Jet Propulsion Laboratory
California Institute of Technology

Persistence: The Value of Taking the Long View

August 15, 2017

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Human/Robotic Mission Systems
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California Institute of Technology

Presented to:
The Aerospace & Defense Forum
San Fernando Valley Chapter
Sherman Oaks, CA

From Caltech students testing rockets to exploring the planets in our lifetime

Caltech students (1936)

Missiles (1940s)

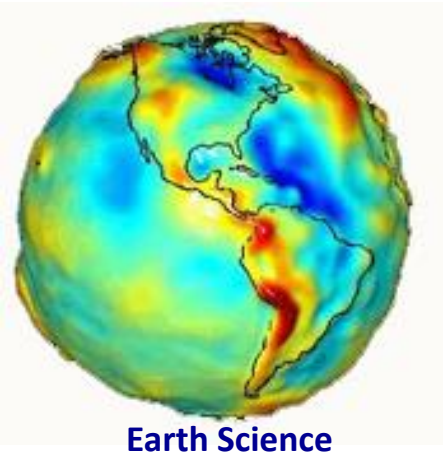
Explorer 1 (1958)

Mars Exploration Rovers

(2004 – present)

Spitzer Space Telescope

(2004 – present)

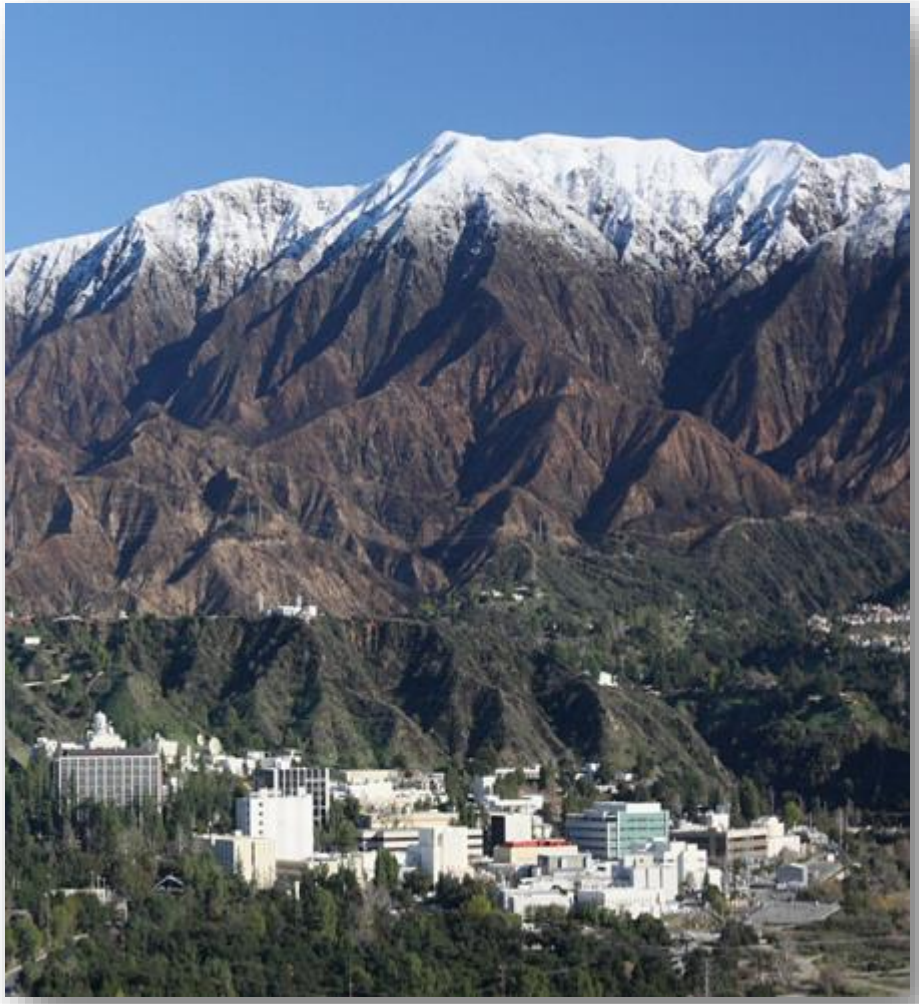


Earth Science

(1978 – present)

JPL is part of NASA and Caltech

- Federally-funded (NASA-owned) Research and Development Center (FFRDC)
- University Operated (Caltech)
- $2.3B Business Base
- 5,600 Employees
- 167 Acres (includes 12 acres leased for parking)
- 139 Buildings; 36 Trailers
- 673,000 Net Square Feet of Office Space
- 906,000 Net Square Feet of Non-Office Space (e.g., Labs)



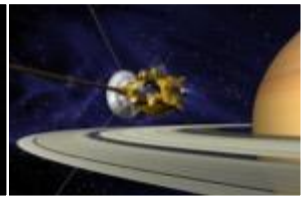
What does JPL buy?

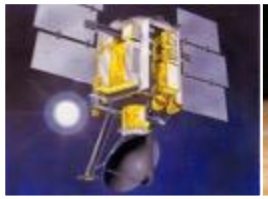
- **JPL Acquisition and Supplier Resources Website**

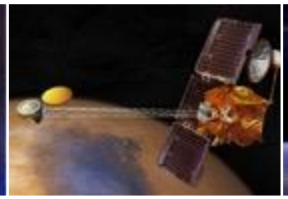
https://www.jpl.nasa.gov/acquisition

19 Spacecraft and 10 instruments Across the Solar System and Beyond


Two Voyagers (1977)


Cassini (1997)


QuickSCAT (1999)


Mars Odyssey (2001)


Jason 2 (2008)

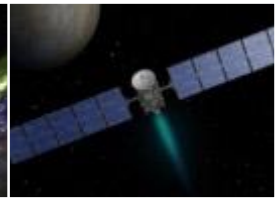

GRACE (2002)


Opportunity (2003)


Spitzer (2003)


Mars Reconnaissance Orbiter (2005)

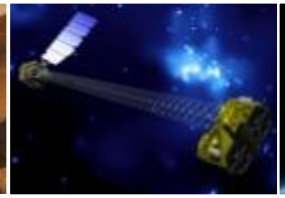

CloudSat (2006)


Dawn (2007)

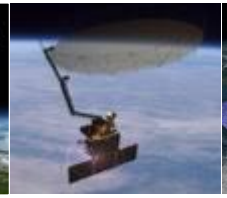

NEOWISE (2009)

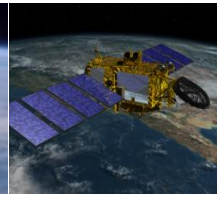

Juno (2011)


Curiosity (2011)


NuSTAR (2012)


OCO-2 (2014)


SMAP (2015)


Jason 3 (2016)

Instruments

Earth Science

- MISR (1999)
- AIRS (2002)
- TES (2004)
- MLS (2004)
- ASTER (2009)
- RapidScat (2014)

(2014)

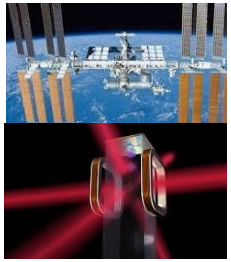
Planetary/Lunar

- MARSIS (2003)
- MIRO (2004)
- Diviner (2004)

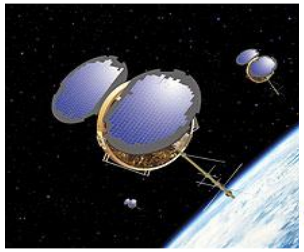
Tech Demo

- OPALS (2014)

