EASY PV platform Architecture Design
EASY-SIST-D5.2

Prepared by
Fabio Menichetti Alberto Mennella Marco Nisi
Verified by
Fabio Menichetti
Approved by
Marco Nisi

Company	
Sistematica S.p.A.	Sistematica soluzioni informatiche

DOCUMENT STATUS SHEET

Issue (*)	DATE	§ - CHANGES	AUTHOR
1.0	30/08/16	Updates as per [AD 2] including better explaination of: ✓ ftp structure and connection between RGS an SC (see section 5.1.1.1) ✓ Automatic report structure (see section 3.1.28) Updates of ✓ Naming convention of System Requirements (Section 3.1) ✓ Section 5.1.1 (SC) and section 5.1.2 (RPAS S/S and RGS S/S) including HW details, info and design finalisation ✓ Conclusion (section 6) ✓ Requirement SR-RPAS.0260 (coverage) text and title changed to “Pilot Visual Feedback” ✓ Requirement SR-RPAS.0270 (Computer Vision Algorihtm) text changed ✓ Requirement SR-SC.0140 (Final Report) text changed ✓ Section 5.1.1.4 (SC Deployment) added.	F. Menichetti, M. Nisi, A. Mennella
1.1	17/11/16	New issue to include RIDs after CDR meeting as per [AD 3]. Comment from Marco Fermi	F. Menichetti, M. Nisi, A. Mennella
1.2	20/02/2017	New issue to include RIDs after CDR meeting as per [AD 3]. Comment from Mike Lissone	F. Menichetti, M. Nisi, A. Mennella

(*) D5.2 issue 1.0 represents the new version of “EASY-PV Platform Architecture Design” which has been updated starting from D5.1 issue 1.1.

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1 INTRODUCTION

1.1 SCOPE

This document aims at presenting the System Requirements generated from User Needs reported in [RD 1] and recommendations derived from the experimental researches reported in [RD 2] and [RD 3]. Finally, the EASY PV architecture is provided also based on outcomes of WP 2 (technological studies) and market analysis (now preliminary included in the road map document, D15.1 and further better detailed in the market analysis document, D11,1). The proposed solution will include several technical and operational configurations. These different scenarios will be also investigated in WP 11 to identify an appropriate business model.

The current final issue (coded D5.2) is delivered for CDR milestone and represents an update of the version delivered for PDR (coded D5.1).

1.2 APPLICABLE DOCUMENTS

ID	Title
[AD 1]	GRANT AGREEMENT NUMBER - 687409 - EASY Pv (25/11/2015)
[AD 2]	DRS of EASY-SIST-D5.1
[AD 3]	DRS of EASY-SIST-D5.2

Table 1-1 Applicable Documents

1.3 REFERENCE DOCUMENTS

ID	Title
[RD 1]	D2.1 - User Needs, Operational Concepts and System Requirements document
[RD 2]	D3.1 - GNSS (including EGNOS and further Galileo) high accuracy algorithms and Techniques for Energy domain document
[RD 3]	D4.1 - RPAS Standardization and Regulation document
[RD 4]	EASY-UNIA-D3.2-Test and Verification Campaign Methodology
[RD 5]	EASY-SIST-D5.1 EASY PV platform Architecture Design (*)

Table 1-2 Reference Documents

(*) D5.1 is the old version of the current (coded D.5.2) document.

1.4 ACRONYMS

Acronym	Description
ACU	Antenna Control Unit
AF	Archiving Facility
C&C	Command and Control
CAA	Civil Aviation Authority
CDR	Critical Design Review
CONOPS	Concept of Operations
COTS	Commercial of The Shelft
CTG	Catalogue Manager
CU	Control Unit
DB	Database
EASY-PV	EGNSS High Accuracy System Improving Photovoltaic Plant maintenance
EDRF	External Data Reception Facility
FTP	File Transfert Protocol
GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
I/F	Interface
IMU	Inertial Measurement Unit
M&C	Monitoring and Control
MAIT	Manufacturing Assembly Integration Test
NAVCOM	Navigation and Communications
OBC	On Board Computer
PDR	Preliminary Design Review
PM	Production Manager
PMS	Payload Management System
PoC	Point of Contact
PV	Photovoltaic
RGS	RPAS Ground Station
RPA	Remotely Piloted Aircraft

Acronym	Description
RPAS	Remotely Piloted Aircraft System
RTK	Real Time Kinematics
S/S	Sub System
SC	Service Centre
TEO	Thermographic Expert Operator
TIR	Thermal Image Camera
VIS	Visual Information System
VTE	Visual Track Energy
ACU	Antenna Control Unit
AF	Archiving Facility
C&C	Command and Control
CAA	Civil Aviation Authority
CDR	Critical Design Review
CONOPS	Concept of Operations
COTS	Commercial of The Shelft
CTG	Catalogue Manager
CU	Control Unit
DB	Database
EASY-PV	EGNSS High Accuracy System Improving Photovoltaic Plant maintenance
EDAS	EGNOS Data Access Service
EDRF	External Data Reception Facility
FTP	File Transfert Protocol
GLONASS	GLObalnaya NAvigationnaya Sputnikovaya Sistema
GNSS	Global Navigation Satellite System
GPIO	General Purpose Input Output
GSD	Ground Sample Distance
HMI	Human Machine Interface
I/F	Interface
IMU	Inertial Measurement Unit
M&C	Monitoring and Control

Acronym	Description
MAIT	Manufacturing Assembly Integration Test
NAVCOM	Navigation and Communications
NLES	Navigational Land Earth Station
NTRIP	Networked Transport of RTCM via Internet Protocol
OBC	On Board Computer
PCB	Printed Circuit Board
PDR	Preliminary Design Review
PM	Production Manager
PMS	Payload Management System
PoC	Point of Contact
PV	Photovoltaic
RGS	RPAS Ground Station
RIMS	Ranging and Integrity Monitoring Station
RPAS	Remotely Piloted Aircraft System
RTCM	Radio Technical Commission for Maritime Services
RTK	Real Time Kinematics
S/S	Sub System
SC	Service Centre
TEO	Thermographic Expert Operator
TIR	Thermal Image Camera
VIS	Visual Information System
VTE	Visual Track Energy

Table 1-3 Acronyms

1.5 NAMING CONVENTION

Naming convention used to classify requirements and interfaces is reported in [RD 4].

2 EASY-PV CONTEXT

The purpose of the EASY PV is to provide a time and cost effective service as direct response to the growing need expressed by several maintainers and PV field owners to decrease the loss of energy production of their plants; the necessity of ESY PV solution is introduced in [RD 1] where the user needs analysis is also provided after a short introduction to the photovoltaic plants common issues.

Having in mind the above scenario, as a first improved solution, the growing technology of RPAS (Remotely Piloted Aircraft Systems) is exploited to gather thermic images which are geo-referenced by GNSS positioning and processed by computer vision algorithms. However, this configuration is very respectful but still not enough in order to provide the required positioning accuracy for the automation and fast identification of the broken modules. Only the aid of accurate positioning allows a cost effective solution to reduce time, costs and risks for personnel involved: the added value provided by the employment of GNSS high accuracy solutions as novelty in the RPAS domain is the key driver for the EASY PV turnkey solution.

The growing technology of RPAS (Remotely Piloted Aircraft Systems) represents a cost effective solution to reduce time, costs and risks for personnel involved in maintenance operations. State-of-the-art solution of PV plants inspections by means of RPAS system are still in an early prototyping phase, being performed by manual RPAS flights and visual live (real time) thermal recognition of broken modules.

Such operations are not fully automated yet and the recognition of a broken module might result very difficult in a large PV plant when considering the GPS positioning accuracy/precision compared with the dimension of a PV module (1,60 m x 1,00 m). Therefore, RPAS navigation based on GPS positioning is very respectful but still not enough in order to provide the required positioning accuracy for the automation and fast identification of the broken modules.

In fact, few RPAS operators that are exploring this market normally integrate in their RPAS rotorcrafts a GPS receiver using pseudorange measurements for RPAS navigation and hovering purposes; when in hovering the RPAS rotorcraft points its thermal camera exactly on its projection on the ground (NADIR point) which corresponds to one PV module.

Figure 2-1- RPAS Rotorcraft searching for hotsposts equipped with thermal camera and GPS Receiver

Having these problems to be solved and these technologies in mind, EASY PV solution is conceived to build up an automatic system for acquiring, geo-referencing and processing both visible and thermal images captured by an RPAS equipped with a GNSS high accuracy receiver, flying over a photovoltaic field. In this way it is possible to easily (i.e. automatically, with safety improvement for operators and saving time) detect the defective module to be replaced.

3 SYSTEM REQUIREMENTS

3.1 REQUIREMENTS CATALOGUE

3.1.1 SR.0010 - PLANT DATA ENTRY

The EASY PV Service Centre shall allow the EASY PV operator to insert plant data including:

Plant parameter	Description
Name	Name provided by the owner, to be inserted within the synoptic
Nominal Power	All plant nominal power expressed in [Kwp]
POD code	Code of the Point of distribution, allowing the plant to be grid connected
POD production availability	YES or NO
POD historical data availability	YES or NO
POD serie start period	yyyy/mm/dd
POD serie end period	yyyy/mm/dd
Measurement Frequency	15min or 1hour
Number of PV modules	Number of PV modules
Number of Strings	Number of Strings
Address (Latitude, Longitude)	Plant address in terms of geographic coordinates
Address	Plant address in terms of municipality, districit, post code, street number
Owner Name	Owner Name
Possibility to access real time PV plant data	YES or NO
Meteo Station Presence	YES or NO
Meteo Station data	Free text describing parameters possibile to be monitored
Possibility to access real time meteo station data	YES or NO
Available Meteo Data Archive in real time	YES or NO
Year of construction	
Subsidy	Subsidy expressed in €/WP
Extra free field	to add overall or specific plant features

Table 3-1 Plant Data Entry

3.1.2 SR.0020 - PLANT REFERENCING

The EASY PV system shall be able to georeference every module of the plant. A Geometric center 2D position for each module shall be

- ✓ identified by real data gathered by means of RPAS post processed by computer vision algorithms.
- ✓ archived at the Service Centre in "plant data entry" section.

3.1.3 SR.0030 - MONITORING OF MAINTENANCE COVERAGE

The EASY PV Service Centre shall have a dedicated functionality to check if a given mission is completely achieved.

Remark. The level of completeness shall be indicated in percentage, where 100% indicates all plants have been analysed;

3.1.4 SR.0040 - PILOTS CONTACT DATABASE

The EASY PV Service Centre shall allow the EASY PV operator to insert RPAS remote pilot data including:

- Name
- RPAS category and CAA registration number
- Contact information (including operational headquarters)
- Availability for operations

3.1.5 SR-0050 - PLANT POC CONTACT DATABASE

The EASY PV Service Centre shall allow the EASY PV operator to insert the plant PoC data including:

- Name
- Contact information
- Availability for operations

3.1.6 SR.0060 – CONTACT INFORMATION HMI

The EASY PV Service Centre shall allow the EASY PV operator to search, visualise, modify and delete the information for each registered PoC plant and RPAS remote pilot.

3.1.7 SR.0070 - RPAS MISSION REQUEST AND PLANNING

The EASY PV Service Centre shall allow the EASY PV operator to plan, modify or delete (to establish a date depending on the RPAS remote pilots availabilities) a mission in order to associate an RPAS remote pilot operating to collect data from a given (already registered) PV plant. Each mission shall be characterized by the following item:

- Mission ID (integer)
- Plant ID (integer)
- RPAS operator
- PoC Plant
- Date of intervention (one or more weeks of the year)

Remark.

Mission operation shall be planned and carried out according to the following environmental conditions: Sunny sky, with solar radiation higher than 700 W/mq, no cloudy or foggy, reduced shadows. Verification of these condition will be conducted by the EASY PV operator by analysing optical images and/or videos.

3.1.8 SR.0080 - PV FAULTS CATEGORIES DATABASE

The EASY PV RPAS and Service Centre shall contain a database of PV modules defects categories, in order to allow both a real-time automatic recognition and classification (RPAS sub-system) and the EASY PV operator (Service Centre sub-system) to further check the anomalies classification

3.1.9 SR.0090 - ANOMALIES AUTONOMOUS RECOGNITION

The EASY PV system shall allow the autonomous anomalies recognition. In particular, images shot by payload sensors (image and IR sensor) shall be processed, georereferenced so that each anomaly is finally spatially linked to a PV module.

3.1.10 SR.0100 - STATIC M&C

The EASY PV Service Centre shall include a fixed M&C system linked to PV plant able to gather

- The plant Productivity
- Status of elements and network

Data shall be managed in real time.

3.1.11 SR.0110 - GEO TAGGED THERMAL AND OPTICAL IMAGES GATHERING

The EASY PV Service Centre shall include for each plant several dedicated sections where the mission collected data are collected in a dedicated DB.

Remark. The EASY PV operator may access and manage the collected products (thermal and optical images and relevant ancillary files) during previously run mission. (see SR-SC.0110).

3.1.12 SR.0120 - PRODUCT HMI

The EASY PV Service Centre shall allow the EASY PV operator to visualise, modify and each item in a dedicated "products HMI" which shall be designed as in the following picture

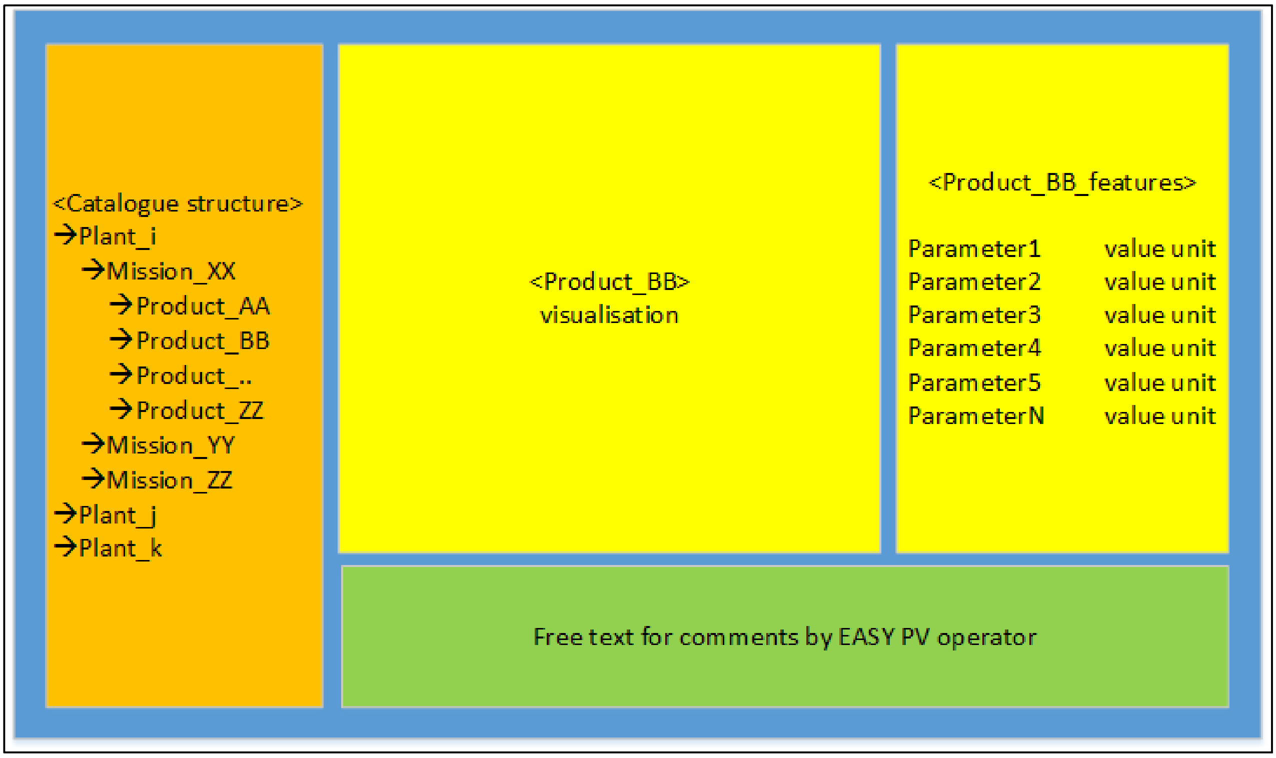


Figure 3-1- Products HMI

Note. Product_AA may assume the following values:

- EPVIRG, in case of thermal images augmented with ancillary information (RPAS GNSS position, timestamp, GNSS/position of centres of each PV panel, ancillary RPAS data such as Ground speed, Height, attitude, …);
- EPVIMG_yyyy_mm_dd_mm:ss, in case of optical images associated to each thermal image;
- EPVVID, in case of videos

3.1.13 SR.0130 - MISSION HMI

The EASY PV Service Centre shall allow the EASY PV operator to visualise a dedicated HMI for each mission which shall include the features as in the following picture.

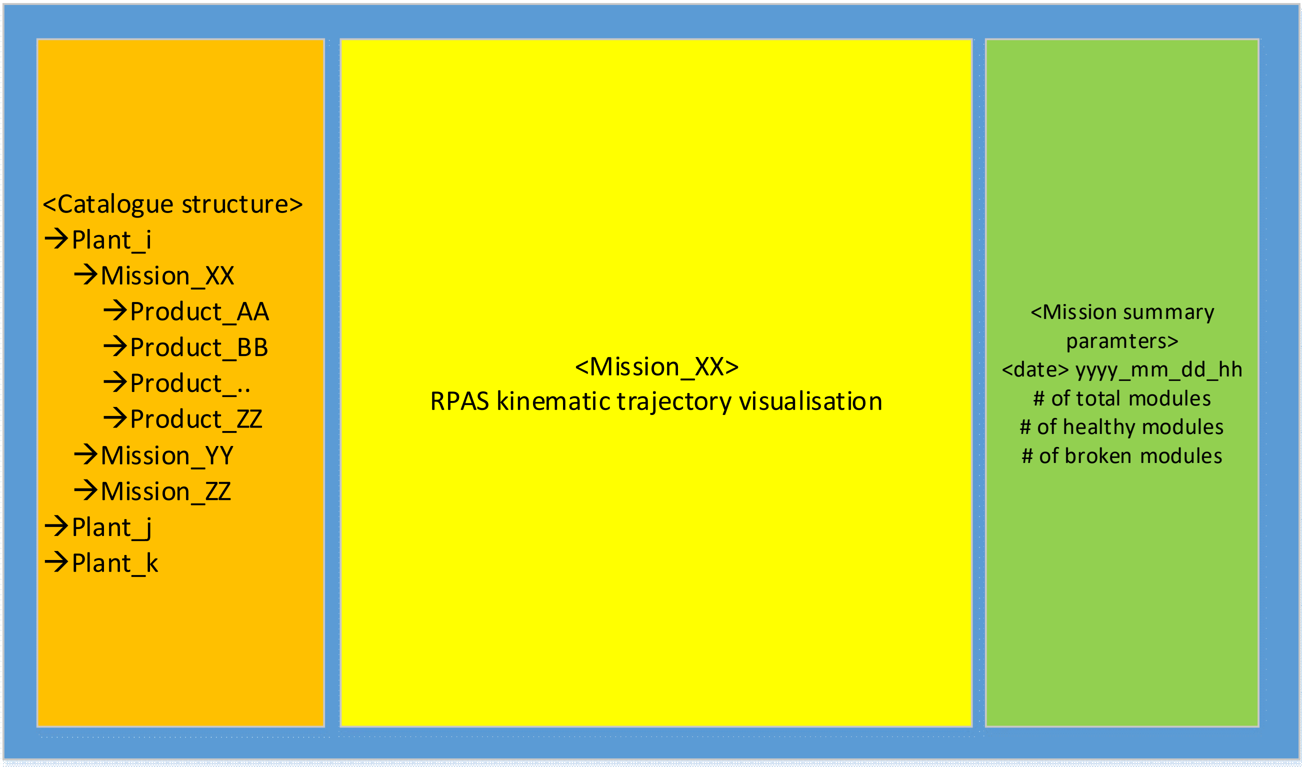


Figure 3-2- Mission HMI

3.1.14 SR.0140 - PLANT HMI

The EASY PV Service Centre shall allow the EASY PV operator to visualise a dedicated HMI for each plant which shall include the features as in the following picture.

