SPADE

Open Call 2

Open Call Technical Annex

OPENING: 24 March 2025

CLOSING: 26 May 2025 at 17:00 CET

** The deadline for submission is as stated in this Guidelines document. Please note that the platform for submission's time depends on the user's configured time zone and may or may not coincide with the correct time (this depends on the user, not the platform for submission). Any discrepancies in system time will not be grounds for deadline extension.*

Project Website: https://spade-horizon.eu/

Open Call platform: https://bit.ly/SPADE_OC2_Applicants

All the Open Call documents and templates available for download at https://spade-horizon.eu/open-call-2-applicants/

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V3.0 28/02/2025

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List of Acronyms

OC	OPEN CALL
FIF	FINANCIAL IDENTIFICATION FORM
UAV	UNMANNED AERIAL VEHICLES
UCU	UNIVERSAL CONSIDERATIONS ACROSS CASE STUDIES
UCU-CH1	UNIVERSAL CONSIDERATIONS ACROSS CASE STUDIES CHALLENGE 1
UCU-CH2	UNIVERSAL CONSIDERATIONS ACROSS CASE STUDIES CHALLENGE 2
UCU-CH3	UNIVERSAL CONSIDERATIONS ACROSS CASE STUDIES CHALLENGE 3
CStudy1	CASE STUDY 1: OPEN-FIELD CASE STUDY INTEGRATION
CStudy1-CH1	CASE STUDY 1. CHALLENGE 1
CStudy1-CH2	CASE STUDY 1. CHALLENGE 2
CStudy2	CASE STUDY 2: FORESTRY CASE STUDY
CStudy2-CH1	CASE STUDY 2. CHALLENGE 1
CStudy2-CH2	CASE STUDY 2. CHALLENGE 2
CStudy3	CASE STUDY 3: LIVESTOCK CASE STUDY INTEGRATION
CStudy3-CH1	CASE STUDY 3. CHALLENGE 1
CStudy3-CH2	CASE STUDY 3. CHALLENGE 2

List of definitions

USE CASE	SPECIFIC CONDITIONS THAT ARE INHERENTLY TIED TO A PARTICULAR COUNTRY OR GEOGRAPHIC AREA REFER TO THE UNIQUE ENVIRONMENTAL, REGULATORY, CULTURAL, AND OPERATIONAL FACTORS OF A LOCATION THAT DIRECTLY INFLUENCE THE APPLICATION OF DRONE TECHNOLOGY IN FORESTRY, LIVESTOCK MANAGEMENT, OR OPEN-FIELD AGRICULTURE.
CASE STUDY	A PRACTICAL APPLICATION SCENARIO FROM A USE CASE.
CHALLENGE	A COMPLEX SITUATION IN OPEN FIELDS, LIVESTOCK, OR FORESTRY THAT REQUIRES INNOVATIVE PROPOSALS FROM APPLICANTS, DESIGNED TO ADDRESS SPECIFIC ISSUES WHILE CONSIDERING THE UNIQUE CONSTRAINTS, OPPORTUNITIES, AND CHARACTERISTICS OF A DEFINED CASE STUDY.

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1. Purpose of Annex 1 – Technical Annex

The purpose of this annex is to provide applicants with an understanding of the main technical components and infrastructure that may be necessary for their applications.

It is important to note that this document constitutes essential and complementary information to the Guidelines for Applicants.

All the requirements compiled in this document for each challenge of the Open Call #2 of SPADE are mandatory to be eligible.

This annex is divided into the following sections:

- General technical requirements:
  - SPADE platform
  - Open-Source recommendations
- Technical Requirements for the Challenges
  - Universal Challenges Across Case Studies (UCU)
    - UCU-CH1: Swarn Communication and Navigation
    - UCU-CH2: Open-Source Tilted Rotor Drone System
    - UCU-CH3: Aerial image processing service
- Case Studies challenges (CStudy)
  - CStudy1: Open-field case study integration
    - CStudy1-CH1: ML-based disease detection in Mediterranean crops
    - CStudy1-CH2: Crop Data Collection and Annotation
  - CStudy2: Forestry case study
    - CStudy2-CH1: Below-Canopy Forest Data Collection and Annotation
    - CSutdy2-CH2: Ultralight Self-Leveling Landing Gear for Quadrotor Drones
  - CStudy3: Livestock Case Study Integration
    - CStudy3-CH1: Virtual Fencing Application for Livestock Grazing Management
    - CStudy3-CH2: Livestock Data Acquisition and ML Model Development

To get more detailed information about the technical requirements of SPADE Open Call #2, you can participate in the Info Days scheduled on:

- **Info Day 1.** [26th March 2025//10:00 Brussels Time*]. General Presentation, Open Source Criteria, and Open Call #2 Presentation.
- **Info Day 2.** [2nd April 2025//10:00 Brussels Time*]. UCU (CH1 and CH2) & CStudy2: Forestry case study.
- **Info Day 3.** [4th April 2025//10:00 Brussels Time*]. UCU (CH3) & CStudy1: Open-field case study integration.

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- **Info Day 4.** [9th April 2025//11:00 Brussels Time*]. CStudy 3: Livestock Case Study Integration.

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2. General technical requirements

As a fundamental part of the application process, we present this Technical Annex detailing the essential requirements and recommendations for the successful integration of your projects.

This document provides a comprehensive guide on the technical criteria to be considered to ensure the efficient implementation and collaboration within the SPADE ecosystem. By adhering to these requirements, you will not only enhance the functionality of your proposals but also facilitate a seamless integration into this specialized environment.

