2.3 Software Architecture for Cloud, Edge and Mixed Solutions), providing the technological framework for scalable and efficient deployment.

2.1. Software Architecture:

REQ-SA-01: Applications shall document the NOSTRADAMUS APIs, developer tools, EO datasets and external data services on which they depend, including the purpose and role of each dependency.

Detailed description of the Cloud, Edge, and Mixed digital architecture (Task 2.3).

The Nostradamus architecture is conceptualized as a Hybrid Edge-to-Cloud "System of Systems" specifically engineered to tackle the significant data fragmentation challenges prevalent across European agriculture sector. This innovative platform is meticulously aligned with crucial European frameworks, including the European Green Deal, the Common Agricultural Policy (CAP), and the broader European strategy for data, thereby establishing a robust, data-centric foundation to bolster the EU's food security and self-sufficiency.

To achieve its goals, the Nostradamus ecosystem employs a "separation of concerns" strategy, segmenting its cloud-native infrastructure into distinct, yet highly integrated, functional pillars. This architecture not only bridges the gap between initial agricultural requirements and the practical development of prototypes, data pipelines, and end-user applications, but it also critically promotes a low-code model-driven approach for application development. This particular innovation is central to the project's vision, as it empowers IT experts, such as SMEs, Agri-industry, Cooperatives, Agri-food companies, or even scientists to construct customized digital solutions without programming expertise, thereby alleviating the traditional technical burden and accelerating the creation of relevant, real-world agricultural applications.

The NOSTRADAMUS architecture is designed as a Hybrid Edge-to-Cloud "System of Systems" specifically engineered to solve the data fragmentation challenges currently facing European agriculture. In strict alignment with the European Green Deal, the Common Agricultural Policy (CAP), and the European strategy for data, the platform establishes a robust, data-centric foundation to support the EU's food security and self-sufficiency. The overall system is architected to conquer the "**four V's of Big Data**", managing the massive **Volume** of Earth Observation (EO) archives, the high **Variety** of heterogeneous IoT and socio-economic data, the sub-second **Velocity** required for near real-time decision-making, and the high **Veracity** necessary for reliable and accurate decision support

The architectural vision is built upon the following core principles:

- (A) **Modularity and Microservices:** The system is composed of loosely coupled components (Data Cubes, IoT Brokers, Processing Engines) deployed as containerized microservices. This ensures that individual modules can be updated, scaled, or replaced without disrupting the broader ecosystem.

- (B) **Open Standards and Interoperability:** To prevent vendor lock-in and ensure wide adoption, the architecture strictly adheres to open standards, including OGC (Open Geospatial Consortium) standards for geospatial data, STAC for data discovery, and OpenAPI v3 for interface specifications.
- (C) **Lambda and Kappa Architecture Fusion:** To reconcile the conflicting needs of real-time monitoring (low latency) and historical analysis (high accuracy), the data processing layer implements a hybrid Lambda/Kappa architecture. This allows the system to process high-velocity streams in real-time while simultaneously maintaining a comprehensive, immutable master dataset for batch processing.

Cyber-Physical Integration: The architecture treats the agricultural environment as a Cyber-Physical System (CPS), where digital applications not only monitor physical assets (sensors, crops) but can also trigger actions (actuators) through a seamless Edge-to-Cloud continuum.

By bridging the gap between field-level event acquisition and high-level cloud-native analytics, the system provides a consolidated, scalable, and interoperable environment for agricultural decision support. To achieve this architectural vision, the platform implements a separation of concerns strategy, dividing the cloud-native infrastructure into three distinct but highly integrated functional pillars: **Data Infrastructure (I)**, the **IoT Observatory (II)**, and the **Low-Code Platform (III)**. As illustrated in FIGURE 1, these layers work in concert to ingest raw data, transform it into actionable intelligence, and deliver it to end-users through automated application generation.

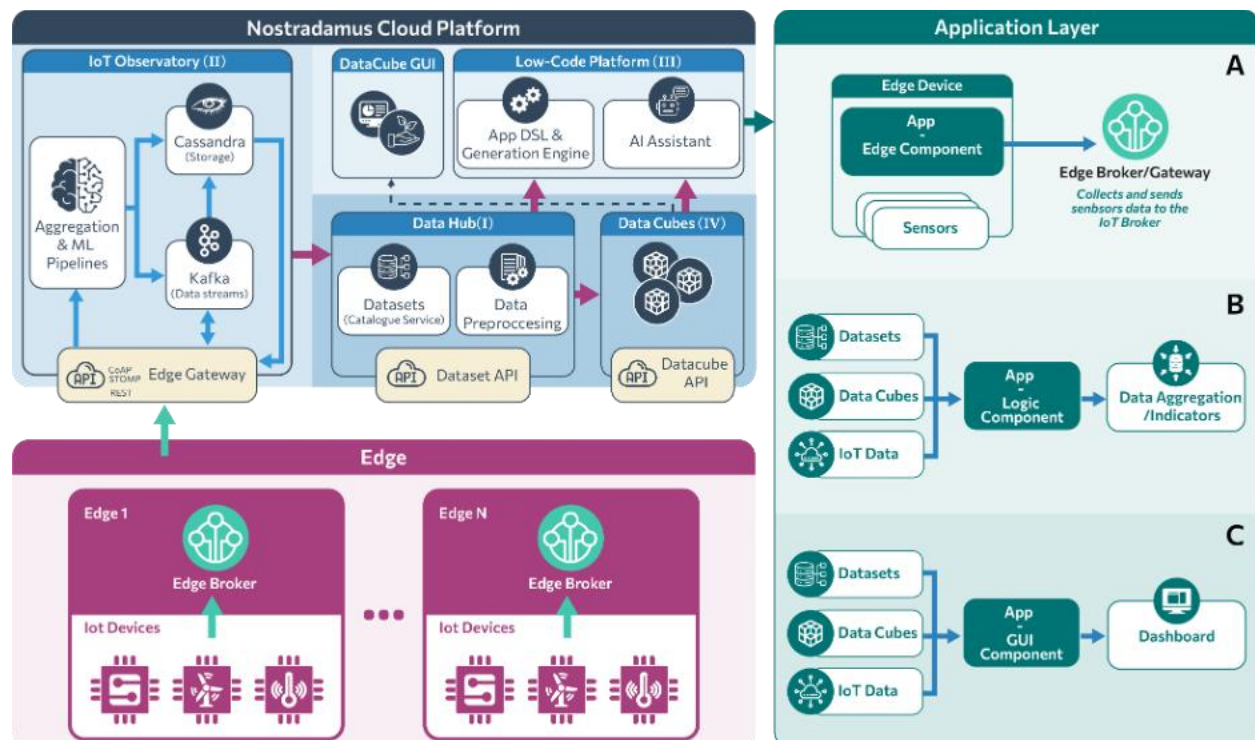


FIGURE 1. NOSTRADAMUS SYSTEM ARCHITECTURE

The architectural framework is divided into three distinct but highly integrated logical layers that work in concert to ingest raw data, transform it into actionable intelligence, and deliver it to end-users via a low/no-code engine that abstracts technicalities and focus on the design and the



automated generation of NOSTRADAMUS applications. The design conforms to the separation of concerns design pattern, as evident in Figure 2, providing 3 individual but interoperable Layers:

- (A) **The Data Infrastructure Layer:** This layer serves as the "Batch Layer" and long-term storage engine. It hosts the Data Hub and Data Cubes, responsible for managing massive static datasets, Earth Observation (EO) archives, and socio-economic indicators. It provides means for multi-dimensional arrays that harmonize geospatial data spatially and temporally, to provide a structured way to store and process information from missions such as Sentinel-1/2 and Landsat.
- (B) **The IoT Observatory Layer:** This layer serves as the "Speed Layer." It is a specialized Big Data Management System (BDMS) designed to ingest, buffer, and process high-velocity sensor data streams with sub-second latency. It is engineered for real-time event handling, by employing a stack of distributed technologies, including Apache Kafka for persistent buffering and Apache Flink for complex event processing, to ingest and process high-throughput sensor streams with sub-second latency.
- (C) **The Low-Code Application Layer:** This layer acts as the interface between the technical infrastructure and the domain experts. Acting as the democratization layer, this component provides the tools necessary for domain experts (SMEs, Agri-industry, Cooperatives, Agri-food companies) to build custom digital solutions. By leveraging Model-Driven Engineering and Domain-Specific Languages (DSLs), the platform utilizes an Application Generation Engine to automatically transform description models into executable software artifacts, alleviating the technical burden of direct programming. Farmers, agronomists, and policy makers are the end-users of the applications powered by NOSTRADAMUS. According to the grant agreement, such applications will support professionals for 2 main activities:
 - a. Digital applications for farm decision-making (notably based on processing/rendering of farming business data)
 - b. Digital applications for policy making and evaluation (notably based on processing/rendering of socio-economic data on farmers and rural communities)

The architectural integrity of the system is built upon the fusion of Lambda and Kappa patterns, a hybrid approach that ensures the platform can calculate real-time ad-hoc user queries while simultaneously maintaining an immutable "source of truth" master dataset for comprehensive historical analysis. Furthermore, the system adopts an API-centric approach, exposing all core functionalities via standardized REST endpoints (OpenAPI v3) and OGC Web Services (WMS/WMTS). This ensures that the NOSTRADAMUS ecosystem remains scalable, modular, and fully interoperable with external EU platforms and third-party tools.

Ultimately, by bridging the gap between field-level IoT data acquisition and high-level cloud-native analytics, this architecture treats the agricultural environment as a Cyber-Physical System (CPS). This creates a seamless Edge-to-Cloud continuum where digital applications not only monitor physical assets like crops and machinery but can also trigger actionable decisions and automated responses to improve yields and reduce agrochemical reliance.

2.1.1 Data Infrastructure

The Data Infrastructure functions as the system's "Batch Layer" and long-term storage engine, responsible for managing massive static datasets and Earth Observation (EO) archives. It provides the foundation for "hard" data handling, including satellite imagery from missions such as Sentinel-1/2 and Landsat.



- **Open Data Cubes:** At the core of this layer is an ensemble of Data Cubes, multi-dimensional arrays that harmonize geospatial data spatially and temporally. This abstraction allows researchers to perform time-series analysis and "pixel-drilling" without the need to manually manage thousands of individual satellite scenes.
- **SpatioTemporal Asset Catalog:** To ensure high performance in data discovery, the infrastructure implements the STAC standard. This decouples metadata (JSON) from the actual data assets (COGs), allowing applications to perform complex spatiotemporal queries—such as filtering by cloud cover or specific geographic polygons—before any heavy data transfer occurs.
- **Data Preprocessing and Pipelines:** The layer incorporates automated pipelines for converting raw EO data into Analysis Ready Data (ARD). These pipelines utilize Common Workflow Language (CWL) and Docker containers to ensure that data acquisition, atmospheric correction, and harmonization processes are fully reproducible and portable across different cloud environments.
- **Cloud Optimized GeoTIFFs:** By storing raster data in COG format, the infrastructure enables HTTP range requests. This allows applications to retrieve only the specific byte-ranges required for a visualization or analysis task, drastically reducing latency and computational overhead.

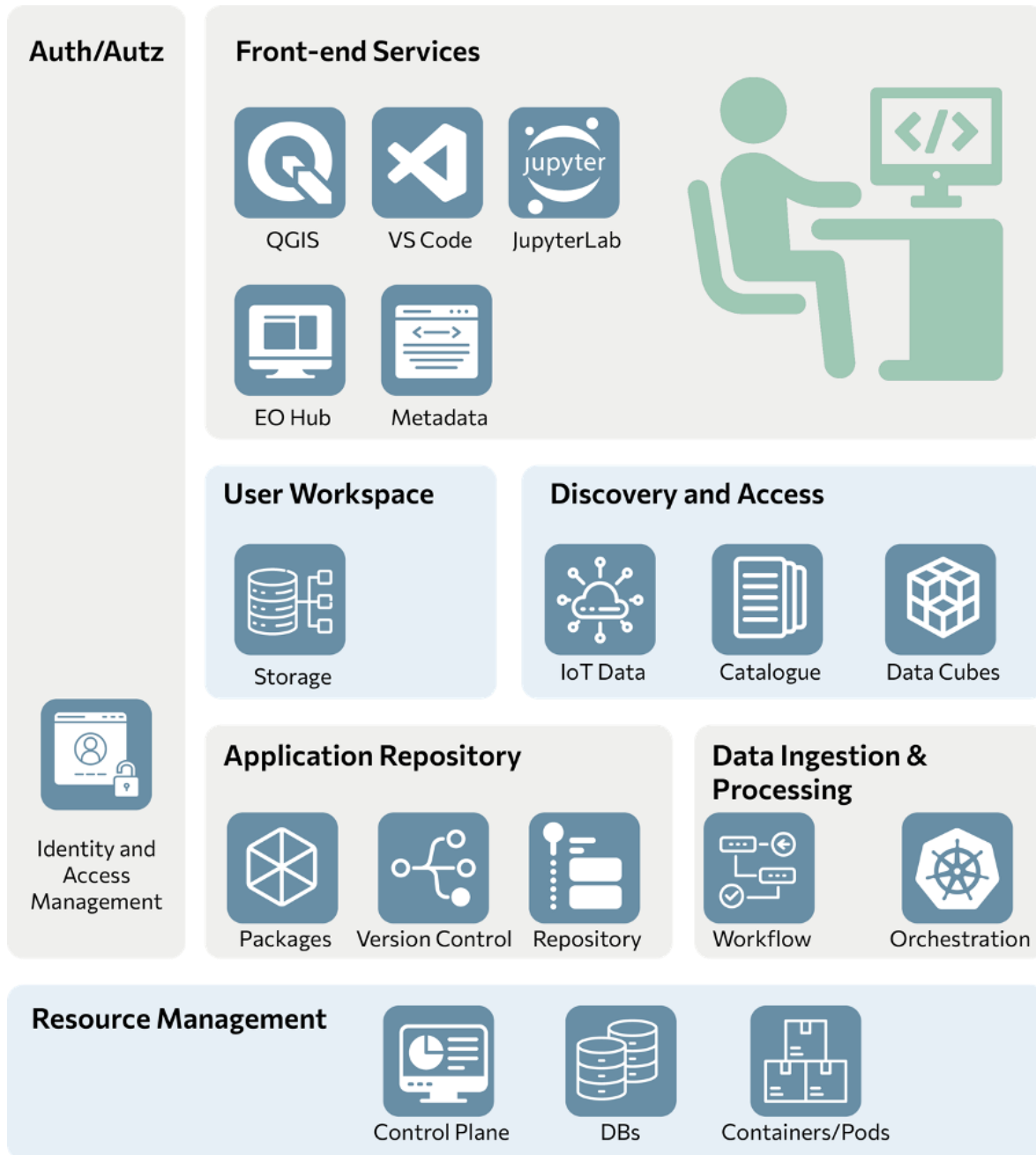


FIGURE 2. DATA HUB INTERNAL ARCHITECTURE

The EO Data Hub is responsible for the ingestion, cataloguing, processing, and distribution of EO data. It provides a cloud-native environment supporting scalable data pipelines, metadata management based on the STAC specification, and execution of processing workflows using containerized applications described with the CWL.

The Data Hub ensures that EO data is transformed into ARD and made available through standardized interfaces. These data products are then consumed by the Data Cube infrastructure, developed by UNIGE, which focuses on structuring, indexing, and enabling analytical access to multi-dimensional

datasets. This separation of concerns allows the Data Hub to act as the data provisioning layer, while the Data Cubes provide the analytical abstraction layer.

The interaction between these components is based on standardized metadata and interoperable data formats, ensuring seamless integration between data ingestion, processing, and higher-level analytics. This architecture enables scalability, reproducibility, and flexibility in supporting both batch and on-demand data processing workflows across the platform.

2.1.2 IoT Observatory

The IoT Observatory (IoT0) is a central and critical component of the NOSTRADAMUS Cloud Platform, designed to address the significant challenges associated with real-time and historical data in agricultural contexts. It functions as a specialized Big Data Management System (BDMS) engineered for real-time event handling, ingesting and processing high-velocity sensor data streams with sub-second latency. The primary objective of the IoT0 is to transform raw agricultural sensor data into actionable intelligence, thereby supporting informed decision-making across the agricultural sector.

The fundamental unit of data managed by the IoT0 is "events," such as sensor readings and actuator states, which are collected from IoT devices. This infrastructure is not merely a database but a complex orchestration of distributed systems focused on effective data management, real-time monitoring, and advanced analytics. The design prioritizes minimal latency for real-time monitoring while also accommodating complex, long-term historical analysis.

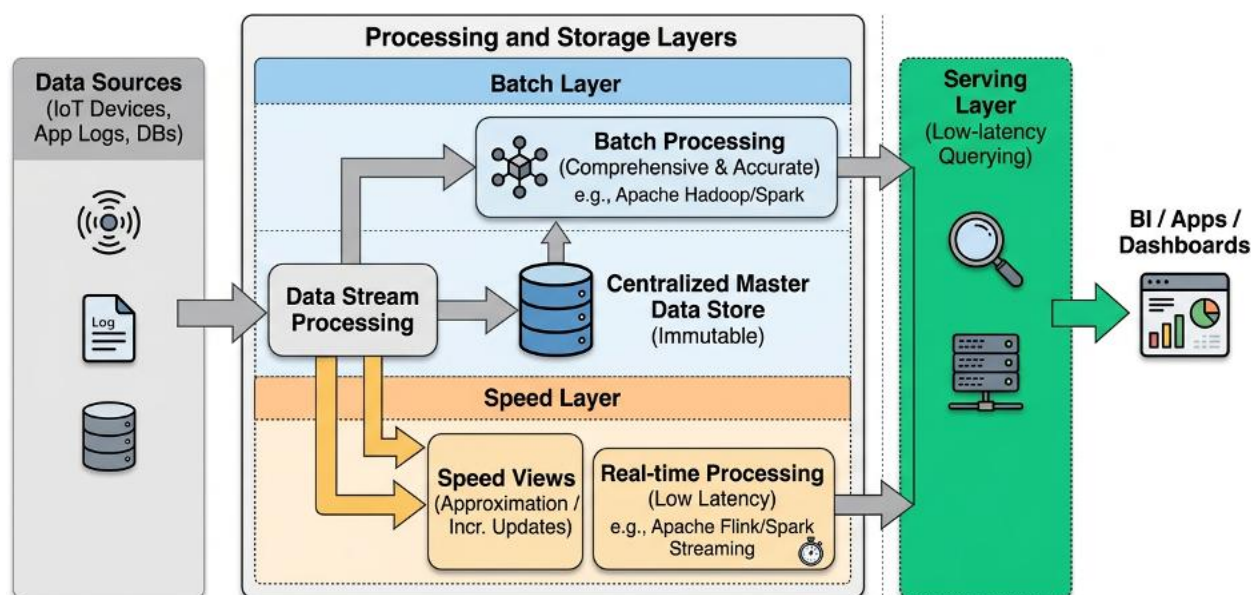


FIGURE 3. LAYERED ARCHITECTURE OF THE NOSTRADAMUS IOT OBSERVATORY

To reconcile the inherent tension between the need for immediate, real-time insights and comprehensive historical accuracy, the IoT Observatory employs a sophisticated hybrid architectural pattern that fuses elements from both Lambda and Kappa architectures. This hybrid approach offers several key advantages:



- Robustness against data latency issues: By separating real-time and batch processing, the system prevents processing bottlenecks even during peak data.
- Capability to replay and reprocess historical data streams: This is crucial for refining or updating algorithms, ensuring that analyses remain current and accurate over time.

