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FINNISH METEOROLOGICAL INSTITUTE

New Initiatives for Space Exploration

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Head of Space and Radar Technology Research
Finnish Meteorological Institute

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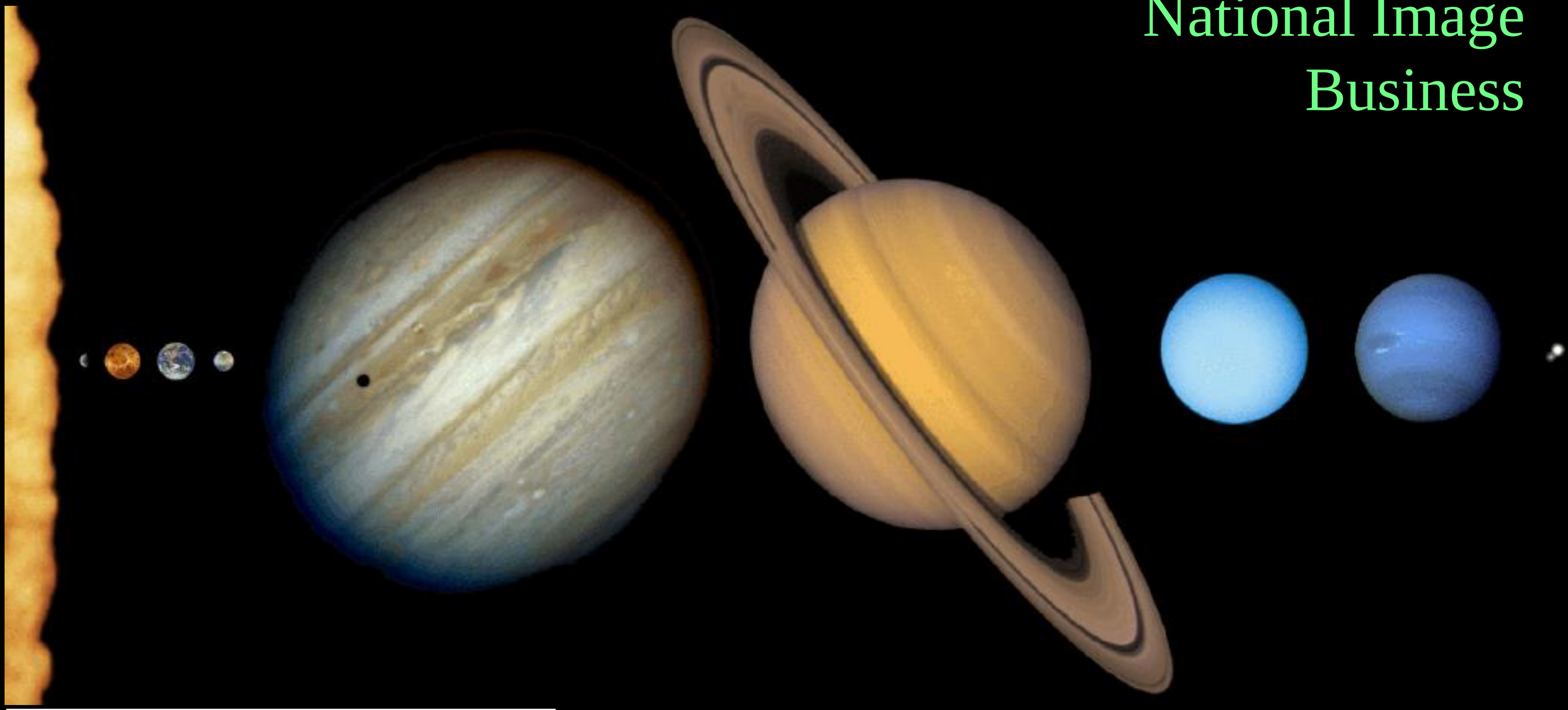
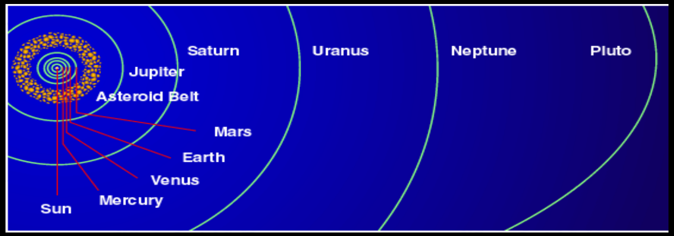
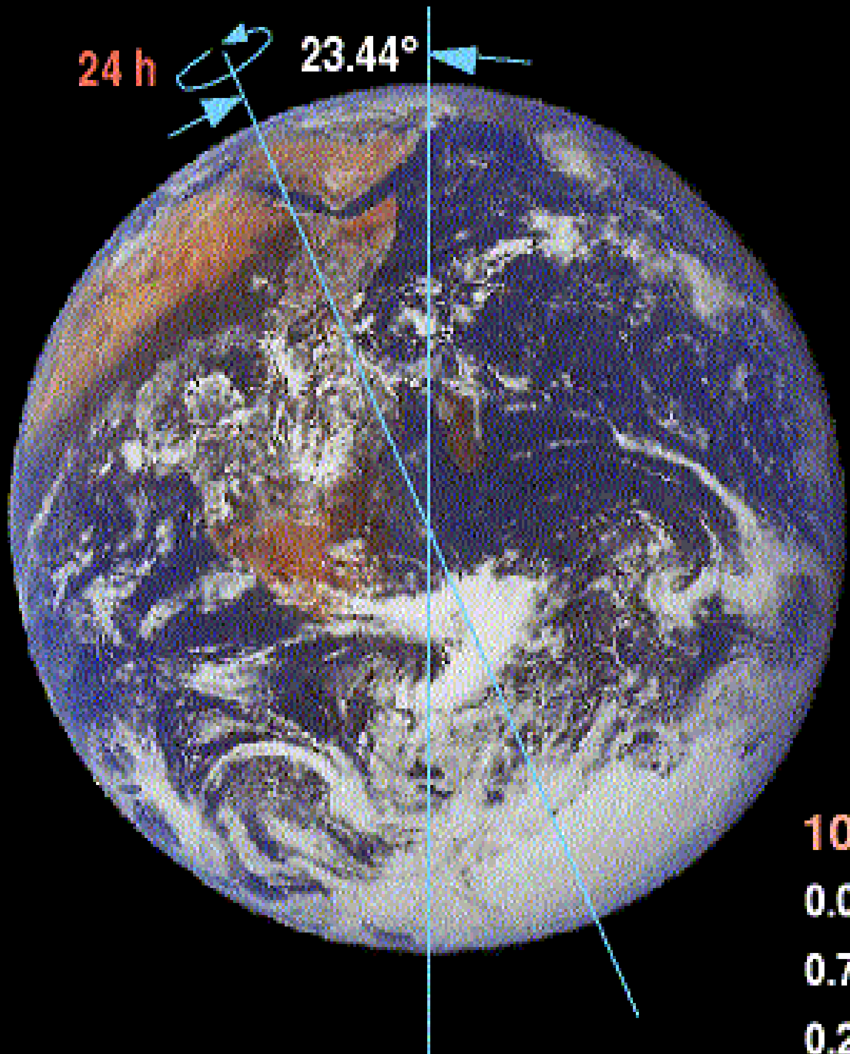
Science & Comparative Planetology
Technology & Competitiveness
International cooperation
National Image
Business







YEAR

365 Days   686 Days (667 Sols)

GRAVITY

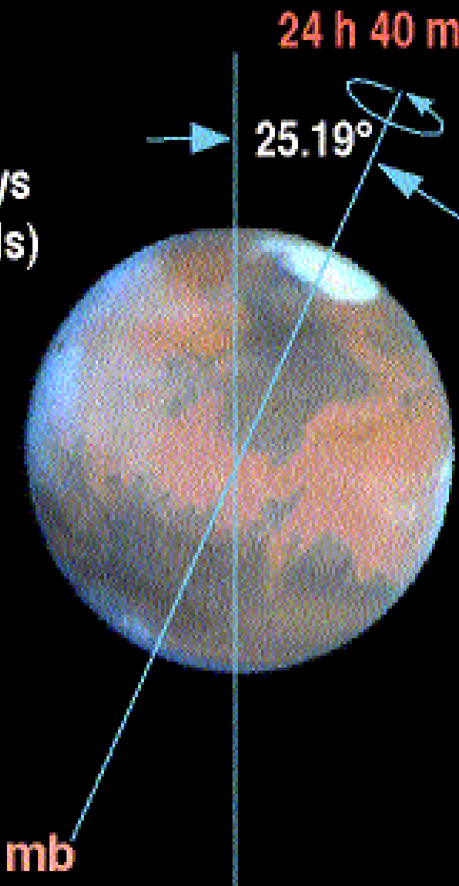
38% of earth

SUNLIGHT

44% of earth

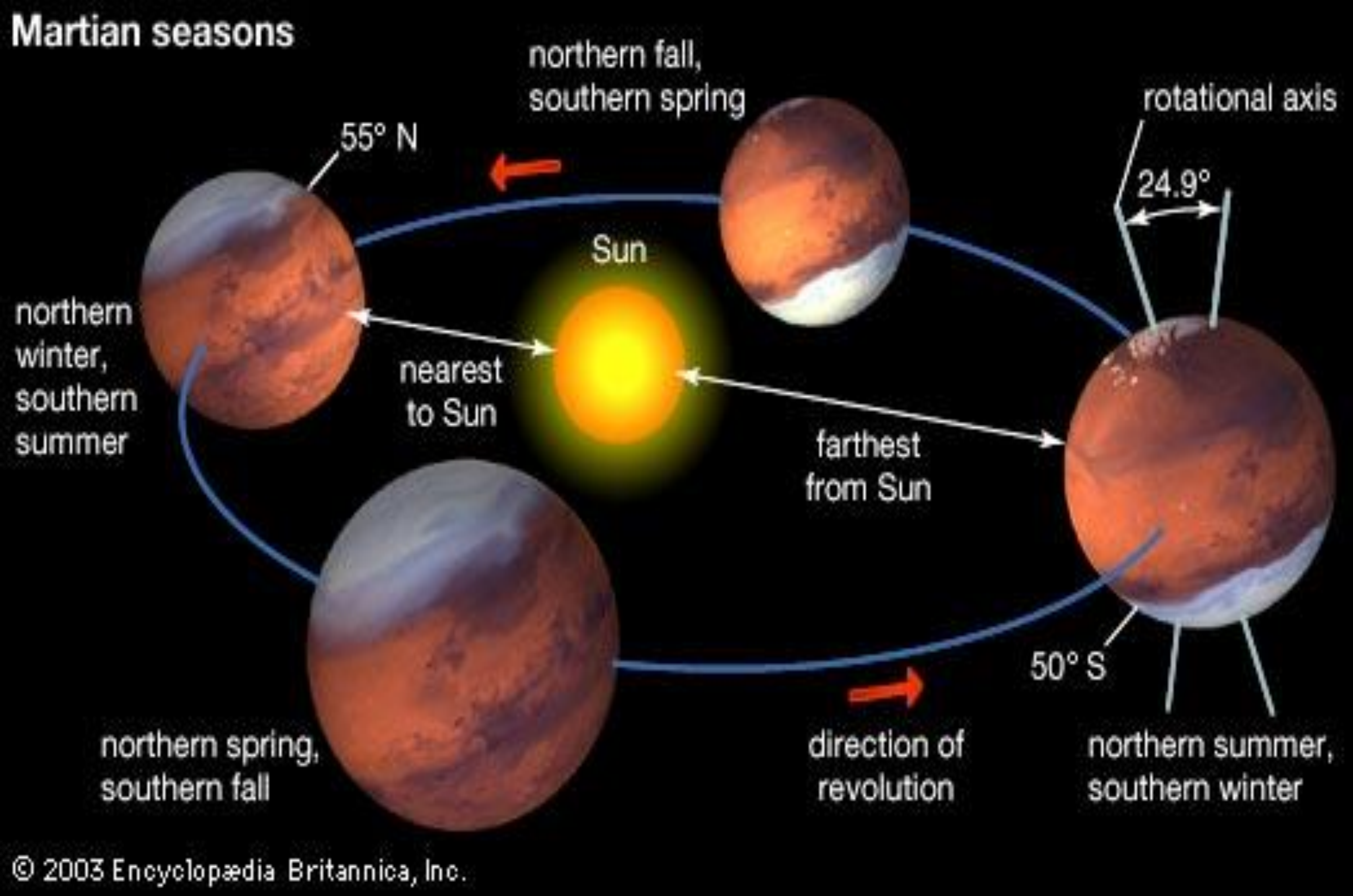
ATMOSPHERE

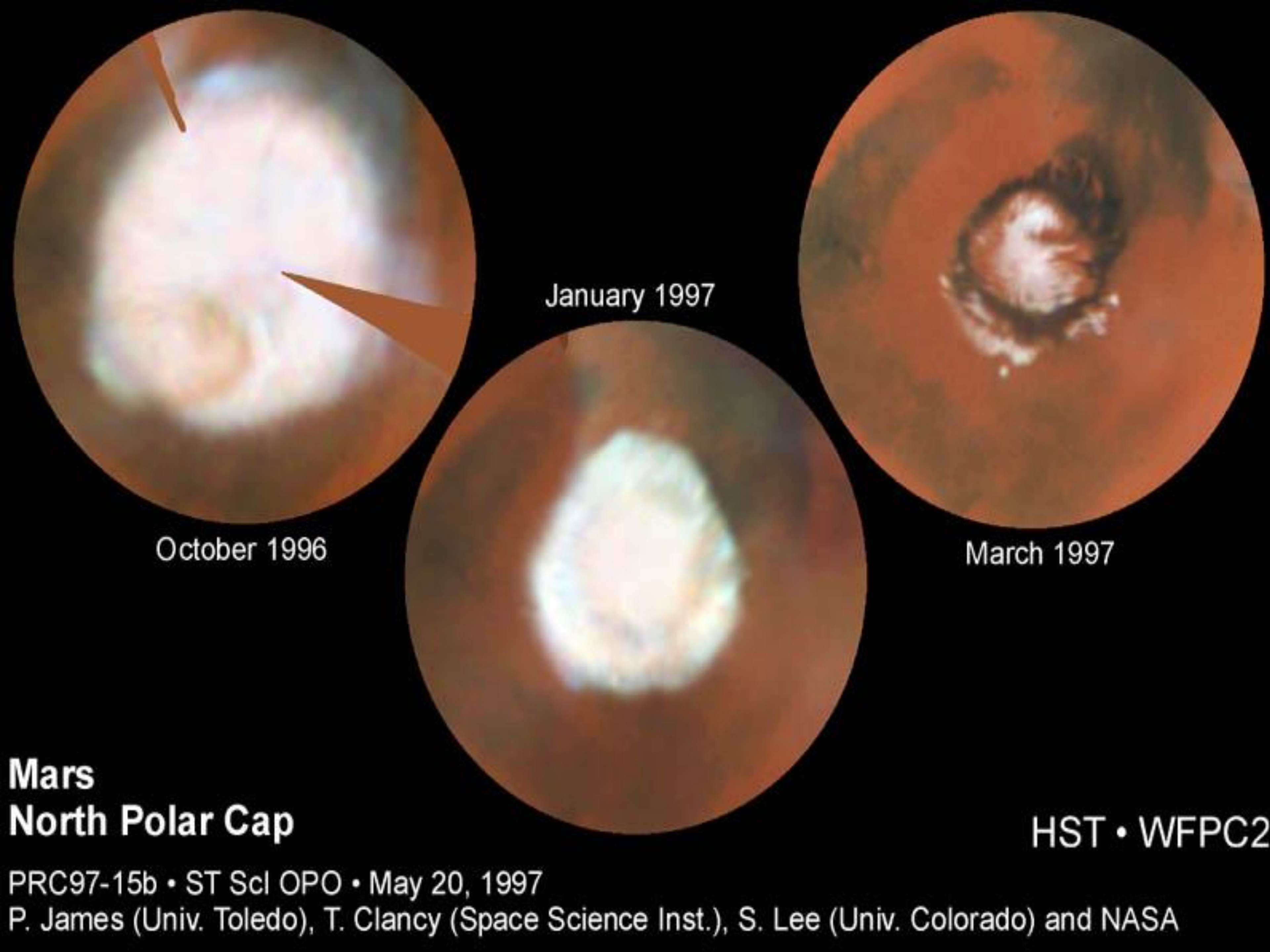
1013mb	Total	7.6 mb
0.00035	CO_2	0.95
0.781	N_2	0.027
0.210	O_2	0.0013
0 to 0.04	H_2O	0 to 0.00021
0.0093	Ar	0.016



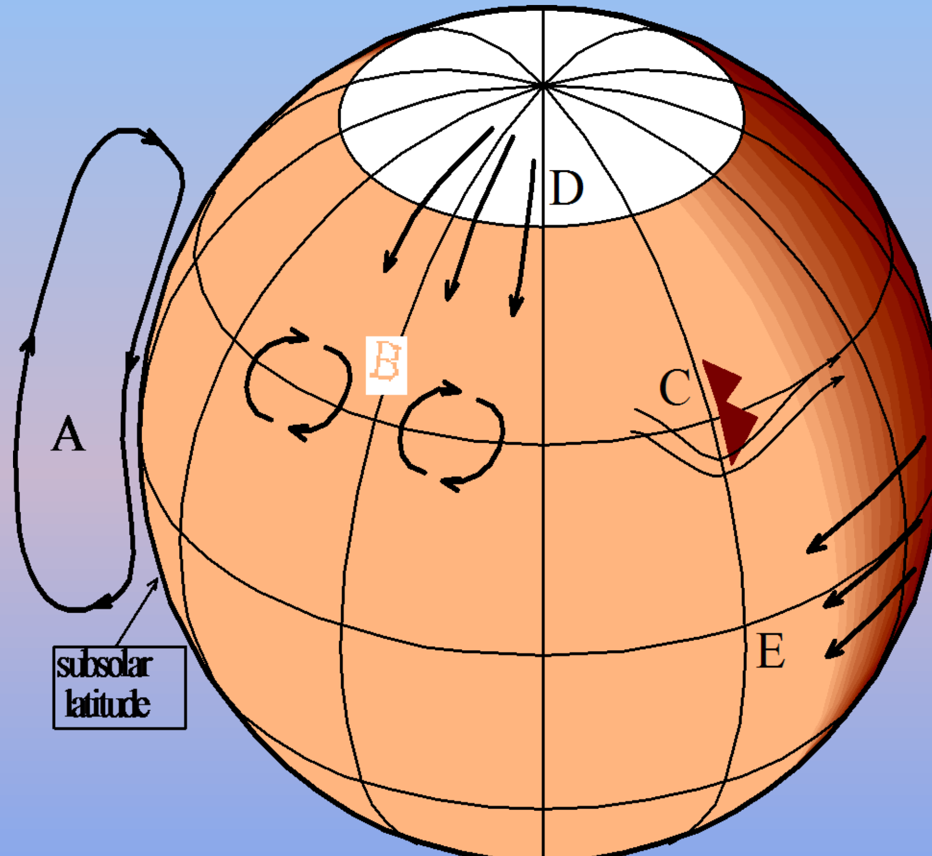
Mars, courtesy
P. James and NASA

Martian Orbit and Insolation

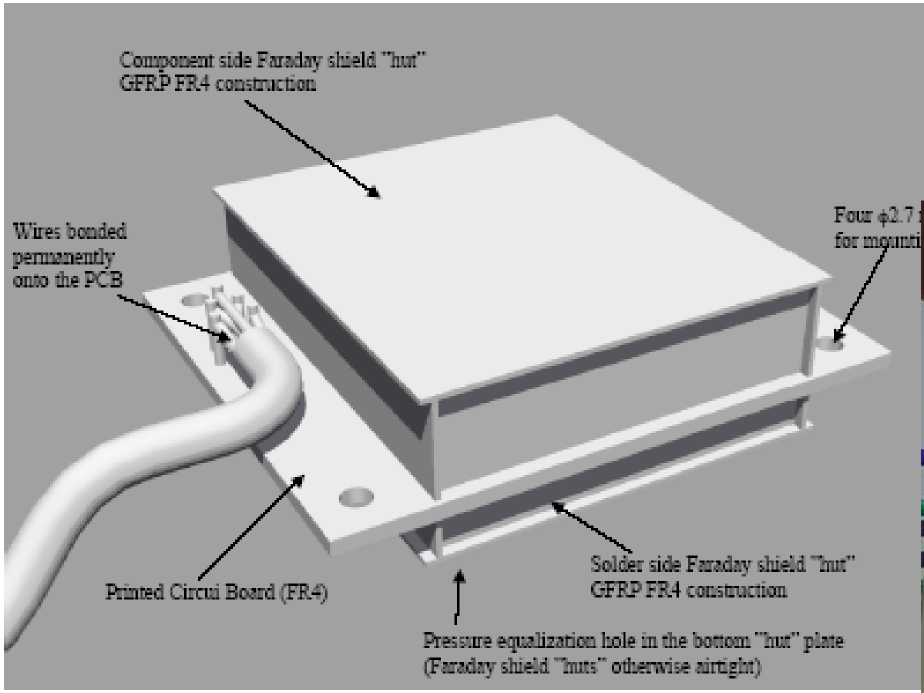


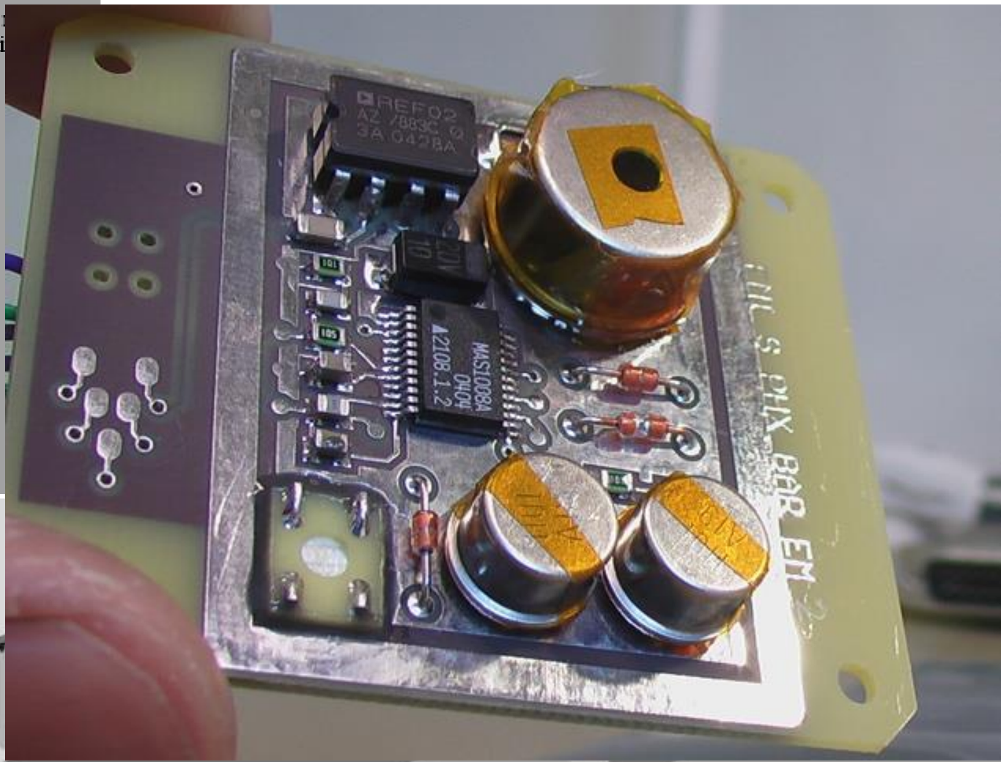

October 1996
January 1997
March 1997
Mars
North Polar Cap
HST • WFPC2
PRC97-15b • ST ScI OPO • May 20, 1997
P. James (Univ. Toledo), T. Clancy (Space Science Inst.), S. Lee (Univ. Colorado) and NASA

