



Matematikken viser vej til Mars

Kim Plauborg

TERMA[®]
ALLIES IN INNOVATION

THE BEGINNING

Terma has been in Space since man walked on the Moon!



EXAMPLES

ERA (ISS)
 AEOLUS
 LISA PATHFINDER
 BEBICOLUMBO
 EXOMARS (1)
 EXOMARS (2)
 MTG
 SOLAR ORBITER
 AQUILA

EXAMPLES

MISSIONS

ESRO IV
 COS-B
 METEOSAT
 EXOSAT
 SPACELAB
 OCG
 LDEF
 OLYMPUS
 ULYSSES (ISPM)
 EURECA
 ISO
 CASSINI/HUYGENS
 SKYNET
 ØRSTED
 XMM-NEWTON
 SAC-C
 INTEGRAL
 MSG-1
 MARS EXPRESS
 ROSETTA
 CRYOSAT 1
 MSG-2
 VENUS EXPRESS
 MITEX VEHICLE
 TACSAT-2
 RADARSAT-2
 HREP
 HERSCHEL
 PLANCK
 CRYOSAT 2
 GALILEO
 TACSAT-4
 MSG-3
 SAPPHIRE
 GAIA
 SENTINEL-1

LAUNCH

1972
 1975
 1977
 1983
 1983
 1983
 1984
 1989
 1990
 1992
 1995
 1997
 1997
 1999
 1999
 2000
 2002
 2002
 2003
 2004
 2005
 2005
 2005
 2006
 2006
 2007
 2009
 2009
 2009
 2010
 2011/2012
 2011
 2012
 2013
 2013
 2014

FROM ESRO TO EXOMARS

Technology evolution and enhancement

- Rosetta
- Mars Express
- Venus Express
- Galileo
- Small GEO
- BepiColombo
- ExoMars



EXAMPLES

ERA (ISS)
 AEOLUS
 LISA PATHFINDER
 BEBICOLUMBO
 EXOMARS (1)
 EXOMARS (2)
 MTG
 SOLAR ORBITER
 AQUILA

EXAMPLES

MISSIONS

ESRO IV
 COS-B
 METEOSAT
 EXOSAT
 SPACELAB
 OCG
 LDEF
 OLYMPUS
 ULYSSES (ISPM)
 EURECA
 ISO
 CASSINI/HUYGENS
 SKYNET
 ØRSTED
 XMM-NEWTON
 SAC-C
 INTEGRAL
 MSG-1
 MARS EXPRESS
 ROSETTA
 CRYOSAT 1
 MSG-2
 VENUS EXPRESS
 MITEX VEHICLE
 TACSAT-2
 RADARSAT-2
 HREP
 HERSCHEL
 PLANCK
 CRYOSAT 2
 GALILEO
 TACSAT-4
 MSG-3
 SAPPHIRE
 GAIA
 SENTINEL-1

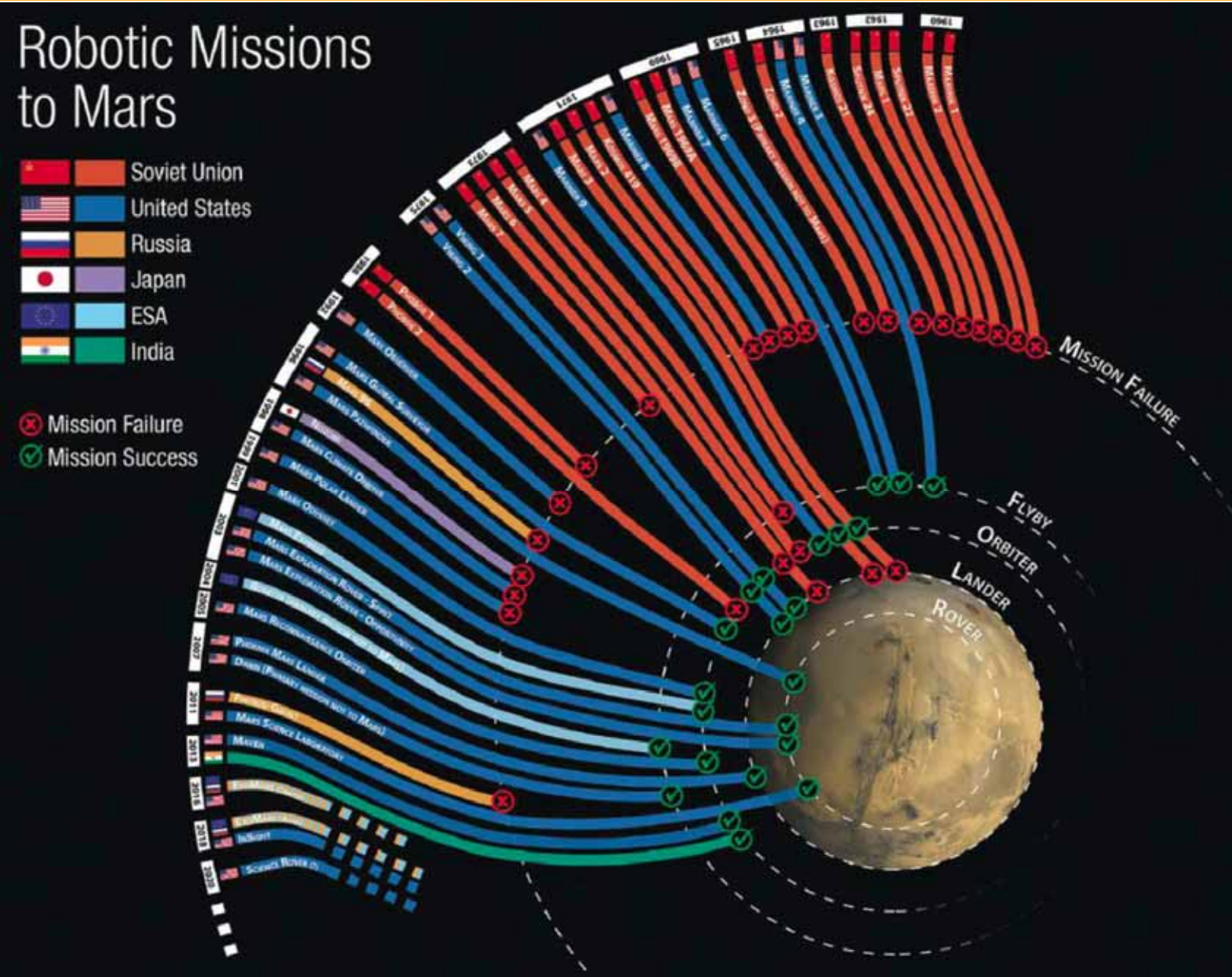
LAUNCH

1972
 1975
 1977
 1983
 1983
 1983
 1984
 1989
 1990
 1992
 1995
 1997
 1997
 1999
 1999
 2000
 2002
 2002
 2003
 2004
 2005
 2005
 2005
 2006
 2006
 2007
 2009
 2009
 2009
 2010
 2011/2012
 2011
 2012
 2013
 2013
 2014

Why go Mars?



Getting to and landing on Mars is difficult !



THE EXOMARS PROGRAMME

Two ESA missions to Mars in cooperation with Roscosmos with the main objective to search for evidence of life



