Aerial Magnetic Sensing with an UAV helicopter

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Outline

- Introduction
- UAV flight system & sensor integration
- Mission planning & waypoint generation
- Aerial magnetic sensing: initial flight tests
- Aerial magnetic sensing after landslide
- Summary

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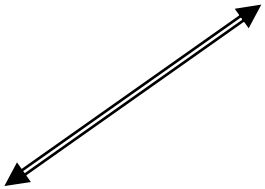
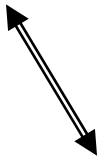
Networking

Lucerne University:
- Mobile data acquisition system
- GPS time synchronization





Aeroscout GmbH:
- UAV system Scout B1-100
- Mission/waypoint planning
- Field experiments

Mobile Geophysical Technologies:
- Sensor data requirements
- Field experiments
- Magnetic data post-processing

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Aeroscout Scout B1-100

Main technical data:

- Main rotor diameter **3.2 m**
- Empty weight **44.0 kg**
- Payload **33.0 kg**
  (incl. fuel, FCS, batteries, gimbal, laser, magnetic sensor, etc.)
- Fuel engine (2 stroke) **100 ccm**
- Cooling system **air-cooled**
- Engine power (approx.) **18 PS**
- Construction **aluminum/ carbon**
- Max. flight duration **~90 min**

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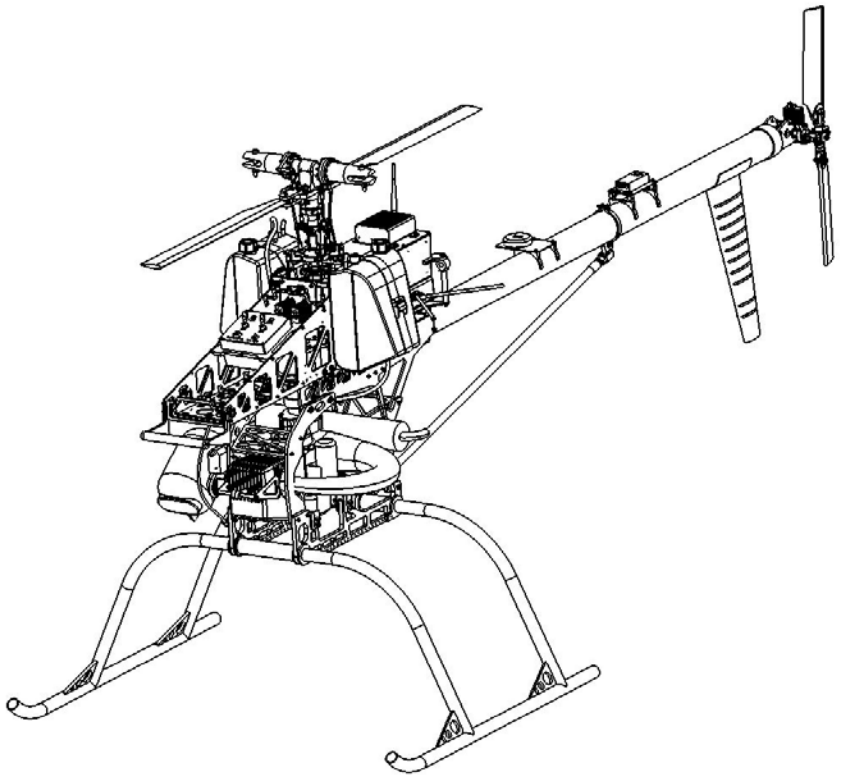
Scout B1-100 UAV Helicopter



Demonstrated Performance

- 1.5h hover flight out of ground effect with maximum payload
- GCS for mission planning and mission monitoring
- Fully automatic lift-off
- Assisted flight mode (joystick mode)
- Mission flight (GPS coordinates)
- Automatic homing flight (e.g., mission interrupt or if data link loss)
- Automatic landing and shut-down of engine (e.g., if data link loss)

