Contour Flying
for Airborne Data Acquisition

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Stuttgart, 10.09.2013

Contour Flying for Airborne Data Acquisition

- Effects of terrain modulation in aerial survey
- "Terrain Following": Multiple Levels vs. Contour Flying
- Flight planning for Contour Flying
  - How to "translate" a DTM contour into a flying contour?
  - Practical constraints
- Contour flying with *CCNS-5*
- Case scenario

Contour Flying for Airborne Data Acquisition

Modulating terrain leads to changing
- Ground Sample Distance
- Overlap
- Measurement Range

Increasing effect for high resolution/low altitude data acquisition

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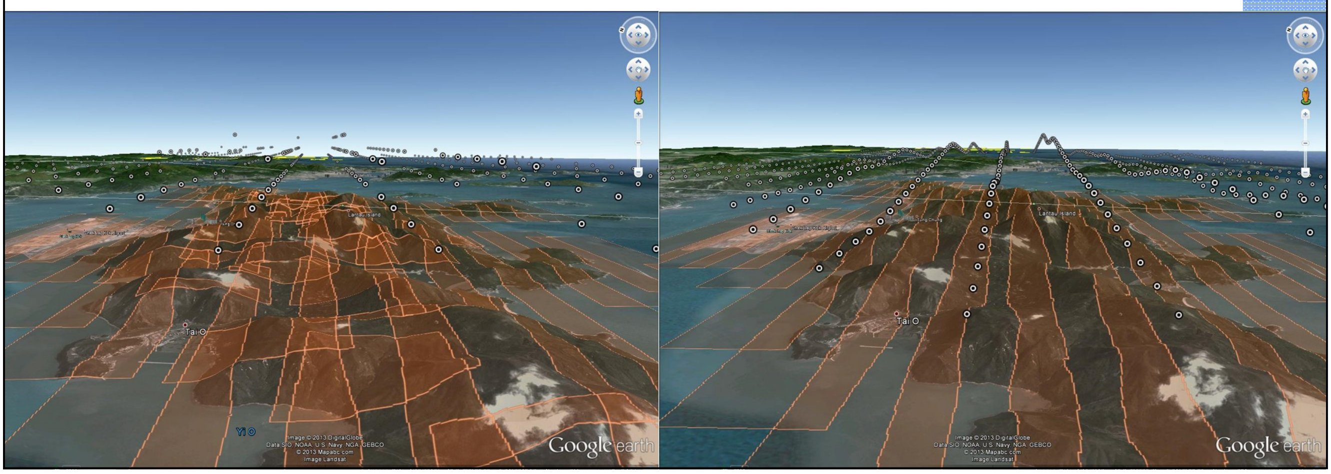
Terrain Following

Multiple Levels: Split the project into areas with similar ground levels, fly one flight level for each area.

Contour Flying (CF): Fly straight lines with changing flight level to achieve a constant AGL.



Terrain Following

Multiple Levels

Pro	Con
• Good resolution and overlap • Constant altitude on line • Well accepted in controlled / crowded airspace	• Larger flying effort • Inhomogeneous GSD • Redundant data due to unwanted overlap

Contour Flying

Pro	Con
• Minimal flying effort • Optimal resolution and overlap in whole area (depending on mission constraints) • Enables optimal conditions for certain geophysical surveys	• Changing the altitude permanently • Additional stress for pilot • Possible problems with ATC

Flight Planning for CF

Topics to be considered during the planning phase are:

- Selection of the Digital Terrain Model (DTM)
- Calculation of the altitude above ground
- How strict should the ground modulation be followed?
- Legal restrictions: minimum altitude above populated areas etc.
- Physical constraints of the aircraft: climb / descent rates
- Speed of change of climb / descent rates

Extremely low AGL and military scenarios are NOT subject to this presentation!

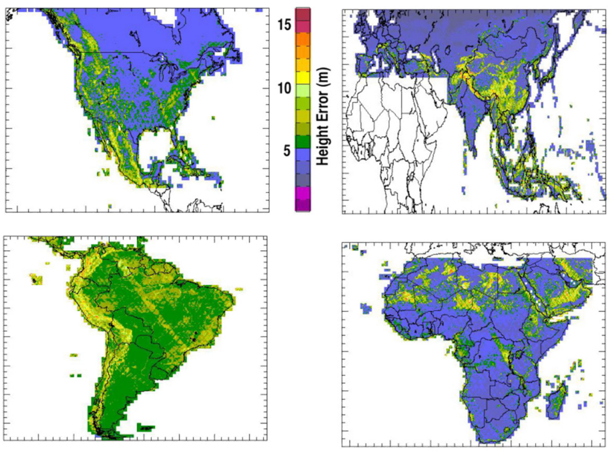
Flight Planning for CF – DTM

Digital Terrain Model (DTM)

- Resolution / grid spacing
- Information / value quality of DTM at grid points:
  - Interpolation mode for grid points: mean, maximum, spline?
  - Quality in absolute value?
- What about solitary high objects: High antennas, wind turbines, industrial chimneys, power lines?

Flight Planning for CF – DTM

Example for an available DTM

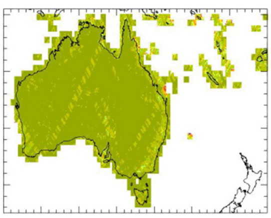


SRTM

(Shuttle Radar Topography Mission [9]):

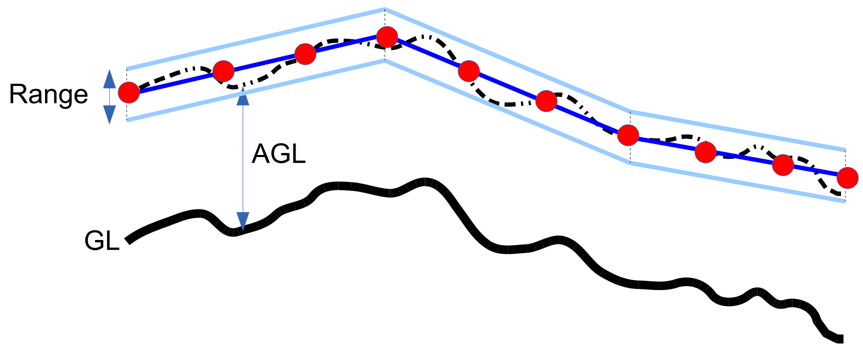
Grid spacing ~90m

(~30m continental US)



Estimated 90% vertical error of the SRTM DTM [8]

DTM Resolution / Terrain Modulation



DTM might contain high modulation frequencies.

