The Field Geophysicist's Destiny

John Steinbeck: Travels with Charley: In Search of America, 1962

"When I was very young and the urge to be someplace else was on me, I was assured by mature people that maturity would cure this itch. When years described me as mature, the remedy prescribed was middle age. In middle age I was assured that greater age would calm my fever and now that I am fifty-eight perhaps senility will do the job. Nothing has worked. I fear the disease is incurable."

DRONES IN GEOPHYSICAL EXPLORATION
AIRBORNE MAGNETICS AND ELECTROMAGNETICS

JOHANNES B. STOLL - CELLE/GERMANY

MOBILE GEOPHYSICAL TECHNOLOGIES GMBH

CONTENT OVERVIEW

- A complex system: Drone Geophysics
- The annoying companion of geophysics: Sources of Electromagnetic Interference Signals generated by Drones
- Small and Light-Weight: geophysical sensors used on drones
  Drone-Borne Magnetometry
  Drone-Borne EM: Very Low Frequency- Method
  Drone-Borne EM: Semi-Airborne Electromagnetics
- Future Trends in Geophysical Exploration

DRONE-BORNE GEOPHYSICS

The link between ground and traditional airborne geophysics

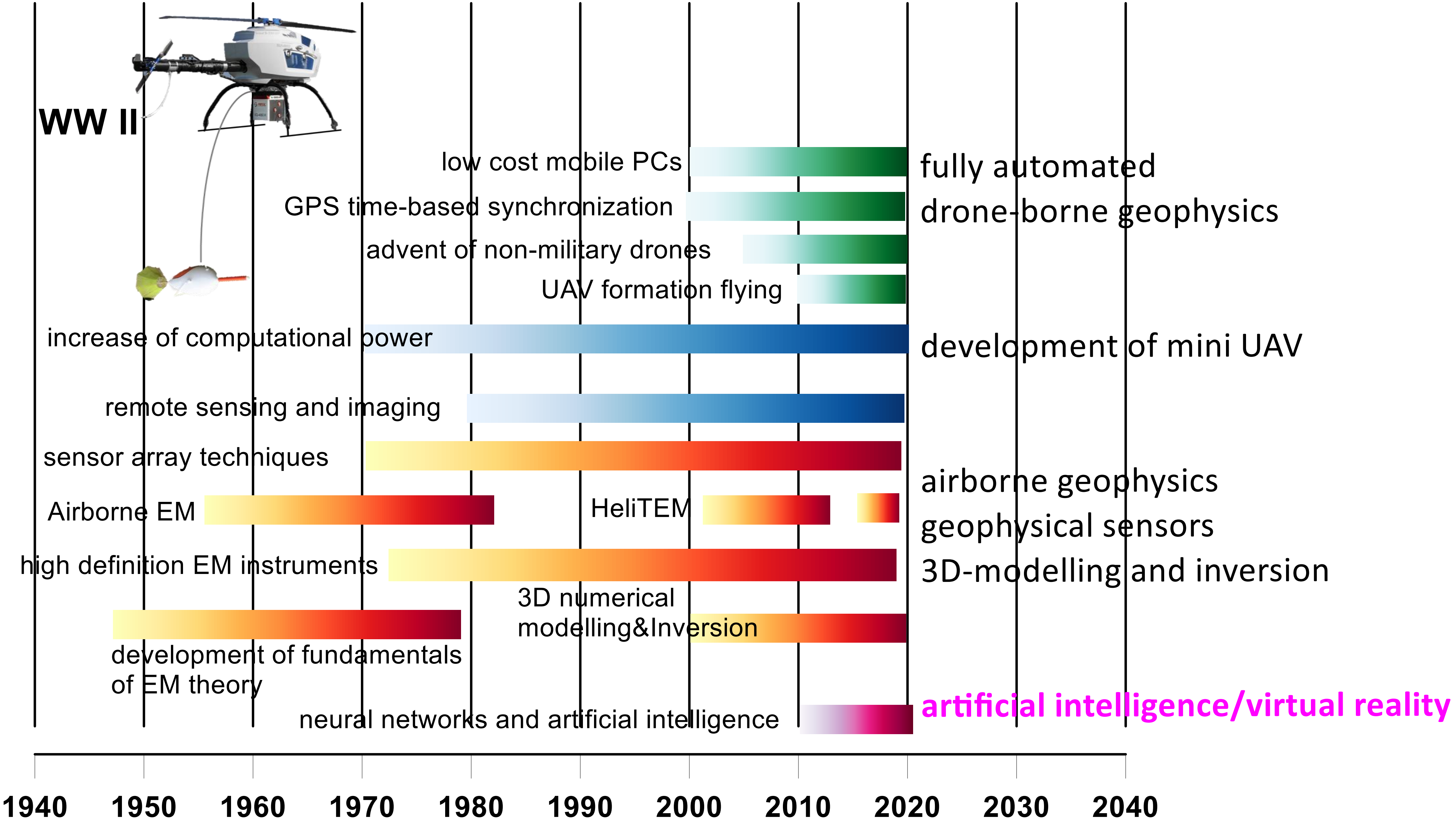
Platform Complexity: No aerial platform does the job perfectly in all cases

Decision to deploy the right platform for a given survey area in terms of:

- Size of survey area and total length of line kilometres
- Flight altitude above ground surface
- Terrain and environment
- accessibility of the terrain

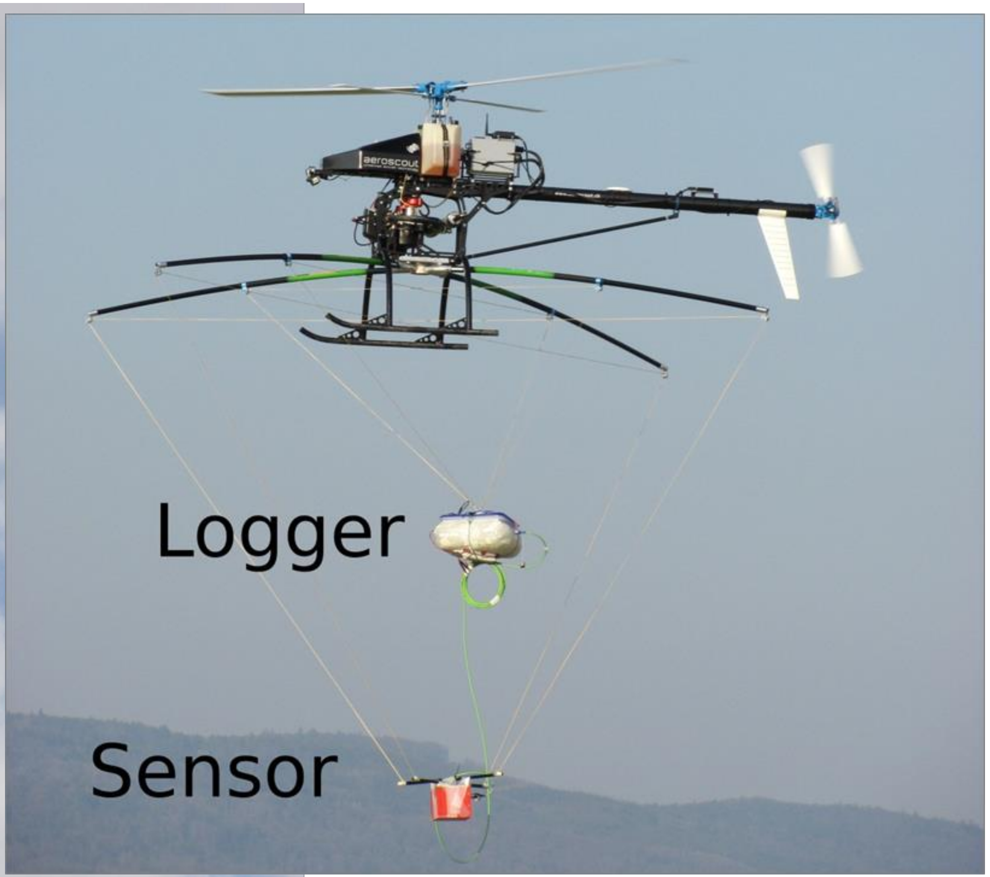
BUT: In commercial projects only the economic viability of an aerial platform will change the game

COMPLEX SYSTEM



Kahramanmaraş/Turkey, 2011 airborne magnetics

Type	SCOUT100B	Aeroscout, CH
MTOW	75kg	
Propulsion	2-stroke fuel engine	
Endurance	up to 90min	
Payload	max 15kg	
Costs	200k€	



Switzerland, 2012
VLF-measurements over gas pipeline
Eroess et al., 2013

COMPLEX SYSTEM

Type	quadrocopter MD100, microdrones
MTOW	5kg
Propulsion	battery driven
Endurance	up to 40min
Payload	max 1kg
Costs	40k€

Type	fixed wing S180, Hanseatic
MTOW	5kg
Propulsion	battery driven
Endurance	up to 30min
Payload	max 1kg
Costs	20k€

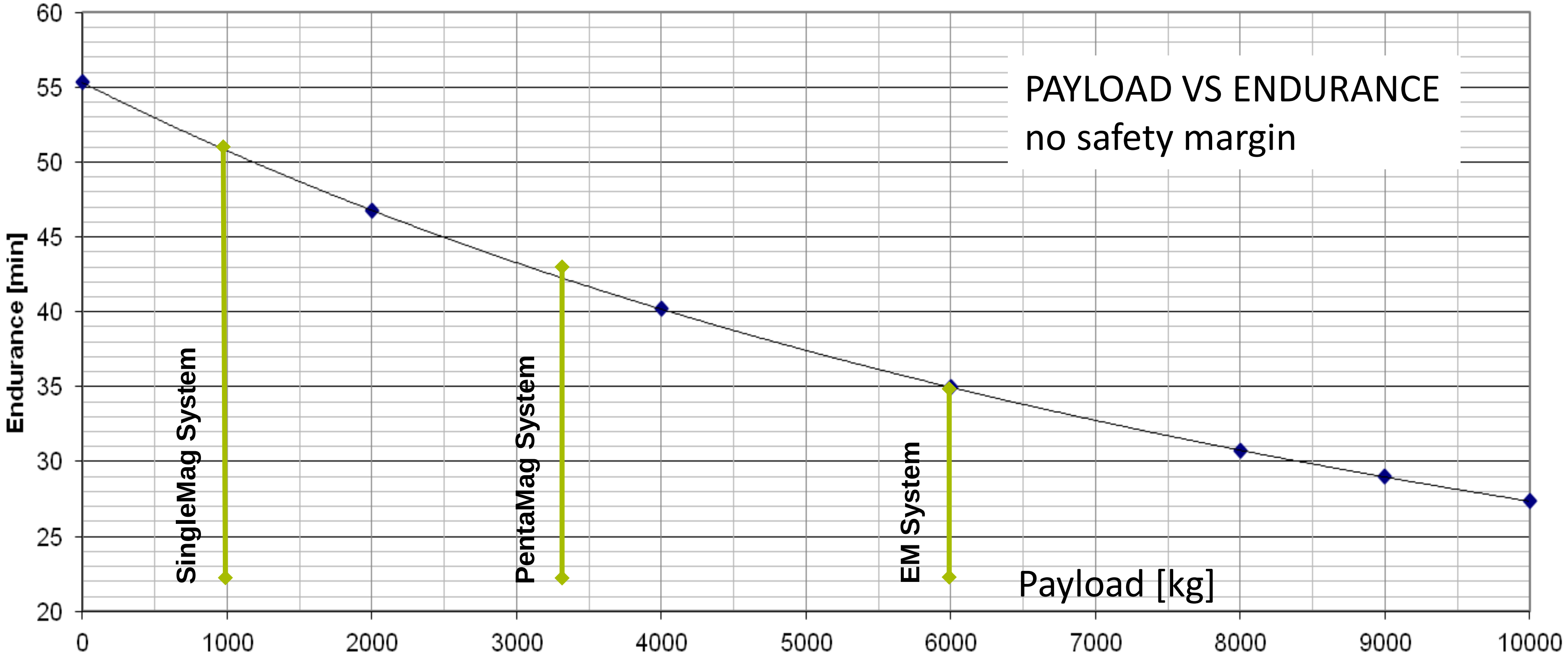
Type	X825, MGT-HAVS
MTOW	25kg
Propulsion	electric motor
Endurance	up to 35min
Payload	max 9kg
Costs	40k€

Type	octoocopter X810, MGT-HAVS
MTOW	10kg
Propulsion	electric motor
Endurance	up to 40min
Payload	max 3.5kg
Costs	30k€

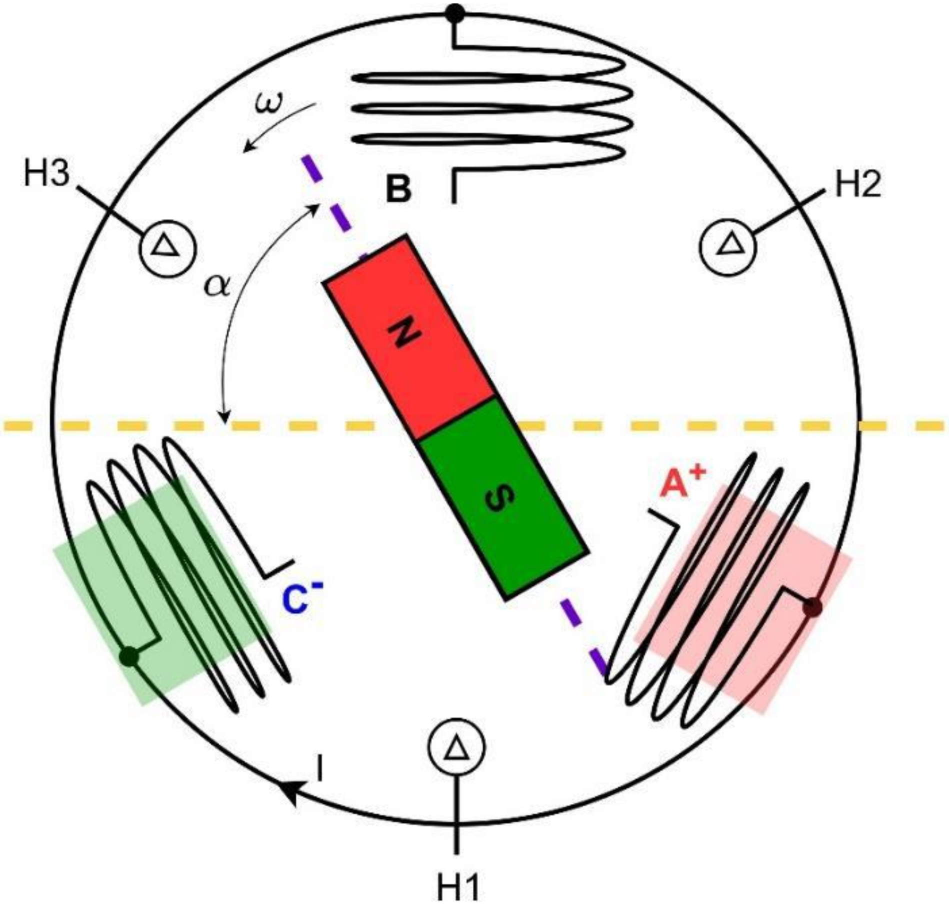
COMPLEX SYSTEM

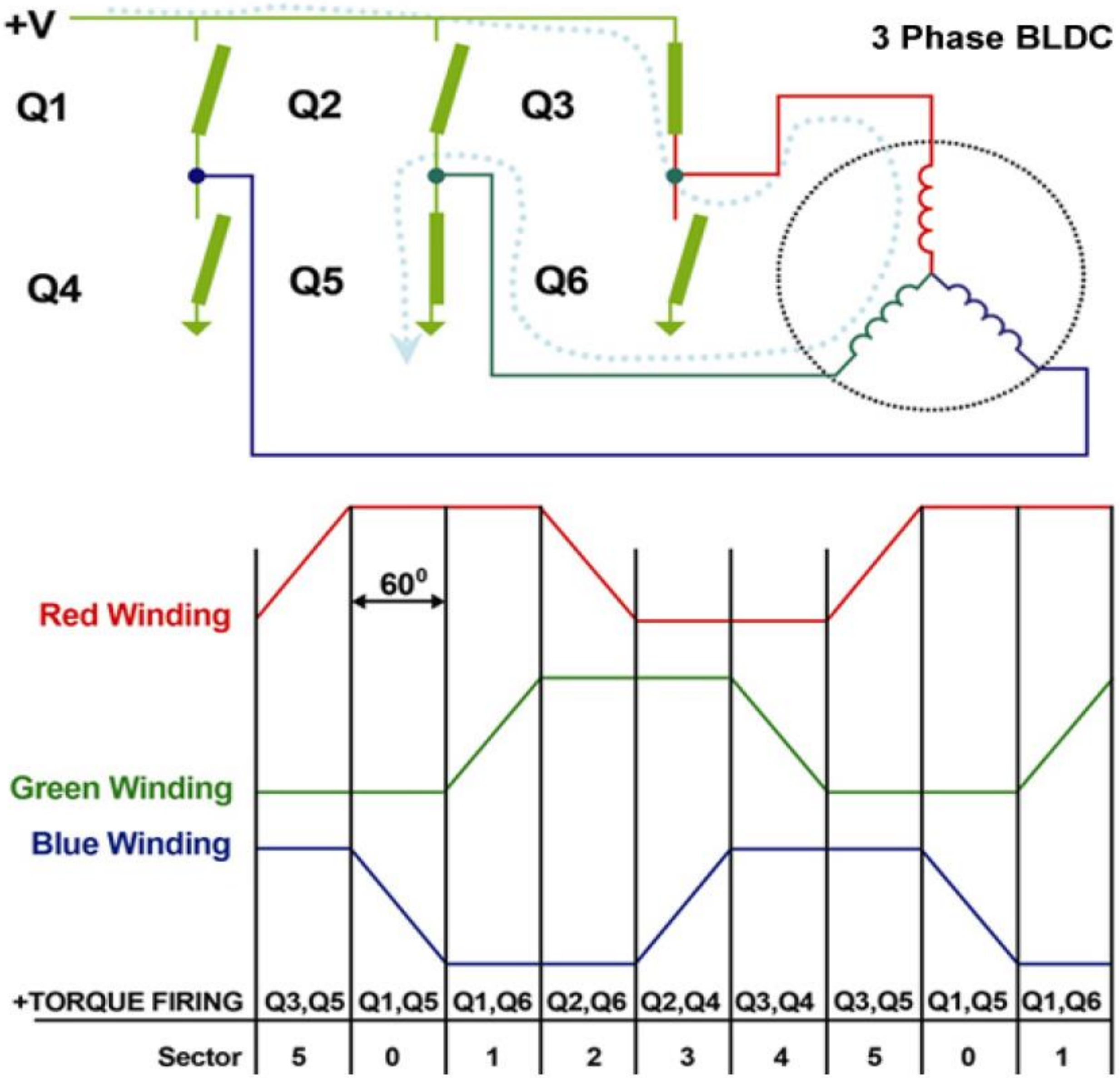
Configuration	Octocopter (8 engines) in coaxial configuration
Endurance	up to 35 min. @ 6 kg payload (EM System)
Max. velocity	horizontal: 15 m/s vertical: 5 m/s
Max. payload	9 kg (@ 25,0 kg Take-Off Weight)
Max. Take-Off weight	25,0 kg
Autopilot Functions	Waypoint Navigation, Terrain Following, Fail Safe Procedures

