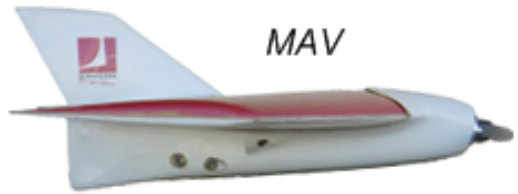
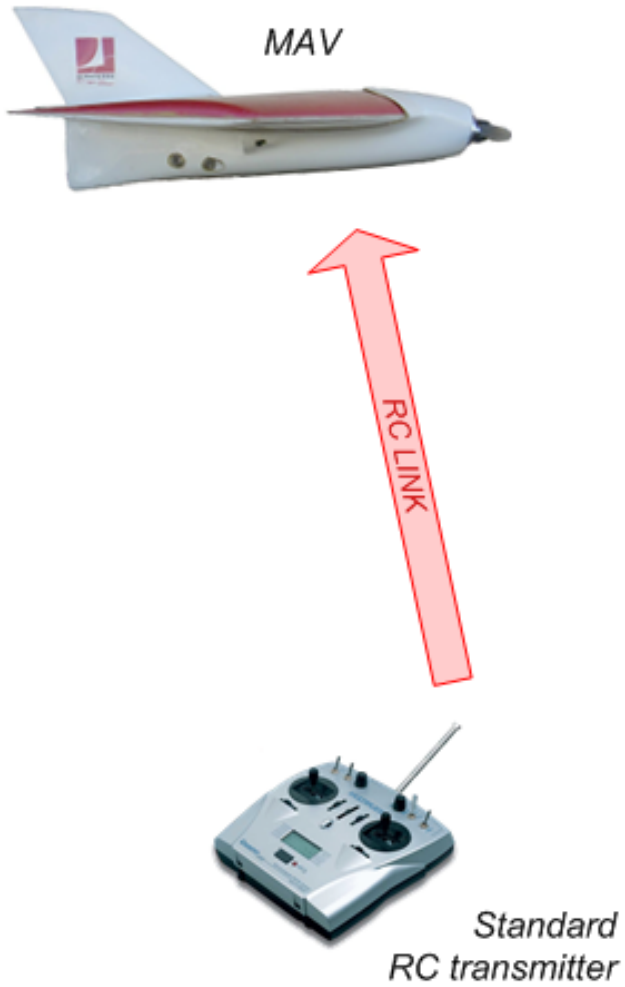
The Paparazzi UAV System

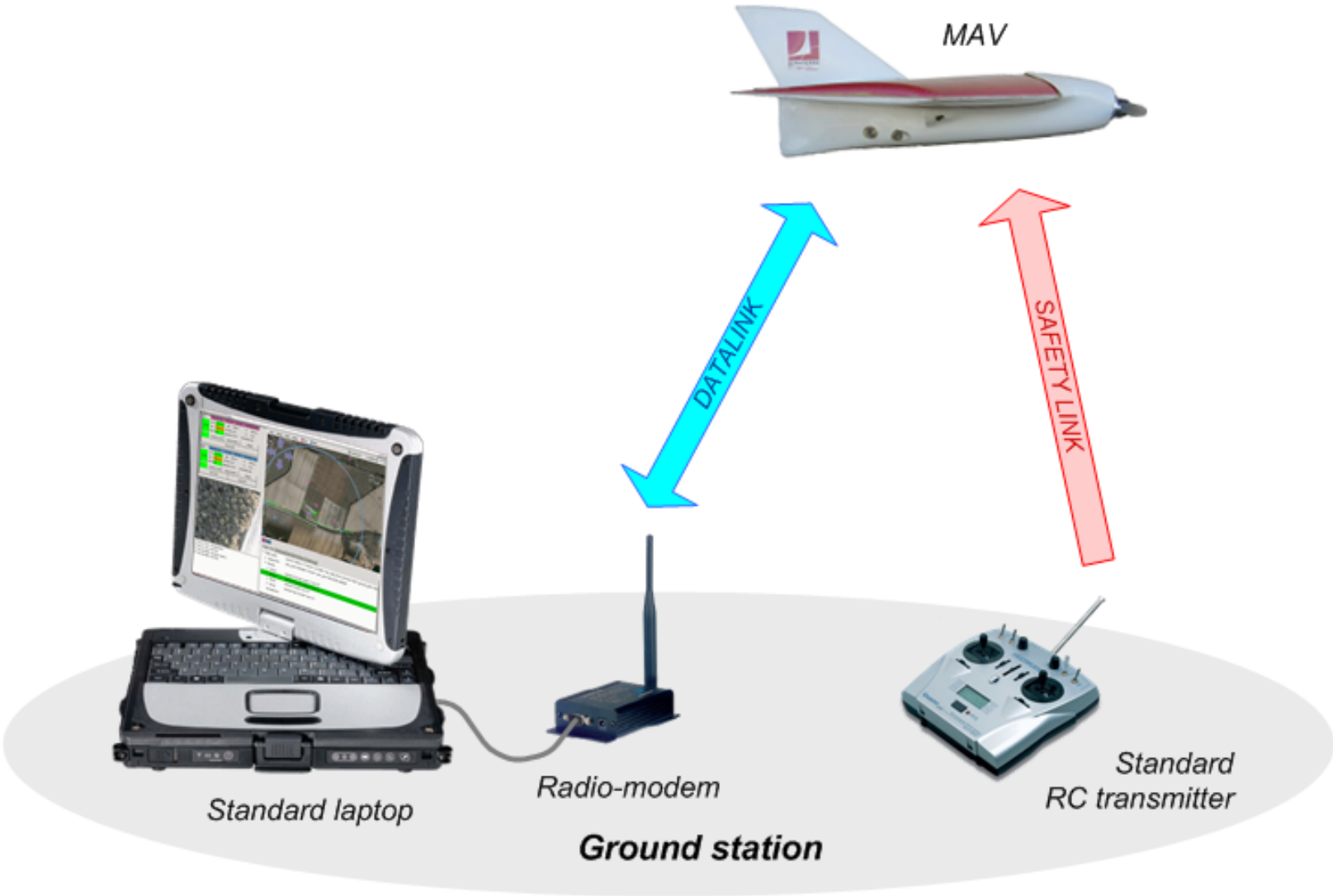
Pascal Brisset

ENAC

Solutions Linux, March 2010


MAV


MAV
RC LINK
Standard
RC transmitter


MAV
DATALINK
SAFETY LINK
Standard laptop
Radio-modem
Standard
RC transmitter
Ground station


Processor
Sensors
Actuators
Propulsion
Payload
MAV
DATALINK
SAFETY LINK
Preparation
Simulation
Tuning
Monitoring
Analysis
Standard laptop
Radio-modem
Standard
RC transmitter
Ground station

Experiments with MAVs

- From 1.4m down to 0.3m
- From 1.4kg down to 250g
- From 1 to 5 vehicles
- From 20min to 60min
- 10km away, 3500m high
- From India to

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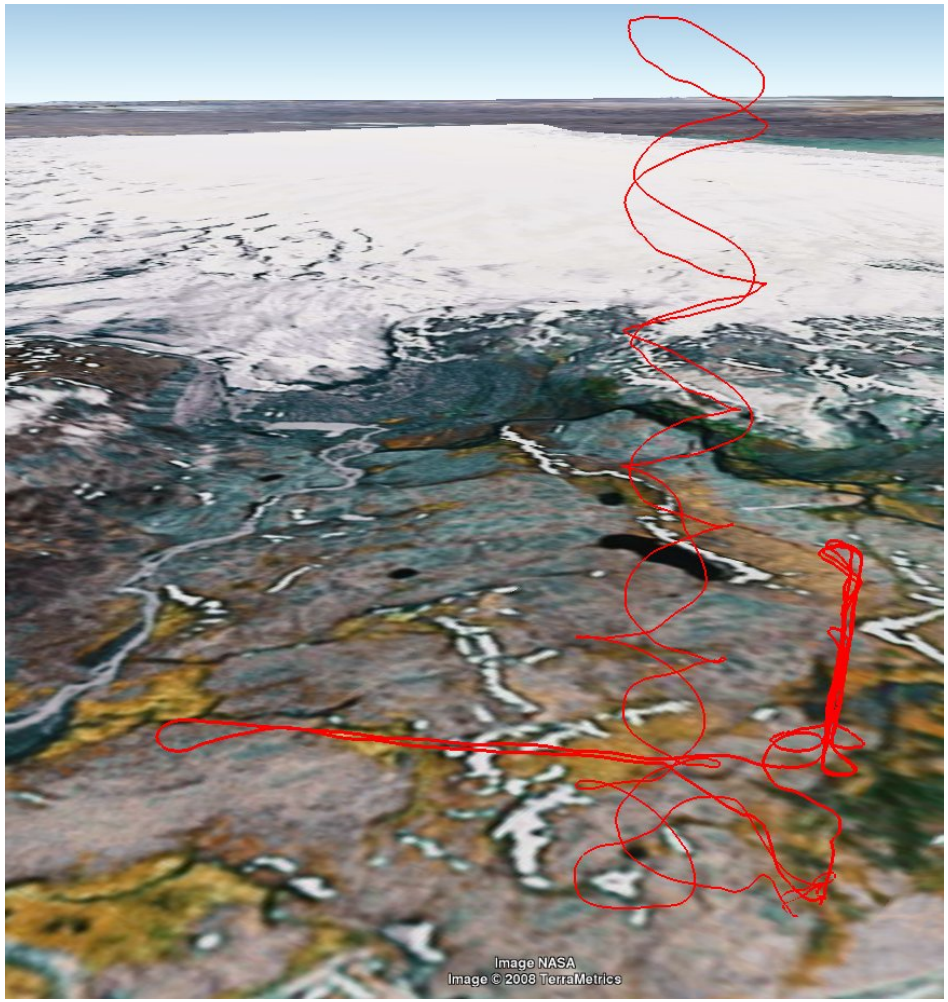

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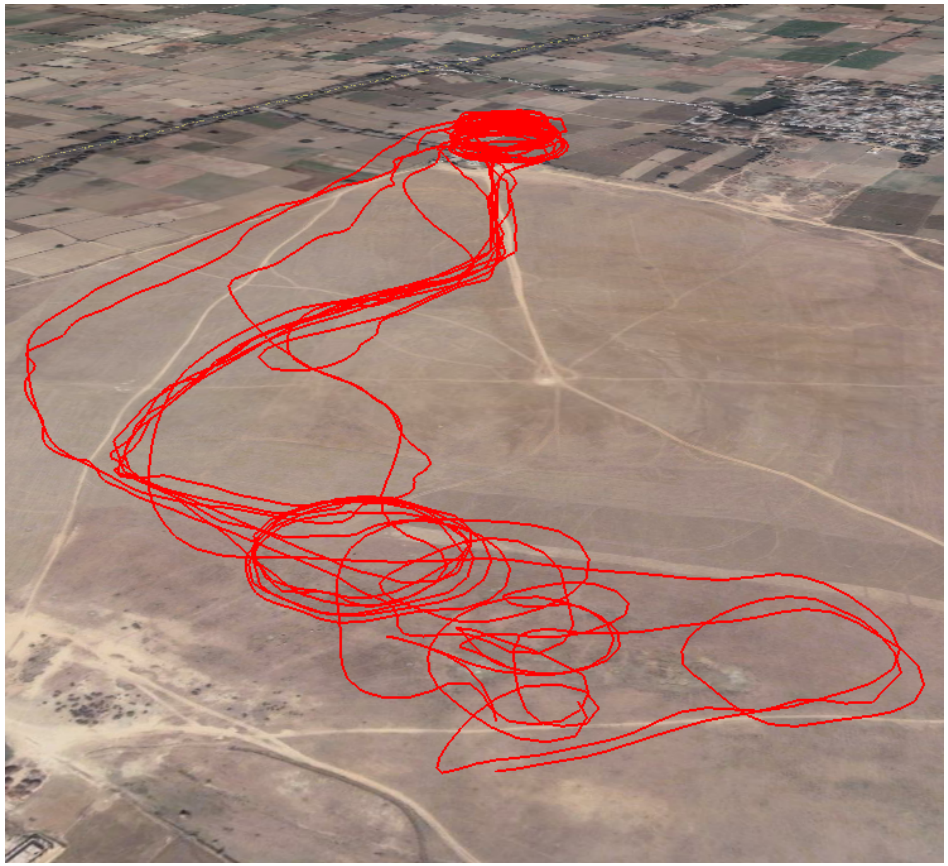

