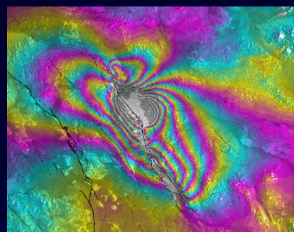
UNINHABITED AERIAL VEHICLES IN THE NASA EARTH SURFACE AND INTERIORS PROGRAM

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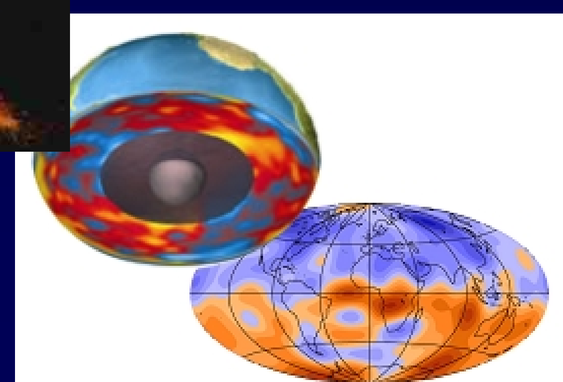
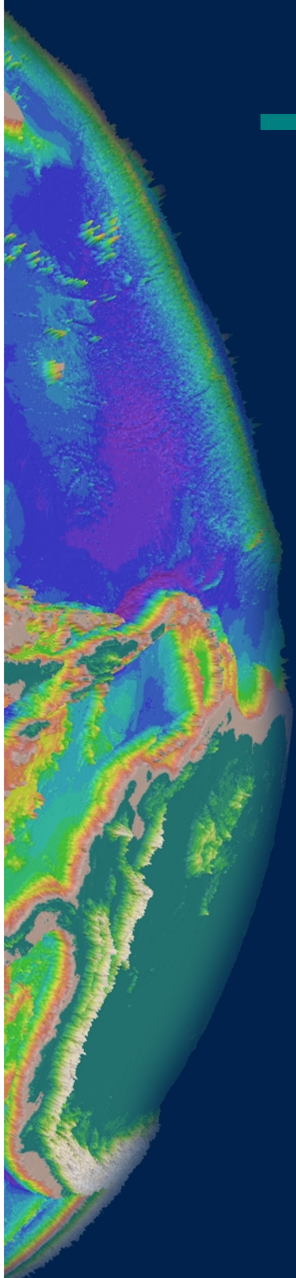


ESI Directed Study Group

- Rick Blakely (USGS)
- Scott Hensley (JPL)
- Chris Jekeli (Ohio State Univ.)
- Bill Krabill (GSFC)
- Scott Luthcke (GSFC)
- TBA others

- John LaBrecque (ESI theme lead)

SESWG



Scientific Imperatives

ESE Goal and Leading Solid Earth Science Questions

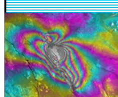
Observe, understand, and model the Earth system to learn how it is changing and the consequences for life on Earth.

How is the Earth's surface being transformed and how can such information be used to predict future changes?

What are the motions of the Earth and the Earth's interior, and what information can be inferred about Earth's internal processes?

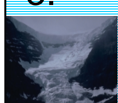
Scientific Challenges Identified by the SESWG

1. What is the nature of deformation at plate boundaries and what are the implications for earthquake hazards?



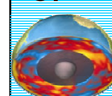
2. How do tectonics and climate interact to shape the Earth's surface and create natural hazards?

3. What are the interactions among ice masses, oceans, and the solid Earth and their implications for sea level change?

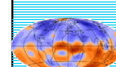


4. How do magmatic systems evolve and under what conditions do volcanoes erupt?

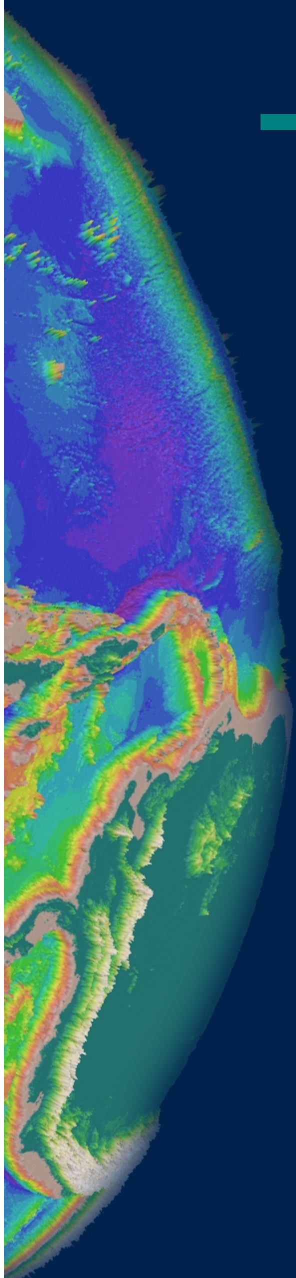
5. What are the dynamics of the mantle and crust and how does the Earth's surface respond?