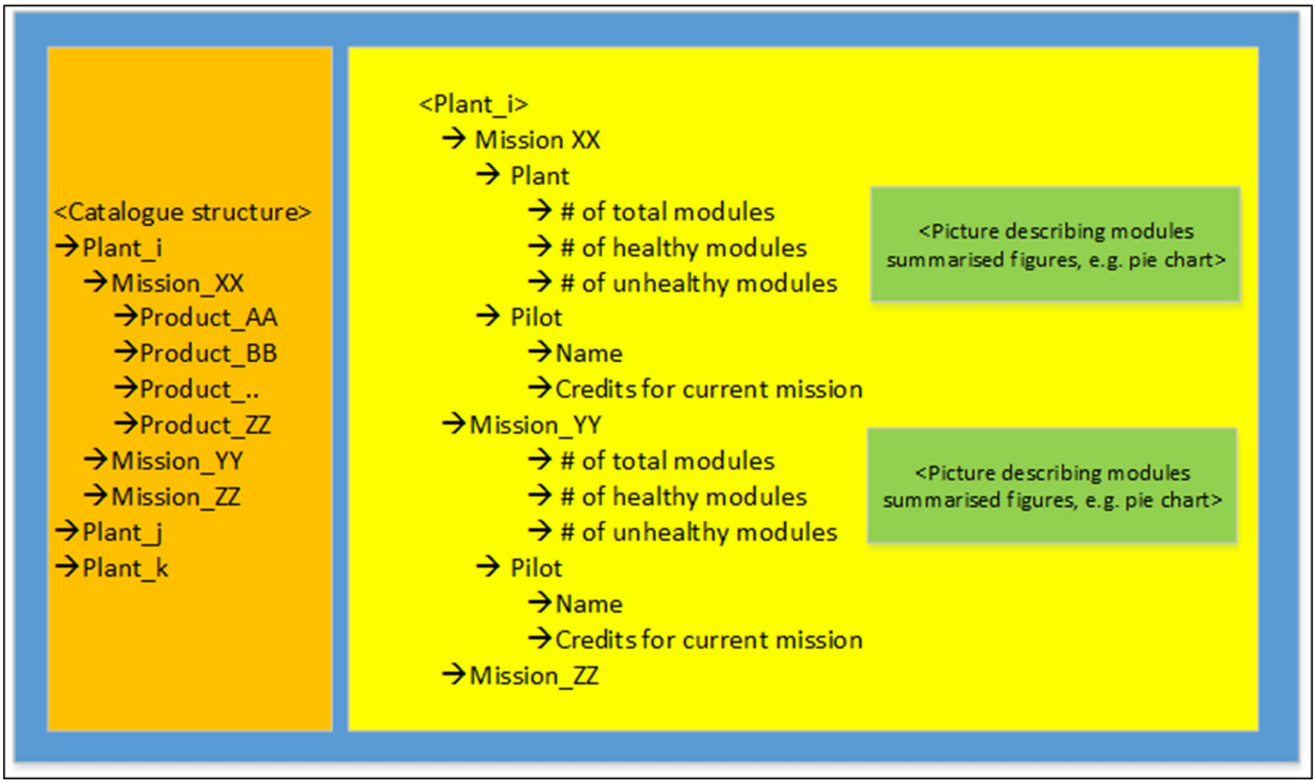


Figure 3-3- Plant HMI

3.1.15 SR.0150 - PRODUCT STRUCTURE

The EASY PV system shall be able to acquire and manage both optical and thermal images. These products will be gathered by RPAS, elaborated by computer vision algorithms and sent to the Service Centre to allow analysis by EASY PV operator. The products will be injected in the system with the formats indicated in the tables below

Name	Description	Format	Note
RPAS operator	Organization or enterprise engaged in or offering to engage in an aircraft operation	String	Static info, configured by RPAS remote pilot
RPAS remote pilot	Person in charge of mission implementation	String	Static info, configured by RPAS remote pilot

Name	Description	Format	Note
RPA	RPA used for mission implementation	String	Static info, configured by RPAS remote pilot
RPAS payload	RPAS Payload used for mission implementation	String	Static info, configured by RPAS remote pilot
Data	Time tag of the collected image according to the format <yyyy_mm_dd_mm:ss>	String	Static info, configured by RPAS remote pilot
Plant	Code of the plant to be monitored	String	Static info, configured by RPAS remote pilot
Scene Centre Horizontal	2D horizontal position (lat_deg,long_deg) of RPAS at same instant of thermic photo gathering according to the format <xx,xxxxx;xxx,xxxxx>	String	Info gathered from GNSS receiver on board the RPAS
Scene Centre Vertical	Vertical position (h_meter) of RPAS at same instant of thermic photo gathering according to the format <xxx,xx>	String	Info gathered from GNSS receiver on board the RPAS
Central 2D Positioning Accuracy	Expected (depending on used payload) accuracy on final positioning, composed by horizontal + vertical sections. It will be expressed in meters and according the following format: <xx,xx m; xx,xx m>	String	Static info, configured by RPAS remote pilot
lat_min	Value of latitude at upper border of the picture in the format <xx,xxxxx>	double	Info gathered from Computer vision algo
lat_max	Value of latitude at lower border of the picture in the format <xx,xxxxx>	double	Info gathered from Computer vision algo
long_min	Value of longitude at left border of the picture in the format <xxx,xxxxx>	double	Info gathered from Computer vision algo
long_max	Value of longitude at right border of the picture in the format <xxx,xxxxx>	double	Info gathered from Computer vision algo

Table 3-2 Product Structure- Optical Image

Name	Description	Format	Note
RPAS operator	Person in charge of mission implementation	String	Static info, configured by RPAS remote pilot

Name	Description	Format	Note
RPA	RPA used for mission implementation	String	Static info, configured by RPAS remote pilot
RPAS payload	RPAS Payload used for mission implementation	String	Static info, configured by RPAS remote pilot
Data	Time tag of the collected image according to the format <yyyy_mm_dd_mm:ss>	String	Static info, configured by RPAS remote pilot
Plant	Code of the plant to be monitored	String	Static info, configured by RPAS remote pilot
Scene Centre Horizontal	2D horizontal position (lat_deg,long_deg) of RPAS at same instant of thermic photo gathering according to the format <xx,xxxxx;xxx,xxxxx>	String	Info gathered from GNSS receiver on board the RPAS
Scene Centre Vertical	Vertical position (h_meter) of RPAS at same instant of thermic photo gathering according to the format <xxx,xx>	String	Info gathered from GNSS receiver on board the RPAS
Central 2D Positioning Accuracy	Expected (depending on used payload) accuracy on final positioning, composed by horizontal + vertical sections. It will be expressed in meters and according the following format: <xx,xx m; xx,xx m>	String	Static info, configured by RPAS remote pilot
Attitude	Attitude (yaw, pitch,roll,heading,angleOfAttack,) of RPAS at same instant of thermic photo gathering according to the format <xx,xxxxx;xx,xxxxx;xx,xxxxx;xx,xxxxx;xx,xxxxx>	String	Info gathered from IMU on board the RPAS
Number of anomalies	Number of anomalies found in the gathered photo	Integer	Info gathered from Computer vision algo
Position of anomaly #1	2D position (lat_deg,long_deg,h_meter) of anomaly #1 at same instant of thermic photo gathering according to the format <xx,xxxxx;xxx,xxxxx,xxx,xx>	String	Info gathered from Computer vision algo
Tenperature of anomaly #1	Temperature [°C] registered for anomaly#1	double	Info gathered from Computer vision algo
Code of anomaly #1	Code for anomaly#1, describing the type of anomaly as defined in the anomaly catalogue	Integer	Info gathered from Computer vision algo
Position of anomaly #2	2D position (lat_deg,long_deg,h_meter) of anomaly #2 at same instant of thermic photo gathering according to the	String	Info gathered from Computer vision algo

Name	Description	Format	Note
	format <xx,xxxxx;xxx,xxxxx,xxx,xx>		
Tenperature of anomaly #2	Temperature [°C] registered for anomaly#2	double	Info gathered from Computer vision algo
Code of anomaly #2	Code for anomaly#2, describing the type of anomaly as defined in the anomaly catalogue	Integer	Info gathered from Computer vision algo
Position of anomaly #n	2D position (lat_deg,long_deg,h_meter) of anomaly #n at same instant of thermic photo gathering according to the format <xx,xxxxx;xxx,xxxxx,xxx,xx>	String	Info gathered from Computer vision algo
Tenperature of anomaly #n	Temperature [°C] registered for anomaly#n	double	Info gathered from Computer vision algo
Code of anomaly #n	Code for anomaly#n, describing the type of anomaly as defined in the anomaly catalogue	Integer	Info gathered from Computer vision algo

Table 3-3 Product Structure- Thermal Image

3.1.16 SR.0160 - SERVICE CENTRE TO RPAS COMMUNICATION (PRODUCTS EXCHANGES)

The EASY PV System shall include a communication link to exchange products between the RPAS and the Service Centre.. This interface shall be based on FTP protocol; FTP server shall be installed @ Service Centre, whereas FTP client shall be installed at every RPAS node.

3.1.17 SR.0170 - SERVICE CENTRE TO RPAS COMMUNICATION (MESSAGES EXCHANGES)

The EASY PV System shall include a communication link to exchange messages between the EASY PV operator the RPAS operator.

Remark This tool may be also an external COTS to be integrated in the EASY PV solution.

3.1.18 SR.0180 - ALARMS, HISTORIC, ANALYSIS TOOL

The EASY PV Service Centre shall include for each plant dedicated sections where the EASY PV operator shall be able to consult historic data of productivity and alarms (if any)

3.1.19 SR.0190 - RPAS MAIT

The RPAS Payload shall not exceed 1 Kg weight and shall have a form factor not exceeding 150x150x100 mm^3

3.1.20 SR.0200 - RPAS OPERATIONS. EMERGENCY PROCEDURES

The RPAS shall include emergency procedures to handle flight contingencies.

3.1.21 SR.0210 - RPAS DATA GEO-REFERENCING

The RPAS payload shall be able to geo tag each frame acquired using thermal and optical camera systems. Every object recognised within the frame shall be geo-referenced with an accuracy level of 50 cm.

3.1.22 SR.0220 - RPAS MISSION CONFIGURATION

The RPAS Payload shall include a SW configuration panel for editing the configurable data to set-up a given mission on the PV Plant.

Remarks: configurable data are mainly temperature on the ground, PV modules altitude, RPAS target altitude, area to be covered and contingent other PV plant information.

3.1.23 SR.0230 - RPAS OPERATIONS MANAGEMENT

The RPAS payload shall include a START/STOP button for starting /ending operations before each RPAS flight.

Remarks: RPAS payload after configuration for the PV plant selected shall be easily operated by RPAS remote pilot (e.g. 1 button operation)

3.1.24 SR.0250 - RPAS DATA ACQUISITION

The RPAS payload shall acquire Thermal and Optical Video at least at 9 fps

Remarks: Thermal videos for civil application cannot exceed 9 fps to be ITAR free compliant

3.1.25 SR.0250 - RPAS DATA STORAGE

The RPAS Payload shall be able to store on SD card (or other equivalent equipment) the thermal and optical video acquired

3.1.26 SR..0260 - PILOT VISUAL FEEDBACK

The RGS and/or RPAS S/S shall be able to provide a real time visual feedback to the pilot to adjust parameters during flight. Such functionality shall provide relevant real time information to the pilot such as:

- ✓ Local Map with RPAS position
- ✓ RPAS Heading, Ground speed and Height
- ✓ GSD and real time percentage of PV plant covered
- ✓ Thermal parameters
- ✓ Visual/Acoustic feedback to the pilot for application warnings

Remarks (such functionality can be implemented using a tablet/smartphone as HMI or with a dedicated app).

3.1.27 SR.0270 - COMPUTER VISION ALGORITHM

The Computer Vision Software shall be able to

- ✓ count PV Panels and provide at the end of each mission the final number of the PV Panels, without prior knowledge of PV Plant detailed planimetry
- ✓ assign the 2D coordinates of the centre of each PV Panel recognized on a video frame from the ancillary information provided and assign 1 unique identifier to each PV Panel

Remarks: The computer Vision Algorithm can be also implemented with a distributed architecture (e.g.: RGS only; RPAS only, RGS + RPAS, …)

3.1.28 SR.0280 - FINAL REPORT

The EASY PV Service Centre shall allow the automatic generation of a final report indicating the status of photovoltaic plant with a predefined template, populated by the information gathered by RPAS on field. The final report has to contain at least the following information:

- Plant site
- Technical data in terms (installation date, productivity)
- Plant Planimetry georeferenced

- Equipment used:
    - <*Thermo camera*
    - <*Optical camera*
    - <*RPAS*>
    - <*Software*>
    - <*…………*>
- Mission data
    - Date
    - Pilot
    - Starting time
    - Ending time
    - <……>
- Summary Results

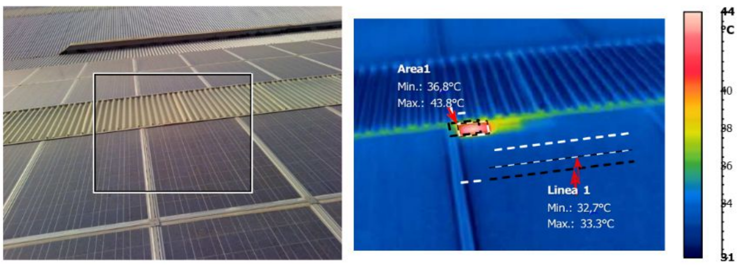
  This section of report will present a list of the panel where an anomaly has been observed. The list has to contain the following information:

Pannel ID	Center Location (geographic coordinates or UTM of center panel)	Anomaly observed	Panel functionality
001		<…>	damaged
002		<…>	partially damaged
…..	…..	<…>	……

- Detailed analysis:

  For each panel listed above a detail analysis has to be described:

    - Optical Image
    - Thermal Image containing indication about the temperature of the panel (min e max) and the temperature of the defected area (see figure below as example)



    - Ispection Date
    - Ispection Hour
    - Center Location
    - Environmental Temperature
    - Notes and comments area

3.2 REQUIREMENT SUMMARY

In this section a table summarising the requirement is reported also indicating

- ✓ type and the verification method according to the methodology reported in [RD 4] (see Table 3-4)
- ✓ traceability versus User needs reported in [RD 1] (see Table 3-5 and Table 3-6).

ReqID	ReqTitle	Type	Verification Method
SR.0010	Plant data entry	Functional	T
SR.0020	Plant referencing	Functional	T
SR.0030	Monitoring of Maintenance coverage	Functional	T
SR.0040	Pilots contact database	Functional	T
SR.0050	Plant PoC contact database	Functional	T
SR.0060	Contact information HMI	Functional	T
SR.0070	RPAS mission request and planning	Functional	T
SR.0080	PV faults categories database	Functional	T
SR.0090	Anomalies autonomous recognition	Functional	T
SR.0100	Static M&C	Functional	T
SR.0110	Geo tagged thermal and optical images gathering	Functional	T
SR.0120	Product HMI	Functional	T
SR.0130	Mission HMI	Functional	T
SR.0140	Plant HMI	Functional	T
SR.0150	Product Structure	Functional	T
SR.0160	Service Centre to RPAS communication (products exhanges)	Functional	T
SR.0170	Service Centre to RPAS communication (messages exhanges)	Functional	T

ReqID	ReqTitle	Type	Verification Method
SR.0180	Alarms, historic, analysis tool	Functional	T
SR.0190	RPAS MAIT	Perfomance	I
SR.0200	RPAS Operations.Emergency procedures	Functional	T
SR.0210	RPAS data georeferencing	Perfomance	T
SR.0220	RPAS mission environment configuration	Functional	T
SR.0230	RPAS operations management	Functional	T
SR.0240	RPAS data acquisition	Functional	T
SR.0250	RPAS data storage	Functional	T
SR.0260	Plant coverage feedback	Functional	T
SR.0270	Computer Vision Algorithm	Functional	T
SR.0280	Final Report	Functional	T

Table 3-4 Requirements Summary

It is noteworthy to say that when possible, each requirement is planned to be verified using test “T” method.