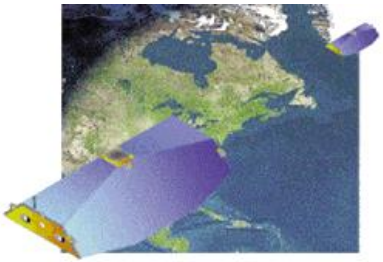
Upcoming Launches



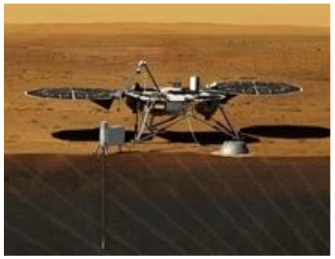
Cold Atom Lab
2017



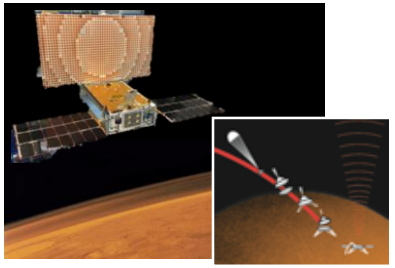
COSMIC-2
2018



GRACE-FO
2018

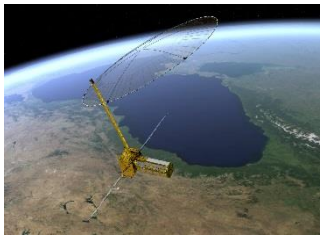


InSIGHT
2018

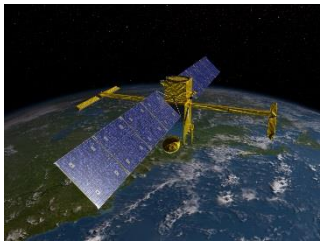


MarCo
2018

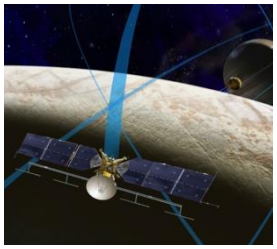
Mars 2020



NISAR 2021



SWOT 2021



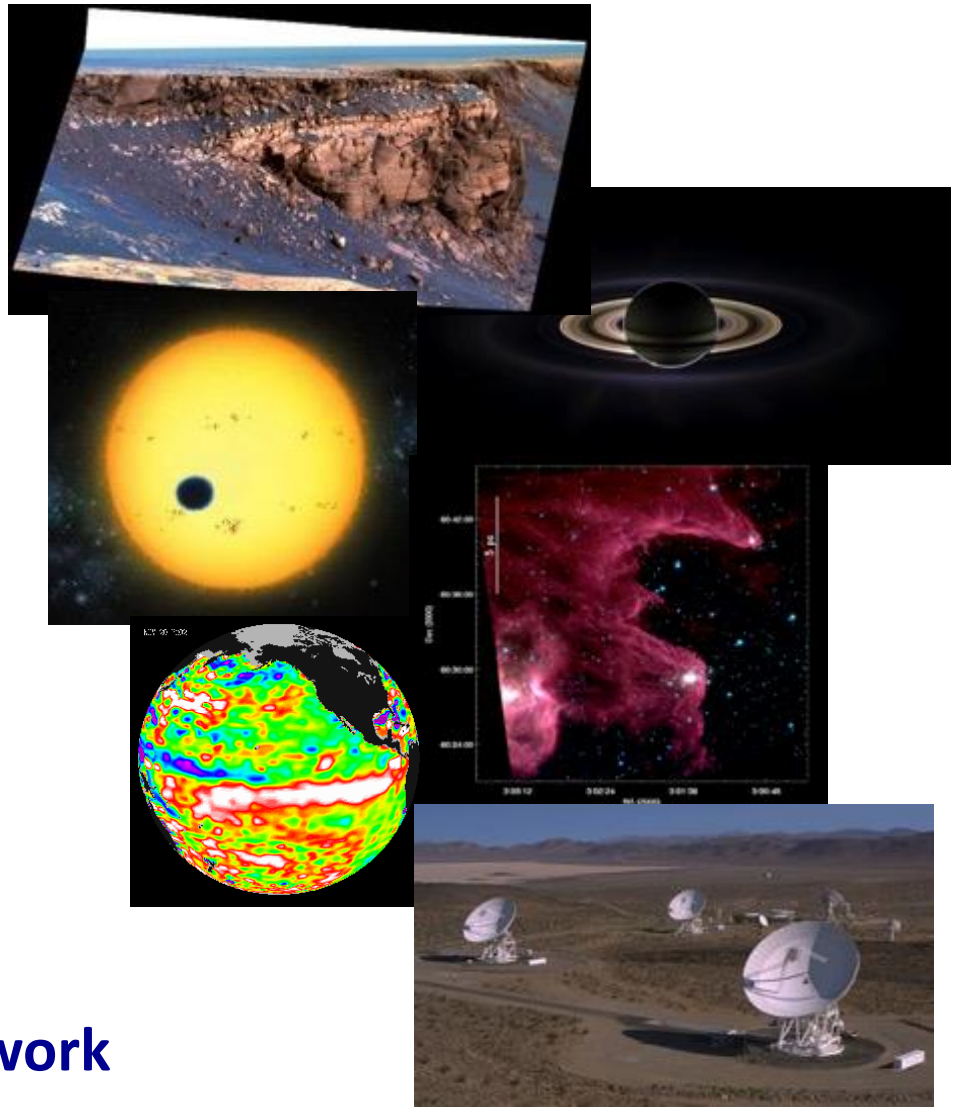
Europa Clipper 2022

WFIRST 2022

Psyche
2022

JPL's mission for NASA is *robotic* space exploration

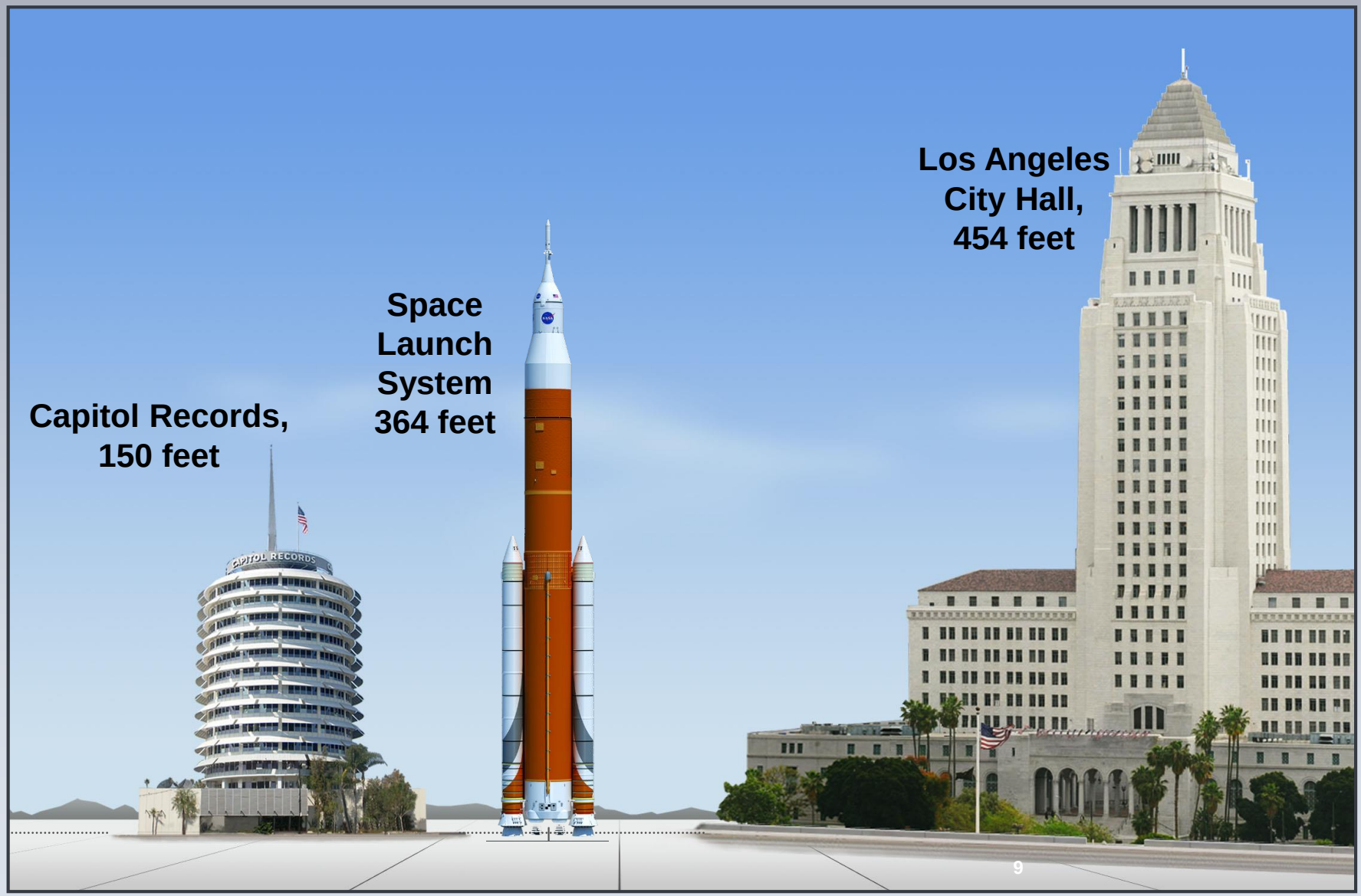
- Mars
- Solar System
- Exoplanets
- Astrophysics
- Earth Science
- Interplanetary Network



JPL also supports *human* space exploration

- **International Space Station**
  - Operations Enhancements
  - Payloads
- **Robotic Precursor Missions & Instruments**
  - Moon, Mars, and Asteroids
- **Current Exploration Systems**
  - Orion Crew Capsule
  - Space Launch System
  - Ground Systems and Operations
- **Planned Exploration Systems**
  - Power and Propulsion Element (PPE)
  - Deep Space Gateway (Habitation + PPE)
- **Robotic Infrastructure**
  - Surface Systems
  - Communications Infrastructure

Space Launch System Size Comparison



Some quotes on planning…

- **“A goal without a plan is just a wish”**

  - Antoine de Saint-Exupéry

- **“By failing to prepare, you are preparing to fail”**

  - Benjamin Franklin

- **“Give me six hours to chop down a tree and I will spend the first four sharpening the axe”**

  - Abraham Lincoln

- **“In preparing for battle, I have always found that plans are useless, but planning is indispensable”**