6. What are the dynamics of the Earth's magnetic field and its interactions with the Earth system?



SESWG



Observational Strategies

- To address the six cross-cutting scientific challenges, a suite of high-priority observational strategies has been identified.
- The motivation for and expected benefits from each observational strategy will be highlighted throughout the presentation.

1. Surface deformation
2. High-resolution topography
3. Variability of Earth's magnetic field
4. Variability of Earth's gravity field
5. Imaging spectroscopy of Earth's changing surface
6. Space geodetic networks and the ITRF
7. Promising techniques and observations

Science Focus Areas

- Topography and surface change
- Sea level change
- Magnetic field origin and evolution
- Hazard warnings
  - Earthquake
  - Volcano
  - Flood, fire, landslide
- Motions of the Earth's interior

Rationale for a UAV Platform:
Polar Theme

- **Expand capability** for remote investigation of the Antarctic Ice Sheet and underlying crust, and the Artic region
  - Map potential fields
  - Map ice sheet topography
  - Map sub-ice topography & ice sheet thickness

- Potential opportunity for an **International Polar Year geophysical platform**

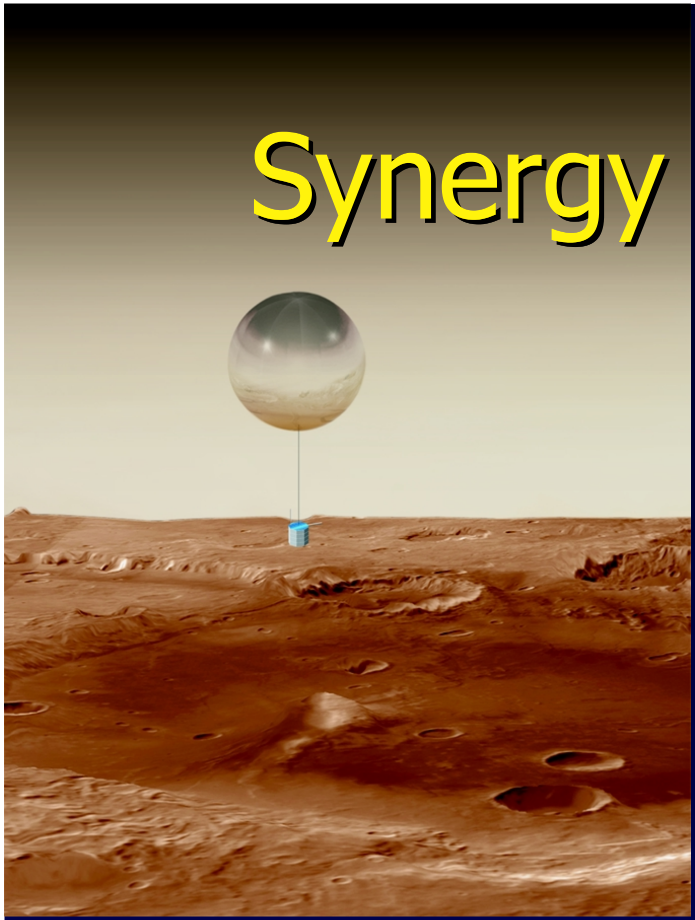
Rationale for a UAV Platform:
Extend Measurement Spectrum

- **Reduce cost** and logistical burden of aerial surveying
- **Sample critical region** between surface (airborne) and satellite vantage points
  - Develop comprehensive subsurface models
- **Improve temporal and spatial resolution, and accuracy** of dynamic fields
  - Gravity changes
  - Conductivity variations
  - Magnetic field fluctuations