Technical Specifications

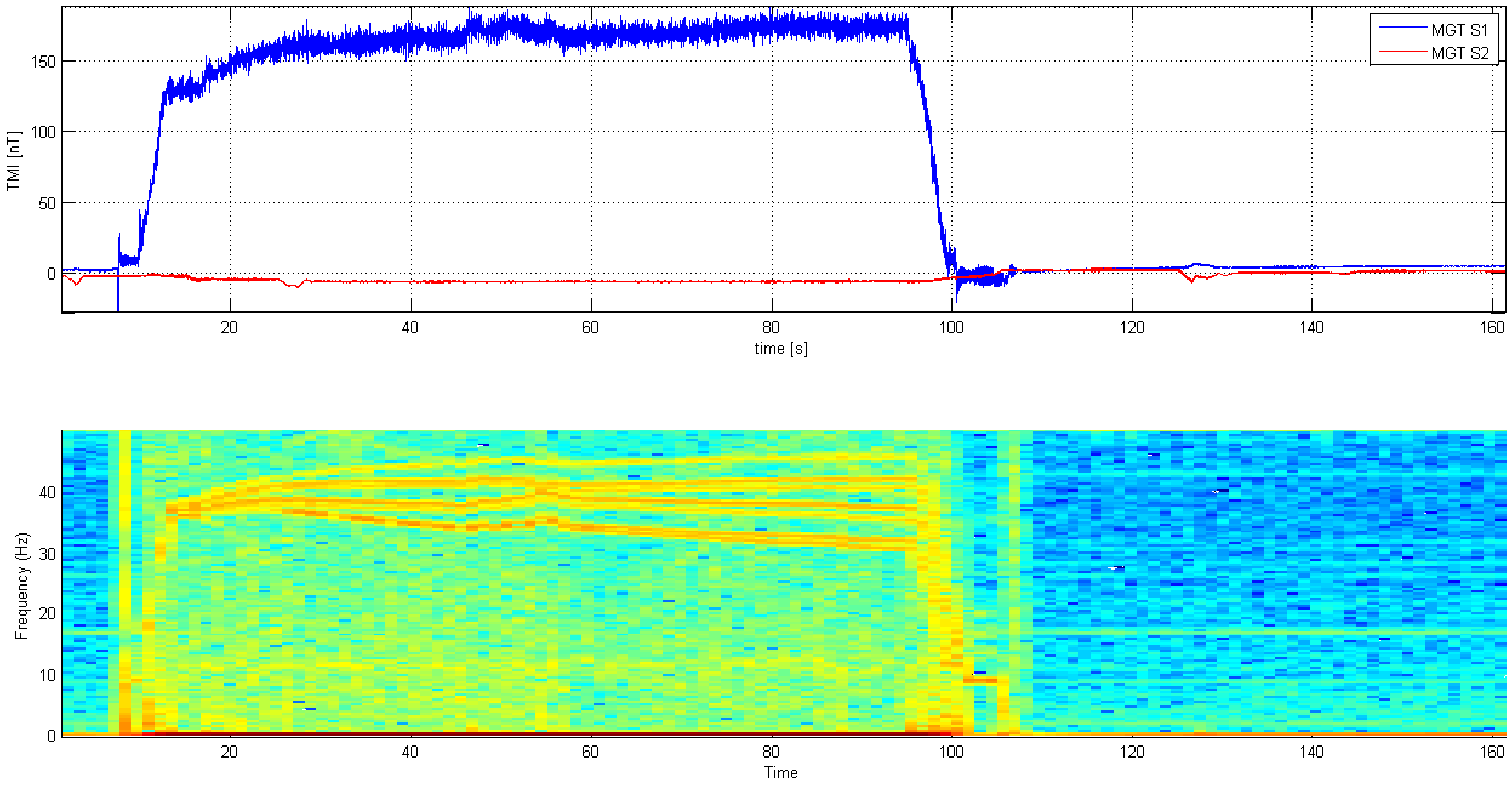


EM INTERFERENCE GENERATED BY DRONES

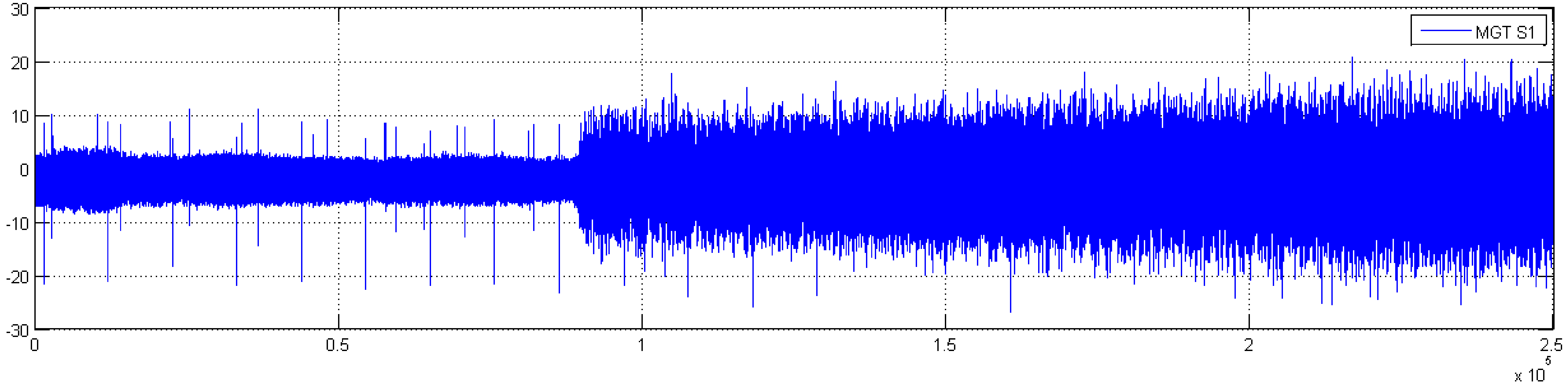


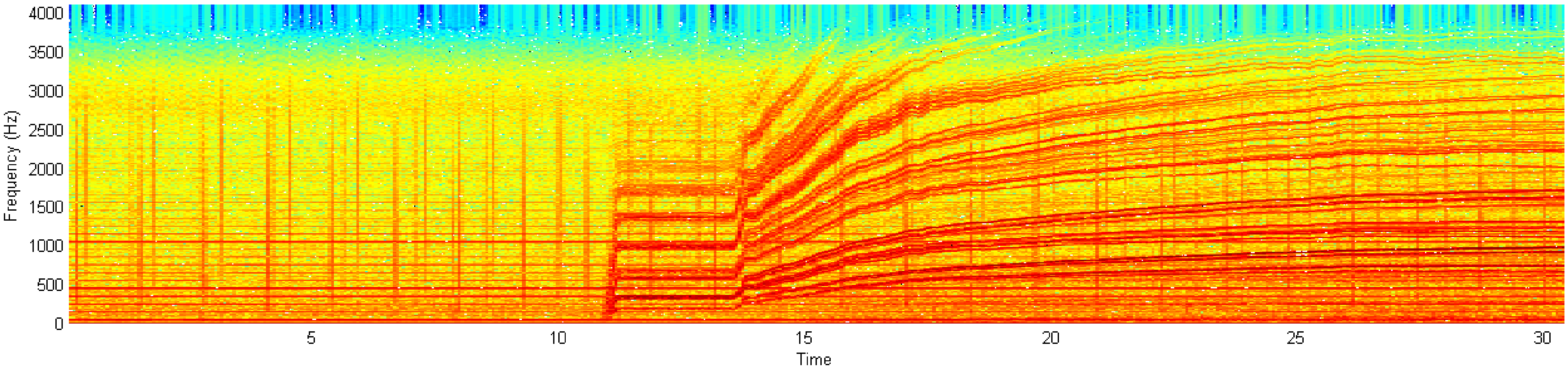


EM INTERFERENCE GENERATED BY DRONES



EM INTERFERENCE GENERATED BY DRONES

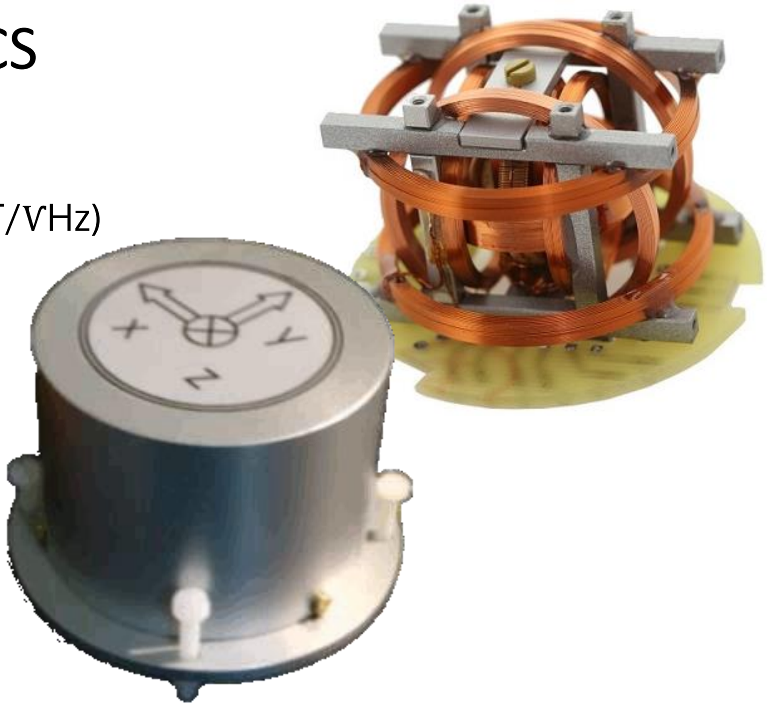




DRONE-BORNE GEOMAGNETICS

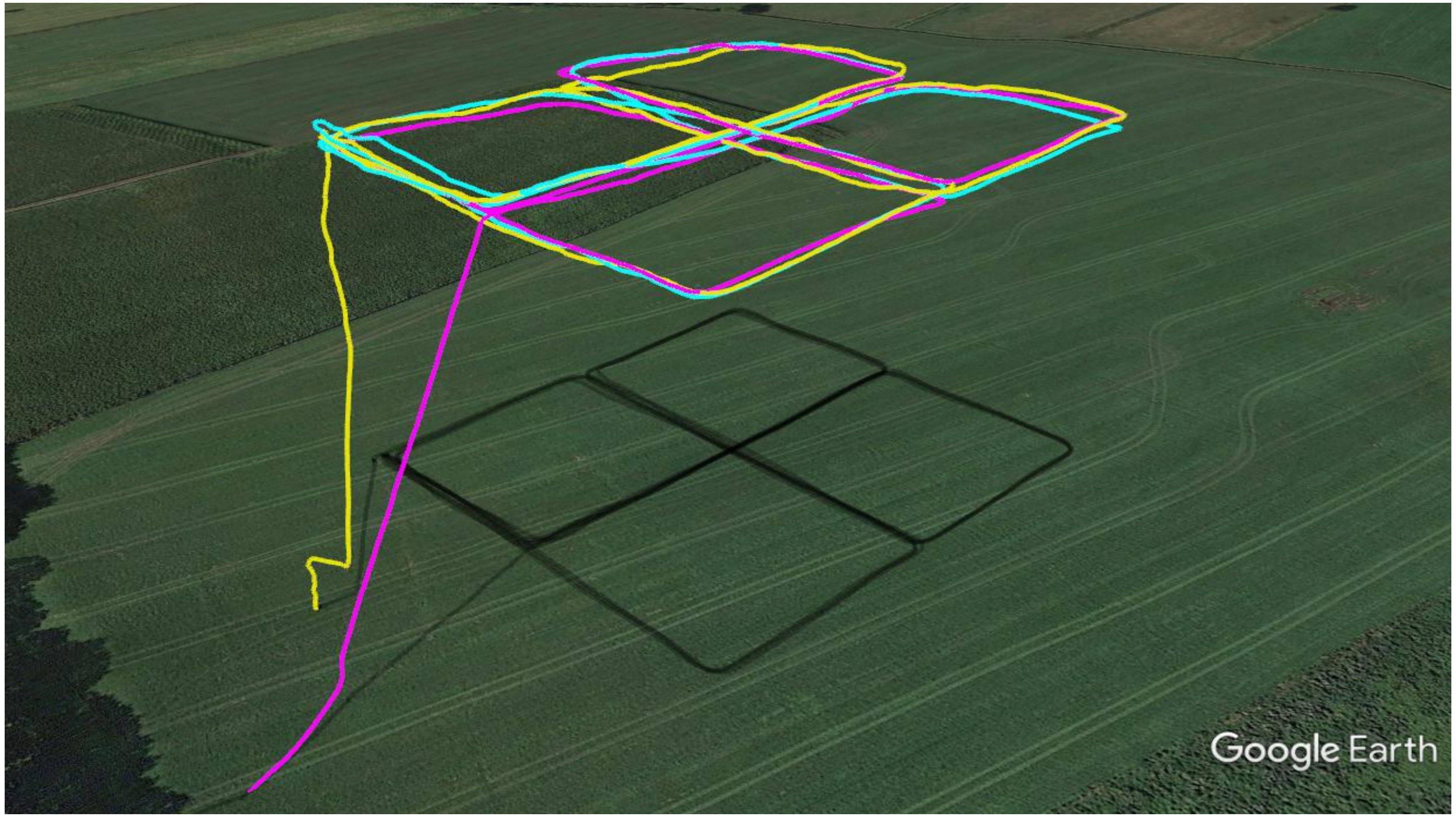
Sensor:

Noise	< 20pT/√Hz (typical < 15pT/√Hz)
Long-term stability	< 10 nT per year
Orientation	X, Y, Z
Range	±65 µT
Orthogonality	<0.02°
Temperature range	-20 to +75 °C

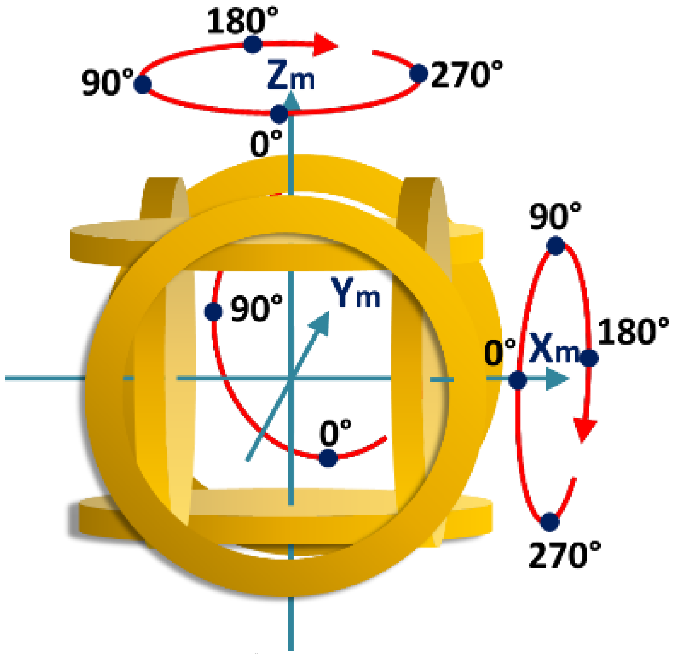


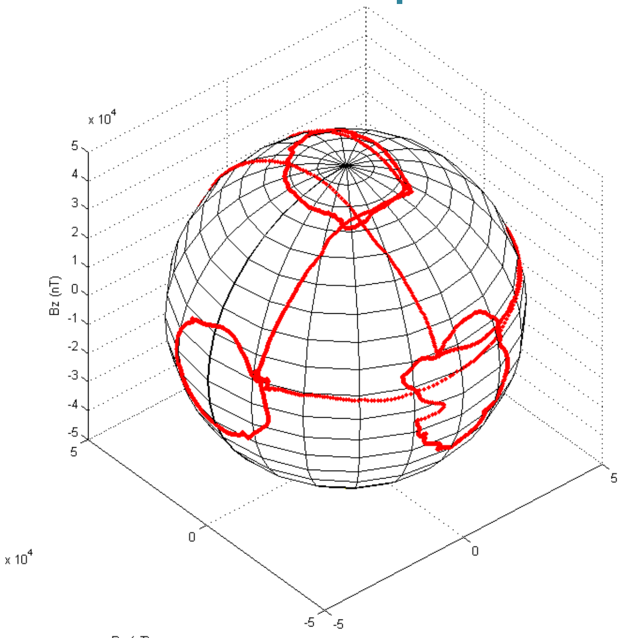
Data Acquisition System:

Field range	± 65 µT
Resolution	10 pT
sample rate	1, 10, 50, 100 Hz
Data format	ASCII, binary
Time and Position	GPS-receiver