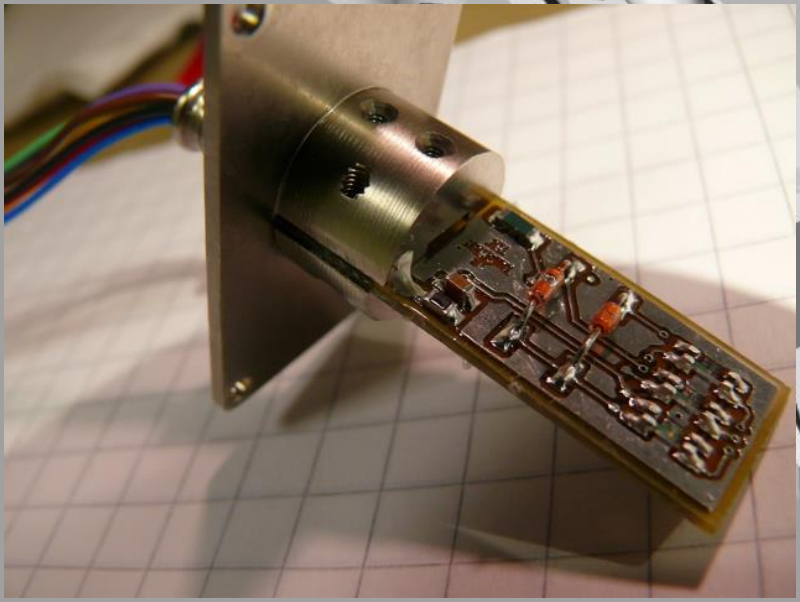
Mars/Earth Atmospheric Motions

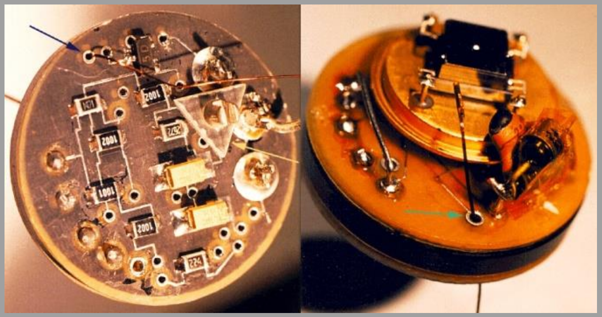


MSL 2011 : DIGIBARO and DIGIHUM

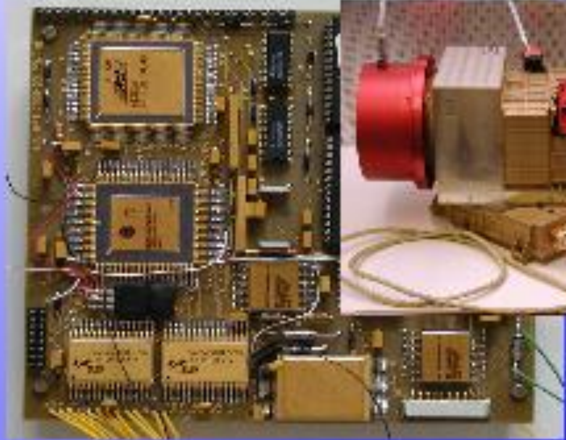


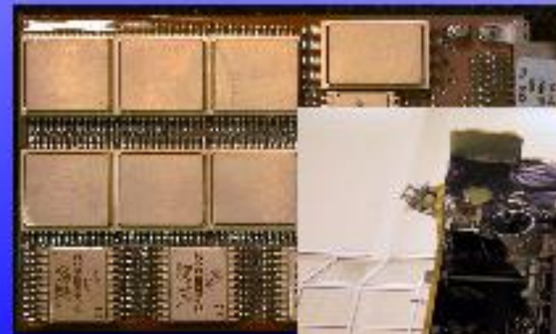




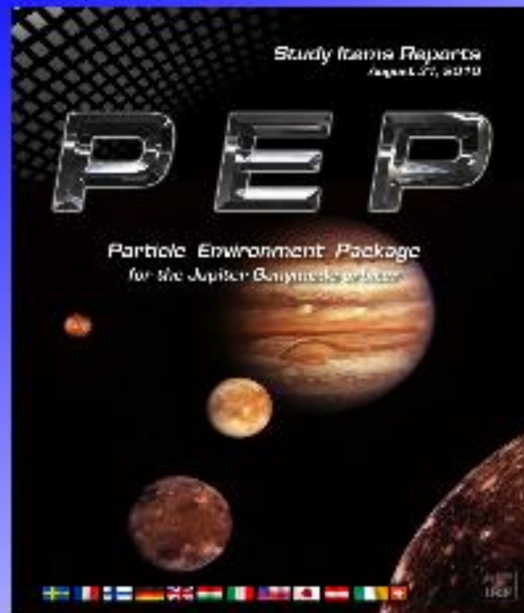


More than 40 flying instruments since 1985





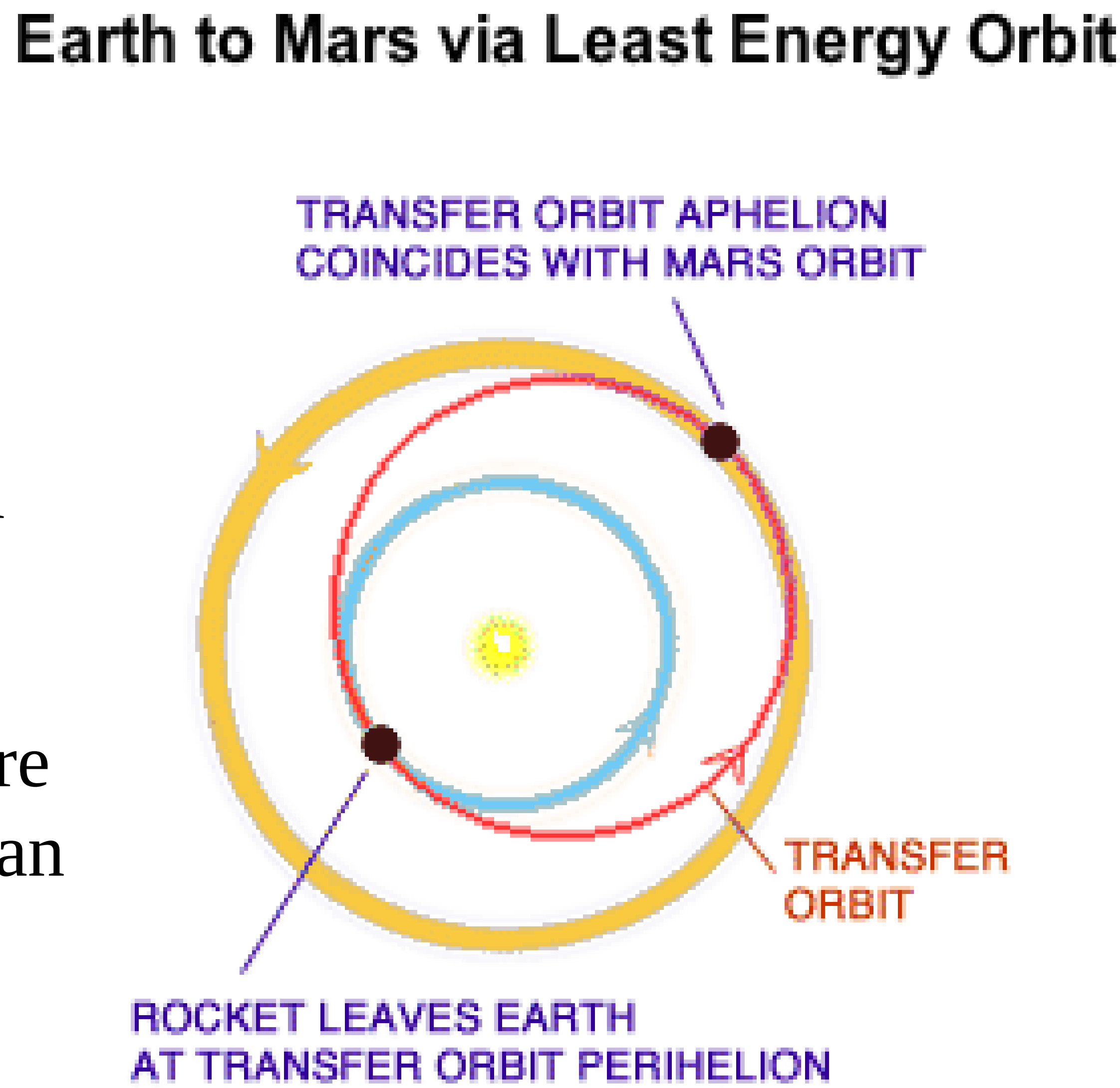
ASPERA DPU Phobos-2
ASPERA-3 / ESA Mars Express
ASPERA-4 / ESA Venus Express
Plasma Monitor & DPU / ESA SMART 1
ROSETTA Lander: Permittivity Probe, DPU Memory
ROSETTA : Cosima DPU SW, ICA DPU, Langmuir probe



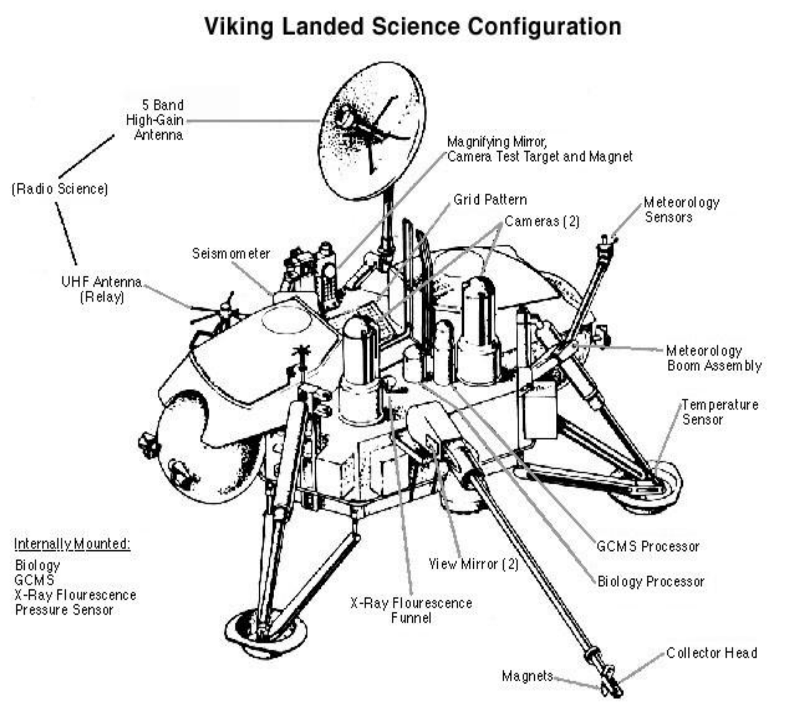
MISSION EARTH to MARS: Hohman transfer orbit

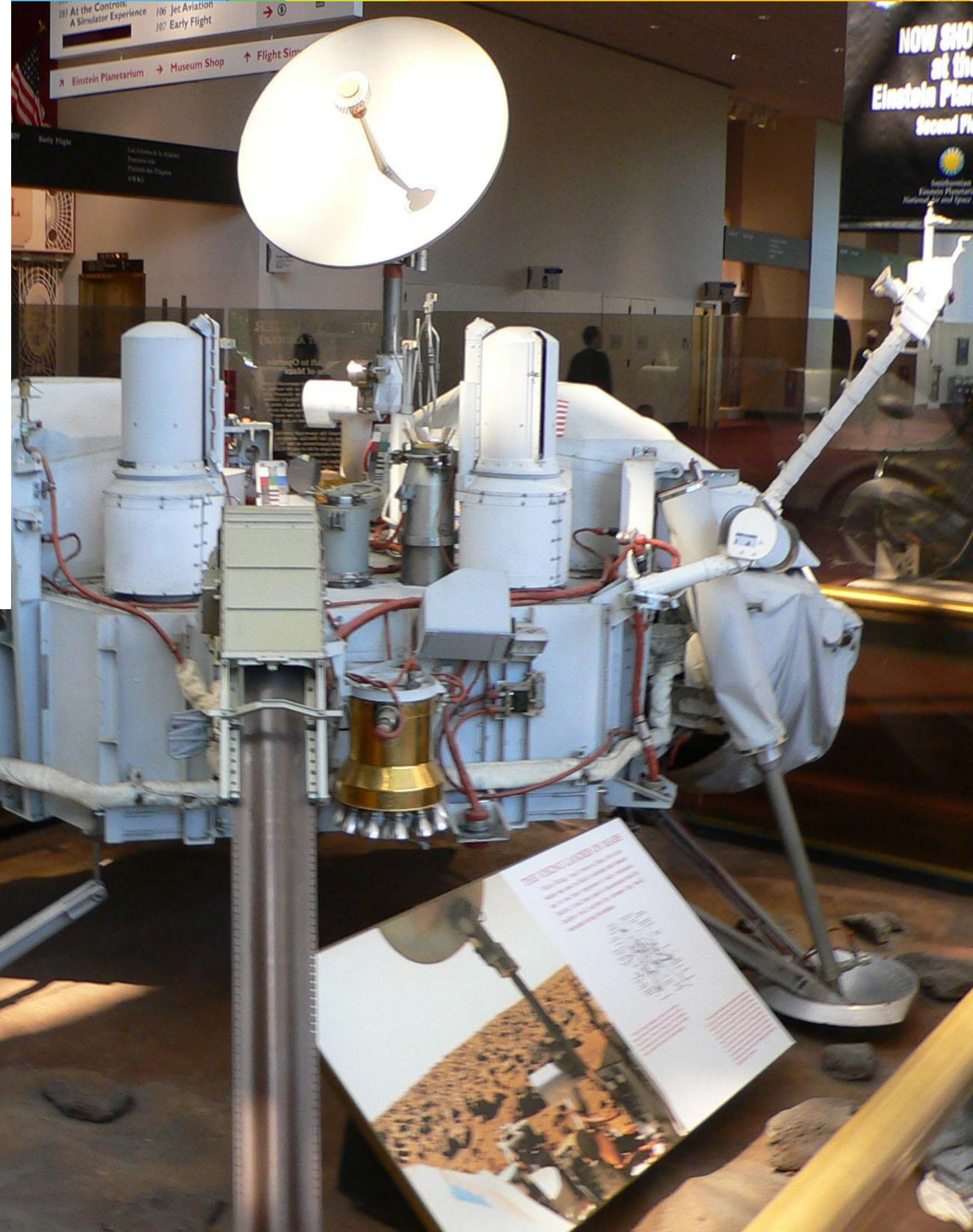
Orbit and Deployment

- Hohman transfer
- Deployment from the orbit around Mars
- Deployment before insertion to Martian orbit saves fuel



Viking Lander





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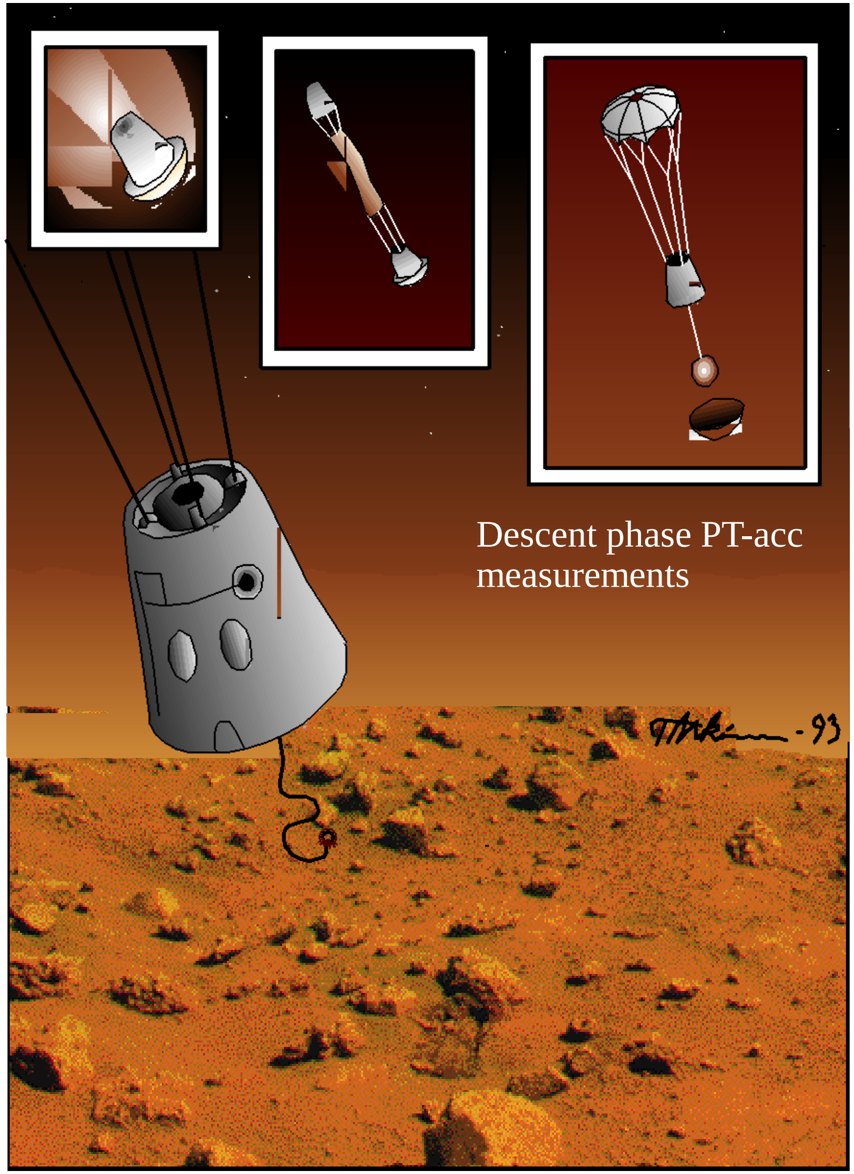
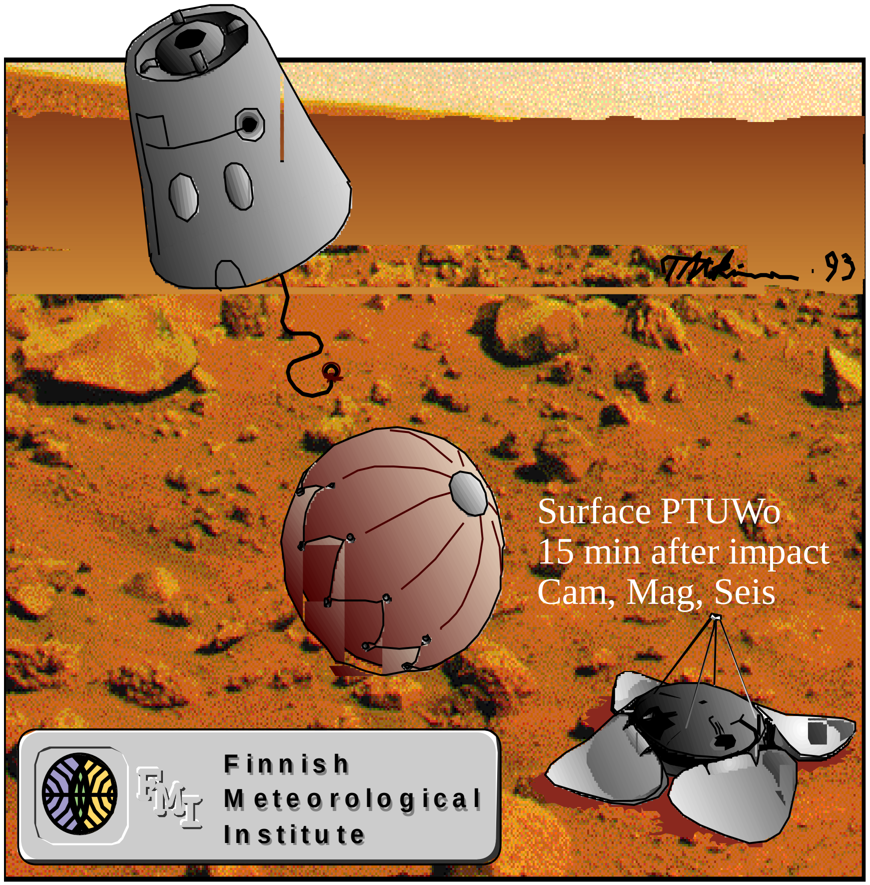
MARS-96 Mission: Small Stations





NASA's Mars Exploration Program

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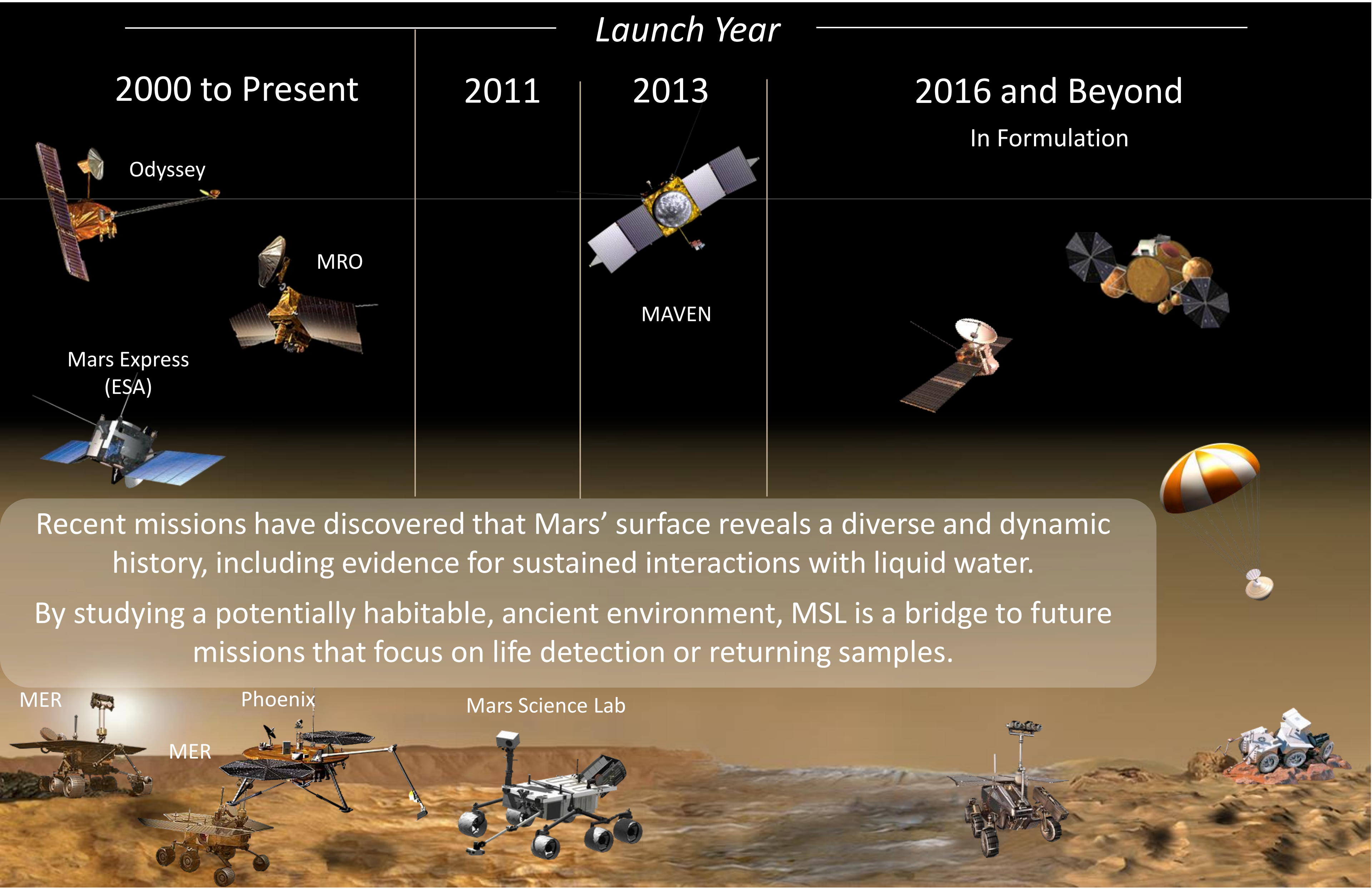
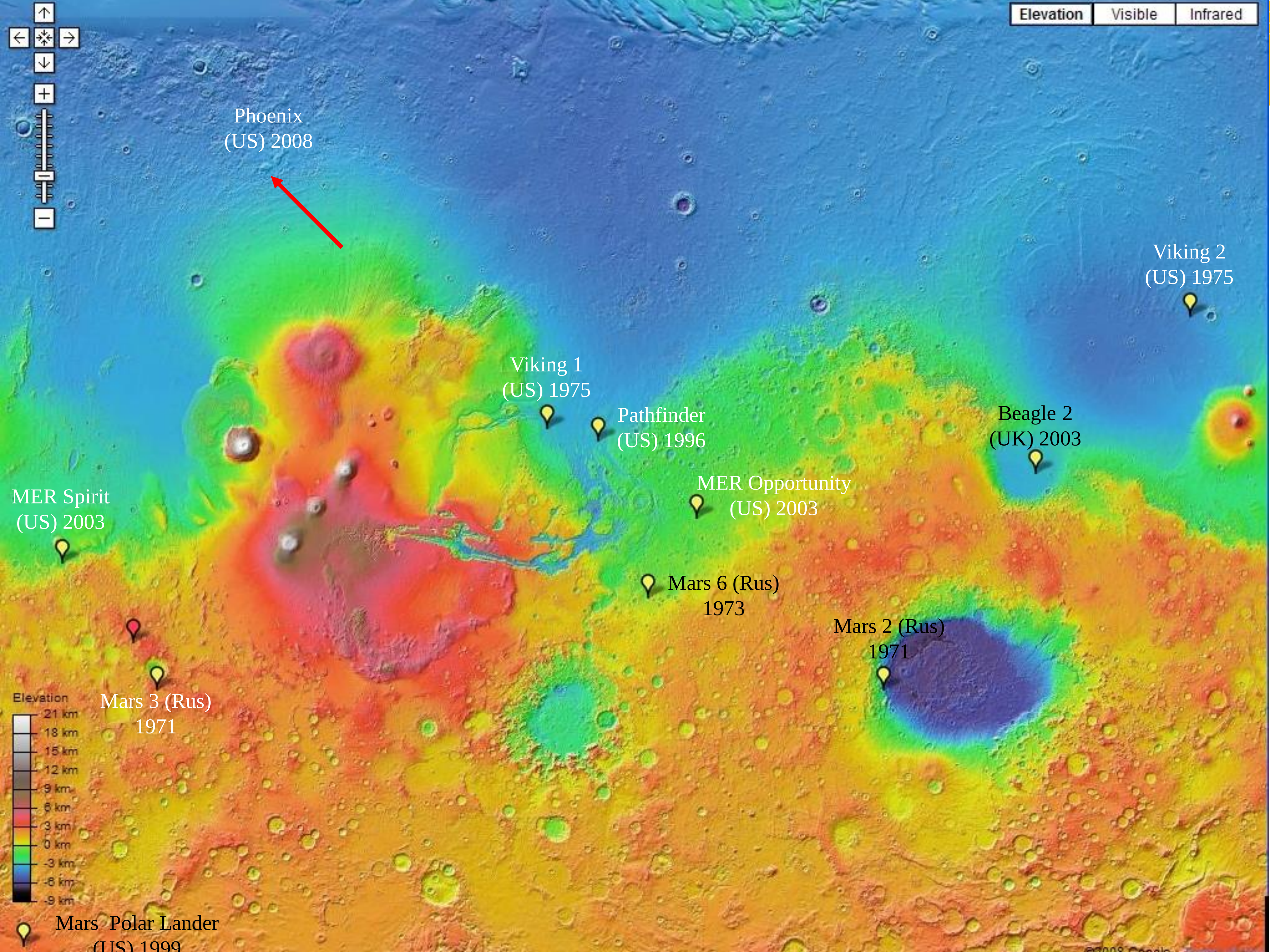


Recent missions have discovered that Mars' surface reveals a diverse and dynamic history, including evidence for sustained interactions with liquid water.