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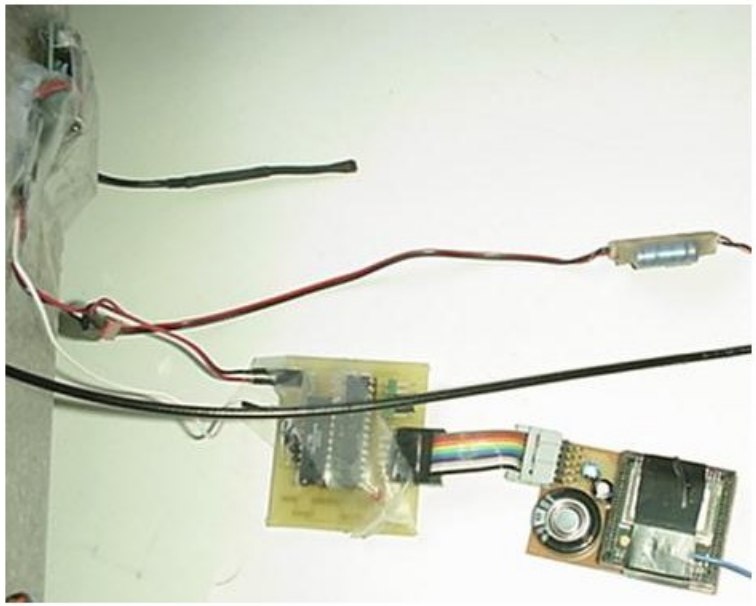
History of the Project

2003



History of the Project

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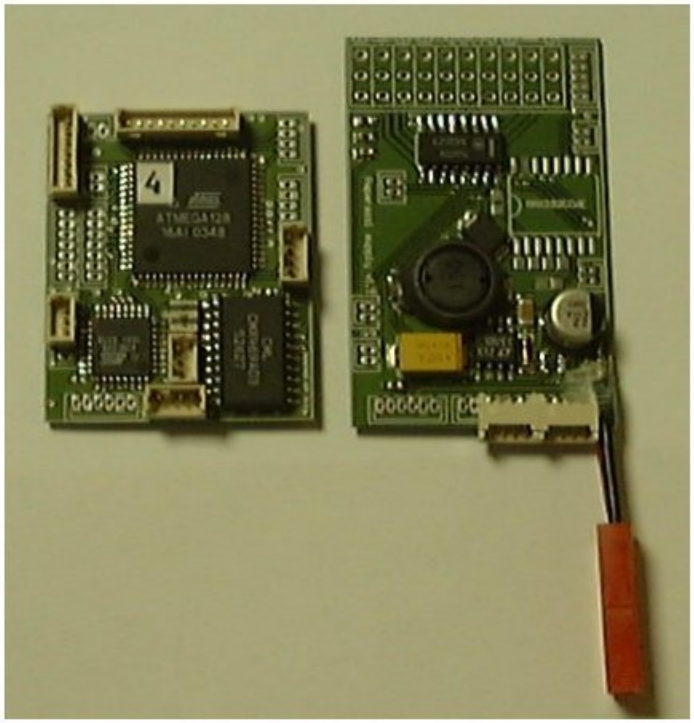

History of the Project

2005

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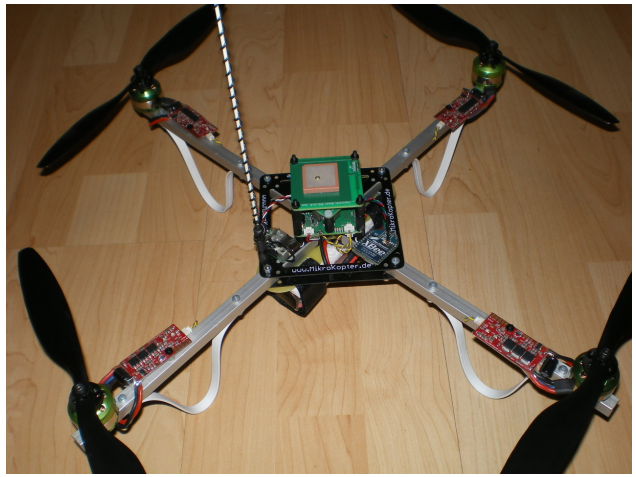
2006

History of the Project

2007

History of the Project

2008



History of the Project

2009

Paparazzi: The Free Autopilot

paparazzi.enac.fr

Goals

- Autonomous flight

Paparazzi: The Free Autopilot

paparazzi.enac.fr

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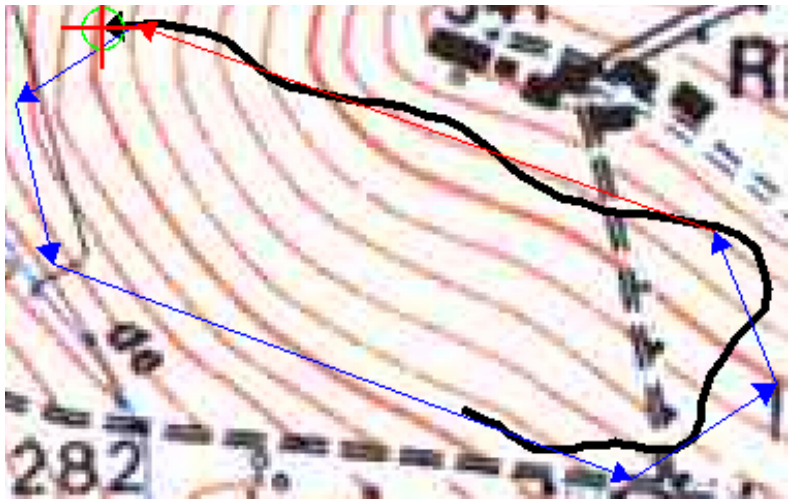
- Autonomous flight
- Safety
- Low cost
- Size
- *Open source*



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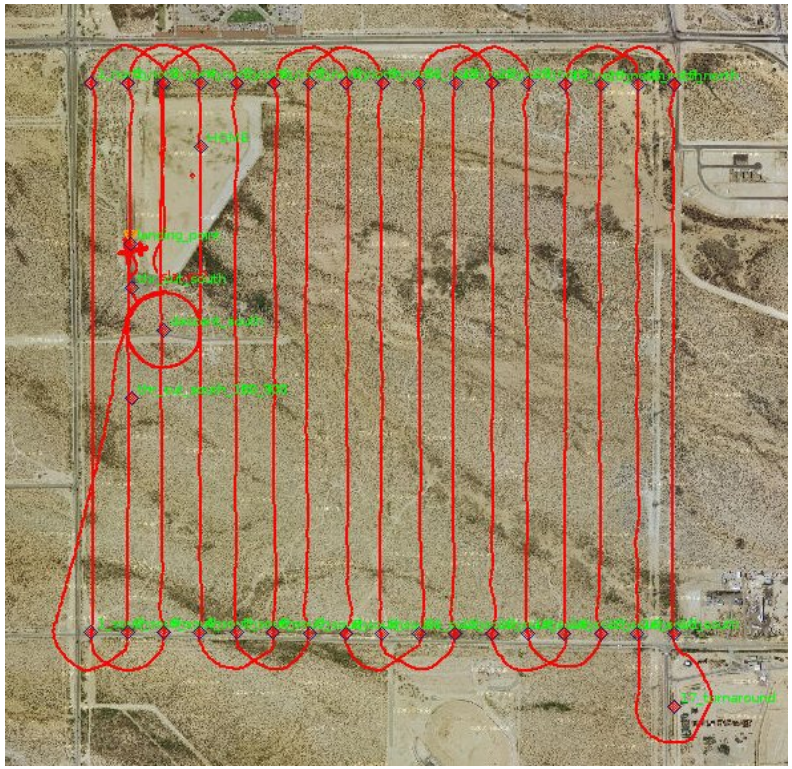

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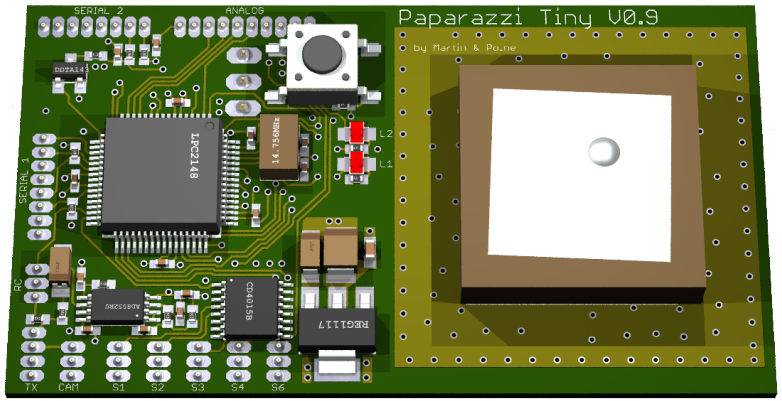

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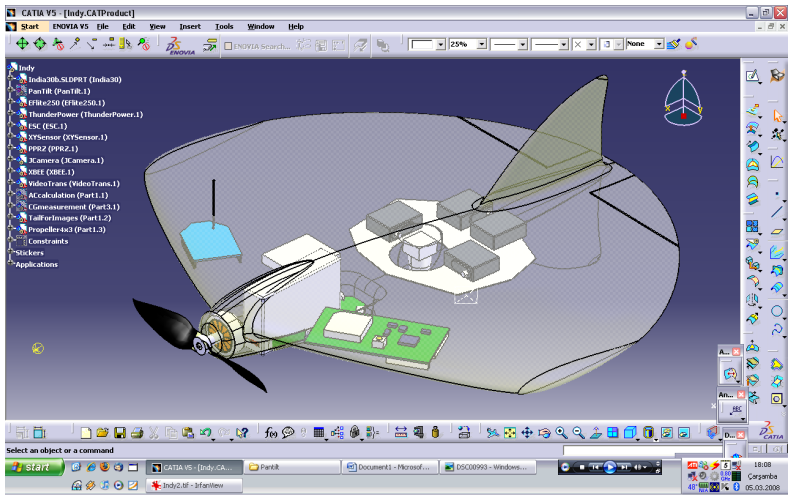

