# ‘Stop and Drop’ Hard Lander Architectures for Europa Astrobiology Investigations.

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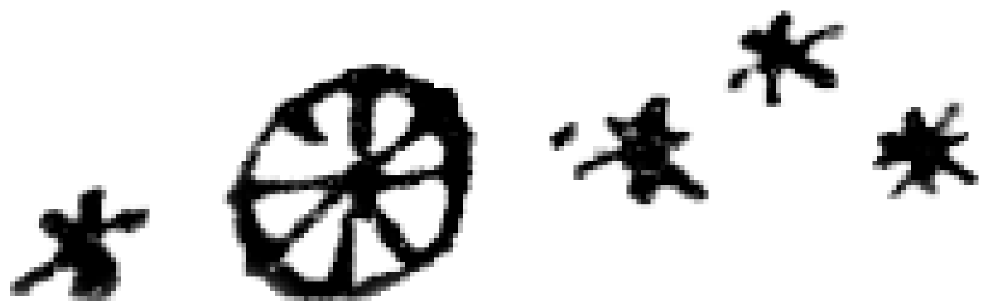
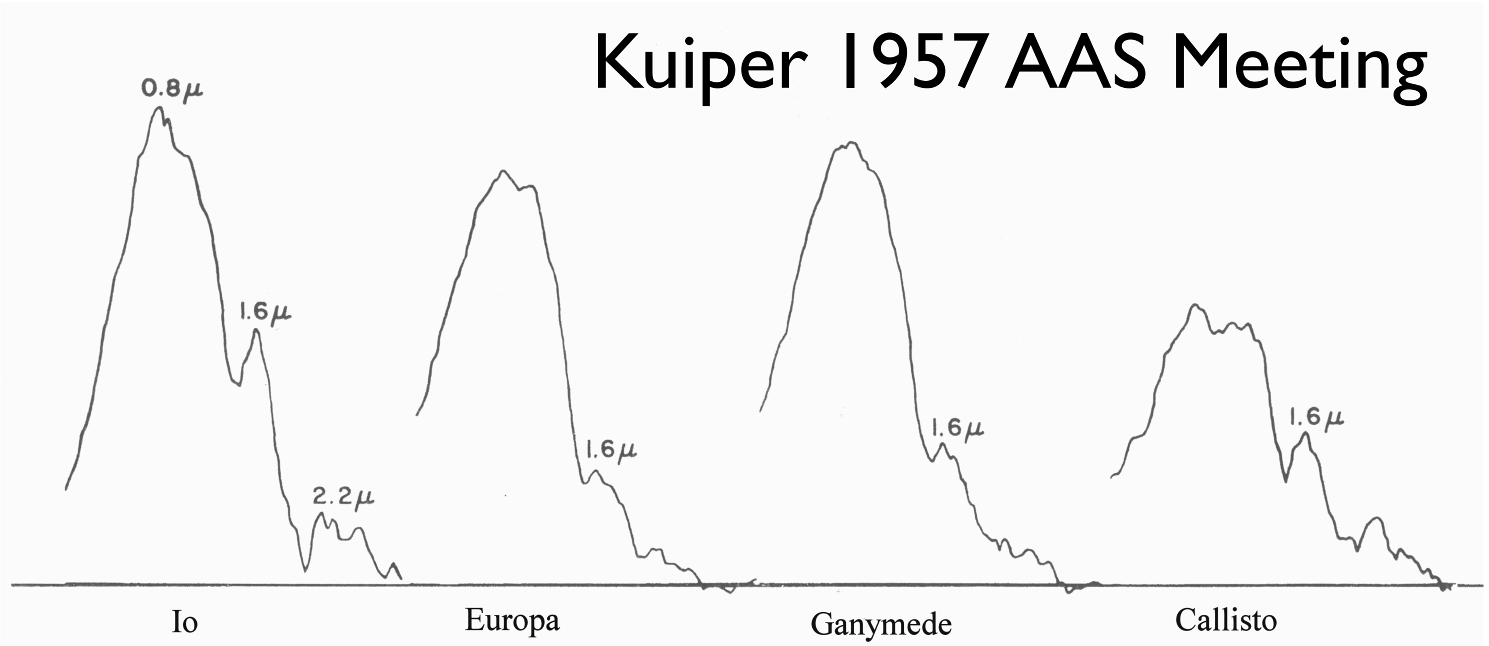
IKI Europa Lander Conference, Feb. 9-13, Moscow, Russia


Image courtesy of D. Cruikshank



Galileo Galilei, 1609 (pub 1610)

Kuiper 1957 AAS Meeting




V. I. Moroz 1965

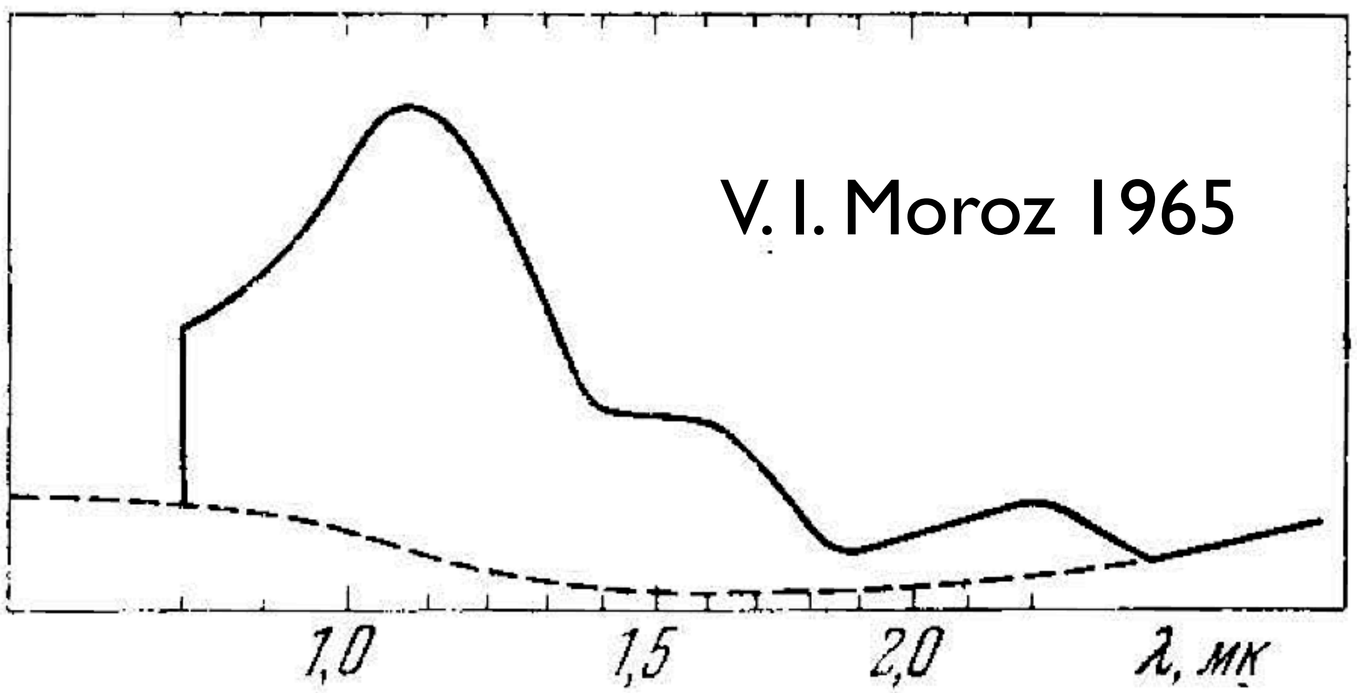
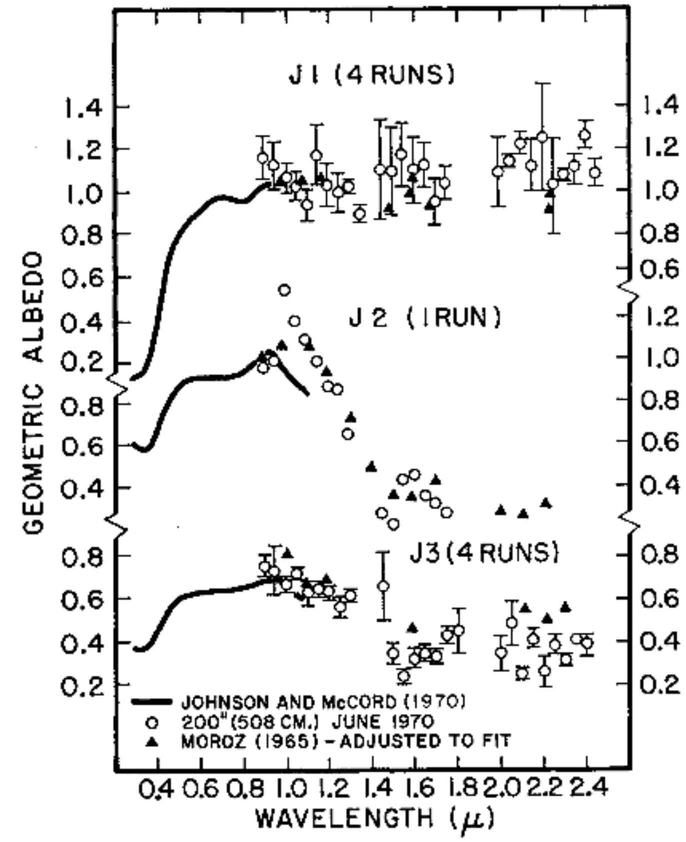
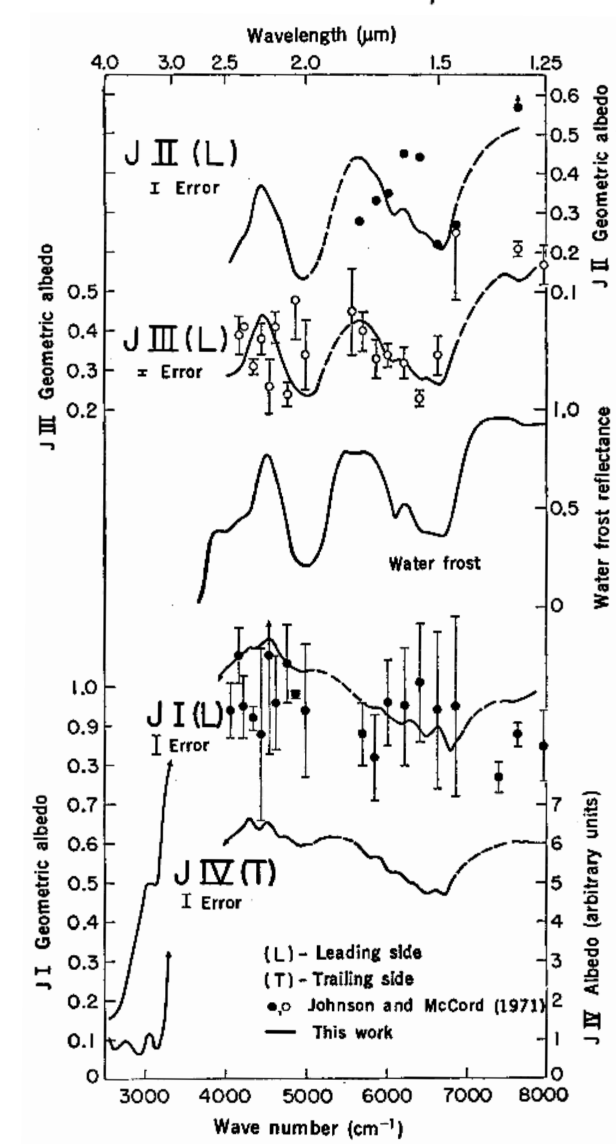



Рис. 198. Спектр Европы, среднее из четырех записей 1.10 1964 г., ЗТШ, Нуль-пункт (пунктир) зависит от длины волны вследствие слабой паразитной подсветки.

