ANT CENTER

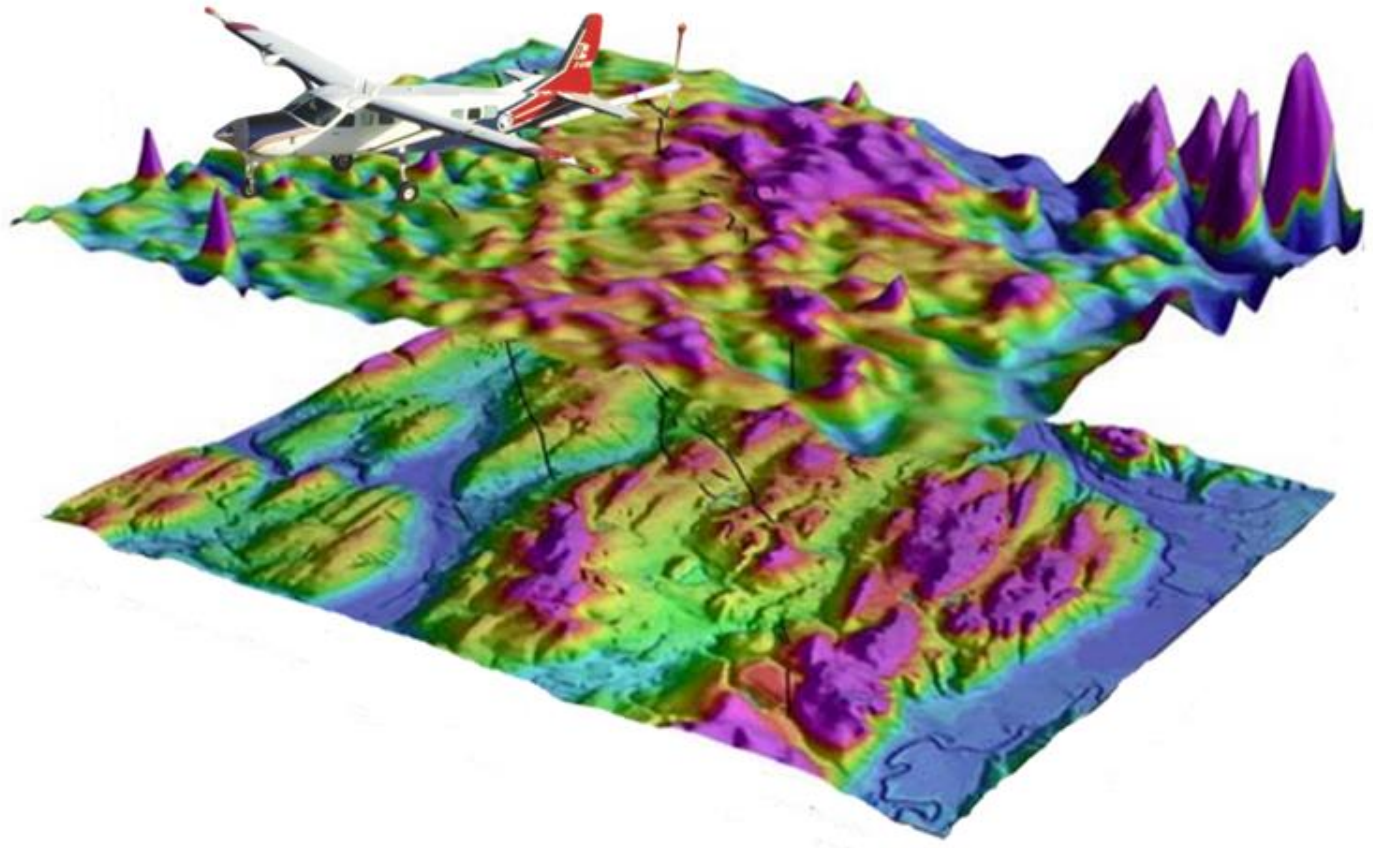
Magnetic Navigation

Dr. Aaron Canciani

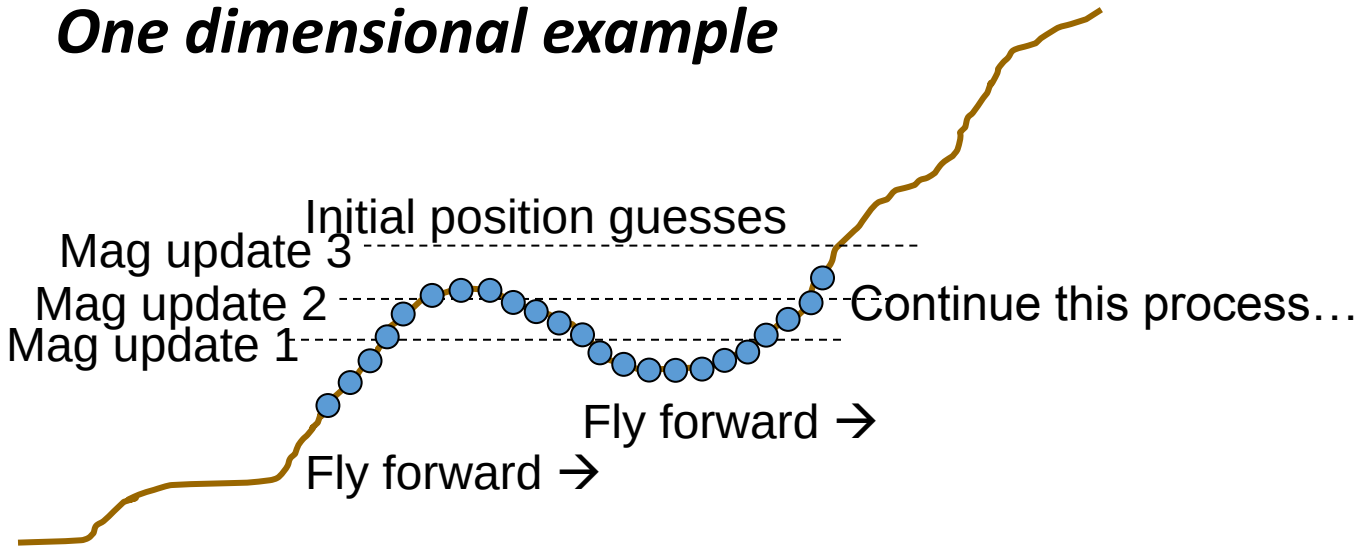
AFIT
Air Force Institute of Technology

What is Magnetic Navigation?

- Map-Based navigation system similar to fielded terrain-following systems
- Uses magnetic anomaly fields maps as the navigation signal
- Concept proven in multiple flight tests
- Many benefits and advantages among the set of alt-PNT strategies



