



Giornata di studio

**Potenzialità e prospettive del rilievo
fotogrammetrico aereo di prossimità
con l'utilizzo di droni:
applicazioni nel campo ambientale
e dei beni culturali**

Palermo, 22 novembre 2013

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Michele Mangiameli ²

Luca Trefiletti ²

Il progetto M.A.R.TE.

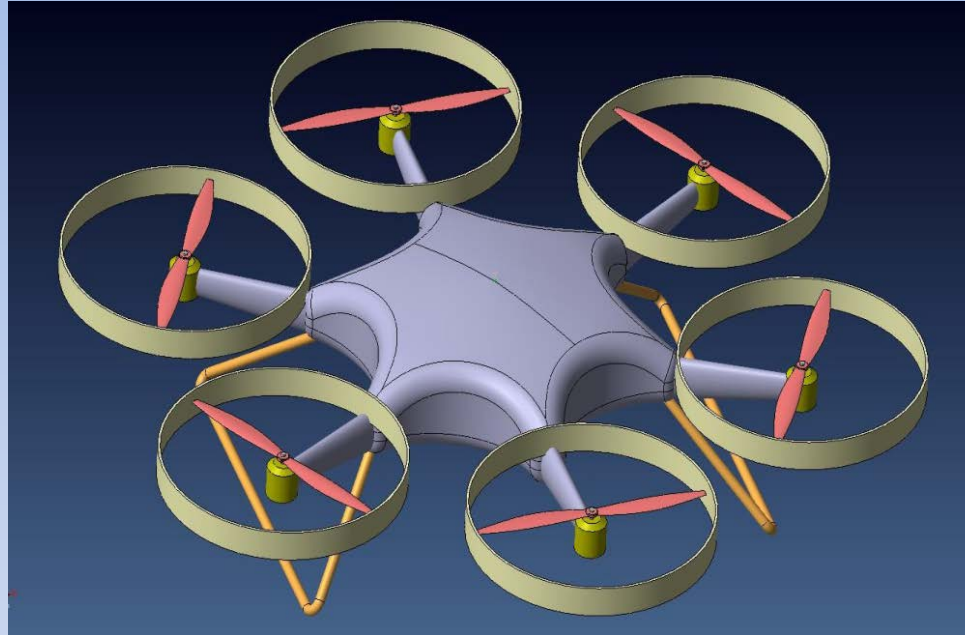
**Mezzo Aereo per il Rilevamento
del Territorio**

¹ Università degli Studi di Catania - ² Libera Università KORE di Enna

Progetto M.A.R.TE.

Mezzo Aereo per il Rilevamento del TErritorio

(Linea di intervento 4.1.1.1 del POR FESR Sicilia 2007-2013)



PARTNER

- **Servizi Tecnologie Management STM S.r.l.**, PMI, Impresa Capofila
- **Sirio Telematica di D'Urso Gaetano e C. SAS**, PMI
- **GGG Elettromeccanica S.r.l.**, PMI
- **Libera Università degli Studi di Enna "Kore"**, Organismo di Ricerca

CONSULENTI

- **Prof. Ing. Giuseppe Mussumeci**, coordinamento scientifico del progetto
- **C.F.M. AIR s.r.l.**, affiancamento nella progettazione strutturale del velivolo
- **Etnamatica** (Spin off Università di Catania), sistema GNSS/IMU di precisione

... un punto di partenza.....

Swiss UAV

... un esempio di UAV evoluto per il rilevamento ambientale e del territorio



VTOL UAV systems





ALREADY INTEGRATED SENSORS:

LIDAR:	RIEGL VQ 480
SENSOR Suite	ESG IMA ³
SAR:	Fraunhofer FKIE SUMATRA
Sense & Avoid:	SPIESS Laser detector
EO/IR:	UAVVision CM160, CM100, IAI POP family, FLIR Cobalt 190, FLIR TALON, DST Series, WESCAM MX10
Chemical Sensor:	Bruker μ RAID



Swiss UAV AG



2008

Turbine	8 kW	Airspeed	0 - 75 km/h
Payload	8 kg	Service ceiling	up to 1,500m ASL
MTOW	45 kg	Endurance	1.5 h
Rotary system	coaxial three blade	Mission radius	25 km
Rotor Ø	2.4 m	Fuel	F34, F44, F54

2009

Turbine	12 kW	Airspeed	0 - 120 km/h
Payload	20 kg	Service ceiling	up to 2.500m ASL
MTOW	95 kg	Endurance	2 h
Rotary system	three blade	Mission radius	40 km
Rotor Ø	3.0 m	Fuel	F34, F44, F54

2010/12

Turbine	30 kW	Airspeed	0 - 120 km/h
Payload	30 kg	Service ceiling	up to 4.500m ASL
MTOW	125 kg	Endurance	4.5 h
Rotary system	three blade	Mission radius	100 km
Rotor Ø	3.5 m	Fuel	F34, F44, F54



Sviluppo e validazione di un sistema di rilevamento aereo

costituito da un **prototipo di UAV** progettato e realizzato

per l'acquisizione di dati territoriali e ambientali

e da una **piattaforma Hw/Sw** appositamente sviluppata per la
gestione del volo e dei dati acquisiti dai sensori a bordo

DESTINATO AL MERCATO DELLA
STRUMENTAZIONE DI INTERESSE
DEI PROFESSIONISTI



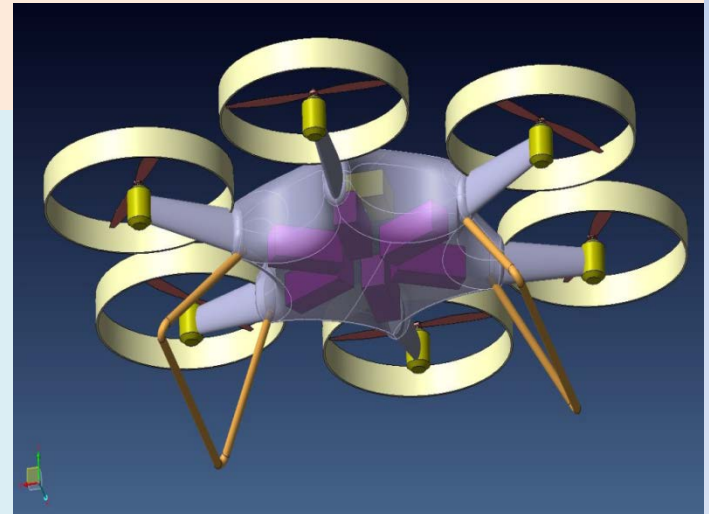
Performante
Maneggevole
Basso costo

Requisiti del velivolo:

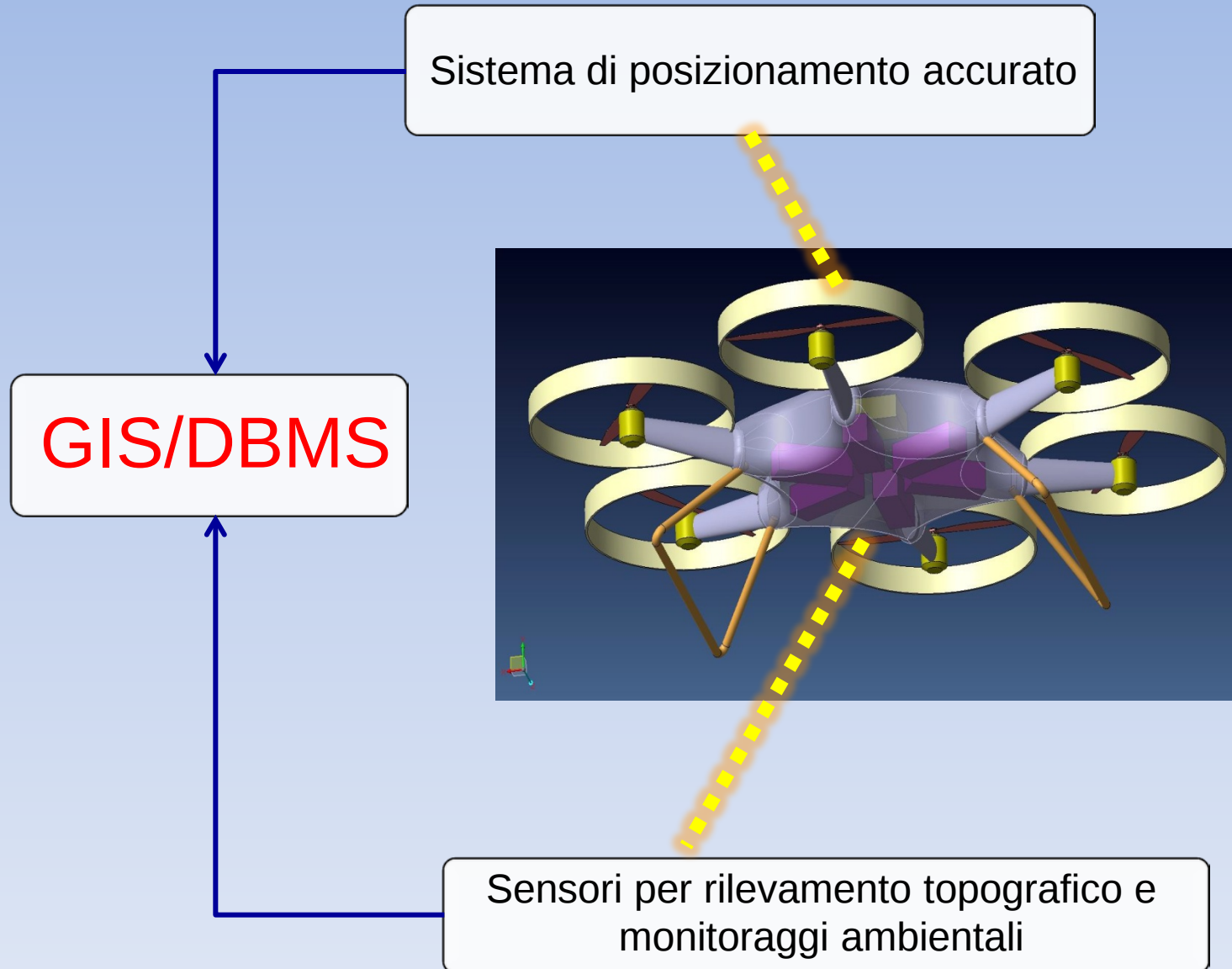
- peso massimo: $\leq 20 \text{ Kg}$ (mini UAV)
- carico utile: $\approx 4 \text{ Kg}^*$
- autonomia di volo: $\geq 20 \text{ minuti}$
- elevata stabilità di posizione e assetto
- manovrabilità
- possibilità di volo autonomo

Tipologie di sensori:

- scanner laser
- fotocamera
- termocamera
- camera multi e iper-spetttrale
- telecamera