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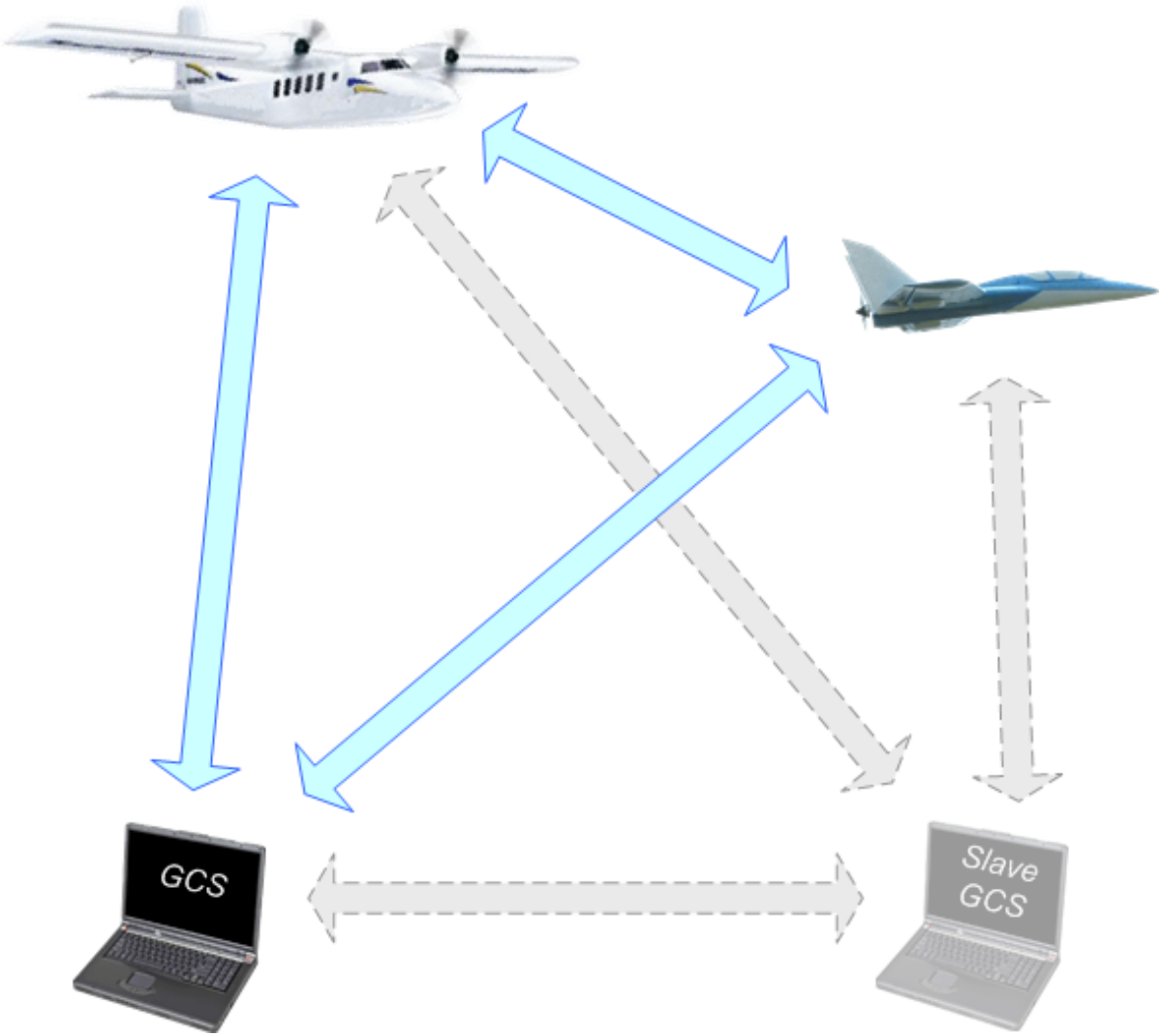
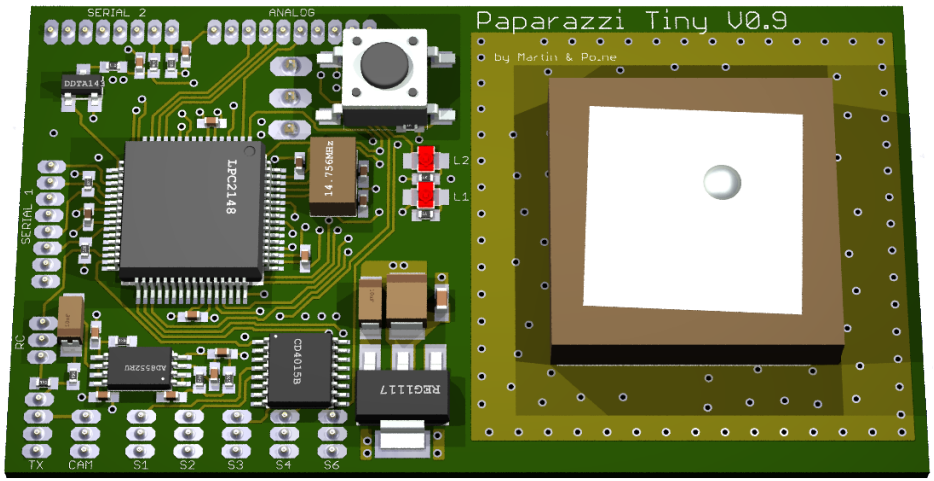
The Paparazzi System



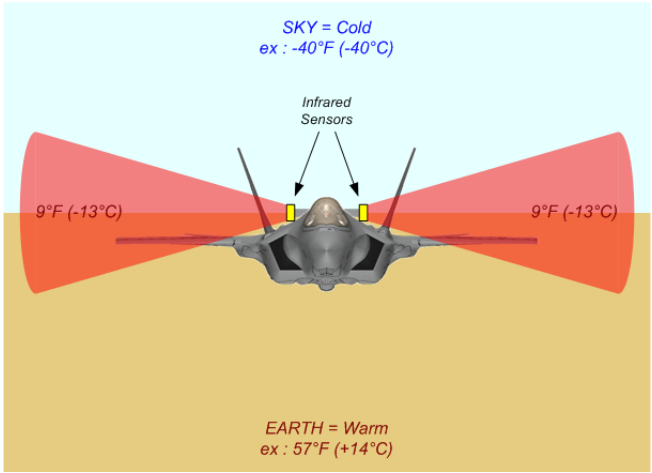
Autopilot

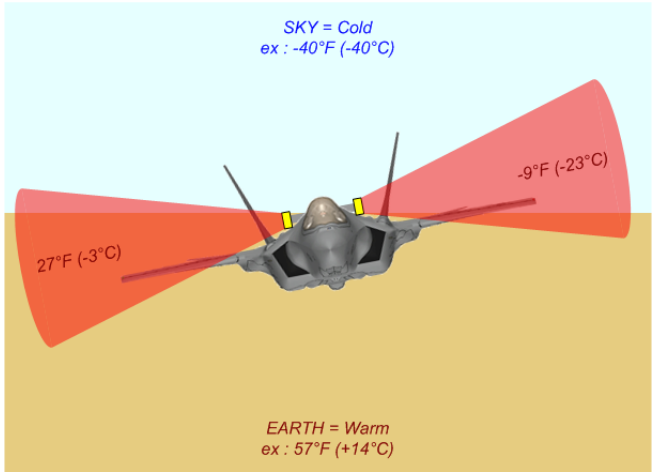
- Processor
- GPS
- Power supply
- 20g



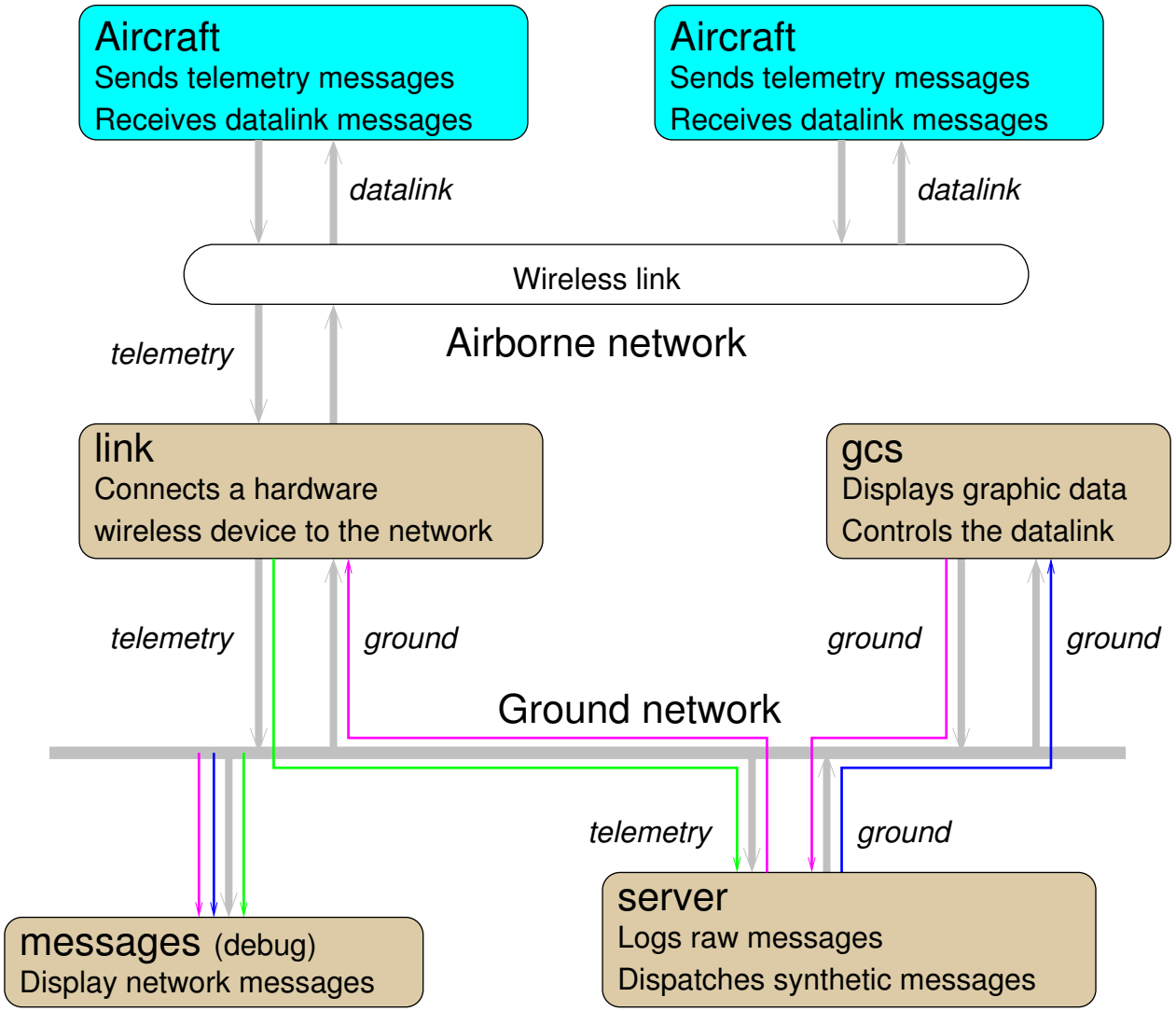
Stabilisation

Attitude Estimation with Infrared

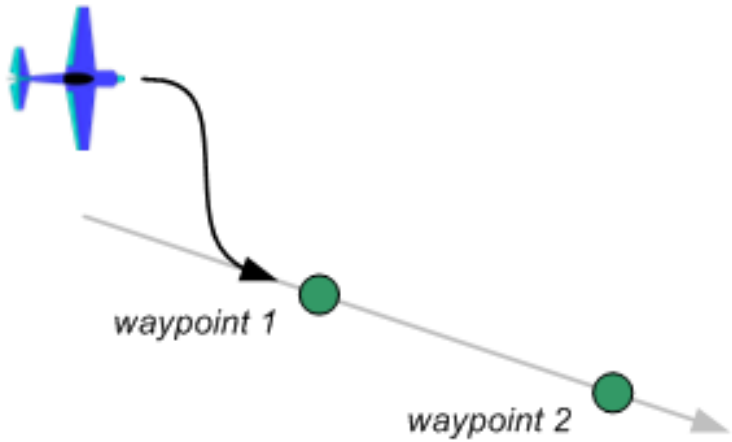




Distributed System



Flight Plan



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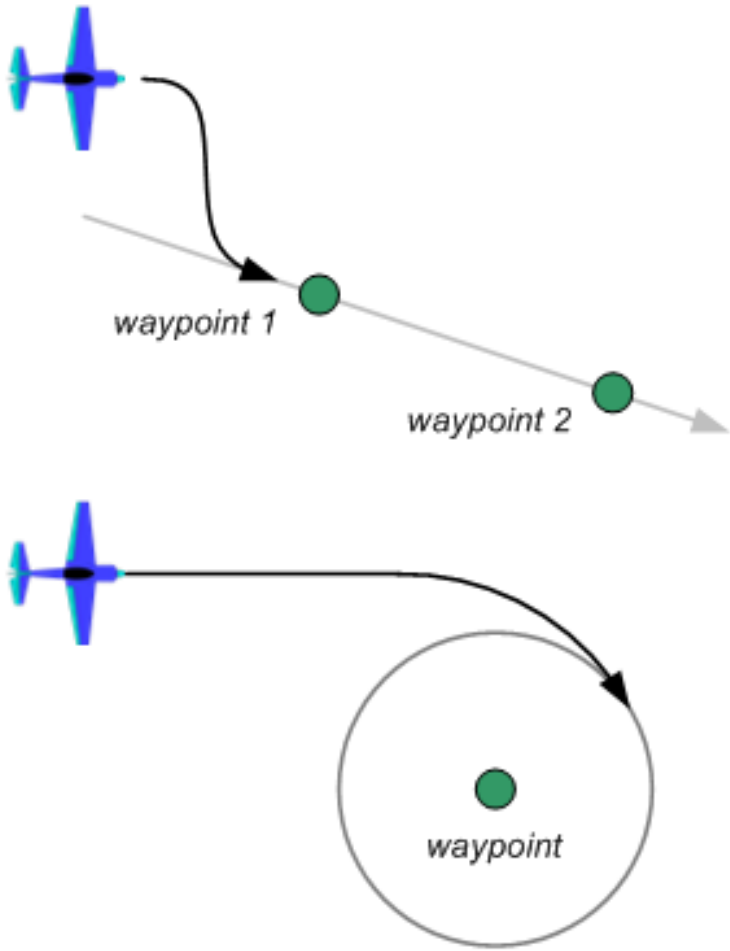

