
Astrodynamics and the First Cubesat Launcher

Drazen Svehla

1st Adria Space Conference, October 3-4, 2019, Zagreb, Croatia

Content

- Space Geodesy
- Satellite Missions in the LEO Orbit
- Cubesat Launcher
- Engineering model
- E2E Simulation

Springer Theses
Recognizing Outstanding Ph.D. Research

Drazen Svehla

Geometrical Theory of Satellite Orbits and Gravity Field

 Springer



Special offer / Get 20% off the printed book or eBook!

Use the following token on Springer.com

55QzN5RRT2fFCYD / Valid Sep 2, 2019 – Sep 30, 2019

**537 pages on high-precision GNSS
(2018)**

**cm-accurate positioning in space
- from LEO up to the Lunar orbit**

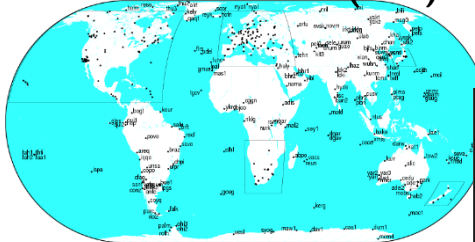
Space Geodesy

Terrestrial Reference Frame (ITRF2014)

VLBI Network (IVS)



GNSS Network (IGS)



SLR Network (ILRS)

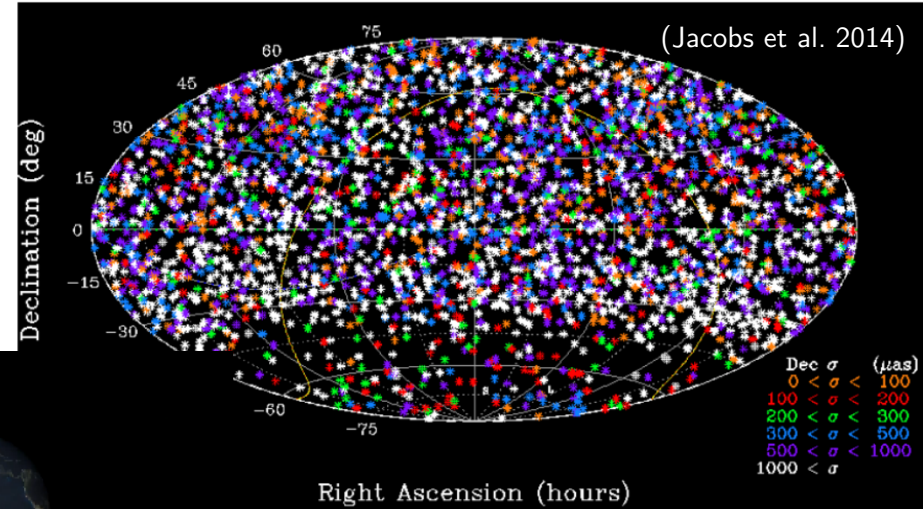


DORIS Network (IDS)



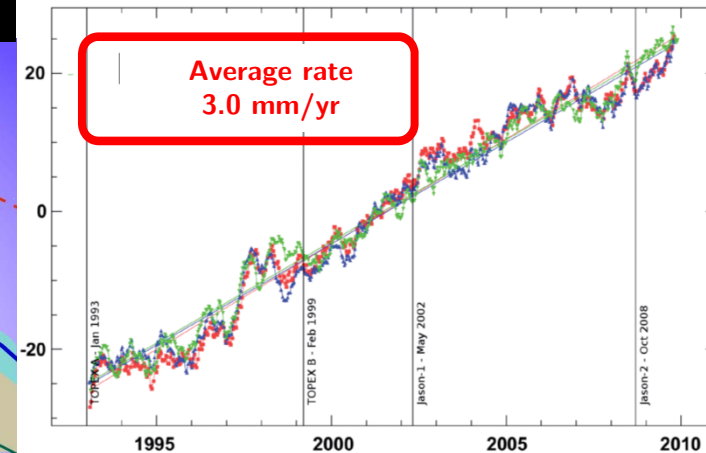
Celestial Reference Frame (ICRF-2)

