www.nautilos-h2020.eu

Organisation CEiiA

D6.5

Report on the testing results of the joint operations of sensors and UAV in ST6.3.3

Date: 2023-11-23

Doc. Version: [VERSION 4]

doi: 10.5281/zenodo.10694771

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101000825 (NAUTILOS). This output reflects only the author's view and the European Union cannot be held responsible for any use that may be made of the information contained therein.

Document Control Information	
Deliverable Title	Report on the testing results of the joint operations of sensors and UAV in ST6.3.3
Work Package Title	Calibration, Validation and Scenario Testing
Deliverable number	D6.5
Description	Report on the testing results of the joint operations of NAUTILOS NIVA sensors (downward-looking multi/hyperspectral cameras) and NIVA UAV at NIVA's Field Research Station in Solbergstrand, Norway
Lead Beneficiary	CEiiA
Lead Authors	João Fortuna, Sabine Marty, Catarina Lemos
Contributors	Medyan Garheeb, Joseph Garret, Andrew King
Submitted by	João Fortuna
Doc. Version (Revision no.)	[VERSION 4]
Sensitivity (Security):	Public
Date:	[2023-11-23]
Doi:	10.5281/zenodo.10694771

Document Approver(s) and Reviewer(s):

NOTE: All Approvers are required. Records of each approver must be maintained. All Reviewers in the list are considered required, unless explicitly listed as Optional.

Name	Role	Action	Date
D. Malardé (NKE)	Review Team 2	*Approve*	22/11/2023

Document history:

The Document Author is authorized to make the following types of changes to the document without requiring that the document be re-approved:

- Editorial, formatting, and spelling
- Clarification

To request a change to this document, contact the Document Author or Owner.

Changes to this document are summarized in the following table in reverse chronological order (latest version first).

Revision	Date	Created by	Short Description of Changes
VERSION 4	2023-11-23	Catarina Lemos	● Final version
VERSION 3	2023-11-15	João Fortuna Sabine Marty Catarina Lemos	● Updated document after revision
VERSION 2	2023-11-07	João Fortuna Sabine Marty Catarina Lemos Andrew King	● Completed content draft, ready for review.
VERSION 1	2023-08-04	João Fortuna	● Updated document skeleton. ● First draft of content.

Configuration Management: Document Location

The latest version of this controlled document is stored in Google Drive: https://docs.google.com/document/d/1pLaLbJXK9K_QkUGYaXeCDe1mBSgDiQGF/edit?usp=sharing&ouid=103598525326971102844&rtpof=true&sd=true.

Nature of the deliverable		
R	Report	**X**
DEC	Websites, patents, filing, etc.	
DEM	Demonstrator	
O	Other	

Dissemination level		
PU	Public	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	

ACKNOWLEDGEMENT

This report forms part of the deliverables from the NAUTILOS project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000825. The Community is not responsible for any use that might be made of the content of this publication.

NAUTILOS - New Approach to Underwater Technologies for Innovative, Low-cost Ocean observation is an H2020 project funded under the Future of Seas and Oceans Flagship Initiative, coordinated by the National Research Council of Italy (CNR, Consiglio Nazionale delle Ricerche). It brings together a group of 21 entities from 11 European countries with multidisciplinary expertise ranging from ocean instrumentation development and integration, ocean sensing and sampling instrumentation, data processing, modelling and control, operational oceanography and biology and ecosystems and biogeochemistry such, water and climate change science, technological marine applications, and research infrastructures.

NAUTILOS will fill-in marine observation and modelling gaps for chemical, biological and deep ocean physics variables through the development of a new generation of cost-effective sensors and samplers, the integration of the aforementioned technologies within observing platforms and their deployment in large-scale demonstrations in European seas. The fundamental aim of the project will be to complement and expand current European observation tools and services, to obtain a collection of data at a much higher spatial resolution, temporal regularity and length than currently available at the European scale, and to further enable and democratise the monitoring of the marine environment to both traditional and non-traditional data users.

NAUTILOS is one of two projects included in the EU´s efforts to support of the European Strategy for Plastics in a Circular Economy by supporting the demonstration of new and innovative technologies to measure the Essential Ocean Variables (EOV).

More information on the project can be found at: https://www.nautilos-h2020.eu/

COPYRIGHT

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This deliverable represents the culmination of work carried out in sub-task (ST) 6.3.3, entitled “Controlled Scenario Testing of Sensors and UAV Platform,” up to M36. It provides a comprehensive report on the controlled scenario testing of Unmanned Aerial Vehicle (UAV) flights and sensors conducted at NIVA's Field Research Station in Solbergstrand, Norway during May 2023. The testing involved NIVA UAVs with NAUTILOS payload, specifically downward looking multi/hyperspectral cameras (T3.2), as extensively detailed in D3.3 “Report on laboratory tests of downward looking sensors”, D5.4 “Report on Integration of Payloads/Sensors on UAV”, and D6.1 “Report on results and methodology of calibration/validation experiments performed in T6.1”.

The controlled scenario testing entailed the execution of 29 UAV flights with the specific objective of validating the field operation of UAV-sensor packages on flight paths over coastal land masses and ocean areas. This included verifying that intended flight paths were followed, that payload integration was successfully achieved, that sensors did not negatively affect flight attributes, and operated as expected in terms of collecting and storing data. The UAV-sensor systems will be part of WP7 demonstrations to measure various essential ocean variables (EOVs) that include physical, biochemical, and biological parameters, such as surface temperature, particulate matter concentration and phytoplankton biomass, and plastic litter.

In the context of ST6.3.3 and, indeed, the broader scope of WP6's-controlled scenario missions, the primary objective was to validate the practical utility of the UAV-sensor packages under realistic operating conditions that can be affected by line of sight and other meteorological conditions (wind, temperature, etc.) that can affect flight performance. This includes evaluating the mechanical and electronic integration proposed in WP5. By doing so, we aim to enhance our understanding of how to optimise NAUTILOS technologies for large-scale demonstrations in European seas, as outlined in WP7. Ultimately, this endeavour contributes to increasing the cost-effectiveness of ocean observation systems, a fundamental goal of the project.

