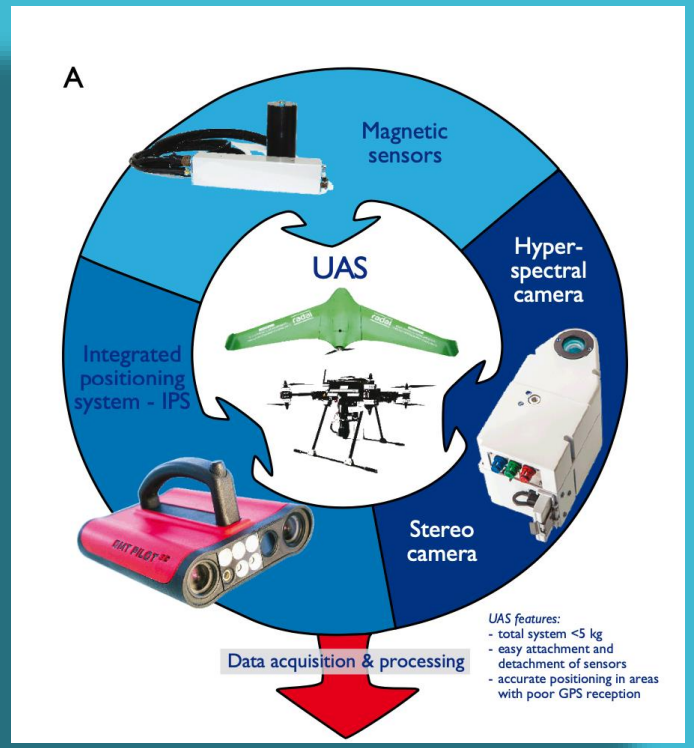
UAS BASED MAGNETIC SURVEY AND HYPERSPECTRAL REMOTE SENSING FOR MINERAL EXPLORATION



Dr. Abhijeet Mukherjee
General Manager(Exploration)
NMDC Limited
(A Government of India Enterprise)

Banded Iron Formation

Diamond

UAS –RECENT ADVANCES

Recent advances in the development of commercial UAVs have showed a vast range of applications, including **mineral exploration, surveillance and environmental monitoring**.

The application of UAVs in geophysical surveys has many advantages:

- Improved safety to survey personnel
- Better cost efficiency
- Better data coverage for the entire site
- Evenly spaced coverage
- Data recorded at lower attitude (As compared to aerial magnetic survey) which leads to higher data resolution.

BACKGROUND

As per the Digital Initiatives of GOI and as per NMDC's Version 2.0 plans it was envisaged to introduce Unmanned Aerial System(UAS) with Magnetic Survey and Hyperspectral Remote Sensing for the first time in India for Mineral Exploration.

NMDC is A Nodal Exploration Agency like GSI . Nowadays with the depletion of surfacial deposits use of Geophysical tools /surveys has become a necessity . Hyperspectral Remote Sensing is a powerful exploration and mapping technique in areas where geological units and mineral compositions can be estimated from spectral features of the electromagnetic spectrum in the visual and infrared range.

The presentation highlights the advantages of the new Technology.

Discussions were held with Scientists of NGRI –CSIR , ISRO, Telangana Civil Aviation officials, University Professors and teaching faculty of IIT -KGP

UAS AND TECHNIQUES USED IN MINERAL EXPLORATION

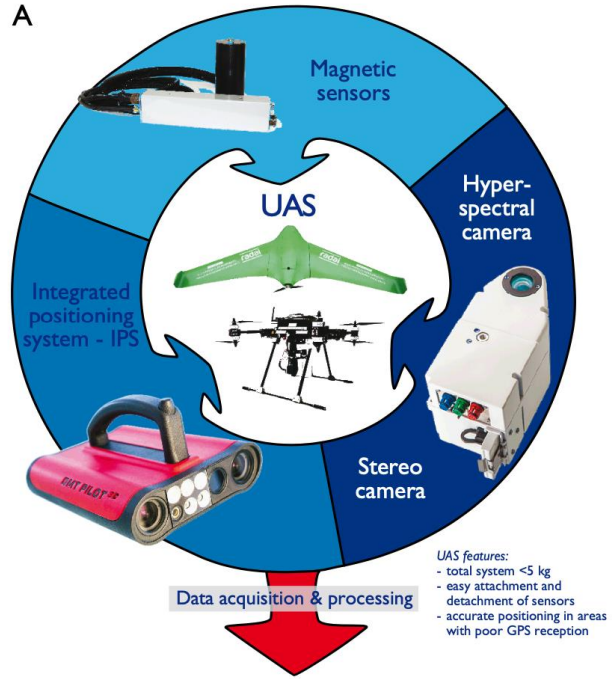
The use of Unmanned Aerial Systems (UAS), also known as drones, is becoming increasingly important for geological applications

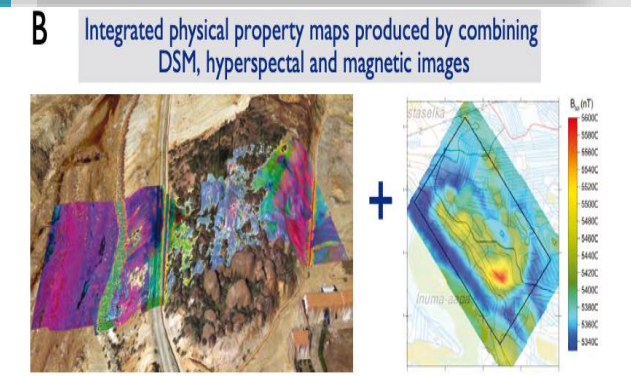
Magnetic and hyperspectral UAS surveys hold particular promise for mineral exploration, and **several groups have recently published studies of magnetic data collected by UAS for such applications**

Combining both techniques is particularly useful.

Magnetic measurements play an important role in mineral exploration, since magnetisation in rocks is mainly associated with magnetite and other iron minerals, which can be used in mapping and targeting of mineral deposits

Hyperspectral Imaging (HSI) is a powerful exploration and mapping technique in areas where the rock surface is well exposed, and where geological units and mineral compositions can be estimated from spectral features of the electromagnetic spectrum with band width of 400-2500 nm.





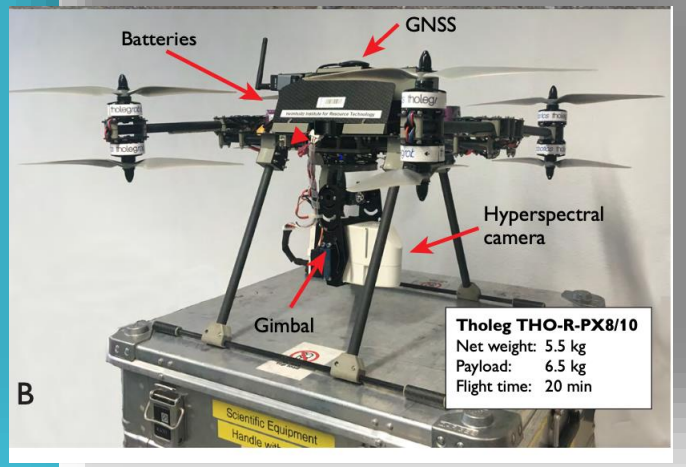
UAS AND PAYLOAD

We focus on small, lightweight solutions with less take-off weight.This is because regulations restrict commercial UAS operations in many countries according to take-off weight, flight height and operating range – typically, only operations in the (extended) visual line of sight are allowed.