Obiettivi del progetto



Il progetto del velivolo

SISTEMA PROPULSIVO

Sistema Propulsivo

Motori elettrici brushless

Eliche

Batterie LiPo



Payload

Autonomia di volo

Il progetto del velivolo

SISTEMA PROPULSIVO



Dualsky



Eflite



Scorpion



APC 16x10E



APC 18x10E



TP 5000 mAh 6s



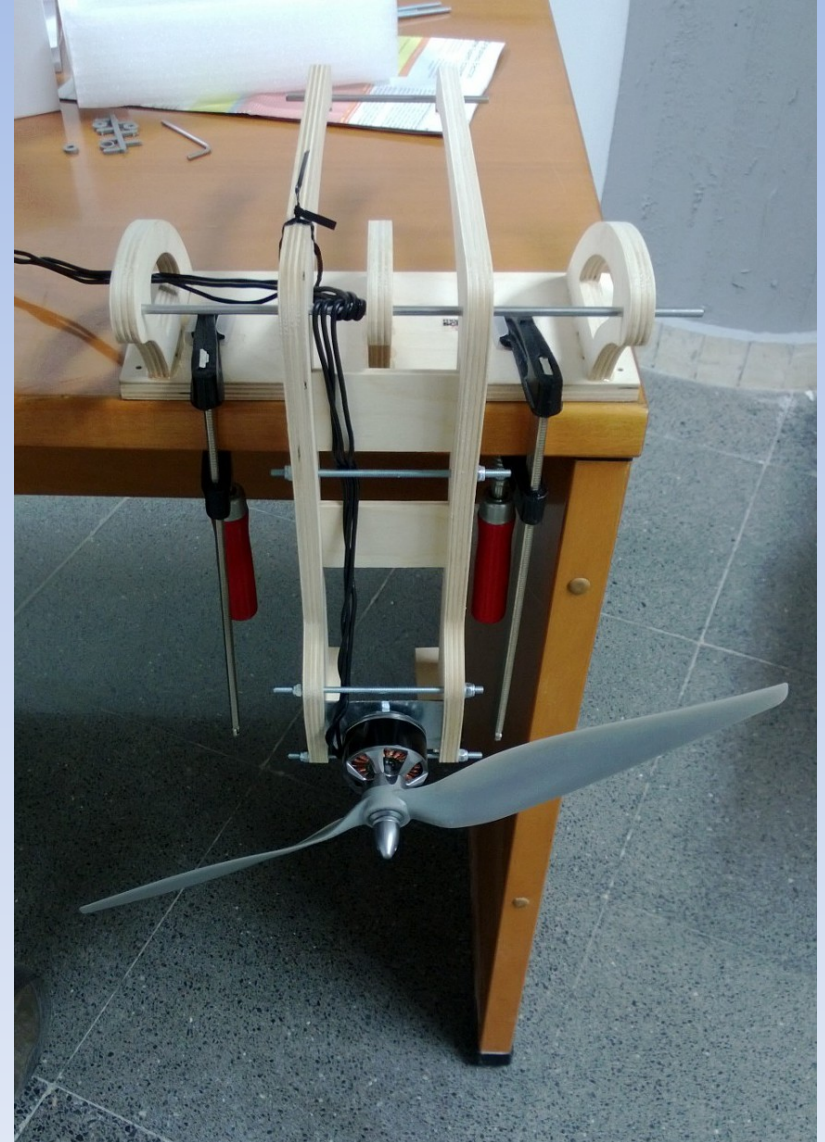
TP 6000 mAh 6s



Turnigy 8000 mAh 6s

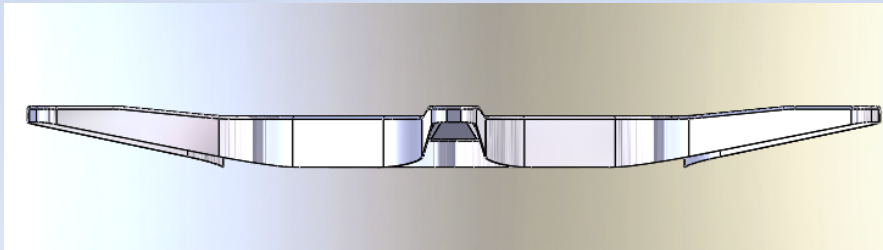
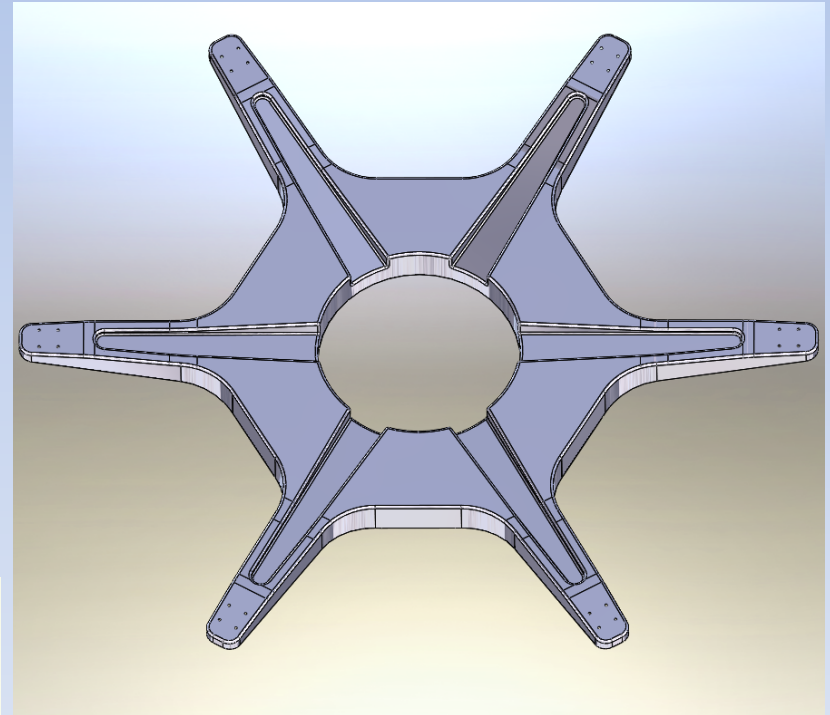
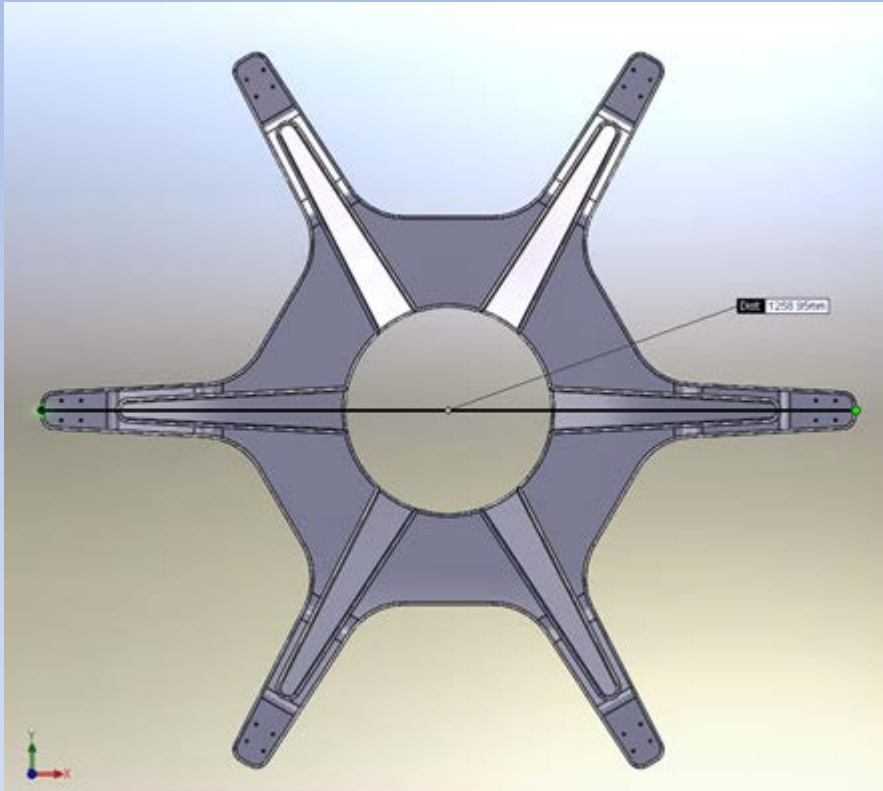
Il progetto del velivolo

SISTEMA PROPULSIVO



Il progetto del velivolo

MODELLO CAD



Il progetto del velivolo

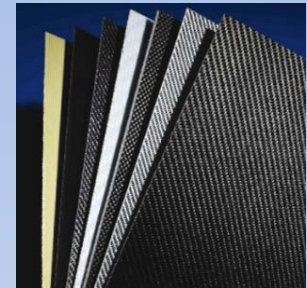
MATERIALI



Tessuto e filo in carbonio



Resina Epoxy e
induritore



Ply /Lamina

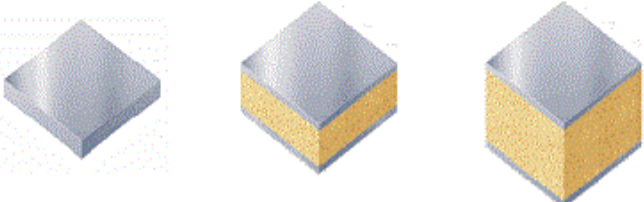


Schiuma



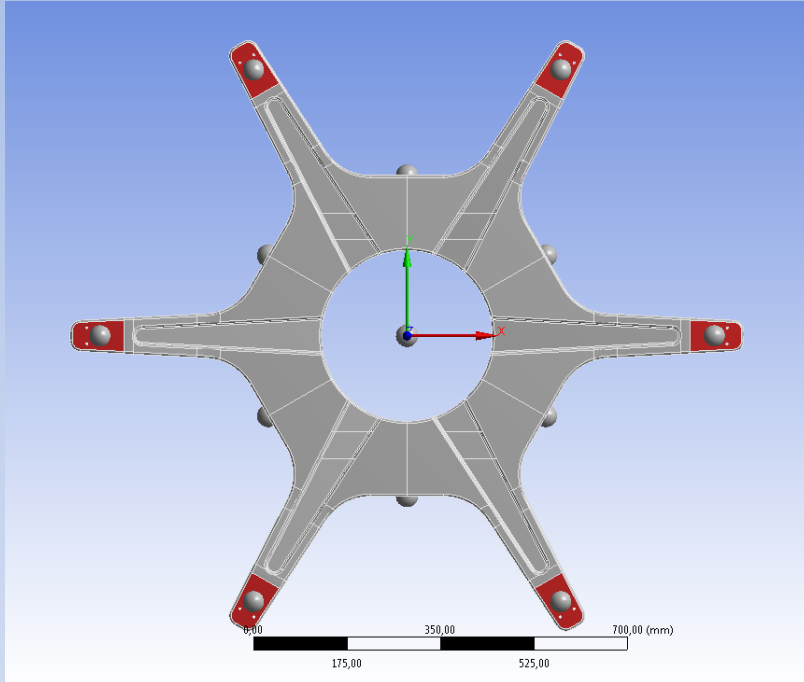
Sandwich

<u>Single Skin - t</u>	<u>Sandwich - 2t</u>	<u>Sandwich - 4t</u>
Weight: 1	Weight: 1	Weight: 1
Strength: 1	Strength: 6	Strength: 6
Stiffness: 1	Stiffness: 12	Stiffness: 48



Il progetto del velivolo

GEOMETRIA E MASSE

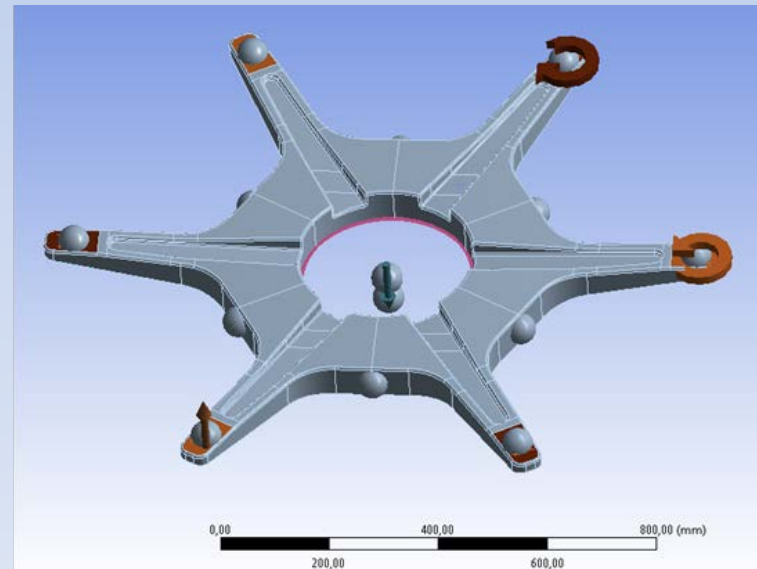


Carichi agenti:

- Campo gravitazionale (su masse)
- Spinte dei motori
- Momenti di reazione dei motori

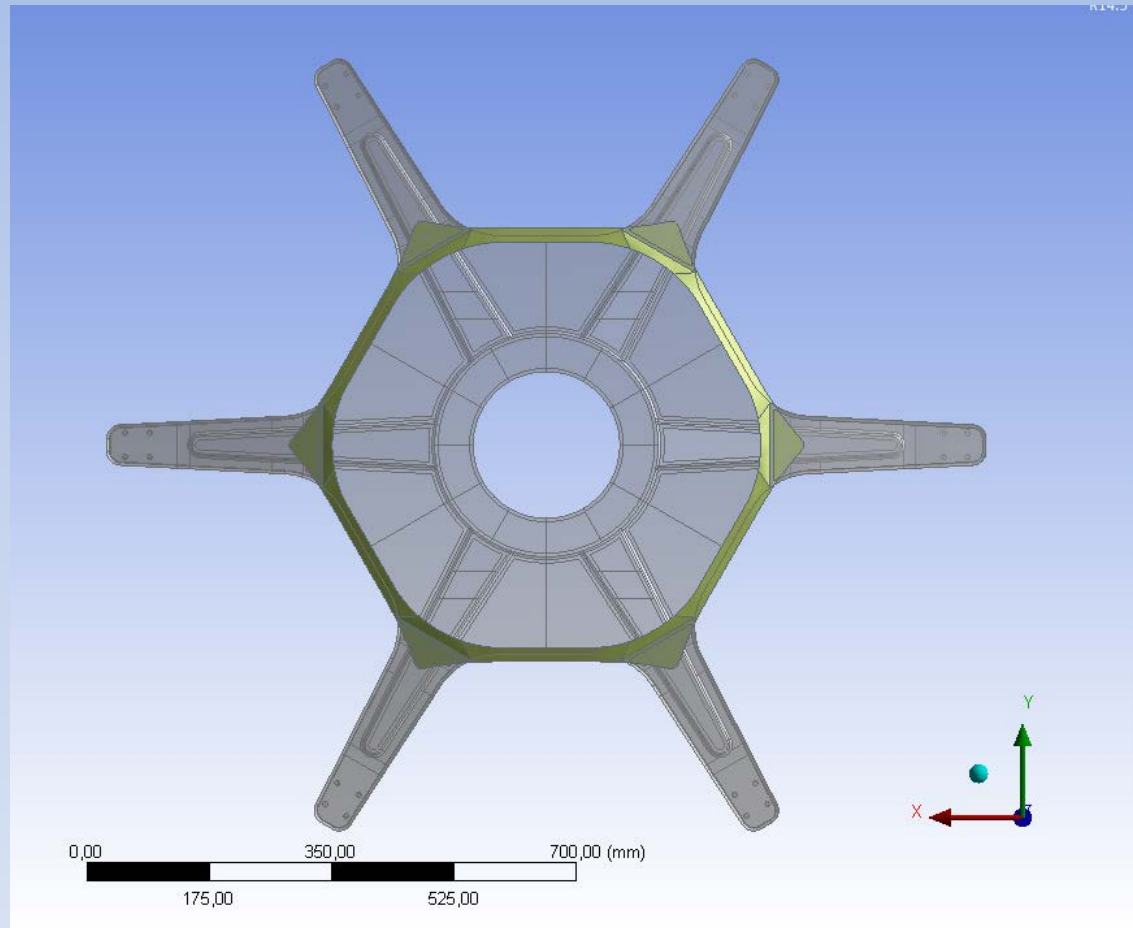
Posizionamento delle masse :

- Motori
- Batterie
- Sistemi Elettronici
- Payload



Il progetto del velivolo

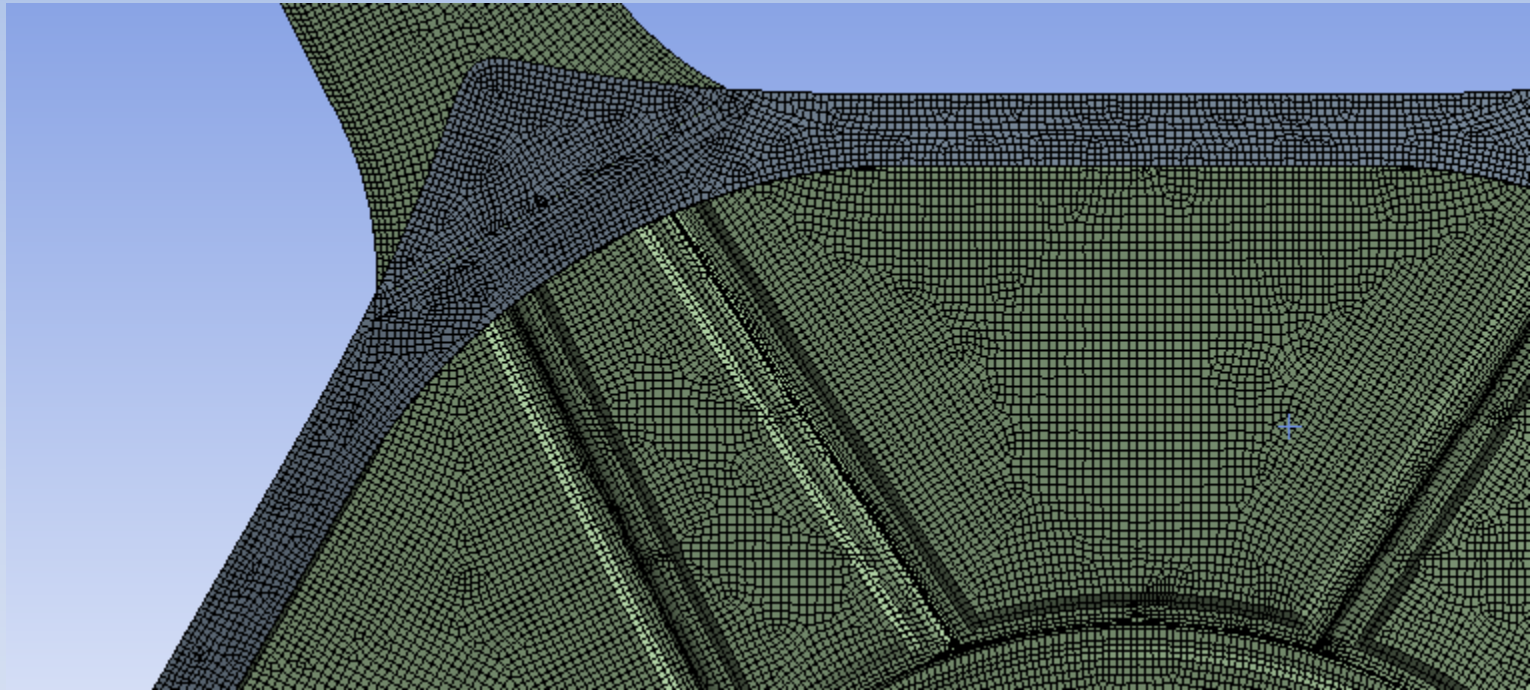
GEOMETRIA E MASSE



Modello con anello di rinforzo inferiore

Il progetto del velivolo

ANALISI STRUTTURALE

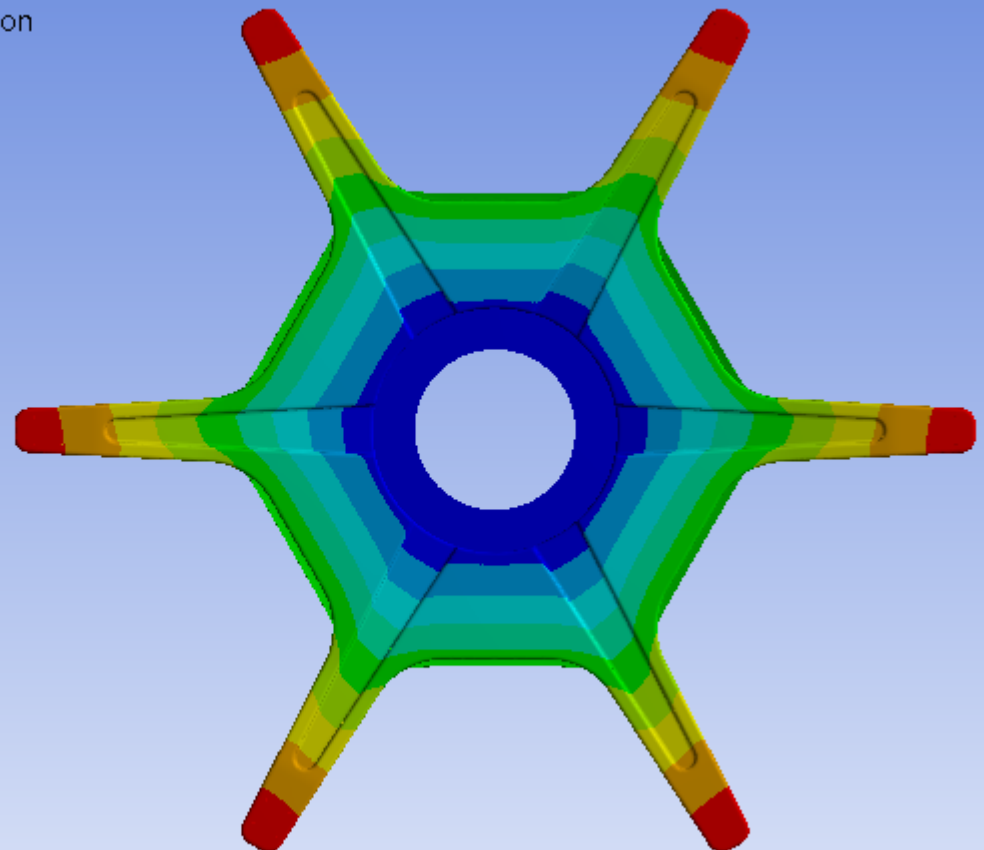
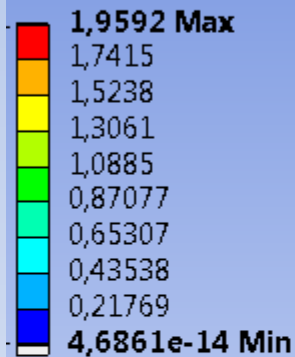