By studying a potentially habitable, ancient environment, MSL is a bridge to future missions that focus on life detection or returning samples.



Elevation
Visible
Infrared
Phoenix
(US) 2008
Viking 2
(US) 1975
Viking 1
(US) 1975
Pathfinder
(US) 1996
Beagle 2
(UK) 2003
MER Opportunity
(US) 2003
MER Spirit
(US) 2003
Mars 6 (Rus)
1973
Mars 2 (Rus)
1971
Mars 3 (Rus)
1971
Elevation
21 km
18 km
15 km
12 km
9 km
6 km
3 km
0 km
-3 km
-6 km
-9 km
Mars Polar Lander
(US) 1999

Surface Pressure

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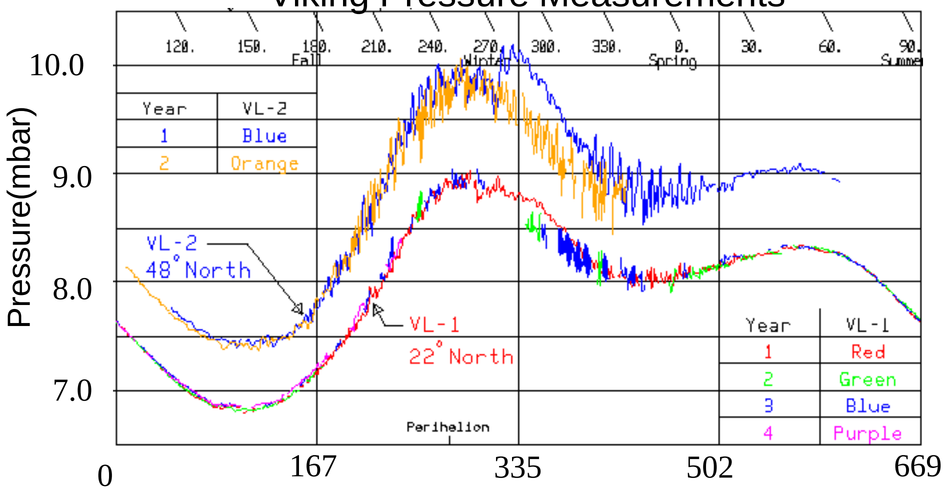
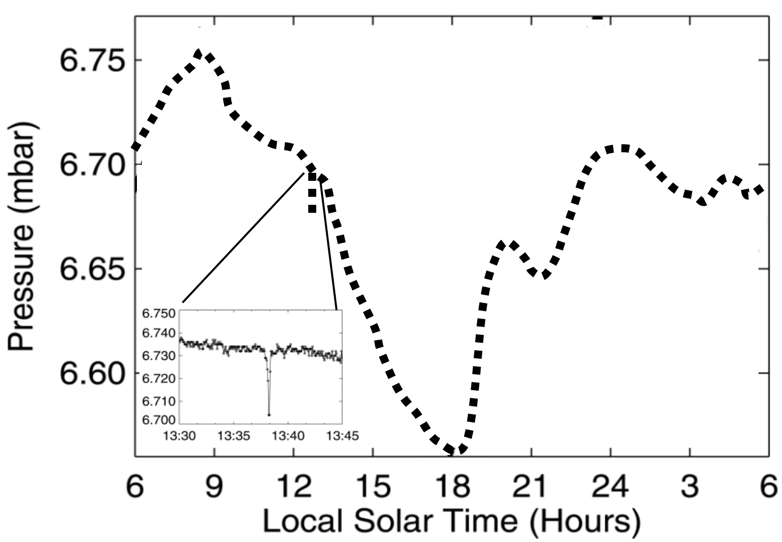
Surface pressure varies on a variety of time scales:

- **The annual CO_2 condensation cycle produces global-scale >25% variations in surface pressure**
- **Episodic large scale dust storms produce >5% pressure changes**
- **Weather fronts produce pressure variations on time scales that vary from hours to weeks**
- **Thermal tides produce a few % variations over the diurnal cycle**
- **Dust devils produce changes on 10…60s time scales**
- **Kelvin waves, and other large-scale phenomena can be monitored with high-resolution pressure data**

Viking Pressure Measurements

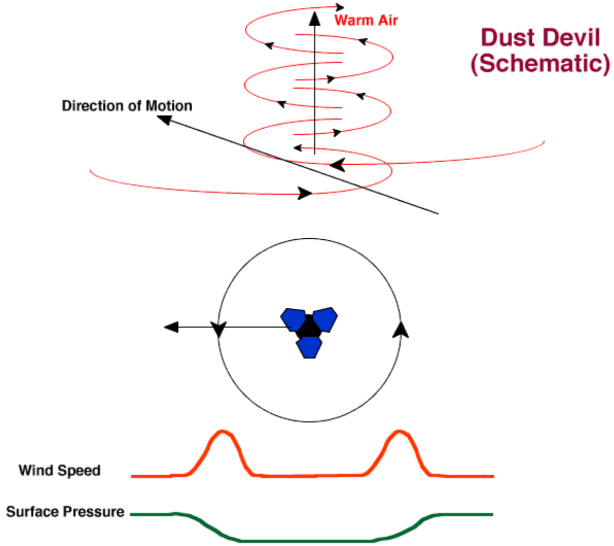


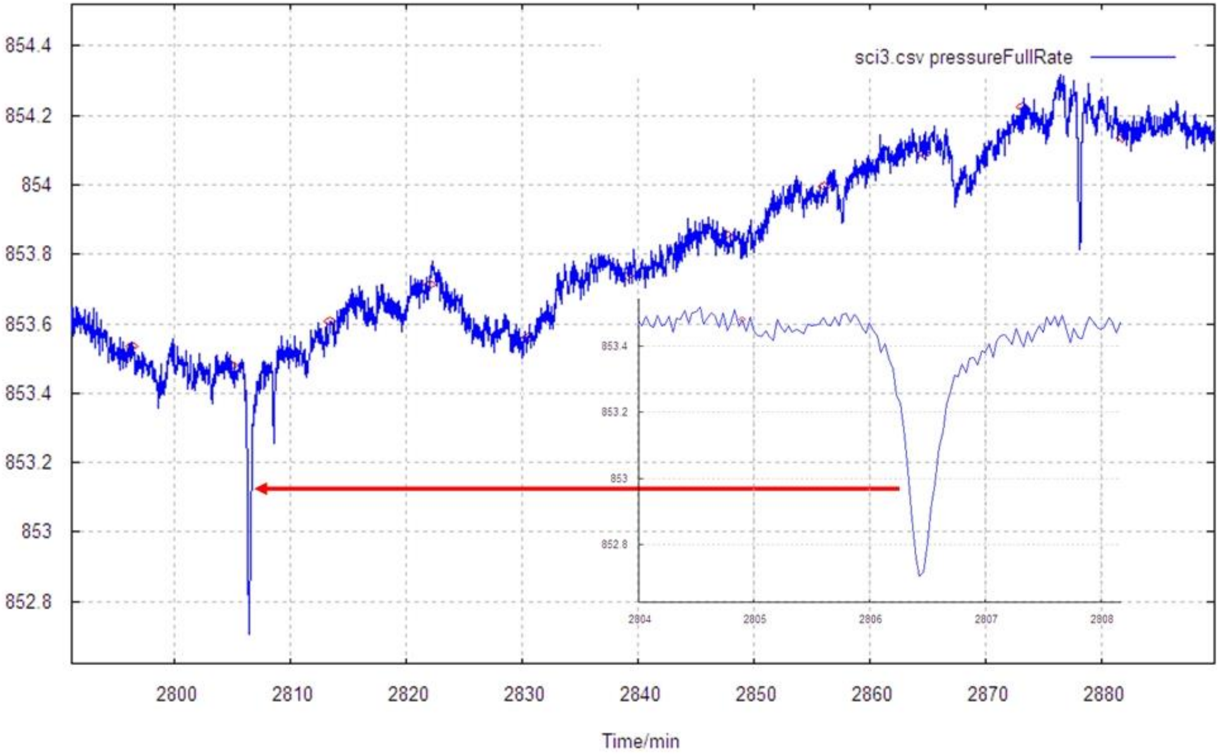
Daily variation and dust devil (MPF)



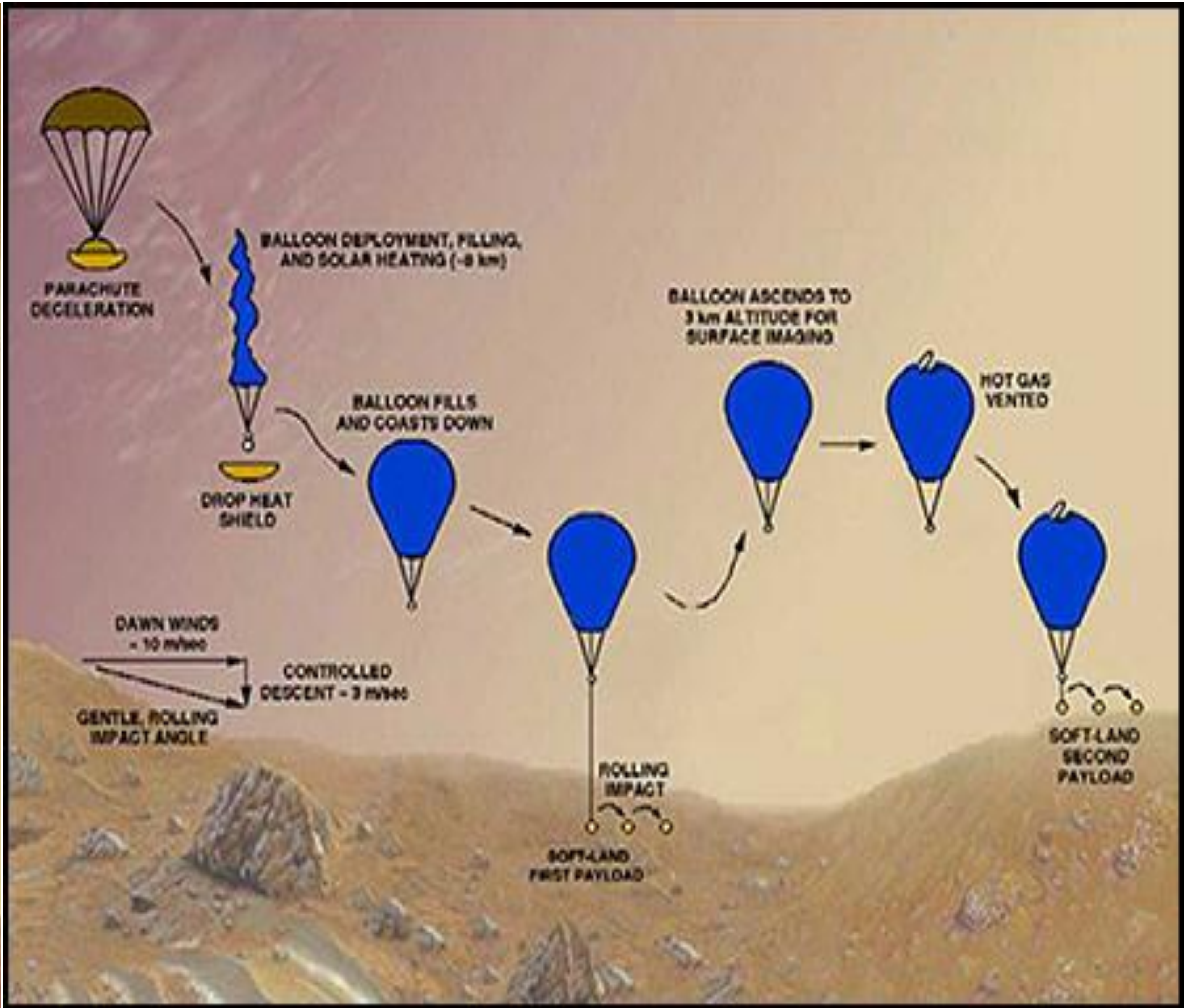
Dust Devils at Mars

- A Martian dust devil recorded by the Mars Phoenix lander
- Typical pressure drop between 1 to 5 Pa





Balloons at Mars: Proposals



MarsPlane

CURIOSITY
Mars
Science
Laboratory

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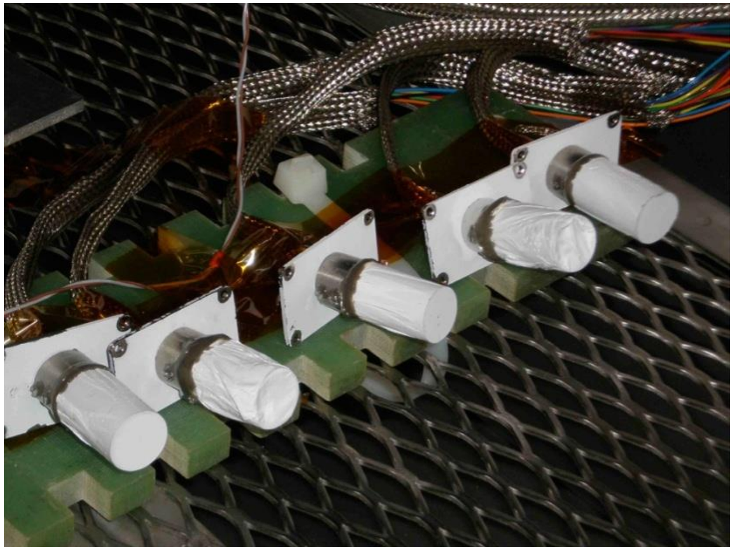
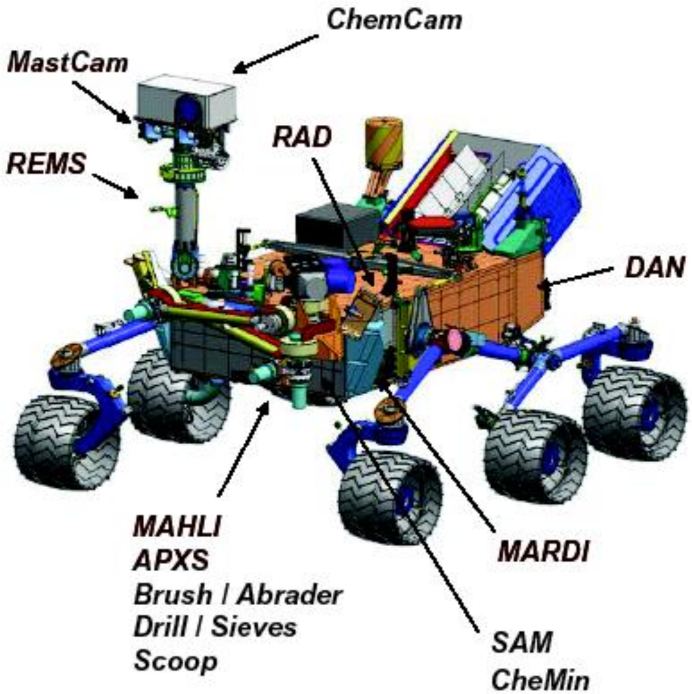
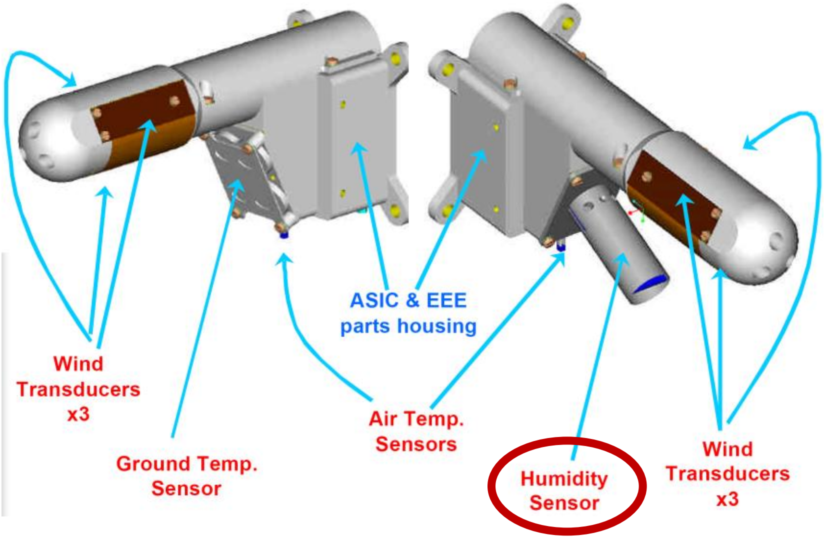
REMS-H Humidity Instrument

REMS-H is located in Boom 2 of the Curiosity rover and therefore under large temperature oscillations. Validation technology tests carried out to assure no degradation along its operational life.







B. Haberle: “The Heartbeat of the Climate System”

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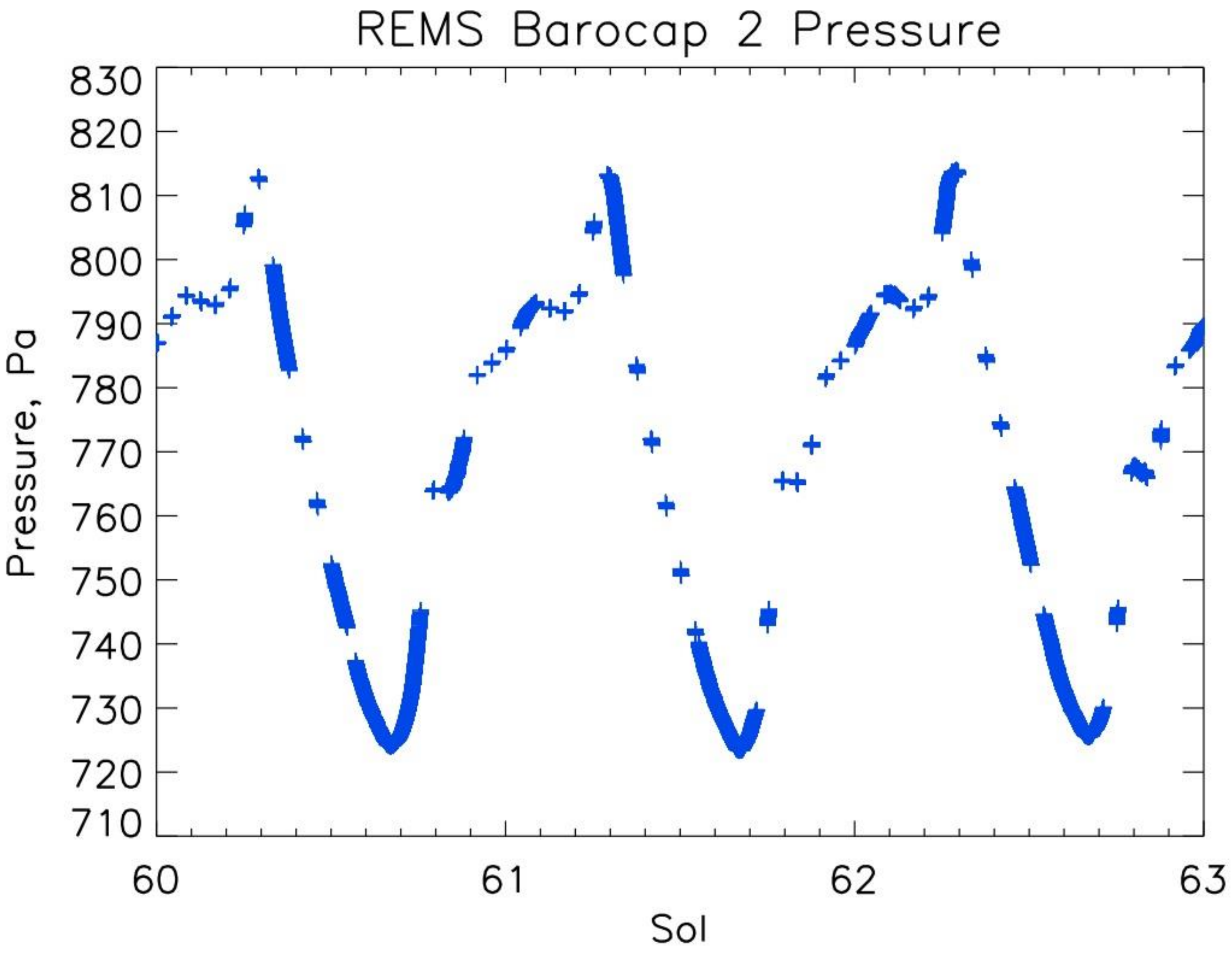
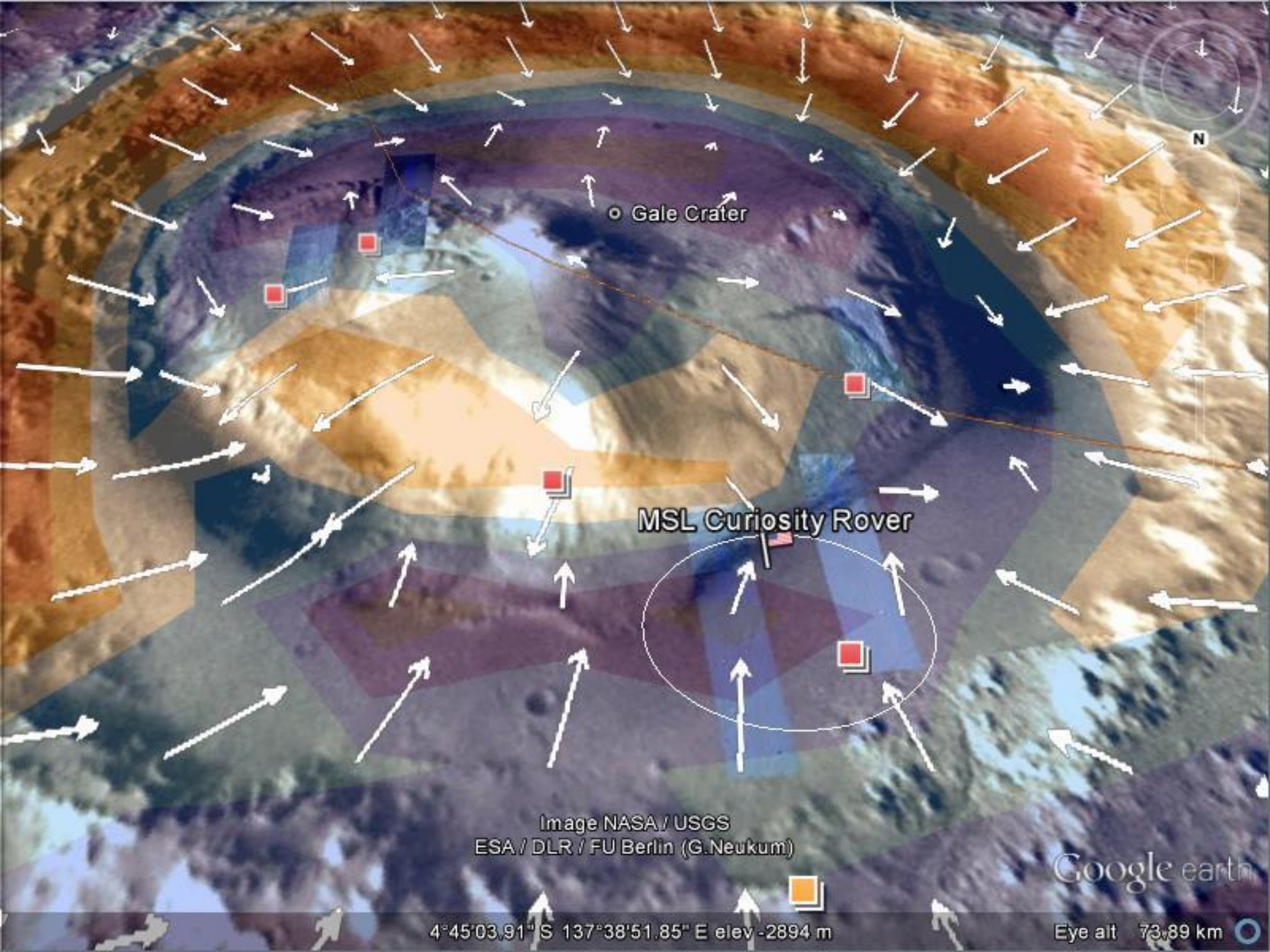