2016 Mission

Trace Gas Orbiter
Schiaparelli

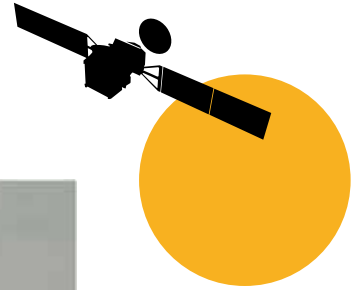
2020 Mission

Rover
Surface platform



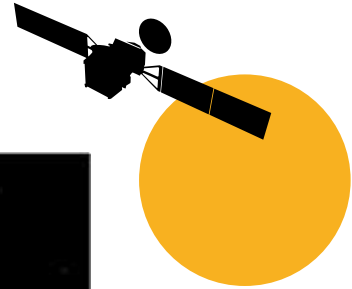
EXOMARS 2016

14th March 2016 Launched from Baikonur cosmodrome, Kazakhstan



EXOMARS 2016

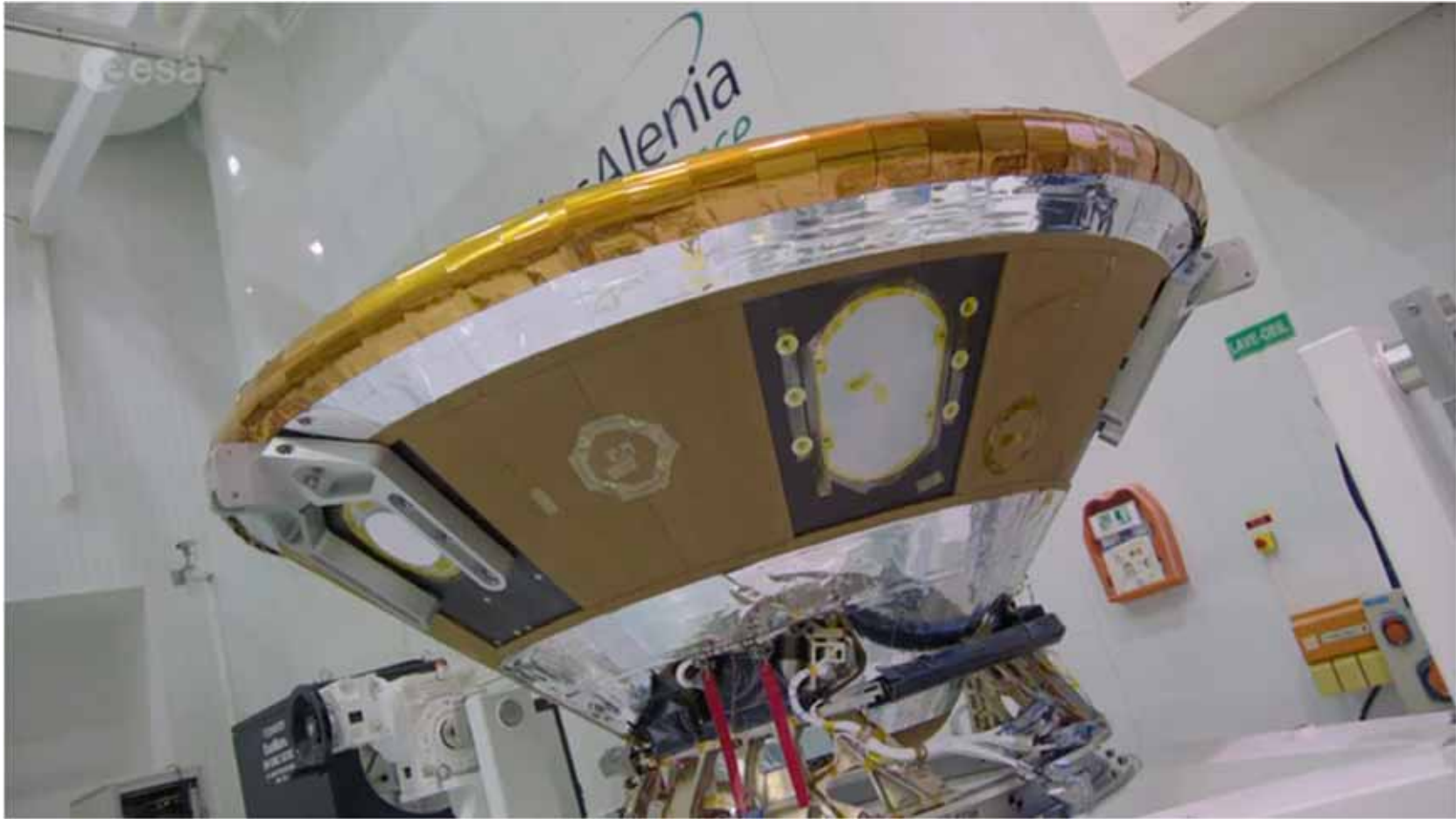
16th October 2016 Separation of Schiaparelli from the orbiter



SCHIAPARELLI



Schiaparelli (EDM) - an entry, descent and landing demonstrator module



EXOMARS 2016



Schiaparelli enters atmosphere

Time: 0 sec
Altitude: 121 km
Speed: 21 000 km/h

Heatshield protection during atmospheric deceleration

Time of maximum heating: 1 min 12 sec
Altitude: 45 km
Speed: 19 000 km/h

Parachute deploys

Time: 3 min 21 sec
Altitude: 11 km
Speed: 1700 km/h

Front shield separates, radar turns on

Time: 4 min 1 sec
Altitude: 7 km
Speed: 320 km/h

Parachute jettisoned with rear cover

Time: 5 min 22 sec
Altitude: 1.2 km
Speed: 240 km/h

Thruster ignition

Time: 5 min 23 sec
Altitude: 1.1 km
Speed: 250 km/h

Thrusters off; freefall

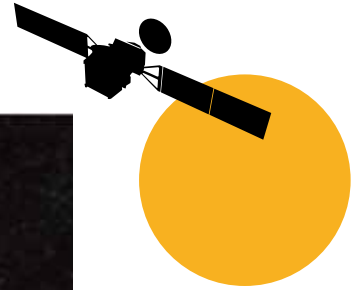
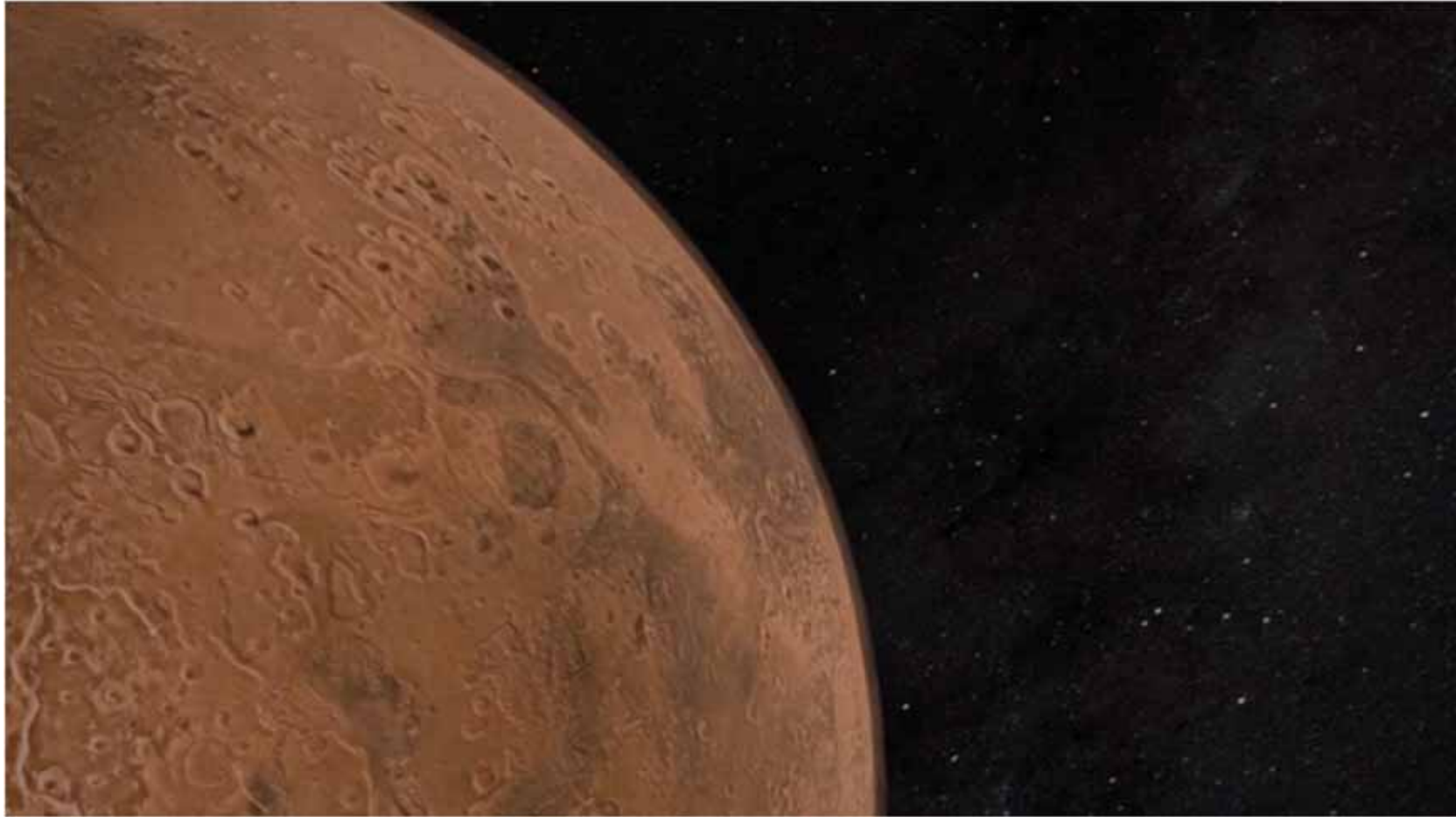
Time: 5 min 52 sec
Altitude: 2 m
Speed: 4 km/h

Touchdown

Time: 5 min 53 sec
Altitude: 0 m
Speed: 10 km/h

EXOMARS 2016

19th October 2016 Landing of Schiaparelli the surface of Mars



EXOMARS 2020





Terma deliveries to the ExoMars 2016 mission

- Remote Terminal Power Unit for Schiaparelli
- Mission Control System
- Spacecraft Simulator
- Support for the Launch and Early Orbit Phase