The IoT Observatory functions as one of the three primary pillars of the overall NOSTRADAMUS hybrid Edge-to-Cloud architecture (Pillar II in FIGURE 3). It acts as the gateway for edge and IoT devices to connect, send, and aggregate data via a unified API. It provides an abstraction layer for connecting to domain-independent Edge systems through an IoT broker, known as the Edge Gateway, which supports communication protocols like MQTT and CoAP. Its outputs are crucial for informed decision-making support and for empowering the development of open-source digital applications by various third parties within the ecosystem.

For comprehensive information and detailed technical specifications of the IoT Observatory, including its technology stack, data schema, security considerations, data flows, and API endpoints, refer to the complete specification document of the Nostradamus IoT that can be accessed on the NOSTRADAMUS Zenodo page here: <https://zenodo.org/records/22685633>

2.1.3 Low-Code Application Platform

The Low-Code Application Platform (LCP) is a pivotal and distinguishing component of the NOSTRADAMUS Cloud Platform, specifically designed to address the challenges of complex cyber-physical application development within the agricultural sector. Its primary objective is to democratize the creation of digital solutions, allowing domain experts such as SMEs, Agri-industry, Cooperatives, and Agri-food companies to build custom applications without requiring technical knowledge. This approach aims to enhance resource efficiency, reduce reliance on agrochemicals, and strengthen resilience against potential disruptions, aligning with key EU frameworks like the European Green Deal and the Common Agricultural Policy.

The LCP's core functionality revolves around enabling the rapid deployment of data-driven digital solutions through abstraction and automation (FIGURE 4). The platform employs a Model-Driven Engineering (MDE) approach, utilizing **Domain-Specific Languages (DSLs)** to allow experts to design, generate, and deploy software for different parts of their applications. This MDE paradigm promotes a "citizen developer" concept, where non-technical users can auto-generate parts or the entirety of their applications simply by designing the solution rather than writing code ("what" instead of "how"). This process is intended to make real-world application development easy, fast, and error-free. DSLs are specialized languages that allow experts to describe specific aspects, such as edge device characteristics, sensor configurations, visualization requirements, and logical data flows, without needing general-purpose programming expertise.

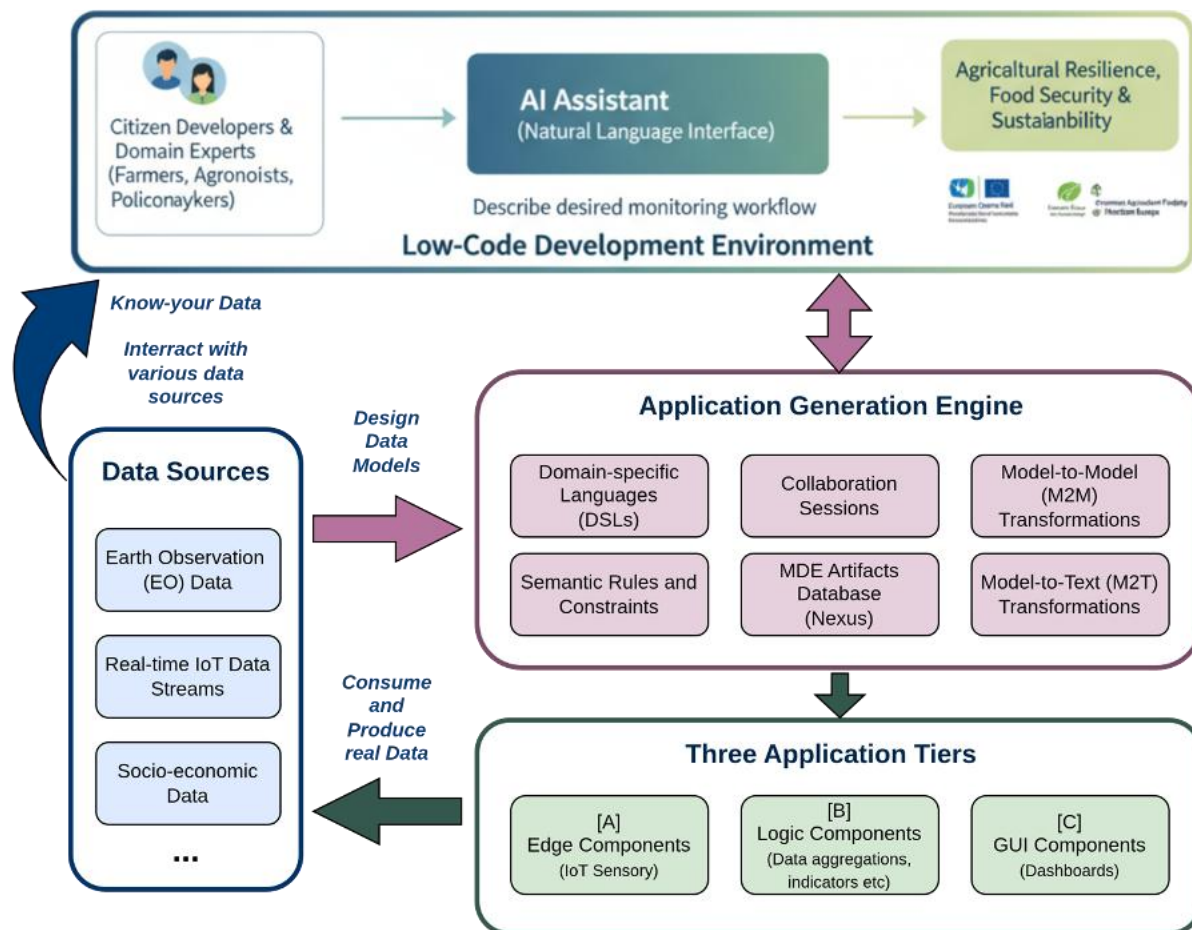


FIGURE 4. APPLICATION GENERATION ENGINE

2.1.4 The Edge-to-Cloud Continuum

The continuum is designed to reconcile the conflicting requirements of sub-second Velocity for immediate field reactions and high-precision Veracity for long-term policy and farm planning. To achieve this, the architecture strategically distributes computational logic across two primary layers:

- **The Edge Layer (Observation):** Positioned directly in the agricultural field, this layer handles immediate, low-latency reactions and localized data filtering. By executing App-Edge Components on embedded devices (e.g., Raspberry Pi, ESP32), the system can perform primary sensory data acquisition and local actuation logic without waiting for cloud roundtrips. This is critical for time-sensitive tasks, such as frost alerts or precision irrigation triggers.
- **The Cloud Layer (Analytical Intelligence):** This layer serves as the "heavy lifting" engine for the project. It manages the massive volume of Earth Observation (EO) archives, the Data Cubes, and complex socio-economic datasets. It implements a fusion of Lambda and Kappa architectural patterns to maintain an immutable "source of truth" while simultaneously calculating real-time ad-hoc user queries.



Furthermore, a core innovation of the NOSTRADAMUS continuum is its focus on areas with weak connectivity, such as the Cyprus demonstration site. Unlike purely cloud-reliant systems, the NOSTRADAMUS architecture acknowledges that agricultural internet access is often intermittent or low-bandwidth.

- **Offline Capability:** By emphasizing edge computing, the framework allows App-Edge Components to continue functioning independently when connectivity is lost.
- **Data Synchronization:** Once a connection is established, the Edge Gateway acts as a robust abstraction layer, utilizing lightweight protocols like MQTT and CoAP to synchronize buffered data with the IoT Observatory.

The continuum facilitates a seamless two-way flow of information that empowers stakeholders across the food supply chain:

1. **Sensing:** Field events are captured by Edge Components and dispatched to the cloud.
2. **Harmonization:** The IoT Observatory ingests these streams, fusing them with satellite-derived Analysis Ready Data (ARD) from the Data Hub.
3. **Analysis:** App-Logic Components execute domain-specific machine learning models to generate high-level food security indicators (e.g., crop suitability or drought indices).
4. **Actionable Insight:** The results are delivered via GUI Components in interactive dashboards, allowing farmers and policymakers to optimize operations, reduce agrochemical use, and improve the overall energy balance of data-driven agriculture.

By orchestrating resources across this continuum, NOSTRADAMUS provides a scalable, open-source pattern for the technological development of EU agriculture, ensuring that advanced digital tools are inclusive, robust, and capable of operating under diverse biogeographical and socio-economic conditions.

2.1.5 Hybrid Applications

The digital solutions developed within the NOSTRADAMUS ecosystem are defined as cyber-physical applications that orchestrate a resource continuum spanning the agricultural field, the network edge, and the cloud. By bridging the gap between field-level sensory events and high-level analytical insights, these applications treat the agricultural environment as an integrated Cyber-Physical System (CPS).

To democratize development and alleviate the deep technical burden traditionally associated with programming such hybrid systems, the architecture decomposes applications into three distinct types of interoperable components:

- **Edge Components** (Tier A): Facilitating primary sensory acquisition and local actuation at the physical interface.
- **Logic Components** (Tier B): Serving as the cloud-based analytical engine for data fusion and indicator generation.
- **GUI Components** (Tier C): Constituting the user-facing layer for visualization and interactive decision support.

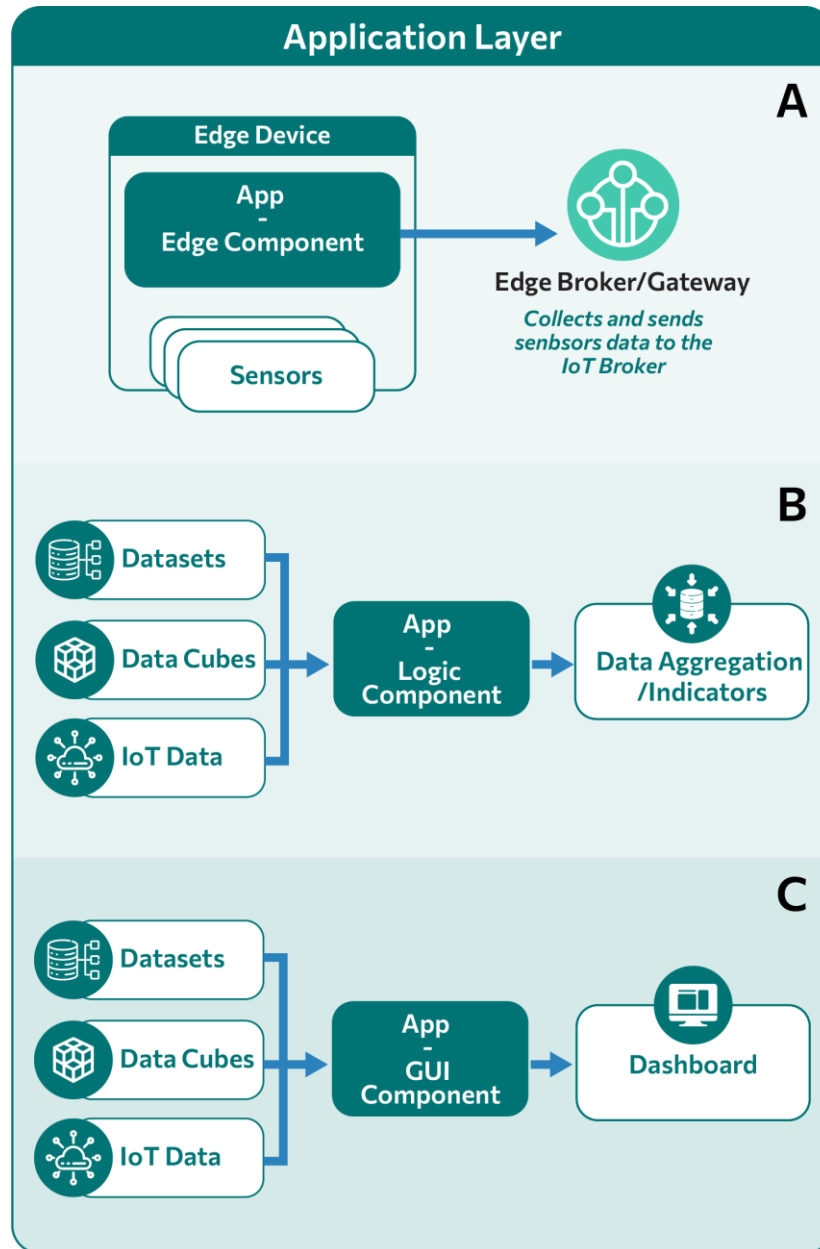


FIGURE 5. NOSTRADAMUS 3-TIER APPLICATIONS

Edge Components are cyber-physical in nature, as these are applications deployed at the edge, providing means of observation from installed sensors in the field, and data feed to the NOSTRADAMUS Cloud via the Edge Gateway of the IoT Observatory. On the other hand, Logic and GUI Components are considered completely digital; these components use data from the Data Hub, IoT and Data Cubes and produce higher level of information, such as indicators and visualizations.

As illustrated in FIGURE 5, these tiers work in concert to transform raw data into actionable intelligence through a structured, quality-aware process. While this section establishes the high-level conceptual framework, a comprehensive technical breakdown of these application tiers,



including their specific data flows, connectivity patterns, and the low-code generation workflow, is detailed in Section 6: Cloud, Edge, and Mixed Applications.

2.2. Application Generation Engine:

The **Application Generation Engine (AGE)** is the core software automation framework of the Nostradamus Low-Code Platform (LCP). The engine is designed to democratize and accelerate the creation of complex cyber-physical applications for the agricultural sector. It serves as the primary technical mechanism to abstract and offload the technical and technological complexity barriers that small and medium enterprises (SMEs), startups, and agricultural experts face when programming distributed hybrid systems.

Technically, the AGE acts as a compiler that translates abstract user-defined models and templates into fully operational, secure, and standardized software components. It utilizes a Model-Driven Engineering (MDE) paradigm, performing automated Model-to-Model (M2M) and Model-to-Text (M2T) transformations. High-level designs and configurations are processed through embedded semantic rules and architectural constraints, producing executable source code and software deployment artifacts. This code conforms automatically to Nostradamus' modular, microservices-based software architecture and standardized data schemas, guaranteeing that generated software is robust, repeatable, and easily deployable.

The MDE process is backed by a centralized Artifacts Database that manages and stores models, templates, transformations, and reusable code components, supporting concurrent collaboration sessions where multiple stakeholders can contribute to the application design process.

2.2.1 Domain-Specific Languages for Agriculture

At the heart of the AGE's operation is the definition and parsing of specialized Domain-Specific Languages (DSLs). Unlike General-Purpose Languages (GPLs) such as Python or Java, these graphical and textual DSLs are tailored specifically to the structural rules and agricultural context of the Nostradamus ecosystem. DSLs allow developers and domain experts to represent their application architecture using high-level concepts rather than programmatic syntax:

1. **Hardware and Network Configurations:** Users describe physical edge device properties (e.g., Raspberry Pi, ESP32 boards), connected sensor configurations (e.g., microclimate, soil moisture, leaf wetness), and communications protocols (e.g., MQTT, CoAP).
2. **Analytical Logic:** Users define graphical or textual data flow models, outlining filtering criteria, stream processing rules, and indicators (such as crop suitability, drought alerts, or soil fertility indices) without needing to write low-level code.
3. **Visual and GUI Requirements:** Users specify the monitoring parameters, dashboard layouts, and visual widgets (e.g., spatial maps, time-series charts, alarm systems) needed for the user interface.

By shifting development focus from manual programming to descriptive modeling, these DSLs ensure that application models are fully reusable and portable across different pilot sites, crops, and regional contexts.

2.2.2 Automatic Generation of the Three-Tier Cyber-Physical Application Model

The AGE is specifically engineered to automate the synthesis of the Nostradamus three-tier cyber-physical application architecture. It transforms user-designed DSL models into functional components across three interoperable layers:

- **App-Edge Components (Tier A):** Designed for deployment on embedded devices (e.g., Raspberry Pi, ESP32) at the physical interface in the field. The AGE automatically generates the software and connectivity code required to handle sensory data acquisition (e.g., temperature, humidity, soil moisture) and local actuation logic (e.g., precision irrigation triggers). These components buffer data locally during connection dropouts to enable independent offline capability in resource-constrained environments, automatically synchronizing with the cloud-side Edge Gateway via lightweight MQTT or CoAP protocols once connectivity is re-established.
- **App-Logic Components (Tier B):** Serving as the cloud-deployed analytical engines. The AGE automatically synthesizes data aggregation, data fusion, and stream processing software. It generates the software needed to programmatically ingest and process heterogeneous real-time streams from Edge Components, historical multi-dimensional arrays from the Data Cubes (IV), and socio-economic datasets. It integrates these inputs with domain-specific algorithms (such as crop growth phenology models or disease risk maps) to produce high-level food security indicators.
- **App-GUI Components (Tier C):** The user-facing presentation layer. The AGE uses the user's visual specifications to automatically generate interactive dashboards and web-based visualization interfaces. The generated GUI handles hybrid data interaction, enabling farmers, advisors, and policymakers to inspect real-time IoT streams alongside Earth Observation (EO) imagery, and customize their dashboard layouts using a palette of predefined visualization components (e.g., spatial zoning maps, alert widgets, and time-series charts).

2.3. Data Cube Services:

Understanding data cubes, and spatiotemporal arrays for time-series analysis of satellite Earth Observations (WP5).

The Data Cube Infrastructure represents the analytical abstraction and high-performance processing pillar of the NOSTRADAMUS platform (Pillar I – Data Infrastructure Layer). It provides a structured, scalable, and harmonized environment designed to manage large-scale multi-temporal Earth Observation (EO) archives, in-situ datasets, and thematic layers. By abstracting raw satellite scenes into multidimensional spatiotemporal arrays (data cubes), the platform eliminates the technical overhead of manual data management, granule discovery, and scene-by-scene calibration, enabling continuous pixel-level analytics, time-series querying, and environmental monitoring across European agro-ecosystems.