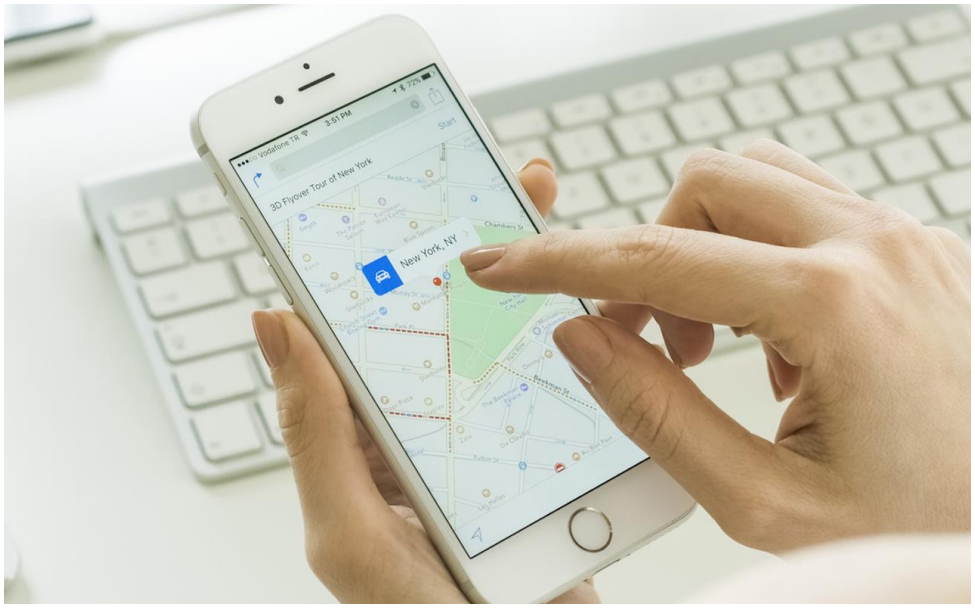
  - Dwight Eisenhower

- **“If you don’t know where you are going, you’ll end up someplace else”**

  - Yogi Berra

Some thoughts on planning…

- Planning is more like a roadmap, not just a fixed itinerary
  - Always focused on getting to the objective
  - Alternative routes are possible, including on-ramps and off-ramps
  - The actual path is subject to change for many reasons



Some thoughts on goals and objectives…

- **Goals can often be too general for planning purposes**
  - **Explore Space**
  - **Get an education**
  - **Improve my business**

Some thoughts on goals and objectives… (cont'd)

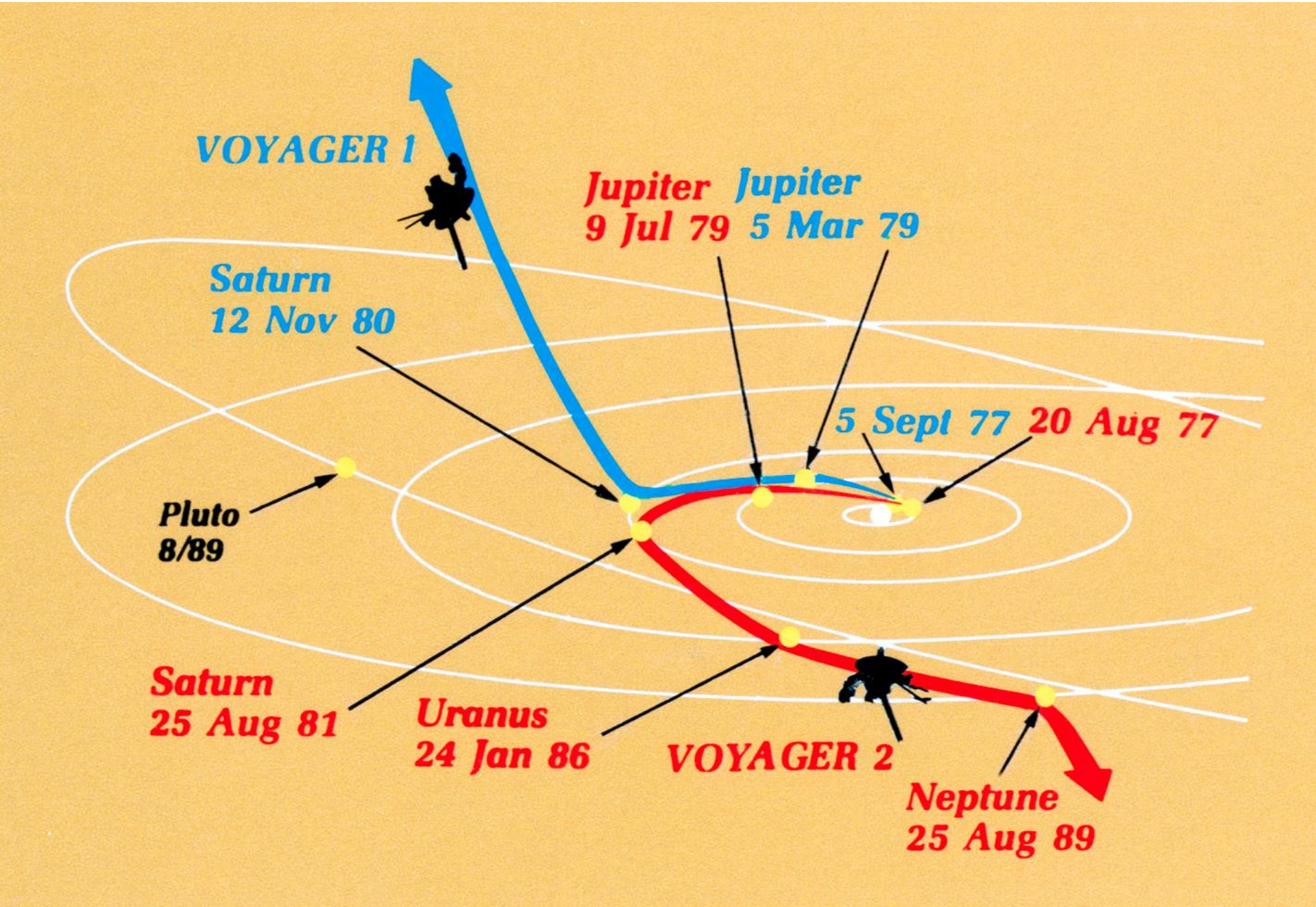
- **Objectives, both long-term and short-term, can drive planning, if they are S.M.A.R.T. (Specific, Measurable, Achievable, Relevant, and Time-tagged)**
  - **"First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth."**

    - John F. Kennedy
  - **Get a B.S. in Engineering in four years**
  - **Double gross sales in two years**

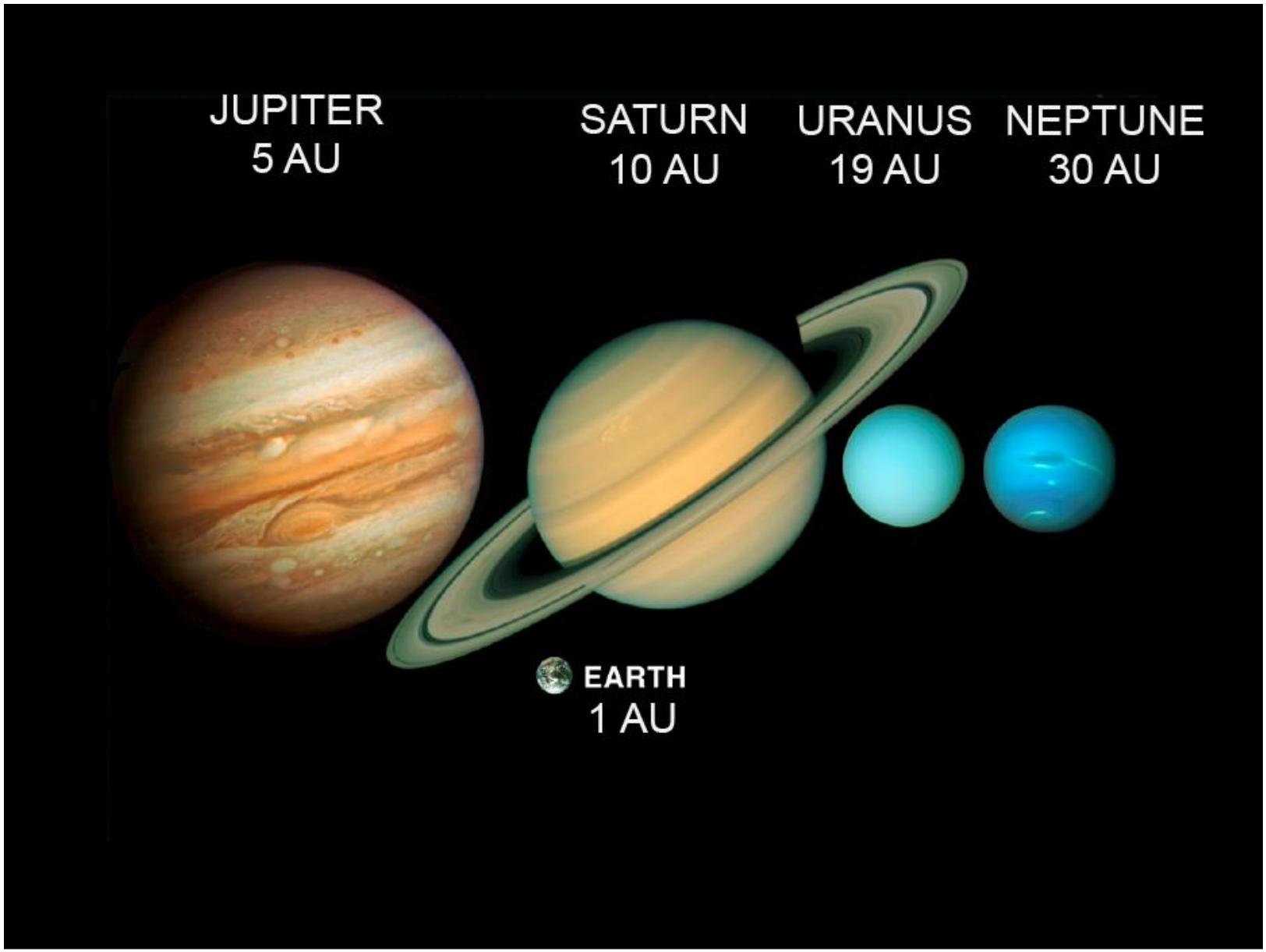
Voyager Example (Grand daddy of them all)…