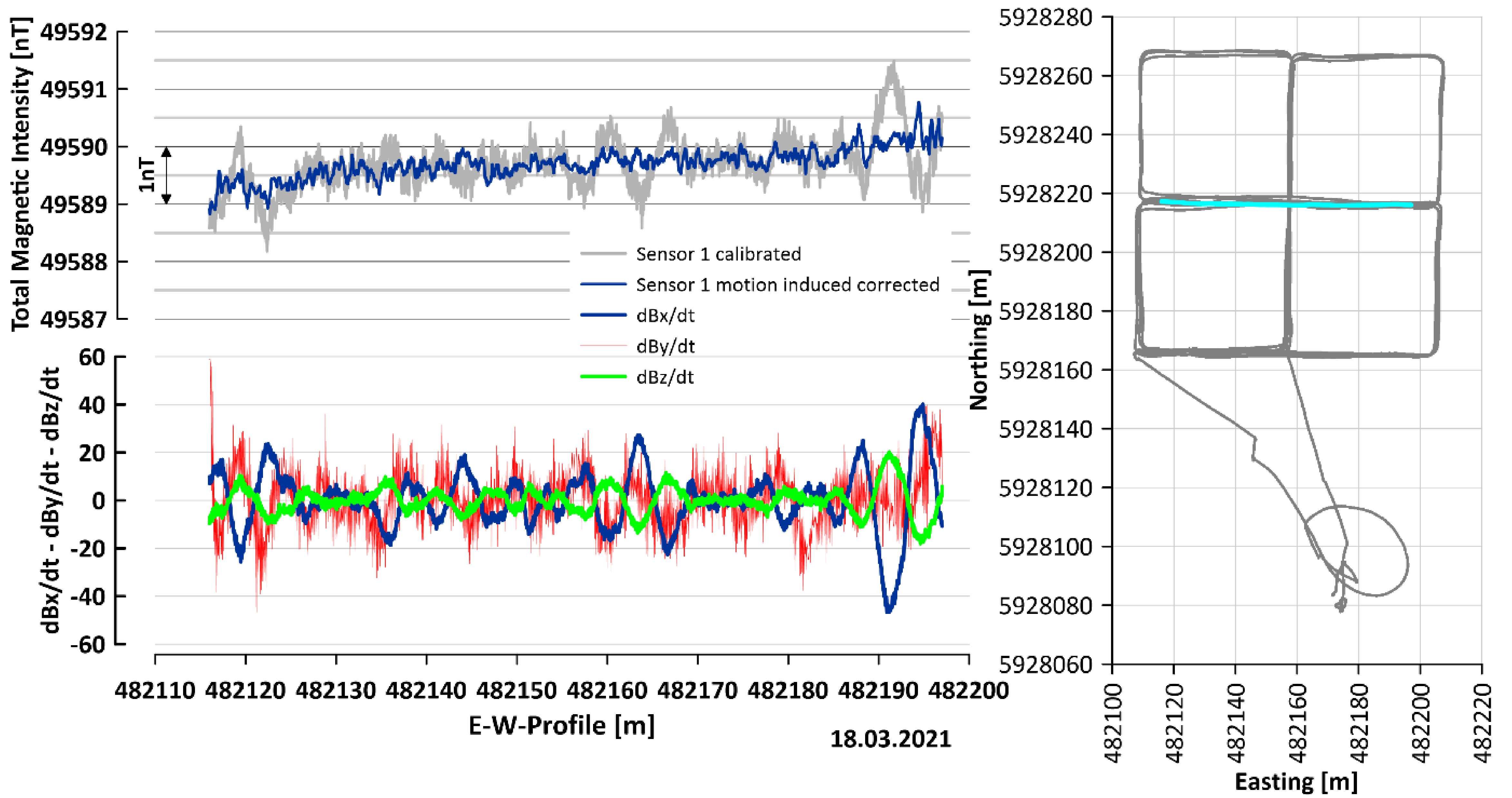


Clover leaf test flight pattern

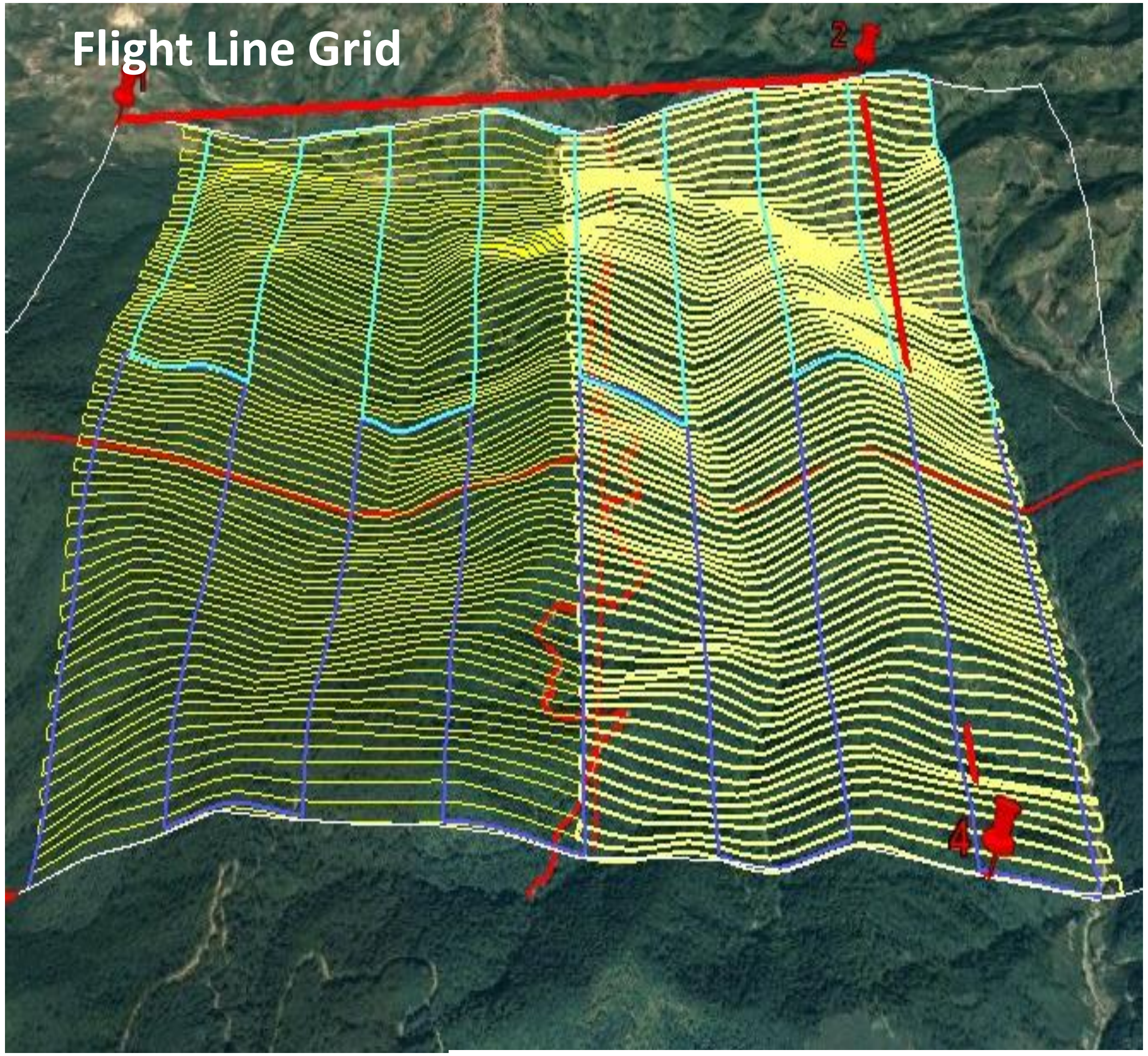




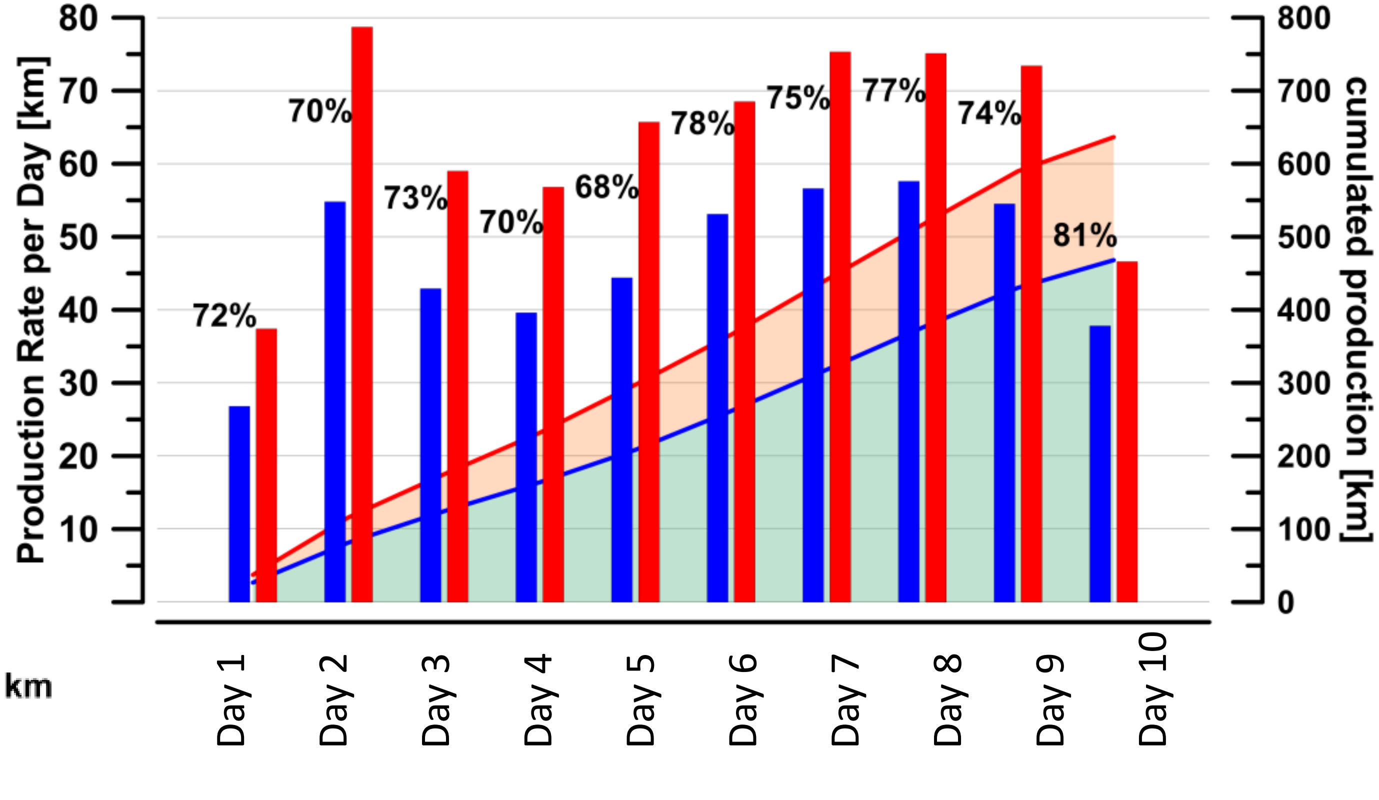
CALIBRATION OF FLUXGATE SENSORS



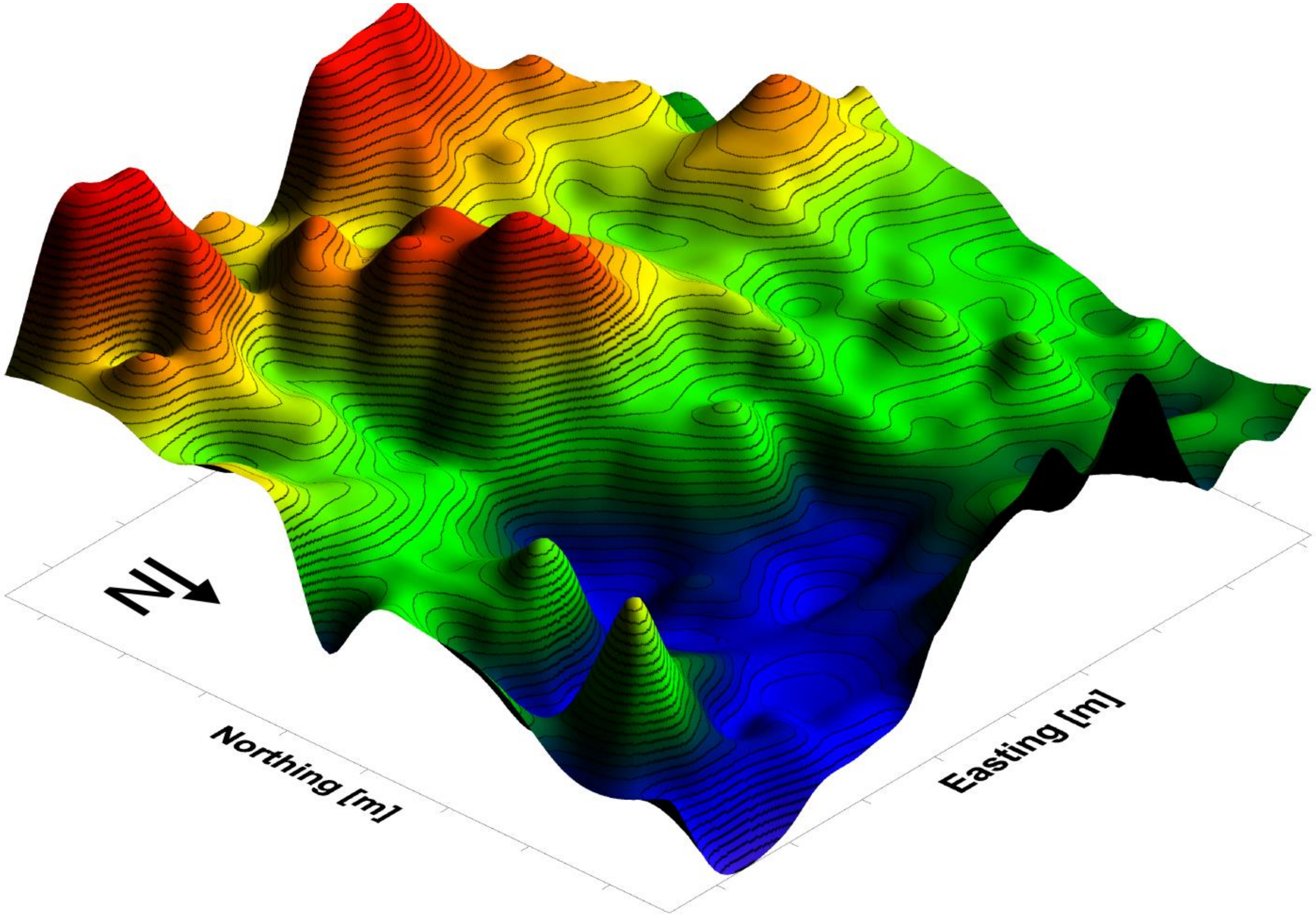
AIRBORNE MAG SURVEY OVER GOLD PROSPECT IN TURKEY



Area Size	4 x 4 km^2
Line spacing| Regular| Tie	50 m|500m
Total Distance	~ 650km
Terrain elevation	150m – 900m
Flight alt	50-100m above ground
Production time	10 days