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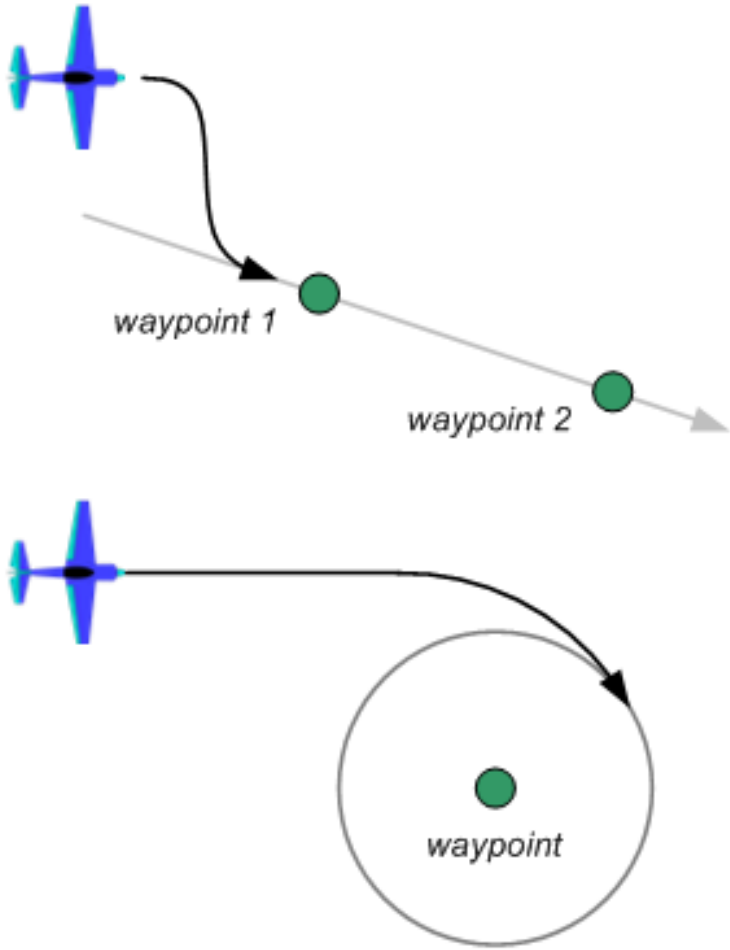

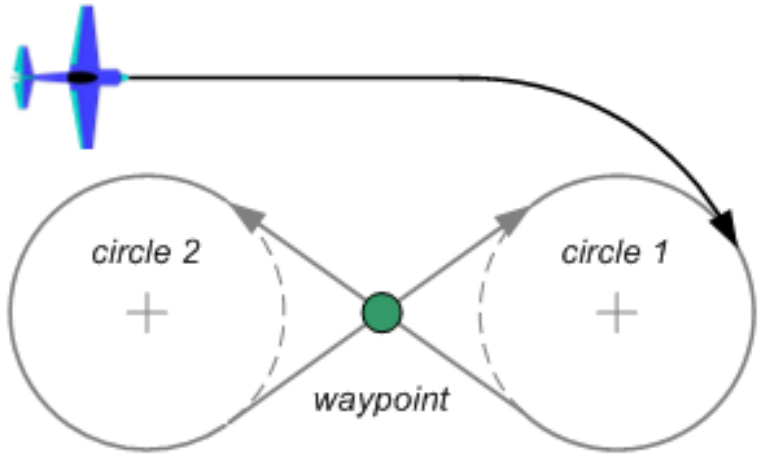

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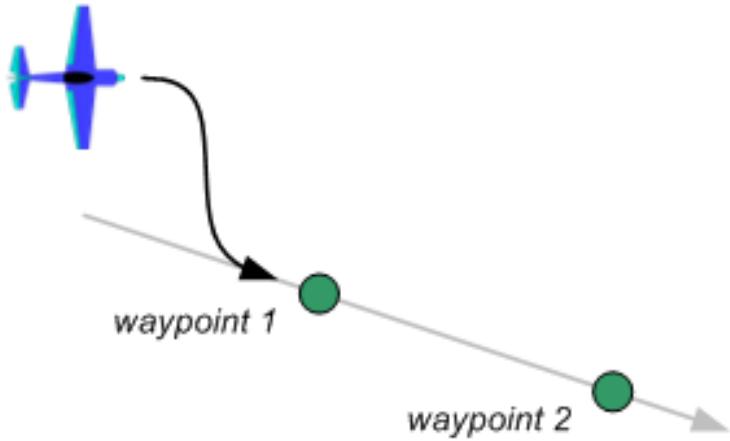

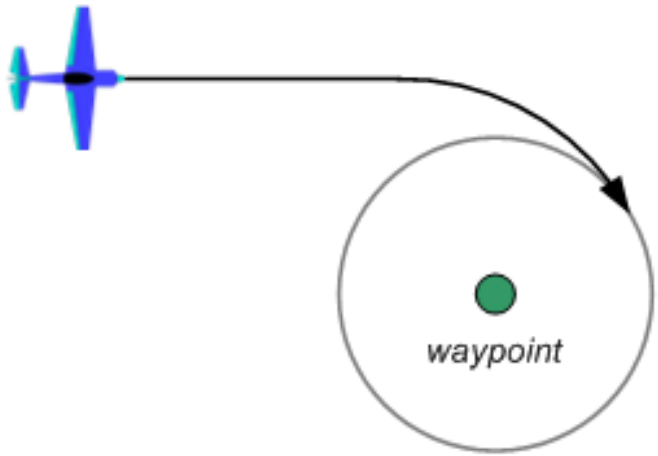

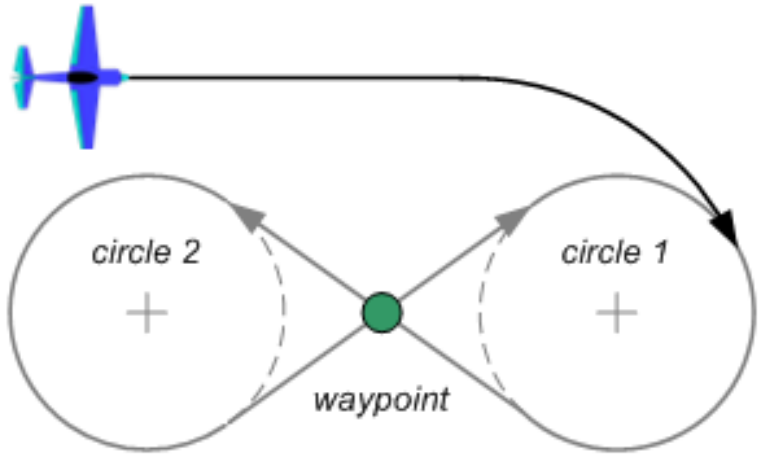

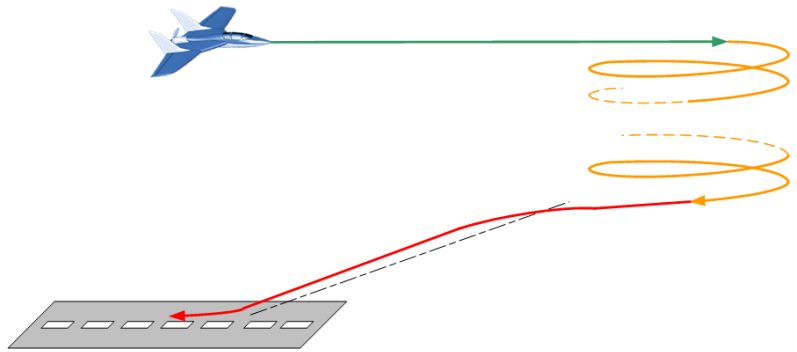

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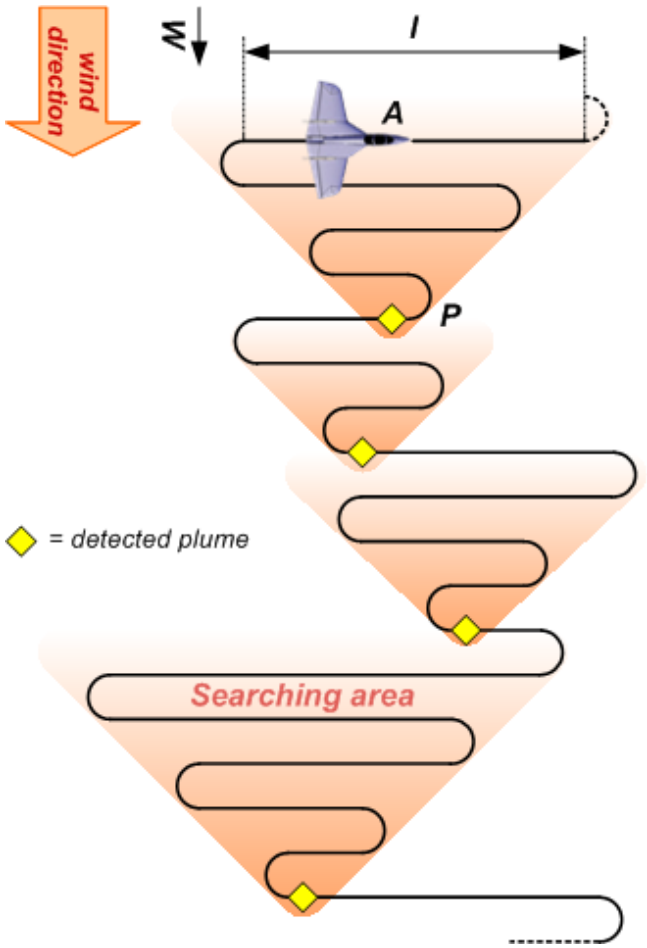
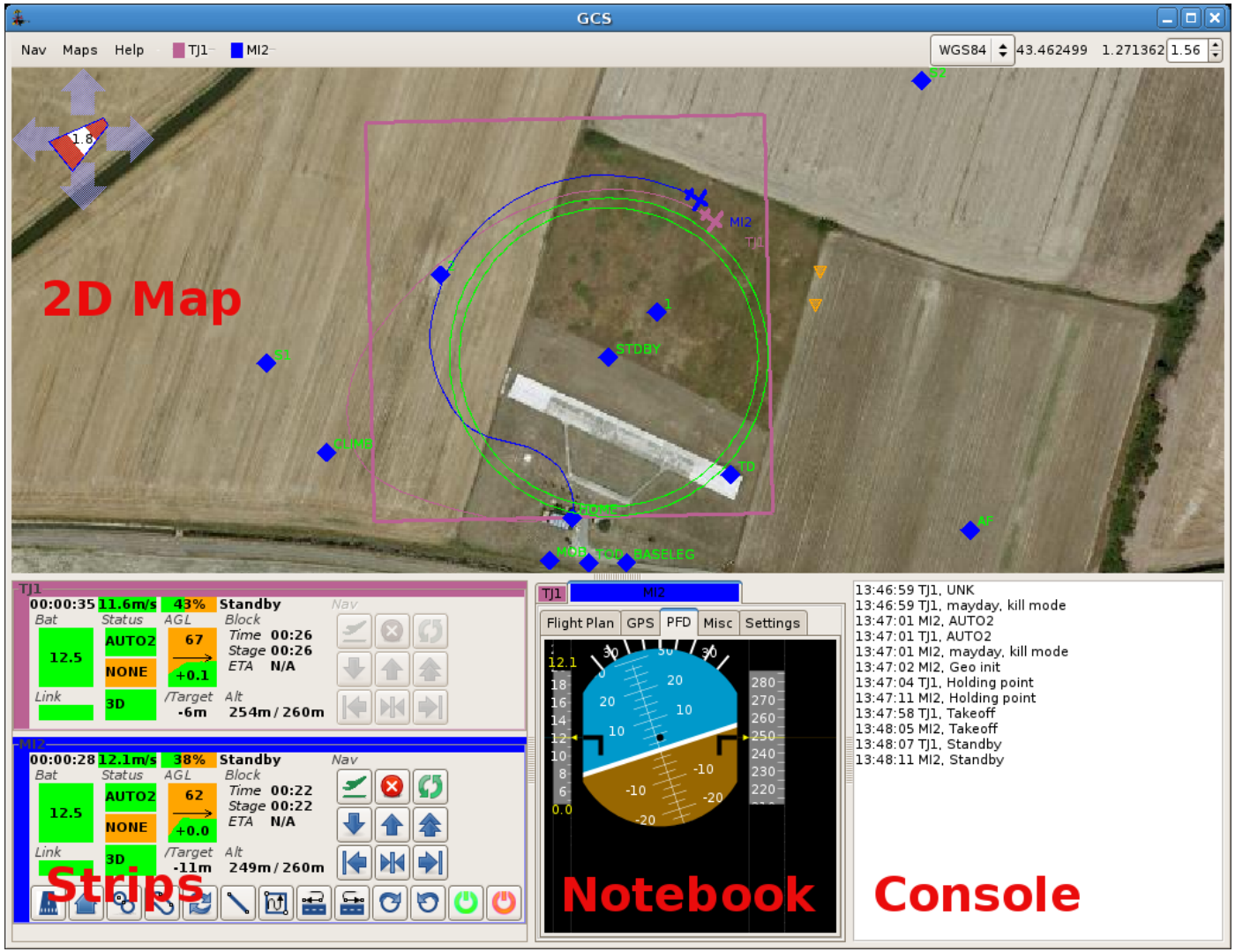