- Ambitious Objective: Outer Planets Grand Tour
- Needed planetary alignment happens only every 175 years
- At first was a much more grandiose mission launched on a Saturn V
- Descoped and budgeted to only visit Jupiter and Saturn
- Result (so far): Grand Tour achieved
- Current Status: Voyager Interstellar Mission

Voyager


VOYAGER 1
Jupiter
9 Jul 79
Jupiter
5 Mar 79
Saturn
12 Nov 80
5 Sept 77
20 Aug 77
Pluto
8/89
Saturn
25 Aug 81
Uranus
24 Jan 86
VOYAGER 2
Neptune
25 Aug 89

Voyager – Planets Visited



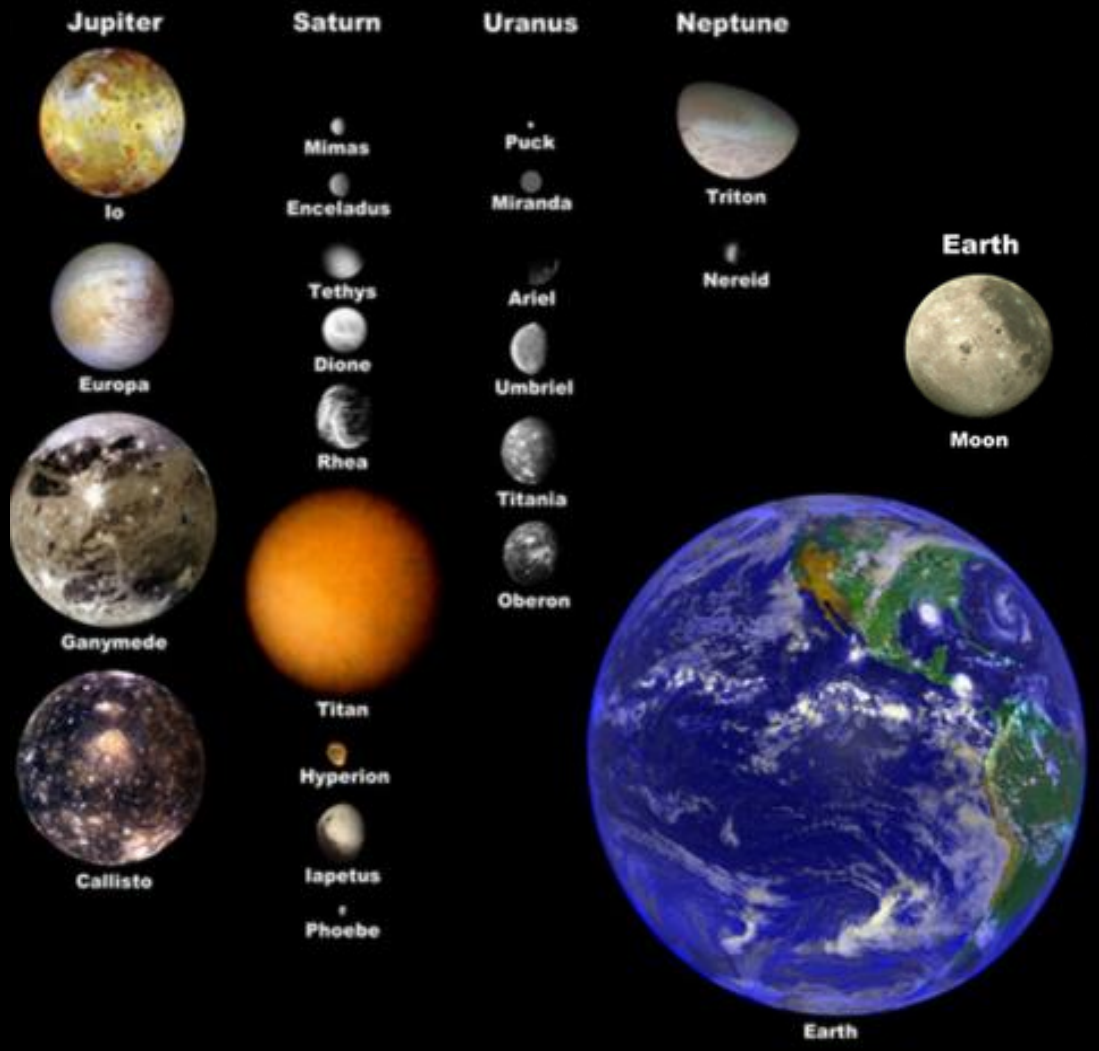
Voyager 1 and 2 explored all four giant outer planets of our solar system, 48 of their moons

Voyager visited eight of Jupiter's moons and discovered three

Voyager took images of 17 of Saturn's moons, including four that they discovered.

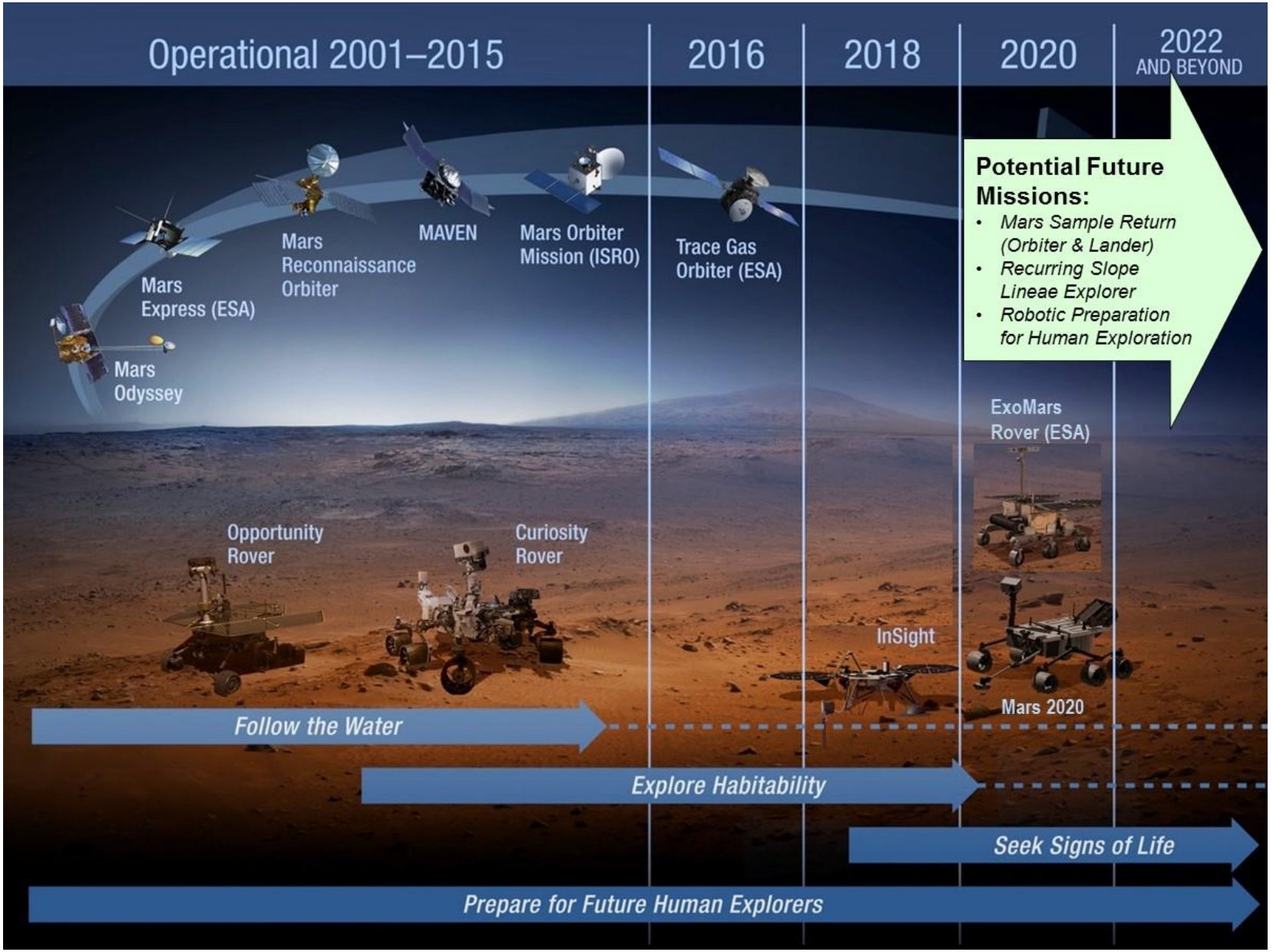
Voyager found 11 new moons at Uranus and visited 16.

