

# **The Design of a Lunar Farside Gravity Mapping Nanosatellite for the European Student Moon Orbiter Mission**

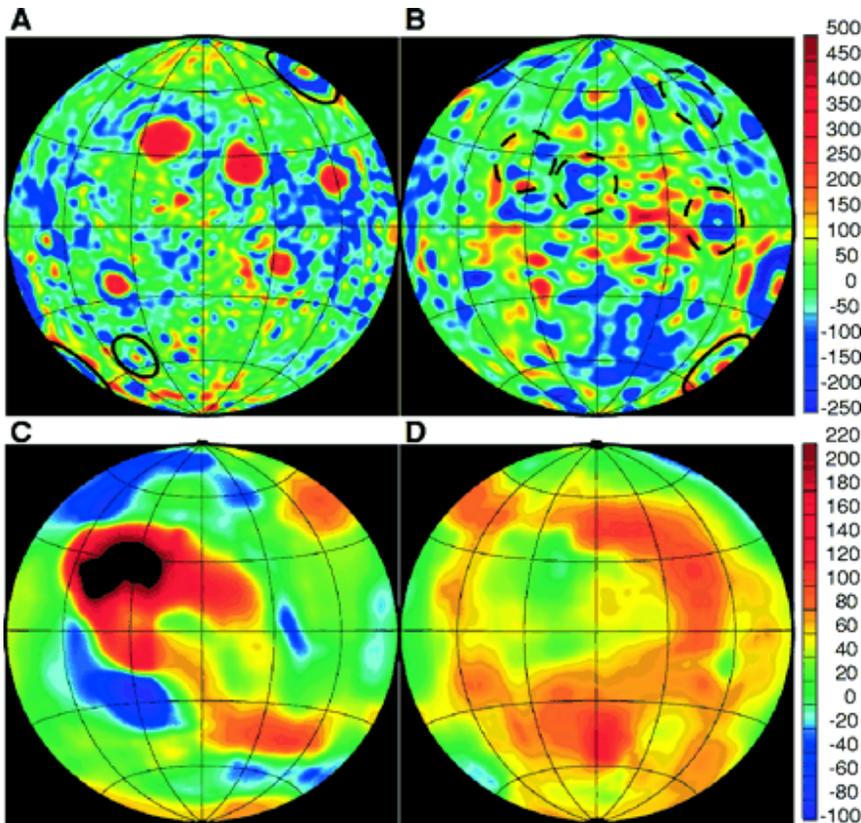
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# Introduction

Anomalous Gravity (mGal at surface)



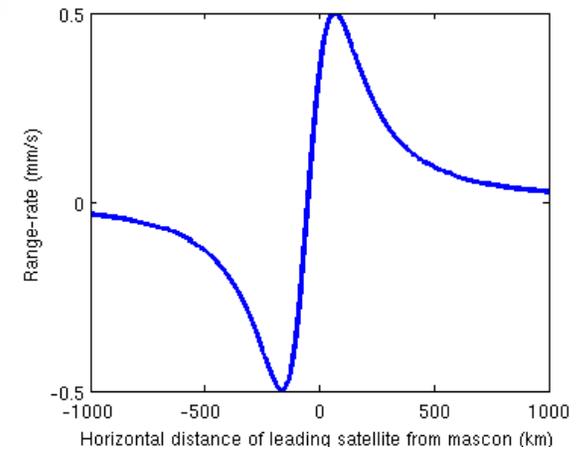
Crustal Thickness (km)

(Lunar Prospector Data, Konopliv)

- Lunar gravity field is “lumpy”
- Gravity map is important for navigation and exploration.
  - Help identify areas with potential high-concentration ice/mineral deposits
  - Lunar geology, crustal thickness, formation of craters and mascons
  - Mission planning
  - Map farside mascons to allow precise navigation during unmanned landings
- Lunette: a portable gravity-mapping nanosatellite payload
- UTIAS/SFL GNB and XPOD design heritage
- Graduate student microsatellite design course