Parent UN title	Parent UN code	Req ID	ReqTitle	Jutification
Detailed Maintenance operations	UN-035	SR.0080	PV faults categories database	The presence of a PV fault categories DB shall allow to provide more info in PV plant health status
		SR.0090	Anomalies autonomous recognition	Anomalies autonomous recognition shall allow to provide more info in PV plant health status
		SR.0110	Geo tagged thermal and optical images gathering	Usage of geotagged optical and thermal images shall allow to provide more info in PV plant health status
		SR.0120	Product HMI	A User interface to be used for product analysis shall allow to provide more info in PV plant health status
		SR.0130	Mission HMI	A User interface to be used for mission analysis shall allow to provide more info in PV plant health status
		SR.0140	Plant HMI	A User interface to be used for plant synoptic analysis shall allow to provide more info in PV plant health status
		SR.0150	Product Structure	A detailed product information shall allow to provide more info in PV plant health status
		SR.0180	Alarms, historic, analysis tool	The possibility to analyse alarms and data history shall allow to provide more info in PV plant health status
		SR.0210	RPAS data georeferencing	RPAS data georeferencing shall allow to provide more info in PV plant health status
		SR.0220	RPAS mission environment configuration	RPAS data mission environment configuration shall allow to provide more info in PV plant health status
		SR.0230	RPAS operations management	RPAS operation management shall allow to provide more info in PV plant health status
		SR.0240	RPAS data acquisition	RPAS data acquisition shall allow to provide more info in PV plant health status
		SR.0250	RPAS data storage	RPAS data georeferencing shall allow to provide more info in PV plant health status
		SR.0270	Computer Vision Algorithm	Usage of computer vision algorithm shall allow to provide more info in PV plant health status
Easy to ue RPAS payload	UN-050	SR.0040	Pilots contact database	The possibility for a pilot or RPAS enthusiast to join the EASY PV consortium for collaboration shall be fostered by easy to use RPAS payload
		SR.0190	RPAS MAIT	An engineered and ready to market RPAS shall foster the possibility for a person to work in Energy-RPAS domain
Maintenance operation Cost reduction	UN-020	SR.0010	Plant data entry	Plant info entry in a centralised DB shall allow to reduce cost afforded for maintenance operations
		SR.0020	Plant referencing	Plant referencing shall allow to reduce cost afforded for maintenance operations
		SR.0030	Monitoring of Maintenance coverage	Monitoring of on filed data collection shall allow to reduce cost afforded for maintenance operations
		SR.0040	Pilots contact database	The presence of pilot DB shall allow to reduce cost afforded for maintenance operations

Parent UN title	Parent UN code	Req ID	ReqTitle	Jutification
		SR.0050	Plant PoC contact database	The presence of PoC DB shall allow to reduce cost afforded for maintenance operations
		SR.0070	RPAS mission request and planning	An RPAS mission request and planning shall allow to reduce cost afforded for maintenance operations
		SR.0080	PV faults categories database	The presence of a PV fault categories DB shall allow to save time devoted to maintenance operations
		SR.0090	Anomalies autonomous recognition	Anomalies autonomous recognition shall allow to save time devoted to maintenance operations
		SR.0110	Geo tagged thermal and optical images gathering	Usage of geotagged optical and thermal images shall allow to reduce cost afforded for maintenance operations
		SR.0120	Product HMI	A User interface to be used for product analysis shall allow to reduce cost afforded for maintenance operations
		SR.0130	Mission HMI	A User interface to be used for mission analysis shall allow to reduce cost afforded for maintenance operations
		SR.0140	Plant HMI	A User interface to be used for plant synoptic analysis shall allow to reduce cost afforded for maintenance operations
		SR.0150	Product Structure	A detailed product information shall allow to reduce cost afforded for maintenance operations
		SR.0160	Service Centre to RPAS communication (products exchanges)	A product exchange between RPAS and SC shall allow to reduce cost afforded for maintenance operations
		SR.0170	Service Centre to RPAS communication (messages exchanges)	The possibility to exchanges messages between RPAS and SC shall allow to reduce cost afforded for maintenance operations
		SR.0210	RPAS data georeferencing	RPAS data georeferencing shall allow to reduce cost afforded for maintenance operations
		SR.0220	RPAS mission environment configuration	RPAS data mission environment configuration shall allow to reduce cost afforded for maintenance operations
		SR.0230	RPAS operations management	RPAS operation management shall allow to reduce cost afforded for maintenance operations
		SR.0240	RPAS data acquisition	RPAS data acquisition shall allow to reduce cost afforded for maintenance operations
		SR.0250	RPAS data storage	RPAS data georeferencing shall allowto reduce cost afforded for maintenance operations
		SR.0260	Plant coverage feedback	Instantaneous feedback about plant coverage to RPAS remote pilot in charge to collect on field data shall allow to to reduce cost afforded for maintenance operations
		SR.0270	Computer Vision Algorithm	Usage of computer vision algorithm shall allow to reduce cost afforded for maintenance operations
Maintenance operation Time reduction	UN-030	SR.0010	Plant data entry	Plant info entry in a centralised DB shall allow to save time devoted to maintenance operations
		SR.0020	Plant referencing	Plant referencing shall allow to save time devoted to maintenance operations
		SR.0030	Monitoring of Maintenance coverage	Monitoring of on filed data collection shall allow to save time devoted to maintenance operations

Parent UN title	Parent UN code	Req ID	ReqTitle	Jutification
		SR.0040	Pilots contact database	The presence of pilot DB shall allow to save time devoted to maintenance operations
		SR.0050	Plant PoC contact database	The presence of PoC DB shall allow to save time devoted to maintenance operations
		SR.0070	RPAS mission request and planning	An RPAS mission request and planning shall allow to save time devoted to maintenance operations
		SR.0080	PV faults categories database	The presence of a PV fault categories DB shall allow to save time devoted to maintenance operations
		SR.0090	Anomalies autonomous recognition	Anomalies autonomous recognition shall allow to save time devoted to maintenance operations
		SR.0110	Geo tagged thermal and optical images gathering	Usage of geotagged optical and thermal images shall allow to save time devoted to maintenance operations
		SR.0120	Product HMI	A User interface to be used for product analysis shall allow to save time devoted to maintenance operations
		SR.0130	Mission HMI	A User interface to be used for mission analysis shall allow to save time devoted to maintenance operations
		SR.0140	Plant HMI	A User interface to be used for plant synoptic analysis shall allow to save time devoted to maintenance operations
		SR.0150	Product Structure	A detailed product information shall allow to save time devoted to maintenance operations
		SR.0160	Service Centre to RPAS communication (products exchanges)	A product exchange between RPAS and SC shall allow to save time devoted to maintenance operations
		SR.0170	Service Centre to RPAS communication (messages exchanges)	The possibility to exchanges messages between RPAS and SC shall allow to save time devoted to maintenance operations
		SR.0210	RPAS data georeferencing	RPAS data georeferencing shall allow to save time devoted to maintenance operations
		SR.0220	RPAS mission environment configuration	RPAS data mission environment configuration shall allow to save time devoted to maintenance operations
		SR.0230	RPAS operations management	RPAS operation management shall allow to save time devoted to maintenance operations
		SR.0240	RPAS data acquisition	RPAS data acquisition shall allow to save time devoted to maintenance operations
		SR.0250	RPAS data storage	RPAS data georeferencing shall allow to save time devoted to maintenance operations
		SR.0260	Plant coverage feedback	Instantaneous feedback about plant coverage to RPAS remote pilot in charge to collect on field data shall allow to save time devoted to maintenance operations
		SR.0270	Computer Vision Algorithm	Usage of computer vision algorithm shall allow to save time devoted to maintenance operations
Maintenance Report Production	UN-015	SR.0060	Contact information HMI	A User interface to be used for general data entry shall be used for automatic report production
		SR.0120	Product HMI	A User interface to be used for product analysis shall be used for automatic report production

Parent UN title	Parent UN code	Req ID	ReqTitle	Jutification
		SR.0130	Mission HMI	A User interface to be used for mission analysis shall be used for automatic report production
		SR.0140	Plant HMI	A User interface to be used for plant synoptic analysis shall be used for automatic report production
		SR.0150	Product Structure	A detailed product information shall be used for automatic report production
		SR.0280	Final Report	An automatic report shall be provided by EASY PV system
Plant productivity enhancement	UN-010	SR.0080	PV faults categories database	The presence of a PV fault categories DB shall allow to better investigate anomalies to improve productivity
		SR.0090	Anomalies autonomous recognition	Anomalies autonomous recognition shall allow to better investigate anomalies to improve productivity
		SR.0100	Static M&C	The presence of a static M&C shall allow to verify if the plant productivity is actually improved or not
		SR.0110	Geo tagged thermal and optical images gathering	Usage of geotagged optical and thermal images shall allow to better investigate anomalies to improve productivity
		SR.0210	RPAS data georeferencing	RPAS data georeferencing shall allow to better investigate anomalies to improve productivity
		SR.0220	RPAS mission environment configuration	RPAS data mission environment configuration shall allow to better investigate anomalies to improve productivity
		SR.0230	RPAS operations management	RPAS operation management shall allow to better investigate anomalies to improve productivity
		SR.0240	RPAS data acquisition	RPAS data acquisition shall allow to better investigate anomalies to improve productivity
		SR.0250	RPAS data storage	RPAS data georeferencing shall allow to better investigate anomalies to improve productivity
		SR.0270	Computer Vision Algorithm	Usage of computer vision algorithm shall allow to better investigate anomalies to improve productivity
PV plant safeguarding during maintenance opertions	UN-045	SR.0200	RPAS Operations.Emergency procedures	Emergency procedures for RPAS guidance shall allow to safeguarde the PV plants during maintenance operations

Table 3-5 User Needs vs System Requirements Traceability

Req ID	ReqTitle	Parent UN title	Parent UN code	Jutification
SR.0010	**Plant data entry**	Maintenance operation Cost reduction	**UN-020**	Plant info entry in a centralised DB shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	Plant info entry in a centralised DB shall allow to save time devoted to maintenance operations
SR.0020	**Plant referencing**	Maintenance operation Cost reduction	**UN-020**	Plant referencing shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	Plant referencing shall allow to save time devoted to maintenance operations
SR.0030	**Monitoring of Maintenance coverage**	Maintenance operation Cost reduction	**UN-020**	Monitoring of on filed data collection shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	Monitoring of on filed data collection shall allow to save time devoted to maintenance operations
SR.0040	**Pilots contact database**	Easy to ue RPAS payload	**UN-050**	The possibility for a pilot or RPAS enthusiast to join the EASY PV consortium for collaboration shall be fostered by easy to use RPAS payload
		Maintenance operation Cost reduction	**UN-020**	The presence of pilot DB shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	The presence of pilot DB shall allow to save time devoted to maintenance operations
SR.0050	**Plant PoC contact database**	Maintenance operation Cost reduction	**UN-020**	The presence of PoC DB shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	The presence of PoC DB shall allow to save time devoted to maintenance operations
SR.0060	**Contact information HMI**	Maintenance Report Production	**UN-015**	A User interface to be used for general data entry shall be used for automatic report production
SR.0070	**RPAS mission request and planning**	Maintenance operation Cost reduction	**UN-020**	An RPAS mission request and planning shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	An RPAS mission request and planning shall allow to save time devoted to maintenance operations
SR.0080	**PV faults categories database**	Detailed Maintenance operations	**UN-035**	The presence of a PV fault categories DB shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	**UN-020**	The presence of a PV fault categories DB shall allow to save time devoted to maintenance operations
		Maintenance operation Time reduction	**UN-030**	The presence of a PV fault categories DB shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	The presence of a PV fault categories DB shall allow to better investigate anomalies to improve productivity
SR.0090	**Anomalies autonomous recognition**	Detailed Maintenance operations	**UN-035**	Anomalies autonomous recognition shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	**UN-020**	Anomalies autonomous recognition shall allow to save time devoted to maintenance operations
		Maintenance operation Time reduction	**UN-030**	Anomalies autonomous recognition shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	Anomalies autonomous recognition shall allow to better investigate anomalies to improve productivity

Req ID	ReqTitle	Parent UN title	Parent UN code	Jutification
SR.0100	Static M&C	Plant productivity enhancement	UN-010	The presence of a static M&C shall allow to verify if the plant productivity is actually improved or not
SR.0110	Geo tagged thermal and optical images gathering	Detailed Maintenance operations	UN-035	Usage of geotagged optical and thermal images shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	UN-020	Usage of geotagged optical and thermal images shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	UN-030	Usage of geotagged optical and thermal images shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	UN-010	Usage of geotagged optical and thermal images shall allow to better investigate anomalies to improve productivity
SR.0120	Product HMI	Detailed Maintenance operations	UN-035	A User interface to be used for product analysis shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	UN-020	A User interface to be used for product analysis shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	UN-030	A User interface to be used for product analysis shall allow to save time devoted to maintenance operations
		Maintenance Report Production	UN-015	A User interface to be used for product analysis shall be used for automatic report production
SR.0130	Mission HMI	Detailed Maintenance operations	UN-035	A User interface to be used for mission analysis shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	UN-020	A User interface to be used for mission analysis shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	UN-030	A User interface to be used for mission analysis shall allow to save time devoted to maintenance operations
		Maintenance Report Production	UN-015	A User interface to be used for mission analysis shall be used for automatic report production
SR.0140	Plant HMI	Detailed Maintenance operations	UN-035	A User interface to be used for plant synoptic analysis shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	UN-020	A User interface to be used for plant synoptic analysis shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	UN-030	A User interface to be used for plant synoptic analysis shall allow to save time devoted to maintenance operations
		Maintenance Report Production	UN-015	A User interface to be used for plant synoptic analysis shall be used for automatic report production
SR.0150	Product Structure	Detailed Maintenance operations	UN-035	A detailed product information shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	UN-020	A detailed product information shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	UN-030	A detailed product information shall allow to save time devoted to maintenance operations
		Maintenance Report Production	UN-015	A detailed product information shall be used for automatic report production
SR.0160	Service Centre to RPAS communication (products exchanges)	Maintenance operation Cost reduction	UN-020	A product exchange between RPAS and SC shall allow to reduce cost afforded for maintenance operations

Req ID	ReqTitle	Parent UN title	Parent UN code	Jutification
		Maintenance operation Time reduction	**UN-030**	A product exchange between RPAS and SC shall allow to save time devoted to maintenance operations
SR.0170	**Service Centre to RPAS communication (messages exchanges)**	Maintenance operation Cost reduction	**UN-020**	The possibility to exchanges messages between RPAS and SC shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	The possibility to exchanges messages between RPAS and SC shall allow to save time devoted to maintenance operations
SR.0180	**Alarms, historic, analysis tool**	Detailed Maintenance operations	**UN-035**	The possibility to analyse alarms and data history shall allow to provide more info in PV plant health status
SR.0190	**RPAS MAIT**	Easy to ue RPAS payload	**UN-050**	An engineered and ready to market RPAS shall foster the possibility for a person to work in Energy-RPAS domain
SR.0200	**RPAS Operations.Emergency procedures**	PV plant safeguarding during maintenance opertions	**UN-045**	Emergency procedures for RPAS guidance shall allow to safeguarde the PV plants during maintenance operations
SR.0210	**RPAS data georeferencing**	Detailed Maintenance operations	**UN-035**	RPAS data georeferencing shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	**UN-020**	RPAS data georeferencing shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	RPAS data georeferencing shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	RPAS data georeferencing shall allow to better investigate anomalies to improve productivity
SR.0220	**RPAS mission environment configuration**	Detailed Maintenance operations	**UN-035**	RPAS data mission environment configuration shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	**UN-020**	RPAS data mission environment configuration shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	RPAS data mission environment configuration shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	RPAS data mission environment configuration shall allow to better investigate anomalies to improve productivity
SR.0230	**RPAS operations management**	Detailed Maintenance operations	**UN-035**	RPAS operation management shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	**UN-020**	RPAS operation management shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	RPAS operation management shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	RPAS operation management shall allow to better investigate anomalies to improve productivity
SR.0240	**RPAS data acquisition**	Detailed Maintenance operations	**UN-035**	RPAS data acquisition shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	**UN-020**	RPAS data acquisition shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	RPAS data acquisition shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	RPAS data acquisition shall allow to better investigate anomalies to improve productivity
SR.0250	**RPAS data storage**	Detailed Maintenance operations	**UN-035**	RPAS data georeferencing shall allow to provide more info in PV plant health status

Req ID	ReqTitle	Parent UN title	Parent UN code	Jutification
		Maintenance operation Cost reduction	**UN-020**	RPAS data georeferencing shall allowto reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	RPAS data georeferencing shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	RPAS data georeferencing shall allow to better investigate anomalies to improve productivity
SR.0260	**Plant coverage feedback**	Maintenance operation Cost reduction	**UN-020**	Instantaneous feedback about plant coverage to RPAS remote pilot in charge to collect on field data shall allow to to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	Instantaneous feedback about plant coverage to RPAS remote pilot in charge to collect on field data shall allow to save time devoted to maintenance operations
SR.0270	**Computer Vision Algorithm**	Detailed Maintenance operations	**UN-035**	Usage of computer vision algorithm shall allow to provide more info in PV plant health status
		Maintenance operation Cost reduction	**UN-020**	Usage of computer vision algorithm shall allow to reduce cost afforded for maintenance operations
		Maintenance operation Time reduction	**UN-030**	Usage of computer vision algorithm shall allow to save time devoted to maintenance operations
		Plant productivity enhancement	**UN-010**	Usage of computer vision algorithm shall allow to better investigate anomalies to improve productivity
SR.0280	**Final Report**	Maintenance Report Production	**UN-015**	An automatic report shall be provided by EASY PV system

Table 3-6 System Requirements vs User Needs Traceability

4 FUNCTIONAL AND OPERATIONAL DESCRIPTION

4.1 ARCHITECTURAL CONCEPT

The EASY PV concept is reported in Figure 4-1.

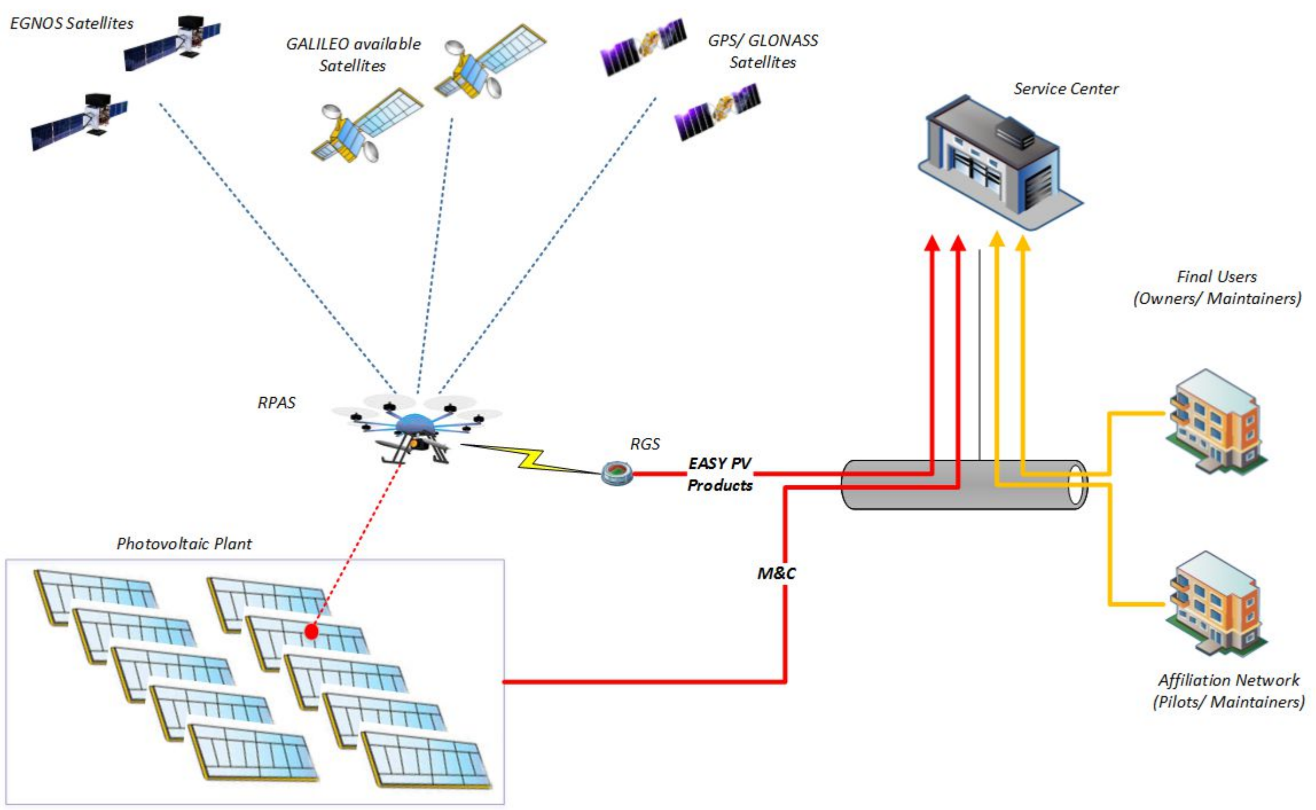


Figure 4-1- EASY PV Concept

An RPAS is performing a mission flying over a photovoltaic field and collecting optical and thermal images. Such products are processed by means of a computer vision algorithm and referenced by means of a GNSS system. Finally, the captured images can be tagged with a very accurate fix information and sent towards the remote service centre in charge of thermal anomalies identification and management.