We urge you to carefully review each section of this annex, addressing aspects ranging from self-containment and accessibility to open-source recommendations. By following these guidelines, you will significantly contribute to the technical excellence and synergy of your projects with SPADE.

2.1 SPADE platform

To ensure the successful integration of your project within the SPADE ecosystem, we have outlined a set of essential technical requirements. By meeting these criteria, you'll not only enhance the functionality of your proposed solutions but also contribute to the seamless integration within the SPADE platform. Let's delve into the specific requirements that will pave the way for a successful collaboration.

Self-Containment and Accessibility:

- Solutions must be self-contained, encompassing all necessary functionalities.
- Input for the service should be facilitated through an API or configuration file, promoting accessibility and ease of use.

Logging Mechanism for Debugging:

- A logging mechanism is crucial, enabling developers and maintainers to efficiently debug errors and ensure smooth operation.

Hardware Agnosticism:

- Solutions should be executable on off-the-shelf hardware.
- Special hardware components (e.g., GPU, TPM) are not required, as their availability will not be guaranteed on the SPADE platform.

Linux OS Compatibility:

- Solutions must be executable on the Linux operating system, ensuring uniformity across the SPADE platform.

Containerization with Docker:

- Containerization is mandatory, with Docker as the designated deployment platform.
- All necessary dependencies must be encapsulated within the provided package for seamless integration.

Comprehensive Documentation:

- Applicants are expected to provide thorough documentation, offering detailed deployment instructions and a user guide for efficient implementation.

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Collaboration with Platform Developers:

- Any additional requirements or specific needs beyond this document should be communicated and discussed with SPADE platform developers during the development phase.

Well-Defined API Specification:

- Solutions must feature a well-defined and documented API, outlining the required input data and the corresponding results computed by the service.

Headless Execution and UI Integration:

- Solutions should be designed for headless execution on a server without a graphical interface.

- If a user interface is necessary, it must be provided through a web-based UI executable on the SPADE platform or an external tool communicating through the specified API.

By meeting these platform requirements, participants will contribute to the seamless integration and functionality of their proposed solutions within the SPADE ecosystem.

2.2 Open-Source requirements

Given that the SPADE common platform operates as an open-source project under the Eclipse Public License **(EPL 2.0)**, we strongly recommend adhering to best practices in open-source development. Therefore, we require that chosen projects initiate the development on the **SPADE Research Labs** infrastructure right from the outset. This infrastructure is supported by the Eclipse Foundation and is hosted on their GitLab platform.

Licenses permitted by SPADE are:

- Eclipse Public License (EPL 2.0)
- Apache 2.0 License
- BSD License
- MIT License

By leveraging the SPADE and Eclipse platforms, developers benefit from the following services:

- Guidance in selecting an industry-friendly open-source license.
- Support for tracking code provenance and properly managing copyrights.
- Assistance in analysing third-party dependencies and ensuring that open-source license compatibility.

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3. Technical Requirements for the Challenges

SPADE is embarking on a comprehensive initiative that encompasses targeted challenges across various domains, including Open-Field Case Studies in Spain, Forestry Case Studies in Norway, and Livestock Case Study in Greece.

In this call, we extend an invitation to applicants to tackle specific challenges tailored to each unique use case, promoting innovation in agricultural practices, forestry management, and livestock breeding. Furthermore, a series of universal challenges is set to cut across all use cases, fostering cross-disciplinary collaboration and addressing broader considerations crucial to the success of the SPADE project.

This section will provide in-depth insights into the technical prerequisites that must be met for each challenge.

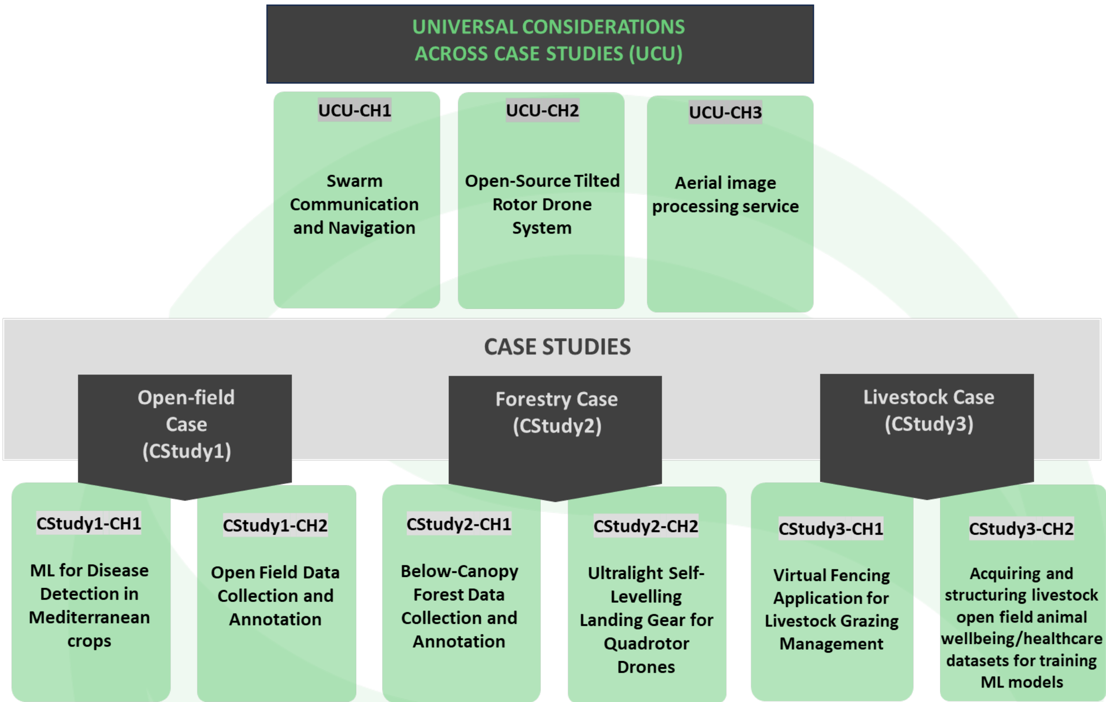

Figure 1. SPADE OC#2. Challenges.