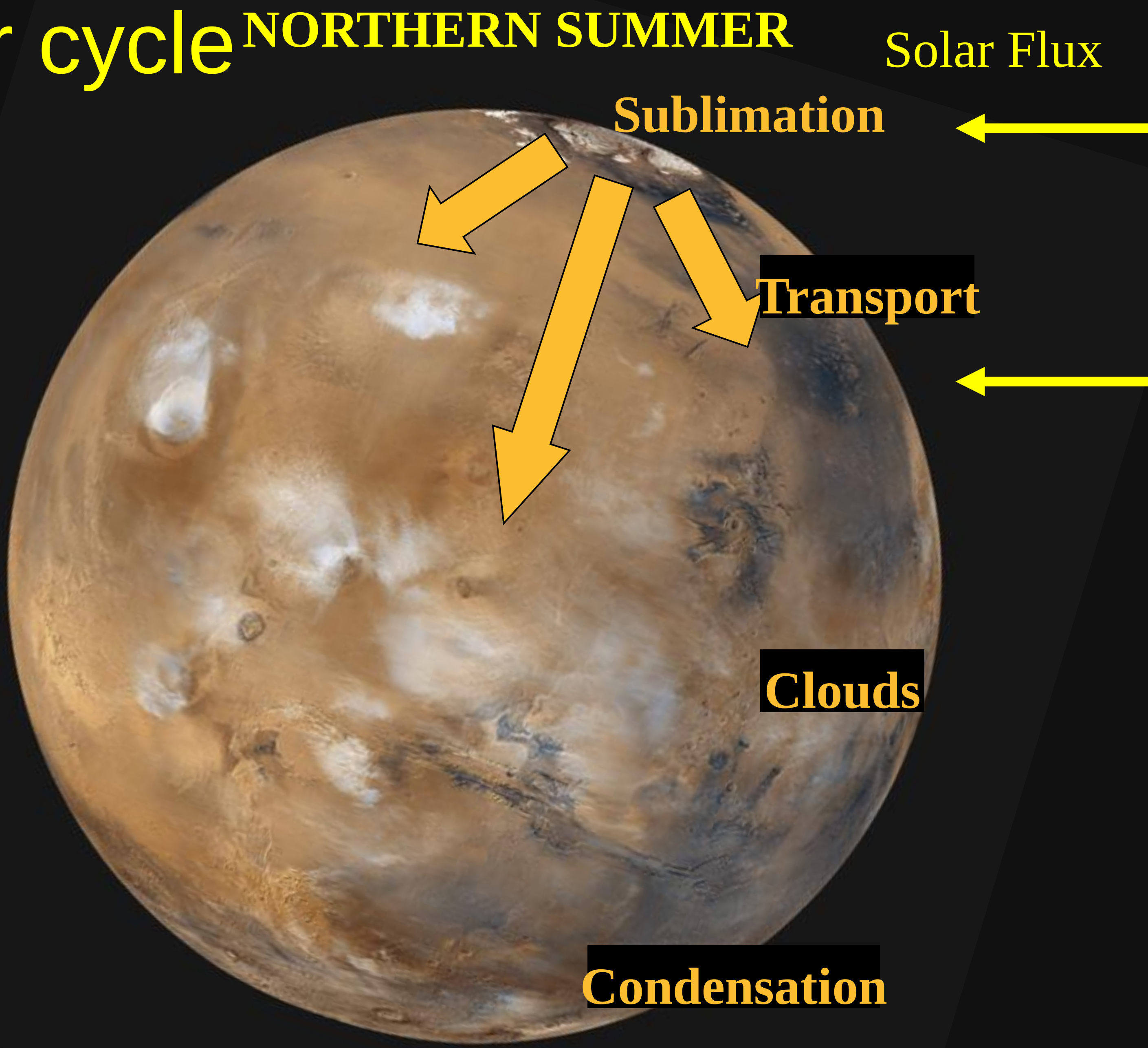
Its Alive, Its Alive!!!

MARS LIMITED AREA MODEL (MLAM & 1D / 2D)

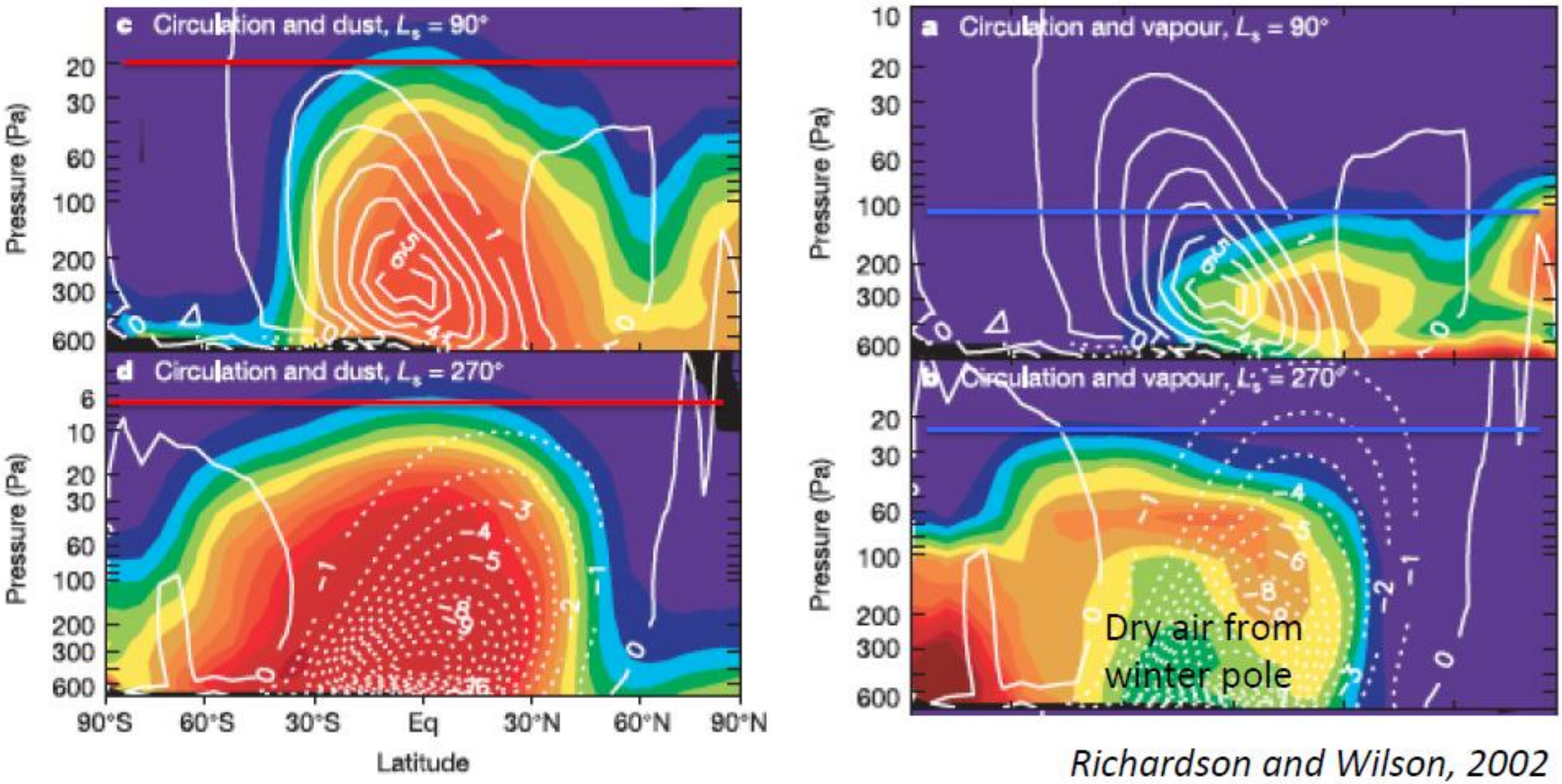
- **HIRLAM (5.0.0) transferred to Mars (UH & FMI)**
- **Hydrostatic primitive eqs (dry, rad. & surface schemes for Mars)**
- **Used successively to simulate several Mars missions (landing) weather**
- **MSL landind weather forecast 2012 :**
  - UKMGCM boundaries
  - MY 26
  - Last TES-assimilated GCM-data year
- **3 simulations, base and 2 nestings**
- **36 sols simulation, 30 after the landing**
- **Predicting quite calm landing weather**


Gale Crater
MSL Curiosity Rover
N
Image NASA / USGS
ESA / DLR / FU Berlin (G.Neukum)
Google earth
4°45'03.91" S 137°38'51.85" E elev -2894 m
Eye alt 73.89 km

Mars water cycle

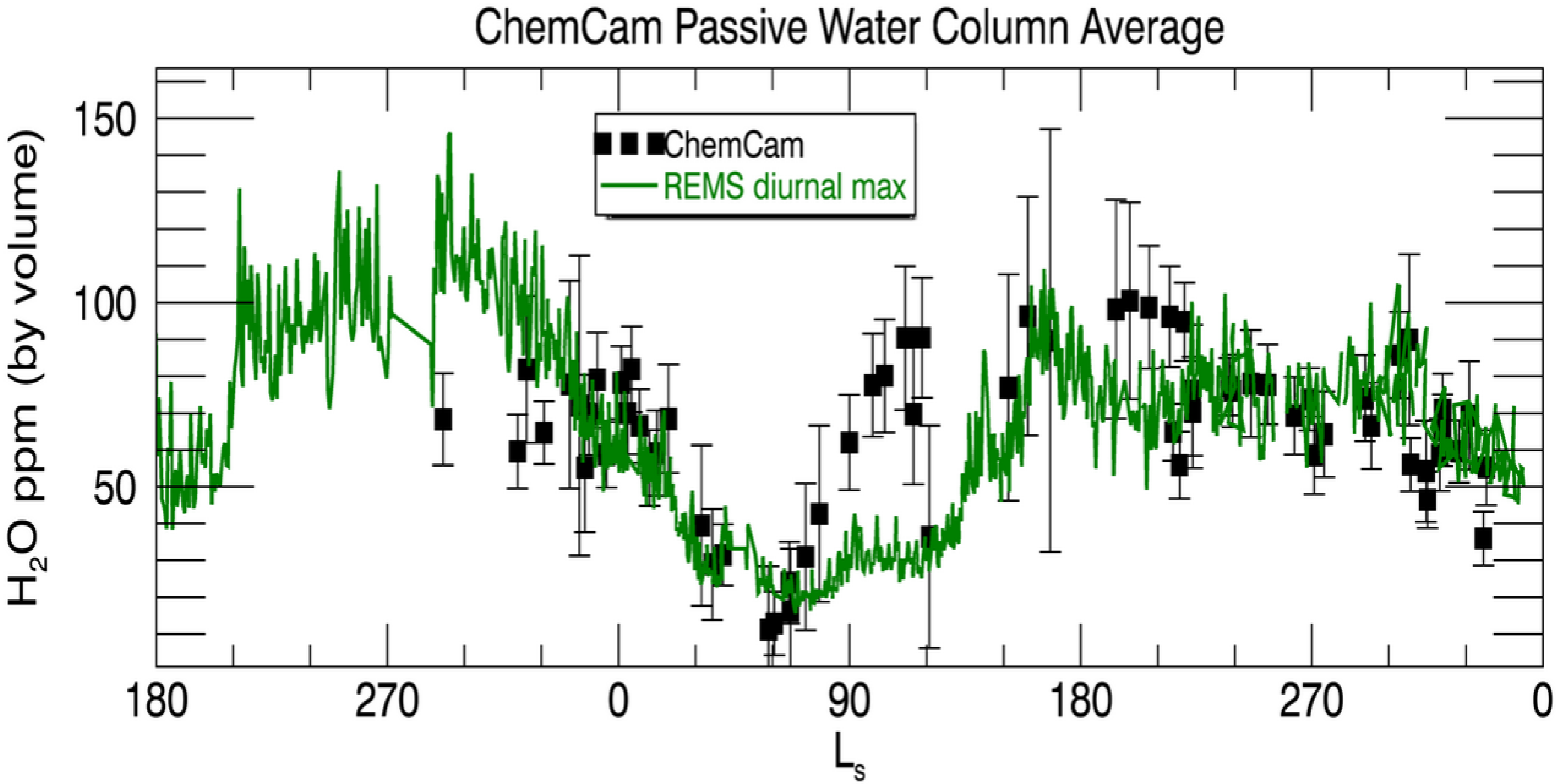


GCM: Circulation of water vapor (and dust)

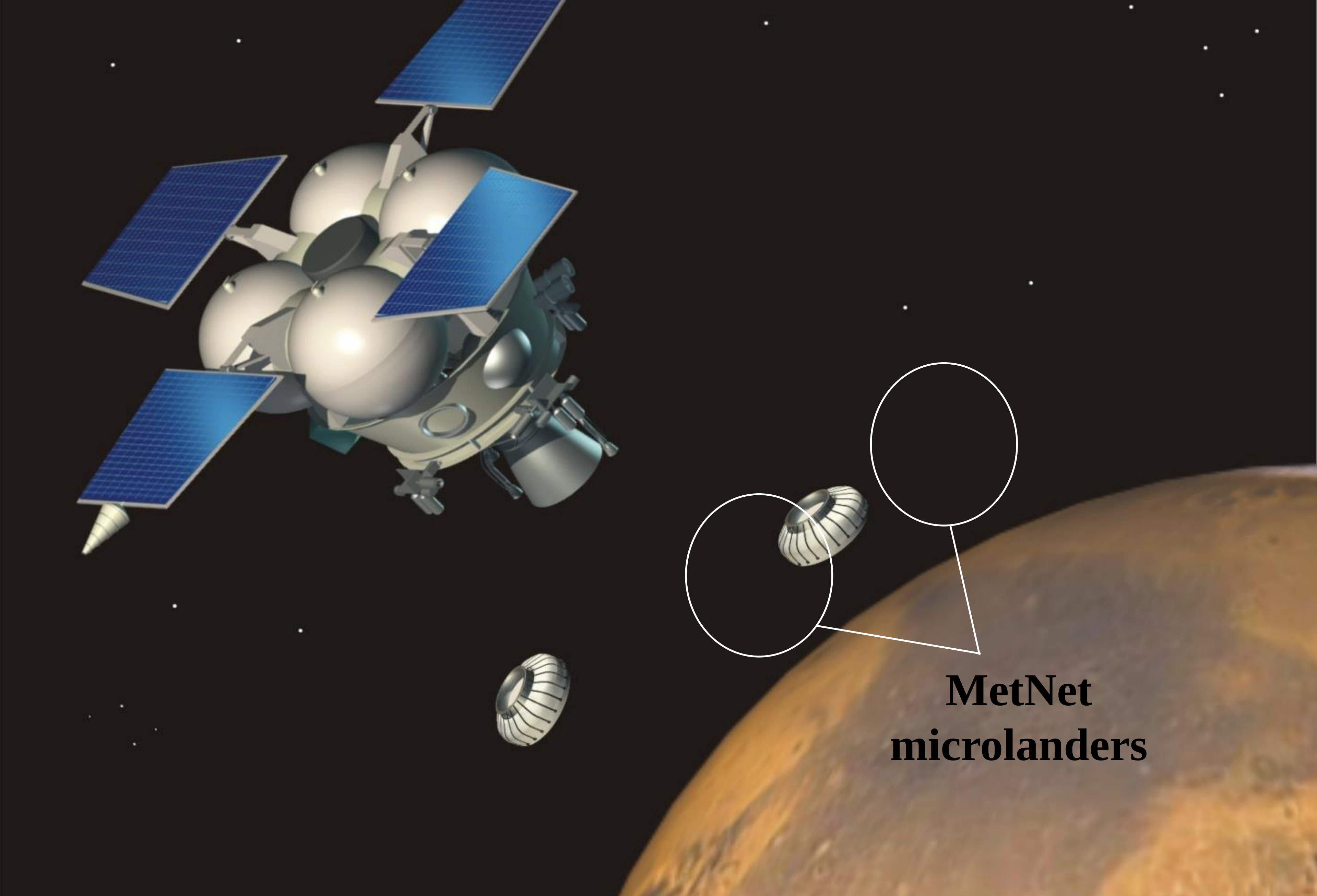


Richardson and Wilson, 2002

ChemCAM & REMS-H



Mars MetNet Mission



MetNet

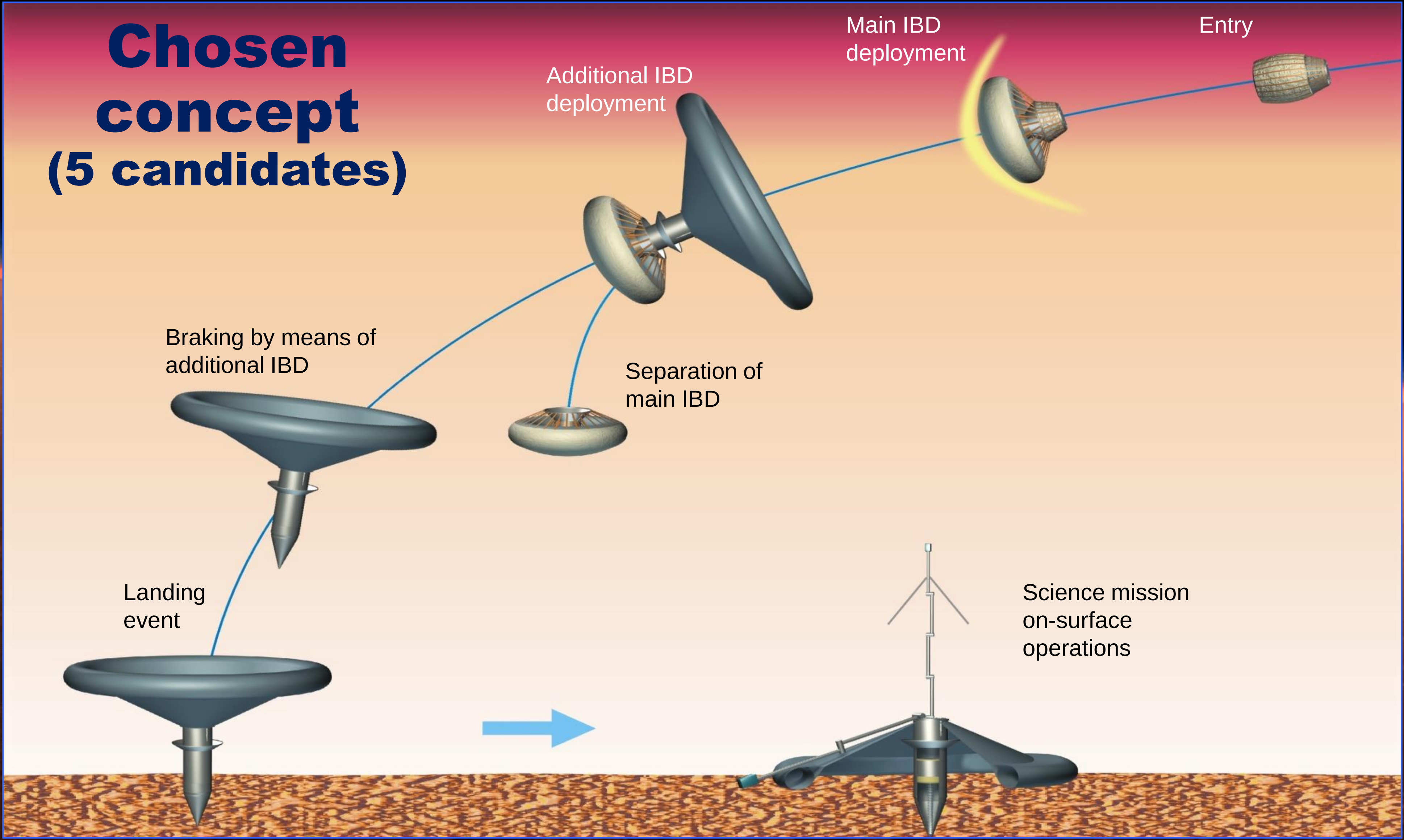
Atmospheric science network for Mars

Finnish Meteorological Institute, Finland
Lavochkin Association, Russia
Russian Space Research Institute, Russia
Instituto Nacional de Técnica Aeroespacial, Spain

Dr. Ari-Matti Harri, Mission Lead
ari-matti.harri@fmi.fi

MetNet – Mission For Mars

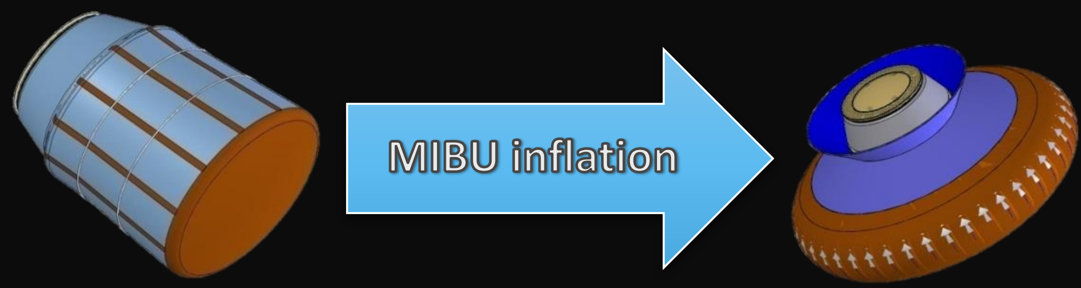
Chosen concept (5 candidates)



Mars MetNet Lander

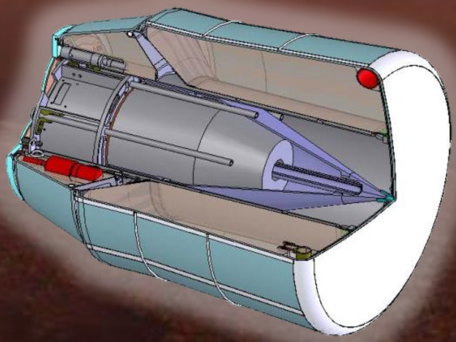
Finnish Meteorological Institute
Russian Space Research Institute
Lavochkin Association, Russia
INTA, Spain

