MapEO Flight Procedures - MSP

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About this document

This document lists the drone data acquisition standards for MapEO phenotyping missions. It contains the details of the equipment to use and the operations to perform before, during and after the drone flights.
This document is part of the 'MapEO Academy procedures', a series of operational procedures to enable our clients and partners to take full control of their drone-based phenotyping work and to ensure a smooth transition into their operations.

Symbols

The warning symbol appears in this document, urging the user to pay more attention to any actions or checks.

References

MapEO reference documents are listed in Table 1

RD1	MapEO Academy - Phenotyping - flight procedures RGB
RD2	MapEO Academy - GCP measurement procedures
RD3	MapEO Academy - Phenotyping - product overview
RD4	MapEO Academy - Phenotyping - product ordering procedures
RD5	MapEO Academy - Phenotyping – data analysis procedures

Table 1: MapEO reference documents

Document change record

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LIST OF ABBREVIATIONS

FOV   Field Of View
GCP   Ground Control Point
GSD   Ground Sampling Distance
KML   Keyhole Markup Language
ROI   Region Of Interest
UAS   Unmanned Aerial System

1.   INTRODUCTION

1.1   What is MapEO?

MapEO is a drone-based high-throughput phenotyping solution for research and breeding. Our online platform gives **plant breeders, researchers and agricultural site managers** a more complete and objective view on experimental field trials of any size: https://mapeo.vito.be/en

1.2   What is phenotyping?

Plant phenotyping is the study of plants in outdoor field experiments. Small patches (plots) of plants are sowed in regular gridded patterns and studied for many traits like emergence, height, flowering, disease, senescence and yield. With drones we fly over these fields and assist in measuring these traits with Imaging techniques. Although such an experimental field may look like an ordinary agricultural field, every Inch Is closely managed and monitored. That Is why at NO circumstances a drone pilot Is allowed on field without proper instruction of the local site manager. This site manager will Indicate where to and where not to walk as we want to avoid stepping on experimental plant material on any time. More: https://emphasis.plant-phenotyping.eu/Plant_Phenotyping

1.3   What is the MapEO Academy?

The MapEO Academy aims at providing a series of operational procedures to enable companies to take full control of their drone-based phenotyping work and to ensure a smooth transition into their operations.
Procedures are classified into different 'modules', dedicated to specific activities and roles, as shown in Table 2.

Module	Document	Who
Phenotyping products	MapEO Academy - Phenotyping - product overview	Coordinator
Ordering procedure	In preparation	Coordinator
GCP measurement	MapEO Academy - GCP measurement procedures	Surveyor & Site Manager
Flight procedures and quality check	MapEO Academy - Phenotyping - flight procedures RGB MapEO Academy - Phenotyping - flight procedures MSP	Pilot
Data analytics	In preparation	Data analyst

Table 2: MapEO Academy documents

2. ROLES AND ACTIVITIES

2.1 In general

The following roles/activities have been identified for the partners in general:

VITO: Main contractor responsible to deliver end products and Image analytics to the customer. Provides drone mission details and procedures towards the drone Pilot and or drone coordinator.

Project Coordinator: Project responsible at the customer side. Orders new drone products at the MAPEO platform

Drone Coordinator: Day-to-day management of drone (UAS) operations and legal registration of drone (UAS) operations and insurance. Provides the drone mission details to the pilot and manage the day-to-day planning with communication from both the drone operator/surveyor and site managers.

Pilot: Performs the drone missions and communicates with Drone coordinator & local site manager on exact timing of the operation.

Surveyor: Places and measures Ground Control Points In the field and sends these measurements to VITO

Site manager: A site manager Is responsible of the experimental field. He/She can define the exact location of the field, GCPs and potentially access points to the field. This site manager can be employed by the customer itself or from a third-party organization but should always be contacted prior to any visit to the field visit (surveying or drone flight).

2.2 Pilot specific

2.2.1 Specific role of the pilot

- The Pilot collects (from the drone coordinator) all info needed to perform the flights in accordance with the required mission specifications.
- The Pilot selects the proper equipment for the flight and makes sure that it is ready to use as described in section 3.1 "General equipment requirements".
- The Pilot prepares the flight in accordance with the instructions as listed in section 4 "Flight preparation".
- The Pilot conducts the flight in accordance with the flight Instructions as listed in section 5 "Flight".
- The Pilot performs a quality check on the acquired data, as described in section 6.1 "At the field".
- The Pilot uploads the acquired data to MapEO, as described in section 6.2 "At the office".