ExoMars RTPU



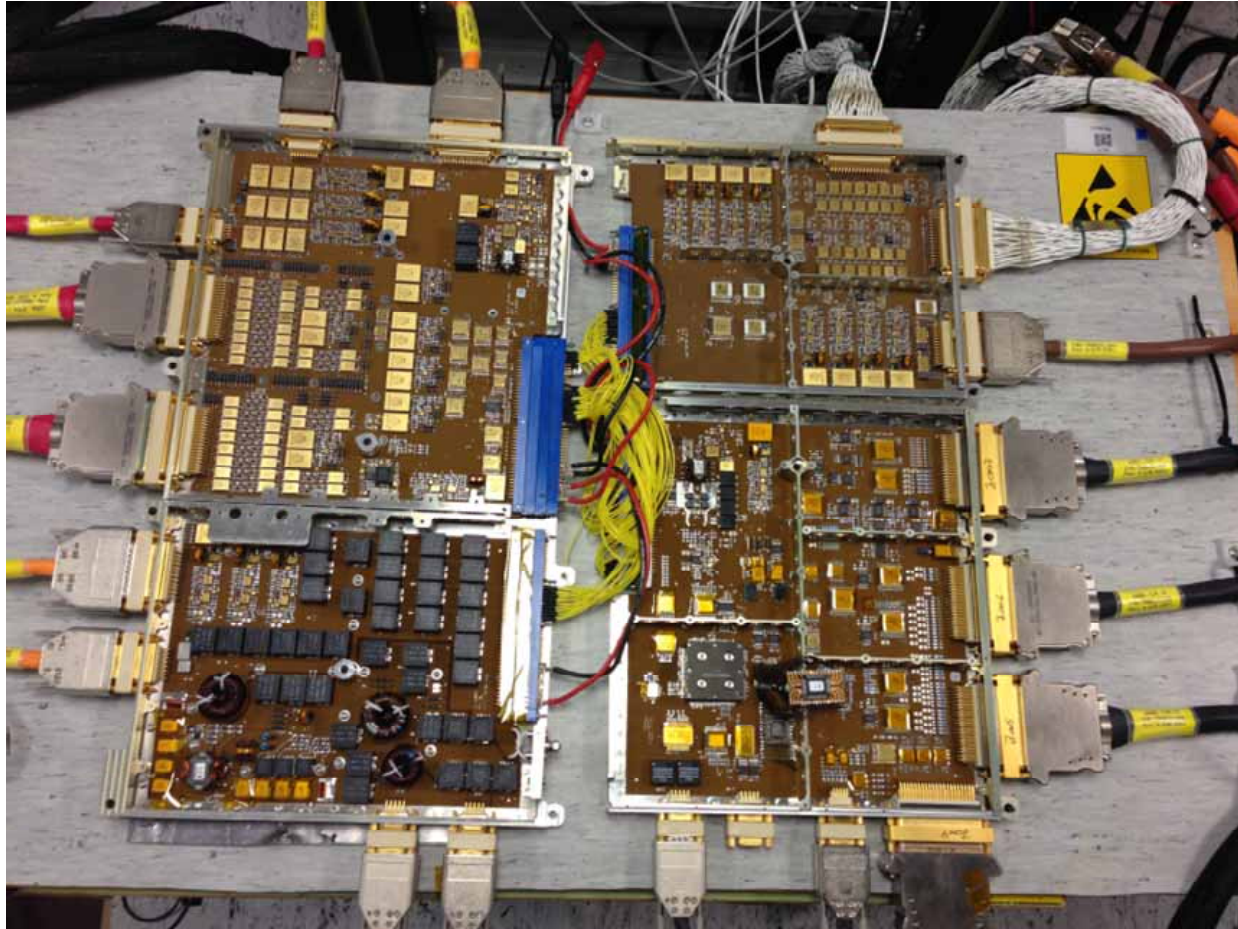
The RTPU is a central unit in the Schiaparelli lander.

The RTPU shall:

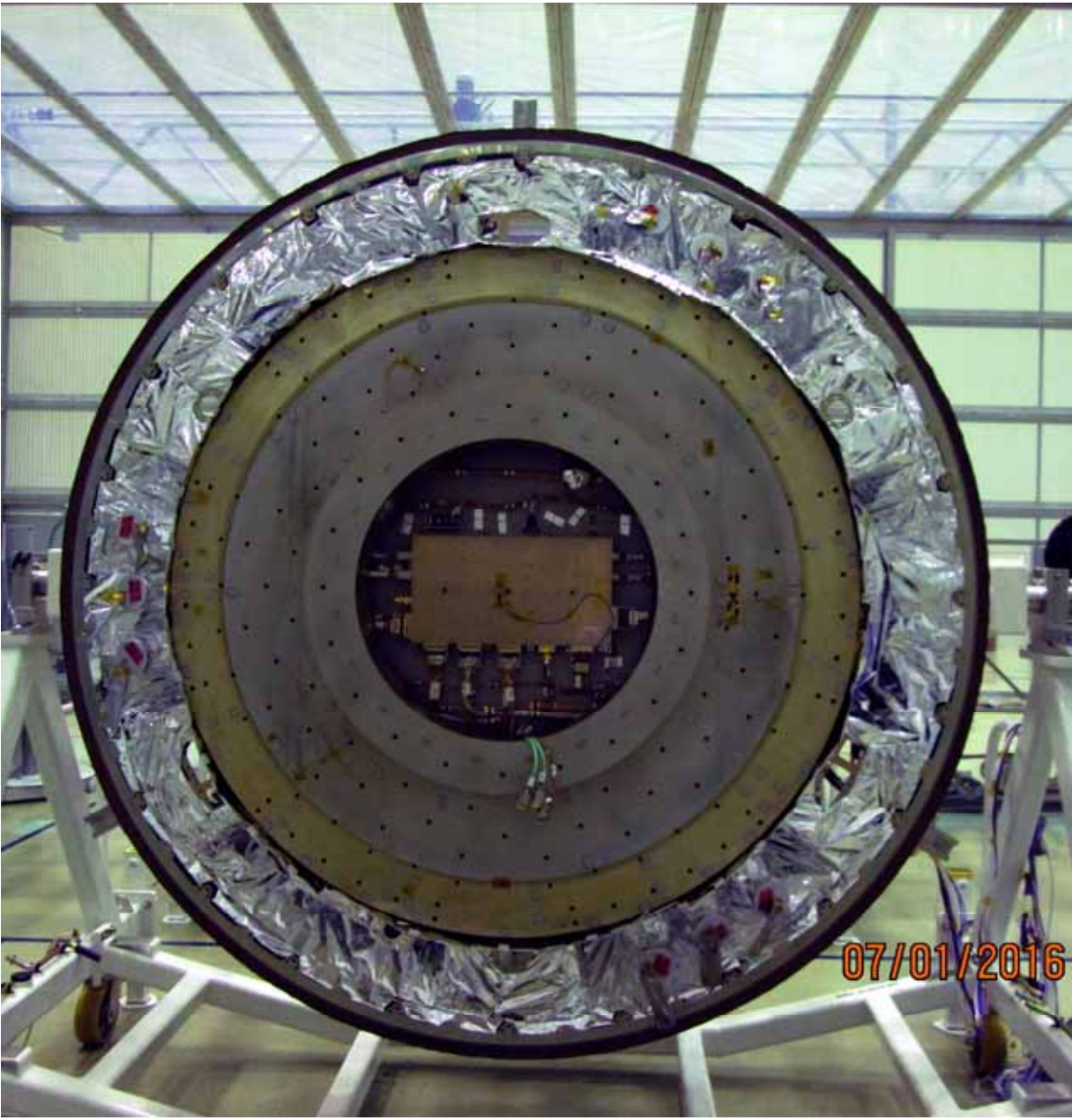
- condition the batteries and stabilize the temperature
- control of the landing via pyros and thrusters
- assemble data from numerous sensors during entry, descent and landing



ExoMars RTPU



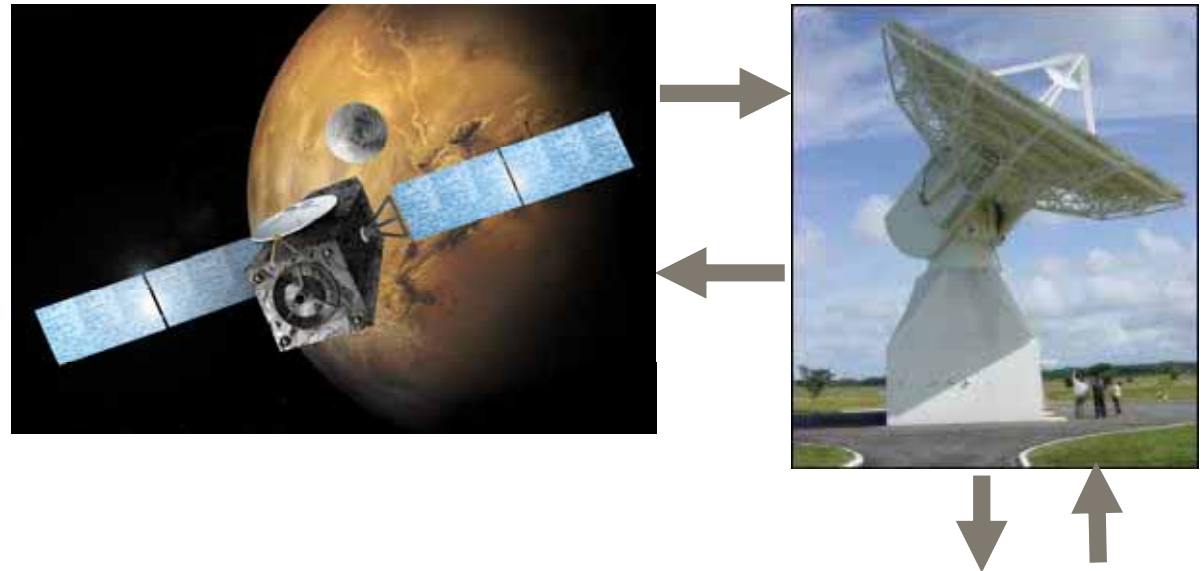
ExoMars RTPU



Mission Control System



- *Advanced distributed software control system for Spacecraft control via sending/receiving TC/TM*
- *Ground segment control*