Analisi FEM: modello con anello di rinforzo inferiore (UniKore)

Il progetto del velivolo

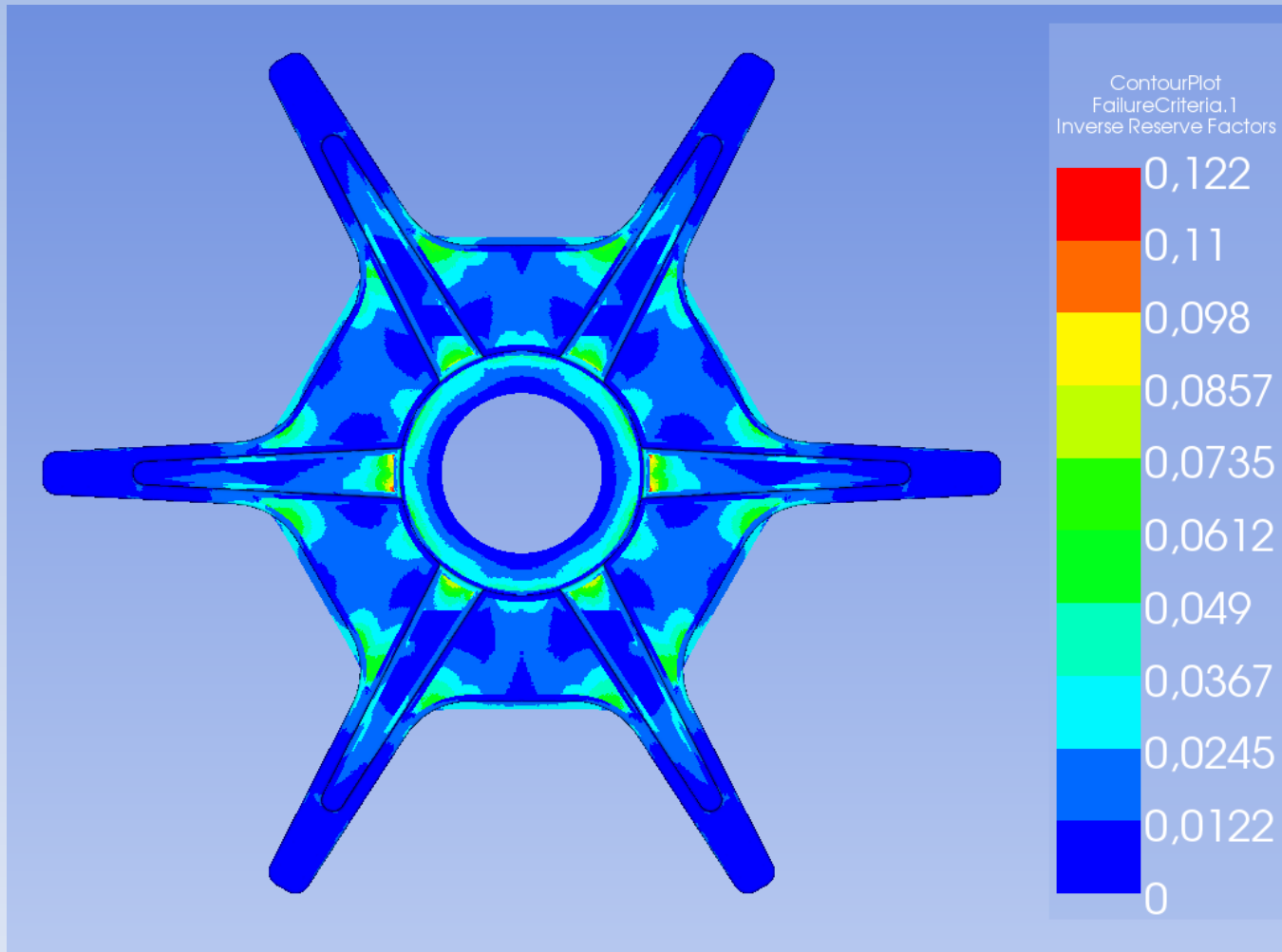
ANALISI DELLE DEFORMAZIONI

C: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
17/11/2013 21:00

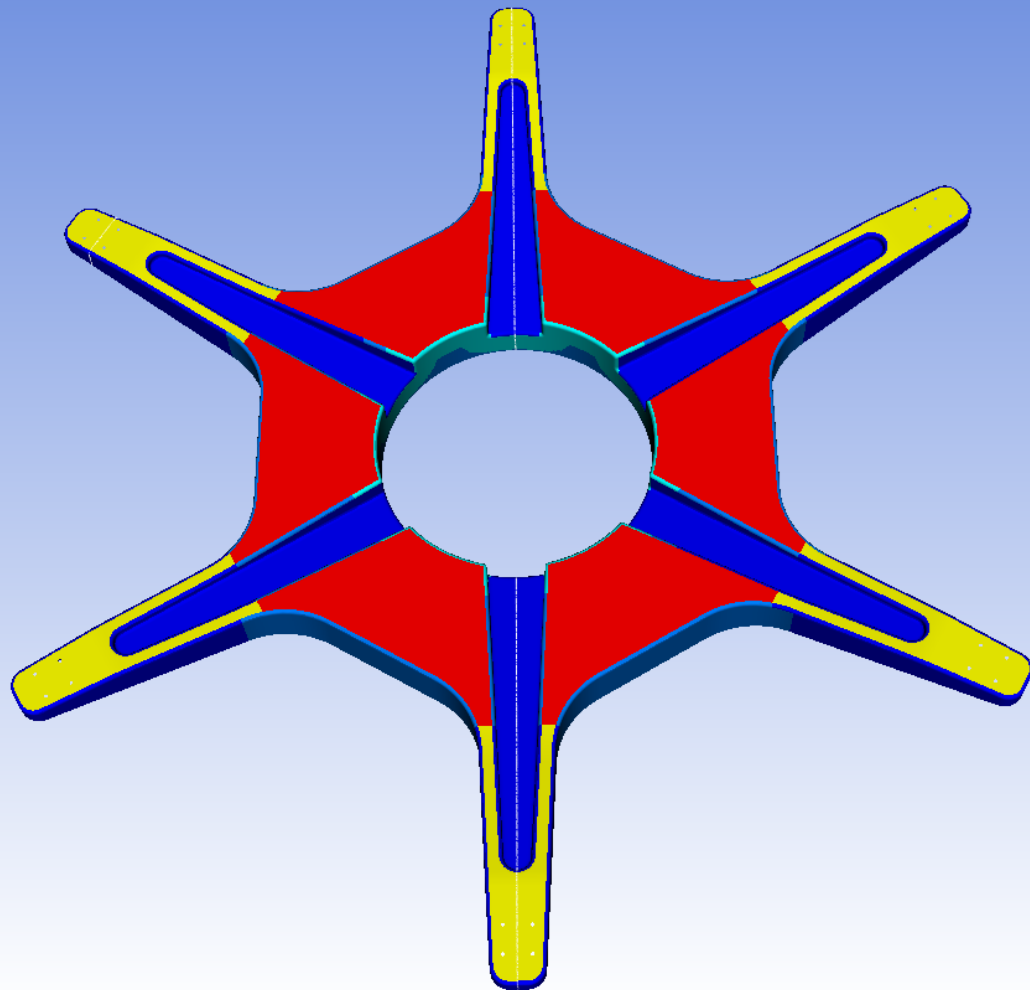


Il progetto del velivolo

INDICE DI ROTTURA



Failure Criteria: Inverse Reserve Factor (<1)