Lightweight systems are also particularly advantageous to support geological field campaigns as they **can be deployed quickly to survey** areas of interest.

In mineral exploration we use both a multi-copter and a fixed-wing UAS as both platforms have advantages.

Multi-copters can fly at low elevation and speed, allowing them to follow strongly varying topography and collect high-resolution data that are comparable to traditional ground surveys.

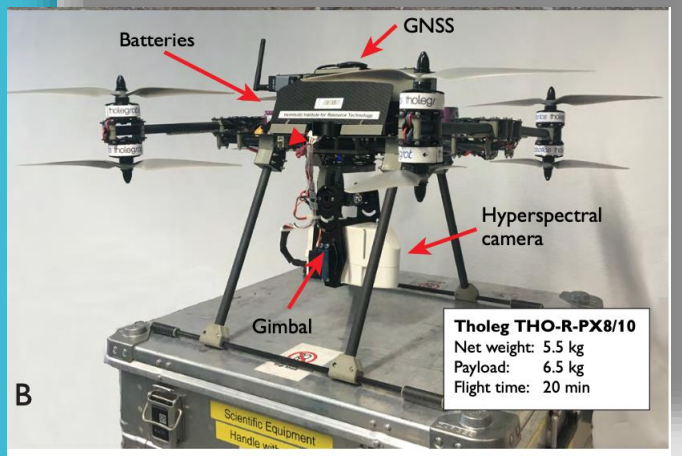


THE FIXED WING AND MULTI-COPTER SYSTEMS

THE FIXED WING SYSTEM is developed by the company *Radai Oy*, Finland. The main characteristic of their **self-constructed planes are long flight times (up to three hours)**, and smooth flight trajectories, which are important for the quality of the acquired magnetic and multispectral data. FIG.A.The same is developed by Drone Destination,Marut etc and these are used for land surveys .

THE MULTI-COPTER SYSTEM is developed by the *Marut Drones*, using a customised UAS and frames, on which different sensors can be quickly attached and detached. FIG.B.Safety of the payload was considered.

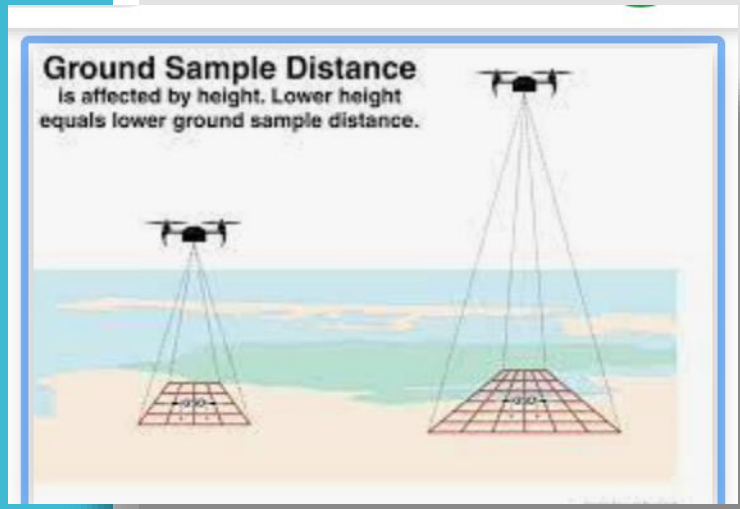
In both platforms, integrated Global Navigation Satellite Systems (GNSS) receivers and Inertial Measurement Units measure the positions and orientations of the UAS.



FLIGHT HEIGHT AND SPACING

DRONE MAGNETIC FLIGHT HEIGHT AND SPACING

Minimum operational altitudes for fixed-wing and multi-copter operations are typically governed by safety margins and terrain undulations, and can be as low as ***c.* 30 m and *c.* 15 m**, respectively.



HYPERSPECTRAL IMAGING AND PHOTOGRAMMETRY

Hyperspectral data are collected at 30mAGL and spacing of 30m (with side overlap of 30%)with the multi-copter platform using This instrument captures data in the electromagnetic spectrum 400–2500 nm

UAS BASED MAGNETIC SURVEY AND HYPERSPECTRAL RS

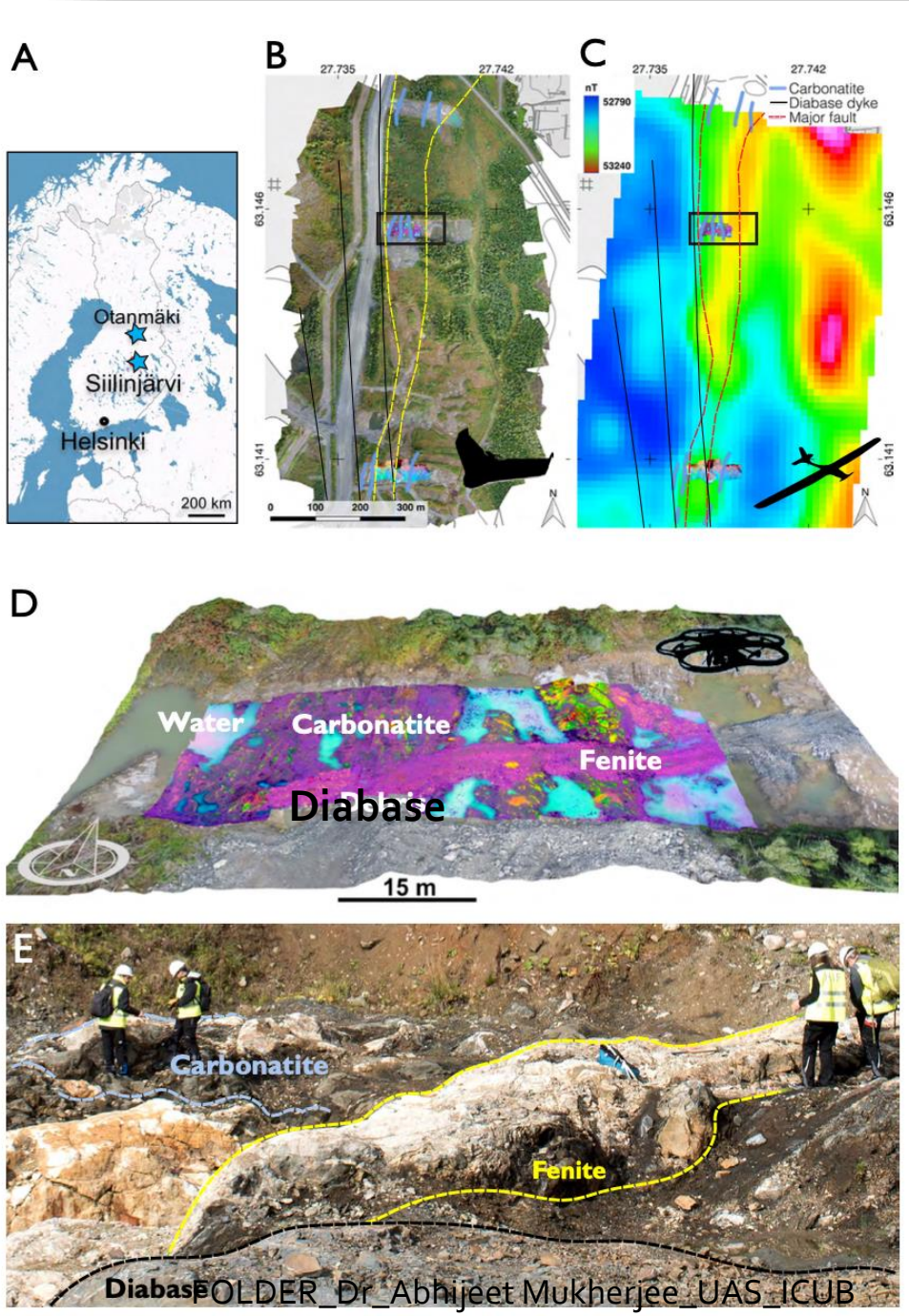
A: Location of field test sites in Finland. Note that only results from Siilinjärvi site, but not from Otanmäki site are presented here.