S/X-band (2/8 GHz) ICRF-2

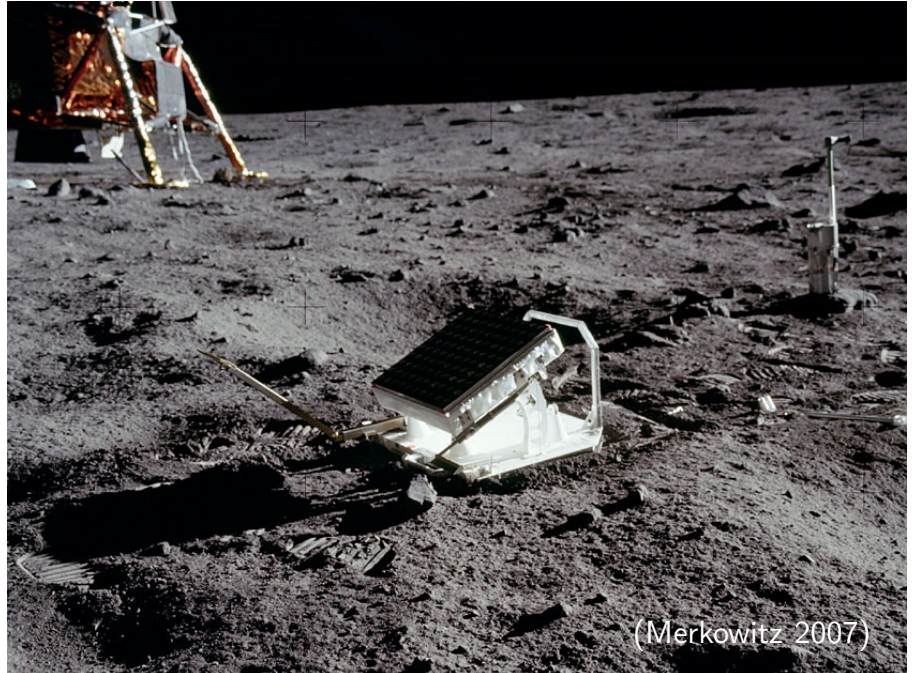
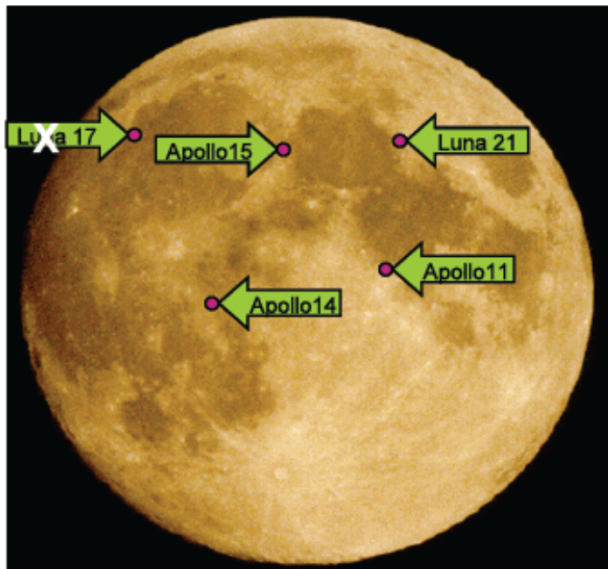
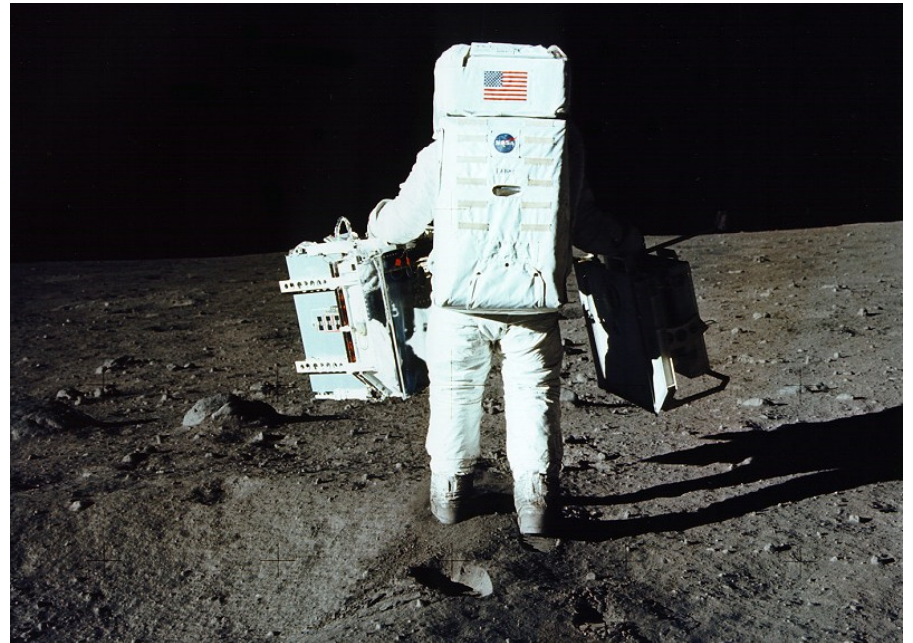
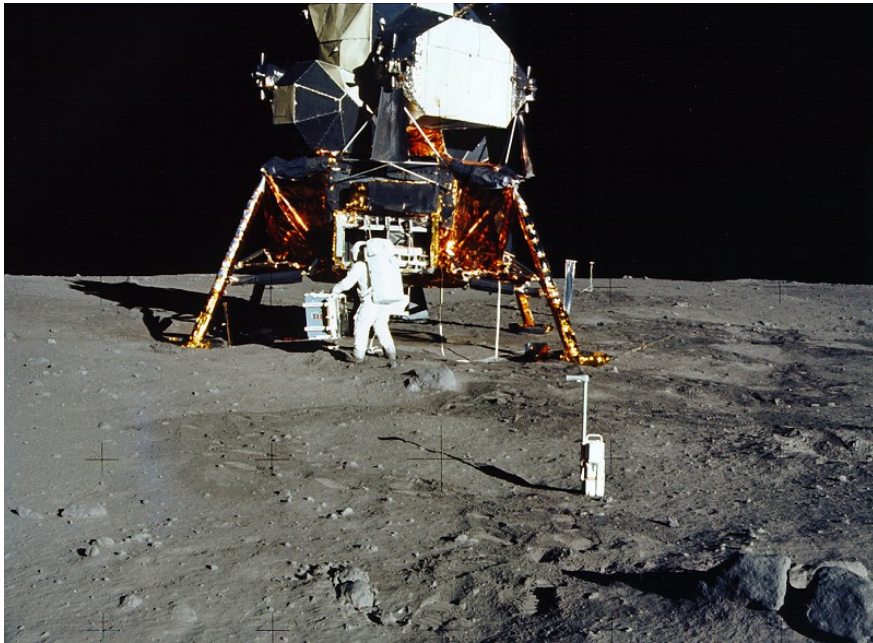


Right Ascension (hours)