⇒ Smoothing might be necessary.

A tolerance range can be defined in which the AGL can vary to allow the definition of intervals of constant ascent/decent.

Climb / Descent Rate

Aircraft Type	Climb Gradient [m/km] (sea level)	Descent Gradient [m/km] (sea level)
Cessna 404	76	39
Cessna 402 STOL kit	68	37
Beechraft Queenair	58	37
BN Islander	115	74
Cessna Grand Caravan	99	62
AutoGyro Cavalon	120	120
Eurocopter ASTAR	247	165

Source: see references [1] and [7] in the paper

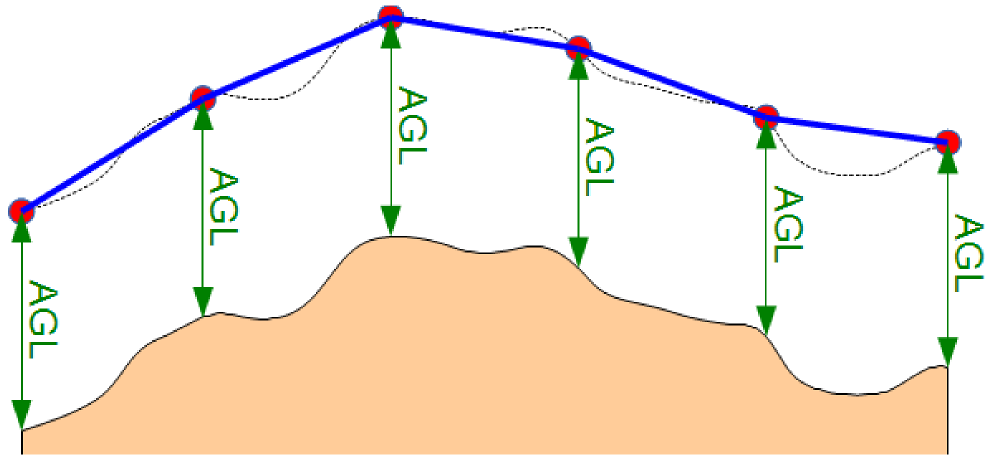
The max. climb/descent rate of the used aircraft has to be taken into account.

⇒ If it is not clear in which direction lines are flown – use the lower value.

⇒ Wind has to be taken into account.