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
AGL	Above ground level
BVLOS	Beyond Visual Line-of-Sight
CDOM	Colour Dissolved Organic Matter
Chl-*a*	Chlorophyll-*a*
DFKI	German Research Center for Artificial Intelligence (Deutsches Forschungszentrum für Künstliche Intelligenz)
EOV	Essential Ocean Variable
GSD	Ground sampling distance
LOS	Line-of-Sight
MSI	Multispectral image
NIR	Near Infrared
NOTAM	Notice to Airmen
NSM	Norwegian National Security Authority
RE	Red Edge
RGB	Red, Green, Blue
UAV	Unmanned Aerial Vehicle

I. INTRODUCTION TO SENSOR/PLATFORM TECHNOLOGY

This report outlines the outcomes of testing conducted within controlled scenarios, focusing on the integration, operation, and calibration/validation of sensors with Unmanned Aerial Vehicle (UAV) platforms. These essential verification and preparatory flights took place in Norway in May 2023 in anticipation of the forthcoming field demonstrations in WP7.

Prior to the controlled scenarios, planned ahead in detail between Norwegian Institute for Water Research (NIVA) and CEiiA, it was necessary to conduct UAV and sensor field verification in which validation flights were carried out and required adjustments were made. This process was essential to guarantee the optimal performance of the integrated platform, readying it for sensor calibration/validation in ST6.1.2 and deployment in T7.2. The sensor calibration/validation results are presented in detail in D6.1 "Report on results and methodology of calibration/validation experiments performed in T6.1".

NIVA's UAV capabilities enabled us to conduct flights at various altitudes and across diverse scenarios (coastal land masses and ocean areas, as fjord, outdoor tank and beach). This broad spectrum of testing scenarios ensures the performance and reliability of the sensor's integration and operation on UAV platforms, which is an essential step of the NAUTILOS project.

II. OBJECTIVES

The primary goal of ST6.3.3 is to validate the seamless operation of drone-borne hyperspectral and multispectral imagers when integrated with Unmanned Aerial Vehicles (UAVs) in real-world field and flying conditions. This comprehensive validation process is essential for ensuring the reliability and efficiency of the integrated imaging systems across a spectrum of environmental variables and operational scenarios. By subjecting the technology to diverse conditions, we aim to fortify the robustness of the drone-borne imagers, addressing potential challenges and refining their performance for optimal functionality in varying circumstances.

Furthermore, the flights conducted within ST6.3.3 offer a unique opportunity for an extended and in-depth comparison of the captured data. Beyond mere validation, these flights facilitate a thorough cross-examination of the drone-captured information with datasets derived from in situ samples, FerryBox instruments, and satellite observations. This meticulous comparison, occurring simultaneously at the same location and time, serves dual purposes. Firstly, it contributes crucial insights for ST6.1.2, allowing for a more comprehensive evaluation of essential ocean variables (EOVs). Secondly, the data collected becomes integral for the comprehensive report outlined in D6.1, enriching the overall dataset and fostering a more nuanced understanding of the marine environment and its intricate dynamics.

III. REFERENCE MATERIAL AND EQUIPMENTS

Validating drone-captured hyperspectral and multispectral data is a pivotal step in ensuring the accuracy and reliability of remote sensing measurements. Apart from the calibration and validation experiments executed by NIVA in the scope of ST 6.1.2 (described in D6.1), field validation experiments are necessary to ensure that sensors and UAVs performed as expected under field conditions. This calibration and validation process involved the use of reference white targets, a hyperspectral radiometer, and a downwelling irradiance sensor. Moreover, this meticulous calibration process plays an essential role in deriving reflectance data from the collected images.

1. REFERENCE MATERIAL

To commence the calibration process, reference plates of Spectralon and other known white targets are strategically placed within the study area, near the take-off and landing location of the drones (Figure 1).

Figure 1. Reference targets for camera calibration.

These targets are carefully chosen due to their known and stable reflectance properties across the spectral range of interest. They serve as critical calibration standards against which the sensor measurements will be compared. Reference white targets are indispensable for the correction of sensor-induced variations and atmospheric influences. Their use ensures that the captured data is accurate and consistent. Capturing samples of these white targets multiple times per flight allows for later calibration of the airborne data, even with changing lighting conditions.

2. REFERENCE INSTRUMENTS

Both airborne hyperspectral and multispectral imagers integrated with NIVA’s UAV, collected data in addition to a ground-based radiometer (TriOS RAMSES hyperspectral radiometer), recorded spectra. Also, since the UAV lacks an onboard downwelling irradiance sensor, we employed a ground-based one.

2.1. TriOS RAMSES Hyperspectral Radiometer

A hyperspectral radiometer, capable of capturing high-resolution spectral data, was employed to measure the radiance values reflected from the reference plates and targets of interest (fjord, outdoor tank, beach). This instrument provides the high-precision spectral radiance measurements that are vital for characterising the radiance properties of the targets.

2.2. Downwelling Irradiance Sensor

A downwelling irradiance sensor was utilised to record the incoming solar radiation at the study site. This sensor measures irradiance from the sun, accounting for variations in solar elevation and atmospheric conditions. These measurements are indispensable for correcting the radiance values obtained from the hyperspectral radiometer and accounting for the influence of changing illumination conditions during data capture. This sensor was mounted alongside the RAMSES radiometer (Figure 2).

Figure 2. Downwelling Irradiance Sensor mounted alongside the RAMSES radiometer.

The calibration process involves a comparison between the spectral radiance measurements of the reference white targets and the corresponding drone-captured data. Disparities or discrepancies between the two datasets are attributed to sensor-specific variations and atmospheric effects. Calibration algorithms are subsequently applied to adjust the drone-captured hyperspectral and multispectral data. This meticulous calibration process is essential for generating reliable and precise remote sensing data. More information about the calibration process is available on D6.1.