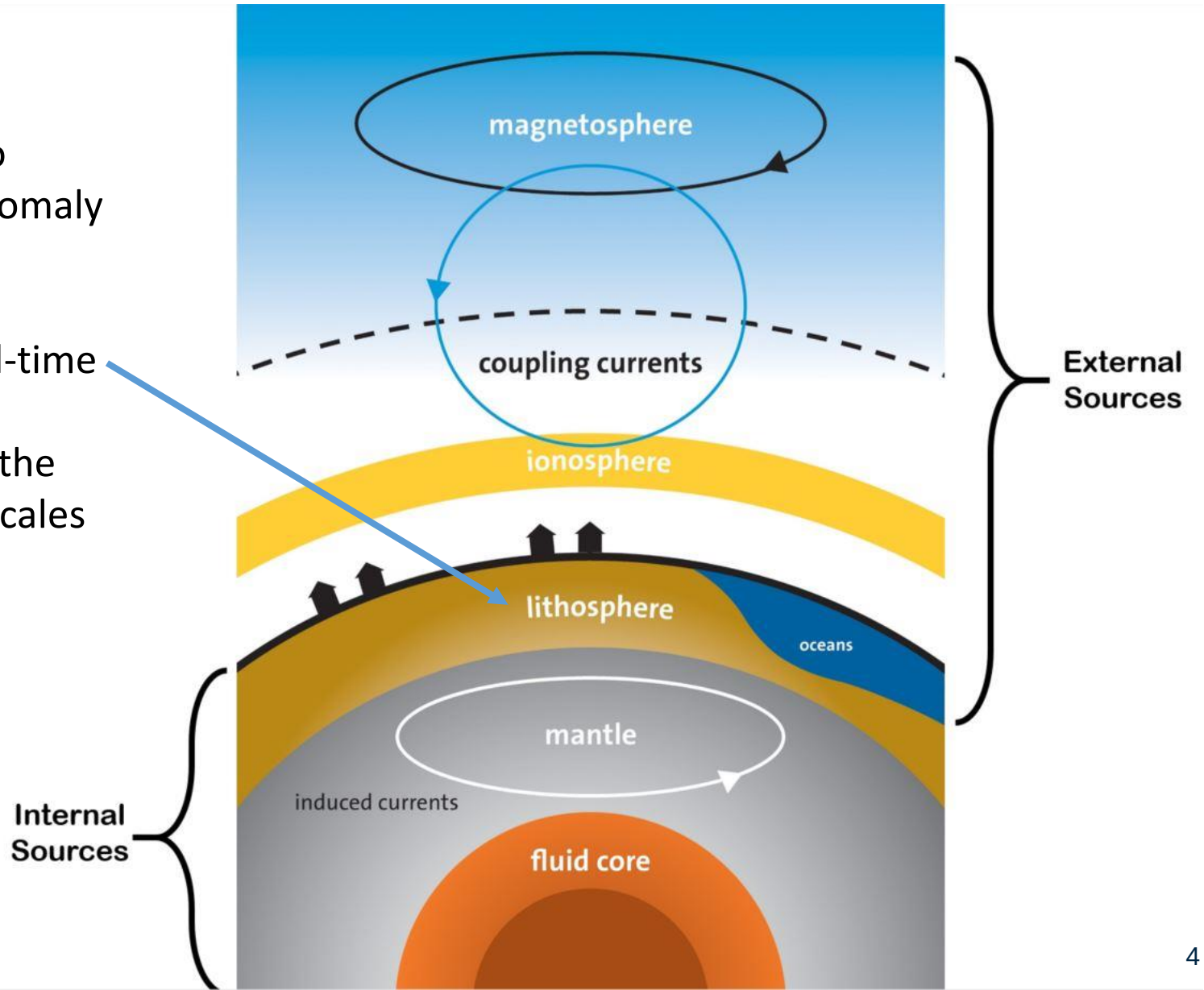
Map-Based Navigation Example



Earth Magnetic Field Components

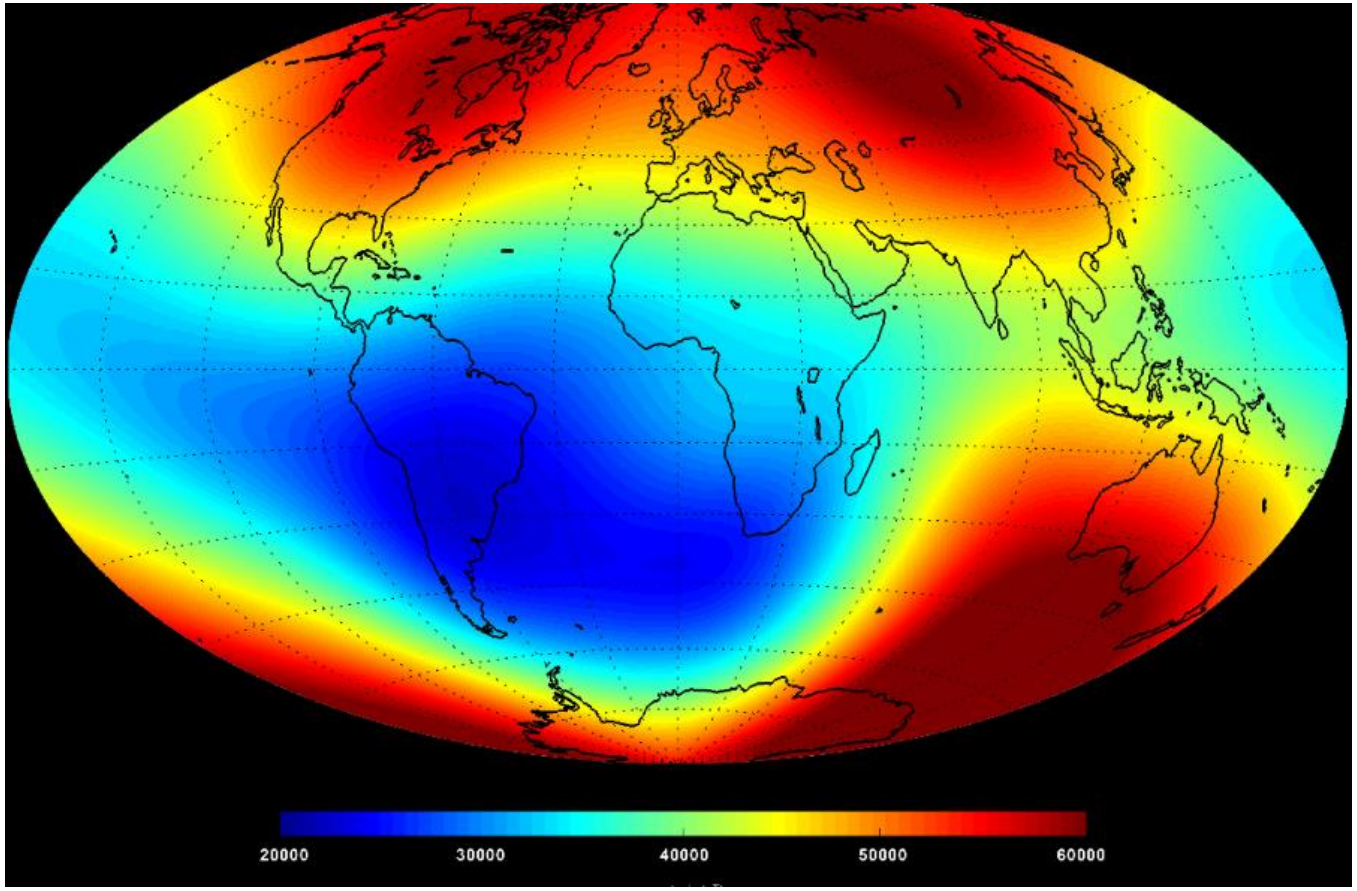
- Magnetic navigation utilizes one specific component of the total magnetic field to navigate – the lithospheric, or crustal anomaly field
- The navigation problem then becomes isolating this component of the field real-time