B: Orthophoto from photogrammetry.

C: Total magnetic intensity maps derived from fixed- wing UASs surveys of the Siilinjärvi test site.

D: Image from a processed hyperspectral multi- copter-based data set draped on the digital surface model from photogrammetry. The hyperspectral image shows the combination of bands 3, 2, 1 of a minimum noise fraction transformation in RGB, where green shading is associated with mainly fenite-hosting rocks. (A second survey was performed in the southern end of the field site (see B and C), but these data are not presented here).

E: Ground sampling for one of the out- crops covered with hyperspectral surveying.



FOLDER_Dr_Abhijeet Mukherjee_UAS_ICUB

SPECIFICATIONS OF UAS- HYPERSPECTRAL INSTRUMENT

Headwall

PRODUCT DATA SHEET

- Smallest and lightest instrument in its class
- 400–2,500nm wavelength range
- Dual VNIR & SWIR sensors with co-aligned pixels
- 640 spatial pixels / 270 VNIR and 267 SWIR spectral pixels
- Suitable for airborne or ground use
- All-reflective, concentric optical design
- Integrated high-performance GPS/IMU
- Solid-state internal data storage
- Optional 16-channel LiDAR

www.headwallphotonics.com

PRODUCT DATA SHEET Headwall

PREMIUM PERFORMANCE IN A SIZE, WEIGHT, AND POWER EFFICIENT PACKAGE

The Headwall Hyperspec® Co-Aligned VNIR/SWIR Sensor is designed for airborne or ground-based hyperspectral imaging. As the smallest and lightest instrument in its class, the sensor can be purchased as part of an integrated turnkey system with a DJI Matrice 600 Pro UAV and other sensor modalities such as LiDAR, as a factory data- and flight-tested payload component for integration onto a customized airborne imaging system, or as a ground-based hyperspectral imaging system with a Field Rotary Kit (part number 1007A-10412 sold separately).

Co-Aligned VNIR-SWIR Sensor		
Spectral range (nm)	VNIR (400–1000)	SWIR (900–2500)
Spectrograph design	High-throughput aberration-corrected concentric imager	
Spectral pixels	270	267
Spatial pixels	640	
Detector pixel pitch (µ)	7.4	15
Dispersion per Pixel (nm/pixel)	2.2	6
FWHM Slit Image (nm)	6	8
F/#	2.5	
Slit width (µ)	20	
Slit length (mm)	6	10.4
Camera technology	CMOS	Stirling-cooled MCT
Max frame rate (Hz)	350	200
Bit depth	12	16
Size (inches / mm)	10.7 x 8.3 x 6.5 / 272 x 211 x 165	
Weight / Weight including LiDAR (kg)	2.83 / 3.63	
Data storage	Internal solid-state drive: 480GB per sensor	
IO connectivity	GigE	
GPS/IMU	Integrated High-Performance model	
Mounting Options (sold separately)	UAV hard-mount / Field Rotary Kit	
LiDAR (16-channel)	Optional for UAV configurations	
Power requirement Typical / Max (W)	26 / 30	
Operational temperature range (°C)	0–40	
Storage temperature range (°C)	-30–60	

April 2021

Contact Information
Headwall Photonics, Inc.
580 Main Street • Bolton, Massachusetts 01740
978-353-4100
information@headwallphotonics.com

Sr. No	Specification	Requirement
1.	VNIR & SWIR hyperspectral imaging sensor preconfigured for airborne data acquisition with UAV	Ability to simultaneously capture Hyperspectral image in VNIR (400-1000 nm) and SWIR (900-2500 nm) spectral regions.
2.	Wavelength range	400 nm – 2500 nm (Hyperspectral data cube from VNIR: 400-1000 nm and SWIR: 900 - 2500 nm separate hyperspectral cube.)
3.	Spectral channels in VNIR	≥ 250 (in VNIR) ≥ 250 (in SWIR)
5.	Spatial pixels	≥ 600 for VNIR ≥ 600 for SWIR
4.	Frame rate VNIR	VNIR ≤ 200 Hz SWIR ≤ 200 Hz
5.	Spectral Resolution (FWHM slit image in nm)	≤ 6 nm for VNIR ≤ 8 nm for SWIR
6.	Angular FOV (mrad)	VNIR and SWIR ≤ 0.6
7.	SNR @ 100% albedo without binning	For 400 - 1000 nm:> 70 @ 450 nm > 125 @ 600 nm > 10 @ 950 nm For 900 - 2500 nm: > 300 @ 1100nm > 500 @ 1700nm > 200 @ 2400nm
8.	Digitization (bit) VNIR and SWIR	12 minimum
9.	Data storage devices integrated with Hyperspectral imager VNIR and SWIR	400 GB SSD for VNIR imager 400 GB SSD for SWIR imager
10.	Reflectance Standard	Minimum 3m X 3m size standard reflectance tarps with at least 2 designated reflectance values White reference Panel of minimum size 10" X 10"

एनएमडीसी
NMDC

11.	Hyperspectral imager payload Weight (kg) (VNIR-SWIR Imager together with data storage devices, High performance GPS/IMU, power supply, mounts and all interface cable)	≤ 5kg
12.	Warranty	1-year warranty
13.	Installation, Training and Demonstration	Installation, training and demonstration for 5 days