One of the key outcomes of this calibration is the derivation of reflectance data. By using the radiance measurements of the reference white targets, along with the irradiance data, a spectral radiance-to-reflectance conversion process is employed. Reflectance represents the ratio of the reflected light to the incoming solar radiation, effectively removing atmospheric influences and sensor-specific variations from the data. The result is a set of accurate reflectance data that represents the true surface properties of the study area (Figure 3).

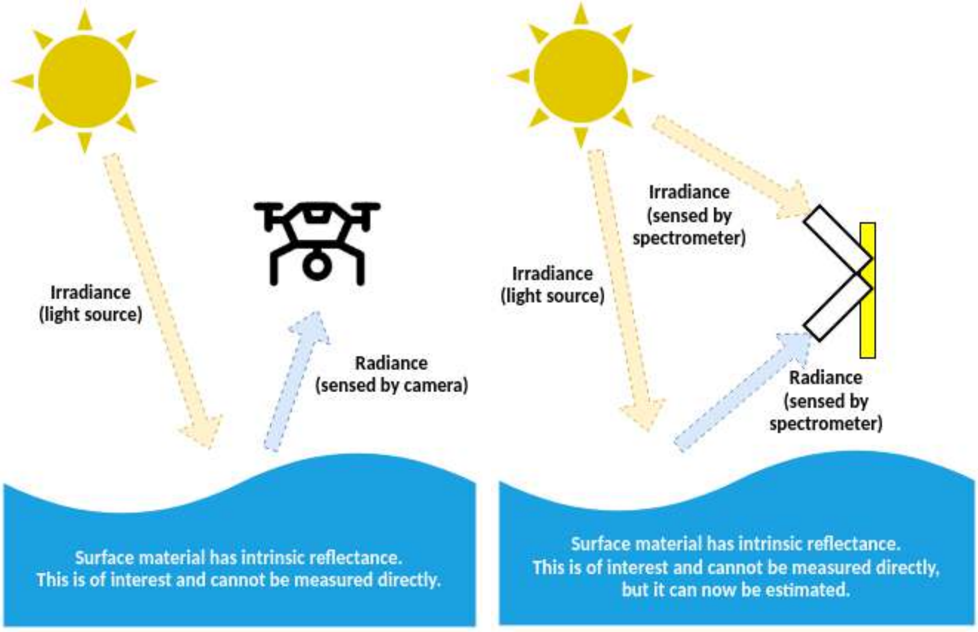


Figure 3: Relationship between reflectance, radiance, and downwelling irradiance in remote sensing. Reflectance is a key parameter for assessing chemical, physical, and biological properties of the target area, but not directly measurable. The airborne system measures radiance, influenced by both downwelling irradiance and target reflectance. Utilizing a spectrometer to quantify downwelling irradiance and concurrently measure target radiance enhances the precision of estimating target reflectance.

IV. FIELD TESTS

1. DESCRIPTION

1.1. Location

Field tests were conducted at NIVA's research station located in Solbergstrand, Norway (Figure 4). The field station is located along the edge of Oslofjord, so both coastal land masses (e.g., sandy beaches, rocky shoreline, etc.; Figure 4 and Figure 5) and coastal water masses were available for scenario testing. The test flights occurred on May 11th and 12th, 2023, coinciding with the calibration workshop.

Figure 4. NIVA Solbergstrand Research Station.

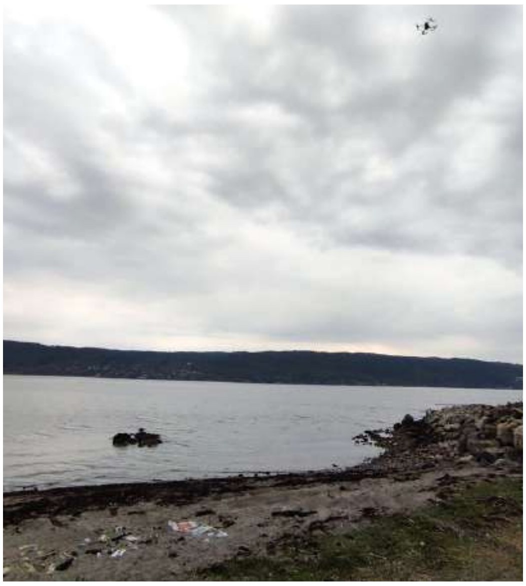


Figure 5. Beach where plastic litter was scattered. UAV is visible near the upper right corner of the image.

1.2. Platforms/Equipment

In this section, we provide visual documentation, including pictures of the UAVs (*UAV 1 – Hyperspectral imager* DJI Matrice 600 Pro*; UAV 2 – Multispectral imager* DJI Matrice 300 RTK*)* equipped with the spectral imagers (Figure 6 and Figure 7).

UAV 1 – Hyperspectral imager DJI Matrice 600 Pro

The Matrice 600 pro is a 1.5m multirotor UAV, capable of carrying up to 6kg, and flying up to 18 m.s-1 (Figure 8). Its high payload capacity allows us to deploy the hyperspectral camera, which weighs over 4kg with its gimbal. The M600 pro is powered by 6 batteries of 22.8V 5700mAh coupled by pairs to provide 46V to the motors. Its autonomy is 15min with its maximum payload and its maximum autonomy is ~30min. The MJI M600 Pro is mainly used to deploy the Specim AFX10.

The hyperspectral camera is a Specim AFX10m, a visible and near infrared (VNIR) hyperspectral imager (400 to 1000 nm with a 5.5 nm spectral resolution) with navigation system (GNSS) and an inertial measurement unit (IMU), included. It has a 1024 pixels resolution with a field of view of 38° which gives a swath of 72 m and a Ground Sample Distance (GSD) of 7 cm at 100 m high or 3.5 cm at 50 m. It has 512 spectral pixels, which gives a 5.5 nm spectral resolution.

Figure 6. UAV 1 – Hyperspectral imager: DJI Matrice 600 Pro, with Specim AFX10 Hyperspectral camera.