- Other components are time varying but the crustal field is static on geological time-scales and is well mapped



Earth's Core Field

- The field most people are familiar with
- Responsible for why your compass points north
- Very little spatial variation – not suitable for absolute positioning
- Changes slowly over time (Re-modeled every 5 years)

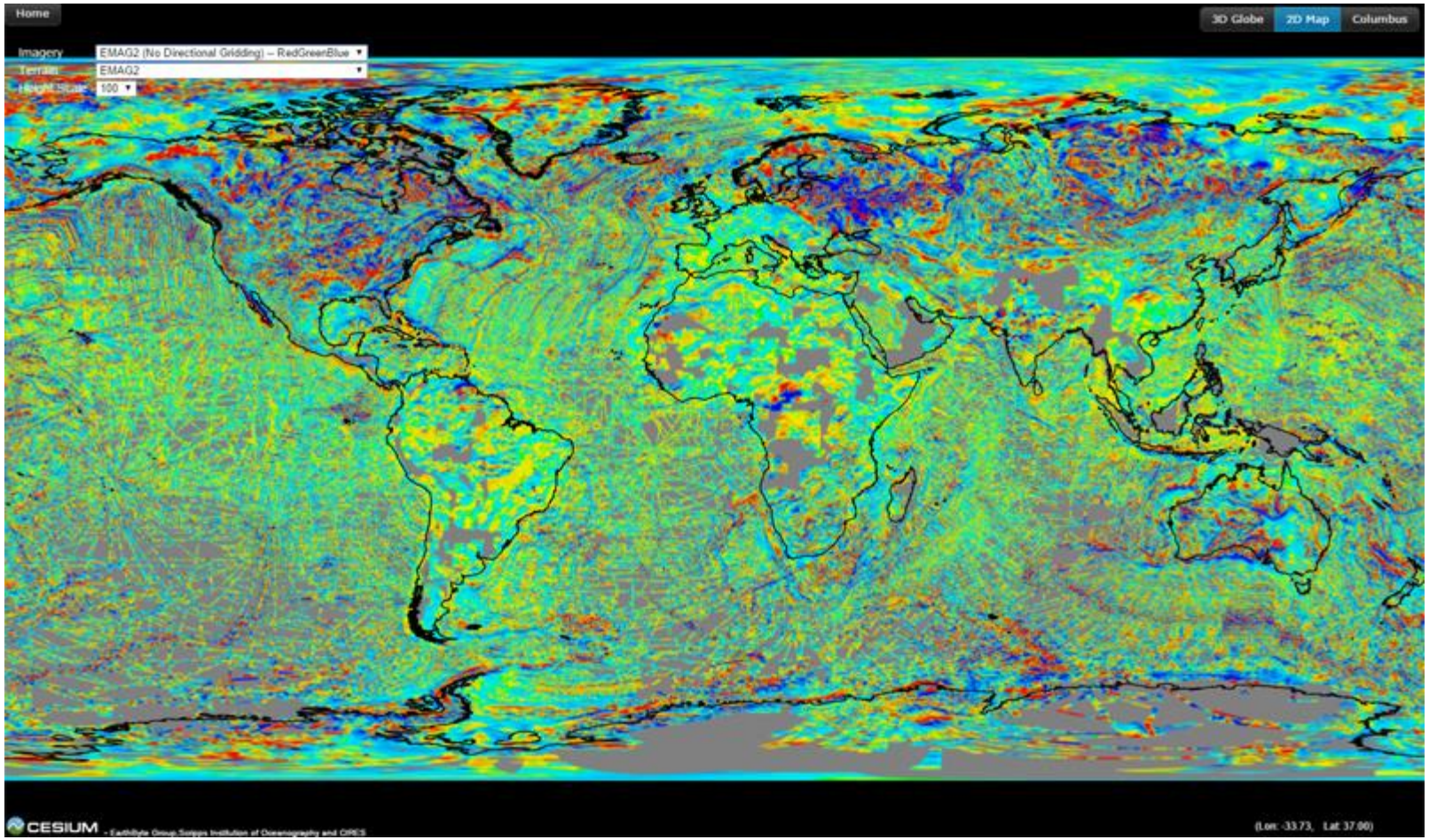


Earth's Crustal Field

(EMAG2 Model Shown)

- Caused by the both remnant and induced magnetization in the Earth's crust
- Far more spatial variation
- Static on geological time scales

- <u>A great candidate signal for navigation</u>



Benefits of Magnetic Navigation

- Vision navigation techniques are a promising alternative navigation technology
- With good features, vision navigation can out-perform magnetic navigation and provide near-GPS level performance
- Vision navigation can struggle over very uniform terrain and depends on lighting conditions and weather

- Terrain-following is a fielded navigation system
- Fails over the 2/3 of the Earth covered by water