METNET
The Next Generation Lander Mission
For Martian Atmospheric Science



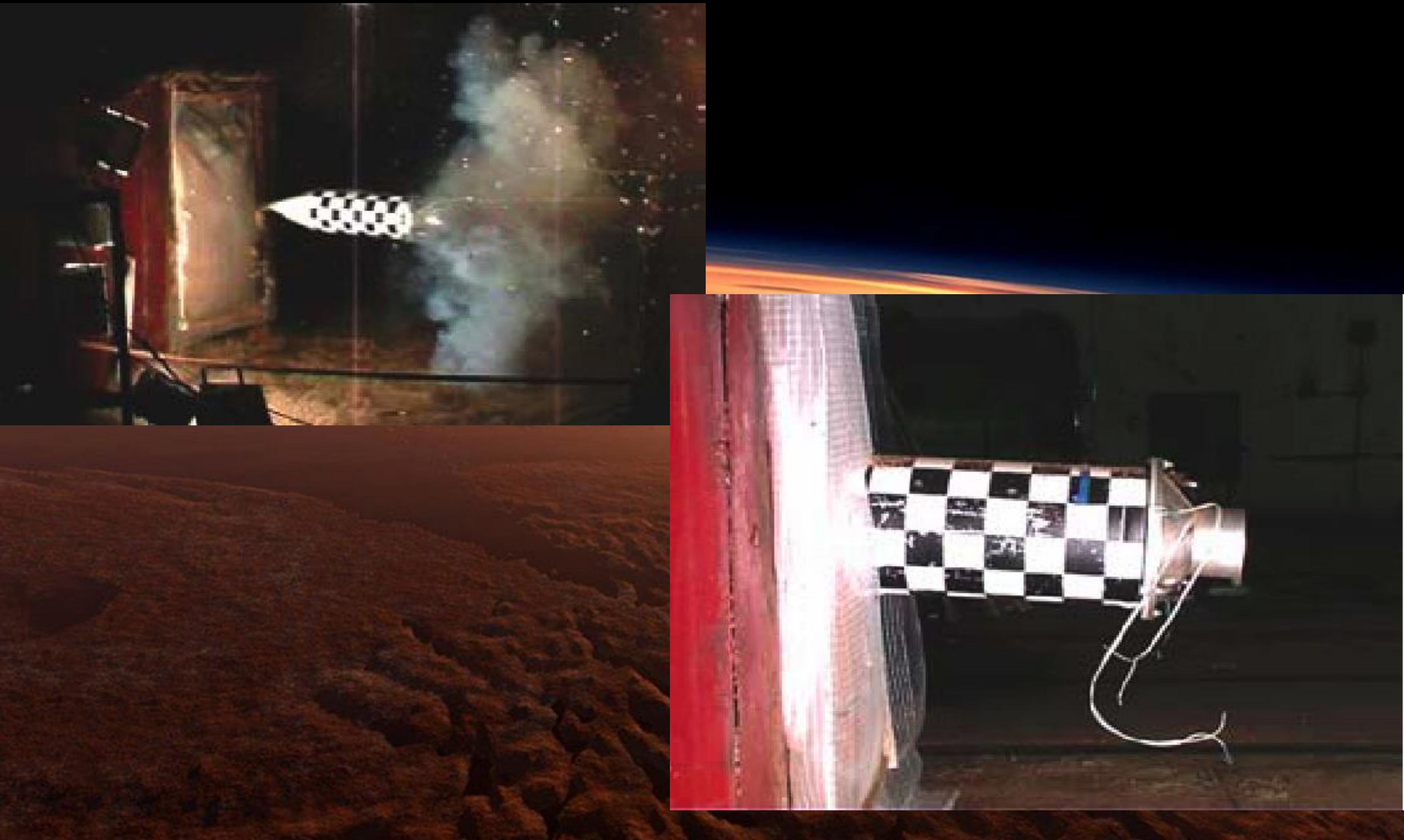
Main Parameters of the MetNet Lander

PARAMETER	VALUE
Vehicle mass	22.2 kg
Payload mass	4.0 kg
Landing speed	55.4 m/s
Diameter of MIBU	1m
Diameter of AIBU	2m

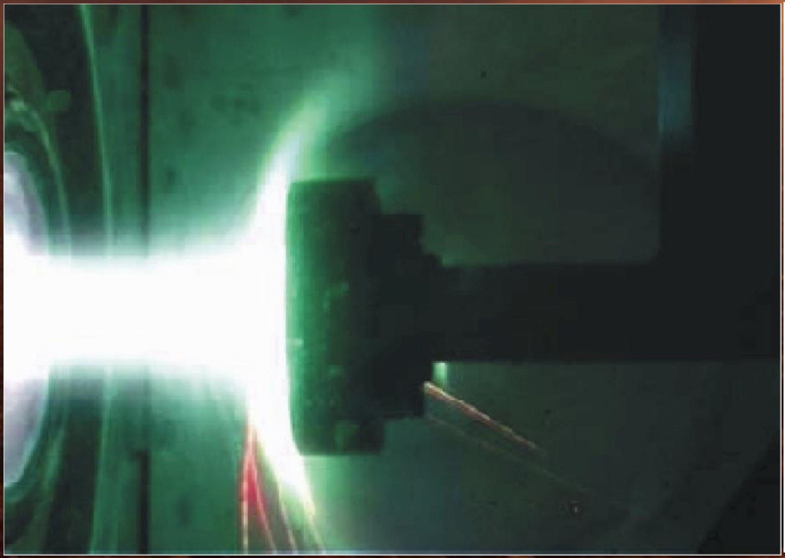


metnet.fmi.fi

MetNet – Mission For Mars



Thermal protection system tests



Low altitude drop test

Event	Time of test cyclogram, sec	Real time, sec	Note
Timer activation	0	0	Standard Moscow time 17h 25 min
Separation from the carrier	5-10	7.8	
AIBD deployment	25	25.0	
AIBD inflation system activation, start of AIBD inflation	27	27.0	
Stop of AIBD inflation, cutting of tube and AIBD inflation system pyro-cartridge cable	127	127.0	
Cutting of front shield connections, front shield separation	130	130.0	
Front shield lowering	-	133.2	
Landing	191	182.8	

MMPM Mass budget

MMPM Mass		Kg
EDLS		12.0
Landing Module		13.2
Lander body	9.2	
P/L Module	4	
Total Entry Mass		22.2

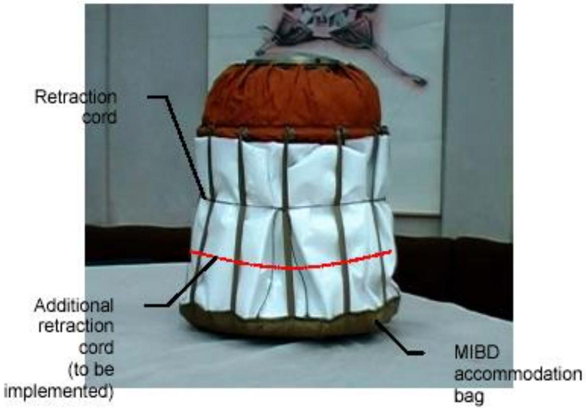


Figure 3-5 MML prototype (folded)


Figure 3-6 MIBD is being inflated

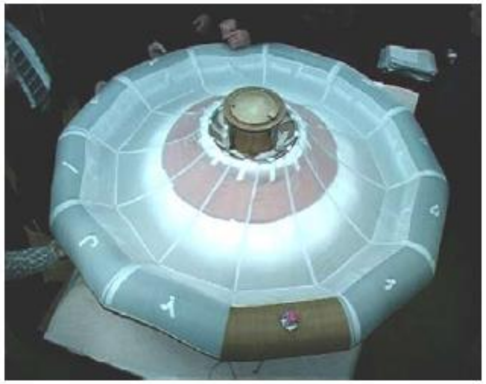
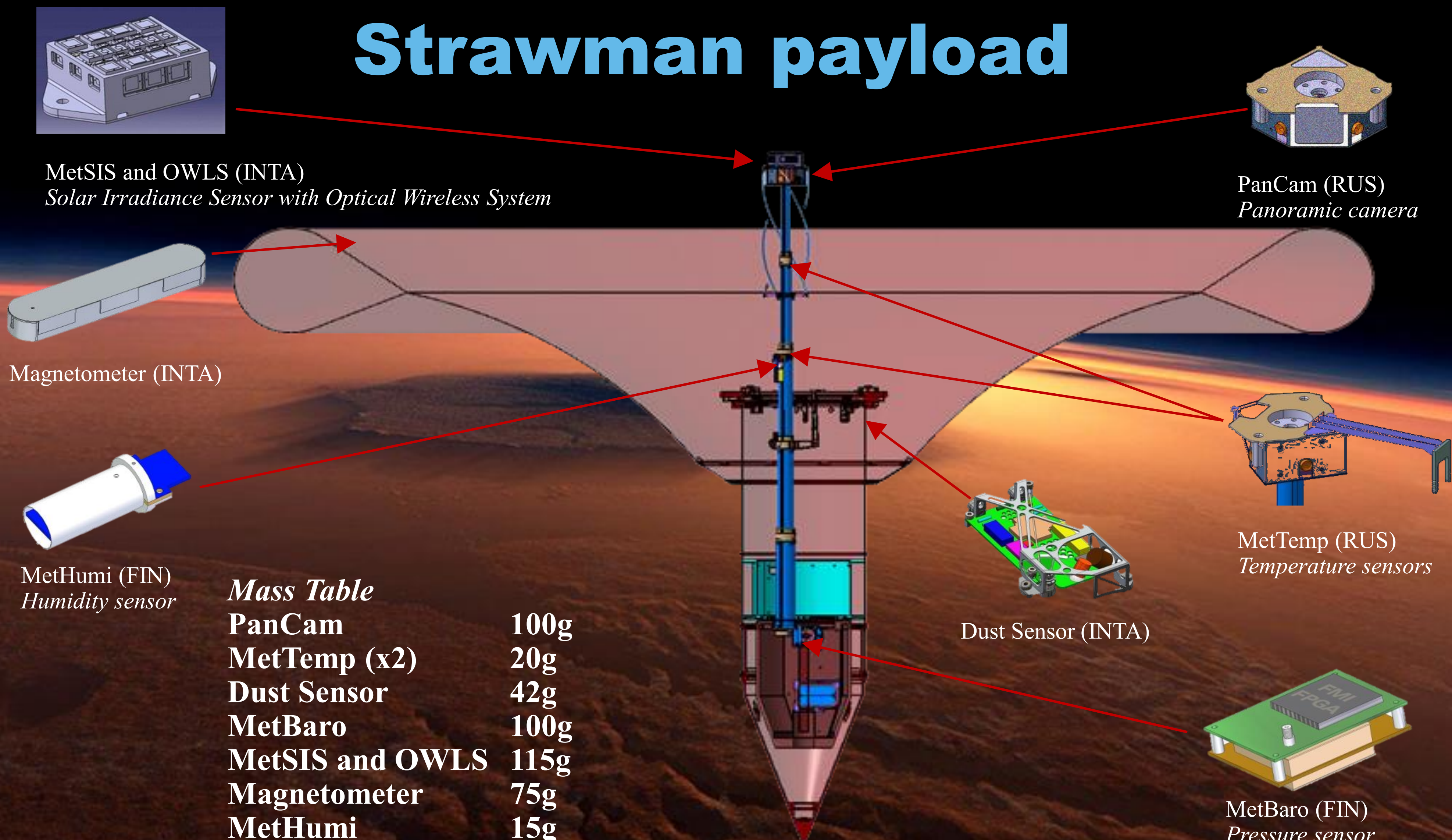


Figure 3-7 MIBD and AIBD fully inflated


Figure 3-8 MML's landing configuration

Strawman payload

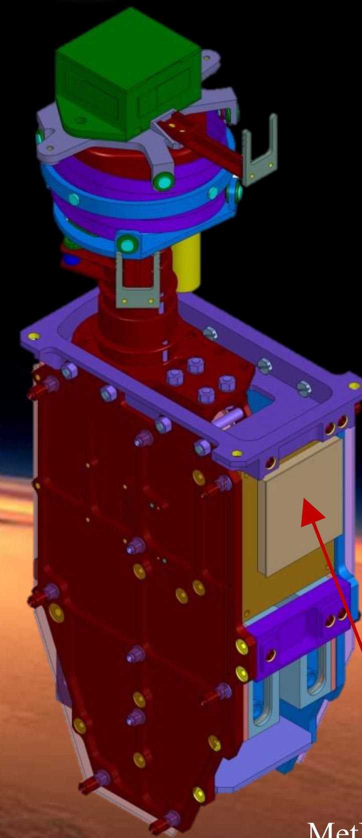


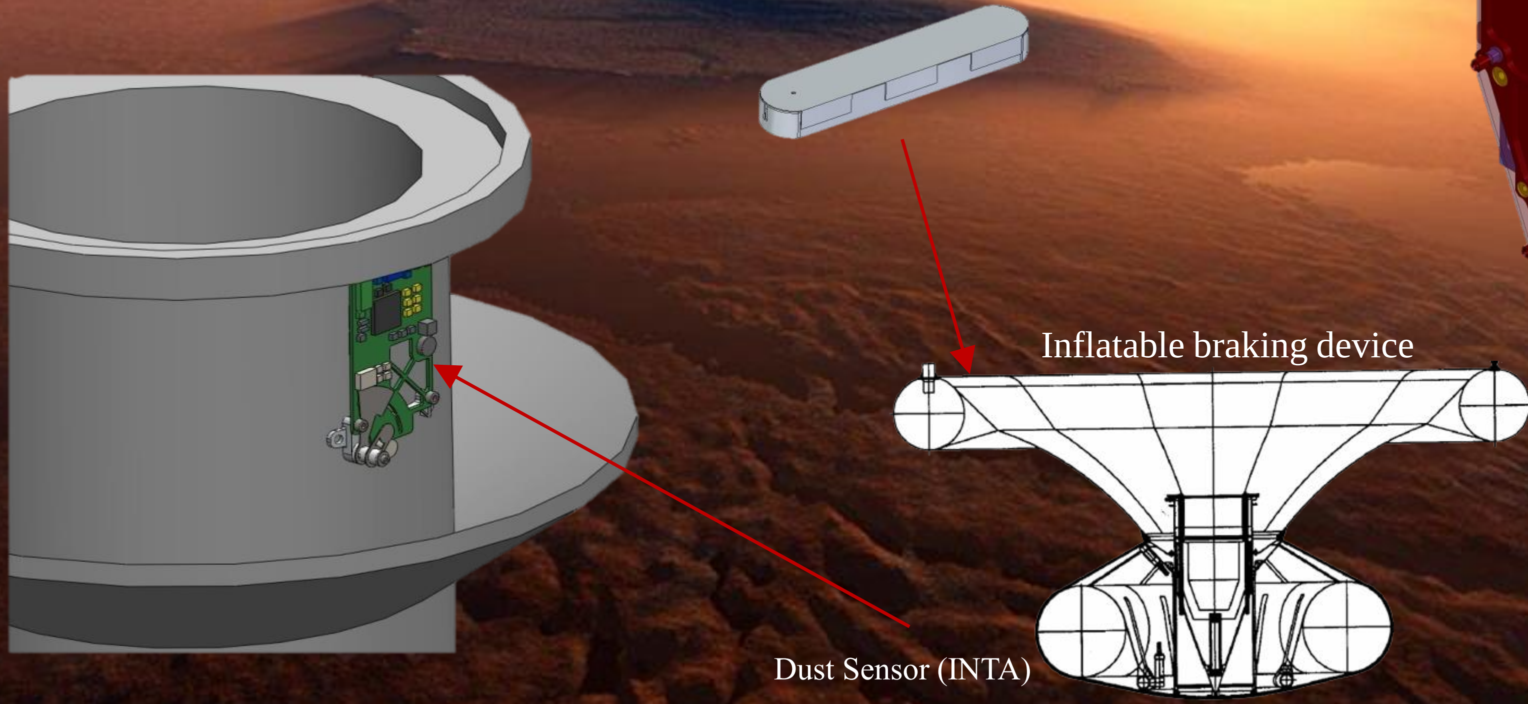
Mass Table

PanCam	**100g**
MetTemp (x2)	**20g**
Dust Sensor	**42g**
MetBaro	**100g**
MetSIS and OWLS	**115g**
Magnetometer	**75g**
MetHumi	**15g**
Instrument reserve	**42g**
Total	**509g**

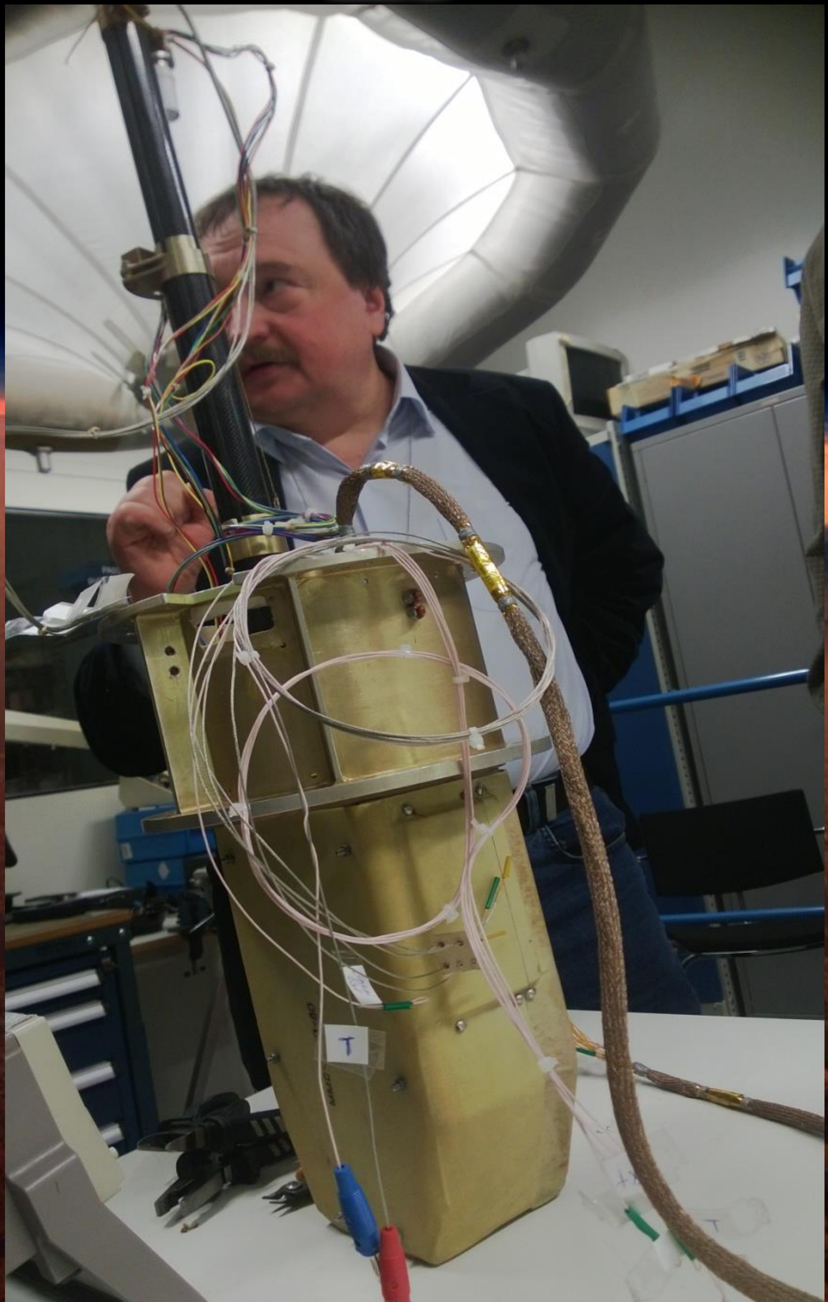
MetNet – Mission For Mars

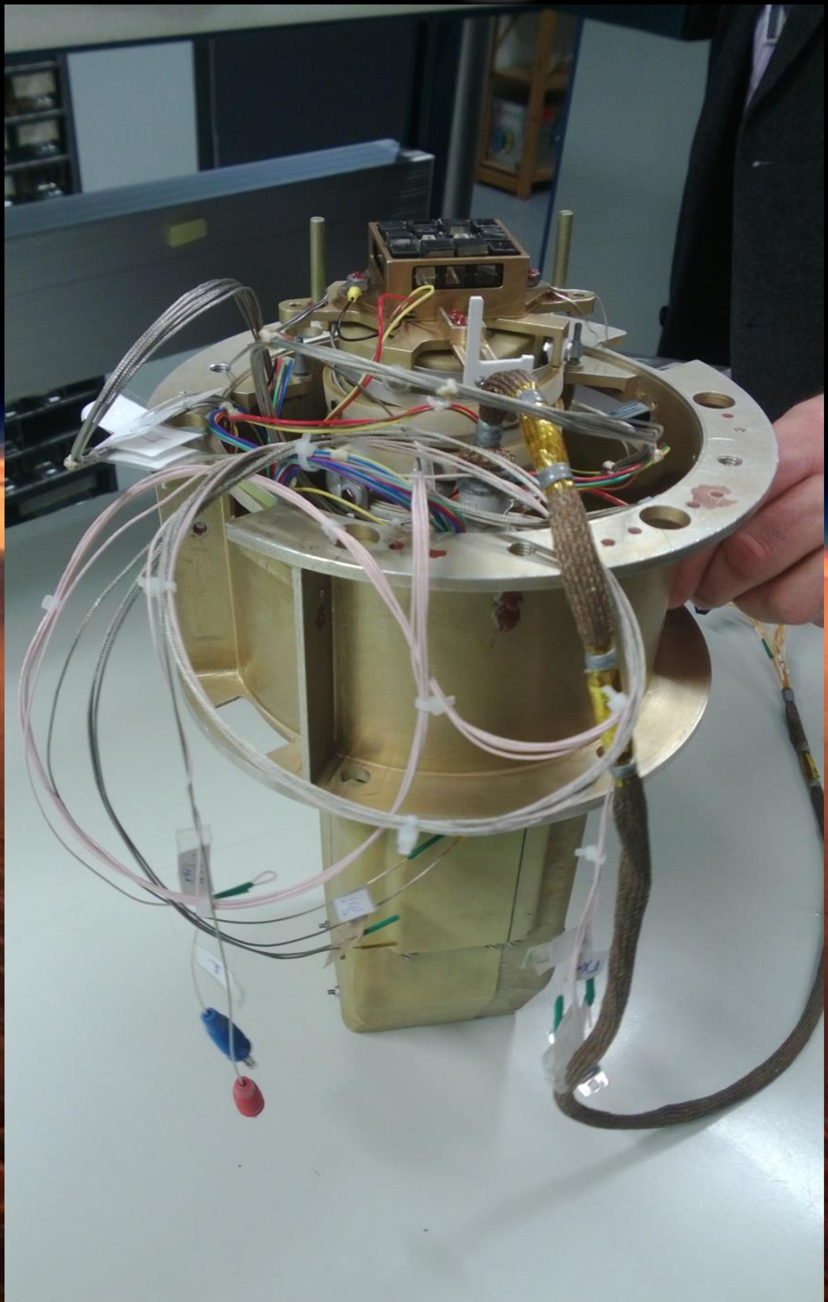
- MetBaro Pressure sensor is located inside he MNL payload bay
- The magnetometer and dust sensor, are located in the payload bay inside the MNL.
    - DS is mounted on the frame of the MNL
    - MAG is mounted on the inflatable braking device