2.3.1. Core Architecture and Technological Foundation

The system is implemented as a cloud-native, containerized Open Data Cube (ODC) architecture orchestrated as modular microservices:

- **Spatiotemporal Index Database:** A relational PostgreSQL/PostGIS database serves as the core indexing engine. It implements the EO3 metadata specification to record spatial footprints, temporal validity, coordinate reference systems, and asset locations, completely decoupling metadata indexation from underlying physical raster storage.
- **Multidimensional Data Cube Engine:** The Open Data Cube core framework abstracts indexed datasets into uniform, multidimensional spatiotemporal arrays. Datasets are loaded as labeled multi-band array structures with explicit spatial dimensions(x, y), a temporal dimension(time), and variable spectral attributes.
- **Distributed and Lazy Processing Layer:** Full native integration with Dask and Dask Distributed provides out-of-core, lazy-evaluation computational capabilities. Queries construct computational graphs deferring actual data retrieval until computation, enabling parallelized chunking across time and space to process multi-gigabyte or multi-terabyte satellite archives without memory exhaustion.
- **Multi-User Interactive Analytics Environment:** A containerized multi-user JupyterHub / JupyterLab interface provides domain scientists, agronomists, and developers with an interactive workspace equipped with geospatial libraries, scientific computing packages, and Dask dashboard integration for real-time monitoring of distributed computations.
- **Role-Based Access and Security Architecture:** The infrastructure implements role-based access control separating administrative functions (such as product creation and catalog-wide indexing) from standard user analytical sessions operating under read-only database roles, ensuring system security and database integrity.

2.3.2. Spatiotemporal Harmonization and Time-Series Analytics

The Data Cube infrastructure facilitates complex time-series analysis and cross-sensor harmonization through advanced spatiotemporal processing capabilities:

- **On-the-Fly Spatial and Temporal Reprojection:** Satellite observations acquired across differing projection systems (e.g., adjacent UTM zones) or spatial resolutions are dynamically reprojected and resampled upon retrieval into a user-specified Coordinate Reference System (CRS) and uniform grid resolution. Resampling methods strictly support continuous variables (bilinear, cubic interpolation) and categorical classifications (nearest neighbor).
- **Automated Quality and Cloud Masking:** Built-in Analysis Ready Data (ARD) processing routines integrate pixel-level data quality layers, such as the Sentinel-2 Scene Classification Layer (SCL) and Landsat Pixel Quality Assessment (QA_PIXEL). The system enables automated cloud, shadow, and invalid pixel filtering, along with minimum valid data thresholds to drop heavily occluded acquisitions from time-series stacks.
- **Statistical and Phenological Compositing:** The analytical engine natively supports temporal aggregations (e.g., mean, median, standard deviation, percentile compositing), vegetation/water index generation (NDVI, NDWI, EVI), and phenological curve extraction to track agricultural crop development and detect anomalies over time.

2.3.3. Available Data Products and Demonstration Site Datasets

The Data Cube infrastructure supports configurable indexing tailored to the geographic bounding boxes and temporal spans of NOSTRADAMUS demonstration sites (including pilot regions in Germany, Serbia, Switzerland, Slovenia, and Cyprus). Demonstration-site datasets are produced on



demand by indexing a chosen bounding box and time interval; the deployment does not ship a fixed global archive. Supported product families include:

- **Optical Earth Observation:** Sentinel-2 Level-2A Bottom-of-Atmosphere (BOA) Surface Reflectance (10m–20m) and Landsat Collection 2 Level-2 Surface Reflectance (30m).
- **Synthetic Aperture Radar (SAR):** Sentinel-1 Radiometrically Terrain Corrected (RTC) Gamma-0 backscatter (VV and VH polarizations) for all-weather radar monitoring and soil moisture assessments.
- **Foundation Model Embeddings:** High-dimensional Foundation Model embeddings (such as AlphaEarth annual 64-band feature embeddings) providing pre-computed representations for machine learning applications.
- **Thematic and Environmental Layers:** Copernicus Land Monitoring Service (CLMS) CLCplus European Land Cover (100m), ESRI Annual Land Use/Land Cover (10m), ESA WorldCover (10m), and NASADEM Digital Elevation Models (30m).

2.3.4. Alignment with NOSTRADAMUS Data Cube Requirements

The implementation aligns with the NOSTRADAMUS Data Cube requirements as follows; access is currently provided through Python/Jupyter interfaces (no REST/OGC coverage query API is exposed by this deployment):

- **Documented Data Cube Interface (REQ-DATA-CUBE-01):** Supported via the Python API and JupyterHub environment; no REST/OGC coverage query API is exposed by this deployment.
- **Multidimensional Selection (REQ-DATA-CUBE-02):** Supported via the Python API for selecting spatial bounding boxes, custom polygon geometries, temporal ranges, and spectral bands.
- **Subset Retrieval and Extraction (REQ-DATA-CUBE-03):** Supported via the Python API, with retrieval of spatial and temporal subsets optimized through Cloud Optimized GeoTIFF range requests.
- **Supported Execution Environments (REQ-DATA-CUBE-04):** Supported through the cloud-native notebook environment, batch processing scripts, and microservice integration patterns.
- **Demonstration-Site Reusability (REQ-DATA-CUBE-05):** Supported through flexible indexing mechanisms to instantiate tailored data cubes over designated NOSTRADAMUS agricultural demo sites.

Integration with 3rd-parties:

The Data Cube Infrastructure is architected to eliminate vendor lock-in and operate seamlessly within the wider European Earth Observation and agricultural data ecosystem:

- **Direct Cloud-Native Data Access:** The infrastructure operates primarily on a cloud-native indexing model where raster data remains hosted in distributed object storage (such as Microsoft Azure Blob Storage, AWS S3, or Copernicus Data Space S3) rather than being duplicated locally. Data is accessed on-demand using HTTP range requests via Cloud Optimized GeoTIFF (COG) formatting and virtual file system abstractions, drastically minimizing network bandwidth, latency, and storage overhead.



- **Microsoft Planetary Computer Integration:** Integrated discovery and authenticated access mechanisms interface with the Planetary Computer STAC API. Built-in Shared Access Signature (SAS) token generation and URL signing routines provide authorized, high-throughput access to global Sentinel-2, Landsat, and environmental datasets.
- **Copernicus Data Space Ecosystem (CDSE) Integration:** Direct interoperability with the European Copernicus Data Space STAC catalog and underlying S3 object storage infrastructure (eodata), enabling access to European Earth Observation assets using S3-compatible authentication protocols.
- **Source Cooperative and Foundation Model Repositories:** Integration with open data repositories hosting foundational Earth Observation models and embeddings, facilitating the incorporation of machine learning feature spaces directly into the data cube.
- **Open Geospatial and Community Tooling Interoperability:** Reusable integration with Digital Earth Africa open-source data handling workflows, masking algorithms, and standardized visualization packages. Modular extension points also enable integration with specialized land cover classification systems (such as the FAO Land Cover Classification System / LCCS).
- **Catalog Exploration and Asset Proxying:** The system provides an integrated Web Catalog Explorer (Cubedash) with built-in asset proxying services. This enables authenticated redirection and streaming of external cloud assets directly to end-user browsers and visualization tools without exposing underlying cloud credentials.
- **Interoperability with NOSTRADAMUS Layers:** The Data Cube services function as the analytical data supply layer (Pillar I) feeding Analysis Ready Data into the Application Generation Engine (AGE), Low-Code Platform (LCP), and domain-specific decision-making applications (e.g., irrigation management, crop rotation, and fertilizer optimization modules).

2.4. Earth Observation (EO) Services:

Ingestion tools, algorithm packaging (OGC standards), and ARD pipelines (Task 3.5).

Applications developed under NOSTRADAMUS Open Call shall integrate with the NOSTRADAMUS Platform APIs and developer tools, as appropriate to the proposed application.

The platform provides STAC-based discovery and access to EO datasets, as well as mechanisms for integrating externally developed algorithms through standardised application packaging.

The Earth Observation (EO) Services provide the necessary ingestion, cataloguing, harmonization, and execution capabilities to transform raw and semi-processed Earth Observation data into Analysis Ready Data (ARD) and actionable agricultural insights. Acting as the operational bridge between external satellite repositories and internal analytical engines, the EO Services ensure standards compliance, computational portability, and reproducible algorithm deployment across the cloud-to-edge continuum.

2.4.1. STAC-Based Discovery and Ingestion Pipelines

Within this deployment, the platform acts as a STAC consumer and indexer: it queries external STAC APIs and ingests their item metadata into the Open Data Cube index. It does not host a STAC

API server itself; the NOSTRADAMUS STAC-compliant catalogue is provided as a separate platform component.

- **STAC Metadata Discovery:** Ingestion workflows rely on the SpatioTemporal Asset Catalog (STAC) standard to search and access EO assets. By querying standardized STAC API endpoints using spatial bounding boxes, temporal windows, and metadata filters, the system programmatically identifies satellite acquisitions and extracts granule-level asset links without manual scene harvesting.
- **Automated STAC-to-DataCube Ingestion:** Automated ingestion pipelines translate STAC Items and Collections into Open Data Cube EO3 metadata definitions. The pipeline supports configurable parallel execution across multi-core systems, accelerating cataloguing for large temporal baselines and multi-tile regional extents.
- **Hybrid Ingestion Modalities:** The ingestion framework supports dual operating modes:
 - *Cloud-Streaming Mode:* Indexes remote asset URLs with signed URL resolvers, streaming data directly during analytical execution.
 - *Filesystem/Local Mode:* Provides ingestion pipelines to download selected STAC assets directly to shared or local file storage, indexing local Cloud Optimized GeoTIFFs for offline processing or high-throughput local compute clusters.

2.4.2. Analysis Ready Data (ARD) Pipelines

- **Level-2 / ARD Product Integration:** The platform ingests already analysis-ready upstream products – Sentinel-2 L2A Bottom-of-Atmosphere surface reflectance, Landsat Collection 2 Level-2 surface reflectance, and Sentinel-1 Radiometrically Terrain Corrected (RTC) backscatter – rather than performing L1→L2 atmospheric correction or RTC generation itself. This avoids the computational burden and inconsistency of raw Level-1 telemetry preprocessing.
- **On-Platform ARD Refinement:** On-platform processing is limited to analysis-time refinement: automated quality filtering, cloud and shadow masking using categorical scene classification bands, nodata handling, radiometric scale factor application, and floating-point conversions.
- **Export and Cataloguing of Added-Value Products:** Downstream analytical workflows can persist derived indicators, composites, and model outputs as Cloud Optimized GeoTIFFs or NetCDF files with full spatial reference metadata, making them immediately available for re-indexing and platform-wide reuse.

2.4.3. Algorithm Packaging, Containerisation, and OGC Compliance

- **Containerized Execution Architecture:** Algorithms and processing pipelines are fully encapsulated within Docker containers containing all required scientific libraries, GDAL drivers, and runtime dependencies. This guarantees deterministic, reproducible execution regardless of the underlying host operating system.
- **Multi-Architecture Deployment:** Container images support multi-architecture compilation (AMD64 and ARM64), ensuring that processing components can be deployed uniformly across enterprise cloud infrastructure, high-performance compute nodes, and field-level edge devices (e.g., embedded single-board computers and edge gateways).



- **Alignment with OGC Standards and CWL (Gap):** CWL workflow descriptors, OGC Earth Observation Application Packaging (OGC 20-089r1), and an OGC API – Processes endpoint are not implemented in this deployment; these are expected to be provided by the wider NOSTRADAMUS platform. Containerised algorithms are designed to be wrapped into CWL and exposed through the platform's processing API.

Integration with 3rd-parties

- **REQ-EO-1:** Applications developed under the Open Call are expected to make use of NOSTRADAMUS EO data pipelines (pre-existing or custom-made for the purpose of the application) and, where relevant, integrate with external EO data repositories and services. Applications shall use the NOSTRADAMUS EO Data Pipelines interfaces to discover and/or access EO datasets, where EO data are required by the application.
- **REQ-EO-02:** Applications shall be capable of using the NOSTRADAMUS demonstration-site datasets already generated and made available for reuse, where these datasets are relevant to the proposed application.
- **REQ-EO-03:** Applicative EO data discovery shall use the NOSTRADAMUS STAC-compliant catalogue interface. The application shall use the metadata and asset references provided by STAC to identify and access relevant EO datasets.
- **REQ-EO-04:** EO data discovery shall support the spatial, temporal and metadata-based selection of EO datasets required by their processing logic. The NOSTRADAMUS STAC interface supports filtering and, where applicable, advanced filtering through CQL.
- **REQ-EO-05:** Where additional EO data processing is required, algorithms shall be packaged in accordance with the NOSTRADAMUS application packaging requirements referenced in the "OGC Earth Observation Application Packaging Best Practice" document (OGC 20-089r1), including CWL and containerisation. EO applications shall be described using Common Workflow Language (CWL) to ensure portable and reproducible execution within the NOSTRADAMUS environment. Processing logic shall be encapsulated in Containers with the dependencies and runtime environment required for execution.
- **REQ-EO-06:** Where the application produces added-value, EO-based datasets intended for reuse within the NOSTRADAMUS Platform, outputs shall comply with the applicable platform metadata requirements and shall be catalogued using STAC, where applicable.
- **REQ-EO-07:** Where an application is intended to be exposed as a reusable processing service, it shall support integration through the NOSTRADAMUS processing API, including OGC API – Processes where applicable. The architecture identifies OGC API – Processes as the interface for execution-as-a-service.

Implementation Status and Mapping to NOSTRADAMUS Requirements

The capabilities provided by the Living Earth Cube in a Box stack align with the NOSTRADAMUS Earth Observation services and third-party integration requirements as follows:

- **REQ-EO-1 (EO Data Pipelines & External Repositories): Met.** The system provides automated pipelines that interface with major external EO data providers (Microsoft Planetary Computer, Copernicus Data Space Ecosystem, Source Cooperative) to discover, ingest, and access satellite collections.

- **REQ-E0-02 (Demonstration-Site Datasets): Supported conditionally.** The platform enables flexible spatiotemporal indexation over defined geographic regions of interest and time intervals, allowing demonstration-site datasets across NOSTRADAMUS agricultural pilots to be generated, loaded, and reused.
- **REQ-E0-03 (STAC-Compliant Discovery): Partial.** The platform acts as a standard-compliant STAC consumer, utilizing STAC Item, Collection, and Asset metadata schemas to query remote repositories and ingest dataset references into the analytical cube. The NOSTRADAMUS STAC-compliant catalogue API is a separate platform component, not hosted by this deployment.
- **REQ-E0-04 (Spatial, Temporal & Property Filtering): Partial.** Discovery and ingestion routines support multi-criteria spatial bounding box filtering, temporal interval constraints, and property queries (e.g., satellite platform selection, cloud cover percentage thresholds) via STAC search and indexing query JSON. No local CQL endpoint is provided.
- **REQ-E0-05 (Algorithm Packaging, CWL & Containerisation): Gap in this deployment.** Algorithms run in fully encapsulated Docker containers with multi-architecture support (AMD64/ARM64). CWL workflow descriptors and OGC Earth Observation Application Packaging (OGC 20-089r1) are not implemented; these are expected to be provided by the wider NOSTRADAMUS platform.
- **REQ-E0-06 (Added-Value Datasets & Cataloguing): Partial.** Output datasets and derived indicators are exported in standardized Cloud Optimized GeoTIFF (COG) or NetCDF formats with complete spatial metadata, and can be indexed as EO3 datasets in the Open Data Cube. No STAC output-publication pipeline is provided.
- **REQ-E0-07 (Processing as a Service & OGC API - Processes): Gap in this deployment.** An OGC API - Processes endpoint is not implemented; it is expected to be provided by the NOSTRADAMUS processing API. Containerised processing algorithms provide clean programmatic entry points designed for registration and invocation through that platform service.

2.5. IoT Observatory Services

Real-time in-situ and remote sensing data streams (Task 3.2).

The Real-Time In-Situ IoT dataset contains meteorological, soil, and agricultural data collected from IoT-enabled monitoring stations deployed across five pilot sites in Germany, Serbia, Switzerland, Slovenia, and Cyprus. The data cover key environmental parameters influencing agricultural production, including air temperature and humidity, air pressure, wind speed and direction, solar radiation, precipitation, soil moisture and temperature, leaf wetness, and phenological indicators.

Each measurement is associated with a timestamp, geographic coordinates, standardized variable name, and unit of measurement, enabling harmonisation and integration of data from different pilots. Data are continuously transmitted to and stored in the Nostradamus IoT Observatory, which provides infrastructure for real-time data ingestion, processing, storage, and querying. The Observatory supports both real-time data streams and historical data access.

Third parties can access authorized data through the Observatory's REST API, allowing them to retrieve historical measurements, subscribe to live data, and perform statistical or real-time aggregations. This enables external researchers, developers, and applications to integrate the data into their own analytical workflows, dashboards, decision-support tools, and data-driven applications.

2.6. Agricultural market and socio-economic data and models

The NOSTRADAMUS Agricultural Market Data and Modelling Service provides access to agricultural market intelligence, socio-economic indicators, production statistics, trade information, and analytical models that support economically informed decision-making across cereal-based production systems and agricultural value chains. The service complements the Earth Observation, IoT, agronomic, socio-economic, and environmental datasets available within the NOSTRADAMUS ecosystem, also introducing the socio-economic dimension required for sustainable and resilient farm management.

The service is built upon the integration of internationally recognized agricultural databases and statistical sources, including FAOSTAT, EUROSTAT, World Bank, GAEZ, and other validated data repositories identified within Task 3.1. These sources provide harmonized and interoperable information on agricultural production, crop yields, market indicators, trade flows, input consumption, productivity trends, socio-economic indicators, and food security metrics.

Particular emphasis is placed on cereal production systems and food-security relevant commodities, supporting the objectives of NOSTRADAMUS related to resilience, sustainability, and evidence-based agricultural decision-making. The service enables users to understand how agronomic performance, climate impacts, irrigation practices, and resource-management decisions translate into economic outcomes. In addition, NOSTRADAMUS allows analysis of socio-economic indicators of food systems, e.g. income, employment, health, demographics, education, tourism, and development.

2.6.1. Data and Model Capabilities

The Agricultural Market Component provides access to datasets and indicators including:

- Crop production, harvested area, and yield statistics for major cereal and agricultural commodities.
- Trade and economic indicators, including import dependency, self-sufficiency ratios, revealed comparative advantages (RCA), and terms-of-trade indicators.
- Agricultural production indices and long-term productivity trends.
- Irrigation infrastructure and irrigated production indicators, including areas equipped for irrigation, water-source information, and irrigated crop performance.
- Land-use, crop-distribution, and utilized agricultural area (UAA) statistics.
- Organic farming and sustainable production indicators.
- Food-security and agricultural resilience indicators derived from international statistical databases.
- Historical datasets support trend analysis, benchmarking, scenario assessment, and policy evaluation.
- Socio-economic datasets for analyzing income, employment, health, agriculture, demographics, education, tourism, and development connected to food systems.



The service supports analytical workflows including market monitoring, productivity benchmarking, resilience assessment, scenario modelling, economic impact analysis, and evaluation of sustainability interventions at farm, regional, and policy levels.

2.6.2. Agricultural market datasets and model outputs

Agricultural market datasets and model outputs will be made available through interoperable services, data catalogues, and APIs aligned with the NOSTRADAMUS data integration framework. The underlying Task 3.1 analysis identified FAOSTAT, EUROSTAT, World Bank, GAEZ and related sources as priority datasets due to their structured catalogues, API availability, standardized metadata, and suitability for integration into digital agriculture applications.