UAS –MAGNETOMETER SPECIFICATIONS

S. No.	Specifications	Details
	Model	MagArrow(Geometrics)
1	Operating Principle	Laser pumped cesium vapor (Cs133 non-radioa
2	Operating Range	20,000 to 100,000 nT
3	Gradient Tolerance	10,000 nT/m
4	Noise/Sensitivity	0.005nT/√Hz_{rms} typical; (SX(export)version: 0.02Nt/√Hz_{rms}
5	Sample Rate	1000 Hz synchronized to GPS 1PPS
6	Bandwidth	400Hz
7	Heading range/error	± 5 nT over entire 360° equatorial and polar spins typical
8	Output	WiFi data download over 2.4 GHz WiFi access Point.
9	GPS	Commercial grade with typical 1 m accuracy.
10	USB Port	Port for USB flash drive.
11	Data Logger	Built in Data Logger.
12	Data Storage	32 GB Micro SD card U3 speed class
13	Data Download	Over WiFi 2.4 GHz using user-supplied browser-capable
14	IMU	Bosch BMI160 Accel/Gyro- 200Hz sample rate insentek Compass-100Hz Sample rate
15	Total Weight	1 Kg
16	Length	1m
17	Battery Connection	2x XT60 connectors for 206 type batteries
18	Battery Recommendations	Non-Magnetic 1800 mAh or 2200 mAh lithium polymer, 3cell, 11.1v Hot swappable
19	Environmental	Operating Temperature -10°C to + 40°C(+14°F to +104°F
20	Humidity	Non- condensing
21	warranty	1 year
22	Accessories	Carrying Case, AC Power adapter and USB drive containing operation manual and software

MagArrow
UAS Deployable Magnetometer

GEOMETRICS
Simplify your search

Survey large areas of inaccessible terrain 10x faster than a typical magnetic survey

The MagArrow by Geometrics is our first ever UAS deployable magnetometer, and it sets a new standard for UAS magnetic surveys. The MagArrow is engineered to address the limitations of both large manned and small helicopter surveys. To meet these special survey conditions, the MagArrow was built with reliability, efficiency, and ease of use in mind.

The vessel is made of an aerodynamic, light-weight carbon fiber shell. Internally the system contains an MFAM miniature magnetometer, GPS, IMU sensors, an SD card, and battery connectors. The MFAM sensors in the MagArrow are our most groundbreaking sensors yet, capable of highly precise measurements in an extremely lightweight and tiny package. Our system ships complete with a full featured data logger.

The MagArrow can be attached easily to a wide variety of enterprise UAS. The 1000 Hz sample rate synchronized to the on-board GPS allows the system to function independently of the UAS and the UAS software. With such a fast sample rate, surveys can be completed at speeds up to 10 m/s with samples collected every 1 cm.

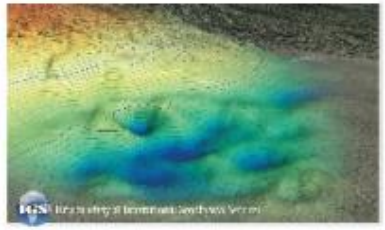
Operation in the field is simple. Survey details are programmed into the user's UAS software of choice. The MagArrow is turned on, and once airborne, preprogrammed GPS waypoints carry the MagArrow in altitude stable survey lines. Once work is completed, data from the MagArrow can be wirelessly downloaded to a computer.

The MagArrow is a robust yet flexible system that can adapt to changing field conditions and new user workflows. How will you use the MagArrow?

FEATURES & BENEFITS

- **Lightweight** – Weighs only 1 kg, allowing a flight time 20% longer* than a 2.5 kg-payload UAS.
- **UAV Agnostic** – Can be easily attached to your existing enterprise UAS.
- **Self-Contained** – GPS, storage, and WiFi on board. No connection to UAS needed.
- **Super-Fast Sampling Rate** – Fly faster, up to 10 m/s with samples every 1 cm. Filter out UAS motor noise.
- **Long Battery Life** – 2 hours of battery life will outlast multiple UAS flights. Hot swappable.
- **No Drop-outs** – Reliable high quality data no matter the sensor orientation.

*DJI Matrice 600 Pro



"The UAS-enabled MagArrow also fills the gap between pilot-on-board aeromagnetic surveys and ground magnetic surveys where the areal size of the survey is too small to justify a pilot-on-board aeromagnetic survey, or the need for low altitude flight operations makes a pilot-on-board survey too risky or too costly."

— Ron Bell of International Geophysical Services, MagArrow user.

GEOMETRICS
Simplify your search

SPECIFICATIONS | **MagArrow** UAS Deployable Magnetometer

POWERFULLY BUILT, SIMPLY EXECUTED

For simplicity in the field, the MagArrow has no external connections, instead containing the GPS, WiFi, and memory on board. Battery packs are hot swappable. All operations are accessed through the web-browser interface. Internal IMU sensors allow for a complete suite of data compensation algorithms to be applied, if desired, to remove platform-induced field variations.

Operating Principle: Laser pumped cesium vapor (Cs133 non-radioactive) total field scalar magnetometer.

Operating Range: 20,000 to 100,000 nT.

Gradient Tolerance: 10,000nT/m.

Operating Zones: Configurable for operation anywhere in the world without dead zones.

Dead Zone: Polar only, 60° inclusive angle.

Noise/Sensitivity: 0.005nT/$\sqrt{Hz}$ typical.

Sample Rate: 1000 Hz, synchronized to GPS 1PPS.

Bandwidth: 400Hz.

Heading Error: ± 5 nT over entire 360° equatorial and polar spins typical.

Output: WiFi data download over 2.4GHz WiFi access point.

GPS: Commercial grade with up to 1 m accuracy.

USB Port: Port for USB flash drive. Used for field upgrades.

Data Logger: Built in Data Logger.

Data Storage: 32 Gbyte Micro SD card, U3 speed class. Not field-accessible. Contact sales for higher capacities.

Data Download: Over WiFi 2.4GHz using user-supplied browser-capable device. 10 minutes of data requires 1 minute to download.

IMU: Bosch BMI160 Accel/Gyro - 200 Hz sample rate. Insentek Compass - 100 Hz Sample rate.

Total Weight: 1 kg without batteries.

Length: 1 m.

BATTERY

Battery Connection: 2x XT60 connectors for 2S6 type batteries.

Battery Recommendations*: Non-magnetic 1800 mAh or 2200 mAh lithium polymer, 3cell 11.1v. Hot swappable.

***Battery NOT Included**

ENVIRONMENTAL

Operating Temperature: -35°C to +45°C (-21°F to +113°F).

Humidity: Non-condensing.

ACCESSORIES

Standard: Carrying case, AC power adapter, USB drive containing operation manual and software, JIS1 screwdriver and drill bit, suspension cords.