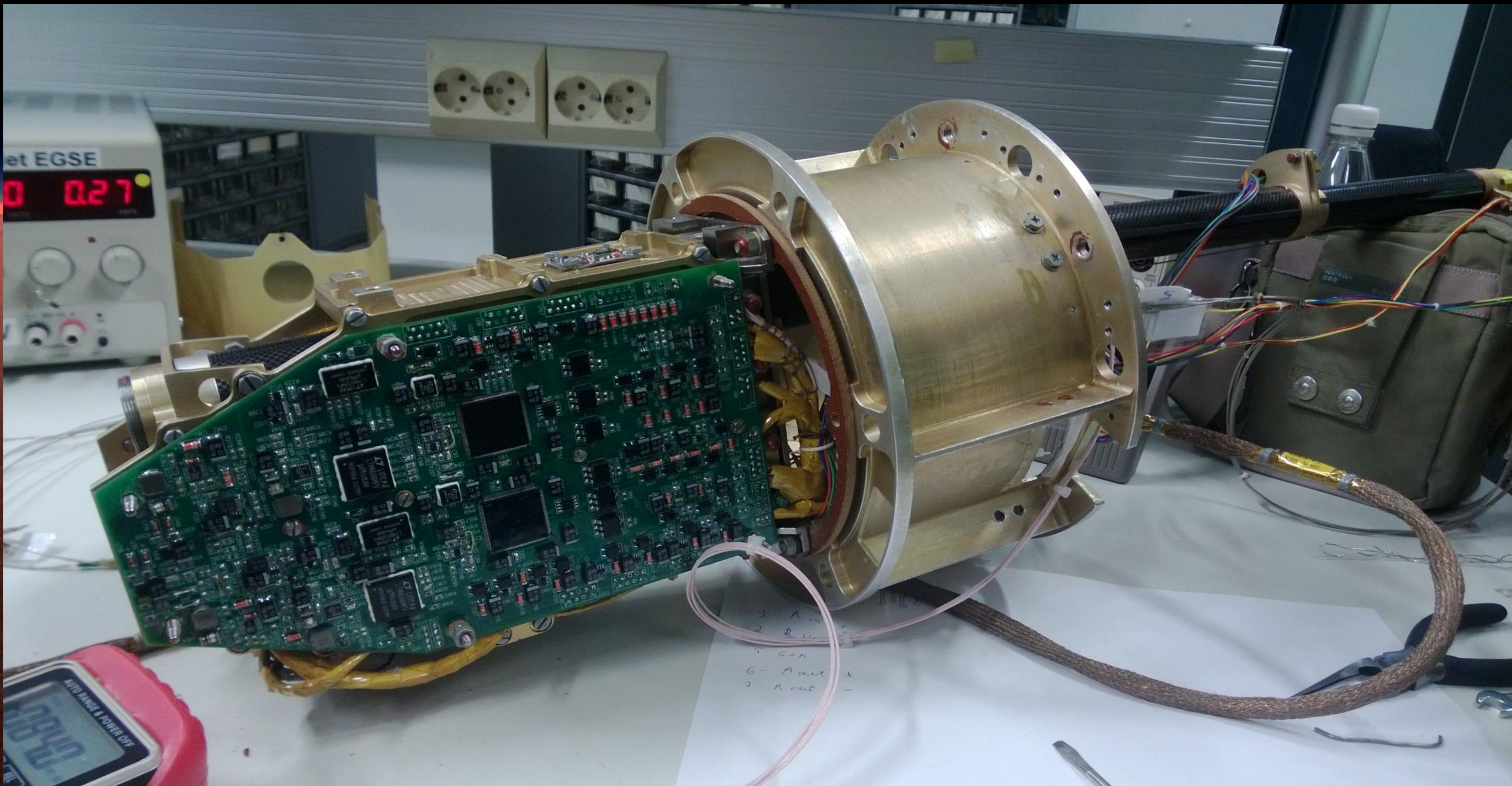


MetNet – Mission For Mars

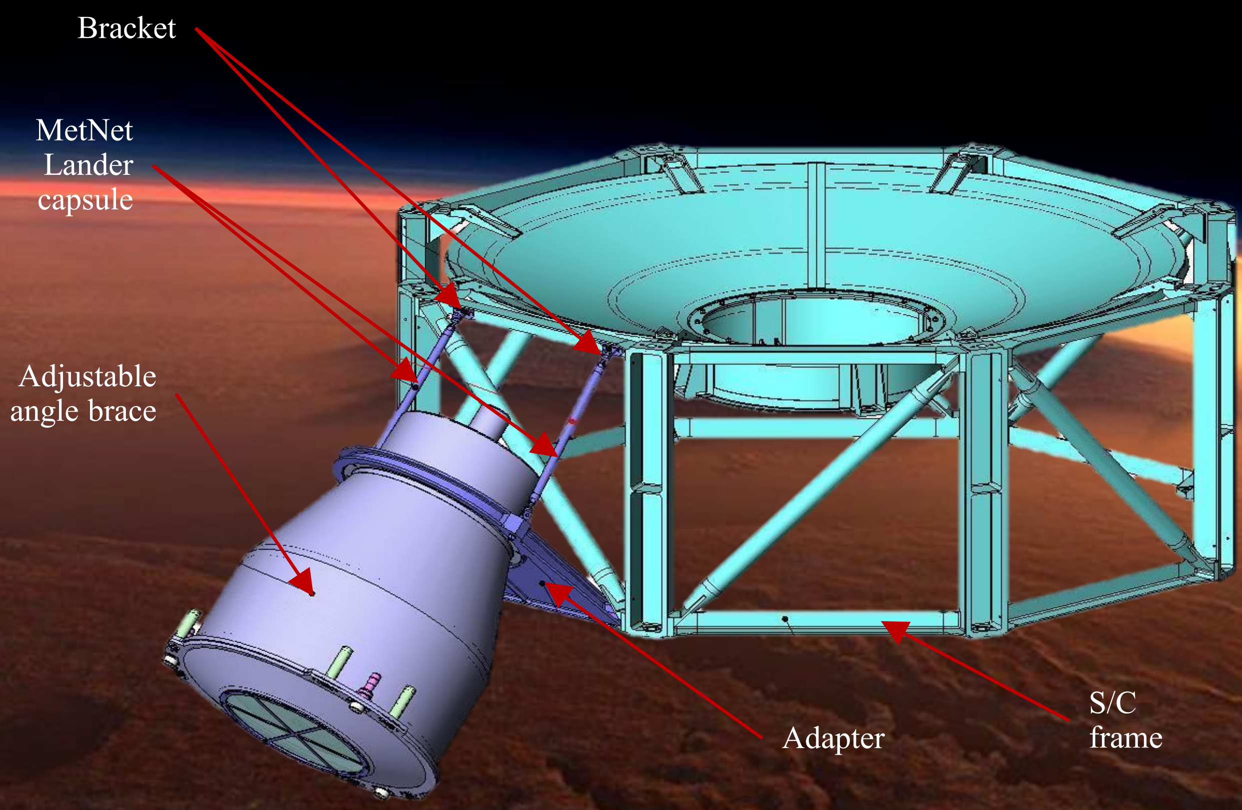




MetNet – Mission For Mars



Mounting the MetNet Lander on S/C

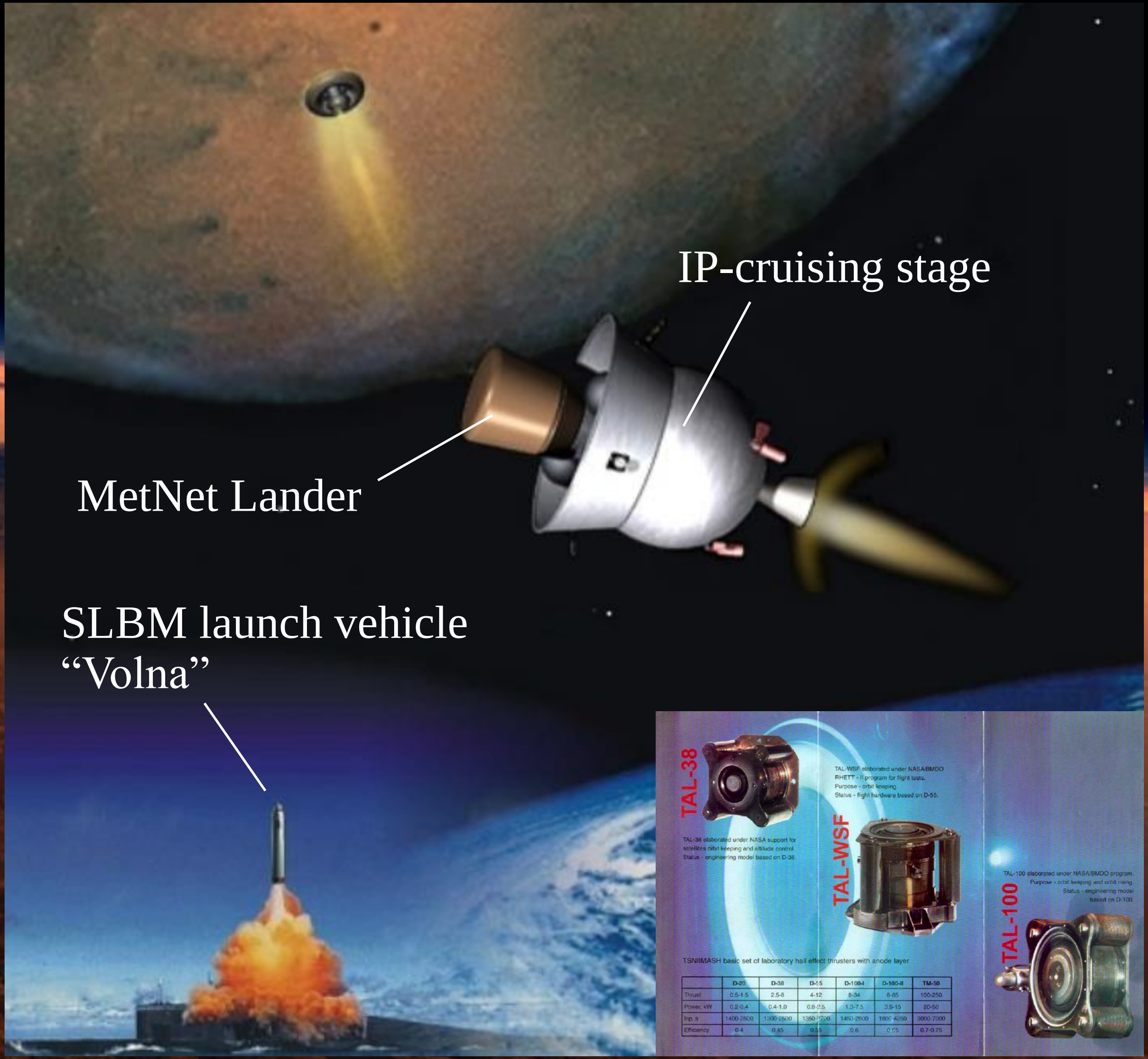


Estimated mass budget of MNL capsule assembly

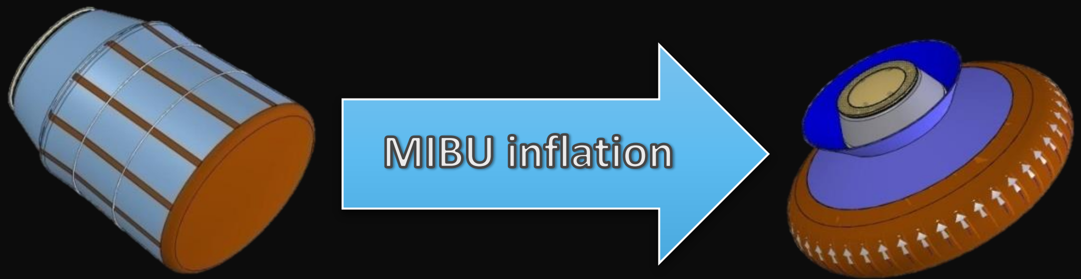
Name	Mass, kg
MNL capsule	50.7
System of the capsule mounting:	10.4
• adapter	8.2
• adjustable angle brace	2×0.38
• bracket	2×0.3
• fasteners	0.8
Total	**61.1**

Optional Mars Mission

- A single MetNet μ-Lander could be sent to Mars using SLBM LV
- Acceleration from LEO by electric propulsion engine (used for more than decade)
- Small interplanetary cruise stage (heritage from earlier missions)
- <u>Low cost</u>
- Requires communications satellite around Mars (MEX, NASAs orbiters, special comsat)



Mars MetNet Lander



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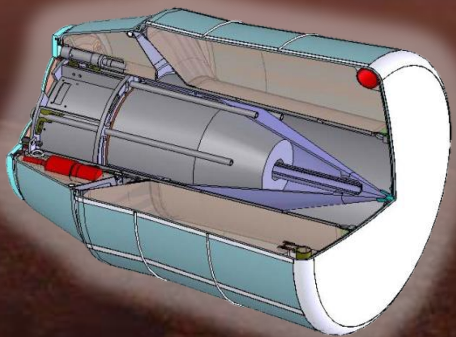
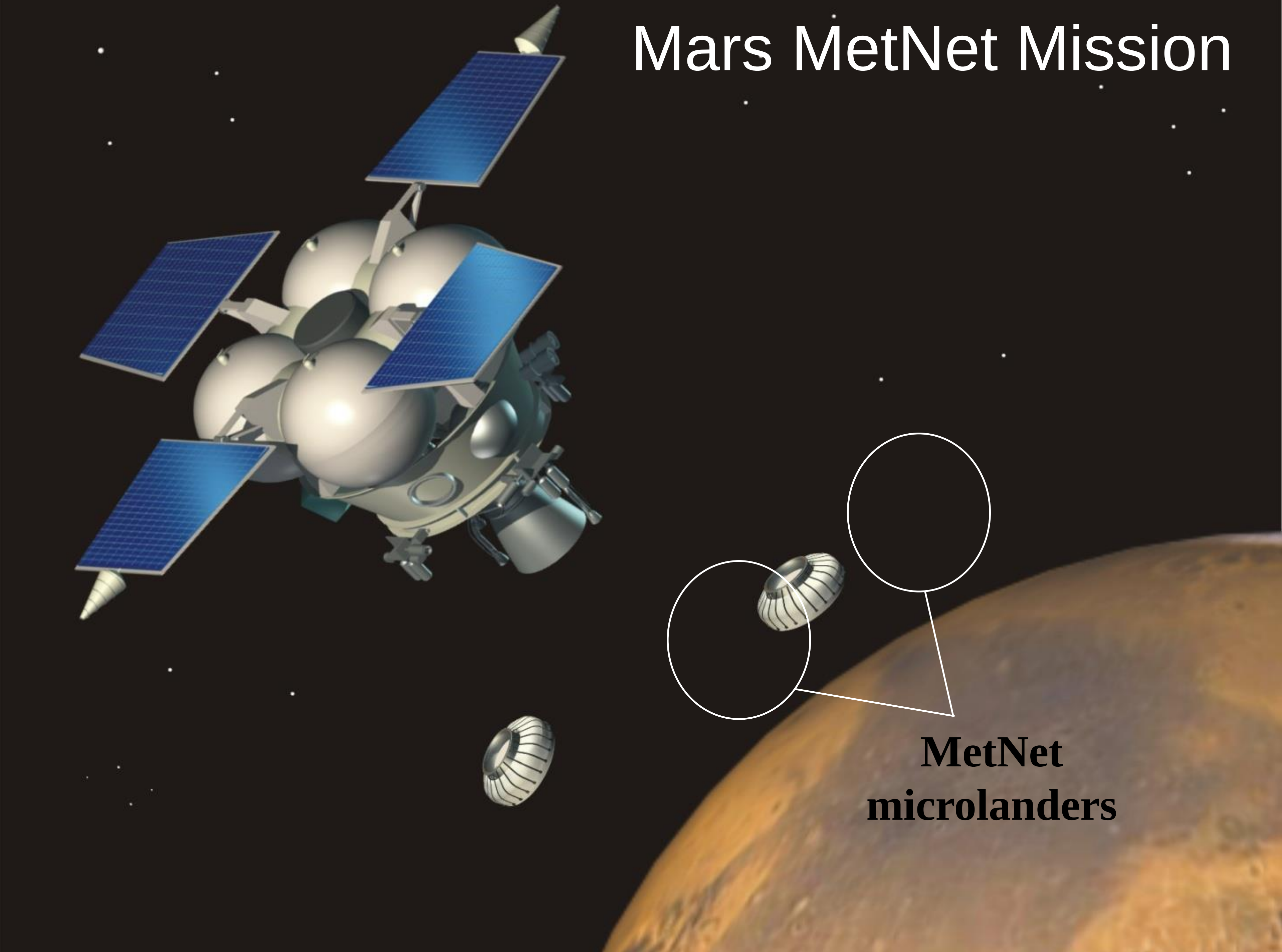


metnet.fmi.fi

Mars MetNet Mission

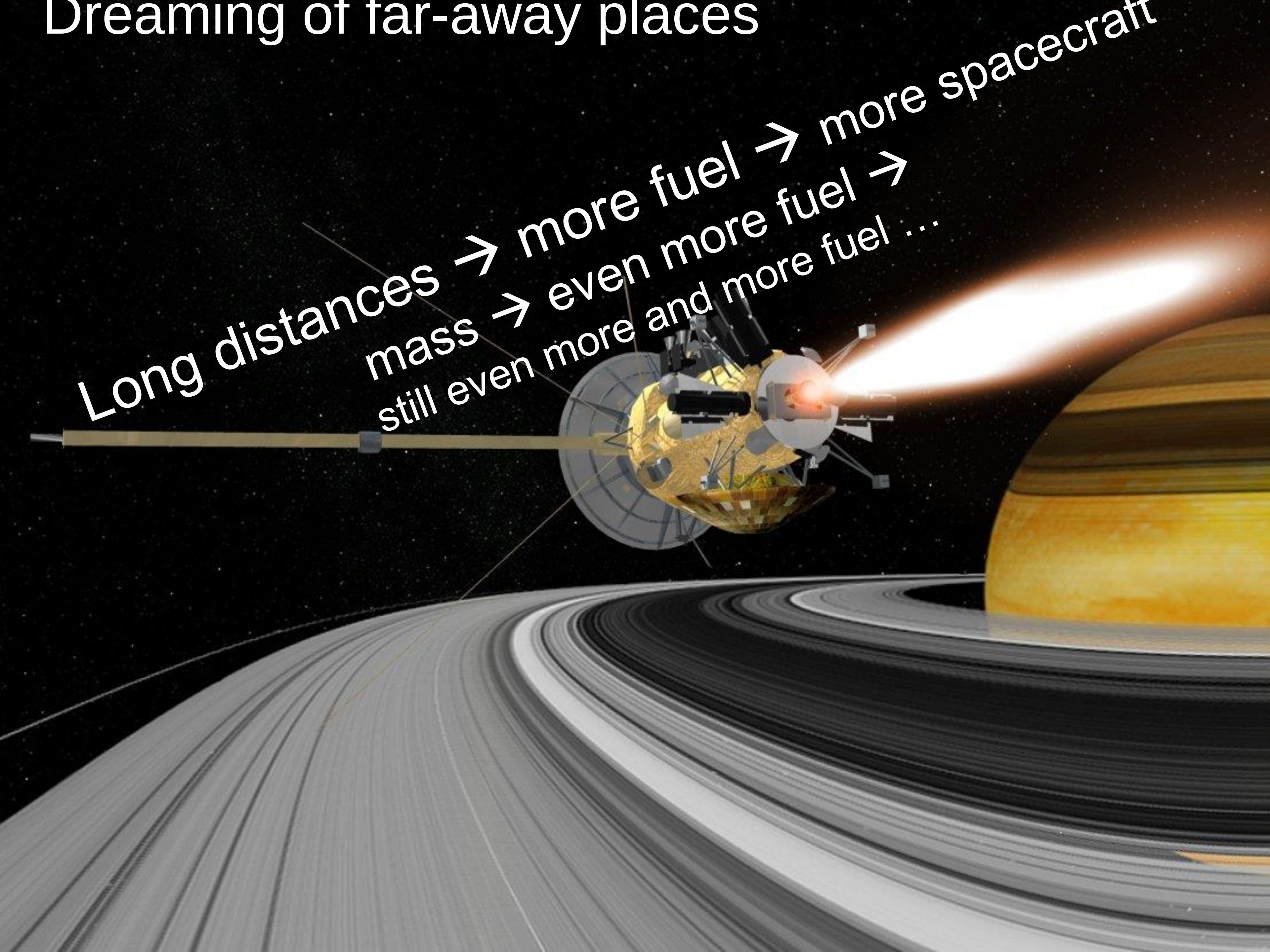


Millions of years ago at Mars … Conference on ”The Earth and its Enigmas”

Dears Colleagues, the future looks bad.
The climate of our dear home planet Mars is royally screwed up.
And, new human race will rise on the Earth, so we’ll go somewhere else.

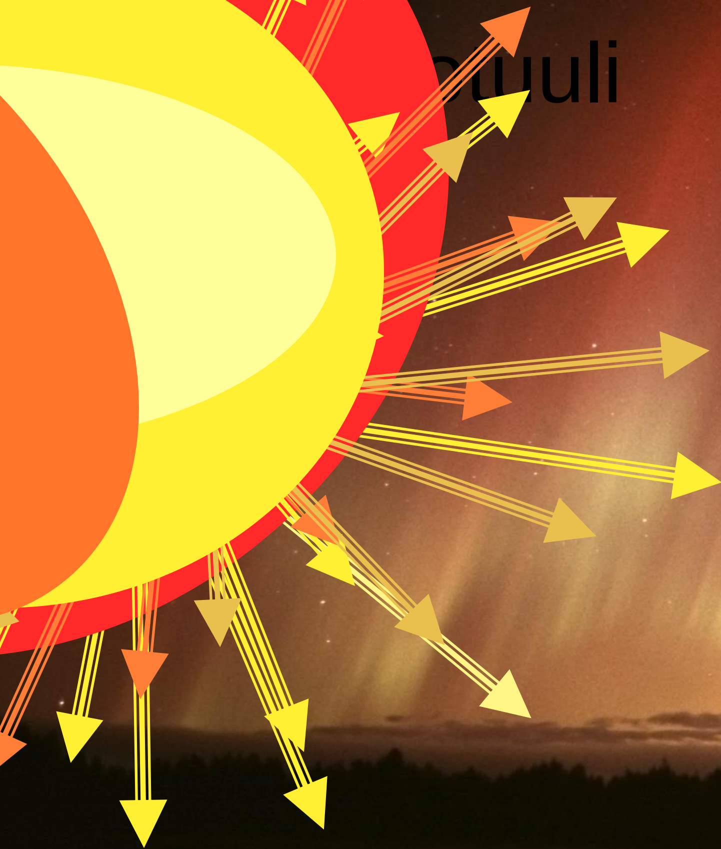
We just need to cover our tracks properly. Let’s split.

Dreaming of far-away places



Long distances → more fuel → more spacecraft mass → even more fuel → still even more and more fuel …

otuuli



- **The Sun is throwing out charged particles.**
- **This phenomen was discovered in 1959**

Particle speed roughly 400 km/s

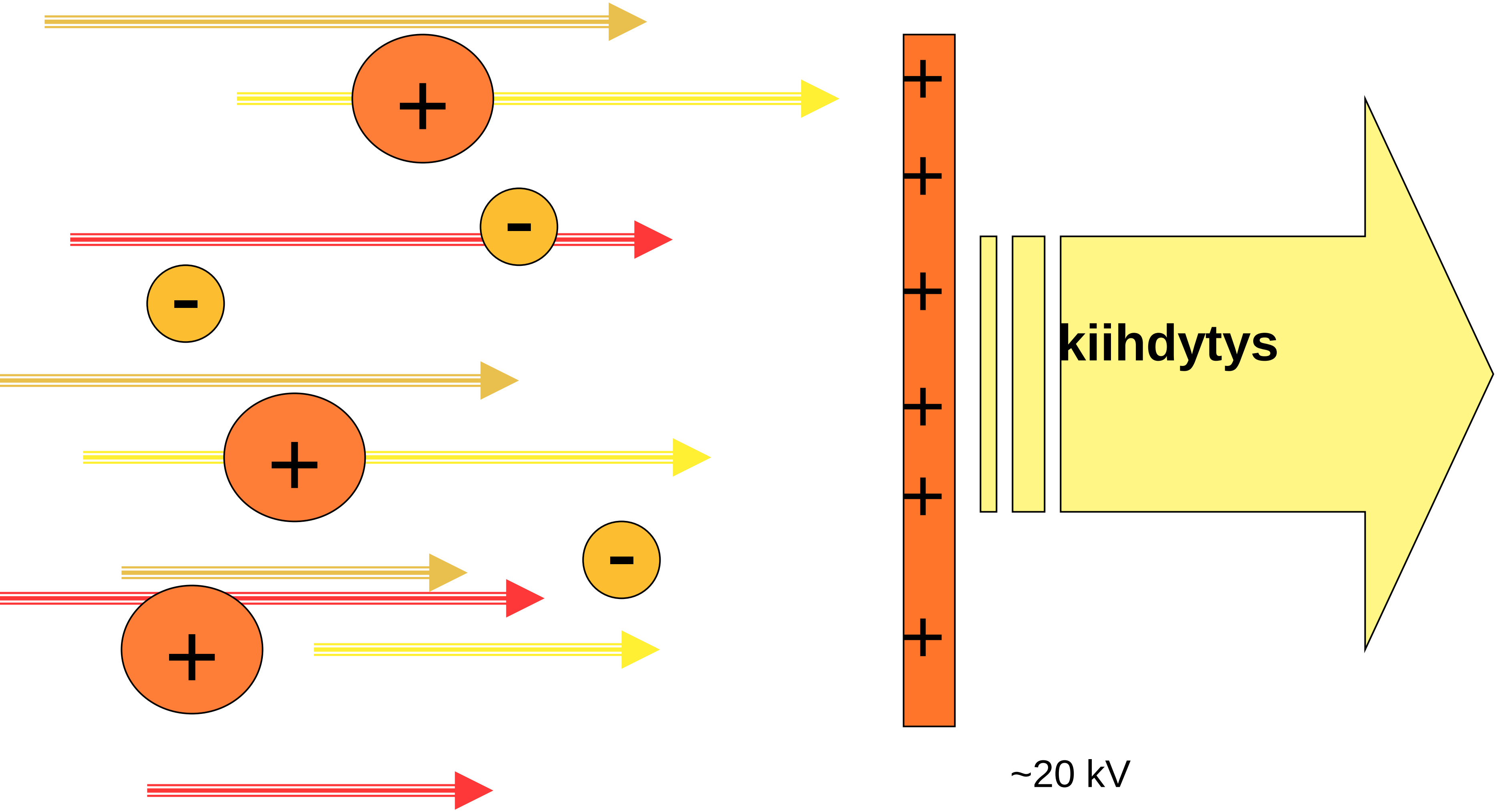
YES, hundreds of kilometeres per second,
that is
1 400 000 km/h!!!