The AFX10 (MJI M600 Pro) acquisition is triggered internally by the Specim software configurable through ethernet connection via cable prior to deployment. During the deployments, the hyperspectral camera is turned on before the flight, recording at a set frequency and associating the frames with the IMU records for geolocation.

UAV 2 – Multispectral imager DJI Matrice 300 RTK

The DJI M300 RTK is a high performance reliable and versatile commercial multirotor UAV with up to 55min of flight (**Errore. L'origine riferimento non è stata trovata.**). It is approximately 1m*1m, has a maximum payload of 2.7 kg and is compatible with numerous models of gimbals. It also allows the use of up to 3 gimbals at the same time, one upward looking and 2 downward looking. The M300 is powered by 2 batteries of 46.2V and 5935mAh in parallel. The DJI Matrice 300 RTK is used to deploy the multispectral sensors. The multispectral sensors can also be combined with RGB, as the M300 had a double gimbal.

Figure 7. UAV 2 – Multispectral imager: DJI Matrice 300 RTK, with Micasense ALTUM PT.

DJI Matrice 300 RTK was deployed with a Micasense camera. It can be triggered in two different ways; using the camera's internal system, it can be set to automatically take shots at distance intervals specific to the altitude, based on overlapping of the images. A typical setup is 70-80% of overlapping forward and 60-70% sidewise for a good compromise between travel speed and data quality. Or it is also possible to trigger the cameras from the drone through the skyport, taking in account the camera's optics properties to calculate the overlapping. For external triggering, the Micasense cameras can be interfaced through three configurable general-purpose input/output (GPIO) pins.Instrument integration on the platforms has been comprehensively detailed in D5.4.

1.3. Deployment

The sensor and UAV deployment followed after critical integration validation activities and pre-deployment testing to ensure the seamless operation of the UAVs. Before the controlled scenario mission (final deployments), a comprehensive verification process was conducted by the UAV pilot to confirm that the onboard systems were functioning as intended. This check ensured that all systems were fully operational and prepared for the mission.

In compliance with aviation safety protocols, a Notice to Airmen (NOTAM) was issued 24 hours prior to the first BVLOS flight, which exceeded LOS parameters. Because we were collecting MSI data, notice was also provided to the Norwegian National Security Authority (NSM).

The UAVs were flown within a combination of line-of-sight (LOS) and beyond-visual-line-of-sight (BVLOS) scenarios, maintaining a distance from the pilot of under 2 km. To facilitate BVLOS operations, NIVA operated under the auspices of the umbrella parent company, Tiepoint AS.

Additional details can be found in D5.4 “Report on Integration of Payloads/Sensors on UAV”.

1.4. Case study - Simulated plastic litter on beach

For the present controlled scenario, here reported, for the purpose of data analysis we conducted an experiment involving the scattering of various polymers and types of plastic, such as bottles, caps, and bags, on a small beach at the research station. Subsequently, the two UAVs conducted flights over the area, capturing images for further analysis (Figure 5). This experiment, and its results, are described in the present deliverable however they will be described in more detail in WP9.

2. RESULTS

2.1. General Results

In total, this controlled scenario accomplished 29 flights (Figure 8). 16 flights were successfully conducted with the UAV carrying the hyperspectral instrument (*UAV 1;* Figure 6), and 13 flights were successfully conducted with the multispectral instrument (*UAV 2;* Figure 7 *and* Figure 9). The flights took place not only over a nearby beach with simulated plastic debris pollution (Figure 5), but also over NIVA's Field Research Station where an outdoor tank with experimental mixtures were prepared (Figure 9) and the coastal ocean water in Oslo fjord that was measured by NIVA's FerryBox and by manual sampling with the goal of performing experiments for D6.1 "Report on results and methodology of calibration/validation experiments performed in T6.1".

Figure 8. Flight path of some of the UAVs flights: line-of-sight (LOS) and beyond-visual-line-of-sight (BVLOS) scenarios.

As previously mentioned, all cameras (both multispectral and hyperspectral) store the collected data internally. The Micasense instruments save the data on their dedicated high-speed CF express type B compact flash memory card which can be read through a USB reader on a computer. On the AFX10, data is stored on internal memory. The data is to be downloaded via file transfer protocol (FTP) with a network cable (RJ45 connector).

All hyperspectral and multispectral camera data recovery was successful, and the estimated ground sampling distance and resolution fell within acceptable ranges. Target spectral resolution for all instruments was achieved as needed for subsequent ST6.1.2 activities (and reported in D5.4 and D6.1).

The achieved coverage met the requirements for the intended controlled scenario mission, and the sensor's payload burden and integration proved to be ready for the following mission in WP7.

