Test and Verification Campaign Report
EASY-AAL-D9.1

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DOCUMENT STATUS SHEET

EDIZ.	DATE	§ - CHANGES	AUTHOR
1.0	30/06/2017	Issue 1.0	Bilal Muhammad
2.0	30/10/2017	Added procedures (section 4) and test report to desribe performance tests (section 5). Sections 6 (DVCM) and 7 (conclusions) have been updated accordingly	Bilal Muhammad Marco Nisi, Fabio Menichetti, Alberto Mennella, Graziano Gagliarde
2.1	05/01/2018	Modified Section 5.10 (to be modified) TEST.0070 to inlude justification about success criteria failure and to include a new step to succesfully pass the test using a more performing configuration. Update of Section 7 (Conclusions)	Bilal Muhammad Marco Nisi Alberto Mennella,

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1 INTRODUCTION

1.1 SCOPE

This document represents the test and verification campaign report and aims to describe main outcomes coming from test activities performed on the target EASY-PV system. It is noteworthy that some preliminary tests are also performed in [RD 3], where demonstration equipment are used instead of the final EASY-PV (RPAS + service centre) platforms to anticipate some results and provide the confidence on expected performances.

All activities are documented according to the strategy reported in [RD 2].

1.2 APPLICABLE DOCUMENTS

ID	Title
[AD 1]	GRANT AGREEMENT NUMBER - 687409 - EASY PV (25/11/2015)

Table 1-1: Applicable Documents

1.3 REFERENCE DOCUMENTS

ID	Title
[RD 1]	EASY-SIST-D5 2-EASY PV Platform Architecture Design v1.2
[RD 2]	EASY-UNIA-D3 2-Test and Verification Campaign Methodology v1.1
[RD 3]	EASY-AAL-D3 1-GNSS high accuracy for Energy domain v3.3
[RD 4]	EASY-TOP-D7.2- RPAS User Manual v1.1
[RD 5]	EASY-SIST-D6.2-Maintenance and M&C platform user manual v1.0

Table 1-2 Reference Documents

1.4 ACRONYMS

Acronym	Description
C&C	Communication and Control
CG	Centre of Gravity
COTS	Commercial Off-The-Shelf
PoC	Point of Contact
DB	Data Base
DGPS	Differential GPS
DVCM	Design Verification Control Matrix
EGNOS	European Geostationary Navigation Overlay Service

Acronym	Description
EMC	Electro Magnetic Compatibility
FOV	Field Of View
FPS	Frames Per Second
GNSS	Global Navigation Satellite System
GSD	Ground Sample Distance
KPI	Key Performance Indicator
NAVCOM	NAVigation and integrated COMmunication
NED	North East Down
NTRIP	Networked Transport of RTCM via Internet Protocol
PIC	Pilot in Command
PPP	Precise Point Positioning
RGS	RPAS Ground Station
RPAS	Remotely Piloted Aircraft System
RTCM	Radio Technical Commission for Maritime Services
RTK	Real Time Kinematic
S/S	Sub System
SDK	Software Development Kit
TIR	Thermal Infra Red
VTE	Visual Track Energy
SR	System Requirement

Table 1-3: Acronyms

1.5 DOCUMENT STRUCTURE

The document includes the following sections:

- ✓ Section 2 illustrates the test cases illustrated with a structure reported in [RD 2].
- ✓ Section 3 provides a summary about the traceability versus the system requirements reported in in [RD 1].
- ✓ Section 4 illustrates the test procedures illustrated with a structure reported in [RD 2].
- ✓ Section 5 evidences main interesting results coming from procedure implementation
- ✓ Section 6 includes the Design Verification Matrix (DVCM) aiming to provide the status of coverage about all the requirements reported in [RD 1].
- ✓ Finally, Section 7 summarises the conclusion of this experimental activity.

2 TEST CASES

This section reports the test cases which are identified in order to cover requirements indicated in [RD 1]

2.1 TEST_EASY.0010 - PLATFORM DATA ENTRY AND CATALOGUES VISUALISATION (SERVICE CENTER)

2.1.1 OBJECTIVE

To verify that all data are correctly inserted by an operator. Data includes catalogue of:

- ✓ Plants
- ✓ PoCs
- ✓ Pilots (including attestation/licence number, and qualification)
- ✓ Thermographic experts
- ✓ Anomalies (kind of)

2.1.2 DESCRIPTION

1. The operator accesses the platform using his credentials.
2. The operator navigates and reaches the HMI where to insert plants information
3. The operator performs a query to verify plants is correctly ingested in the DB
4. Steps 2. and 3. are repeated for PoCs, pilots, thermographic experts and anomalies data entry

2.1.3 REQUIRED DATA

Pre-condition: operator has valid credentials.
Required Data: all data to be inserted, which are gathered using offline processes, i.e. not managed by the EASY-PV platform. As an example, the operator may collect info by received e-mails

2.1.4 PASS/FAIL CRITERIA

All data are correctly inserted in the DB structure and it is possible to retrieve them in further consultations

2.1.5 PROCEDURE ID

PROC_EASY.0010

2.2 TEST_EASY.0020 - MISSION PLANNING (SERVICE CENTER)

2.2.1 OBJECTIVE

To generate a valid mission with needed information to be shared with all actors involved in.
Based on request (sent by mail by a customer, so outside the platform), the operator shall use a dedicated GUI where He can select:

- ✓ Pilot
- ✓ PoC
- ✓ Plant
- ✓ Date (planned)

Such information (together with Mission ID, automatically generated) are sent via mail to the PoC and the pilot. Pilot will use info to configure the RPAS specifically for the mission.

2.2.2 DESCRIPTION

1. The operator accesses the platform using his credentials.
2. The operator navigates and reaches the HMI where to manage missions' information
3. The operator generates a new mission by entering the following information (by filling in the template in the HMI)
    - Selected plant
    - Selected pilot
    - Selected PoC
    - Selected Thermographic expert
    - Mission specification which indicates if the involved plant has been monitored with previous missions or not
    - Planned date.

Note. All the above information is possible to be entered either making a selection starting from data already inserted into the DB or as a free text insertion. In case of this last option, all DB will be updated so that all the following catalogues are consistent:

- plants
- pilots
- PoCs
- Thermographic experts
- missions

4. The operator exports all missions' parameters which include also a ""mission ID"" in addition to the above item listed in step 3.

Note. The mission when generated is managed as in ""planned"" status.

Such information (together with Mission ID, automatically generated) are sent via e-mail to the PoC and the pilot. Pilot will use info to configure the RPAS specifically for the mission

2.2.3 REQUIRED DATA

Pre-condition: operator has valid credentials.

Required Data: all data to be inserted are either already present in the DB or are gathered using offline processes. As an example, the operator may collect info by received e-mails

2.2.4 PASS/FAIL CRITERIA

Mission is correctly generated in ""planned"" status and all info are exported to be sent to all actors via e-mails or other communication media.

2.2.5 PROCEDURE ID

PROC_EASY.0020

2.3 TEST_EASY.0025 - MISSION IMPLEMENTATION (RPAS/ RGS PLATFORMS)

2.3.1 OBJECTIVE

To check if all data gathered during a mission are correctly archived on the RGS platform.

2.3.2 DESCRIPTION

1. The pilot performs a fly over a photovoltaic field
2. The pilot accesses the RGS platform using his credentials.
3. The pilot reaches the HMI where to download data from RPAS
4. The pilot reaches the HMI where to manage data processing
5. The pilot reaches the HMI where to manage data transferring to the service centre.

2.3.3 REQUIRED DATA

Pre-condition: pilot has valid credentials to access RGS

Required Data: info from missions planning retrieved by mails.

2.3.4 PASS/FAIL CRITERIA

All Mission data are downloaded from RPAS to RGS platform. Data transfer toward to service center is correctly performed. This last step is locally verified by a right generation of formatted files followed by a message visible in a dedicated HMI confirming the transfer process completion. Complete verification at service centre side is managed in TEST_EASY.0030

2.3.5 PROCEDURE ID

PROC_EASY.0025

2.4 TEST_EASY.0030 - PLANTS SYNOPTIC ANALYSIS AFTER MISSION IMPLEMENTATION (SERVICE CENTER)

2.4.1 OBJECTIVE

To check if all data gathered during a mission are correctly retrieved and accessible using the centralised platform by all the involved actors.

2.4.2 DESCRIPTION

1. The operator accesses the platform using his credentials.
2. The operator navigates and reaches the HMI where plant synoptic is managed. This view allows to verify the correct import of each panel in the plant (or manually adding missing panels...)
3. The operator navigates and reaches the HMI where each mission is managed. This view allows to verify the plant status in terms of envisaged anomalies in the given mission
4. The operator selects a panel in the synoptic and navigates to reach a view where all products related to the panel are represented. This view allows to visualise any detailed data
5. The operator comes back to point 3. and navigates to reach an HMI where flown trajectory is shown

2.4.3 REQUIRED DATA

Pre-condition: operator has valid credentials.

Required Data: at least one mission has to be implemented, i.e. data have to be retrieved in a dedicated campaign.

2.4.4 PASS/FAIL CRITERIA

Mission status moves to ""implemented"" and all data are correctly ingested in the central platform and are available to be accessed for consultation.

2.4.5 PROCEDURE ID

PROC_EASY.0030

2.5 TEST_EASY.0040 - REPORT GENERATION (SERVICE CENTER)

2.5.1 OBJECTIVE

To allow to generate a report based on a template reported in SR.0280 (see [RD 1])

2.5.2 DESCRIPTION

1. The operator accesses the platform using his credentials.
2. The operator navigates and reaches the HMI where plant synoptic is managed. This view allows to verify the correct import of each panel in the plant (or mannually adding missing panels...)
3. The operator navigates and reaches the HMI where each mission is managed. This view allows to verify the plant status in terms of envisaged anomalies in the given mission
4. The operator selects a panel in the synoptic and navigates to reach a view where all products related to the panel are represented. This view allows to visualise any detailed data
5. The operator comes back to point 3. and navigates to reach an HMI where flown trajectory is shown

2.5.3 REQUIRED DATA

Pre-condition: operator has valid credentials.
Required Data: at least one mission has to be implemented, i.e. data have to be retrieved in a dedicated campaign.

2.5.4 PASS/FAIL CRITERIA

Mission status moves to "finalised" and all data are correctly exported in a dedicated report.

2.5.5 PROCEDURE ID

PROC_EASY.0040

2.6 TEST_EASY.0050 - PLANT PRODUCTIVITY MONITORING (SERVICE CENTER)

2.6.1 OBJECTIVE

VTE is conceived to be an independent section within the EASY-PV project framework, unless the plant data entry ingestion
No particular modifications are expected to VTE based on EASY-PV reqs. VTE has to be used as it is during demo activities to show actual productivity measurements.

2.6.2 DESCRIPTION

1. The operator accesses the platform using his credentials.
2. The operator navigates and reaches the HMI where each mission is managed.

3. The operator selects the panel whose details have to be included in the report.
4. The operator selects a panel in the synoptic and navigates to reach a view where all products related to the panel are represented.
5. The operator selects the products whose details have to be included in the report and contingently enter a Description
6. The operator comes back to point 2. and contingently enter a description related to selected mission.
7. The operator generates the report in pdf format

2.6.3 REQUIRED DATA

Pre-condition: operator has valid credentials.

Required Data: plant has to be monitored with static systems allowing to send to the platform the electrical measurements.

2.6.4 PASS/FAIL CRITERIA

All static data are retrieved for a given plant including info about productivity. Dedicated reports are generated.

2.6.5 PROCEDURE ID

PROC_EASY.0050

2.7 TEST_EASY.0060 - RPAS OPERATIONS. EMERGENCY PROCEDURES (LOSS OF COMMUNICATION AND CONTROL LINK)

2.7.1 OBJECTIVE

During flight operations over PV plants, RPAS must prove their reliability and prevent or mitigate potential hazardous situations to structures and people, especially for those not involved in flight operations and not under control of the Pilot in command.

RPA, pilot and RPAS Operator's crew shall prove safety of operations by applying aircraft manual procedures and/or those described in RPAS operator's MANOPS.

A limited subset of emergency procedures significant for the PV plants inspection operations has been selected to be tested.

The objective of this test case is to assess the overall safety level provided by the EPV100 Aircraft by simulating the loss (or a heavy degradation) of primary the C&C link

2.7.2 DESCRIPTION

1. The pilot operates EPV100 aircraft according to normal procedures described in EPV 100 flight manual (see [RD 4]) (per-flight checklist and take off) and RPAS operator MANOPS
2. After taking off, the Pilot (P-Mode) operates the aircraft to hover in a point of the sky about 70 m (horizontally) and 20 m (vertically) from the HOME point position.
3. The pilot informs the crew about the starting of the test and turn off the Remote Controller to simulate the loss of C&C link
4. The pilot implements the procedure ""Return-to-Home (autonomously)"" described in EPV100 flight manual and follows the aircraft in VLOS conditions from the beginning of the manoeuvre till landing to HOME point and motors stop.
5. The pilot implements Post-Flight Check list as for normal flight operations
6. The pilot repeats the procedure also for Manual (A-Mode) and IOC Mode (F-Mode)

2.7.3 REQUIRED DATA

Pre-condition: RPA ""airworthiness"" according to RPAS operator's Manual
valid Pilot in command attestation/licence
valid Pilot in command LAPL (or class 2) certificate
CAA authorization for RPAS operator
Required Data: N.A.

2.7.4 PASS/FAIL CRITERIA

The aircraft implements autonomously the navigation from the point where C&C loss failure has been simulated towards the home point. The test is passed if the aircraft lands safely to the home point without any assistance of the pilot.

2.7.5 PROCEDURE ID

PROC_EASY.0060

2.8 TEST_EASY.0061 - RPAS OPERATIONS.EMERGENCY PROCEDURES (VIOLATION OF THE LIMITS OF AREA OF OPERATIONS)

2.8.1 OBJECTIVE

The objective of this this test case is to assess the overall level safety provided by the EPV100 Aircraft by simulating the violation of the limits horizontal and vertical limits of the area of operations

2.8.2 DESCRIPTION

1. The pilot operates EPV100 aircraft according to normal procedures described in EPV 100 flight manual [RD 4](per-flight checklist and take off) and RPAS operator MANOPS
2. After Taking off the Pilot (P-Mode) operates the aircraft to hover in a holding point in the sky about 50 m (horizontally) and 30 m (vertically) from the HOME point position.
3. The pilot informs the crew about the starting of the test and move to RPA outside the horizontal limits
4. When the distance from home indicator on Pilot's console reaches the horizontal geofence limit (100 m), the RPA will stop moving further and the pilot will be warned by a message on the pilot's console.
5. The pilot replaces the RPA in the holding point and repeat the procedure for the vertical limit.
6. The pilot repeats the whale procedure also for Manual (A-Mode) and IOC Mode (F-Mode) before landing.

2.8.3 REQUIRED DATA

Pre-condition: RPA ""airworthiness"" according to RPAS operator's MANOPS
valid Pilot in command attestation/licence
valid Pilot in command LAPL (or class 2) certificate
CAA authorization for RPAS operator
Geofence limits set to: 100m horizontal, 50m vertical
Required Data: N.A.

2.8.4 PASS/FAIL CRITERIA

The test is passed if the aircraft stops before the geofence limits set even if the pilot tries to overcommand the RPA beyond the limits.

2.8.5 PROCEDURE ID

PROC_EASY.0061

2.9 TEST_EASY.0062 - RPAS OPERATIONS.EMERGENCY PROCEDURES (RPA "FLY-AWAY")

2.9.1 OBJECTIVE

The objective of this test case is to assess the overall level safety provided by the EPV100 Aircraft by simulating the unlikely event of ""fly-away"" (loss of control of the aircraft) and the flight termination of its flight. This test will be performed on the ground only (destructive test in the air)

2.9.2 DESCRIPTION

1. The pilot operates EPV100 aircraft according to normal procedures described in EPV 100 flight manual and RPAS operators manual (per-flight checklist and take off)
2. The pilot arms the aircraft (motor spinning with no propellers) without taking off
3. A trained operator (Observer) will safely hold the RPA and move it within the area of operations (e.g. 100 m from the pilot)
4. The pilot informs the crew about the starting of the test and cut off the RPA motors by implementing the "Flight Termination" procedure described in the EPV100 aircraft flight manual
5. the observer and the pilot verify the motor cut-off effect on the RPA.

2.9.3 REQUIRED DATA

Pre-condition: Observer trained internally by RPAS Operator for the implementation of test
Required Data: N.A.

2.9.4 PASS/FAIL CRITERIA

The test is passed if the aircraft cut-off its engines during the ""simulated flight"" after the pilot command

2.9.5 PROCEDURE ID

PROC_EASY.0062

2.10 TEST_EASY.0070 - PANEL GEOREFERENCING PERFORMANCE

2.10.1 OBJECTIVE

The objective of this test is to assess the GNSS/computer vision algorithm E2E performances for the identification of a single Panel and its related precision.

2.10.2 DESCRIPTION

1. The testing team places one single PV Panel on the ground with each corner marked with a survey nail in case of need for further tests.
2. The pilot sets the GNSS Master station in a suitable position according with EPV100 flight manual [RD 4] and marks on the GCP position after the success of survey-in procedure [RD4].
3. The pilot operates EPV100 aircraft according to normal procedures described in EPV100 flight manual [RD 4] and RPAS operator's manual and flies the RPA over the Panel at a height of ranging for 5 to 10 meters.
4. The pilot checks on the thermal video output if the Panel's shape is recognized by the software at each fly-by over the Panel. The fly-bys over the Panel are repeated for at least 15 times;
5. The pilot lands the aircraft and the testing team verifies in post processing from the log of the RPAS OBC, the occurrences of panel recognition with respect to the number of fly-bys and the related baselines for each passage.

2.10.3 REQUIRED DATA

Pre-condition:

- ✓ RPA ""airworthiness"" according to RPAS operator's MANOPS
- ✓ valid Pilot in command attestation/licence
- ✓ valid Pilot in command LAPL (or class 2) certificate
- ✓ CAA authorization for RPAS operator
- ✓ 1 PV Panel of 160cmx100cm needed for test placed with a corner in correspondence of a GCP acquired.

Required Data:

- ✓ GCP position of GNSS Master Station;
- ✓ ""FIXED SOLUTION"" provided by EASY-PV payload and RGS GNSS Master station.

2.10.4 PASS/FAIL CRITERIA

The test is passed if the ID of the Panel generated after a fly-by is coincident with the ID generated offline by GCP measurements previously surveyed with a more accurate GNSS RTK system. It means that the evaluated center of panel f elaborated by the algorithm has to have a measurement error bounded in 0,50 (2sigma).