Mean Sea Level Rise



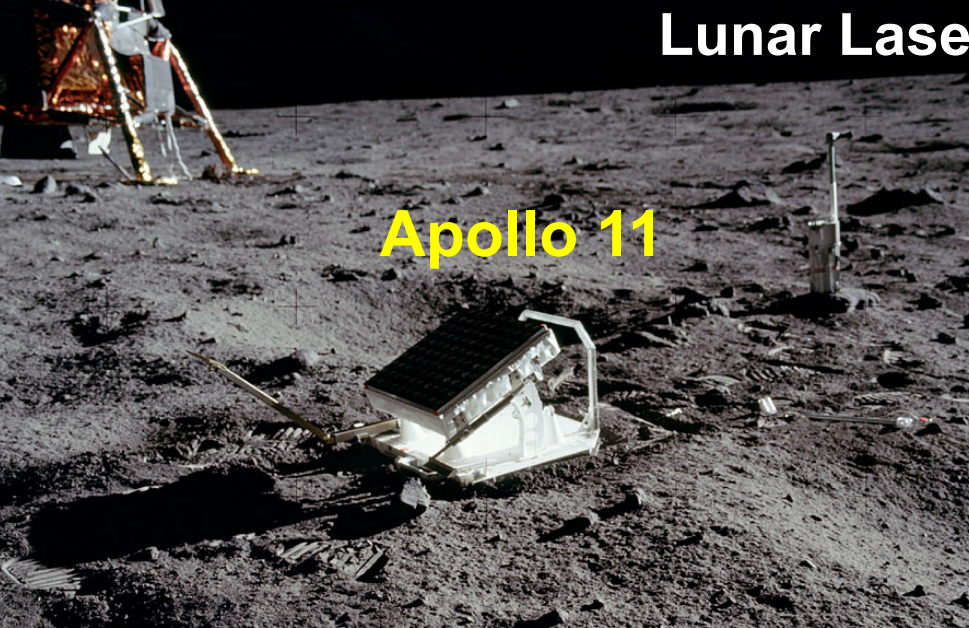
Lunar Geodesy: Lunar Laser Ranging



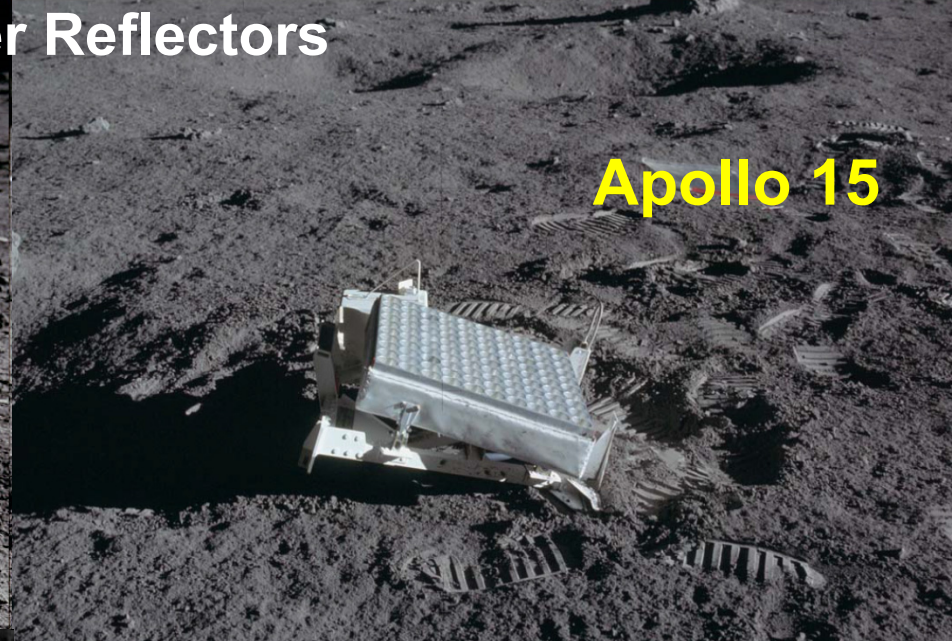
Due to the tides, Moon-Earth distance
is increasing at a rate of 3.8 cm/yr

(Merkowitz 2007)