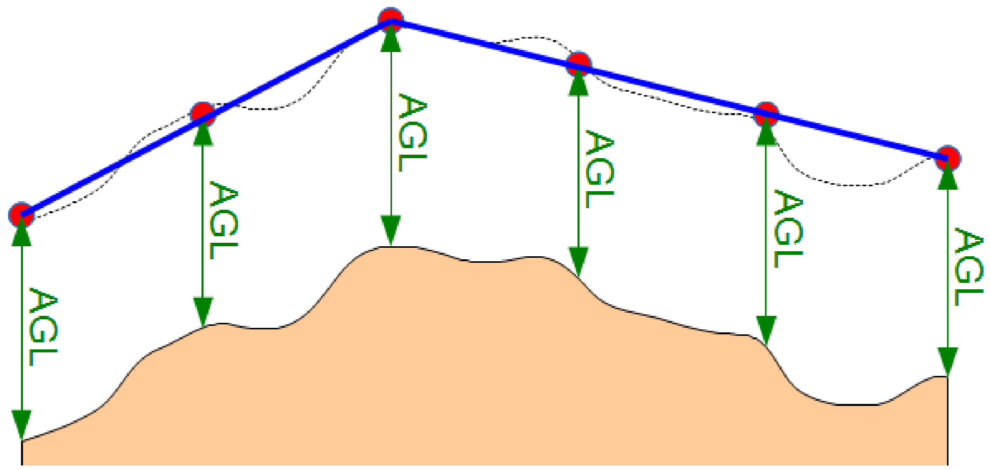
DTM & limited Ascend Rate I

Approximation between events



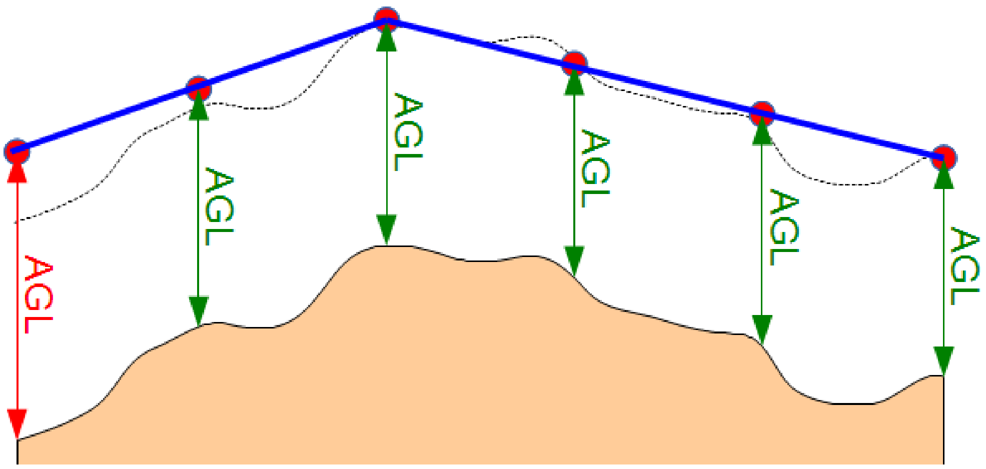
DTM & limited Ascend Rate II

Ascent / decent approximation



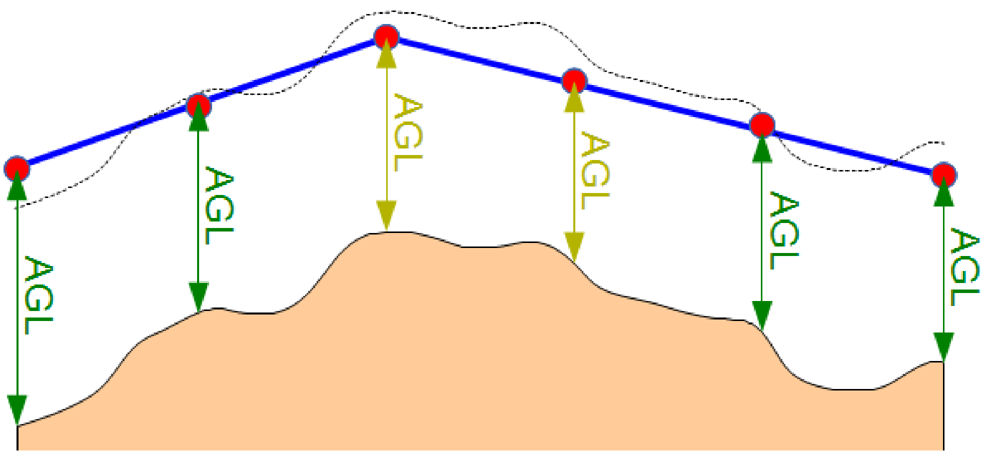
DTM & limited Ascend Rate III

Ascent / decent limitation

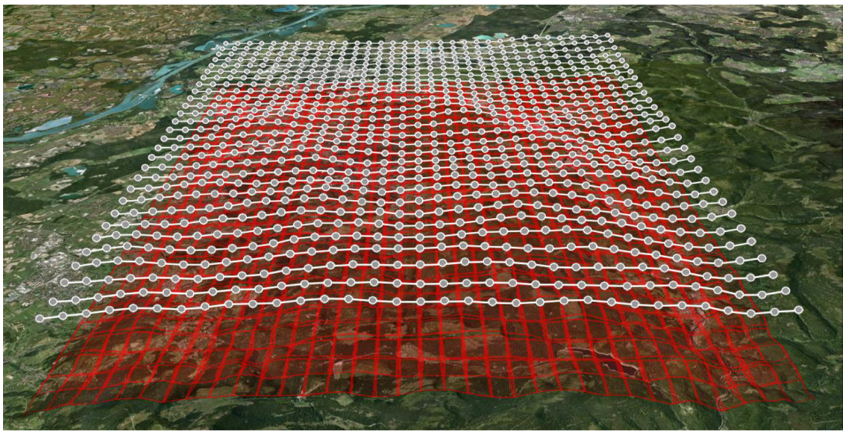


DTM & limited Ascend Rate IV

Ascent / decent limitation with peak valley weighting



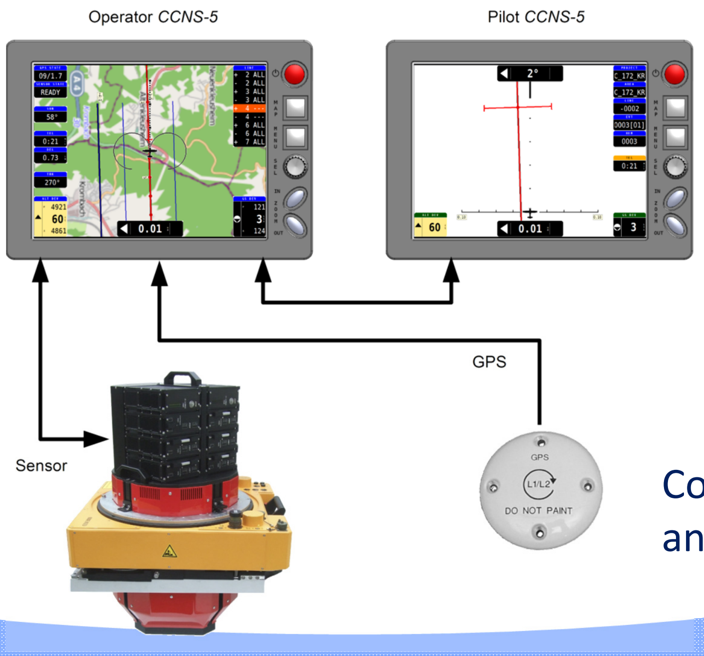
Mission Planning / Block Configuration



Neglecting the modulation in the extent of a single image, the planning looks like the planning for a flat area.

Contour Flying – *CCNS-5*

Two screens of the *CCNS-5* can show different information at the same time.



Pilot:

- Stay on planned path
- Communicate with ATC
- Access the next line …

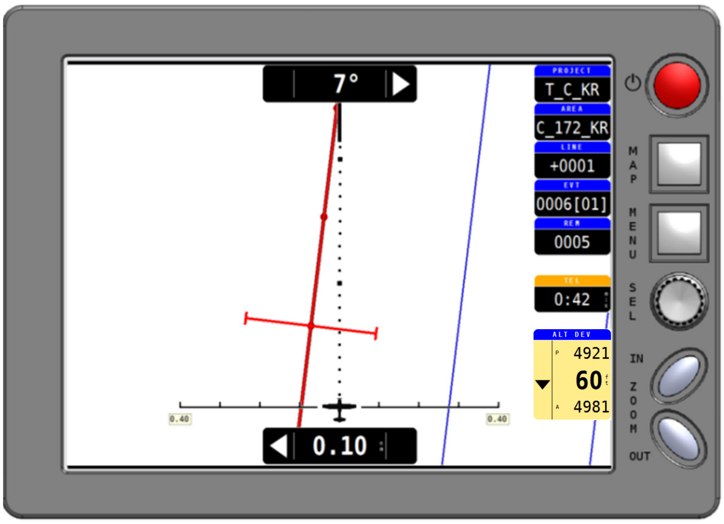
Operator:

- Sensor status
- Mission progress …

Configurable graphical elements and info boxes.