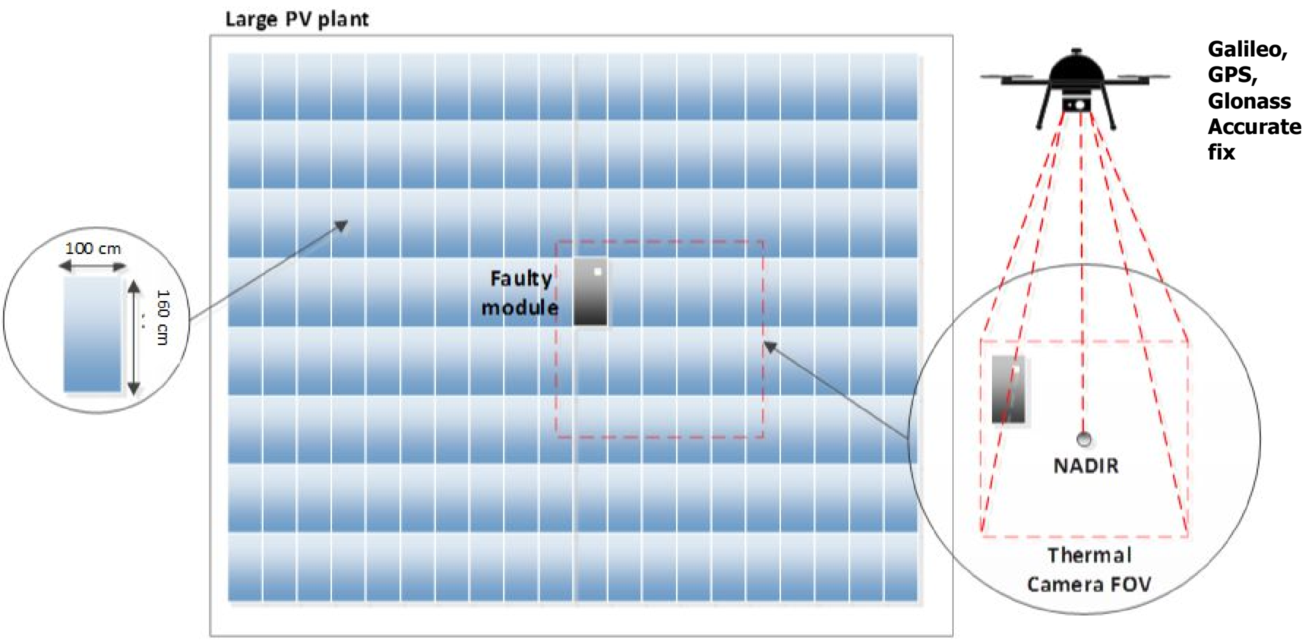


Figure 4-2- EASY PV Solution based on GNSS aided hotspots discovery

The accurate positioning provided by GNSS enhances the automation of the entire process when comparing the resolution of such GNSS positioning system with the physical dimension of PV modules to be inspected (see Figure 4-2) by the on board thermal camera

4.2 CONCEPT OF OPERATIONS

4.2.1 INVOLVED ACTORS

Easy-Pv solution will include different actors involved in CONcept of OPerations.

It is noteworthy to say that a person may assume also a part or the totality of the below roles depending on the adopted business model.

The following actor roles are identified:

- ✓ **RPAS remote pilot**: Professional Pilot in charge of PV Plant aerial survey with his RPAS equipment and payload
- ✓ **RPAS Operator**: Aerial Operator allowed by national CAA to perform specialized aerial work over a PV plant.

RPAS Operator and RPAS remote pilot may be the same person in case of a micro registered business. In the EASY-PV framework RPAS remote pilot and Operator are assumed to be the same person.

- ✓ **Service Centre (SC) Operator**: Back-end (Service centre) Operator, in charge of Service Centre platform accounting

- ✓ **Thermographic Expert Operator**: Person with experience in thermographic image analysis who is in charge to draw-up the final Report about the plant status
- ✓ **Plant POC**: Point of Contact with PV Plant Owners/ Maintainer. He is in charge to manage contractual and commercial exchanges with the final Owner/ Maintainer.

4.2.2 Operations and Functional Chains

Figure 4-3 describes the EASY PV operations.

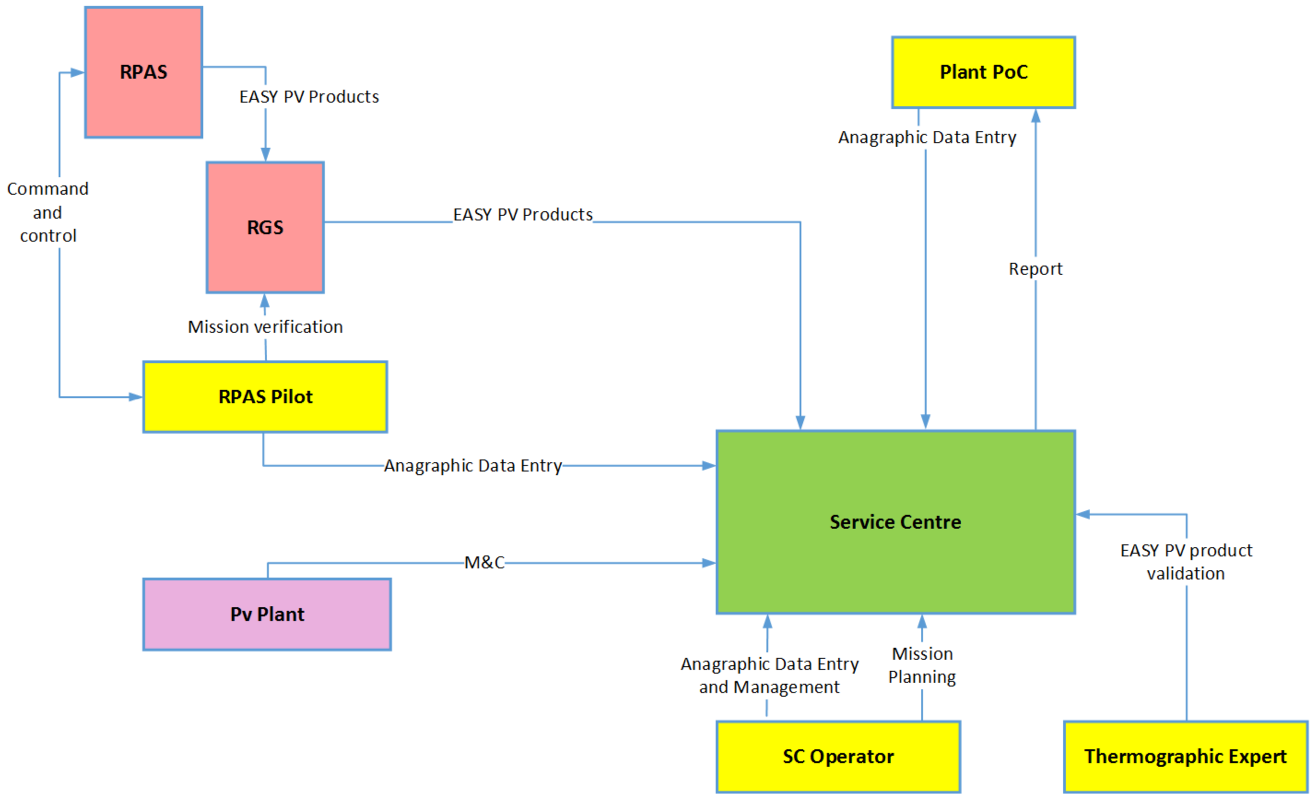


Figure 4-3- EASY PV Functional chains

In particular, the following main functional chains are identified:

1. Data entry and management. During this phase the SC operator injects in the SC platform the PV plants data. Generally, this step is accomplished by the support of the PoC plant who knows the information to be inserted in the system DB. Note that also Pilot and PoC contact information are inserted in the DB

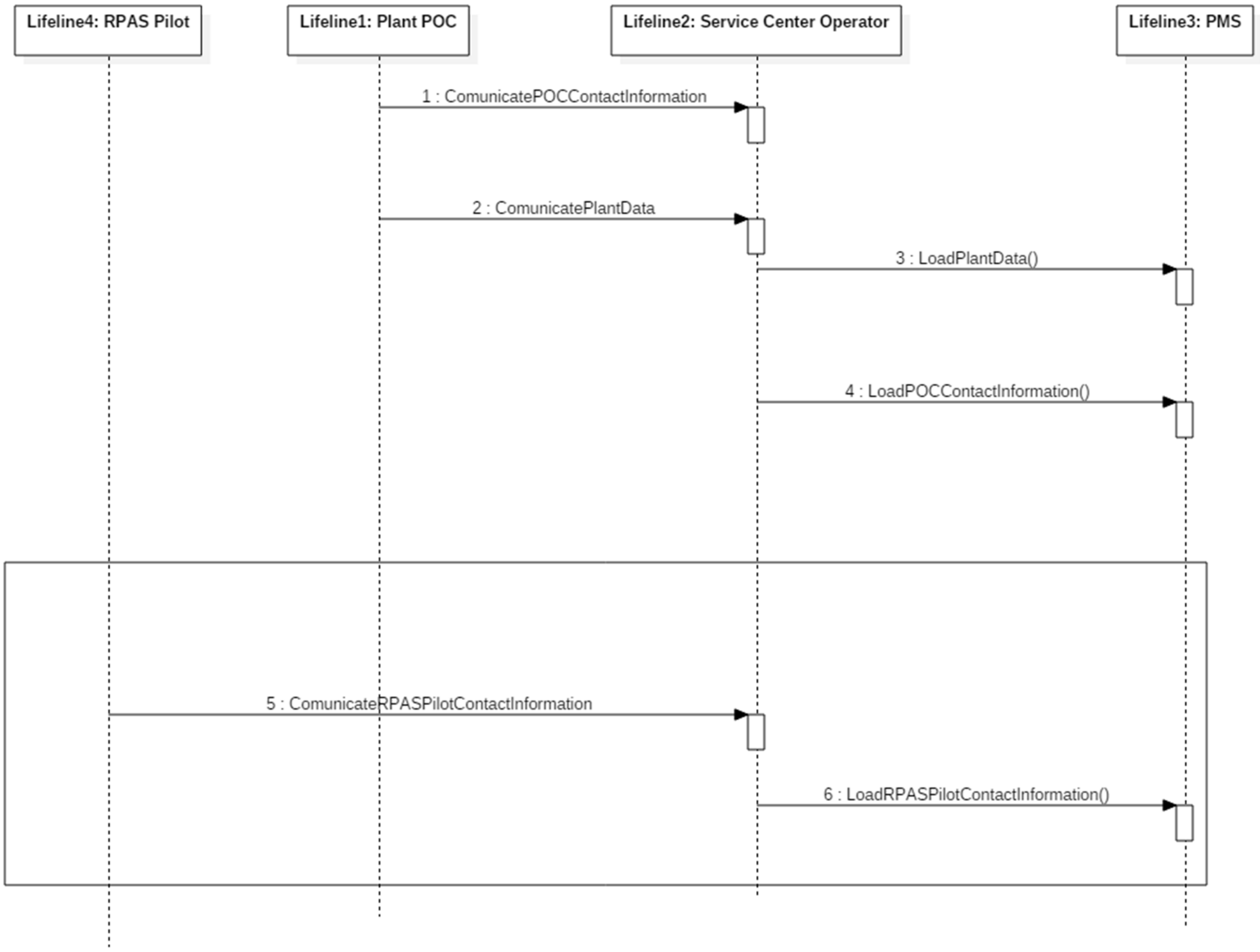


Figure 4-4- Data entry and management on the SC platform RPAS data acquisition

2. Mission planning. This chain refers to mission organisation for on field data collection. As both the PoC and the RPAS remote pilot have to attend, they communicate their availability to SC operator or directly by accessing the SC. Based on these information, the SC operator generates a date and relevant ancillary data to implement the mission.

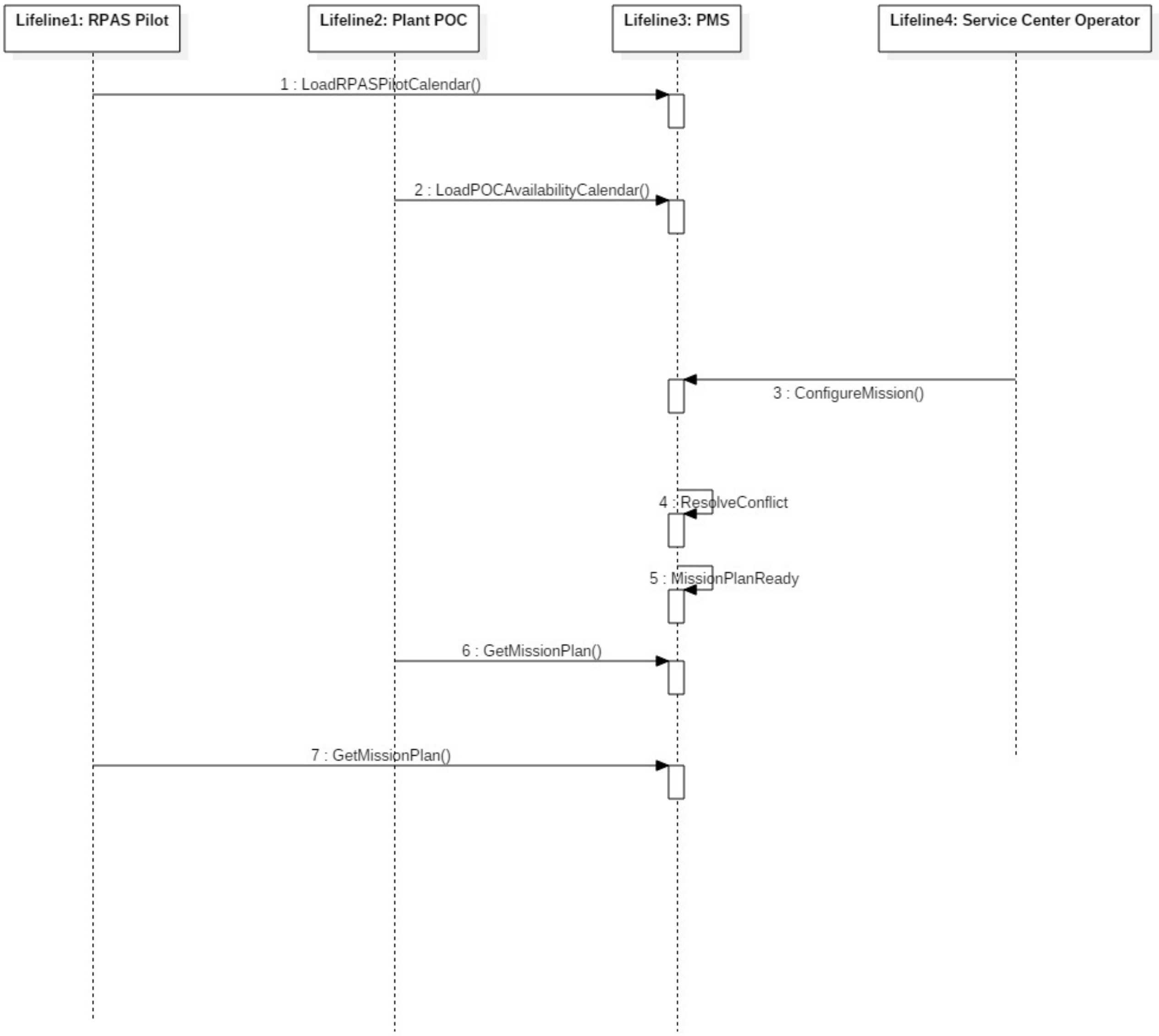


Figure 4-5- Mission Planning

3. <u>Mission on field execution at RPAS side</u>. The RPAS remote pilot executes the above assigned mission by command and controlling the RPAS flying over the target PV plant. Data are collected in several sessions (each lasting from 10 to 20 minutes depending on environmental conditions) where the RPAS takes off, collects data and lands to finally export the EASY PV products to the RGS which implements a first elaboration. At this step the RPAS remote pilot is able to verify if the plant is completely covered and subsequently to send on field data to the Service Centre. The RPAS remote pilot manages both RPAS and RGS elements, as reported in Figure 4-6

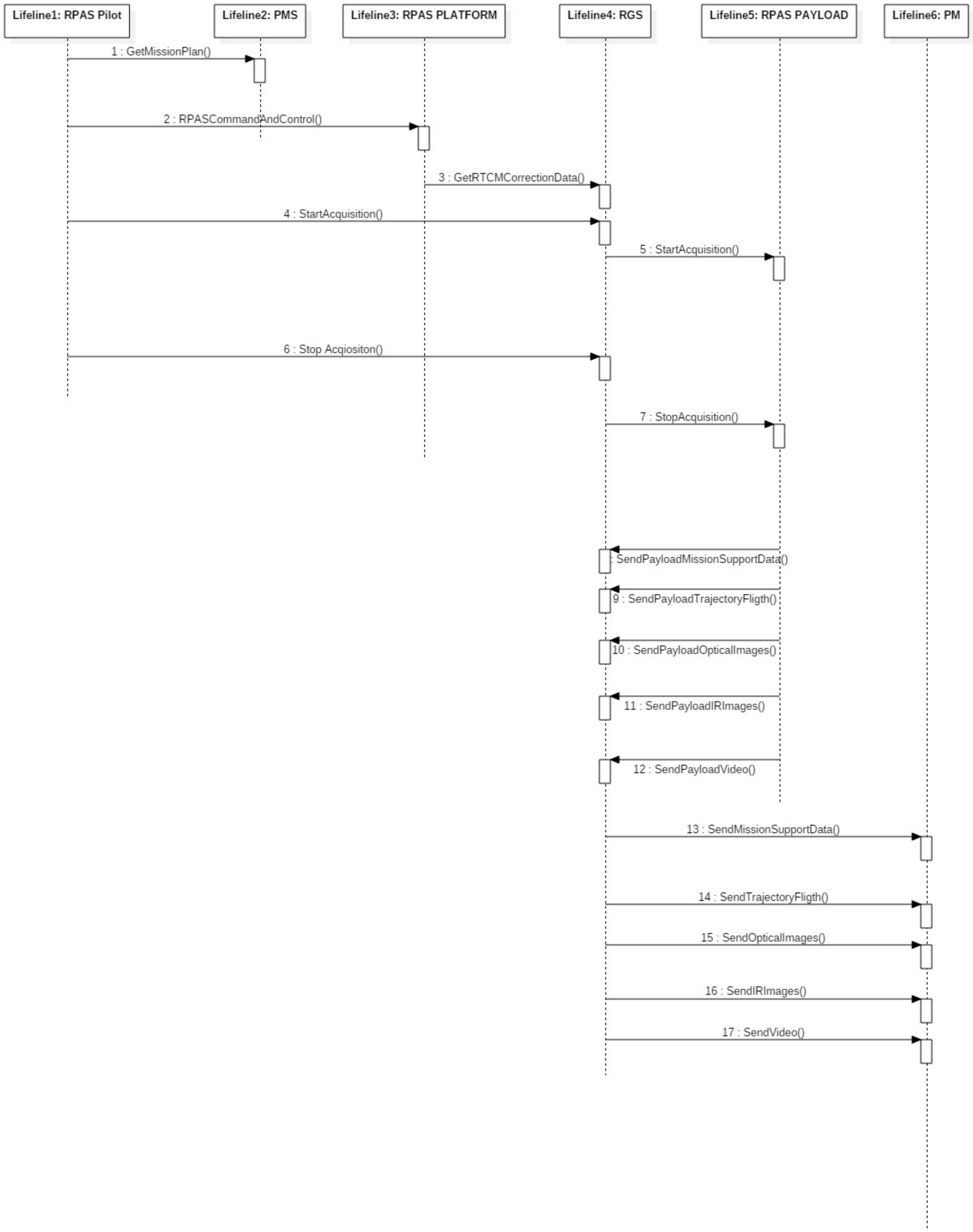


Figure 4-6- RPAS data acquisition

4. <u>Data Management @ Service Centre Side.</u> Once data of every PV plant in the DB are gathered at the Service Centre side, the Thermographic expert is able to make analysis (including historical comparisons) and to finally generate a report to be finally managed by the PoC plant for commercial and contractual purposes.

