New Generation Helicopter Time Domain Systems.

A Decade in Australia

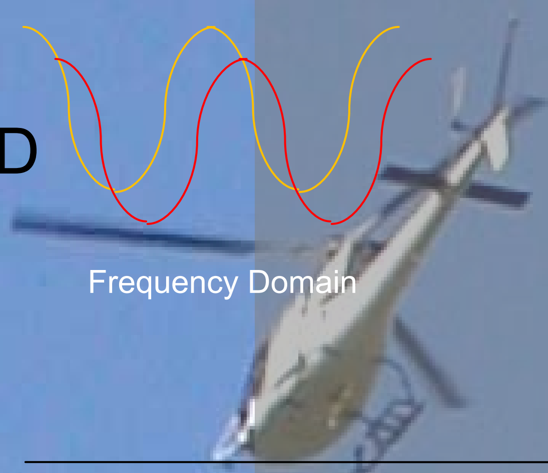
Andrew Boyd
Integrated Geophysical Solutions Pty Ltd

Outline

- Key design characteristics of a HTDEM system
- A History of HTDEM in Australia and Systems in Use
- Applications
- Interpretation
- Over the Rainbow

Numerous Flavours of Airborne EM. Platform and Waveform

FD

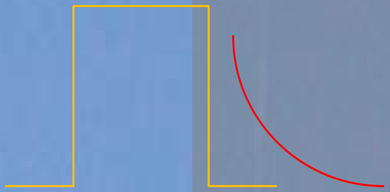


Frequency Domain

Geol Survey Finland
en.gtk.fi

DIGHEM
www.fugroairborne.com

TD



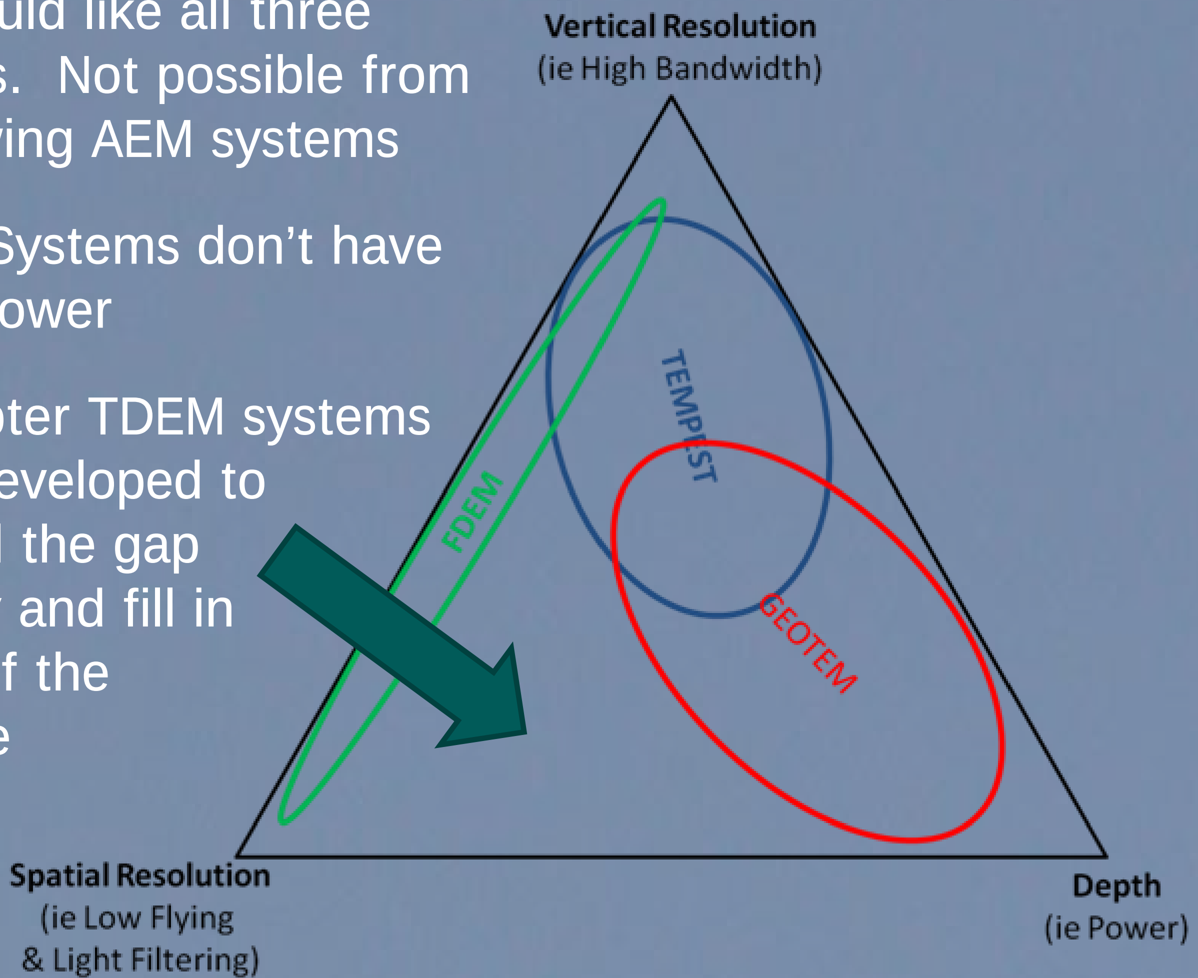
Time Domain

Geotem
www.fugroairborne.com

www.gpxsurveys.com.au

AEM Systems

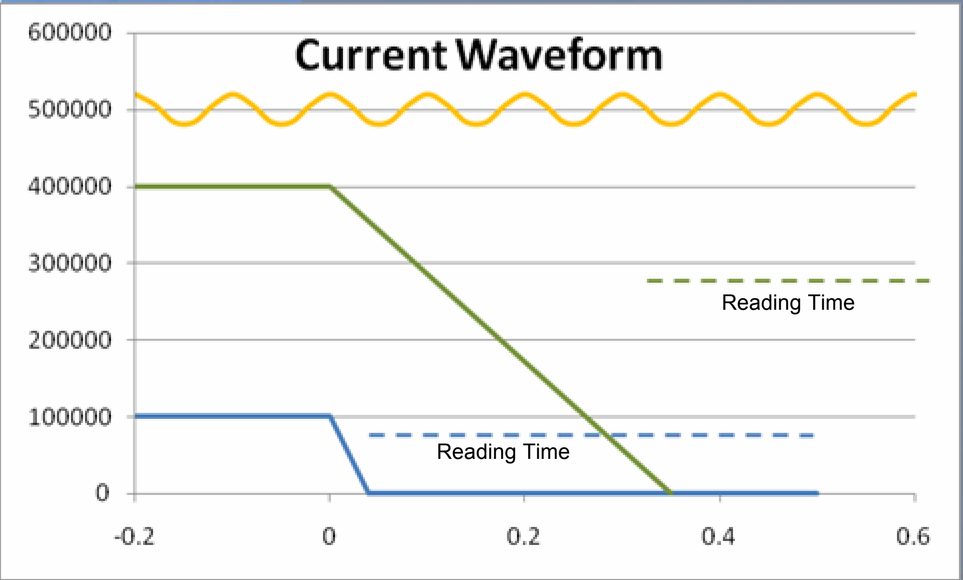
- We would like all three corners. Not possible from fixed wing AEM systems
- FDEM Systems don't have large power
- Helicopter TDEM systems have developed to help fill the gap and try and fill in more of the triangle

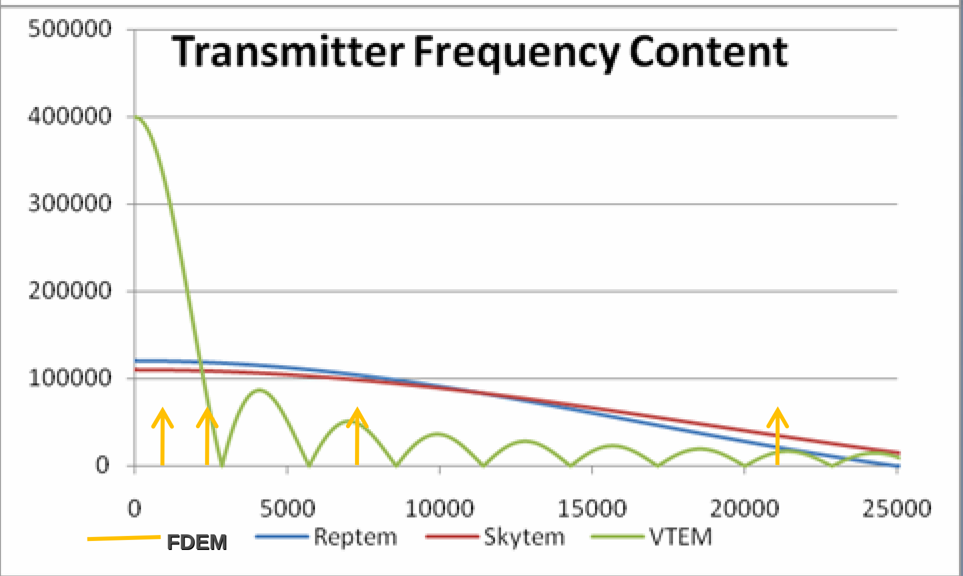


Key factors to development

- **Design Objectives**
  - **Time Domain, broad bandwidth**
  - **Symmetric response**
  - **Low flying,**
    - **Closer to bedrock targets**
    - **high spatial resolution for mapping**
  - **Ease of installation, improved mobility & deployment**