2.10.5 PROCEDURE ID

PROC_EASY.0070

3 REQUIREMENTS VS TEST CASES TRACEABILITY

This section summarises the traceability versus the system requirements reported in in [RD 1]. Blank cell indicates requirement is not verified per test

3.1 SYSTEM REQUIREMENTS VERSUS TEST CASES

SR ID	SR title	TC ID	TC Title
SR.0010	Plant data entry	TEST_EASY.0010	Platform Data entry and catalogues visualisation
SR.0020	Plant referencing	TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0030	Monitoring of Maintenance coverage	TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0040	Pilots contact database	TEST_EASY.0010	Platform Data entry and catalogues visualisation
		TEST_EASY.0020	Mission Planning
SR.0050	Plant PoC contact database	TEST_EASY.0010	Platform Data entry and catalogues visualisation
		TEST_EASY.0020	Mission Planning
SR.0060	Contact information HMI	TEST_EASY.0010	Platform Data entry and catalogues visualisation
		TEST_EASY.0020	Mission Planning
SR.0070	RPAS mission request and planning	TEST_EASY.0020	Mission Planning
SR.0080	PV faults categories database	TEST_EASY.0010	Platform Data entry and catalogues visualisation
SR.0090	Anomalies autonomous recognition	TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0100	Static M&C	TEST_EASY.0050	Plant Monitoring
SR.0110	Geo tagged thermal and optical images gathering	TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0120	Product HMI	TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0130	Mission HMI	TEST_EASY.0020	Mission Planning
		TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0140	Plant HMI	TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0150	Product Structure	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
		TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation

SR.0160	Service Centre to RPAS communication (products exchanges)	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
		TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0170	Service Centre to RPAS communication (messages exchanges)	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
		TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation
SR.0180	Alarms, historic, analysis tool	TEST_EASY.0050	Plant Monitoring
SR.0190	RPAS MAIT	Verified per Inspection (see section 5.11)	
SR.0200	RPAS Operations. Emergency procedures	TEST_EASY.0060	RPAS Operations. Emergency procedures (Loss of Communication and Control Link)
		TEST_EASY.0061	RPAS Operations. Emergency procedures (Violation of the limits of area of operations)
		TEST_EASY.0062	RPAS Operations. Emergency procedures (RPA "Fly-away")
SR.0210	RPAS data georeferencing	TEST_EASY.0070	RPAS data georeferencing performance
SR.0220	RPAS mission environment configuration	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
SR.0230	RPAS operations management	TEST_EASY.0060	RPAS Operations. Emergency procedures (Loss of Communication and Control Link)
SR.0240	RPAS data acquisition	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
SR.0250	RPAS data storage	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
SR.0260	Plant coverage feedback	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
SR.0270	Computer Vision Algorithm	TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)
SR.0280	Final Report	TEST_EASY.0040	Report Generation

Table 3-1 System Requirements vs Test Cases

3.2 TEST CASES VERSUS SYSTEM REQUIREMENTS

TC ID	TC Title	SR ID	SR title
TEST_EASY.0010	Platform Data entry and catalogues visualisation	SR.0010	Plant data entry
		SR.0040	Pilots contact database
		SR.0050	Plant PoC contact database
		SR.0060	Contact information HMI
		SR.0080	PV faults categories database
TEST_EASY.0020	Mission Planning	SR.0040	Pilots contact database
		SR.0050	Plant PoC contact database
		SR.0060	Contact information HMI
		SR.0070	RPAS mission request and planning
		SR.0130	Mission HMI
TEST_ EASY.0025	Mission Implementation (RPAS/ RGS platforms)	SR.0150	Product Structure
		SR.0160	Service Centre to RPAS communication (products exchanges)
		SR.0170	Service Centre to RPAS communication (messages exchanges)
		SR.0220	RPAS mission environment configuration
		SR.0240	RPAS data acquisition
		SR.0250	RPAS data storage
		SR.0260	Plant coverage feedback
		SR.0270	Computer Vision Algorithm
TEST_EASY.0030	Plants Synoptic Analysis After Mission Implementation	SR.0020	Plant referencing
		SR.0030	Monitoring of Maintenance coverage
		SR.0090	Anomalies autonomous recognition
		SR.0110	Geo tagged thermal and optical images gathering

TC ID	TC Title	SR ID	SR title
		SR.0120	Product HMI
		SR.0130	Mission HMI
		SR.0140	Plant HMI
		SR.0150	Product Structure
		SR.0160	Service Centre to RPAS communication (products exchanges)
		SR.0170	Service Centre to RPAS communication (messages exchanges)
TEST_EASY.0040	Report Generation	SR.0280	Final Report
TEST_EASY.0050	Plant Monitoring	SR.0100	Static M&C
		SR.0180	Alarms, historic, analysis tool
TEST_EASY.0060	RPAS Operations. Emergency procedures (Loss of Communication and Control Link)	SR.0200	RPAS Operations.Emergency procedures
		SR.0230	RPAS operations management
TEST_EASY.0061	RPAS Operations. Emergency procedures (Violation of the limits of area of operations)	SR.0200	RPAS Operations. Emergency procedures
TEST_EASY.0062	RPAS Operations. Emergency procedures (RPA "Fly-away")	SR.0200	RPAS Operations. Emergency procedures
TEST_EASY.0070	RPAS data georeferencing performance	SR.0210	RPAS data georeferencing

Table 3-23-3 Test Cases vs System Requirements

4 TEST PROCEDURES

4.1 PROC_EASY.0010 - PLANT DATA ENTRY AND CATALOGUES VISUALISATION (SERVICE CENTER)

PROC_EASY.0010. Platform Data entry and catalogues visualisation (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Log in*** The operator accesses the platform using his credentials. Info: ✓ Platform available at www.easypv-vte.grupposistematica.it/vteMenu/app ✓ Username: epv; Password: epv	The operator correctly accesses and the main page appears	As expected	
S_020	***Plant data Entry: configuration 1/2*** The operator accesses the configuration panel navigating the following path: CONFIGURATOR→IMPIANTI→IMPIANTI	The configuration panel IMPIANTI relevant to plants appears.	As expected	Several type of plants are possible to be inserted. This step allows to insert a PV plant
S_030	***Plant data Entry: configuration 2/2*** Following data are inserted: *Tipologia: CAMPO FOTOVOLTAICO* *Nodo VTE: impianto vigili urbani* *Descrizione: test vigili urbani* *Data inizio esercizio: 9/25/2017* *Data fine esercizio:* *Azienda: epv* *Regione: CAMPANIA* *Provincia: CASERTA* *Comune: SAN NICOLA LA STRADA*	Once the plant is ingested it appears in the main menu CONFIGURATOR → IMPIANTI → IMPIANTI	As expected	PoCs, pilots and thermographic experts data entry is managed contextually to the Mission planning dedicated section

PROC_EASY.0010. Platform Data entry and catalogues visualisation (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
	Indirizzo: via test *Numero civico: 12* *Cap: 81020* *Localita': vigli urbani* *Latitudine/Longitudine: 41.015138; 14.320679* *Altezza: 0* *Attivo:*			

Procedure has been successfully executed and final outcomes are reported in section 5.

4.2 PROC_EASY.0020 - MISSION PLANNING (SERVICE CENTER)

PROC_EASY.0020. Mission Planning (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Log in*** The operator accesses the platform using his credentials. Info: ✓ Platform available at easypv-vte.grupposistematica.it/vteMenu/app ✓ Username: epv; Password: epv	The operator correctly accesses and the main page appears	As expected	
S_020	**Thermographic section** The operator accesses "Thermographic analysis" section and navigate using the path "MAIN→ Mission browser"	The operator correctly accesses and the mission catalogue appears	As expected	

PROC_EASY.0020. Mission Planning (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_030	**New mission creation** The operator creates a new mission by pressing the button "New" in the window "Mission Browser" and filling the form "Description" by adding: ✓ Plant ✓ Status ✓ Planning Date ✓ Pilot ✓ Contact ✓ Thermographic Analyst ✓ Comments Finally he clicks on "Notify mission" so that each actor involved in the mission is alerted by mail	The mission is created and Pilot, Contact and Thermographic expert are notified about.		When selecting people, pay attention to check the mail address is filled in, otherwise mission cannot be correctly modified

Procedure has been successfully executed and final outcomes are reported in section 5.

4.3 PROC_EASY.0025 - MISSION IMPLEMENTATION (RPAS/ RGS PLATFORMS)

PROC_EASY.0025. Mission implementation (RPAS/RGS Platform)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Log in*** The pilot accesses with his credential on the RGS Pilot's application in the section "RGS Manager": ✓ On RGS Pilot's application (Tablet) open: "RGS Manager" ✓ name: demo; Password: demo	The pilot is connected to the Service Centre though the RGS Pilot's application.	As expected	

PROC_EASY.0025. Mission implementation (RPAS/RGS Platform)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_020	***New Mission Configuration*** The pilot browses the RGS Manager application in the section "Mission Browser" and selects a "new mission" called "Test Vigili Urbani". The pilot inserts the following application after prompted by the application: ✓ Plant ID ✓ Acquisition day: ✓ Meteo conditions: ✓ Environment Temp [C°]: ✓ Irradiation [W/m^2]: ✓ RPA operational height [m]: ✓ Panels length [cm]: ✓ Panels height [cm]: ✓ Number of Panels: The pilot prepares the RPAS for inspections and deploys GNSS Master station and chose one suitable GCP according to EPV100 User Manual ([RD 4] §9.2.1) initialization and deployment procedure of GNSS Master station. After initialization process conclusion The pilot inserts in the RGS application the results of survey obtained by the GNSS Master station: ✓ GCP position latitude [°'.D]: ✓ GCP position longitude [°'.D]: ✓ GCP position altitude [m]: ✓ GCP instrumental height [cm]:	The pilot configures a new mission on a new PV Plant and sends the data to the Service Centre	As expected	

PROC_EASY.0025. Mission implementation (RPAS/RGS Platform)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
	The pilot sends the data to Service Centre though RGS Manager application (the GCP position; the data will be available to the Pilot for next inspections on this PV Plant)			
S_030	***Mission implementation and data processing*** The pilot performs according to EPV100 User Manual [RD4] the following: ✓ pre-flight check list ✓ take off ✓ PV Panel inspection ✓ Landing ✓ Post-flight Check List The pilot browses the RGS Manager application in the section “Data Processing” and do the following actions: ✓ Connect to EASY-PV payload ✓ Download “aerial work” ✓ In the Tab “Process aerial work” run “Process data” and wait for the result of Computer Vision Algorithm ✓ After the “Process data” conclusion the data report is visualized with: o Panels identified: o Panels anomalies: ✓ The Pilot sends the data to the service centre using the Tab “Send Data to Service Centre and visualizes the message “Data uploaded successfully”	The pilot implements the mission and sends results to service centre	As expected	“Process aerial work” required multiple runs to achieve the final results with some manual interventions. The final results were sent to the service centre though wi-fi connection instead of using 3G network

Procedure has been successfully executed and final outcomes are reported in section 5.

4.4 PROC_EASY.0030 - PLANTS SYNOPTIC ANALYSIS AFTER MISSION IMPLEMENTATION (SERVICE CENTER)

PROC_EASY.0030. Plants Synoptic Analysis After Mission Implementation (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Log in*** The operator accesses the platform using his credentials. Info: ✓ Platform available at easypv-vte.gruppositematica.it/vteMenu/app ✓ Username: epv; Password: epv	The operator correctly accesses and the main page appears	As expected	
S_020	**Thermographic section** The operator accesses “Thermographic analysis” section and navigate using the path “MAIN→ Mission browser”	The operator correctly accesses and the mission catalogue appears	As expected	
S_030	**Mission selection** The operator selects a given mission (e.g. Mission ID 10014) and navigates to reach “Topology” section where plant synoptic is managed.	The operator is able to have a synoptic showing the plant overall status. This view allows to verify the correct import of each panel in the plant (or manually adding missing panels...)	As expected	
S_040	**Anomaly selection and analysis** The operator selects a panel in the synoptic and navigates to reach a view where all products related to the panel are represented. This view allows to visualise any detailed data	The operator is able to analyse the anomaly and contingently add comments, discard	As expected	

PROC_EASY.0030. Plants Synoptic Analysis After Mission Implementation (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
		anomalies and validate products associations.		
S_050	**Products** The operator navigates to reach “Product” section where all data are included for further investigation. Here he is able also to select the NMEA file containing the trajectory flown and to download the file itself		As expected	

Procedure has been successfully executed and final outcomes are reported in section 5.

4.5 PROC_EASY.0040 – REPORT GENERATION (SERVICE CENTER)

PROC_EASY.0040 – Report Generation (SERVICE CENTER)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Log in*** The operator accesses the platform using his credentials. Info: ✓ Platform available at easypv-vte.grupposistematica.it/vteMenu/app ✓ Username: epv; Password: epv	The operator correctly accesses and the main page appears	As expected	
S_020	**Thermographic section** The operator accesses “Thermographic analysis” section and navigate using the path “MAIN→ Mission browser”	The operator correctly accesses and the mission catalogue appears	As expected	

PROC_EASY.0040 – Report Generation (SERVICE CENTER)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_030	**Report creation** The operator selects a mission in status "imported" or "approved" or "closed" and keep the "Description" tab activated. Finally, he clicks on "Create Report" button to generate the document. After the "quick look" appears he is able to finally download the report in ".pdf" format.		As expected	

Procedure has been successfully executed and final outcomes are reported in section 5.

4.6 PROC_EASY.0050 – PLANT PRODUCTIVITY MONITORING (SERVICE CENTER)

PROC_EASY.0050. Plant productivity monitoring (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Log in*** The operator accesses the platform using his credentials. Info: ✓ Platform available at easypv-vte.grupposistematica.it/vteMenu/app ✓ Username: epv; Password: epv	The operator correctly accesses and the main page appears	As expected	Main page is in "visualTrack" framework which includes EASY-PV as a dedicated section

PROC_EASY.0050. Plant productivity monitoring (Service Center)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_020	**Visual Track** The operator accesses "Productivity Monitoring (VISUAL TRACK)" section and selects a given plant to be monitored	The operator can access to several type of view both indicating monitoring issues and plant productivity	As expected	

Procedure has been successfully executed and final outcomes are reported in section 5.

4.7 PROC_EASY.0060 - RPAS OPERATIONS. EMERGENCY PROCEDURES (LOSS OF COMMUNICATION AND CONTROL LINK)

TEST_EASY.0060. RPAS Operations. Emergency procedures (Loss of Communication and Control Link)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Pre Flight and Take Off*** ✓ The pilot deploys EPV100 aircraft for operations and execute pre-flight check list (§6.1 [RD 4]); ✓ The pilot implements take-off with EPV100 aircraft (§6.3 [RD 4]);	RPA in flight in P-Mode (GNSS assisted)	As expected	No findings on pre-flight check list
S_020	***Navigation to designed point*** ✓ The pilot controls (§4.3 [RD 4]) the EPV100 aircraft during navigation up to the designated point in the air (70 meters horizontally from the HOME point and 20 meters vertically with respect to the HOME point height); ✓ The pilot checks the position of RPA on RGS through Flight telemetry (Tablet Application Interface §4.2.1 [RD 4]): o Distance "D": >70 m o Height "H" > 20 m	RPA navigates towards designed point	As expected	
S_030	***Execution of Emergency procedure in P-Mode (GNSS assisted) and Landing*** ✓ Once the conditions of distance and height in S_020 have been verified, the pilot informs the crew about the starting of the execution of test and turns off the Remote Controller of RGS to simulate the loss of C&C link with EPV100 aircraft in P- Mode (GNSS assisted) ✓ During Execution of test the Pilots checks as per emergency procedure (§5.1 [RD 4]), the following: o RPA: Press and hold the RTH button for 3 seconds; o RPA: Confirm the visualization of rapid flashing of the yellow aircraft rear LED	RPA performs autonomous navigation towards Home point in P-Mode, Lands and stops engines without pilot intervention	As expected	No findings on post-flight check list

TEST_EASY.0060. RPAS Operations. Emergency procedures (Loss of Communication and Control Link)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
	○ RGS: Confirm the visualization of status “”FAIL SAFE” (red) on the application screen ○ RPA: Keep VLOS conditions with the aircraft during its autonomous flight trajectory towards HOME point ○ RPA: Check RPA hovering on the home point for 15 seconds. ○ RPA: Check autonomous descend of RPA (1 m/s) till touchdown ○ RPA: Wait for automatic engine stop. ○ RPA: Turn off RPA battery ○ RGS: Turn off Remote Controller ✓ The pilot execute post-flight check list (§6.2 [RD 4]);			
S_040	***Execution of Emergency procedure in IOC (F—Mode) and Landing*** The pilot repeats the steps S_010, S_020 and S_030 for IOC (F-Mode);	RPA performs autonomous navigation towards Home point in F-Mode, Lands and stops engines without pilot intervention	As expected	No findings on pre-flight check list and post-flight check-list
S_050	***Execution of Emergency procedure in A-Mode (Manual) and Landing*** The pilot repeats the steps S_010, S_020 and S_030 for Manual (A-Mode)	RPA performs autonomous navigation towards Home point in A-Mode, Lands and stops engines without pilot intervention	As expected	No findings on pre-flight check list and post-flight check-list

Procedure has been successfully executed and final outcomes are reported in section 5.

4.8 PROC_EASY.0061 - RPAS OPERATIONS.EMERGENCY PROCEDURES (VIOLATION OF THE LIMITS OF AREA OF OPERATIONS)

TEST_EASY.0061. RPAS Operations. Emergency procedures (Violation of the limits of area of Operations)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***GeoFence Configuration*** ✓ The pilot configures the RGS through Geofence configuration (Tablet Application – Operational Risk Assessment §8.2.1 [RD 4] the following: o Maximum altitude: "30 meters" o Maximum flight distance altitude: "100 meters"	Pilot performs RPAS Geofence configuration	As expected	
S_020	***Pre Flight and Take Off in P-Mode*** ✓ The pilot deploys EPV100 aircraft for operations and execute pre-flight check list (§6.1 [RD 4]); ✓ The pilot implements take-off with EPV100 aircraft (§6.3 [RD 4]);	RPA in flight in P-Mode (GNSS assisted)	As expected	No findings on pre-flight check list
S_030	***Navigation outside the horizontal geofence limits in P-Mode*** ✓ The pilot controls (§4.3 [RD 4]) the EPV100 aircraft in P-Mode at height of 15 meters during navigation beyond the horizontal limit of 100 meters; ✓ The pilot checks the position of RPA on RGS through Flight telemetry (Tablet Application Interface §4.2.1 [RD 4]) till: o Distance "D": ≥100 m ✓ The pilot verifies:	RPA navigates beyond horizontal defined limits	As expected	

TEST_EASY.0061. RPAS Operations. Emergency procedures (Violation of the limits of area of Operations)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
	○ visually: The RPA is stuck on the position and does not move beyond horizontally even with full stick control; ○ on RGS through Flight telemetry (Tablet Application Interface §4.2.1 [RD 4]) the pop up message: "maximum distance reached" with visual and vocal warning.			
S_040	***Navigation outside the vertical geofence limits in P-Mode*** ✓ The pilot controls (§4.3 [RD 4] the EPV100 aircraft in P-Mode at a distance of 100 meters and beyond the vertical limit of 30 meters; ✓ The pilot checks the position of RPA on RGS through Flight telemetry (Tablet Application Interface §4.2.1 [RD 4]) till: ○ Distance "D": =100 m ○ "H": ≥30 m ✓ The pilot verifies: ○ visually: The RPA is stuck on the vertical position with (D=100 m and H=30 m) and does not move beyond vertically even with full stick control; ○ on RGS through Flight telemetry (Tablet Application Interface §4.2.1 [RD 4]) the pop up message: "maximum vertical limit reached" with visual and vocal warning.	RPA climbs beyond vertical defined limits	As expected	
S_050	***Landing in P-Mode (GNSS assisted) and Post flight Check list*** ✓ The pilot execute Landing (§6.4 [RD 4]) on HOME point; ✓ The pilot execute post-flight check list (§6.2 [RD 4])	Pilot lands RPA on HOME point	As expected	No findings on post-flight check-list
S_060	***Execution Violation of Limits in A-Mode (Manual)*** ✓ The pilot repeats the steps from S_020 to S_050, in A-Mode (Manual)	Geofencing Limits (horizontal and	As expected	

TEST_EASY.0061. RPAS Operations. Emergency procedures (Violation of the limits of area of Operations)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
		vertical) are respected even in A-Mode		
S_070	***Execution Violation of Limits in F-Mode (IOC)*** The pilot repeats the steps from S_020 to S_050, in F-Mode (IOC)	Geofencing Limits (horizontal and vertical) are respected even in F-Mode (IOC)	As expected	

Procedure has been successfully executed and final outcomes are reported in section 5.

4.9 PROC_EASY.0062 - RPAS OPERATIONS.EMERGENCY PROCEDURES (RPA "FLY-AWAY")

TEST_EASY.0062. RPAS Operations. Emergency procedures (RPA “Fly Away”)				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Pre Flight configuration*** ✓ The pilot deploys EPV100 aircraft for operations and removes the propellers from the engines. ✓ The pilot sets the RPA in P-Mode and starts the engines.	RPA in P-Mode (GNSS assisted)	As expected	
S_020	***Transport of RPA towards the designed point*** ✓ The pilot appoints an observer to carry the EPV100 aircraft at a ground horizontal distance of 100 meters from the HOME point. ✓ The pilot checks the position of RPA carried by the observer on RGS through Flight telemetry (Tablet Application Interface §4.2.1 [RD 4])	RPA is transported towards the designed point	As expected	

TEST_EASY.0062. RPAS Operations. Emergency procedures (RPA "Fly Away")				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
	o Distance "D": ≥100 m o Height "H" > 0 m			
S_030	***Simulation of the Emergency procedure "Fly Away" in P-Mode*** ✓ Once the condition of distance described in S_020 has been verified, the pilot informs the crew about the starting of the execution of test and performs the flight Termination Procedure (§5.6 [RD 4]) o RGS: Use the following combination of stick and hold it for 3 seconds. o The pilots move the left stick down-right (diagonal) at 100% of intensity with his left thumb and contemporary push the RTH button with his right thumb ((§4.3 [RD 4]) o RGS: a long sound beep will confirm the procedure o RPA: The motors will immediately stop spinning.	RPA stops engines after flight termination procedure	As expected	
S_040	***Simulation of the Emergency procedure "Fly Away" in IOC (F-Mode)*** ✓ The pilot repeats the steps S_010, S_020 and S_030 for IOC (F-Mode);	RPA in F-Mode (IOC) RPA is transported towards the designed point RPA stops engines after flight termination procedure in F-Mode (IOC)	As expected	
S_050	***Simulation of the Emergency procedure "Fly Away" in Manual (A-Mode)*** ✓ The pilot repeats the steps S_010, S_020 and S_030 for (A-Mode);	RPA in A-Mode (Manual) RPA is transported towards the designed point RPA stops engines after flight termination	As expected	

TEST_EASY.0062. RPAS Operations. Emergency procedures (RPA "Fly Away")				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
		procedure in A-Mode (Manual)		

Procedure has been successfully executed and final outcomes are reported in section 5.