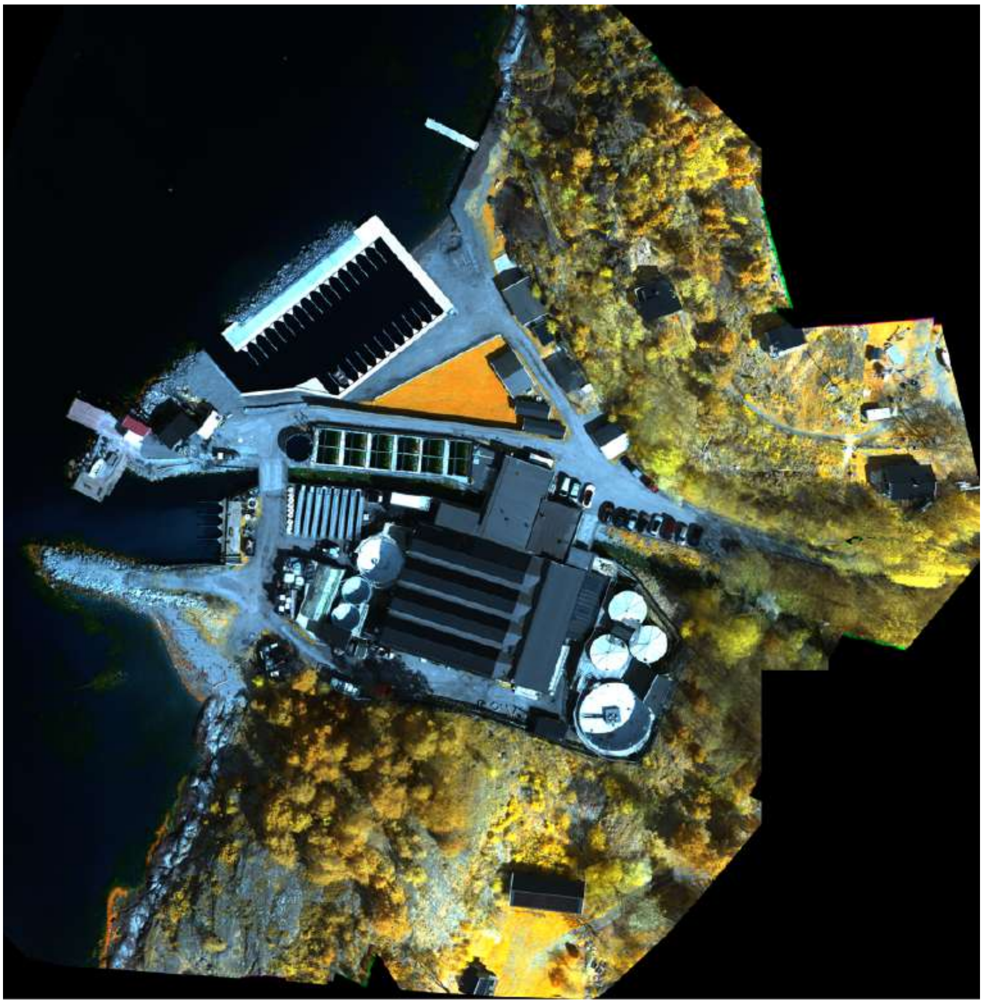
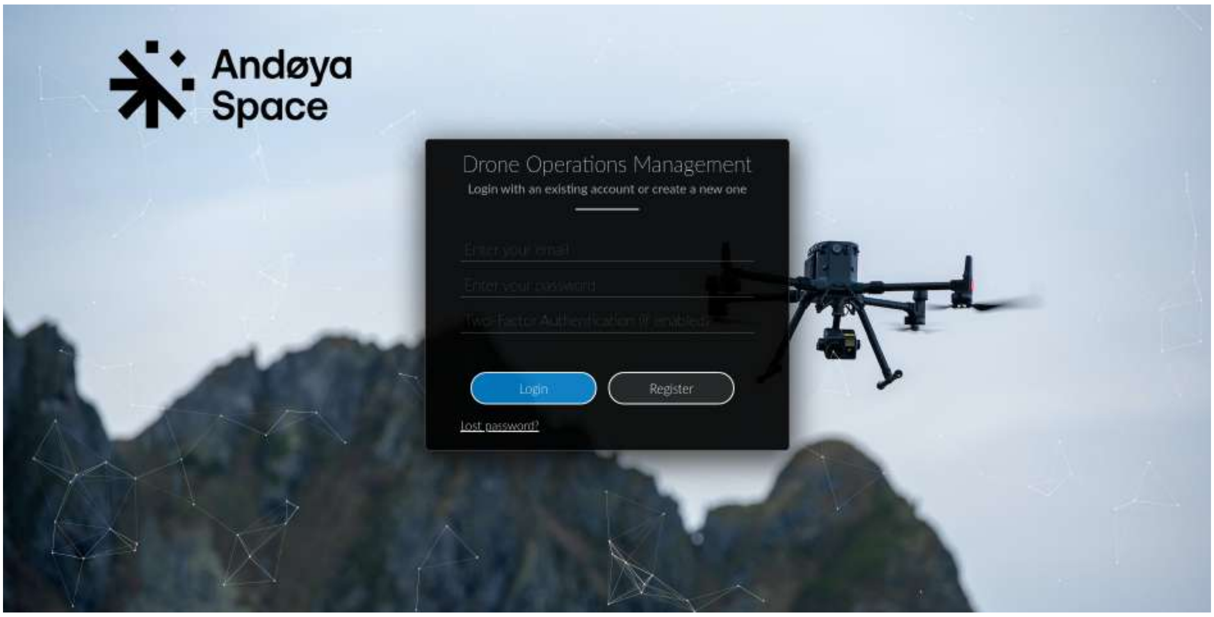


Figure 9. Multispectral image, Near Infrared - Red Edge - Red - Green - Blue map, 80m high above NIVA's marine research station at Solbergstrand, May 2023.

The mission was documented in dronelogbook.com (for NIVA) and https://andoyaspace.dronelogbook.com/ (for Tiepoint) (Figure 10). These log files are available upon request (considering files size, they are not reported as attachment) and include information for several variables: time, lat, long and alt (Figure 8).



Drone Operations Management

Login with an existing account or create a new one

Figure 10. Andoya Space webportal of the UAVs flights.

While data from flights over the beach with simulated plastic litter are described in the next chapter, the sensor data from flights over the outdoor tank and Oslo fjord are described in detail in D6.1 ”Reports on results and methodology of calibration/validation experiments performed in T6.1”.

2.2 Simulated plastic litter on beach – multispectral camera results

Data was collected with the UAV-Micasense Altum PT camera package (UAV 2) over a beach where plastic litter was placed. Flight altitude above ground level (AGL) was 80 m for the images that will be used for ocean colour, and 20 m for the plastic litter dataset collected over a beach next to the station. For the marine litter algorithm development (DFKI), high spatial resolution is needed for smaller objects detection. The ground sample distance (GSD) is ~3.5 cm at 80 m AGL, and ~0.8 cm at 20 m.

Ground reference points were taken with an Emild reach RS2 GPS to increase the positioning accuracy (Figure 11).

Figure 11. Ground reference point acquisition with high resolution GPS.

The overlapped images collected during the flight were then stitched together into a georeferenced map using the ground reference points through the Pix4D software (Figure 12).