Voyager imaged eight of Neptune's moons, discovering five of them.



Outer Planet Moons Scaled to Earth's Moon

Robotic Mars Exploration Missions



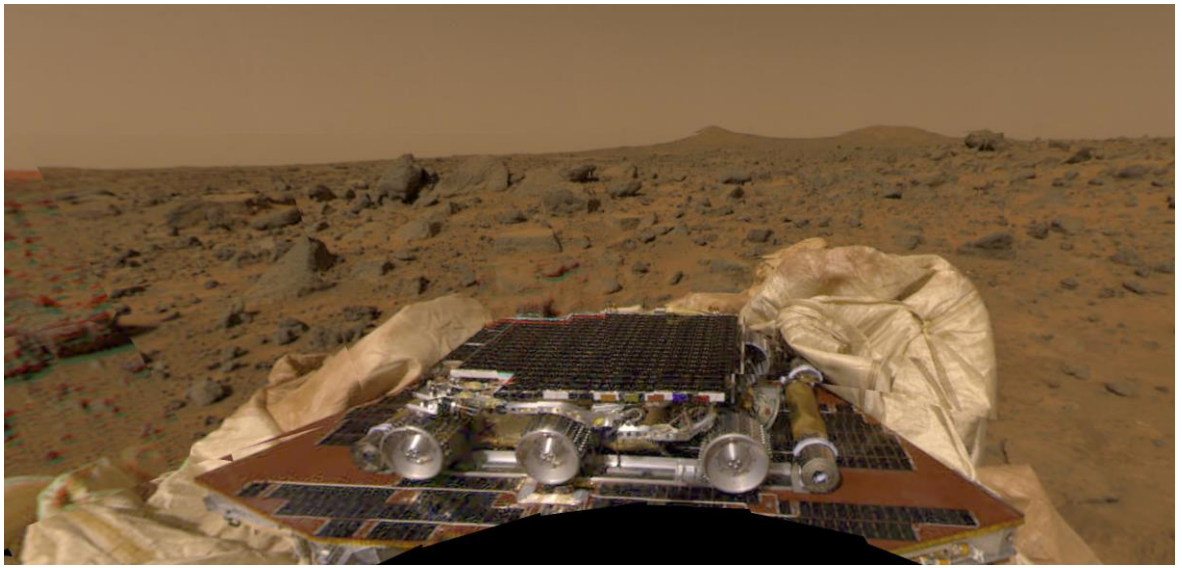
But, how did we get there…

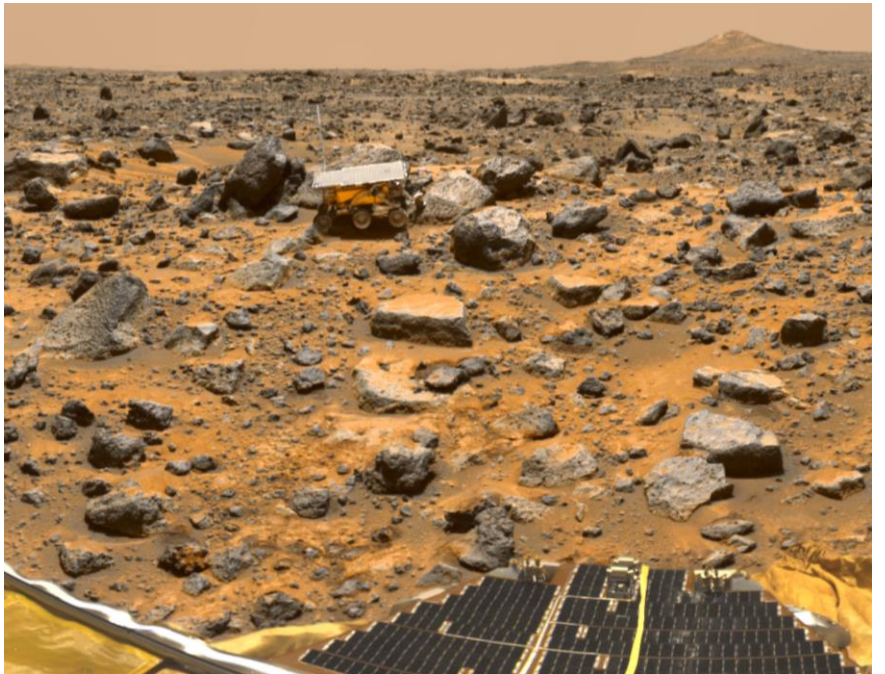
Donna Shirley and the rover “Sojourner Truth”

And the rest is history, and the future…

Tony Spear and Team celebrating the Mars Pathfinder landing

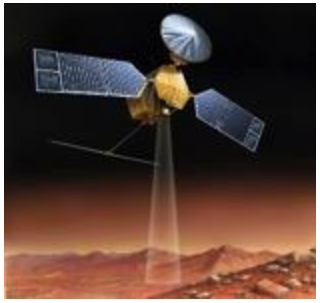
Pathfinder landed on Mars' Ares Vallis - July 4, 1997





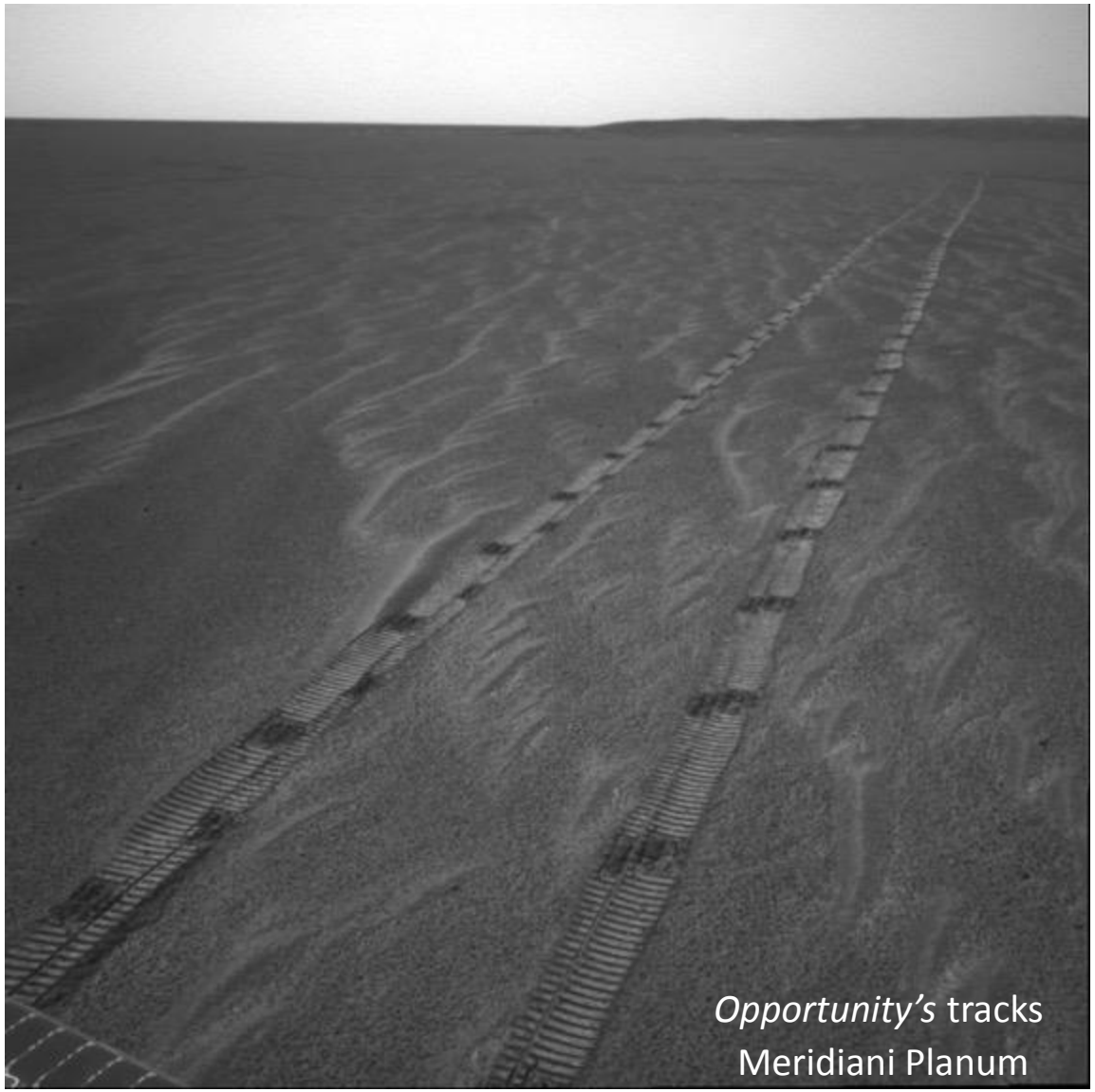
Now: A continuous robotic presence on and in-orbit around Mars