Rationale for a UAV Platform:
Enable New Measurements

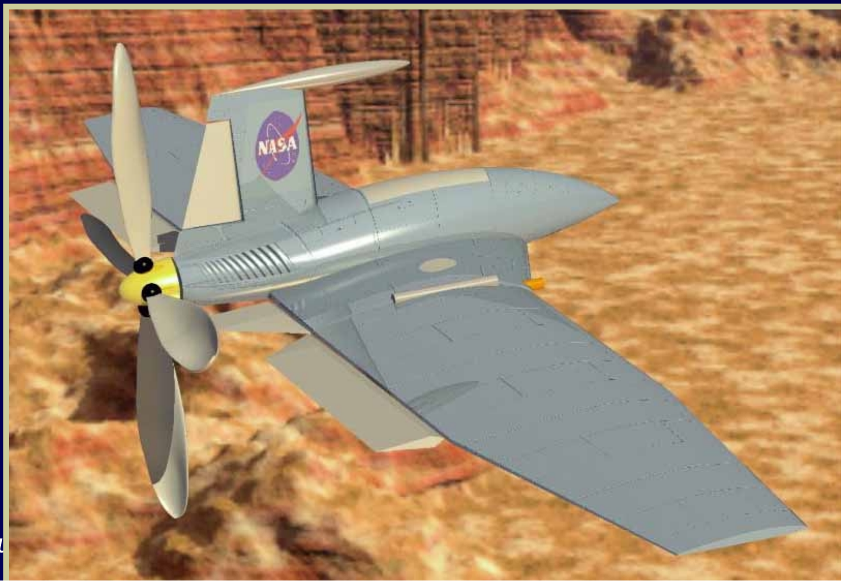
- **Hyperspectral** and **SAR** mapping with reduced cost and expanded capability
  - Predecessor to a SAR constellation to monitor deforming areas for earthquake and volcano hazards
  - Monitor volcanic plume emissions
  - Coastal topography mapping
  - Monitor changes in land surface cover (diurnal to inter-annual scales)
- Develop **EM sounding** capability to monitor magma motion, crustal fluids and subsurface structure

Synergy with Mars Program



- Keen interest in aerial platforms within the future Mars program
- Lightweight, low power and compact instruments **are key to capable systems**

- UAV platforms on Earth can be used as testbeds to demonstrate technology for Mars



System Architectures

- Small, agile UAV configured for long-range flight in polar environment
- Larger, more capable platform for radar, spectrometry, and comprehensive payloads
  - power, data storage and downlink
  - Synthetic Aperture Radar UAV study
- Formation Flying for gravity sensing and or interferometry, constellations
- Range of observing altitudes

Polar (IPY) Platform

- Small, agile UAV configured for long-range flight in polar environment
  - Low-cost platform operations
  - Access to key coastal areas from shipboard operations
- Compact, lightweight and low-power payload
  - vector helium magnetometer
  - IMU/accelerometer gravity sensing system
  - LIDAR
  - Radar Sounder
- Measuring Ice Sheet thickness is best achieved from a suborbital platform

Golden Eye UAV

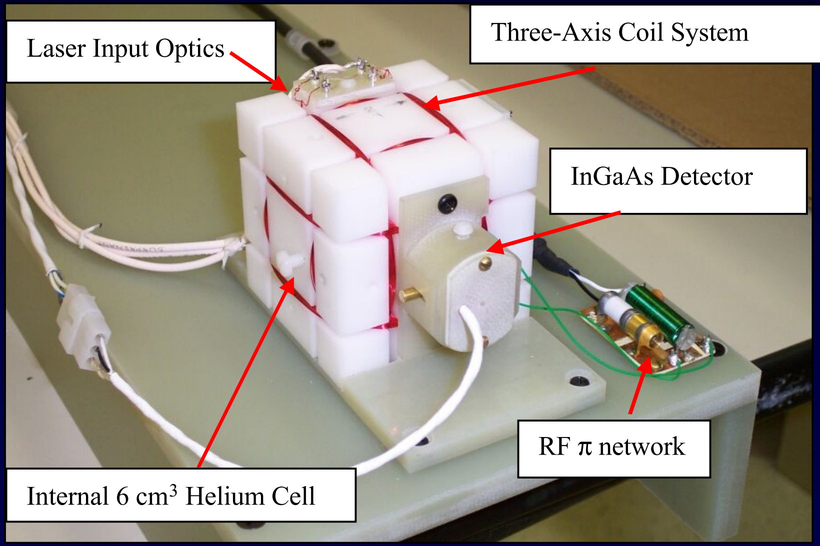
- Vertical Take-off, horizontal flight
- Fully autonomous or user-controlled
- Highly capable Inertial Measurement Unit (IMU)
- Designed for shipboard operations (short fins) with 300 km flight range
- Longer range possible for land-based operations (500 km)
- 10 kg payload envelope
- Low-rate telemetry system