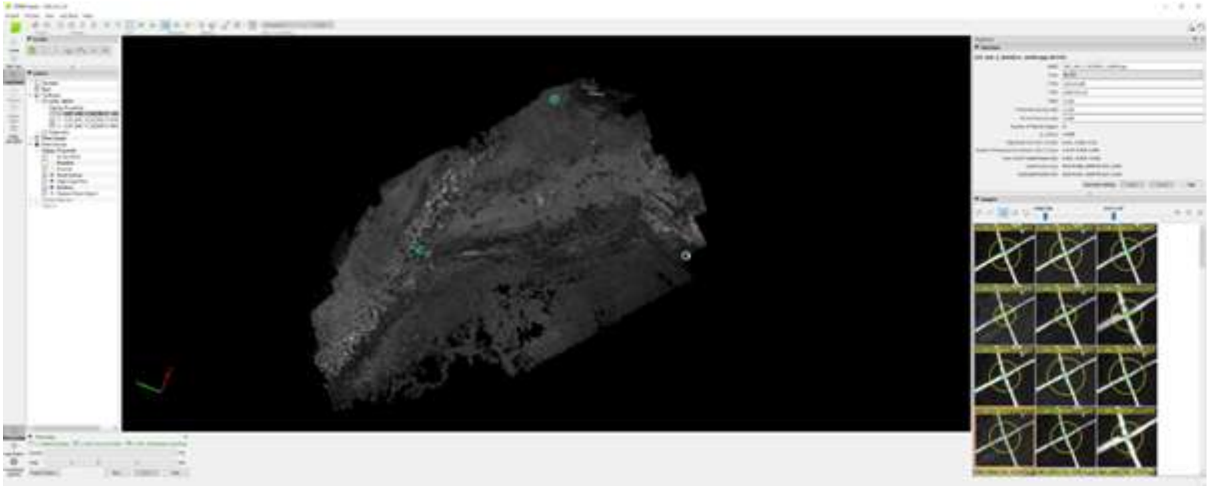


Figure 12. Pix4D software interface with reference points over the stitched images.

Pix4D also applies the manufacturer calibration and generates point clouds which are then used to create spatially accurate high resolution RGB or multispectral maps (Figure 13). These maps are known as orthomosaics.

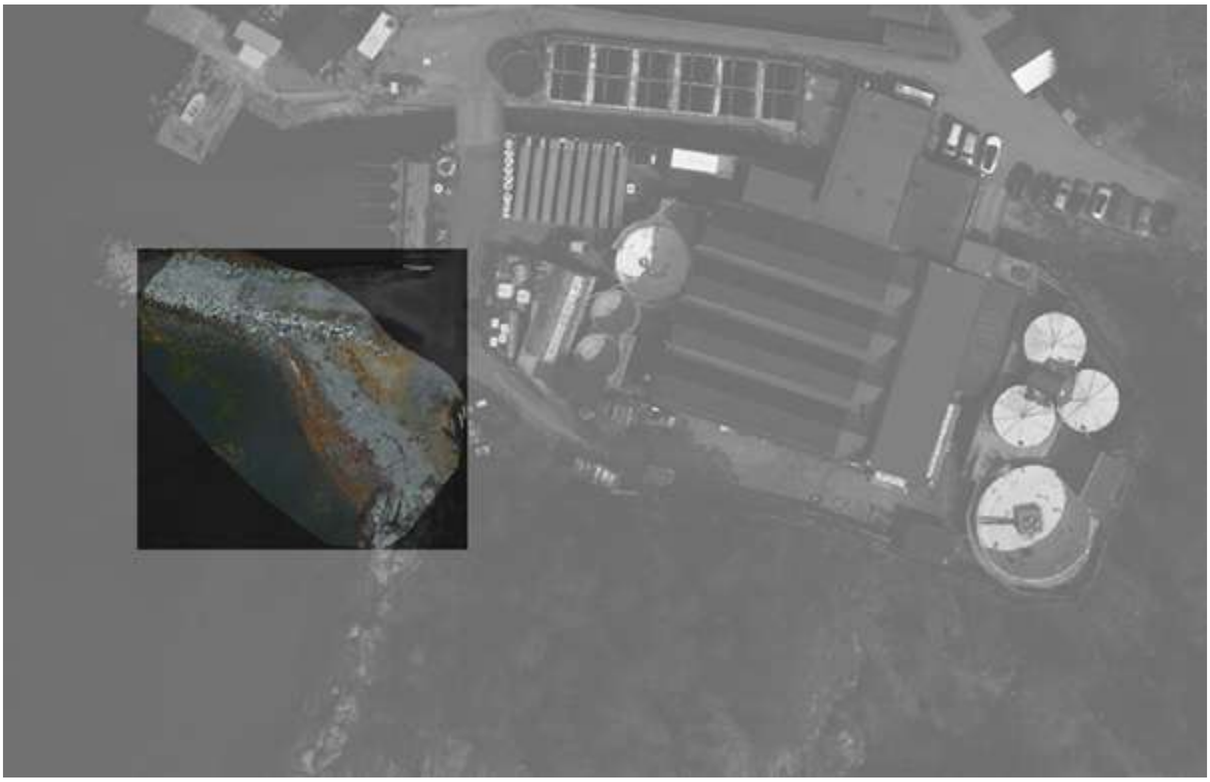


Figure 13. Composite image made out of data collected by the multispectral Altum PT camera: in grey levels, a band of the stitched images over NIVA's marine station, and in RGB the high spatial resolution data set of the plastic litter disposed on the beach next to the marine station.

The UAV flight paths sufficiently overlapped with reference points as evidenced by images that were successfully stitched together and geopositioned, generating high resolution maps for each of the six wavelength bands. For visualisation, combinations of RGB or other bands are generated, such as on Figure 14. When zooming in on Figure 15, we can see that the stitching of the images has been perfectly executed, with no gaps or shifts between the images, the scene is perfectly uniform. When zooming more into the false colour map (Figure 14), we can see that the spatial resolution allows recognition of the different types of litter (Figure 16).