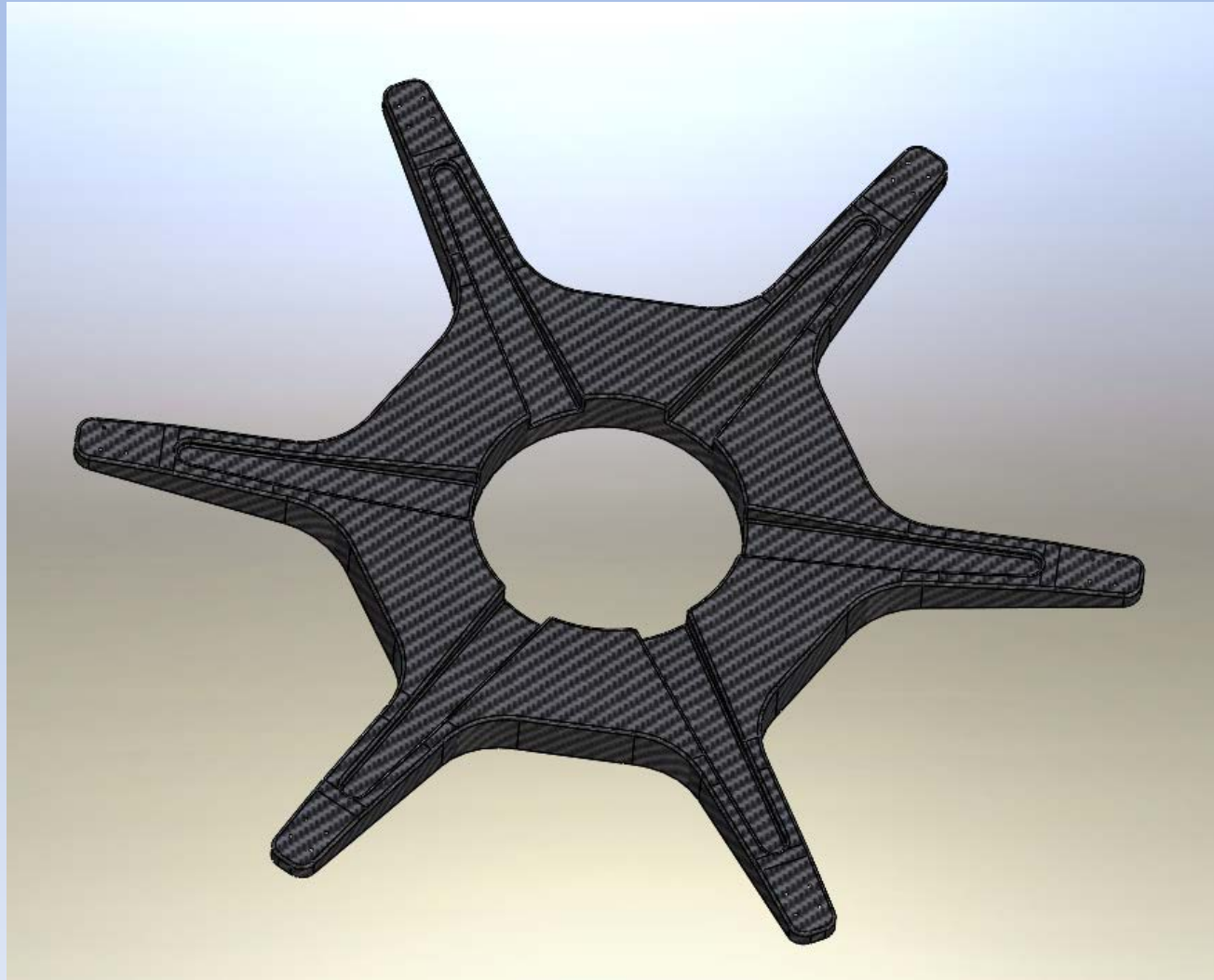


ContourPlot
Thickness



Il progetto del velivolo

RENDERING COMPONENTE FINITO

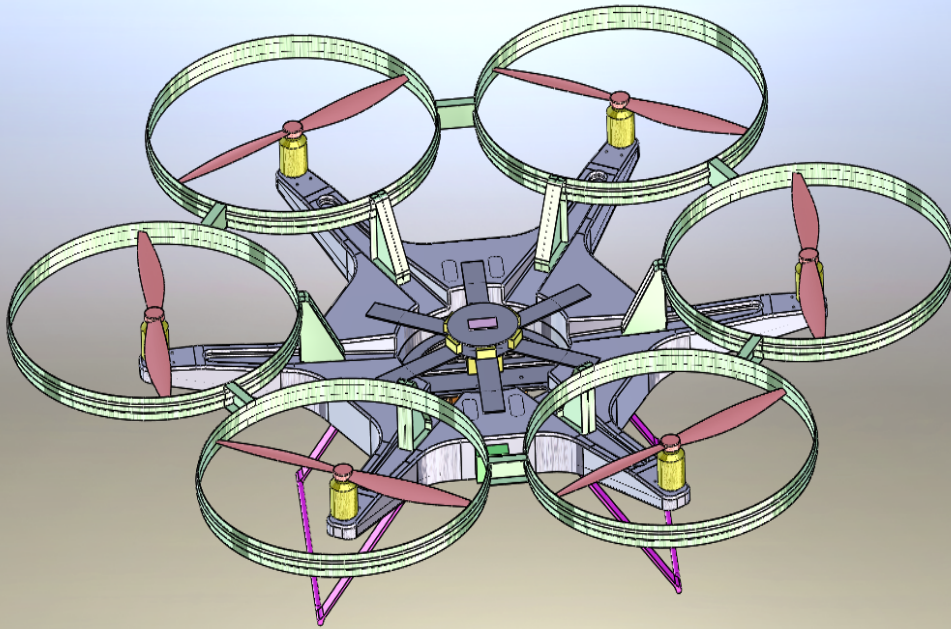


La costruzione del velivolo

COMPONENTE IN RESINA

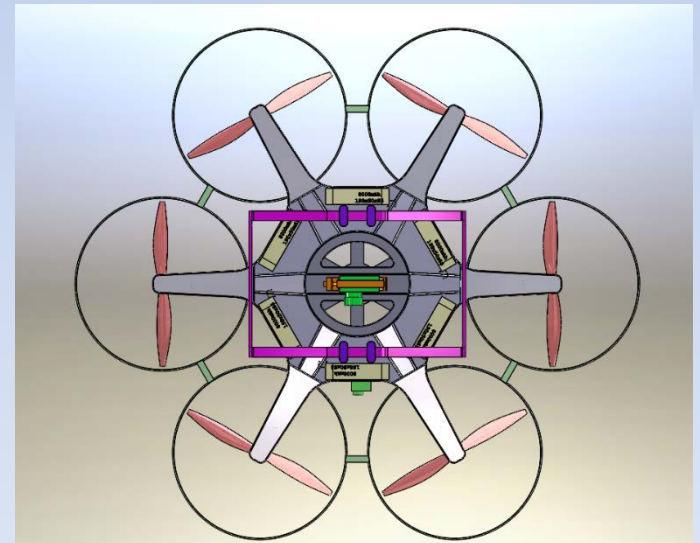
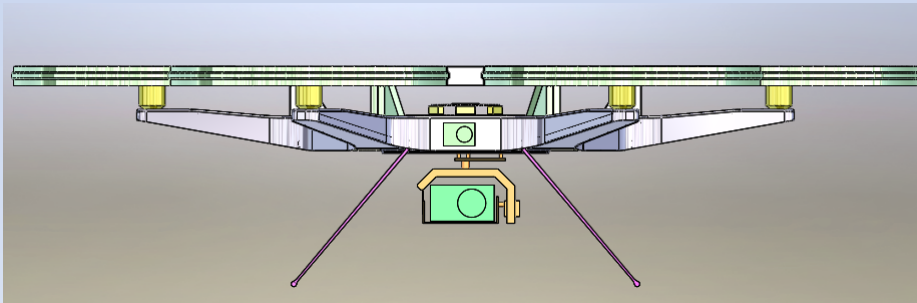
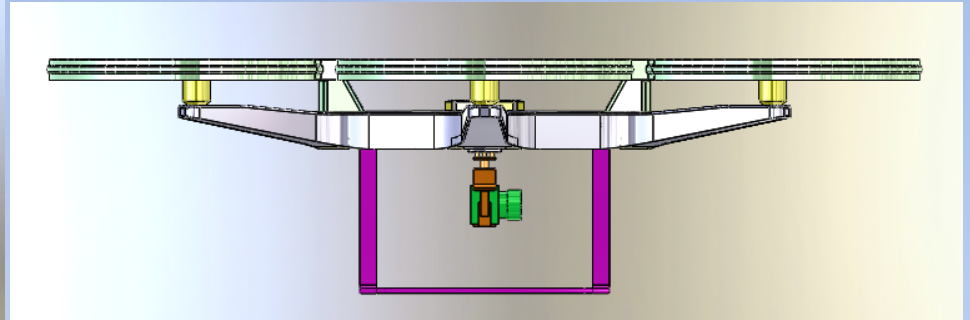
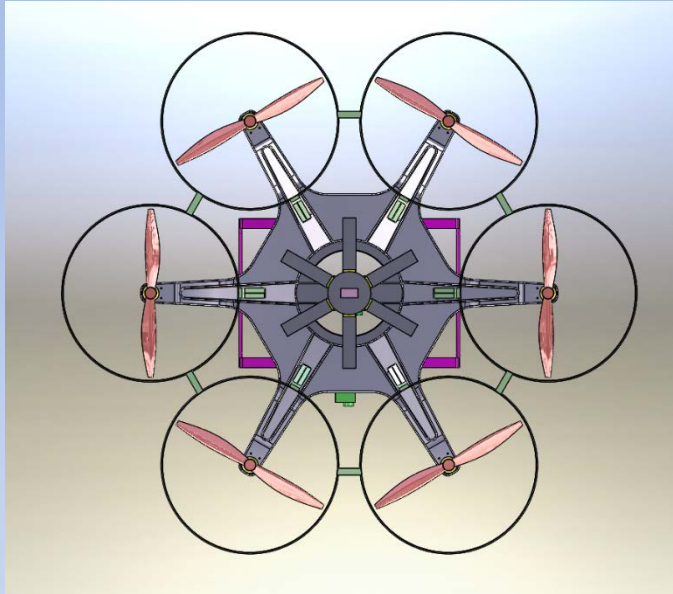


Caratteristiche fisiche del prototipo



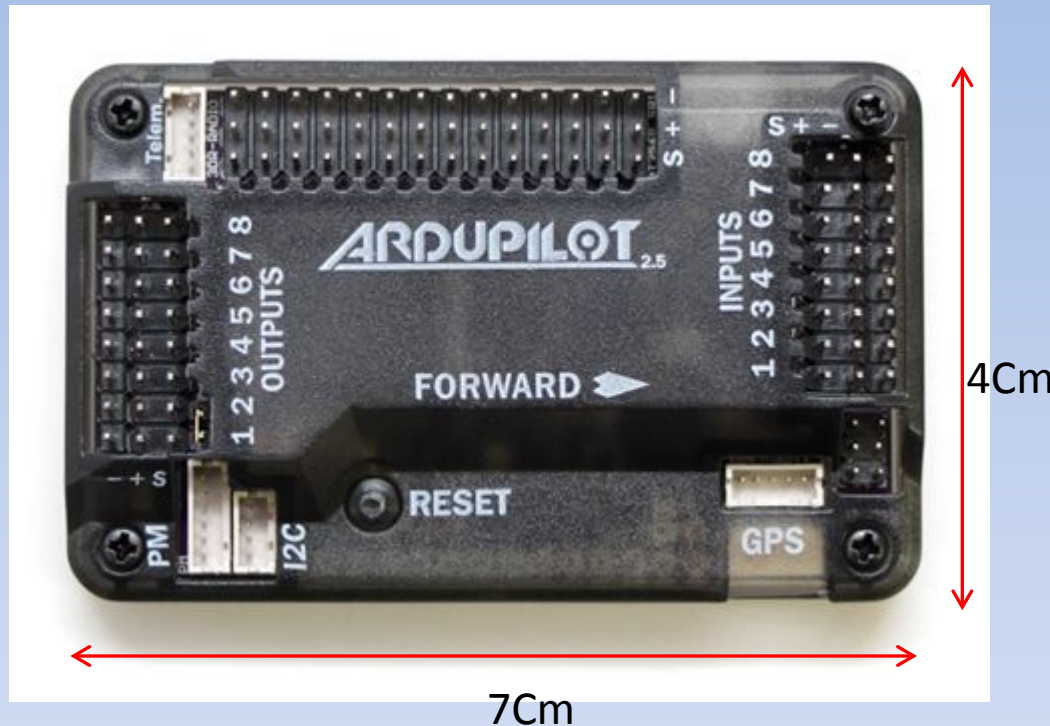
Struttura:	composito in fibra di carbonio;
Propulsione:	6 motori elettrici brushless;
Diametro:	1200mm
Altezza:	450mm
Peso:	18 Kg
Payload:	4 Kg

Caratteristiche fisiche del prototipo



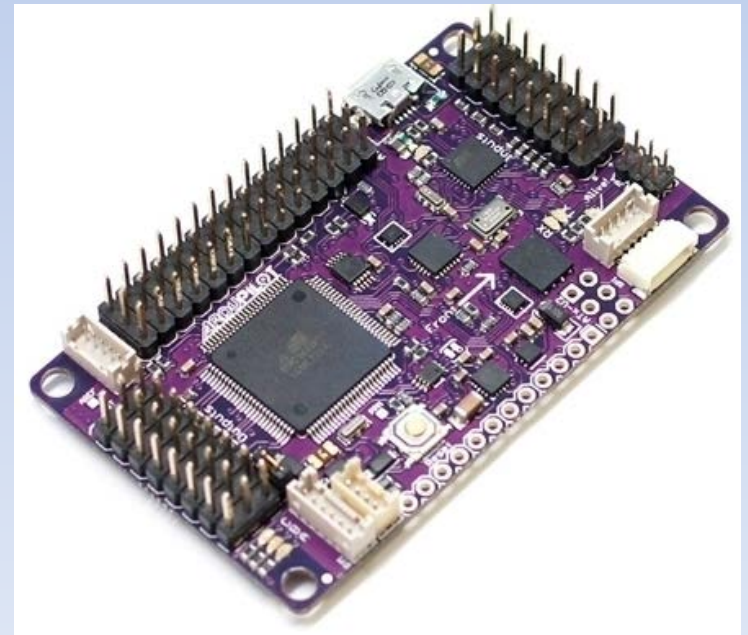
Sistema di controllo del volo

ARDUPILOT



Sensori/dispositivi gestiti:

- GPS/GNSS
- IMU
- Motori (attuatori)



The screenshot displays the Ardupilot Config/Tuning interface. The top navigation bar includes tabs for FLIGHT DATA, FLIGHT PLAN, INITIAL SETUP, CONFIG/TUNING (selected), SIMULATION, TERMINAL, HELP, and DONATE. A 'COM22' status indicator and a 'Link Stats...' link are also present. The left sidebar lists 'Flight Modes' with 'APM:Plane Pids' selected, and other options like 'Standard Params', 'Advanced Params', 'Full Parameter List', 'Planner', and 'Help'. The main area is divided into several parameter groups:

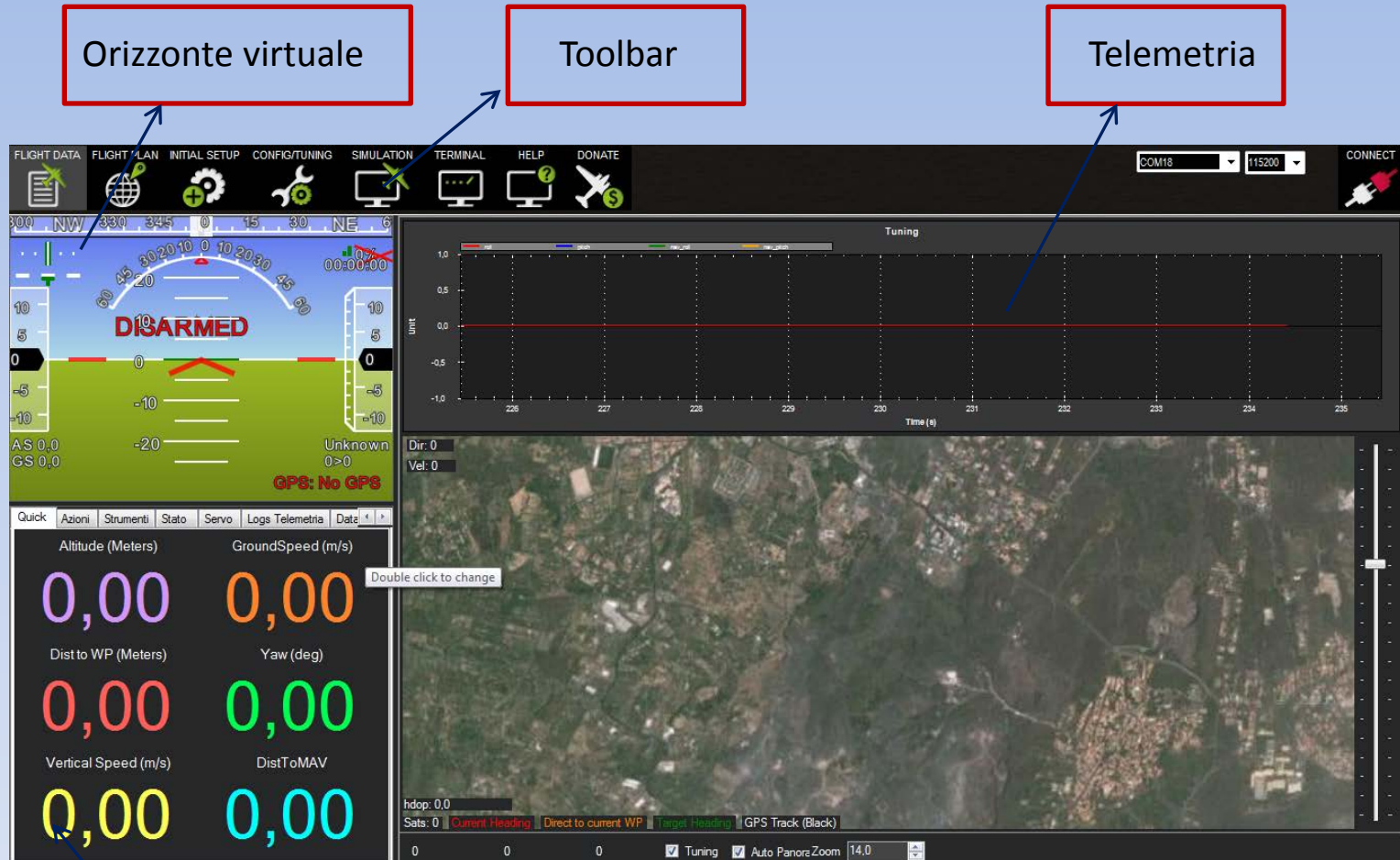
- Servo Roll Pid:** P=0.160, I=0.000, D=0.020, INT_MAX=15.0
- Servo Pitch Pid:** P=0.400, I=0.000, D=0.020, INT_MAX=15.0
- Servo Yaw:** Yaw 2 roll=1.0, Integral=0.000, Dampening=0.000, Intergrator Max=15.0
- L1 Control - Turn Control:** Period=29.0, Damping=0.800
- TECS:** Climb Max (m/s)=5.0, Sink Min (m/s)=2.0, Sink Max (m/s)=5.0, Pitch Dampening=0.000, Time Const=5.0
- Other Mix's:** P to T=0, Rudder Mix=0.500
- Throttle 0-100%:** Cruise=45.0, Min=30.0, Max=80.0, SlewRate=100.0
- Navigation Angles:** Bank Max=35.0, Pitch Max=15.0, Pitch Min=-15.0
- Airspeed m/s:** Cruise=18.0, FBW min=15.0, FBW max=25.0, Ratio=3.430

At the bottom, there are 'Write Params' and 'Refresh Params' buttons.

Controllore PID di Ardupilot

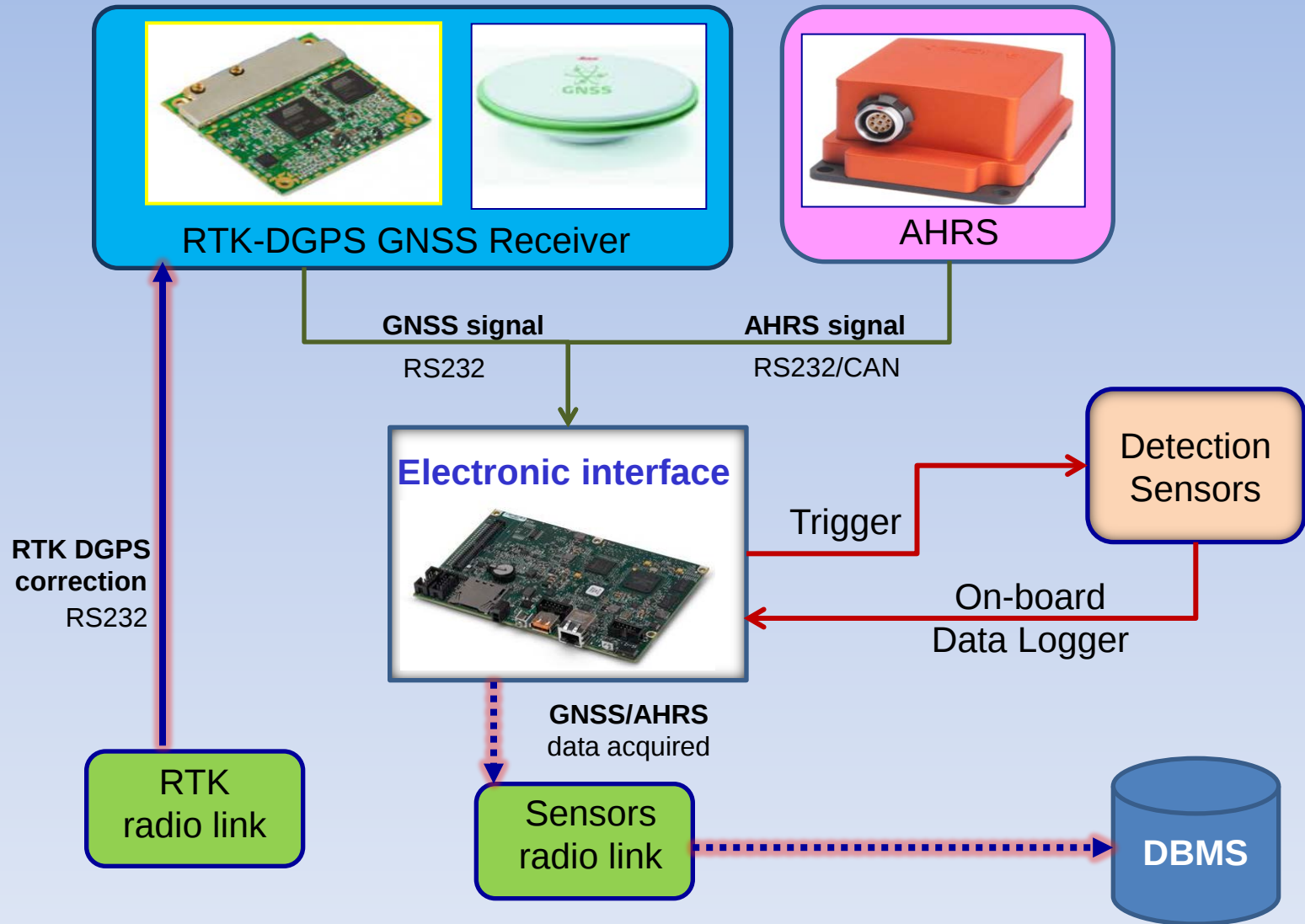
Sistema di controllo del volo

ARDUPILOT



Ground Control Station Ardupilot

Sistema GNSS-IMU



Sensori di rilevamento

Fotocamera a lenti intercambiabili



Sony NEX 7 (24.3 MP)