- Magnetic navigation is available globally, including over water, and does not depend on time of day or weather

Benefits of Magnetic Navigation

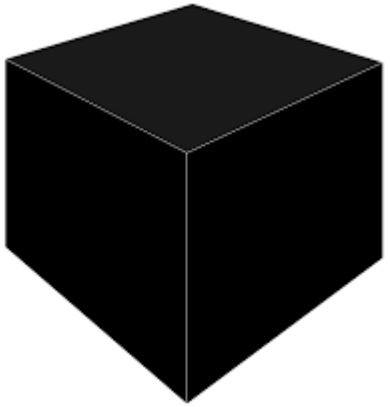
- With good signal availability, certain SOO's can provide near GPS level accuracy
- Signals of opportunity are highly dependent on location
- Any system based on infrastructure can be attacked/disrupted

- Star trackers can perform well and even operate in daylight conditions
- Star trackers can fail in cloudy conditions

- <u>Magnetic navigation is has no attackable infrastructure and does not depend on weather</u>

Benefits of Magnetic Navigation

- Magnetic navigation is a passive navigation system, emitting no signal unlike similar fielded terrain-following systems



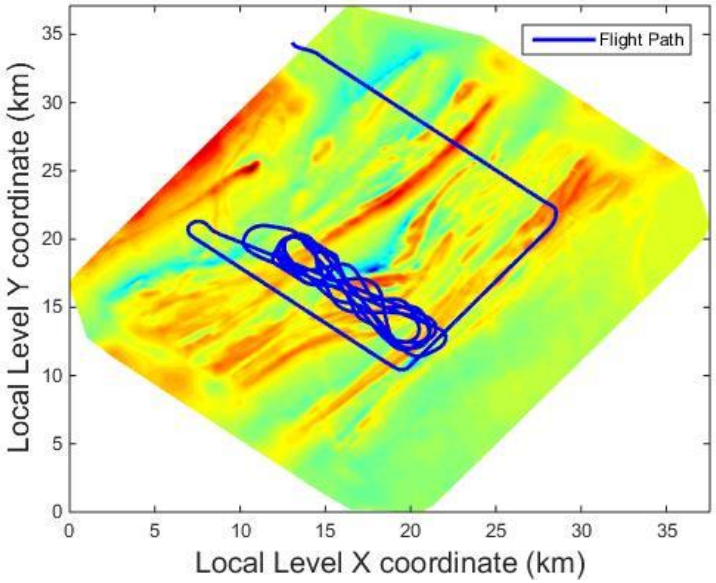
- Magnetic navigation is nearly un-jammable
  - DC magnetic fields decay at $\frac{1}{r^3}$ vs $\frac{1}{r^2}$ for propagating RF energy
  - It would take an unrealistically large amount of energy to disrupt signal
  - Signal caused by hundreds of kilometers of magnetically susceptible material underground