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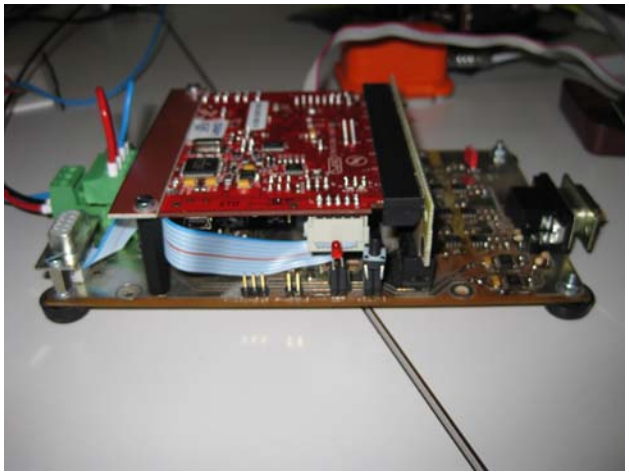
Magnetic Data Acquisition Unit



Main requirements:

- continuous highly sensitive magnetic sensor data acquisition with user defined sampling rate
- time synchronization with GPS sync signal (1 PPS)
- onboard data storage (SD slot)
- LED status display on the field (e.g., idle, acquire, storage, translate)
- parallel IMU data acquisition for magnetometer attitude information (e.g., separate RS-232 port)

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System Integration „Magnetic“

Installed components:

- Inertial measurement unit
- (D)GPS receiver
- **Data acquisition module**
- **Magnetometer module**
- Computer board
- Manual backup receiver
- Data link module
- **Flight control system**
- Redundant power supply
- Barometric sensor

(initial flight testing 2010)

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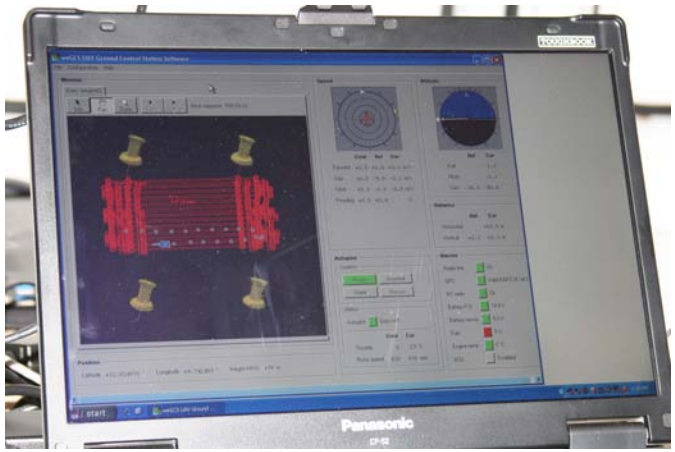
Mission Planning



Main requirements:

- Mission (waypoint) planning should be automated once the flight area is known.
- The magnetic sensor should have almost no or less pendulum movements.
- Movements of the magnetic sensor should be known.
- Altitude of the magnetic sensor above ground should be as constant as possible.
- The magnetic sensor should not rotate around its mounting axis (no cable).
- The distance between to two flight lines should be less than 2m if possible.
- During the sensing process, the flight velocity should be constant.