Broad Bandwidth

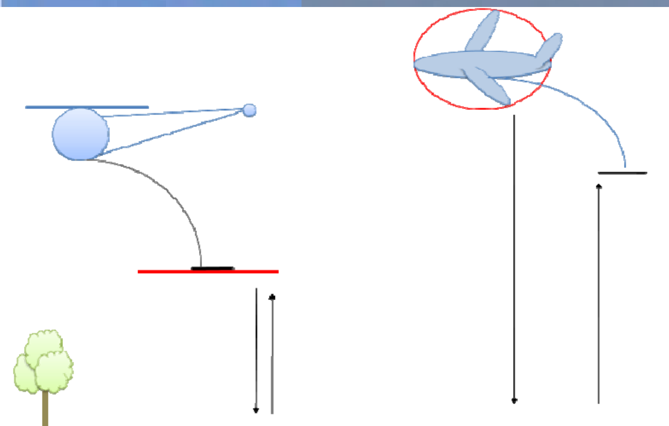


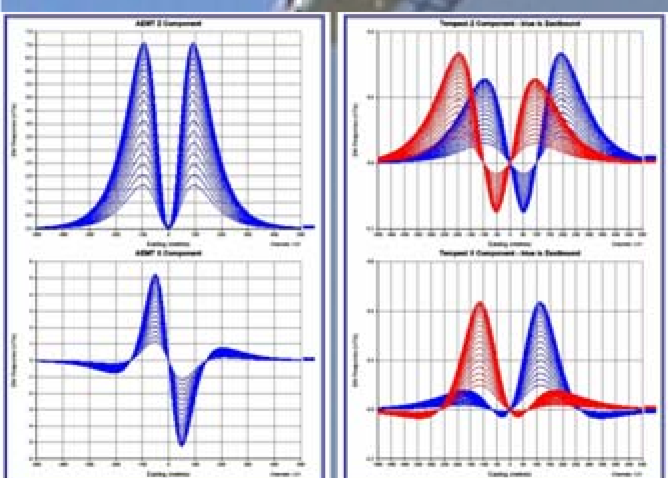


- Time domain systems transmit multiple frequencies at once. **The broader the frequencies the broader the range of geological scenarios that can be handled.** This gives an immense advantage over frequency domain helicopter systems
- A sharp termination of TD waveform generates high and broad frequency content.
- High frequencies improve vertical resolution and mapping ability
- Power improves depth penetration but reduces ability to have a sharp termination. So often a trade off with depth and vertical resolution/fidelity

Symmetry

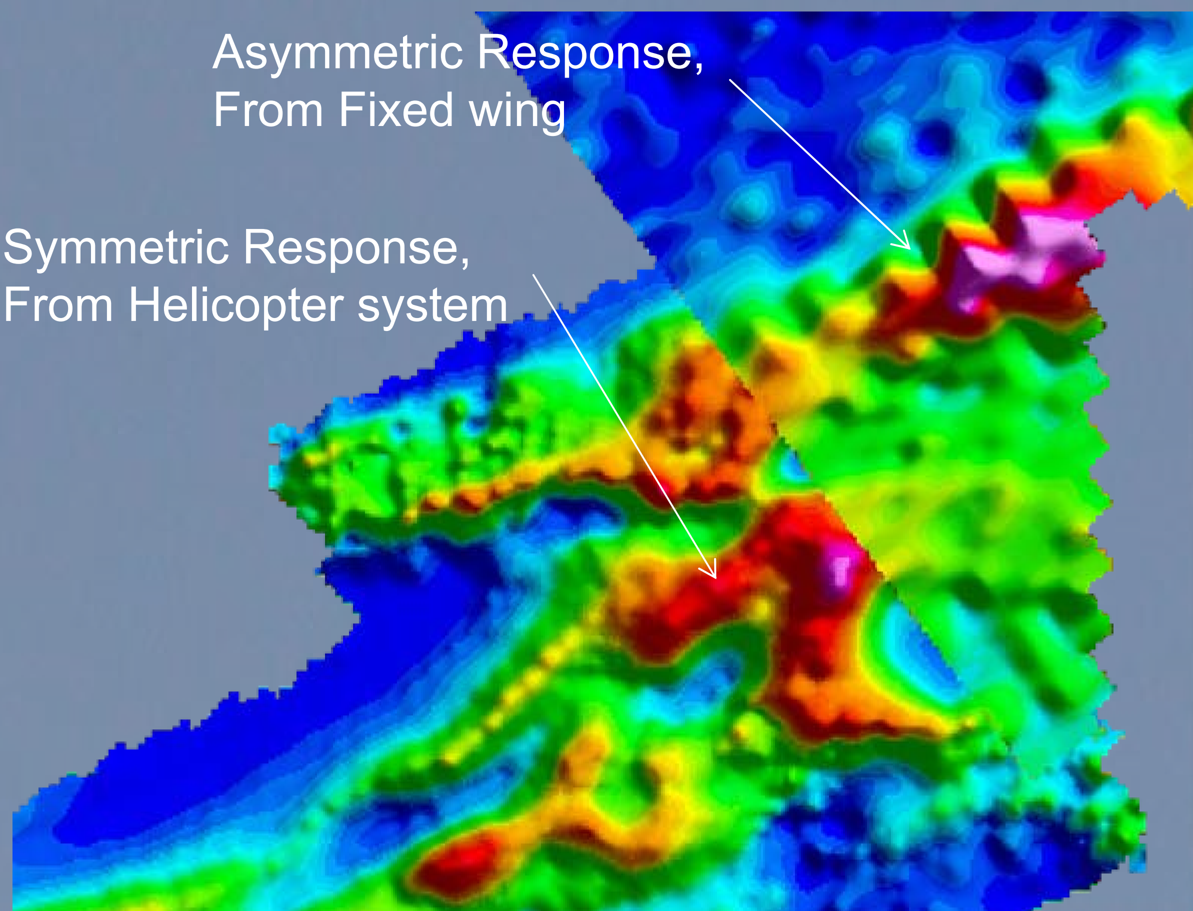
- In-loop or Coincident loop Geometry.
- No Asymmetry, **no dependence on direction of flying**





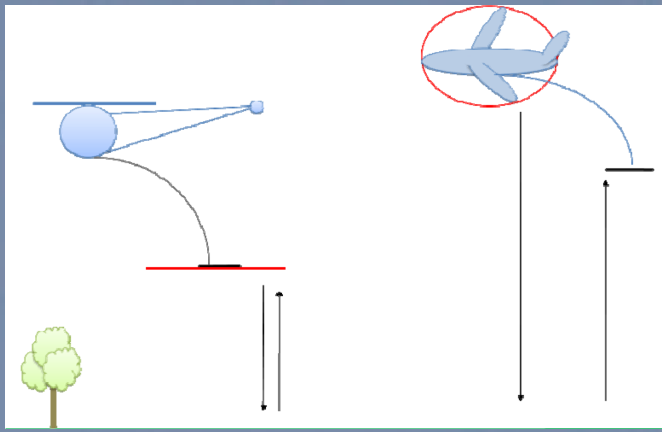
In Loop
symmetric response

Fixed Wing-asymmetry
Directional dependence

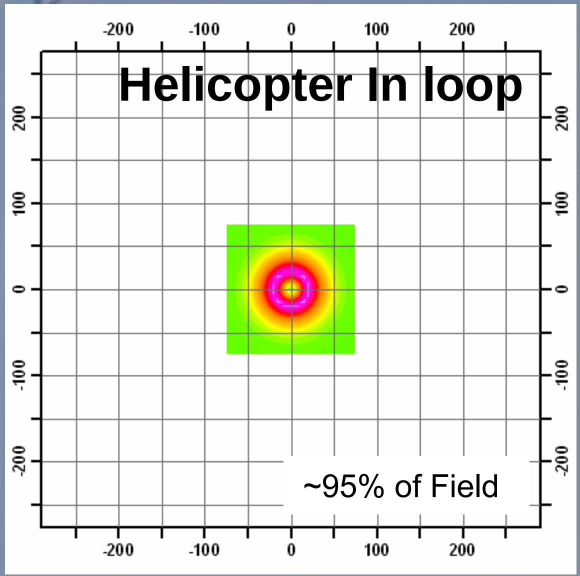


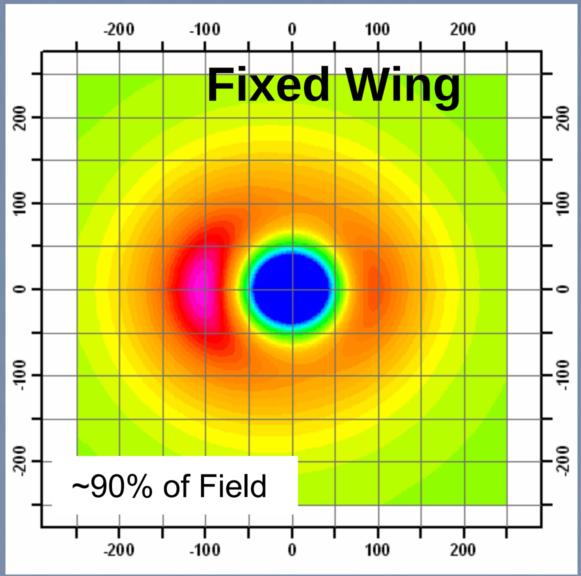
Flying Height & Footprint

- Foot print or Field of View of system is area energised (normally based on very early time) .
- **The higher you are, the broader you see**
- Foot print gets bigger with depth, so resolution goes down