A Versatile Interface



To be free (or not to be)

Software

- GNU/Linux Debian and Ubuntu
- GCC for x86, AVR, ARM...
- OCaml compiler, runtime and libraries (XML, network...)
- GTK Toolkit (OCaml bindings), glade generator
- Ivy software bus
- Subversion
- Mediawiki

Hardware Design

- Eagle (freeware and academic licence)
- Protel

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Paparazzi Contents

What Paparazzi makes available, under GPL:

- Source code (C, OCaml, XML...)
- Board schematics and layout (Eagle, Protel and Gerber formats)
- Documentation (GNU FDL)

How:

- Subversion server (`svn.savannah.gnu.org`)
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MAV Competitions

- JMD03, Toulouse, France: 1st place with the Twinstar
- EMAV04, Braunschweig, Germany: 1st place with the Microjet
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- MAV05, Garmisch, Germany: 4 Paparazzi teams at the first 4 places
- EMAV06, Braunschweig, Germany : all the teams were equipped with Paparazzi
- MAV06, Sandestin, Florida: 2nd and 3rd places
- MAV07, Toulouse, France: 1st place (tie), 3rd, 4th and 5th places
- MAV08, Agra, India: Tie
- Concours DGA 08-09: 1st with a quadrotor
- IMAV09, Pensacola, Florida: 1st place (ISAE)
- AUVSI (Students), Maryland: 1st place (Utah State University)

Martin Müller Engineering, Germany

Martin Müller is one of the main contributors of the project.

Active since 2004

- MAV05
- Iceland, 2007
- Spitzberg, 2008
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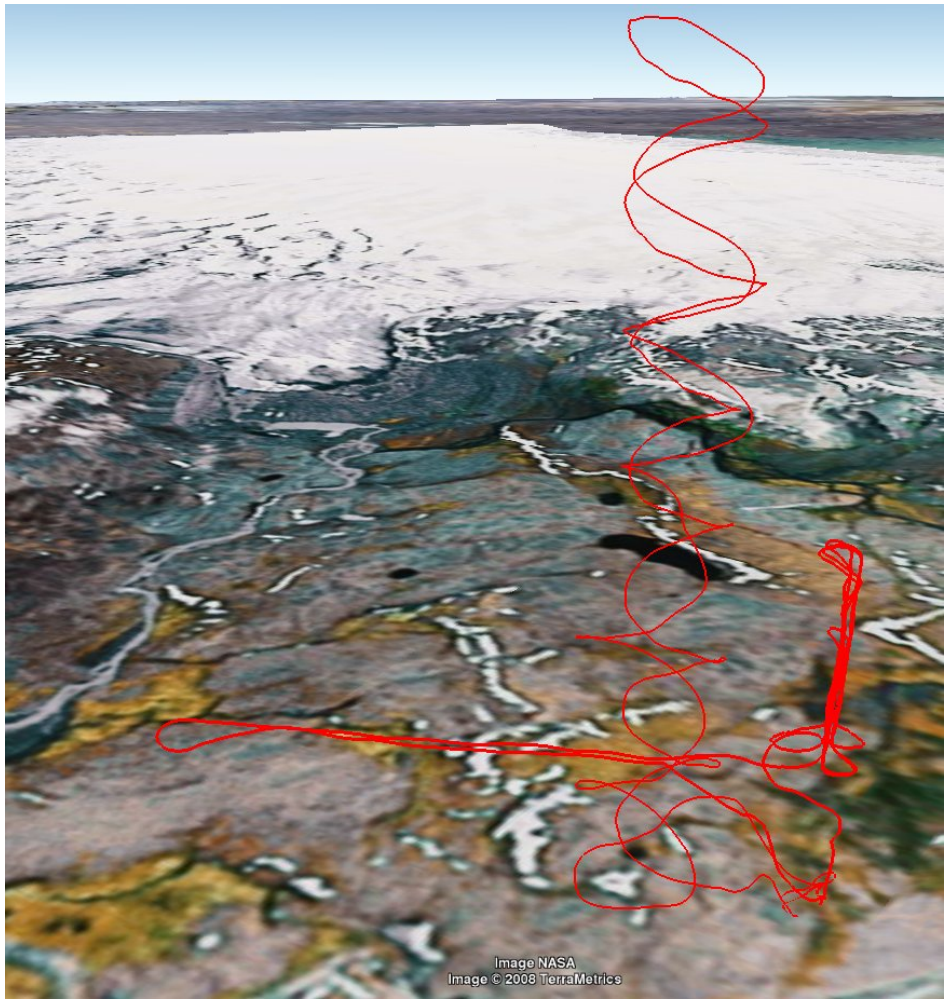

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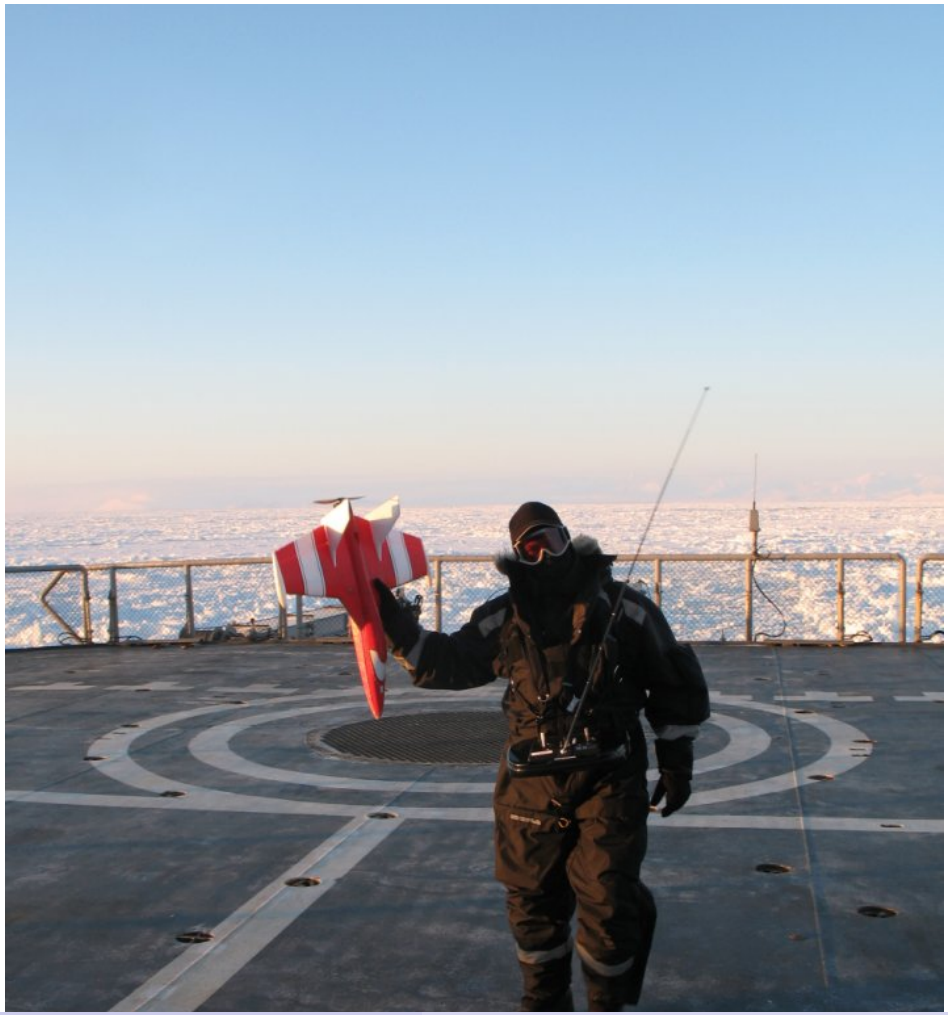

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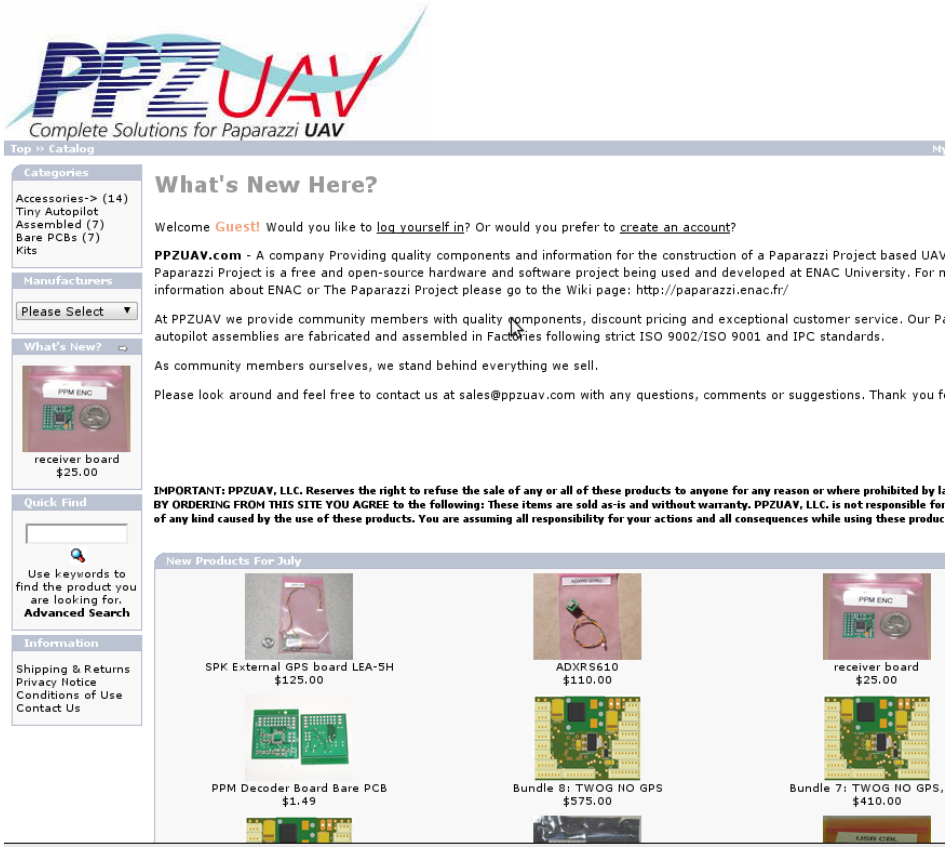
Hardware Providers