Warranty: 1 year

GEOMETRICS
Simplify your search

GEOMETRICS INC. 2190 Fortune Drive, San Jose, California 95131, USA
Tel: 408-954-0522 • Fax: 408-954-0902 • Email: sales@geometrics.com

GEOMETRICS EUROPE 20 Eden Way, Pages Industrial Park, Leighton Buzzard LU7 4TZ, UK
Tel: 44-1525-383438 • Fax: 44-1525-382200 • Email: chris@geometrics.co.uk

GEOMETRICS CHINA Laurel Geophysical Instruments Limited
8F, Building 1, Danwei Plaza, 7 Qingnian Road, Chaoyang District, Beijing, 100025 China
Tel: +86-10-85850099 • Fax: +86-10-85850991 • laurel@laurelgeophysics.com.cn

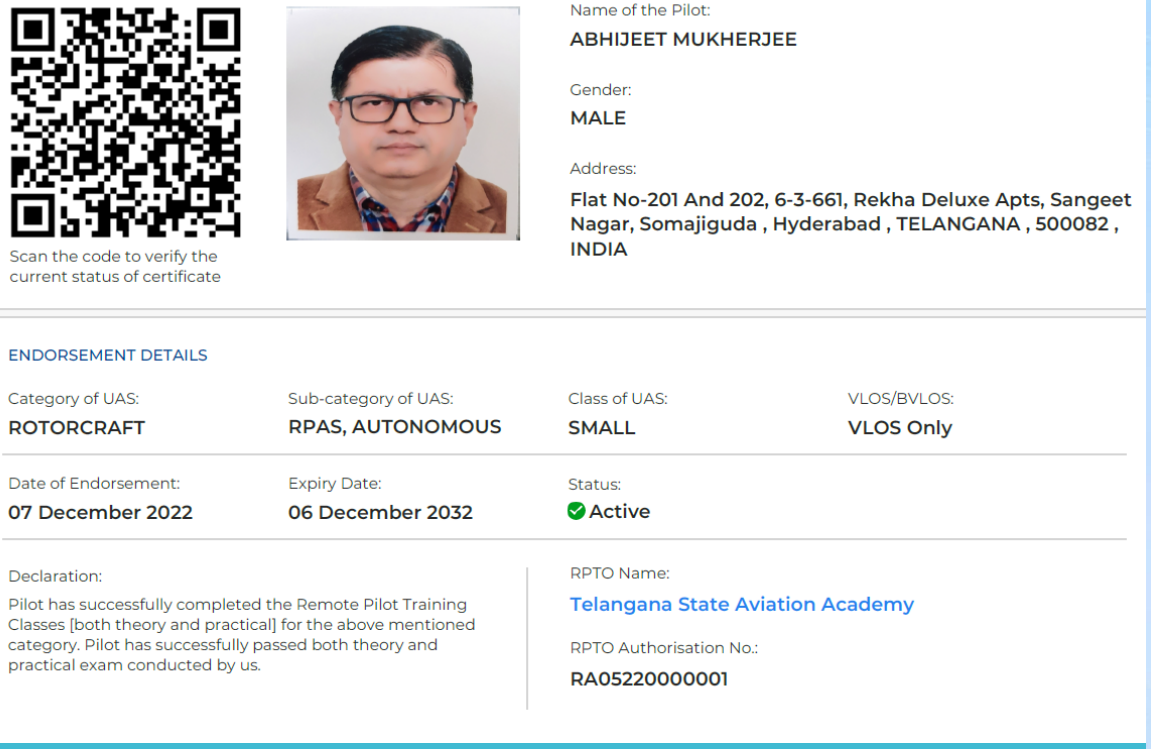
UAV- SPECIFICATIONS

S. No.	Specifications	Octacopter
1	UAV type	Octo-copter
2	Payload capacity	8 kg excluding batteries and any other devices required for the UAV itself
3	Endurance	15-20 minutes with full payload depending on wind condition with 20% of safety margin
4	Range	1 km LoS
5	Altitude	1 km LoS
6	Positioning Accuracy	Within 2m
7	Stability at a location (as measured in Altitude Hold mode)	Within 0.5m in all axes, for minimum 5 minutes
8	Frame	Carbon Fiber material for extreme sturdiness and lightweight
9	Motors	High Efficiency Brushless DC Motors
10	Propeller	Carbon Fiber Material
11	ESC	Built-in Heatsink
12	Joints & Screws	Joints & Screws
13	Landing Gear	Carbon Fiber
14	Surface area required for landing	Maximum 2 sqm
15	Auto-pilot	Advanced GPS with Waypoint (Auto)
		Manual Mode
		Altitude Hold Mode
16	Intelligence features	Go Home & Auto Landing
		Enhanced Fail-
		Safe Low-Voltage Protection
17	Payload carrying	3-Axis Gimbal support must be present
18	Battery	Li-Po batteries 12S
19	Safety Switch	Motor will only start when ON
20	Sensors	Gyroscope 16-
		bit Magnetometer 14-bit
		3-Axis Accelerometer
		Barometer
		IMU
	Interfaces	UART ports, one high power capable, 2 with HW flow control
		RSSI (PWM or Voltage) input
		I2C


NMDC
RESPONSIBLE MINING
#NMDCAdvancedTech
NMDC spearheads Drone Based Mineral Exploration, redefining precision and efficiency. As the first CPSE in India to pioneer Drone-based Surveys involving Hyperspectral and magnetic Studies, we're forging ahead into uncharted territories


NMDC
RESPONSIBLE MINING
MAJHGAWAN DIAMOND MINE
PANNA
NMDC becomes the
first mining company in the world
to conduct drone based magnetic data
acquisition over a mechanised diamond mine
www.nmdc.co.in

DGCA APPROVED DRONE PILOT CERTIFICATION FROM-TSAA



Scan the code to verify the current status of certificate

Name of the Pilot:
ABHIJEET MUKHERJEE

Gender:
MALE

Address:
Flat No-201 And 202, 6-3-661, Rekha Deluxe Apts, Sangeet Nagar, Somajiguda , Hyderabad , TELANGANA , 500082 , INDIA

ENDORSEMENT DETAILS

Category of UAS:	Sub-category of UAS:	Class of UAS:	VLOS/BVLOS:
ROTORCRAFT	RPAS, AUTONOMOUS	SMALL	VLOS Only

Date of Endorsement:	Expiry Date:	Status:
07 December 2022	06 December 2032	Active

Declaration:
Pilot has successfully completed the Remote Pilot Training Classes [both theory and practical] for the above mentioned category. Pilot has successfully passed both theory and practical exam conducted by us.