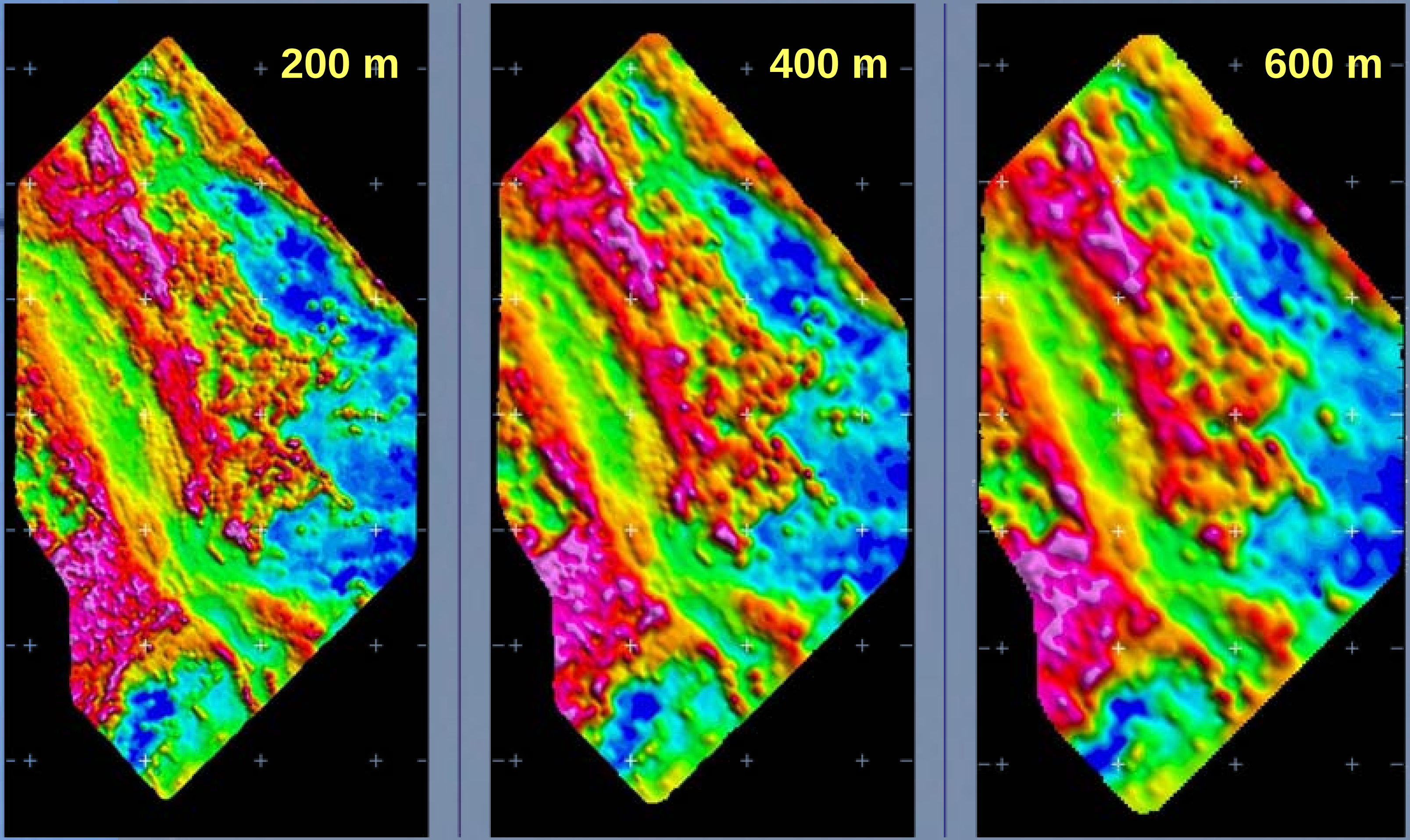


Vertical Foot Print



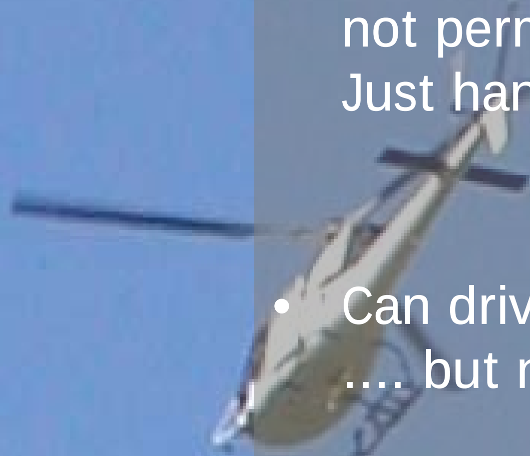


Flying Height– Controls benefit of line spacing



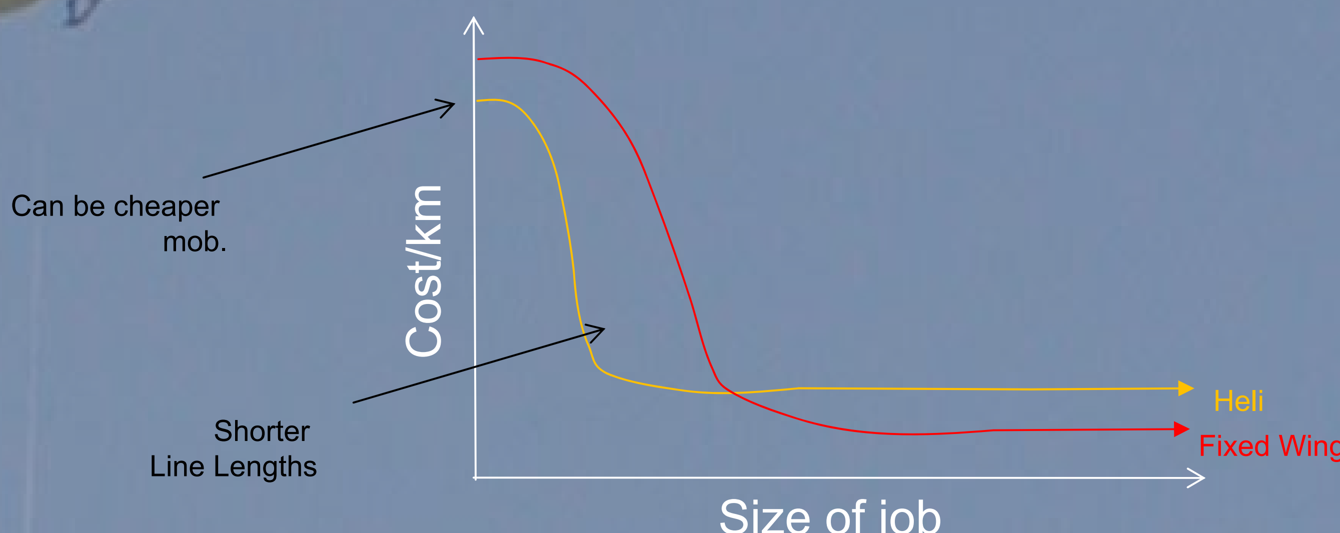
SkyTEM data courtesy Geoforce

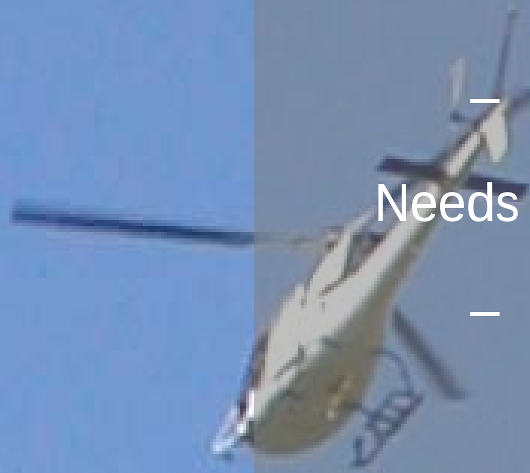
Ease of Installation



- Allows aircraft of convenience, not permanently installed, Just hang it on

- Can drive down survey cost…. …. but not necessarily for ever





Key factors to development

Technology Drivers

- Composite materials
- Electronics, smaller form and power

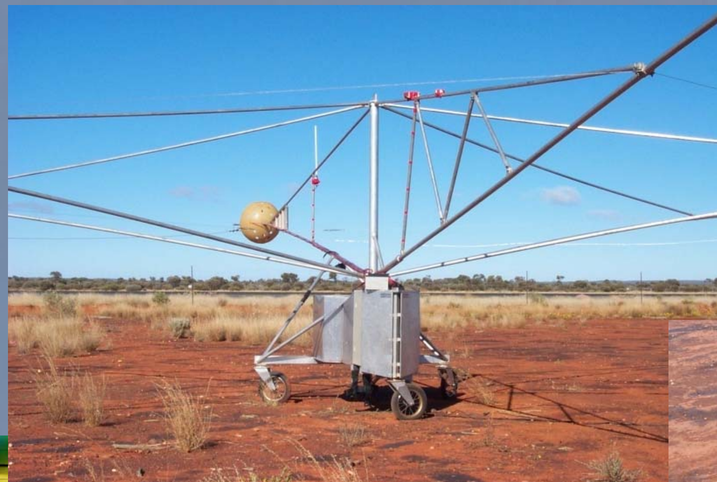
Needs to be light and fit on a hook

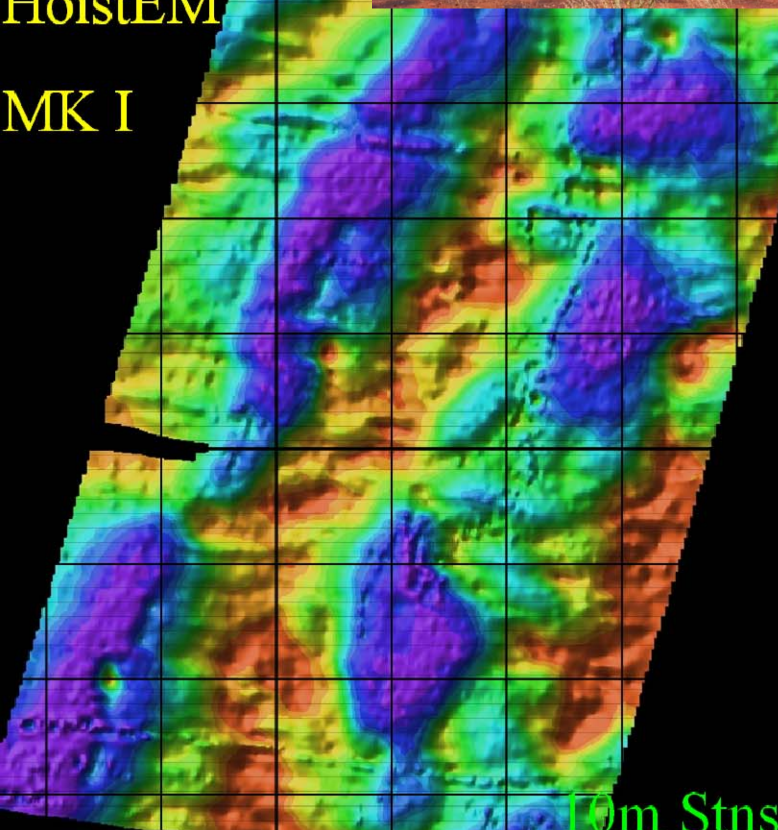
- Trade offs in for intended use
  - Weight,
  - Power and Bandwidth
  - Flying speed (aka cost)