Straw IPY Science Requirements

- Measure vector mag field variations at 2 Hz with < 2 nT accuracy per component
- Measure gravity anomalies to few mgal accuracy
- Measure ice sheet elevation to 10 cm absolute accuracy
- Measure ice sheet thickness to required accuracy and relative bedrock topography to 10 m

Magnetometer

SELF-CALIBRATING VECTOR HELIUM MAGNETOMETER SENSOR UNIT

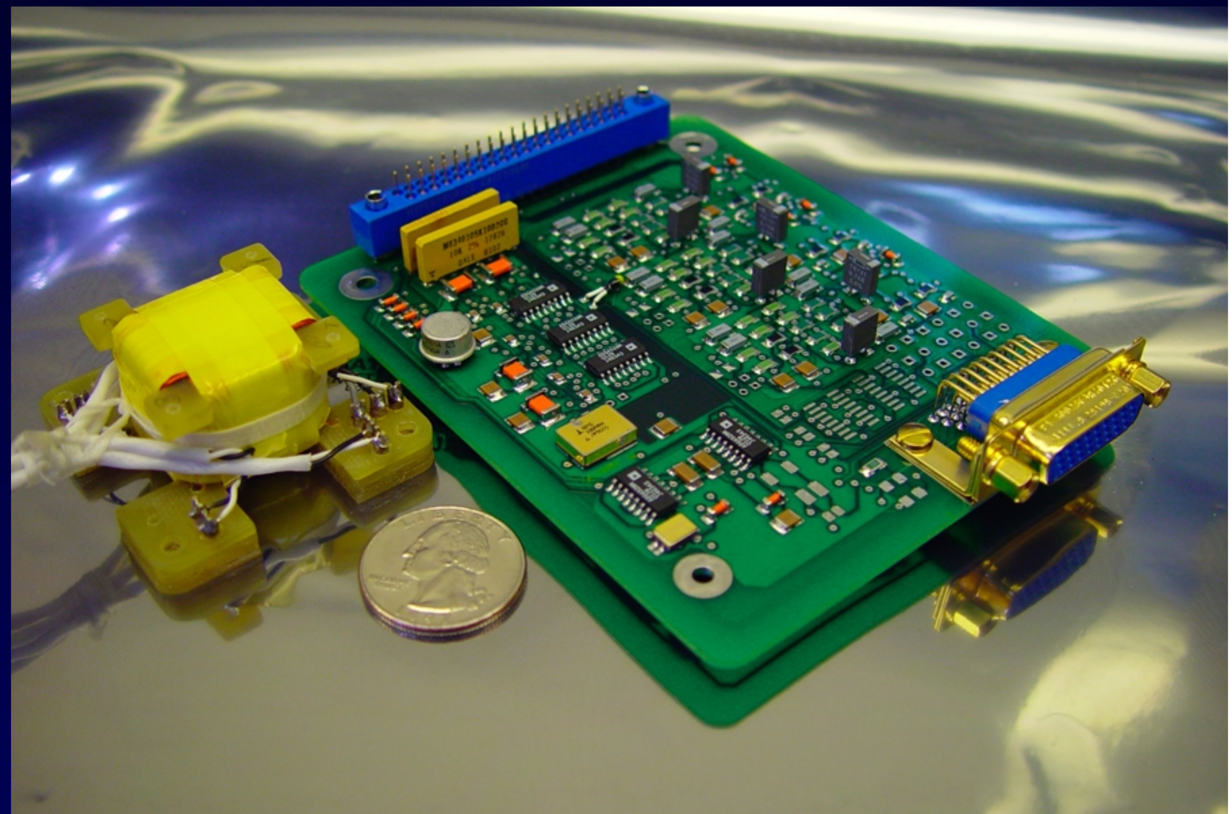


- Vector accuracy <±100 nT, scalar and self-cal accuracy is <±1 nT
- Sensor Unit size is 6 x 6 x 12 cm
- 5 cm diameter orthogonal coil system
- Electronics need to be reduced in size and weight
- Configuration as shown is 304 grams

POLATOMIC

Magnetometer

- Small fluxgate may suffice with ground calibrations
- Space-qualified
- <1 kg, few watts



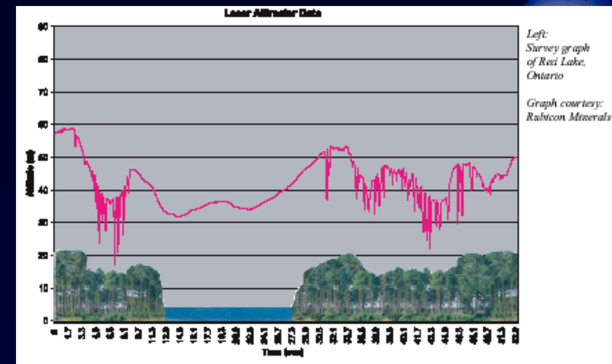
- Platform attitude from IMU meets accuracy required