Third-party beneficiaries may integrate these datasets and services to:

- Combine crop-yield forecasts generated by NOSTRADAMUS modules with production and market indicators for improved farm decision support.
- Assess economic impacts of drought, irrigation, fertilization, and crop-management strategies.
- Support resource-allocation decisions by linking agronomic performance with production and market trends.
- Develop food-security and resilience-oriented advisory tools.
- Generate regional benchmarking and comparative analyses across production systems.
- Support business planning, investment decisions, and sustainability assessments through integrated environmental and economic indicators.

Access to data will follow FAIR principles and will be supported through documented APIs and machine-readable formats, enabling seamless integration with the NOSTRADAMUS Data Cube infrastructure, Application Generation Engine, IoT Observatory, and Earth Observation services.

2.6.3. Expected Benefits

The Agricultural Market Data and Modelling Service strengthens the economic dimension of the NOSTRADAMUS ecosystem by enabling:

- Data-driven and economically informed farm management decisions.
- Improved understanding of production, market, and food-security risks.
- Evaluation of trade-offs between productivity, profitability, and sustainability.
- Enhanced resilience assessment under changing climatic and market conditions.
- Better integration of agronomic, environmental, and economic intelligence within digital agriculture applications.
- Stronger support for European food security objectives and sustainable cereal production systems.
- Advanced equipment with data for socioeconomic analysis of food systems.

This service provides the economic and market intelligence layer required to transform NOSTRADAMUS technical outputs into actionable decision-support solutions for farmers, cooperatives, advisors, agri-food businesses, and public stakeholders.



2.7. Integration with Third Parties and Open Call #1 Beneficiaries

For third-party beneficiaries funded under **Open Call #1**, the IoT, DataCube, Low-Code Platform and AGE are critical enablers. Third parties must design, develop, and validate applications that remain interoperable with the Nostradamus ecosystem, building upon its hybrid architecture and data infrastructure.

The integration of third-party software with the platform is facilitated through standard, reusable low-code components, templates, and libraries:

- **Bootstrapping Software and Templates:** The bootstrapping templates, and domain-specific languages. These templates act as pre-configured code structures that handle basic cloud-edge data routing, authentication, and service discovery out of the box, allowing third-party developers to jump directly to designing custom business logic and UI dashboards.
- **Ecosystem Connectivity via APIs:** Generated applications must leverage Nostradamus' standardized, secure interfaces:
 - **IoT Observatory Ingestion:** Applications interacting with IoT telemetry must use the open-source **IoT Python SDK**. This client library abstracts the underlying Apache Kafka streaming and Cassandra database structures, enabling applications to send data, run dynamic queries, and execute simple/complex aggregations securely via the Edge Gateway using Master, Read, and Write API keys.
 - **Data Cube and Earth Observation Access:** Applications requiring satellite imagery must interface with the Open Data Cube (ODC) Python API inside the standardized Cube-in-a-Box (Ciab) container image (ghcr.io/livingearthlab/cube-in-a-box), querying metadata through the standards-compliant STAC catalogue service and pulling partial raster assets as Cloud Optimized GeoTIFFs (COGs) via pre-signed, time-bound URLs.

2.8. Modules Developed within Nostradamus Project

Technical specifications for the four WP4 modules (Drought, Yield, Soil, Pest)

The NOSTRADAMUS project develops four interoperable core modules addressing key challenges in sustainable agriculture: drought and vegetation stress monitoring, crop suitability and yield estimation, soil fertility and crop nutritional management, and sustainable pest management. Each module combines Earth Observation, environmental, agronomic, and socio-economic data to generate actionable insights that support farmers, advisors, policymakers, and other stakeholders. The modules are validated at dedicated demonstration sites and designed to be scalable, interoperable, and reusable by Third Parties through the NOSTRADAMUS platform.

- **M1: Early warning system for drought and vegetation stress monitoring (Germany + 1 replication site).**

Description: The Drought Monitoring Module delivers spatial drought monitoring and early-warning information. The module is based upon a Combined Drought Indicator (CDI) approach, which

integrates vegetation, thermal, soil moisture, and precipitation data. Input datasets include Normalized Difference Vegetation Index (NDVI) from Sentinel-2, Land Surface Temperature (LST) from Sentinel-3, Surface Soil Moisture (SSM) from the Global Land Service of Copernicus (CGLS), and the Standardized Precipitation Index (SPI) based on Climate Hazards Center InfraRed Precipitation with Station data (CHIRPS). Short-range to seasonal meteorological forecasts are incorporated to support predictive drought outlooks and probabilistic early-warning capabilities.

Based on the developed input datasets, Module 1 derives spatially explicit information on the current drought status, distinguishing between different drought severity levels, and provides spatially explicit early warnings of potential drought and drought-affected areas. The module generates drought status maps at 10 m resolution using Sentinel-2-derived vegetation indicators as the spatial backbone, while coarser-resolution variables (e.g., soil moisture, precipitation, LST) are spatially harmonised and resampled prior to integration. Results are stored as georeferenced raster datasets in GeoTIFF format.

Applicable demonstration sites: The module is primarily developed and validated at the German demonstration site, with replication and validation at the Swiss demonstration site to assess its transferability across different agro-climatic conditions and farming systems.

Integration with third parties: Third parties can use the output drought monitoring and early-warning datasets, and other data and products available through the NOSTRADAMUS platform and APIs, to develop digital applications to support adaptation measures and informed decision-making regarding irrigation strategies, water resource efficiency, crop selection, agricultural management, drought resilience, and climate adaptation.

- **M2: Crop suitability and agricultural yield estimation (Serbia + 1 replication site).**

Description: The Crop Suitability and Agricultural Yield Estimation module provides **actionable insights** to support sustainable and economically viable agricultural production. It integrates Sentinel-2 imagery, weather data, soil characteristics, terrain attributes, field observations, and agricultural market data to generate spatially explicit indicators of crop condition, yield potential, and economic performance.

AI-based models analyse multi-source data to estimate crop yields, monitor crop development, evaluate crop suitability, and assess the economics of growing different crops by incorporating historical prices, production costs, profitability, and risk. The models have been trained on **more than 10,000 field-level data points** collected from local producers, agribusinesses, seed companies, and other stakeholders. Module outputs are provided as **250 m raster layers**, with the spatial resolution determined by the availability of soil maps, enabling consistent regional-scale assessments and comparisons.

Applicable demonstration sites: The module is primarily developed and validated at the Serbia demonstration site, with replication and validation in Slovenia to assess its transferability across different agro-climatic conditions and farming systems.

Integration with third parties: Third parties can use crop suitability maps, yield forecasts, and other EO-derived products through the NOSTRADAMUS platform and APIs to develop digital applications for precision agriculture, crop planning, farm management, and climate adaptation. The module is fully interoperable with the NOSTRADAMUS Data Cubes, Earth Observation services, IoT



Observatory, and other modules, enabling the development of scalable applications for AI and data powered agriculture.

- **M3: Soil fertility and crop nutritional management (Slovenia + 1 replication site).**

Description: The Soil Fertility and Crop Nutritional Management module provides data-driven recommendations for improving soil fertility, crop nutrition, and the efficiency of fertiliser application. It integrates Earth Observation data from satellites and drones, agricultural-field information, soil and plant laboratory analyses, crop-management data, and high-frequency measurements from IoT sensors. The sensor data include parameters such as air temperature, humidity, air pressure, soil moisture, soil temperature, and leaf wetness.

AI-based data processing and multi-source data fusion are used to monitor crop development and nutritional status, identify spatial hotspots requiring specific treatment, and generate crop and site-specific recommendations concerning the appropriate fertiliser type, quantity, and application time. The module can also support recommendations regarding crop rotation and other management practices that improve long-term soil fertility. Its objective is to optimise crop yields while reducing fertiliser consumption, production costs, nutrient losses, and the environmental impacts associated with excessive nitrogen and phosphorus application.

The technical development and validation activities include more than 20 IoT sensors, more than 20 soil analyses, more than 20 field experiments, and the participation of at least one experimental farm. Field polygons and associated metadata are handled in SQL, JSON, and GeoJSON formats; laboratory analyses are available in JSON, CSV, and SQL; and IoT measurements are exchanged through a structured JSON data model.

Applicable demonstration sites: The module is primarily developed and validated at the Slovenia demonstration site. It will subsequently be scaled to the Serbia demonstration site, where it will be adapted to locally available soil, crop, field-management, laboratory, Earth Observation, and IoT data. This replication will be used to assess the module's transferability across different agro-climatic conditions and farming systems. Although the module's technical architecture supports scaling to other NOSTRADAMUS demonstration sites, the planned replication within the project focuses on Serbia.

Integration with third parties: The module is integrated with the NOSTRADAMUS Data Cubes and the DIH AGRIFOOD Data Space, which provides access to field information, IoT measurements, and soil-analysis data. It can ingest information from external Earth Observation services, agricultural field registers, farm-management information systems, soil laboratories, advisory services, and third-party IoT platforms. Standard formats such as JSON, GeoJSON, CSV, and SQL facilitate technical interoperability and data exchange.

The resulting soil-fertility indicators, hotspot maps, and fertilisation recommendations can be made available through the NOSTRADAMUS platform and APIs for use by agricultural advisory tools, farm-management applications, decision-support systems, and precision-farming equipment. Data providers retain control over restricted and sensitive datasets, while personal and farm-level information is anonymised or pseudonymised before being shared.

- **M4: Sustainable and efficient pest management (Cyprus + 1 replication site).**



Description: The Sustainable and Efficient Pest Management module is an early warning system for cereal pests and diseases, combining satellite-based EO, IoT, weather, soil, and crop data. It integrates Sentinel-2 spectral indices (NDVI, EVI), ERA5 climate data, SoilGrids soil texture data, and local IoT and in-situ crop observations to first estimate the Zadoks growth stage of cereal crops using machine learning (Random Forest, SVM, XGBoost, CatBoost), then trigger a rule-based disease-detection component that generates daily, georeferenced (10 m resolution, EPSG:4326) disease-risk maps. The module allows farmers to identify field-level disease hotspots, anticipate outbreak risk, and target pesticide use only where and when it is needed, potentially reducing both crop losses and chemical input.

Applicable demonstration sites: The module is primarily developed and validated at the Cyprus demonstration site, on wheat and barley plots at the Agricultural Research Institute's Acheleia experimental station (Acheleia area, Morokampos site, Paphos). It will be replicated and validated at the DLG demonstration site near Bernburg, Germany, a cereal (barley and wheat) production area with a distinctly different, temperate-continental agro-climatic regime, chosen to test the module's transferability across Mediterranean and Central European farming and disease-risk conditions.

Integration with third parties: Through the Nostradamus platform and APIs, Third Parties can access the module's crop-phenology time-series, Zadoks growth-stage estimates, and disease-risk/early-warning maps to develop digital applications for precision pest management, targeted spraying, advisory tools, and climate-adapted crop protection. The module is interoperable with the Nostradamus Data Cubes, EO services, and IoT Observatory. Note that the output risk/early-warning products are made widely accessible, but the underlying pest and disease risk-quantification models themselves are not released as open source, as they remain proprietary IP and a core asset of ECoE.

For further details on the technical specifications and requirements of the core software modules, data models, and analytical tools developed within the project, reference is made to *Deliverable D2.1: Needs-based data requirements (M16)*, which is publicly available on the official **NOSTRADAMUS Zenodo repository**: <https://doi.org/10.5281/zenodo.21905118>

3. NOSTRADAMUS Applications

The Nostradamus Open Call #1 will fund applications targeting farmers, cooperatives, farm advisors, and agri-industrial actors. These applications will provide real-time, data-informed recommendations to improve farm management, resource efficiency, and resilience under varying climatic and socio-economic conditions. All applications must be developed as **open-source digital applications** supporting sustainable and efficient agricultural production systems, with a focus on cereal-based systems and food security, and **must address** one of the following thematic domains:



IMPORTANT NOTE ON TOPIC & MODULE SELECTION:

The five NOSTRADAMUS Open Call #1 Topics are **directly aligned** with the core NOSTRADAMUS Modules detailed in Section 2.8 of Annex 1.1.

By selecting a Topic (T1-T4), applicants commit to utilizing the corresponding Module (M1-M4) and its underlying datasets as the foundation for their digital application.

For Topic 5 (Open Topic), applicants must integrate at least two of the four core modules.

Choosing a topic automatically assigns the core module and associated data assets that must be built upon and validated during the project.

The link between the **NOSTRADAMUS Topics and Modules** is available in the table below:

TABLE 3. NOSTRADAMUS TOPICS REFERENCE TO THE DEVELOPED MODULES

T1	Sustainable crop production and optimisation of cereal-based systems under changing climate and soil conditions.	Module 2 Crop Suitability
T2	Nutrient and soil health management, integrating soil fertility indicators, organic matter dynamics, and precision fertilisation models	Module 3 Soil and Nutrition
T3	Water resource efficiency and drought resilience, using the Early Warning System outputs and IoT-based soil moisture monitoring.	Module 1 Drought Monitoring
T4	Smart and predictive pest and disease management to support the EU objective of reducing pesticide dependency and enhancing sustainability.	Module 4 Pest Management
T5	Open topic: Integrated, cross-domain decision-support applications combining multiple topics (an open proposal from the applicants for an application that combines at least 2 of the previous topics T1-T4)	Any 2 of the above listed Modules corresponding to the chosen topics

Modules details are available in Section [Modules Developed within Nostradamus Project](#).

Pilot (demonstration sites) sites details are available in Section [Demonstration Sites](#).

3.1. Hybrid Edge-to-Cloud Architectural Context

To ensure architectural compliance, applicants are required to implement and compare edge, cloud, and mixed computing solutions, mapping their implementation to the three functional tiers:

1. App-Edge Components (Tier A): Run directly in the field on low-power single-board computers or microcontrollers (e.g., Raspberry Pi, ESP32) for primary observation, local threshold-based alerting (e.g., immediate frost alarms), and actuator execution.



2. App-Logic Components (Tier B): Reside predominantly in the cloud as the analytical core, fusing multi-source telemetry from the IoT Observatory with Earth Observation arrays from the Data Cubes and statistical socio-economic datasets.
3. App-GUI Components (Tier C): Serve as the user-facing web or mobile interface, dynamically visualizing derived indicators and decision-support dashboards.

3.2. Obligatory General Requirements:

All applications must:

- Use **one or more of the outcomes** from the **modules** developed within Nostradamus, as well as the open-access data utilized for their development (including calibration and validation datasets) as described in section Modules **Developed within Nostradamus Project**.
- Integrate **additional external databases**, where relevant. If such datasets are used, they must be made openly accessible after the project's completion and shared with the Nostradamus consortium, ensuring full compliance with FAIR data principles. Any such external dataset must likewise be entered in the Nostradamus Data Dictionary by completing a "Name Data Entry" in the Nostradamus Data Dictionary, following the General Format template (Data Source Name, Description, Version, Data Source Type, Data Type, Format, Spatial/Temporal Coverage, Update Frequency, Responsible Partner, Licensing/Access Rights, Linked Core Modules, and the remaining fields as specified).
- Build on the feedback, needs, and challenges identified by stakeholders through the established MAPs (D1.1 – MAA Strategic Plan MAPs) and the **survey** conducted. Each application must reflect the priorities and insights expressed by stakeholders surrounding the demonstration sites, ensuring that the resulting solutions are user-oriented, context-specific, and co-created.
- Adopt **open-source principles**, ensuring transparency, accessibility, and user empowerment. Beneficiaries are encouraged to co-develop with farmers and advisors possessing advanced digital skills, ensuring user-friendliness and strengthening digital capacities across the agricultural sector.
- Include **social, economic, and environmental considerations**, integrating perspectives from SSH to enhance user acceptance, trust in data sharing, and inclusivity.
- Contribute to interoperability, supporting the European Data Strategy and enabling integration with other EU-funded digital agriculture initiatives and infrastructures.
- Promote international cooperation and upscaling, where relevant, by demonstrating transferability of the developed applications to other regional or climatic contexts in Europe and beyond.

All applications under this Open Call must also:

- Provide decision-support capabilities for farmers, cooperatives, farm advisors, and agri-industrial stakeholders to assess trade-offs between productivity, resilience, and sustainability.
- Incorporate IoT-driven data integration and EO analytics to enhance precision, data availability, and interoperability at the farm and community levels.



- Implement and compare edge, cloud, and mixed computing solutions to enable real-time analytics and robust operation under varying connectivity conditions.
- Design digital services that reduce administrative burdens for farmers and enhance data interoperability across agricultural systems and value chains.
- Demonstrate **positive impact on the effectiveness, feasibility, and sustainability** of the developed cloud-, edge-, and mixed digital applications, including technical performance (accuracy, scalability, reliability), socio-economic benefits for farmers and agri-businesses (productivity, resilience), and environmental improvements.

3.3. Development & Execution Environment Requirements and Roadmap

This section defines the baseline for proposal submission, the execution options currently under final validation, and the timeline for confirmation of the final deployment setup. It is part of the official baseline for Open Call #1 evaluation.

3.3.1. Base Architectural Framework & Baseline for Proposals

To accommodate diverse technical architectures and ensure equal treatment of all applicants, NOSTRADAMUS Open Call #1 supports development across Cloud, Edge, and Mixed (Hybrid) paradigms.

To ensure maximum operational feasibility and eliminate technical risk for Third Parties, applications must be designed with **architectural flexibility**, so that the solution can adapt seamlessly to the final deployment environment.

Baseline freeze: Proposals shall be prepared on the basis of the frozen baseline described in this Annex 1.1, Sections 2 & 3 (Edge-to-Cloud architecture; Data Cube APIs and data schemas; IoT Observatory interfaces; Application Generation Engine principles, including Jupyter Notebooks, containerized packaging per Docker/OCI and CWL workflow descriptors where applicable).

Target vs operational status: References to the Data Cube Ecosystem, Data Cubes, IoT Observatory and Low-Code Application Platform in this Annex describe the target interfaces and standards for interoperability. Component maturity is stated where known.

No post-publication eligibility change: No new eligibility or selection criteria will be introduced after the launch of the Open Call. Operational details confirmed later are implementation guidance only.

3.3.2. Execution Options – Status at Publication

Applicants shall design portable solutions able to run in any of the options below, subject to final confirmation under Section 3.3.3. Availability statements are not service-level agreements (SLAs):

TABLE 4. EXECUTION OPTIONS

Option	Description
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A. DataHub workspaces (reference)	Managed JupyterHub spawning containerized JupyterLab / VS Code / QGIS with pre-installed toolboxes, persistent workspace, Harbor/GitLab registry, CWL execution.
B. Pre-configured VM / container images	Versioned VM images / OCI images reproducing the DataHub toolchain for offline or local execution (hash and publish date to be given in the onboarding pack).
C. Applicant-side containerized execution	Applicant runs OCI/CWL-compliant containers locally or on own cloud, interacting only via public Nostradamus APIs (DataHub, Data Cubes, IoT0). Applicant lists base image and package lockfile in the proposal.