Contour Flying – Flight Guidance

Flying constant height levels (standard)



Direct commands for horizontal corrections.
Graphical prediction about future events.

ALT DEV - current altitude deviation to next event

red- critical warning
yellow - warning
black - no warning

CCNS-5

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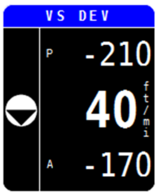
CCNS-5 Info Boxes

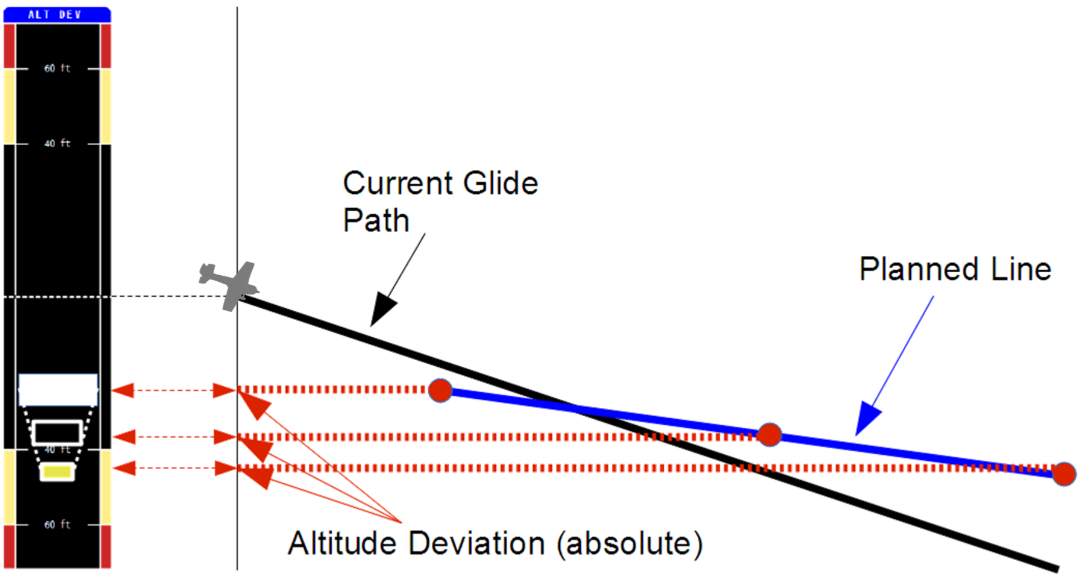
Vertical Speed Indicator



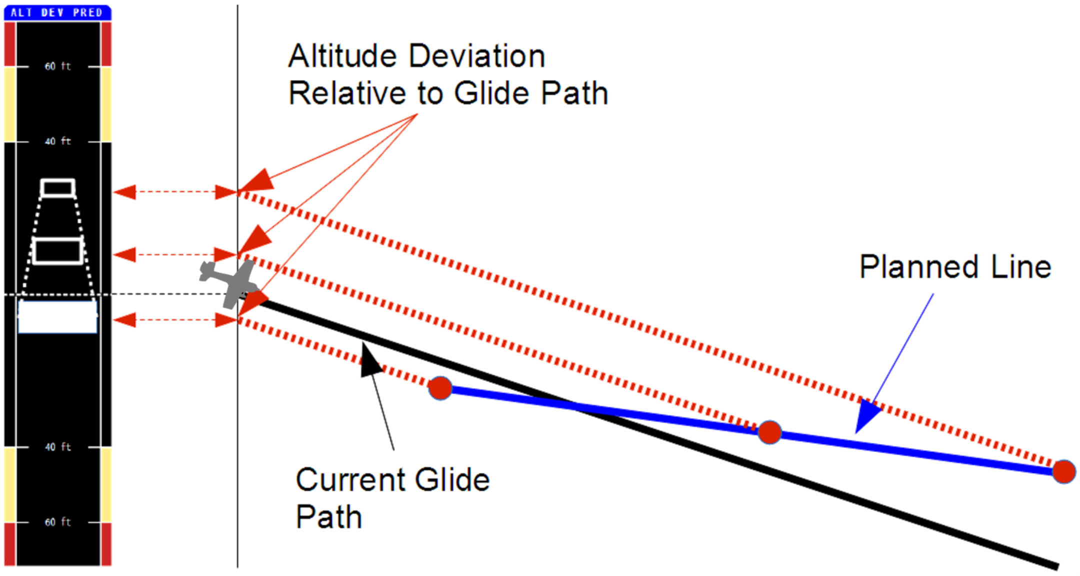
VS DEV - vertical speed deviation between planned and actually flown ascent/descent

red- critical warning
yellow - warning
black - no warning

CCNS-5 Alt. Dev. Bar



CCNS-5 Alt. Dev. Prediction Bar



CCNS-5 Screen Example

ALT DEV PRED bar: The next event is above the aircraft.
The following events are even higher: Pull up.

ALT DEV: Aircraft should be 14ft higher (small black arrow in circle) but is still sufficiently close to the planned altitude (indicated by black background).
The planned altitude is 3883ft.

VS DEV box: The aircraft should be pulled up (arrow showing up, warning color) to reduce the current descent by 210 ft/min.
Planned descent is -170 ft/min for the current speed.