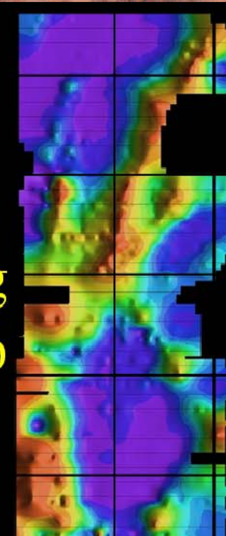
Lets look at systems having operated in Australia and see how these compromises have manifested themselves…

10 years of HTDEM in Aus

- Circa 1999-2000 Normandy Poshem
- Mapping structure for Au

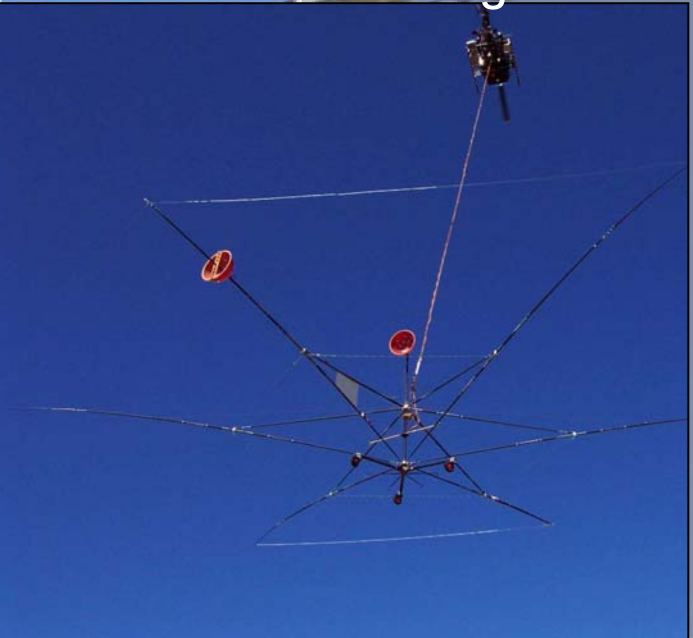






Hoistem MkII

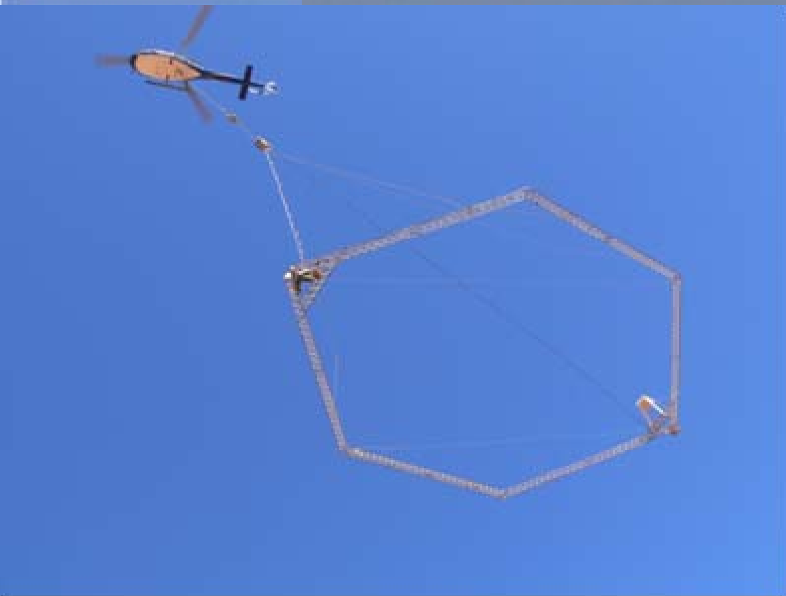
- Australian developed by Normandy, used for JV and commercial surveys. Focus on mapping capability. High bandwidth
- All composite construction
- Was commercially operated by GPX Airborne 2001-2007
- still flown by Newmont in various places around the globe




VTEM

- North American design and manufacture
- Highest moment system flying, focus on bedrock conductor detection. Not designed for mapping
- Multi-turn transmitter used to get power. Slow ramp off as a result, reduces bandwidth for vertical resolution
- Running from Helicopter power (weight)

www.geotechairborne.com.au



Skytem

- Developed in Denmark initially for water applications and brought to Australia for mapping capability
- Novel dual square waveform gives high and low power during flight. Low power option provides for very shallow mapping

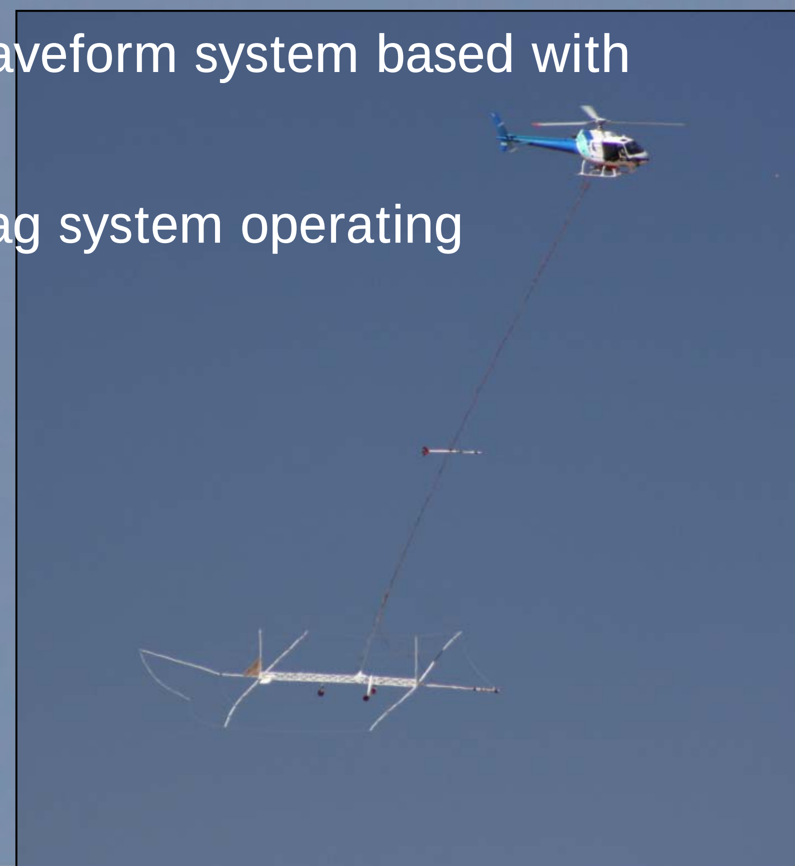
  Power 113,000Am^2 & 12,500 Am^2

  Turnoff 31µs & 4µs

- High drag, Slow flying
- Measures horizontal (X) and vertical (Z) components which can help in bedrock conductor interpretation

Reptem

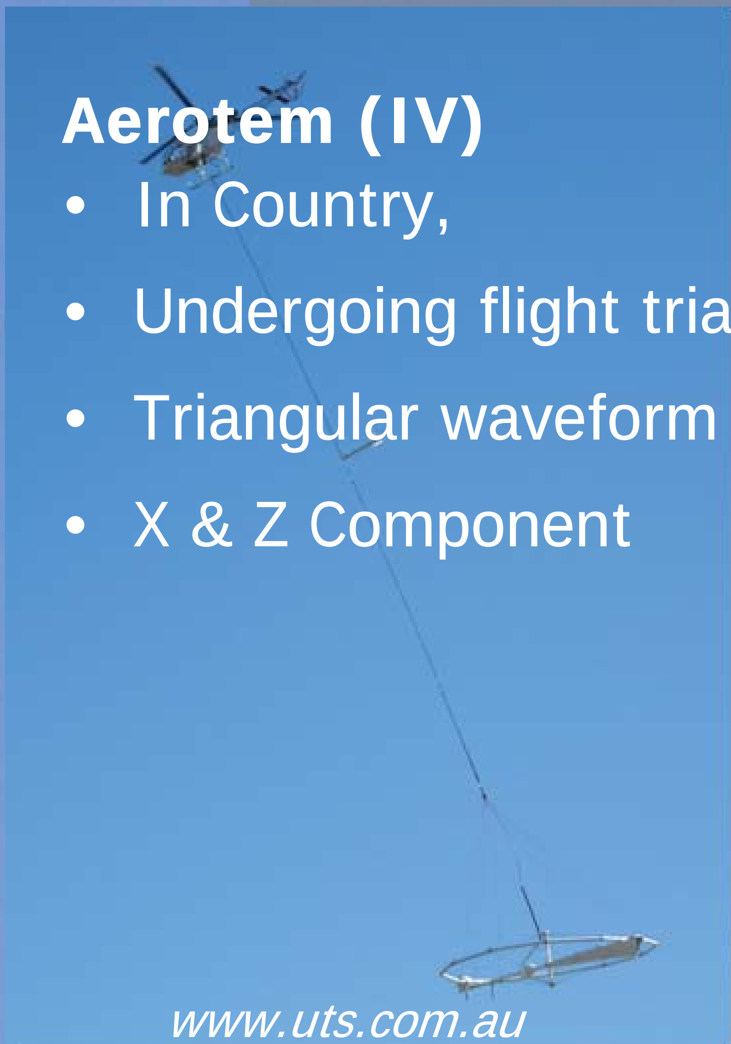
- Australian made and developed to replace Hoistem
- Originally provided by two different groups GPX Surveys and Geosolutions. Now solely through Geosolutions
- High bandwidth, square waveform system based with mapping focus
- Aerodynamically lowest drag system operating