Note on local development: Developing directly on an unmanaged host OS without container/image pinning is discouraged due to reproducibility risk (operating-system and package-version drift) but is not ineligible if API conformance is demonstrated.

Portability guidance: Applicants are encouraged (not required) to describe in their proposals how their architecture remains portable across Options A-C (e.g., container manifest, externalized configuration/secrets, no hard-coded endpoints, pinned dependencies). This statement is assessed under feasibility, not as a pass/fail infrastructure commitment.

3.3.3. Infrastructure Finalization & Communication Timeline

- **Final Environment Confirmation:** The definitive execution environment setup (including server resource allocations, specific VM image availability, and final DataHub workspace parameters) will be finalized by the Consortium prior to the start of the sub-grant execution phase and will be **officially communicated to all selected Third Parties during Sprint 1** (Training & Technical Onboarding).
- **Onboarding & Alignment:** During Sprint 1 (Program Months 1-2 / Project M33-M34), funded Third Parties will receive hands-on technical onboarding, dedicated mentor guidance, and access to the final deployment setup. If adjustments to an application's deployment configuration are necessitated by the finalized consortium infrastructure, these will be mutually agreed upon during Sprint 1 without altering the original scope, objectives, or grant budget of the Third-Party project.

Legal safeguard: Clarifications provided during Sprint 1 do not constitute new eligibility criteria within the meaning of EU equal-treatment rules.

3.4. Maturity of the Proposed Solution and Readiness Levels

Digital Applications developed by Third Parties under the Open Call are expected to **start at a minimum of TRL 4** – Technology validated in lab and **reach a minimum of TRL 7** – System prototype demonstration in operational environment by the end of the project. Full TRL definitions are provided in TABLE 5. STANDARD HORIZON EUROPE TRL DEFINITIONS of this document. In practice, this means applicants entering the Open Call at TRL 4 must move their solution from a lab-validated prototype to one demonstrated under real-world, operational conditions at Nostradamus' sites, i.e.

tested by, or with, actual end-users (farmers, advisors, agri-industrial actors), within the project's 12-month funding window (Training – Design – Development/Validation – Demonstration/Assessment).

TABLE 5. STANDARD HORIZON EUROPE TRL DEFINITIONS

Level	Official Horizon Europe Definition
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (<i>industrially relevant environment in the case of key enabling technologies</i>)
TRL 6	Technology demonstrated in relevant environment (<i>industrially relevant environment in the case of key enabling technologies</i>)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (<i>competitive manufacturing in the case of key enabling technologies, or in space</i>)

3.5. Interoperability Standards:

All applications developed under Nostradamus Open Cal #1 shall be designed to ensure interoperability with the Nostradamus data infrastructure, and, where applicable, with external agricultural, Earth Observation (EO) and European data infrastructures. Third Parties shall therefore adopt open, widely used and machine-readable standards and formats and shall adequately document the interfaces, data structures and metadata required for integration of their applications into the Nostradamus ecosystem.

Adherence to the FAIR principles, REST APIs and relevant OGC/ISO standards is required. Data generated, processed or exchanged by the applications shall be managed in accordance with the FAIR principles – Findable, Accessible, Interoperable and Reusable – so that data and associated metadata can be discovered, accessed under clearly defined conditions, integrated across systems and reused beyond the original application context. Third parties shall provide sufficient metadata, provenance information and technical documentation to support these principles.

Applications shall expose and/or consume data through documented, machine readable interfaces. Where relevant, REST APIs shall be used to enable standardized exchange of data and services between Third-Party applications, Nostradamus components and external systems. For geospatial data, Earth Observation products and related services, applicants shall use relevant Open Geospatial Consortium (OGC) and International Organization for Standardization (ISO) standards, particularly where these are required for interoperability with the Nostradamus Data Cube infrastructure, catalogues and external geospatial services.

Appropriate standardized formats shall be used according to the type of information handled. Indicative formats currently supported within Nostradamus include GeoTIFF and NetCDF for EO



data; GeoPackage (GPKG) and other standard geospatial formats; CSV, JSON and XML for IoT and tabular datasets; and HDF5, TFRecord and ONNX for AI model outputs. Metadata shall, where applicable, comply with the INSPIRE Directive and make use of established controlled vocabularies and semantic resources, including AGROVOC and GEMET.

Data discovery and exchange mechanisms shall be compatible with the Nostradamus Data Cube infrastructure and its catalogue, metadata and API services. Third Parties shall provide sufficient technical documentation describing the data formats, schemas, metadata, APIs, dependencies and interoperability mechanisms implemented in their applications.

Datasets generated by Third Parties and intended for integration into or reuse through Nostradamus shall be accompanied by appropriate metadata and documentation in accordance with the Nostradamus Data Dictionary requirements.

3.6. Programming and Open Source:

Applications interacting with the Nostradamus IoT Observatory (IoT0) system must be developed using the IoT0 SDK² (except for software/firmware running on constrained IoT devices), that is developed in Python 3.9+ programming language. The IoT0 SDK provides an abstraction layer and enables rapid development of data ingestion from the IoT and Edge layers, while also provides methods for querying historical and real-time data and applying data aggregation functions dynamically. The project is open-source and licensed under the MIT License.

Applications that use NOSTRADAMUS Data Cube data shall be developed in Python 3 within the Cube in a Box (CiaB) environment – the reference Open Data Cube deployment maintained by UNIGE/GRID-Geneva (MIT License).

Development shall use the NOSTRADAMUS JupyterHub / JupyterLab service. Each user has a persistent workspace; shared demonstration notebooks are provided on the platform. The runtime is the public container image `ghcr.io/livingearthlab/cube-in-a-box`, which includes GDAL, Python 3, and a curated geospatial stack. Batch or pipeline work shall use the same image or an environment built from the public requirements.txt. Additional dependencies shall be declared in requirements.txt and shall not conflict with the base image unless justified under REQ-PROG-10.

Integration with the Data Cube shall use the standard Open Data Cube Python API (`datacube.Datacube`, `dc.load`) for spatial, temporal, and thematic selection. Cloud-hosted assets shall be accessed through signed URLs or deployment credentials configured in the platform environment (e.g. Planetary Computer or Copernicus Data Space), not by copying full archives locally when partial access is sufficient.

Demonstration-site datasets shall be indexed and verified through the platform indexing workflow and the Data Cube Explorer. Reference notebooks and helper libraries are provided on the platform for common loading, mapping, masking, and plotting tasks.

Derived products intended for reuse shall be exported as Cloud Optimized GeoTIFF or NetCDF and may be re-indexed in the Data Cube where appropriate. EO ingestion shall use the NOSTRADAMUS

² <https://github.com/robotics-4-all/nostradamus-ioto-sdk>



EO pipelines and STAC-based discovery (Section 4.1). IoT data shall be accessed only through the documented IoT interfaces, not by direct connection to sensors. Outputs may be consumed by the Application Generation Engine and low-code components as files or Python modules.

AUTH and Terradue provide complementary requirements for the **Application Generation Engine**, broader platform APIs, and EO pipeline integration.

REQ-POS-01: Applications developed under Nostradamus Open Call #1 shall follow the Open Science and open-source principles adopted by the Nostradamus project. Source code developed within the funded activities shall be made publicly available through an appropriate version-controlled repository, subject to legitimate restrictions concerning personal data, confidential or security-sensitive information, pre-existing Intellectual Property Rights (IPR), and the protection and exploitation of project results.

REQ-POS-02: The public availability of source code shall be accompanied by sufficient documentation to enable the understanding, reproducibility, reuse and further development of the application. Third Parties shall therefore provide, as appropriate, installation and deployment instructions, software dependencies, configuration requirements, API documentation and information necessary for integration of the developed application with the Nostradamus ecosystem. Appropriate licensing information shall accompany publicly released software and other reusable outputs.

REQ-POS-03: In accordance with the Nostradamus approach to Open Science, the principle of “as open as possible, as closed as necessary” shall apply. Open-source repositories shall not contain personal data, confidential or proprietary information, credentials, access tokens, security keys, or other information subject to legal, ethical, contractual or security restrictions.

REQ-POS-04: Applications shall be developed using programming languages, frameworks and tools that enable their effective integration with the Nostradamus architecture, data infrastructure, Application Generation Engine (AGE), APIs and other services.

REQ-POS-05: Public repositories shall not contain personal data, confidential or proprietary information, credentials, access tokens, security keys or other information subject to legal, ethical, contractual or security restrictions.

REQ-POS-06: Where software components, libraries, datasets or other resources developed by third parties are incorporated into an application, applicants shall ensure compliance with the applicable licenses and Intellectual Property Rights and shall appropriately document such dependencies.

REQ-PROG-07: Applications shall be developed using Python or the programming environments and AGE tools supported by the NOSTRADAMUS Platform, as appropriate to the proposed application.

REQ-PROG-08: Application source code, configuration, workflows and other software artefacts necessary for reproducibility shall be maintained under version control.

REQ-PROG-09: Applications shall provide sufficient testing to demonstrate their correct integration with the NOSTRADAMUS APIs, developer tools and relevant datasets.



REQ-PROG-10: Software developed under the Open Call shall not introduce dependencies on proprietary or platform-specific technologies that prevent its integration with the NOSTRADAMUS environment, unless explicitly justified by the proposed application.

3.7. Computational Efficiency

Particular attention should be paid to the energy performance of the chosen computing architecture, assessing trade-offs between edge, cloud, and mixed approaches.

This section defines the mandatory technical specifications and guidelines regarding the computational efficiency, energy performance, and connectivity resilience of the digital solutions developed under Nostradamus Open Call #1.

Given that the Nostradamus digital ecosystem is engineered to support sustainable and resilient European agriculture under the European Green Deal and the Common Agricultural Policy (CAP), applicants must treat computational resources as finite constraints. The system architecture is designed as a hybrid Edge-to-Cloud "System of Systems" specifically optimized to overcome field-level constraints such as weak connectivity and high energy overheads.

3.7.1 Connectivity Resilience and Offline Operation

Agricultural environments across Europe frequently suffer from intermittent, low-bandwidth, or weak network connectivity. This is typified by the Mediterranean pilot site in Cyprus, which faces critical connectivity limitations alongside significant drought pressures.

To operate reliably under these real-world constraints, applications must adhere to the following resilience standards:

- **Offline Capability**
 - **Autonomous Local Sensing & Control:** App-Edge Components (Tier A) must continue to function independently of the cloud during network blackouts. Local microcontrollers must execute primary sensory acquisition and maintain safety-critical local control loops (e.g., shutting down a precision irrigation pump based on physical soil moisture thresholds) without cloud roundtrips.
 - **Local Telemetry Buffering:** Edge devices must implement secure local ring-buffers (using non-volatile flash memory or SD cards) to temporarily log telemetry events when the Edge Gateway is unreachable. No data shall be lost during short-term connection drops.
- **Bandwidth-Optimized Data Synchronization**
 - **Lightweight Protocols:** Once the network connection is re-established, the Edge device must synchronize its buffered data with the IoT Observatory's Edge Gateway. The synchronization must utilize lightweight, low-overhead communication protocols:
 - **MQTT (Message Queuing Telemetry Transport):** Standard for low-power publish-subscribe client-server telemetry streaming.



- **CoAP (Constrained Application Protocol):** An optimized, lightweight UDP-based protocol (currently under development) specifically for highly constrained IoT devices in remote fields with poor network conditions.
- **Decoupled Backpressure Protection:** Telemetry streams are published to dedicated, partitioned topics. This distributed message-brokering infrastructure decouples data ingestion from active stream analytics (ksqlDB and Apache Flink), ensuring that sudden bursts of synchronized data from reconnected devices do not overwhelm cloud processing pipelines.

3.7.2. Energy Performance and Trade-Off Assessment

Under the Horizon Europe framework, Nostradamus targets achieving energy saving in agricultural production through data-driven operational optimization (such as reducing machinery runtimes, optimizing water pumps, and reducing chemical applications). To achieve this, the energy balance of the software solutions must be carefully managed.

Open Call participants must assess and document the trade-offs across the three paradigm architectures:

TABLE 6. ENERGY-PERFORMANCE TRADE-OFF OF HYBRID EDGE-TO-CLOUD APPLICATIONS

Metric / Constraint	Edge-Only Processing (Tier A)	Cloud-Only Processing (Tier B)	Mixed/Hybrid Paradigm (Tier A + B)
Local Energy Draw (Field)	Low power (mWatts to single-digit Watts) on embedded boards; battery or solar-powered.	Extremely low (sensors only stream raw data continuously).	Balanced; edge performs filtering, active radio sleep states are optimized.
Radio Transmission Overhead	Minimal; only pre-filtered anomalies or aggregated averages are transmitted.	High; raw, high-frequency telemetry streams are constantly transmitted, consuming substantial battery power.	Optimized; edge buffers and sends compressed packets using MQTT/CoAP.
Cloud Computing Energy I/O	Zero.	High computational energy required for raw ingestion, streaming processing, and long-term storage I/O.	Optimized; cloud focuses on multi-source data fusion, batch analysis, and model retraining.
Decision-Support Latency	Sub-second local actuation; immune to network latency.	Network-dependent latency; vulnerable to network blackouts.	Sub-second latency for critical events (edge); deeper historical queries are serving-layer driven (cloud).



4. Resources and Assets Provided by the Consortium

4.1. Data Access:

Protocols for existing databases (weather, soil, socio-economic) and STAC-based discovery.

4.1.1. General Requirements

REQ-DATA-01: Applications developed under NOSTRADAMUS Open Call #1 shall use the documented NOSTRADAMUS data APIs and interfaces to access platform-provided data, where relevant to the proposed application.

REQ-DATA-02: The three principal NOSTRADAMUS data interfaces available to applications are:

- EO Data Pipelines, for EO data discovery, access and ingestion;
- Data Cube interfaces, for access to prepared multi-dimensional agricultural datasets; These as preprocessed, gridded, harmonised multidimensional data structures accessible both from notebook environments and processing pipelines.
- IoT data-stream interfaces, for access to in-situ sensor measurements.

REQ-DATA-03: The application proposal shall identify which of the NOSTRADAMUS data interfaces will be used and describe how the corresponding data will contribute to the application.

4.1.2. EO Data Pipelines

REQ-DATA-EO-01: The NOSTRADAMUS EO Data interface shall provide standards-based discovery of EO datasets through a STAC-compliant catalogue API.

REQ-DATA-EO-02: Applications shall be capable of querying EO datasets using spatial, temporal and metadata/property criteria, as required by their use case.

REQ-DATA-EO-03: Where advanced filtering is required, applications should use the filtering capabilities provided by the NOSTRADAMUS STAC interface, including CQL where supported.

REQ-DATA-EO-04: Applications shall use STAC Items, Collections and asset references to identify the EO data required for processing, rather than relying on undocumented catalogue or storage interfaces.

REQ-DATA-EO-05: Applications shall use the NOSTRADAMUS mechanisms for authenticated access to protected EO assets, including signed URLs or API-based access where applicable.

REQ-DATA-EO-06: Where applicable, applications should support cloud-native access to EO data, including partial access to cloud-optimised assets rather than requiring unnecessary full-data downloads.



4.1.3. DataCubes

REQ-DATA-CUBE-01: Applications using NOSTRADAMUS Data Cube data shall access the Data Cube through the documented Data Cube API or interface provided by the platform.

REQ-DATA-CUBE-02: Applications shall be capable of identifying and selecting the relevant spatial, temporal and thematic dimensions of the available Data Cube data, as required by the application.

REQ-DATA-CUBE-03: Applications shall be capable of retrieving or processing the relevant Data Cube subsets required for their analysis, using the mechanisms provided by the Data Cube service.

REQ-DATA-CUBE-04: Applications shall be capable of using Data Cube data from the supported NOSTRADAMUS development and processing environments, where applicable.

REQ-DATA-CUBE-05: Applications shall identify the NOSTRADAMUS demonstration-site Data Cube datasets used for development, testing or demonstration, where applicable.

4.1.4. Data Cube Interface

Third-party applications access NOSTRADAMUS Data Cube data through the documented Python interface and the NOSTRADAMUS JupyterHub environment described in Section 3.4. There is no separate public REST or OGC coverage API exposed by the CiaB deployment; access is through the Open Data Cube Python API inside the platform runtime.

Discovery and selection. Indexed products, spatial and temporal coverage, and dataset metadata are visible in the Data Cube Explorer web catalogue. Applications select data by product name, area of interest, time range, and measurements using `dc.load` or equivalent Open Data Cube calls.

Retrieval. Subsets are retrieved as in-memory arrays or exported files. For cloud-hosted assets, the platform streams only the required portions of Cloud Optimized GeoTIFFs rather than downloading full scenes.

Authentication. Access to protected cloud assets uses credentials and signed URLs supplied by the deployment environment. Applications shall not store secrets in public repositories.

Demonstration sites. Site-specific cubes are prepared by indexing EO products over each pilot bounding box and time window. Third parties shall identify which indexed products they use for development, testing, and demonstration, as required by REQ-DATA-CUBE-05.

Environments. The same Data Cube interface is available in interactive notebooks and in batch jobs using the CiaB container image or an equivalent environment built from the public requirements.txt.

Limits. STAC catalogue services, CWL workflow packaging, and OGC API – Processes execution are provided by other NOSTRADAMUS platform components (see Sections 2.4 and 4.1 EO Data Pipelines), not by the CiaB deployment itself.



4.1.5. IoT Data Streams

REQ-DATA-IOT0-01: Applications using in-situ sensor measurements shall access IoT data streams through the documented NOSTRADAMUS IoT interfaces, rather than accessing the underlying IoT infrastructure directly.

REQ-DATA-IOT0-02: Applications shall be capable of consuming the authorised in-situ sensor measurements made available through the NOSTRADAMUS IoT infrastructure, as required by the proposed use case.

REQ-DATA-IOT0-03: Applications shall handle the metadata associated with IoT measurements necessary to interpret the observations, including, where provided, measurement time, sensor/source identification, measured variable and units.

REQ-DATA-IOT0-04: Applications shall use the NOSTRADAMUS authentication and authorisation mechanisms for access to protected IoT data streams, where applicable.

4.1.6. Reusable Demonstration Site Datasets (see also section 4.4)

REQ-DATA-DEMO-01: NOSTRADAMUS shall provide selected demonstration-site datasets for reuse by Third Parties during application development and testing.

REQ-DATA-DEMO-02: Third-party applications shall be capable of using the relevant demonstration-site datasets through the corresponding NOSTRADAMUS data interfaces.

REQ-DATA-DEMO-03: Applications shall identify the demonstration datasets used to develop, test or validate the proposed application, including the relevant site and data type.

4.2. Technical Mentorship:

Each selected project will be assigned with a mentor to guide and support the implementation of the Programme according to the selected topic and the expertise of the assigned partner in the respective thematic domain:

TABLE 7. PARTNERS TO BE ASSIGNED AS PRIMARY MENTORS TO THE SELECTED PROPOSALS

Topic	NOSTRADAMUS Partner
T1	BIOS
T2	ITC
T3	DLR
T4	ECoE
T5	Depending on the thematic domains included in the selected proposal under T5 (Open topic).