# Gravity Mapping

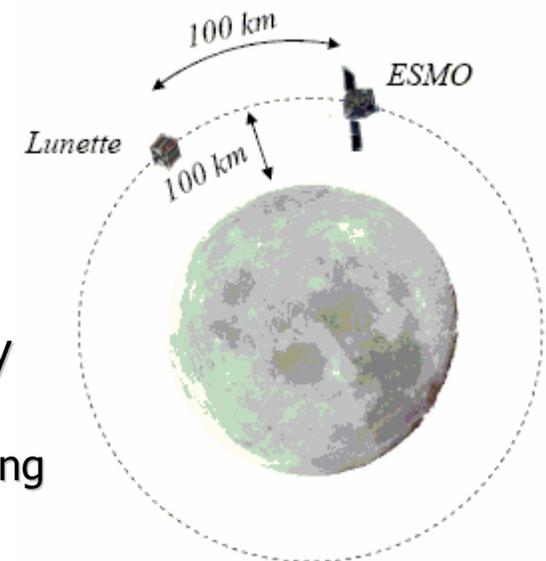
- Discovery of Mass Concentrations "MASCONS," Lunar Orbiter, 1968
- Apollo, Clementine, Lunar Prospector radio tracking
- Nearside gravity map developed to medium accuracy:
  - Nearside maps complete to 10-20 mGal level.
  - Far side maps about 5 times worse.
- Various proposals for multi-hundred-million-\$ gravity mapping missions (e.g. ESA's MORO), none yet flown.
- Future missions include JAXA's SELENE to fly in a low Lunar orbit with a high-orbit relay satellite.
- Lunette: full-sphere gravity mapping, 2011



**Range-rate signature of a 20 mGal peak surface anomaly generated by a point mass, observed by two spacecraft at 100km altitude, with an along-track separation of 100km**

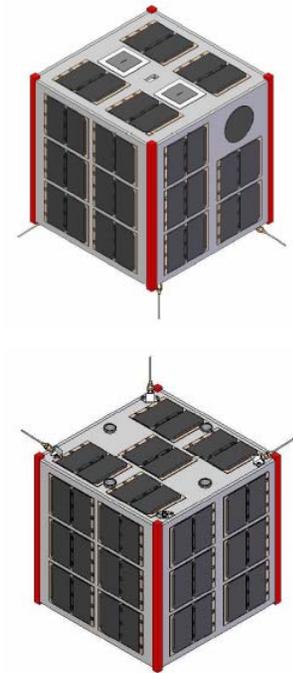
# Mission Concept

- Map Lunar farside gravity field, to 10-20 mGal
- Ejectable nanosatellite measuring relative range rate using radio tracking
- Primary payload for the European Student Moon Orbiter (ESMO) under ESA's SSETI Program.
  - Microsatellite, to launch in 2011
  - ESMO currently finishing Phase A study
- Mission Profile:
  - Science orbit: 100km circular polar
  - Two-weeks per full-sphere map
  - Orbit corrections every 7 days, polar gap 2x/day
  - 10 weeks "minimum mission"
    - 4 weeks commissioning and drift, 6 weeks mapping
  - Additional 4 weeks "full mission"
    - 1-degree plane change maneuver, 4 weeks mapping, additional mapping possible afterwards