4.10 PROC_EASY.0070 – PANEL GEO-REFERENCING PERFORMANCES

TEST_EASY.0070. RPAS Data GEO Referencing Performances				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
S_010	***Set up and Data Acquisition*** The pilot operates EPV100 aircraft according to normal procedures described in EPV 100 flight manual [RD 4] and flies the RPA over the Panel for at least 40 times at a vertical distance of about 5 meters from the panel. After landing the pilots connects with a laptop to EASY-PV payload though wi-fi connection trough ftp client (SSH connection): ✓ Wi-Fi network: IntelJoule_2.4GHZNew ✓ Password: 1234567890 ✓ Host name (ip address): 192.168.2.1 ✓ Port: 22	Data gathering from EASY-Pv Payload	As expected	

TEST_EASY.0070. RPAS Data GEO Referencing Performances				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
	✓ Username: joule ✓ Password: joule			
S_020	***Computer Vision algorithm settings*** The pilot, through the SSH connection, sets in the configuration file "easypv.cfg" the path of thermal images recorded during the mission (e.g. /mnt/data/media/Test/PHOTOS) and then launches on EASY-PV payload the computer vision algorithm through the following command: ./EasyPVAlgorithm	Settings of the algorithm	As expected	
S_030	***Flight and Data retrieval*** The pilot flies the RPA with applying normal procedures [RD4]. After landing the output of the process is available in the folder: /mnt/data/Output/EPV_MISSIONS/MISSION_MissionID with the format MISSION_MissionID.xml The XML file is ready to be processed for the analysis When finished the output of the process is available in the folder: /mnt/data/Output/EPV_MISSIONS/MISSION_MissionID	Generation of a XML file containing the vertexes of the Panel; generation of a log file for the analysis	As expected	Tuning of the algorithm was needed before achieving the optimal recognition results

TEST_EASY.0070. RPAS Data GEO Referencing Performances				
Step	**Activity description**	**Expected Result**	**Obtained Result**	**Notes**
	with the format MISSION_MissionID.xml The XML file is ready to be processed for the analysis			

Procedure has been successfully executed and final outcomes are reported in section 5.

5 TEST REPORT

This section reports outcomes derived from run procedures.

Functional tests are shortly described aiming to show the evidence on how the system actually implements required features. More emphasis is devoted to the performance test which definitely confirms an anomaly can be correctly recognised and geo-referenced.

5.1 PLANT DATA ENTRY AND CATALOGUES VISUALISATION

This section reports outputs achieved by running procedure PROC_EASY.0010. In particular, Figure 1 shows how the service centre correctly manages the plant information data ingestion.

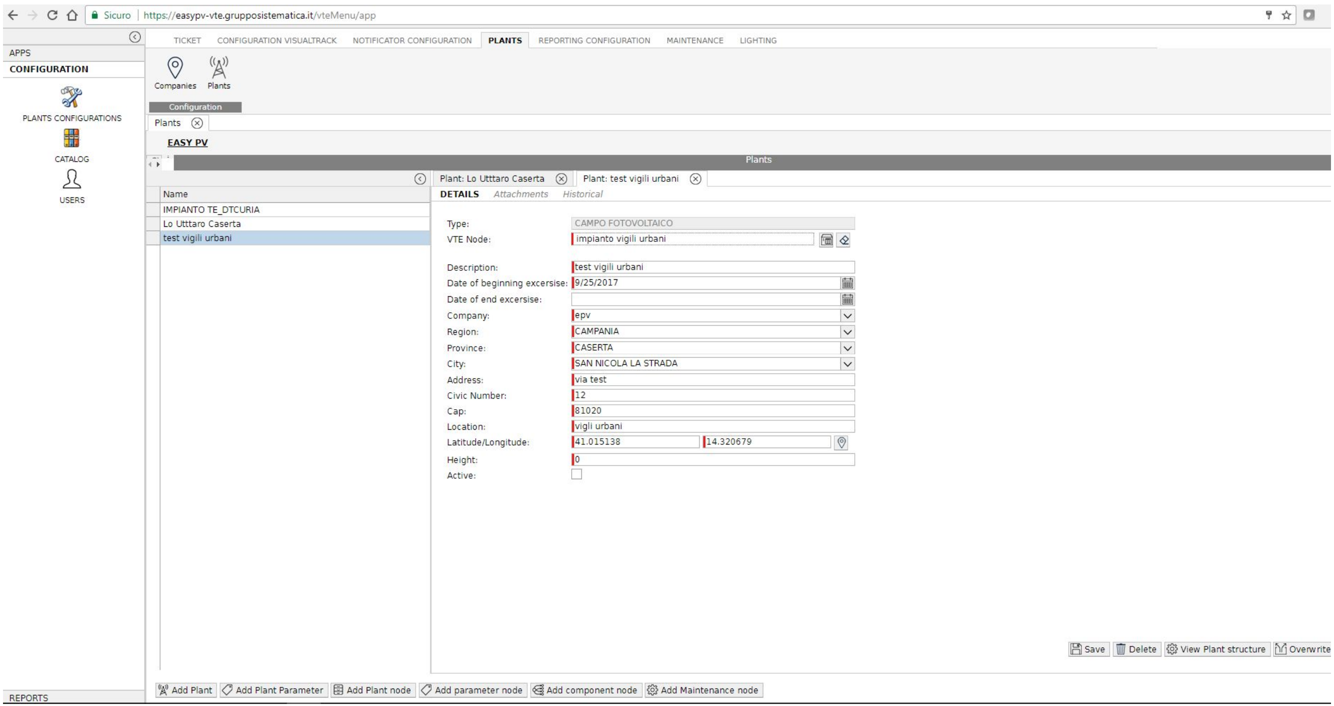

Figure 1 Plant data entry

5.2 MISSION PLANNING

This section reports outputs achieved by running procedure PROC_EASY.0020. In particular, Figure 2 and Figure 3 describes the mission generation process starting from the platform data entry to the final mission notification by e-mail to each involved actor.

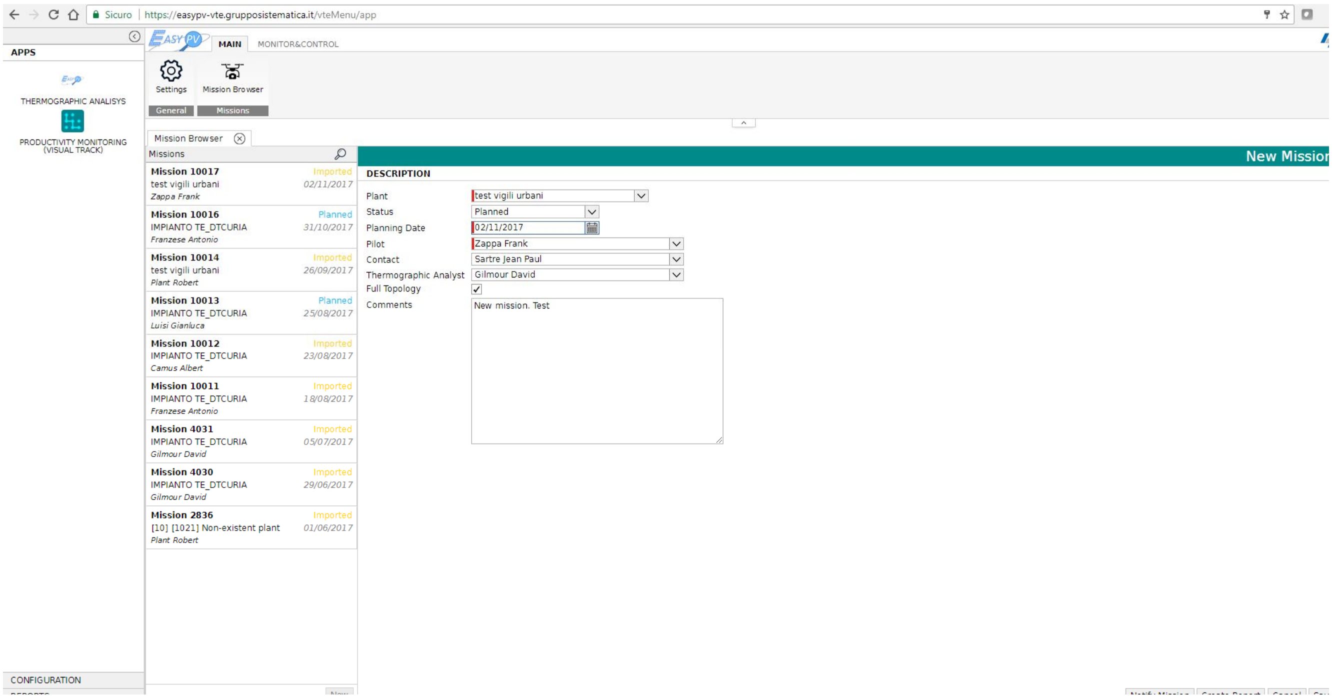

Figure 2 Mission generation

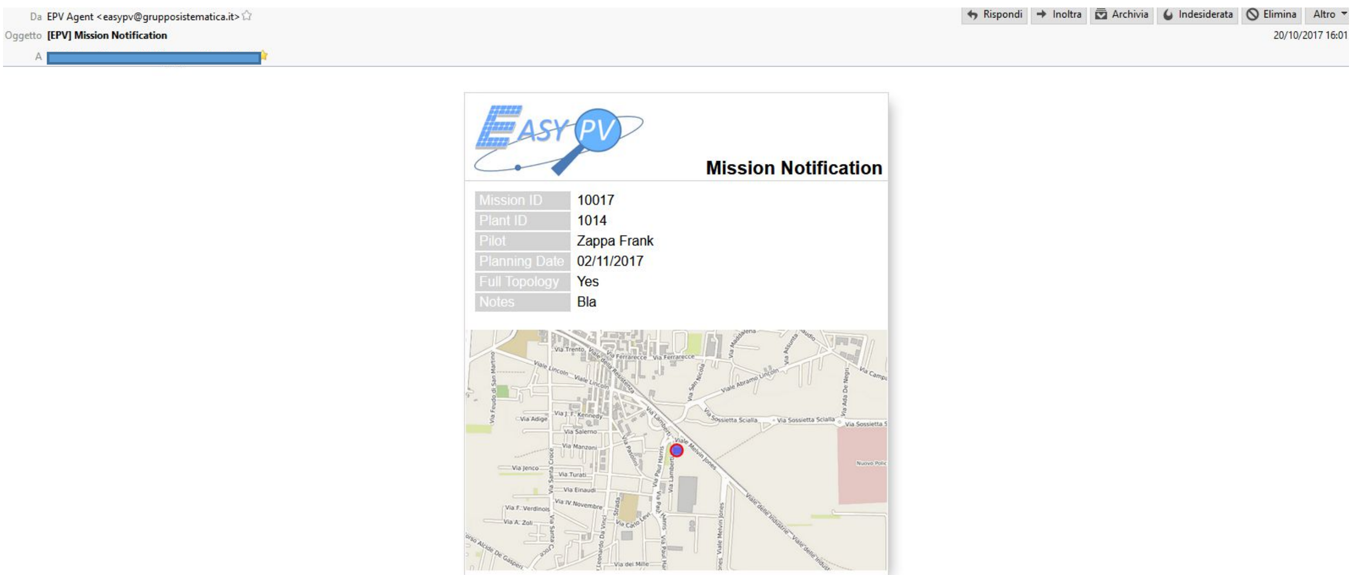

Figure 3 Mission notification

5.3 MISSION IMPLEMENTATION (RPAS/ RGS PLATFORMS)

This section reports the outputs achieved by running procedure PROC_EASY.0025. As reported in section 2.3, PROC_EASY.0020 implementation is a precondition.

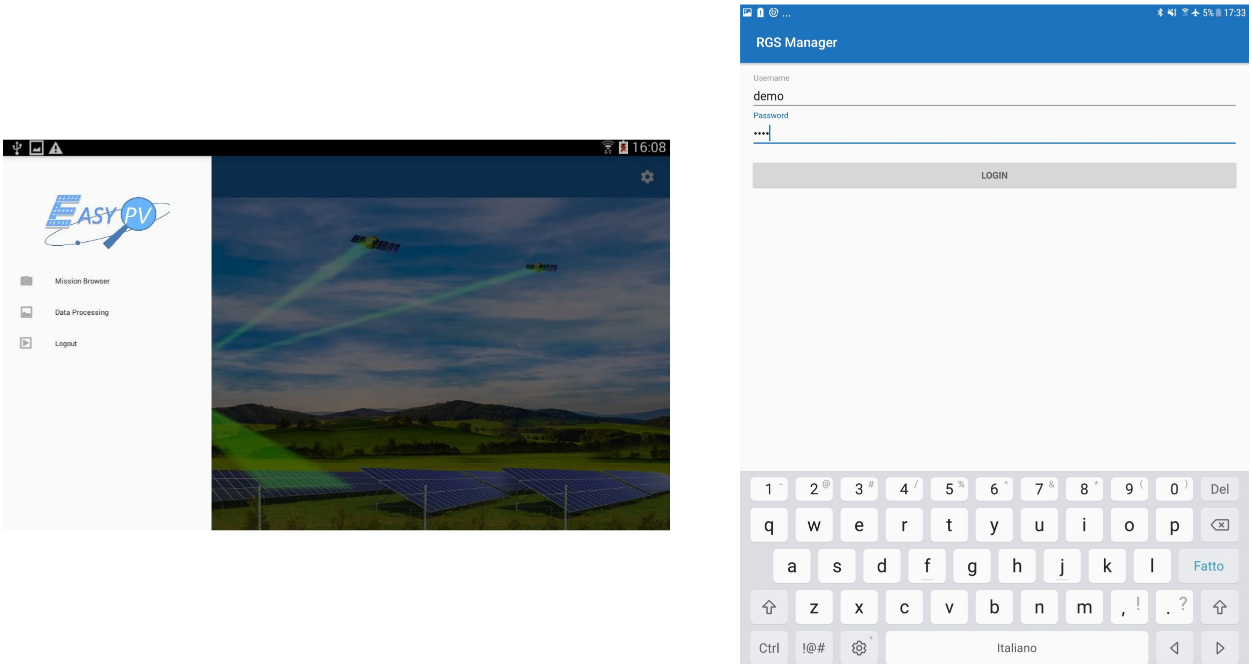

Figure 4 Pilot log-in to Service Center though RGS Manager

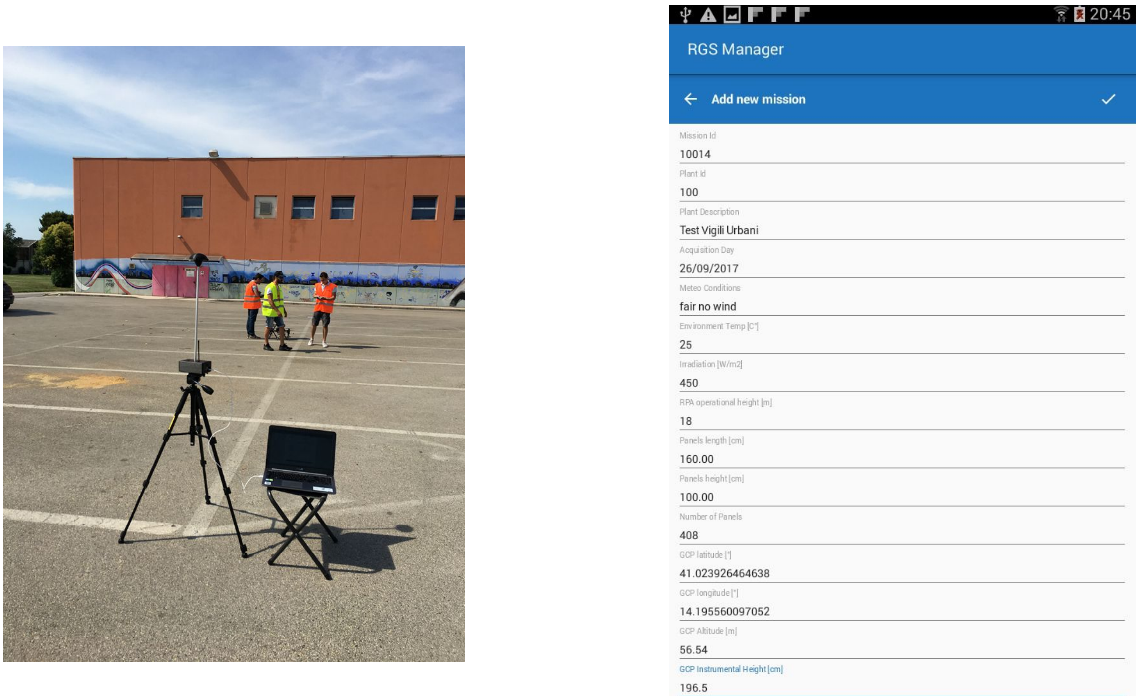

Figure 5 GNSS Master station initialization (Survey-in) and Pilot data Entry

The RPAS used is for this test is the EPV100 [RD4] which has been manually piloted over the PV plant by an experienced certified pilot. The RPAS carried the Easy-PV payload with both thermal and optical sensors and GNSS RTK receiver (ROVER) . The thermal camera used for thermal images acquisition in the 7.5 – 13.5 µm spectral band is a Flir Vue Pro (336x256). The RPAS has been equipped by both U-blox NEO-M8N - code observable measurements capability - and U-blox NEO-M8P (phase measurements capability). The patch antenna used is the Tallysmann TW2710, equipped with 12 cm diameter ground plane.

The Following picture reports the trajectory flown by the RPAS

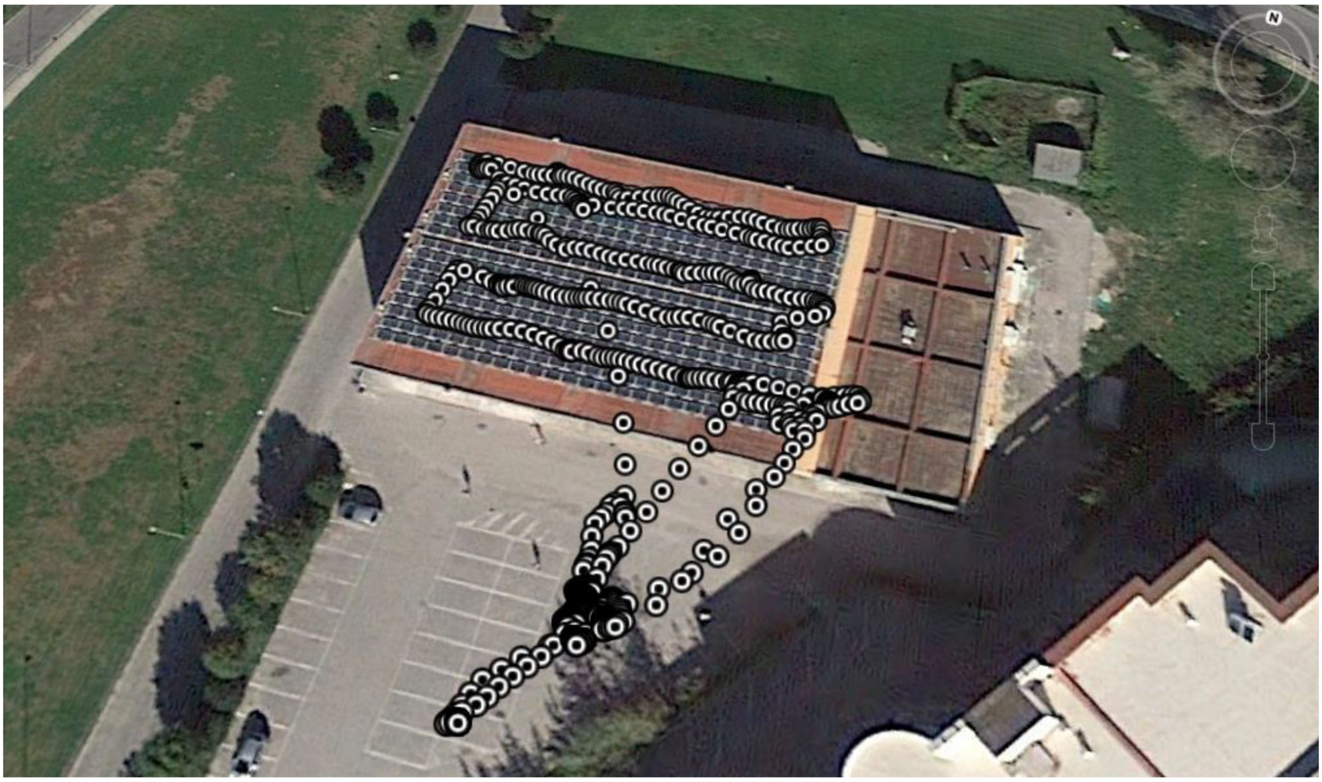

Figure 6 Trajectory flown with Ublox M8P (RTK fixed/float solutions)

In Figure 7 a sequence of panel detection and identification is shown. Panels are detected using the proposed correlation-based template matching approach for both datasets. After detection, the logged positions are used to generate unique IDs to identify them consistently during the flight session. This can be seen in Figure 7a) and Figure 7b): numeration remains consistent even in presence of panels identified several times (that highly influenced by the threshold parameter: the lower is the threshold, the higher is the number of multiple identification). Identifiers can be wrongly generated in case of missed panel as in Figure 7c): in this case if the panel is correctly detected in subsequent shot during the flight, it gets an higher identifier that will be consistent within the flight session but could be not unique across different sessions.