To support third parties (sub-projects) funded under Open Call #1, a dedicated **Technical Helpdesk / Mentorship Pool** composed of key NOSTRADAMUS consortium partners will be established as described in TABLE 8. TECHNICAL HELPDESK & MENTORSHIP POOL OVERVIEW Rather than functioning as continuous, day-to-day project operational staff, this unit operates on demand and upon request whenever third-party projects encounter specific technical challenges or require domain-specific expertise related to the project's infrastructure and core assets.

TABLE 8. TECHNICAL HELPDESK & MENTORSHIP POOL OVERVIEW

Technical component	Responsible partner
Software Architecture	AUTH
Application Generation Engine	AUTH
Data Cube Infrastructure	UNIGE
Earth Observation (EO) Services	Terradue, UNIGE
The IoT Observatory	BioSense (for IoT data pipeline) and AUTH (for Observatory)
Agricultural market and socio-economic data and models	Agfutura (for market aspect) and HSG (for socio-economic aspect)
Modules developed within Nostradamus project:	Four WP4 modules (Drought, Yield, Soil, Pest):
• M1. Early warning system for drought and vegetation stress monitoring	DLR
• M2. Crop suitability and agricultural yield estimation	BIOSENSE
• M3. Soil fertility and crop nutritional management	ITC
• M4. Suitable and Efficient Pest Management	ECoE
Administrative contact point (for reporting, reviews, and other administrative processes) and communication, dissemination, and exploitation support	F6S IE

Each selected sub-project will be assigned a primary lead mentor/contact partner based on its main domain focus (TABLE 7). The broader helpdesk pool will be activated as an expert unit upon request to resolve multi-disciplinary technical queries, conduct periodic sprint reviews, and ensure the seamless integration of third-party open-source applications into the NOSTRADAMUS ecosystem.

4.3. Training for Third Parties

The selected third-party beneficiaries will participate in a mandatory 2-month training phase (minimum 10 hours guided learning + self-study, practical implementation, and assessment), delivered and supported by the Nostradamus consortium. The programme includes structured learning modules, hands-on exercises, self-study and mentoring sessions.



The purpose of this phase is to enable the third-party beneficiaries to acquire the necessary competences to work with the Nostradamus architecture and methodology.

By the end of the NOSTRADAMUS 12-months programme, each third party must submit the following:

- Proof of participation in the mandatory trainings delivered by the consortium (proof of test of architecture with feedback for project)
- Use-case brief describing the target users, the problem addressed, the intended functionality of the application, data requirements, and expected impact (end of second sprint)
- Proof of work for on-site implementation (e.g. short demo or training video for project partners and end users) (end of sprint 3 or 4)

Note: as part of the "Sprint 4 - Demonstration & Assessment" described in section 5.4, each third-party beneficiary will conduct one training session to train the respective Nostradamus target groups on how to effectively apply their application during the time period June-August 2028.

The estimated training units / topics, requirements and expected results from the training during Sprint 1 of the NOSTRADAMUS Programme are explained in Section 5: *NOSTRADAMUS Implementation Framework (The 12-Month Programme)* of the current document, TABLE 11. SPRINT 1 - Training & Technical Onboarding. As the training programme for Third Parties is currently in development, the final curriculum will be announced to the selected applicants after the Programme start.

The tentative curriculum consists of the following training (sub-)units:

Training Unit 1 – Data Governance and Stakeholder Co-Creation

- Sub-Unit 1.1 – EU data governance frameworks
- Sub-Unit 1.2 – Stakeholder engagement and co-creation methods
- Sub-Unit 1.3 – Social and environmental aspects
- Sub-Unit 1.4 – Stakeholder needs and barriers

Training Unit 2 – Nostradamus digital ecosystem

- Sub-Unit 2.1 – Conceptual Architecture of the Ecosystem
- Sub-Unit 2.2 – Interaction of Ecosystem Components
- Sub-Unit 2.3 – Overview of Nostradamus Open-Source Tools
- Sub-Unit 2.4 – Interoperability with EU Digital Agriculture Initiatives

Training Unit 3 – Data usage

- Sub-Unit 3.1 – Nostradamus EO Data Pipelines Principles
- Sub-Unit 3.2 – Nostradamus Data Cube Principles
- Sub-Unit 3.3 – IoT Data Streams Principles
- Sub-Unit 3.4 – EO Data Pipelines Setup Operations
- Sub-Unit 3.5 – Data Cube Setup Operations
- Sub-Unit 3.6 – IoT Setup Operations



Training Unit 4 – Application development tools

- Sub-Unit 4.1 – Bootstrapping Software Part 1: Client SDKs
- Sub-Unit 4.2 – Bootstrapping Software Part 2: "Models" Core Module
- Sub-Unit 4.3 – Data Cube Integration
- Sub-Unit 4.4 – IoT & Edge Integration
- Sub-Unit 4.5 – Data Hub Integration
- Sub-Unit 4.6 – Algorithm Integration and Packaging: Develop, Test, and Validate Earth Observation (EO) Application Packages (OGC-compliant)
- Sub-Unit 4.7 – Scientific Notebooks IDE
- Sub-Unit 4.8 – Nostradamus Low-Code Platform & Application Generation Engine

4.4. Demonstration Sites

This project incorporates **five demonstration sites** spanning diverse biogeographical and socio-economic regions. These sites will serve not only as pilot locations for refining and testing the core modules and applications but also as multi-dimensional assets (demonstration of digital applications, training activities, visits with young scientists, visits with IT experts and farmers' associations to identify the challenges and limitations of current technologies, etc.). Third Parties may potentially utilize pilot sites to develop and exhibit digital applications.

TABLE 9. NOSTRADAMUS DEMONSTRATION SITES

Country	NOSTRADAMUS Partners responsible/involved
Germany	DLG
Serbia	BIOS, CROPT
Switzerland	WBF, Agroscope
Slovenia	ITC, KGZS - ZAVOD MS
Cyprus	EcoE, MARDE

• **Germany (DLG)**

The International Crop Production Center (IPZ) is part of the DLG Competence Center Agriculture and Food. Approximately 20 DLG expert committees are related to the IPZ and are involved in the development of suitable research projects. It's located in Saxony-Anhalt on the southern edge of the Magdeburg Plain, between Halle and Magdeburg, directly on the A14 motorway and in close proximity to the Strenzfeld campus of Anhalt University of Applied Sciences and the Saxony-Anhalt State Institute for Agriculture and Horticulture.

The **location** is characterised by the rain shadow of the Harz Mountains. At an altitude of 80 m above sea level, the average annual rainfall is 511 mm and the average annual temperature is 10.1 °C. The predominant soil type is loess-black earth with a field capacity of 250 mm and a soil rating of 65–94. The soil type can be described as silty loam(uL) with the following proportions: clay: 22%, silt: 70%, sand: 8%. The slope is level and the pH value is slightly above neutral.

Crop rotation: Diverse, 10-year crop rotation with a constant alternation between summer and winter crops, as well as cereal and legume crops.

Crops: Wheat, durum wheat, spelt, barley; rapeseed; sugar beet, Marker pea propagation, grain maize, biodiversity areas, and split-plot trials.

Facilities: The site has its own equipment for soil preparation, cultivation, fertilisation, plant protection and harvesting. This is supplemented by the cooperative use of field trial equipment from the site partners Anhalt University of Applied Sciences, Strenzfeld Campus, and the State Institute for Agriculture and Horticulture, as well as by external trial service providers.

• **Serbia (BIOS, CROPT)**

The Serbian demonstration site is **located in** the Autonomous Province of Vojvodina, within the Pannonian biogeographical region, one of Europe's most productive agricultural areas. The site is jointly operated by the BioSense Institute and Crompt and serves as the primary pilot for the development and validation of crop suitability and agricultural yield estimation services.

The region is characterised by fertile chernozem soils, predominantly flat terrain, and intensive agricultural production focused on cereals, industrial crops, and oilseeds.

The pilot covers representative agricultural landscapes managed by both individual farmers and commercial agricultural enterprises, enabling the validation of digital services under diverse farm sizes and management practices.

Major **crops** include maize, wheat, sunflower, soybean, sugar beet, and rapeseed. The region also experiences increasing impacts of climate change, including more frequent droughts, heatwaves, and waterlogging events, making it highly relevant for testing climate-resilient decision-support tools.

• **Switzerland (WBF, Agroscope)**

The Swiss Future Farm (SFF), the demonstration site in Switzerland, is an innovative agricultural hub focused on precision farming, automation, and sustainable practices. It integrates advanced technologies like robotics, digital tools, and data analytics to optimize farming efficiency and reduce environmental impact. The farm serves as a research and collaboration platform, promoting knowledge exchange and innovation in agriculture. It also provides education and training to farmers, showcasing the future of sustainable and tech-driven farming.

The farm incorporates automated machinery and robotics to perform various tasks such as planting, weeding, and harvesting. In addition, digital tools and platforms are used for farm management, including software for monitoring crop health, soil conditions, and weather patterns.

The Swiss Future Farm is **located in** Tänikon in the Swiss Plateau at an altitude of 536 meters above sea level with an average annual temperature of 9.1°C and 1169 mm of precipitation. The farm encompasses 81 ha of agricultural land, split into 55 ha of cropland, 20 ha of grassland, and 6 ha of biodiversity area. Main arable **crops** include wheat, barley, maize, sugar beet, and rapeseed. There are also an emissions research barn and a dairy barn for 65 cows.



• Slovenia (ITC, KGZS - ZAVOD MS)

The Slovenian demonstration site is **located in** the Pomurje region in north-eastern Slovenia, close to the borders with Austria, Hungary, and Croatia. It forms part of the Pannonian Plain and represents one of Slovenia's most important agricultural areas. The landscape combines fertile plains along the Mura River with hilly areas to the north. Agricultural production is characterised by relatively small and fragmented farms, with wheat, barley, oats, spelt, and maize among the main arable crops.

The demonstration environment includes operational agricultural fields and a regional network of more than 20 weather stations and IoT devices, including soil-moisture and soil-temperature sensors. Machinery data and other locally available agricultural information may also be used. The site provides a real-life environment for demonstrating and testing digital agricultural applications and for organising field demonstrations, training activities, stakeholder workshops, and visits involving farmers, agricultural advisors, young scientists, IT experts, SMEs, and farmers' associations.

Physical access may include visits to selected farms, agricultural fields, sensors, and other relevant infrastructure. Digital access may include selected datasets and digital services available within the Slovenian pilot environment. The exact scope, procedures, and conditions for physical and digital access have not yet been defined and will be agreed during the preparation of individual demonstration and third-party activities.

Third parties may potentially use the Slovenian demonstration site to develop, test, validate, or demonstrate digital applications. Such activities will be coordinated by ITC and KGZS in cooperation with the participating farms and other relevant stakeholders.

• Cyprus (EcoE, MARDE)

The Cyprus demonstration site is **located** at the Acheleia Experimental Station, part of the Agricultural Research Institute of Cyprus (ARI), under the Ministry of Agriculture, Rural Development and Environment, about 7 km southeast of Paphos town. Within Nostradamus, the site's activities are technically supported by the Eratosthenes Centre of Excellence (ECoE). The Station covers a total of 51 ha across three main parts (the old station, the new station, and the Morokampos area), and hosts a range of research activities spanning cereals, viticulture, citrus, and tropical-subtropical crops, alongside greenhouse and screen-house facilities.

The site is characterised by a Mediterranean climate, with mild, wet winters (average annual rainfall of 420 mm, 90% falling between October and March) followed by a long dry period, and average temperatures ranging from 12.4/15.1°C in January to 25.3/34.0°C in August. Soils are clay loam, alkaline (pH 7–8.5), with only a small fraction of the land irrigated. **Cereals** are cultivated mainly in the Morokampos area, covering approximately 7 ha, at a seeding rate of 25 kg/ha, making the site directly relevant to Nostradamus' cereal-supply-chain focus. More broadly, the Paphos district, where the site is located, faces increasing pressure from recurring drought, which has contributed to a decline in regional agricultural productivity in recent years.

The demonstration environment includes a METER ATMOS 41 meteorological IoT station (12 weather variables, adjustable transmission frequency, typically 15-minute intervals) and METER TEROS 12 soil sensors installed at three depths (10, 30, and 50 cm), measuring soil moisture, temperature, and



electrical conductivity, complemented by weekly field-based observations of crop biotic and abiotic stress (pests, diseases, water/nutrient stress). The site engages local farmers, agri-SMEs, plant protection companies, and the Department of Agriculture, supporting the development and validation of early-warning tools for pest, disease, and drought risk.

For further comprehensive technical details on the underlying data requirements, analytical specifications, and the characterisation of the project's pilot/demonstration sites, reference is made to *Deliverable D2.1: Needs-based data requirements (M16)*, which is publicly available for download on the official **NOSTRADAMUS Zenodo repository**: <https://doi.org/10.5281/zenodo.21905118>

4.5. Development Environment

Access to JupyterHub-based environments and temporary private data repositories.

The development environment is an important part of the NOSTRADAMUS developer contract. The architecture specifies **JupyterHub** as the mechanism for provisioning isolated development sessions such as JupyterLab, Code Server or QGIS, connected to persistent workspaces and authorised data resources.

REQ-DEV-01: Third-party application developers shall use the NOSTRADAMUS-provided Development Environment for the development and testing of their applications, unless an alternative environment is explicitly agreed with NOSTRADAMUS.

REQ-DEV-02: Applications shall make use of the software libraries, development tools and data access interfaces pre-integrated into the NOSTRADAMUS Development Environment, where these provide the required functionality. In particular, developers shall use the environment's integrated access to the NOSTRADAMUS EO Data Pipelines, Data Cube services and IoT data streams, as well as the NOSTRADAMUS demonstration-site datasets made available for development and testing.

REQ-DEV-03: Developers shall not duplicate or independently implement data access mechanisms that are already provided by the NOSTRADAMUS Development Environment and Platform APIs. Applications shall use the documented platform interfaces for accessing NOSTRADAMUS data and services. Developers shall develop and test their applications using the software runtime, libraries and tools provided by the NOSTRADAMUS Development Environment, and shall identify any additional software dependencies required by their application.

REQ-DEV-04: Application development artefacts, including source code, notebooks, configuration, workflows and test data or results, shall be managed using the project workspace and version-control mechanisms provided or supported by the NOSTRADAMUS Platform, as applicable.



5. NOSTRADAMUS Implementation Framework (The 12-Month Programme)

The **NOSTRADAMUS 12-Month (Sprint) Programme** provides a structured, milestone-driven framework designed to guide and support funded Third Parties (sub-grantees) in developing, validating, and demonstrating high-impact, open-source digital applications.

To ensure technical robustness, end-user alignment, and seamless integration with the NOSTRADAMUS ecosystem (including Data Cubes, the IoT Observatory, EO data pipelines, and the Application Generation Engine), sub-projects operate under a staged implementation workflow. This workflow is structured into **4 (four) sequential Sprints executed over a 12-month period**:

- **Sprint 1 (Training):** Onboarding, technical alignment, and capacity building on NOSTRADAMUS assets, architectures, and data governance.
- **Sprint 2 (Design):** User-centred functional specification, technical design, and integration setup fine-tuned with stakeholder input.
- **Sprint 3 (Development & Validation):** Implementation, data integration, and operational prototyping, followed by technical and user-oriented validation under real field conditions.
- **Sprint 4 (Demonstration & Assessment):** On-site demonstration, knowledge transfer, third-party-led training, and final technical and impact assessment.

TABLE 10. NOSTRADAMUS OPEN CALL #1: PROGRAMME (12 MONTHS)

NOSTRADAMUS PROGRAMME: 12-Months, 4 Sprints				
Name	SPRINT 1	SPRINT 2	SPRINT 3	SPRINT 4
	<i>Training</i>	<i>Design</i>	<i>Development & Validation</i>	<i>Demonstration & Assessment</i>
Focus	<i>Mandatory 2-month phase to acquire Nostradamus competences.</i>	<i>Co-creation with stakeholders from MAPs.</i>	<i>Integrating with Data Cubes and prototype testing.</i>	<i>On-site demo events and impact evaluation</i>
Programme months	M1-M2	M3-M4	M5-M10	M11-M12
Duration	2 months	2 months	6 months	2 months

The breakdown of the 4 Sprints, including the goals and sought impact, expected results, milestone objectives, and contractual deliverables required from Third Parties across the 12-month program duration, required evidence and KPIs, is presented in **TABLES 9-12** below for each individual Sprint.