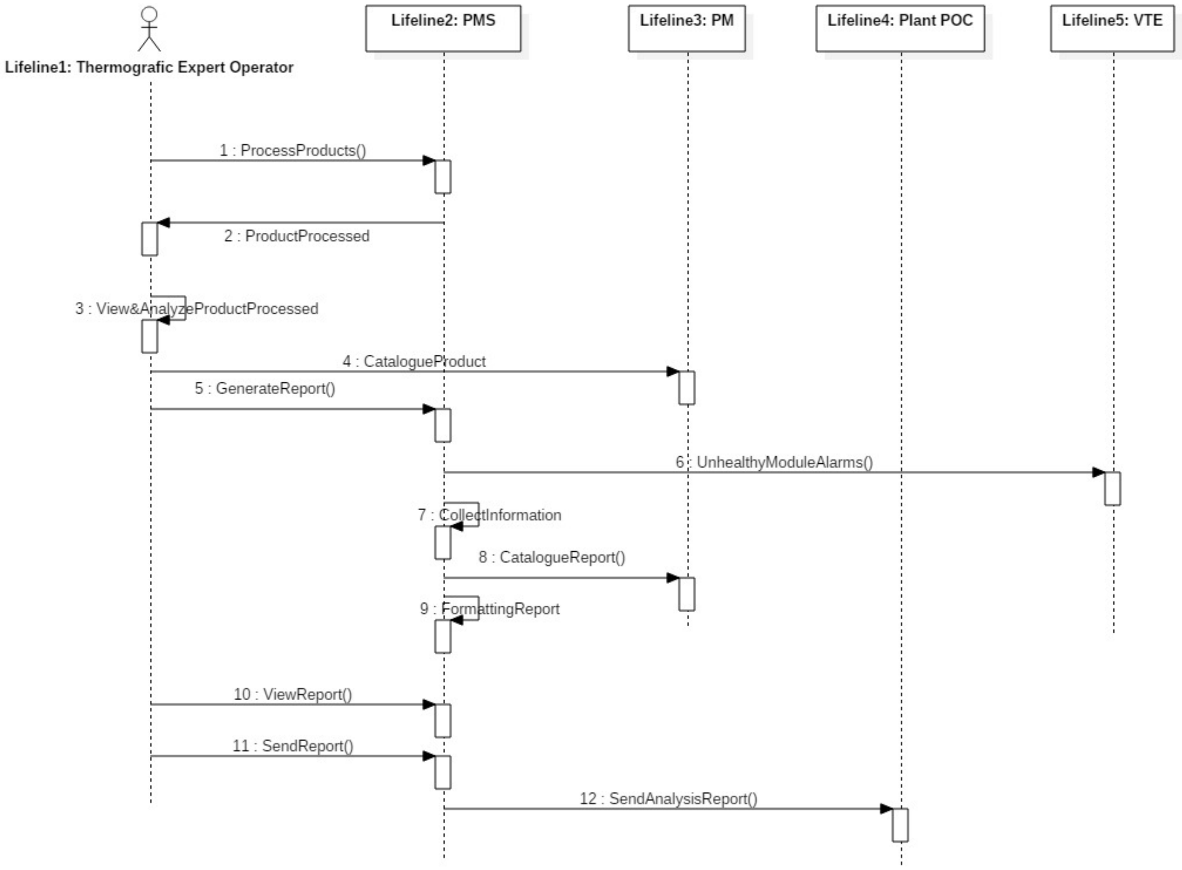


Figure 4-7 – Data Post Processing @ Service Centre side

5 PHYSICAL ARCHITECTURE

5.1 THE EASY PV SYSTEM

The Figure 5-1 depicts the context in which EASY-PV operates showing the interface with the external system or actors involved. For a description of actors see section 4.2.1..

The external entities interfaced by EASY-PV are:

- ✓ **GNSS SIGNAL**: represents the Navigation signal received from GNSS.
- ✓ **PV Plant:** represents the photovoltaic plant interfaced by EASY-PV.

The same figure contains the description of physical architecture of the EASY-PV system i.e. the arrangement of elements, their decomposition in subsytems, interfaces (internal and external), which form the basis of a system or product design to satisfy the functional architecture and the technical requirements.

All EASY-PV system has been decomposed in three subsytems:

- RPAS: is the Remotely Piloted Aircraft Systems with the payload
- RGS: is the Ground segment that interfaces with the RPAS
- SERVICE CENTER: is the subsystem able to manage all EASY-PV information regarding mission, acquired data, actors, report, and plant monitoring.

For each identified subsystem, a detailed description is presented in the next sections.

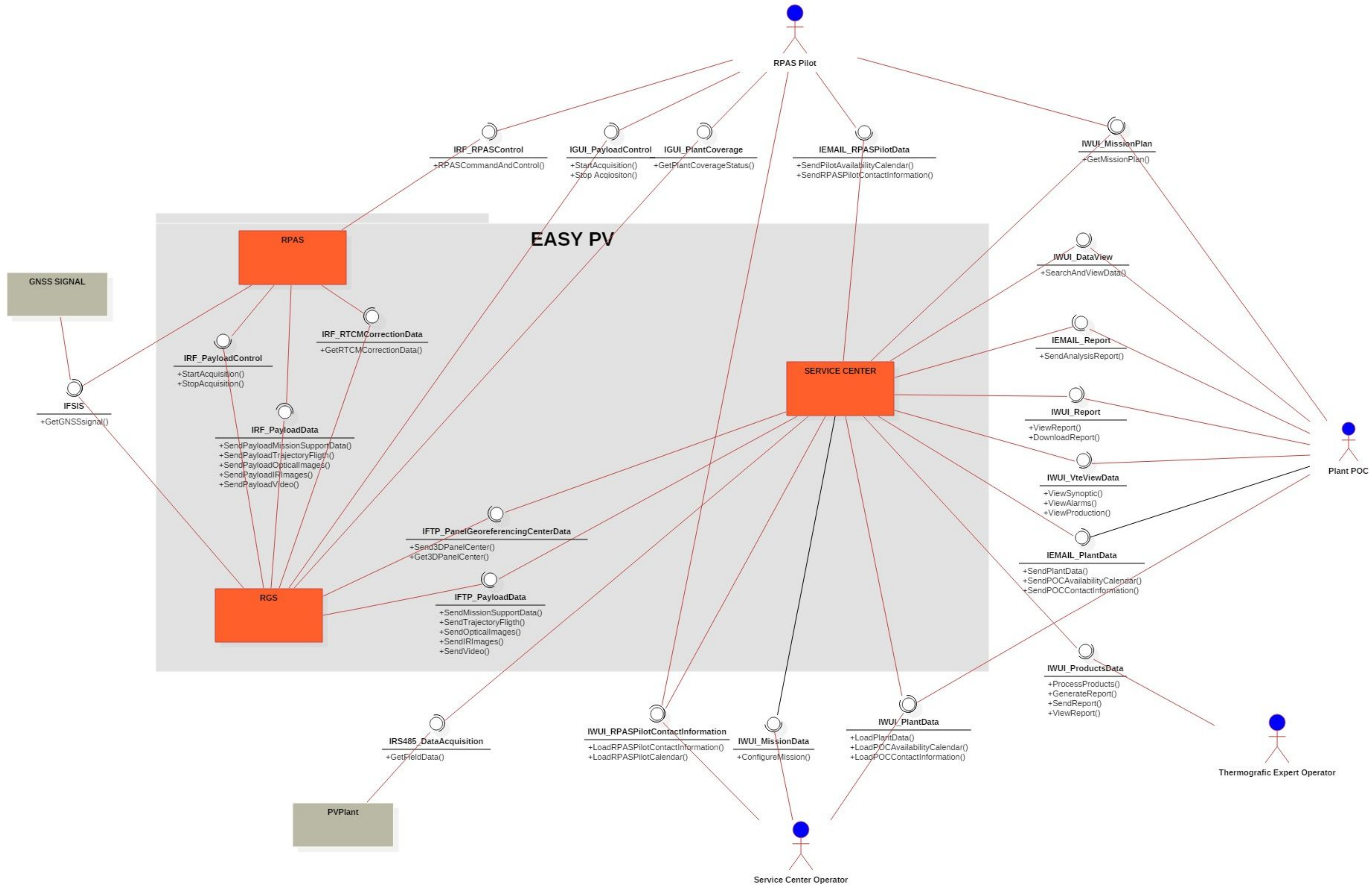


Figure 5-1 – Easy PV Components

5.1.1 The Service Center Subsystem

Service Center is the subsystem of the EASY-PV devoted to manage all aspects related to production, delivery, archiving and cataloguing of data acquired and processed. In Figure 5-2 is shown the SC context and its decomposition in main component.

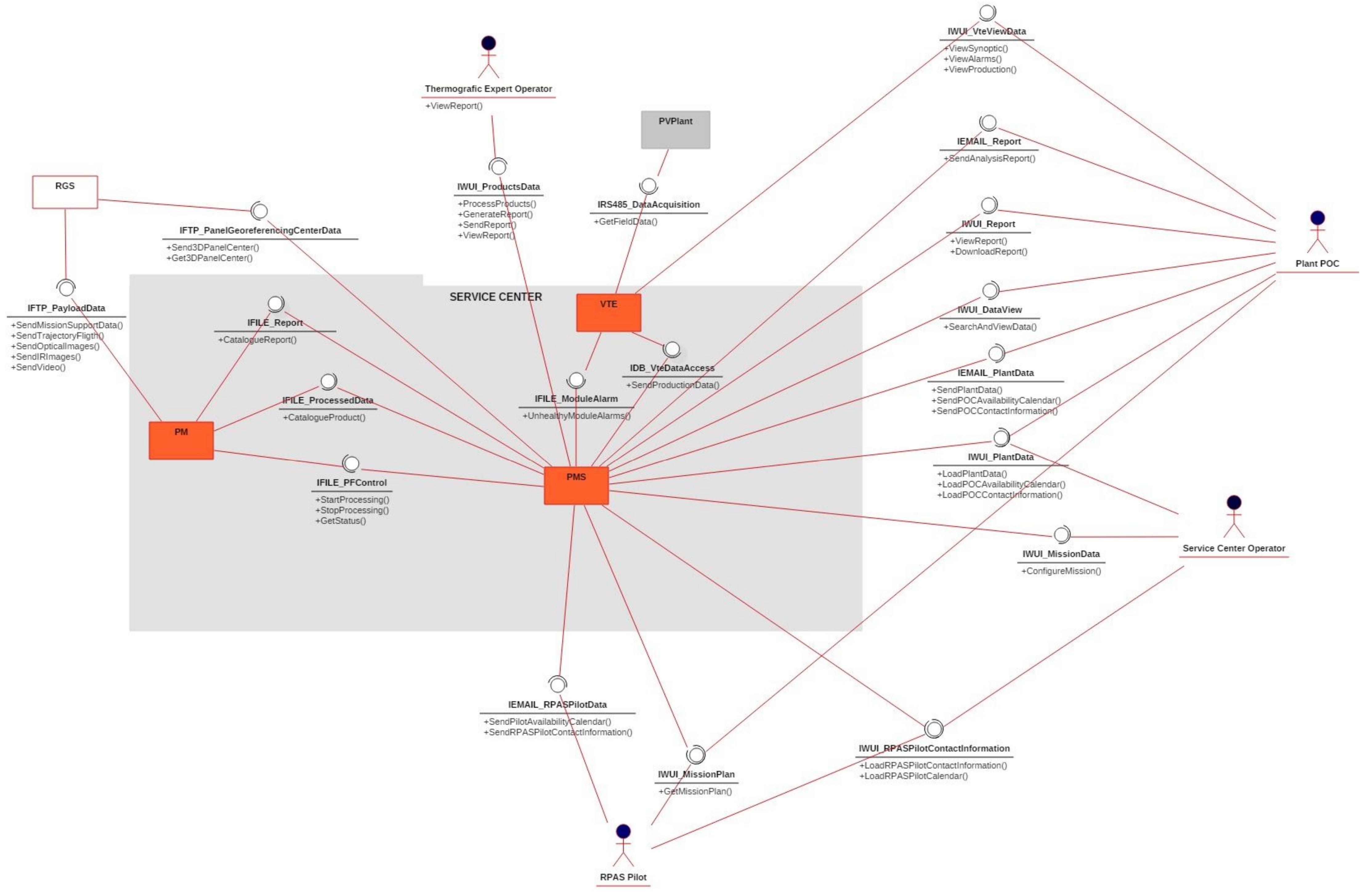


Figure 5-2 – Service Center Decomposition

Main functions of the SC and their allocations to component are the following:

SC Functional Area	Component Allocation
Product Archiving and Cataloguing	PM – Production Manager
RGS Data Reception	PM – Production Manager
Mission Planning	PMS – Payload Management System
Post Processing Management	PMS – Payload Management System
Product Validation	PMS – Payload management System
Product Delivery and Distribution	PMS – Payload Management System
RPAS remote pilot Management	PMS – Payload management System
PLANT POC Data Management	PMS – Payload management System
PV-PLANT Monitoring and Control	VTE - Visual Track Energy

Table 5-1 SC Components Allocation

For each SC functional area, a description will be provided in the following paragraphs, while the description of the physical component shall be carried out at section 5.1.1.1, 5.1.1.2 and 5.1.1.3.

- **Product Archiving and Cataloguing**

  This function takes into account all the activities involved in the data and product cataloguing and archiving. Archiving is the capability to store data and products in order to be retrieved for future activities. Cataloguing is the capability to store information useful to retrieve the products and data and to do statistical computation.

  The archiving and cataloguing functions includes at least the following:

– catalogue and archive policies management
– cataloguing and archiving of Mission data, acquired by RGS subsystem:
– cataloguing and archiving of the following data:
  - Optical Image
  - Thermal Images
  - Video
  - Support data
  - Post Processed Products
– retrieval of previously archived and catalogued data / products;
– catalogue browsing;

- **RGS Data Reception**

  This function takes into account all the activities involved in the reception of external data, including at least:

  – data (products, support data, etc.) electronically received from RGS;
  – data (products, support data, etc.) received via media (DVD, USB) and handled by the operator, which is in charge to manage the reception via a proper console which will support the operations in order to catalogue the media and then to download the data received via media and submit them to cataloguing and archiving.

- **Mission Planning**

  This function takes into account all the activities on mission planning, organization and cooperation between the various actors involved throughout the mission process.

- **Post Processing Management**

  This function takes into account all the activities involved in the post processing of an acquired/catalogued products. These activities can be operated in automatic mode or manually by Thermografic Expert Operator

- **Product Validation**

  This function takes into account all the activities involved in the product Validation before Delivery. This function is used mainly by the Thermographic Expert Operator to see the products, processing it, make analysis, write annotations, etc…

- **Product Delivery and Distribution**

  This function takes into account all the activities involved in Delivery and Distribution to the final user (Plant POC) of validated products, including at least:

  - Report Formatting
  - Report Archiving
  - Report Distribution

- **RPAS remote pilot Management**

  This function takes into account all the activities involved in the RPAS remote pilot management, including at least:

  – RPAS remote pilot contact data
  – RPAS remote pilot calendar management
  – RPAS remote pilot Mission Plan distribution

- **PLANT POC Data Management**

This function takes into account all the activities involved in the PLANT POC management, including at least:

- Plant data management
- Plant POC contact data management
- Plant POC Mission calendar management
- Plant POC Mission Plan distribution

- **PV-PLANT Monitoring and Control**

  This function takes into account all the activities involved in the management and presentation of information coming from the PV-PLANT:

- Monitoring and Control of plant elements status
- Alarm supervision
- Production parameters supervision

5.1.1.1 Production Manager - PM

The Production Manager component is devoted to manage all aspects relating to ingestion, archiving and cataloguing of data acquired and post processed.

External Data Reception Facility (EDRF)

The External Data Reception Facility (EDRF) is a component of the PM in charge of managing the reception of all external data (both Products and Support Data) coming via both electronic link (ftp site) and media.

If the data are received from electronic link the normalisation and screening activities are started automatically.

When the data is on the disk the normalisation and screening activities can be started manually.