2.2.2 Specific deliverables of the pilot

The aerial data collected on site will be provided to VITO at the end of each single operation and uploaded by the pilot to the MapEO platform, **provided that the acquired dataset meets the quality requirements (cfr section 6.1.1)!**

Minimal quality level of the Aerial Data:

QC (tick)	Data to be checked
	Weather during the flight was according to the instructions
	Drone and camera used for the flight are listed in section 3.2 and 3.3 of this manual
	3 calibration images are taken before and after each flight
	The Region Of Interest (ROI) is fully covered with no data gaps
	The flight path has been aligned to fly along the longest axis of the field (Figure 1)
	2 additional flight lines have been acquired outside the boundary area, to ensure enough sideward overlap within the ROI (Figure 2)
	All flight lines have been extended beyond the boundary area with 2 additional image acquisition points to ensure enough forward overlap within the ROI (Figure 2)
	The overlap is in line with the expectations
	The image resolution or Ground Sampling Distance (GSD) is according to specifications
	All images are geotagged
	Image quality (in-focus, no blur, not corrupted, taken with highest resolution)

Table 3: Minimal quality checks of the aerial data

Flight lines - Always along the longest axis of the field

Figure 1: Flight lines - alignment

Flight lines
- **margin of 2 additional flight lines (sideward)**
- **margin of 2 additional image acquisition points (forward)**

outside the region boundary

Figure 2: Flight lines - margins

2.2.3 Specific timings for the pilot

Timing	Action
X-minimum 48h	The Pilot checks the weather conditions and informs the Drone Coordinator and site manager about the provisional flight date.
X-minimum 24h	The Pilot prepares the flights and makes practical arrangements with the site manager on site access.
X	The Pilot performs the flight. Upon successful data acquisition, the Pilot performs a data quality check using the MapEO Field Software tool, as explained in section 6.1 "At the field". If the flight cannot be performed during the planned time range, it may be rescheduled.
X + maximum 8h	When data acquisition was successful and data quality is adequate, the Pilot notifies the Drone Coordinator that the flight has been executed.
X + maximum 24h	The Pilot uploads the acquired drone data to the MapEO platform.

Table 4: Specific timings for the pilot

3. EQUIPMENT DETAILS

3.1 General equipment requirements

When selecting the platform/sensor combination, the pilot should carefully check the received **mission specifications**, which are a combination of required sensor and required data resolution.

For MSP missions this can be:

- MSP-**10**-1: MSP sensor with **1cm** resolution

- MSP-**20**-1: MSP sensor with **2cm** resolution

- MSP-**30**-1: MSP sensor with **3cm** resolution

- MSP-**50**-1 MSP sensor with **5cm** resolution

- MSP-**100**-1: MSP sensor with **10cm** resolution

More details on supported platform/sensor combinations for each of these drone mission specs are provided in section 3.3 "Cameras".

The equipment used for the drone flights must be in accordance with the information the pilot has communicated at the time of the flight planning.

Before performing the drone flights, the pilot will ensure that:
- the drone and associated equipment have the latest firmware available
- all the equipment (IMU, compass, etc.) has been properly calibrated before each flight

3.2   Drones

Following table lists all drones which can be used for the **multi-spectral** flight. In case you would need to fly another drone please contact your drone coordinator and VITO contact person.

Drone	Specs	Picture
Inspire 1	Max Weight: 3060g Flight time: 15min RTK: No Camera: X4S, X5s, XT, XT2, Micasense	
M200/M210	Max Weight: 6kg Flight time: 20min RTK: No Camera: X4S, X5s, XT, XT2, Micasense Software: DJI GS PRO	
M300	Max Weight:9kg Flight time: 55min RTK: Yes Camera: P1,XT2, Micasense	
M600	Max Weight:15kg Flight time: 15min RTK: No Camera: X4S, X5s, XT, XT2, Micasense	

Table 5: supported drones

3.3   Cameras

Following table lists all cameras which can be used for the **multi-spectral** missions. In case you would need to use another camera please contact your drone coordinator and VITO contact person.