5.1. Sprint 1 – Training

TABLE 11. SPRINT 1 - Training & Technical Onboarding

SPRINT 1: Training		
Impact	<i>Ensure the effective onboarding of Third Parties into the Nostradamus ecosystem, enabling them to understand the conceptual framework, the architecture, data infrastructure, core modules, interoperability requirements, and stakeholder-driven objectives. This sprint builds the foundations for technically sound, user-oriented, and impact-driven application development aligned with Nostradamus expected outcomes.</i>	
Goal	<i>To equip Third Parties with the technical knowledge, methodological guidance, and ecosystem awareness required to design and implement user-oriented, interoperable, open-source digital applications fully aligned with Nostradamus tools, data assets, standards, and stakeholder needs.</i>	
Category	Expected Results	Measurable Impact
<i>Capacity building</i>	Third Parties trained on Data Governance and Stakeholder Co-Creation, Nostradamus Digital Ecosystem, Data Usage, Application Development Tools	100% of Third Parties complete mandatory training sessions and onboarding activities (minimum of 10 hours synchronous guided learning + self-study, practical implementation, and assessment)
<i>Technical readiness</i>	Access to and initial utilization of Nostradamus infrastructure and tools	Verified access to all required services and at least one successful proof-of-connection
<i>Stakeholder alignment</i>	Clear understanding of how to integrate diverse user needs and how to align application scope with MAPs and surveys	Submission of validated use-case brief linked to demonstration sites
Milestone #	Milestone description	Evidence:
MIL 1.1	Completion of the mandatory training phase covering Nostradamus architecture, ecosystem, Data Cubes, IoT Observatory, EO integration, application generation engine, interoperability standards, stakeholder co-creation, social and environmental aspects, and data management.	Proof of participation, training attendance records, and successful technical onboarding.
MIL 1.2	Use-case definition and formal confirmation of project alignment with the	Approved use-case brief.



	selected demonstration sites, and stakeholder needs.	
MIL 1.3	Initial communication and dissemination setup: Establishment of early visibility for the Third-Party project within the Nostradamus communication ecosystem.	Published project profile and initial communication materials.
Deliverable #	Deliverable description	KPIs:
DEL 1.1	Learning and feedback report: Participation in Nostradamus training activities, including feedback on architecture usability and infrastructure access.	Proof of participation in all mandatory trainings, Evidence of initial testing of Nostradamus architecture and tools
DEL 1.2	Project initiation and work plan: Use case brief with integrated assessment checklist, outlining the application scope, objectives, target users, selected Nostradamus modules and datasets, development plan, and preliminary technical design.	Use case brief with clearly defined work plan and requirements (including workflow diagrams)
DEL 1.3	Kick-off and early visibility package: Launch of Third-Party project communication activities aligned with Nostradamus dissemination strategy.	One kick-off communication item (newsletter/article); at least one social media post per month during Sprint 1; publishable project summary and profile of the beneficiary for inclusion on the Nostradamus website

5.2. Sprint 2 – Design

TABLE 12. SPRINT 2 - Design & User Specification

SPRINT 2: Design	
Impact	<i>The application design is co-created and fine-tuned on the feedback, needs, and challenges identified through the established Multi-Actor Platforms (MAPs) and stakeholder surveys (D1.1 – MAA Strategic Plan). The solution reflects real user priorities from the demonstration site contexts, ensuring relevance, usability, and alignment with operational and policy needs.</i>
Goal	<i>To translate validated stakeholder needs and Nostradamus technical capabilities into a coherent, user-oriented application design, including</i>



	<i>functional requirements, data flows, interoperability architecture, and deployment strategy across cloud, edge, or mixed environments.</i>	
Category	Expected Results	Measurable Impact
<i>User-centred design</i>	Stakeholder needs and challenges systematically integrated into the application design	Evidence of stakeholder input incorporated into functional and non-functional requirements
<i>Functional specification</i>	Clearly defined application scope, functionality, and user workflows	Approved use-case brief and functional specifications
<i>Technical design</i>	Defined data pipelines, system architecture, and interoperability mechanisms aligned with Nostradamus	Complete technical design documentation validated by mentors
<i>Deployment strategy</i>	Clear design for cloud, edge, or mixed execution adapted to resource-constrained environments.	Defined architecture and deployment pathway per use case
Milestone #	Milestone description	Evidence:
MIL 2.1	Refined concept and design strategy: Finalisation of the application concept, objectives, and development strategy based on Sprint 1 outcomes and available Nostradamus assets.	Approved refined concept note, architecture outline, and development roadmap.
MIL 2.2	Validation of stakeholder needs and requirements: Validation and incorporation of stakeholder requirements derived from MAPs, surveys, interviews, or co-creation workshops.	Documentation of stakeholder feedback (e.g. meetings, or workshops) and explanation of how inputs were integrated.
MIL 2.3	Ongoing communication and dissemination: Continued communication activities to ensure transparency, visibility, and engagement with the Nostradamus ecosystem and target users.	Published communication outputs and dissemination records.
Deliverable #	Deliverable description	KPIs



DEL 2.1	Sprint 2_ design and specification report: Comprehensive design documentation describing the proposed digital application.	Documented evidence that stakeholder needs (MAPs, surveys, interviews, or co-creation workshops) were incorporated into the functional specification Defined deployment strategy (cloud, edge, or mixed) validated by mentors Technical design documentation approved/signed off by mentors
DEL 2.2	Communication and visibility outputs (Sprint 2): Ongoing dissemination of project progress aligned with the Nostradamus communication strategy.	At least one social media post per month during Sprint 2 One publishable progress update describing design outcomes and next steps Continued visibility of the Third-Party project profile on Nostradamus communication channels

5.3. Sprint 3 - Development & Validation

TABLE 13. SPRINT 3 - Development & Technical Validation

SPRINT 3: Development & Validation	
Impact	<i>The developed application reaches an operational prototype level, demonstrating the effective use of the Nostradamus data infrastructure, core modules, and cloud-edge-mixed architecture. Validation activities confirm the technical feasibility, usability, performance, and relevance of the application under real or realistic operating conditions, including demonstration and replication contexts. Validation activities confirm the technical feasibility, usability, performance, and relevance of the application under real or realistic operating conditions, including demonstration and replication contexts, and generate structured evidence and datasets required to support Task 6.4 monitoring and Task 6.5 impact evaluation activities of the Nostradamus consortium.</i>
Goal	<i>To implement, integrate, and validate the digital application as a functional, interoperable, and open-source solution, ensuring alignment with user needs, Nostradamus technical specifications, and expected project impacts on sustainability, efficiency, and decision-making.</i>



Category	Expected Results	Measurable Impact
Application development	Functional application implemented according to approved design and specifications	Working prototype
Technical integration	Successful utilization of Nostradamus data sources; data cubes, IoT Observatory, EO pipelines, and core modules	Verified data ingestion, processing, and output generation
Validation and testing	Application validated for performance, reliability, usability, and scalability	Documented validation results and test reports
User feedback	Initial user feedback collected from demonstration site stakeholders	Evidence of user testing sessions and incorporated feedback
Milestone #	Milestone description	Evidence:
MIL 3.1	Application Development: Implementation of the application core functionalities, including data ingestion, analytics and visualisation components, and decision-support features, in accordance with the approved design and open-source requirements.	Functional prototype deployed in a development or staging environment and accessible for testing.
MIL 3.2	Application Validation: Technical, functional, and user-oriented validation of the application using Nostradamus demonstration site data and, where relevant, replication contexts. Validation covers performance, usability, interoperability, scalability, and operation under cloud, edge, or mixed configurations.	Validation report, test results, and documented feedback from users or mentors, including structured inputs (technical metrics, validation results, and user feedback) explicitly formatted to support Nostradamus Task 6.4 and Task 6.5 assessment workflows.
MIL 3.3	Communication and Dissemination Activities: Continued communication and outreach to ensure visibility of development progress and	Published communication outputs and dissemination records.



	engagement with the Nostradamus ecosystem.	
Deliverable #	Deliverable description	KPIs
DEL 3.1	Development and Validation Report: Comprehensive documentation of development and validation activities.	• One Sprint 3 report describing implemented functionalities, technical architecture, data integration, and validation methodology • Technical documentation of the developed application (APIs, data flows, deployment setup) • Validation report covering technical performance, usability, and operational testing • Proof of work demonstrating application functionality, such as a short demo video, recorded walkthrough, or training-oriented presentation for consortium partners and end users • Structured validation datasets, performance indicators, and documentation provided in a format compatible with Nostradamus Task 6.4 monitoring and Task 6.5 technical, socio-economic, and environmental impact evaluation
DEL 3.2	Communication and Dissemination Outputs (Sprint 3): Visibility actions highlighting development and validation progress.	• At least one social media post per month during Sprint 3 • One publishable progress summary describing the application status, validation outcomes, and expected benefits • Presentation or demonstration of the application in at least one relevant event, workshop, or internal Nostradamus meeting • One guest appearance in Nostradamus podcast series per Demo Site/Pilot.



5.4. Sprint 4 - Demonstration & Assessment

TABLE 14. SPRINT 4 - Demonstration, Assessment & Knowledge Transfer

Sprint 4 - Demonstration & Assessment		
Impact	The developed digital application is demonstrated and transferred to end users through structured training activities led by the Third Parties, enabling effective uptake, replication, and operational use of the solution. Training, knowledge-transfer material, and practice abstracts ensure that results are actionable, scalable, reproducible and aligned with the needs of relevant stakeholders, contributing to sustained impact beyond the project lifetime. The activities in this sprint directly support Nostradamus Task 6.4 and Task 6.5 by supplying consolidated technical evidence, socio-economic and environmental impact data, and practice-oriented knowledge required for project-wide evaluation, replication, and policy-relevant assessment.	
Goal	To demonstrate the application in operational conditions (minimum TRL 7 achieved), assess its technical and socio-economic performance, transfer knowledge through targeted training activities and materials, and formally document outcomes in practice abstracts and replication assets supporting long-term uptake and sustainability.	
Category	Expected Results	Measurable Impact
Sustainability	<i>Future viability supported by trained users and transferable knowledge assets</i>	<i>Validated Sustainability and Replication (Exploitation) Strategy, accompanied by publicly reusable training material and at least one practice abstract</i>
Impact Achievement	<i>Demonstrated impact verified through assessment and user feedback</i>	<i>Measurable improvement in decision-making efficiency and data availability compared to the M2 baseline</i>
Knowledge Transfer	<i>Capacity building of stakeholders through Third-Party-led training</i>	<i>At least one training session delivered to stakeholders, with documented participation and reusable training material</i>
Replicability	<i>Results packaged for replication</i>	<i>Practice abstract and replication toolkit openly available via Nostradamus channels</i>
Milestone #	Milestone description	Evidence:
MIL 4.1	Demonstration and training of the application: Demonstration of the developed application at least one Nostradamus demonstration site,	Demonstration records, training agendas, participant lists, and participant feedback.



	combined with Third-Party-led training activities for end users.	
MIL 4.2	Final Assessment of the Solution and Training Effectiveness: Comprehensive assessment of the technical performance, usability, socio-economic and environmental impacts, and effectiveness of training and knowledge-transfer activities. The assessment will provide structured inputs for Nostradamus Task 6.4 (monitoring, validation, and quality assurance) and Task 6.5 (technical, socio-economic, and environmental impact evaluation).	Final assessment report, stakeholder surveys, and training evaluation summary.
MIL 4.3	Exploitation, Sustainability, and Replication Strategy: Definition of post-project sustainability and replication pathways, including training-based uptake and capacity-building mechanisms.	Submitted exploitation and sustainability plan.
MIL 4.4	Communication, Dissemination, and Knowledge Transfer (Closing Phase): Final dissemination of results, training outputs, and practice abstracts.	Published communication materials and dissemination records
Deliverable #	Deliverable description	KPIs:
DEL 4.1	Demonstration and Training Outputs: Demonstration of the application combined with stakeholder training activities.	• Demonstration of the solution at least one Nostradamus demonstration site • At least one Third Party-led training session delivered to relevant stakeholders • Training participation records and structured feedback collected from participants
DEL 4.2	Training Material and Knowledge Assets: reusable material enabling replication and long-term uptake of the solution.	• Training material package (e.g., presentations, user manuals, short tutorials, and/or recorded sessions)



		prepared and delivered to the consortium • Training material suitable for publication through Nostradamus dissemination and exploitation channels.
DEL 4.3	Sprint 4 Assessment Report and Practice Abstract: Final assessment of the solution and its impact, documented in both technical and practice-oriented formats.	• One Sprint 4 report including final technical documentation, deployment description, validation results, and impact assessment. • Surveys conducted with stakeholders, including analysis of results and identified improvement measures. • At least one practice abstract prepared under the EIP-AGRI common format.
DEL 4.4	Exploitation and sustainability plan: Strategic framework for post-project continuation and scaling.	• One exploitation and sustainability strategy defining target users, replication contexts, and potential funding or adoption pathways.
DEL 4.5	Final Communication and Dissemination Package: Closing communication activities ensuring visibility and uptake of results.	• ≥1 social media post per month during Sprint 4 • One final article, press release, etc. announcing results and impact • One publishable summary for the Nostradamus website • One short promotional or demonstration video showcasing the application and training activities (1 video per Demo/Pilot site showcasing their work and achievements)

The completion of each Sprint will be formally marked by the Third Party's submission of an **Implementation Report** (1-4), accompanied by all corresponding deliverables, technical documentation, and supporting evidence as specified in Tables 9–12 above.



Submitted Implementation Reports and their annexes will undergo a rigorous evaluation by consortium experts to assess project progress and technical quality. Formal acceptance of the Implementation Report by the consortium is a strict prerequisite for the Third-Party project to advance to the subsequent Sprint and to trigger the release of the corresponding stage payment.

6. NOSTRADAMUS Stakeholders Alignment

Alignment with stakeholders' needs is a formal requirement for all Digital Applications developed under the OC. Proposed solutions must directly reflect the challenges, decision-support needs, and functional, data, interoperability, and usability requirements identified by farmers, advisors, cooperatives, agri-industry, technology and data providers, public authorities, NGOs, and researchers across the Nostradamus demonstration sites and beyond. To ground this requirement in evidence, Nostradamus conducted a dedicated stakeholders' alignment survey, designed to (i) better understand current challenges and decision-making needs related to agrochemical dependence, digitalisation, food security, and agricultural resilience, (ii) collect needs, expectations, and constraints from a wide range of stakeholders across agriculture and food systems, and (iii) provide structured input for the OC funding Decision-Making applications on the Nostradamus data infrastructure. The survey targeted thirteen categories of actors, spanning farmers/primary producers, advisors and extension services, cooperatives, agri-industry and input suppliers, agri-food companies, technology and data providers, public authorities and administrations, NGOs, researchers, and financial/insurance actors. It combined a common core section (respondent context and decision-support needs) with role-based modules tailored to four groups (Farmers/Producers, Advisors/Cooperatives, Policymakers/Public Administration/NGOs, and Technology and Data Providers), before closing with shared concluding questions asked of all respondents, covering topics such as validation practices, willingness to co-develop or pilot new applications, and interest in joint innovation within a shared infrastructure. Responses were collected anonymously and analysed in aggregate.

The survey ran from June 2026 to September 2026. Results are available at: <https://nostradamus-project.eu/wp-content/uploads/2026/09/NOSTRADAMUS-Stakeholder-Survey-Analysis.pdf>

Beyond the survey, alignment with stakeholder needs must remain an active, ongoing process. Applicants are expected to involve stakeholders directly in the co-development of their applications, drawing on the priorities and insights gathered through the project's Multi-Actor Platforms (MAPs) and the survey results referenced above, to ensure solutions remain user-oriented, context-specific, and genuinely co-created rather than developed in isolation. In addition, applications must include validation with end users as a form of ongoing stakeholder engagement, demonstrating that the developed solution has been tested with, and refined based on feedback from, the actors it is intended to serve (e.g. farmers, advisors, agri-industrial actors) at the demonstration sites, not only assessed against technical performance criteria.

7. NOSTRADAMUS Data Management, Privacy and Security Aspects

All Third Parties funded under Nostradamus Open Call #1 shall manage data generated, collected, processed or reused during implementation in accordance with the Nostradamus Data Management

framework, the Horizon Europe Open Science requirements, the FAIR Data Principles, applicable data protection legislation and the Nostradamus General Ethical Guidelines. Appropriate data management, privacy and security measures shall be implemented throughout the entire lifecycle of the developed applications and associated datasets.

FAIR Data Principles. Data generated or processed by Third Parties shall, to the extent possible, be managed according to the FAIR principles – Findable, Accessible, Interoperable and Reusable. Relevant datasets shall be accompanied by sufficient metadata and documentation describing their origin, content, processing history, quality and conditions for access and reuse. Appropriate persistent identifiers, standardized metadata, controlled vocabularies and machine-readable formats shall be used where applicable. Publicly shareable datasets shall be made accessible through appropriate trusted repositories, while restricted datasets shall remain subject to controlled-access mechanisms.

Open Science and Open Source. Nostradamus follows the principle of maximizing openness of research outputs while protecting legitimate interests, confidential information, personal data and Intellectual Property Rights. Non-personal and non-protectable research data generated through the funded activities shall therefore be made openly accessible and reusable where feasible. Software developed under the Open Call shall comply with the open-source requirements specified in Section 3.4. Public repositories shall not contain personal data, confidential business information, credentials, security-sensitive information or other information subject to access restrictions.

Privacy by Design and GDPR compliance. Any processing of personal data shall comply with the General Data Protection Regulation (EU) 2016/679 (GDPR) and applicable national data-protection legislation. Data protection and privacy requirements shall be incorporated from the design stage of the application and throughout its lifecycle. Third Parties shall apply the principles of lawfulness, fairness and transparency, purpose limitation, data minimisation, accuracy, storage limitation, integrity and confidentiality, and accountability. Where consent constitutes the applicable legal basis for processing, it shall be informed, explicit and appropriately documented. Personal data shall be anonymised or pseudonymised wherever appropriate.

Data Security and Access Control. Third Parties shall implement appropriate technical and organisational measures proportionate to the nature and sensitivity of the data processed. Depending on the application and data concerned, these may include encryption of data in transit and at rest, secure authentication and authorisation, role-based access control (RBAC), multi-factor authentication (MFA), audit logging, secure backup and recovery mechanisms, and appropriate monitoring and security-review procedures. Access to restricted datasets shall be limited to authorised users and, where applicable, governed through Data Use Agreements or equivalent arrangements.

Interoperability. Data generated, exchanged or integrated by Third-Party applications shall comply with the interoperability requirements specified in Section 3.4. Appropriate standardized data formats, metadata conventions, controlled vocabularies, APIs and relevant OGC/ISO standards shall be applied to facilitate integration with the Nostradamus Data Cube infrastructure and reuse across platforms and services.



Confidential and Open Call data. Particular attention shall be given to information collected or generated in connection with the Open Call. This may include sensitive personal data as well as confidential or commercially sensitive business information provided by Third Parties. Such information shall not automatically be considered open data. Its access, processing, storage, disclosure and subsequent use shall be governed by the applicable legal and contractual requirements, confidentiality arrangements and NOSTRADAMUS data-management procedures.

Third Parties shall provide the Nostradamus Consortium with the documentation and information necessary to verify compliance with these data-management, privacy, security and Open Science requirements during implementation of the funded activities.

More details about the adopted strategies in the areas listed above by the NOSTRADAMUS project are available in the public deliverables accessible on the project Zenodo page: [D7.2 Data Management Plan\(M6\)](#), [D7.2 Data Management Plan\(M12\)](#), [D7.1 Project Management and Quality Plan \(M6\)](#) and [D7.1 Project Management and Quality Plan \(M12\)](#).

8. Demonstration and Training Events

Demonstration and capacity-building activities are central to the NOSTRADAMUS Multi-Actor Approach(MAA), bridging technical application development with real-world end-user uptake. Third Parties funded under Open Call #1 are required to actively participate in and conduct targeted demonstration and training activities during the project lifecycle.

8.1 On-Site Demonstration Requirements

- **Single Site Scope:**

To ensure operational and financial feasibility within the allocated sub-project budget (€50,000 cap), each funded Third Party is required to physically demonstrate and validate its digital application at **1(one) primary NOSTRADAMUS demonstration site** corresponding to its selected Open Call topic. The applicants are invited to choose and commit to the selected primary demonstration site by selecting the country in which it is established as listed in the table below:

IMPORTANT INSTRUCTIONS FOR APPLICANTS:

1. When you develop your proposal first, **select ONE Topic** (T1-T5) as listed in the table below.
2. Under your selected topic, check **ONE** box to **choose your PRIMARY Demonstration Site**. This will be the single physical location for your on-site trials, user workshops, and training events.
3. The remaining country in the **pair** will automatically serve as your SECONDARY Regional Context. Your solution must be digitally/virtually validated for transferability in this 2nd region using Nostradamus Data Cubes, EO layers, or IoT streams (no physical travel or hardware trials required).