Real Time Simulator and LEOP support



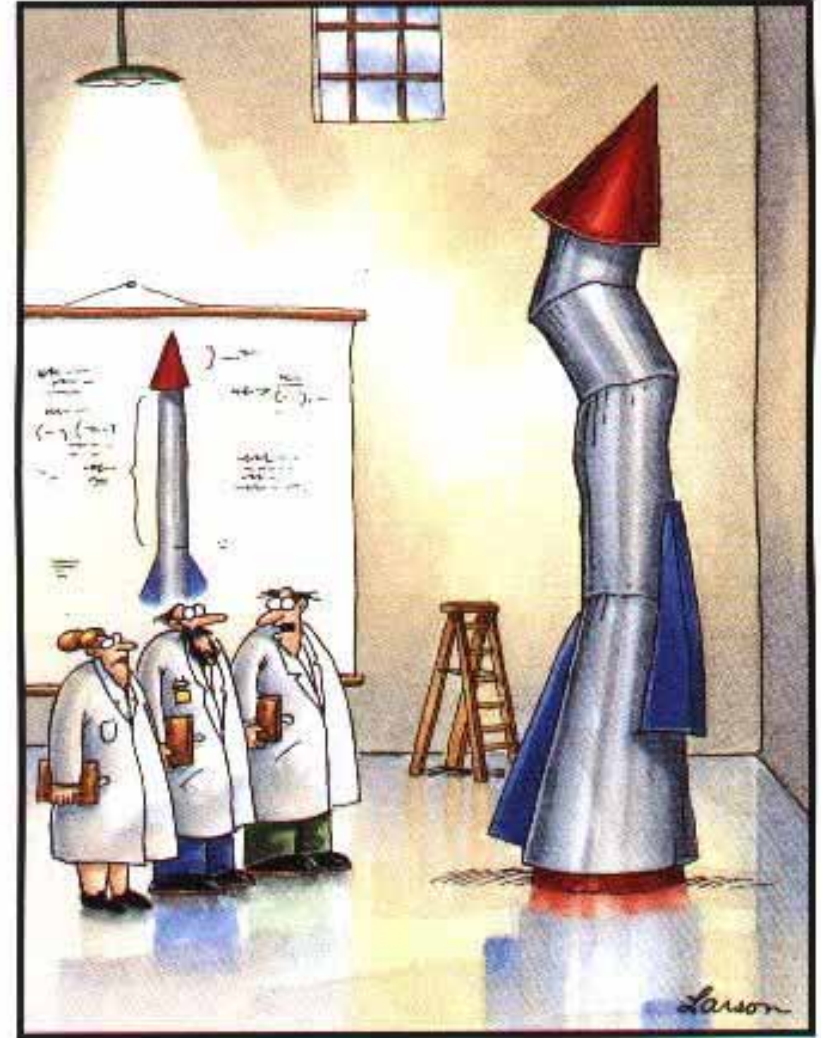
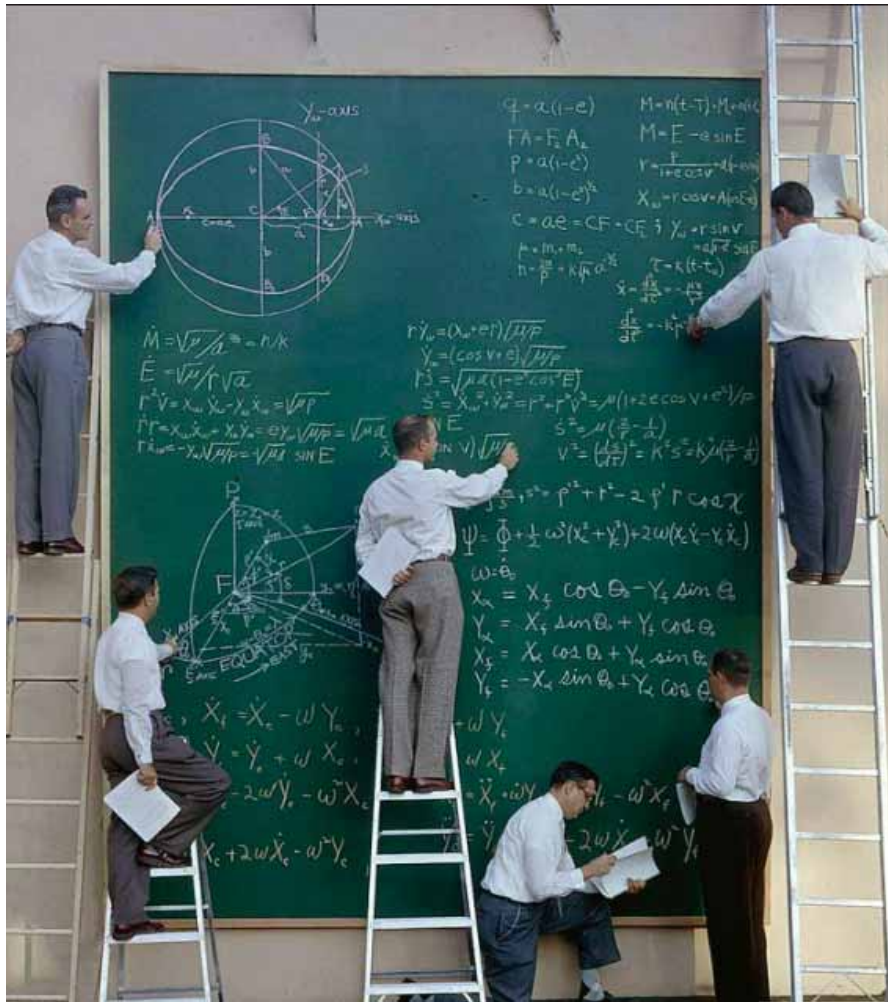
- *The simulator is an “add-on” to the Mission Control System*
- *Simulates the spacecrafts such that the simulator mirrors the actual spacecrafts “one-to-one”*
- *Used for preparation of procedures to be uploaded to the spacecrafts (procedure generation and test)*
- *Used for test of critical sub systems before launch*
- *Used for operator training*



Math show the way to Mars



Which role does math play in a mission like ExoMars?

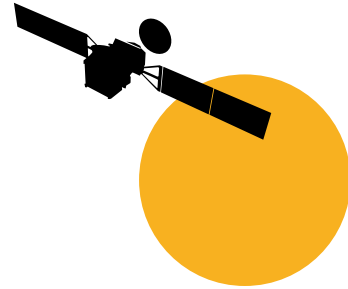
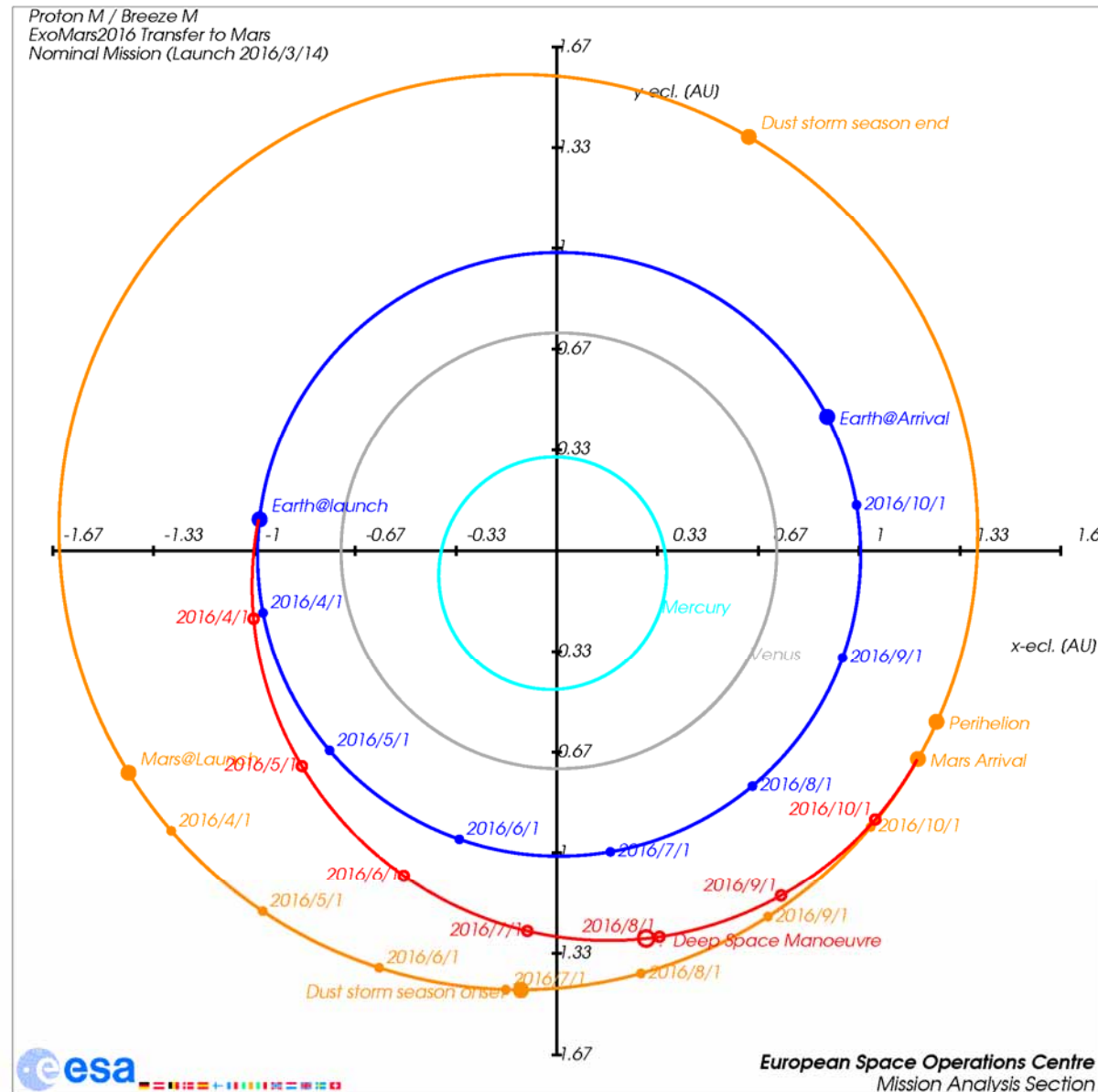


"It's time we face reality, my friends. ...
We're not exactly rocket scientists."