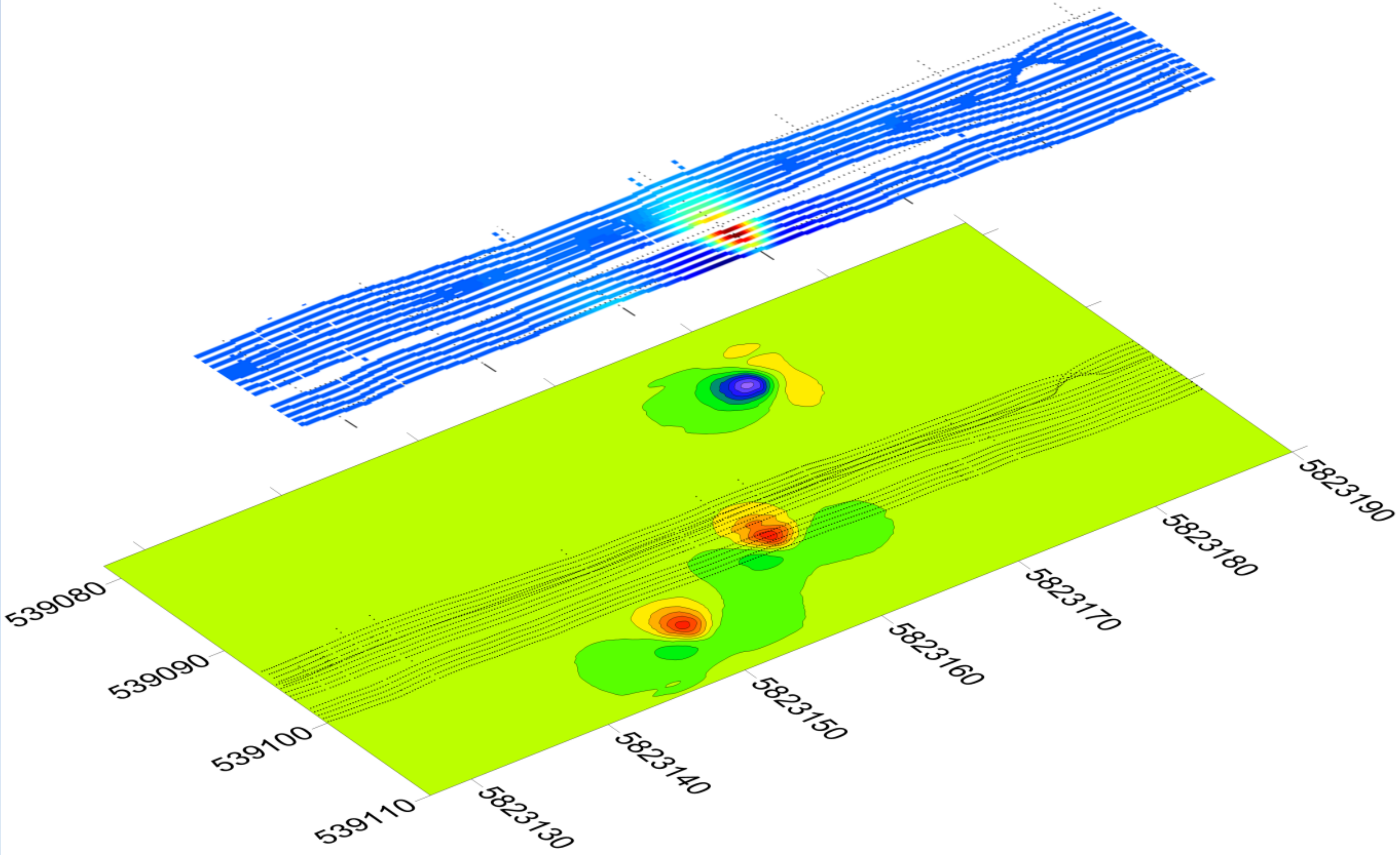


AIRBORNE MAG SURVEY OVER GOLD PROSPECT IN TURKEY

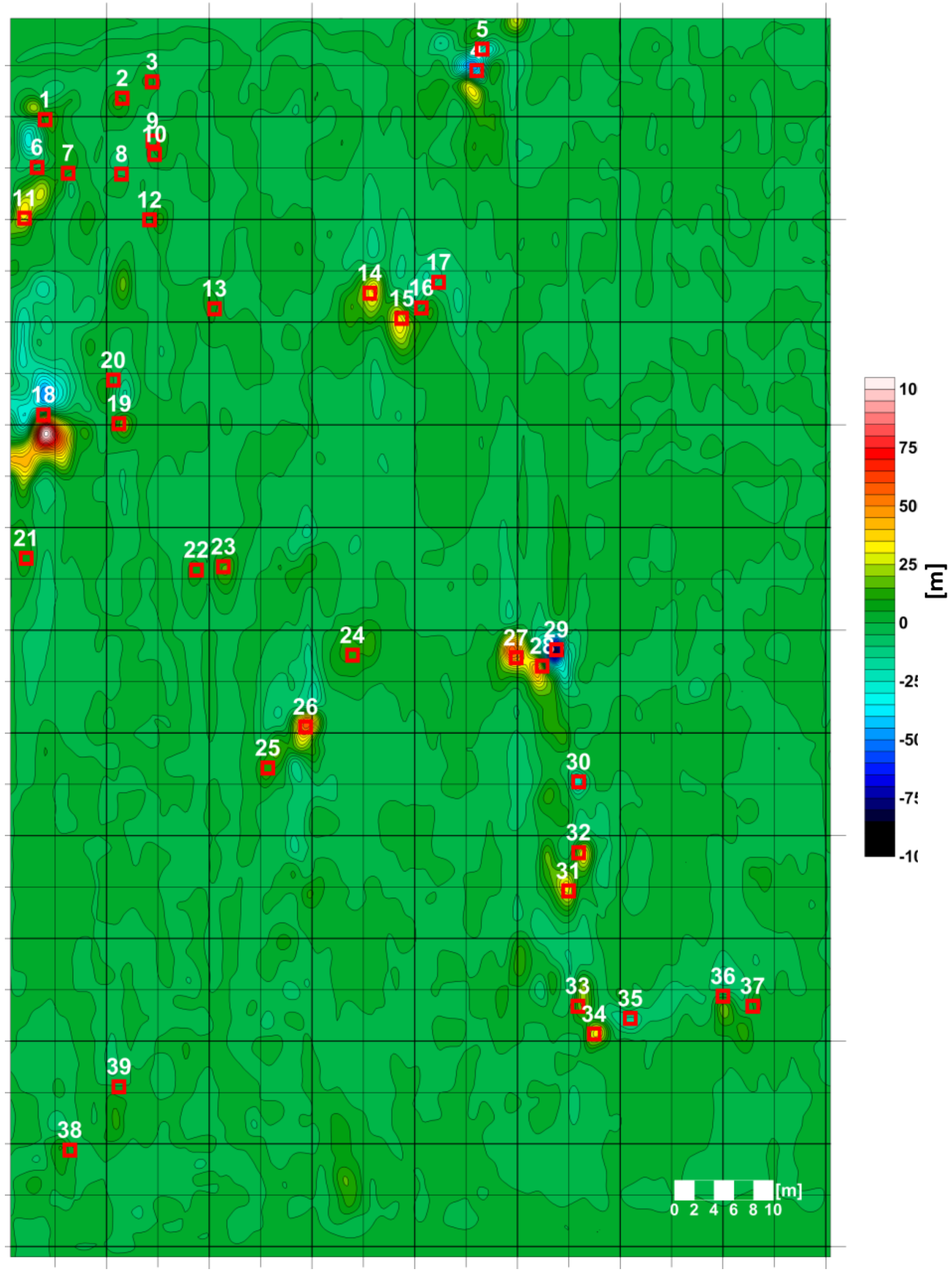


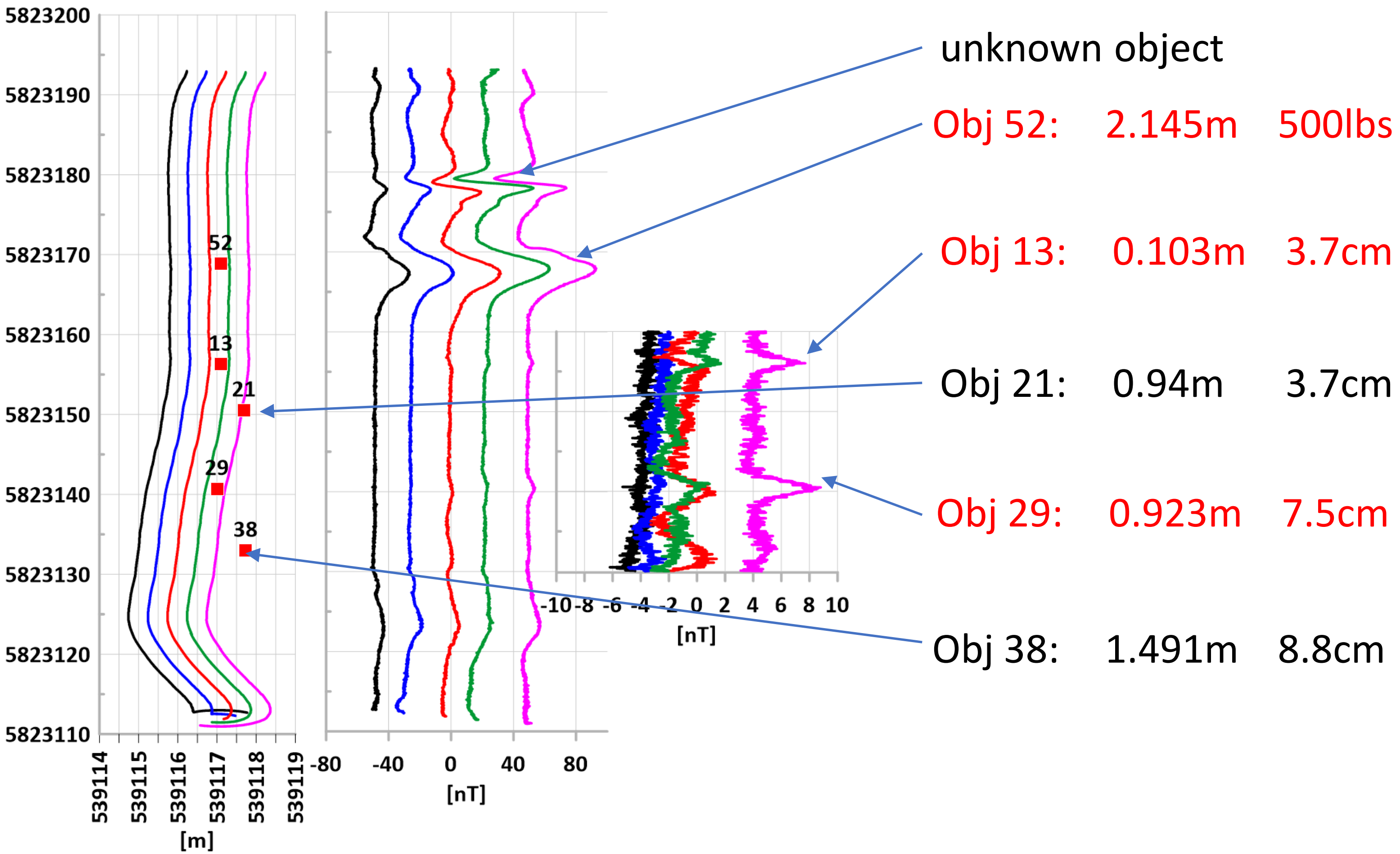
Total Magnetic intensity (TMI)

MULTICOPTER BORNE UXO DETECTION IN GERMANY

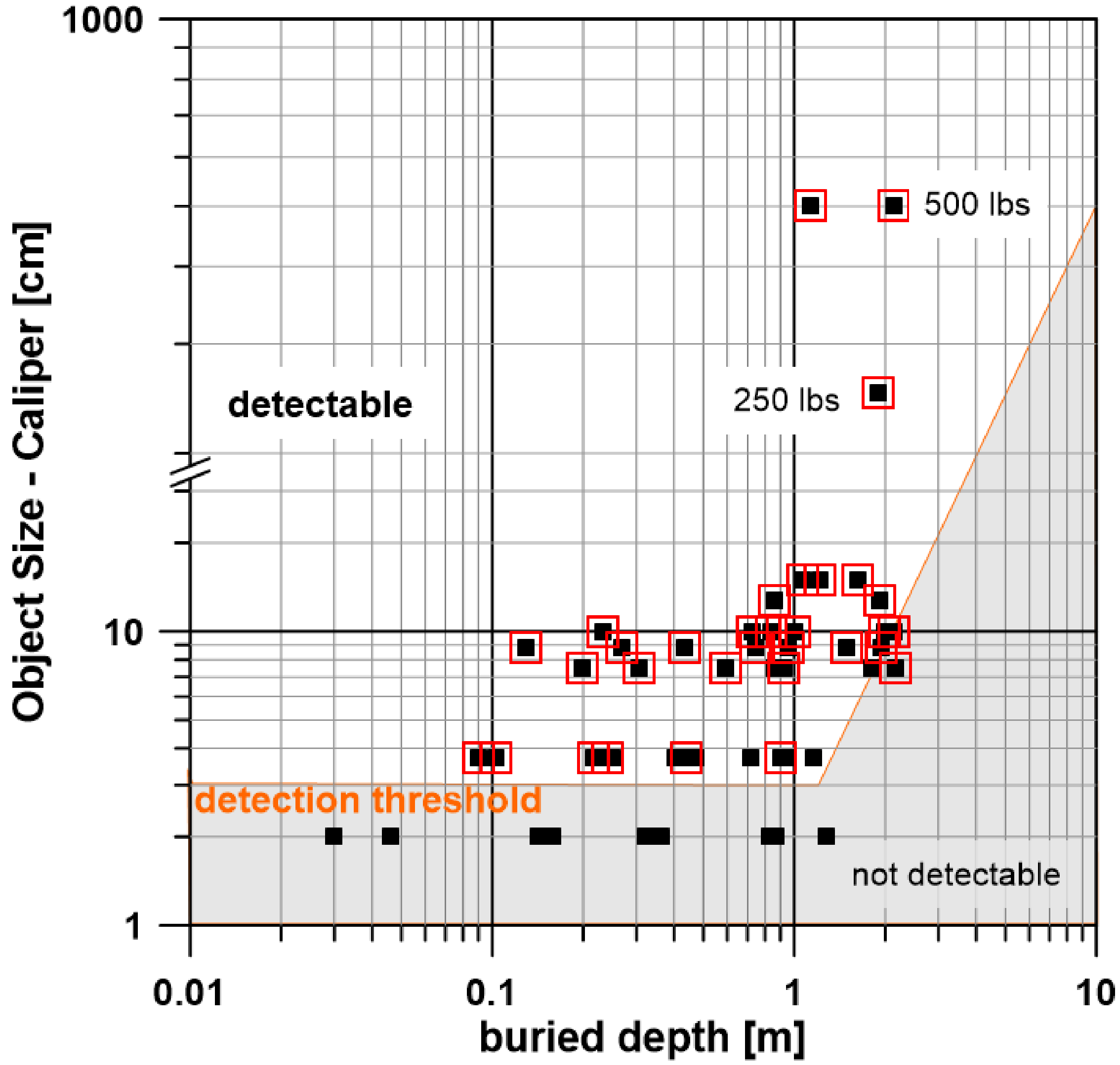


MULTICOPTER BORNE UXO DETECTION IN GERMANY

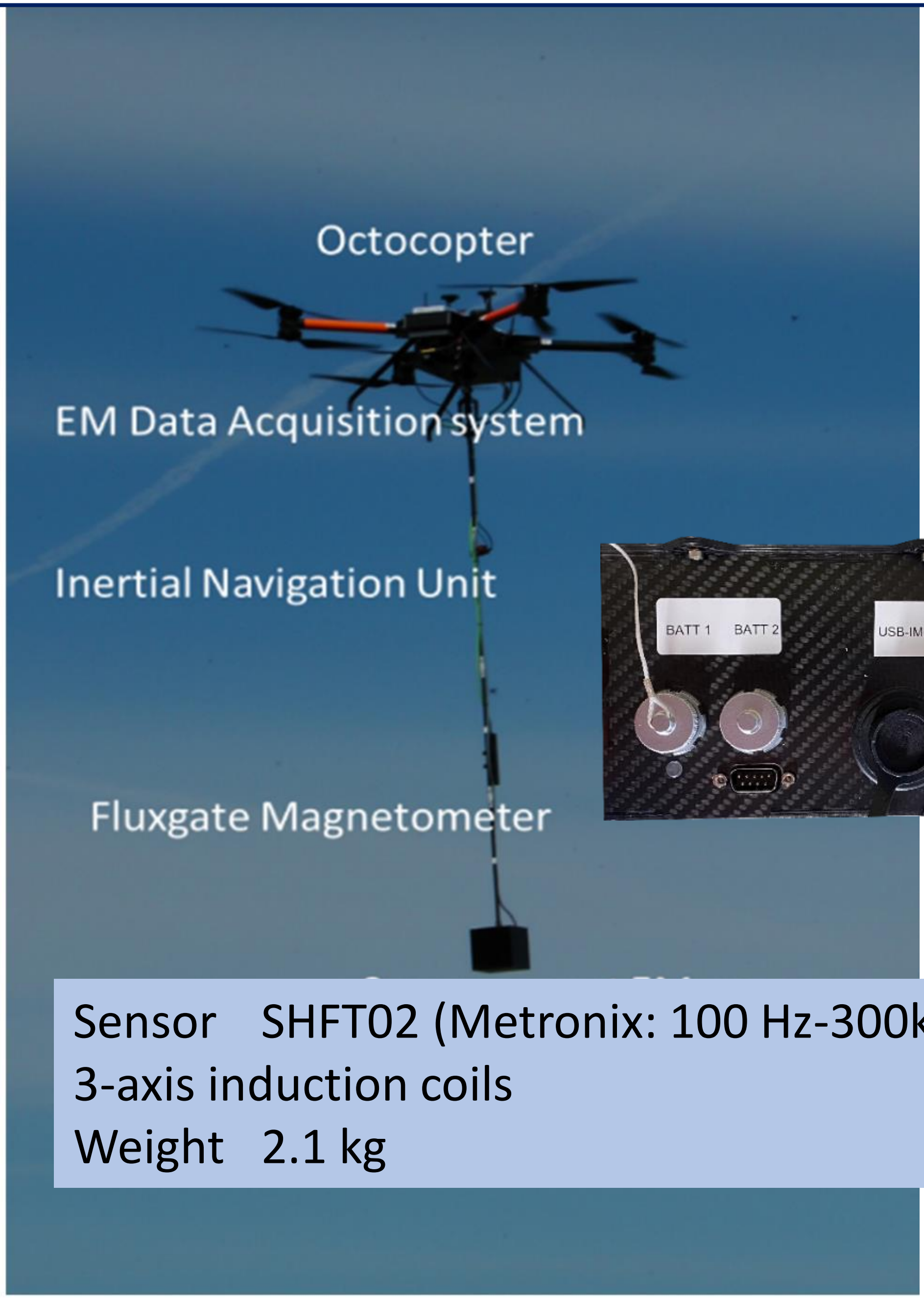




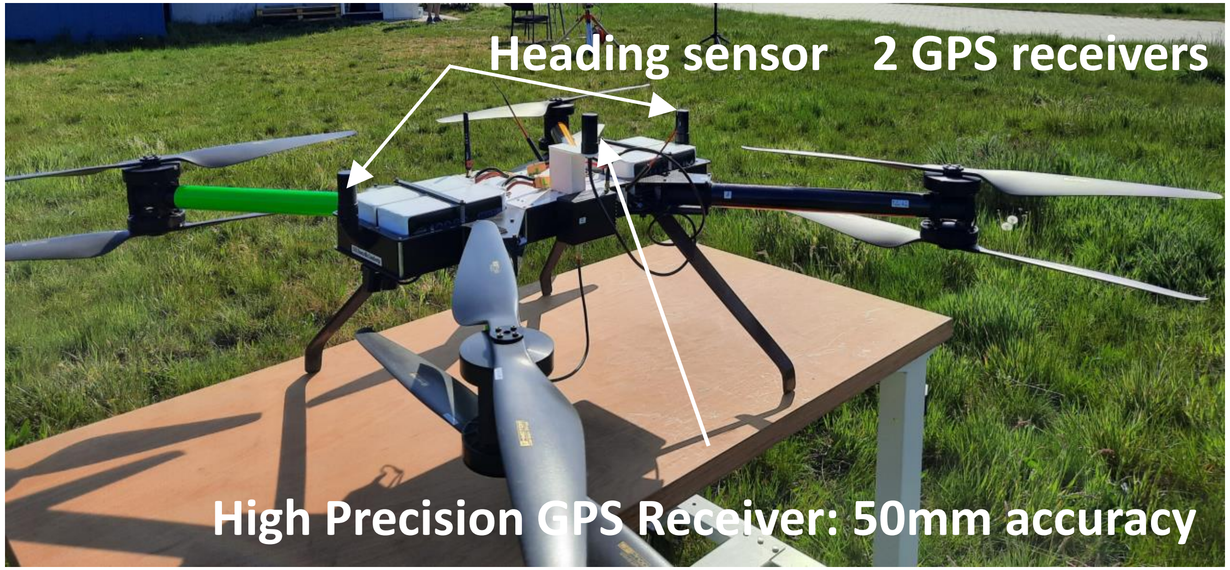
MULTICOPTER BORNE UXO DETECTION IN GERMANY



MULTICOPTER BORNE ELECTROMAGNETICS

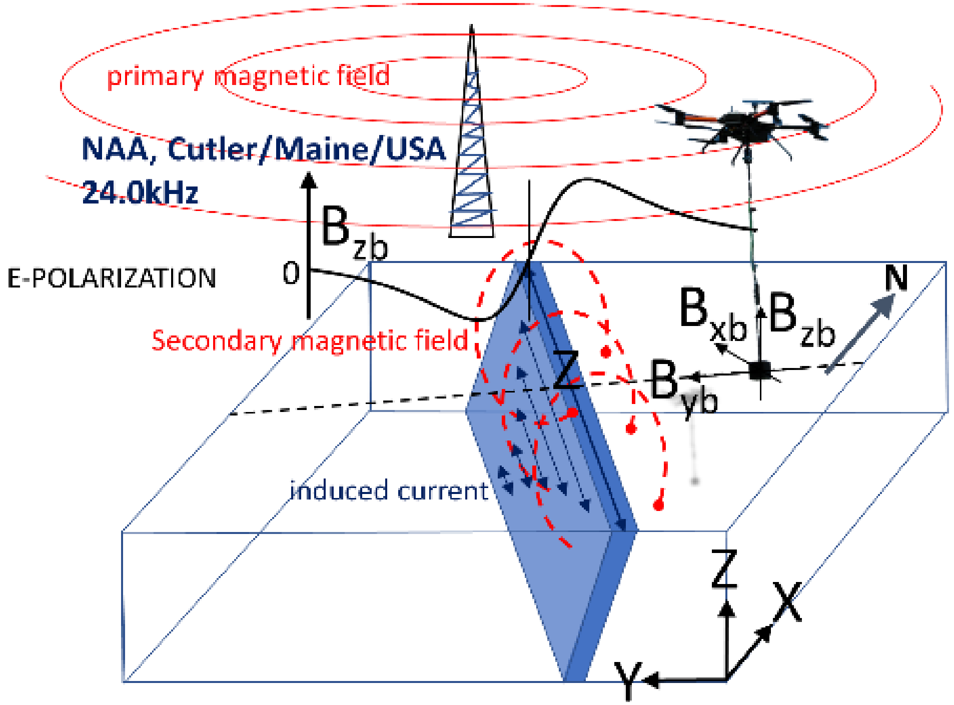


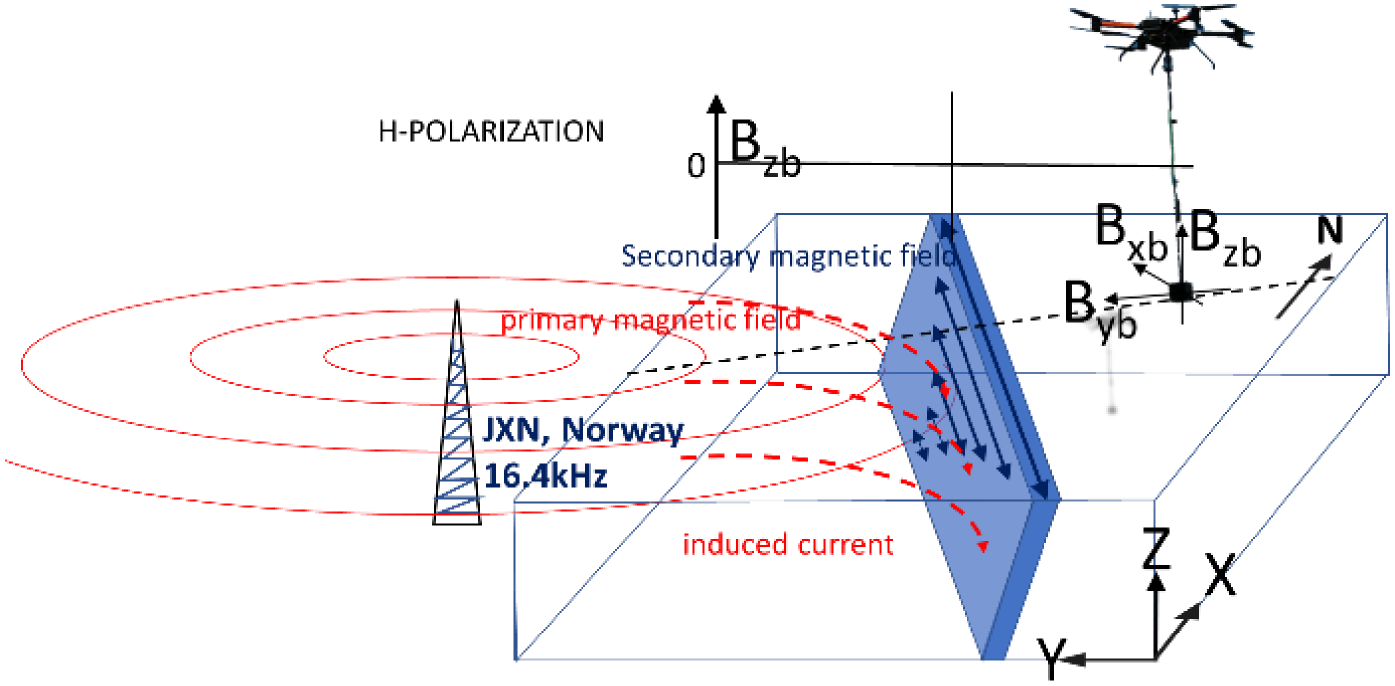
Sensor SHFT02 (Metronix: 100 Hz-300kHz
3-axis induction coils
Weight 2.1 kg



3 channels	Hx, Hy, Hz
Sample rate	524kHz
Weight	ca. 4.0 kg

VERY LOW FREQUENCY METHOD





$$\text{TIPPER } A(\omega) = \frac{H_Z(\omega)}{H_X(\omega)} \quad \text{TIPPER } B(\omega) = \frac{H_Z(\omega)}{H_Y(\omega)}$$