XTEM

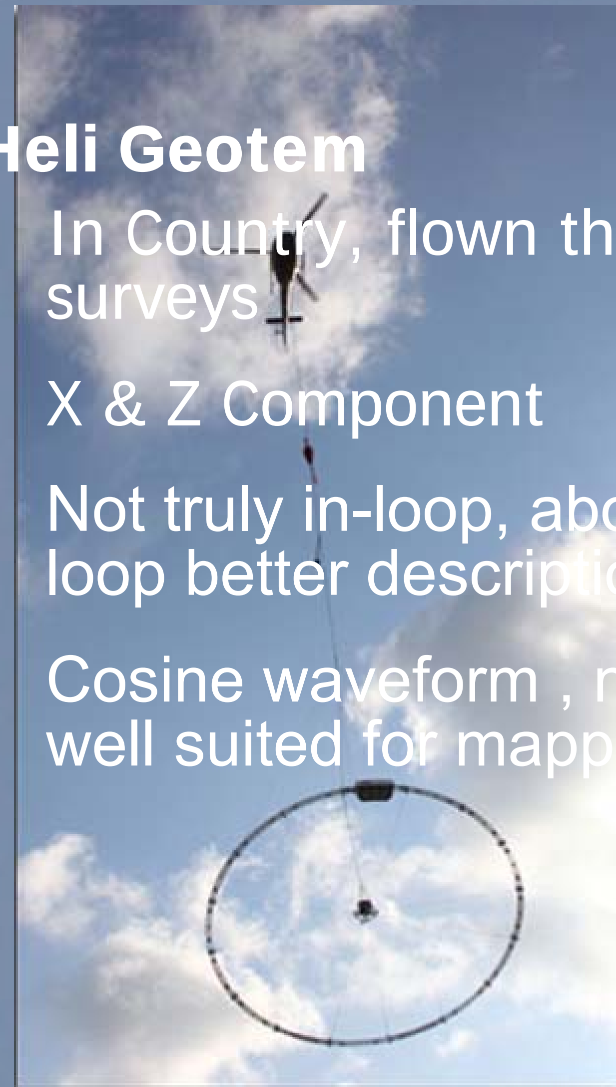
- New system in 2009
- Australian made and developed
- High bandwidth square waveform system, mapping focus
- A retro look and feel…?

Imminent (as always....)



Aerotem (IV)

- In Country,
- Undergoing flight trials
- Triangular waveform
- X & Z Component



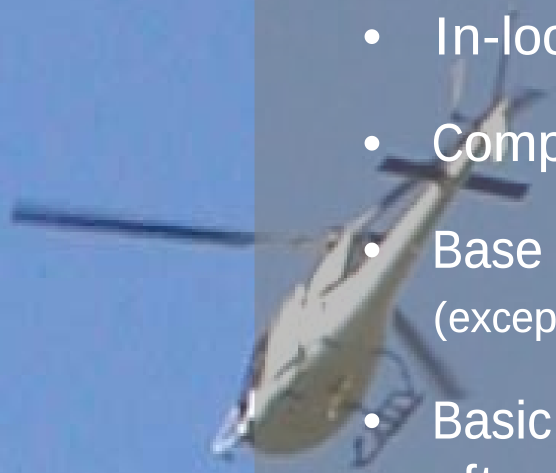
Heli Geotem

- In Country, flown three surveys
- X & Z Component
- Not truly in-loop, above loop better description.
- Cosine waveform , not well suited for mapping

What's

In Common

- Low flying
- In-loop Geometry
- Composite material
- Base Frequency – 25Hz
  (except in rare occasions)
- Basic specifications can often be tweaked for application, if the last 10% is critical ….



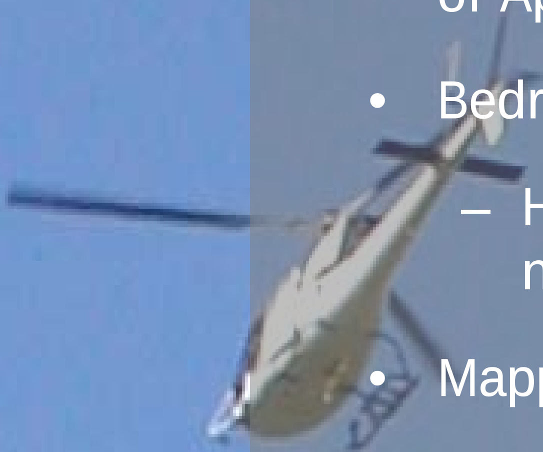
Different

- Power & resultant
- Waveform Shape with implications on bandwidth

	VTEM	Skytem	GPXTEM	Reptem
Moment (Am2)	400,000	110,000	105,000	115,000
Duty Cycle	50%	50%	25%	25%
Tx Alt	40	40	40	40
Rx Alt	40	40	40	40
Coil Orientation	Z	Z,X	Z	Z
Waveform	Trapezoidal	Square	Square	Square
Ramp Off (us)	350	35 (4)	40	35

Applications

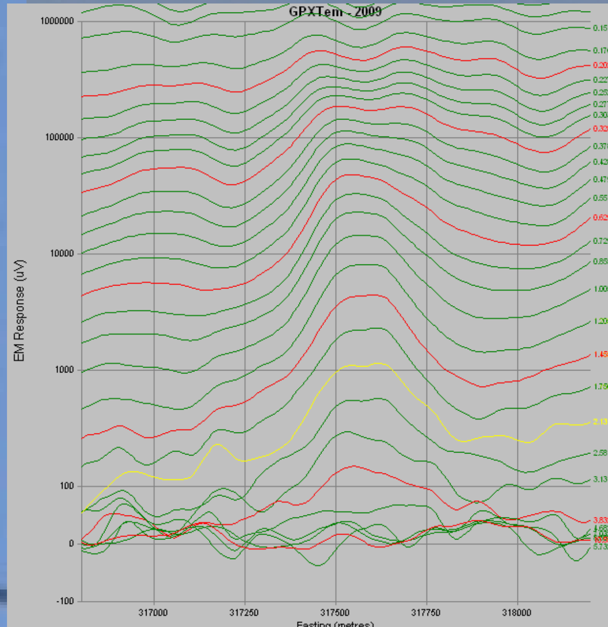
These variations have implication for the two main spheres of Application

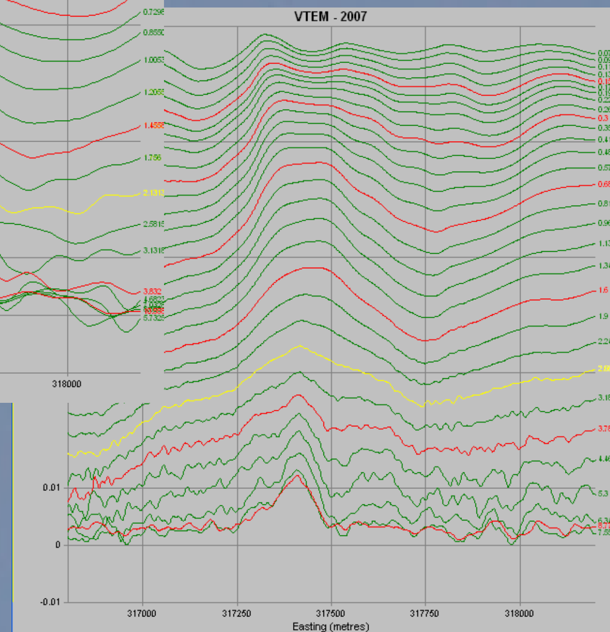


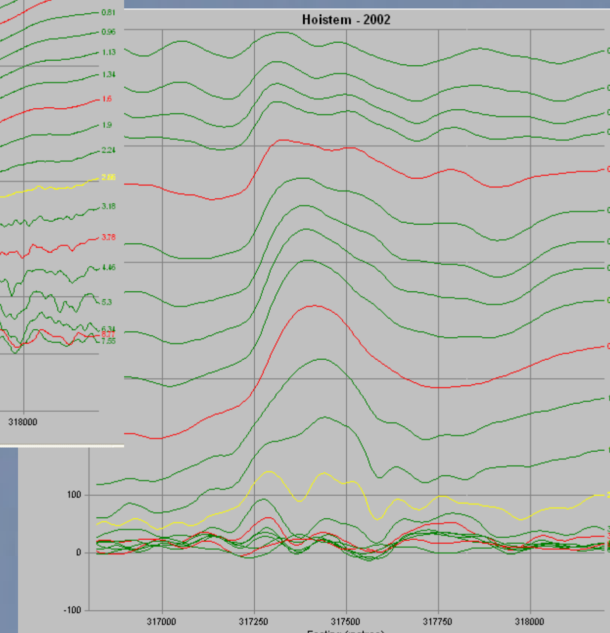
- Bedrock Conductors
  - Higher power normally better. High frequencies may not be as important
- Mapping
  - Spatial content, vertical and horizontal. →Bandwidth
- It is hard to have high power and preserve high frequency bandwidth….