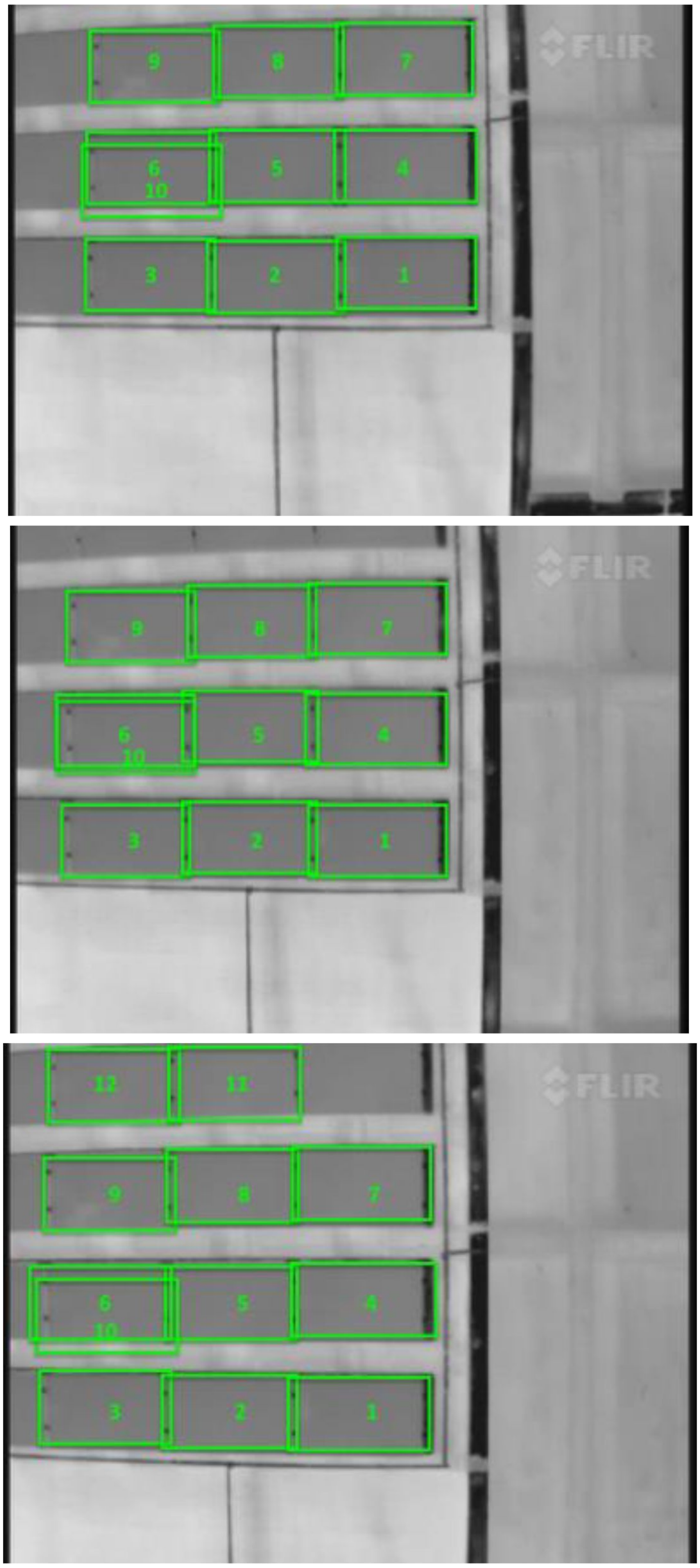

Figure 7 Template matching and panel identification sub-sequence

a) *Detected and identified panels.*

b) *Numeration remains consistent*

c) *A false negative*

5.4 PLANTS SYNOPTIC ANALYSIS AFTER MISSION IMPLEMENTATION

This section reports outputs achieved by running procedure PROC_EASY.0030.
As reported in section 2.4, PROC_EASY.0025 implementation is a precondition.
In particular, Figure 8 illustrates how an operator can visualise all retrieved information for a given mission and further include his comments and accept or discard anomalies.

Figure 8 Plant status analysis

The above information is then analysed to measure the performances of EASY-PV solution

In particular, the *precision* and *recall* approach is used and herein recapped in the following.

Precision, also referred to as positive predictive value, has been computed as the proportion of the examples that truly belong to a specific class among all those which were assigned to that class. It is the ratio of the number of correct items that are detected by the total number of irrelevant and relevant items detected. Finally, it is the fraction of correctly identified panel.

Recall, also referred to as the true positive rate or sensitivity, has been computed as the proportion of items that were assigned to a specific class, among all the items that truly belong to that class, i.e., how much the class has been covered. It is the ratio of the number of relevant items detected to the total number of relevant items in the search space. Finally, it provides an indication about the identification process exhaustiveness.

Precision and recall are then defined as [1]:

$$Precision = \frac{t_p}{t_p + f_p}$$
$$Recall = \frac{t_p}{t_p + f_n}$$

where:

- t_p represents true positive, which is the total number of panels *existing* and *correctly* identified.
- f_p represents false positive, which is the total number of panels *non-existing* and *wrongly* identified.
- f_n represents false negative, which is the total number of panels *existing* and *wrongly* identified.

It is noteworthy that wrong geo-referencing impacts on:

- f_p subset when positioning errors occurs causing an actual panel to be identified with so different geocentric points to be considered as physically distinguished.
- f_n subset when positioning errors occurs causing two actual panels to be identified with a comparable geocentric points to be considered as physically unique.

The above effects are managed also considering a threshold *T* used to make measurements of several panel geocentric centres to converge in one unique geometric point.

A wrong computer vision analysis impacts on:

- f_p subset when vision interpretation errors occur, causing a not existing panel to be identified as an actual one (recognition of a wrong object).
- f_n subset when vision interpretation errors occur causing an existing panel not to be identified (missing recognition)

Now, a measure that combines precision and recall is the harmonic mean of precision and recall, the traditional F-measure or balanced F-Score F_β:

$$F_\beta = (1 + \beta^2)\frac{Precision \cdot Recall}{Precision + Recall}$$

where β is a weight to balance Precision and Recall parameters. In case $\beta = 1$, Precision and Recall are evenly weighted [3] so that:

$$F_1 = F = 2\frac{Precision \cdot Recall}{Precision + Recall}$$

The following section presents results obtained considering F-measure, which is a function of t_p, f_n, T, as the key indicator for the algorithm performance evaluation.

Dataset		Threshold T [m]	t_p	f_p	Precision	f_n	Recall	F-measure
Thermal Imagery	GNSS observables							
Sequence of 1596 images	U-blox NEO-M8P	0,2	408	318	0,56	0	1,00	0,72
		0,4	398	113	0,78	10	0,98	0,87
		0,5	400	7	0,98	8	0,98	0,98
		0,6	398	7	0,98	10	0,98	0,98
		0,8	349	5	0,99	59	0,86	0,92
		1	276	3	0,99	132	0,68	0,80

Table 5-1 F-measure performances

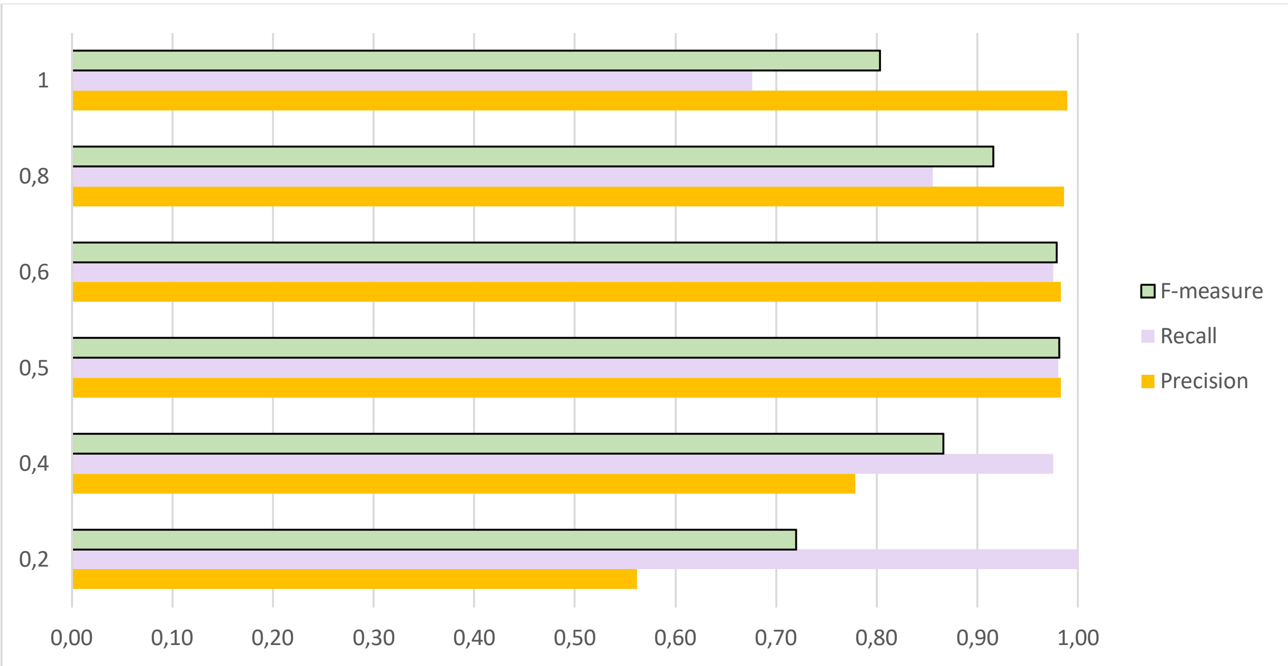

Figure 9 F-measure performances

In particular, several analyses have been performed varying the value assigned for the Threshold T.

It has been verified that the more the T:

- ✓ the lower the t_p as more panels are recognized with the same geographical center and identification as well; this is a negative trend.
- ✓ the lower the f_p as less panels are wrongly recognized; this is a positive trend.
- ✓ The higher the f_n as more missing recognitions are experienced; this is a negative trend.

So a trade-off has been identified with T=0,50m and it is interesting to observe it has same magnitude of end to end geo-referencing error as reported in [RD 3].

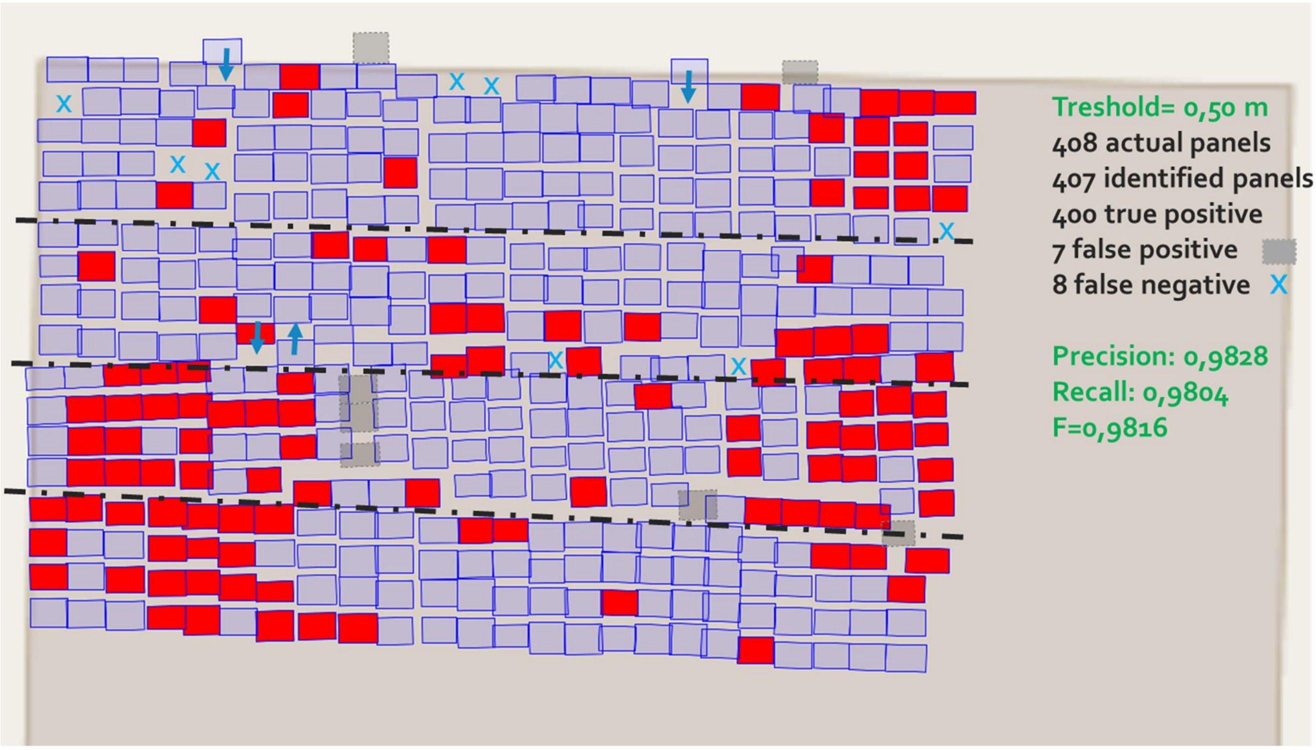

Figure 10 Panel recognition performances for T=0,50m

It is noteworthy that, even if error budget analysis (reported in [RD 3]) revealed thermal images quality (focal length distortion of low cost lenses) as the main contribution to be dealt with , also a possible improvement of other sources of error (e.g. EGNSS precision) may also increases performances as threshold may be lowered avoiding missing panels (f_n)

5.5 REPORT GENERATION

This section reports outputs achieved by running procedure PROC_EASY.0040. In particular, Figure 11 illustrates how an operator can generate a report including all retrieved information for a given mission and his comments.

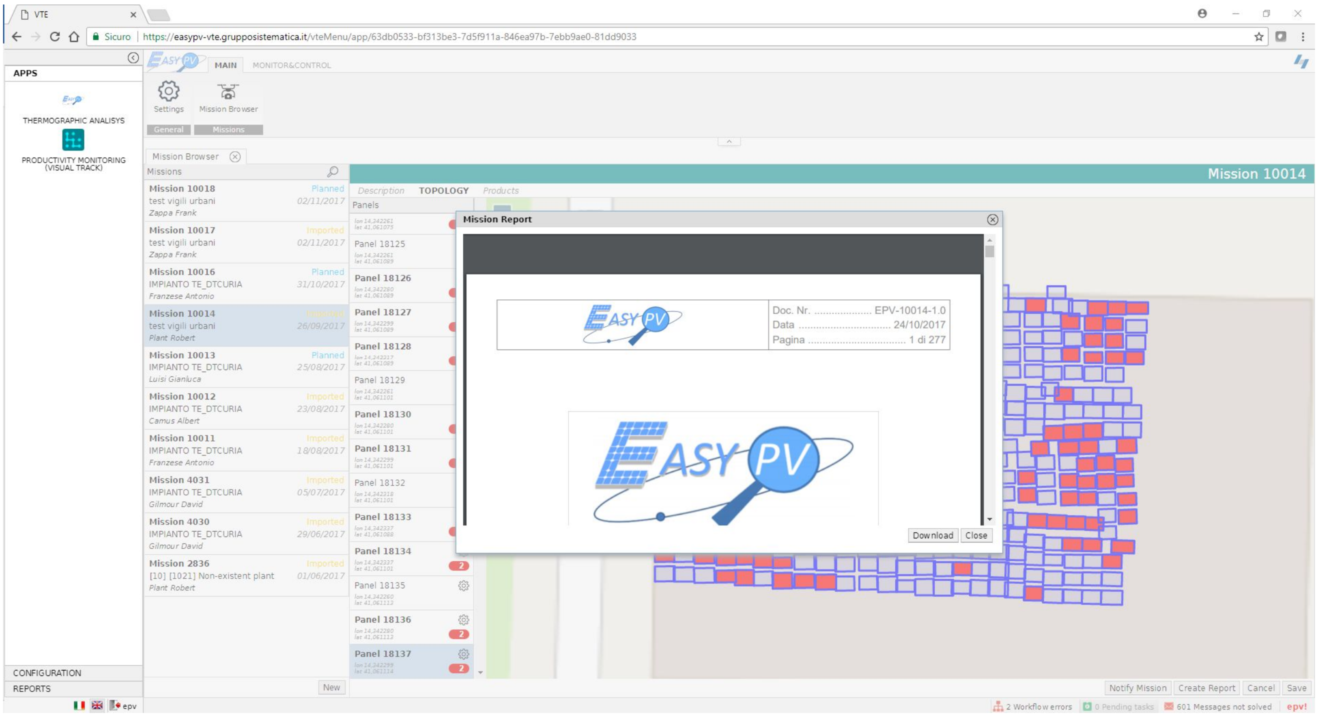

Figure 11 Report generation

5.6 PLANT MONITORING

This section reports outputs achieved by running procedure PROC_EASY.0050. In particular, following pictures report a sample of monitored data using “Visual Track” giving evidence of a plant productivity.

Figure 12 Monitored plants synoptic

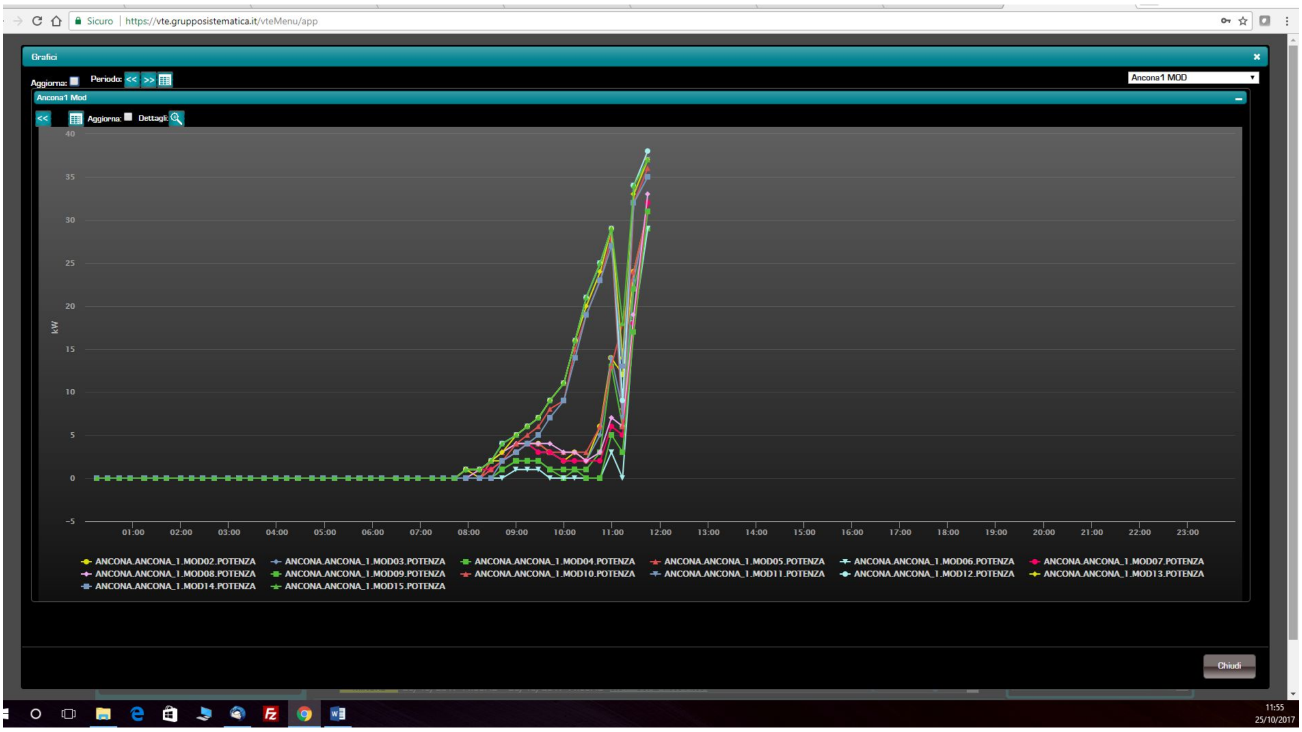

Figure 13 Plant productivity

5.7 RPAS OPERATIONS. EMERGENCY PROCEDURES (LOSS OF COMMUNICATION AND CONTROL LINK)

This section reports some outputs achieved by running the emergency procedure PROC_EASY.0060. In particular, the following pictures report a set of expected events experienced during the implementation of the procedure. In particular Figure 14 gives evidence of the warning messages due to loss of communication Link.