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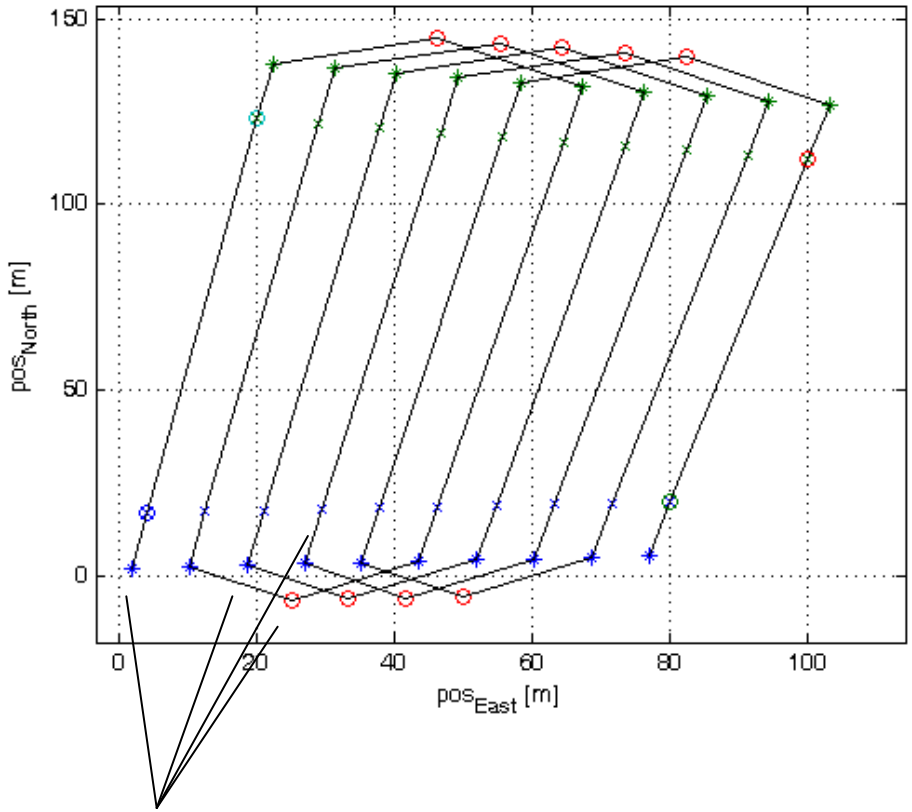
Mission Planning



WP parameter: cruise/stop behavior
speed selection
de/acceleration rate

Initial mission planning:

1. Define flight area.
2. Fill flight area with parallel flight lines.
3. Add curves with reduced flight velocity at the end of each line.
4. Calculate required waypoint list.
5. Export waypoint list to ground control station.
6. Upload mission to onboard flight control system.

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Mission Planning Details

Configuration parameters:

a) Line spacing parameter dB=9m

b) De/acceleration distance dS=15m

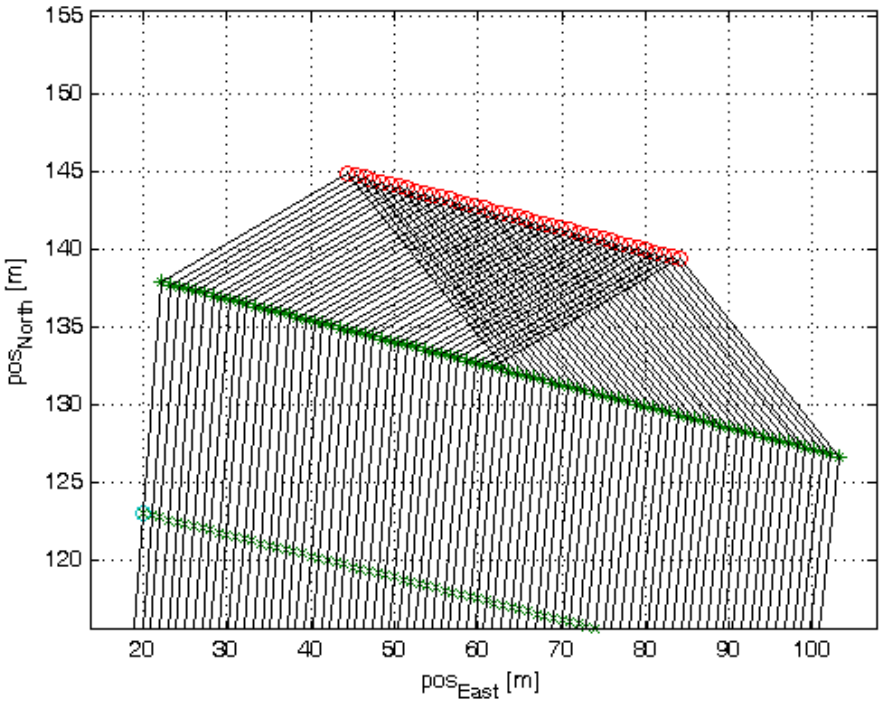
c) Rough turn radius dR=10m

Problem: →

If dB=1m, a substantial part of the flight time is lost during the turn.