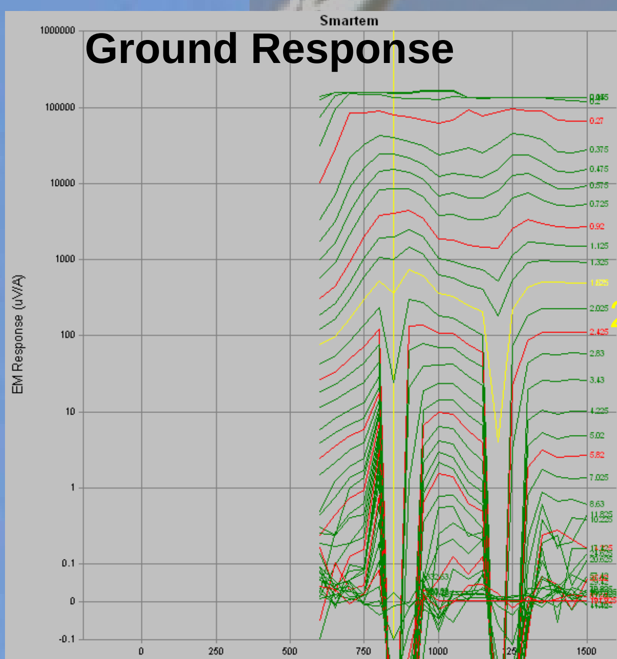
Basemetal

Nepean NiS







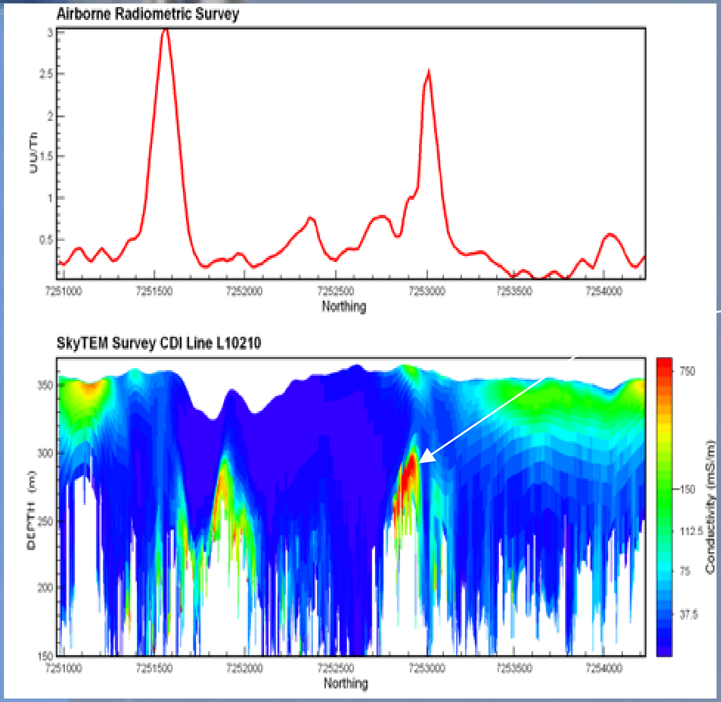


- Though HTDEM systems, don't extend in time as far as ground systems, more may or may not be happening once you have flown over…

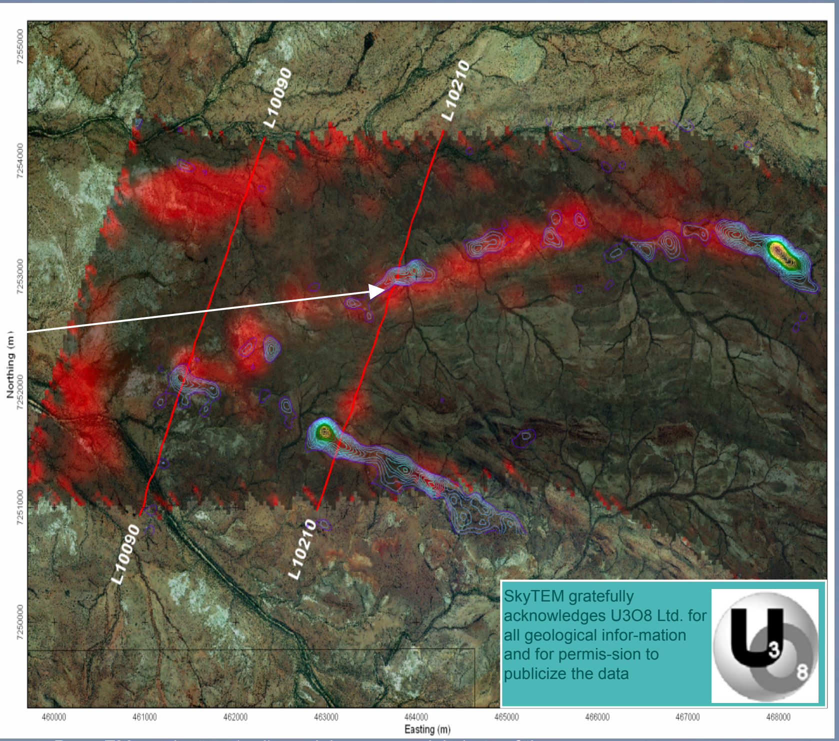
Data Courtesy of Focus Minerals Ltd, & GPX Surveys

Unconformity Related

- Depth of exploration is controlled as much by conductor size as system power



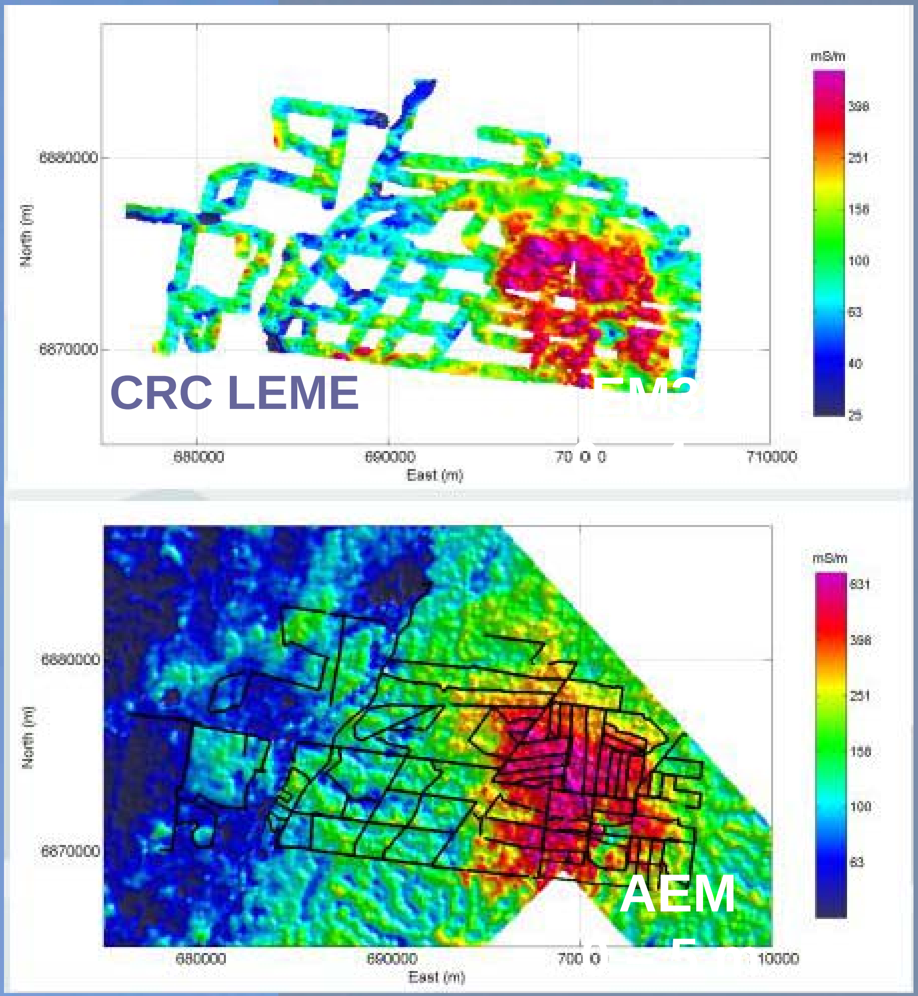
Conductivity depth section highlighting the proximity of the buried conductor (in red) to surficial uranium anomalies.



Deep EM conductors (red) overlain on an aerial photo of the survey area. Coloured contour lines show uranium anomalies detected by an airborne radiometric survey.