3.1 Universal Challenges Across Case Studies (UCU)

3.1.1 UCU-CH1: Swarm Communication and Navigation

Objectives

The primary purpose is to develop a system that enables a group of drones to communicate and navigate effectively, a fundamental requirement for applications such as surveillance, exploration, or extensive area mapping. Key tasks for the participants will be to:

- Developing robust inter-drone communications, allowing for reliable control and relaying of sensor data.
- Assembling a central, global map based on point-cloud data incoming from swarm drones.
- Sending navigational commands to the drone participants to complete the map.

Implementation

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The developed algorithm should solve the problem of using many drones to collaboratively survey an area.

- A centralized computer will plan the paths for each swarm drone participant.
- Swarm drones stream point cloud, GPS, and IMU data back to the central computer, which uses this to build a single, cohesive map.
- The algorithm should be able to handle adding to, or filling gaps in a pre-existing point cloud.
- The navigation commands from the centralized computer should adaptively fill in voids in the available point cloud data.
- Assembly of the point clouds between swarm drones should be done using a graph-SLAM approach (based on GTSAM).

The algorithm must have a simple manner for the user to input the desired polygonal region to be mapped.

Control and software

Software is expected to use ROS2 as a framework for implementation. Software should be based on ROS2 (Humble), deployed from a docker image. Both drones can be assumed to have an on-board Jetson Orin Nano or NX computer or a similar CPU to provide computational power.

Hardware

The developed algorithms should be mostly hardware-agnostic. However, applicants will be required to validate their design on custom SPADE drones. These drones have the following specifications:

- Based on the QAV250 drone kits: https://holybro.com/products/qav250-kit
- PX4 flight controller
- Onboard Jetson Orin Nano or NX computer (or similar CPU)
- Onboard Livox MID360 LiDAR sensor.

Participants can add additional communication hardware to the drone, if needed and within weight budget of drone. Electrical power from the drone batteries can be assumed available (4S, 14.8-16.8V).

The swarm drones can accept waypoint commands (via a ROS2 topic) and will navigate to said point while avoiding obstacles in the path.

Open Source

All software components must be open source and developed transparently on the SPADE Research Labs infrastructure to ensure community access and contribution. Similarly, all mechanical and electrical drawings must also be made open source under the CC BY 4.0 license.

Algorithms are encouraged to leverage pre-existing repositories. However, all codebase dependencies must be licensed under one of the approved weak copyleft or permissive open-source licenses: EPL 2.0, Apache 2.0, MIT, BSD, or CC BY 4.0 (for documentation).

Dependencies under strong copyleft licenses, such as GPL or AGPL, are not permitted unless they are optional and can be replaced by an alternative library. If your code depends on (A)GPL-licensed components, any derivative work would be required to adopt the same license, which is not aligned with our objectives.

Completion Criteria

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A successful system should be demonstrated controlling swarm members (at least 2) to map a forest plot (approximately 50x50m) in an open, Scots-pine forest.

3.1.2 UCU-CH2: Open-Source Tilted Rotor Drone System

Objectives

The challenge aims to design an open-source omnidirectional navigation system using a tilted rotor drone. Proposals will envision to provide smooth 360-degree movement and deliver a functional drone, open-source hardware designs, software, and comprehensive documentation to the SPADE project.

Implementation

The project integrates hardware and software development:

- **Hardware**: Design tilted rotors and a vectored thrust system.
- **Software**: Develop a controller for rotor tilt and speed, extending PX4 capabilities.
- **Integration**: Test and assemble all components into a functional system.

Hardware

- **Tilted Rotor Design**: Enables multidirectional thrust for seamless omnidirectional movement. Includes precision tilt mechanisms and lightweight materials for efficiency.
- **Frame and Structure**: Robust design to house rotors and computing units while supporting sensor integration.
- **Vectored Thrust Controller**: Adjusts rotor tilt and speed dynamically, interfacing with PX4 for precise control.

Software

- **Vectored Thrust Controller Software**: Manages real-time control of rotor behavior and integrates with PX4 flight controller.
- **Onboard Computing Unit**: Executes flight control operations, ensuring real-time coordination and dynamic motion.

Open Source

All software components must be open source and developed transparently on the SPADE Research Labs infrastructure to ensure community access and contribution. Similarly, all mechanical and electrical drawings must also be made open source under the CC BY 4.0 license.

Algorithms are encouraged to leverage pre-existing repositories. However, all codebase dependencies must be licensed under one of the approved weak copyleft or permissive open-source licenses: EPL 2.0, Apache 2.0, MIT, BSD, or CC BY 4.0 (for documentation).

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Sensor Integration

- **Compatibility**: Supports GPS, IMUs, and additional sensors for advanced capabilities.
- **Implementation**: Sensor data processed through PX4, with extensible design for future integrations.