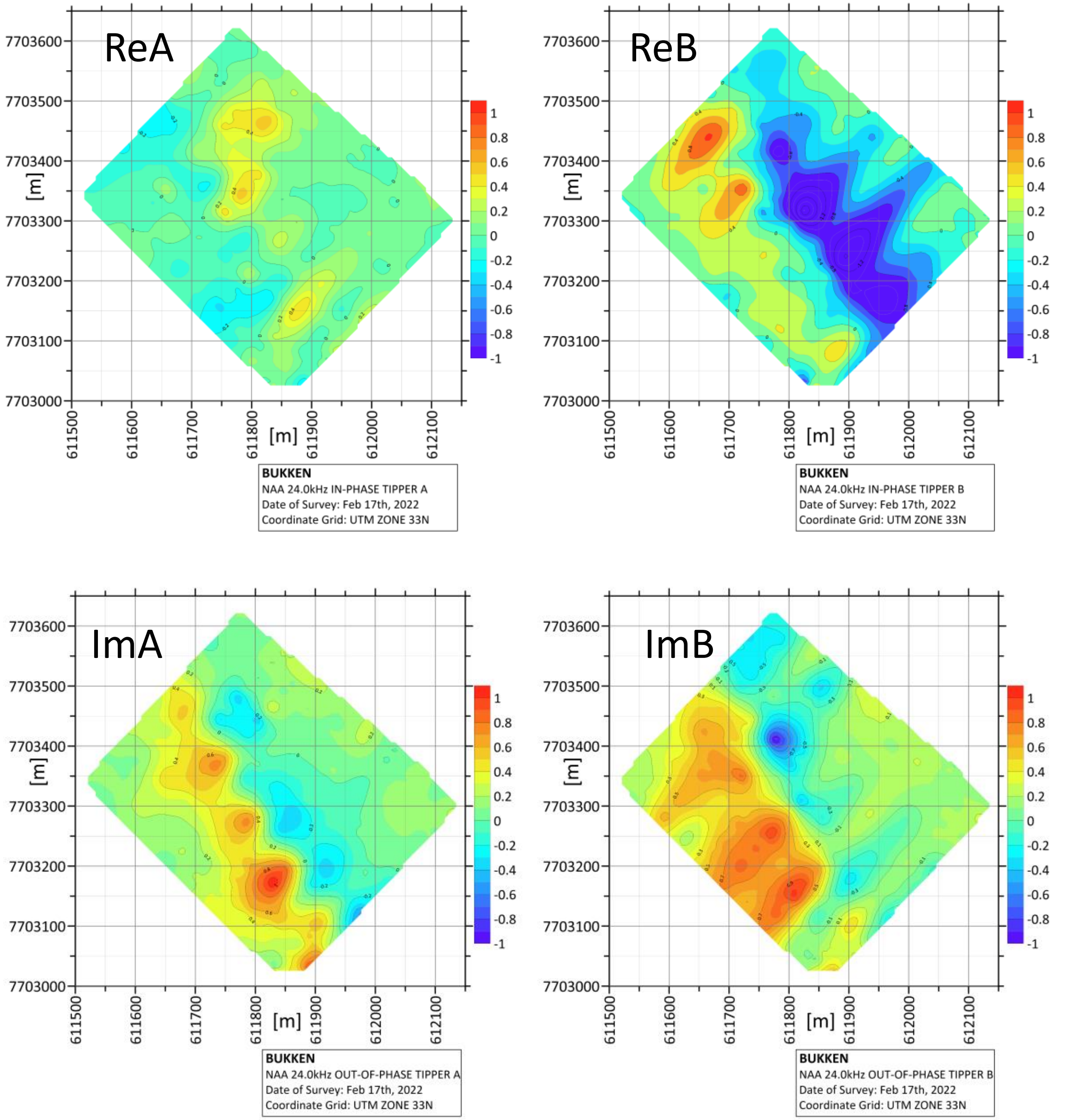
$$\text{geomagtransferfkt} \quad H_z(\omega) = A(\omega) \cdot H_x(\omega) + B(\omega) \cdot H_y(\omega)$$

$$\text{PEAKER} \quad P = \frac{\partial A}{\partial x} + \frac{\partial B}{\partial x} = \nabla_h \cdot (A, B)$$