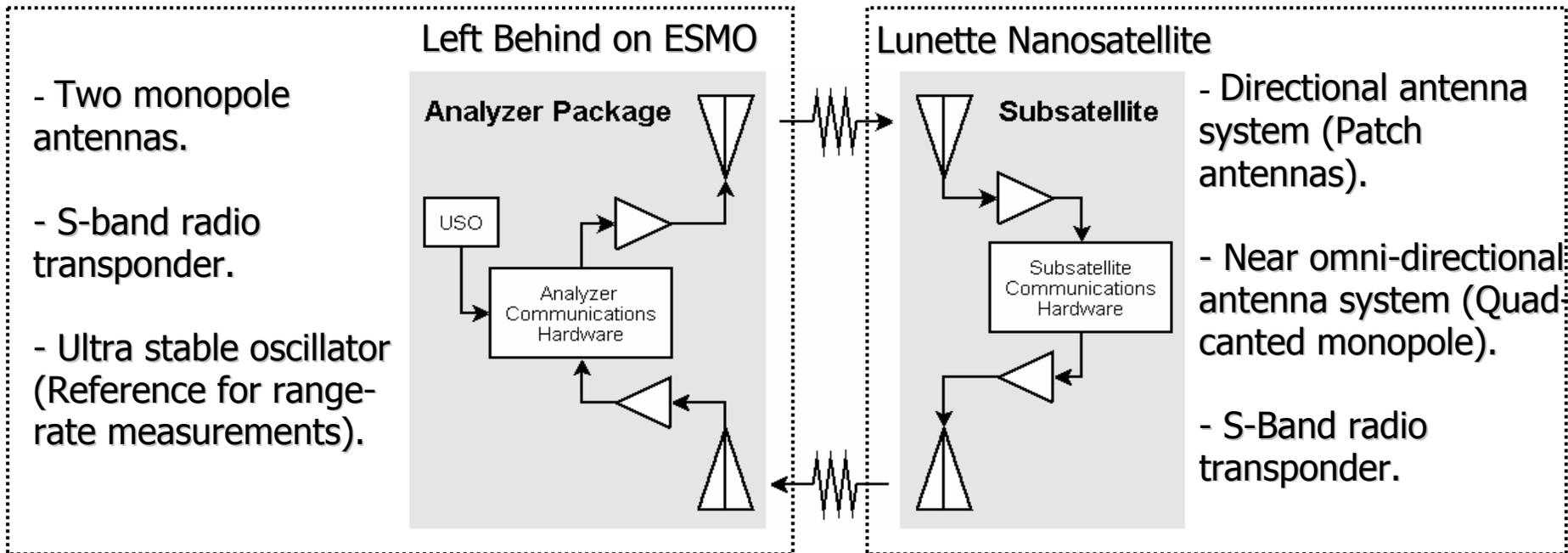
# Design

- Modified UTIAS/SFL Generic Nanosatellite Bus
  - BRITE Constellation (CanX-3) and the CanX-4/CanX-5 formation flying mission.
  - 25-cm cube, 8-12 solar panels on every face
  - Directional S-band antennas, quad-canted monopole antennas for omni-directional coverage
  - Propulsion system, star tracker, 3-axis attitude control
  - Science instrument: ranging radio transponder
- Modified UTIAS/SFL XPOD Nanosatellite Launch System
  - Customizable ejection system, used to eject GNB satellites from launch vehicles or parent satellites
  - Provides structural support, power and data connection during transfer
- Analyzer electronics package on parent satellite
  - Antennas, computer, ultra-stable oscillator



# Communications Design

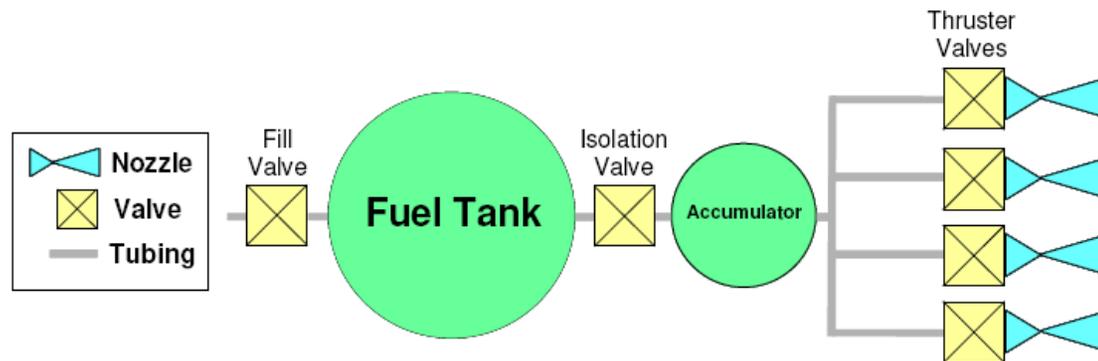
- High precision range-rate (1 mm/s) measurements via Doppler shift
- Lower precision range (1 km) measurements via direct retransmission
- Data & command transmission between spacecraft.



-> Radio is operated in 4 different modes which combine science measurements and data/commands transmission with the two different antenna gains.