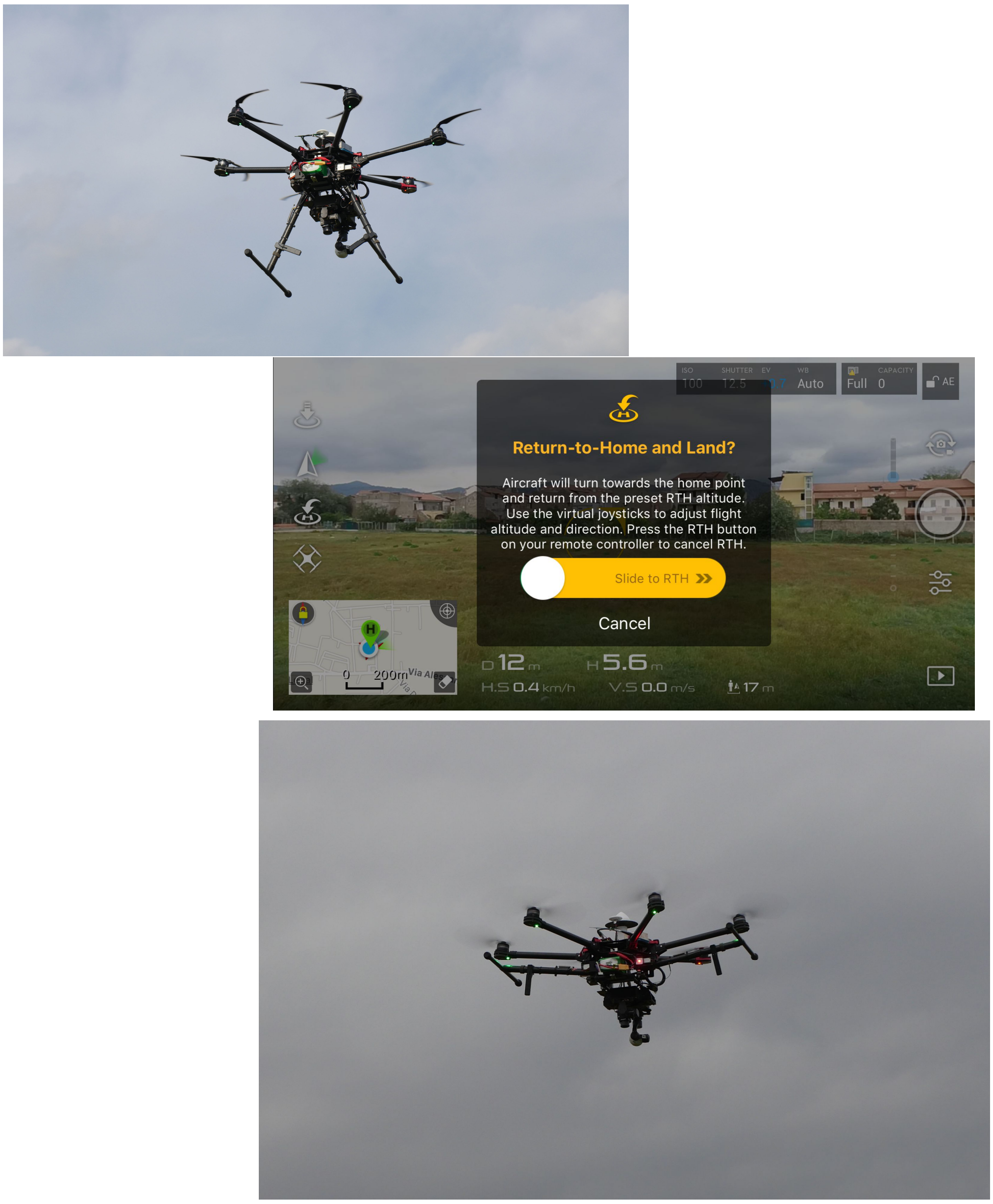

Figure 14 Emergency Procedure: Loss of Communication Link (Take-off, Pilot's application feedback and automatic RTH procedure [RD4])

5.8 RPAS OPERATIONS. EMERGENCY PROCEDURES (VIOLATION OF THE LIMITS OF AREA OF OPERATIONS)

This section reports some output from the Pilot's Tablet application achieved by running the emergency procedure PROC_EASY.0061. In particular, the following pictures report the configuration of the Geofence limits (both vertical and horizontal) according to EPV100 Manual [RD4] and the feedback to the pilot during the event of violation of limits of Area of Operations as showed in Figure 14.

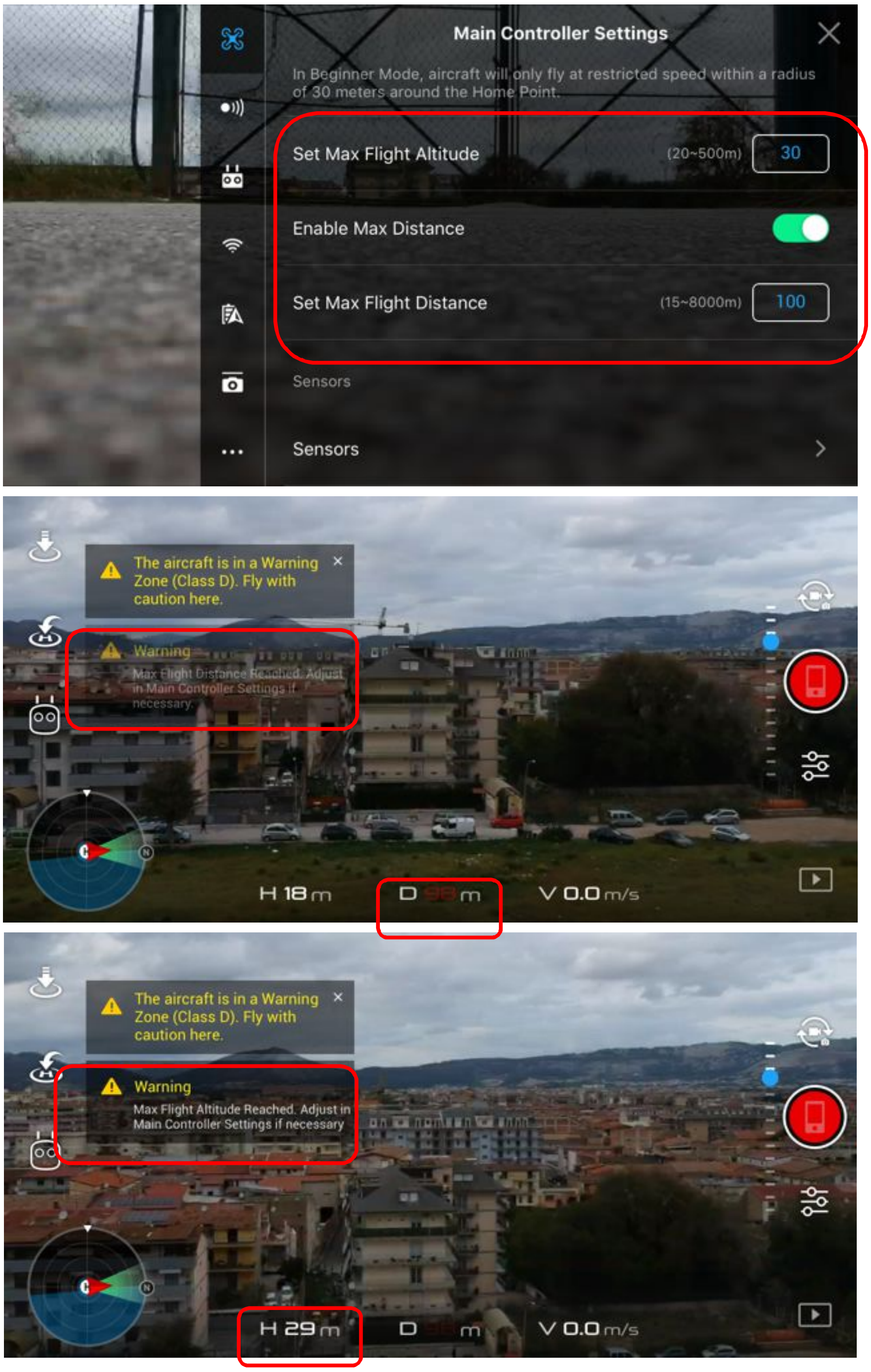

Figure 15 Emergency Procedure: violation of Limits of Area of Operations (Configuration and feedback to Pilot)

5.9 RPAS OPERATIONS. EMERGENCY PROCEDURES (RPA "FLY-AWAY")

This section reports a picture of the emergency procedure "Flight Termination" reported in EPV100 flight Manual [RD4] from the RGS Pilot Console, which has been implemented on the ground according to PROC_EASY.0062 because of its destructive effects. The combination of sticks used by the pilot for 3 seconds determined the effect of stopping the engines while running as expected.

Figure 16 Emergency Procedure: Flight Termination (RD[4])

5.10 PANEL GEO-REFERENCING PERFORMANCES

5.10.1 STEP 1: USING UBLOX M8P

According to procedure TEST_EASY.0070, one unique panel has been positioned on the ground and the GNSS Master station has been placed in survey-in mode over the designed GCP.

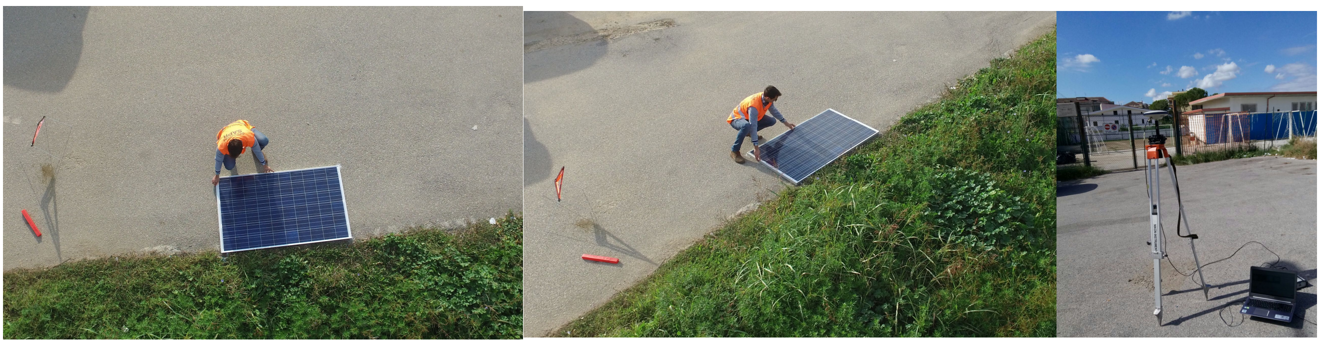

Figure 17 Panel positioned for testing and RGS during Survey-in

The pilot operated the RPA over the panel for 44 fly-bys collecting for each passages the following information:

- Recognition of the Panel through Computer Vision Algorithm (flag “0” or “1”);
- Geographical coordinates of the Panel (phi, lambda, i.e. latitude and longitude expressed in decimal) for each vertex in case of success of recognition of the Algorithm;
- Thermal-Infra-Red pictures for each fly-by collected (used only in post processing for verification).

These data and the position of the GCP after survey-in procedure have been used for post processing analysis and are reported in Table 5-2 Test data set. Each Vertex of the panel is expressed in phi, lambda after the internal calculation performed on the EASY-Pv Payload on-board computer (OBC), therefore the results of the geographic positions of the vertexes of the Panels is performed being affected by all the sources of errors identified in [RD 3]

OCCUR RENCES	ID. FLAG	VERTEX1 phi	VERTEX1 lambda	VERTEX2 phi	VERTEX2 lambda	VERTEX3 phi	VERTEX3 lambda	VERTEX4 phi	VERTEX4 lambda
FLY-BY1	1	41,044817462	14,331783846	41,044806152	14,331793599		14,331783640	41,044812539	14,331773887
FLY-BY2	1	41,044816511	14,331784499	41,044804815	14,331794625	41,044799879	14,331784677	41,044811574	14,331774552
FLY-BY3	0								
FLY-BY4	1	41,044819286	14,331782855	41,044807490	14,331792999	41,044802577	14,331783031	41,044814374	14,331772888
FLY-BY5	1	41,044820814	14,331780915	41,044808775	14,331791316	41,044803846	14,331781362	41,044815885	14,331770961
FLY-BY6	1	41,044820245	14,331781021	41,044809065	14,331790322	41,044804266	14,331780258	41,044815446	14,331770957
FLY-BY7	1	41,044819487	14,331781898	41,044808157	14,331791493	41,044803297	14,331781480	41,044814627	14,331771885
FLY-BY8	1	41,044818337	14,331783399	41,044806373	14,331793483	41,044801529	14,331783457	41,044813493	14,331773373
FLY-BY9	1	41,044821656	14,331783087	41,044809575	14,331792307	41,044805070	14,331782009	41,044817150	14,331772789
FLY-BY10	1	41,044822872	14,331782044	41,044810683	14,331791424	41,044806150	14,331781148	41,044818339	14,331771767
FLY-BY11	1	41,044822720	14,331784751	41,044810626	14,331793993	41,044806117	14,331783699	41,044818211	14,331774456
FLY-BY12	1	41,044823397	14,331784055	41,044811444	14,331793305	41,044806892	14,331783042	41,044818845	14,331773793
FLY-BY13	1	41,044823431	14,331783877	41,044811257	14,331793293	41,044806707	14,331783030	41,044818881	14,331773614
FLY-BY14	1	41,044822830	14,331783493	41,044810671	14,331792941	41,044806106	14,331782690	41,044818265	14,331773241
FLY-BY15	1	41,044823629	14,331784114	41,044811319	14,331793591	41,044806784	14,331783316	41,044819095	14,331773838
FLY-BY16	0								
FLY-BY17	1	41,044821537	14,331784579	41,044809631	14,331793750	41,044805095	14,331783476	41,044817001	14,331774305
FLY-BY18	1	41,044821666	14,331783533	41,044809634	14,331792839	41,044805084	14,331782576	41,044817116	14,331773270
FLY-BY19	1	41,044822471	14,331782452	41,044810311	14,331791977	41,044805718	14,331781747	41,044817878	14,331772222
FLY-BY20	1	41,044820994	14,331783643	41,044808580	14,331793300	41,044804032	14,331783101	41,044816447	14,331773444
FLY-BY21	1	41,044817089	14,331784926	41,044805851	14,331793600	41,044801308	14,331783331	41,044812546	14,331774657
FLY-BY22	1	41,044820812	14,331781723	41,044809161	14,331790750	41,044804605	14,331780491	41,044816256	14,331771464
FLY-BY23	1	41,044818177	14,331783594	41,044806320	14,331792738	41,044801780	14,331782467	41,044813636	14,331773323
FLY-BY24	1	41,044817487	14,331784843	41,044805631	14,331794205	41,044801011	14,331783996	41,044812866	14,331774634
FLY-BY25	1	41,044819911	14,331781641	41,044807732	14,331791123	41,044803160	14,331780877	41,044815339	14,331771395
FLY-BY26	1	41,044818628	14,331781375	41,044807685	14,331789945	41,044803093	14,331779715	41,044814036	14,331771144
FLY-BY27	1	41,044818644	14,331779705	41,044806249	14,331789404	41,044802153	14,331780273	41,044814549	14,331770574
FLY-BY28	1	41,044820447	14,331780179	41,044808710	14,331789478	41,044804078	14,331779279	41,044815815	14,331769979
FLY-BY29	1	41,044818800	14,331773191	41,044806494	14,331783033	41,044801830	14,331772859	41,044814136	14,331763017
FLY-BY30	1	41,044819930	14,331776559	41,044807345	14,331785822	41,044803013	14,331775555	41,044815599	14,331766292

OCCUR RENCES	ID. FLAG	VERTEX1 phi	VERTEX1 lambda	VERTEX2 phi	VERTEX2 lambda	VERTEX3 phi	VERTEX3 lambda	VERTEX4 phi	VERTEX4 lambda
FLY-BY31	1	41,044824833	14,331773053	41,044812307	14,331782454	41,044807923	14,331772262	41,044820450	14,331762861
FLY-BY32	1	41,044820646	14,331777374	41,044808041	14,331786591	41,044803712	14,331776262	41,044816317	14,331767045
FLY-BY33	0								
FLY-BY34	1	41,044821768	14,331775766	41,044809541	14,331784518	41,044805251	14,331774061	41,044817478	14,331765309
FLY-BY35	1	41,044819695	14,331777735	41,044807143	14,331786914	41,044802781	14,331776509	41,044815334	14,331767329
FLY-BY36	1	41,044820695	14,331777081	41,044808373	14,331786000	41,044804046	14,331775570	41,044816368	14,331766651
FLY-BY37	1	41,044818370	14,331777167	41,044805917	14,331786630	41,044801426	14,331776321	41,044813879	14,331766858
FLY-BY38	1	41,044822030	14,331772471	41,044809653	14,331781796	41,044805191	14,331771464	41,044817569	14,331762140
FLY-BY39	1	41,044818992	14,331777450	41,044806629	14,331786917	41,044802113	14,331776627	41,044814475	14,331767160
FLY-BY40	1	41,044822878	14,331773947	41,044810383	14,331783422	41,044806079	14,331773520	41,044818574	14,331764045
FLY-BY41	1	41,044819920	14,331774940	41,044807405	14,331784368	41,044802957	14,331774067	41,044815472	14,331764639
FLY-BY42	1	41,044821070	14,331780438	41,044808499	14,331789735	41,044804125	14,331779416	41,044816696	14,331770119
FLY-BY43	1	41,044821698	14,331772186	41,044809212	14,331781463	41,044804798	14,331771097	41,044817283	14,331761820
FLY-BY44	1	41,044822117	14,331772492	41,044809916	14,331781763	41,044805426	14,331771453	41,044817627	14,331762183
FLY-BY45	1	41,044818800	14,331773191	41,04480649	14,33178303	41,04480183	14,33177286	41,04481414	14,33176302

RGS Survey-in		
GCP phi [°]	GCP lambda [°]	GCP alt [m]
41,0448174621	14,3317935990	1,920000000

Table 5-2 Test data set

The first results show that the computer vision algorithm succeeded 42 times over 45 flybys on the PV panel on a vertical distance of about 8 meters from the RPA's thermal camera, which is the typical vertical distance from the panels used during real inspections.

This failure ratio is 7% which is quite a high value not experienced in other campaign sessions. As a first analysis of collected thermal images, it occurs that wrongly panel boundaries are recognised by the automated algorithm itself which provided unsatisfactory performances as elaborating images with low irradiance (uncomfortable meteo conditions).

Figure 18 Pilot's HMI during test

In coincidence of the flybys where the algorithm did not succeed in the recognition, no information of the vertexes are available with respect to Table 5-2 Test data set. However, it must be considered that during normal operations, panels are inspected with multiple thermal images from different RPA passages.

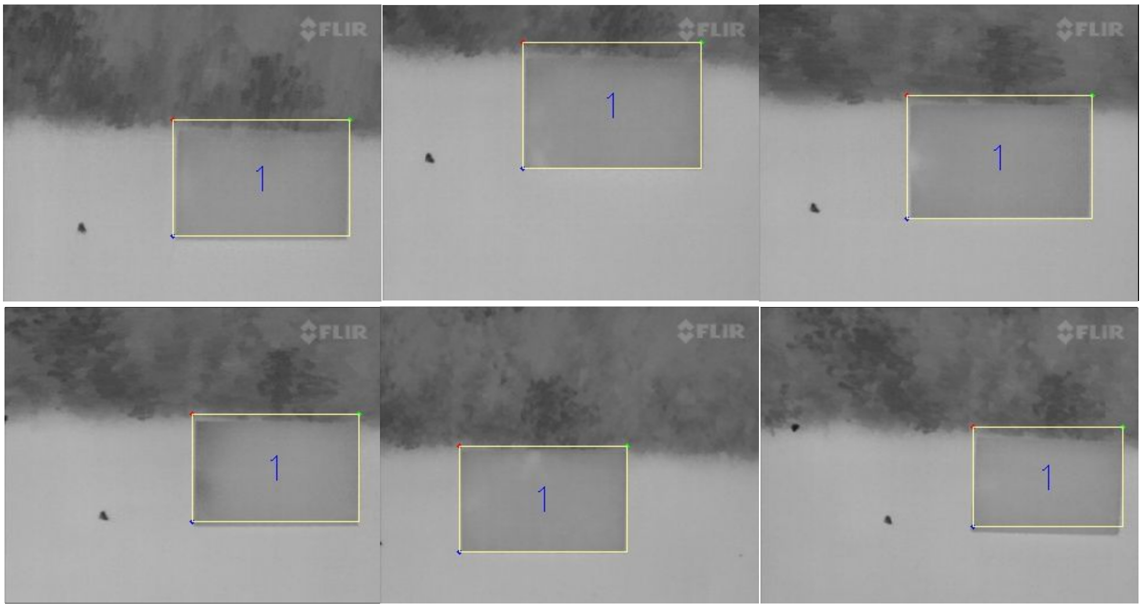

Figure 19 Fly-by sequence and Panel identified

The centre of panel, taken as reference, has been calculated after the first fly-by. In fact the algorithm after the first sequence of images and the recognition of the panel, assigned a fist ID to the panel (ID1 in Figure 19) based on the average of the positions of the vertexes (coming from measured positions in each image (generally in number of 4/5 for each fly-by).