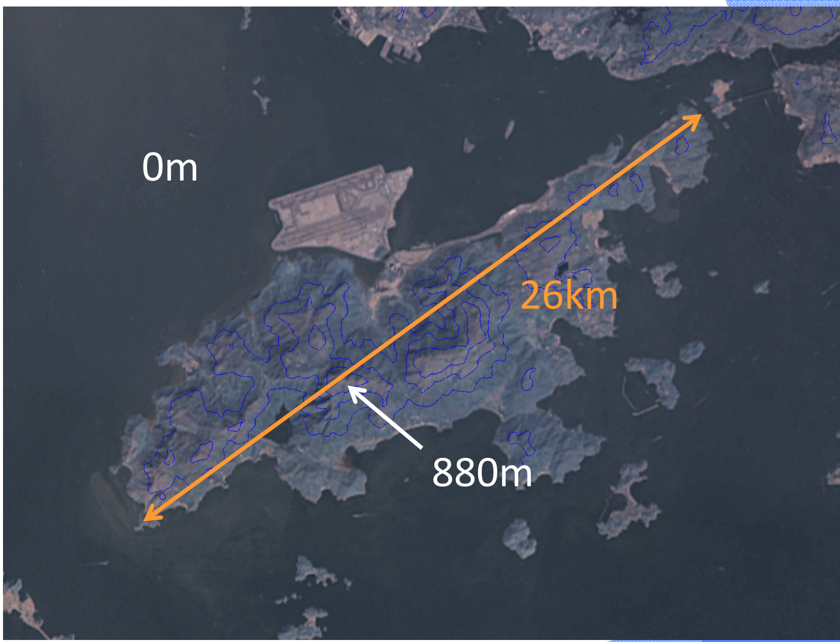
Planning Scenario Lantau I

30 % forward and

side overlap

DigiCam 50mm

20cm GSD



Planning Scenario Lantau

Example “Lantau Island” (Hongkong)