RPTO Name:
Telangana State Aviation Academy

RPTO Authorisation No.:
RA05220000001

Its important to follow Drone Rules Aug-2021 of Ministry of Civil Aviation

UAS-SOFTWARES USED

FOR FLYING THE OCTACOPTER DRONE
MISSION PLANNER

FOR PROCESSING THE MAGNETIC DATA
GEOMETRICS
GEOSOFT OASIS MONTAGE

FOR HYPERSPECTRAL DATA PROCESSING
HYPERSPEC-III
ENVI

FOR OVERLAY OF MULTIPLE DATA SETS
ARC-GIS

UAS-SOFTWARES USED FOR HYPERSPECTRAL RS

Acquisition Software

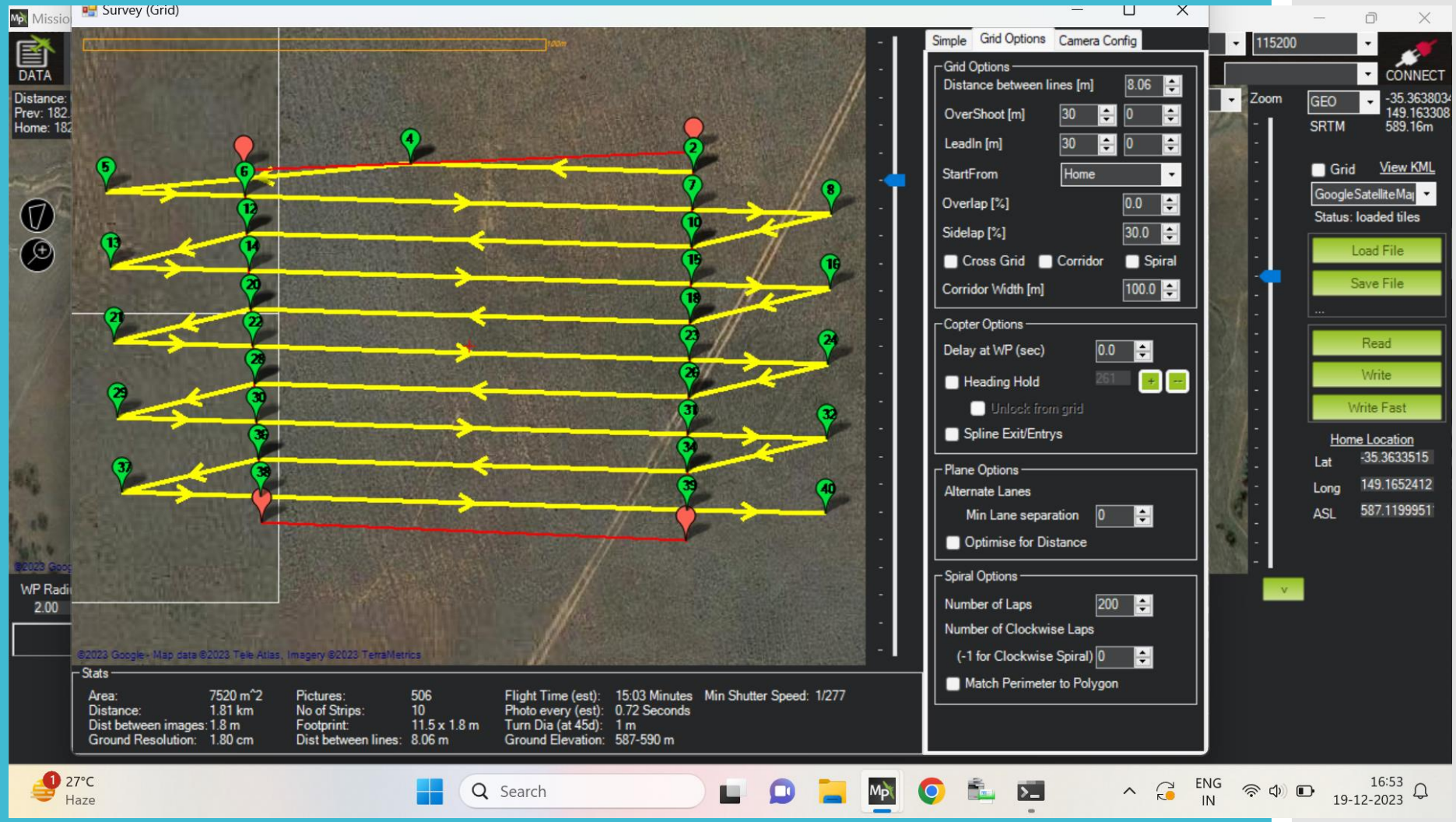
- Hyperspec III – SWIR (For configuration, data acquisition and data downloading)
- HSInsight – VNIR (For configuration and data acquisition)

Browser

Data Downloading and processing software

- POSPac – GPS data processing
- FileZilla – VNIR data downloading
- Spectral View – SWIR data downloading + Processing VNIR & SWIR data
- CloudCompare – LiDAR
- Trajectory Plotter – Plotting GPS data
- Batch processing tool – Batch conversion and processing

MISSION PLANNER IS USED TO FLY THE OCTACOPTER DRONE



UAS-SURVEY DESIGN

Site topography

Access roads & launch stations

Weather conditions

Flight line spacing (Data Resolution)

Flight heights (Data Resolution)

Area coverage

Geology and mineralisation zone

Survey duration
(Direct cost impact)

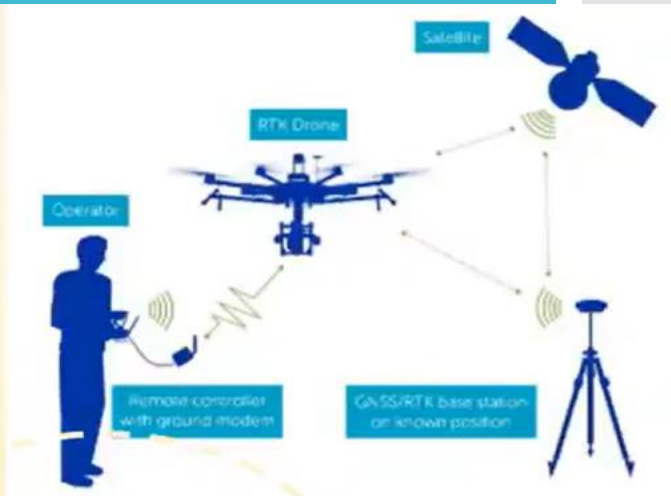
UAS-SURVEY LINE FOR MINERAL EXPLORATION AND DESIGN

Survey line for mineral exploration:

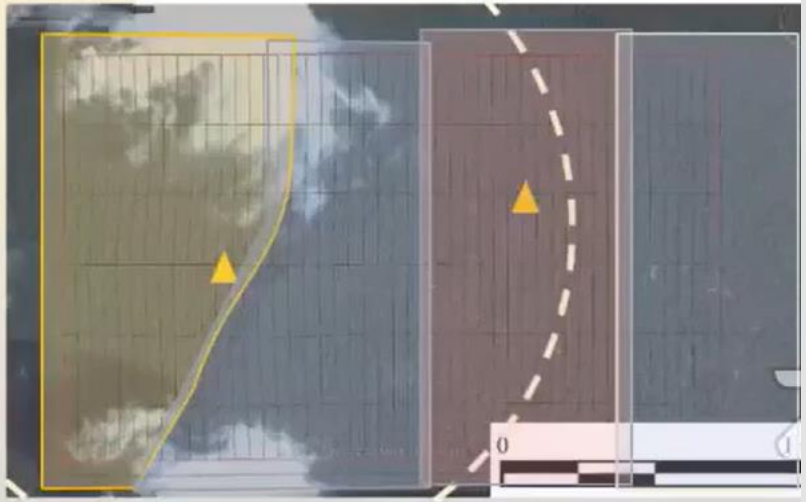
- ✓ 25 to 50m m line spacing in N-S direction (*Earth magnetic inclination at equator is zero*)
- ✓ 200m line spacing in E-W direction
- ✓ Preferably survey lines should cross perpendicularly to the orientation of mineralisation zone.