2001 Mars Odyssey



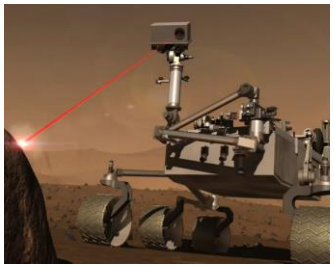
Mars Reconnaissance Orbiter

Mars Express (ESA)



Opportunity's tracks Meridiani Planum

Opportunity

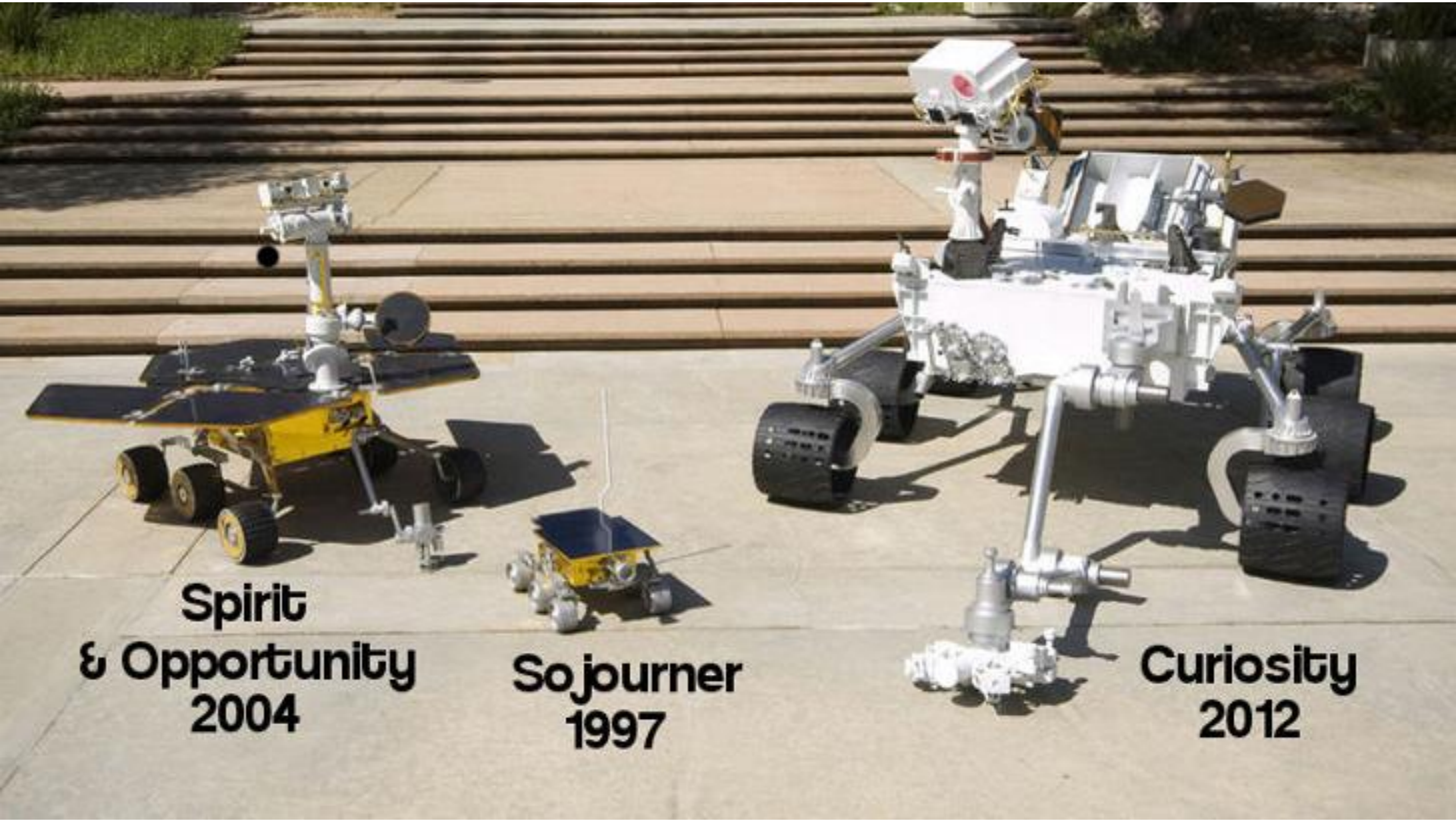


Curiosity

"Do not go where the path may lead, go instead where there is no path and leave a trail"

--- Ralph Waldo Emerson

Mars Rovers Family Portrait: Adding capability over time



Mars Science Laboratory (Curiosity Rover) Example…

- Look for evidence of conditions conducive to past or present life
- Wheel wear problem…

Curiosity's primary scientific goal is to explore and quantitatively assess a local region on Mars' surface as a potential habitat for life, past or present

- Biological potential
- Geology and geochemistry
- Water, weather, and climate
- Radiation levels and hazards