$$r^3 \gg r^2$$

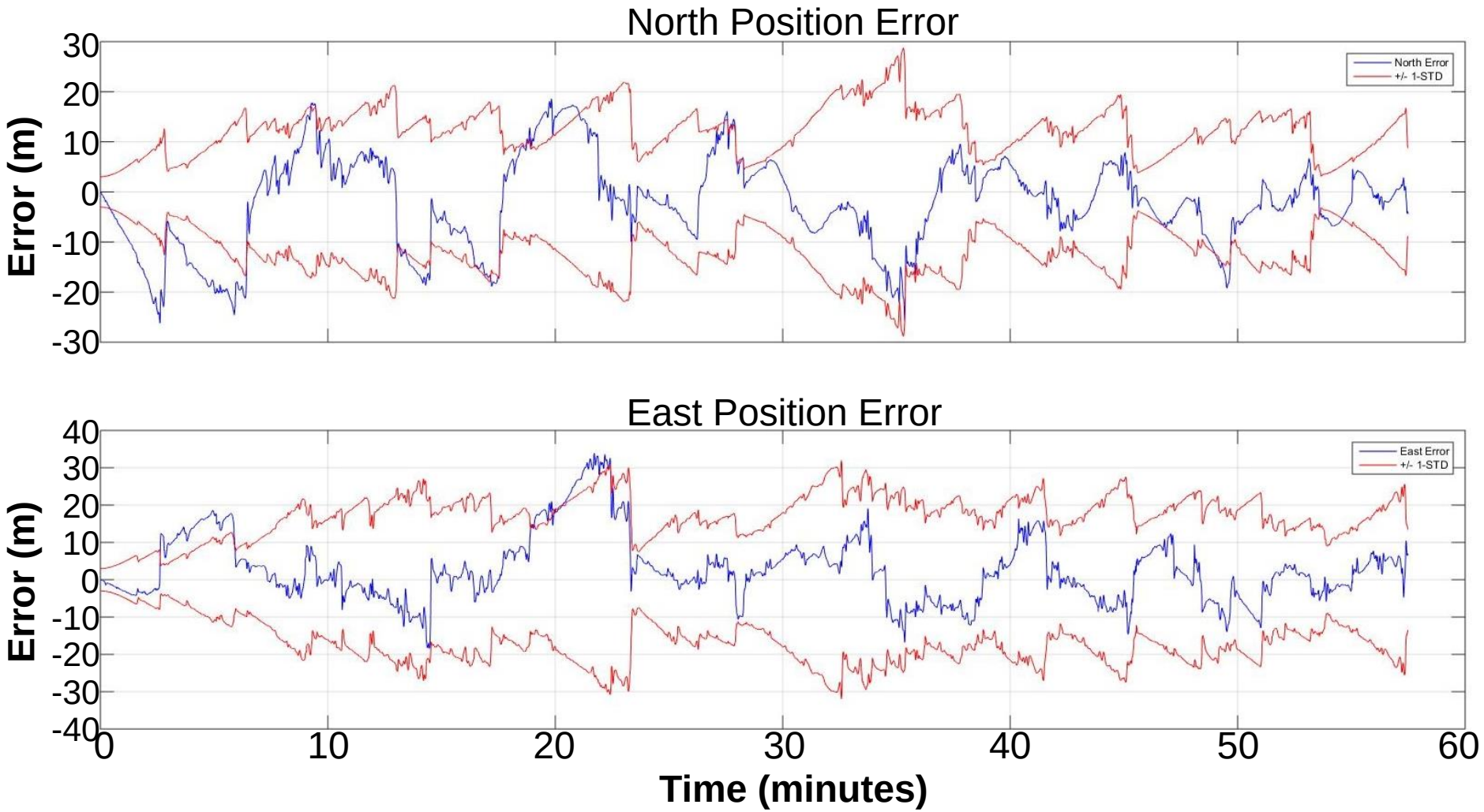
Current State of Magnetic Navigation

- Scalar magnetic navigation is a flight-test proven navigation technique
- Two ideal-case flight tests have taken place
  - High quality magnetic maps
  - Clean magnetic environment (calibrated)
  - Lower altitudes
  - Achieved accuracies of tens of meters over time-scales of hours
- Two other flight tests have taken place with
  - Inaccurate magnetic maps
  - Uncalibrated platform
  - Higher altitudes