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Completion Criteria

- **Functional Drone**: Achieves 360-degree movement with precise rotor control.
- **Hardware Documentation**: Open-source specifications for all critical components.
- **Software Deliverables**: Vectored thrust controller and PX4 integration files.
- **Comprehensive Manuals**: Instructions for assembly, operation, and future modifications.

3.1.3 UCU-CH3: Aerial image processing service

The challenge focuses on developing an Open-Source online solution capable of processing photogrammetry data from drones and exporting the relevant orthomosaics.

Objectives

The main objective of this project is to develop and deploy an AWS-based system for uploading raw images, processing them into orthomosaics, and integrating with a third-party microservice for data storage and further analysis. The system will include:

- APIs for image upload
- processing options
- data download
- radiometric calibration
- geometric correction - georeferencing (using ground control points)
- multiple data outputs
- possibility to connect to Management Information Systems

Implementation

The project will be implemented in several phases aligned with the proposed timeline:

<u>Planning and Requirements Analysis</u>

- Define project scope, objectives, and deliverables.
- Gather detailed requirements, including radiometric calibration and FMIS connection needs.
- Conduct a feasibility study and risk assessment.
- Create detailed project plan and timeline.

<u>Infrastructure Setup</u>

- Set up AWS environment (VPC, EC2, S3, RDS, etc.).
- Configure network settings, security groups (authentication), and IAM roles.
- Establish initial connections with an FMIS.

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- Set up logging and monitoring frameworks.

API Development for Raw Image Upload

- Design API architecture and endpoints for raw image upload.
- Include support for radiometric calibration images.
- Develop the image upload API.
- Implement error handling, logging, and initial security measures.

Image Processing Development

- Develop the image processing module, including orthomosaic and point cloud creation and radiometric calibration processing.
- Integrate point-cloud and elevation data creation options.
- Ensure the processing module supports multiple data outputs (.ply, .tiff, .csv).
- Integrate the image processing module with the upload API.

Output Infrastructure and Authentication Implementation

- Develop an API for data download.
- Ensure it supports various data formats and outputs.
- Implement authentication mechanisms (OAuth, JWT).
- Begin integration with a third-party microservice for data upload.

Testing, Deployment, and Monitoring

- Conduct unit testing, integration testing, and load testing.
- Validate API endpoints, data processing accuracy, and output formats.
- Deploy the system to production.
- Set up comprehensive monitoring tools to track KPIs such as uptime, response time, processing time, and security incidents.
- Final Review and Optimization
- Review system performance, optimize processes, and ensure all KPIs are met.

Open Source

All software components must be open source and developed transparently on the SPADE Research Labs infrastructure to ensure community access and contribution. Algorithms are encouraged to leverage pre-existing repositories. However, all codebase dependencies must be licensed under one of the approved weak copyleft or permissive open-source licenses: EPL 2.0, Apache 2.0, MIT, BSD, or CC BY 4.0 (for documentation).

Dependencies under strong copyleft licenses, such as GPL or AGPL, are not permitted unless they are optional and can be replaced by an alternative library. If your code depends on (A)GPL-licensed components, any derivative work would be required to adopt the same license, which is not aligned with our objectives.

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Completion Criteria

The project will be considered complete upon the fulfilment of the following criteria:

- All KPIs are successfully implemented.
- All deliverables are accepted.
- All tools are developed according to the requirements and criteria as listed above.
- The system is fully deployed and evaluated by the SPADE experts.

3.2 Case Studies challenges (CStudy)

3.2.1 CStudy1: Open-field case study integration

3.2.1.1 CStudy1-CH1:ML-based disease detection in Mediterranean crops

Objectives

The main objective of this project is to develop innovative machine learning (ML) solutions for the detection of diseases affecting Mediterranean crops, with a particular focus on olive groves, citrus trees, and potato crops. This includes:

- Developing ML algorithms capable of analyzing orthomosaic maps and raw RGB/multispectral images for disease detection.
- Detecting Alternaria (*Alternaria solani* and *Alternaria alternata*) in potato crops and Olive Leaf Spot (Repilo - *Fusicladium oleagineum*) in olive trees.
- Generating intuitive visualizations, such as heatmaps, to inform users of the location and severity of disease outbreaks.
- Creating a standalone application and integrating the solution within the SPADE platform for Windows and Linux systems.
- Improving agricultural disease management by leveraging drone technology and ML for early disease detection.

Implementation

The project will be implemented in several phases aligned with the proposed timeline:

Month 1:

- Preparation of the Initial Report detailing methodologies, timelines, and KPIs.
- Functional analysis of the algorithms and selection of ML models (e.g., CNNs, Random Forests).

Month 3:

- Development and testing of the initial prototype for disease detection.
- Interim report assessing KPI fulfilment and model performance.

Month 6:

- Final model development and deployment.
- Visualization through heatmaps to display affected areas and disease severity.
- Delivery of a standalone application compatible with Windows and Linux.
- Final report evaluating KPIs and overall project success.

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Hardware

- The project will utilize the following hardware:
- Drones equipped with RGB and multispectral cameras for data acquisition.
- High-performance computing servers for model training and data processing.
- End-user devices (PCs and laptops) for running the standalone application on Windows/Linux systems.