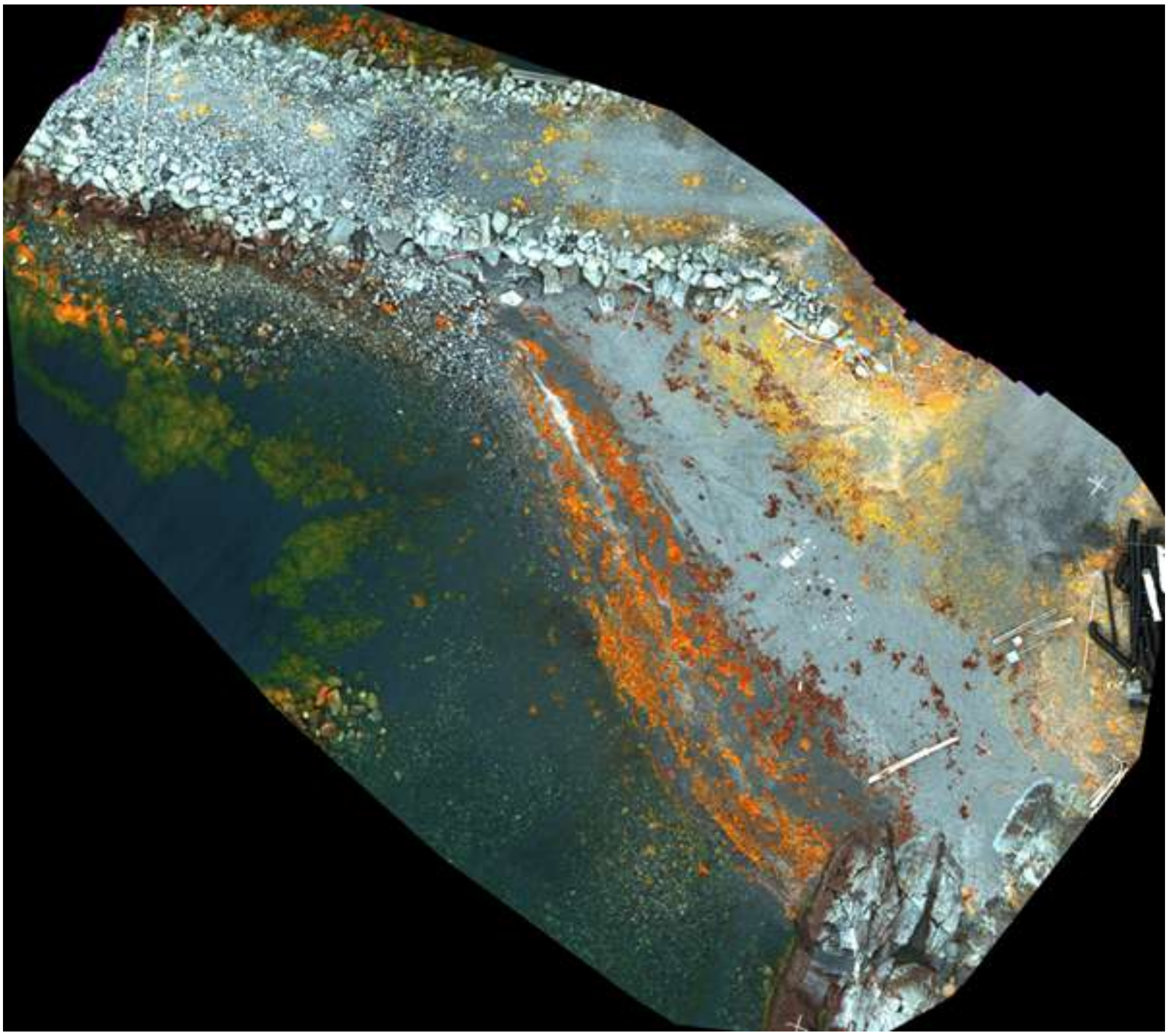


Figure 14. False colour Altum PT multispectral camera map over the beach with plastic litter.

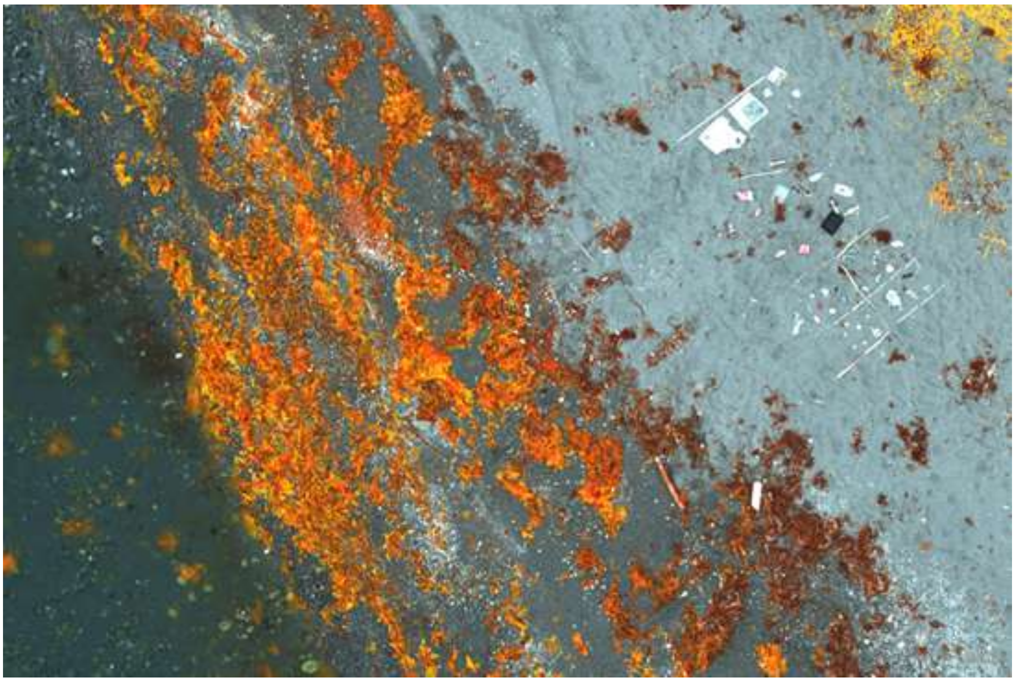


Figure 15: Zoom in Figure 14.