Comparison of

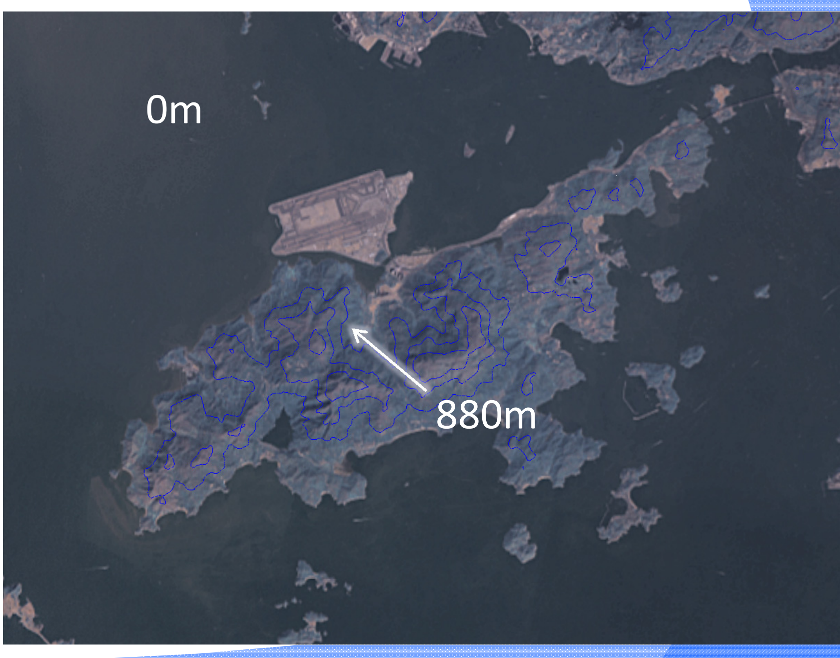
- GSD Distribution
- Flying Effort

Ground level range

0m – 880m

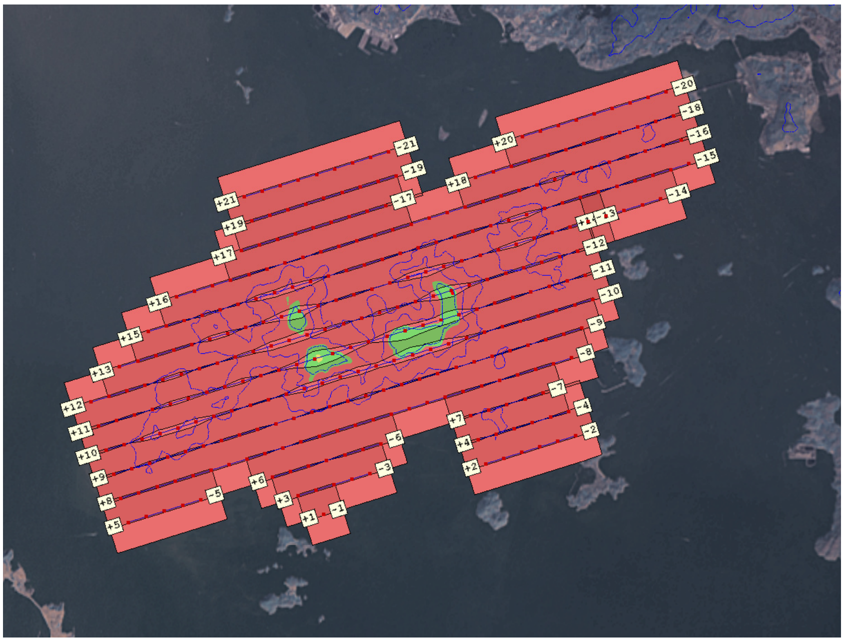
Nominal GSD

20cm



Planning Scenario Lantau I

Fixed Level (no DTM used): Planned GL 700m



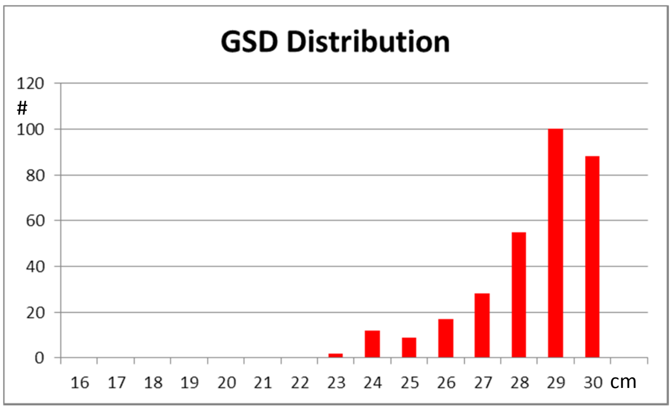
GSD ok: 18-22cm

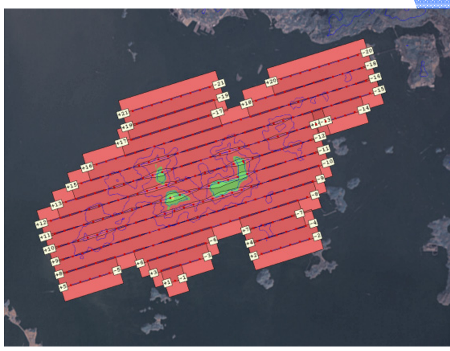
GSD low: < 18cm

GSD high: > 22cm

Planning Scenario Lantau I

Fixed Level (no DTM used): Planned GL 700m



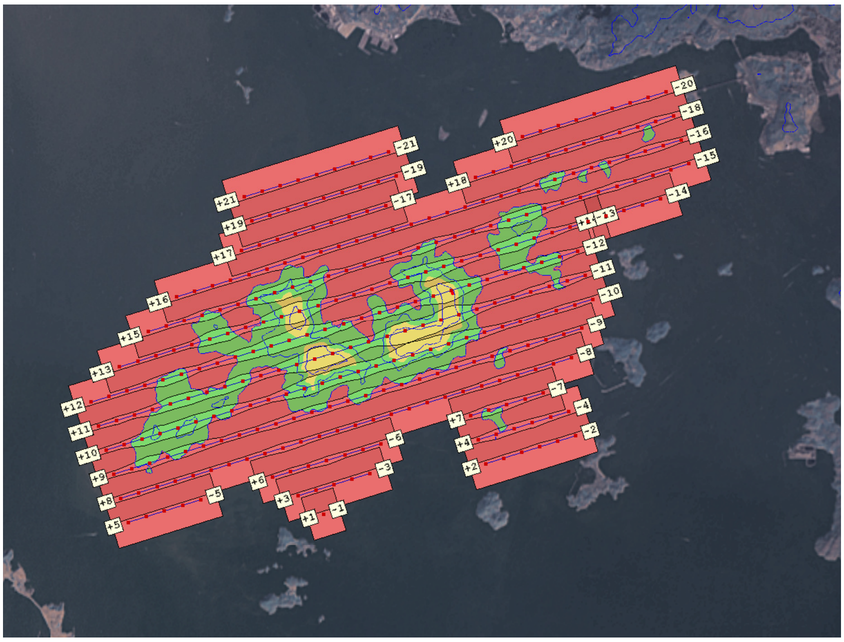


Flight Time: ~ 1h 50min

Exposures: 311

Planning Scenario Lantau II

Fixed Level (no DTM used): Planned GL 350m



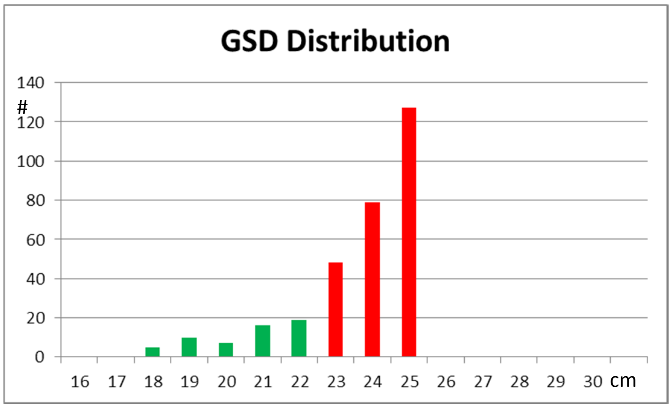
GSD ok: 18-22cm

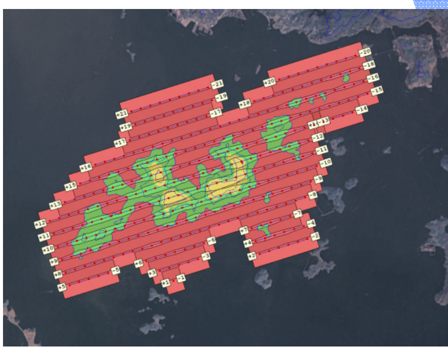
GSD low: < 18cm

GSD high: > 22cm

Planning Scenario Lantau II

Fixed Level (no DTM used): Planned GL 350m