Sensori di rilevamento

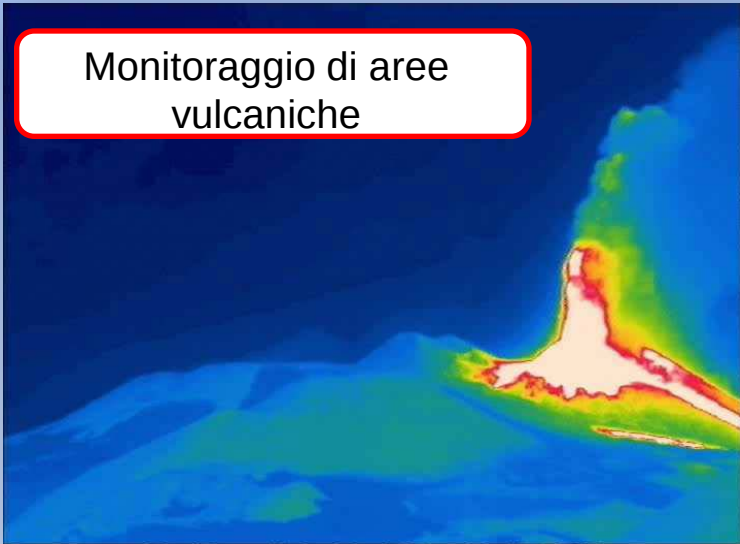
Termocamera



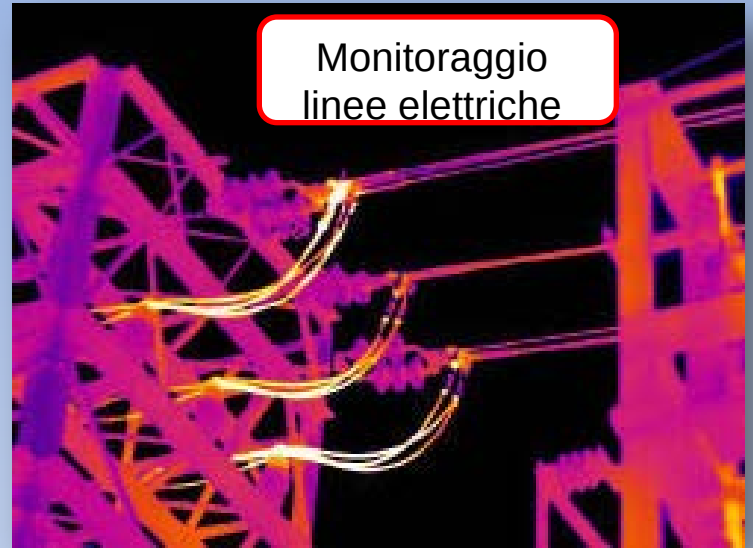
FLIR – TAU 640

- Dimension: 44.5 x 44.5 x 30.0 mm;
- Weight: 72g;
- Power consumption: 900 mW;
- Scene Range: -25°C to +135°C;
- Outputs: 640 x 480 (NTSC);
640 x 512 (PAL);
- Spectral Band: 7.5 - 13.5 μm ;

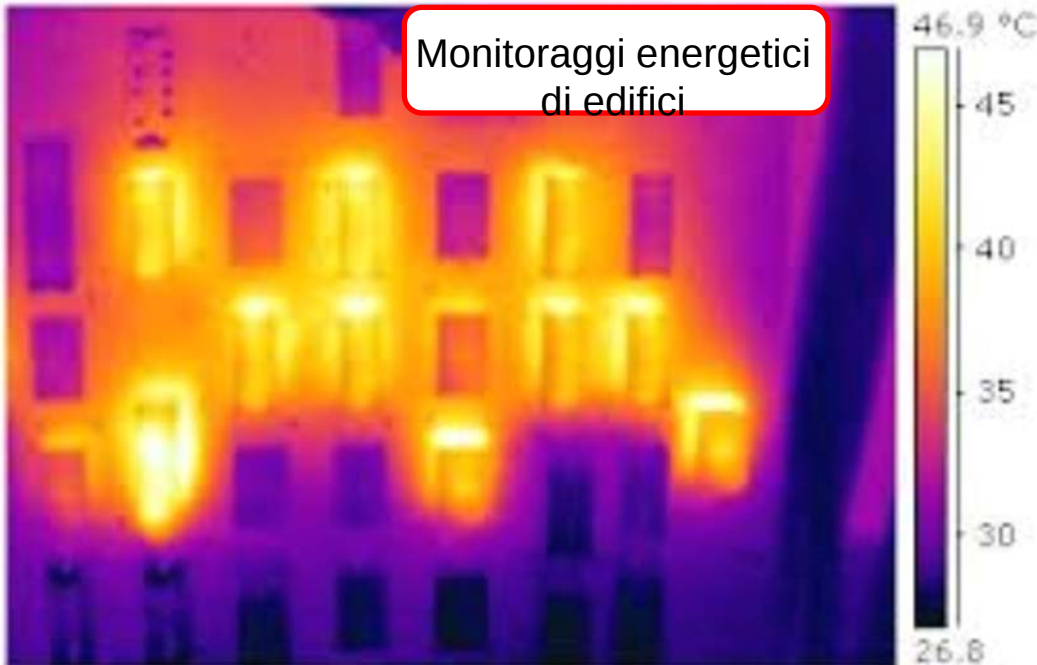
Monitoraggio di aree
vulcaniche



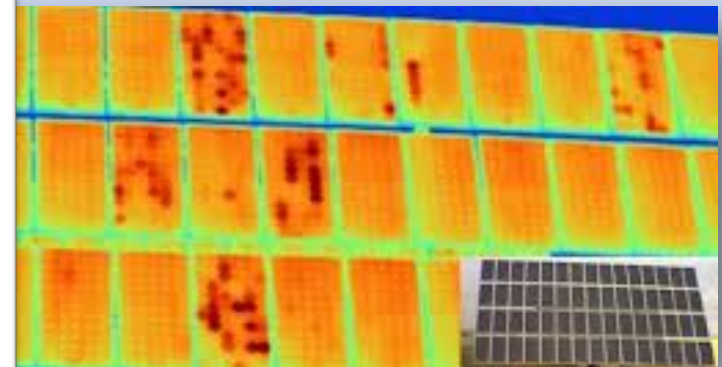
Monitoraggio
linee elettriche



Monitoraggi energetici
di edifici



Monitoraggio di sistemi
fotovoltaici



Sensori per rilevamento topografico e monitoraggi ambientali

SCANNER LASER



Hokuio UTM-30LX

External Dimension: 62mm×62mm×87.5mm

Weight: 210g;

Power consumption: Less than 8W;

Ethernet interface;

Scan Angle : 270°;

Angular Resolution: 0.25°;

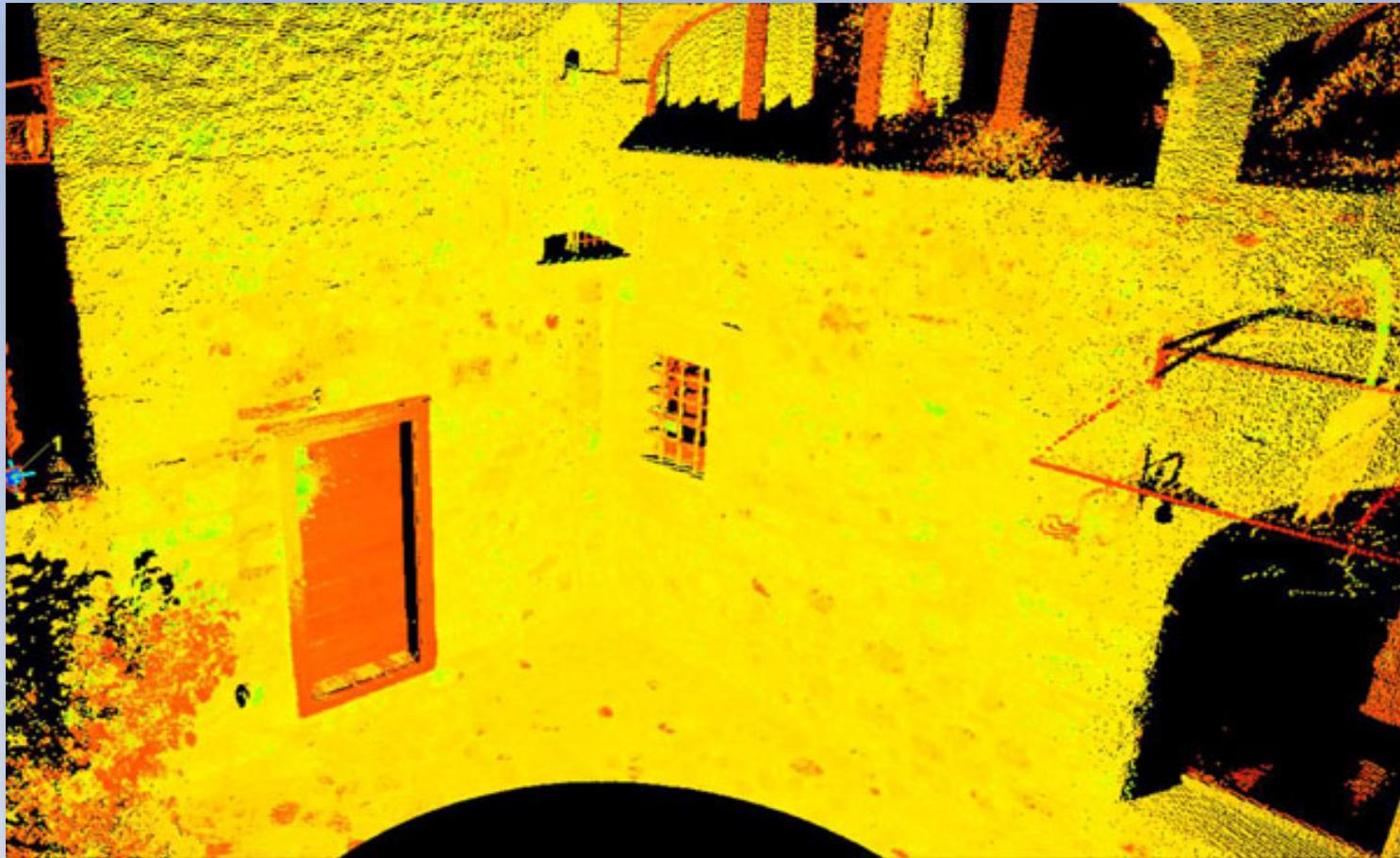
Scan Speed: 25 ms;

Accuracy: 0.1-10m: ±30mm, 10-30m : ±50mm;

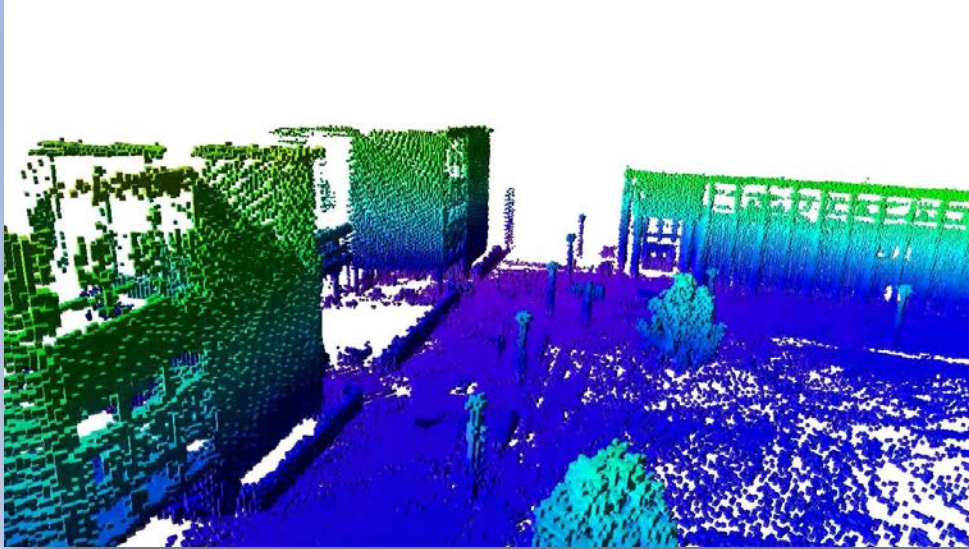
Light Source: $\lambda=905\text{nm}$, Laser class 1.

Risoluzione al suolo: ca. 13 cm a 30m

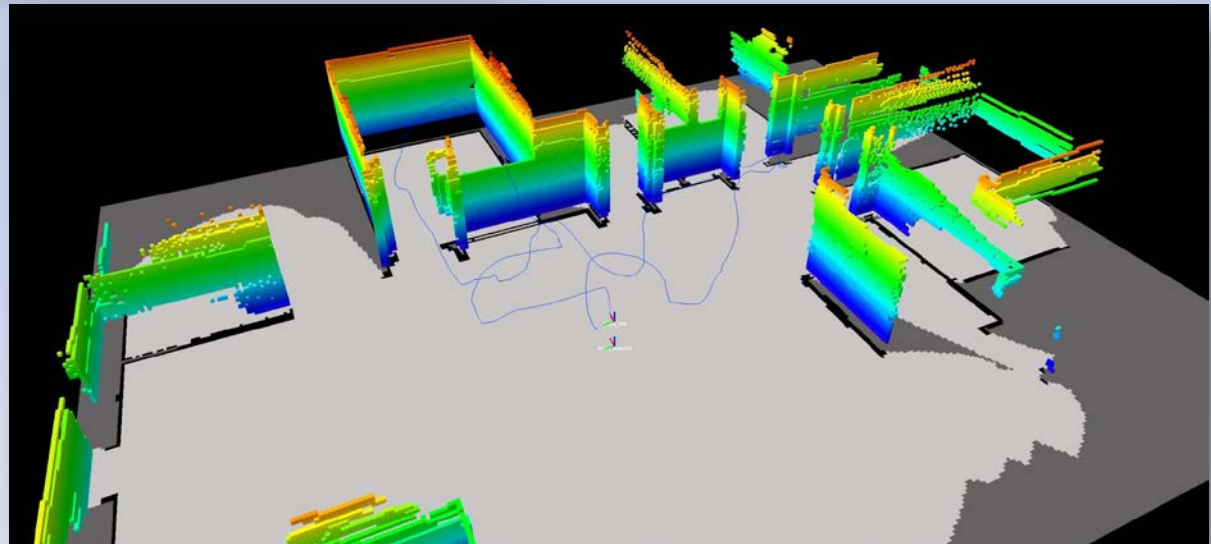
Sensori di rilevamento **SCANNER LASER**



Scanner laser per la navigazione



Riconoscimento
degli ostacoli
presenti lungo la
traiettoria

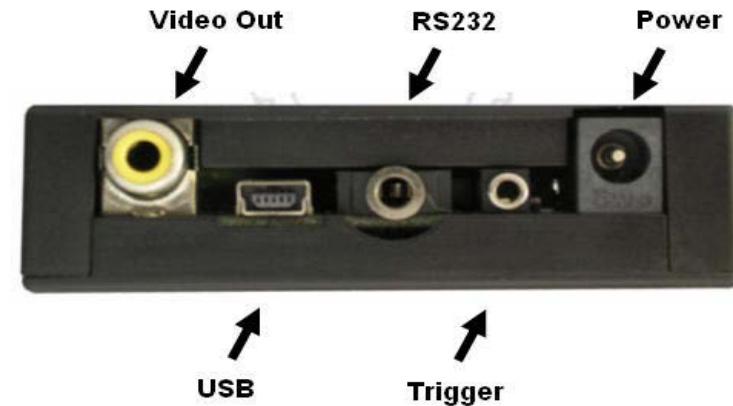


Sensori di rilevamento

Camera multispettrale



TETRACAM ADC Lite



Sensore CMOS **3,2 Mpixel** (2048x1536 pixel)

Tre canali nelle lunghezze d'onda del **VERDE**, **ROSSO** e **INFRAROSSO VICINO**
(simili alle bande TM2, TM3 e TM4 Landsat)

Dimensioni: **114** mm x **77**mm x **60,5** mm (con lente da 8,5 mm)

Peso: **200** gr.