The structure of received data is:

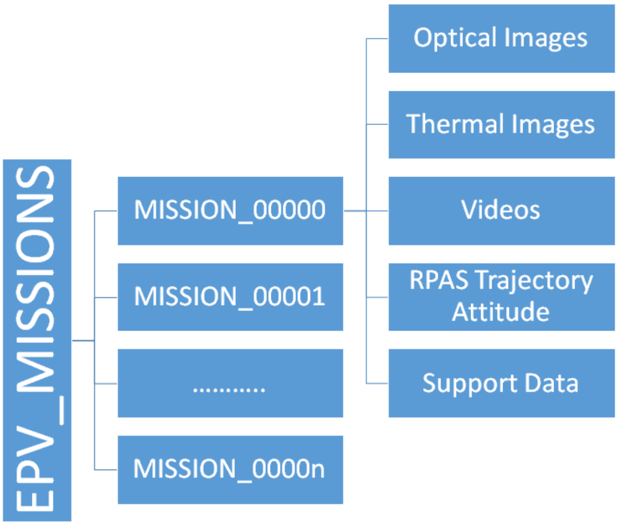


Figure 5-3 – FTP Data Structure

Each mission directory will contain all mission data, in particular:

- ✓ Optical Images, gathered from the RPAS optical payload
- ✓ Thermal Image, gathered from the thermal payload
- ✓ Videos, gathered from RPAS optical and thermal sensors
- ✓ RPAS actual Trajectory and Attitude
- ✓ Support Data, which are .xml files used
  - o to synchronise the connection from the RGS to the SC, i.e. to trigger the SC processor when all mission data (as shown in the bullets above) are completely uploaded
  - o to summarize general information about a given mission (see Figure 5-4)

```xml
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE EasyPVMissionData SYSTEM "file:///D:/DEV/EPV/DOC/EasyPVMissionData.dtd">
<EasyPVMissionData>
  <Mission>
    <MissionId>123</MissionId>
    <PlantId>123</PlantId>
    <AcquisitionDate>YYYY/MM/DD</AcquisitionDate>
    <RPAS>
      <Operator>Operator_DATA</Operator>
      <Machine>Machine_DATA</Machine>
      <Payload>Payload_DATA</Payload>
    </RPAS>
  </Mission>
  <Video>
    <FileName>FileName_DATA</FileName>
  </Video>
  <OpticalImage>
    <FileName>FileName_DATA</FileName>
    <AcquisitionTime>AcquisitionTime_DATA</AcquisitionTime>
    <CentrePos>
      <lat>lat_DATA</lat>
      <lon>lon_DATA</lon>
      <height>height_DATA</height>
    </CentrePos>
    <PosAccuracy>
      <lat_err>lat_err_DATA</lat_err>
      <lon_err>lon_err_DATA</lon_err>
      <h_err>h_err_DATA</h_err>
    </PosAccuracy>
    <Area>
      <lat_min>lat_min_DATA</lat_min>
      <lon_min>lon_min_DATA</lon_min>
      <lat_max>lat_max_DATA</lat_max>
      <lon_max>lon_max_DATA</lon_max>
    </Area>
  </OpticalImage>
  <Thermalmage>
    <FileName>FileName_DATA</FileName>
    <AcquisitionTime>AcquisitionTime_DATA</AcquisitionTime>
    <CentrePos>
      <lat>lat_DATA</lat>
      <lon>lon_DATA</lon>
      <height>height_DATA</height>
    </CentrePos>
    <PosAccuracy>
      <lat_err>lat_err_DATA</lat_err>
      <lon_err>lon_err_DATA</lon_err>
      <h_err>h_err_DATA</h_err>
    </PosAccuracy>
    <CentreAttitude>
      <yaw>yaw_DATA</yaw>
      <pitch>pitch_DATA</pitch>
      <roll>roll_DATA</roll>
      <heading>heading_DATA</heading>
      <angleOfAttack>angleOfAttack_DATA</angleOfAttack>
    </CentreAttitude>
    <Anomaly>
      <CentrePos>
        <lat>lat_DATA</lat>
        <lon>lon_DATA</lon>
        <height>height_DATA</height>
      </CentrePos>
      <Temperature>Temperature_DATA</Temperature>
      <Code>Code_DATA</Code>
    </Anomaly>
  </Thermalmage>
</EasyPVMissionData>
```


Figure 5-4 – xml mission file

Before submit the data for cataloguing a normalization process starts to convert the received files in an internal format for cataloguing.

Catalogue Manager (CTG)

The Catalogue Manager is the component that manages the catalogue and the cataloguing functions at service centre level. The catalogue contains, in its dedicated database tables, the metadata relevant in the EASY-PV system for Products and Support Data.

The CTG as component that manages EASY-PV catalogue, logically provides the following functionalities, which are physically implemented by the CTG:

- Cataloguing of generated or received Products, Support Data;
- Archiving (on-line) of catalogued products and support data;
- Deletion, invalidation and re-validation of products;
- Local Catalogue Browsing by means of a dedicated GUI;
- Remote Catalogue Browsing exploiting the interoperability protocol;
- Management and evaluation of configurable Cataloguing and Archiving Policies;
- Management of configurable periodic rolling policies;
- Event and Log Management;
- Extraction of metadata from data.

Archiving Facility (AF)

This component allows data storage and data sharing between the EASY-PV processing nodes in an effective way with respect to system performances and to disk space usage.

To enhance data security, md5 check is performed on files moving from / to AF; for each file to be stored on AF, the md5 signature is calculated and stored in the system database. Once a previous archived file is retrieved from AF, its md5 signature is calculated again and compared with the one stored in the system database to ensure data integrity and security. The checking operation is performed in parallel with processing tasks and, in case of check failure, blocks the delivery of the datum. The above operations are performed in the framework of the file archive and retrieval policies, so in the framework of processing and delivery workflows

Besides this, the AF component provides EASY-PV data protection by implementing the backup and restore strategy. The AF component has the following main functionalities:

- provide a shared storage area for components

- provide the archive area for generated and externally received products and support data
- provide backup/restore for the archive.

AF is mainly composed by HW / SW COTS sub-components. The backup/restore functionalities is provided through a centralised engine that manages the backup/restore policies in terms of managed clients, saved data, backup schedule and media library allocation. Backup and restore is performed on archived data by means of the AF COTS.

The Archive Area is made visible to EASY-PV components by means of a FTP server located on the Storage Server.

5.1.1.2 Payload Management System – PMS

Payload Management System is the real front end for all actors involved in EASY-PV. It has to collects all information of EASY-PV in terms of actors and Plant.

When all data exchanged between RPAS and SC as per interface PM-200-001 have been gathered, the mission plan has to be prepared and shared between actors. After mission execution a post processing can be activated (see Figure 4-7) by Thermographic Expert Operator. The result after validation (analyse process) is available for cataloguing and archiving.

TEO will activate the report generation (through a web user interface) that at the end of process will be catalogued and archived and ready to be sent to the final user (Plant POC). It has to be underlined that PMS in order to generate the report needs to recovers data from VTE system to have the Plant Production data.

The communication with different actors will be implemented in two ways: email or direct access via Internet to EASY-PV.

5.1.1.3 Visual Track Energy – VTE

Visual Track Energy is a Sistematica vertical solution dedicated to energy management system. It is a general purpose platform, fully configurable and customizable and provides typical functionalities of a last generation of SCADA (*Supervisory, Control and Data Acquisition*) system (p.e.: web based, and app). It is s software web-based platform that provides remote monitoring and centralized control of distributed plant. This is implemented by interfacing several types of device like inverter and PLC.

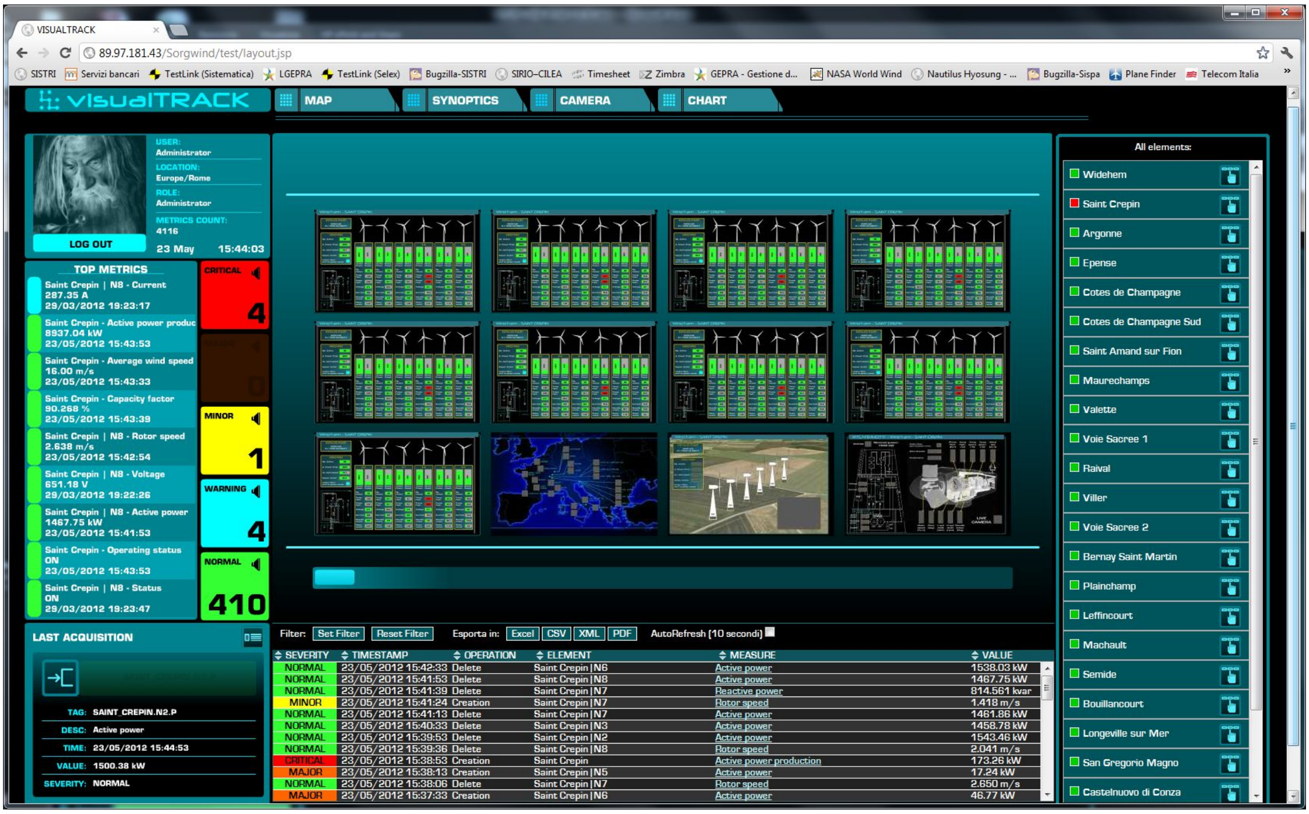
VTE functionalities are described in the following macro areas:

- **Configuration:** allows to configure the service and resources to be monitored defining typology, reference thresholds, severity level etc..
- **Monitoring:** allows monitoring the resources status showing the information based on different view (services, Resources, node, groups). The main functionalities are:

- Raw data acquisition from periphery (plant field data)
- Processing and validation of data acquired
- Alarms generation and propagation
- Historical archiving of acquired data

- **Control:** allows to send command to peripheral devices either manually or through automated procedures, activated from monitoring function or through applications that implement specific logic
- **Report e statistics:** allows to carry out analysis and statistics on acquired and processed data and to export the result.

Figure 5-5 shows the VTE principal view in a sample configuration. The initial screen display is designed to have an overall picture of the summary very effectively with all relevant information, such as the logged-in user, the list of alarms , the latest acquired metrics, etc.



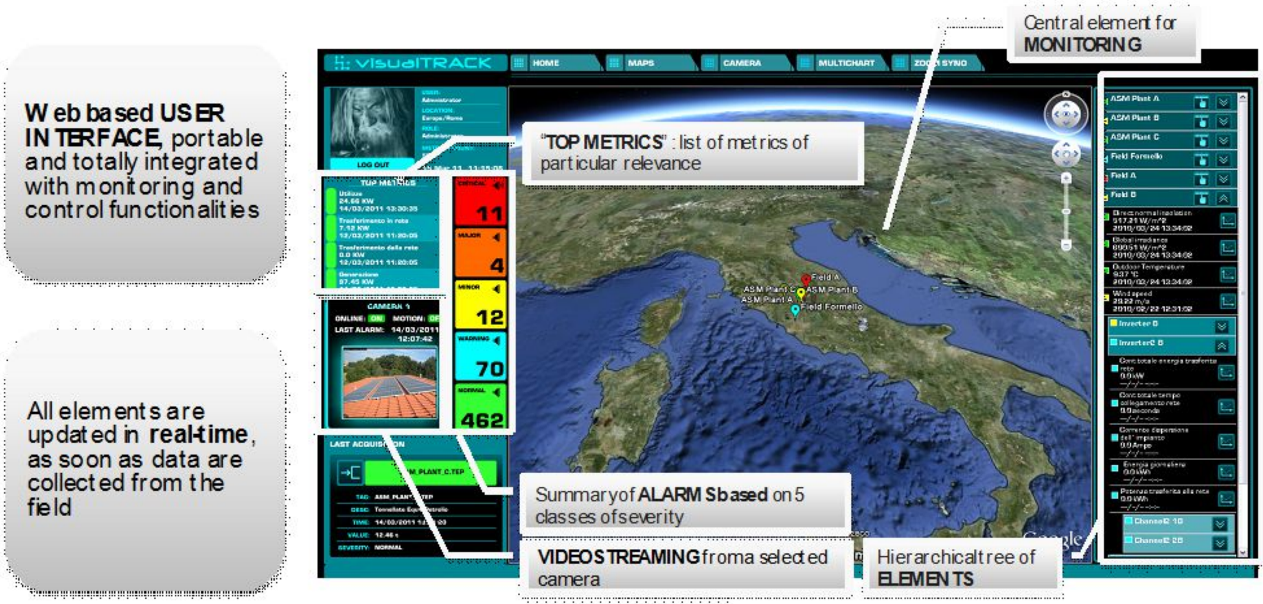


Figure 5-5 – VTE Synoptics

VT allows the acquisition, processing and validation of data coming from the periphery, the generation and management of alerts and notifications, the management of callback entry / exit from the alarm condition, the projection on the geographical map of the monitored data, the production of custom graphics and statistics, the production of plant synoptic.

VT acquires the data from the sensors, processes them, subjects them to a verification and validation process and then make them accessible to the user via web pages. Any anomalies in the monitored values originate an alarm management mechanism.

The archived data are displayed to the user through appropriate views, such as charts, reports, screening of digital mapping.

The webapp module is the interface made available to the final customer for access to system features. And 'essentially it based on web-based interface to VT.

Once logged in, the user is presented the VT home screen. The monitoring console consists of the following elements:

- Central monitoring device
- List of diagnostic "TOP METRICS" special importance
- summarized data about alarms divided by 5 severity classes
- streaming on top of a selected camera
- hierarchical tree of elements

The GUI is designed on a new visual paradigm through which the user can access all the information at any level of detail and from any location: from a global view of the system through the digital map, across the synoptic mode , up to the vision of information and graphics of detail.

VT allows you to configure and store the master data of the various sites also managing geographically referenced information that characterize the site.

In the Easy-PV context the physical parameters are those typical of a photovoltaic plant, in particular:

- electric energy data
  - measurement of electrical power (active and reactive)
  - measurement of electrical energy (active and reactive)
  - measurement of electrical voltage and current in AC and CC
  - power factor
  - network frequency
  - working status (alarms, warnings, diagnostics). There are two way for alarms acqiusitoins:

1. directly from the field (field measurement)
2. from PMS about the unhealthy Module Alarms arising from a mission

– environment parameter like temperature, irradiation level

The above measurements have to be available to PMS in order to generate the final report.

5.1.1.4 Service Center Deployment

This paragraph presents the hardware architecture; the Table 5-2 contains or address information related to the hosts software configuration; any further detail or modification available during sub-system development will be reported in document updates.

Host type & reference	O.S.	Database Server	Application server	Allocated Component	Detail	Sizing
Servers						
SRV#1	RHEL 6.2		x	VTE	Server side, web applications (Apache-Tomcat)	Medium
SRV #2	RHEL 6.2		x	PMS, PM	Server side, web applications (Apache-Tomcat)	Medium
SRV #3	RHEL 6.2	X		Database	Postgres database and Archiving	High with disk array for storage

Table 5-2 Service Center Deployment

5.1.2 The RPAS and RGS Subsystems

The main architecture of RPAS and RGS subsystems of EASY-PV are described in Figure 5-6, where the following elements are identified:

- ✓ RPAS, composed by a
  - o Platform (generally a COTS or self-built drone), a payload, described in section 5.1.2.2
  - o C&C Ground Station, generally a COTS
  - o RPAS Payload,
- ✓ RGS, described in section 5.1.2.3
- ✓ Communication Links between Subsystems

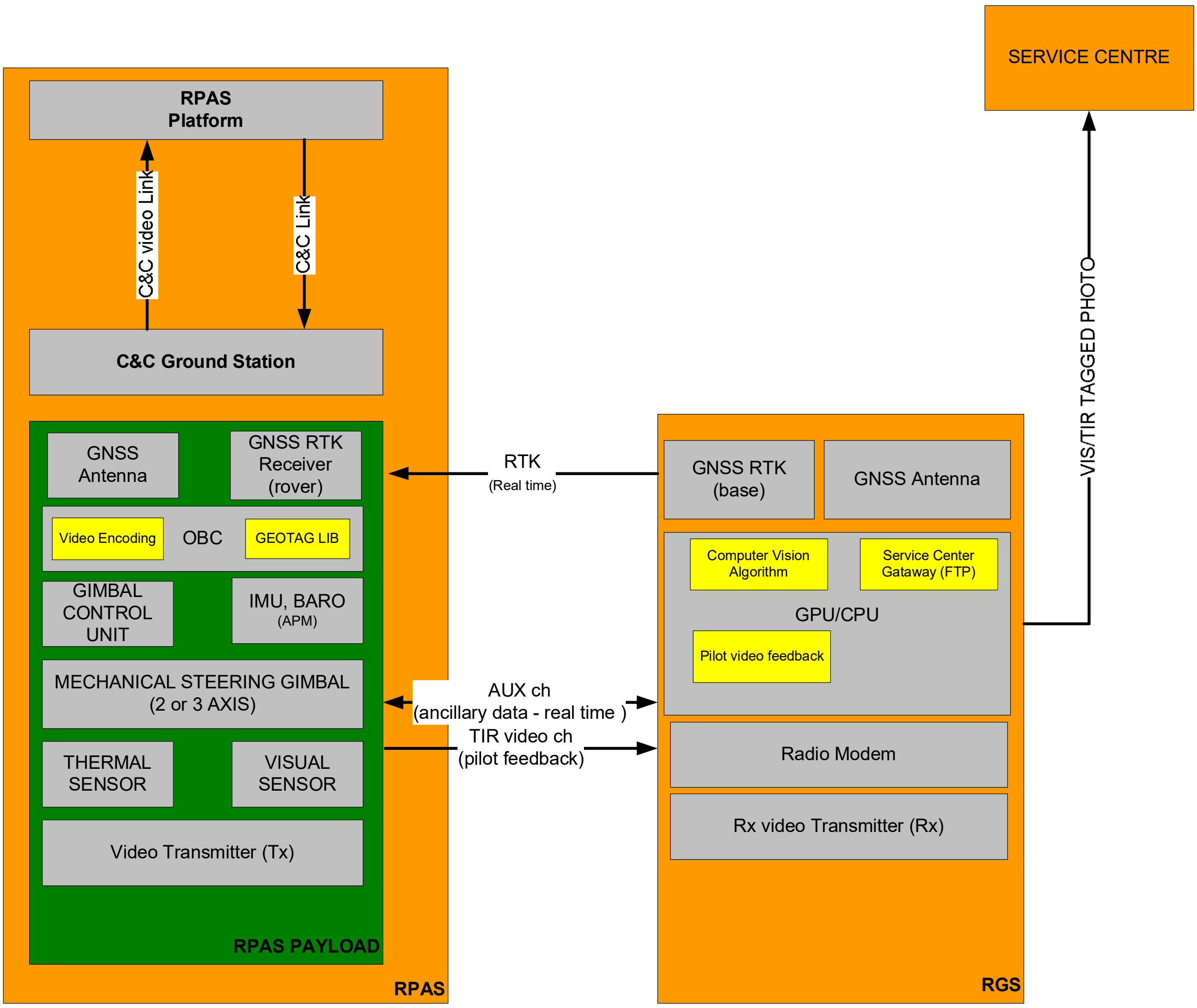


Figure 5-6- RPAS and RGS logical architecture

The current configuration foresees that the RPAS platform is unbounded to the payload for navigation purposes, however some exploitation of features already provided by the RPAS platform can be used, without interfering to GNC functions, assuring safety of operations. The main reason to unbound to Payload to RPAS platform is to keep a scalable payload that can be used with different kind of RPAS available on the market today and in future with minor modification / configuration. Since Market analysis results are partially available at this stage of the program (market analysis results drive the detailed design of the architecture), a more conservative architecture design of RPAS and RGS is proposed. However the implementation of the architecture design proposed in Figure 5-6 can be enriched by means of new digital video links available and eventually with the SDK available from some RPAS manufacturers, after market analysis confirmation (e.g. model of business, product /service, …).