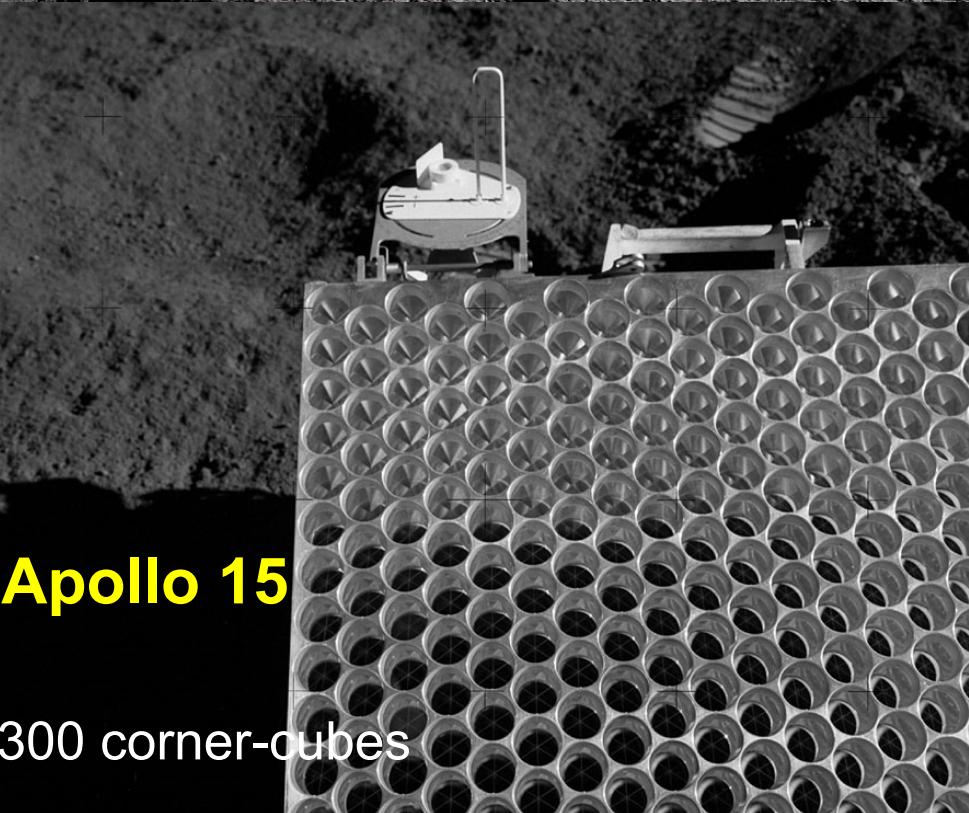
Lunar Laser Reflectors



Apollo 11

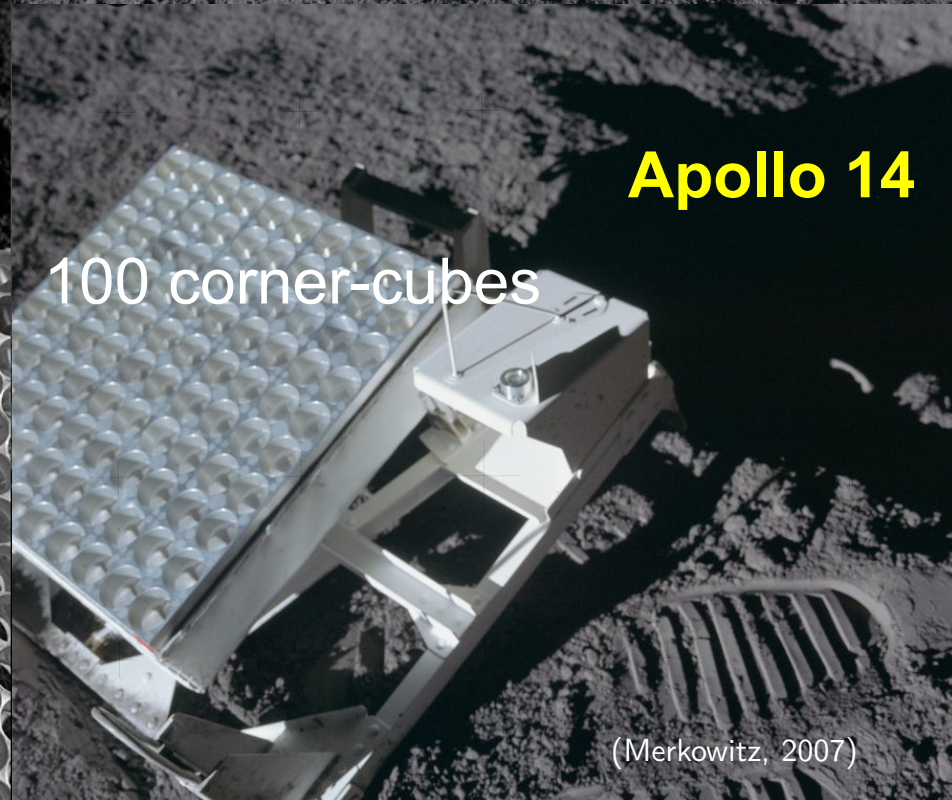


Apollo 15



Apollo 15

300 corner-cubes

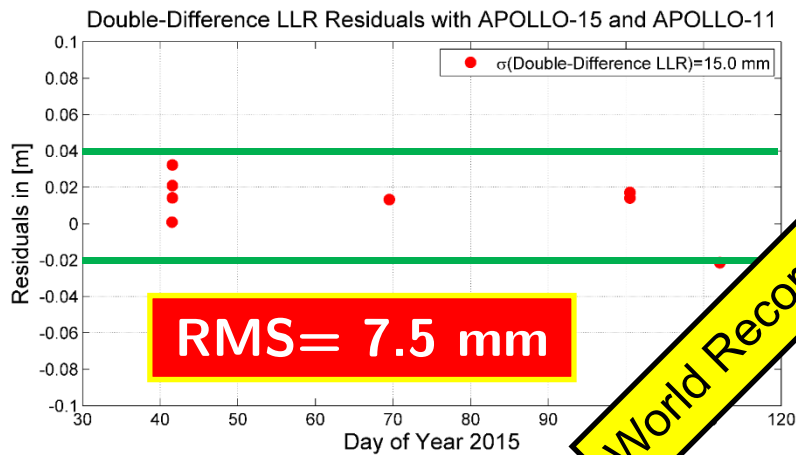
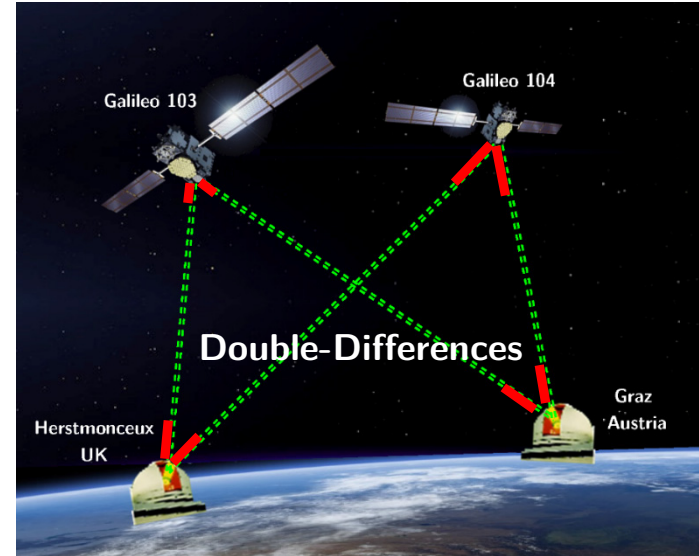
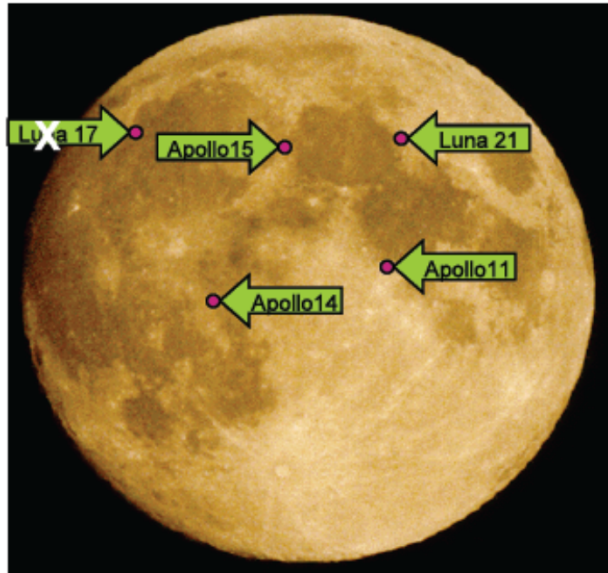


100 corner-cubes

Apollo 14

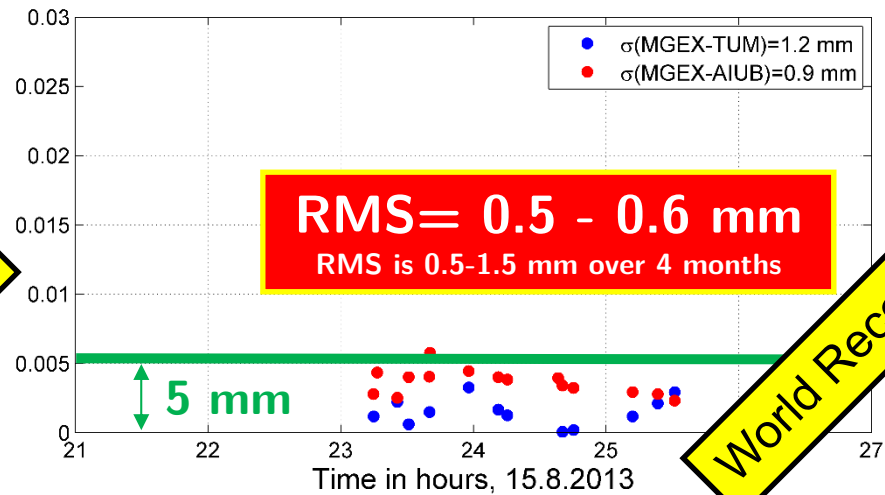
(Merkowitz, 2007)

Lunar and Satellite Laser Ranging



World Record

SLR Double-Differences: Galileo 103 and 104

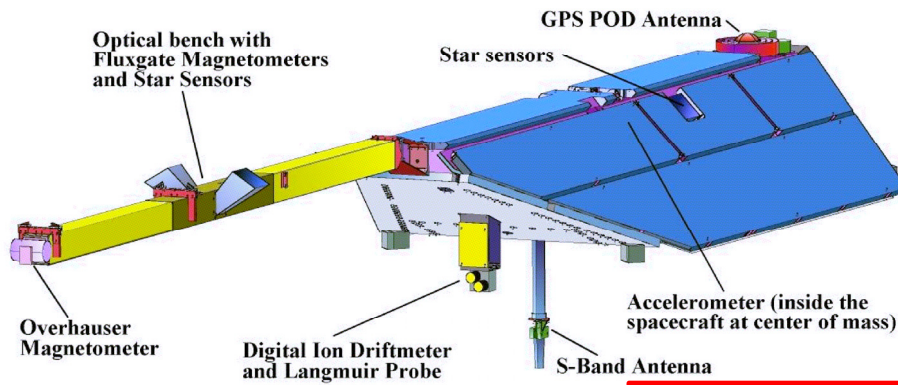


(Svehla and Rothacher, 2013)