Kuva: Jouni Jussila

Charges with similar sign repulse
Opposite signs attract each other

600 AD Thales of Miletus wrote about static electrocity !

Let us place a charged object in solar wind :



The charged object could be a wire, it is easy to control ?!.

How much wire is needed ?

~0.5 mN/km →

2000 km of wire will produce

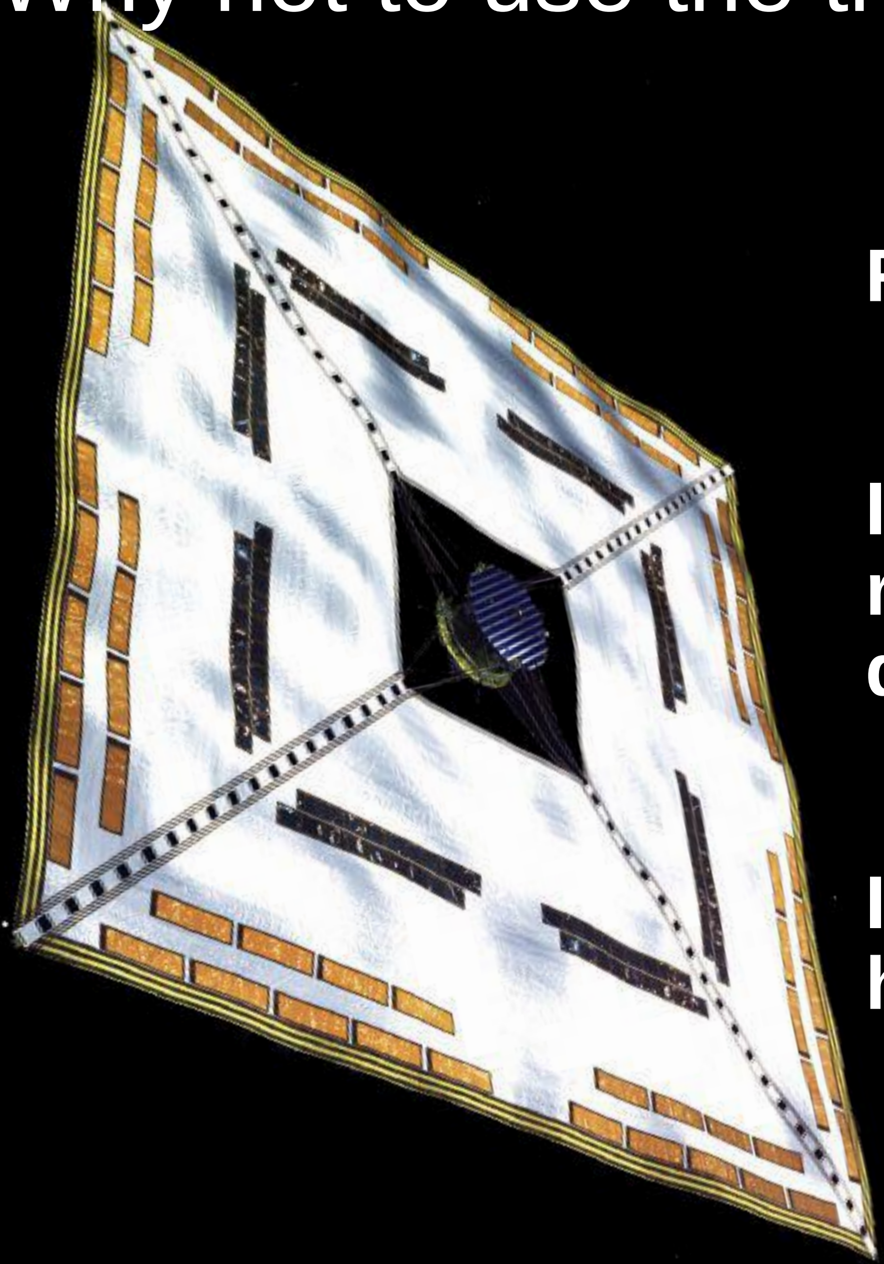
1 Newton

100 wires each 20 km would produce 1 N !!

Does it sound to be small ?

In space things are different …

Why not to use the traditional photon sail ?



Requires a 2D structure

Ikaros was launched recently. The sail diameter is 20 m →

1 mN

It is much easier to handle 2 km of wire

If that apple would push your car

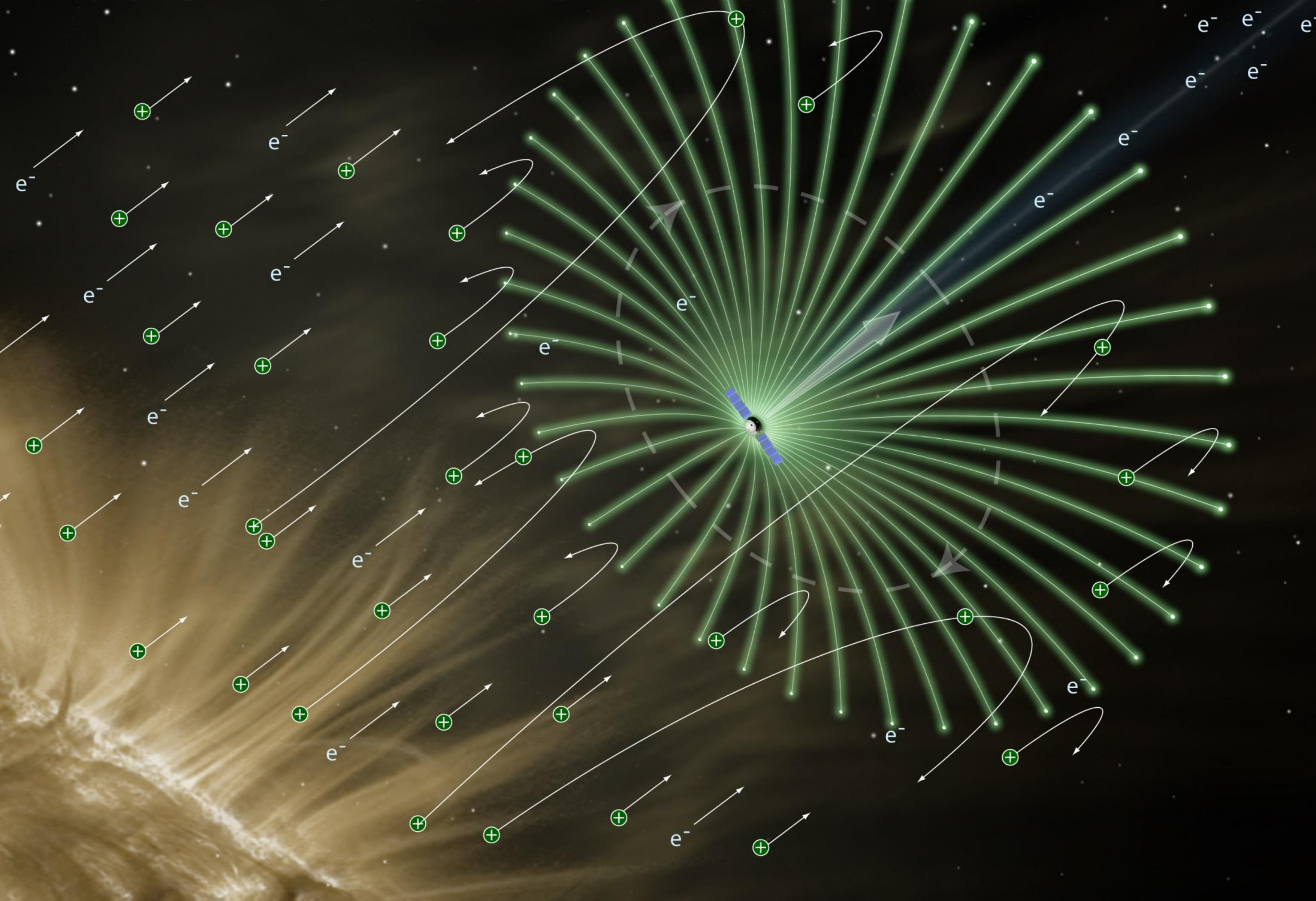
…after one year it would be speeding 31 km/s, that is

110 000 km/h

Continuous propulsion without fuel !!!

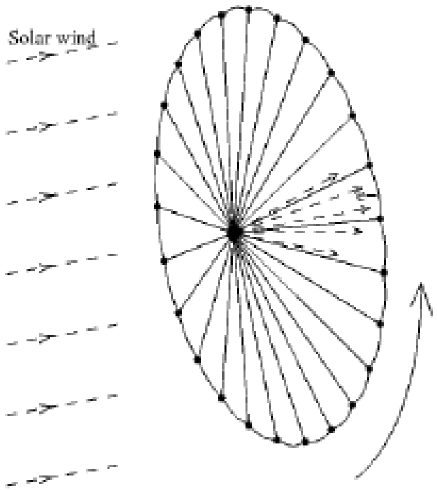

?
But 2000 km wire sounds very long …
doesn’t it get entangled ??

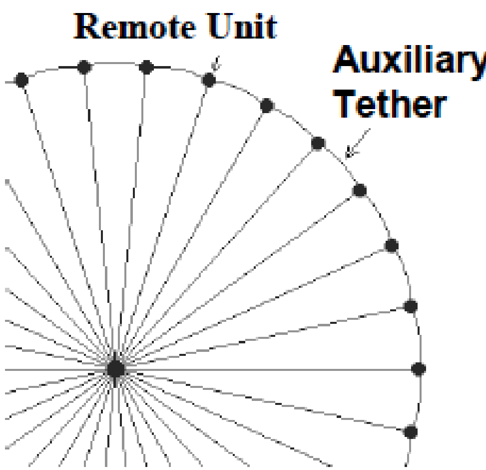
Let’s make the wires roll !



E-sail construction

- Positive tethers (10-20 km length made of 25-50 um wire, +20-40 kV voltage)
- Up to 1 N thrust (scales as *1/r*) from 100-200 kg unit (30 km/s delta-v per year to 1000 kg spacecraft)
- Power consumption modest, scales as *1/r²*
- Baseline approach uses non-conducting **Auxiliary Tethers** to stabilise flight without active control
- "**Remote Units**" at tips contain auxtether reels and spinup propulsion/spin control





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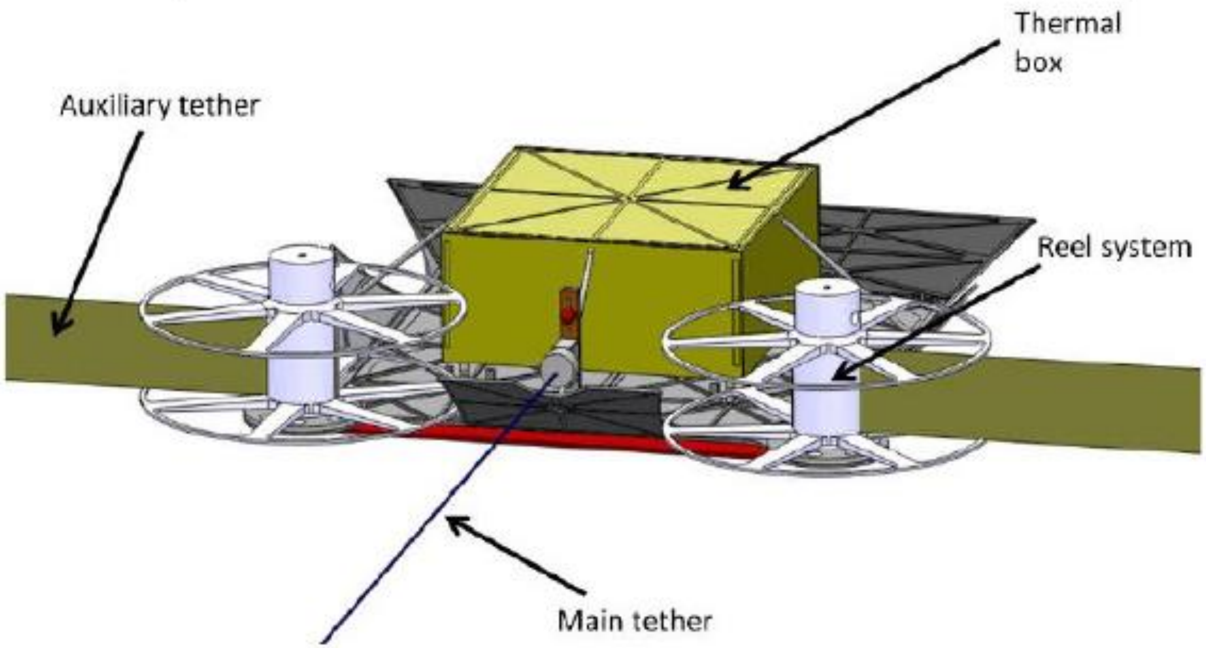
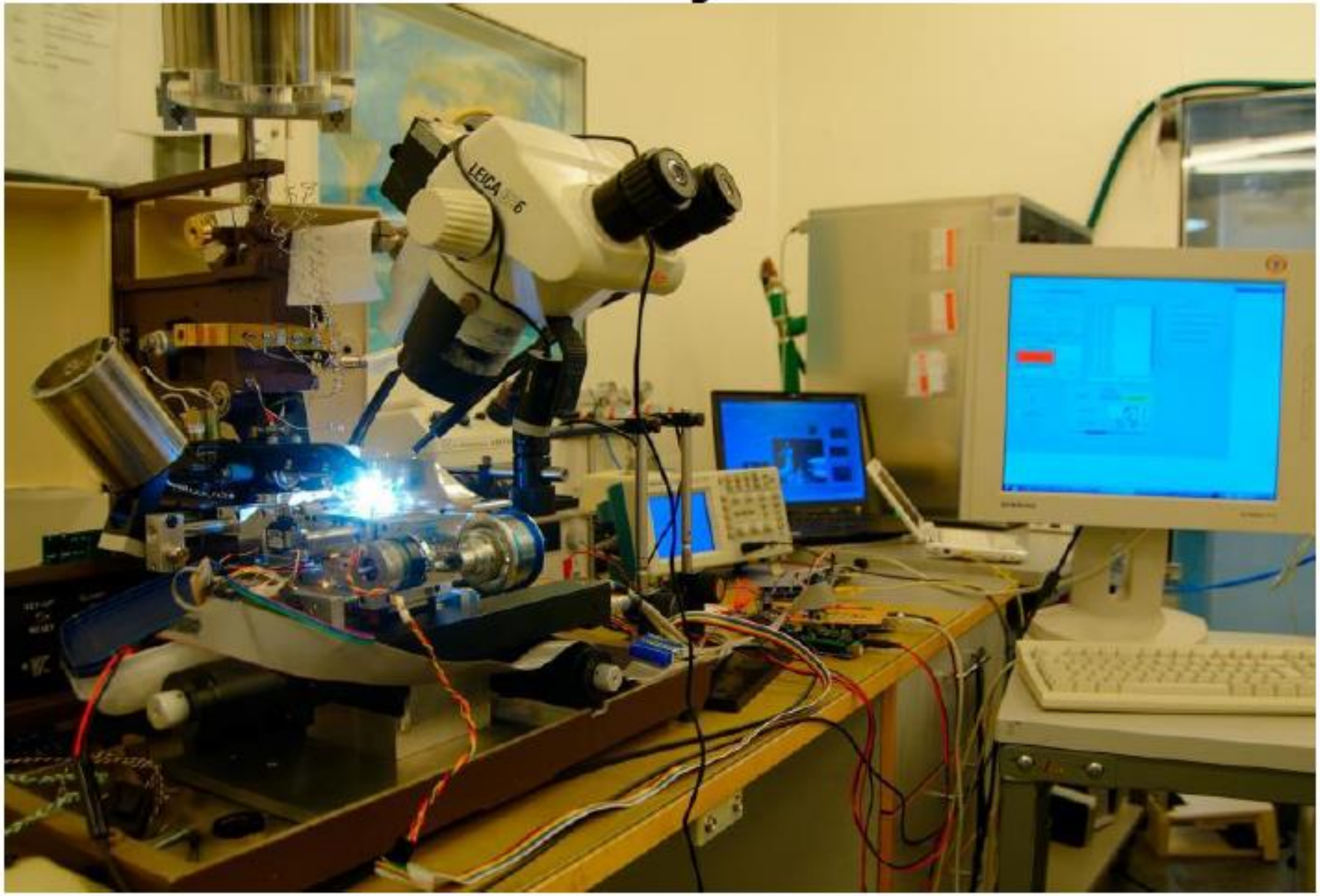
E-sail "Remote Unit"

- Reels of auxiliary tethers and cold gas (or FEEP) thrusters to initiate and control spin



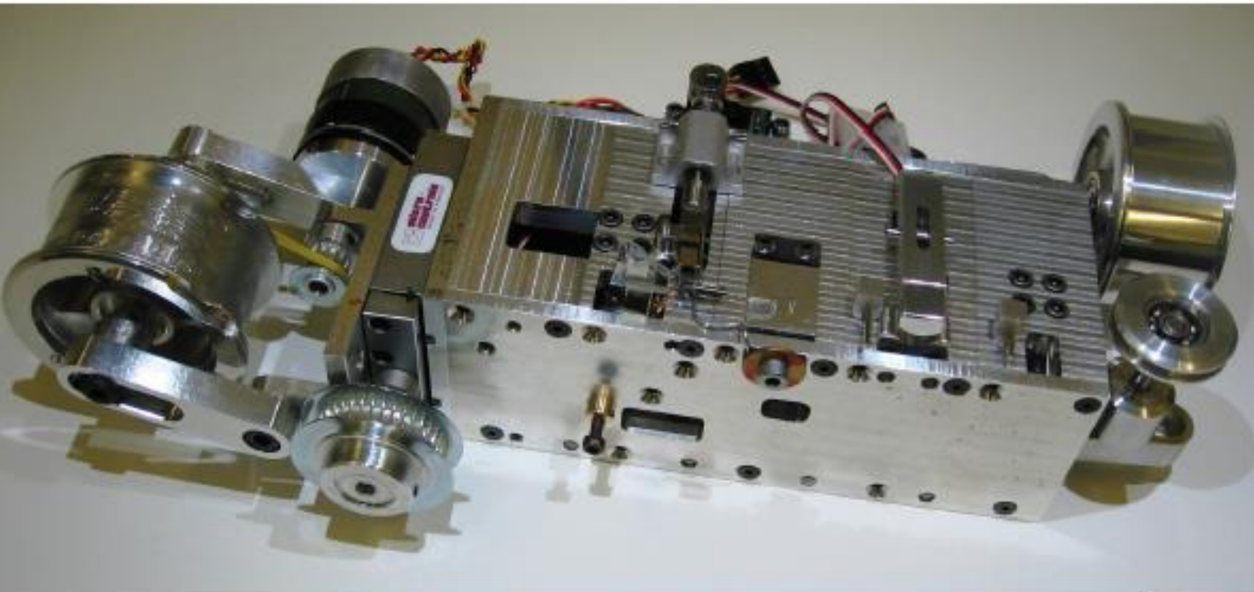
- Remote Unit m=0.56 kg (CG version dry), allowed solar distance range 0.9-4 au

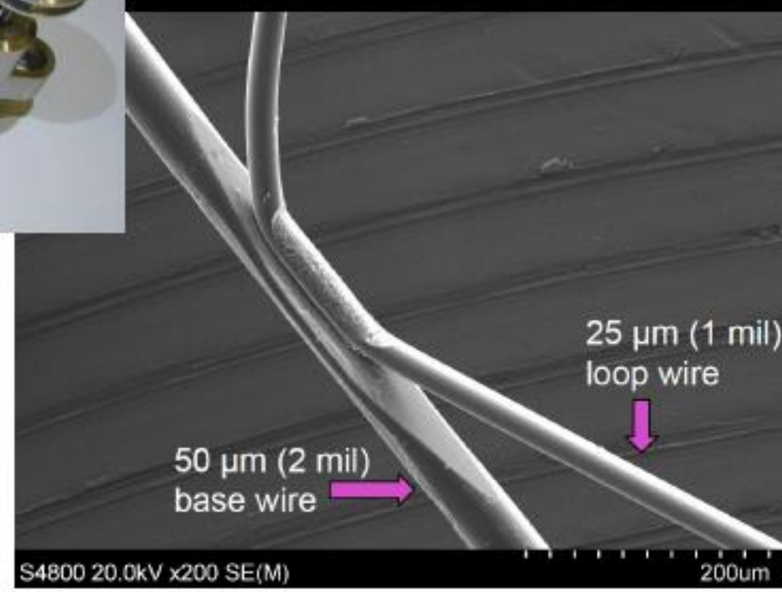
E-sail tether factory



http://www.electric-sailing.fi

Tether factory and its product





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E-sail EU FP7 project

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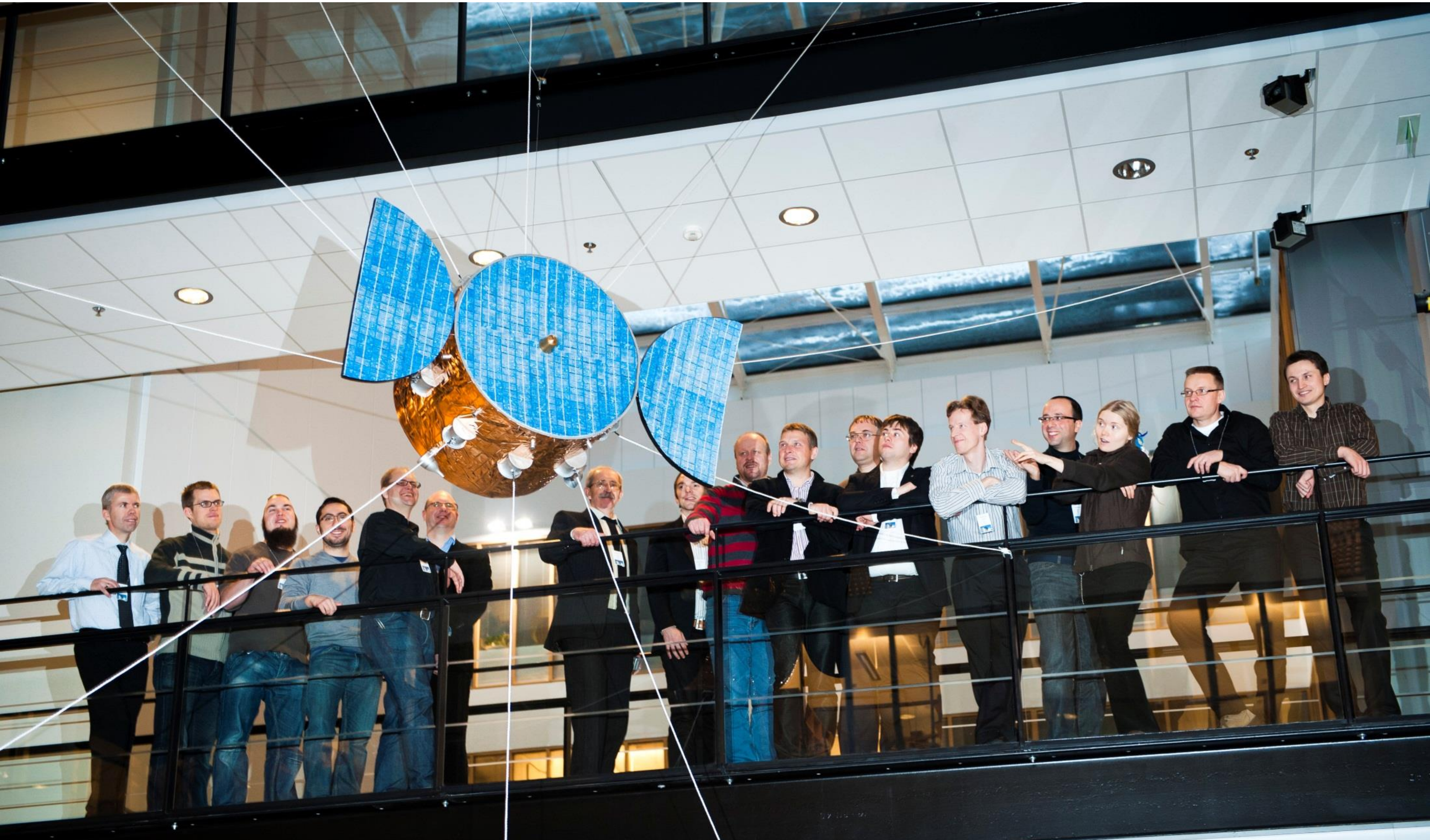
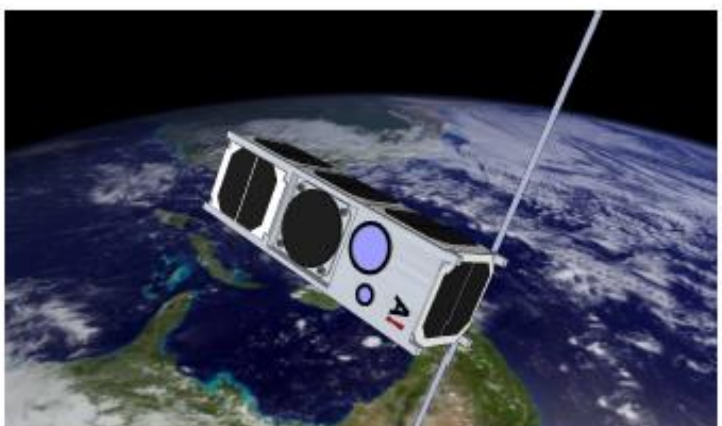