Moreover, a payload unbounded to RPAS is also valuable to leave to the pilot the possibility to use his/her own drone in combination with Easy-PV payload and RGS. A suitable RPAS with EASY-PV integrated Payload will be implemented in the relative WP, however the very same payload, with little modification/configuration will be tested also on other RPAS platforms available in TopView premises.

5.1.2.1 RPAS Candidate Platforms

The RPAS candidate platforms suitable to embark EASY-PV payload are the following:

- DJI MATRICE M100 Quadcopter;
- TOPVIEW MANTIDE 900 (Self Built hexacopter, tailored on S900 frame)
- TOPVIEW GEKO V2 Quadcopter (Self Built quadcopter)

DJI Matrice M100 is a 3,6 Kg very light quadcopter suitable for Developers and Researchers; in fact it allows to add components, customize the payload and fly with any devices like cameras, sensors, computing boards, communication tools, gathering data while completing complex jobs.

It implements new digital video link communications with remote control stations and provides developers with a new Software Development Kit from DJI (On-Board SDK, Guidance SDK and Mobile SDK) which could be very useful for the implementation of the RPAS architecture proposed or future EASY-PV upgrades.

One MATRICE M100 has already been acquired by consortium (TopView) which is studying and assessing the Software Development Kit provided for Linux, STM32 and Android platforms.

Moreover the consortium have been using MATRICE M100 for the preliminary assessment on field of the EASY-PV Core GNSS and Computer vision Algorithm.

MATRICE M100 is the first candidate for Easy-PV RPAS and Payload implementation.

Figure 5-7- DJI MATRICE M100 with no payload and with optical payload used for testing

<u>TOPVIEW MANTIDE 900</u> is a RPAS of 8,2 Kg that has been approved by italian civil CAA (ENAC) for flight operations with reference #6446 of 24th March 2016. It is a general purpose light hexacopter based on DJI S900 frame capable to embark a 3,3 Kg payload, very useful at first stage of testing when it is expected a heavier payload composed by different development boards not yet integrated. This platform has large space to integrate sensors, On-Board Computers and high accuracy GNSS receivers as in Figure 5-8, to be used in EASY-PV RPAS architecture design.

However this drone still implements analogic VHF C&C for live video feedback to the pilot, therefore some upgrades may be also considered.

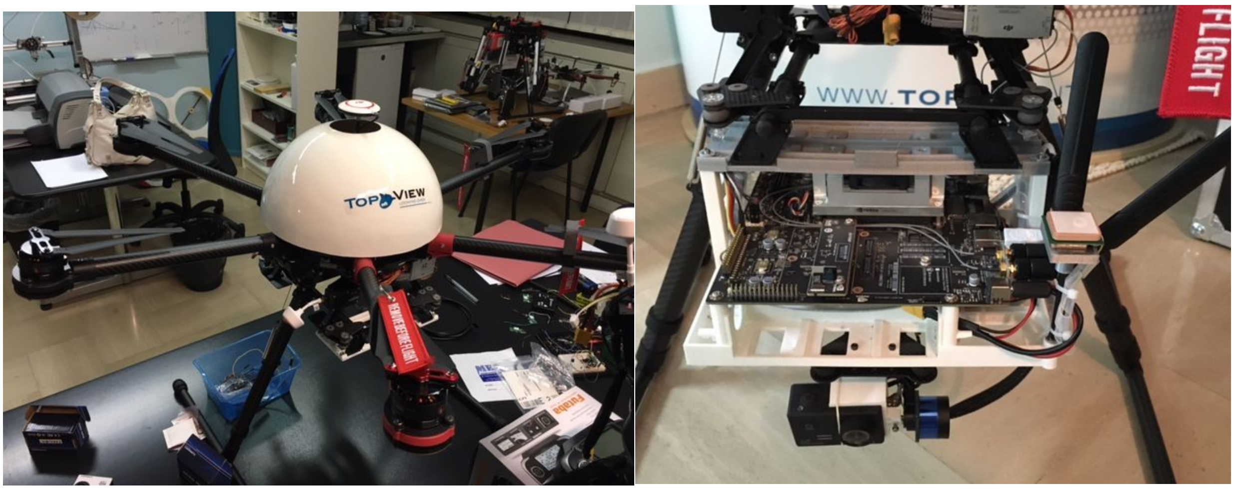


Figure 5-8- TOPVIEW MANTIDE 900 with no payload and with a high performance On-Board Computer Payload

<u>TOPVIEW GEKO V2</u> it is a very light RPAS of 2,6 Kg designed and integrated inside TOPVIEW laboratories, based on GEKO V1 project an RPAS authorized by Italian CAA with ref # 5480 of 13-10-2015. This RPAS has an open source core which has been tailored and configured having thermal inspection applications in mind. A customized GEKO RPAS for EASY-PV (without payload) has been already produced and presented by the consortium at Energy Session during European Space Solutions 2016 at the Hague. This platform represents a general purpose auto-built drone with the minima requirements to embark Easy-Pv Payolad.

Figure 5-9- TOPVIEW GEKO V1 (left) and GEKO V2 (right) tailored for Easy-Pv project.

The RPAS C&C station used by the pilot is generally composed by a radio control and an optical video feedback (analogic or digital). Some C&C ground station suitable for Easy-PV RPAS are presented in Figure 5-10; the picture of the analogic Ground Station has been taken during a recent RPAS PV inspection made by the consortium to refine requirements considering the point of view of the pilots for EASY-PV RPAS and RGS usability.

Figure 5-10- C&C Ground stations with digital (left) video or analogic (right) video feedback

5.1.2.2 RPAS Payload

The RPAS Payload is composed by different units:

- **OBC:** The On Board Computer hosting a GNSS GEOTAG Library. This unit is responsible for:
    - Interface and handling all payload sensors (Barometer, GNSS Receiver, IMU)
    - Handling Thermal Camera
    - Handling Optical Camera (or interface RPAS optical Camera)
    - GeoTagging and enrich each frame with ancillary information (GNSS high accuracy positioning + attitude and other Metadata)
    - Storing data (TIR/VIS video/photo on board)
    - Handling the on-board live NAVCOM and Thermal data to pilot in real time (this is needed for pilot live video thermal feedback purposes only - no C&C)
    - Handling Video Encoding (e.g. H.264 codec or RAW images,…); some intelligence of computer vision algorithm can be also considered in the relative software module.
- **RTK GNSS Receiver and Antenna:** A Multi Constellation GNSS Receiver (GPS + GLONASS+ Galileo) with RTK capabilities and a high update rate. (e.g. 5 – 10 Hz). Sensors with embedded IMU can be also considered (e.g. U-Blox M8 series)
- **Gimbal:** will be implemented by a 2 or 3 Axis Mechanical Gimbal with its dedicated electronic Control Unit. The Gimbal will be designed for housing Thermal sensor (and optionally visual sensors) with a custom design.
- **Thermal and Visual Sensors** will be implemented by commercial sensors (COTS) available in the market (e.g. FLIR VUE PRO or FLIR TAU2)

The Main OBC software will include a GEO Tagging Module able to tag with high accuracy the thermal and/or optical image collected for each generated frame. The GNSS and Computer Vision algorithm mechanism are detailed in the Technical Note (to be annexed to the present document by sept. 30th).

The **OBC Unit** of Payload can be implemented with different Hardware such as:

- ODROID XU-4 Octacore; based on A15 2GHz and Cortex™-A7 Octa core CPUs
- Raspberry Pi 3 Quad Core (Rpi3); a 1.2GHz 64-bit quad-core based on ARMv8 CPU
- NVidia Jetson Tx-1 Quad-core ARM® Cortex®-A57 with CPUs with Nvidia Maxwell GPU 256 CUDA cores

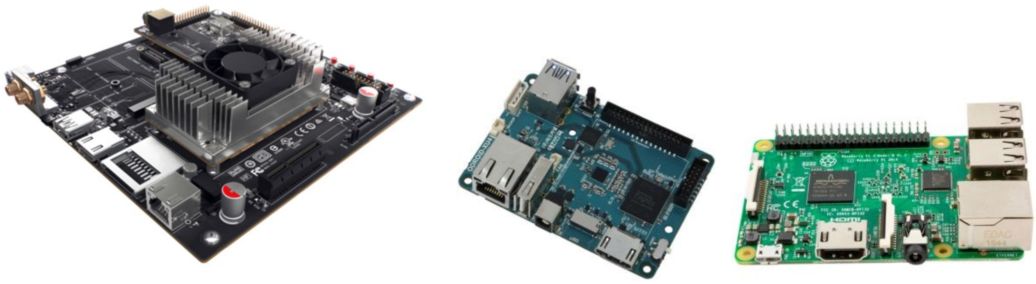


Figure 5-11- NVidia Jetson Tx1 (left), Odorid XU-4 (center) Raspberry Pi 3 (right)

These development boards have sufficient calculation power to handle digital thermal (and optionally optical) video streams and to perform in parallel all the tasks needed in Easy PV Payload (e.g. interface GNSS Receiver, GEOTagging video frames, Store Video with GNSS and attitude metadata,…), moreover all these boards have a large number of GPIO and ports to interface the rest of the hardware and sensors of the payload.

The Nvidia Jetson TX1 is a supercomputer capable of delivering high performance and power efficiency needed for the latest visual computing applications with 256 Cuda Cores, delivering over 1 TeraFLOPs of performance. Moroever it implements a dual antenna WiFi module capable of long range (tested up to 200 metres with a connected Tablet).

These board can be a suitable candidate for EASY-PV payload to give additional information to the Pilot in real time during inspections, moving some more recognition logic inside the payload.

All boards supports Linux OS and OpenCV (a popular Computer Vision software library for image processing).

Sensors such as barometer and accelerometer can be acquired and mounted on a dedicated PCB and piloted over a I2C bus, however very powerful and affordable development boards which integrate all inertial and barometric sensors are already available on the market and can be used in order to develop a first prototype. ArduPilotMega is a popular project based on a Atmel ATMega2560 chip (Arduino) that can be used to acquire attitude, angular rotations and pressure data.

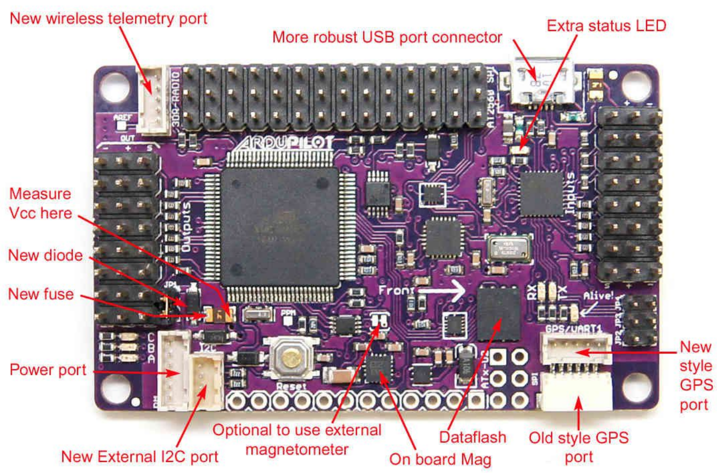


Figure 5-12- ArduPilotMega Development Board

The thermal camera (and eventually the optical camera) shall be placed on a dedicated gimbal. The gimbal mechanics will be implemented with a custom design in case of both cameras on the same gimbal or with a COTS (if any), therefore some mechanical design (2D printed) may be needed in order to create the suitable mechanical interfaces for the gimbal.

A 2 or 3 degrees' gimbal can be implemented with different COTS platforms available. The Yaw axis is useless for EASY-PV application since the yaw axis is in-built with drone longitudinal axis (X axis in Body-Frame reference), however a third axis could be considered for other applications.

In Figure 5-13 are reported two 32 bit boards available implementing the gimbal motors control (YAW, PITCH and ROLL) with a final angular resolution up to 0.01°.

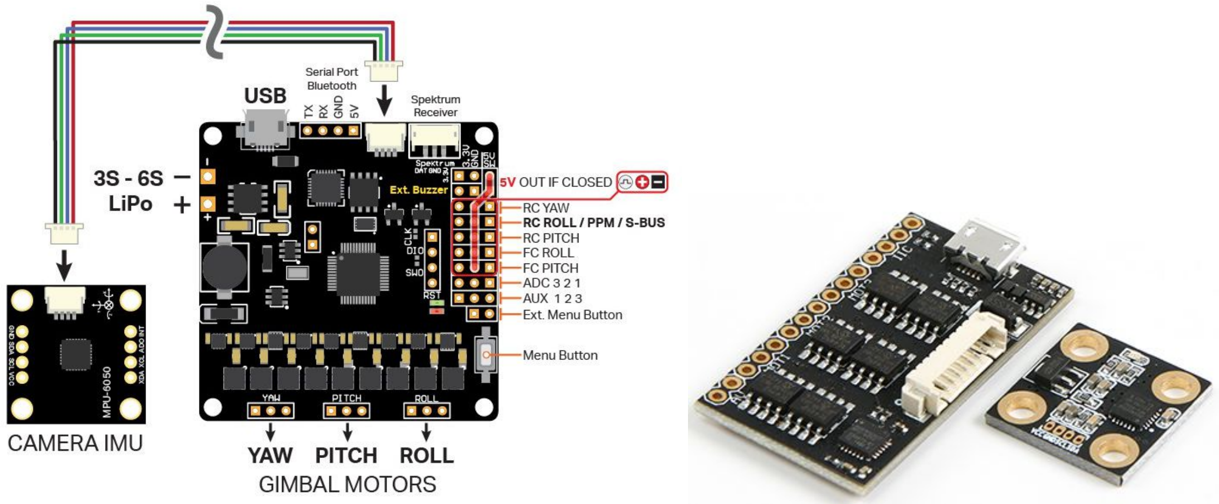


Figure 5-13- ALEXMOS and STORM32 board for gimbal motors control

The main sensor to be installed on the gimbal is represented by the thermal camera. Two candidate models of camera have been selected, both capable of 336×256 or 640×512 pixels resolutions and 14 bit pixel depth.

Figure 5-14- FLIR VuePro and FLIR TAU2

The final camera shall be defined considering different aspects such as radiometric capabilities, price, resolution, HW interface and supported protocols, typology of final link towards pilot (analogic or digital).

In fact the thermal video link to the pilot for feedback can be implemented in FM over a broadcast unencrypted transmission (e.g. 5.8 GHz analogic link) or over an encrypted digital channel (e.g. 5.8 GHz WiFi or other digital protocols)

The high accuracy GNSS receiver considered at this stage of the program is represented by the Ublox M8P chipset (available on a development board) implementing the concept of Rover in RTK technology.

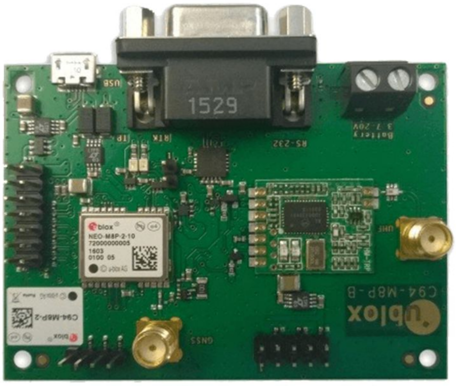


Figure 5-15- UBlox M8P Development Board

The development board offer also a 433 MHz radio link for a point to point Rover – Base connection.

5.1.2.3 RGS

The RGS, which also includes the Remote pilot station (RPS) needed to pilot the RPAS, is composed by:

- **Main CPU:** with a sufficient number GPUs able to perform demanding graphical operations. In a first instance the Development board Jetson Tx1 (256 GPU Cuda cores) based on Nvidia Tegra processor has been selected. This module will be the target hardware platform for the implementation of the main SW application needed in Easy-PV RPAS S/S. The main software modules within the Main CPU Unit are:
    - **Computer vision algorithm:** After each RPAS mission the thermal and optical videos stored on RPAS payload will be given in input to this module (off-line). The output will be a series of thermal and optical images covering the whole PV plant. The PV Panels with thermal anomalies (based on a database classification) will be tagged with visual aids by SW augmented by accuracy GNSS information. The SW shall be able to assign the geographical coordinates of the centre of each PV Panel recognized on the video frame from the ancillary information provided and assign 1 unique identifier to each PV Panel (Panels count). Moreover, false positive shall be discarded. The computer vision algorithm can be also implemented over a distributed architecture, moving some recognition capabilities on-board.

  - **Pilot Video Feedback:** acts as a real time video feedback to the RPAS remote pilot, implementing also some coverage features. The data provided by this module are precious information to the pilot to have a real time feedback of Panels irradiation and an estimation of the area covered directly on field of operations. This module uses both ancillary data provided by AUX Channel (NAVCOM, Attitude, RPAS height,…) and Computer Vision Algorithm information such as PV panels count. The output of this module can be displayed to the pilot on a dedicated Tablet/smartphone app.
  - **Service centre gateway:** It is responsible for the generation of all the application and transport layers towards service centre, according to the defined protocol (e.g. FTP / XML). It also handles clearance from the Service Centre for the fulfilment of each mission.
- **GNSS RTK: Master** It is the RTK Base Station connected to the main CPU of RGS actually implemented by a private RTK GNSS multi-constellation as identified in D3.1 “GNSS high accuracy algorithms and techniques for Energy domain”. The data from this module are transmitted in real time towards the RPAS payload by means of dedicated radio-modem implementing a serial end-to-end link.
- **RadioModem**: Used for receiving the real time ancillary data (AUX channel - NAVCOM data, attitude, etc..) that will be used by the pilot for coverage module.