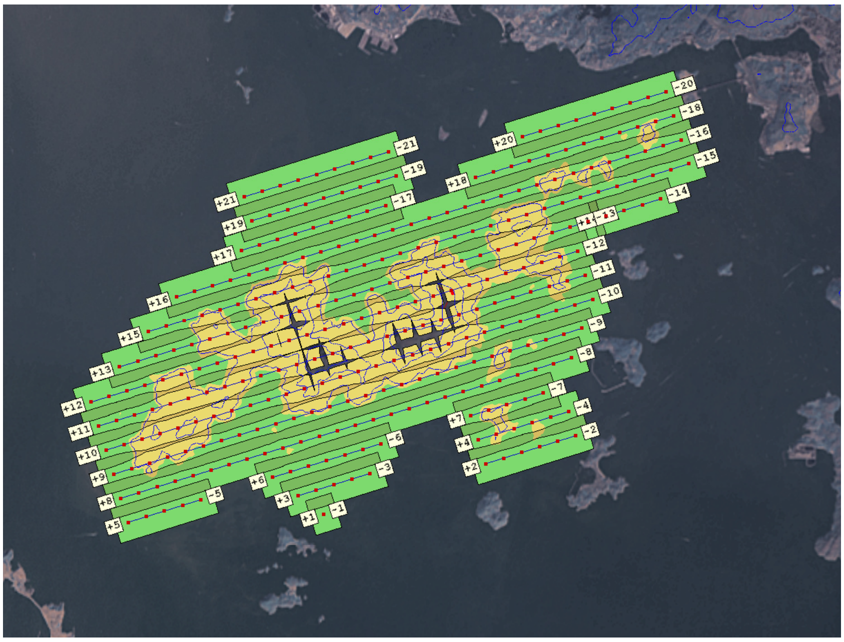


Flight Time: ~ 1h 50min

Exposures: 311

Planning Scenario Lantau III

Fixed Level (no DTM used): Planned GL 0m



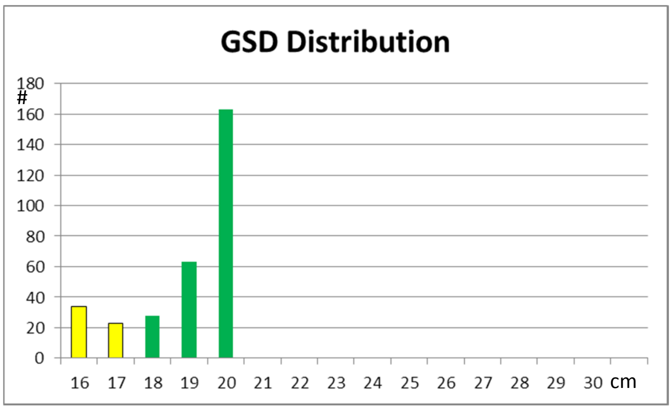
GSD ok: 18-22cm

GSD low: < 18cm

GSD high: > 22cm

Planning Scenario Lantau III

Fixed Level (no DTM used): Planned GL 0m

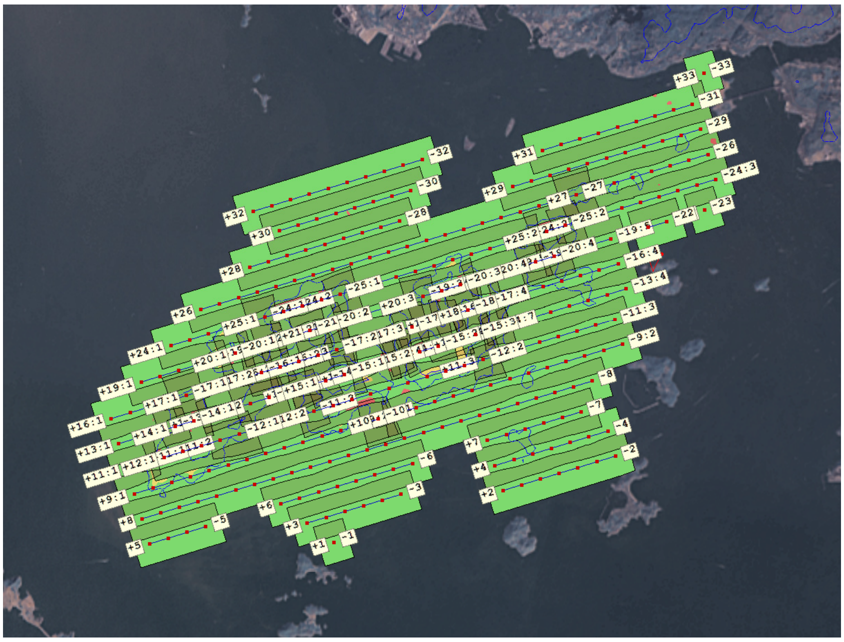


Flight Time: ~ 1h 50min

Exposures: 311

Planning Scenario Lantau IV

Multi Levels: Planned Alt: 1600m , 1900m, 2200m



GSD ok: 18-22cm

GSD low: < 18cm

GSD high: > 22cm

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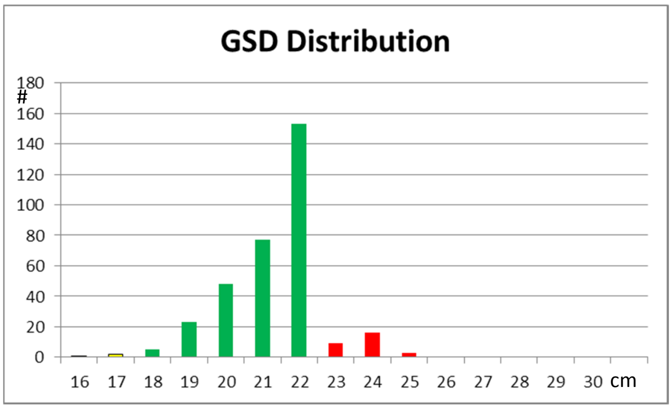
Planning Scenario Lantau IV

Multi Levels: Planned Alt: 1600m , 1900m, 2200m



Flight Time: ~ 3h 15min

Exposures: 337

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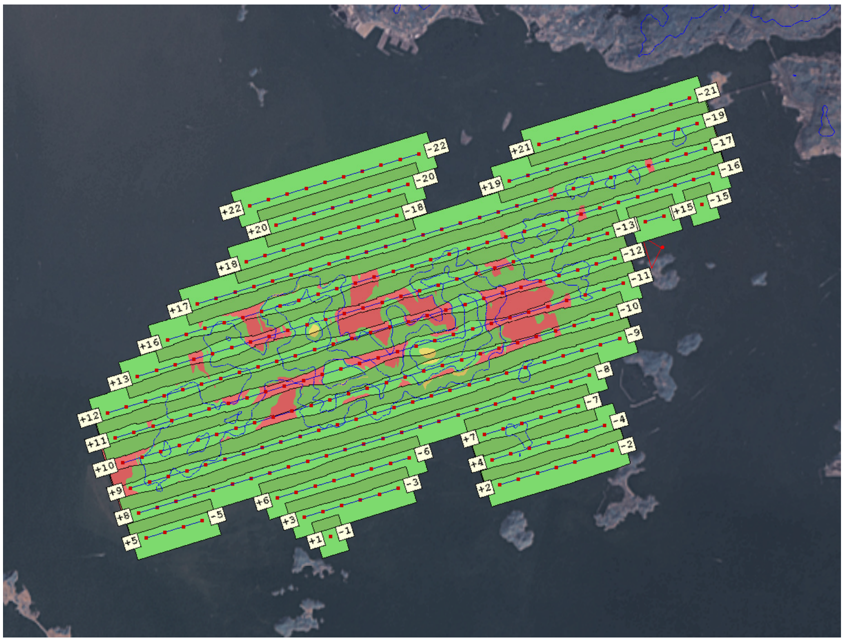
Planning Scenario Lantau V