Note that the Horizontal Field of View (HFOV) mentioned is the across-track viewing angle, which is depending on the lens focal length.

Camera	Specs	Flight height and acceptable drone mission specs	Picture
MicaSense RedEdge-M	Resolution: 1.2MP HFOV: 47° Bands: Blue, Green, Red, Rededge, NIR	70m - MSP-50-1 45m - MSP-30-1 30m - MSP-20-1	
MicaSense RedEdge-MX or MicaSense-P	Resolution: 1.2MP HFOV: 47° Bands: Blue, Green, Red, Rededge, NIR	70m - MSP-50-1 45m - MSP-30-1 30m - MSP-20-1	
MicaSense Altum or MicaSense Altum-PT	Resolution: 3.2MP HFOV: 47° Bands: Blue, Green, Red, Rededge, NIR, TIR	150m - MSP-50-1 60m - MSP-30-1 60m - MSP-20-1 30m - MSP-10-1	

Table 6: supported MSP cameras

3.4 Software applications

3.4.1 Flight Software

Following table lists all flight software applications which can be used for the **multi-spectral** missions. In case you would need to use another application please contact your VITO contact person.

Application name	website	OS
DJI GS Pro	https://www.dji.com/be/ground-station-pro	IOS
Pix4D capture	https://www.pix4d.com/product/pix4dcapture	IOS & android
UGCS **(*)**	https://www.ugcs.com/	IOS & android + desktops
DJI pilot (2) **(*) (**)**	https://www.dji.com/be/downloads/djiapp/dji-pilot	IOS & android

Table 7: supported flight software applications

(*) These apps allow flight lines with a constant height above a digital terrain model layer that can be imported, which is recommended when working in hilly areas.
(**) Terrain following is only possible in DJI Pilot (2) for the DJI M300.

Instructions on how to use specific flight applications for the MicaSense camera can be found here:

- **https://support.micasense.com/hc/en-us/articles/360010377894-Using-Pix4Dcapture-with-MicaSense-Sensors**
- **https://support.micasense.com/hc/en-us/articles/360009279853-MicaSense-Sensor-parameters-for-DJI-GS-Pro**
- **https://support.micasense.com/hc/en-us/sections/115000477347-Documentation**
- **https://support.micasense.com/hc/en-us/articles/360023136753-DJI-Pilot-and-MicaSense-Sensors**

3.4.2 MapEO Field Software

> **The MapEO Field Software comes with a detailed User Manual and a concise Quick Start guide. Please have a thorough review of the manual before going to the field to ensure proper use.**

The MapEO field software tool is used to check if drone data acquired meets the quality requirement for further uploading and processing in the MapEO processing platform.
The verification step is conducted in the field just after the drone mission and analyses data quality and coverage/completeness. More details on this assessment using the field software are provided in section 6.1.1 "Data quality checking".

Data upload can be carried out back in the office once internet connection is available, as described in section 6.2 "At the office".

The jar-file to install the MAPEO Field Software can be downloaded here:
https://remotesensing.vito.be/software/uav-pc/fieldsoftware/MAPEO-Field-Software.jar

The quick start guide to get you up and running can be downloaded here:
https://remotesensing.vito.be/software/uav-pc/documentation/generic/MapEO_field_software_Quick_Start_Guide.pdf

The detailed software user manual can be downloaded here:
https://remotesensing.vito.be/software/uav-pc/documentation/generic/MAPEO_field_software_manual.pdf

> The account to access the MapEO field software tool can be obtained from your coordinator.
> First time login requires **Internet connection**, check this before going into the field!
>
> In case you are performing drone flights for different MapEO customers, note that there will be a separate account for each of these customers!

4. FLIGHT PREPARATION

4.1 Flight preparation steps

During flight preparation the pilot prepares the equipment and communicates towards the site manager to ensure a smooth flight operation.

Following steps need to be followed when a drone flight is confirmed:
- Check the weather conditions and communicate to the Coordinator the provisional flight date, which is the date when the Pilot can perform the drone flight (if the conditions don't change).
- Verify whether any permissions are required for performing the drone flight, and in case of temporarily active military geo-zones, verify when flights can be performed.
- Verify whether all permissions for the drone mission have been obtained.
- Verify whether the drones and associated equipment needed for the drone mission is ready for the flight.