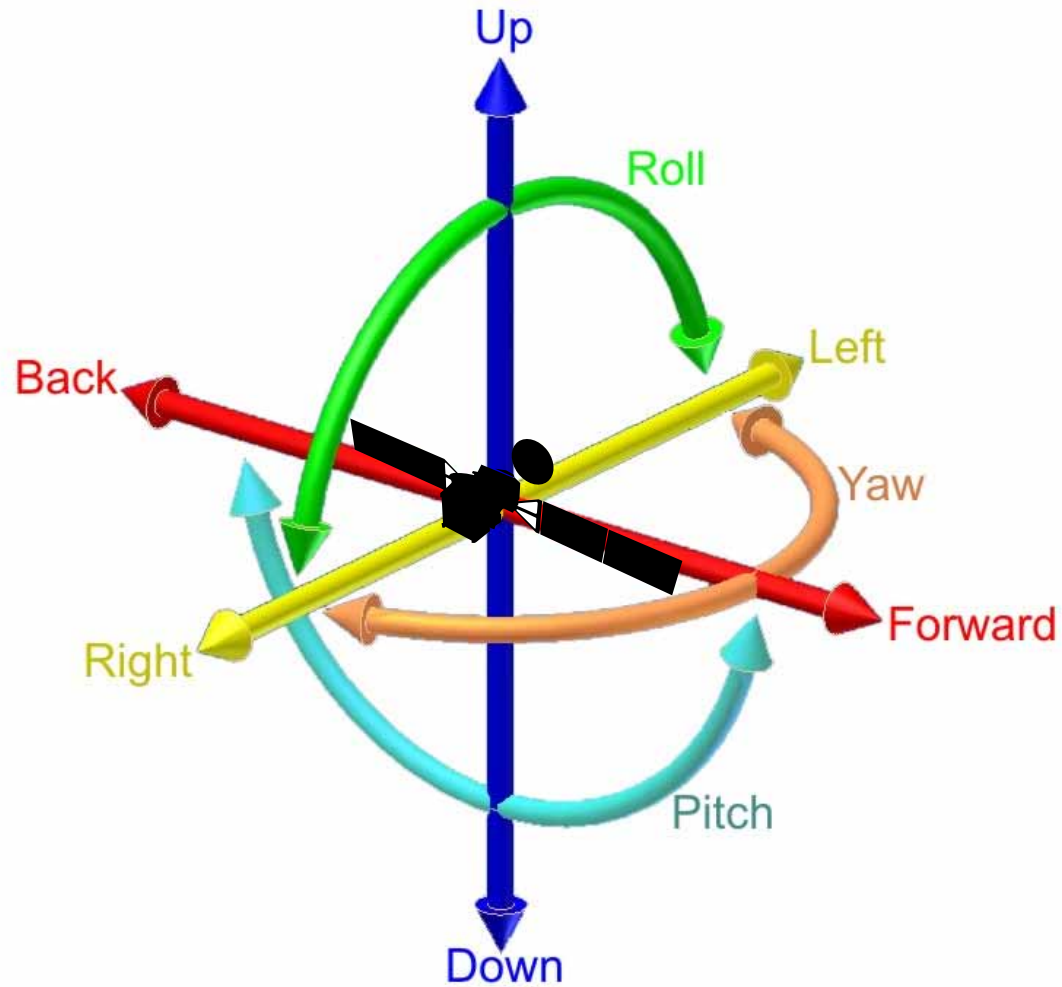
How do you find the way to Mars?



A short flight to Mars



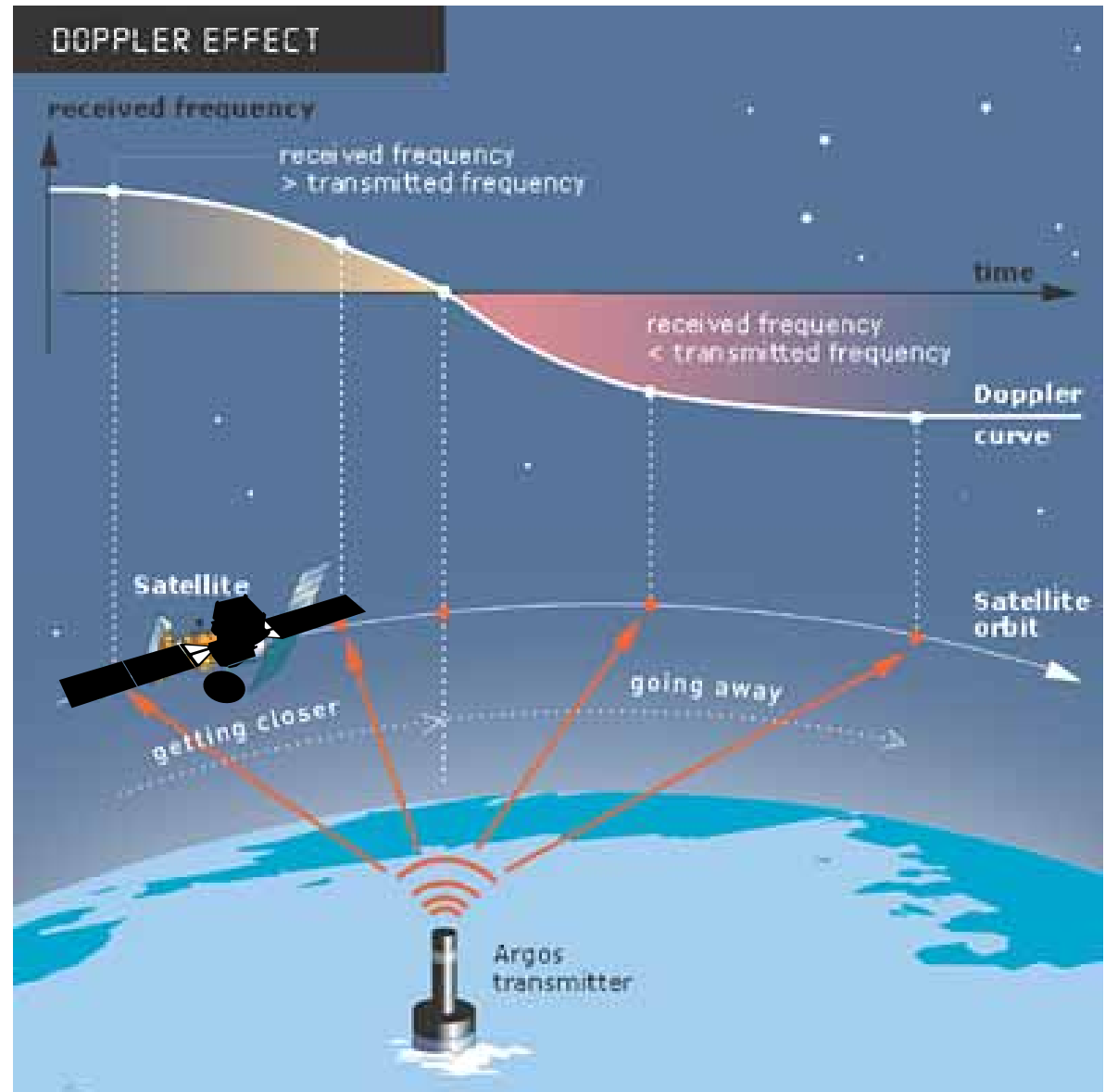
How do you find the way to Mars?



How do you find the way to Mars?



Position and flight direction



How do you find the way to Mars?



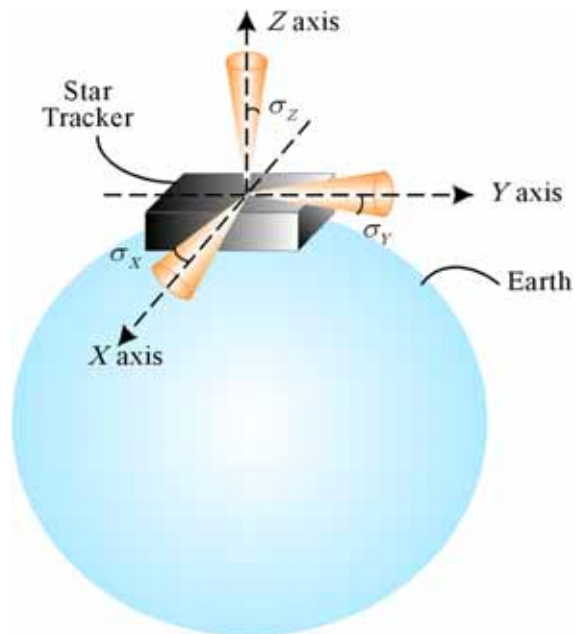
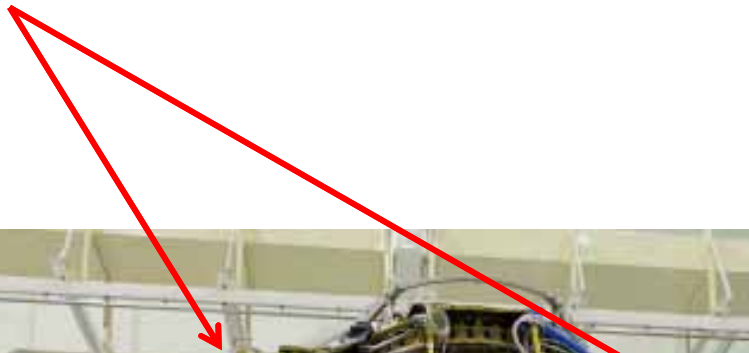
Attitude