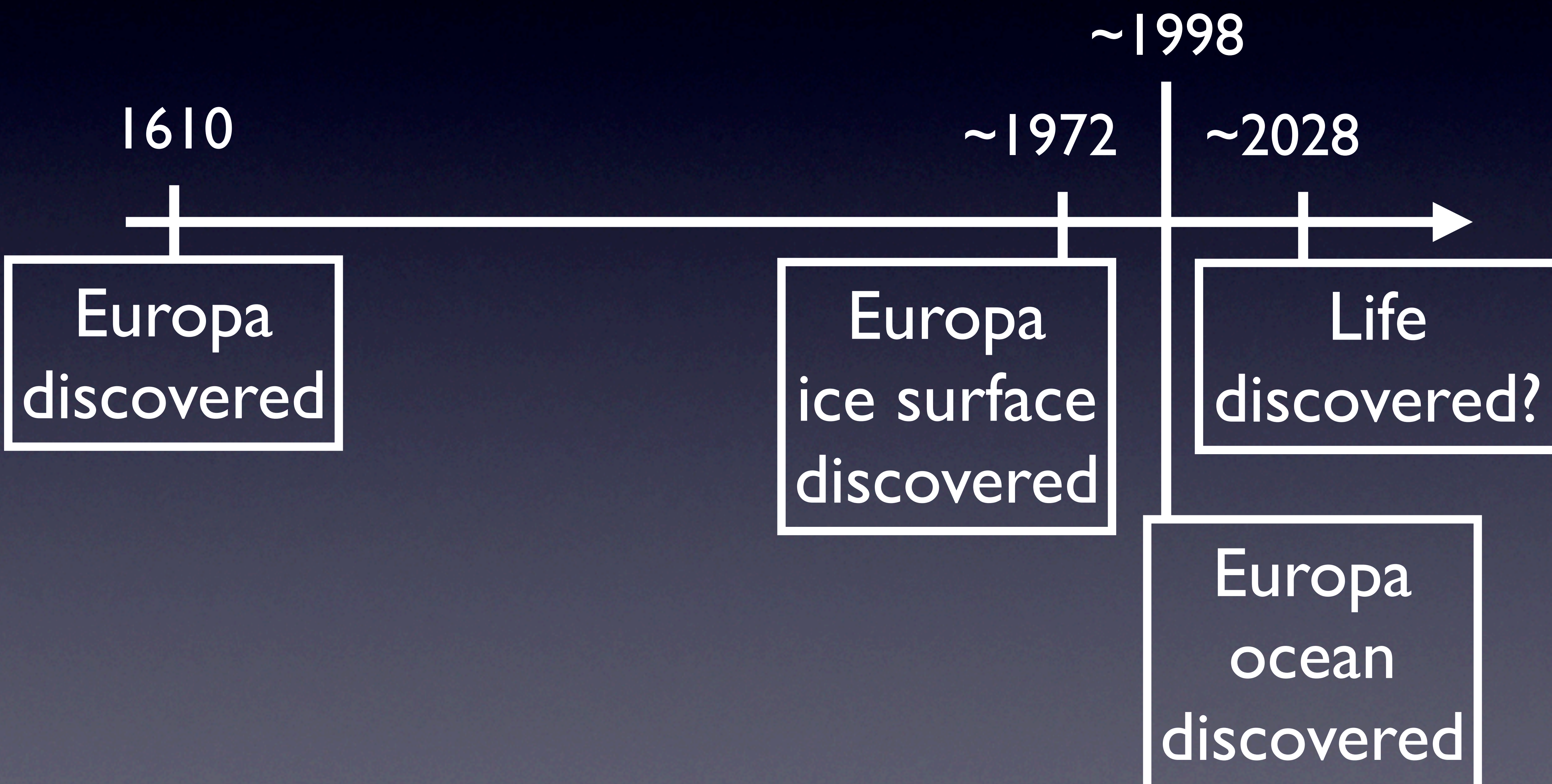



Johnson and McCord 1971

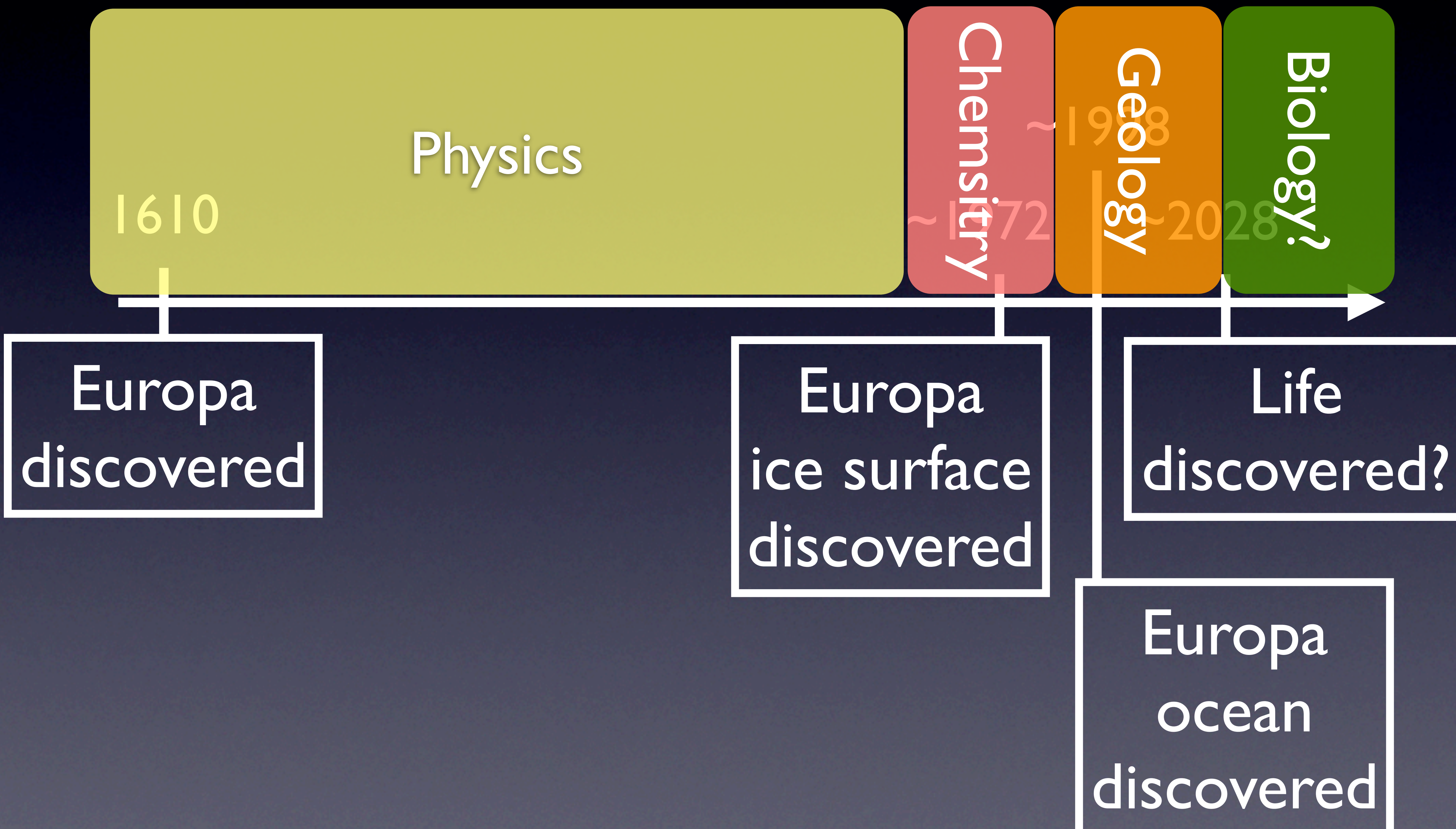



Pilcher et al. 1972

# Europa Astrobiology



# Europa Astrobiology

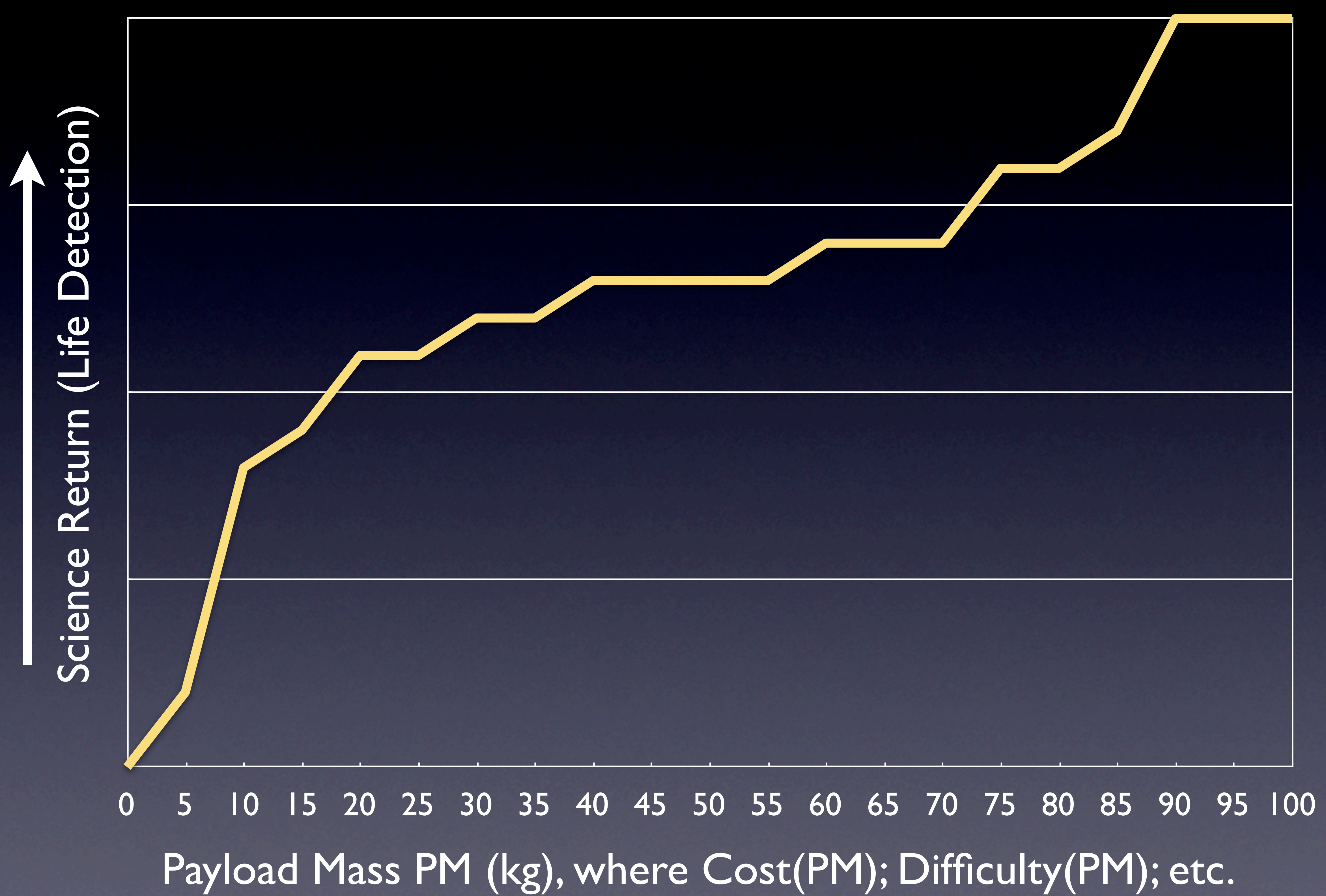


# Clark et al. Europa Orbiter 2008 Studies

| Atlas V 551 Launch Capability | |
|---|---|
| Launch | Mass margin (kg) |
| Oct. 2018 | 130 |
| June 2019 | 241 |
| Dec. 2019 | -116 |
| March 2020 | 262 |
| March 2020 | 327 |
| May 2021 | 73 |
| Nov. 2021 | 165 |
| March 2023 | -40 |

Mass available after adding 'sweet spot' instruments. Does not account for accommodation, margin, shielding, or power needs.

# Science Return as a function of instrumentation delivered to surface



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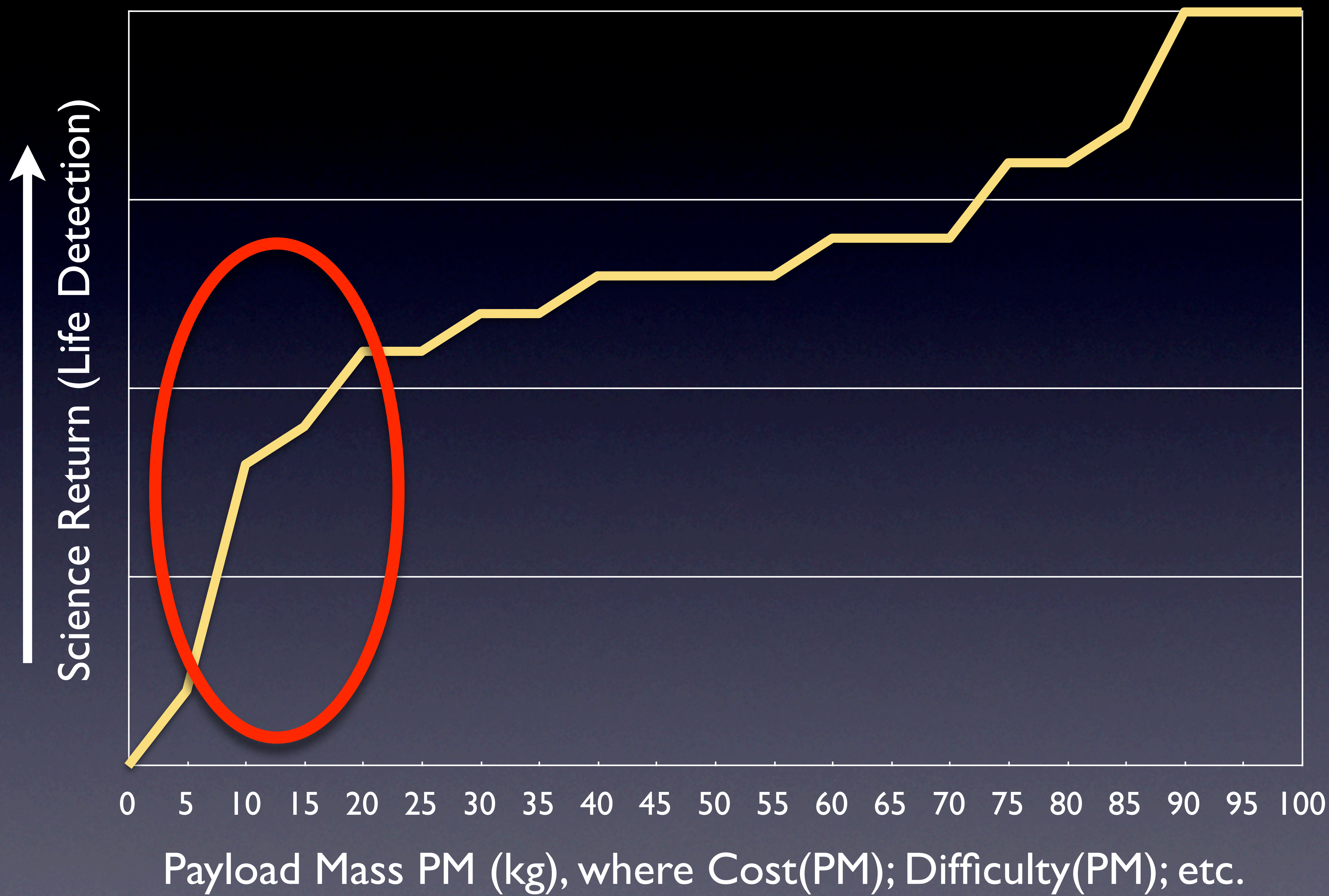

# Relevance to recommendations and science goals of the NASA Decadal Survey*

Goal 2.1: Characterize the surface composition, especially compounds of interest to prebiotic chemistry.

Theme 2.1: What is the chemical composition of the water-rich phase?

Theme 2.4: Can and does life exist in the internal ocean of an icy satellite?

Theme 4.2.1: Is there extant life in the outer solar system?

*Goals overlap significantly with the NASA Astrobiology Roadmap (2008).