Following steps need to be followed at least 24 hours before each drone mission:
- Check the mission KML file which defines the area to be flown. In case it was not provided by the drone coordinator, you can download it using the MapEO field software (see note below).
- Check the elevation profile of the site. If the area is hilly perform the flight preparation with a suitable application which has a follow-terrain mode. Elevation differences can be spotted by overlaying the mission KML file on google earth.
  Following table can be used as a guideline to decide whether or not to use the follow-terrain mode:

Pixel resolution	Max. terrain elevation difference
1 cm	2.5 m
2 cm	5 m
3 cm	7.5 m
5 cm	12.5 m
10 cm	

Table 8: pixel resolution vs max terrain elevation difference

- Prepare the inspection in DJI Pilot, GSPro and/or any other recommended application specified in Section 3.4.1 "Flight Software". Specific details on settings for DJI GSPro and DJI Pilot are specified in section 4.4 "Flight software settings."
- Check if the flight plan can be uploaded to your drone and the drone can be armed for take-off : depending on the drone type and flight planning/control app, there may be significant limits on the number of waypoints that can be uploaded at once. If you receive a warning that the waypoint limit will be exceeded, the region of interest needs to be split in multiple zones
- Install the MicaSense camera on your drone, as described in section 4.2 "Mounting the MicaSense camera on the drone"
- Ensure the camera is properly configured for the flights, as described in section 4.3 "Configuring the MicaSense camera"
- Ensure that enough batteries are ready for use based on the planned flight time.

- Ensure all necessary safety equipment is available for the drone flights
- Account for any known obstacles onsite and plan the flights accordingly to ensure the full coverage of the zone ordered.
- Call the site manager to arrange the meet-up on-site. In case planning is changed (weather/no-go from site manager), notify the Coordinator and wait for confirmation for postponing the flight.

IMPORTANT NOTE (1) on accessing the correct KML file for mission preparation

The correct mission boundary files are stored on the MapEO servers and synchronized with the Pilot MapEO Field Software as soon as you sign in and are connected to the internet. It can be accessed on PC by typing in your windows explorer:
"%appdata%/Mapeo Field Software"

4.2 Mounting the MicaSense camera on the drone

A general user guide for MicaSense sensors is given here:
https://support.micasense.com/hc/en-us/articles/360039671254-User-Guide-for-MicaSense-Sensors

A detailed description of the cameras and integration possibilities are given here:
https://support.micasense.com/hc/en-us/articles/115003537673-RedEdge-M-User-Manual-PDF-

https://support.micasense.com/hc/en-us/articles/360011389334-RedEdge-MX-Integration-Guide

https://support.micasense.com/hc/en-us/articles/4419868608407-Altum-PT-Integration-Guide

Note that for each of the MicaSense cameras, a choice can be made between a quick mount kit and a DJI Skyport mount (Skyport vs Quick Mount Kit – MicaSense Knowledge Base). The extra cost of the DJI Skyport mount brings the availability of communication with the drone through the Payload SDK (PSDK) protocol, which allows, among other things, the camera to be triggered by the autopilot, thereby eliminating the need to set the triggering through the MicaSense app (see section 4.3 "Configuring the MicaSense camera").

For INSPIRE 1:

• Convert the drone out of travel mode to upward position and shut it down

• Securely attach the Micasense camera to the drone using the DJI quick mount

• Place the GPS and light sensor by unscrewing the two silver screws on the drone

• Insert the wifi dongle and a formatted SD card in the camera. (use the SD card which comes with the camera. If you are using another SD card, make sure that cardformat is FAT32)

• Plug in the cable coming from the GPS/DLS (be careful with the cables)

• Check all cables and solid attachment of the camera **doublechecking the 5° forward angle** of the camera.

• Turn on the drone and check if the blue LED of the micasense gps is lighting.

Figure 3: Mounting a MicaSense camera on an Inspire1 drone

For M200 series: https://www.youtube.com/watch?v=inYJOEjhKXQ

For M300 series: https://www.youtube.com/watch?v=inYJOEjhKXQ

4.3   Configuring the MicaSense camera

After Installing the camera on the drone and before going to the field, the flight altitude of your next mission should be properly configured.