Flight Test 1



Flight Test 1

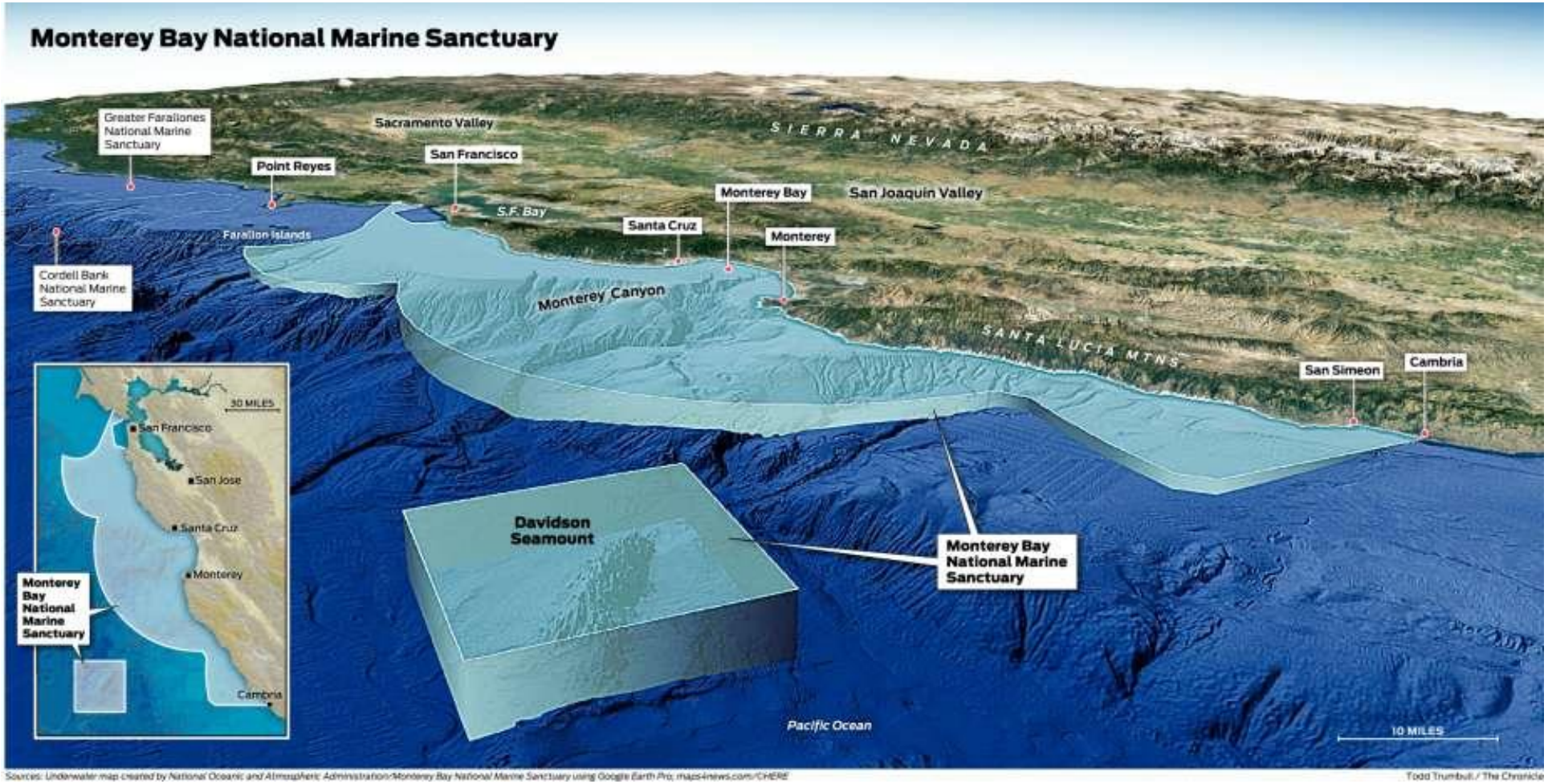


Flight Test 1

	North Channel	East Channel
Mean	-2.2 m	2.7 m
Standard Deviation	9.0 m	8.9 m
DRMS	13.1 m	
Unaided INS DRMS	230 m	