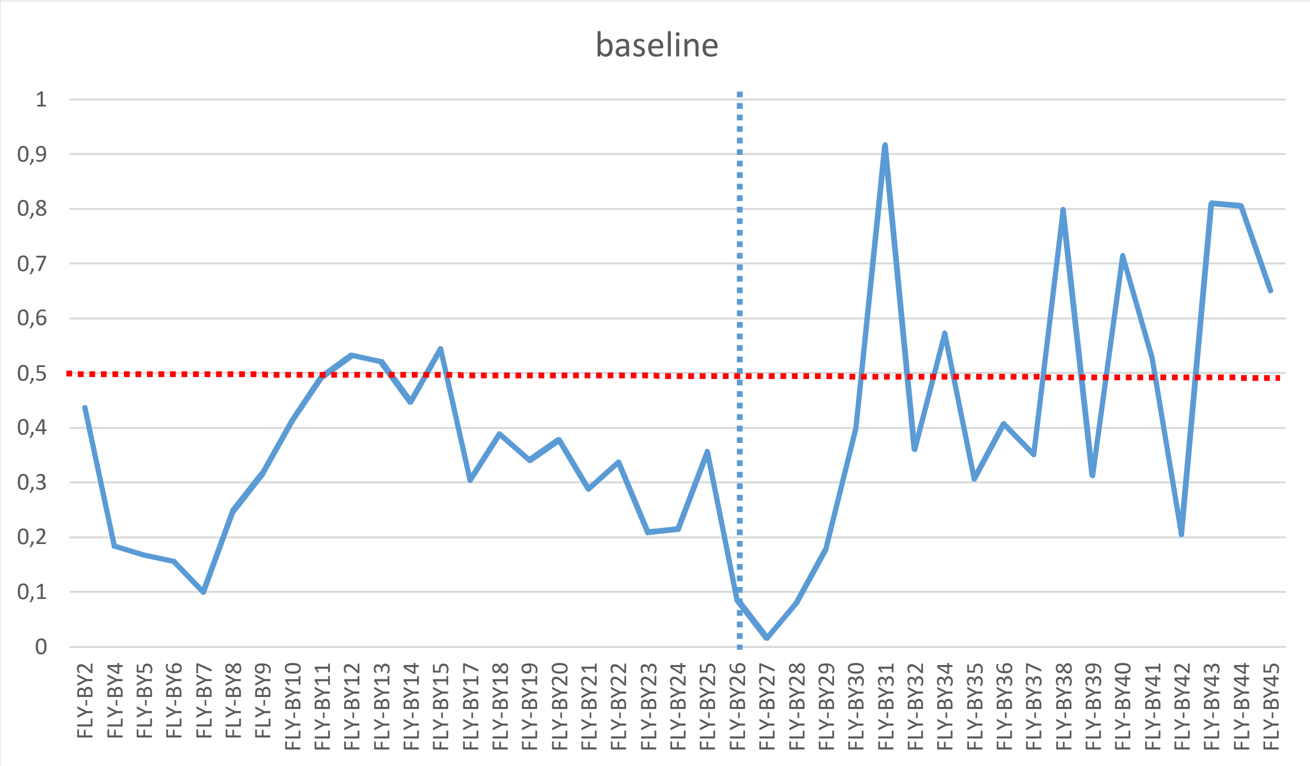

Figure 20 baselines calculated for each fly-by

With respect of the first average position of the center of Panel, a sequence of baselines for the next flybys has been calculated after transformation of the positions obtained in the NED reference frame.
The baselines calculated in post processing after the E2E test are reported in Figure 20, where absolute value of baselines are evaluated. In particular, the following observations are noted:

- ✓ Fly-bys are realised in two different time using two battery packages: Fly-by 26 to Fly-by 45 are flown after switching off/on the RPAS to allow battery change.
- ✓ several values are identified over the threshold of 0,5 m (red dotted line)

As a first conclusion Figure 20 provides an indication about a missing fulfilment of SR.0210 accuracy requirement.

However, based on a statistical approach, a statistical analysis about panel georeferencing end to end accuracy is reported in Table 5-3.

baseline [m]	*dist_east [m]*	*dist_north [m]*	*FLY-ID*
			FLY-BY1
0,437156421	0,323219216	-0,294338367	FLY-BY2
0,185194922	0,184945863	0,009601398	FLY-BY4
0,168183343	0,033244445	0,164864926	FLY-BY5
0,156827641	-0,008699873	0,156586146	FLY-BY6
0,100038536	0,079517685	0,060701289	FLY-BY7
0,247387676	0,225692373	-0,101309502	FLY-BY8
0,318087845	0,151722433	0,279571423	FLY-BY9
0,413342684	0,071679393	0,407080138	FLY-BY10
0,493082698	0,292664587	0,396834961	FLY-BY11
0,532525654	0,235842225	0,477453681	FLY-BY12
0,521472912	0,22783582	0,469068052	FLY-BY13
0,448132807	0,197386262	0,402320365	FLY-BY14
0,544986951	0,249795645	0,484368571	FLY-BY15
0,305501068	0,168197556	0,255030361	FLY-BY17
0,389249563	0,276084394	0,274395025	FLY-BY18
0,341580236	0,194297177	0,280937119	FLY-BY19
0,378418162	0,114022981	0,360831076	FLY-BY20
0,288353839	0,220985194	0,185238982	FLY-BY21
0,33826702	0,284574125	-0,182871932	FLY-BY22
0,209148942	0,030596657	0,206898827	FLY-BY23
0,215041823	0,192279815	-0,096288414	FLY-BY24
0,356277398	0,30903464	-0,177288398	FLY-BY25
0,088056143	0,043373283	0,076633169	FLY-BY26
0,016747099	-0,016664251	0,001663756	FLY-BY27
0,0804933	-0,063378789	-0,049621573	FLY-BY28
0,178965453	-0,085254558	0,157354039	FLY-BY29
0,399974269	-0,393889928	0,069499214	FLY-BY30
0,916156378	-0,679640847	0,614353992	FLY-BY31
0,36161859	-0,329922741	0,148050631	FLY-BY32
0,572363402	-0,490008821	0,295789148	FLY-BY34
0,307494244	-0,304390504	0,043579023	FLY-BY35
0,408100199	-0,37132069	0,169312485	FLY-BY36
0,352240006	-0,33614294	-0,105266068	FLY-BY37
0,798957101	-0,73761899	0,307002728	FLY-BY38
0,313090628	-0,311388228	-0,032605415	FLY-BY39
0,714054823	-0,589195785	0,403388915	FLY-BY40
0,5285824	-0,524472088	0,065790449	FLY-BY41
0,20629593	-0,068590307	0,194559452	FLY-BY42
0,810192381	-0,765042505	0,266686445	FLY-BY43
0,805600767	-0,737198706	0,324854835	FLY-BY44
0,651426866	-0,648749992	-0,058994999	FLY-BY45
mean	-0,081818995	0,168578438	0,187384731
*2*std*	0,684634762	0,416783604	0,801519388

Table 5-3 Statistical analysis about panel georeferencing end to end accuracy

The above results confirm that SR.0210 requirement cannot be fulfilled with the configuration used in this test due to the high standard deviation experienced (i.e. 2*std=0,80 m).

As a further analysis, Table 5-4 reports statistical values per separated sessions.

	dist_east [m]	*dist_north [m]*	*Total*
Fly-by1 to Fly-by 45			
mean	-0,081818995	0,168578438	0,187384731
*2*std*	0,684634762	0,416783604	0,801519388
Fly-by1 to Fly-by 25			
mean	0,15609247	0,19048069	0,246267644
*2*std*	0,189109471	0,414975453	0,45603401
Fly-by26 to Fly-by 45			
mean	-0,352313812	0,189012621	0,399813448
*2*std*	0,690716971	0,355945791	0,777037541

Table 5-4 Statistical analysis about panel georeferencing end to end accuracy considering separated sessions

It is noted that:

- ✓ First session (Fly-by1 to Fly-by 25) data is again not compliant, still being limited over the threshold
- ✓ Second session (Fly-by26 to Fly-by 45) includes worst results (0,78 m standard deviation) and additionally an offset along with east direction is noted so that mean value moves from 0,12 m to -0,35m.

Finally, it is assumed that TEST_EASY.0070 has not passed successfully. However, an important lesson learnt is experienced about the management of an offset to harmonise different campaigns implemented in different days (or even part of the day), basically because the satellite constellation deployment is changing.

Now, based on outcomes provided by [RD 3] (in particular TEST_GNSS.0060), a new approach is proposed in section 5.10.2 by replacing the single frequency ublox M8P receiver with dual frequency North RTKite. Indeed, TEST_GNSS.0060 performed a comparison between the above mentioned receiver, allowing to point out different performances in terms of accuracy (only GNSS component).

In consequence of TEST.0070 results, the upgrade of EASY-PV RPAS payload to integrate the dual frequency receiver now is deemed justified, even though a higher cost of the component itself, having a minor impact in the business value proposition.

5.10.2 STEP 2: USING NORTH RTKITE

This section reports a new test campaign implemented by repeating the procedure described in section 4.10. However, the following modifications are taken into account in order to realise a more exhaustive scenario with complete datasets including both static (RPAS hovering) and cinematic conditions:

- ✓ A dual frequency receiver North RTKite is used augmented with data from Regione Campania having master stations 1,5 km far from the RTK rover installed on board the RPAS and configured to performed measurements at 5Hz.
- ✓ A 3x3 matrix (9 panels) representing a real photovoltaic plant has been observed as reference target instead of a single panel as reported in §4.10.

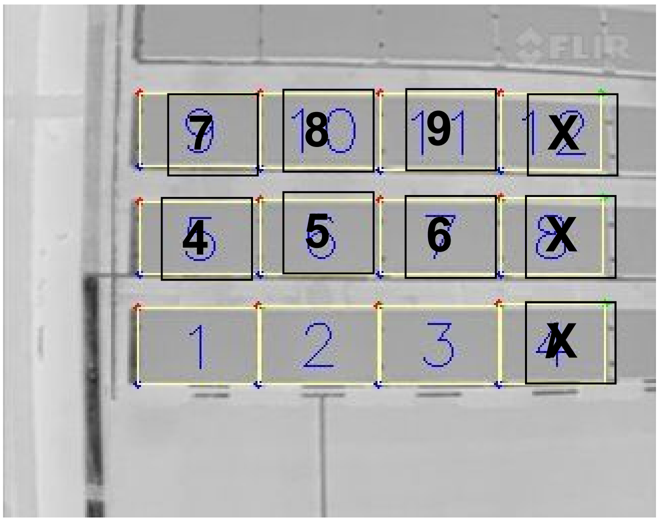

Figure 21 – Reference target panels as acquired by the thermal camera

It has to be noted that the thermal camera was able to recognise more panels than needed (as it should be) so a quick processing activity has been performed to assign correct panel_ID, as shown in figure above.

- ✓ Several datasets have been collected:
  - o A static acquisition campaign has been performed in 16-12-2017 along with the morning (dataset1) and afternoon (dataset2)
  - o A cinematic acquisition (RPAS moving with velocity of 3m/s) in 20-12-2017 during the afternoon (dataset3).

Final outcomes for each session are reported in following tables where each value is represented in meters, after a conversion from geodetic lat/lon to local ENU coordinate system), where the following parameters are analysed:

- ✓ Baseline, as the distance between each panel center identified in a given fly-by and fly-by1, selected as reference; this is an absolute value.
- ✓ Dist_east, the east component of the baseline including both positive and negative values;
- ✓ Dist_north; the north component of the baseline including both positive and negative values;

Panel 1

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,169564	-0,15969	0,057027	FLY-BY2
0,15447	-0,15227	-0,02599	FLY-BY3
0,203649	-0,20365	-0,00014	FLY-BY4
0,247167	-0,23105	0,087789	FLY-BY5
0,219834	-0,21983	-0,00136	FLY-BY6
0,293051	-0,15996	0,245543	FLY-BY7
0,246354	-0,1359	0,20548	FLY-BY8
0,302256	-0,17112	0,249152	FLY-BY9
0,274487	-0,26547	-0,06977	FLY-BY10
0,224585	-0,19814	0,105725	FLY-BY11
0,20771	-0,20148	0,050475	FLY-BY12
0,217088	-0,1868	0,110611	FLY-BY13
0,218408	-0,21823	0,008746	FLY-BY14
0,193412	-0,18944	-0,03898	FLY-BY15
0,074147	-0,06386	0,037676	FLY-BY16
0,078274	0,013974	-0,07702	FLY-BY17
0,164451	0,092147	-0,13621	FLY-BY18
mean	-0,15593	0,047574	0,163024
2*std	0,177154	0,214793	0,278423

Panel 2

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,130691	-0,07269	0,108612	FLY-BY2
0,10262	-0,10141	-0,01569	FLY-BY3
0,106131	-0,10259	0,027181	FLY-BY4
0,211431	-0,17106	0,124271	FLY-BY5
0,122188	-0,12216	-0,1495	FLY-BY6
0,266369	-0,16639	0,055697	FLY-BY7
0,236128	-0,07748	0,070745	FLY-BY8
0,305602	-0,16769	0,103173	FLY-BY9
0,283235	-0,27678	-0,21245	FLY-BY10
0,198918	-0,17305	-0,05422	FLY-BY11
0,11433	-0,1061	-0,10972	FLY-BY12
0,19771	-0,14723	-0,02035	FLY-BY13
0,151562	-0,15078	-0,1369	FLY-BY14
0,124099	-0,12382	-0,16069	FLY-BY15
0,059393	-0,01631	-0,0952	FLY-BY16
0,031267	-0,02347	-0,17297	FLY-BY17
0,156717	0,053313	-0,29968	FLY-BY18
mean	-0,11445	-0,05516	0,12705
2*std	0,146011	0,243255	0,283711

Panel 3

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,176501	-0,08937	0,152201	FLY-BY2
0,194596	-0,19457	-0,00314	FLY-BY3
0,137775	-0,11884	0,069715	FLY-BY4
0,238758	-0,20066	0,129379	FLY-BY5
0,191829	-0,19173	-0,00605	FLY-BY6
0,318112	-0,26423	0,177133	FLY-BY7
0,274931	-0,12373	0,245515	FLY-BY8
0,317262	-0,18028	0,261063	FLY-BY9
0,272533	-0,26982	-0,03834	FLY-BY10
0,26487	-0,25171	0,082459	FLY-BY11
0,163775	-0,16221	0,0226	FLY-BY12
0,279901	-0,24784	0,130074	FLY-BY13
0,214515	-0,21308	0,024738	FLY-BY14
0,185997	-0,186	-0,00019	FLY-BY15
0,10058	-0,08425	0,054945	FLY-BY16
0,071125	-0,06271	0,033566	FLY-BY17
0,14694	-0,00351	-0,1469	FLY-BY18
mean	-0,16733	0,069927	0,18135
2*std	0,148401	0,202064	0,250705

Panel 4

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,202668	-0,17997	0,093203	FLY-BY2
0,190373	-0,18253	-0,05408	FLY-BY3
0,225044	-0,22325	0,028319	FLY-BY4
0,294087	-0,24421	0,163862	FLY-BY5
0,236126	-0,23254	0,04098	FLY-BY6
0,277133	-0,17601	0,214059	FLY-BY7
0,276248	-0,16221	0,22361	FLY-BY8
0,338564	-0,20445	0,269864	FLY-BY9
0,307319	-0,29697	-0,07907	FLY-BY10
0,227371	-0,2117	0,082959	FLY-BY11
0,233891	-0,21401	0,094369	FLY-BY12
0,24702	-0,21718	0,117691	FLY-BY13
0,256842	-0,25679	0,004998	FLY-BY14
0,192208	-0,1922	-0,00214	FLY-BY15
0,098214	-0,08057	0,056166	FLY-BY16
0,095955	-0,05359	-0,0796	FLY-BY17
0,145338	-0,02448	-0,14326	FLY-BY18
mean	-0,18545	0,060702	0,195132
2*std	0,139335	0,223811	0,263639

Panel 5

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,137048	-0,06483	0,120745	FLY-BY2
0,101009	-0,09257	-0,04042	FLY-BY3
0,100426	-0,08368	0,055528	FLY-BY4
0,183915	-0,1168	0,142067	FLY-BY5
0,118846	-0,11863	0,007247	FLY-BY6
0,242456	-0,14451	0,19468	FLY-BY7
0,230035	-0,07578	0,217196	FLY-BY8
0,288759	-0,13552	0,254983	FLY-BY9
0,241885	-0,23261	-0,06636	FLY-BY10
0,166953	-0,14849	0,076323	FLY-BY11
0,102529	-0,08971	0,049642	FLY-BY12
0,19028	-0,16114	0,101199	FLY-BY13
0,174384	-0,17385	-0,01363	FLY-BY14
0,098927	-0,09669	-0,02093	FLY-BY15
0,038974	-0,0041	0,038758	FLY-BY16
0,069149	-0,03661	-0,05866	FLY-BY17
0,16707	0,050329	-0,15931	FLY-BY18
mean	-0,10148	0,052885	0,114434
2*std	0,129287	0,214727	0,250644

Panel 6

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,166615	-0,06729	0,152423	FLY-BY2
0,148654	-0,14659	-0,02465	FLY-BY3
0,112654	-0,07275	0,086012	FLY-BY4
0,161659	-0,11745	0,111083	FLY-BY5
0,149593	-0,14756	-0,02457	FLY-BY6
0,28267	-0,21775	0,180243	FLY-BY7
0,247623	-0,09496	0,22869	FLY-BY8
0,272734	-0,10866	0,250152	FLY-BY9
0,214794	-0,21233	-0,03246	FLY-BY10
0,209888	-0,19104	0,086929	FLY-BY11
0,094294	-0,09398	0,007746	FLY-BY12
0,228165	-0,20983	0,089622	FLY-BY13
0,185041	-0,18316	-0,02632	FLY-BY14
0,135986	-0,13094	-0,0367	FLY-BY15
0,051664	-0,04503	0,025321	FLY-BY16
0,05568	-0,04789	-0,0284	FLY-BY17
0,160218	0,031794	-0,15703	FLY-BY18
mean	-0,12091	0,05224	0,13171
2*std	0,134661	0,211437	0,250678

Panel 7

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,193909	-0,17072	0,091954	FLY-BY2
0,207299	-0,18551	-0,09251	FLY-BY3
0,233954	-0,22838	0,050753	FLY-BY4
0,250057	-0,22225	0,114609	FLY-BY5
0,212609	-0,21254	-0,0055	FLY-BY6
0,203243	-0,17324	0,10628	FLY-BY7
0,217841	-0,16765	0,139097	FLY-BY8
0,338069	-0,21044	0,264589	FLY-BY9
0,327308	-0,31404	-0,09226	FLY-BY10
0,231506	-0,22479	0,055361	FLY-BY11
0,22082	-0,20865	0,072297	FLY-BY12
0,211883	-0,21142	-0,01394	FLY-BY13
0,268887	-0,2686	-0,01235	FLY-BY14
0,20255	-0,18562	-0,08107	FLY-BY15
0,066152	-0,06462	-0,01416	FLY-BY16
0,169017	-0,10335	-0,13374	FLY-BY17
0,183345	-0,10354	-0,15131	FLY-BY18
mean	-0,19149	0,017536	0,192292
2*std	0,117701	0,213035	0,243388

Panel 8

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,137132	-0,06859	0,118746	FLY-BY2
0,123936	-0,09557	-0,0789	FLY-BY3
0,110773	-0,08822	0,066994	FLY-BY4
0,156602	-0,08561	0,131128	FLY-BY5
0,114374	-0,11436	-0,00183	FLY-BY6
0,17351	-0,13039	0,11447	FLY-BY7
0,190936	-0,08399	0,171469	FLY-BY8
0,277762	-0,11638	0,252206	FLY-BY9
0,223231	-0,21382	-0,06413	FLY-BY10
0,162827	-0,15025	0,062746	FLY-BY11
0,125768	-0,08954	0,088317	FLY-BY12
0,175366	-0,17253	0,031429	FLY-BY13
0,187736	-0,18766	-0,00544	FLY-BY14
0,118305	-0,09202	-0,07435	FLY-BY15
0,011534	0,009919	-0,00589	FLY-BY16
0,106045	-0,0626	-0,0856	FLY-BY17
0,154778	0,044634	-0,1482	FLY-BY18
mean	-0,09982	0,033715	0,105362
2*std	0,124619	0,206097	0,240844