http://ppzuav.com



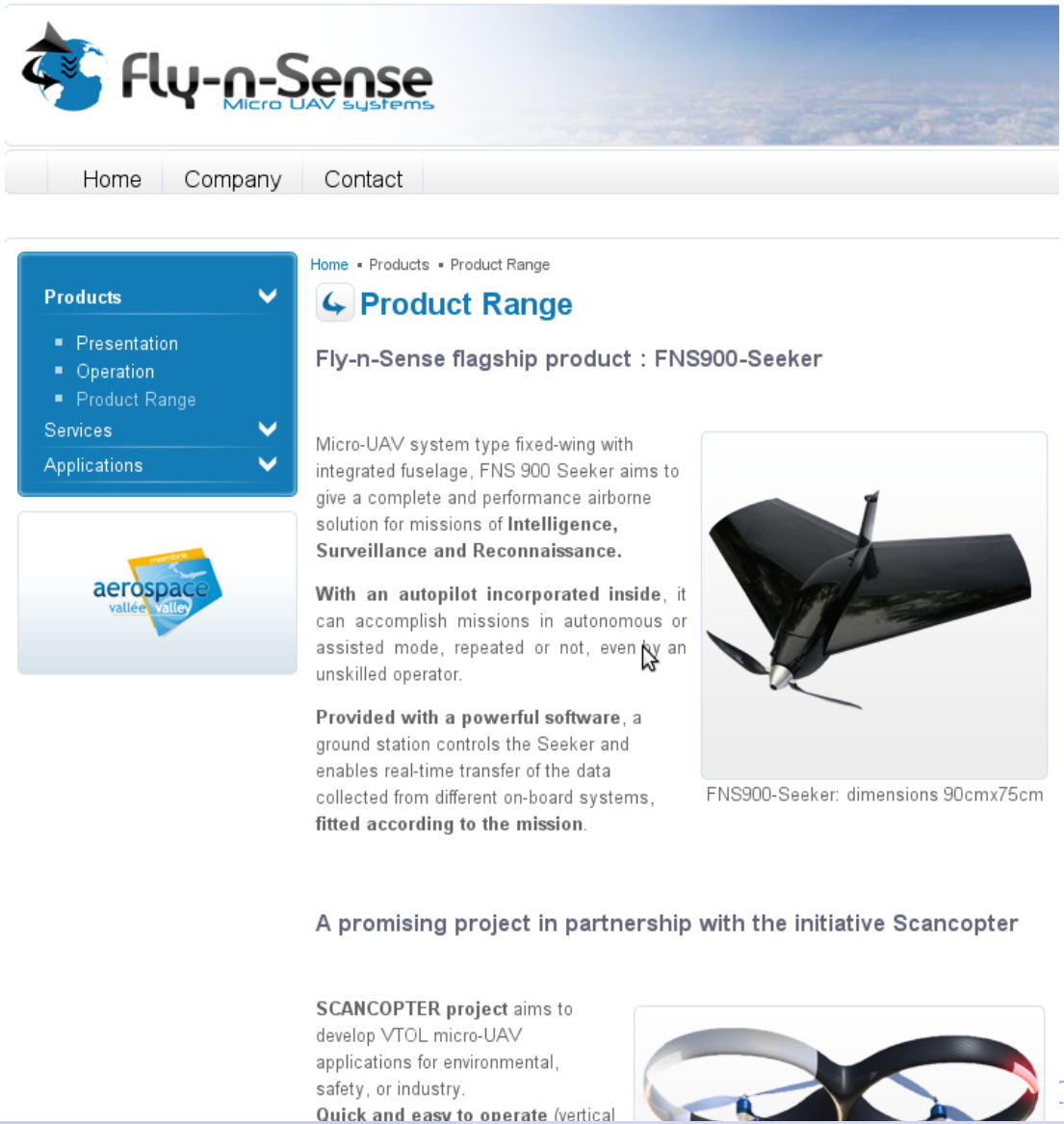
http://chebuzz.com/paparazzi

Fly'n'Sense, Bordeaux, France

http://www.fly-n-sense.com/

A company which

- is using the Paparazzi autopilot;
- got training from ENAC;
- is selling a micro UAV system;
- sells service and consulting.



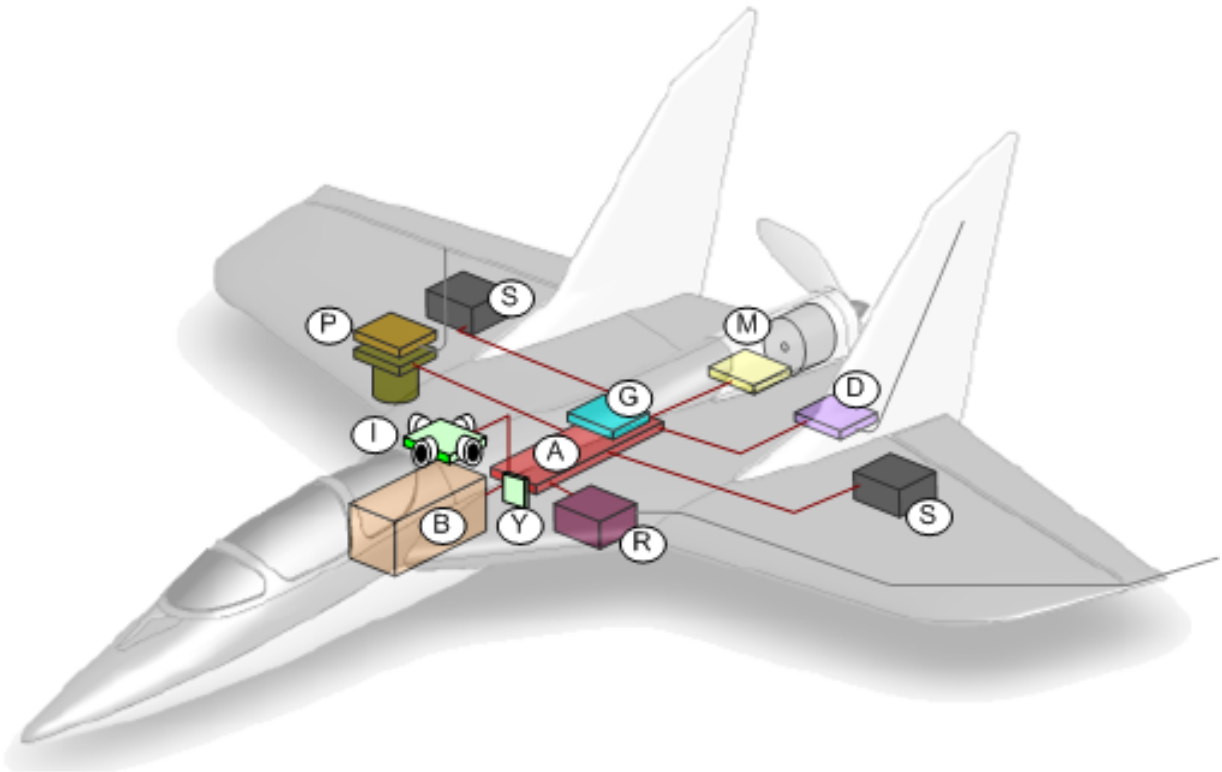
Thalès Robotics, France

- Got a contract with ENAC in 2005
- Demonstate a Paparazzi Aircraft in 2008
- Advertize it at the Paris Air Show in 2009

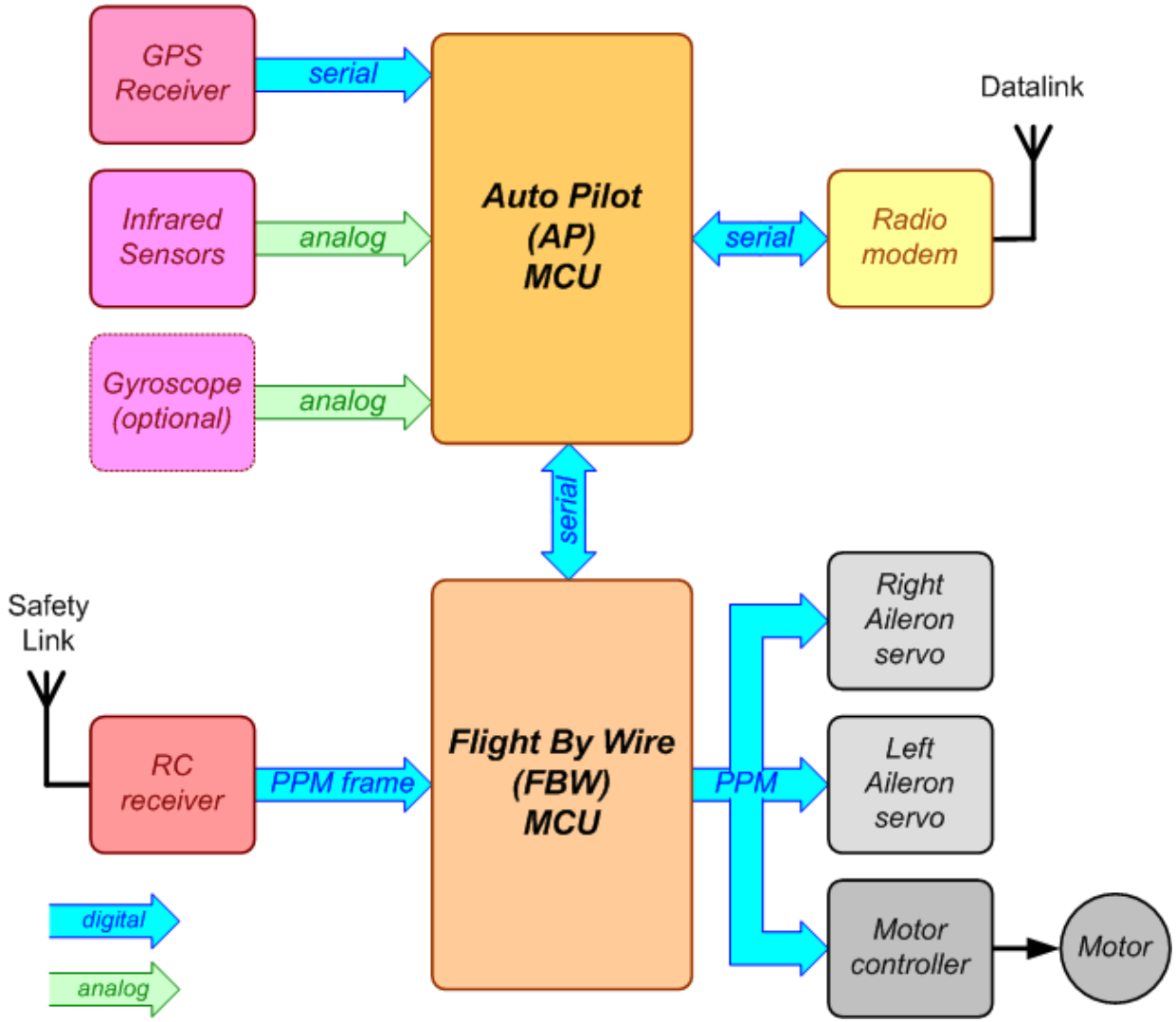
(from `http://newton.ee.auth.gr/aerial_space/docs/CS_4.pdf`)

Airborne Components

A **utopilot**
B attery
D **atalink**
G **PS**
I **nfrared**
M otor
P **ayload**
R eceiver
S ervo
GY **ro**



Airborne Hardware

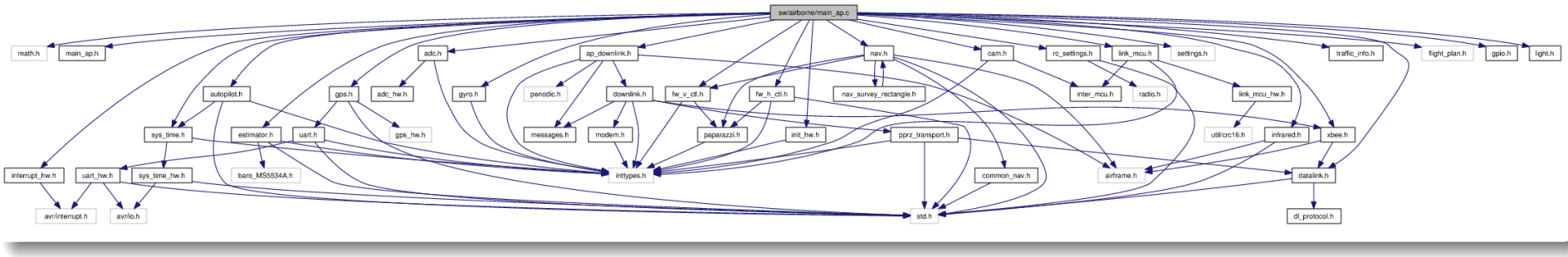


Size does matter?