The Specification design of RPAS and RGS subsystems with the relevant communication links shall be provided in the relative RPAS Work Package.

5.1.2.4 Deployment constraints

The Easy-PV primary solution is based on a custom payload to be installed on a suitable RPAS, controlled by a dedicated Ground Station (RGS). The user of this solution will be the large community of registered RPAS remote pilots and aerial operators widely spread over the area of operations, as well as new professionals attracted by new business opportunities.

It is very likely that such community already have a registered RPAS, therefore the only constraints applicable (apart from RPAS airworthiness and related “permit to fly”) will be related to the compliance of RPAS to payload’s weights, form factor and other physical constraints. The payload therefore shall be designed which such constraints in mind and a target class of RPAS platforms described in §5.1.2.1

The payload will include an independent GNSS Receiver RTK enabled more precise and accurate compared to the embedded RPAS GNSS receiver used for navigation, guidance and control purposes. It will be selected according to the analysis performed in [RD 2]

The Payload will be completely independent from the RPAS platform; this is basically considered in order to leave to the pilot the possibility to use his/her own drone in combination with Easy-PV payload and RGS.

The Easy-PV payload will be easily detachable and could be integrated in different RPAS platform according to some minor requirements.

5.1.2.4.1 Power Consumption

The power consumption of the RPAS payload is based on the preliminary design provided and the COTS envisaged. A more detailed current drains for each unit will be specified in the next phases, however a typical power consumption of 10 W for the whole payload is considered at this stage with a dedicated embedded LiPo/LiFe battery. This consumption may significantly increase considering some images recognition on board.

The battery capacity shall be traded off in order to keep the payload weight as low as possible and, on the other hand, to ensure to the pilot sufficient time for RPAS operations without the necessity to change battery on field.

Power safe design can be also considered (if required) instead of switching off the payload after each flight session.

Power safe mode for GNSS receiver (lower performance) will be considered only during standby operations (no-fly)

RPAS power bus interface can be also considered.

5.1.2.4.2 Dimensions

The RPAS payload form factor shall not exceed 150x150x100 mm3; this preliminary form factor fits with most commercial drones in the range 3 Kg – 10 Kg of MTOW. Some Constraints may be superimposed by COTS form factors.

The Payload shall be designed with a solid and compact shape, however some constraints to the GNSS antenna shall be applied in order to minimize possible EM interference (e.g. moving the antenna as much as possible from high interferences sources such as RPAS battery cables and motors) with RPAS avionics.

The payload shall be able also to dump vibrations (e.g. rubber dumpers for high frequencies vibrations and mechanical correction for accurate Nadiral view).

The Dimension of GNSS receiver do not represent any criticalities in the overall form factor constraints of payload (OEM – commercial COTS are considered at this stage).

5.1.2.4.3 Weight

The RPAS Payload shall not exceed 1 Kg weight (0,700 Kg - nice to have) and shall be designed with one button operations in order to start/stop the acquisition phase before the RPAS flight and minimize the effort to the pilot.

The impact of GNSS avionics (considering also its harness) is small when compared to the main items concurring in the overall weight budget:

- TIR Sensor

- Gimbal Mechanism
- Battery
- Case
- OBC main board

5.2 EASY PV INTERFACES

5.2.1 INTERNAL I/FS

5.2.1.1 VTE-100-001

Item Flow Id	VTE-100-001
Item Flow Name	IFILE_ModuleAlarm
Implemented by	VTE
Used by	PMS
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	SERVICE CENTER
Data Destination component	VTE
Description	This interface is used from SERVICE CENTER::PMS to send alarms of unhealthy modules discovered during mission.
Methods	unhealthyModuleAlarms()

5.2.1.2 VTE-200-001

Item Flow Id	VTE-200-001
Item Flow Name	IDB_VteDataAccess
Implemented by	VTE
Used by	PMS
Data Source	SERVICE CENTER
Data Source component	VTE
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	This interface manages the flow from SERVICE CENTER::VTE to SERVICE CENTER::PMS to get the plant production data necessary to PMS to make and deliver the report.
Methods	SendProductionData()

5.2.1.3 PMS-100-001

Item Flow Id	PMS-100-001
Item Flow Name	IFILE_PFControl
Implemented by	PMS
Used by	PM
Data Source	SERVICE CENTER
Data Source component	PM
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	This interface is used from Production Manager to request to Payload Manager to execute a production (processing, formatting) on archived product and to monitor the status of the production. The interface is based on file (xml).
Methods	StartProcessing() StopProcessing() GetStatus()

5.2.1.4 PMS-200-001

Item Flow Id	PMS-200-001
Item Flow Name	IFTP_PanelGeoreferencingCenterData
Implemented by	PMS
Used by	RGS
Data Source	RGS or SERVICE CENTRE
Data Source component	RGS or PMS
Data Destination	SERVICE CENTER or RGS
Data Destination component	PMS or RGS
Description	This interface manages the flow from/to Service Center to/from RGS in order to: – provide to Service Center the 2D position (lat, lon) of each plant panel. This is used during first mission in order to centrally georeferenced each panel.

	– provide to RGS the 2D position (lat, lon) of each plant panel. This is used before executing a real mission in order to transfer to the RPAS subsystem (RGS) the georeferencing info about the plant actually to be monitored. It is based on ftp mechanism (FTP server architecturally assigned to Service Center::Payload Manager System). Note: 2D position of defective panel (center) is evaluated by RPAS subsystem, whereas the Service Centre associates this position to a coded panel and allow historical comparisons with other maintenance campaigns.
Methods	Send2DPanelCenter() Get2DPanelCenter()

5.2.1.5 PM-100-001

Item Flow Id	PM-100-001
Item Flow Name	IFILE_ProcessedData
Implemented by	PM
Used by	PMS
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	SERVICE CENTER
Data Destination component	PM
Description	This interface is used from Payload Manager to catalog a product after a production. The interface is based on file (Product + XML Metadata).
Methods	CatalogueProduct()

5.2.1.6 PM-200-001

Item Flow Id	PM-200-001
Item Flow Name	IFTP_PayloadData
Implemented by	PM
Used by	RGS

Data Source	RGS
Data Source component	RGS
Data Destination	SERVICE CENTER
Data Destination component	PM
Description	This interface manages the flow from RPAS Ground Segment to Service Center of all data coming from a mission of a plant. It is based on ftp mechanism (FTP server architecturally assigned to Service Center::Production Manager). The flow consists of the following data type: – 1 XML file containing support data – 1 ASCII formatted file containing the trajectory attitude – n Optical images files coming from optical camera on payload – n Thermal images files coming from thermal camera on payload – 1 Video
Methods	SendMissionSupportData() SendTrajectoryFligth() SendOpticalImages() SendIRImages() SendVideo()

5.2.1.7 RPASPAYLOAD-100-001

Item Flow Id	RPASPAYLOAD-100-001
Item Flow Name	IRF_PayloadControl
Implemented by	RPAS PAYLOAD
Used by	RGS
Data Source	RGS
Data Source component	RGS
Data Destination	RPAS
Data Destination component	RPAS PAYLOAD

Description	This represents the request to RPAS::PAYLOAD coming from RGS to start and stop the data acquisition. It is implemented on a Radio Frequency systems.
Methods	StartAcquisition() StopAcquisition()

5.2.1.8 RGS-100-001

Item Flow Id	RGS-100-001
Item Flow Name	IRF_PayloadData
Implemented by	RGS
Used by	RPAS PAYLOAD
Data Source	RPAS
Data Source component	RPAS PAYLOAD
Data Destination	RGS
Data Destination component	RGS
Description	This interface manages the flow from RPAS::PAYLOAD to RGS of all data coming from a mission of a plant. It is implemented on a Radio Frequency systems. The flow consists of the following data type: – 1 XML file containing support data- – 1 ASCII formatted file containing the trajectory attitude – n Optical images files coming from optical camera on payload – n Thermal images files coming from thermal camera on payload – 1 Video
Methods	SendPayloadMissionSupportData() SendPayloadTrajectoryFligth() SendPayloadOpticalImages() SendPayloadIRImages() SendPayloadVideo()

5.2.1.9 RGS-100-001

Item Flow Id	RGS-100-001
Item Flow Name	IRF_RTCMCorrectionData
Implemented by	RGS
Used by	RPAS PLATFORM
Data Source	RGS
Data Source component	RGS
Data Destination	RPAS
Data Destination component	RPAS PLATFORM
Description	Radio Frequency Interface to send RTCM Correction data to RPAS::DRONE from RGS.
Methods	GetRTCMCorrectionData()

5.2.2 EXTERNAL I/FS

5.2.2.1 EPV-0100-001

Item Flow Id	EPV-0100-001
Item Flow Name	IEMAIL_PlantData
Implemented by	PMS
Used by	Plant POC
Data Source	Plant POC
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	This interface manages the flow from Plant POC to submit all data (Plant and POC availability) to Service Center. All this information are preparatory to implement a mission Plan. The flow is based on email.
Methods	SendPlantData() SendPOCAvailabilityCalendar() SendPOCContactInformation()

5.2.2.2 EPV-0200-001

Item Flow Id	EPV-0200-001
Item Flow Name	IEMAIL_RPASPilotData
Implemented by	RPAS remote pilot
Used by	PMS
Data Source	RPAS remote pilot
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	This interface manages the flow from RPAS remote pilot to submit contact information data and availability to Service Center. All this information is preparatory to implement a mission Plan. The flow is based on email.

Methods	SendPilotAvailabilityCalendar() SendRPASPilotContactInformation()

5.2.2.3 EPV-0300-001

Item Flow Id	EPV-0300-001
Item Flow Name	IEMAIL_Report
Implemented by	Plant POC
Used by	PMS
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	Plant POC
Data Destination component	
Description	This interface interface manages the flow from Service Center to Plant POC containing the final mission report. The flow is based on email with file (or files) in attach containing all relevant mission information.
Methods	SendAnalysisReport()

5.2.2.4 EPV-0400-001

Item Flow Id	EPV-0400-001
Item Flow Name	IFSIS
Implemented by	GNSS SIGNAL
Used by	RGS
Data Source	GNSS SIGNAL
Data Source component	
Data Destination	RGS
Data Destination component	
Description	This represents the GNSS Signal In Space received at Ground Segment Level. The SIS is received from a receiver sited on RGS.
Methods	GetGNSSsignal()

5.2.2.5 EPV-0400-002

Item Flow Id	EPV-0400-002

Item Flow Name	IFSIS
Implemented by	GNSS SIGNAL
Used by	RPAS PLATFORM
Data Source	GNSS SIGNAL
Data Source component	
Data Destination	RPAS
Data Destination component	RPAS PLATFORM
Description	This represents the GNSS Signal In Space received at RPAS Segment Level. The SIS is received from a receiver sited on RPAS PLATFORM.
Methods	GetGNSSsignal()

5.2.2.6 EPV-0500-001

Item Flow Id	EPV-0500-001
Item Flow Name	IGUI_PayloadControl
Implemented by	RGS
Used by	RPAS remote pilot
Data Source	RPAS remote pilot
Data Source component	
Data Destination	RGS
Data Destination component	
Description	This represent the request to RGS coming from RPAS remote pilot to start and stop the data acquisition. It is implemented on a dedicated GUI on RGS.
Methods	StartAcquisition() StopAcquisition()

5.2.2.7 EPV-0600-001

Item Flow Id	EPV-0600-001
Item Flow Name	IGUI_PlantCoverage
Implemented by	RGS
Used by	RPAS remote pilot

Data Source	RPAS remote pilot
Data Source component	
Data Destination	RGS
Data Destination component	
Description	This represents the information shown on RGS GUI for RPAS remote pilot to see the coverage mission Status . It is implemented on a dedicated GUI on RGS.
Methods	GetPlantCoverageStatus()

5.2.2.8 EPV-0700-001

Item Flow Id	EPV-0700-001
Item Flow Name	IRF_RPASControl
Implemented by	RPAS PLATFORM
Used by	RPAS remote pilot
Data Source	RPAS remote pilot
Data Source component	
Data Destination	RPAS
Data Destination component	RPAS PLATFORM
Description	Radio Frequency Interface to send command to RPAS::DRONE from RPAS remote pilot.
Methods	RPASCommandAndControl()

5.2.2.9 EPV-0800-001

Item Flow Id	EPV-0800-001
Item Flow Name	IRS485_DataAcquisition
Implemented by	PVPlant
Used by	PMS
Data Source	PVPlant
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS

Description	This interface manages the flow from PVPlant to SERVICE CENTER::VTE (Visual Track Energy) containing: - production data of PV Plant - alarms all PvPlant data It is implemented on communication standard RS485.
Methods	GetFieldData()

5.2.2.10 EPV-0900-001

Item Flow Id	EPV-0900-001
Item Flow Name	IWUI_DataView
Implemented by	PMS
Used by	Plant POC
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	Plant POC
Data Destination component	
Description	Web User Interface provided from SERVICE CENTER::PMS to Plant POC to see Plant data: - Plant data - POC contact information - POC calendar.
Methods	SearchAndViewData()

5.2.2.11 EPV-1000-001

Item Flow Id	EPV-1000-001
Item Flow Name	IWUI_MissionData
Implemented by	PMS
Used by	Sevice Center Operator
Data Source	Sevice Center Operator
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS

Description	Web User Interface provided from SERVICE CENTER::PMS to SCO to prepare (validate mission plan, resolve conflict) and configure mission data.
Methods	ConfigureMission()

5.2.2.12 EPV-1100-001

Item Flow Id	EPV-1100-001
Item Flow Name	IWUI_MissionPlan
Implemented by	PMS
Used by	Plant POC
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	Plant POC
Data Destination component	
Description	Web User Interface provided from SERVICE CENTER::PMS to Plant POC to view Mission Plan.
Methods	GetMissionPlan()

5.2.2.13 EPV-1100-002

Item Flow Id	EPV-1100-002
Item Flow Name	IWUI_MissionPlan
Implemented by	PMS
Used by	RPAS remote pilot
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	RPAS remote pilot
Data Destination component	
Description	Web User Interface provided from SERVICE CENTER::PMS to RPAS remote pilot to view Mission Plan.
Methods	GetMissonPlan()

5.2.2.14 EPV-1200-001

Item Flow Id	EPV-1100-002
Item Flow Name	IWUI_MissionPlan
Implemented by	PMS
Used by	RPAS remote pilot
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	RPAS remote pilot
Data Destination component	
Description	Web User Interface provided from SERVICE CENTER::PMS to RPAS remote pilot to view Mission Plan.
Methods	GetMissonPlan()

5.2.2.15 EPV-1200-002

Item Flow Id	EPV-1200-002
Item Flow Name	IWUI_PlantData
Implemented by	PMS
Used by	Plant POC
Data Source	Plant POC
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	Web User Interface provided from SERVICE CENTER::PMS to Plant POC (Point of Contact) to upload: - Plant data - POC contact information - POC calendar.
Methods	LoadPlantData() LoadPOCAvailabilityCalendar() LoadPOCContactInformation()

5.2.2.16 EPV-1300-001

Item Flow Id	EPV-1300-001

Item Flow Name	IWUI_ProductsData
Implemented by	PMS
Used by	Thermografic Expert Operator
Data Source	Thermografic Expert Operator
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	This represent the User interface provided from Service Center::PMS to TEO (Thermografic Expert Operator) in order see the mission product, analyze product and generate the final report. It is implemented as Web User Interface.
Methods	ProcessProducts() GenerateReport() Sendreport() ViewReport()

5.2.2.17 EPV-1400-001

Item Flow Id	EPV-1400-001
Item Flow Name	IWUI_RPASPilotContactInformation
Implemented by	PMS
Used by	Service Center Operator
Data Source	Service Center Operator
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	Web User Interface provided from SERVICE CENTER::PMS to SCO (Service center Operator) to upload RPAS remote pilot contactinformation and calendar.
Methods	LoadRPASPilotContactInformation() LoadRPASPilotCalendar()

5.2.2.18 EPV-1400-002

Item Flow Id	EPV-1400-002

Item Flow Name	IWUI_RPASPilotContactInformation
Implemented by	PMS
Used by	RPAS remote pilot
Data Source	RPAS remote pilot
Data Source component	
Data Destination	SERVICE CENTER
Data Destination component	PMS
Description	Web User Interface provided from SERVICE CENTER::PMS to RPAS remote pilot to upload contact information and calendar.
Methods	LoadRPASPilotContactInformation() LoadRPASPilotCalendar()

5.2.2.19 EPV-1500-001

Item Flow Id	EPV-1500-001
Item Flow Name	IWUI_Report
Implemented by	PMS
Used by	Plant POC
Data Source	SERVICE CENTER
Data Source component	PMS
Data Destination	Plant POC
Data Destination component	
Description	Web User Interface provided from SERVICE CENTER::PMS to Plant POC to view and download report.
Methods	ViewReport() DownloadReport()

5.2.2.20 EPV-1600-001

Item Flow Id	EPV-1600-001
Item Flow Name	IWUI_VteViewData
Implemented by	VTE
Used by	Plant POC
Data Source	SERVICE CENTER
Data Source component	VTE

Data Destination	Plant POC
Data Destination component	
Description	Web User Interface provided from SERVICE CENTER::VTE to Plant POC to view synoptic, alarms, and production data.
Methods	ViewSynoptic() ViewAlarms() ViewProduction()

6 CONCLUSIONS

This document delivered for CDR milestone represents the final version of the Architecture Design. Even if a detailed architecture information has been already provided for PDR version, this final issue now includes the finalized design.

System requirements, which have been issued starting from the user needs as reported in section 3.2, have been confirmed and in particular SR.0280 (Final report) has been further clarified. A traceability matrix is also included to link in both directions System Requirements to the User Needs.

The EASY-PV functionalities are also completed. The only open point (which will not impact the designed architecture, but only the As-built deployment) refers to the choice of the equipment (i.e. GNSS receiver, thermal cameras, gimbal, etc) to be installed on board the RPAS and RGS. Details on this analysis are reported in AnnexD3.1 “End to end EASY-PV algorithm”, where an evaluation is performed to be confident to achieve SR.0210; RTK is confirmed as the more appropriate technique as reported in detail in [RD 2], where it is also identified a GNSS receiver (i.e. u-blox M8P) expected to be uploaded very soon (beginning 2017) with Galileo features.

Finally, the high level architecture of both the service center and the RPAS sub systems are clarified also including HW details: RPAS is in charge to effectively collect on field data to be sent to the service center which will provide a final automatic report ready to be dispatched to the final user in a very short time and including exhaustive information about the PV plant health status.

END OF DOCUMENT