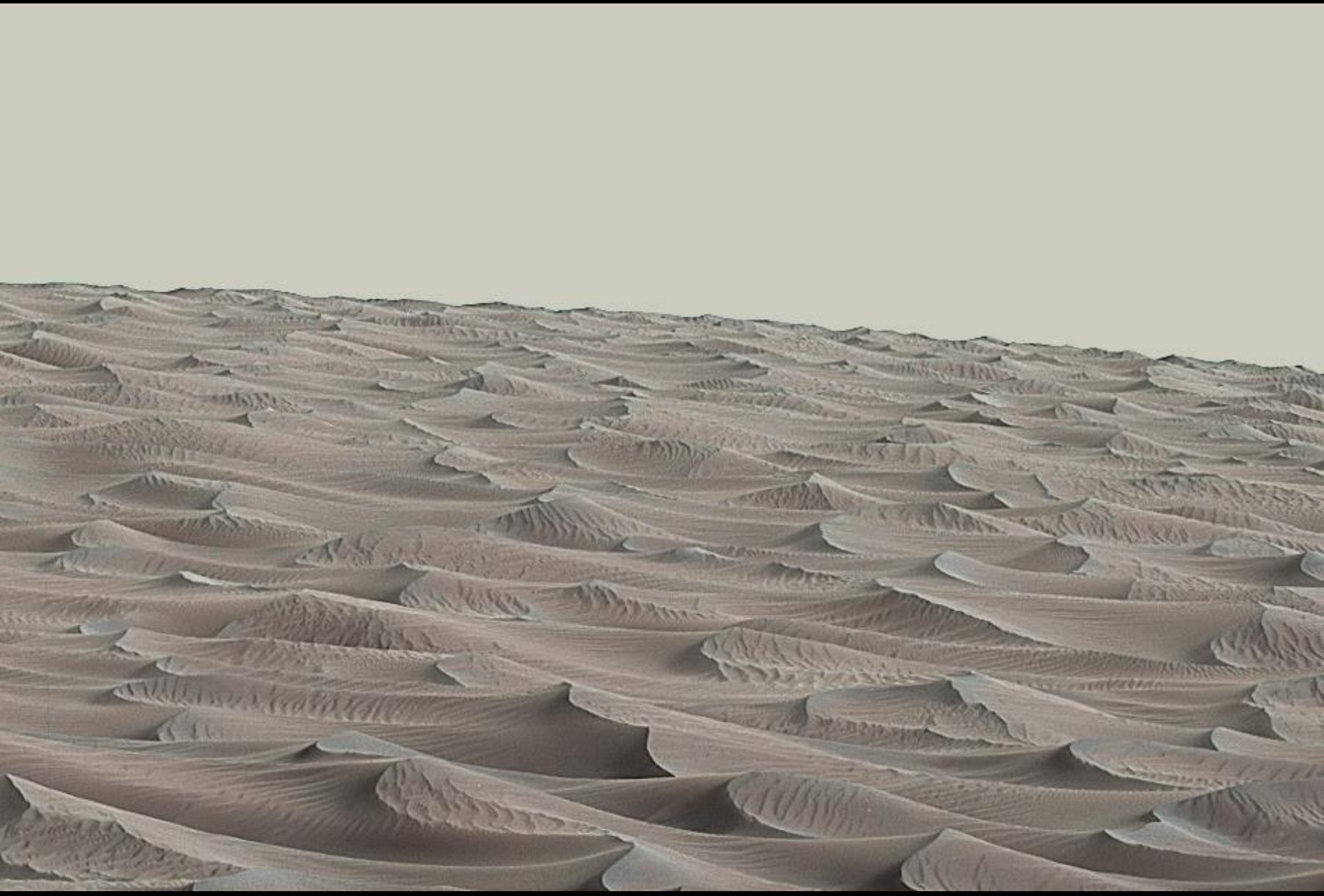
NASA/JPL-Caltech

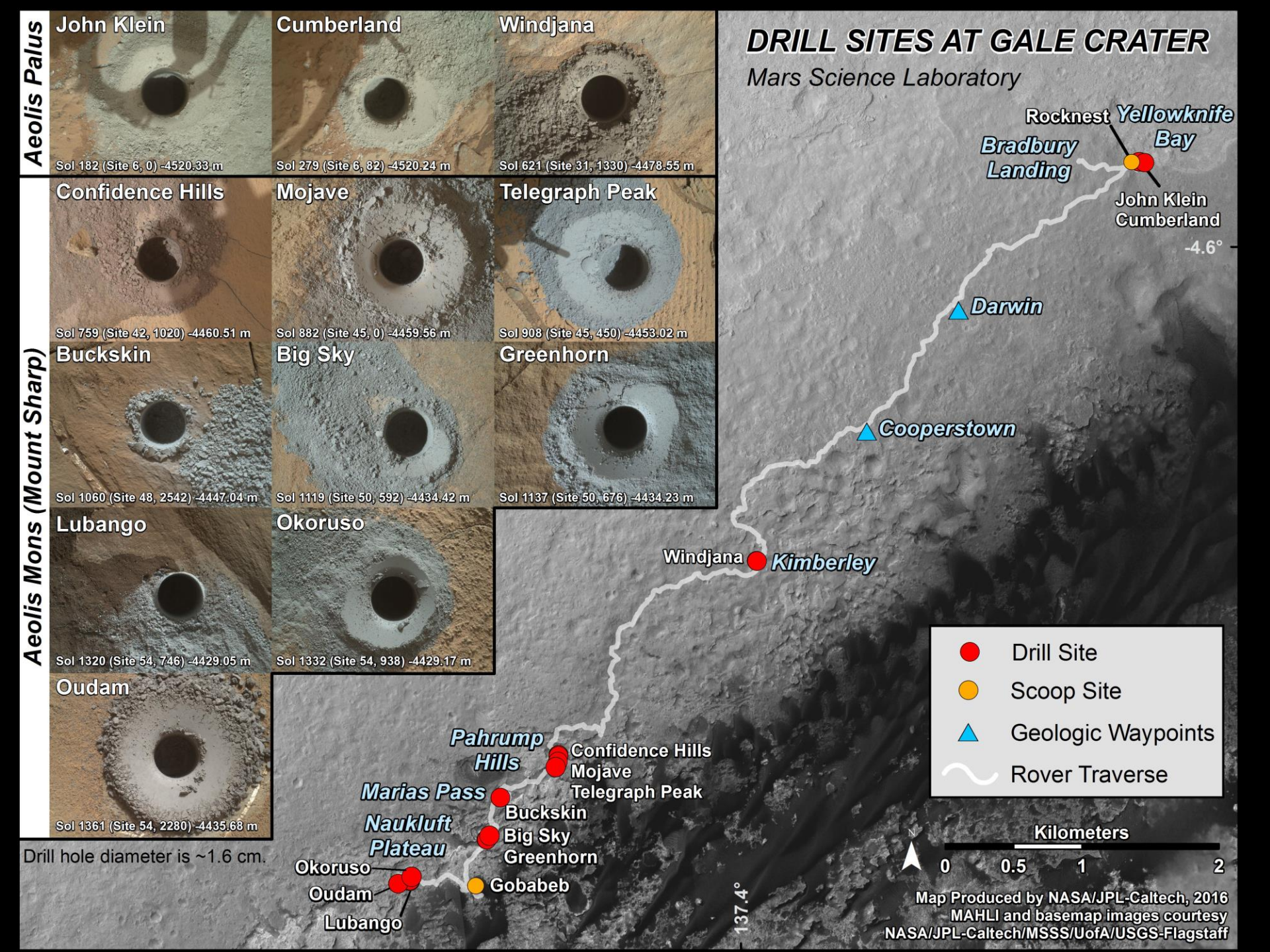
150-km Gale Crater contains a 5-km high mound of stratified rock. Strata in the lower section of the mound vary in mineralogy and texture, suggesting that they may have recorded environmental changes over time.

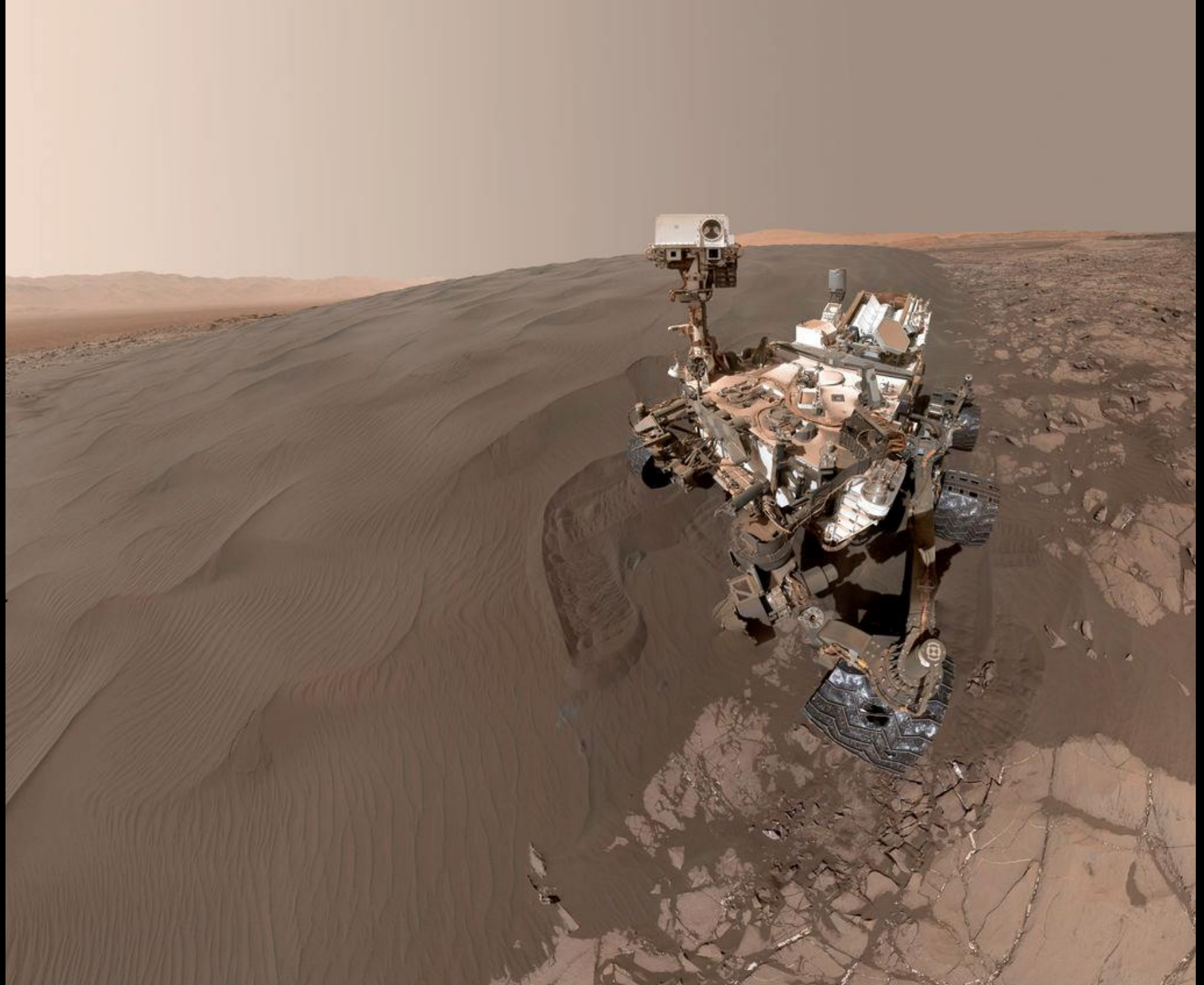
CURIOSITY

CURIOSITY

August 5, 2012: “Touchdown confirmed.”
“Let’s see where Curiosity will take us.”