Solution:

Further segmentation of the flight area with additional parameter.



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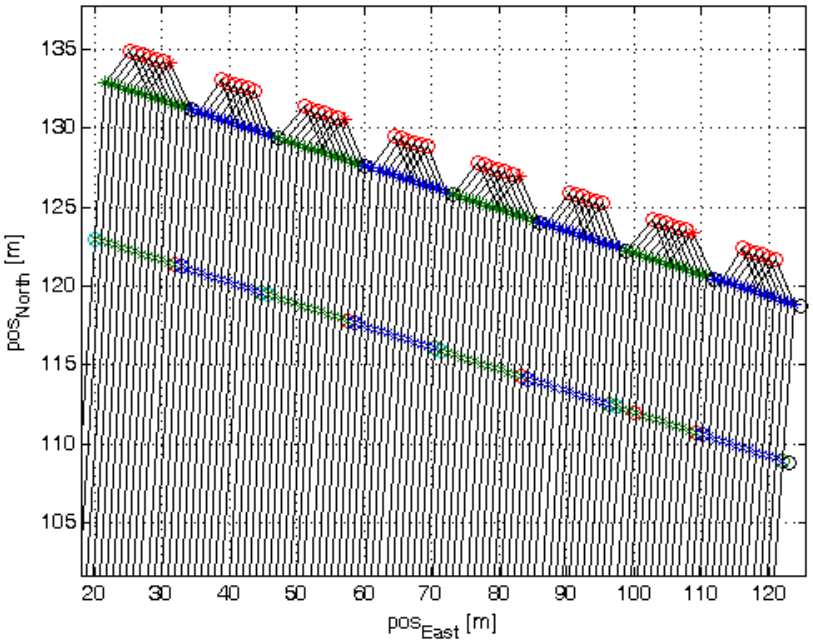
Advanced Mission Planning

Advantages:

a) Flight time spent in not relevant flight area is considerably reduced.

b) The desired magnetic data is collected segment by segment and not over the whole field.

c) Downscaling to very small line spacing dB is possible.



Remaining challenge:

The number of waypoints is very high (in our test case 520).

Solution:

Waypoint handling with a Matlab Script which generates the desired XML waypoint format for the flight control.

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Magnetic Sensing Testing

Flight video:

-Recorded Dec. 2010
-Test field 60x80m
-Outside temp. -7degC
-Wind approx. 3-5 m/s

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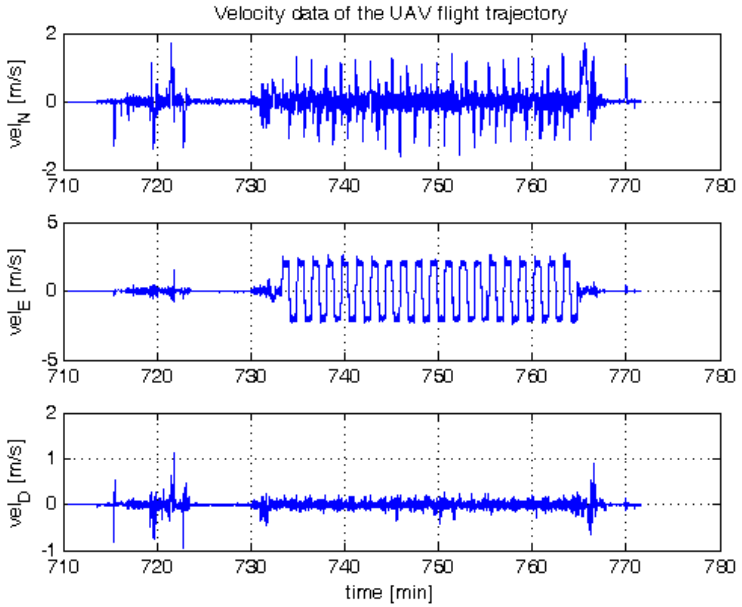
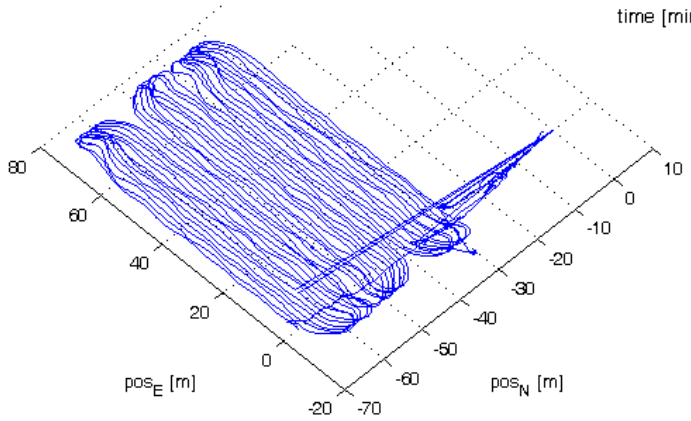
Post-flight analysis