Software

The software stack will include:

- Machine Learning frameworks: i.e. TensorFlow, PyTorch, and scikit-learn for model development.
- Image processing tools: i.e. OpenCV for image preprocessing.
- Visualization libraries: i.e. Matplotlib, Plotly for generating heatmaps.
- API development tools: i.e. Flask or FastAPI for integration with the SPADE platform.
- Standalone application development tools: i.e. PyInstaller for packaging the software for Windows and Linux.

Open Source

The project will prioritize the use of open-source tools and libraries to ensure transparency, reproducibility, and cost-efficiency. Where possible, newly developed tools and algorithms will be released under open-source licenses to contribute to the wider research community.

All software components must be open source and developed transparently on the SPADE Research Labs infrastructure to ensure community access and contribution. Algorithms are encouraged to leverage pre-existing repositories. However, all codebase dependencies must be licensed under one of the approved weak copyleft or permissive open-source licenses: EPL 2.0, Apache 2.0, MIT, BSD, or CC BY 4.0 (for documentation).

Dependences under strong copyleft licenses, such as GPL or AGPL, are not permitted unless they are optional and can be replaced by an alternative library. If your code depends on (A)GPL-licensed components, any derivative work would be required to adopt the same license, which is not aligned with our objectives.

Sensor Integration

Drone-based RGB and multispectral sensors will be integrated into the ML workflow. The orthomosaic maps and raw images captured will serve as input data for the ML algorithms. Sensor calibration and data preprocessing will be optimized to ensure high-quality data analysis.

Completion Criteria

The project will be considered complete upon the fulfilment of the following criteria:

- Successful detection of Alternaria in potatoes and Repilo in olive trees with high accuracy.
- Deployment of the solution on the SPADE ML infrastructure (developed in OC1) and as a standalone application for Windows and Linux.
- Effective visualization of disease occurrence through heatmaps.
- Submission of all reports (Initial, Interim, and Final) meeting the project requirements.
- Demonstration of the solution's usability and performance to stakeholders.

3.2.1.2 CStudy1-CH2: Open Field Data Collection and Annotation

Objectives

The objective of this challenge is to prepare open datasets that may be utilised as a solid foundation for training ML models focused to solve specific issues in crop production. The main task of the successful candidate will be to collect and annotate raw data acquired using UAV(s) and the produced othromosaics from numerous fields cultivated with crops of interest (commonly grown in the Mediterranean region). The applicant will be required to collect and annotate data based on their region. The annotations should include:

- Annotations of the cultivated crop
- Annotations of the developed weeds (if exist)
- Annotations of the field boundaries
- Annotations of any developed visible (to any spectrum) disease.
- Annotations of any objects visible in the field of interest related or unrelated to the crop.

The annotated datasets produced in this challenge will provide solid foundation for training ML models to address key crop production challenges such as:

- Weed detection
- Plant/tree species identification and counting
- Tree canopy coverage estimation
- Field area segmentation
- Object identification in various crop types (e.g., grapevines, orchards, and arable crops common in Mediterranean regions).

Applicants must have extensive experience in labelling /annotating data to ensure quality of annotation.

Implementation

- The challenge will develop two different open-source datasets addressing different crops of different crop types (grapevines, orchards, arable crops) that are common in the mediterranean regions.
- Applicants will be required to annotate data from a minimum of 40 fields (20 arable crop cultivations and 20 orchards or vineyards) each field with a minimum size of 1 ha. In the case it is not possible to collect 40 fields sized of more than 1 ha each, more fields can be added to ensure the minimum coverage of 40 ha.
- Annotation data should consist of selected items that better correspond to the above requirements.
- The applicants are responsible of pre-processing the raw data to generate orthomosaics. Pre-processing operations should include at least radiometric calibration in cases that a multispectral or hyperspectral camera was used.
- In tandem with the dataset, the deliverables should also include scripts in python that splits large orthomosaics into smaller sections that could be fed into Machine Learning models
- Data labelling must be done in a 2-stage approach including labelling and reviewing for quality control.

Hardware

The applicants should use their own UAV(s) equipped with RGB, Thermal, Multispectral or Hyperspectral sensor depending on the application.

Software

Annotation of the data will be done using an open-source software (preferably Lebelme).

Open Source

All datasets must be made publicly available in alignment with Open Science principles, ensuring accessibility, transparency, and reproducibility. The datasets must be licensed under CC BY 4.0, allowing unrestricted sharing and use, provided proper attribution is given.

Please check detailed requirements at the Appendix 4.1

Completion Criteria

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The project is considered complete when the required datasets are collected and annotated, reviewed internally by the beneficiary and evaluated for accuracy by the SPADE partners. The structuring and preparation of datasets must be high-quality, the datasets must be accurately labelled, suitable for training machine learning models. Datasets must be comprehensively organized, validated, and structured for real-world application scenarios that will be agreed during the Design Document development stage.

3.2.2 CStudy2: Forestry case study

3.2.2.1. CStudy2-CH1: Below-Canopy Forest Data Collection and Annotation

Objectives

The goal of this challenge is to annotate and collect below-canopy image/video and point cloud (LiDAR) datasets from forests throughout Europe. Applicants will be provided with datasets to annotate and segment, and the applicant will also be required to collect data forest local to their region using a data acquisition module developed in SPADE. Applicants must show they have experience labelling annotating forest sensor data to ensure quality of annotation.