Panel 9

baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,154661	-0,07029	0,137764	FLY-BY2
0,121073	-0,11146	-0,04728	FLY-BY3
0,11325	-0,05262	0,100283	FLY-BY4
0,158066	-0,0763	0,13843	FLY-BY5
0,133497	-0,13338	0,005664	FLY-BY6
0,231066	-0,19278	0,12738	FLY-BY7
0,233827	-0,10501	0,208923	FLY-BY8
0,257862	-0,06401	0,249791	FLY-BY9
0,19463	-0,19388	-0,0171	FLY-BY10
0,180037	-0,1563	0,089344	FLY-BY11
0,105227	-0,06014	0,086345	FLY-BY12
0,228808	-0,21298	0,083625	FLY-BY13
0,16117	-0,16084	0,010273	FLY-BY14
0,115259	-0,10377	-0,05017	FLY-BY15
0,011056	-0,00733	0,008274	FLY-BY16
0,074475	-0,06193	-0,04137	FLY-BY17
0,149542	0,039086	-0,14434	FLY-BY18
mean	-0,10141	0,055637	0,115668
2*std	0,132188	0,198864	0,238789

Summary

Panel 1			
mean	-0,15593	0,047574	0,163024
2*std	0,177154	0,214793	0,278423
Panel 2			
mean	-0,11445	-0,05516	0,12705
2*std	0,146011	0,243255	0,283711
Panel 3			
mean	-0,16733	0,069927	0,18135
2*std	0,148401	0,202064	0,250705
Panel 4			
mean	-0,18545	0,060702	0,195132
2*std	0,139335	0,223811	0,263639
Panel 5			
mean	-0,10148	0,052885	0,114434
2*std	0,129287	0,214727	0,250644
Panel 6			
mean	-0,12091	0,05224	0,13171
2*std	0,134661	0,211437	0,250678
Panel 7			
mean	-0,19149	0,017536	0,192292
2*std	0,117701	0,213035	0,243388
Panel 8			
mean	-0,09982	0,033715	0,105362
2*std	0,124619	0,206097	0,240844
Panel 9			
mean	-0,10141	0,055637	0,115668
2*std	0,132188	0,198864	0,238789

Table 5-5 Statistical analysis about Dataset 1 (static conditions – morning 16-12-2017)

Panel 1			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,193027	-0,01406	0,192514	FLY-BY2
0,017262	0,004917	-0,01655	FLY-BY3
0,037216	-0,03112	0,020406	FLY-BY4
0,24018	0,049909	0,234937	FLY-BY5
0,075088	-0,07462	0,008357	FLY-BY6
0,393053	-0,15408	0,361596	FLY-BY7
0,293534	-0,05562	0,288216	FLY-BY8
0,274683	-0,08097	0,262479	FLY-BY9
0,148759	-0,14086	-0,04784	FLY-BY10
0,075123	0,073991	0,012993	FLY-BY11
0,137666	-0,07414	0,115997	FLY-BY12
0,173635	2,1E-05	0,173635	FLY-BY13
0,04115	0,041083	-0,00236	FLY-BY14
0,136397	-0,11442	-0,07424	FLY-BY15
0,080486	0,018303	-0,07838	FLY-BY16
mean	-0,03678	0,096785	0,103537
2*std	0,134934	0,279497	0,310364

Panel 2			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,130691	-0,07269	0,108612	FLY-BY2
0,10262	-0,10141	-0,01569	FLY-BY3
0,106131	-0,10259	0,027181	FLY-BY4
0,211431	-0,17106	0,124271	FLY-BY5
0,122188	-0,12216	-0,19393	FLY-BY6
0,266369	-0,16639	0,011275	FLY-BY7
0,236128	-0,07748	0,026323	FLY-BY8
0,305602	-0,16769	0,058751	FLY-BY9
0,283235	-0,27678	-0,25687	FLY-BY10
0,198918	-0,17305	-0,09864	FLY-BY11
0,11433	-0,1061	-0,15414	FLY-BY12
0,19771	-0,14723	-0,06477	FLY-BY13
0,151562	-0,15078	-0,18132	FLY-BY14
0,124099	-0,12382	-0,20512	FLY-BY15
0,059393	-0,01631	-0,13962	FLY-BY16
mean	-0,11621	-0,0561	0,12904
2*std	0,115148	0,235276	0,261942

Panel 3			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,140455	0,028726	0,137486	FLY-BY2
0,165548	-0,15759	0,050725	FLY-BY3
0,153154	-0,10118	0,11497	FLY-BY4
0,248337	-0,14351	0,202676	FLY-BY5
0,094093	-0,08687	0,036149	FLY-BY6
0,304346	-0,14267	0,268837	FLY-BY7
0,23312	-0,23305	0,005803	FLY-BY8
0,183178	-0,17269	0,061081	FLY-BY9
0,108009	-0,09938	0,042312	FLY-BY10
0,211986	-0,17156	0,124521	FLY-BY11
0,141422	-0,14101	0,010856	FLY-BY12
0,252792	-0,21464	0,133544	FLY-BY13
0,307671	-0,15546	0,265505	FLY-BY14
0,165289	-0,16519	0,005636	FLY-BY15
0,102199	0,003383	0,102143	FLY-BY16
mean	-0,11486	0,091897	0,147101
2*std	0,137654	0,168613	0,217667

Panel 4			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,122127	-0,10515	0,062108	FLY-BY2
0,135912	-0,10478	-0,08657	FLY-BY3
0,136413	-0,131	-0,03804	FLY-BY4
0,252576	-0,19966	0,1547	FLY-BY5
0,22131	-0,19388	-0,10672	FLY-BY6
0,133753	-0,09364	0,095508	FLY-BY7
0,244313	-0,12985	0,206951	FLY-BY8
0,163693	-0,11346	0,117996	FLY-BY9
0,295981	-0,2686	-0,12433	FLY-BY10
0,120639	-0,11251	0,043534	FLY-BY11
0,118344	-0,1165	0,020795	FLY-BY12
0,216174	-0,14363	0,161558	FLY-BY13
0,190909	-0,18808	-0,03276	FLY-BY14
0,2253	-0,18547	-0,12791	FLY-BY15
0,084554	-0,04653	0,070603	FLY-BY16
mean	-0,12545	0,024555	0,127835
2*std	0,106907	0,212089	0,237509

Panel 5			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,15411	-0,05012	0,145732	FLY-BY2
0,115836	-0,04423	-0,10706	FLY-BY3
0,148589	-0,07107	0,13049	FLY-BY4
0,178294	-0,09999	0,14762	FLY-BY5
0,13753	-0,13544	0,023905	FLY-BY6
0,195339	-0,1214	0,153034	FLY-BY7
0,198747	-0,05056	0,192209	FLY-BY8
0,287976	-0,14393	0,24943	FLY-BY9
0,199816	-0,18848	-0,06636	FLY-BY10
0,155384	-0,14849	0,045783	FLY-BY11
0,109505	-0,10442	0,032984	FLY-BY12
0,198576	-0,16744	0,106752	FLY-BY13
0,132557	-0,12762	-0,03584	FLY-BY14
0,138318	-0,1219	-0,06536	FLY-BY15
0,025212	-0,0041	0,024876	FLY-BY16
mean	-0,09289	0,057541	0,109271
2*std	0,099721	0,203983	0,227054

Panel 6			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,168672	-0,10721	0,130212	FLY-BY2
0,159068	-0,13399	-0,08573	FLY-BY3
0,131955	-0,10007	0,086012	FLY-BY4
0,16987	-0,14477	0,088872	FLY-BY5
0,121335	-0,12024	-0,01624	FLY-BY6
0,257291	-0,20304	0,158032	FLY-BY7
0,24756	-0,11808	0,217585	FLY-BY8
0,177114	-0,09816	0,147426	FLY-BY9
0,266256	-0,25225	-0,08521	FLY-BY10
0,198829	-0,18263	0,078599	FLY-BY11
0,078508	-0,07716	-0,01446	FLY-BY12
0,211316	-0,19932	0,070187	FLY-BY13
0,192688	-0,19157	-0,02077	FLY-BY14
0,174175	-0,14775	-0,09223	FLY-BY15
0,040949	-0,04083	0,00311	FLY-BY16
mean	-0,12453	0,039141	0,13054
2*std	0,108005	0,187561	0,216435

Panel 7			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,193909	-0,17072	0,091954	FLY-BY2
0,207299	-0,18551	-0,09251	FLY-BY3
0,233954	-0,22838	0,050753	FLY-BY4
0,250057	-0,22225	0,114609	FLY-BY5
0,206529	-0,20623	-0,01105	FLY-BY6
0,207446	-0,16063	0,131267	FLY-BY7
0,228403	-0,15294	0,169637	FLY-BY8
0,354935	-0,25667	0,245155	FLY-BY9
0,284944	-0,28041	-0,05061	FLY-BY10
0,235437	-0,2353	0,008163	FLY-BY11
0,242458	-0,23387	0,063968	FLY-BY12
0,230607	-0,23034	-0,01116	FLY-BY13
0,295658	-0,28331	-0,08454	FLY-BY14
0,189161	-0,17091	-0,08107	FLY-BY15
0,035999	-0,0331	-0,01416	FLY-BY16
mean	-0,17945	0,0312	0,182137
2*std	0,120703	0,193883	0,228385

Panel 8			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,057932	-0,00555	0,057665	FLY-BY2
0,136555	-0,04514	-0,12888	FLY-BY3
0,008613	-0,00626	0,005914	FLY-BY4
0,151973	-0,06039	0,139458	FLY-BY5
0,099285	-0,09755	-0,01849	FLY-BY6
0,172489	-0,08416	0,150563	FLY-BY7
0,12303	-0,04827	0,113165	FLY-BY8
0,218489	-0,10587	0,191126	FLY-BY9
0,196406	-0,16549	-0,10578	FLY-BY10
0,15788	-0,12083	0,101616	FLY-BY11
0,030706	-0,0307	-0,00053	FLY-BY12
0,110476	-0,10948	0,014771	FLY-BY13
0,152786	-0,14773	0,038981	FLY-BY14
0,126666	-0,07101	-0,10489	FLY-BY15
0,024135	0,022527	-0,00866	FLY-BY16
mean	-0,06329	0,026237	0,068511
2*std	0,104575	0,188208	0,215309

Panel 9			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,198095	-0,02826	0,196068	FLY-BY2
0,134002	-0,11776	-0,06394	FLY-BY3
0,128047	-8,4E-05	0,128047	FLY-BY4
0,148296	-0,05319	0,13843	FLY-BY5
0,088425	-0,08294	0,030651	FLY-BY6
0,272963	-0,20749	0,177355	FLY-BY7
0,320351	-0,0945	0,306096	FLY-BY8
0,316016	-0,07031	0,308095	FLY-BY9
0,160991	-0,15815	0,030096	FLY-BY10
0,17304	-0,12478	0,119884	FLY-BY11
0,112578	-0,04543	0,103004	FLY-BY12
0,26801	-0,22559	0,144705	FLY-BY13
0,155777	-0,15034	0,040813	FLY-BY14
0,102217	-0,08906	-0,05017	FLY-BY15
0,026039	0,01368	0,022155	FLY-BY16
mean	-0,08437	0,095958	0,127772
2*std	0,135083	0,214908	0,253836

Summary			
Panel 1			
mean	-0,03678	0,096785	0,103537
2*std	0,134934	0,279497	0,310364
Panel 2			
mean	-0,11621	-0,0561	0,12904
2*std	0,115148	0,235276	0,261942
Panel 3			
mean	-0,11486	0,091897	0,147101
2*std	0,137654	0,168613	0,217667
Panel 4			
mean	-0,12545	0,024555	0,127835
2*std	0,106907	0,212089	0,237509
Panel 5			
mean	-0,09289	0,057541	0,109271
2*std	0,099721	0,203983	0,227054
Panel 6			
mean	-0,12453	0,039141	0,13054
2*std	0,108005	0,187561	0,216435
Panel 7			
mean	-0,17945	0,0312	0,182137
2*std	0,120703	0,193883	0,228385
Panel 8			
mean	-0,06329	0,026237	0,068511
2*std	0,104575	0,188208	0,215309
Panel 9			
mean	-0,08437	0,095958	0,127772
2*std	0,135083	0,214908	0,253836

Table 5-6 Statistical analysis about Dataset 2 (static conditions – afternoon 16-12-2017)

Panel 1			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,107714	0,087272	0,063135	FLY-BY2
0,208511	-0,19608	0,070909	FLY-BY3
0,322106	-0,18865	0,26108	FLY-BY4
0,060789	0,060234	0,008199	FLY-BY5
0,18685	0,000189	-0,18685	FLY-BY5
0,167161	-0,05221	0,158798	FLY-BY7
0,027421	-0,02701	0,00472	FLY-BY8
0,232616	-0,15143	0,176578	FLY-BY9
0,228168	-0,11753	0,195568	FLY-BY10
0,06183	-0,01374	-0,06028	FLY-BY11
0,17376	-0,01822	0,172802	FLY-BY12
0,08864	-0,08841	0,006423	FLY-BY13
0,16509	-0,16311	-0,02552	FLY-BY14
0,080549	0,067855	0,043404	FLY-BY15
0,073731	0,064324	-0,03604	FLY-BY16
0,117994	0,068387	-0,09616	FLY-BY17
mean	-0,03341	0,037838	0,050475
2*std	0,191012	0,233262	0,301491

Panel 2			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,091746	0,06547	0,064273	FLY-BY2
0,217651	-0,20664	0,068364	FLY-BY3
0,295714	-0,14479	0,257842	FLY-BY4
0,143486	0,13151	-0,02337	FLY-BY5
0,146406	0,066983	-0,21095	FLY-BY5
0,238042	-0,11576	0,127239	FLY-BY7
0,0717	-0,03649	-0,01904	FLY-BY8
0,317925	-0,19988	0,166475	FLY-BY9
0,261678	-0,05893	0,174193	FLY-BY10
0,074991	-0,04655	-0,02197	FLY-BY11
0,230482	-0,00762	0,149594	FLY-BY12
0,107498	-0,08379	-0,01342	FLY-BY13
0,172814	-0,14375	0,015162	FLY-BY14
0,209594	0,052805	0,122071	FLY-BY15
0,1514	0,051726	0,061527	FLY-BY16
0,142589	0,091275	0,028785	FLY-BY17
mean	-0,02922	0,047339	0,055631
2*std	0,200879	0,208637	0,289623

Panel 3			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,059474	0,017841	0,056735	FLY-BY2
0,2636	-0,25639	0,061215	FLY-BY3
0,309679	-0,17746	0,253792	FLY-BY4
0,117555	0,058553	0,101935	FLY-BY5
0,074508	-0,01057	-0,07375	FLY-BY5
0,326923	-0,20514	0,254547	FLY-BY7
0,138497	-0,07146	0,118637	FLY-BY8
0,401105	-0,24225	0,319686	FLY-BY9
0,338152	-0,1251	0,314161	FLY-BY10
0,212724	-0,12183	0,17438	FLY-BY11
0,322045	-0,11362	0,301334	FLY-BY12
0,189177	-0,13158	0,135918	FLY-BY13
0,29313	-0,20314	0,211324	FLY-BY14
0,355075	-0,05764	0,350365	FLY-BY15
0,329843	-0,08412	0,318936	FLY-BY16
0,306108	0,019886	0,305462	FLY-BY17
mean	-0,0852	0,160234	0,181478
2*std	0,187198	0,249698	0,312078

Panel 4			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,192871	0,159834	0,107945	FLY-BY2
0,161028	-0,14935	0,060192	FLY-BY3
0,305573	-0,12485	0,278904	FLY-BY4
0,043507	-0,00721	0,042904	FLY-BY5
0,158274	-0,10738	-0,11627	FLY-BY5
0,176134	-0,0551	0,167293	FLY-BY7
0,059333	-0,05927	-0,00278	FLY-BY8
0,245822	-0,17862	0,168887	FLY-BY9
0,204072	-0,09927	0,178299	FLY-BY10
0,113616	-0,07723	-0,08333	FLY-BY11
0,169361	-0,03203	0,166305	FLY-BY12
0,139251	-0,13899	-0,00855	FLY-BY13
0,194523	-0,19155	-0,03387	FLY-BY14
0,034357	-0,03364	0,006997	FLY-BY15
0,061332	-0,02299	-0,05686	FLY-BY16
0,087996	-0,04936	-0,07285	FLY-BY17
mean	-0,05835	0,040161	0,070835
2*std	0,161112	0,218655	0,271601

Panel 5			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,130237	0,123266	0,042039	FLY-BY2
0,181403	-0,17263	0,055736	FLY-BY3
0,290305	-0,10535	0,270516	FLY-BY4
0,103223	0,049856	0,090385	FLY-BY5
0,068806	-0,0595	-0,03455	FLY-BY5
0,245051	-0,12634	0,209969	FLY-BY7
0,100567	-0,07147	0,070751	FLY-BY8
0,316395	-0,21295	0,234007	FLY-BY9
0,254731	-0,07892	0,242197	FLY-BY10
0,123966	-0,11938	0,033414	FLY-BY11
0,230718	-0,06068	0,222596	FLY-BY12
0,120364	-0,10324	0,061881	FLY-BY13
0,208884	-0,19052	0,085647	FLY-BY14
0,182898	-0,05734	0,173676	FLY-BY15
0,144587	-0,06665	0,12831	FLY-BY16
0,12869	-0,05928	0,114225	FLY-BY17
mean	-0,06556	0,10004	0,119606
2*std	0,160717	0,178853	0,240454

Panel 6			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,11875	0,10891	0,047332	FLY-BY2
0,225411	-0,22017	0,048314	FLY-BY3
0,295289	-0,12568	0,267207	FLY-BY4
0,128296	-0,02258	0,126293	FLY-BY5
0,124432	-0,12314	0,017866	FLY-BY5
0,311765	-0,18931	0,247706	FLY-BY7
0,167153	-0,09283	0,139005	FLY-BY8
0,390638	-0,24795	0,301862	FLY-BY9
0,336209	-0,14454	0,303555	FLY-BY10
0,238014	-0,18927	0,144321	FLY-BY11
0,318691	-0,15912	0,276125	FLY-BY12
0,195019	-0,12914	0,146135	FLY-BY13
0,31214	-0,24906	0,188151	FLY-BY14
0,374006	-0,1654	0,335447	FLY-BY15
0,367636	-0,20039	0,30822	FLY-BY16
0,328277	-0,11958	0,305721	FLY-BY17
mean	-0,11346	0,160163	0,19628
2*std	0,179792	0,220922	0,284836

Panel 7			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,107203	0,101954	0,033136	FLY-BY2
0,102471	-0,1003	0,020976	FLY-BY3
0,287632	-0,07086	0,278768	FLY-BY4
0,091163	-0,07975	0,044168	FLY-BY5
0,213099	-0,2118	0,023475	FLY-BY5
0,153358	-0,05717	0,142303	FLY-BY7
0,095571	-0,09271	0,023208	FLY-BY8
0,246269	-0,19283	0,153187	FLY-BY9
0,210664	-0,07723	0,195998	FLY-BY10
0,165289	-0,14066	-0,0868	FLY-BY11
0,146215	-0,0352	0,141915	FLY-BY12
0,175158	-0,173	0,027436	FLY-BY13
0,216381	-0,21519	-0,02265	FLY-BY14
0,137992	-0,1317	0,041206	FLY-BY15
0,153835	-0,11455	-0,10268	FLY-BY16
0,18326	-0,16529	-0,07914	FLY-BY17
mean	-0,08781	0,041725	0,097222
2*std	0,157413	0,200531	0,254934

Panel 8			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,14457	0,136883	0,046513	FLY-BY2
0,128774	-0,12778	0,015937	FLY-BY3
0,274534	-0,06779	0,266033	FLY-BY4
0,106588	-0,03678	0,100042	FLY-BY5
0,190465	-0,18214	0,055694	FLY-BY5
0,224405	-0,12713	0,184918	FLY-BY7
0,132947	-0,10477	0,081837	FLY-BY8
0,31155	-0,2157	0,224804	FLY-BY9
0,263245	-0,08182	0,250207	FLY-BY10
0,188477	-0,18741	0,020046	FLY-BY11
0,215582	-0,08938	0,196179	FLY-BY12
0,147038	-0,1182	0,087456	FLY-BY13
0,229895	-0,21913	0,069539	FLY-BY14
0,238039	-0,16087	0,175449	FLY-BY15
0,208381	-0,18857	0,088678	FLY-BY16
0,238138	-0,20405	0,122772	FLY-BY17
mean	-0,09873	0,099305	0,140034
2*std	0,177139	0,163339	0,240952

Panel 9			
baseline	dist_east	dist_north	FLY-ID
			FLY-BY1
0,148726	0,142001	0,044219	FLY-BY2
0,177075	-0,17696	0,006494	FLY-BY3
0,262865	-0,07902	0,250706	FLY-BY4
0,180268	-0,10581	0,145946	FLY-BY5
0,268807	-0,25977	0,069115	FLY-BY5
0,286042	-0,17927	0,222893	FLY-BY7
0,181504	-0,11153	0,143194	FLY-BY8
0,3766	-0,24784	0,283555	FLY-BY9
0,327882	-0,14815	0,292502	FLY-BY10
0,281832	-0,25771	0,114083	FLY-BY11
0,315866	-0,18149	0,258519	FLY-BY12
0,185231	-0,12391	0,137682	FLY-BY13
0,328468	-0,28674	0,160226	FLY-BY14
0,327882	-0,14815	0,292502	FLY-BY15
0,16488	0,142001	0,083792	FLY-BY16
0,16488	0,142001	0,083792	FLY-BY17
mean	-0,09402	0,129461	0,159999
2*std	0,272491	0,192075	0,333383

Summary			
Panel 1			
mean	-0,03341	0,037838	0,050475
2*std	0,191012	0,233262	0,301491
Panel 2			
mean	-0,02922	0,047339	0,055631
2*std	0,200879	0,208637	0,289623
Panel 3			
mean	-0,0852	0,160234	0,181478
2*std	0,187198	0,249698	0,312078
Panel 4			
mean	-0,05835	0,040161	0,070835
2*std	0,161112	0,218655	0,271601
Panel 5			
mean	-0,06556	0,10004	0,119606
2*std	0,160717	0,178853	0,240454
Panel 6			
mean	-0,11346	0,160163	0,19628
2*std	0,179792	0,220922	0,284836
Panel 7			
mean	-0,08781	0,041725	0,097222
2*std	0,157413	0,200531	0,254934
Panel 8			
mean	-0,09873	0,099305	0,140034
2*std	0,177139	0,163339	0,240952
Panel 9			
mean	-0,09402	0,129461	0,159999
2*std	0,272491	0,192075	0,333383

Table 5-7 Statistical analysis about Dataset 3 (cinematic conditions 3m/s - morning 20-12-2017)

Based on the above tables, we argue that for each separated dataset the SR.0210 is fulfilled, even if in some fly-bys the margin is decreasing. As an example panel 9 in dataset 3 is quite close (even still fulfilling the requirement) to the threshold as geo-referencing algorithm is not performing as expected.