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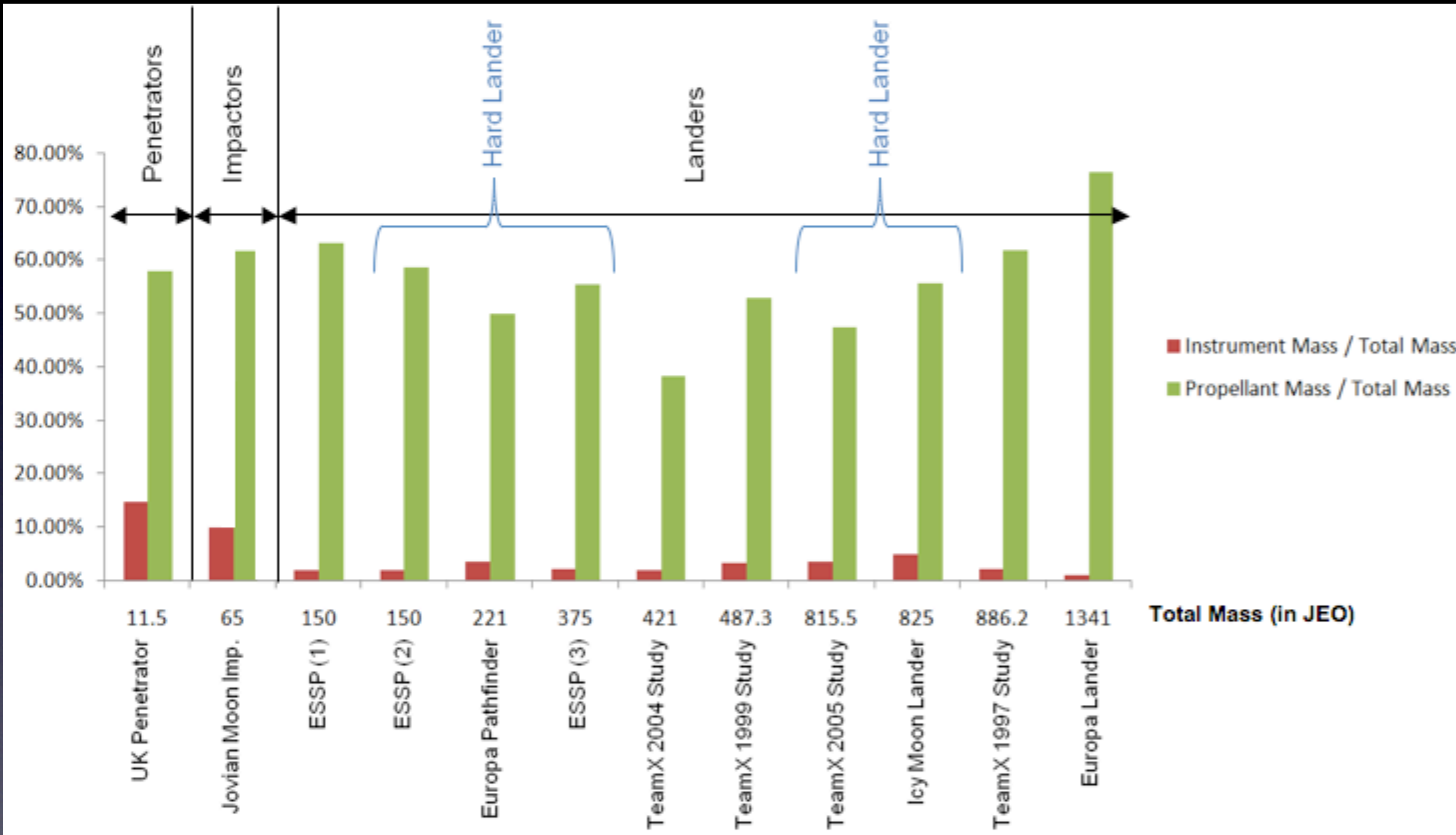
## Critical advantages of *in situ* analysis

- Ground truth orbital measurements
- Enhanced concentration/Detection limits

# Definitions

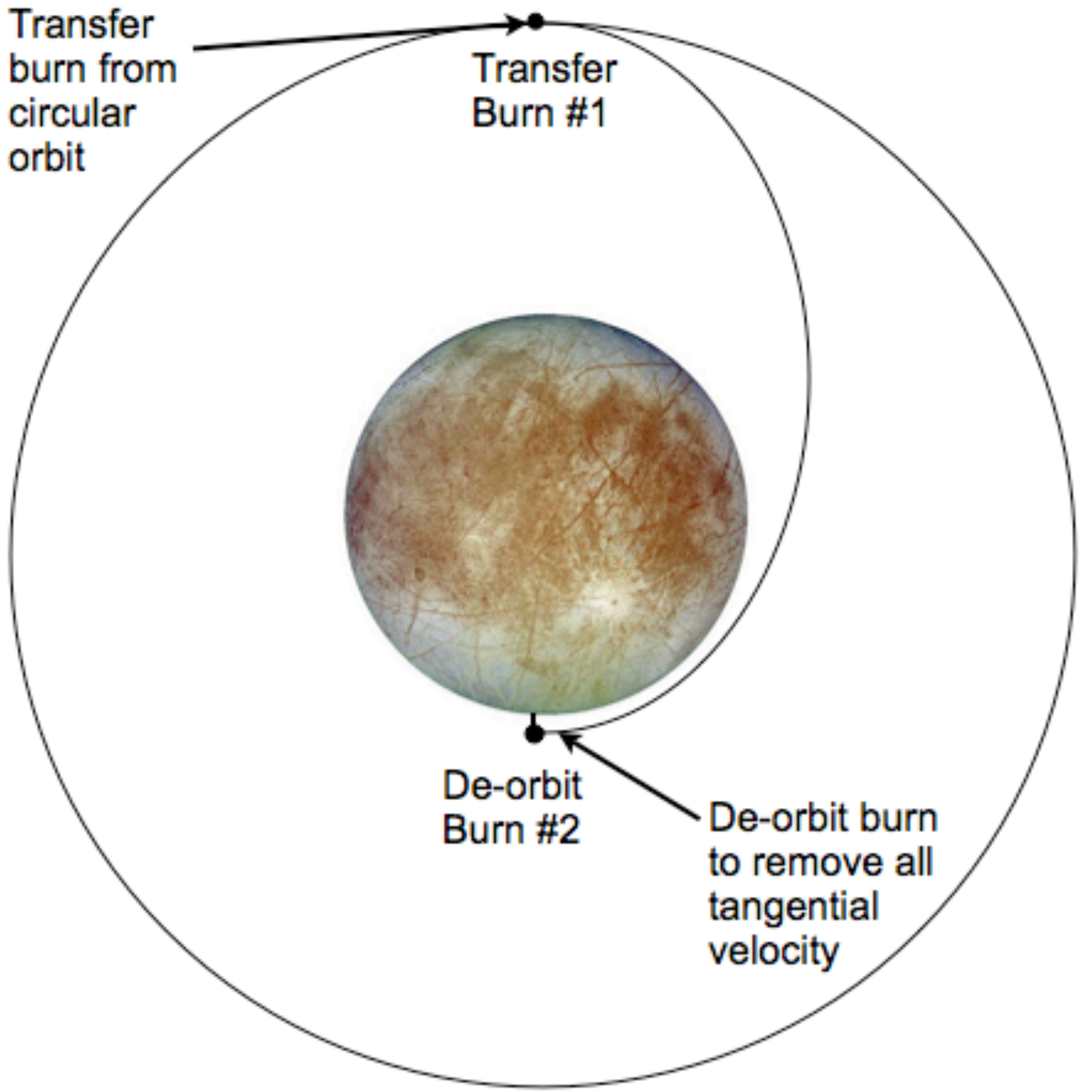
| Sub Satellite | Penetrator | Impactor |
|---|---|---|
| • Performs science in orbit or during descent to mission termination impact | • Performs sub-surface science<br>• Impacts at high velocity, penetrating the surface like a bullet | • Performs science during descent<br>• Impact with the surface is designed to shoot ejecta up to be analyzed from orbit |

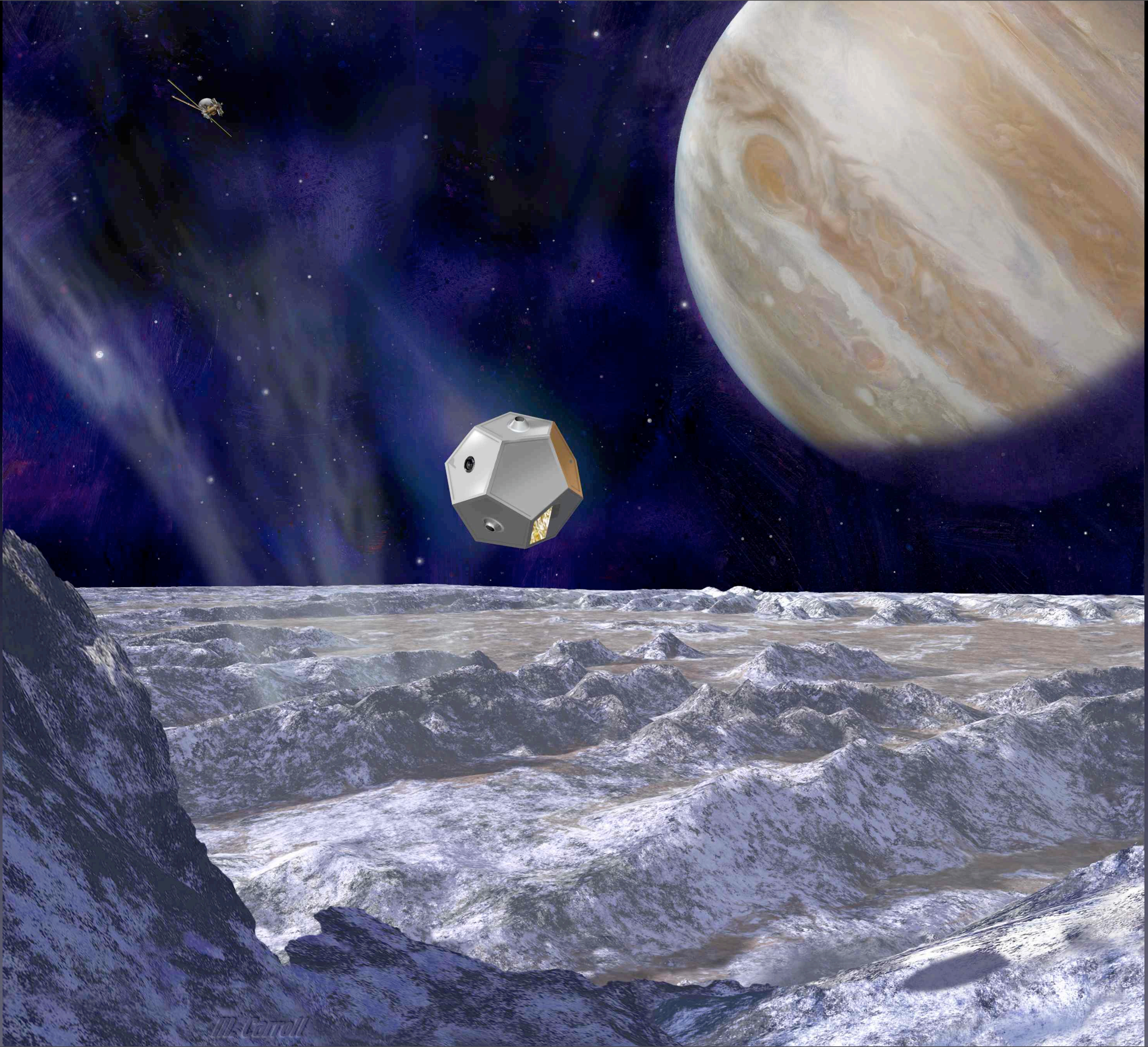
| Lander | | |
|---|---|---|
| Performs science on the surface | | |
| **Very Hard** | **Hard** | **Soft** |
| • Drops from as high as 10 km | • Drops from as high as 1 km or as low as 10m | • Touches down with minimal accelerations |



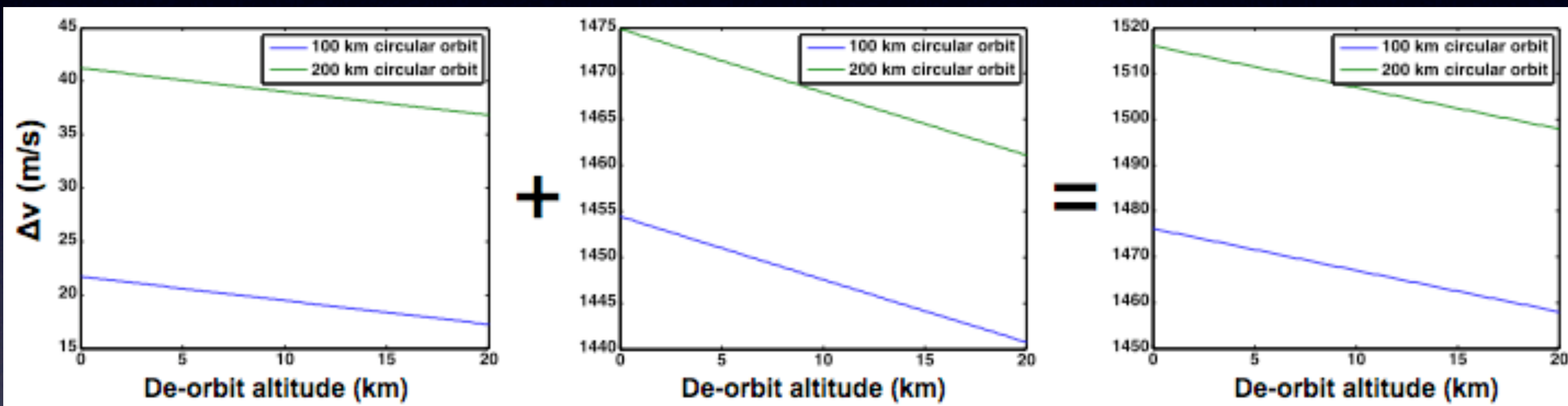
Penetrators
Impactors
Landers
Hard Lander
Hard Lander
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Instrument Mass / Total Mass
Propellant Mass / Total Mass
Total Mass (in JEO)
11.5
65
150
150
221
375
421
487.3
815.5
825
886.2
1341
UK Penetrator
Jovian Moon Imp.
ESSP (1)
ESSP (2)
Europa Pathfinder
ESSP (3)
TeamX 2004 Study
TeamX 1999 Study
TeamX 2005 Study
Icy Moon Lander
TeamX 1997 Study
Europa Lander

# “Stop and Drop” Hard Lander





# Burn Δv's and deorbit altitude

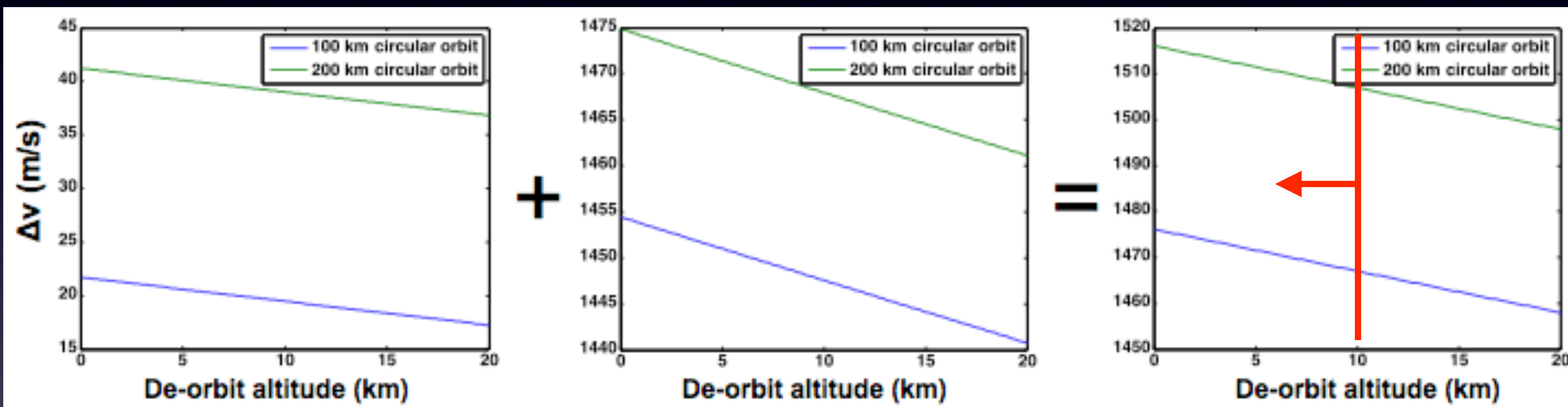



Burn 1

Burn 2

'Drop Point'