Implementation

- Reviewers will be required to annotate the point clouds and video streams for a minimum of 10 plots (50m x 50m each). Additionally, a minimum of 200 short, 30 second video streams must be annotated. Applications capable of labelling higher amounts of data will be preferred.
- Annotation of point clouds will involve segmenting individual trees and labelling classes such as: wood, leaf, ground, lying deadwood, low vegetation, water, etc. Image/video labelling will additionally involve classes such as grasses, bushes, mosses, lichen, soil, ferns, etc.
- Applicants will be supplied with a handheld data collection module, featuring an onboard computer, camera, and LiDAR system, that can collect datasets simply by walking with the device. The raw data collected will be sent to SPADE partners for assembly and data processing before annotation. A minimum of 4 (50m x 50m) plots of different forest types must be collected.
- Applicants will be supplied with further assembled datasets from throughout Europe, to complete the data to be labelling.
- Data labelling must be done in a 2-stage approach with labelling and reviewing for quality control. NIBIO, as a SPADE partner, will also review data at milestones.

Hardware

Datasets collected by the applicant will use a data acquisition system developed within SPADE. This system combines a battery system, onboard PC, GPS, camera, LiDAR and IMU. It will be handheld, and data can be collected simply by walking through the forest. The raw data collected will be sent to SPADE partners for assembly and data processing before annotation.

Software

- Annotation of the point cloud data will be done using Darwin V7 Lab software. SPADE partners will provide the licensing for this software.
- Annotation of the image data will be done in CloudCompare software (open source).

Open Source

All datasets must be made publicly available in alignment with Open Science principles, ensuring accessibility, transparency, and reproducibility. The datasets must be licensed under CC BY 4.0, allowing unrestricted sharing and use, provided proper attribution is given.

Please check detailed requirements at the Appendix 4.1.

Completion Criteria

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The project is considered complete when the required data is collected and annotated, reviewed internally, and reviewed for accuracy by SPADE partners.

3.2.2.2. CStudy2-CH2: Ultralight Self-Levelling Landing Gear for Quadrotor Drones

Objectives

The goal of this challenge is to develop ultra-lightweight drone legs capable of linearly adjusting their height to level the drone. The proposed design should be a scalable solution that can be adapted to a variety of quadrotor sizes. Applicants will be required to validate their design by implementing the system for two SPADE drones, a medium-sized quadrotor and large seedling-planting quadrotor. The solution should follow the approximate design shown in the image below, with one telescoping leg under each of the four rotors.

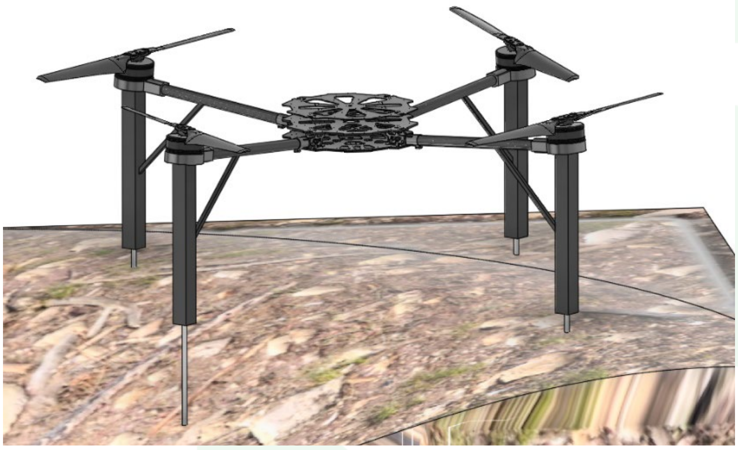

Figure 2. Approximate solution design

Implementation

A landing gear system must be designed, capable of being readily scaled to a variety of drone sizes. The design must be validated in two sample scenarios: a medium sized 500mm drone, and a larger planting drone.

- Medium-sized quadrotor: 500 mm wingspan, 26 kg load capacity on legs (combined). Onboard power: 6S LiPo or 12V 5A.
- Large tree-planting quadrotor: 1300 mm wingspan, 60 kg load capacity on legs (combined). Onboard power: 12s LiPo or 12V 5A

Control and software

Applicants must develop a control system capable of using the on-board IMU data, downward facing lidar data, and data from any sensors integrated into their leg design to successful control and adapt the leg length to a given landing site. Both drones can be assumed to have an on-board Jetson Orin Nano or NX computer or a similar CPU to provide computational power. Electrical power from the drone batteries can be assumed available. Software must run in a ROS2 (Humble) docker image.

Hardware

The developed hardware must be as lightweight as possible, to stay within the weight restrictions of the drone hardware and avoid overly affecting flight time. To this end, the developed design should prioritize lightweight components where possible, such as carbon fibre structures, aluminium or plastic lead screw/gearing, BLDC motors, lightweight and compact motor drivers, etc.

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Open Source

The project will prioritize the use of open-source tools and libraries to ensure transparency, reproducibility, and cost-efficiency. Where possible, newly developed tools and algorithms will be released under open-source licenses to contribute to the wider research community.

All software components must be open source and developed transparently on the SPADE Research Labs infrastructure to ensure community access and contribution. Algorithms are encouraged to leverage pre-existing repositories. However, all codebase dependencies must be licensed under one of the approved weak copyleft or permissive open-source licenses: EPL 2.0, Apache 2.0, MIT, BSD, or CC BY 4.0 (for documentation).

Dependencies under strong copyleft licenses, such as GPL or AGPL, are not permitted unless they are optional and can be replaced by an alternative library. If your code depends on (A)GPL-licensed components, any derivative work would be required to adopt the same license, which is not aligned with our objectives.