As a justification of this occurrence, it has been verified that the impacting error source is relevant to computer vision recognition algorithm failing to correctly identify boundaries. Moreover, the above introduced test campaign are performed in December, period of the year where irradiance is very low, so causing additional complexity for panel recognition and geo-referencing.

Figure 22 – pre-flight operations before test

Figure 23 – RPA during flight operations (bad irradiance conditions)

Now, still another point has to be finalised. Indeed, in each campaign the baseline has been evaluated considering as a reference the panel position identified during the first fly-by. During the first phase of this TEST_0070 (i.e. step 1, using u-blox) a possible offset was identified when the RPAS flies again over the same position of the plant in a further mission (e.g. several days after or even after a switch off/ switch on).

Based on the data analysed for the above datasets, the offset is confirmed (probably depending on changing of satellites in field of view). So, from an operational point of view, in each session a point (coincident with the center of panel 5) is measured in order to have east and north offsets with reference to the first campaign (as reported in the table below)

	offset_east [m]	*offset_north [m]*
DATASET 2	-0,086578454	-0,081070078
DATASET 3	0,384317972	-0,056014042

Table 5-8 Offsets among different sessions

Having the above information each measured position of the panel is modified to lead back to a single reference.

Results are reported in Table 5-9, where also position in ENU system (i.e. east and north value) is reported.

All data reported in a final reference system after applying the offsets as reported in Table 5-8.

east [m]	north [m]	baseline [m]	dist_east [m]	dist_north [m]	FLY-ID
11,82096393	-47,94876883				DATASET1.FLY-BY1
11,75613516	-47,82802407	0,137047673	-0,064828769	0,120744753	DATASET1.FLY-BY2
11,72839643	-47,98919273	0,101009076	-0,092567497	-0,040423904	DATASET1.FLY-BY3
11,73728543	-47,89324115	0,100426161	-0,083678495	0,05552768	DATASET1.FLY-BY4
11,70416707	-47,80670141	0,183914804	-0,116796855	0,142067413	DATASET1.FLY-BY5
11,70233884	-47,94152229	0,118846221	-0,11862509	0,007246535	DATASET1.FLY-BY6
11,67644936	-47,75408902	0,242455538	-0,144514569	0,194679807	DATASET1.FLY-BY7
11,74518676	-47,73157271	0,230035499	-0,075777161	0,217196116	DATASET1.FLY-BY8
11,68544343	-47,69378612	0,288759391	-0,135520497	0,254982707	DATASET1.FLY-BY9
11,58835788	-48,01512387	0,241885435	-0,232606044	-0,066355046	DATASET1.FLY-BY10
11,67247767	-47,87244598	0,166953119	-0,14848625	0,076322849	DATASET1.FLY-BY11
11,73125436	-47,89912706	0,10252859	-0,089709567	0,049641771	DATASET1.FLY-BY12
11,65982713	-47,84756962	0,190279651	-0,161136791	0,101199209	DATASET1.FLY-BY13
11,64711355	-47,96240056	0,174383993	-0,173850375	-0,013631734	DATASET1.FLY-BY14
11,72427765	-47,96970256	0,098926525	-0,096686278	-0,02093373	DATASET1.FLY-BY15
11,81686616	-47,91001059	0,038974253	-0,004097766	0,038758234	DATASET1.FLY-BY17
11,78435721	-48,00743362	0,069149182	-0,036606714	-0,058664792	DATASET1.FLY-BY18
11,87129291	-48,10807744	0,167069564	0,05032898	-0,15930861	DATASET1.FLY-BY19
11,93528111	-47,86769884	0,140145501	0,114317181	0,081069992	DATASET2.FLY-BY1
11,88516227	-47,72196671	0,235713019	0,064198343	0,226802117	DATASET2.FLY-BY2
11,89104624	-47,97475587	0,074745284	0,070082316	-0,025987045	DATASET2.FLY-BY3
11,86421112	-47,73720899	0,215934909	0,043247198	0,211559838	DATASET2.FLY-BY4
11,8352956	-47,7200787	0,229138765	0,014331676	0,228690132	DATASET2.FLY-BY5
11,79984467	-47,84379401	0,107078174	-0,021119259	0,104974817	DATASET2.FLY-BY6
11,81388214	-47,71466473	0,234211192	-0,007081781	0,234104102	DATASET2.FLY-BY7
11,88472097	-47,67549015	0,280617522	0,063757045	0,273278672	DATASET2.FLY-BY8
11,79135493	-47,61826887	0,331823618	-0,02960899	0,330499956	DATASET2.FLY-BY9
11,74680486	-47,93405395	0,075604861	-0,074159069	0,014714875	DATASET2.FLY-BY10
11,78679486	-47,82191614	0,131374009	-0,034169069	0,12685269	DATASET2.FLY-BY11
11,83086161	-47,83471531	0,114482181	0,009897682	0,114053521	DATASET2.FLY-BY12
11,76784006	-47,76094686	0,195190255	-0,053123867	0,187821965	DATASET2.FLY-BY13
11,80766194	-47,90354166	0,047142753	-0,013301981	0,045227166	DATASET2.FLY-BY14
11,8133778	-47,93305456	0,017449567	-0,007586122	0,015714266	DATASET2.FLY-BY15
11,93118334	-47,84282249	0,152882131	0,110219414	0,105946339	DATASET2.FLY-BY16
11,73894555	-47,98037775	0,177124287	0,034778481	-0,173676338	DATASET3.FLY-BY1
11,86221127	-47,93833898	0,205685242	0,158044204	-0,131637564	DATASET3.FLY-BY2
11,5663175	-47,92464169	0,181417786	-0,137849569	-0,117940278	DATASET3.FLY-BY3
11,63359933	-47,70986126	0,119824131	-0,070567744	0,096840157	DATASET3.FLY-BY4
11,78880171	-47,88999287	0,118745483	0,084634641	-0,083291459	DATASET3.FLY-BY5
11,67944388	-48,01492967	0,209690825	-0,024723192	-0,208228254	DATASET3.FLY-BY5
11,61260195	-47,77040846	0,09849543	-0,09156512	0,036292956	DATASET3.FLY-BY7
11,6674742	-47,90962721	0,109270703	-0,036692873	-0,102925797	DATASET3.FLY-BY8
11,52599828	-47,74637044	0,188106205	-0,17816879	0,060330973	DATASET3.FLY-BY9
11,66002677	-47,73818035	0,081507684	-0,044140301	0,068521066	DATASET3.FLY-BY10
11,61956745	-47,94696385	0,163800633	-0,084599617	-0,14026244	DATASET3.FLY-BY11
11,67826708	-47,7577816	0,055353023	-0,025899986	0,048919811	DATASET3.FLY-BY12
11,63570635	-47,91849676	0,131091835	-0,068460721	-0,111795344	DATASET3.FLY-BY13
11,54842742	-47,89473083	0,17889666	-0,155739648	-0,088029411	DATASET3.FLY-BY14
11,68160133	-47,80670138	0,022565735	-0,022565735	3,81614E-08	DATASET3.FLY-BY15
11,67229905	-47,85206736	0,055440417	-0,031868015	-0,04536595	DATASET3.FLY-BY16
11,67966803	-47,86615286	0,064301461	-0,02449904	-0,05945145	DATASET3.FLY-BY17

Table 5-9 Panel 2 referencing after applying offsets to all dataset (using panel 5 as reference point for offset identification)

	All DATASETs		
	dist_east [m]	dist_north [m]	Total [m]
mean	-0,043902841	0,044453468	0,062478558
2*std	0,165307417	0,255736893	0,304512563
	DATASET1		
	dist_east [m]	dist_north [m]	Total [m]
mean	-0,101479985	0,05288525	0,114433548
2*std	0,129286665	0,214726792	0,250644443
	DATASET2		
	dist_east [m]	dist_north [m]	Total [m]
mean	-0,092892599	0,057541385	0,109270517
2*std	0,099720931	0,203983302	0,227053852
	DATASET3		
	dist_east [m]	dist_north [m]	Total [m]
mean	-0,06555586	0,100039923	0,11960584
2*std	0,160717137	0,178852863	0,240454455

Table 5-10 Statistical analysis considering all datasets compared to single data set sessions

After offset implementation, final statistical data are as presented in the table above which provides evidence of SR.0210 requirement fulfilment even considering the difficult meteorological conditions where data are collected in the field as above documented.

Considering all the datasets, we can observe that having more samples, mean value is decreasing (6,24 cm) whereas standard deviation is increasing to 30 cm. This can be justified as positions in dataset 2 and 3 are evaluated again after applying offsets causing a larger range of observed data.

5.11 RPAS MAIT

The tests for RPAS EPV100 (and Mantide900, a bigger RPAS with a similar manual) have been performed according to TopView MANOPS and the authorization obtained, compliant to ENAC RPAS regulation issue 2 rev2 22/12/2016.

In particular, the following all pre-conditions involving aerial work with RPAS for testing were successfully achieved:

- Pre-condition: RPA ""airworthiness"" according to RPAS operator's MANOPS
- valid Pilot in command attestation/licence
- valid Pilot in command LAPL (or class 2) certificate
- CAA authorization for RPAS operator

In this section evidence of the authorizations is provided and some pictures taken during RPAS Manufacturing, assembly and testing.

ENTE NAZIONALE PER L'AVIAZIONE CIVILE

Home > La Regolazione per la Sicurezza > Navigabilità > Sistemi Aeromobili a Pilotaggio Remoto (Droni) > Operatori SAPR > Dichiarazioni Operatori

Elenco delle Dichiarazioni rese dagli Operatori SAPR per Operazioni Specializzate non Critiche ai sensi degli artt. 75 e 76 del D.P.R. 445/2000

Dichiarazioni Pervenute dal 16/09/2015 ad oggi

Riferimento Enac | Operatore: TOPVIEW | Ricerca

N.B. Per analisi di dettaglio occorre utilizzare i filtri "Riferimento Enac" ed "Operatore".

▲ Rif.Enac▼	▲ Data Informativa ▼	▲ Numero di Protocollo ▼	▲ Data Dichiarazione ▼	▲ Operatore▼	▲ Costruttore ▼	Tipo	MTOM	Classificazione	APR	SPR	Flight Controller
15301	25/10/2017	APR-2017-0006140	25/10/2017	TOPVIEW SRL SAN NICOLA LA STRADA, 25D 81020 VIA PERTINI (CE) email: info@topview.it pec: topview@pec.it tel: 0823424244 3472332620	TOPVIEW	EPV100	Kg. 3,60	-	TV-APR-005	TV-SPR-005	M11DA003FF
15300	25/10/2017	APR-2017-0006140	25/10/2017	TOPVIEW SRL SAN NICOLA LA STRADA, 25D 81020 VIA PERTINI (CE) email: info@topview.it pec: topview@pec.it tel: 0823424244 3472332620	TOPVIEW	TV300S	Kg. 0,30	Inoffensivo	TV-APR-011	TV-SPR-011	0ASDE9G1B100E3
8072	26/08/2016	APR-2016-0001215	26/08/2016	TopView S.r.l. Largo Santi Cosma e Damiano, 23 81020 San Nicola la Strada (CE) email: alberto.mennella@topview.it pec: salvatore.mennella@ordingce.it tel: 0823 1554429	DJI	PH3 pro	Kg. 1,40	-	TV-APR-004	TV-SPR-004	P76DCF16017444
6446	24/03/2016		23/02/2016	TopView S.r.l. Largo Santi Cosma e Damiano, 23 81020 San Nicola la Strada (CE) email: alberto.mennella@topview.it pec: salvatore.mennella@ordingce.it tel: 0823 1554429	TopView	MANTIDE 900	Kg. 8,20	N.D.	TV-APR-003	TV-SPR-001	02E0035493
5835	30/12/2015		02/12/2015	TopView S.r.l. Largo Santi Cosma e Damiano, 23 81020 San Nicola la Strada (CE) email: alberto.mennella@topview.it pec: salvatore.mennella@ordingce.it tel: 0823 1554429	TopView	APIS 550	Kg. 2,40	N.D.	TV-APR-002	TV-SPR-002	1001264755

Figure 24 Authorization for EPV100 and other RPASs used for tests

ENAC-PROT-10/04/2017-0037051-P

ENAC
ENTE NAZIONALE PER L'AVIAZIONE CIVILE

Direzione Regolazione Navigabilità

TopView S.r.l.
Via Santi Cosma e Damiano, 23
81020 San Nicola La Strada (CE)
topview@pec.it

Oggetto: Progetto ENAC APR No. 9942 – Autorizzazione per Operazioni Specializzate Critiche

Sulla base della domanda di autorizzazione Prot. 33967 del 03/04/2017, si comunica che, ai sensi del Regolamento "Mezzi Aerei a Pilotaggio Remoto", codesta società è autorizzata ad operare con il SAPR TopView – Mantide 900 di seguito identificato:

APR: TV-APR-003
SPR: TV-SPR-001
Flight Controller: 02E0035493
Peso: 8,2 kg

nello scenario S03, allegato alla presente, nel rispetto delle limitazioni e condizioni in esso contenute.

I pertinenti Manuali devono essere resi coerenti con le prescrizioni relative allo scenario applicabile.

Nel caso in cui una delle prescrizioni operative elencate nello scenario non sia rispettata è necessaria un'autorizzazione ad hoc dell'ENAC.

La presente autorizzazione copre esclusivamente gli aspetti di competenza dell'ENAC e deve essere mantenuta durante le operazioni presso la stazione di controllo.

Per ogni altro aspetto è responsabilità dell'Operatore ottenere i pertinenti permessi dalle istituzioni pubbliche e/o dal proprietario dell'area delle operazioni.

Cordiali saluti

p.d. Giuseppe Daniele Carrabba

BOLLO ASSOLTO IN MODO VIRTUALE AUT.DIREZ.REG. ENTRATE LAZIO N. 135047/98 DEL 30/11/1998

Fabrizio D'Urso
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Figure 25 Authorization for critical operations

Figure 26 Payload Manufacturing and RPAS assembly and testing

Figure 27 Operational testing (Cuneo)

6 DVCM

This section reports the current status of the DVCM.

All requirements are verified using method test (T) with the exception of SR.0190 RPAS MAIT which has been verified by inspection.

All evidences are reported in section 5.

ReqID	ReqTitle	Type	Verification Method	Status of Compliance	Close-out status
SR.0010	Plant data entry	Functional	T	C	Closed
SR.0020	Plant referencing	Functional	T	C	Closed
SR.0030	Monitoring of Maintenance coverage	Functional	T	C	Closed
SR.0040	Pilots contact database	Functional	T	C	Closed
SR.0050	Plant PoC contact database	Functional	T	C	Closed
SR.0060	Contact information HMI	Functional	T	C	Closed
SR.0070	RPAS mission request and planning	Functional	T	C	Closed
SR.0080	PV faults categories database	Functional	T	C	Closed
SR.0090	Anomalies autonomous recognition	Functional	T	C	Closed
SR.0100	Static M&C	Functional	T	C	Closed
SR.0110	Geo tagged thermal and optical images gathering	Functional	T	C	Closed
SR.0120	Product HMI	Functional	T	C	Closed
SR.0130	Mission HMI	Functional	T	C	Closed
SR.0140	Plant HMI	Functional	T	C	Closed
SR.0150	Product Structure	Functional	T	C	Closed
SR.0160	Service Centre to RPAS communication (products exchanges)	Functional	T	C	Closed
SR.0170	Service Centre to RPAS communication (messages exchanges)	Functional	T	C	Closed
SR.0180	Alarms, historic, analysis tool	Functional	T	C	Closed
SR.0190	RPAS MAIT	Functional	I	C	Closed
SR.0200	RPAS Operations.Emergency procedures	Functional	T	C	Closed

ReqID	ReqTitle	Type	Verification Method	Status of Compliance	Close-out status
SR.0210	RPAS data georeferencing	Perfomance	T	C	Closed
SR.0220	RPAS mission environment configuration	Functional	T	C	Closed
SR.0230	RPAS operations management	Functional	T	C	Closed
SR.0240	RPAS data acquisition	Functional	T	C	Closed
SR.0250	RPAS data storage	Functional	T	C	Closed
SR.0260	Plant coverage feedback	Functional	T	C	Closed
SR.0270	Computer Vision Algorithm	Functional	T	C	Closed
SR.0280	Final Report	Functional	T	C	Closed

Table 6-1 DVCM

7 CONCLUSIONS

This document summarises the test cases, procedures and reports of session campaign activities performed using the final EASY-PV architecture which has been finalised taking into account recommendations coming from [RD 3].

It is noteworthy that all requirements are now covered being requested functionalities and performances fulfilled.

Two major tests are worthy to be summarised as pointing out end to end performances of the EASY-PV system where TEST_EASY.0070 (panel geo-referencing performances) is complementary to TEST_EASY.0030 (Plants Synoptic Analysis After Mission Implementation); indeed, this last one verifies how algorithm performs in a given mission for all the panels involved providing an indication about the exhaustiveness of panel identification, whereas TEST_EASY.0070 is analysing a limited selection of panels and focuses on the repeatability of measurements over several missions to avoid that wrong panel/anomaly association happens.

In particular,

- ✓ TEST_EASY.0030, providing a synoptic of data for a given mission: given a plant composed by 408 actual panels, there are:
  - 407 identified panels
  - 400 true positive (correctly recognised)
  - 7 false positive (wrongly identified)
  - 8 false negative (missed recognition)

  The above data are summarised using the F-measure statistical approach providing the following values:
  - Precision: 0,9828
  - Recall: 0,9804
  - F=0,9816

  Finally, results from this on-field tests show that the EASY PV solution is able to recognize more than 98% of faulty panels in a very limited fraction of time which is instead usually needed by manual operations.

- ✓ TEST_EASY.0070, describing how the algorithm recognises, identifies and geo-references a 3x3 matrix of real panel in the plant: it provides evidence that SR.0210 in [RD 1] can be fulfilled. even considering several missions performed in different periods; in other words, each time the RPAS is flying over the plant , it can correctly recognise a panel as catalogued and georeferenced several missions before in the past. This definitely allows to minimise the occurrence that a wrong panel association happens.

END OF DOCUMENT