# Burn Δv's and deorbit altitude

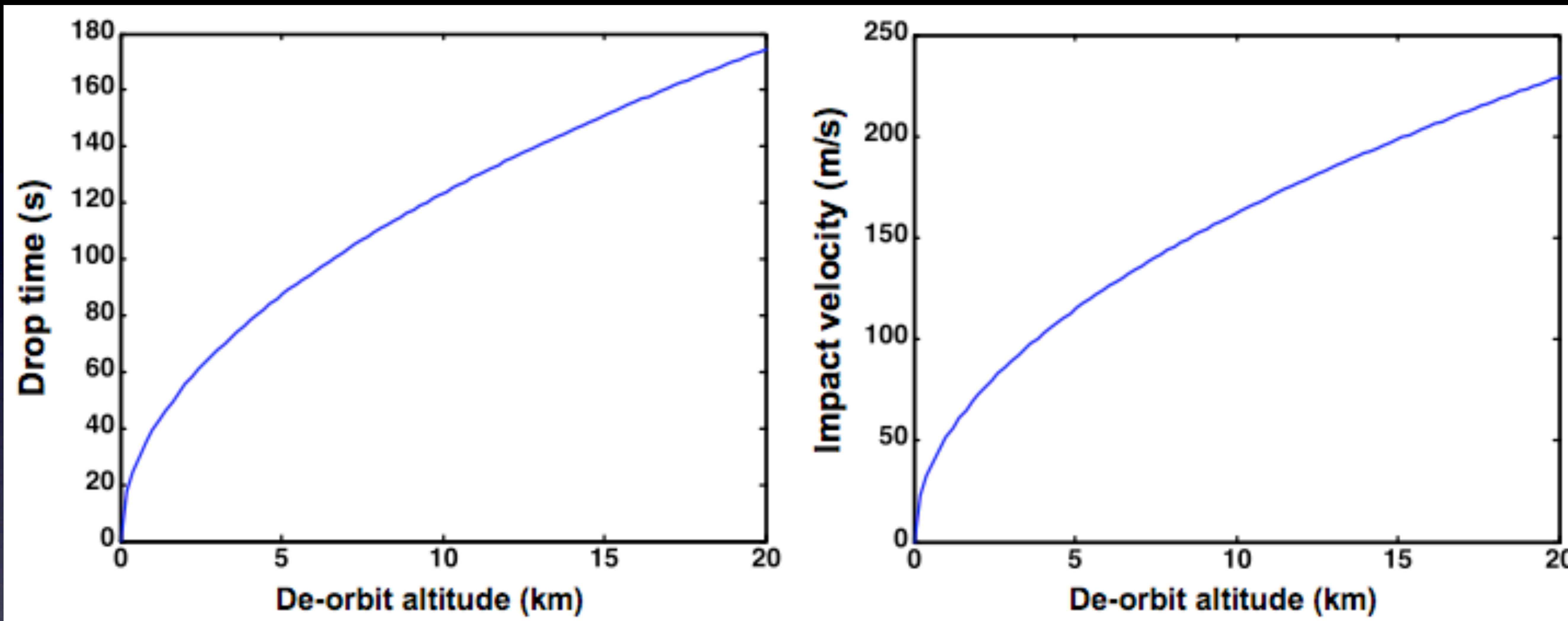



Burn 1

Burn 2

'Drop Point'

# Impact Velocity & Drop Time




200 km orbit Δv ~ 1510 km/s
100 km orbit Δv ~ 1465 km/s

100 kg probe: 35-55 kg propellant and Isp 200-360 s

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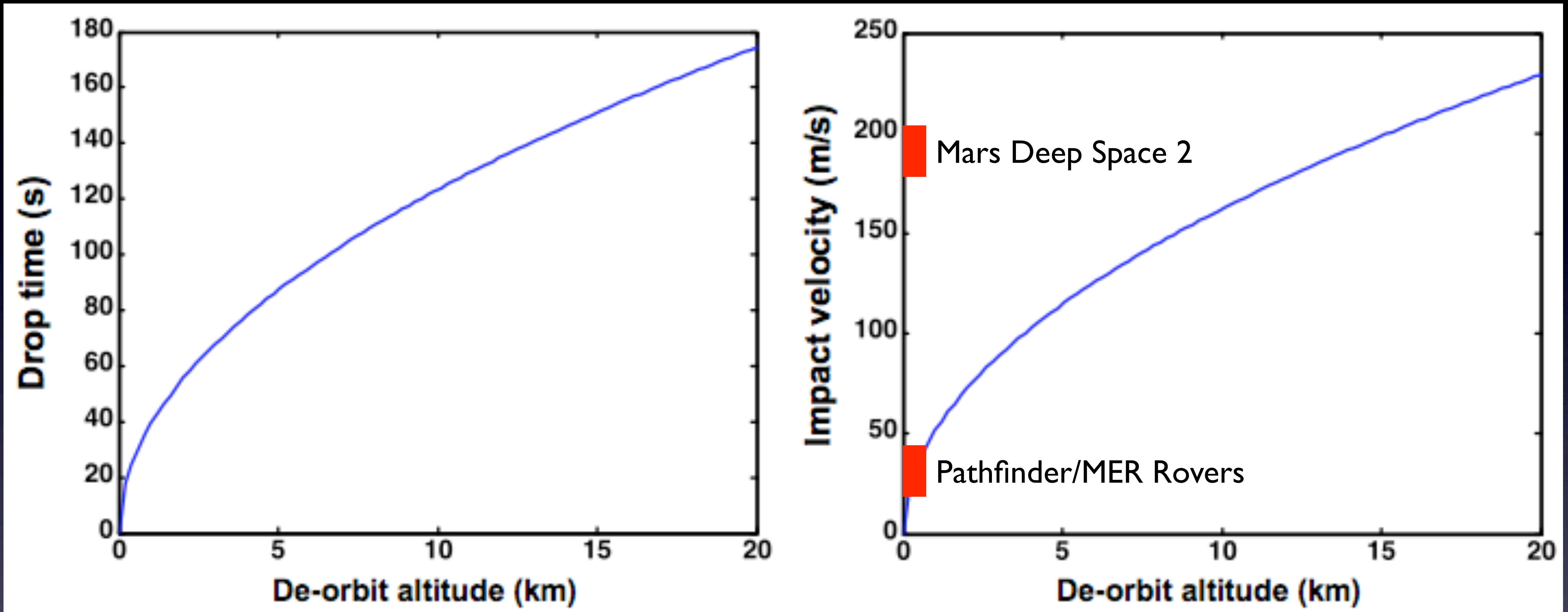


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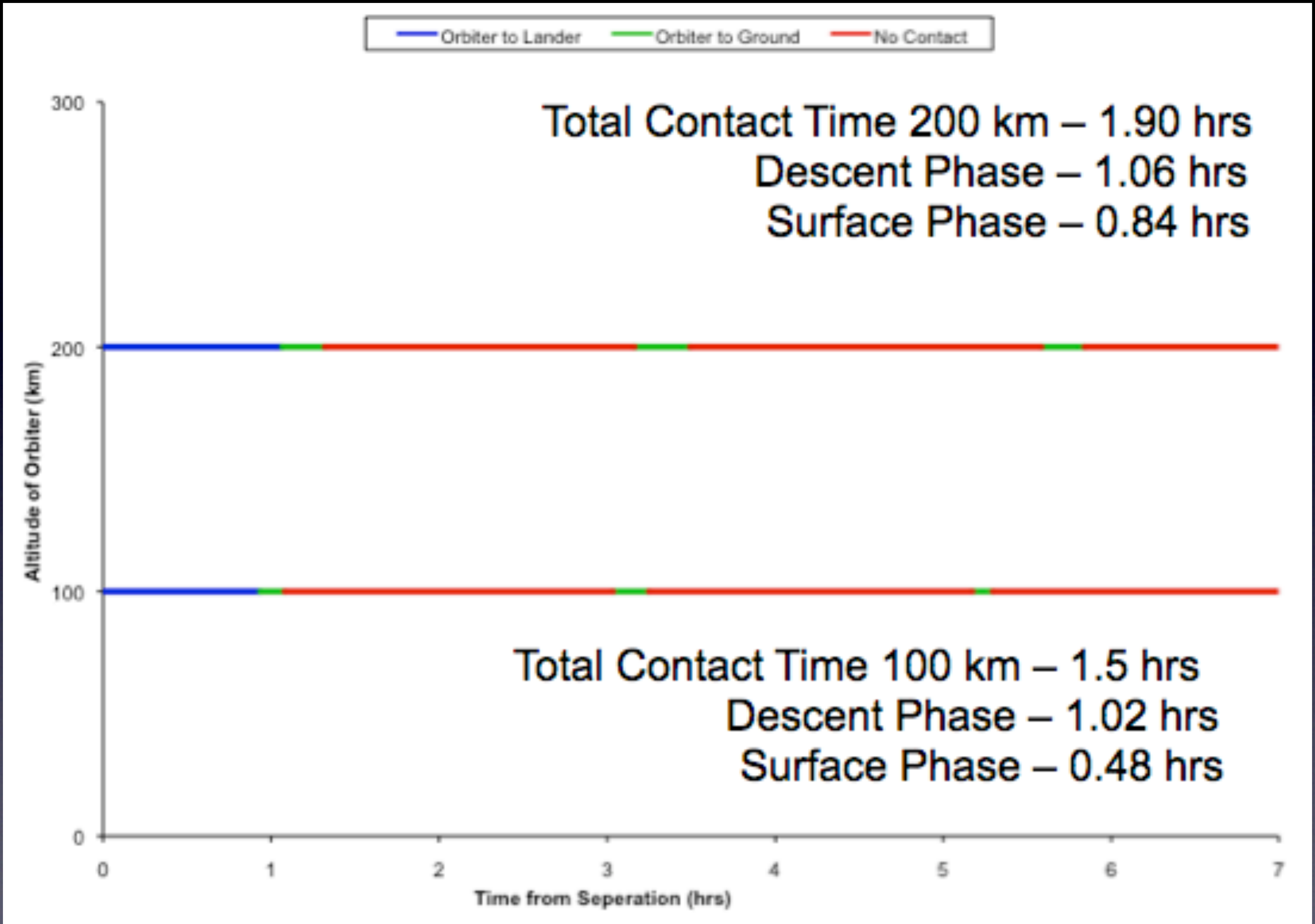
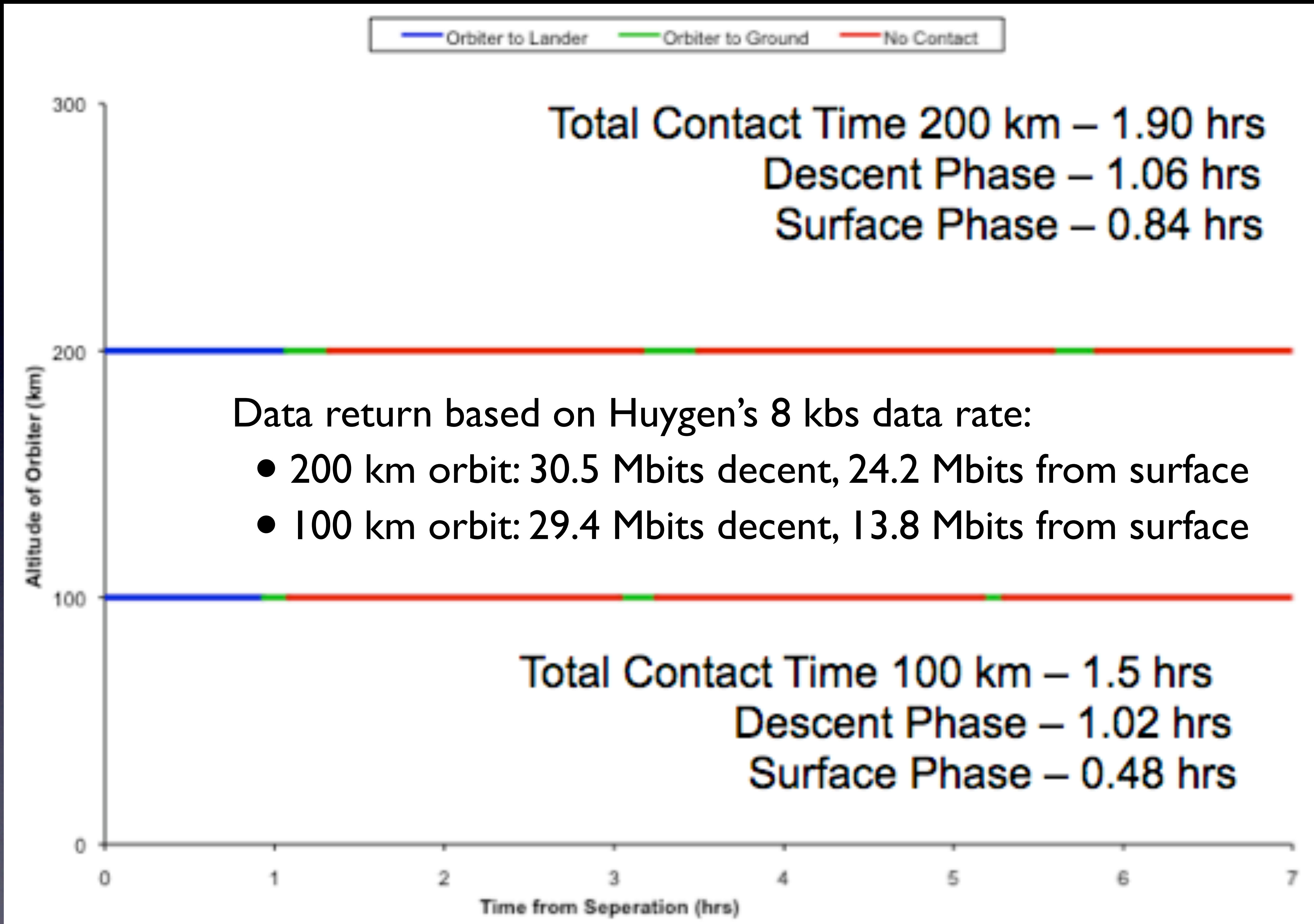

Orbiter to Lander
Orbiter to Ground
No Contact
Total Contact Time 200 km – 1.90 hrs
Descent Phase – 1.06 hrs
Surface Phase – 0.84 hrs
Total Contact Time 100 km – 1.5 hrs
Descent Phase – 1.02 hrs
Surface Phase – 0.48 hrs
Altitude of Orbiter (km)
300
200
100
0
0
1
2
3
4
5
6
7
Time from Seperation (hrs)




Data return based on Huygen's 8 kbs data rate:

- 200 km orbit: 30.5 Mbits decent, 24.2 Mbits from surface
- 100 km orbit: 29.4 Mbits decent, 13.8 Mbits from surface

# Lander Lifetime
## (Science, Radiation & Power Considerations)

| | |
|---|---|
| ~7 hours | First phase: decent plus 3 orbits |
| ~30 hours | First phase, plus 8.5 hour ‘dark’ phase, then 13 hrs for next 6-7 orbits |
| ~7 + *n*21.5 hours | First phase, plus 21.5 hours to achieve each increment of ‘dark’ phase plus subsequent communication orbits. |
| Full Europan day (85.2 hours) | Lander should survive for ~93 hours in order to communicate all data back to orbiter. |