# Propulsion Design

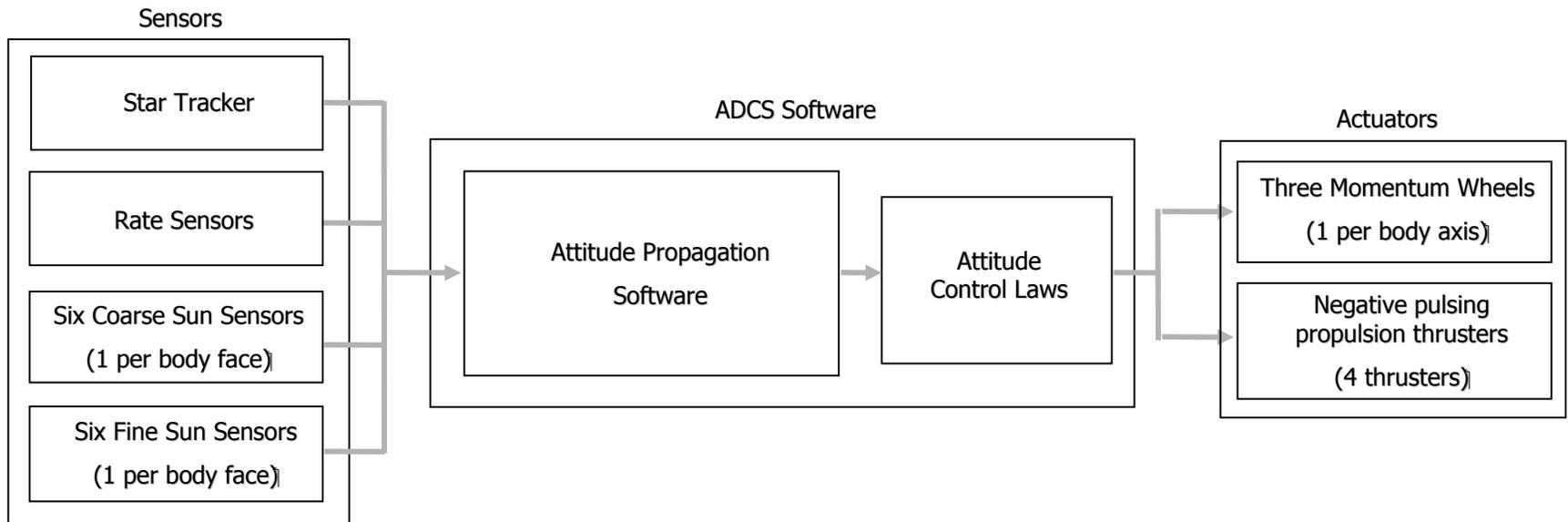
- Maintain the required 100 km circular along-track orbital formation with the parent satellite.
- Trimming of the stored angular momentum on the attitude control reaction wheels from secular perturbations.



- N<sub>2</sub>O 100 m/s cold gas system using negative pulsing of the four canted thrusters for attitude control.
- Performance in excess of 60s Isp, thrust magnitude of 0.3 N per thruster and a minimum impulse bit of 10 mN-s.
- Variations in thrust magnitudes avoided by actively regulating the pressure in the accumulator volume.

# ADCS Design

- 3-Axis control for high stability antenna pointing for high precision range-rate measurements while maintaining a favorable attitude for power generation.
- Thruster pointing and holding during orbital maintenance thrusting maneuvers.



- Star tracker is duty cycled for power considerations and attitude is propagated using other sensors.
- Duty cycle depends on the attitude solution accuracy required for the operation. (High update coarse attitude solution employed during thrusting)

# Conclusions

- The technology developed at UTIAS-SFL enabled the development of a **low-cost** ejectable subsatellite payload capable of advancing the current state of lunar science by constructing high-resolution full-sphere gravity maps for:
  - Geologic exploration
  - Mission planning
- This is achieved by Lunette combining:
  - An adapted CanX Generic Nanosatellite Bus.
  - A 100 m/s propulsion system capable of attitude control and orbital maintenance.
  - An attitude determination and control system capable of generating precise attitude knowledge necessary for the processing of range-rate data.
  - A communications system capable of measuring the range and range-rate between Lunette and the parent spacecraft to a high degree of accuracy.

# Acknowledgements

## Partners



## Sponsors