3 canali
nel visibile e NIR
Diversamente configurabili
mediante filtri

Dimensioni

122 x 78 x 41 mm³ (senza lente)

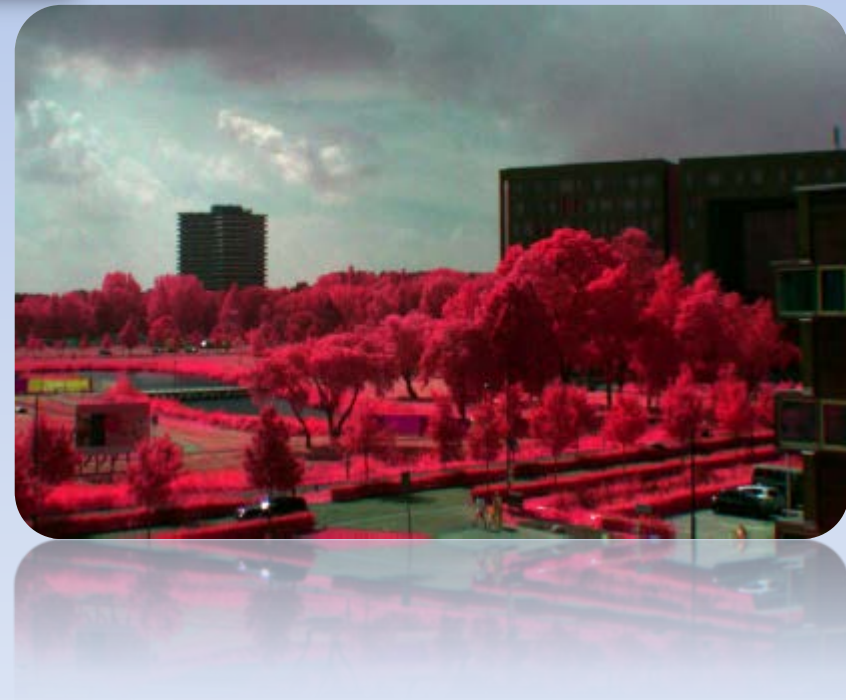
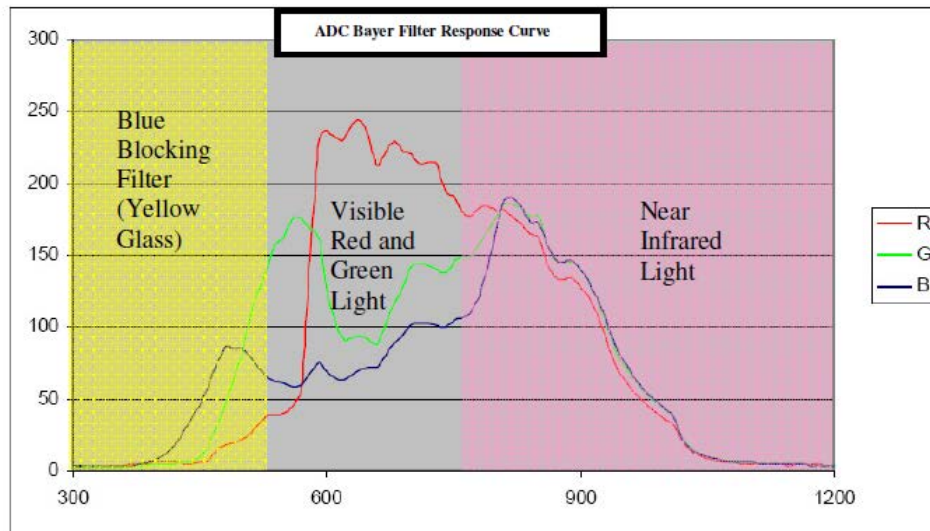
Peso

340 gr. senza batterie interne

520 gr. con batterie alcaline AA



Camera multispettrale (Green, Red, Nir)



Camera multispettrale a sei canali

The New *Mini* MCA (Multi Channel Camera)

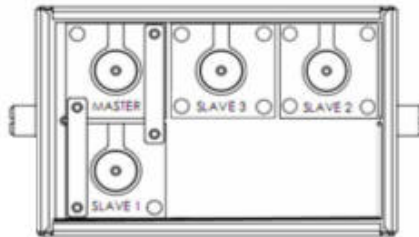


Mini MCA 6

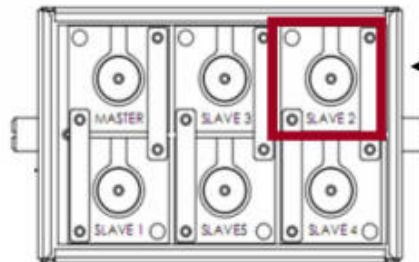
Peso: 700gr
Dimensioni: 115mmx78mmx80 mm



Mini-MCA4

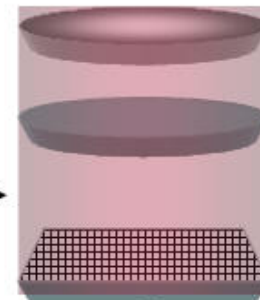


Mini-MCA6



Optical Block

One Mini-MCA Channel



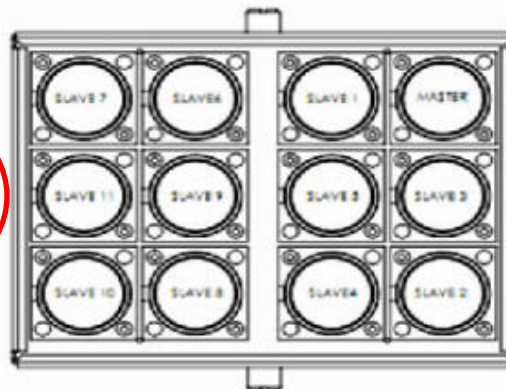
Lens

Filter

Image Sensor

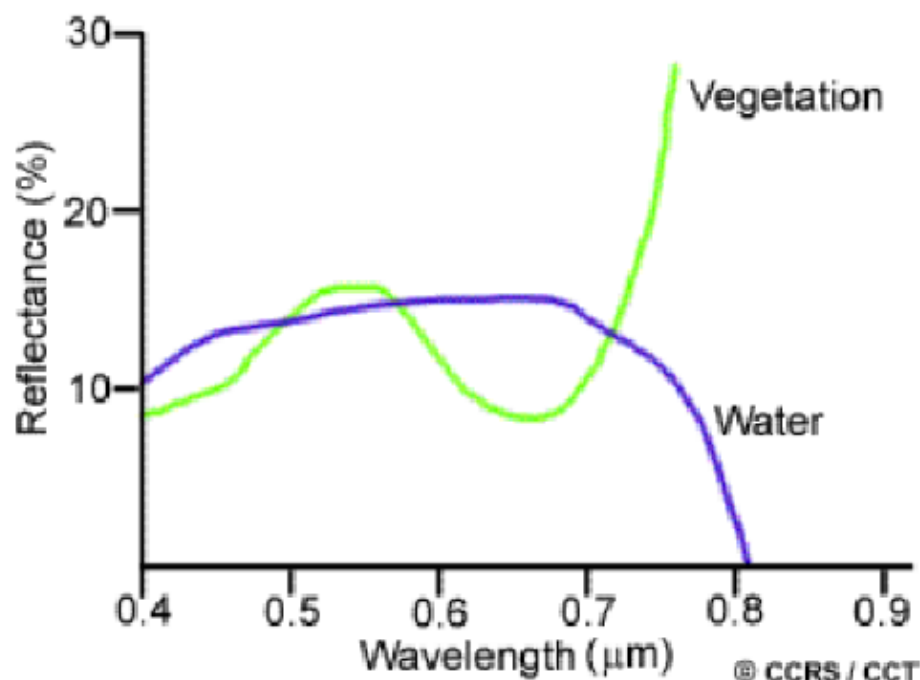
2 GB Memory

Mini-MCA12

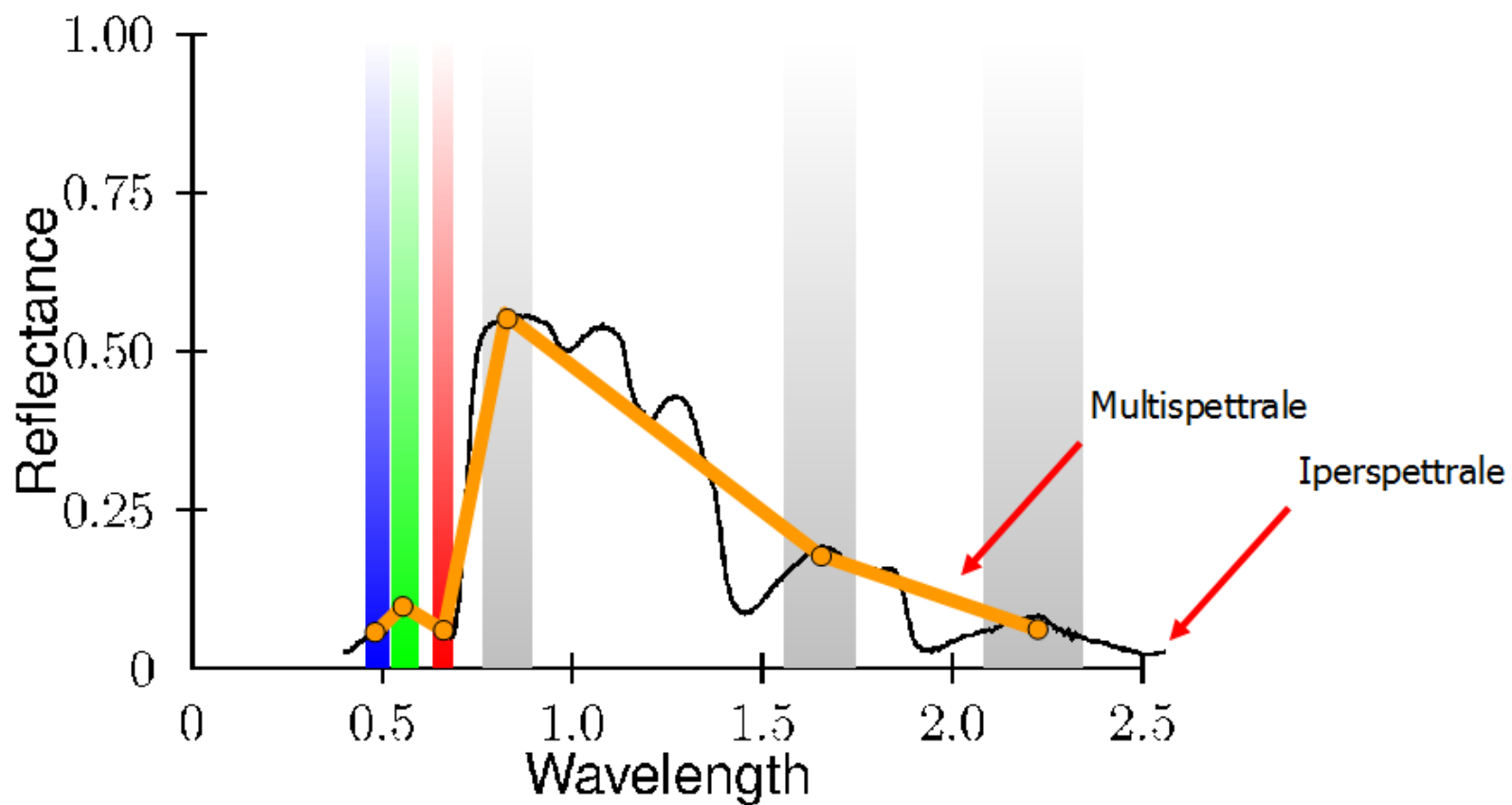


La curva di riflettanza

Descrive l'andamento della riflettanza, per una data superficie, in funzione della lunghezza d'onda (intervallo spettrale).



costruzione della curva di riflettanza



Possibilità di impiego di **camere iper-spettrali** a basso costo (e peso)

TMP-HSP (Tempestini Group) è una fotocamera compatta in grado di catturare immagini in tempo reale nelle bande elettromagnetiche comprese tra **200nm (ultravioletto)** e **2500nm (infrarosso)**.



TMP-HSP	200 SERIE T	1700 SERIE T
Range spettrale (copertura continua) canali/bande spettrali pixels spaziali	400-1000nm fino a1000 1600	1000-1700nm fino a 380 640
Campo visivo Tipo telecamera Montatura lenti standard c-mount Dimensioni Peso	30 gradi CCD/KAI-2001 25.4cmx10.16cmx12.7cm 3.18kg	

HySpex main specifications

	VNIR-1024	VNIR-1600	SWIR-320i	SWIR-320m	SWIR-320m-e
Spectral range	0.4 – 1.0 μm	0.4 – 1.0 μm	0.9 – 1.7 μm	1.3 – 2.5 μm	1.0 – 2.5 μm
Spatial pixels	1024	1600	320	320	320
FOV across track ¹	16°	17°	14°	14°	13.5°
Pixel FOV across/- along track ¹	0.28 mrad/ 0.56 mrad	0.18 mrad/ 0.36 mrad	0.75 mrad/ 0.75 mrad	0.75 mrad/ 0.75 mrad	0.75 mrad/ 0.75 mrad
Spectral sampl. ²	5.4 nm	3.7 nm	5 nm	5 nm	6 nm
# of bands ²	108	160	145	240	256
Spectral binning ³	2, 4, 8	2, 4, 8	-	-	-
Digitization	12 bit	12 bit	12 bit (CL: 14 bit)	14 bit	14 bit
Max frame rate	690 fps	135 fps ⁴	350 fps	100 fps	100 fps
Sensor head weight	TBD	4.6 kg	6.8 kg	7.0 kg	7.5 kg
Sensor head dim. (l·w·h in cm)	TBD	31.5 x 8.4 x 13.8	32.0 x 14.0 x 15.2	36.0 x 14.0 x 15.2	36.0 x 14.0 x 15.2
Sensor head power consumption	~6 w	~6 w	~30 w	~100 w	~100 w
FPA temperature	NA	NA	~260 K	~200 K	~200 K
Camera interface	Camera Link	Camera Link	USB 2.0 or Camera Link	Camera Link	Camera Link

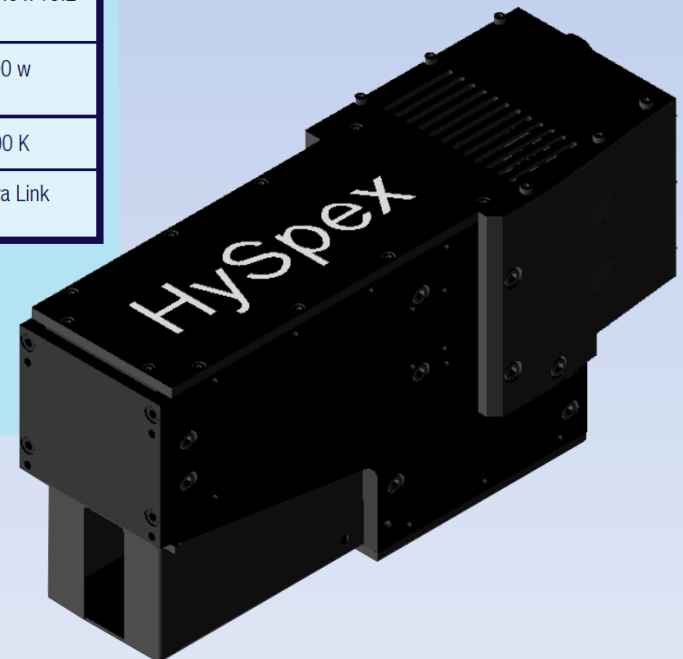
All specifications are subject to changes due to ongoing developments.