- Power on the drone and ensure that camera is powered as well
- Insert WIFI dongle on the camera
- Connect to the camera using WIFI via your ipad or phone
- Go to following page in your browser 192.168.10.254
- Only in case you are using the Quick Mount kit, set the following camera capture configuration (settings tab):
  - o **Auto-capture mode: overlap**
  - o **Target altitude: Set mission altitude in meter**
  - o **Along-track Overlap: 80%**
  - o **Check the GPS status: Green blinking line in the GPS**
- **Image format should be TIF (default)**
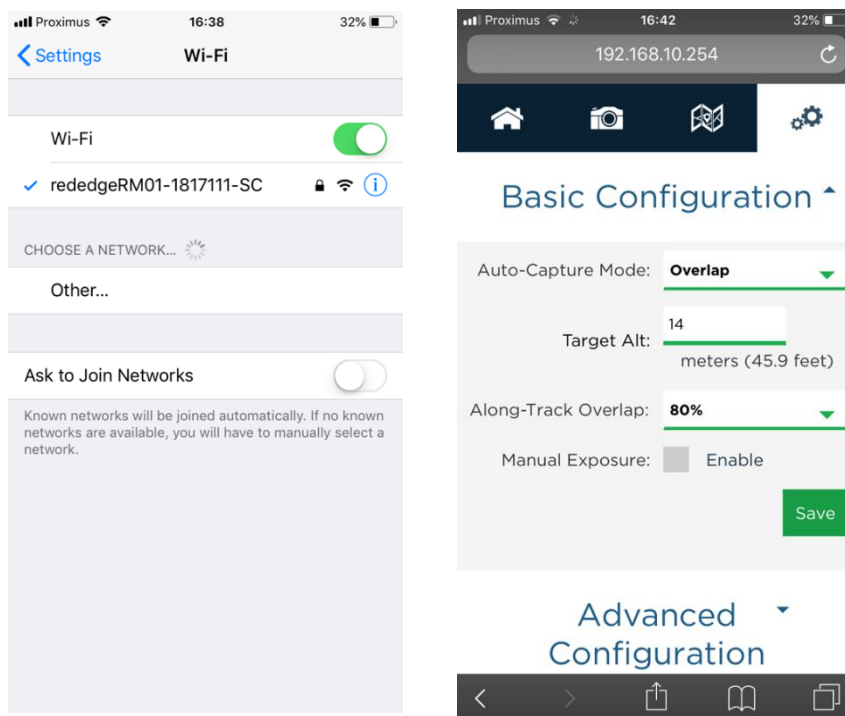

Figure 4: Configuring the MicaSense camera

IMPORTANT NOTE (2) on the magnetic calibration of the MicaSense cameras

If this is your first flight with the camera, perform the magnetometer calibration, as explained in this video:

https://support.micasense.com/hc/en-us/articles/115001432308-DLS-Integration-Guide-Magnetometer-Calibration

Check the results of the calibration using the included compass.
Max deviation should not be larger than 5°

4.4   Flight software settings

Plant Phenotyping MSP - DJI GSPRO

<table>
<tr><td rowspan="2"></td><td colspan="2">Data Product</td><td>Plant Phenotyping (MSP)</td></tr>
<tr><td colspan="2">Flight Type</td><td>MSP</td></tr>
<tr><td rowspan="13">GSPro settings</td><td>General</td><td>Product Type</td><td>3D Map Area</td></tr>
<tr><td rowspan="4">Basic parameters</td><td>Shooting angle</td><td>Parallel to main path</td></tr>
<tr><td>Capture mode</td><td>Capture at Equal Distance Interval</td></tr>
<tr><td>Flight course mode</td><td>Scan Mode</td></tr>
<tr><td>Resolution</td><td>1cm/px; 2 cm/px; 3cm/px or 5cm/px</td></tr>
<tr><td rowspan="8">Advanced parameters</td><td>Front overlap</td><td>80</td></tr>
<tr><td>Side overlap</td><td>80</td></tr>
<tr><td>Gimbal pitch</td><td>-90 (nadir)</td></tr>
<tr><td>Course Angle</td><td>Use the Course Angle to align the flight path to fly along the longest axis of the field</td></tr>
<tr><td>Margin</td><td>Adjust such that the flight path Is at least 2 flight lines outside the boundaries in all directions</td></tr>
<tr><td>Flight lines</td><td>Area should be completely covered and extended with at least 2 flight lines at each side. This because we should at least have pictures of all **GCPs** from all directions! Along the longest axis of the field!</td></tr>
<tr><td>Timing & cloud cover</td><td>From 10am - 4pm
No cloud cover restrictions</td></tr>
<tr><td>Example</td><td>
Overcast: OK   Blue sky: OK   Changing light- NOT OK
Check predicted weather conditions. The above weather and timing limitations should be taken into account depending on the product type.</td></tr>
</table>