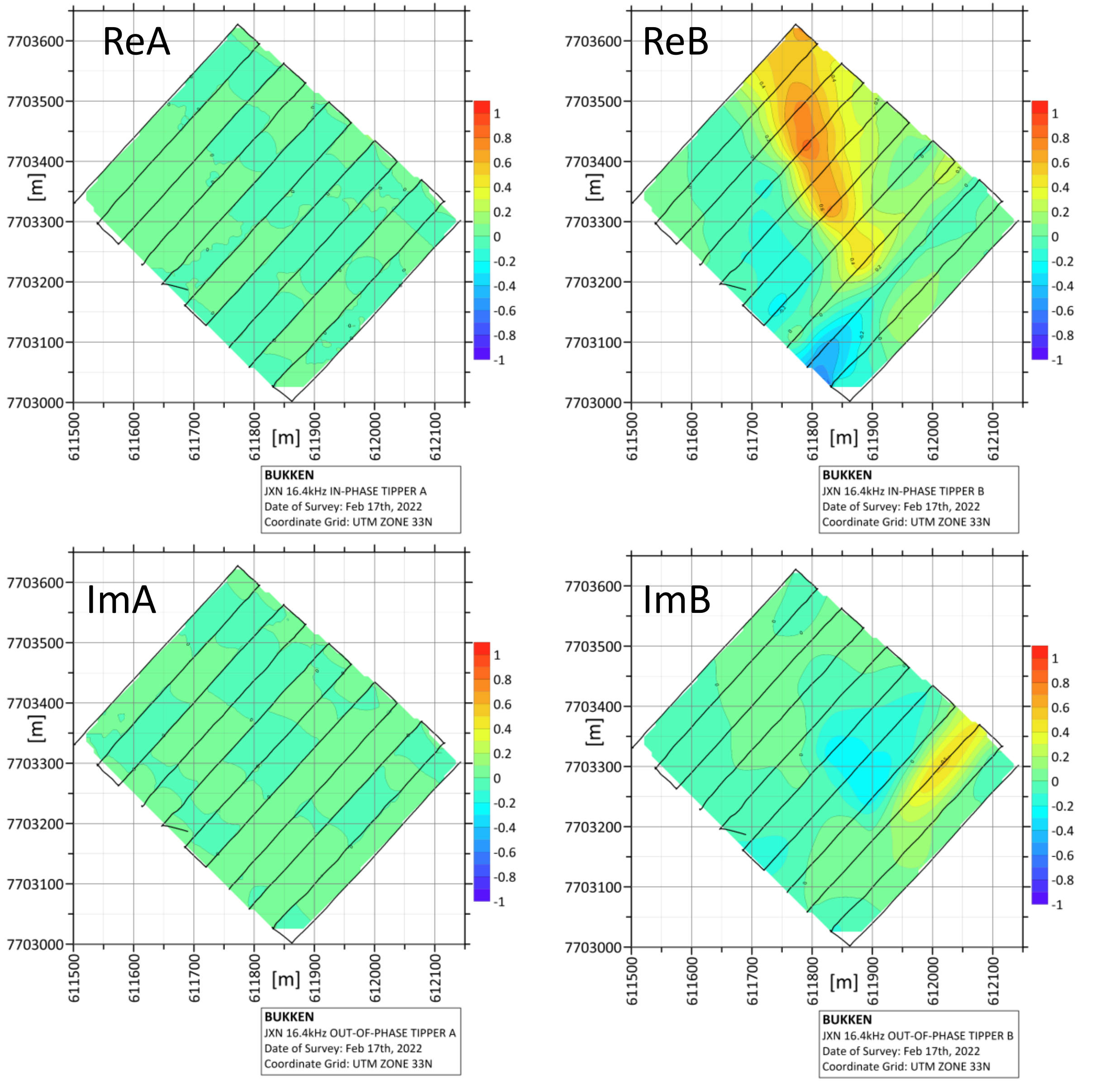
Pedersen et al, 1994

VLF-EM PROJECT IN NORTH NORWAY

VLF-EM PROJECT IN NORTH NORWAY



NAA, 24.0kHz

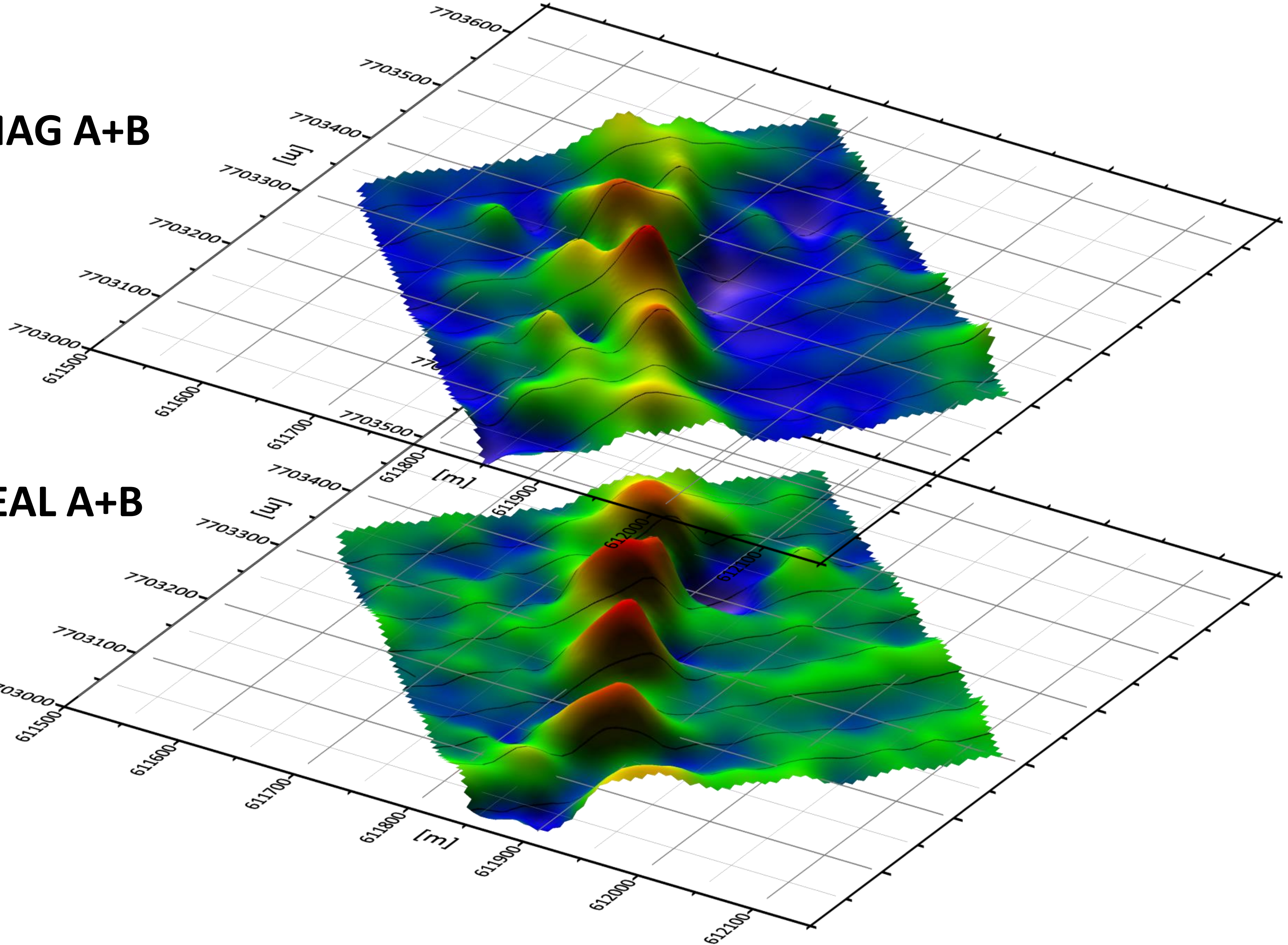


JXN,16.4kHz

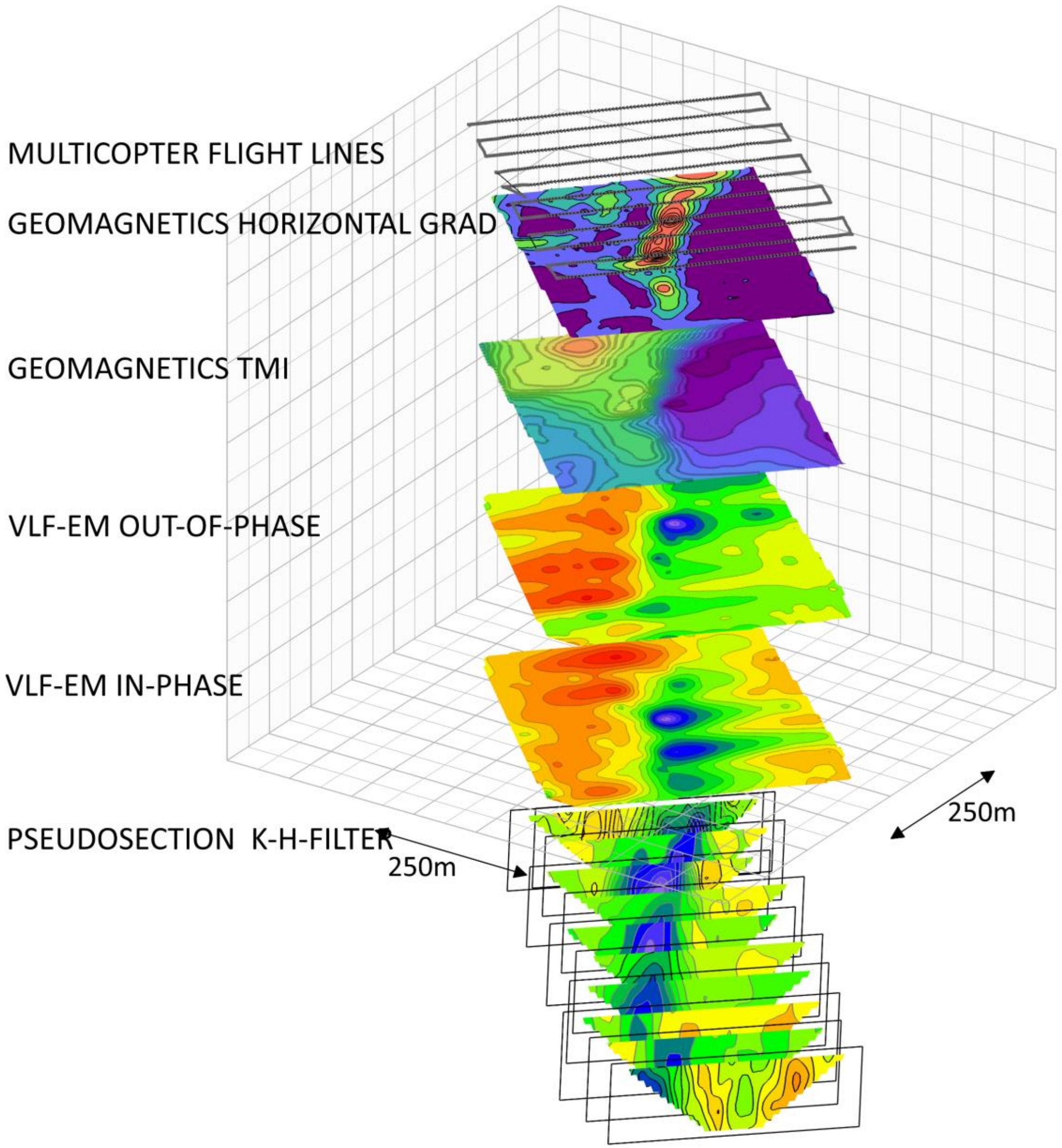
VLF-EM PROJECT IN NORTH NORWAY

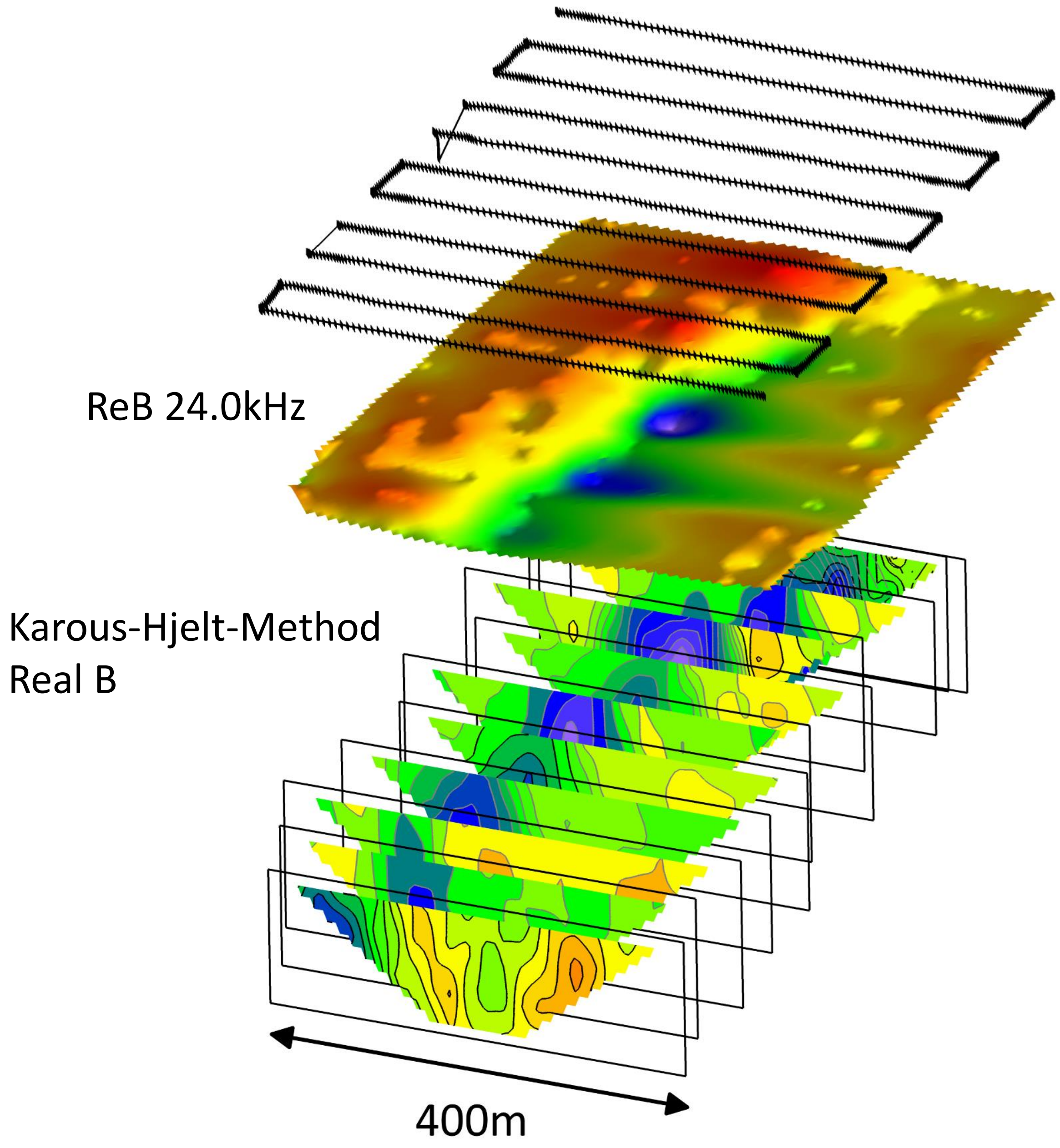
PEAKER IMAG A+B

PEAKER REAL A+B

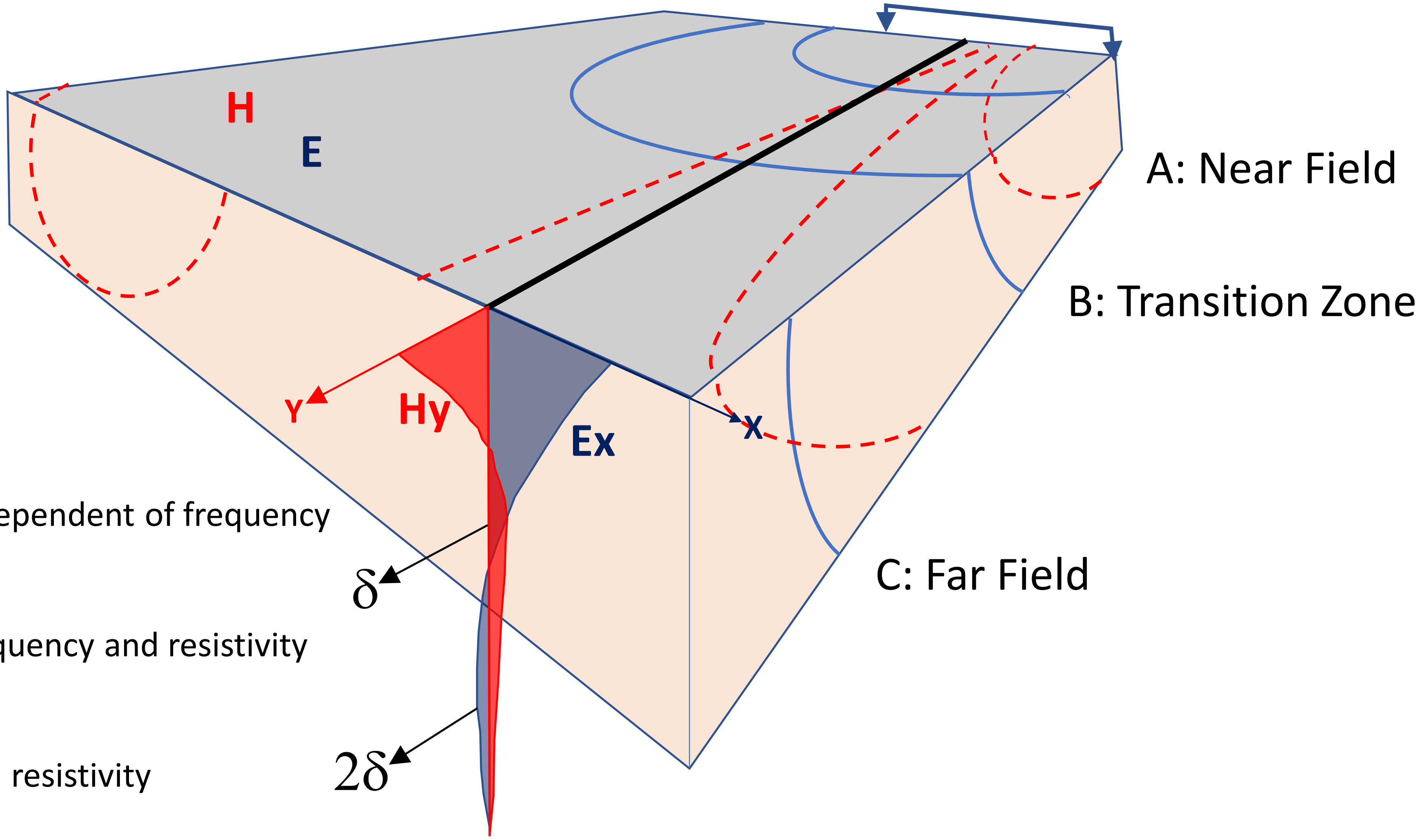


VLF-EM PROJECT IN NORTH NORWAY





SEMI-AIRBORNE ELECTROMAGNETICS

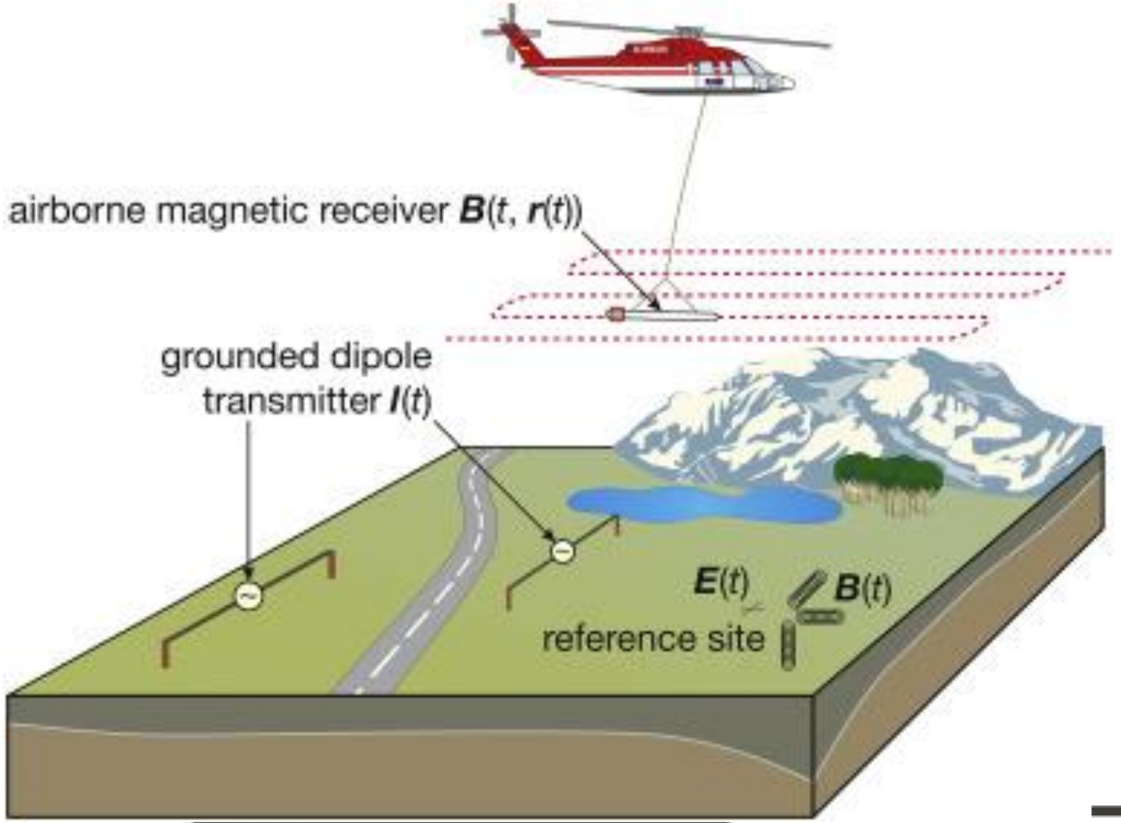


A: NEAR FIELD rA << δ
D depends on geometry, independent of frequency

B: TRANSITION ZONE rB ~ δ
D depends on geometry, frequency and resistivity

C: FAR FIELD rC >> δ
D depends on frequency and resistivity

SEMI-AIRBORNE ELECTROMAGNETICS



DESMEX

Deep Electromagnetic Sounding for Mineral Exploration

BMBF funded Programme

WWU MÜNSTER

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

iMAR NAVIGATION & CONTROL

Leibniz ipht LEIBNIZ-INSTITUT für PHOTONISCHE TECHNOLOGIEN