Flight data analysis:

- Very high flight path accuracy (within a few dm).
- Very accurate velocity during magnetic sensing process.
- Less pendulum movements of magnetic sensor.
- Reduced flight velocity in curves avoids oscillations of the mounted magnetic sensor.
- Very precise altitude (DGPS).
- Several magnetic objects could be detected below the surface.

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UAV Magnetic Sensing Applied

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Aerial Magnetic Sensing

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Aerial Magnetic Sensing

General remarks:

- Daylight coal mining completely collapsed and multiple workers have been killed (Turkey, February 2011).
- Initial mining depth 160m, remaining depth about 90m.
- Very difficult flight area (…).
- Exact coordinates of the flight area not available (no “Google Earth”).
- Turkish national and local TV stations report from site.
- Site only accessible with many restrictions.
- Employees/workers with full support and high expectations.

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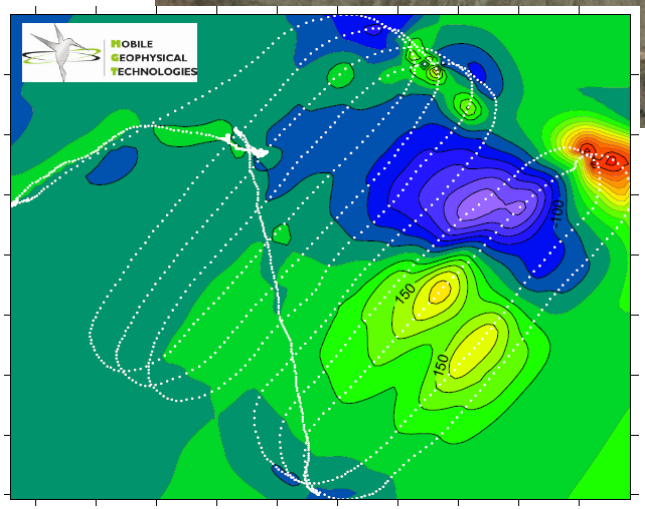
Aerial Magnetic Sensing



Mission summary:

- Demanding mission planning in the field (only rough estimates of flight area available, walls, etc.).
- Improvised take-off and landing platform with only 2x4m size.
- On-site modification required of the magnetic sensor mounting.
- Multiple missions have been flown with constant altitude.
- Faulty DGPS communication occurred due to interferences.

Main result:

- Magnetic map of flown area could be generated for each mission with various magnetic objects identified.

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Summary

- UAV-based magnetic sensing is possible with various sensor configurations.
- Flight accuracy and data processing for magnetic sensing is very demanding (e.g., compared to standard UAV flights such as aerial photography or surveillance).
- Automated mission planning with automated waypoint generation is necessary (i.e., hundreds of waypoints).
- New locations / real applications => new and not expected challenges.
- Post-processing of flight data has shown good results (i.e., position/velocity accuracy, altitude precision, wind robustness).
- Post-processing of magnetic data results in accurate magnetic maps.

THANK YOU FOR YOUR ATTENTION!

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