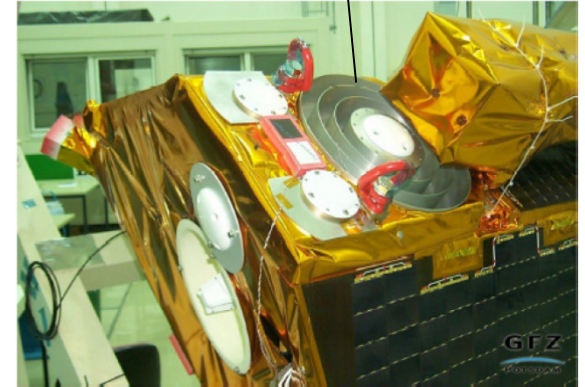
GPS and Earth Observation

CHAMP satellite

Altitude 400 km



GPS antenna

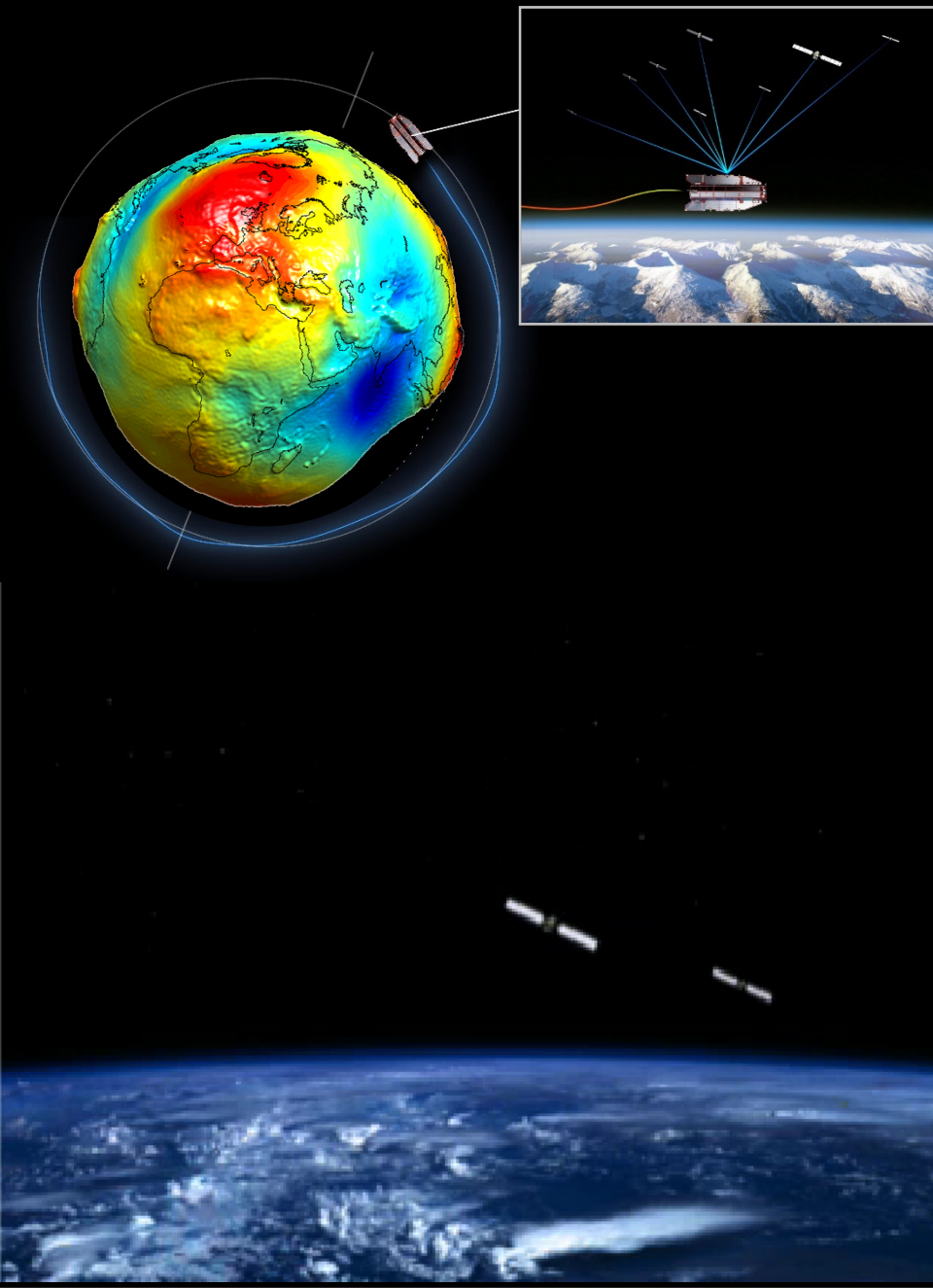


GOCE satellite

Altitude 220 km

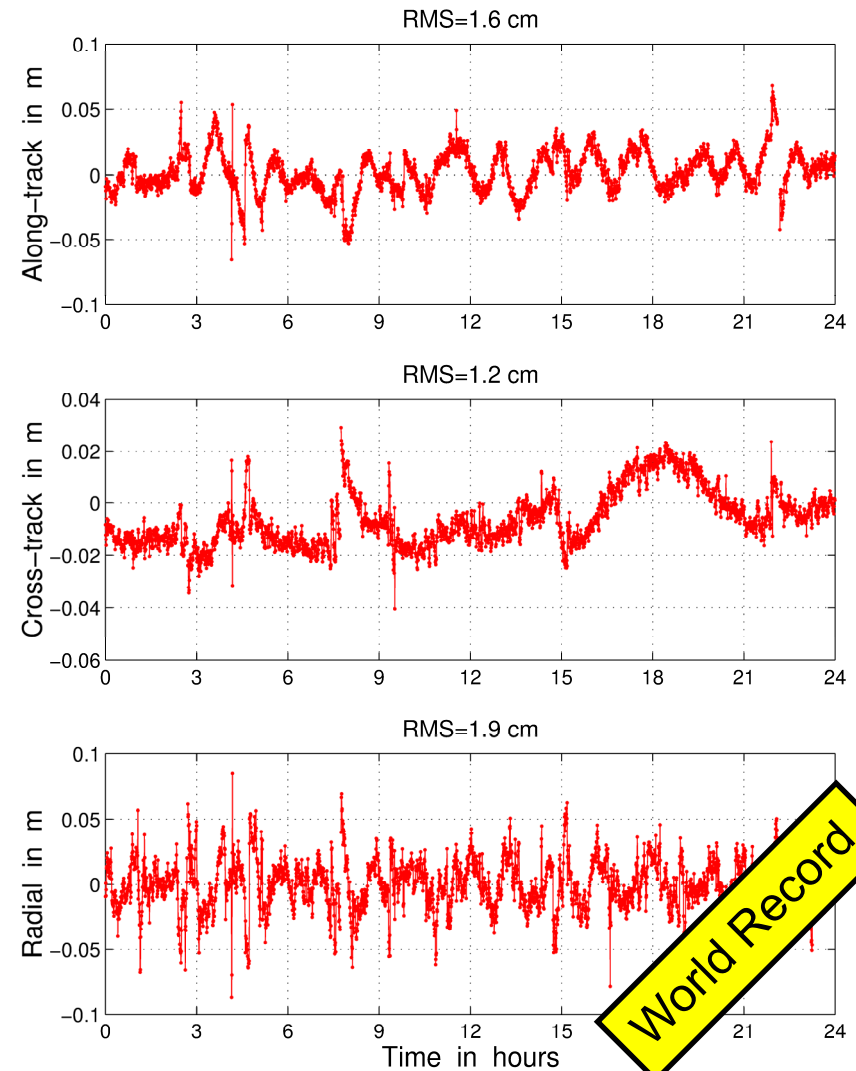


Earth Observation - Gravity

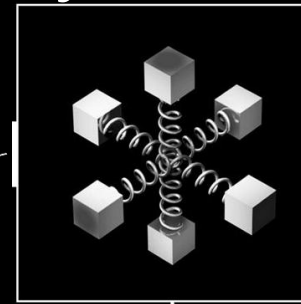
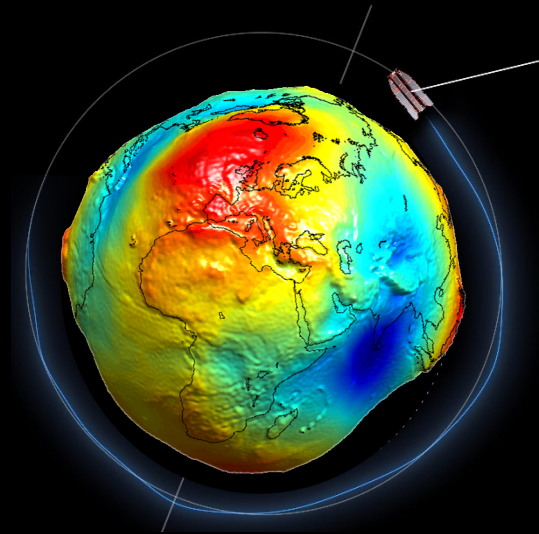
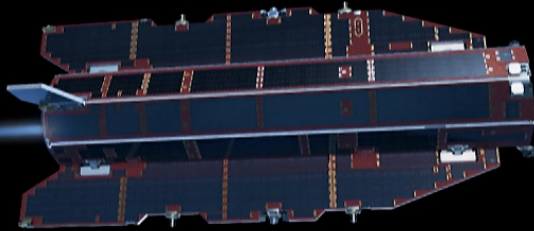


Orbit of CHAMP Satellite Based on GPS