LIAG Leibniz-Institut für Angewandte Geophysik

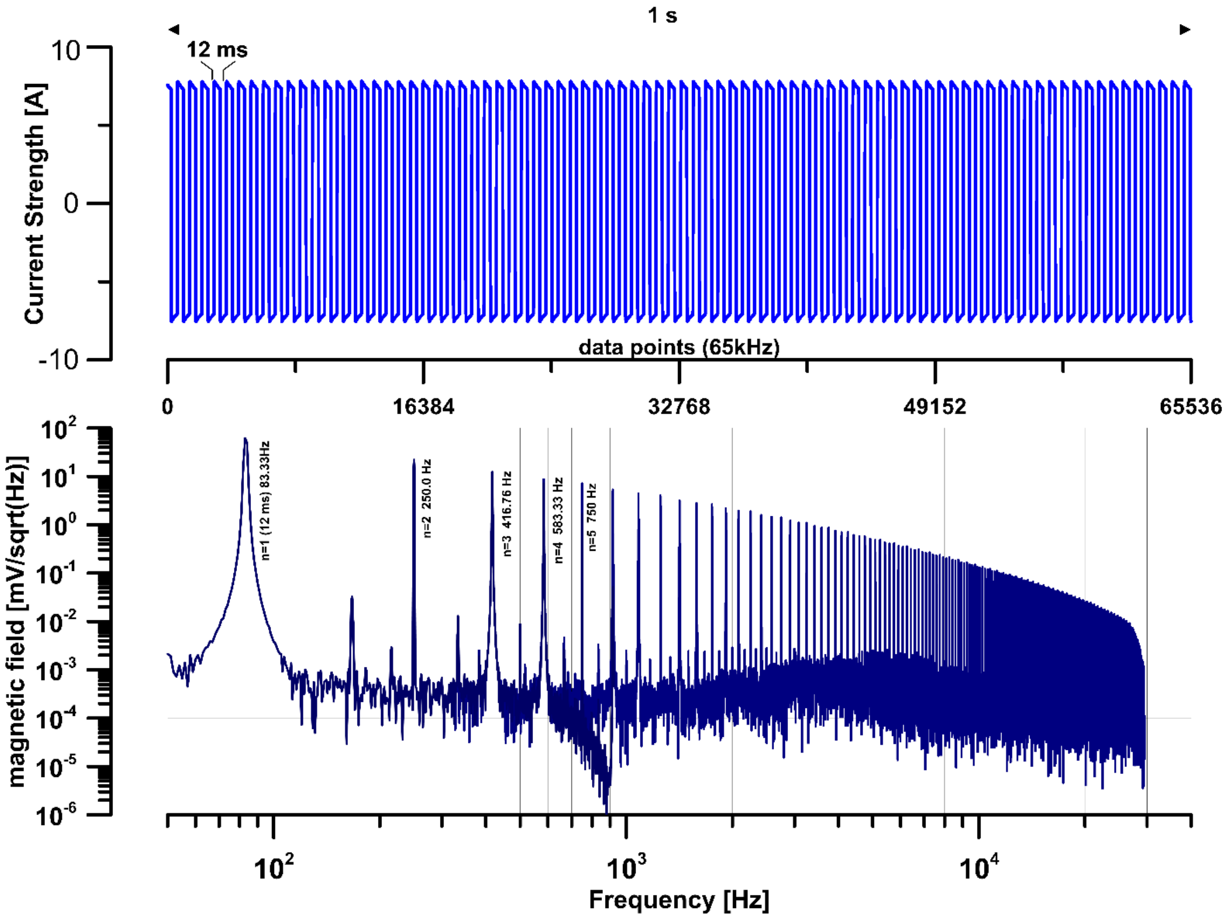
IGM Geophysics Cologne

supracon SQUID and Microfabrication Technologies

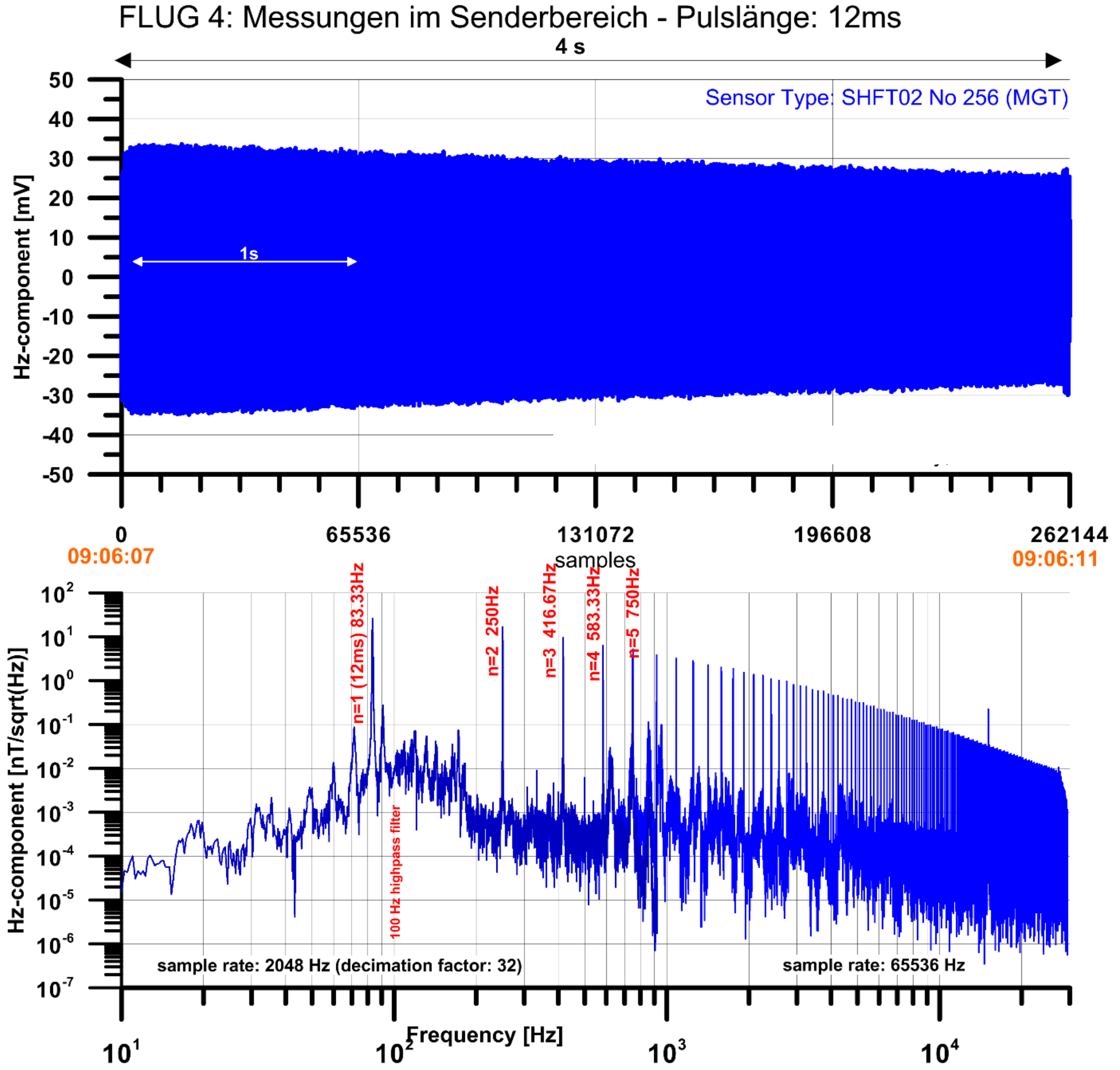
terratec Geophysical Services

DMT

SEMI-AIRBORNE ELECTROMAGNETICS



TRANSMITTER TX

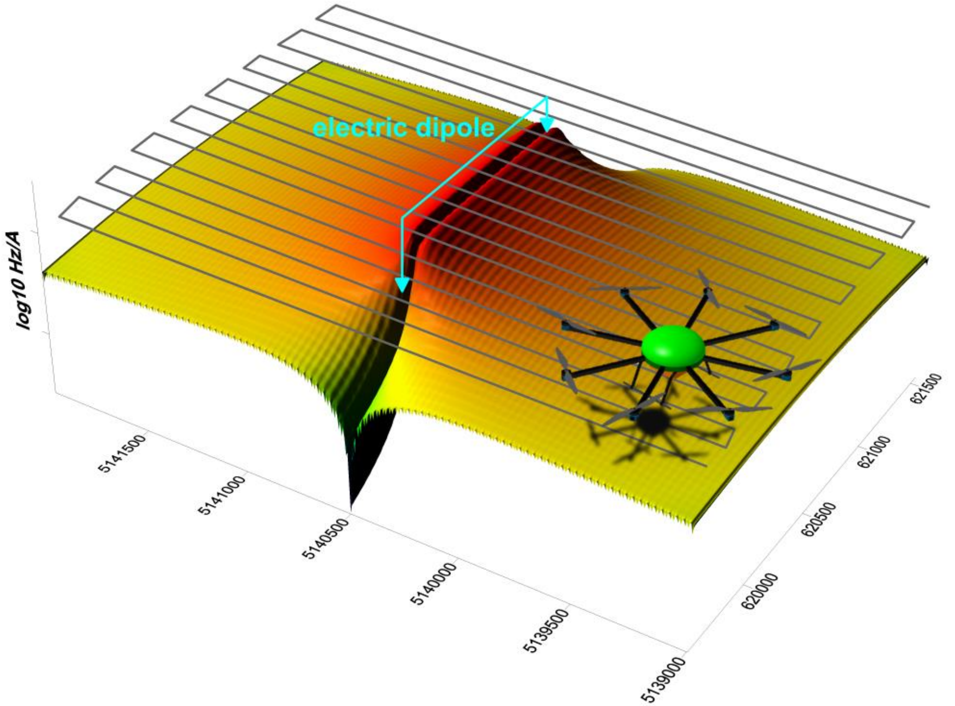


RECEIVER RX

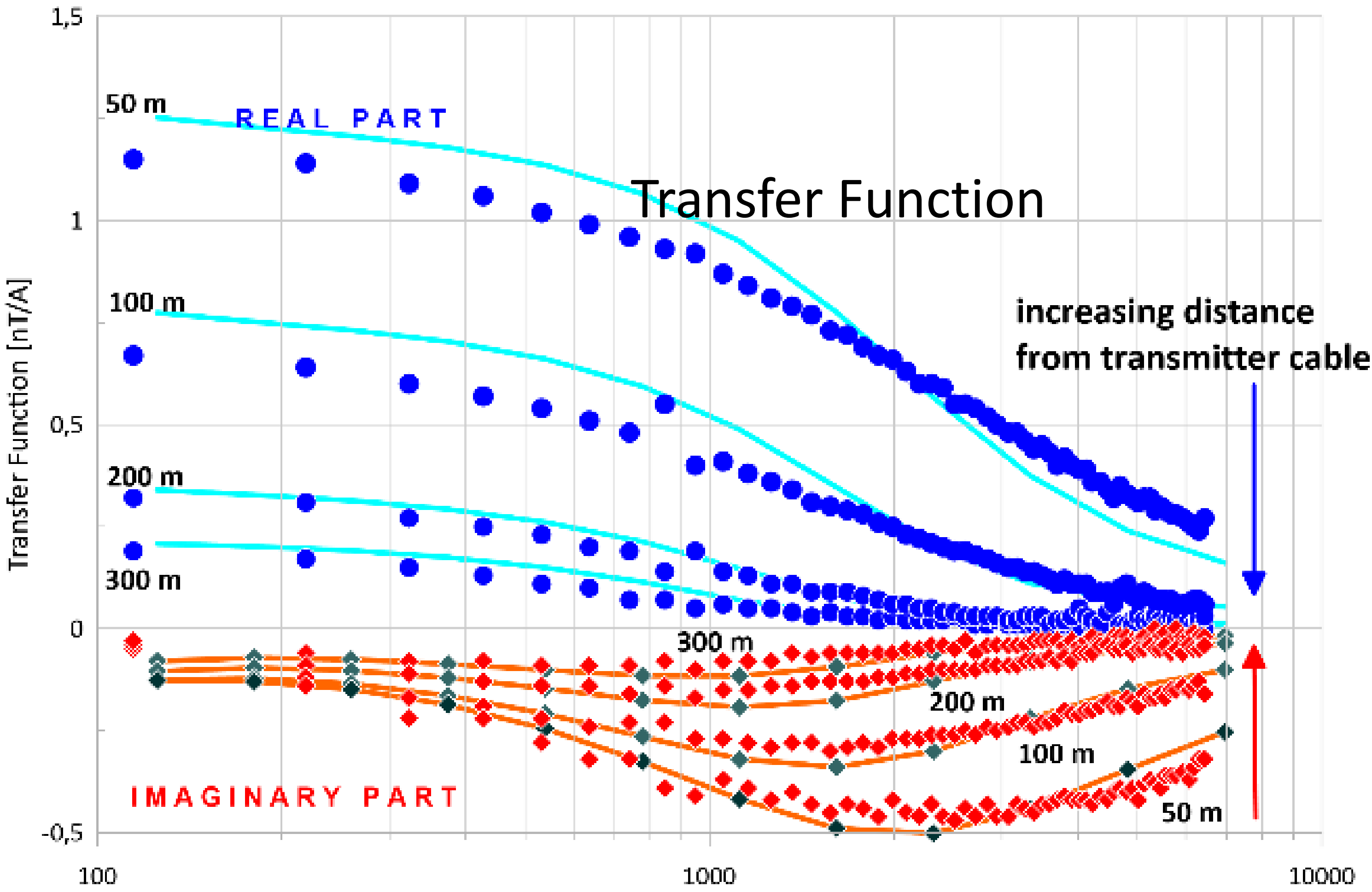
SEMI-AIRBORNE ELECTROMAGNETICS

FROM TIME SERIES TO TRANSFER FUNCTION

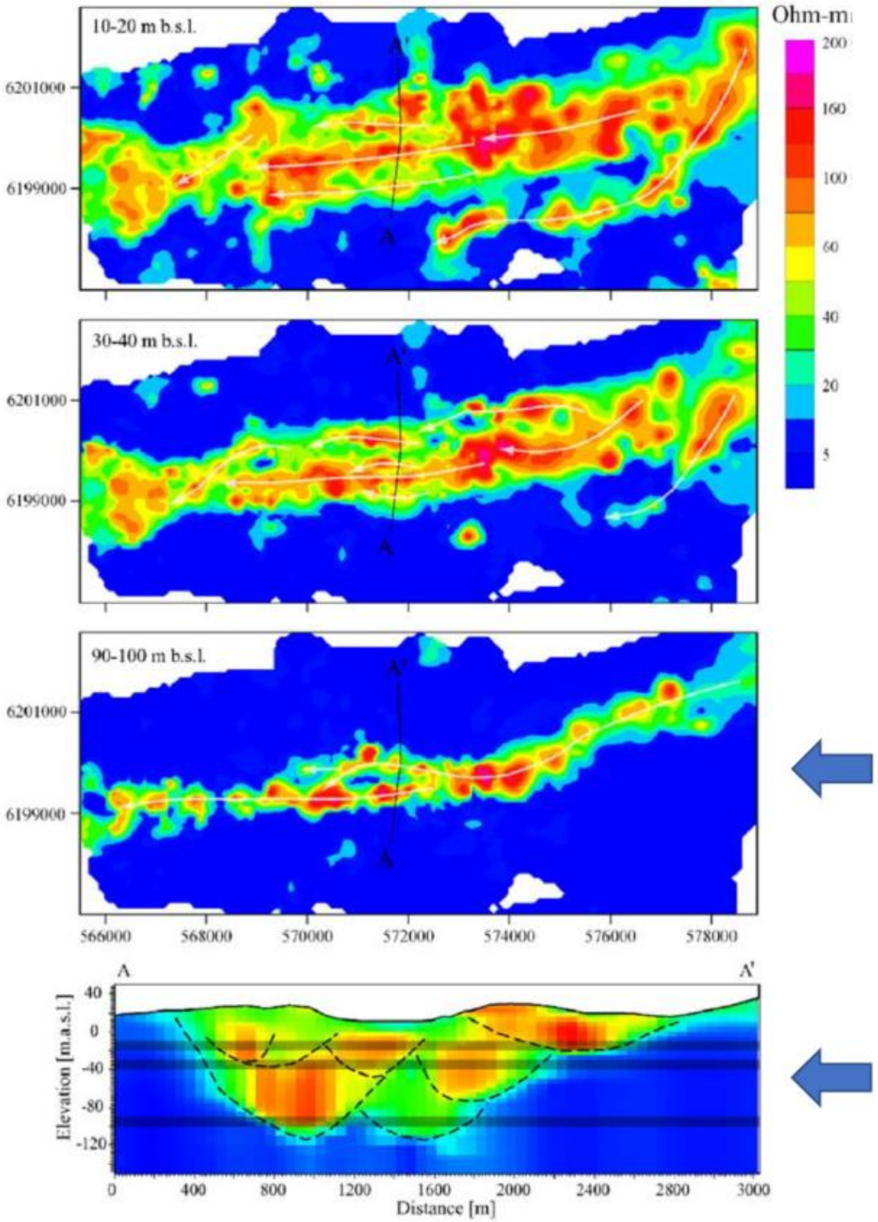
Field Data



Transfer Function

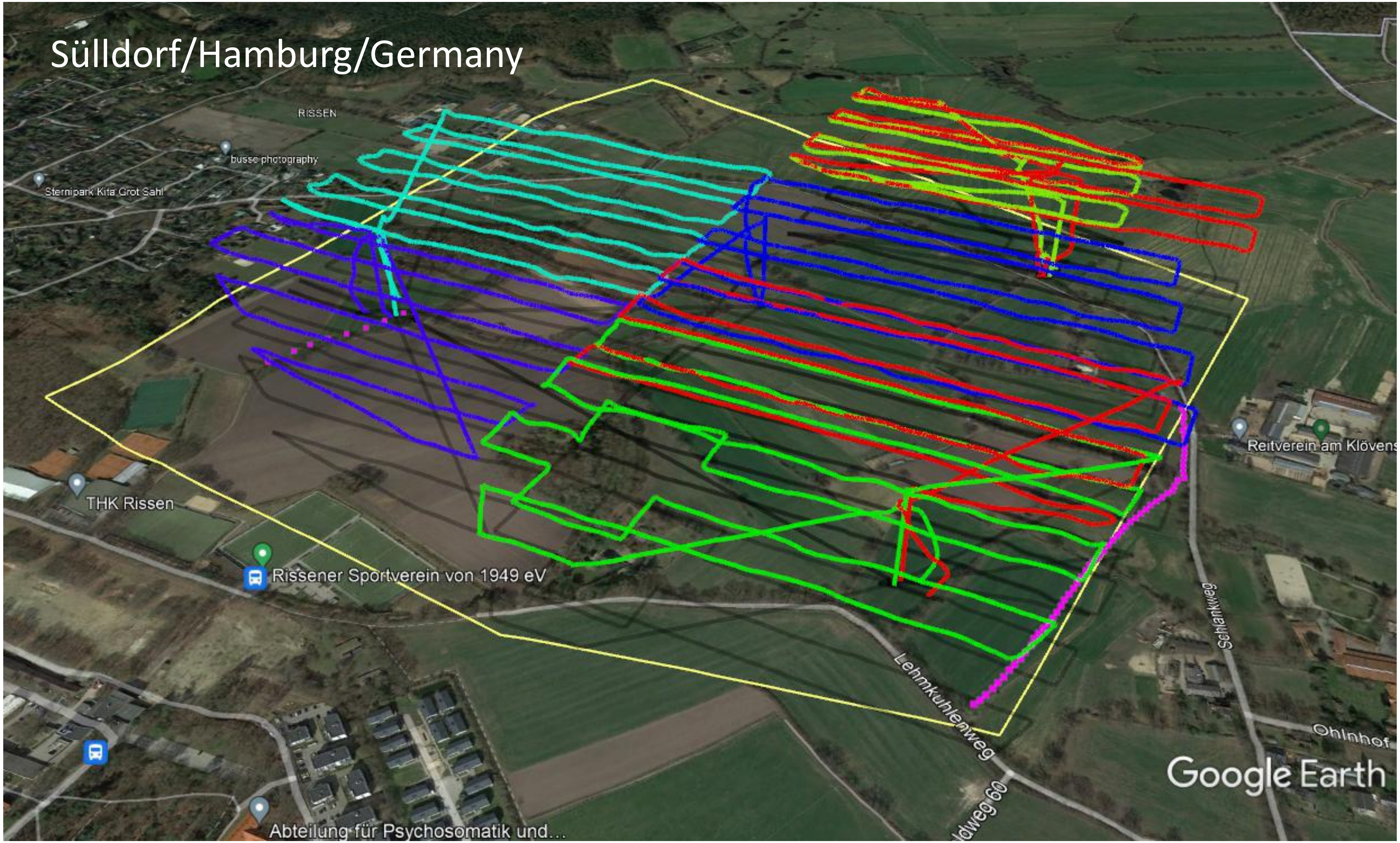


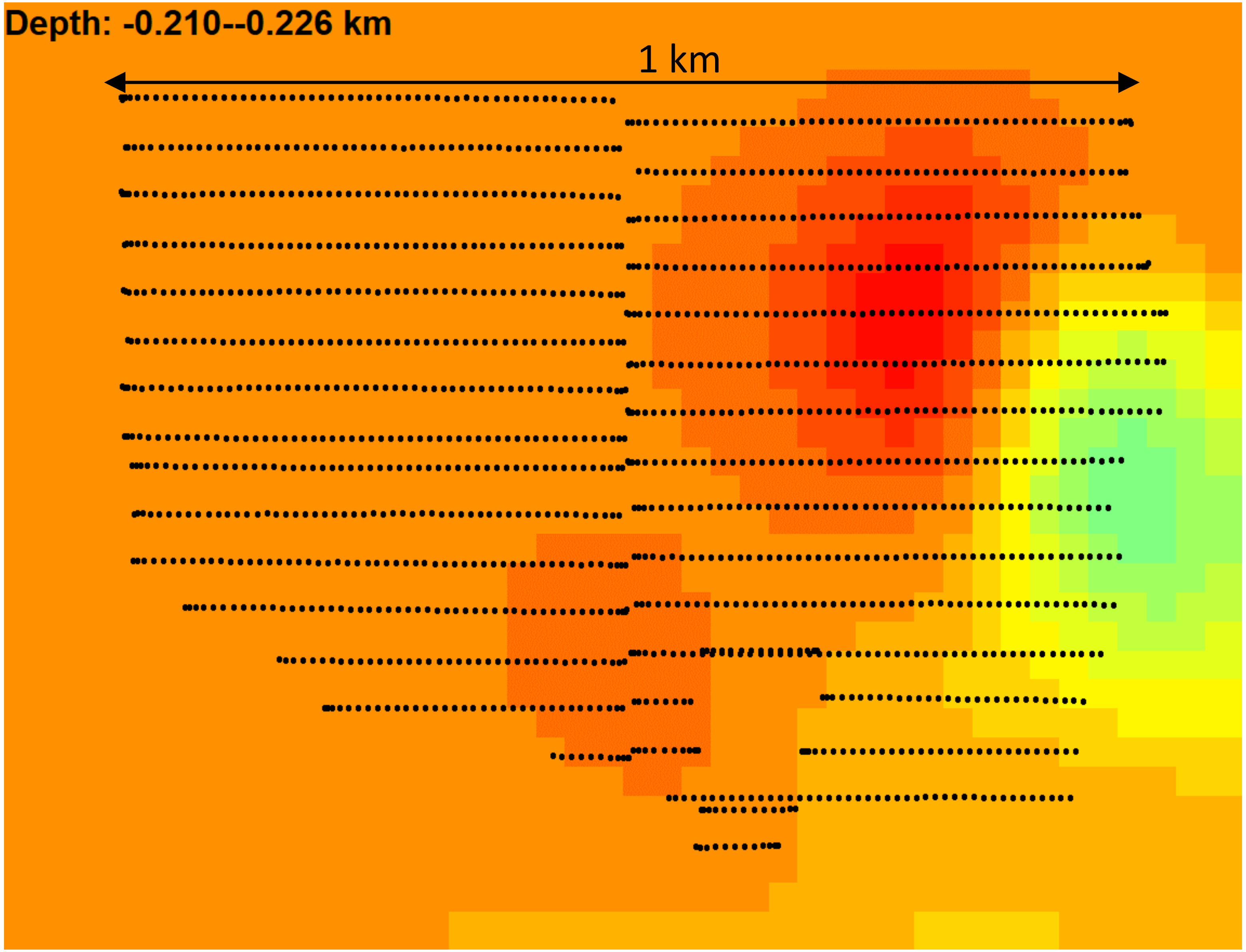
SEMI-AIRBORNE ELECTROMAGNETICS



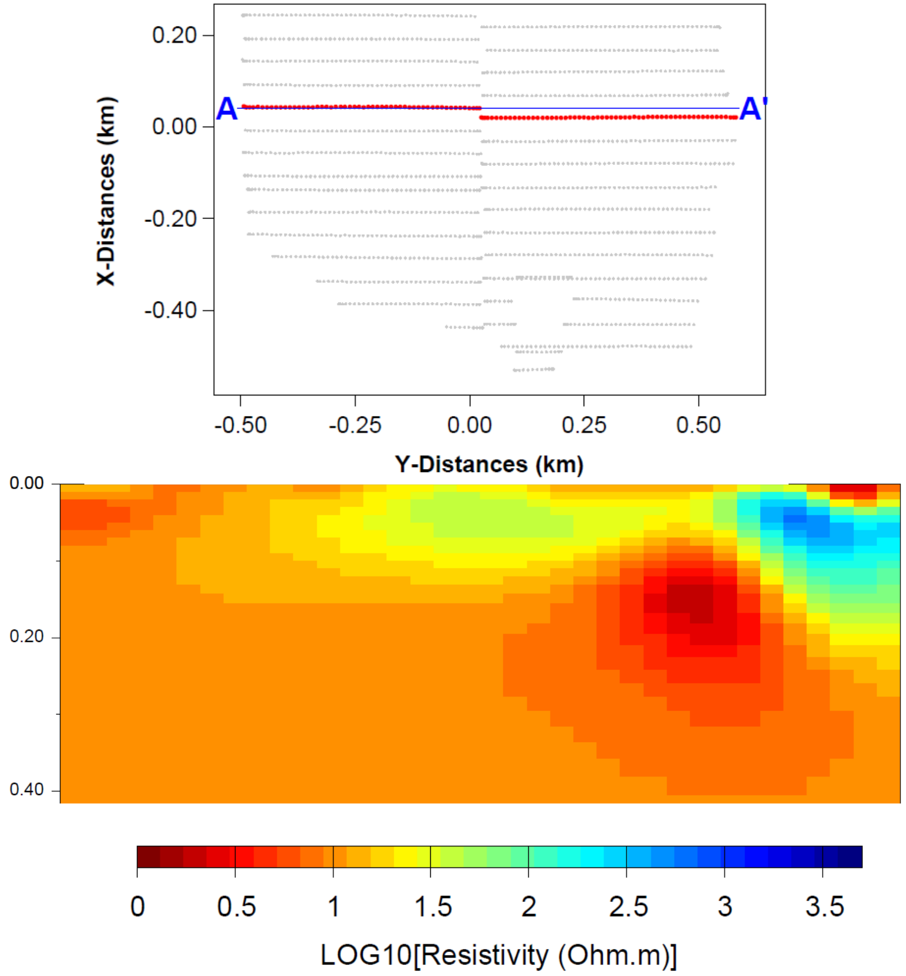
PALEOCHANNEL
SkyTEM, DENMARK

DETECTION OF A PALEOCHANNEL



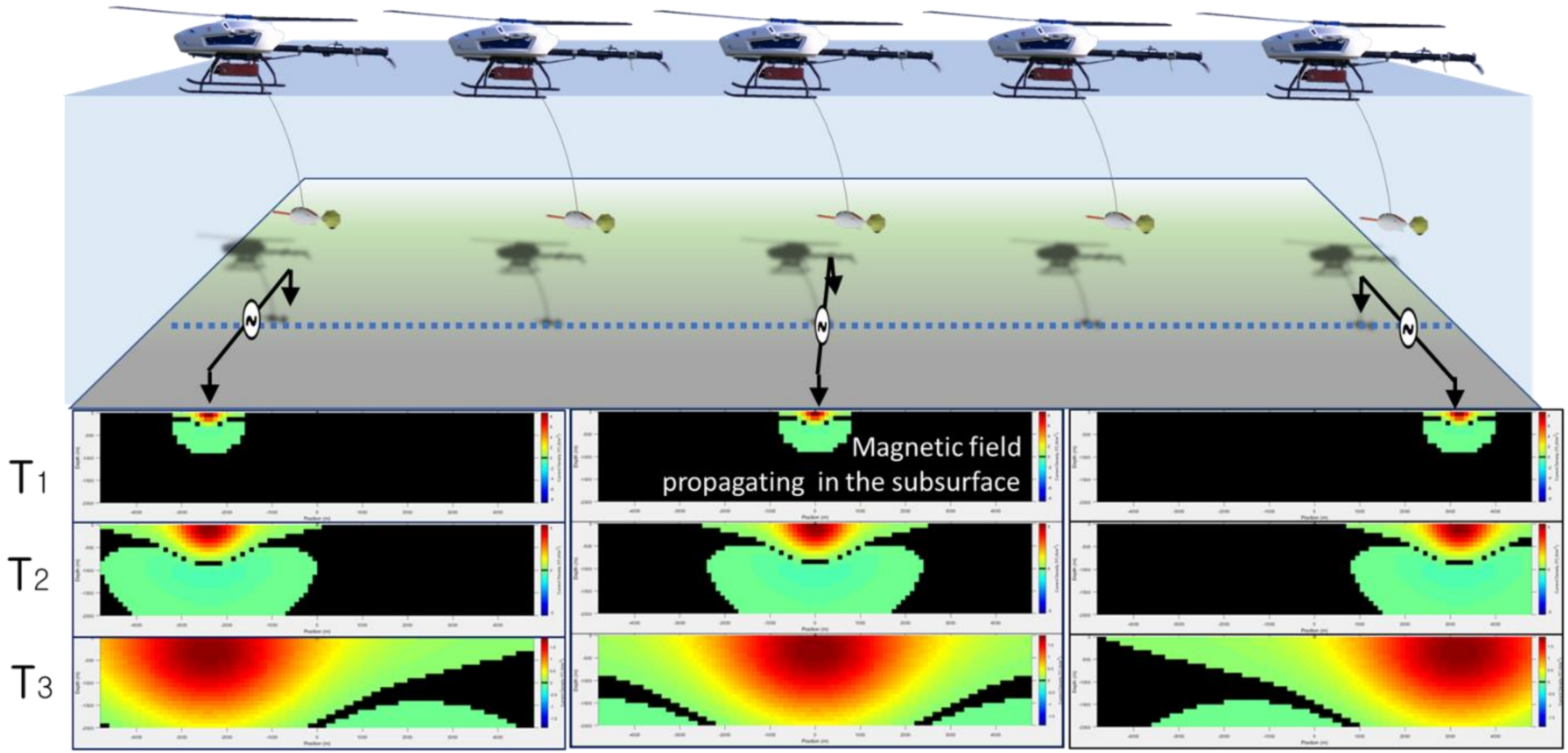


GROUNDWATER EXPLORATION IN GERMANY



Results of 3D Inversion provided by MODEM: Naser Meqbel, 2022

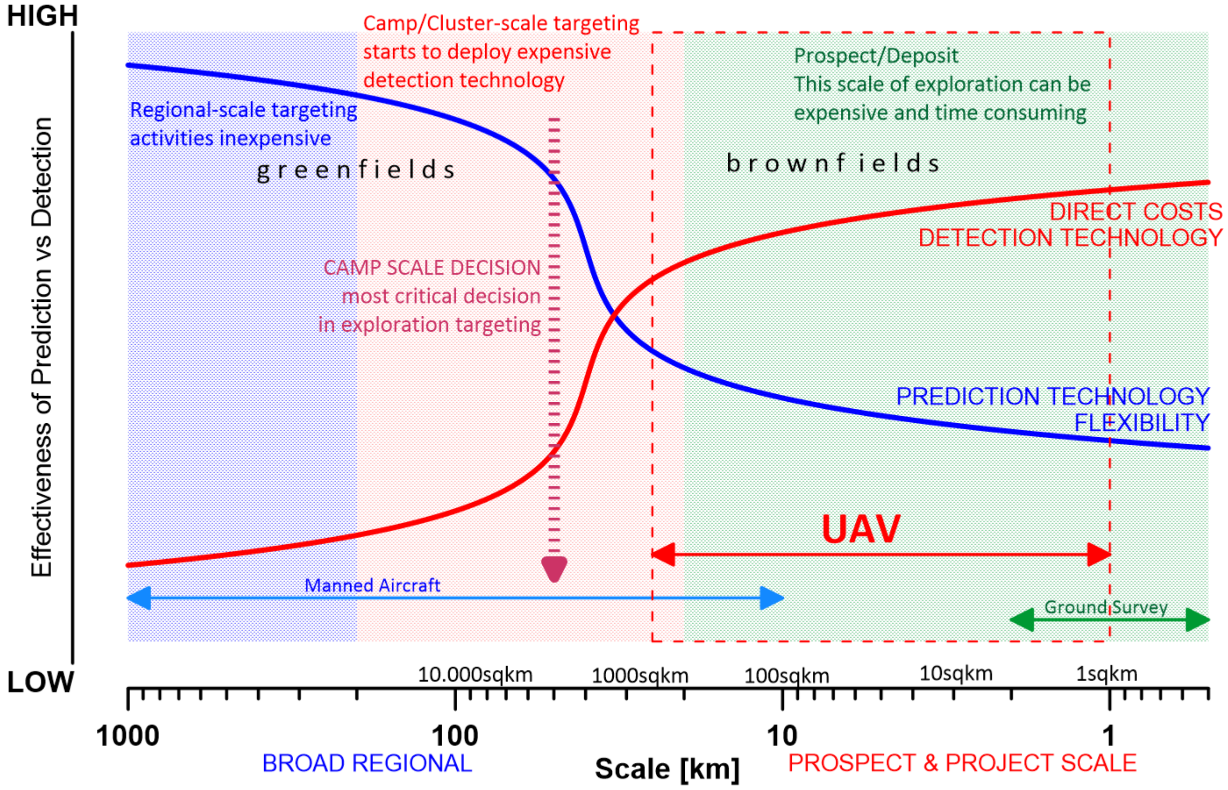
INTERFEROGRAPHIC TEM IMAGING METHOD – BRYAN JAMES