Mapping

Able to replicate very shallow information from the air



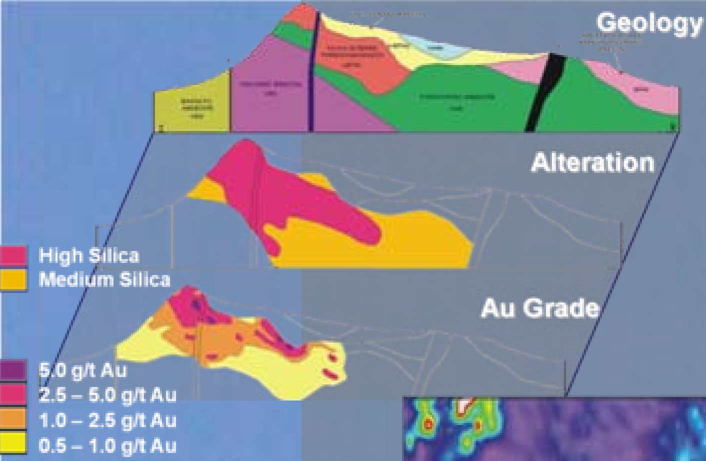
Skytem Image courtesy of Geoforce

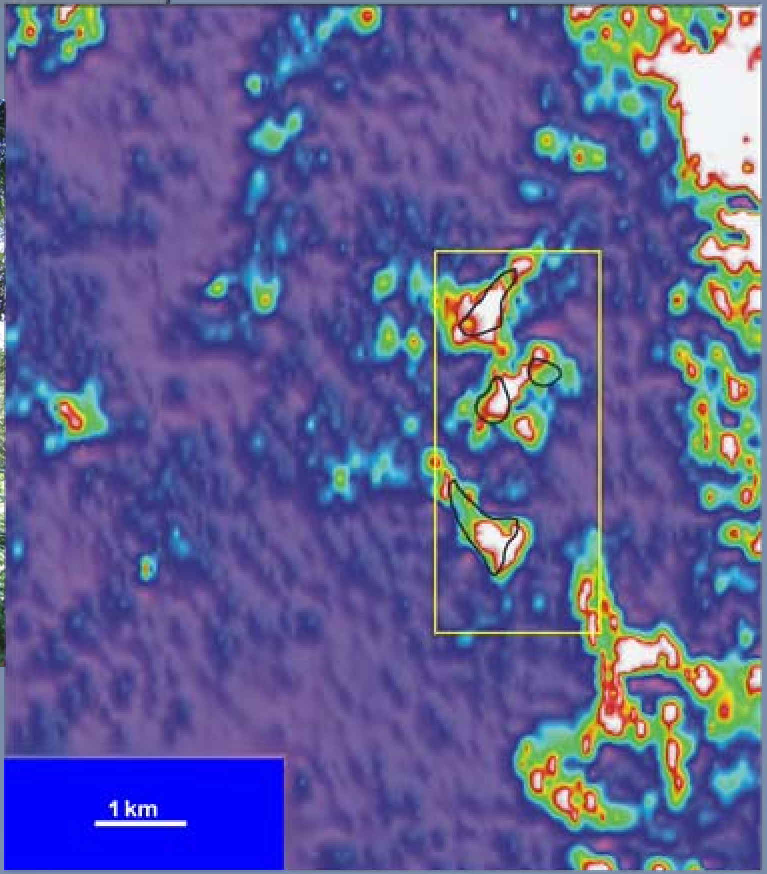
Top: Ground based EM31 mapping ~top 5m
Bottom: Skytem top 5m conductivity

- Shallowest information which can be derived from AEM data is an average of the conductivity within the top 4 – 10 m
  - Easier to get shallow information if conductivity is high
- Systems optimised to provide shallow information are those which measure at high frequency or early delay time
- Fast turn off and system fidelity important

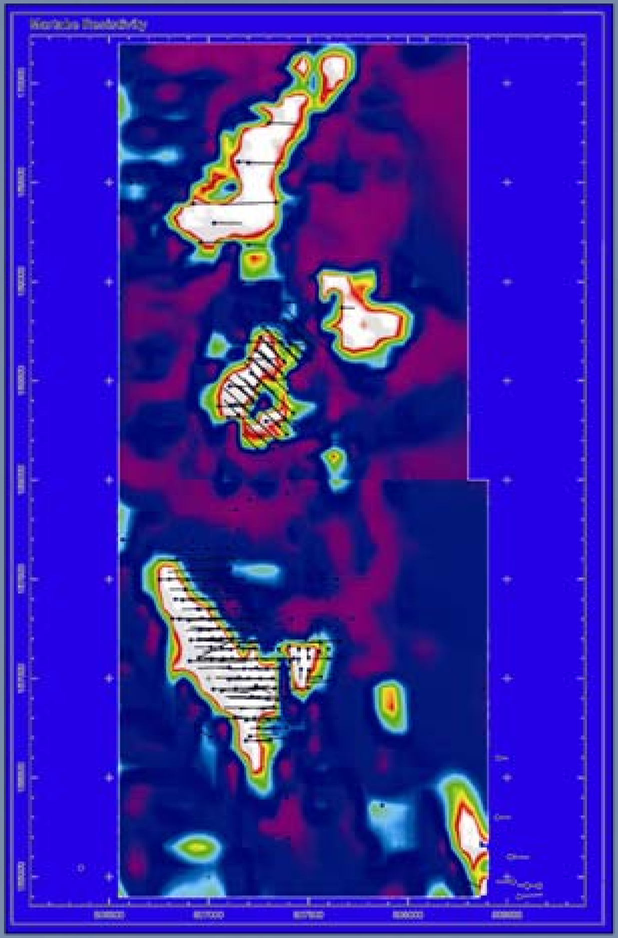
Not just Conductors
Silica - Martabe, Indonesia

- High sulfidation epithermal situated in North Sumatra
- 5.8 Moz Au @ 1.4 g/t Au
- Gold hosted by resistive silica bodies





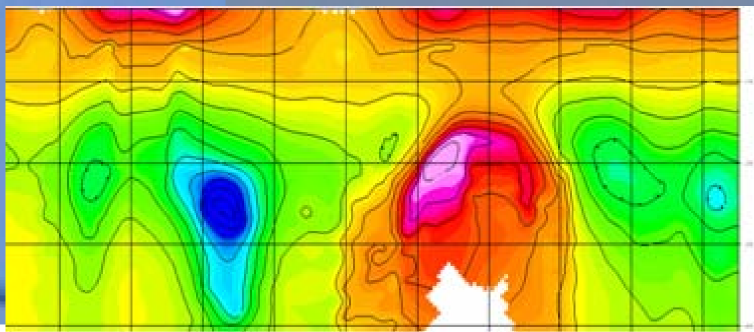
HOISTEM 50m Depth Slice

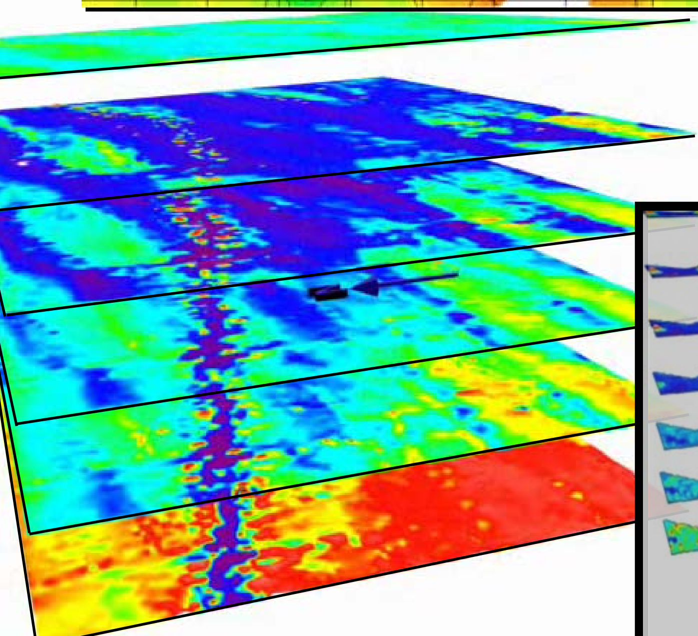


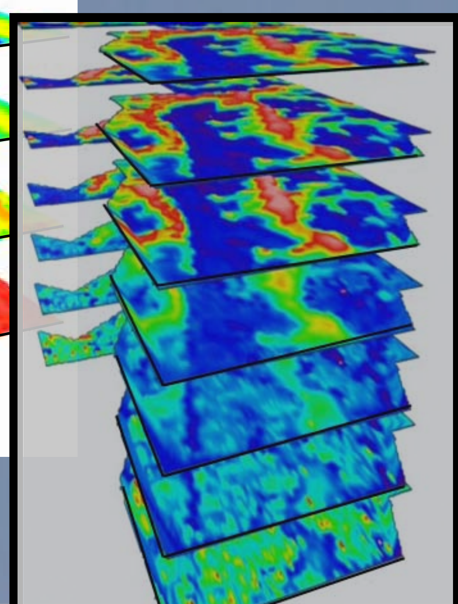
Resistivity 50m Depth Slice

Data courtesy Terry Hoschke - Newmont

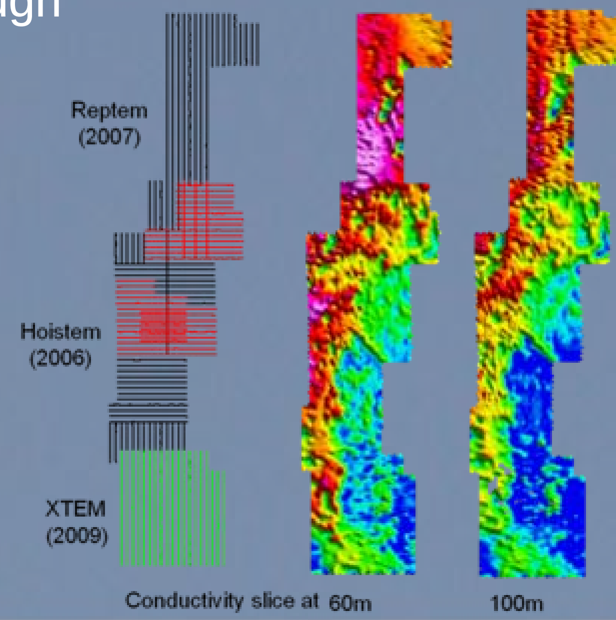
Interpretation & Presentation



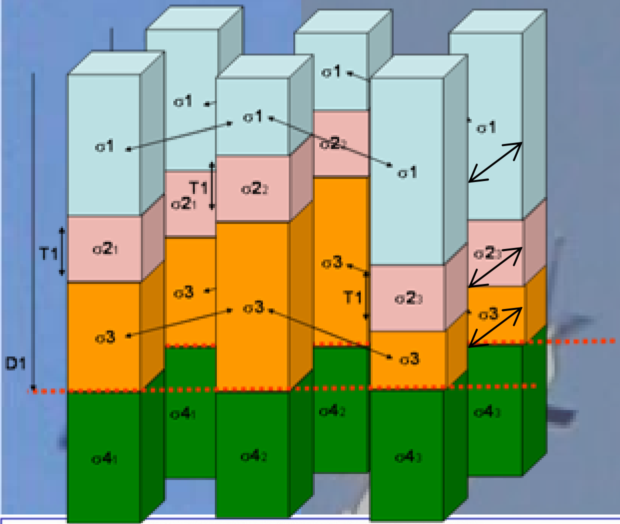




- Conductivity Depth Transform/Images (CDT/CDI) still most common presentation.
- Simple, fast and provide an ability standardise
- Should be a minimum expected product when mapping
- 1D transformation/sounding – the world isn't 1D though



Layered Inversions - Lateral



- CDIs being replaced by layered inversions with lateral constraints or lateral stratigraphic requirements

  (eg. Aarhus Workbench and Fullager Geophysic's Amity).