Low Altitude ☑
Good Map ☑
Clean Platform ☑

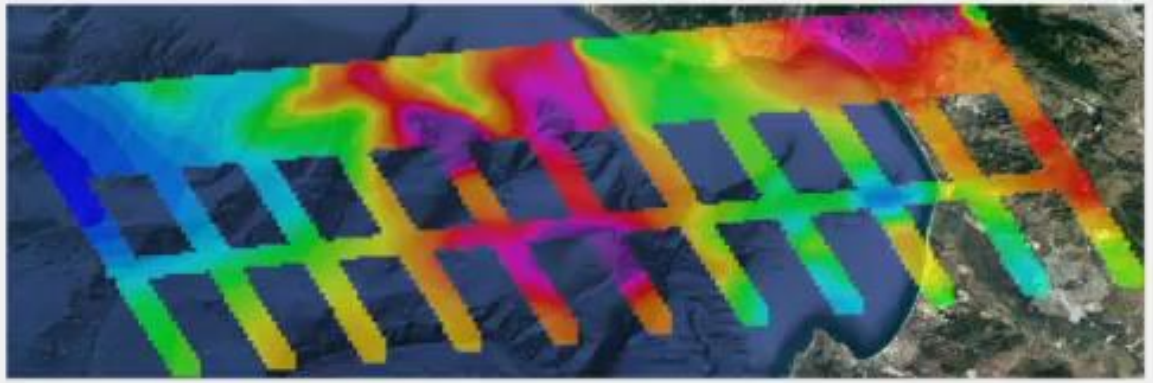
Flight Test 2



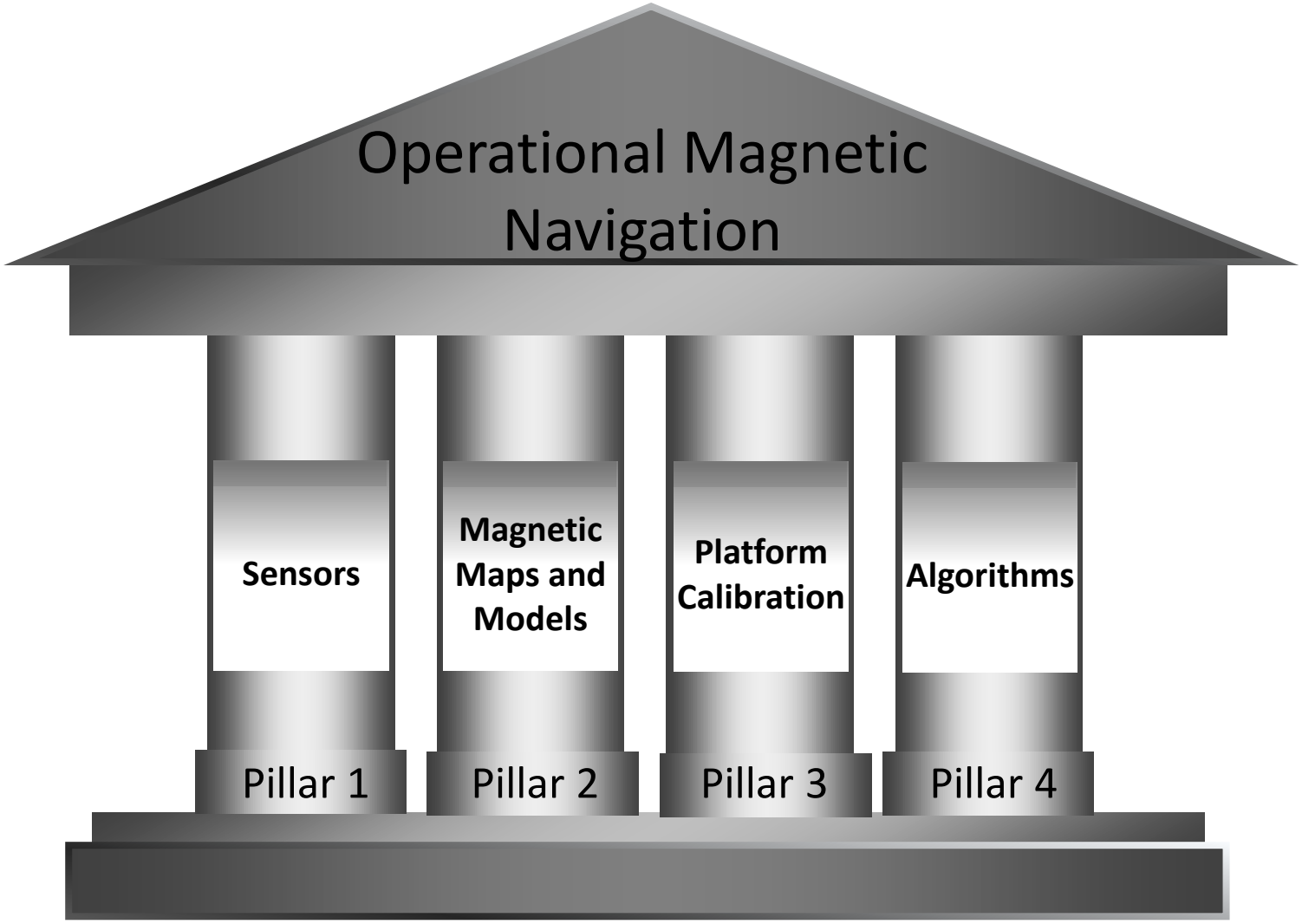
Flight Test 2

Low Altitude ☑
Good Map ☑
Clean Platform ☑

Red = Truth
Green = INS
Black = Mag-Nav Filter



The Four Pillars of Magnetic Navigation



Questions?