Mission Planning

- ✓ Line of sight aviation (*Depends on topography & terrain awareness*)
- ✓ DEM / DSM / DTM
- ✓ Distance from launching station (Ideally *within1km radius*)
- ✓ Battery power consumption (*30 to 40 minutes per set*)
- ✓ Survey flight paths follow terrain (*Maintain at 20m above tree line*)
- ✓ Speed 3 – 7 m/s (11 – 25 km/h)



Source: www.droneassemble.com/



UAS-MAGNETIC DATA PROCESSING

Geosoft's Oasis Montaj is a popular software to process and visualise the dataset. The following processing flows are commonly applied to the geomagnetic dataset.

1. Check for erroneous data points
2. Integrate magnetic data with GPS positions
3. Apply diurnal correction (Using base station observation)
4. Apply total intensity of the earth's magnetic field for the study area (IGRF model prediction)
5. Generate Total Magnetic Intensity (TMI) map (Geosoft Oasis Montaj software)

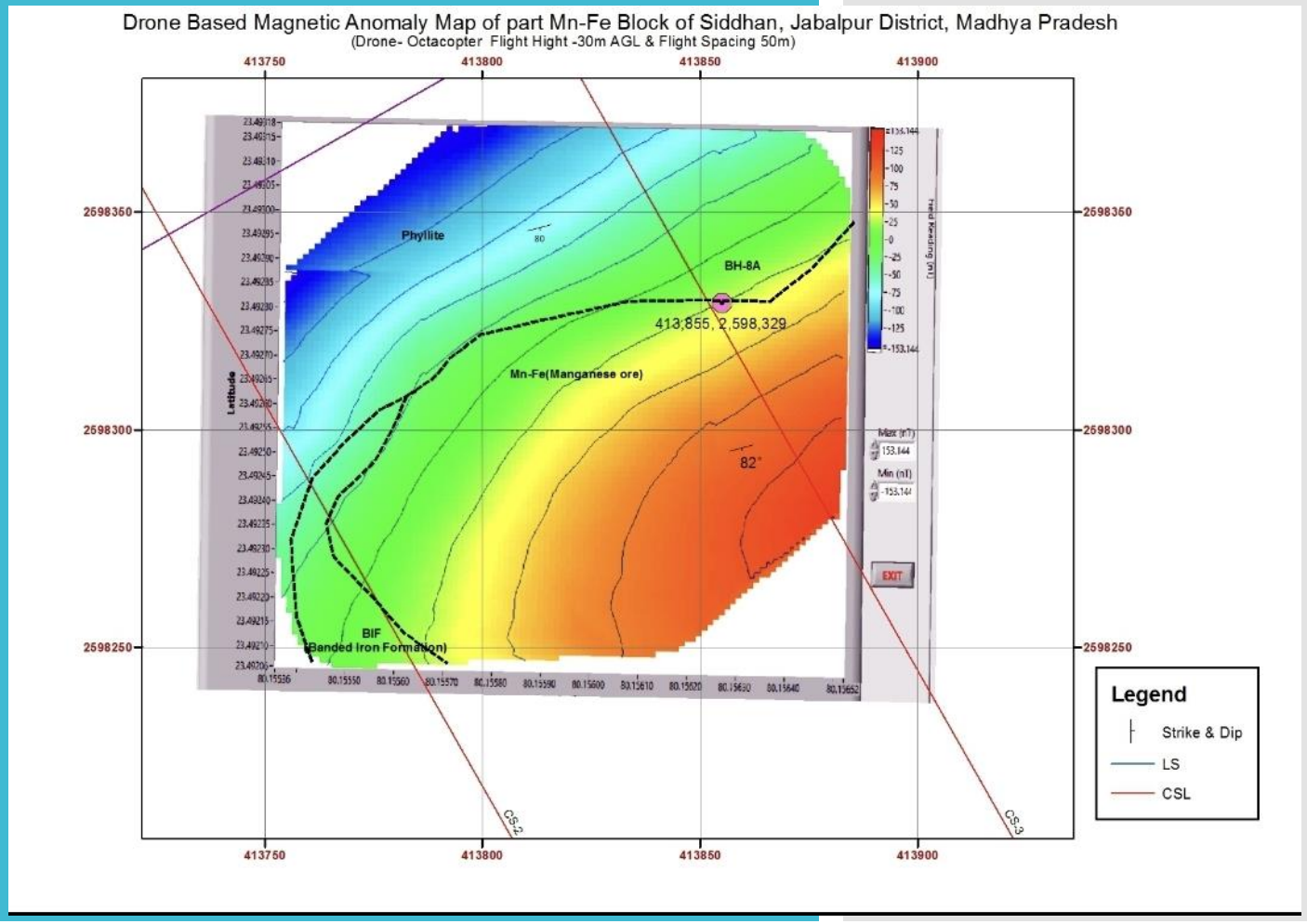
WE ALSO USE THE GEOMETRICS SOFTWARE FOR PROCESSING THE MAGNETIC DATA

UAS BASED MAGNETIC SURVEYS SAVE TIME AND COST WHEN COMPARED WITH TRADITIONAL FWMSAND HBMS

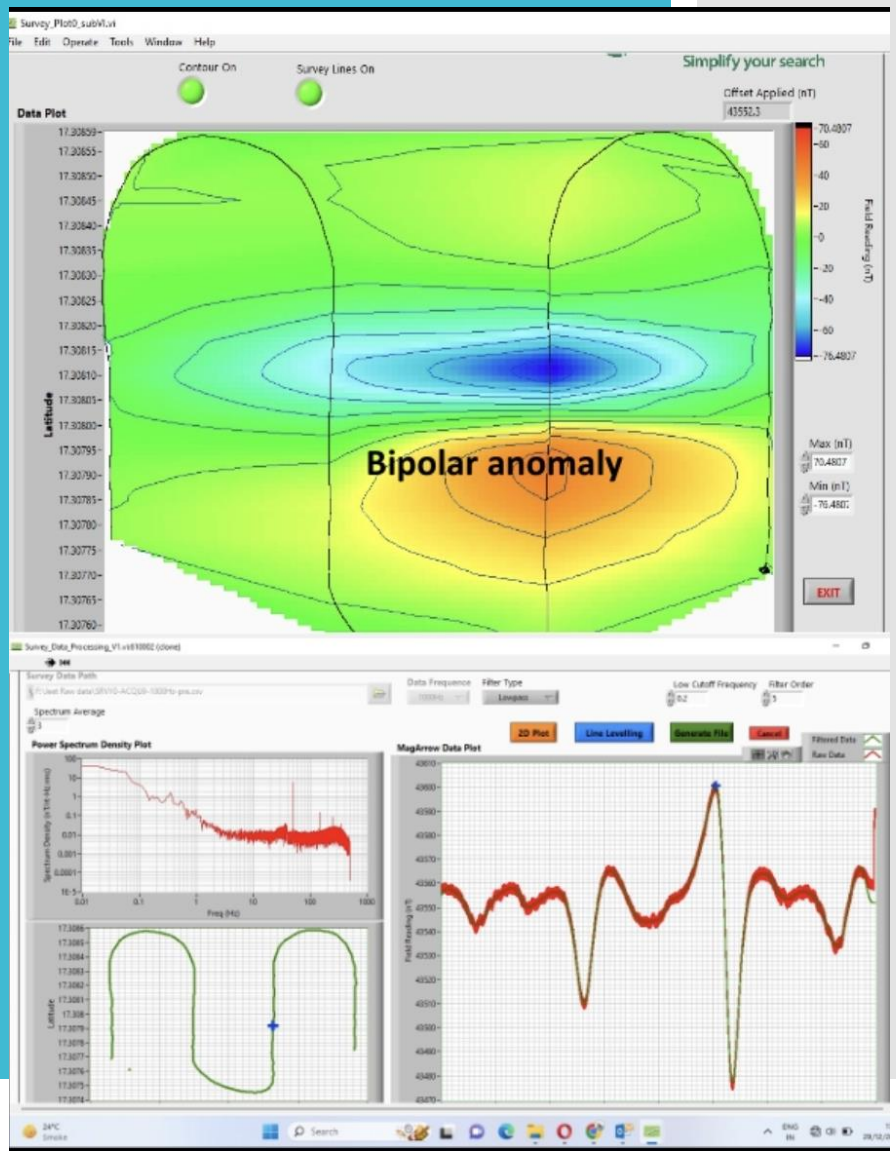
Unmanned Aerial Vehicle (UAV) Magnetic Survey is a recent technique that uses unmanned aircraft (drone) and magnetometers equipped with geo-referencing systems and other navigation instruments to perform magnetic scans.