TABLE 15. NOSTRADAMUS DEMONSTRATION SITES AVAILABILITY PER TOPIC

TOPIC NAME (thematic domain)		Demonstration Site Options (Select ONE Primary Site)
☐	T1	Sustainable crop production and optimisation of cereal-based systems under changing climate and soil conditions.
☐	T2	Nutrient and soil health management, integrating soil fertility indicators, organic matter dynamics, and precision fertilisation models
☐	T3	Water resource efficiency and drought resilience, using the Early Warning System outputs and IoT-based soil moisture monitoring.
☐	T4	Smart and predictive pest and disease management to support the EU objective of reducing pesticide dependency and enhancing sustainability.
☐	T5	Open topic: Integrated, cross-domain decision-support applications combining multiple topics: 1. 2. State clearly which (at least 2 of the topics listed above T1-T4) will be addressed by your proposed solution
		Select ONE Primary Country from those available for your combined topics: ☐ Serbia ☐ Switzerland ☐ Slovenia ☐ Cyprus ☐ Germany

- **Demonstration Event Organization:**

Each Third Party must organize and conduct **at least 1 (one) dedicated on-site or hybrid demonstration event/workshop** at its selected primary demonstration site. The event must engage a minimum of **10 participants**, actively involving key target groups such as local farmers, agricultural advisors, young scientists, agri-SMEs, and regional agricultural authorities.

- **Consortium Support:**

The NOSTRADAMUS consortium partners responsible for the respective demonstration sites (DLG in Germany, BioSense in Serbia, ECoE/MARDE in Cyprus, ITC/KGZS in Slovenia, Agroscope/WBF in Switzerland) will provide logistical support, facilitate local MAP stakeholder connections, and site access to facilitate the successful execution of demonstration events.

- **Digital Transferability (Secondary Regional Context):**

Physical field trials and travel are strictly limited to the primary demonstration site. Demonstration of applicability to a secondary European regional context (replication) shall be conducted purely via data-driven desktop simulations, algorithm re-calibration, or virtual scenario analysis utilizing the platform's Data Cubes, IoT Observatory streams, and Earth Observation layers.

8.2 Training Co-Creation and Knowledge Transfer

- **Third-Party-Led Training Sessions:**

During Sprint 4 (Demonstration & Assessment), each Third Party must design and deliver **at least 1(one) structured training session** (on-site or hybrid) targeting end-users (farmers, advisors, cooperatives, etc.). These sessions Third Parties will train end-users how to effectively apply their digital applications to access, analyse and monitor data and inform evidence-based decision making. It is **allowed** that the training session is combined with the Demonstration Event at the chosen primary Demonstration Site. Extra online training sessions (in addition to the on-site one) could be organized by the Third parties as needed/requested by the consortium.

- **Co-Creation of Reusable Training Assets:**

Third Parties shall contribute to the consortium's broader capacity-building framework (Task 6.3 led by HSG) by producing open-source, reusable training assets. These assets will have the form of reusable training packages that must be submitted under **Deliverable 4.2** and must include user manuals, step-by-step presentation decks, recorded training sessions or short instructional tutorials suitable for publication on the NOSTRADAMUS e-learning/exploitation platform. Format and scope of the training material package to be co-developed and delivered by the Third parties will be agreed with the consortium upon completion of Sprint 1.

- **Dissemination of the results:**

In addition to the obligatory training material package within Deliverable 4.2 (ref. *TABLE 14. SPRINT 4 - Demonstration, Assessment & Knowledge Transfer*), as a mandatory output under Sprints 3/4, each Third Party must submit a **short promotional and demonstration video or recorded walkthrough** (1 video per sub-project) showcasing the application's functionality, user interface, and field-level operational deployment (as part of Deliverable 3.1 / Deliverable 4.5).

8.3 Inclusivity, Social Sciences & Humanities (SSH), and Outreach Targets

- **Social Sciences & Humanities (SSH) Integration:**

Third Parties should demonstrate how they integrate relevant human, economic, and organizational factors into the design of their solutions, into demonstrations and training activities. Third Parties must design user interfaces and workflows that minimise unnecessary administrative burdens and accommodate different levels of digital literacy among target users.

- **Gender, Diversity, Inclusion & Equal Opportunities:**

Third Parties should consider gender, diversity and inclusion in the design and implementation of their proposed solutions. In line with the project's General Ethical Guidelines, Third Parties must



ensure that demonstrations and training activities promote inclusive and equitable participation in demonstration/training events, and consider the needs of different target groups, thereby promoting equal opportunities across all activities.

- **Areas with Weak Connectivity & Marginalized Groups:**

Applications and demonstration activities must showcase operational resilience in environments with intermittent Internet access (e.g., field-level edge buffering), ensuring inclusive access for smallholder farmers and other disadvantaged or marginalized rural communities (e.g. older farmers, farmers with disabilities). Third Parties should describe appropriate measures to address identified barriers.

- **Contribution to Project-Wide Reach:**

Third-Party demonstration, communication, and dissemination activities must actively contribute to the NOSTRADAMUS consortium's target of reaching and engaging **at least 1,000 farmers** across the EU during the project lifecycle.

9. Communication, Dissemination and Exploitation

Communication, Dissemination, and Exploitation (C&D&E) are integral components of the NOSTRADAMUS 12-month program. They ensure that digital applications developed by Third Parties achieve maximum visibility, actively engage key target groups across European agricultural knowledge networks, and establish clear pathways for post-project sustainability and market uptake. All funded Third Parties must strictly comply with the frameworks, KPIs, and reporting workflows detailed below.

9.1. Communication and Outreach Strategy

Third Parties are required to execute a proactive, multi-channel communication campaign during their 12-month project lifecycle.

- **Visual Identity & EU Funding Acknowledgement:**

All communication materials, presentations, software interfaces, videos, and publications produced by Third Parties must display the official **NOSTRADAMUS logo** alongside the **European Union emblem** and funding statement as stated in the Sub-grant Agreement template (Annex 5 to the Open Call #1 documentation kit):

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them."

(Where applicable, co-funding by the Swiss State Secretariat for Education, Research and Innovation - SERI must also be displayed).

- **Social Media & Digital Channels:**



Third Parties must maintain active digital outreach throughout all 4 Sprints:

- **Social Media Engagement:** Publish **at least one (1) social media post per month** across professional platforms (LinkedIn, Twitter/X, etc.) using the official hashtags #NostradamusProject, #DigitalAgriculture, and #EUFoodSecurity, tagging official project handles.
 - **Website & Profile Promotion:** Submit a publishable project profile, beneficiary profile presentation/summary, and logo for inclusion on the official NOSTRADAMUS website.
 - **Media & Podcast Participation:** Participate in **at least 1(one) guest appearance** in the official NOSTRADAMUS Podcast Series and contribute to project press releases, e-newsletters, or blog posts.
- **Target Audience Outreach:**

Communication activities must collectively contribute to the consortium's overarching goal of reaching and engaging **at least 1,000 primary producers/farmers** across the EU.

More details about the adopted D&C&E strategy by the NOSTRADAMUS project are available in the public deliverable accessible on the project Zenodo page: [D1.3 Dissemination, exploitation & communication Plan](#) (M6).

9.2. Dissemination Obligations & EIP-AGRI Practice Abstracts

Dissemination activities focus on sharing technical results, software code, and scientific insights with expert, advisory, and policy communities.

- **EIP-AGRI Practice Abstract Requirement (Mandatory Deliverable DEL 4.3):**

In accordance with Task 6.4 and the EIP-AGRI common format, each Third Party must author and submit **at least 1 (one) Practice Abstract**. Practice Abstracts must follow the agreed format and summarize the operational recommendations, practical benefits, and field-level usability of the developed application in clear, non-technical language for immediate distribution via the **EU-FarmBook** platform and national AKIS networks.

- **Open Science & Source Code Release (REQ-POS-01 to REQ-POS-06):**

All software developed under Open Call #1 must comply with the principle "*as open as possible, as closed as necessary*". Source code must be deposited in a public, version-controlled repository (e.g., GitHub, GitLab) under a recognized open-source license (e.g., MIT, Apache 2.0). Repositories must include complete deployment documentation, developer APIs, and requirements files. *Note: Public repositories must strictly exclude credentials, access tokens, or sensitive personal data.*

- **Scientific & Technical Dissemination:**



Where applicable, Third Parties are encouraged to present technical findings at scientific conferences, submit peer-reviewed open-access journal articles, and demonstrate solutions at relevant agricultural trade fairs or industry forums.

9.3. Exploitation, Sustainability, and Scaling Pathways

Third Parties must ensure that their applications do not terminate at the end of the sub-grant, but remain operationally viable and transferable across European agro-ecosystems.

- **Exploitation & Sustainability Plan (Deliverable DEL 4.4):**

During Sprint 4, each Third Party must submit a formal **Exploitation and Sustainability Strategy**. This plan must outline:

- **Target Users & Business Models:** Clear definition of primary end-users (farmers, cooperatives, advisors, agri-tech SMEs) and long-term maintenance/revenue models.
- **Replication & Transferability:** Pathways for scaling the solution to secondary European regional contexts or agro-climatic zones.
- **Ecosystem Integration:** Mechanisms for continued interaction with the NOSTRADAMUS Data Cubes, IoT Observatory streams, and regional Multi-Actor Platforms (MAPs).

- **Key Exploitable Results (KER) Alignment:**

Third-Party outputs will be integrated into the broader NOSTRADAMUS Exploitation Strategy (coordinated by F6S in Task 1.4) and highlighted during the project's formal Exploitation Workshops.

9.4. Milestone & KPI Summary Matrix per Sprint (for Communication, Dissemination and Exploitation)

To enforce strict compliance, C&D&E obligations are mapped directly into the 4-Sprint program lifecycle, with stage payments contingent upon technical review and formal milestone approval:

TABLE 16. C&D&E Milestone & KPI Summary Matrix

Sprint / Phase	Program Months	C&D&E Deliverables & Milestones	Mandatory KPIs & Evidence Required
Sprint 1 (Training)	M1-M2	DEL 1.3: Kick-off & Early Visibility Package MIL 1.3: Communication Setup	• Published Third-Party project profile for Nostradamus website. • 1 kick-off newsletter/article item. • ≥1 social media post per month.
Sprint 2	M3-M4	DEL 2.2: Communication &	• ≥1 social media post per month.



(Design)		Visibility Outputs (Sprint 2) MIL 2.3: Stakeholder Engagement	• 1 publishable progress update detailing design co-creation with MAP stakeholders.
Sprint 3 (Development & Validation)	M5–M10	DEL 3.1(Part): Proof of Work Video DEL 3.2: Dissemination Outputs (Sprint 3) MIL 3.3: Development Outreaurveych	• Short promotional/demonstration video or recorded walkthrough of the functional prototype. • 1 guest appearance in NOSTRADAMUS Podcast Series. • Presentation at ≥ 1 relevant event/workshop. • ≥ 1 social media post per month.
Sprint 4 (Demonstration & Assessment)	M11–M12	DEL 4.1: Demo & Training Outputs DEL 4.2: Reusable Training Assets DEL 4.3: Assessment Report & Practice Abstract DEL 4.4: Exploitation & Sustainability Plan DEL 4.5: Final C&D Package MIL 4.4: Closing Knowledge Transfer	• On-site demonstration event at 1 demo site (≥ 10 participants). • Delivery of ≥ 1 Third-Party-led stakeholder training session. • 1 Practice Abstract in EIP-AGRI format. • Public release of open-source repository. • Final Exploitation & Sustainability Plan. • Final article/press release and website closing summary.

10. Technical Key Performance Indicators (KPIs)

10.1 Performance Targets

Required evidence of yield increase (>15%), pesticide reduction (>40%), or water savings (>20%).

Third-Party applications must provide measurable evidence of impact aligned with NOSTRADAMUS' own project-level significance targets: **>15% increase in crop yields, >40% reduction in pesticide use, or >20% reduction in water consumption**, attributable to the use of the developed digital solution. Applicants are not expected to demonstrate all three simultaneously, but must show credible, field-tested evidence for **at least one target relevant to their application's function**.

10.2 Scalability & Transferability

Demonstrating application viability in different European regional contexts.

Beyond performance at the selected demonstration site, applications must demonstrate potential viability in an additional European regional context, showing that results are not artefacts of a single agro-climatic or socio-economic setting. This can be evidenced through a credible transferability



assessment covering differences in climate, soil, farm structure, or connectivity, consistent with the project's broader scalability and transferability approach.

As already explained in section 8.1 each Third-Party application is required to be physically/operationally demonstrated and validated at **1 (one) primary NOSTRADAMUS demonstration site** corresponding to the selected topic. Applicants are **not** expected to conduct field deployments or physical activities at multiple demonstration sites, given the budget and travel constraints of the sub-grant.

However, beyond physical validation at the chosen **primary demonstration site**, applications must demonstrate **potential viability and transferability** to an additional European regional context. This transferability does not require on-site testing; rather, it must be demonstrated through a **credible desk-based or digital transferability assessment** (e.g., re-running algorithms using local Data Cube/EO layers, adapting parameters for different soil/climatic data, or analyzing structural/connectivity differences), consistent with the project's broader scalability and transferability framework.

TABLE 17. PLANNED MODULES SCALABILITY ACROSS DEMONSTRATION SITES defines data availability for scalability validation across all demonstration sites. In accordance with the selection procedures set forth in Section 8.1 *On-Site Demonstration Requirements*, the choice of a Primary Demonstration Site **automatically binds** the Third Party **to the paired secondary country** for replication and transferability validation. Third Parties shall limit physical field deployment, stakeholder workshops, and training events to the Primary Demonstration Site. **Validation** in the paired secondary country shall be **achieved via desktop digital transferability evaluations** utilizing the platform's multi-dimensional Data Cubes, remote sensing layers, and IoT Observatory streams.

TABLE 17. PLANNED MODULES SCALABILITY ACROSS DEMONSTRATION SITES

	Topic 3 Water resource efficiency and drought resilience	Topic 1 Sustainable crop production	Topic 2 Nutrient and soil health management	Topic 4 Smart and predictive pest and disease management	Topic 5 Open Topic (at least two of the topics 1-4)
	Module 1 Drought Monitoring	Module 2 Crop Suitability	Module 3 Soil and Nutrition	Module 4 Pest Management	
Pilot 1 Germany	Available	NA	NA	Available	Depending on the selected two topics (1-4) to be combined in the proposed digital application
Pilot 2 Serbia	NA	Available	Available	NA	
Pilot 3 Switzerland	Available	NA	NA	NA	
Pilot 4 Slovenia	NA	Available	Available	NA	
Pilot 5 Cyprus	NA	NA	NA	Available	



Respectively, the physical field trials, hardware installation and travel are limited to the primary demonstration site. For the **secondary demonstration site (replication site)**, Third Parties shall deliver a functional replication of their application (without on-site activities), consisting of:

- a. the application configured and executed on the secondary site's Data Cube, IoT Observatory streams and Earth Observation layers, for at least one growing season available in the platform;
- b. recalibrated parameters and thresholds adapted to the secondary site's crops, soil and climate, documented in a short replication note;
- c. the resulting output layers, indicators or recommendations, delivered in the same format as for the primary site and made available through the NOSTRADAMUS platform to the consortium partner responsible for the secondary site;
- d. a transferability assessment comparing the two sites (performance, limitations, data gaps) and stating what would be required for operational use at the secondary site.

The consortium partner responsible for the secondary site will provide remote access to site data and feedback from its Multi-Actor Platform on the replicated outputs.

11. Annexes and Technical Schematics

11.1. Data Dictionary Outline

Format for metadata and dataset documentation.

All datasets used or generated within Nostradamus, including those collected or produced by consortium partners across the project's Work Packages, as well as datasets used or produced by Third Parties, must be documented in the Nostradamus Data Dictionary. By systematically recording each dataset's structure, semantics, provenance, format, and processing history, the Data Dictionary makes the project's data environment transparent and reusable across the consortium, Third Parties, and future users. Each dataset must be entered using the standard "Name Data Entry" template, covering: Data Source Name, Description, Version, Data Source Type, Data Format, Spatial and Temporal Coverage, Update Frequency, Responsible Partner/Data Owner, Contact Point, Licensing/Access Rights, Data Sensitivity Level, Accessibility, Units, Coordinate Reference System, Linked Core Modules, MAP Feedback (where applicable), and Validation/Verification, together with an Attribute Metadata Table for any structured variables (columns/fields). This consistent documentation ensures full compliance with FAIR data principles and supports interoperability across the Data Cube Ecosystem, in alignment with the European Strategy for Data.

11.2. Site Instrumentation Lists

The five NOSTRADAMUS demonstration sites provide complementary agricultural machinery, sensor networks, Earth Observation resources, field observations and digital farm-management technologies that may support the development and validation of new digital applications.

The German demonstration site is equipped with agricultural machinery for tillage, cultivation, fertilisation, crop protection and harvesting, complemented by field-trial technologies provided by cooperating organisations. Relevant existing resources include agronomic observations, UAV data



for crop-performance and pest monitoring, soil-moisture information and data from irrigation experiments.

The Serbian demonstration site includes a regional network of sensors and weather stations providing hourly measurements of parameters such as soil moisture, temperature and precipitation. These measurements are complemented by field-operation, input-use, yield, soil and terrain data.

The Swiss demonstration site combines GPS-supported precision farming, sensors, data analytics, automated machinery, robotics and farm-management information systems. Its available information sources include weather-station measurements, satellite imagery, field and machinery data, soil-related information and dairy-farm data.

The Slovenian demonstration site includes more than 20 weather stations and IoT devices deployed across the Pomurje region, including soil-moisture and soil-temperature sensors. Available measurements include temperature, humidity, air pressure, soil moisture and leaf wetness, generally recorded at intervals of 5-20 minutes, together with relevant machinery and field information.

At the Cyprus demonstration site, the instrumentation includes a METER ATMOS 41 IoT meteorological station measuring 12 weather parameters and three METER TEROS 12 sensors installed at depths of 10, 30 and 50 cm to measure soil moisture, soil temperature and electrical conductivity. These measurements are complemented by geolocated field observations of crop pests, diseases, water stress and nutrient stress.

Further information is available in [Deliverable D2.1. Needs-based data requirements \(M16\)](#). Chapters 2-6 describe the demonstration sites in Germany, Serbia, Switzerland, Slovenia and Cyprus. Sections 2.3, 3.3, 4.3, 5.3 and 6.3 describe the available datasets, sensors and related technologies, while Sections 2.4, 3.4, 4.4, 5.4 and 6.4 provide information on data-collection and update timelines. Appendix A in D2.1 contains more detailed dataset specifications, and Sections 7.7, 8.7, 9.7 and 10.7 describe the data requirements of the four core modules. The public deliverable is available at: <https://doi.org/10.5281/zenodo.21905118>

12. Concluding Remarks

Annex 1.1 (Technical Specification) establishes the authoritative technical framework and operational guidelines for Third Parties participating in NOSTRADAMUS Open Call #1 (Digital Applications for Farm Decision Making and Agribusiness). By providing direct, open-source access to the NOSTRADAMUS Data SILO - encompassing multi-dimensional Open Data Cubes, the real-time IoT Observatory, Analysis Ready Data (ARD) Earth Observation pipelines, and socio-economic datasets - the project eliminates traditional data engineering barriers. This foundation enables Third-Party beneficiaries to focus their resources on co-creating high-impact, user-oriented decision-support applications.