Table 9: Typical DJI GSPRO settings for plant phenotyping MSP flights

Plant Phenotyping MSP - DJI Pilot

			Data Product	Plant Phenotyping (MSP)
			Flight Type	**MSP**
DJI Polit settings		General	Mission Type	Mapping
	Basic parameters		Smart Oblique	OFF
			Altitude mode	Relative to take-off point (ALT)
			Target Surface to Take-off	Set elevation difference between take-off and elevation at ROI
			GSD	1cm/px; 2 cm/px; 3cm/px or 5cm/px
			Take-off Speed	Default
	Advanced parameters		Front overlap	80
			Side overlap	80
			Course Angle	Use the Course Angle to align the flight path as such to fly along the longest axis of the field
			Margin	Adjust such that the flight path Is at least 2 flight lines outside the boundaries in all directions
			Photo Mode	Trigger on Distance
			Focus Mode	First Waypoint Autofocus
			Dewarping	OFF
			Flight lines	Area should be completely covered and extended with at least 2 flight lines at each side. This because we should at least have pictures of all **GCPs** from all directions! Along the longest axis of the field!
			Timing & cloud cover	From 10am - 4pm No cloud cover restrictions

Example	
	Overcast: OK Blue sky: OK Changing light- NOT OK Check predicted weather conditions. The above weather and timing limitations should be taken into account depending on the product type.

Table 10: Typical DJI Pilot settings for plant phenotyping MSP flights

5.   FLIGHT

5.1   General

- The drone flight is conducted following the highest quality standards as is expected from a professional pilot.
- The pilot completes the flight of the entire area **without breaks longer than 30 minutes**. In case there is a need for a longer break, the pilot shall repeat the flight of the entire area.

5.2   Weather and light conditions

The ideal conditions for multispectral data capture are a **clear sunny day** or **an overcast day with uniform cloud coverage**. In both cases, the lighting is consistent.

The most difficult lighting conditions to work with are partially cloudy days with sharp transitions from shadow to sun. These kinds of conditions will most likely produce anomalies in the multispectral data. These anomalies negatively affect the composites and vegetation indices generated from the dataset, rendering the data sub-optimal in many cases.

5.3   Re-planning a flight

In case the planning is changed (e.g. due to bad weather or no-go from the site manager), notify your coordinator and site manager and wait for confirmation to postpone the flight.

5.4   Upon arrival at the site

The pilot meets with the site manager and:
- Prepares the drone for the flight, checks the prepared flight parameters and adapt camera settings to light conditions, flight characteristics and camera specifications to get sharp images.
- Takes 3 pictures of the calibration target, see the Important Note below
- Finds a suitable take off area, checks weather conditions and flies the mission.
- Immediately after landing, takes 3 calibration pictures again.
- Turn off camera by pressing the shutter button for 3 seconds before turning off the drone!! (Not doing so can corrupt the SD card as the camera is constantly writing a log file on it)

IMPORTANT NOTES (3) on flying the RedEdge-M(X) & Altum camera's:

Before taking off and immediately after landing, take 3 pictures of the calibration target in automatic panel detection mode as explained in this video:
https://www.youtube.com/watch?v=3ODSGnf1Iwg

Pay attention to the position of your drone/panel relatively to the sun:

Make sure the drone/camera is positioned such that the full calibration target is imaged:

If this automatic panel detection does not work, please update the camera firmware to the latest version. If this still is not working, you can capture the calibration images manually (Check for blue LED on MicaSense when taking these pictures)
Notify MicaSense support to report this issue!