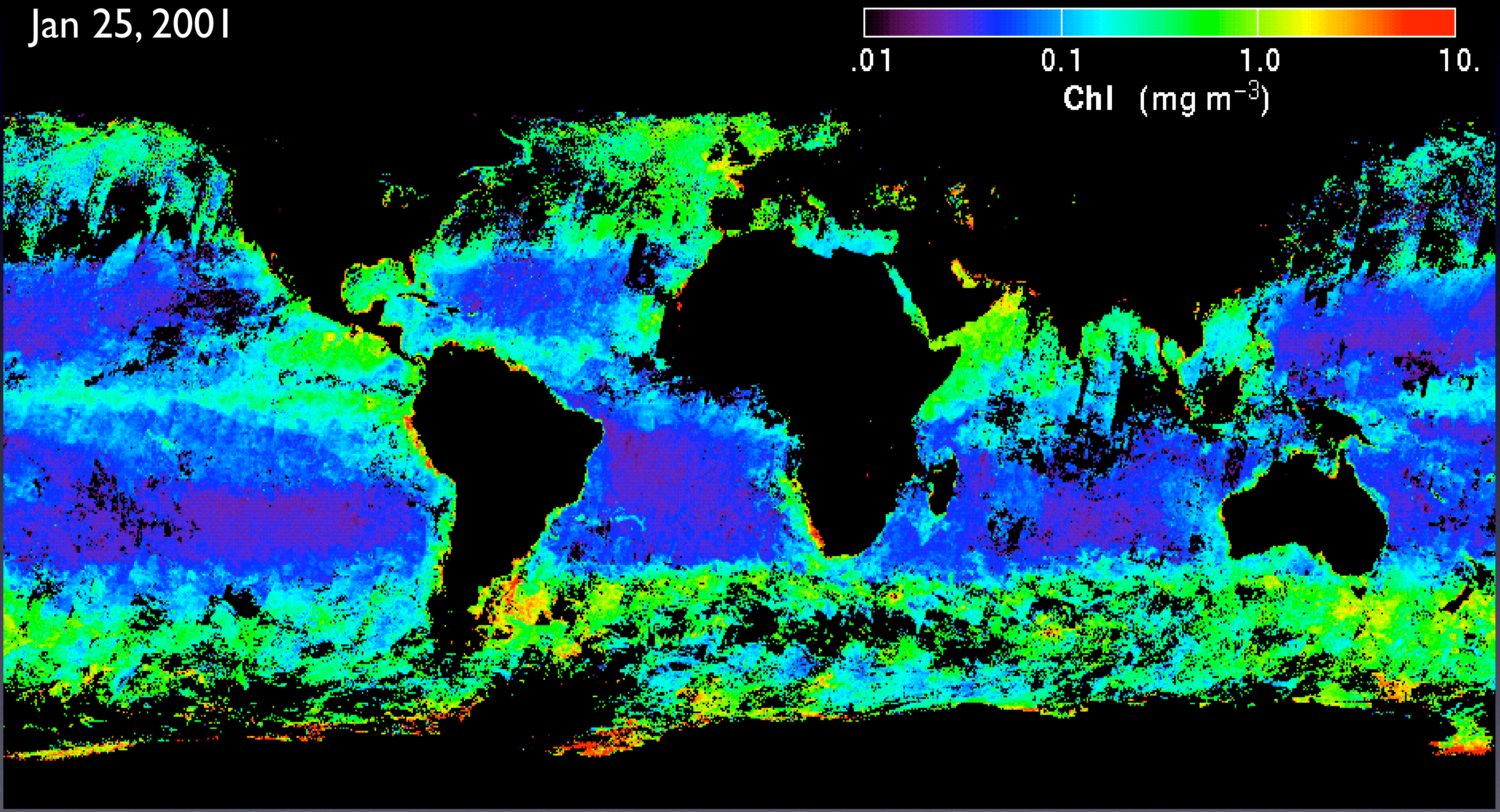
# Lessons learned from Viking Landers

1) If the payload permits, conduct experiments that assume contrasting definitions for life.
2) Given limited payload, the biochemical definition deserves priority.
3) Establishing the geological and chemical context of the environment is critical.
4) Life-detection experiments should provide valuable information regardless of the biology results.
5) Exploration need not, and often cannot, be hypothesis testing. Planetary missions are often missions of exploration, and therefore the above guidelines must be put in the context of exploration and discovery driven science.

Chyba and Phillips (2001)

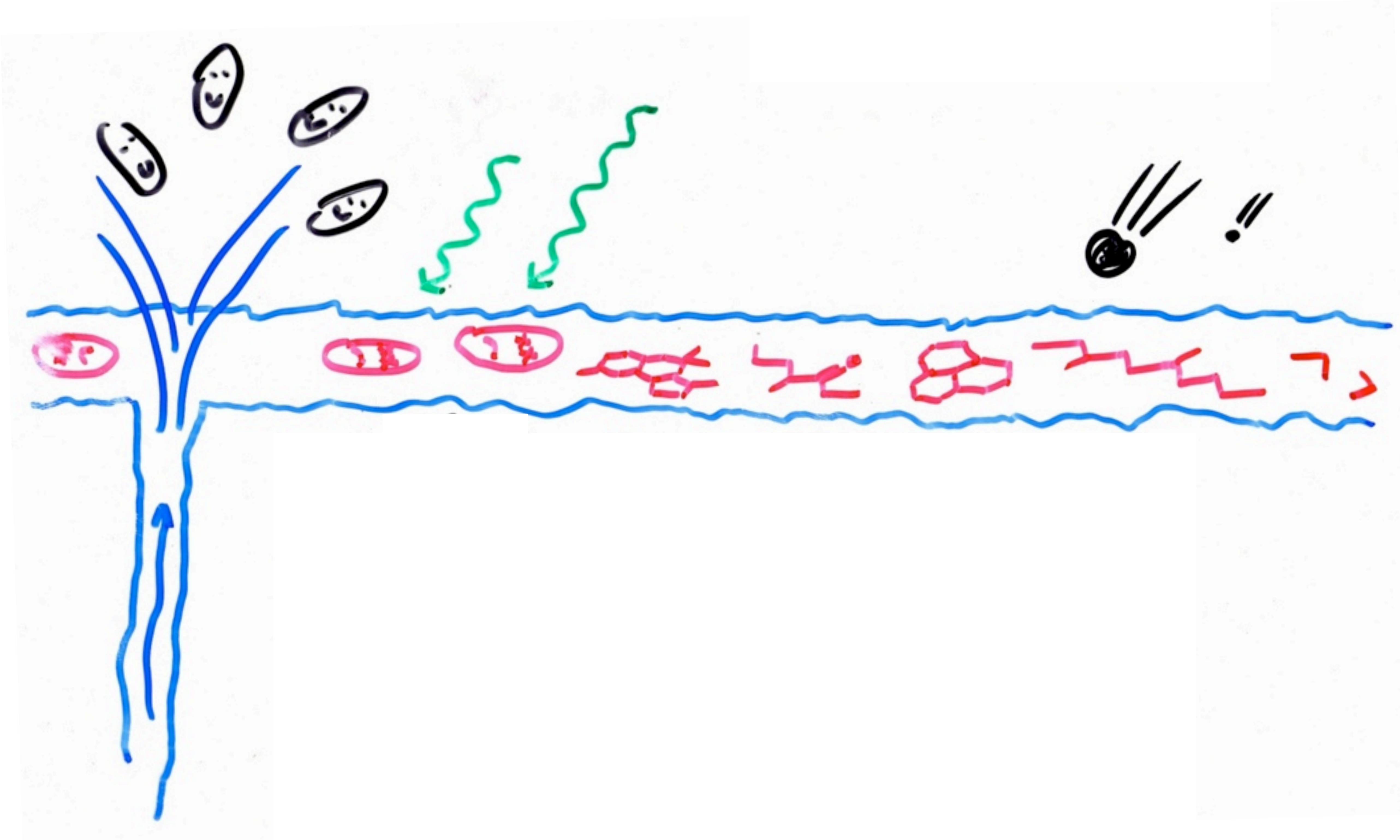
# Chlorophyll-a mapping of Earth's ocean

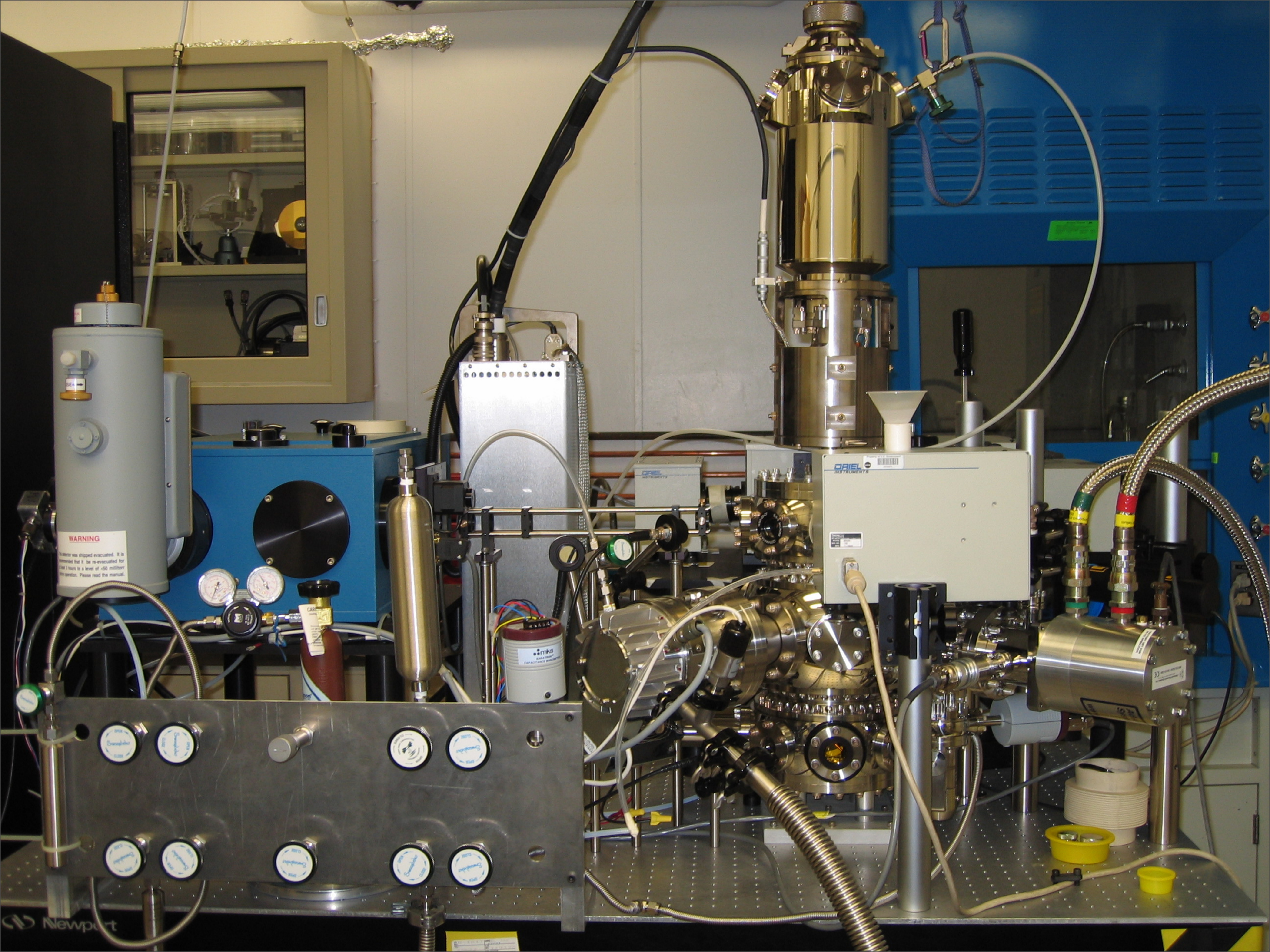
Jan 25, 2001

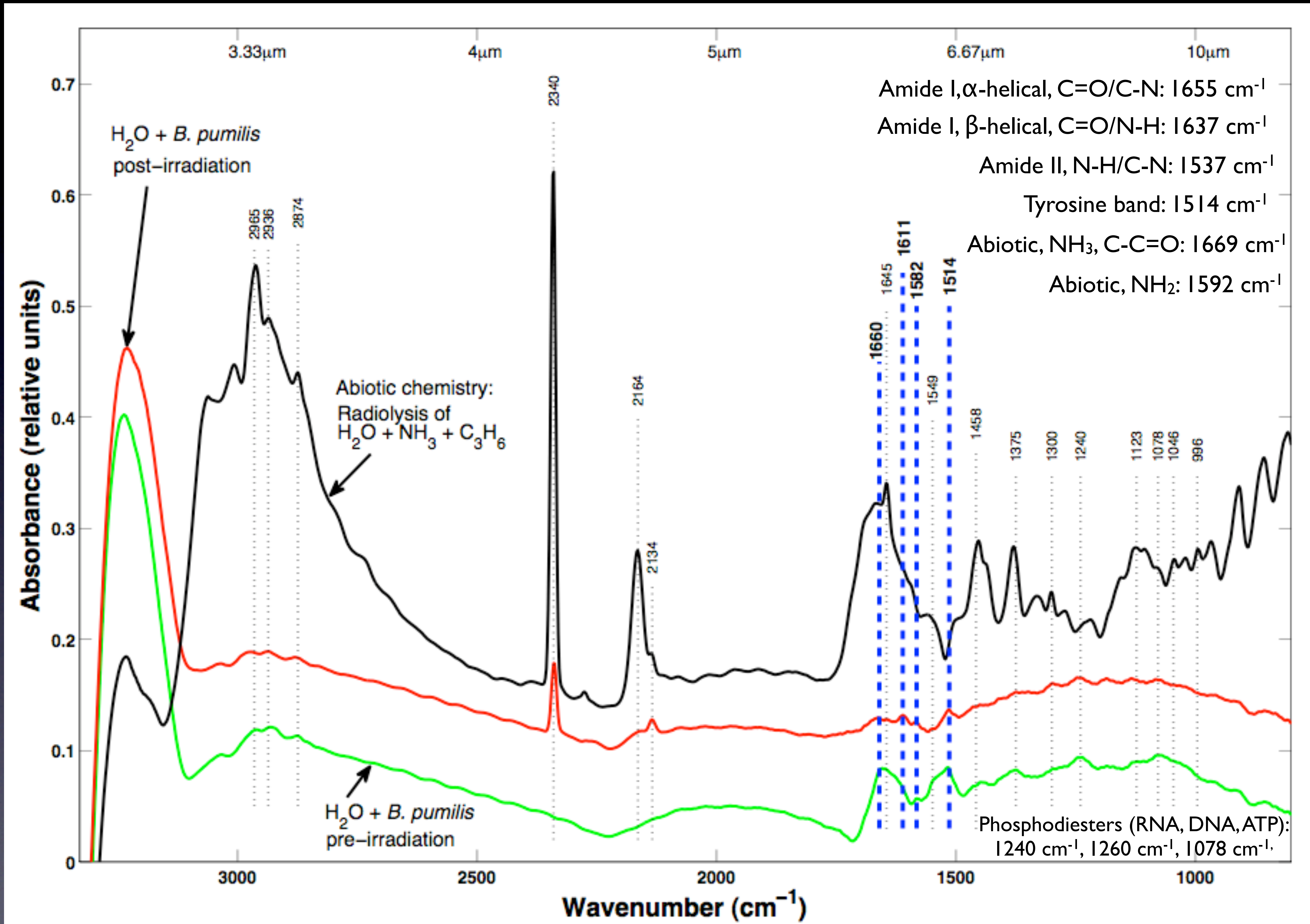



Terra satellite, Moderate Resolution Imaging Spectroradiometer (MODIS)