Figure 16. Zoom in Figure 15

Knowing the size of the marine litter samples placed on the beach, it is possible to verify the spatial resolution of the acquired images. For example, in Figure 17, the blue circled item is 10×10 cm, the green item is 2.5×2.5 cm, and the orange item is 1×1 cm. We can see that the 1×1 cm object is resolved with 3 pixels, minimum resolution in terms of object detection, meaning that the target spatial resolution <1 cm is achieved.

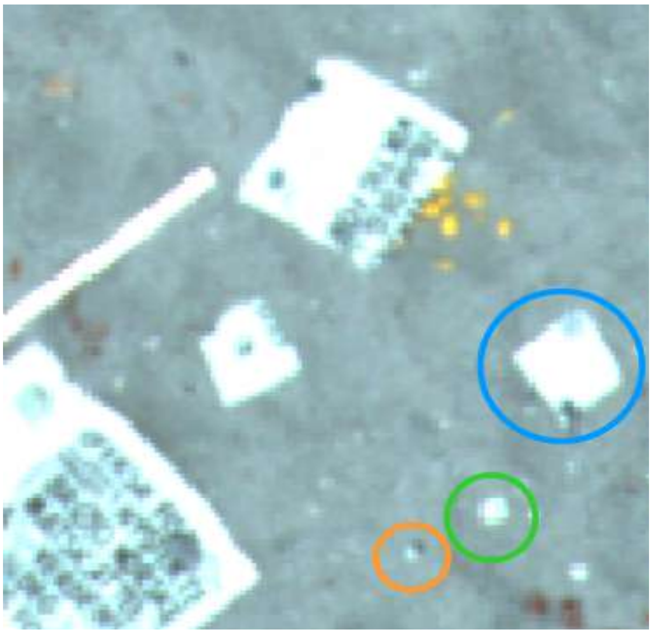


Figure 17. Zoom in Figure 16; the map into plastic litters of known size. The item circled in blue is 10×10 cm, the item circled in green is 2.5×2.5 cm, and the item circled in orange is 1×1 cm.

2.3 Simulated plastic litter on beach - hyperspectral camera results

The UAV-Specim AFX10 package (UAV 1 – Hyperspectral) was also successfully deployed over the beach where plastic litter was placed.

Hyperspectral data processing and analysis mainly plays a vital role in detection, identification, discrimination, and estimation of earth surface materials. One of the ultimate aims of hyperspectral data processing and analysis is to achieve high classification accuracy. The classification accuracy of hyperspectral data most probably depends upon image-derived endmembers. Ideally, an endmember is defined as a spectrally unique, idealized, and pure signature of a surface material. Accurate extraction of endmembers is a crucial step in hyperspectral data analysis, impacting the quality of subsequent processes and the overall accuracy of classification results. Researchers and practitioners continue to develop and refine techniques to improve endmember extraction methods and enhance the capabilities of hyperspectral data analysis (Chen et al, 2020).

Using the Deep Endmember Hierarchy technique, the images were partitioned into constituent spectra. A set of endmembers was calculated over the smaller region, zooming in on the plastic to extract plastic litter spectra (Figure 18; Figure 19).

Figure 18. Left: AFX10 hyperspectral camera RGB image over the beach (bright white object if the reference target).

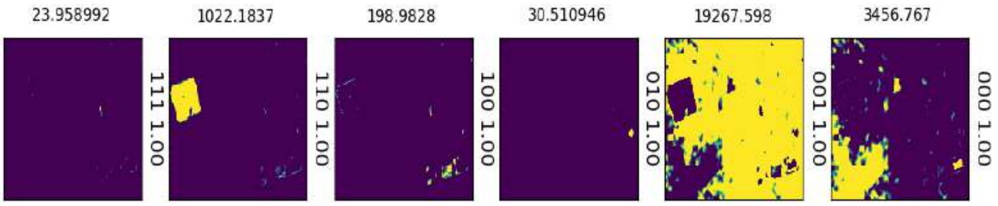


Figure 19: Partitioned scene from Figure 18.

SUMMARY

The present deliverable reports all controlled scenario activities: integration validation and calibration flights. These efforts were dedicated to ensuring the seamless operation of the NIVA’s UAV platforms for the acquisition of both multi- and hyperspectral data.

Twenty-nine flights were conducted in the field area of the NIVA's research station located in Solbergstrand, Norway. Flights were successfully performed over coastal land areas and coastal water masses with UAV-hyperspectral camera and UAV-multispectral camera packages. The scenario testing confirmed that UAV-camera packages were able to fly with the additional payloads and natural flying conditions. The planned flight paths were sufficiently followed to enable stitching of images to provide a coherent and consistent view of the areas of interest. A test scenario of simulated plastic litter of different sizes placed on a nearby beach confirmed that the UAV-camera packages were able to capture images with image spatial resolution of <1 cm and spectral patterns from different polymer types was discernible, as expected.

Following the scenario testing of the UAV-camera packages, further calibration/validation tests with the hyperspectral and multispectral cameras will be performed WP6 and WP9, and reported in D6.1, providing further insights and outcomes to better prepare the UAV-camera package for WP7 T7.2 demonstrations.

APPENDIX: REFERENCES AND RELATED DOCUMENTS

Chen, J., Song, Y., & Li, H. (Eds.). (2020). Processing and Analysis of Hyperspectral Data. IntechOpen. doi: 10.5772/intechopen.78179

ID	Reference or Related Document	Source or Link/Location
D5.4	Report on integration of payloads/sensors on UAV	**NAUTILOS Team GDrive**
D6.1	Report on results and methodology of calibration/validation experiments performed in T6.1	**NAUTILOS Team GDrive**
D3.3	Downward looking sensors laboratory tests	**NAUTILOS Team GDrive**