Star Trackers



Two star trackers mounted on ExoMars

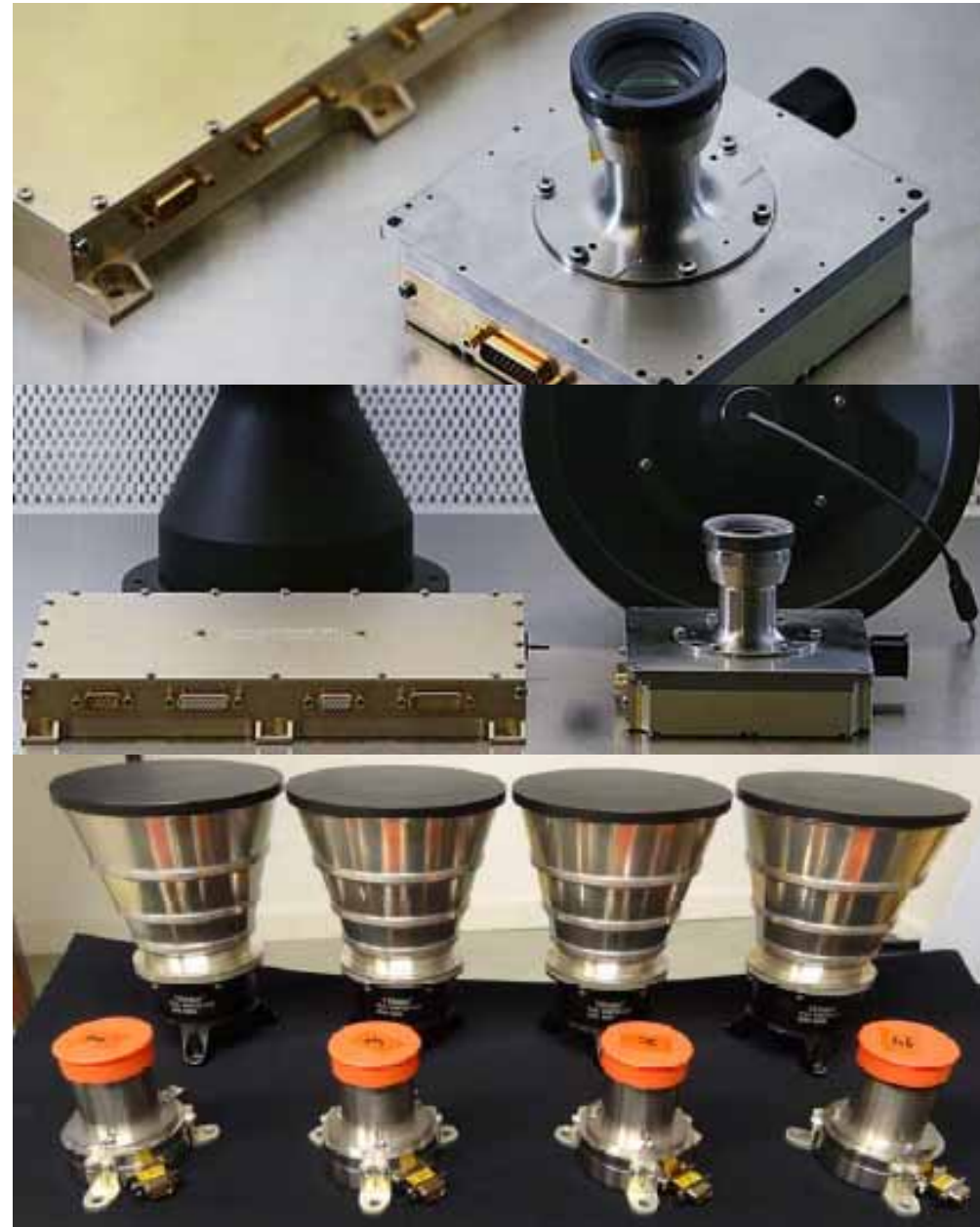
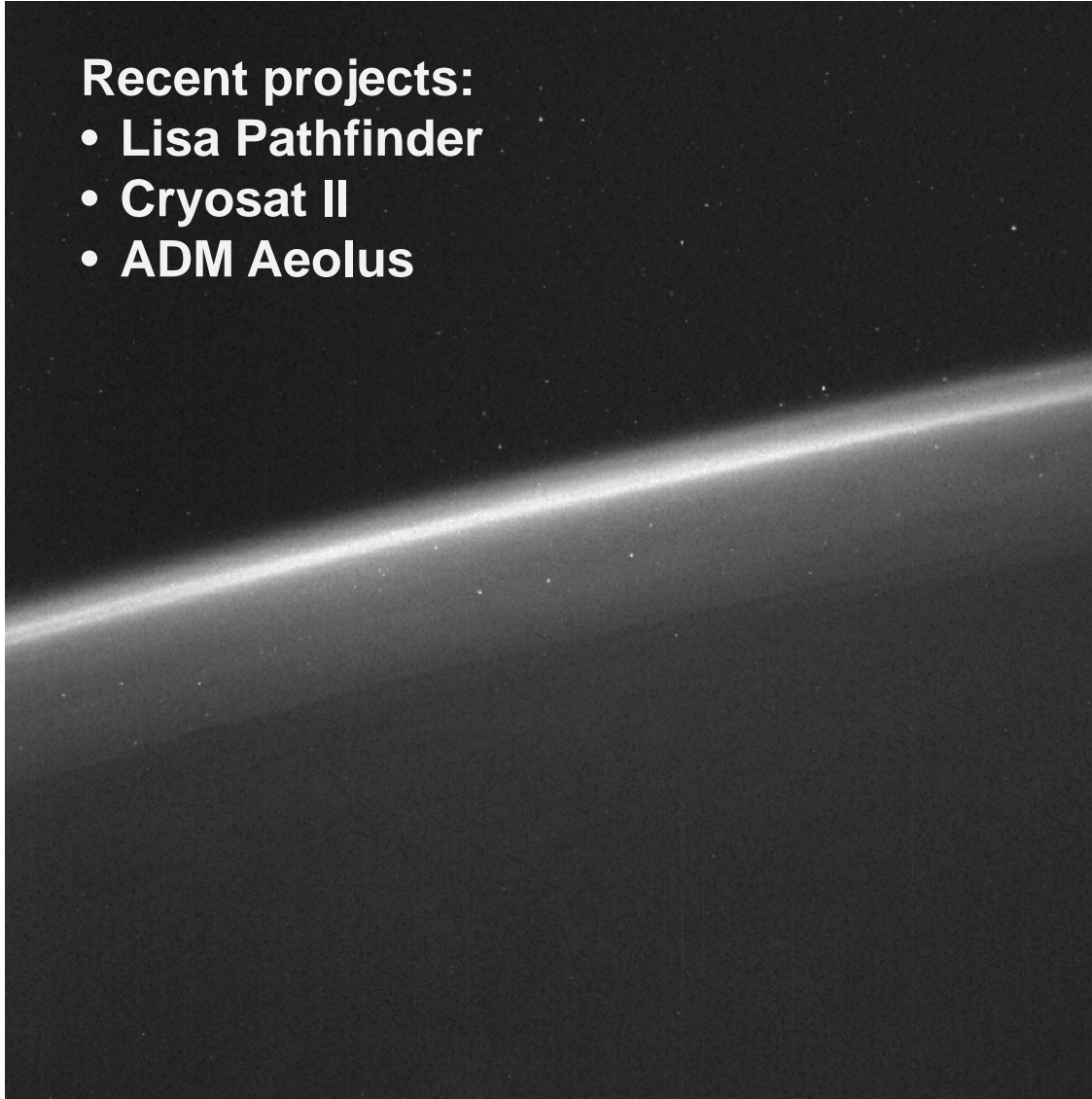


Star Trackers

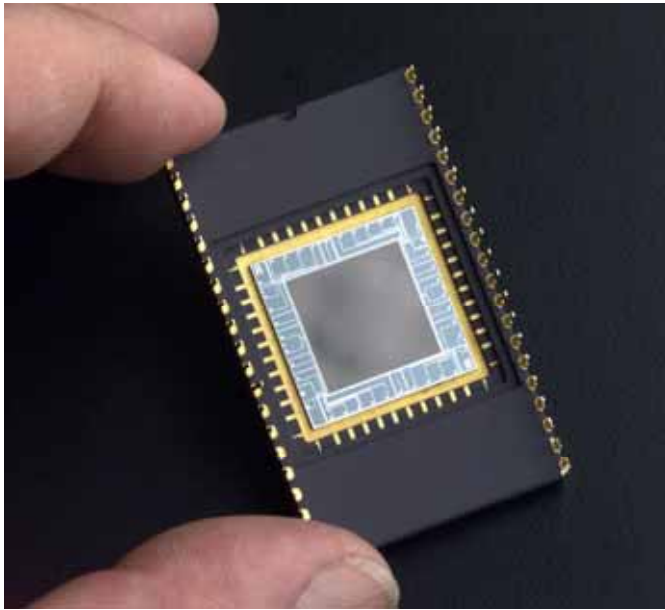
Fully autonomous attitude
determination with high accuracy

Recent projects:

- Lisa Pathfinder
- Cryosat II
- ADM Aeolus

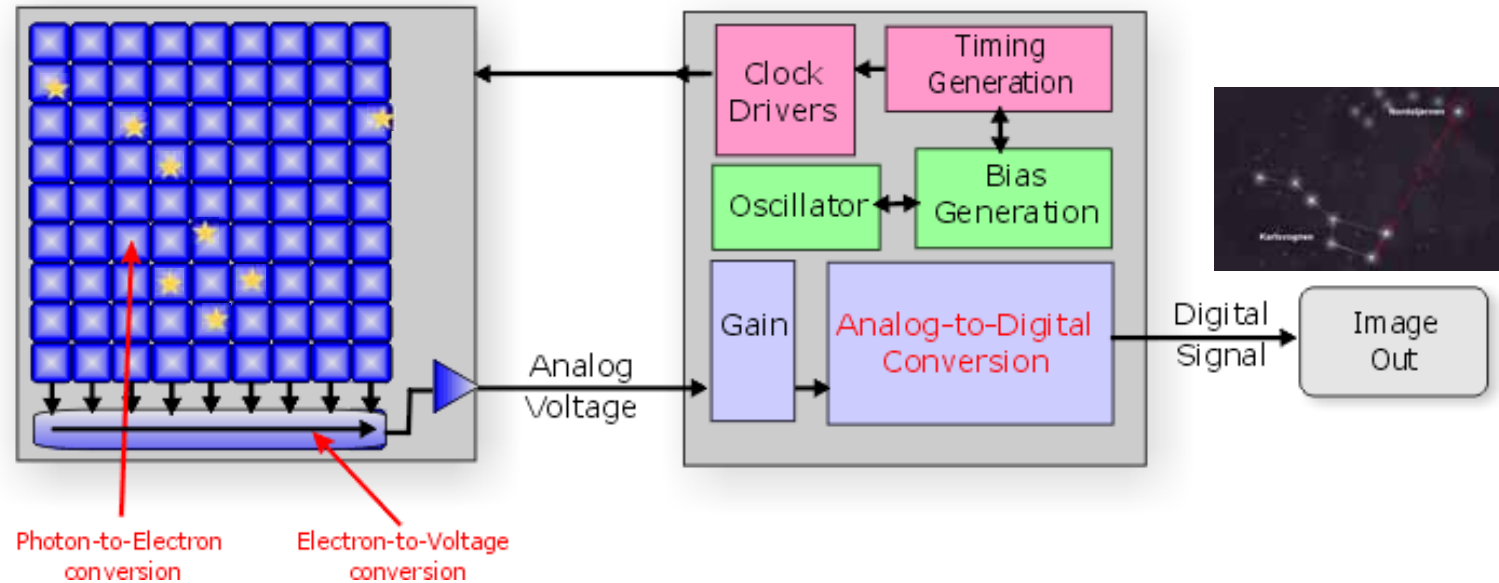


Star Trackers

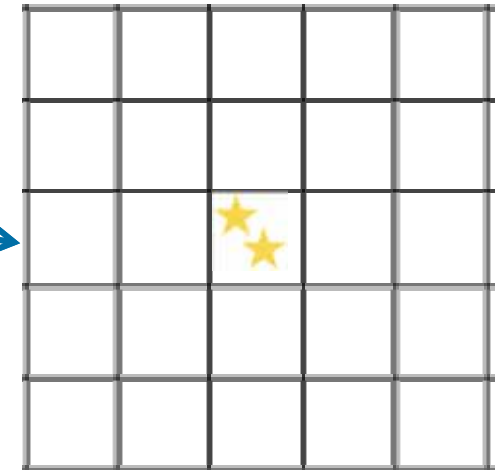
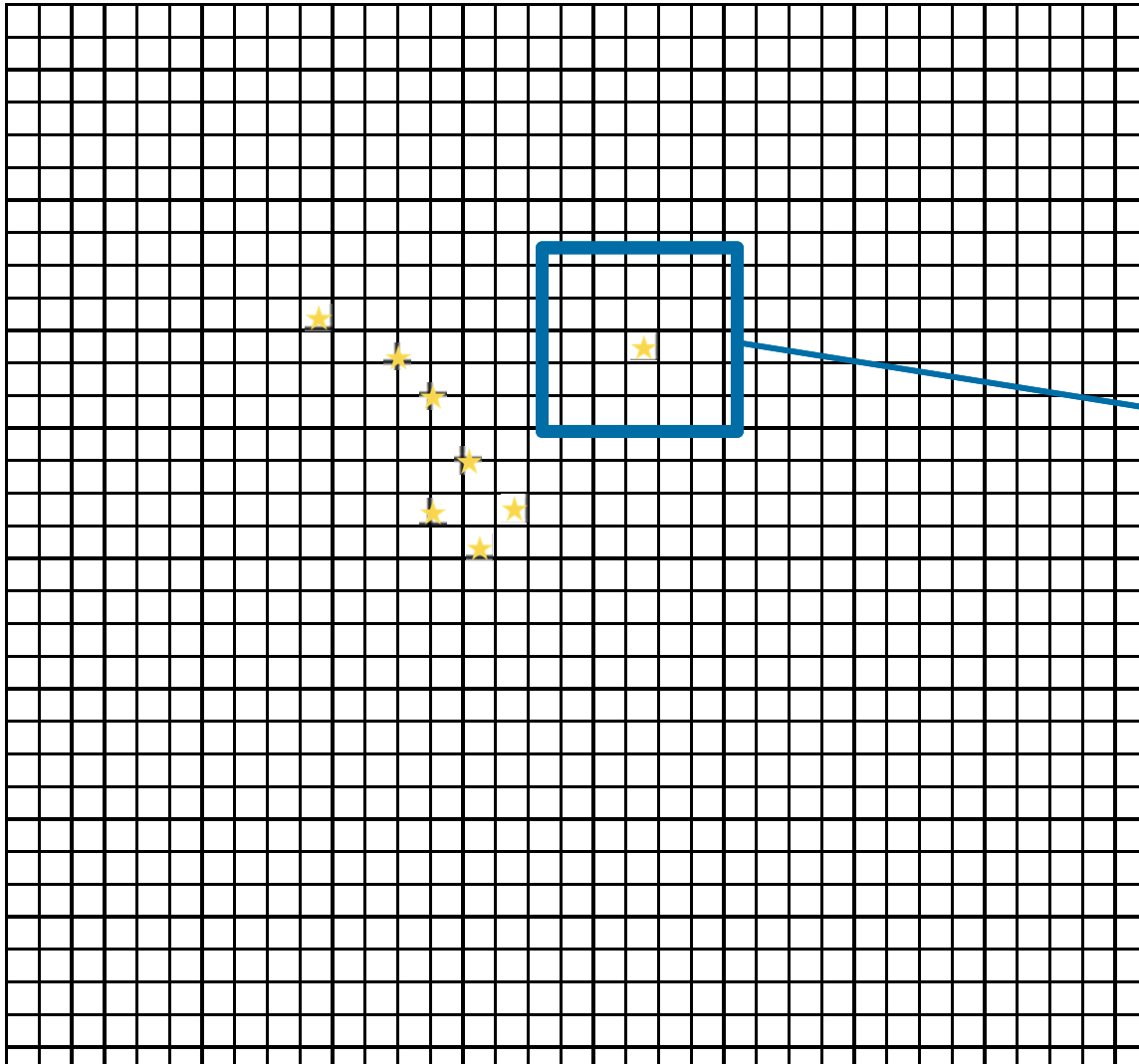


Charge-Coupled Device

Camera Circuit Board



Star Trackers



	0%	0%	0%	0%	0%	0%
	0%	0%	0%	0%	0%	0%
	100%	0%	0%	100%	0%	0%
	0%	0%	0%	0%	0%	0%
	0%	0%	0%	0%	0%	0%
	0%	0%	100%	0%	0%	100%
x	2,5					
y	2,5					



How can we make this more precise?

MATH

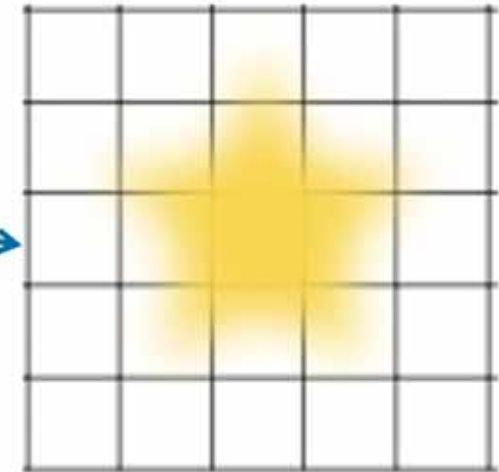
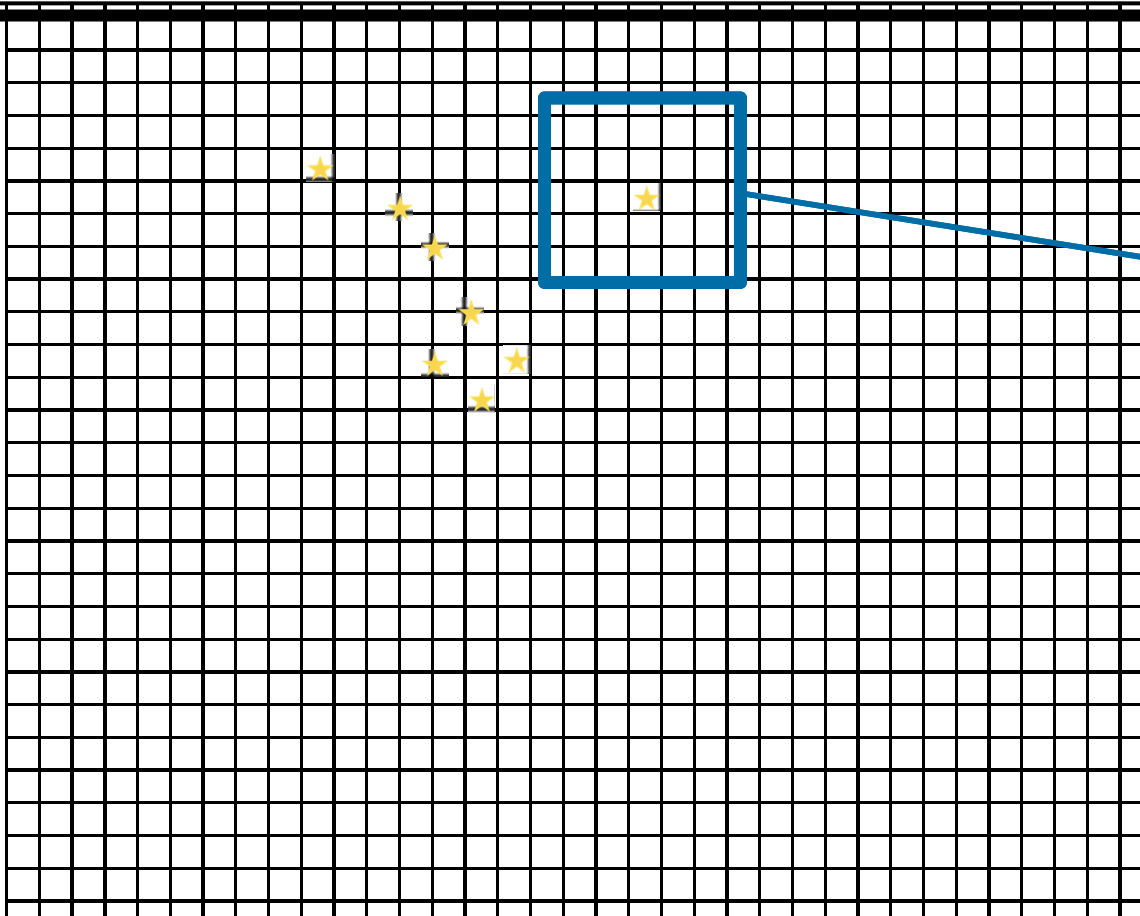
AND SOME OPTICS OUT OF FOCUS