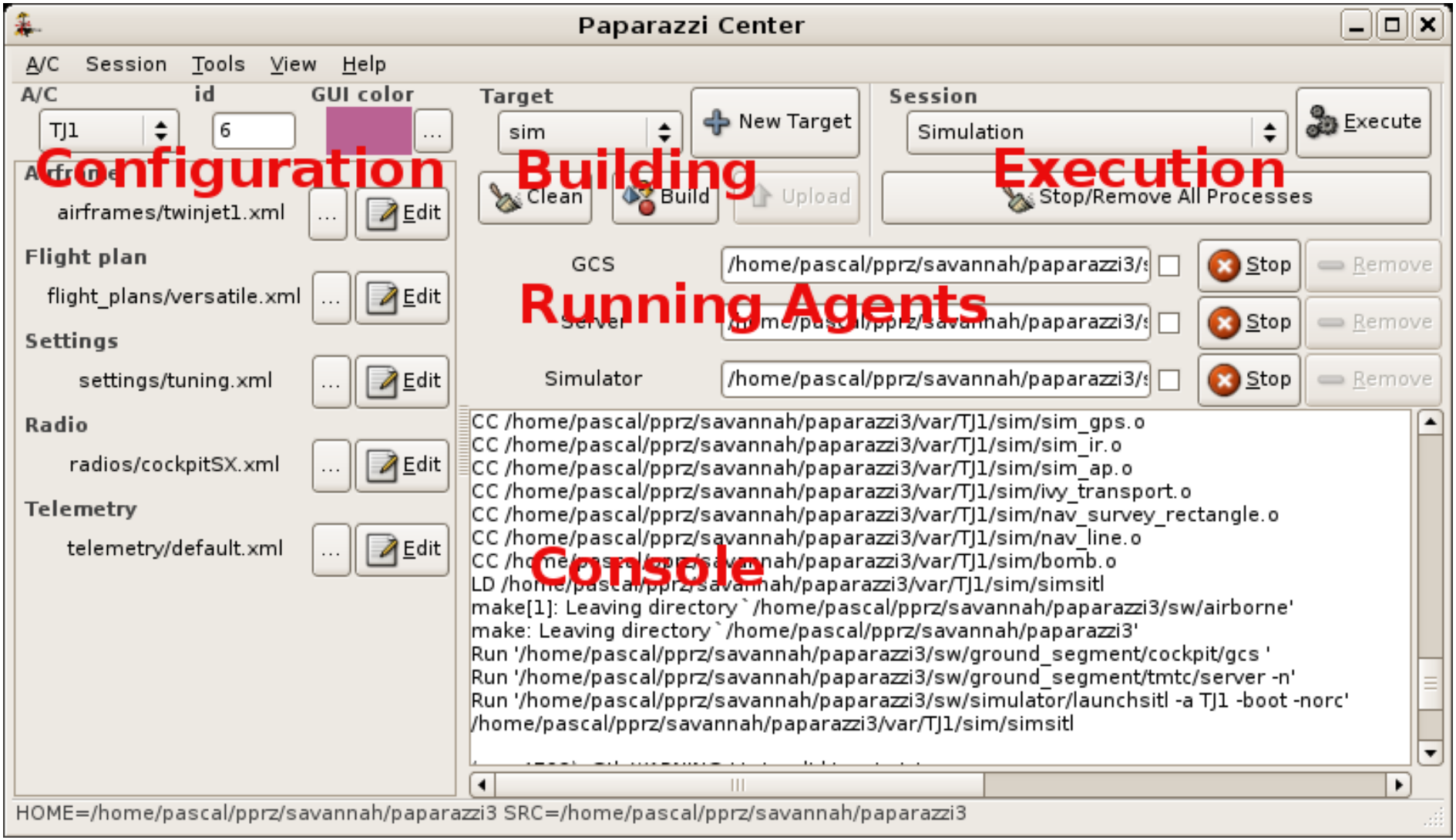
Line, Word and Char Counts

```
pascal@debian:airborne% wc *.[ch] arm7/*.[ch]
24491   84360 688041 total
```

Dependencies



Configure, Compile, Upload and Run



Flight Plan

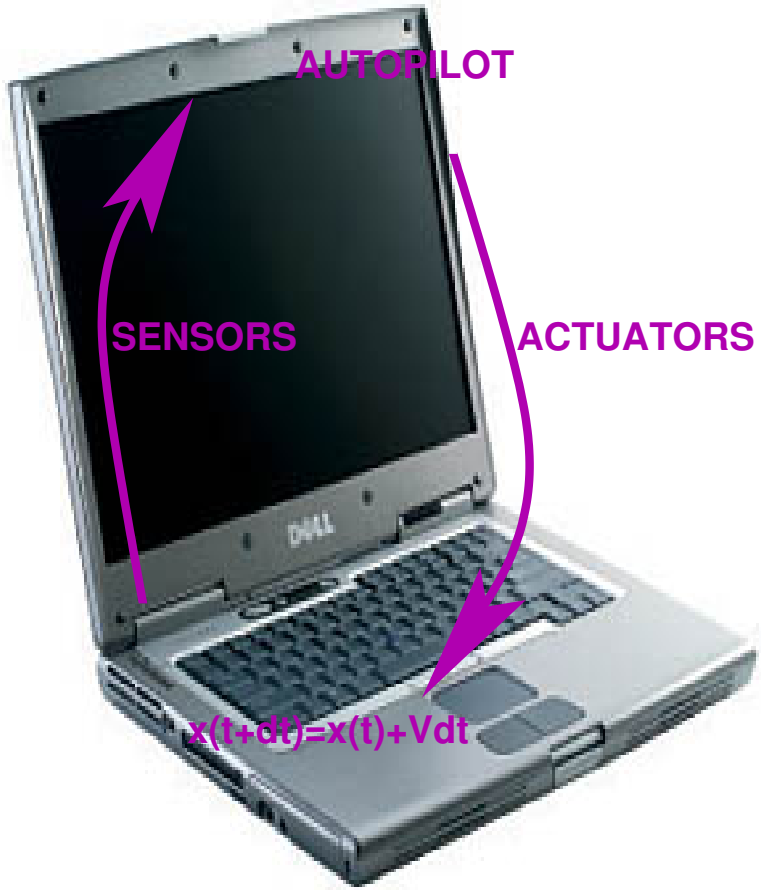
Three Elements

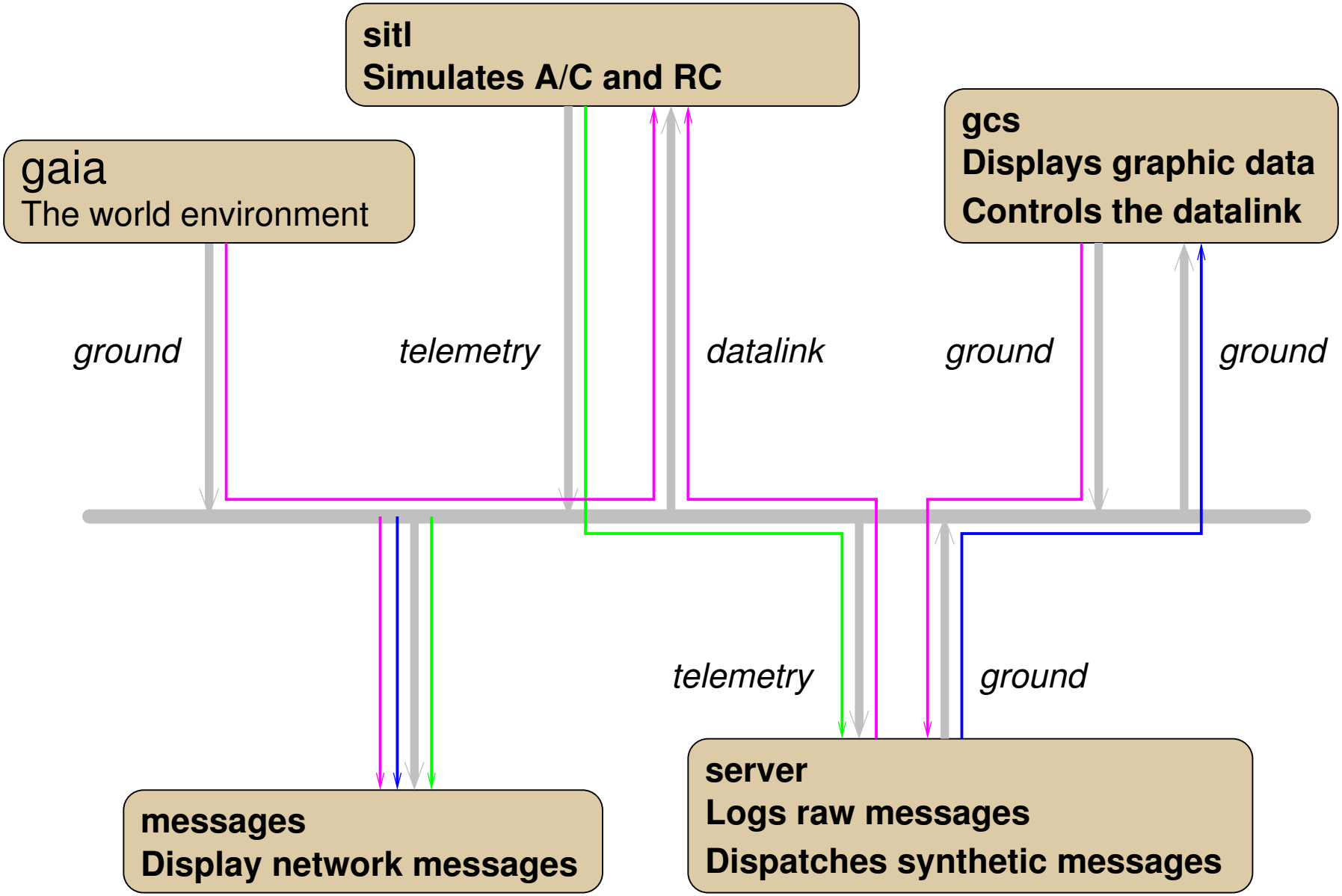
- Header: Localization
- Waypoints
- Blocks: sequences of instructions

```
<flight_plan name="Muret" lat0="43.46223" lon0="1.27289"
             max_dist_from_home="300"
             ground_alt="185" security_height="50" alt="250">
  <waypoints>
    <waypoint name="HOME" x="0" y="0"/>
    <waypoint name="AIRWAY" x="80" y="20" alt="185"/>
    ...
  </waypoints>
  <blocks>
    <block name="cercle"><circle radius="100" wp="HOME"/></block>
    <block name="glide12">
```