Gravity System

- ‘Strapdown’ gravity system under development for higher accuracy (C. Jekeli, Ohio State)
- Future quantum gravity gradiometer sensor to detect very subtle changes

- Guidestar IMU (COTS)
  - Integral to the Golden Eye vehicle
  - GPS, Roll, Pitch, Heading in Dynamic Environments
  - Solid-State MEMS gyros and Accelerometers
  - Requires high-precision accelerometers to improve performance

LIDAR

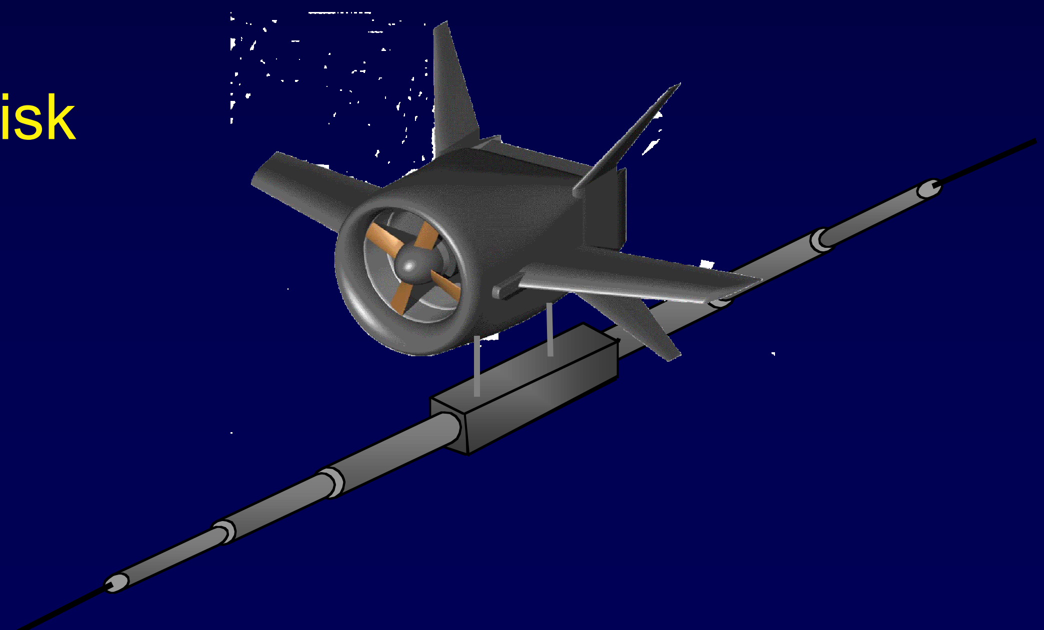


- COTS LIDAR Used on Mars Scout Mission “Phoenix,” developed by Optech Incorporated, Toronto, Canada
  - **Accuracy**
    - From -10ºC to 0ºC, less than 5 cm
    - From 0ºC to +45ºC, less than 4 cm
  - **Acquisition Time** 0.01 seconds
  - **Range & Track Rate**
    - 350 m to a 20% reflective target
    - 525 m to a 45% reflective target (typ. reflectance)
  - **Weight & Dimensions** 1.5 kg, 218 x 133 x 87 mm
  - **Laser Characteristics** 904 nm (IR), 0.3° diverg.
  - FDA Class IIIb laser, Class I laser option available
- A desired option is a miniature scanning lidar system under development at Goddard Space Flight Center

Radar Sounder

- Sounder design is a radar with a center frequency around 50 MHz with a 10 MHz bandwidth (possibly 15 MHz).
- Data is stored to disk during flight

Power	?? W
Mass	< 9.1 Kg
Center Frequency	50 MHz
Bandwidth	10-15 MHz
Data Rate	40 MB/sec
Data Volume (2 hours)	288 GB



Summary

- ESI has many high priority science questions that can be attacked using suborbital platforms – some require them
- Near-term applications and far-term needs have been identified
- Suborbital measurements are critical for cost-effectively improving the spatial and temporal resolution of dynamic systems
- Capable suborbital platforms enable new science measurements
  - Ice sheet thickness
  - EM sounding
- Synergy with Mars Exploration Program