DRILL SITES AT GALE CRATER
Mars Science Laboratory
Aeolis Palus
Aeolis Mons (Mount Sharp)
John Klein
Sol 182 (Site 6, 0) -4520.33 m
Cumberland
Sol 279 (Site 6, 82) -4520.24 m
Windjana
Sol 621 (Site 31, 1330) -4478.55 m
Confidence Hills
Sol 759 (Site 42, 1020) -4460.51 m
Mojave
Sol 882 (Site 45, 0) -4459.56 m
Telegraph Peak
Sol 908 (Site 45, 450) -4453.02 m
Buckskin
Sol 1060 (Site 48, 2542) -4447.04 m
Big Sky
Sol 1119 (Site 50, 592) -4434.42 m
Greenhorn
Sol 1137 (Site 50, 676) -4434.23 m
Lubango
Sol 1320 (Site 54, 746) -4429.05 m
Okoruso
Sol 1332 (Site 54, 938) -4429.17 m
Oudam
Sol 1361 (Site 54, 2280) -4435.68 m
Drill hole diameter is ~1.6 cm.
Rocknest
Yellowknife Bay
Bradbury Landing
John Klein
Cumberland
-4.6°
Darwin
Cooperstown
Windjana
Kimberley
Pahrump Hills
Confidence Hills
Mojave
Telegraph Peak
Marias Pass
Buckskin
Naukluft Plateau
Big Sky
Greenhorn
Okoruso
Oudam
Lubango
Gobabeb
137.4°
Drill Site
Scoop Site
Geologic Waypoints
Rover Traverse
N
Kilometers
0
0.5
1
2
Map Produced by NASA/JPL-Caltech, 2016
MAHLI and basemap images courtesy
NASA/JPL-Caltech/MSSS/UofA/USGS-Flagstaff

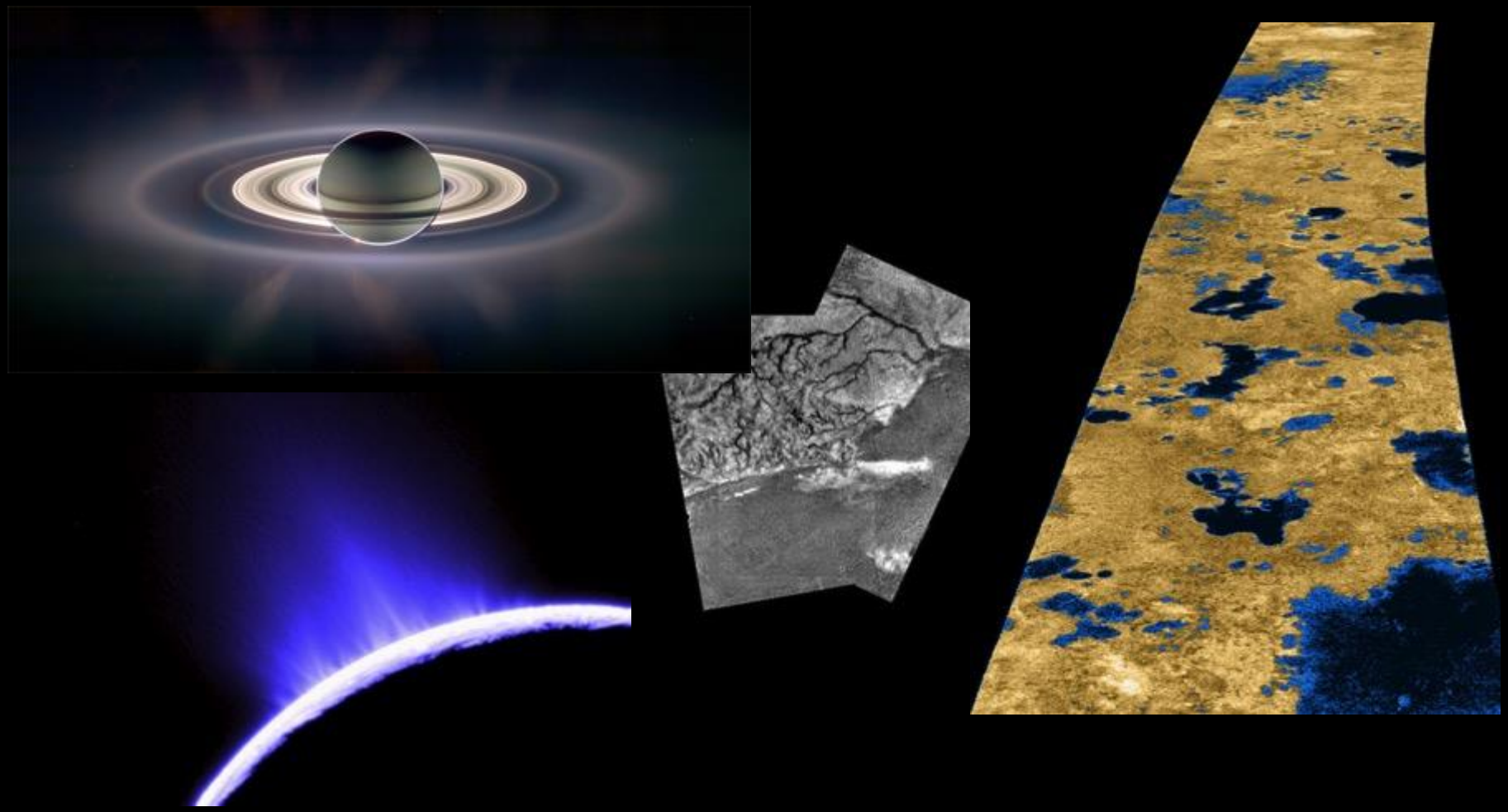



4°40'S
137°22'E
962
964
960
963
967
971
990
987
976/978
981
986
983
984
Marias Pass
Buckskin
1073
1074
1078
1080
1083
1085
1087
1093
1094
1098
Stimson Sandstone Ridges
Bridger Basin
Big Sky/Greenhorn
1153
1155
1158
N
50
METERS

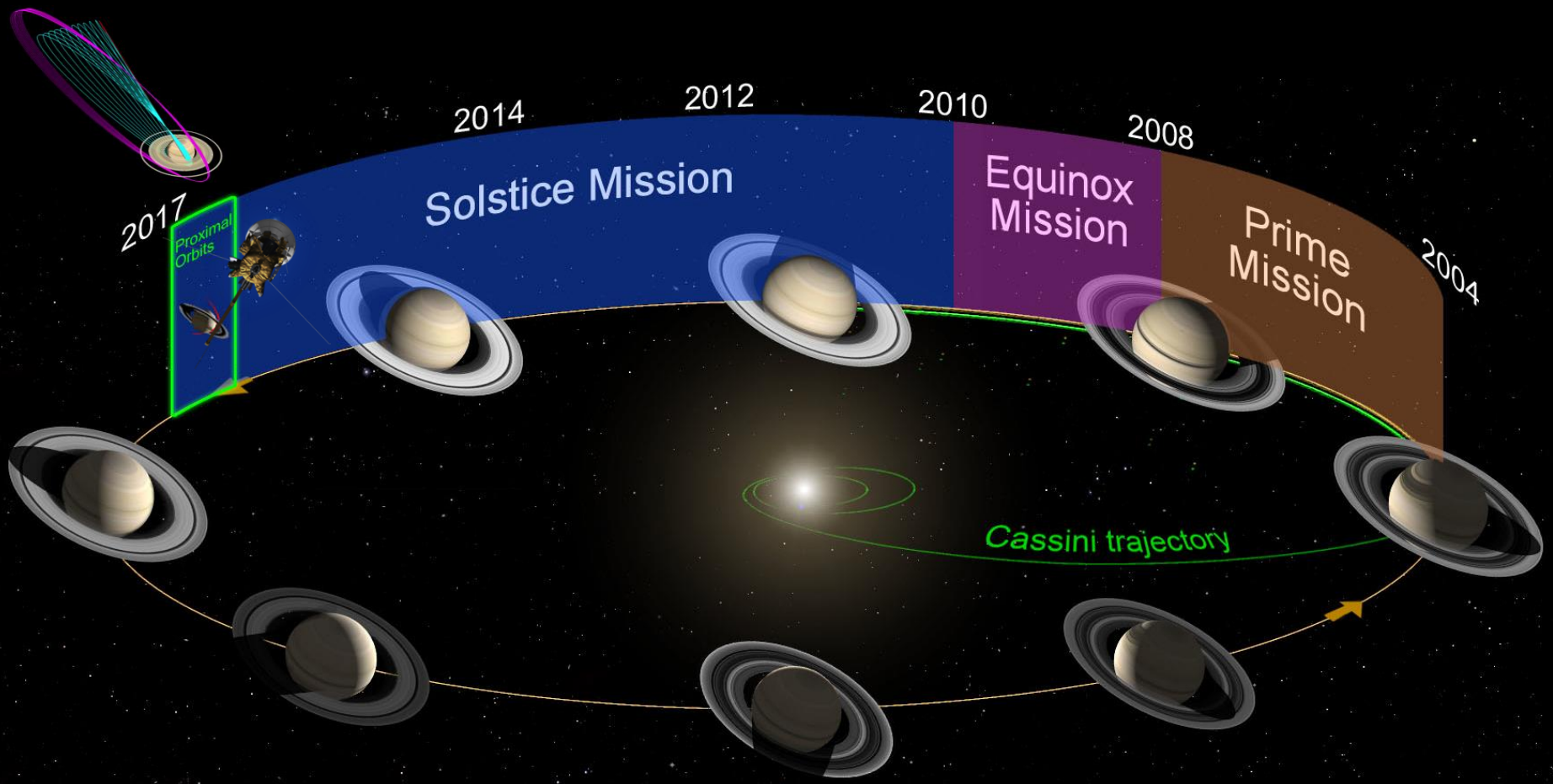
Cassini Program Example…

- **Multiple extended missions**
- **Grand Finale**

Cassini/Huygens studies Saturn, Enceladus' geysers, and Titan's lakes



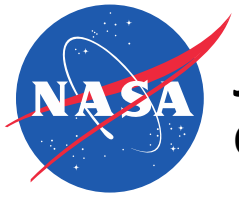
Cassini-Huygens Mission Overview



Grand Finale Video…

- **Going out in a blaze of glory**

https://www.youtube.com/watch?v=xrGAQCq9BMU



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