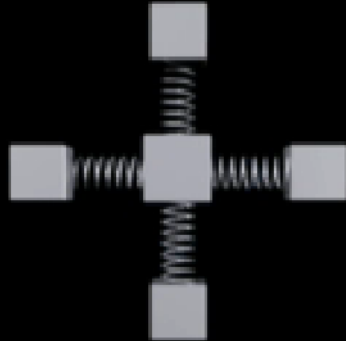
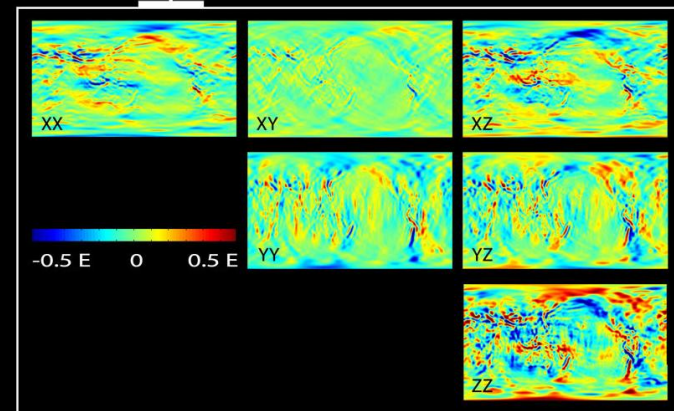
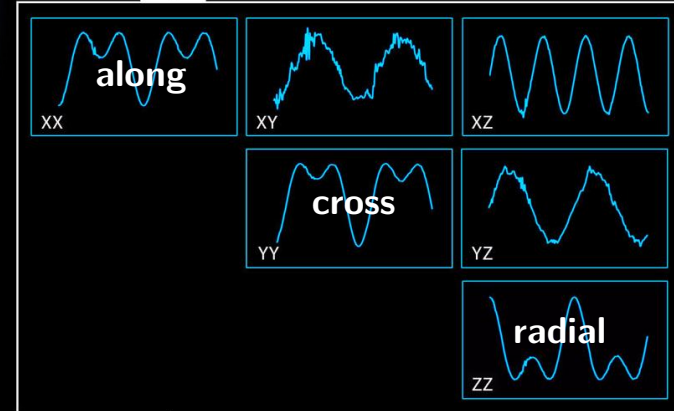
(Svehla and Rothacher, 2003)



Gravitational Gradiometry



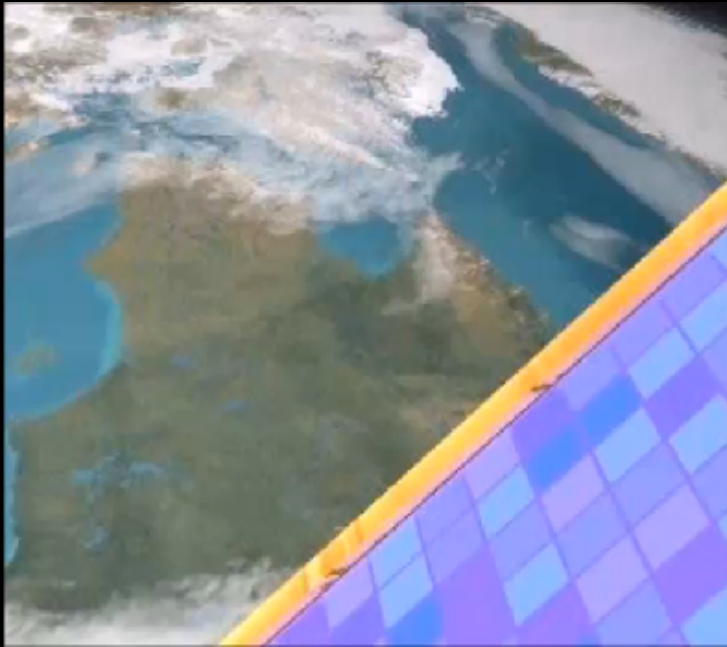
$$5 \times 10^{-12} \text{ m/s}^2 \text{ over } 1 \text{ m} \\ = 5 \times 10^{-3} \text{ E/Hz}^{1/2}$$



GRACE Mission

Satellite-to-Satellite Tracking

K/Ka-band (10 μm)