Sensor Integration

- The supplied drones will have an on-board IMU sensor capable of sensing drone tilt (integrated into the drone's flight controller).
- Downward-facing Lidar sensors (Livox MID360 sensors) may be assumed to be available to scan the ground below the drone
- The developed solution should have a means of sensing ground contact in each leg, and if possible, a way of quantifying the load magnitude (e.g. strain gauge or current measurement on the motor).
- The developed system must have a way of measuring the current leg actuator, preferably in an absolute manner to avoid the need for homing at startup (absolute encoder or similar).

Completion Criteria

A successful system must successfully demonstrate take-off and landing of the two drone systems with a ground height deviation at the landing site of at least 20% of the drone's wingspan on two of the legs. A safe angle of the drone body must be always maintained.

3.2.3 CStudy3: Livestock Case Study Integration

3.2.3.1. CStudy3-CH1: Virtual Fencing Application for Livestock Grazing Management

Objectives

Develop a virtual fence thresholding application for targeted grazing management through existing SPADE modules (SPADE Livestock Platform (SLP), Parrot Anafi USA UAV and animal collars).

Implementation

The implementation of the prototype subsystem will involve integrating UAVs, animal collar transceivers, and the SPADE Livestock Platform (SLP) to create a dynamic, real-time livestock monitoring system. The system will manage virtual fences, collect data on trespassing events, and provide alerts and insights for farm operators, all while being tested and validated in real-world conditions to ensure robustness and reliability. The SLP will serve as the central software hub for managing and analysing data from the UAVs and collars.

Hardware

UAVs: The testing UAV platform will be the Parrot Anafi USA. This device has a full SDK support and a software simulator. In case the actual h/w will be demanded (e.g. for the final testing and validation) then SPADE partners will organise a bootcamp to provide the UAV platform (Parrot Anafi USA) and the OC2 contractors will have to integrate

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the final solution and deal with any open issues. Animal collar transceivers: commercial collar transceivers or custom transceivers developed by SPADE partners will be provided.

Software

SPADE will make available all necessary s/w modules and subsystems, including those coming out from the first set of s/w delivered by the OC1 contractors. Especially for the Integration of the virtual fence thresholding application with the SPADE Livestock Platform (SLP), access to the SPADE Livestock pilot environment will be provided to the OC2 contractors for achieving monitoring of livestock trespassing, defining dynamic virtual fences, and collecting relevant data regarding trespassing events.

Open Source

All software components must be open source and developed transparently on the SPADE Research Labs infrastructure to ensure community access and contribution. Algorithms are encouraged to leverage pre-existing repositories. However, all codebase dependencies must be licensed under one of the approved weak copyleft or permissive open-source licenses: EPL 2.0, Apache 2.0, MIT, BSD, or CC BY 4.0 (for documentation).

Dependencies under strong copyleft licenses, such as GPL or AGPL, are not permitted unless they are optional and can be replaced by an alternative library. If your code depends on (A)GPL-licensed components, any derivative work would be required to adopt the same license, which is not aligned with our objectives.**Sensor Integration**

If the OC2 contractors require additional sensors or sensor controllers to achieve the requested application, they need to provide own test sensor devices and solution, and SPADE OC2 supervisor(s) will need to agree upon before integrating it with the SPADE Livestock Platform SLP.

Completion Criteria

The OC2 contractors will be asked to fully comply with the need to work in harmony with any hardware required by SPADE (e.g. UAVs, collar transceivers etc). The expected outcome needs to be a robust (sub)-system capable of monitoring livestock movements, detecting trespassing events, and collecting valuable data for real-time decision-making and long-term analysis (expected TRL6). Fluent integration of any third party components and the SPADE Livestock Platform (SLP) will be the cornerstone acceptance criterion. The functional performance (TRL6) of the delivered OC2 application, (for managing dynamic virtual fences, improving livestock management, and ensuring effective testing) as well a full scale validation at real-world conditions, will be the final acceptance criterion for this thematic area.

Completion will be evaluated based on the successful development and testing of a prototype that implements user scenarios where virtual fences are used to monitor livestock trespassing and collect data on these events. These scenarios will include monitoring grazing animals, grazing land thresholding, UAV flying along a virtual fencing zone, and developing of SPADE ML datasets to be stored on SLP.

Access to a livestock farm is necessary to carry out the testing phase effectively. The solution should be validated **against user scenarios that will be defined during the Design Document** deliverable stage, which is the starting project milestone. The Design Document will be developed **in agreement to the OC2 supervisors** and is **a mandatory step** that unless reached the project cannot continue.

3.2.3.2. CStudy3-CH2: Acquiring and structuring livestock open field animal wellbeing/healthcare datasets for training ML models

Objectives

Creating annotated datasets for livestock disease detection from images and videos captured by drones that will serve as a solid foundation for training livestock disease detection machine learning models.

Implementation

To implement the process of creating a high-quality, annotated dataset from drone-captured images and videos in a livestock farm, applicants should follow the stages: secure access to a livestock farm, data collection, preprocessing,

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annotation, structuring, and validation. The goal is to create a dataset suitable for training a machine learning model for livestock disease detection.

Hardware

Contractors will need to provide own UAVs equipped with camera and any other sensors or required hardware features to capture high resolution images and mp4 videos along with metadata i.e. timestamp, GPS coordinates, and other relevant contextual details such as weather and environmental conditions.

Software

SPADE will define during the Design Document stage all necessary specifications for the structure, storage, usability and interoperability of the datasets to be captured. The size of the datasets will need to be a commitment reported at proposal submission and will be taken as an evaluation criterion.