Aalto-1 E-sail test mission

- 3-U CubeSat, work led by Aalto University, Finland
- 100 m tether, similar orbit as ESTCube-1
- Satellite carries also other payloads
- Planned launch 2015



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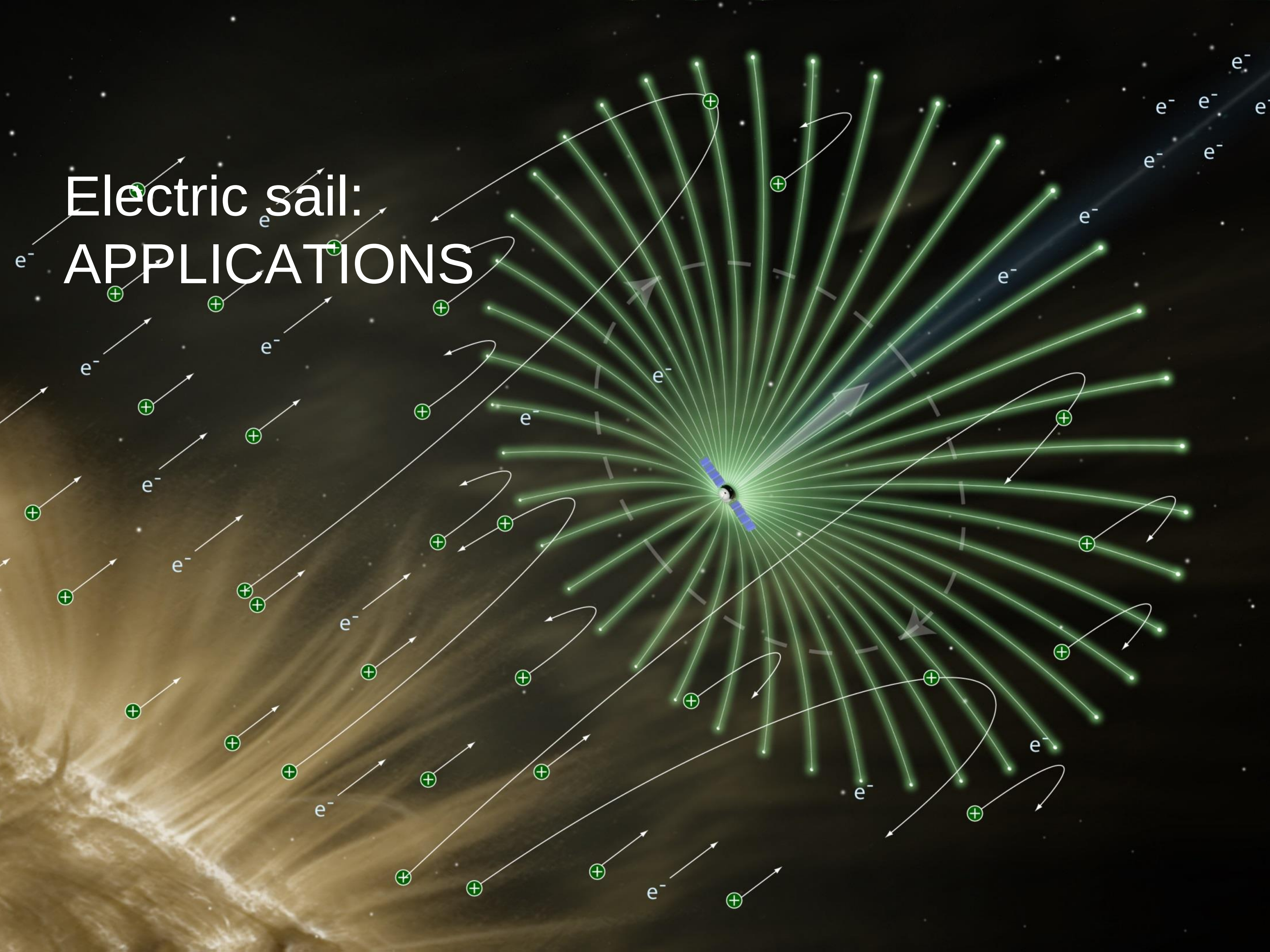
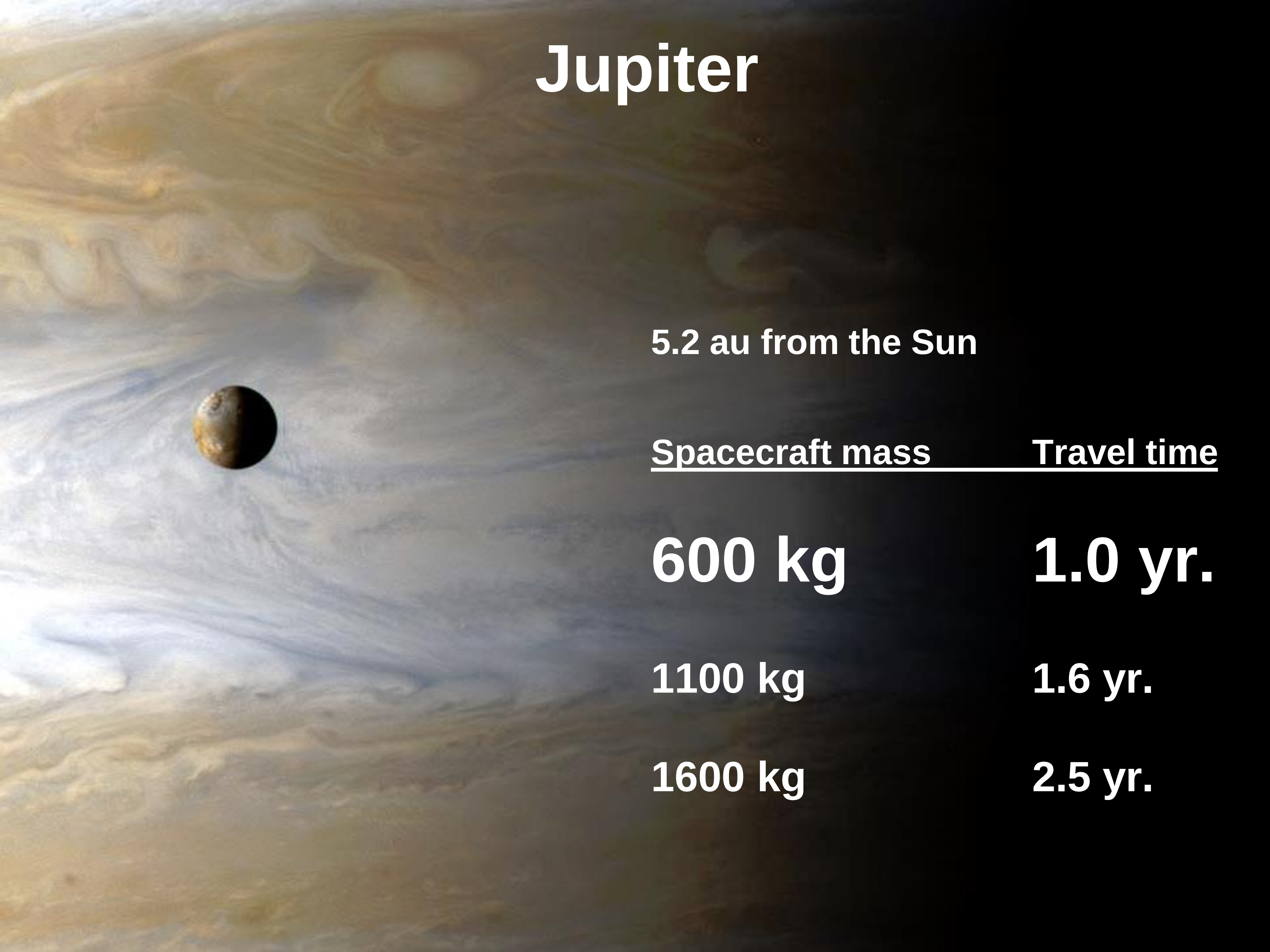
Aalto-1

Electric sail:
APPLICATIONS

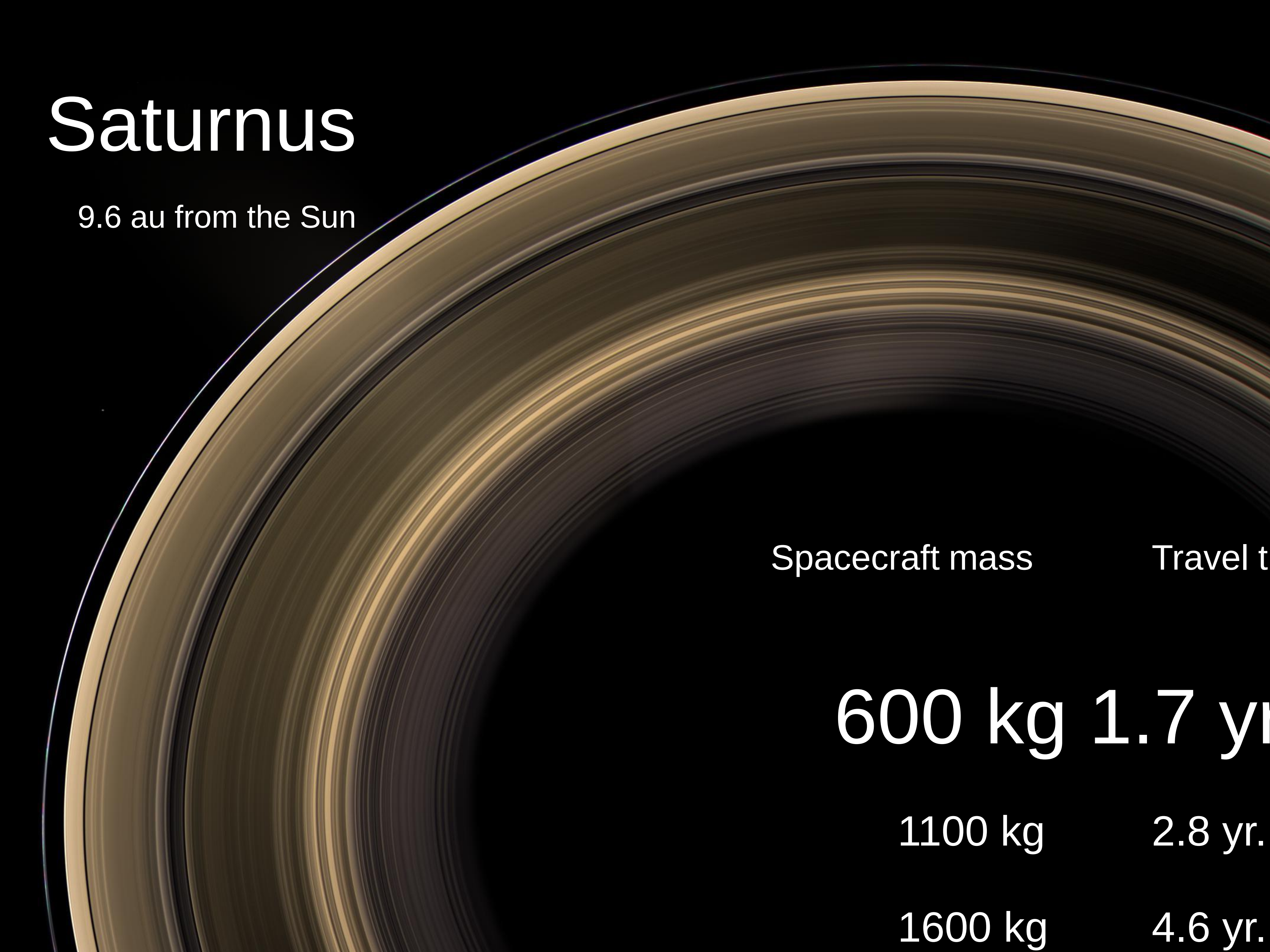


Jupiter



5.2 au from the Sun

Spacecraft mass	Travel time
600 kg	**1.0 yr.**
1100 kg	1.6 yr.
1600 kg	2.5 yr.

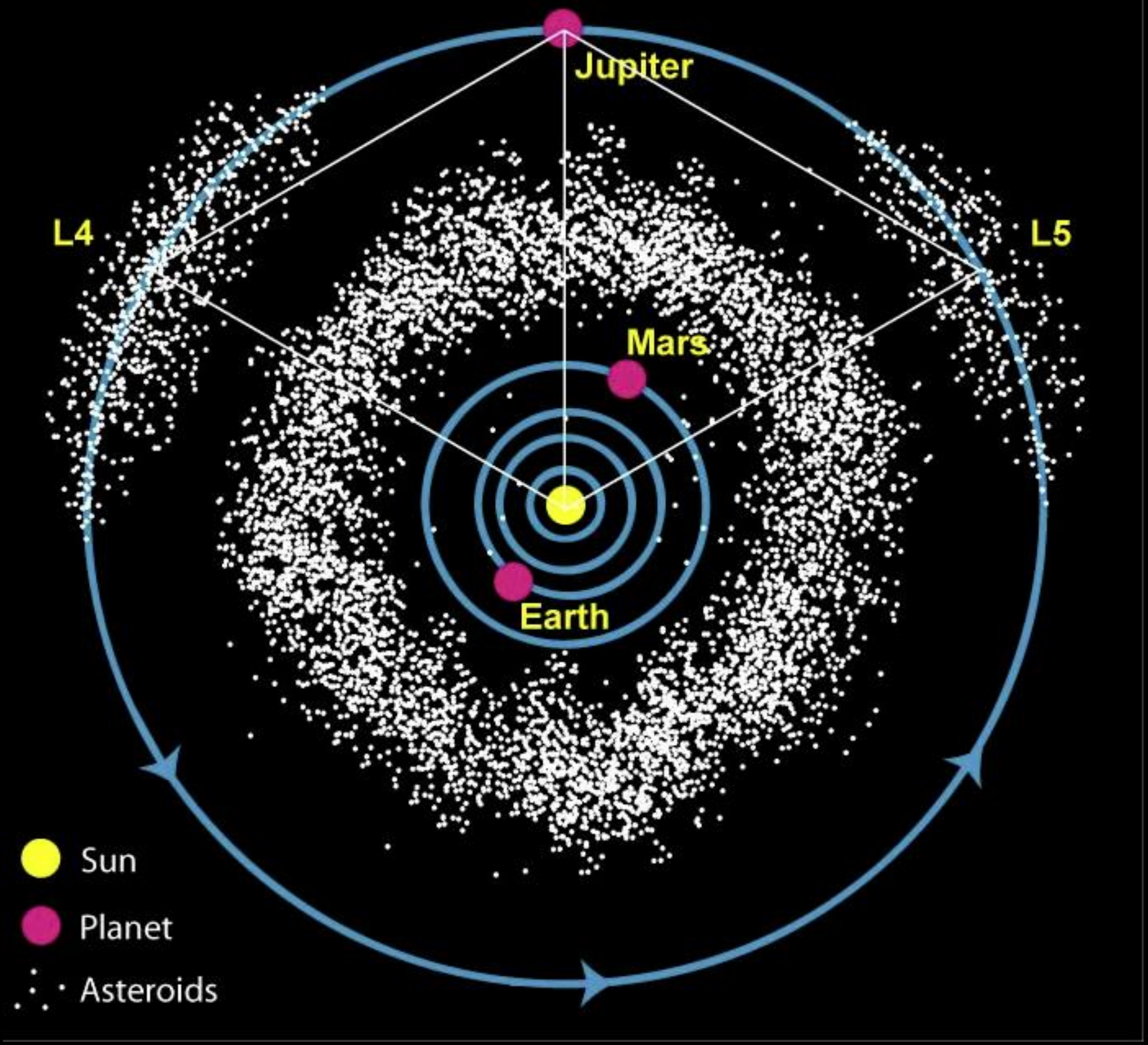


Saturnus
9.6 au from the Sun
Spacecraft mass
Travel t
600 kg 1.7 yr
1100 kg
2.8 yr.
1600 kg
4.6 yr.

Asteroid zone round trip

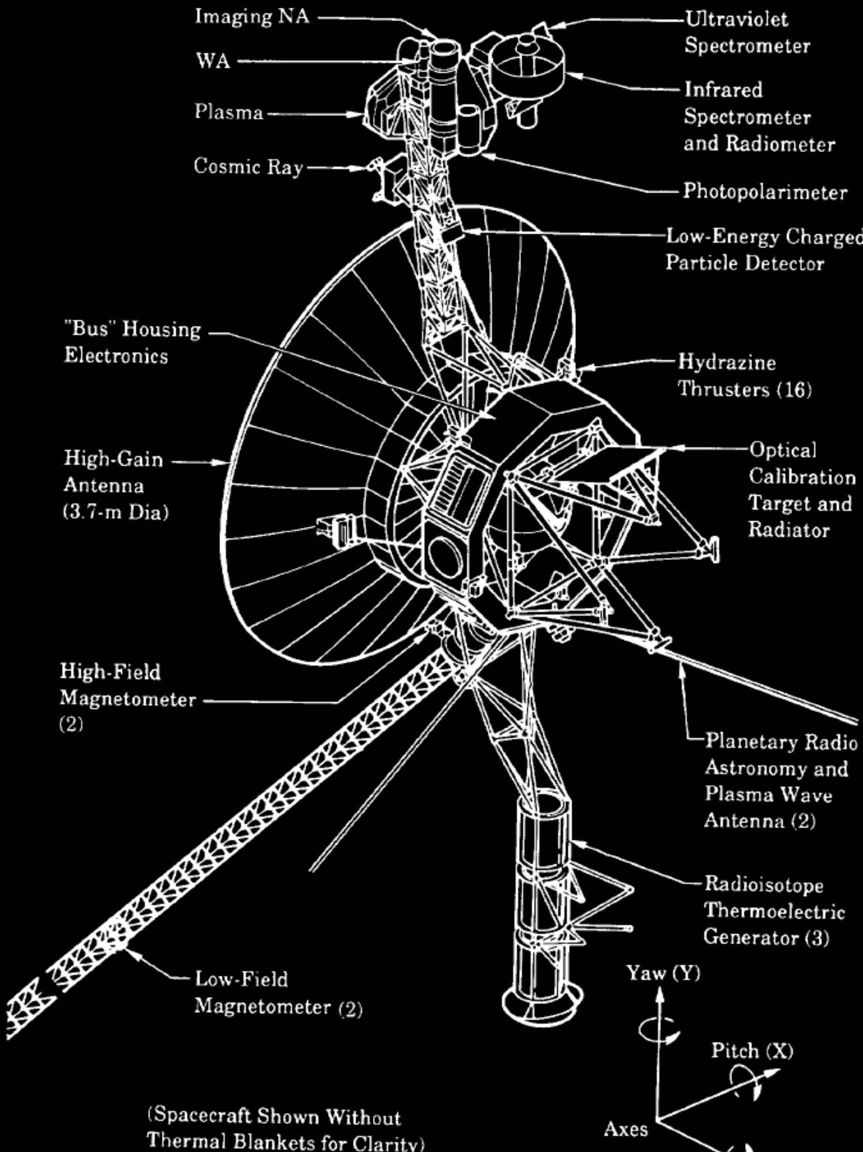
Would require about 100 000 kg of chemical fuel,
or 2000 kg solar cells.

Mining activity in Solar system ?



- Vettä asteroideilta
- Vedestä polttoainetta $H_2O \rightarrow H_2 + O$
- Polttoaineen haku sähköpurjeella

Still further …

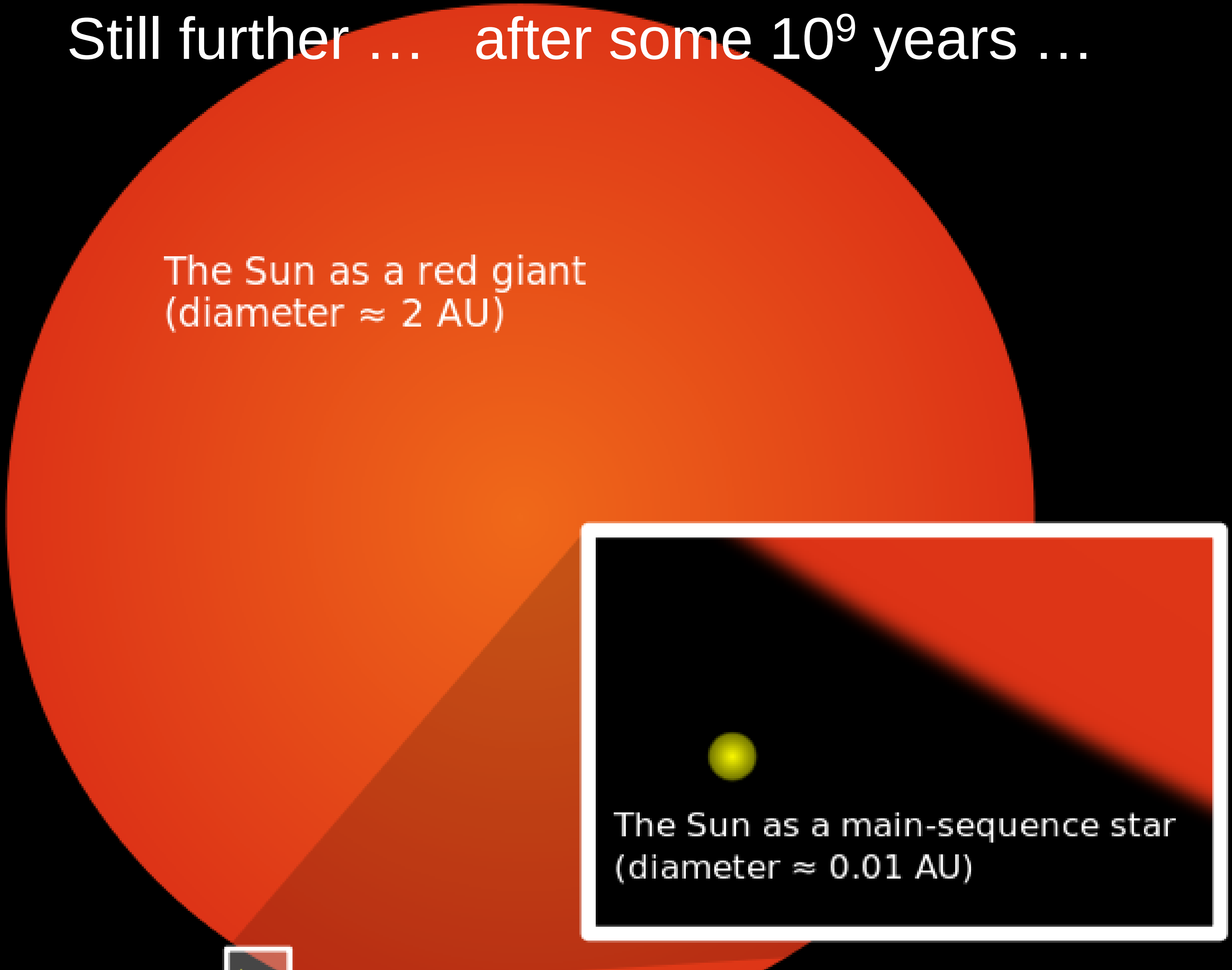


Voyagers were launched in 1977.

Voyager 1 is now over 100 AU from the Sun …

Electric sail could speed past the Voyagers in 8 years !!!

Still further … after some 10^9 years …



Conclusions

- Mars is the sister planet of Earth and is hence extremely interesting object for exploration
- Mars is currently also a key science discipline in the field of planetary research, and is likely to stay in focus at least for the next decade.
- **INITIATIVE:**
  Network Mission is badly needed → METNET !
- Exploration of outer solar system requires technological breakthroughs → ELECTRIC SAIL
- **INITIATIVE:**
  Network ELECTRIC SAIL enables fast missions – even beyond Jupiter
- Valuable materials from asteroids, other planetary bodies
- Fast mission even out of Solar System …

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International cooperation
National Image
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