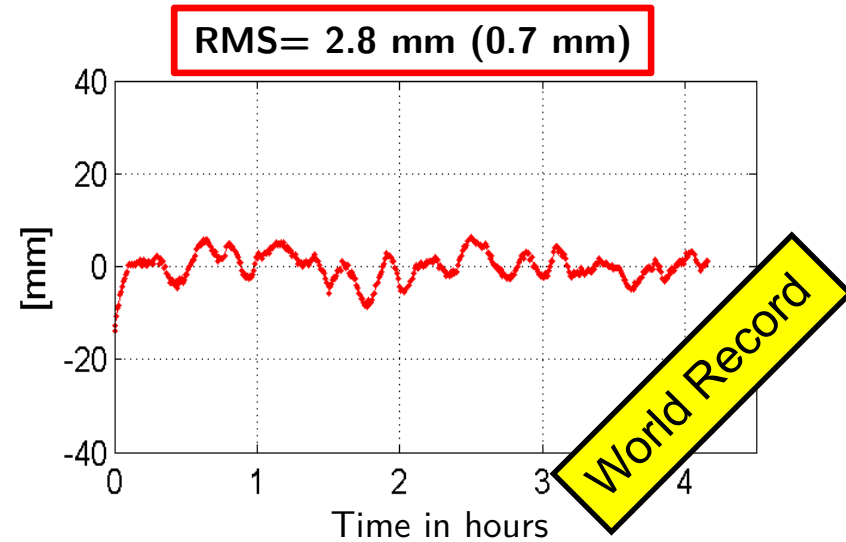


Orbit Separation 200 km

Altitude=500 km
Inclination=89°

NASA/DLR GRACE Mission

GPS vector between the two satellites
separated by 200 km

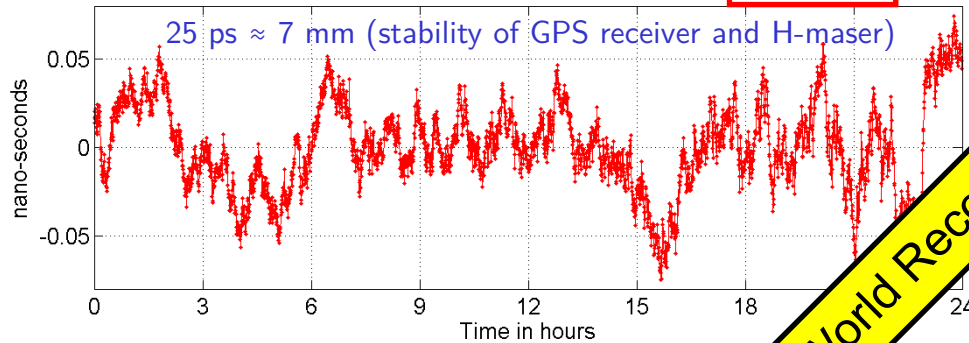


Time/Frequency Transfer with GPS

Time Between Colorado Springs and USNO

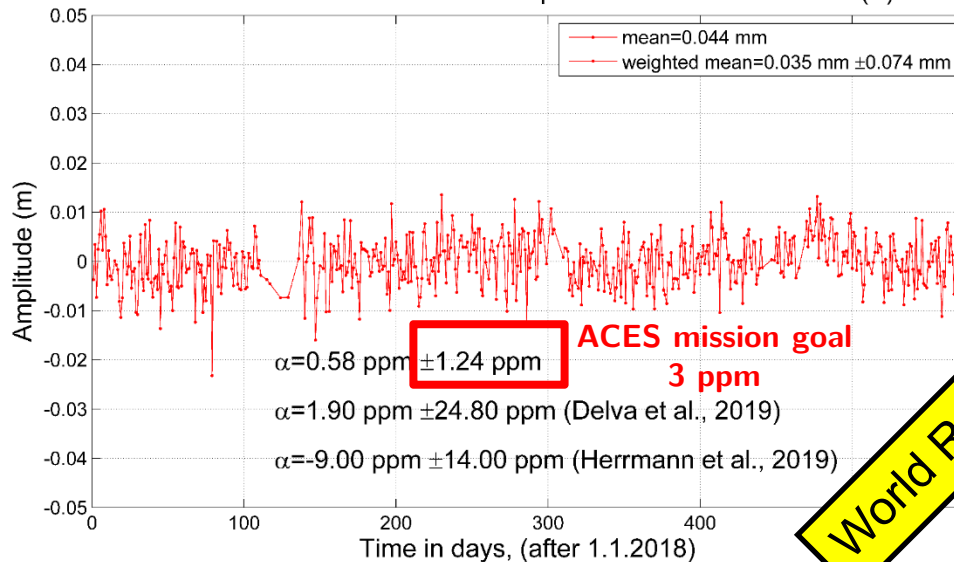
AMC2-USNO Clock difference after removing bias/drift, **STD=0.025 ns**

25 ps \approx 7 mm (stability of GPS receiver and H-maser)



New Test of the Gravitational Redshift (ACES mission goal 3 ppm)

Galileo E14: Estimated Clock Amplitude at Orbit Period: $A \cdot \sin(E)$



Topical Team on Geodesy
Applications of the ACES Mission

ACES and FUTURE GNSS-BASED EARTH OBSERVATION and NAVIGATION

26 – 27 May 2008, Munich, Germany

Institute of Astronomical and Physical Geodesy
Technische Universität München, Germany

PROCEEDINGS



Drazen Svehla, Christophe Salomon, Luigi Cacciapuoti
Editors

**ESA Topical Team on Geodesy
2005-2009**

Cubesat Launcher – Concept and Funding

JAXA – Japan (2018)



February 3, 2018: JAXA launched the smallest rocket to ever insert an object in orbit around Earth with the TRICOM 1R satellite (4 kg)

9.5 m tall and 52 cm in diameter



Goals:

- 1) The 4-m Rocket to Launch 1 kg into Space
- 2) The First Single Stage to Orbit

Motivation:

We need to pioneer a new rocket specific impulse: above the limit of $I_{sp}=400$ s