Star Trackers



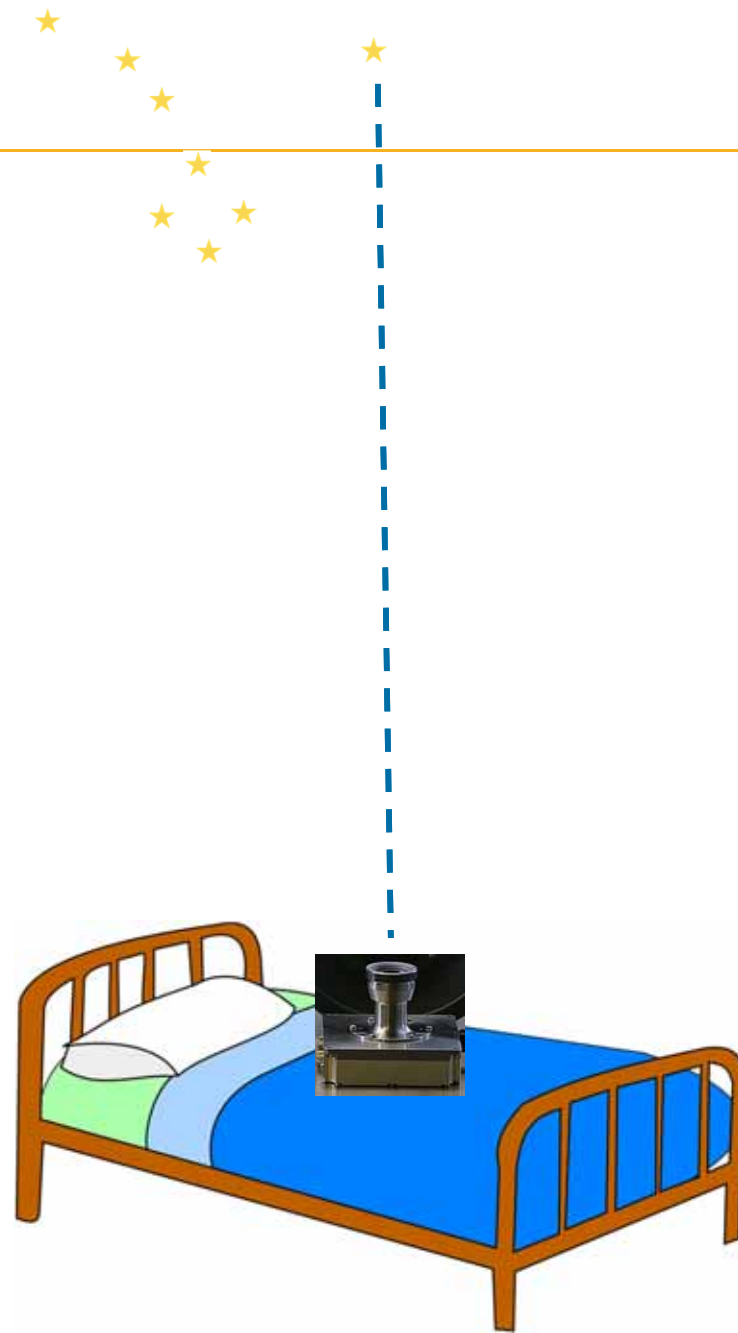
The centroid of a plane figure X can be computed by dividing it into a finite number of simpler figures X_1, X_2, \dots, X_n , computing the centroid C_i and area A_i of each part, and then computing

$$C_x = \frac{\sum C_{ix} A_i}{\sum A_i}, C_y = \frac{\sum C_{iy} A_i}{\sum A_i}$$

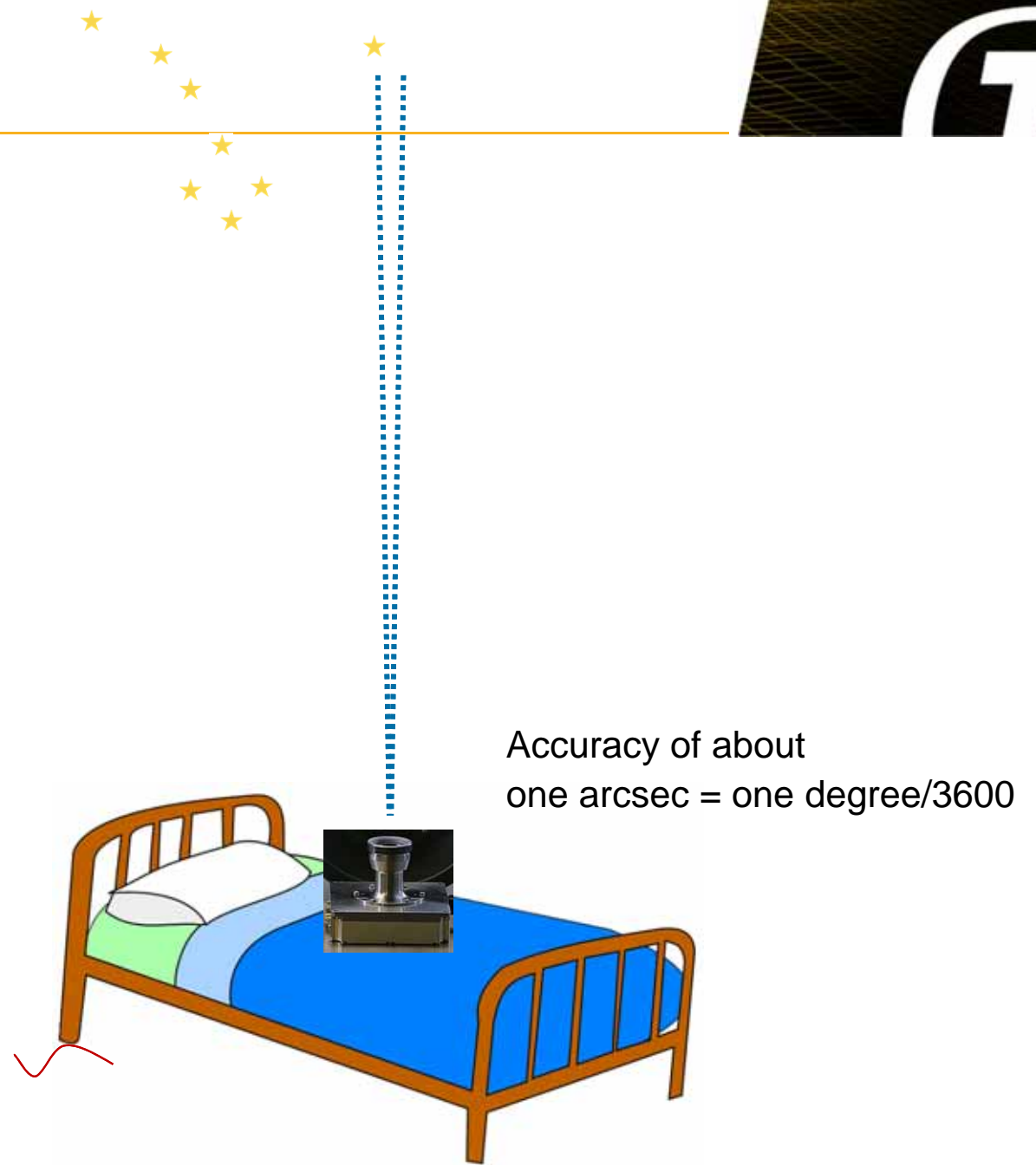


0%	0%	0%	0%	0%	0%	0%
30%	0%	5%	15%	10%	0%	0%
55%	0%	10%	25%	20%	0%	0%
15%	0%	0%	10%	5%	0%	0%
0%	0%	0%	0%	0%	0%	0%
	0%	15%	50%	35%	0%	100%
x	2,7					
y	2,65					

Star Trackers



Star Trackers



Math is the basis for space exploration



ExoMars 2020



ExoMars 2020





Meet us at

www.terma.com

www.terma.com/press/newsletter

www.linkedin.com/company/terma-a-s

www.twitter.com/terma_global

www.youtube.com/user/TermaTV



TERMA[®]
ALLIES IN INNOVATION