¹ Can be doubled with field expander.

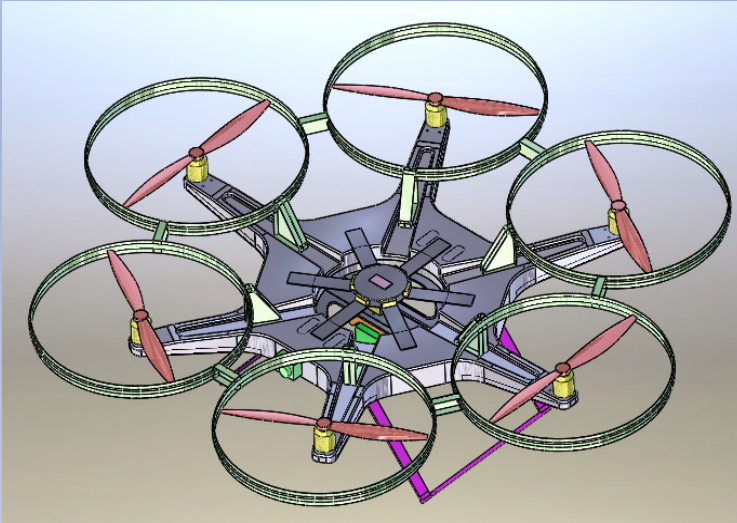
² At standard binning configuration.

³ Standard binning mode in bold.

⁴ At full resolution. Can be increased by binning/subwindowing.



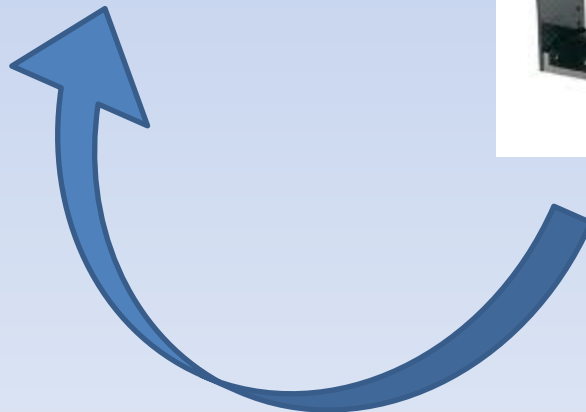
Gimbal e sistema di controllo



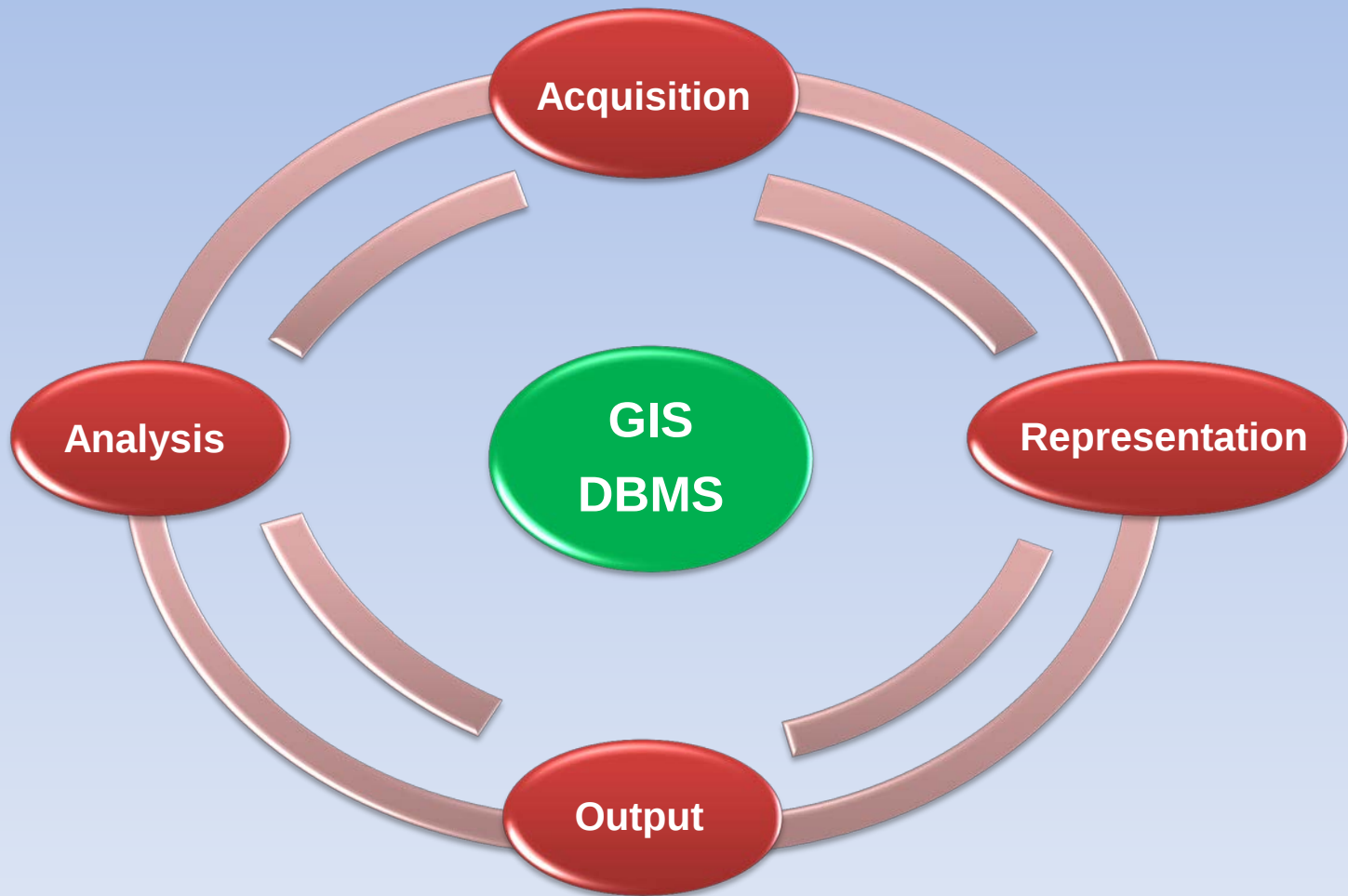
Sensor pitch

Control system

Sensor roll

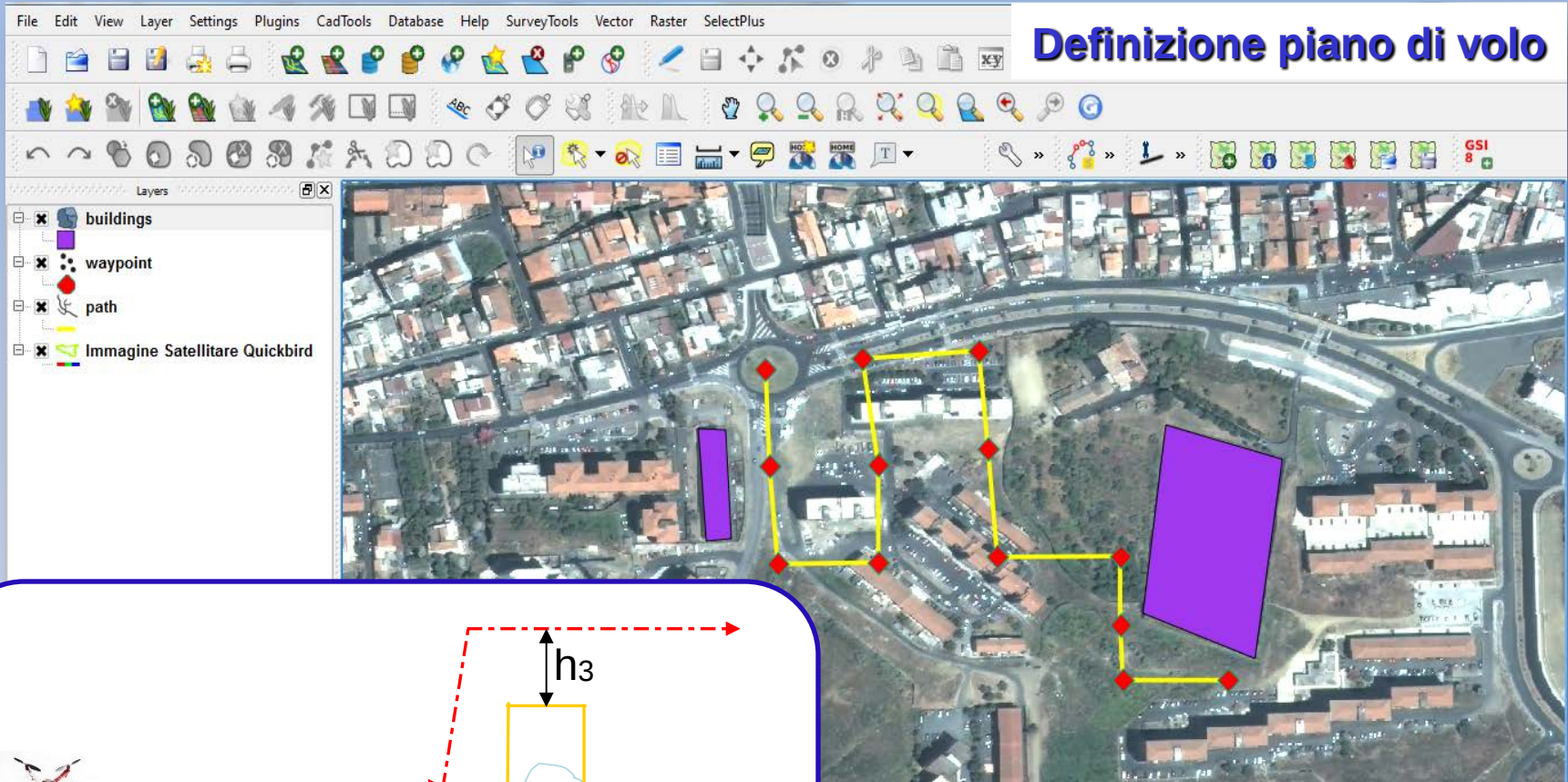


Sistema di navigazione e gestione dati sviluppato in ambienti **GIS open source**