- 1D model, but solved over 3D extent.

  Improves continuity of interpretation and units in many situations where result may be numerically ambiguous.

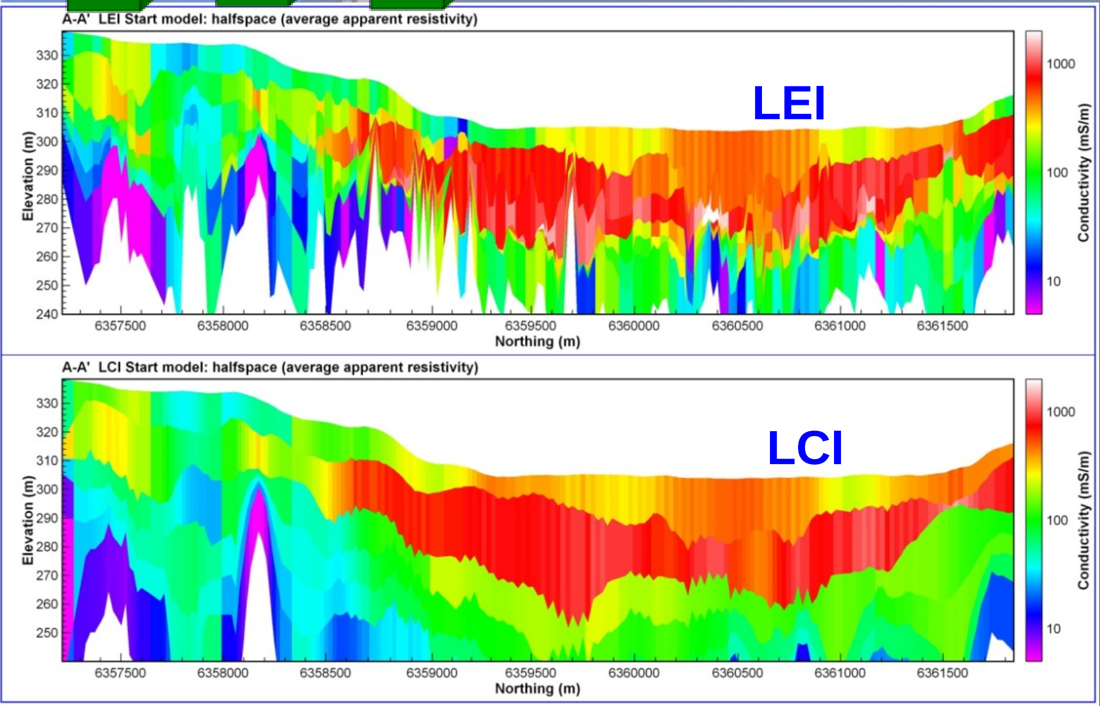
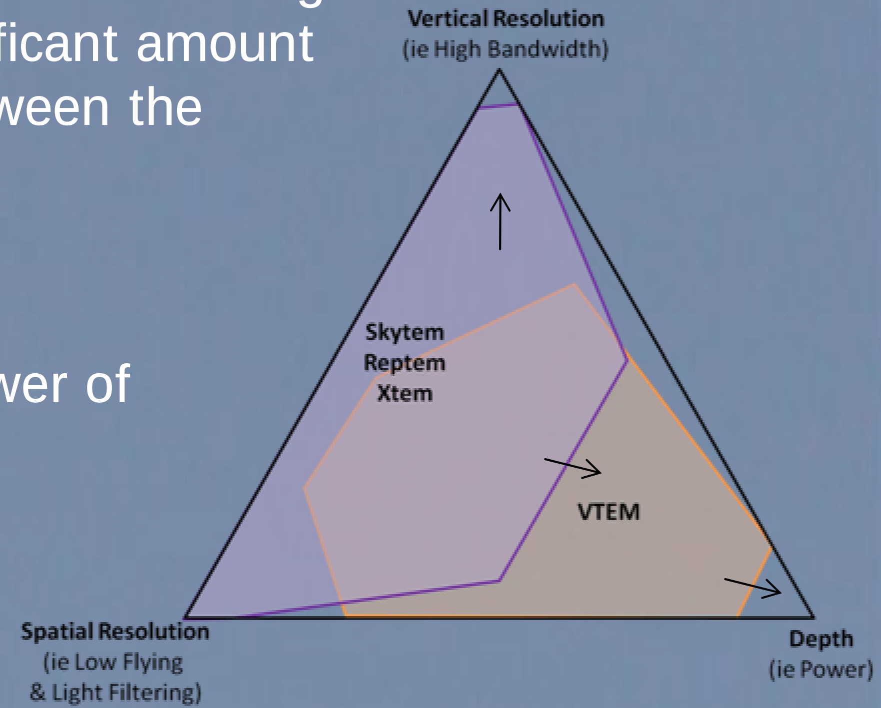


Image courtesy of Geoforce

Whats Next...

- HTDEM Systems now cover a broad range of our required need, with a significant amount of overlap in capability between the systems.

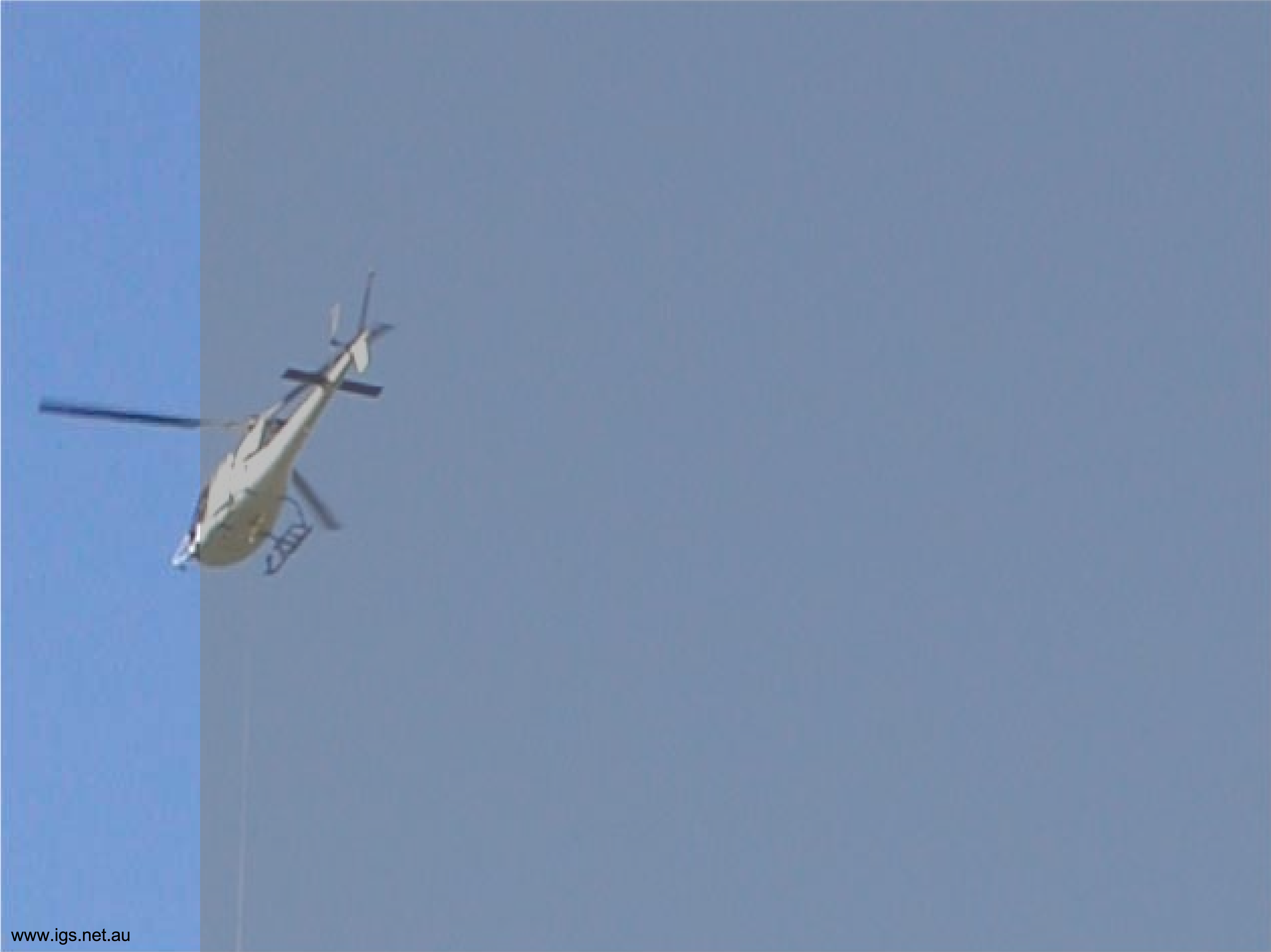


Acquisition System

- Increased moment and power of systems
- Increased use of cunning waveforms to preserve bandwidth
- Spatial resolution can't be improved by flying lower. Cheaper to allow denser line spacings?

Interpretation

- Improved inversions and interpretation tools. Increased use of apriori information and constraints to allow for better extraction of 3D information and query of large volumes of data


www.igs.net.au