Open Source

All datasets must be made publicly available in alignment with Open Science principles, ensuring accessibility, transparency, and reproducibility. The datasets must be licensed under CC BY 4.0, allowing unrestricted sharing and use, provided proper attribution is given.

Please check detailed requirements at the Appendix 4.1

Completion Criteria

The completion of this open call will be evaluated based on the successful and secure collection, annotation, structuring, and preparation of a high-quality, accurately labelled dataset that is suitable for training machine learning models for livestock disease detection. The contractors need to commit to ensuring Secure Access to a Livestock Farm and integration with the SPADE Livestock cloud Platform (SLP). Where and when appropriate, permissions and protocols will need to be followed by the contractors for safe and authorized data collection. Datasets must be comprehensively organized, validated, and structured for real-world application scenarios that will be agreed during the Design Document development stage. During this stage, use cases will be defined to include selected ML models for testing training datasets. Contractors' responsibility is to provide a consistent training dataset and to fine tune the selected ML models to reach an agreed, during the Design Document development stage, detection accuracy.

Overall, reaching the completion criteria will be evaluated via ensuring that the acquired datasets can be used for training ML models, to be selected (during the Design Document development stage), capable of assisting in livestock health monitoring and disease management with high level accuracy. Completion will be evaluated based on the successful development and testing of a prototype that implements the abovementioned agreed (and/or to be agreed) conditions and user scenarios. The Design Document will be developed **in agreement to the OC2 supervisors** and is **a mandatory step** that unless reached the project cannot continue.

4. Appendix

4.1 Documentation Requirements for Generating Datasets

When creating datasets for this project, it is essential that they are thoroughly documented to meet Open Science principles, ensure reusability, and comply with standards for public access. This documentation will help others understand, use, and cite the datasets effectively.

4.1.1 Standardized Metadata

Each dataset needs to be accompanied by consistent metadata to ensure clarity and consistency across all datasets.

- **Title**: A concise, descriptive name for the dataset (e.g., UAV-based Crop Monitoring Data for AI Models).
- **Abstract**: A brief summary (~200-300 words) explaining:

What the dataset contains.
How it was collected (e.g., UAV flights, sensors used).
The potential use cases (e.g., training AI models for precision agriculture).

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- **Keywords**: Include relevant terms (e.g., UAV, precision agriculture, AI models, remote sensing).
- **Authors & Affiliations:** List all dataset creators and their institutions.
- **License**: Specify the open-access license (e.g., CC BY 4.0).
- **Versioning**: If there are multiple versions, include a version number (e.g., v1.0).

4.1.2 README File for Each Dataset

Each dataset should be accompanied by a README file that provides detailed information on how the data can be used. The README should include:

- **Dataset Overview**: A short description of the dataset, including its source, purpose, and scope.
- **File Structure**: Clearly list the files included in the dataset and their types (e.g., CSV files, GeoTIFFs, etc.).
- **Data Dictionary**: Define each column/variable, its units, and any relevant details (e.g., temperature in °C, coordinates in WGS84).
- **Preprocessing**: Describe any preprocessing steps you've done to clean or transform the data (e.g., removal of outliers, normalization).
- **Usage Instructions**: Provide step-by-step instructions for accessing, downloading, and using the data (e.g., how to load CSV into Python using pandas).
- **Citation Guidelines**: Provide a citation format for users who want to reference the dataset (e.g., Author(s), Year, Dataset Title, DOI).

4.1.3 Dataset Accessibility & Open Science Compliance

To ensure the dataset is open, accessible, and reusable:

- **Data Formats**: Ensure the dataset is stored in widely-used formats (e.g., CSV, JSON, GeoTIFF) that are easily accessible.
- **DOI Assignment**: The dataset must be assigned a DOI to make it citable and ensure its long-term availability. Use repositories like Zenodo or Dataverse for this purpose.
- **Public Access**: The dataset must be available without restrictions. No closed or paywalled repositories.

4.1.4 Interoperability & FAIR Principles

Each dataset must be FAIR (Findable, Accessible, Interoperable, and Reusable):

- **Findable**: Use standardized naming conventions, include a DOI, and ensure metadata is complete.
- **Accessible**: The dataset should be available for download, with minimal barriers to access.
- **Interoperable**: Use common data formats and ensure that the dataset can easily integrate with other systems.
- **Reusable:** Provide clear documentation, a license that allows reuse (e.g., CC BY), and metadata that ensures the data can be used by others in the future.

4.1.5 Repository Choice

All datasets must be uploaded to open-access repositories that follow Open Science principles:

- **Zenodo** (recommended for general datasets)
- **Dataverse** (if more structured, academic datasets are needed)
- **EOSC** repositories (if your datasets are part of EU-funded research)
- **Radiant Earth MLHub** (for geospatial and AI-related datasets)

The repositories will automatically assign DOIs and ensure long-term access.

4.1.6 Documentation Examples & Templates

To help with this, here are some example templates:

- **README Template**: A sample file you can use to describe your datasets.
- **Metadata Schema**: A standard schema (JSON, YAML, or XML) to ensure consistency across datasets.
- **Dataset Landing Page**: A basic layout for the project's central documentation page.

4.1.7 Final Checklist for Each Dataset

Before submitting a dataset, please ensure:

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- The metadata is filled out correctly.
- A detailed README file is provided.
- The dataset is publicly accessible under an open-access license.
- The dataset is assigned a DOI.
- The dataset is stored in a FAIR-compliant repository.

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