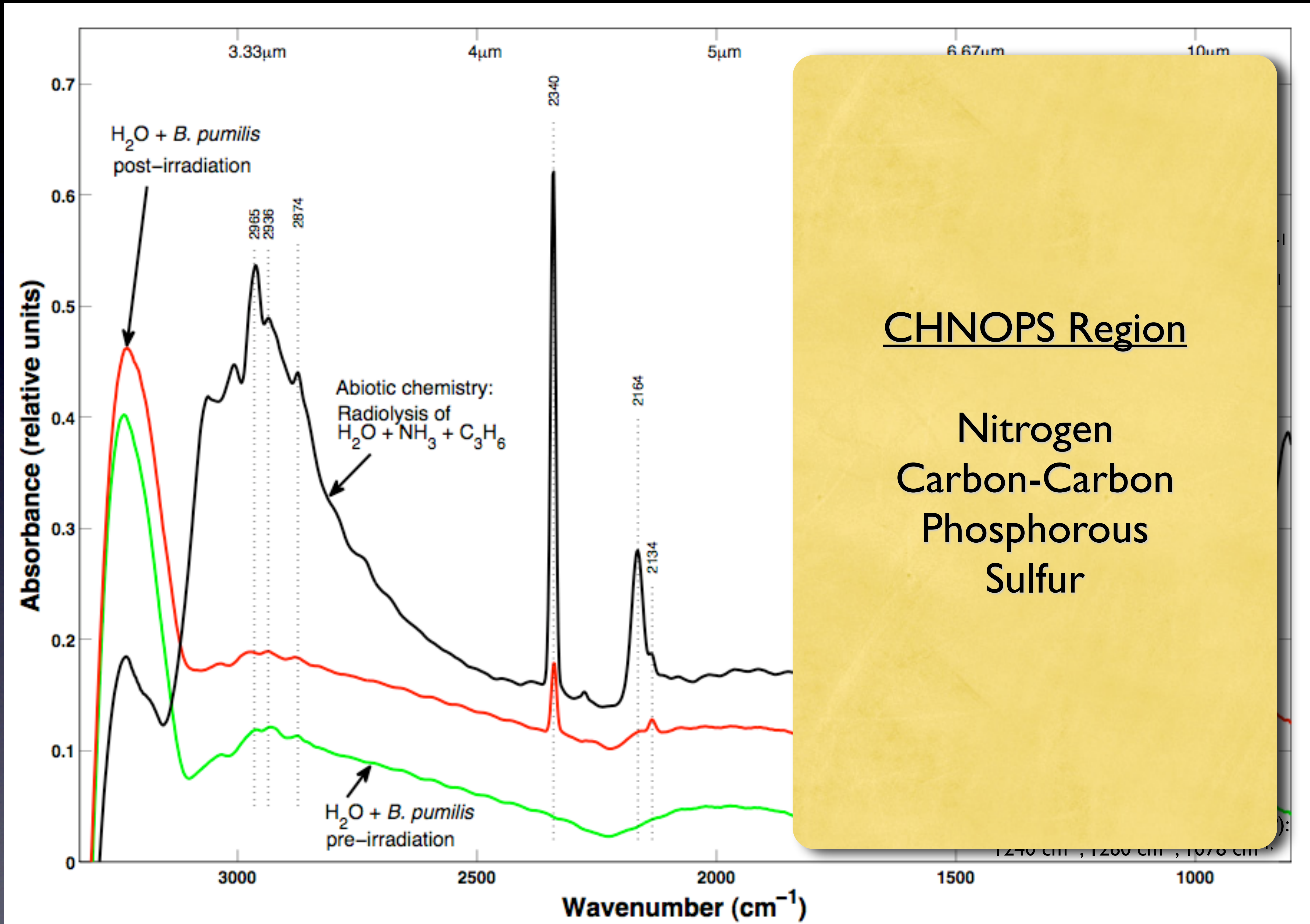
# Life Detection on Icy Worlds
# Biosignatures vs. Abiotic Radiolytic Chemistry




WARNING
ORIEL INSTRUMENTS
mks
Newport



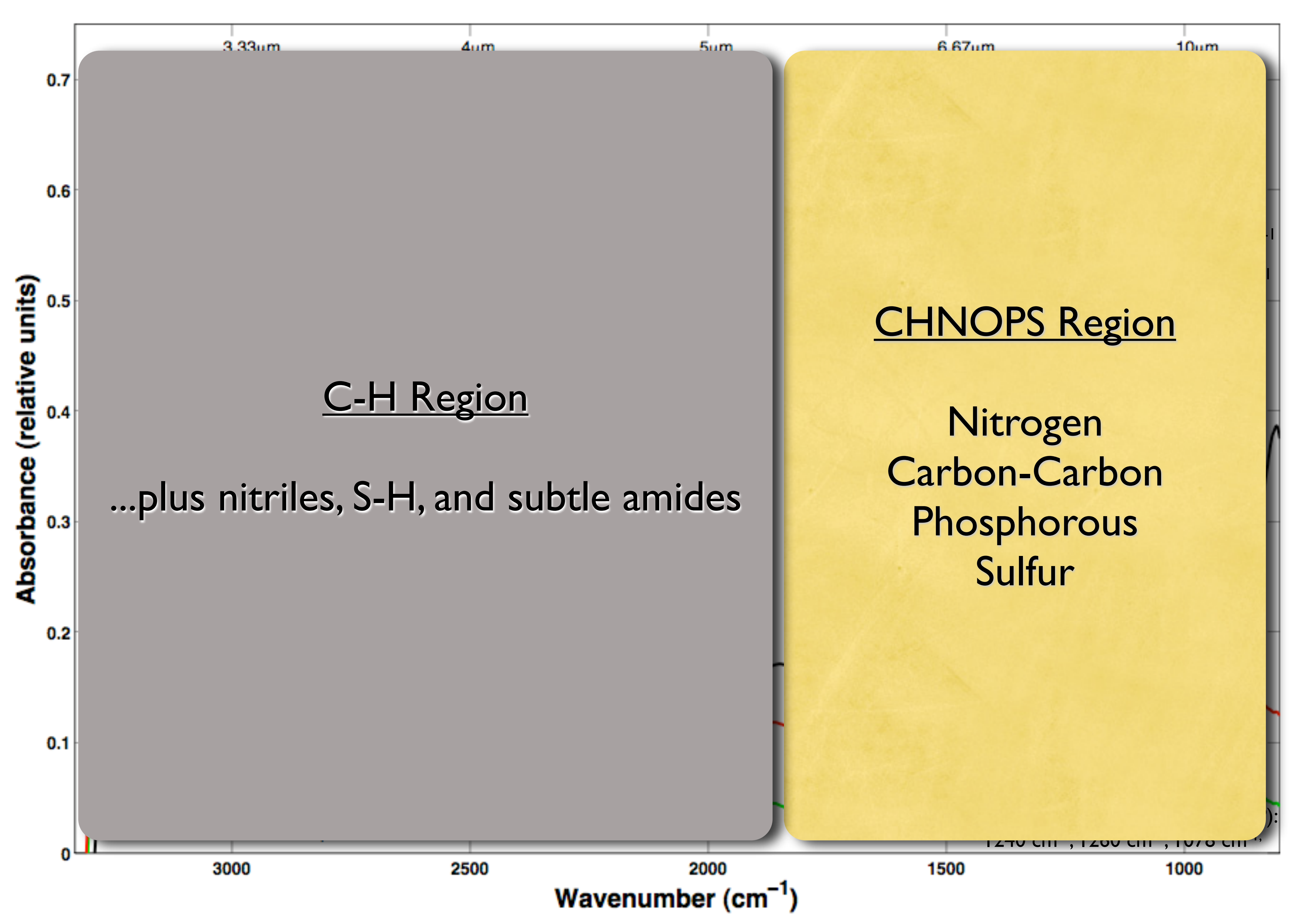

Hand & Carlson, *in prep*




<u>CHNOPS Region</u>

Nitrogen
Carbon-Carbon
Phosphorous
Sulfur

Hand & Carlson, *in prep*




Hand & Carlson, *in prep*

# Notional Payload Possibilities

| Instrument | Source or Heritage | Mass (kg) |
|---|---|---|
| Accelerometer | TEAMX 2005 | 0.05 |
| GCMS | TEAMX 2005 | 3.4 |
| Camera | Mars Surveyor | 0.35 |
| Temp Sensor | TEAMX 2005 | 0.28 |
| Raman Spectrometer | TEAMX 2005 | 1.5 |
| Ion Specific Wet Chemistry Array | TEAMX 2005 | 0.11 |
| Radiation Sensor | TEAMX 2005 | 0.005 |
| Magnetometer | TEAMX 2005 | 0.7 |
| Microseismometer | TEAMX 2005 | 0.3 |
| Sample Acquisition System | TEAMX 2005 | 4 |
| INMS | Huygens | 9.25 |

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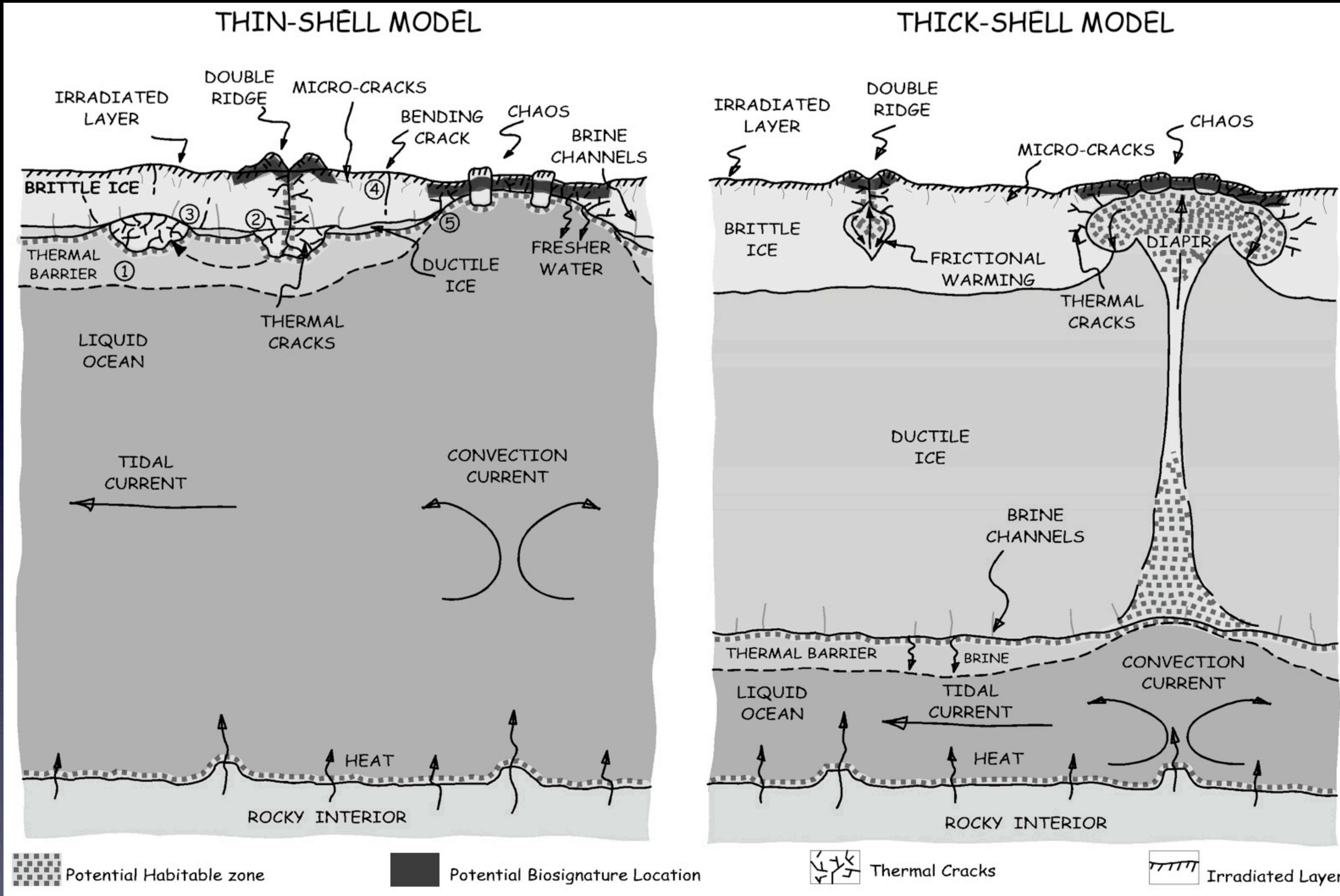