Software In The Loop Simulation

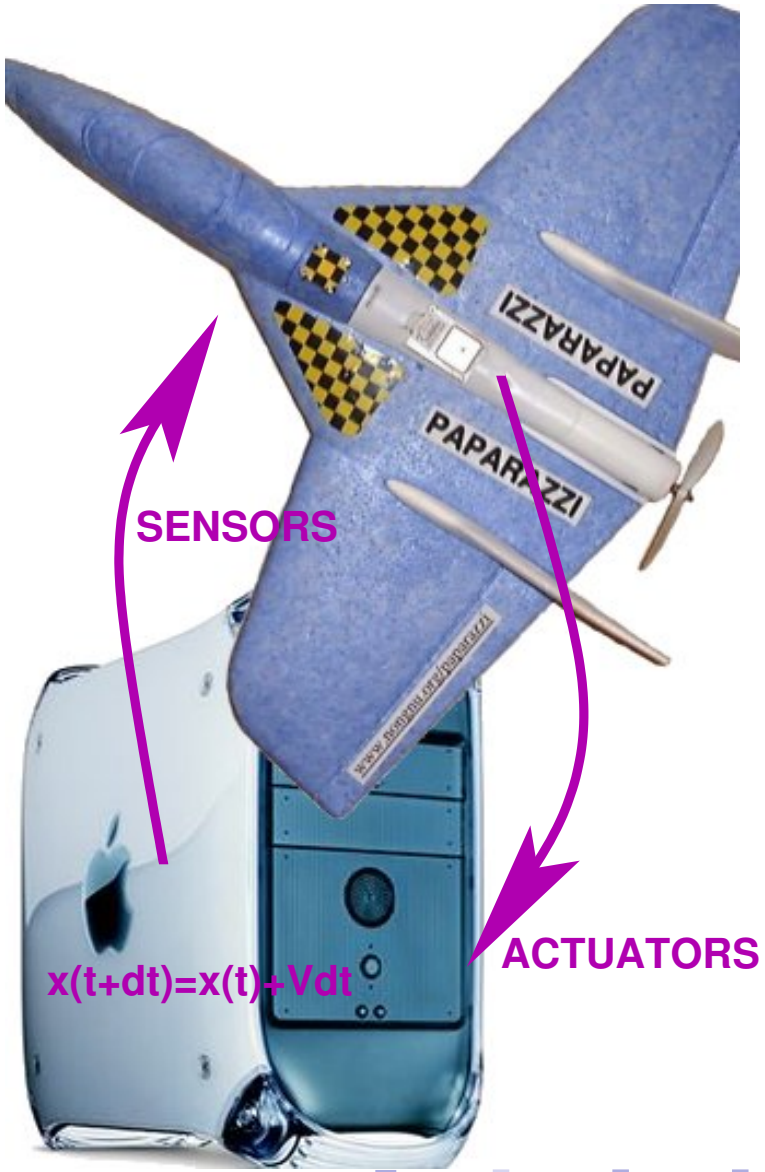
- Autopilot compiled for the x86 host
- Simulator
  - Flight Model
  - Sensors
  - Actuators

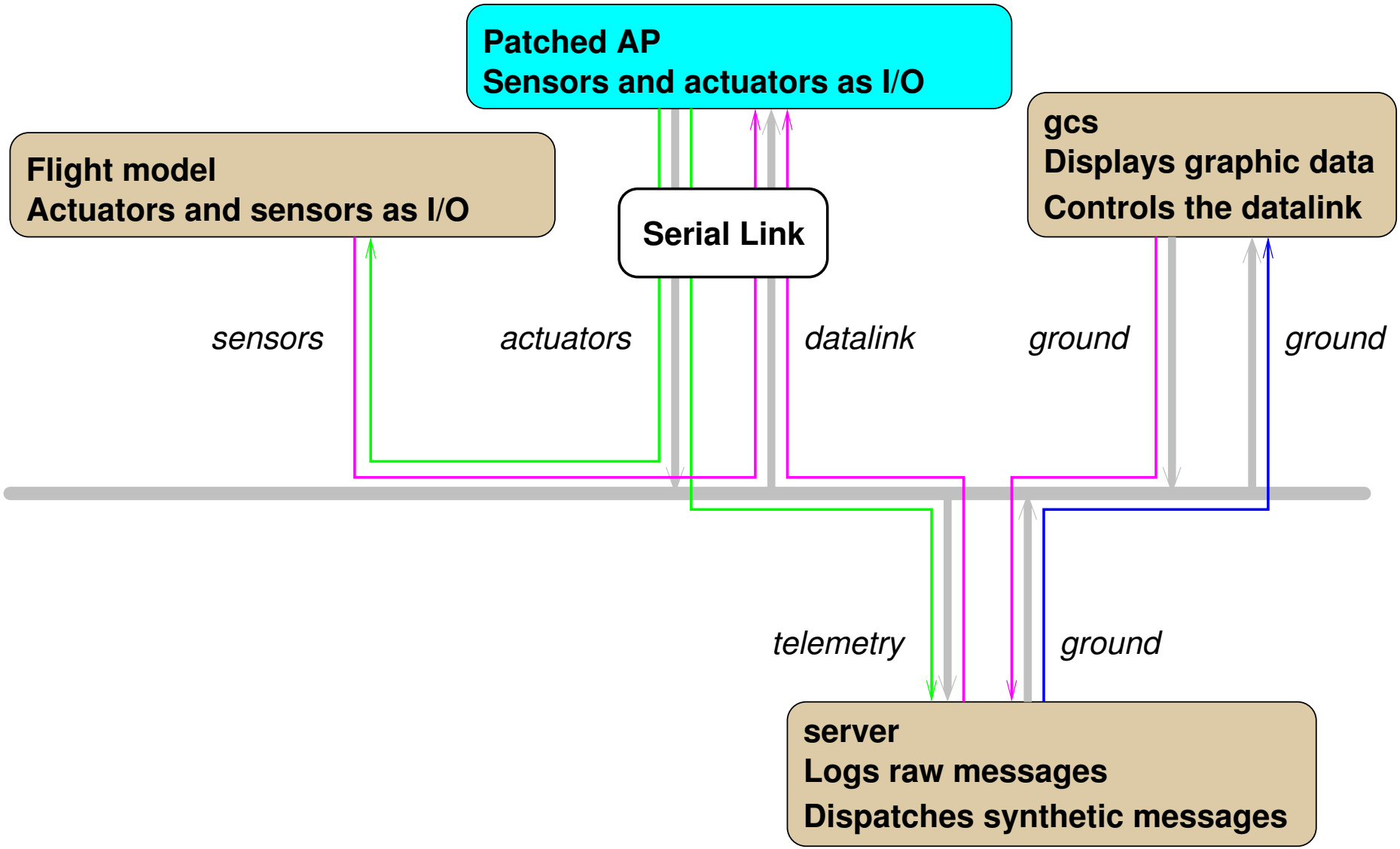



sitl
Simulates A/C and RC
gaia
The world environment
gcs
Displays graphic data
Controls the datalink
ground
telemetry
datalink
ground
ground
telemetry
ground
messages
Display network messages
server
Logs raw messages
Dispatches synthetic messages

Hardare In The Loop Simulation

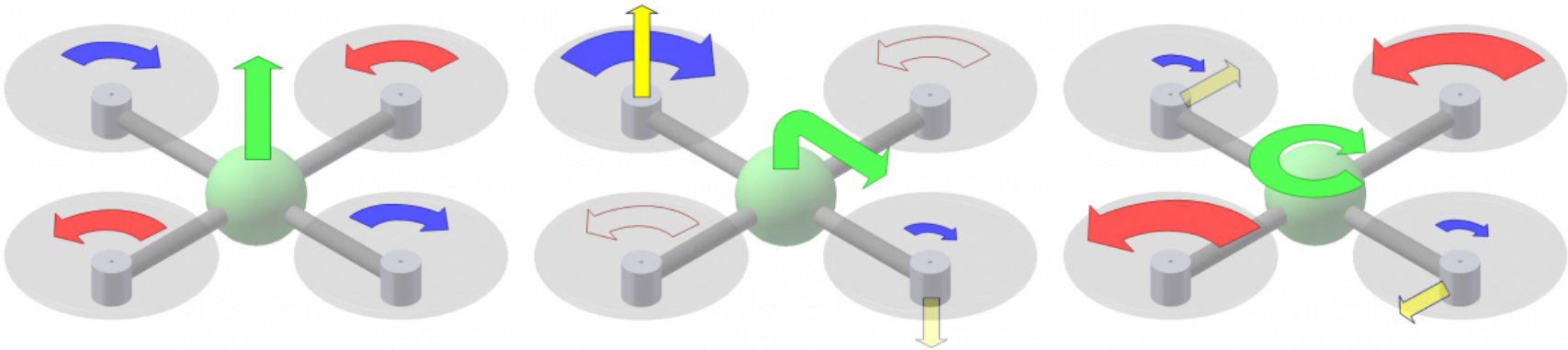
- Autopilot running on airborne hardware
- Sensors replaced by serial input
- Actuatos replaced by serial output
- Simulator




Patched AP
Sensors and actuators as I/O
Flight model
Actuators and sensors as I/O
Serial Link
gcs
Displays graphic data
Controls the datalink
sensors
actuators
datalink
ground
ground
telemetry
ground
server
Logs raw messages
Dispatches synthetic messages

Flight control principles

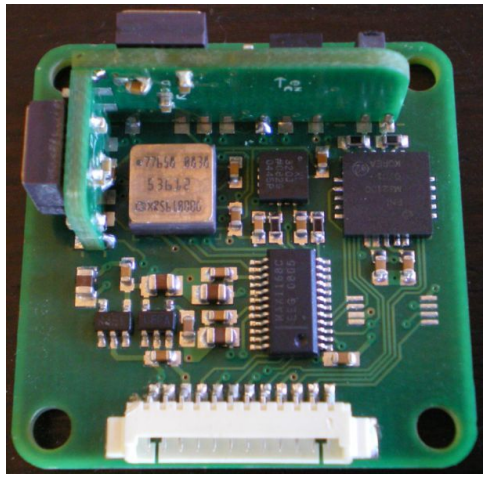
- No mechanical parts except motor propellers
- Control is achieved only by changing the motors' speeds



State Estimation

Attitude estimation

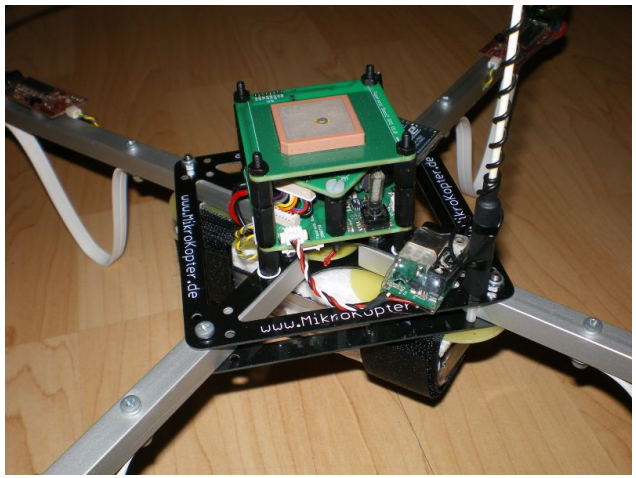
- Infrared sensors are not fast enough and can't be used indoor
- Inertial Measurement Unit (IMU) is needed but requires filters to estimate the attitude
- Gyroscopes and accelerometers are fused with a complementary filter
  - Gyro integration is fast but has a drift
  - Accelerometers measure the gravity and correct the drift



State estimation

Position and heading estimation

- Horizontal position and velocity : GPS receiver
- Altitude : barometer and accelerometers integrated with a Kalman filter
- Heading : complementary filter between gyroscopes and magnetometers



Navigation

Use existing interfaces

- Same flight plan mechanism
- Same GCS for all aircraft
- Most of the procedures are available for quads (waypoint, circle, segment, +hovering)

Performances

- Endurance : 10 to 20 min
- Weight : 450 g, payload : 200 to 300 g
- Horizontal speed : 5 m/s controlled, 10 m/s max
- Vertical acceleration : 3g up, 1g down
- Horizontal accuracy : 5 to 8 m
- Vertical accuracy : 10 cm with important drift ! (several meters)
- Wind : flies with 10 m/s of wind but autonomous navigation abilities greatly reduced

Flying Autonomously in a Few Steps

1. Get and build a model aircraft (airframe, servos, motor, controller, radio receiver, radio transmitter)

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6. Upload the airborne code, start and throw
7. Have a drink while looking at the GCS

Thanks

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