SpaceX: $I_{sp}=321$ s

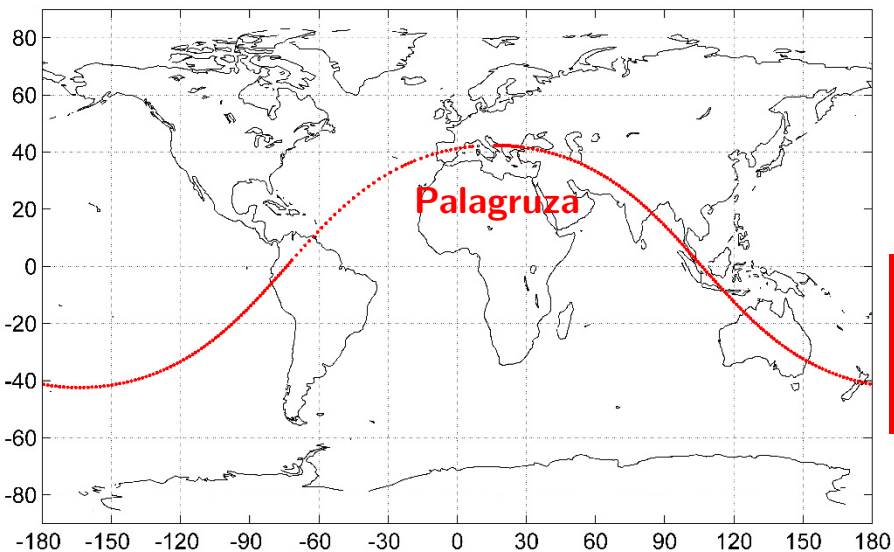
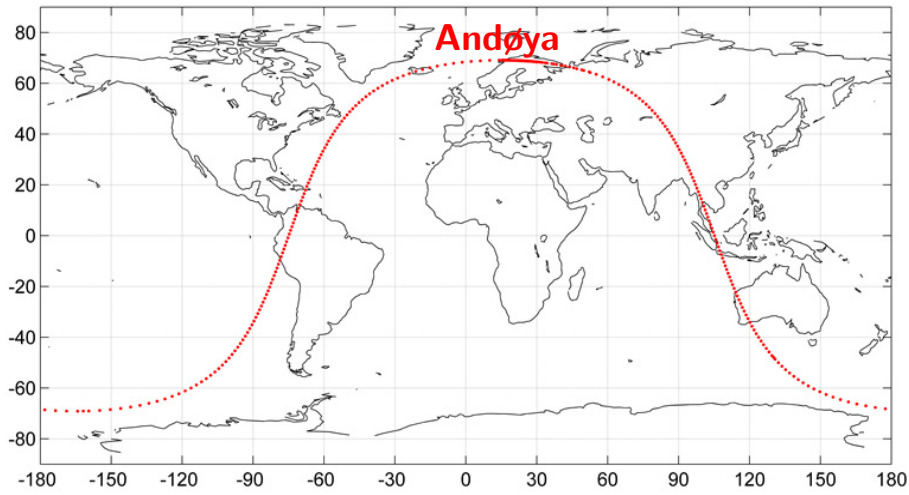
RocketLab: $I_{sp}=303$ s

Funding Interests:

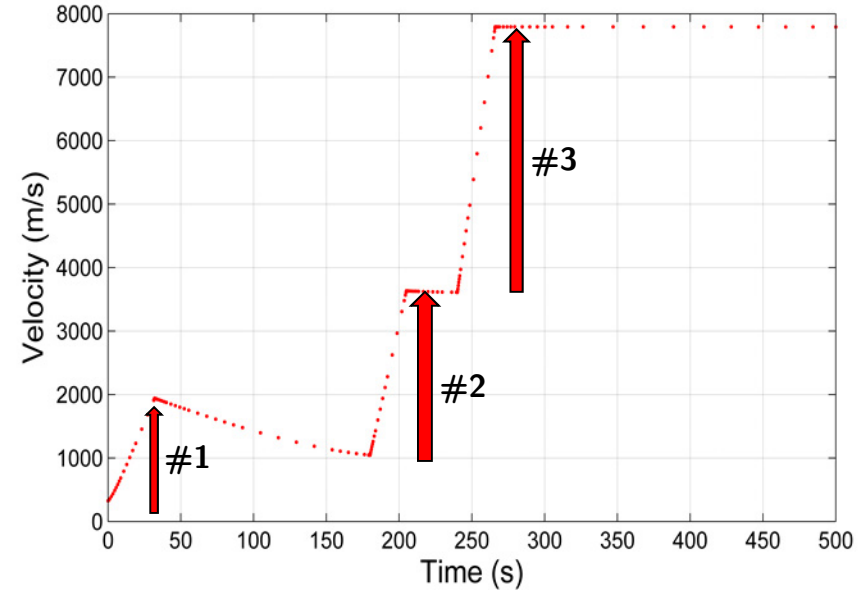
ESA, DLR, Swiss Space Office

End-to-End Simulation of the JAXA Launch

Ground Track



Velocity Profile

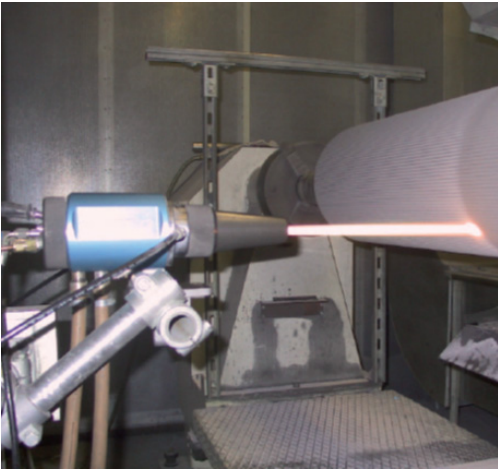


Goals:

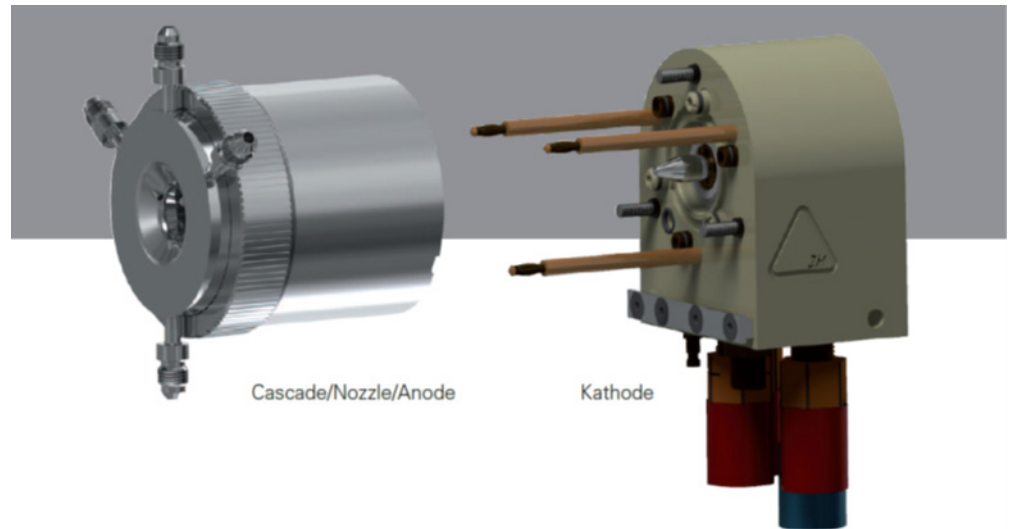
- 1) The 4-m Rocket to Launch 1 kg into Space
- 2) The First Single Stage to Orbit

Cubesat Launcher - Engineering Model

H₂+O₂ propulsion



Plasma Technology



UniBW in Munich (Prof. Schein)

Developments at DLR



(See talk by O. Bozic)

Thank You