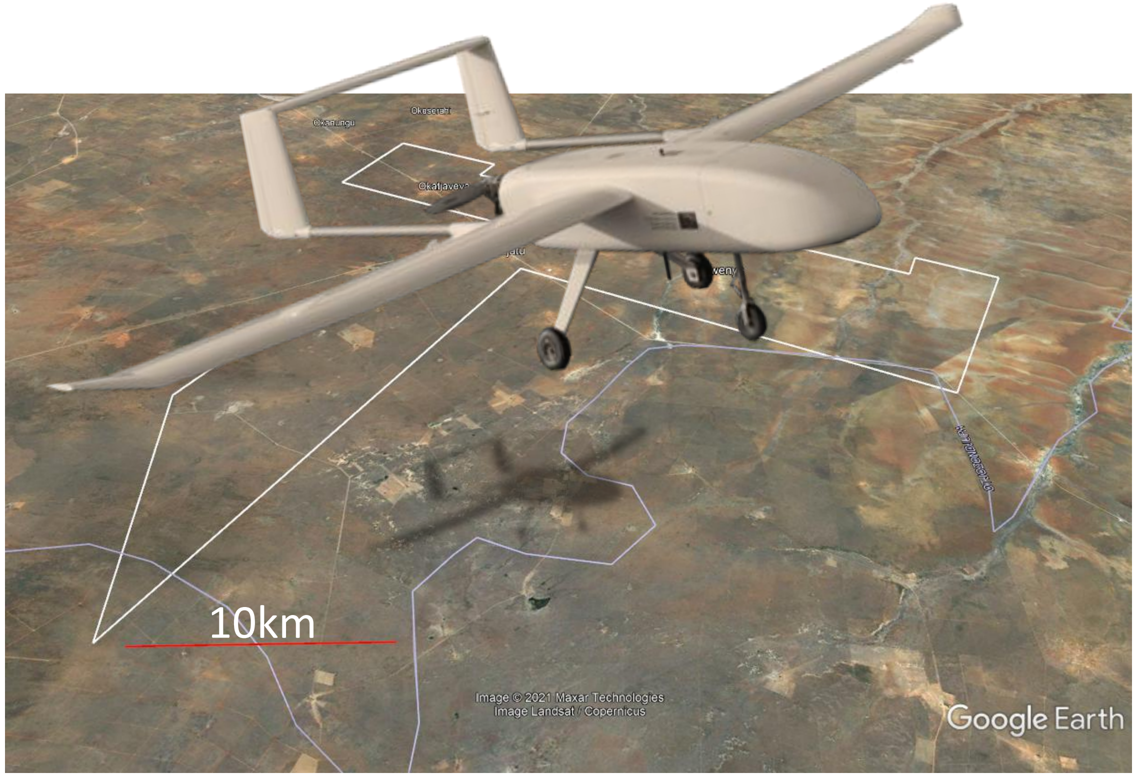


FUTURE TRENDS IN EXPLORATION

25KG LONG ENDURANCE FIXED WING UAV

„Camp-Scale Decision!“

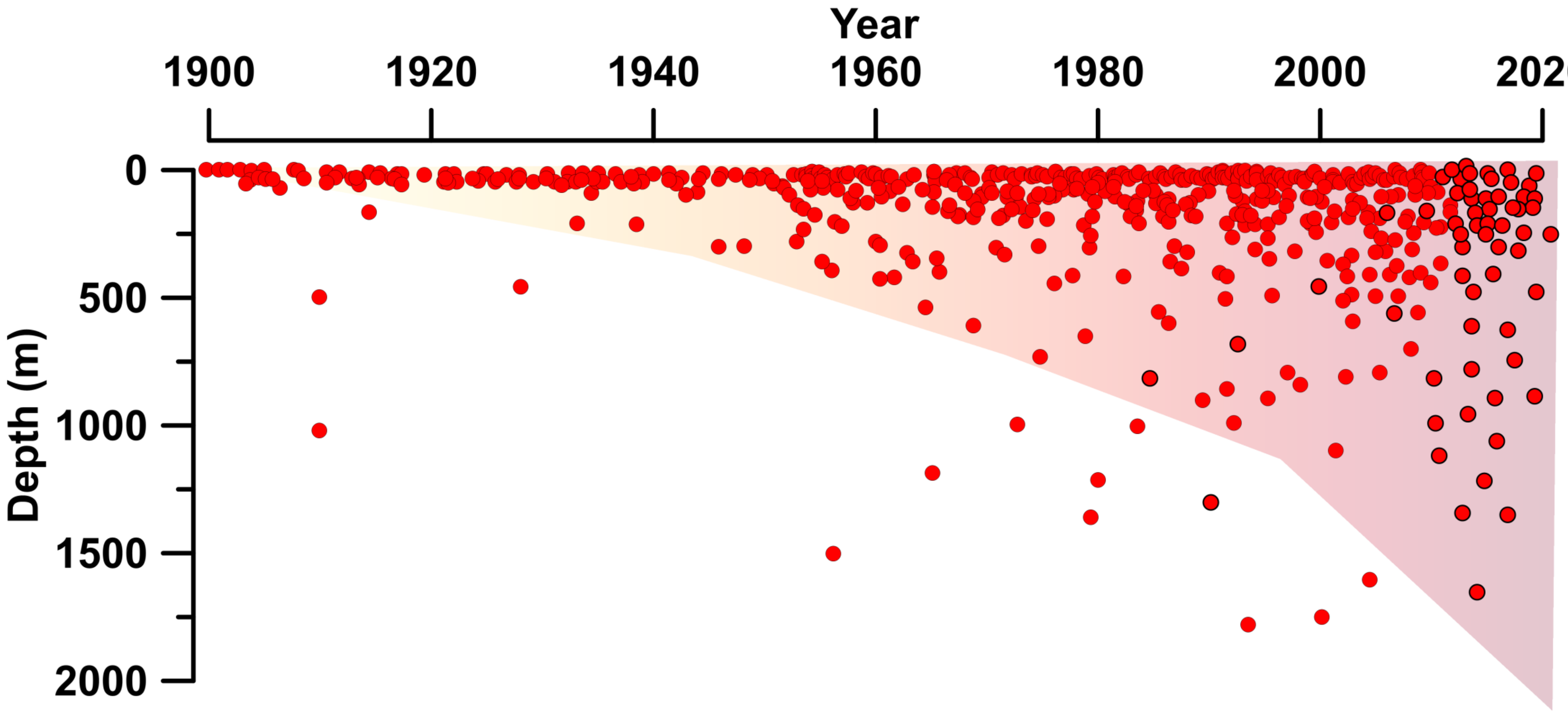




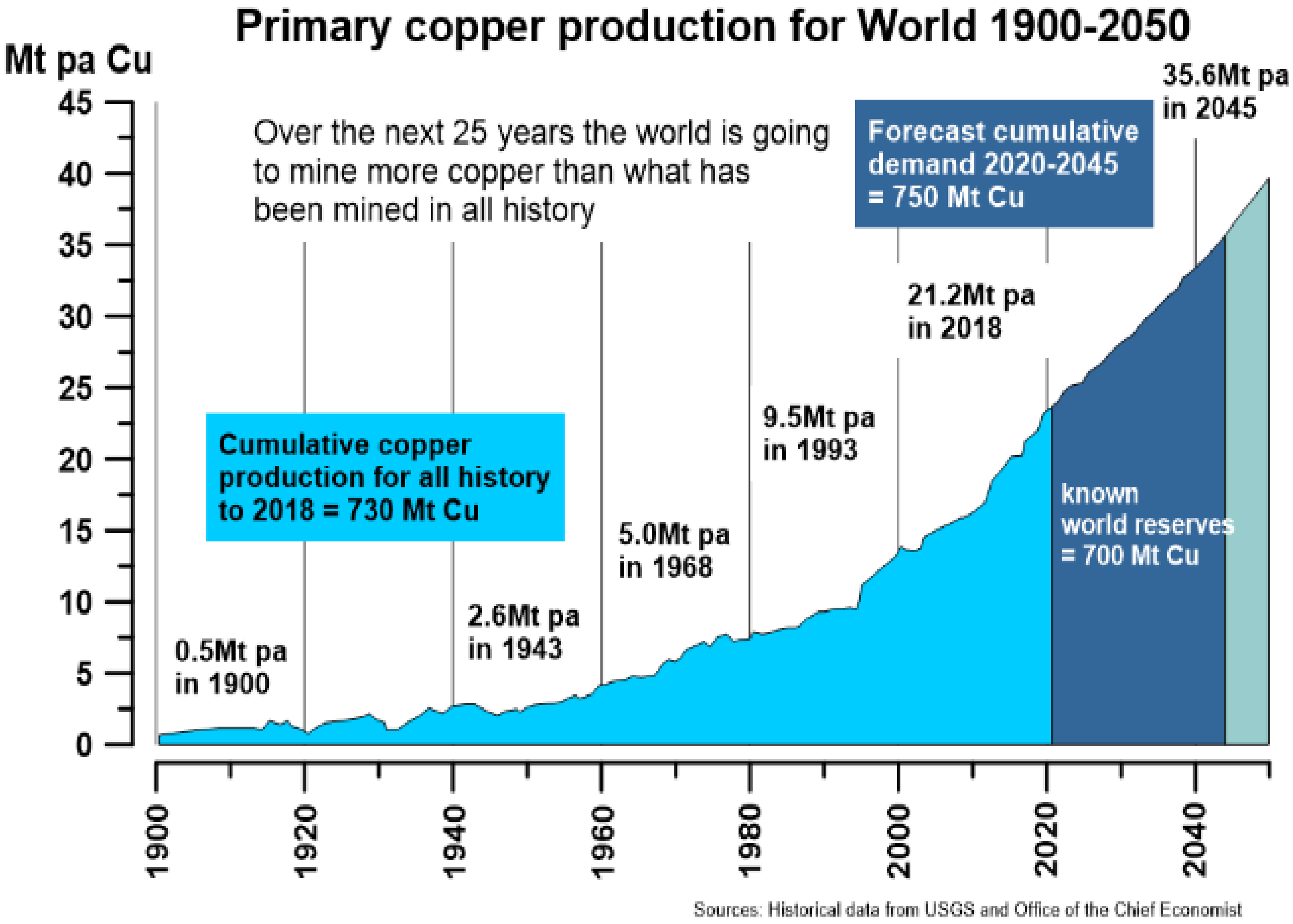
Direct Costs per Line km: 5-7€/km

3 hrs flight time
Payload 5kg
Avg. speed 100km/h
Daily production rate: 500km

Progressively exploring under deeper cover

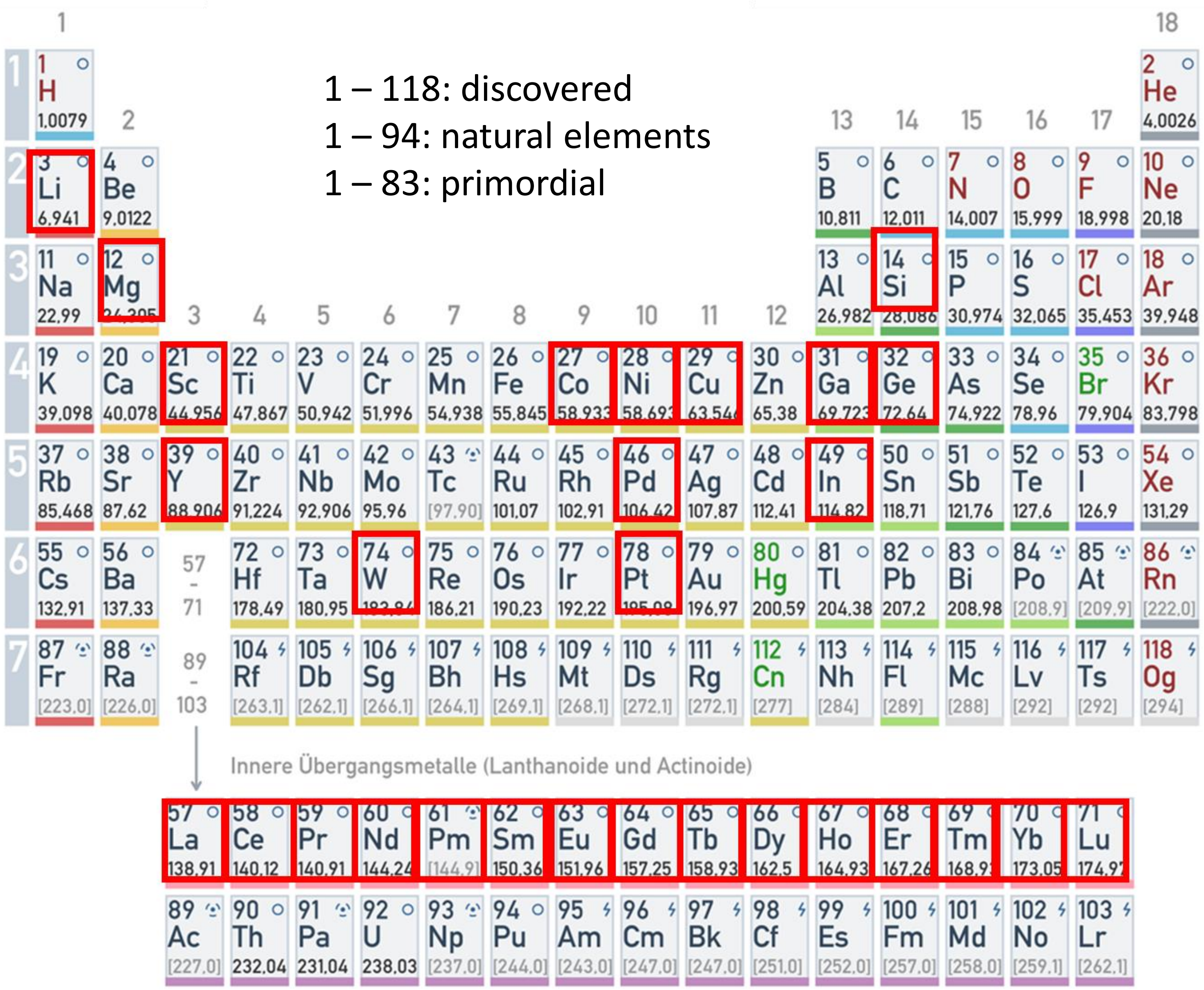


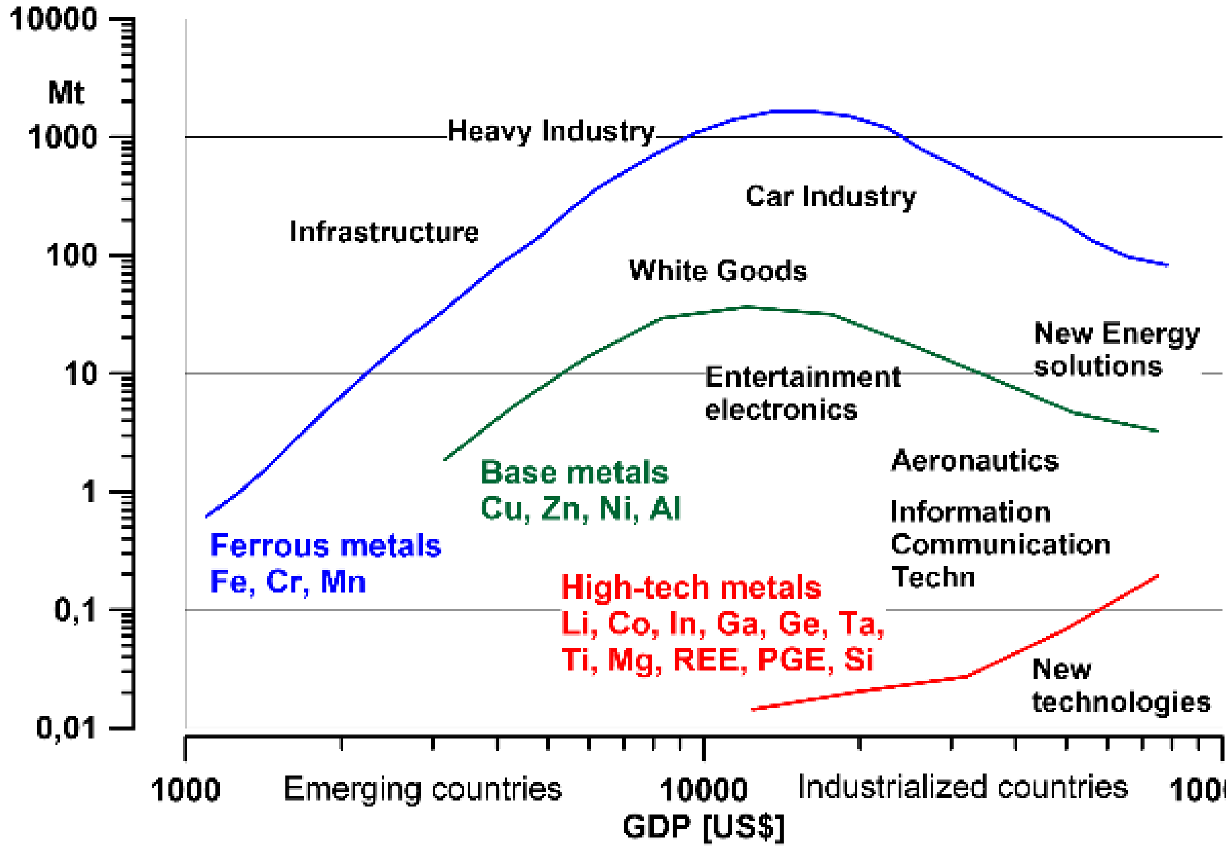
after Schodde, 2020


Primary copper production for World 1900-2050
Mt pa Cu
45
40
35
30
25
20
15
10
5
0
Over the next 25 years the world is going to mine more copper than what has been mined in all history
Forecast cumulative demand 2020-2045 = 750 Mt Cu
35.6Mt pa in 2045
21.2Mt pa in 2018
9.5Mt pa in 1993
5.0Mt pa in 1968
2.6Mt pa in 1943
0.5Mt pa in 1900
Cumulative copper production for all history to 2018 = 730 Mt Cu
known world reserves = 700 Mt Cu
1900
1920
1940
1960
1980
2000
2020
2040
Sources: Historical data from USGS and Office of the Chief Economist

FUTURE TRENDS IN EXPLORATION

Silizium	14
Kobalt	27
Nickel	28
Gallium	31
Germanium	32
Indium	49
Kupfer	29
Lithium	3
Platin	78
Magnesium	12
Wolfram	74
Palladium	46
Scandium	21
Yttrium	39
Lanthan	57
Gadolinium	64
Cer	58
Terbium	65
Praseodym	59
Dysprosium	66
Neodym	60
Holmium	67
Promethium	61
Erbium	68
Samarium	62
Thulium	69
Europium	63
Ytterbium	70
Lutetium	71





Trends in demand for earth resources by regions.

Assessment of Criticality


THANK YOU
Provinz Innlandet/Norwegen, Nov 2020