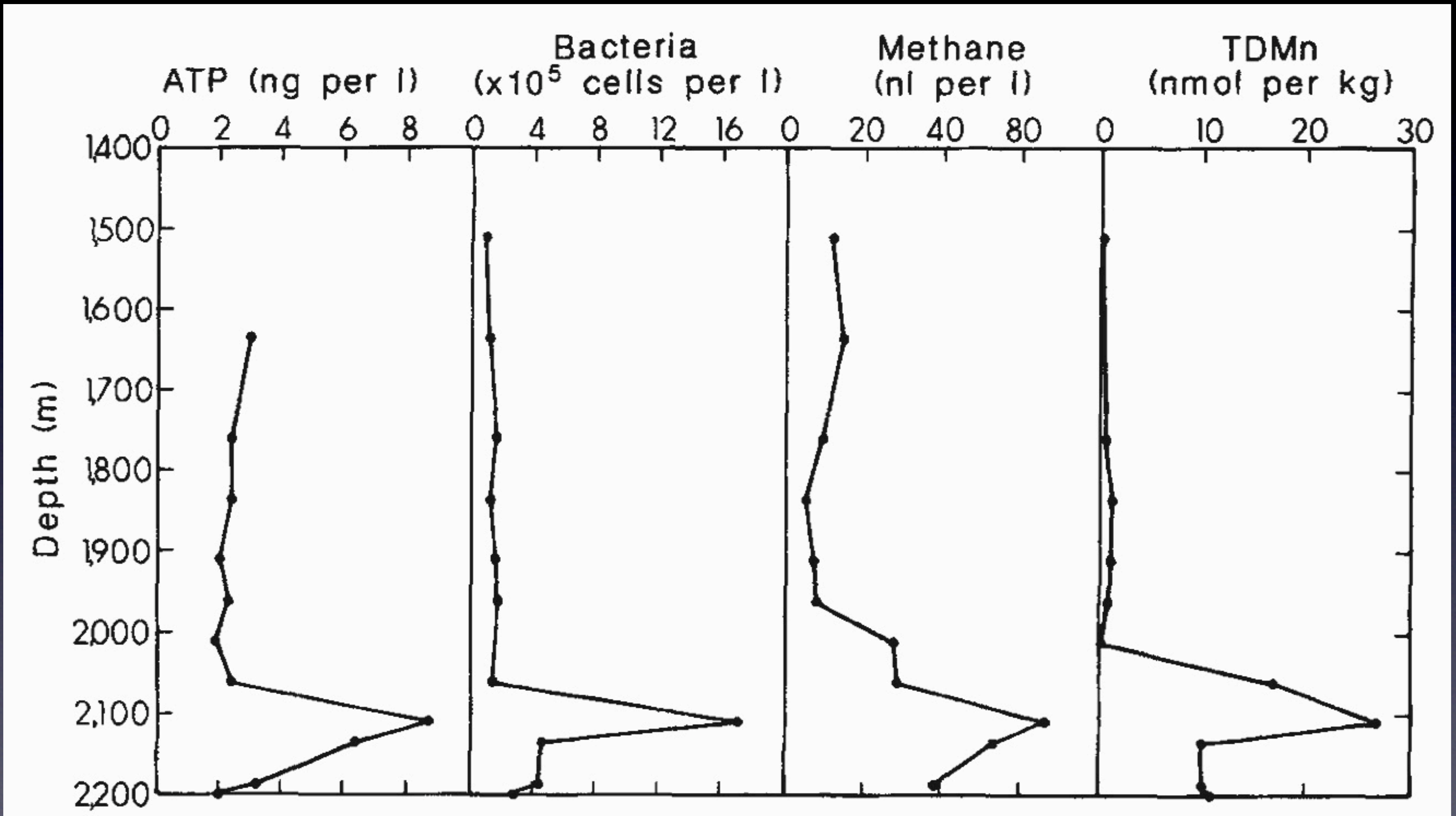

adapted from Figueredo et al. 2003

# Bacterial abundance in select terrestrial ecosystems

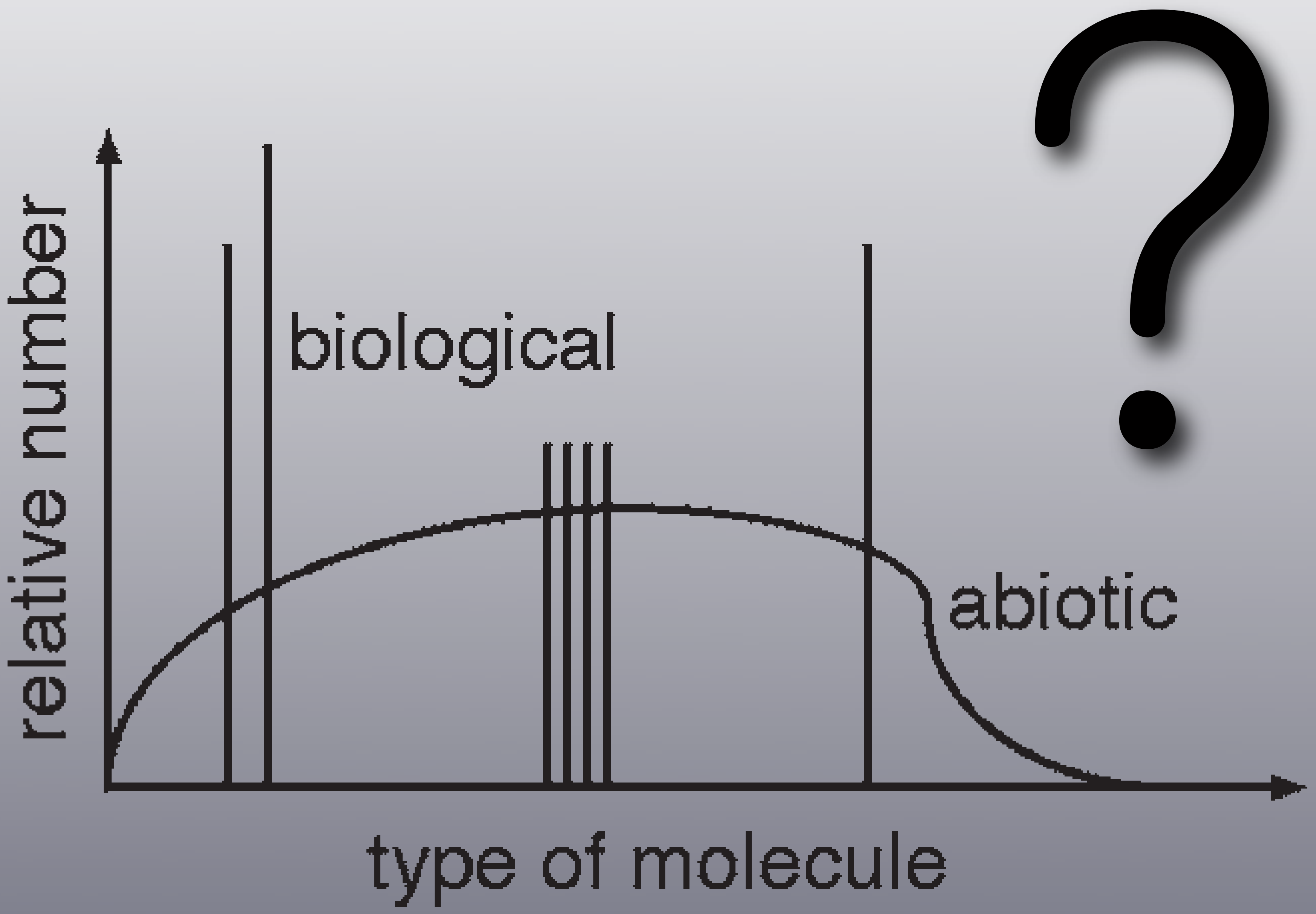
| | Abundance (cells $ml^{-1}$) | References |
|---|---|---|
| Ocean, surface | $5\times10^3$ – $5\times10^5$ | [1, 2] |
| Ocean, deep basins | $10^3$–$10^4$ | [3] |
| Hydrothermal vents | $10^5$–$10^9$ (in suspension) | [3] |
| Hot Springs | ~$10^6$ | [4] |
| Microbial mats | $10^7$-$10^9$ | [6] |
| Sierra Snowpack | $10^3$–$10^4$ | [5] |
| Glacial ice | 120 | [1] |
| Vostok accretion ice | 83-260 | [1] |
| Vostok water (predicted) | 150 | [1] |

Hand et al. 2009

# Plumes above hydrothermal vents on Earth



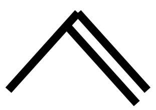

Winn and Karl (1986)

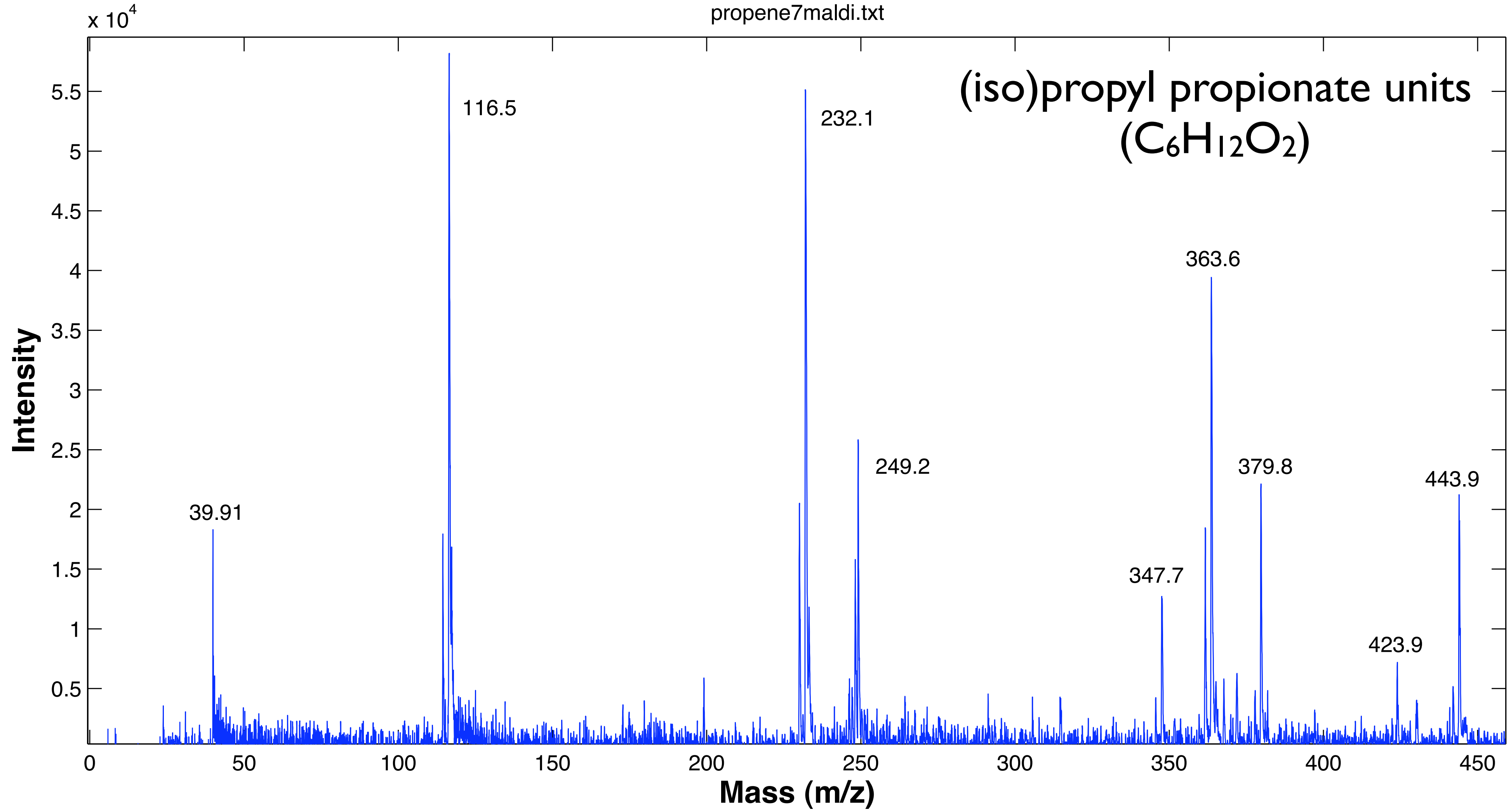



McKay, 2004

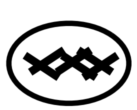
# MALDI (Matrix-Assisted Laser Desorption/Ionization) analysis:

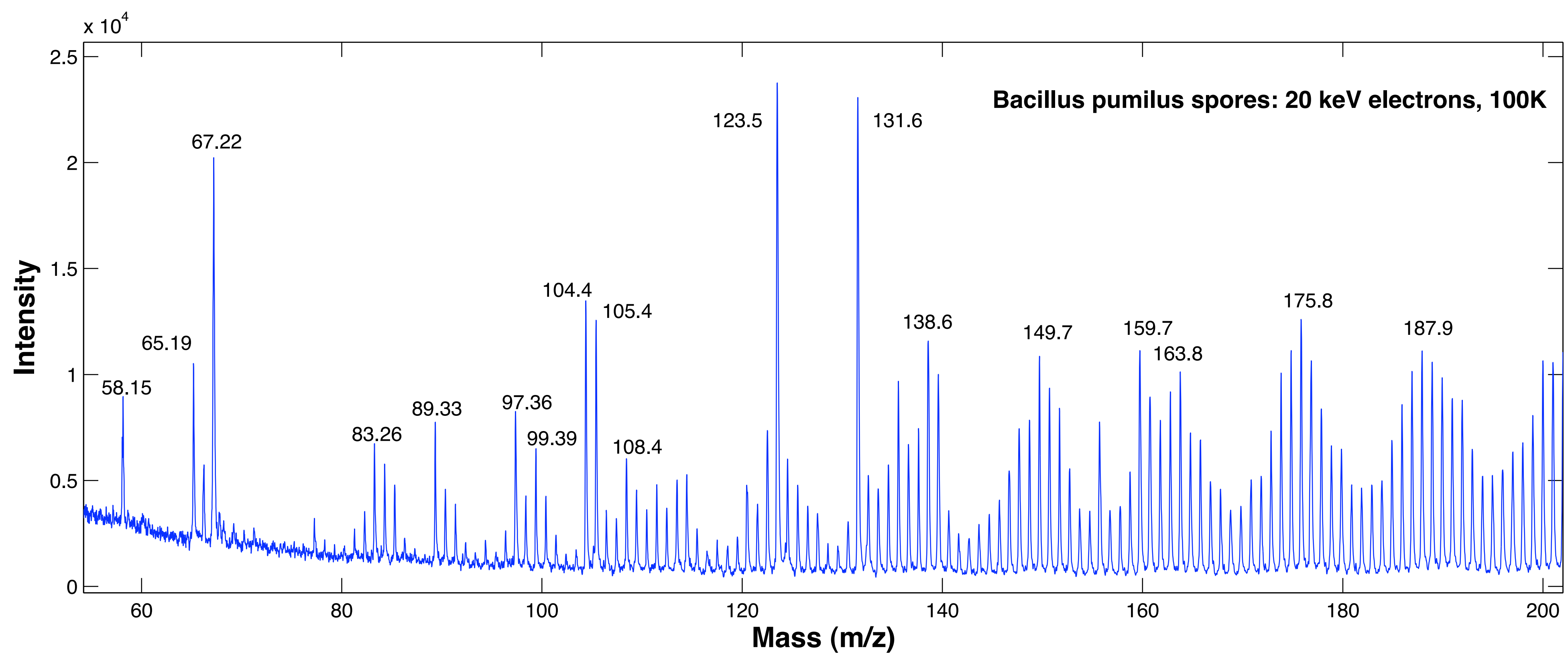
## Propene






## *Bacillus pumilis*



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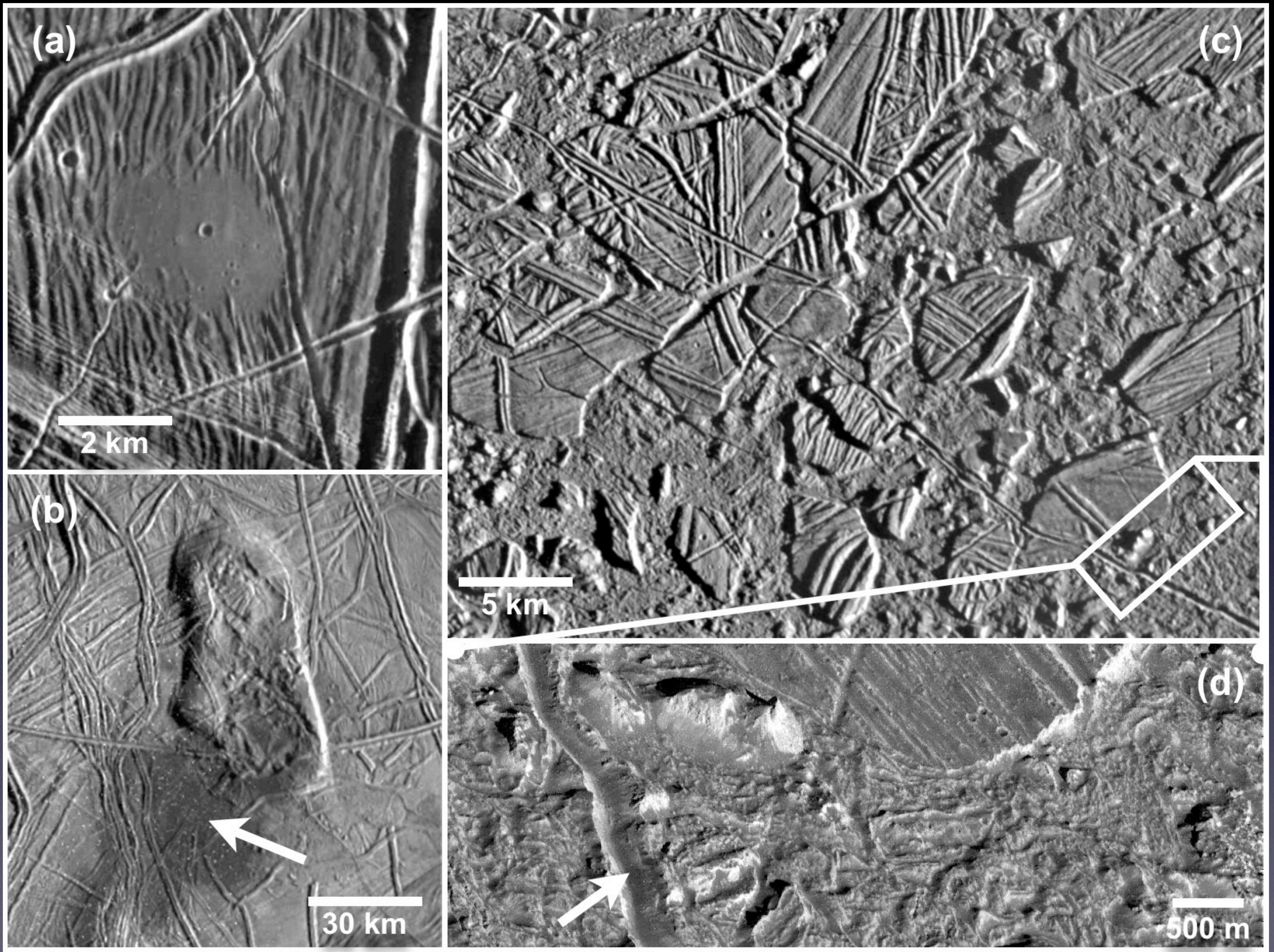
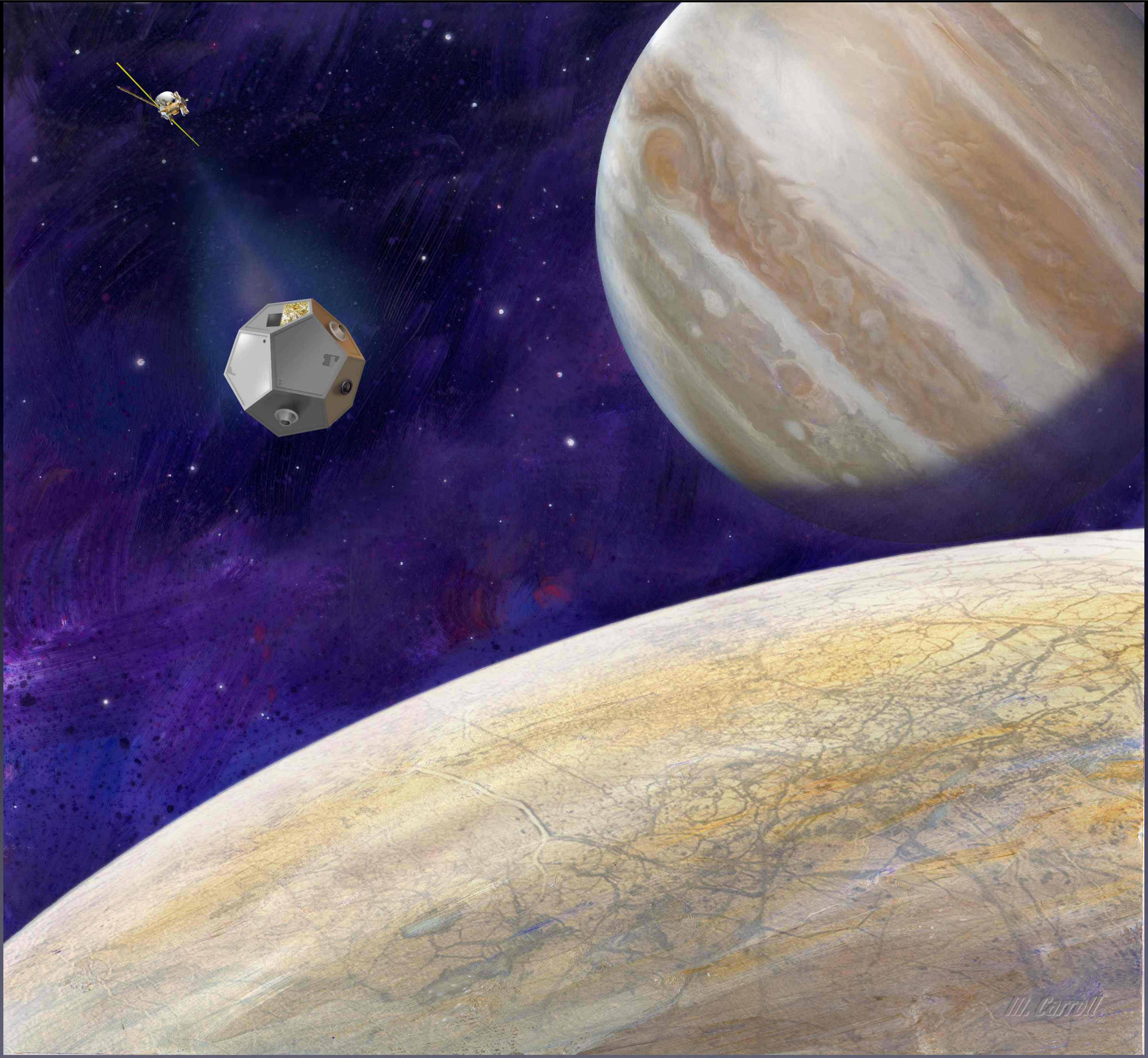
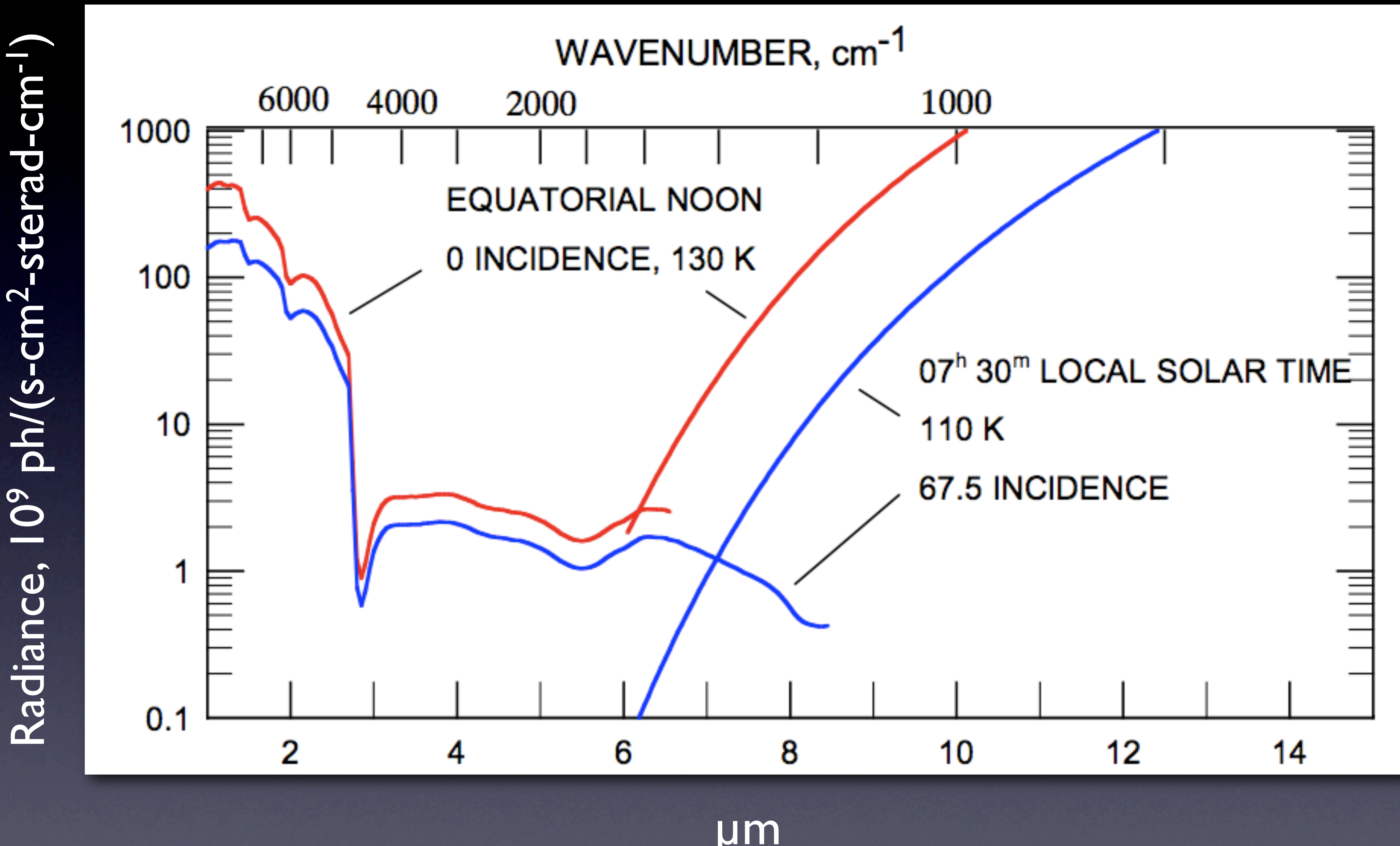
IKI, esp Anna & Andre

M Carroll (artwork)

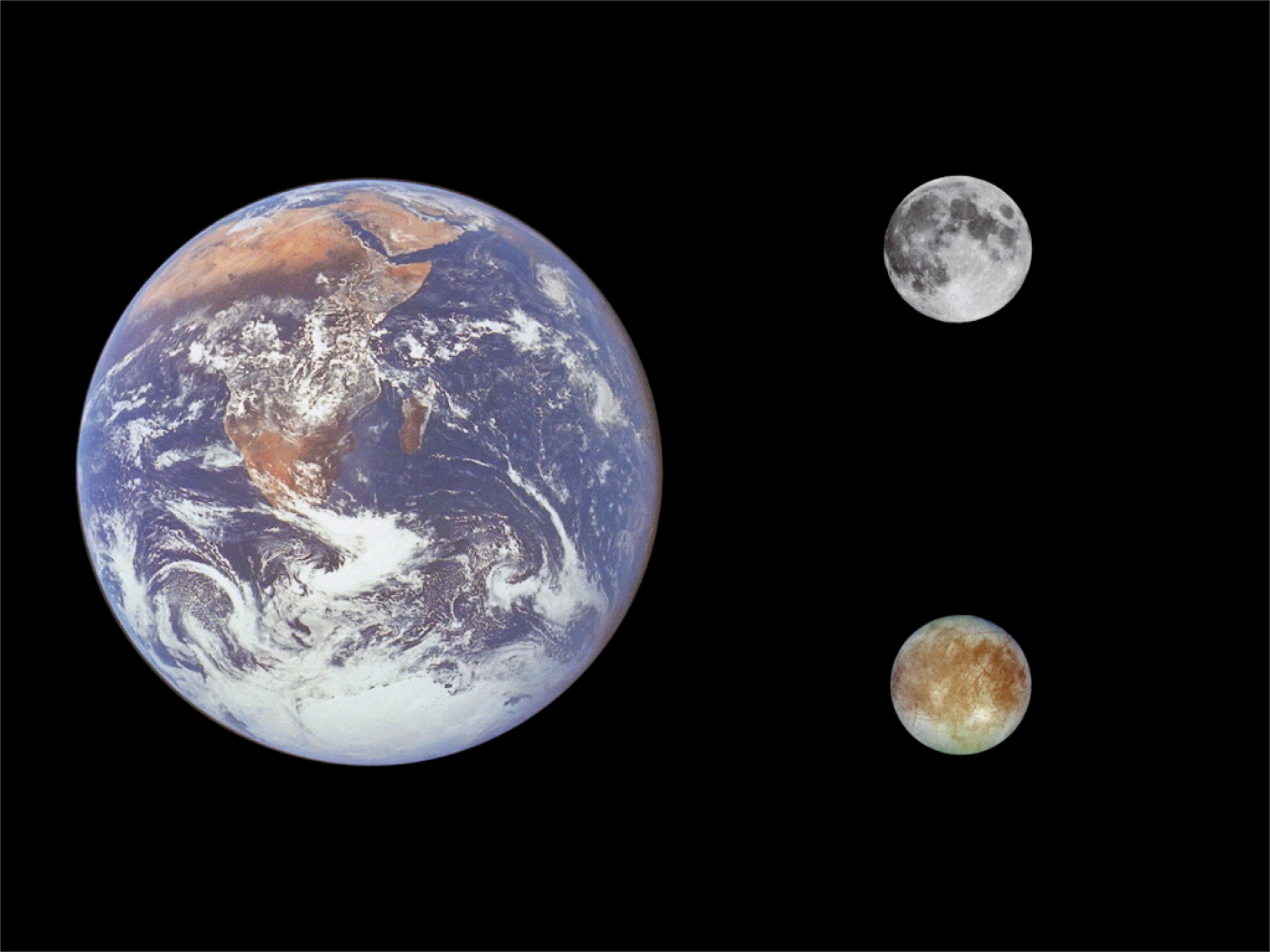
R.W. Carlson


(a)
2 km
(b)
30 km
(c)
5 km
(d)
500 m


M. Carroll




Europa surface temperature: 70-130K



# Geological criteria to guide the search for biosignatures

Figueredo et al. (2003)

1) Evidence for high material mobility.
2) Concentration of non-ice components.
3) Relative youth.
4) Textural roughness.
5) Evidence for stable or gradually changing environments.