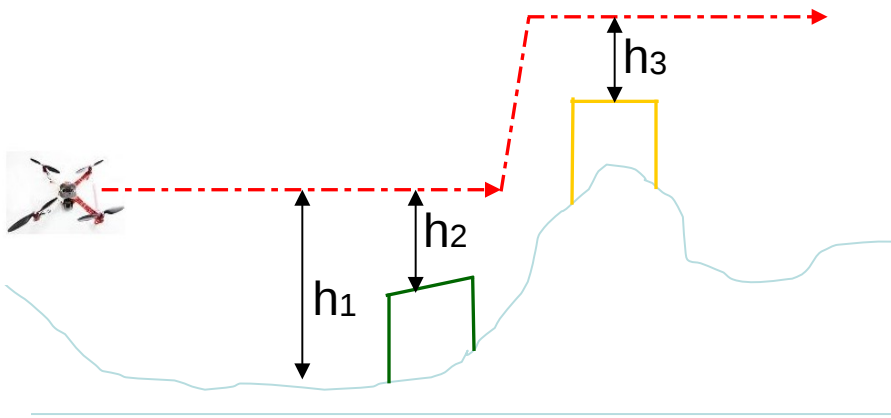


Desktop GIS

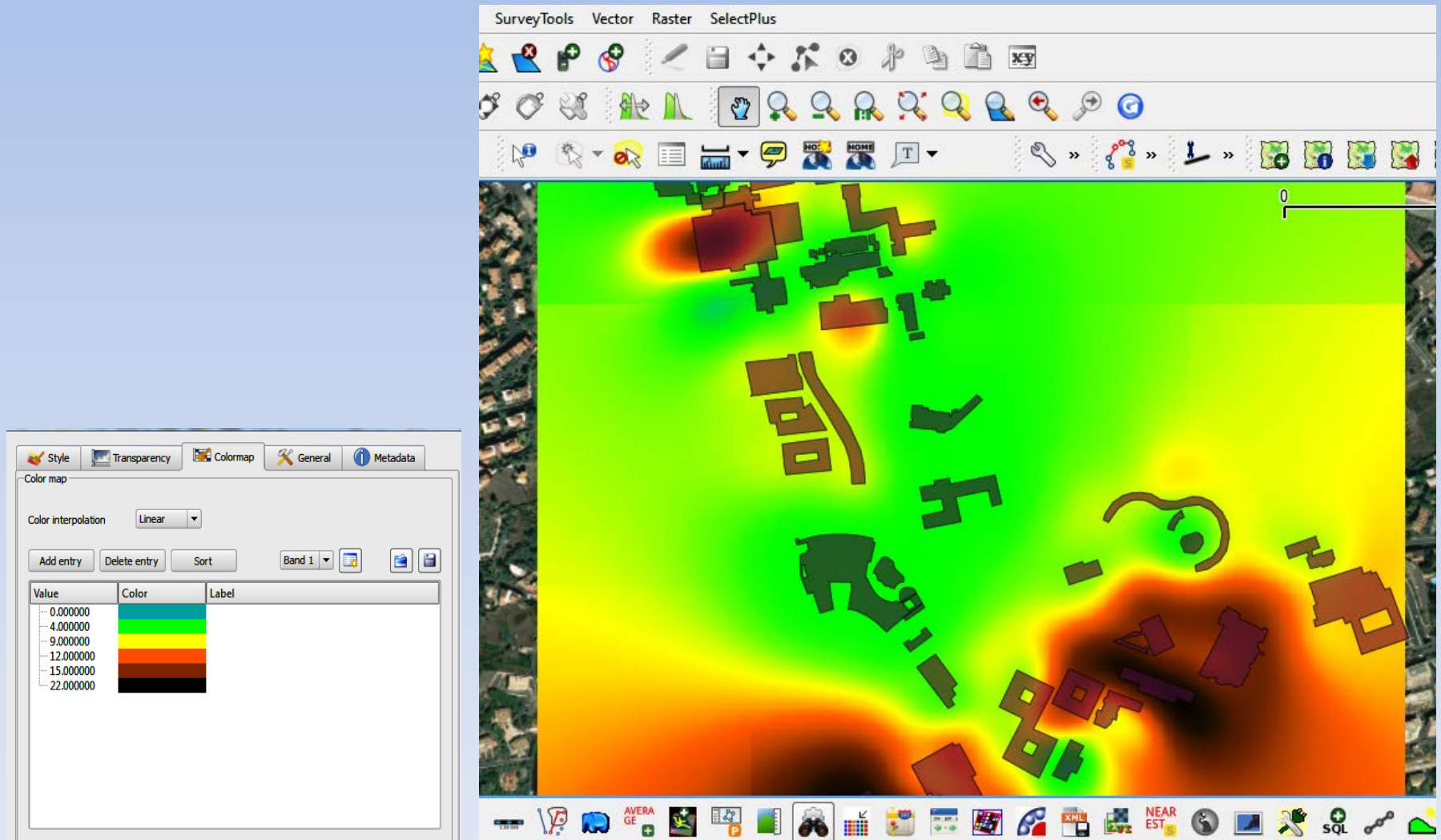
Definizione piano di volo

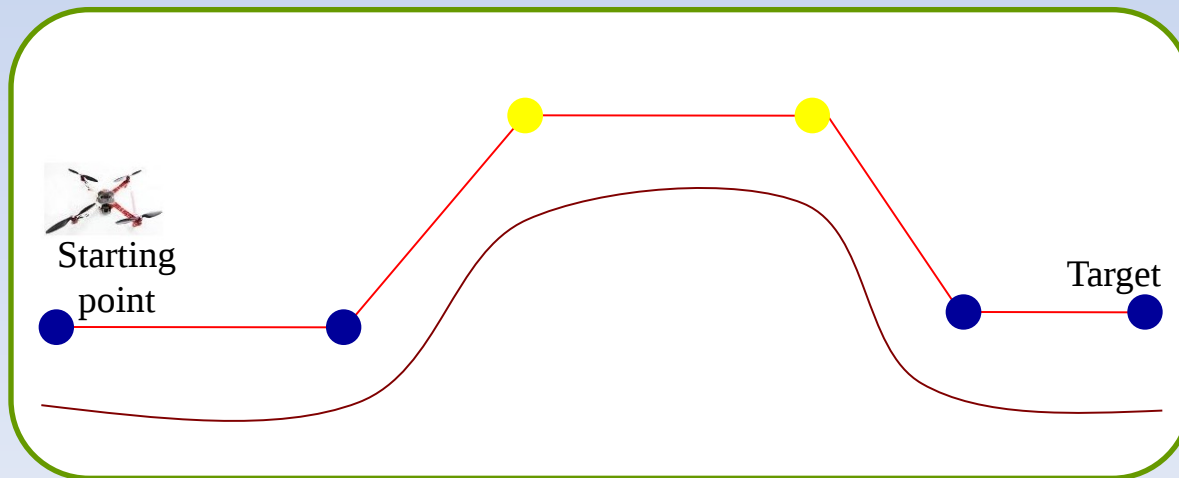
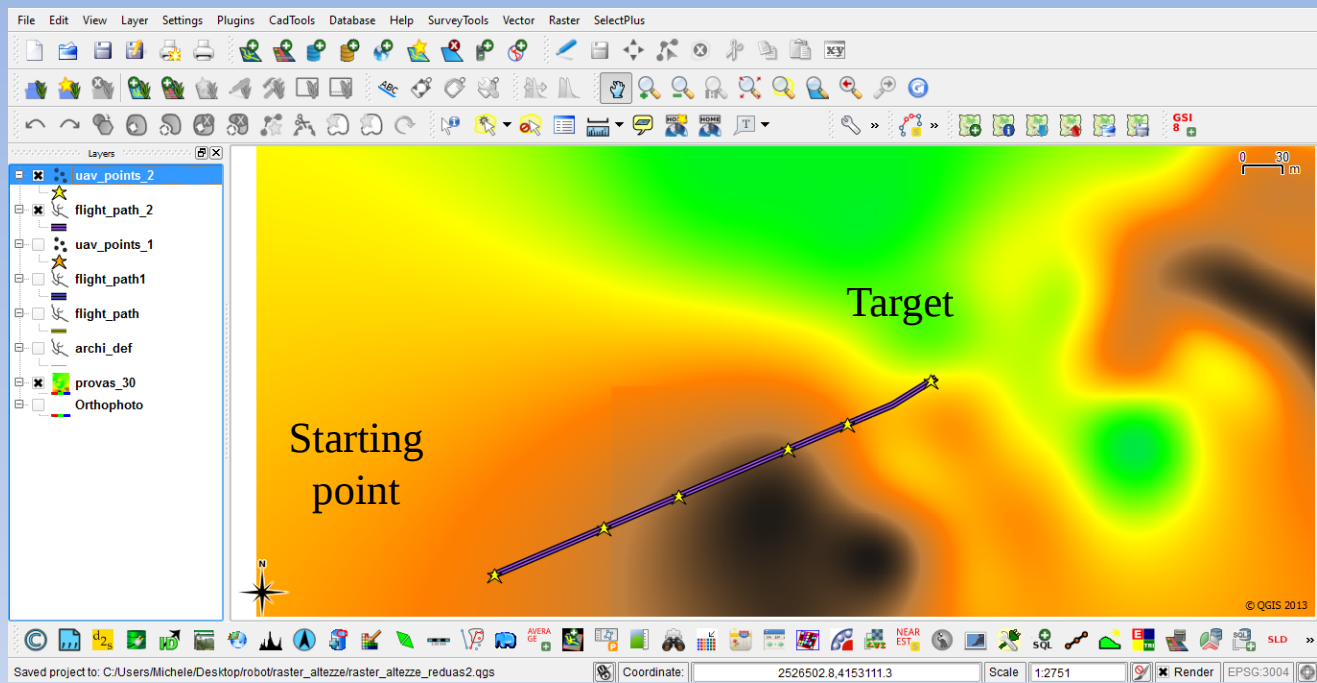


.. con attenzione alla quota di volo

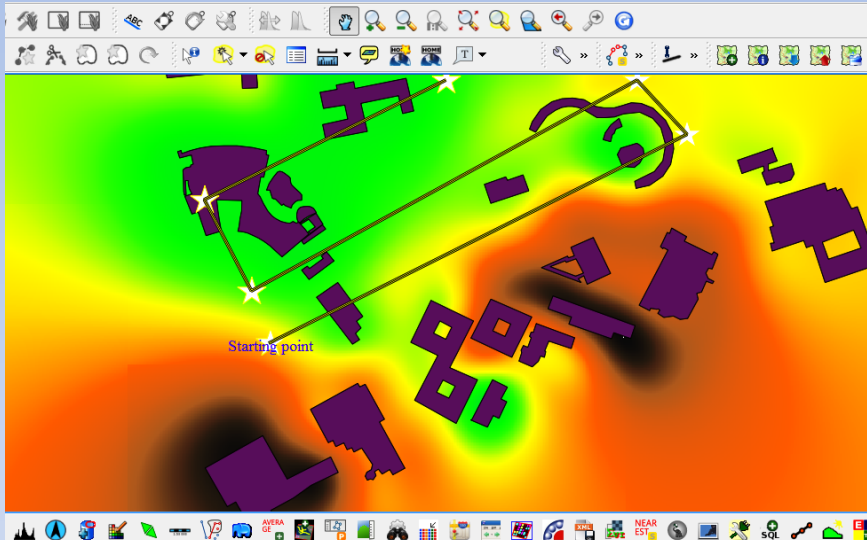


Generazione di una **mappa delle variazioni di altezza** del suolo e degli ostacoli alla navigazione eventualmente presenti (edifici, tralicci, ..)



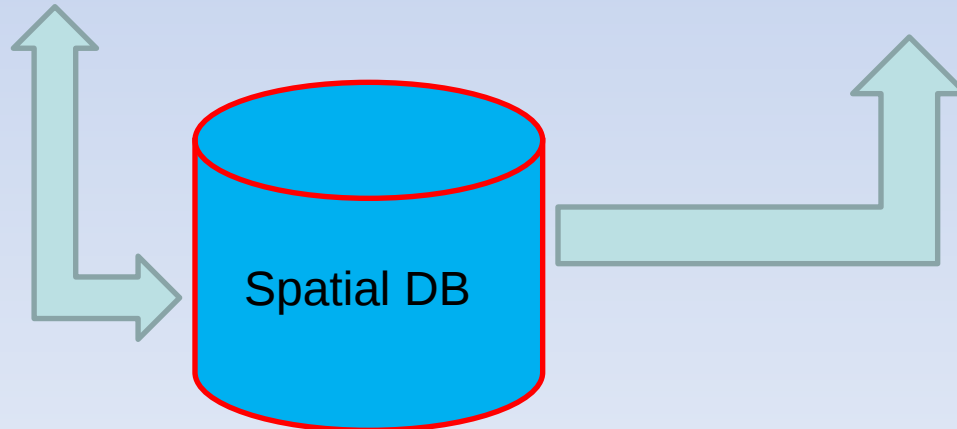


Definizione plano-altimetrica del piano di volo



Sequenza di waypoints

```
coordinate_m - Blocco note
File Modifica Formato Visualizza ?
POINT(15.0754893040972 37.5258074740708) 0101000020E61000002E97B888A6262E403090C8A84DC34240 15.0754893040972 37.5258074740708 \N
POINT(15.0748574984197 37.5259780616038) 0101000020E61000005E25D7B853262E403B80C63F53C34240 15.0748574984197 37.5259780616038 \N
POINT(15.0748574984197 37.5259780616038) 0101000020E61000005E25D7B853262E403B80C63F53C34240 15.0748574984197 37.5259780616038 \N
POINT(15.0742098976002 37.5261644442786) 0101000020E6100000F976F6D6FE252E404F3F445B59C34240 15.0742098976002 37.5261644442786 \N
POINT(15.0742098976002 37.5261644442786) 0101000020E6100000F976F6D6FE252E404F3F445B59C34240 15.0742098976002 37.5261644442786 \N
POINT(15.0737344638279 37.5262765897864) 0101000020E610000036750D86C0252E4039E402085DC34240 15.0737344638279 37.5262765897864 \N
POINT(15.0737344638279 37.5262765897864) 0101000020E610000036750D86C0252E4039E402085DC34240 15.0737344638279 37.5262765897864 \N
POINT(15.0734043453614 37.5263413498683) 0101000020E61000004A6C1D4195252E40C11842275FC34240 15.0734043453614 37.5263413498683 \N
POINT(15.0734043453614 37.5263413498683) 0101000020E61000004A6C1D4195252E40C11842275FC34240 15.0734043453614 37.5263413498683 \N
POINT(15.0734086413662 37.5264050334612) 0101000020E6100000C0D243D195252E403495793D61C34240 15.0734086413662 37.5264050334612 \N
POINT(15.0734086413662 37.5264050334612) 0101000020E6100000C0D243D195252E403495793D61C34240 15.0734086413662 37.5264050334612 \N
POINT(15.0734318721416 37.5264854476837) 0101000020E610000019AAC2DC98252E408AC09E063C34240 15.0734318721416 37.5264854476837 \N
POINT(15.0734318721416 37.5264854476837) 0101000020E610000019AAC2DC98252E408AC09E063C34240 15.0734318721416 37.5264854476837 \N
POINT(15.0735212294118 37.526616185338) 0101000020E610000052C51793A4252E4016C98E2868C34240 15.0735212294118 37.526616185338 \N
POINT(15.0735212294118 37.526616185338) 0101000020E610000052C51793A4252E4016C98E2868C34240 15.0735212294118 37.526616185338 \N
POINT(15.073608783431 37.5266748678521) 0101000020E6100000A911E80CB0252E40638602156AC34240 15.073608783431 37.5266748678521 \N
POINT(15.073608783431 37.5266748678521) 0101000020E6100000A911E80CB0252E40638602156AC34240 15.073608783431 37.5266748678521 \N
POINT(15.0737856947204 37.5267713649191) 0101000020E61000003879133DC7252E40F657C3E6DC34240 15.0737856947204 37.5267713649191 \N
POINT(15.0737856947204 37.5267713649191) 0101000020E61000003879133DC7252E40F657C3E6DC34240 15.0737856947204 37.5267713649191 \N
POINT(15.0738845176763 37.5268041475271) 0101000020E61000006D330631D4252E4056837C516EC34240 15.0738845176763 37.5268041475271 \N
POINT(15.0738845176763 37.5268041475271) 0101000020E61000006D330631D4252E4056837C516EC34240 15.0738845176763 37.5268041475271 \N
POINT(15.0741356604331 37.526884702751) 0101000020E6100000180EFA18F5252E40038A3BF570C34240 15.0741356604331 37.526884702751 \N
POINT(15.0741356604331 37.526884702751) 0101000020E6100000180EFA18F5252E40038A3BF570C34240 15.0741356604331 37.526884702751 \N
POINT(15.0745968785777 37.5270094843723) 0101000020E6100000F38FE38F31262E40CA07FA0B75C34240 15.0745968785777 37.5270094843723 \N
POINT(15.0745968785777 37.5270094843723) 0101000020E6100000F38FE38F31262E40CA07FA0B75C34240 15.0745968785777 37.5270094843723 \N
POINT(15.074596319579 37.5270667417618) 0101000020E61000006011A5FD2D262E408E5649EC76C34240 15.074596319579 37.5270667417618 \N
POINT(15.074596319579 37.5270667417618) 0101000020E61000006011A5FD2D262E408E5649EC76C34240 15.074596319579 37.5270667417618 \N
POINT(15.0745427802166 37.527127530583) 0101000020E6100000CE5DA6782A262E405B9A68EA78C34240 15.0745427802166 37.527127530583 \N
POINT(15.0745427802166 37.527127530583) 0101000020E6100000CE5DA6782A262E405B9A68EA78C34240 15.0745427802166 37.527127530583 \N
POINT(15.0744843381914 37.5271749384841) 0101000020E61000004A31A9CF22262E40A0F07E877AC34240 15.0744843381914 37.5271749384841 \N
```



Real time tracking

Lon: 15.069802

Lat: 37.530416

Coordinates list

Vertices of the path

Vertices of the path: 5

Markers name: marker 1

latitude: 37.51154332676

longitude: 15.0987666734

Save Marker

Serial GPS data :

MB,V,,,,,,,,V,N*04\$GPGGA,,,,,0,02,,,M,,M,,*64\$GPGSA,A,1,02,,

Longitude : Unknown

Latitude : Unknown

Velocity (m/s) : 1.696

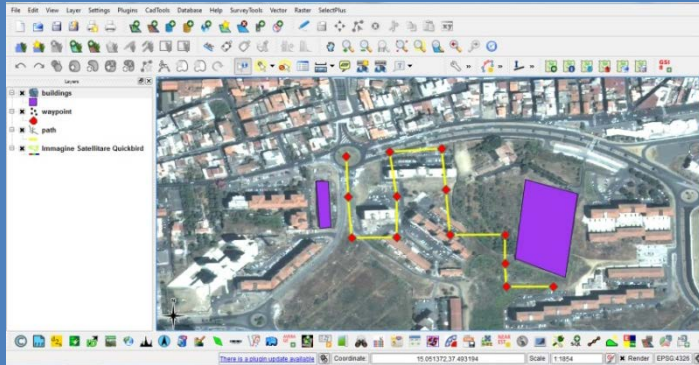
GPS Status : Lost connection

Save mission

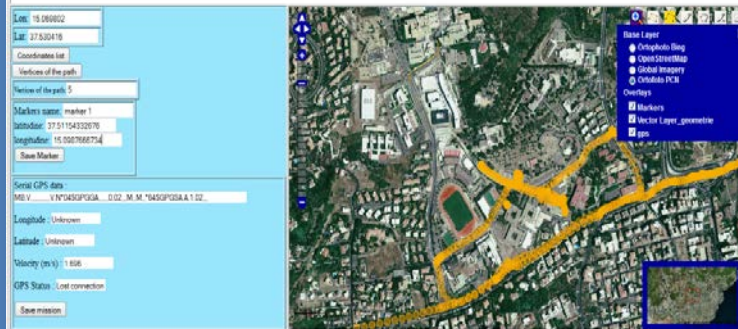


Architettura del sistema di gestione del volo e dei dati acquisiti

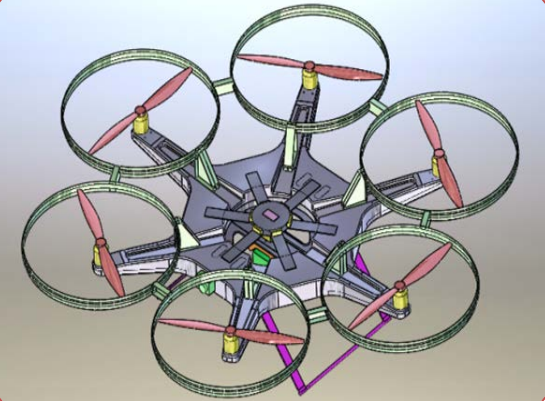
Piattaforma GIS



WEBGIS PLATFORM



Gestione volo



Archiviazione dati georeferenziati

Spatial
DB

Grazie per l'attenzione