UAV magnetic fills in the gap between the traditional ground magnetic and airborne magnetic, due to the possibility of designing automated missions, performing low altitude flights, and covering long distances in a short time; UAV magnetic surveys become much more controlled and precise, obtaining high precision magnetic results.

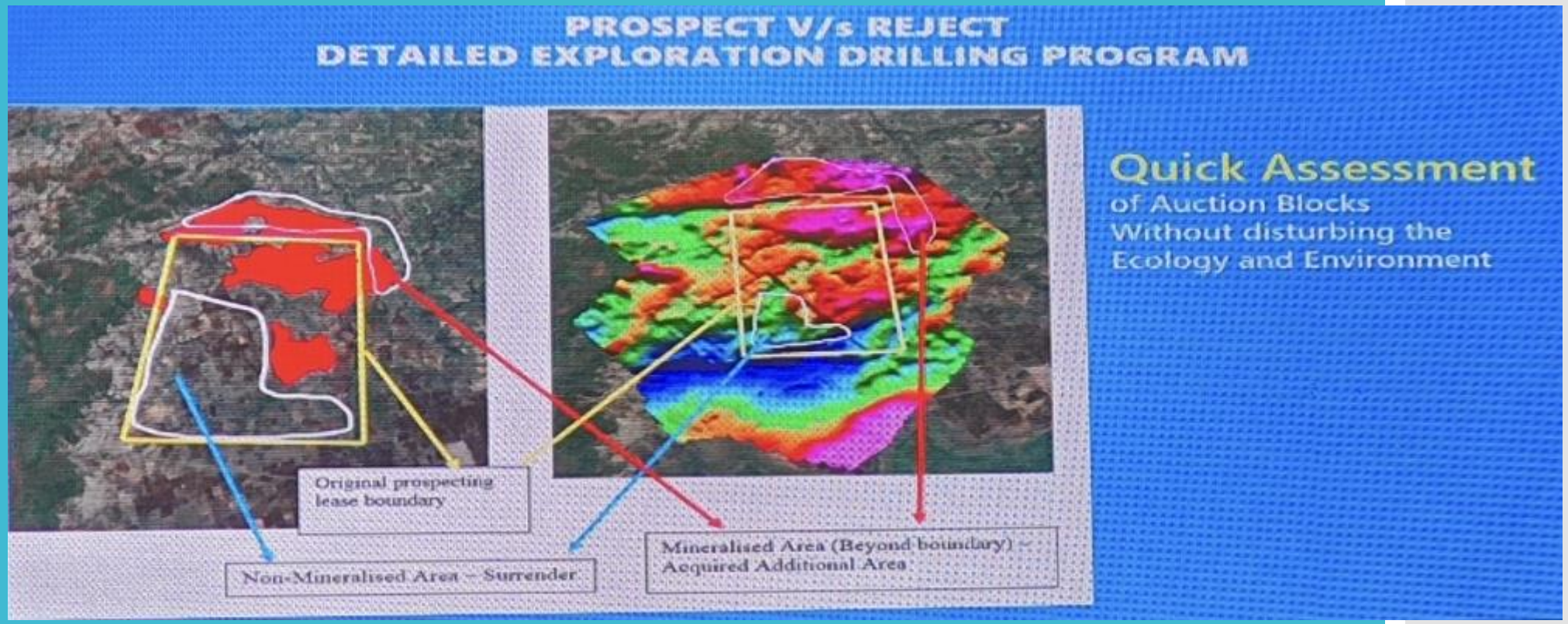
UAS BASED MAGNETIC SURVEY OVER PART OF Mn-Fe BLOCK IN SIDHAN , JABALPUR DISTRICT , MADHYA PRADESH



UAS BASED MAGNETIC SURVEY BY NMDC OVER IRON ORE TARGETS



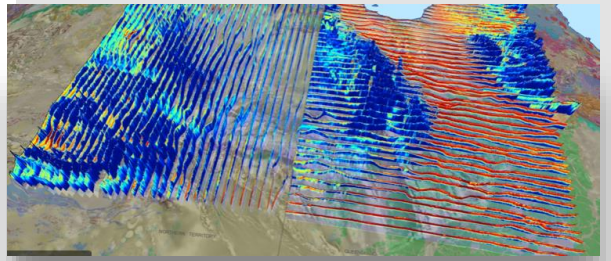
UAS BASED MAGNETIC SURVEYS HELP IN QUICK ASSESSMENT



UTILITY OF UAS-MAGNETICS AND HYPERSPECTRAL STUDIES

The findings based on the Hi-tech surveys /algorithms / models generated by the UAS-HYPERSPECTRAL AND MAGNETICS would be helpful in generating various **"synthetic models"/** locating promising mineralized areas and / or mineral findings. These findings would be useful to the Mineral Industry/ State Governments .

None of the findings would be published /patented and the same would be given free of cost to the Institute /State Government/MOM,GOI and published.



“To master a new technology, you have to play with it”

- Jordan Peterson

THANK YOU