Contour Flying: Ascent/Descent max. 100m/1000m,
80% Peak Focus



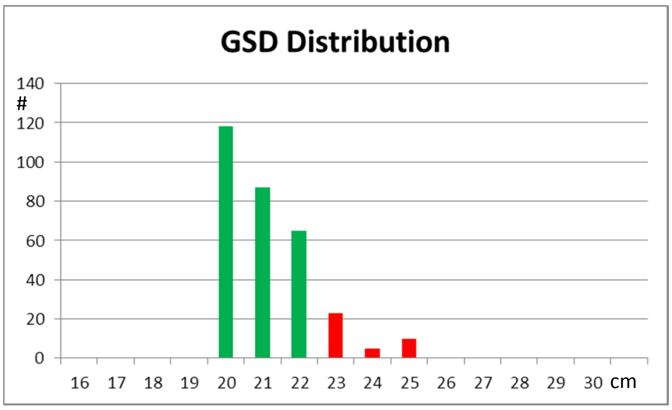
GSD ok: 18-22cm

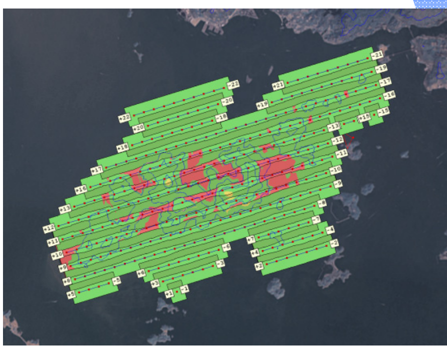
GSD low: < 18cm

GSD high: > 22cm

Planning Scenario Lantau V

Contour Flying: Ascent/Descent max. 100m/1000m,
80% Peak Focus





Flight Time: ~ 1h 50min

Exposures: 308

Planning Scenario Lantau VI

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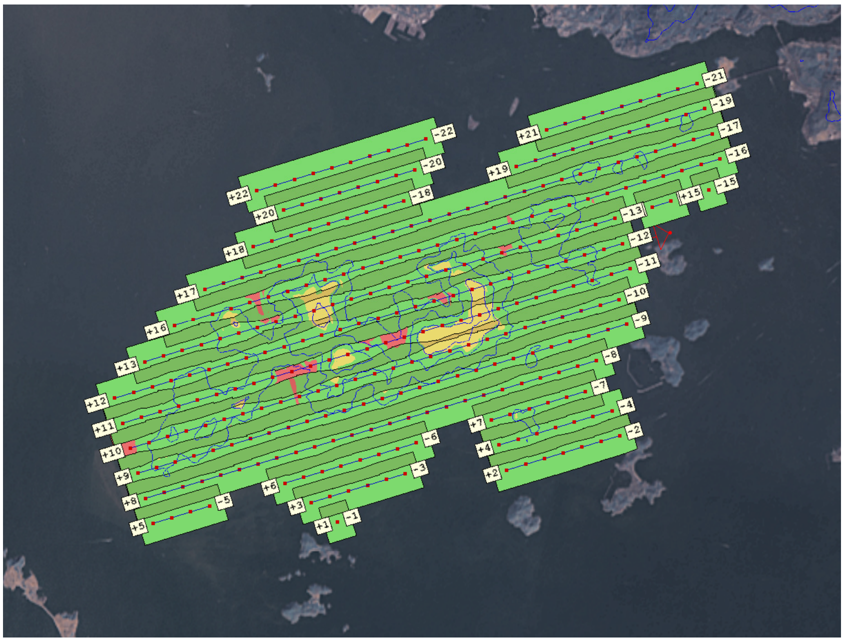
Contour Flying: Ascent/Descent max. 100m/1000m,
50% Peak Focus



GSD ok: 18-22cm

GSD low: < 18cm

GSD high: > 22cm

Planning Scenario Lantau VI

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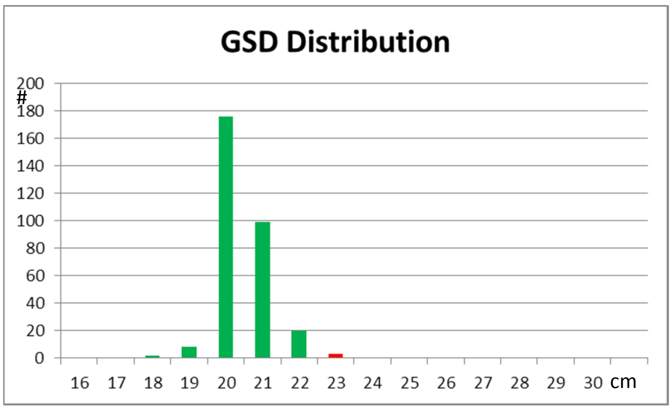
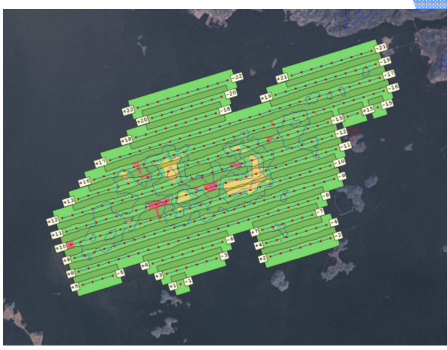
Contour Flying: Ascent/Descent max. 100m/1000m,
50% Peak Focus





Flight Time: ~ 1h 50min

Exposures: 308

Contour Flying for Airborne Data Acquisition

High resolution aerial survey in low altitudes suffers from the effect of terrain modulation. Adapting the flying height to the varying terrain height can improve data quality and the efficiency of the data collection.

The *CCNS-5* together with the *IGIplan* mission planning software provides tools to conduct efficient terrain following missions.

The practical applicability of this technique is mainly determined by safety constraints and by the local legal regulations.