6. POST-FLIGHT

6.1 At the field

After completing the drone flight, the pilot will:

- Copy all the data on the laptop and ensure all the pictures are well organized on the computer, i.e. per customer, location and date, and that possible duplicate file name issues are solved. Instructions on how to organize/name the acquired drone data files and how to handle duplicate file names are provided in the MapEO field software user manual. The download link for this user manual is provided in section 3.4.2 "MapEO Field Software"
- Open the MapEO field software, select the correct mission and camera type, and check that all data collected is satisfying the quality and completeness criteria, as described in section 6.1.1 "Data quality checking".
- Inform the Coordinator about completing the drone mission.

In case there is an issue with the data collected, the COMPLETE ARE NEEDS TO BE RE-FLOWN, not only the problematic line or area!

6.1.1 Data quality checking

The pilot will use the MapEO field software tool to check if the acquired drone data meets the quality requirements for further uploading and processing in the MapEO platform.

The field software quick start guide provides a brief description of the different steps in this quality check, full details can be found in the user manual. The download link for both documents is provided in section 3.4.2 "MapEO Field Software".

This is a summary of the different steps in the quality check:
- Open the tool, login with the provided user account and select "New" to start the quality check of the new mission
- Select the proper drone Mission ID of your flight, choose your camera type and verify the locations ROI and GCP info
- Add image data from the local drive containing the drone Image data and verify image quality
- Select start and stop position of the mission and verify images selected for upload
- Verify the availability and quality of the calibration images
- Verify image overlap
- Verify mission metadata
- Verify overall drone mission quality
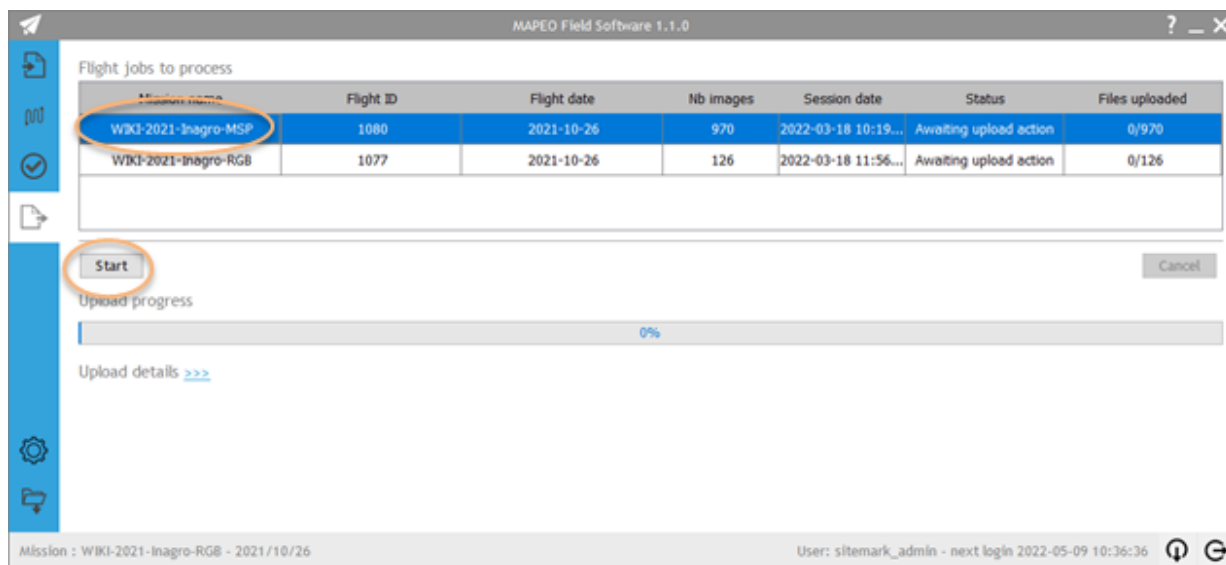
6.2   At the office

Upon arrival at the office the Pilot shall:

- Open the MapEO field software and **Upload** the data and flight log on the MapEO platform.
  Mission upload can be conducted by clicking the last tab "mission upload"
  The upload can be started by clicking the "Start" button. It can take some seconds before the actual upload is starting, the progress can be followed in the "upload details" screen.

Leave the application open and do not shut down the PC before the upload is finished!

- Verify that upload Is completed

The end