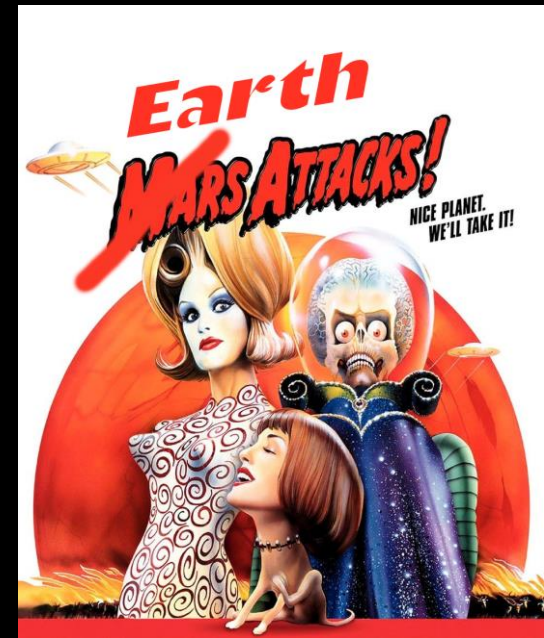


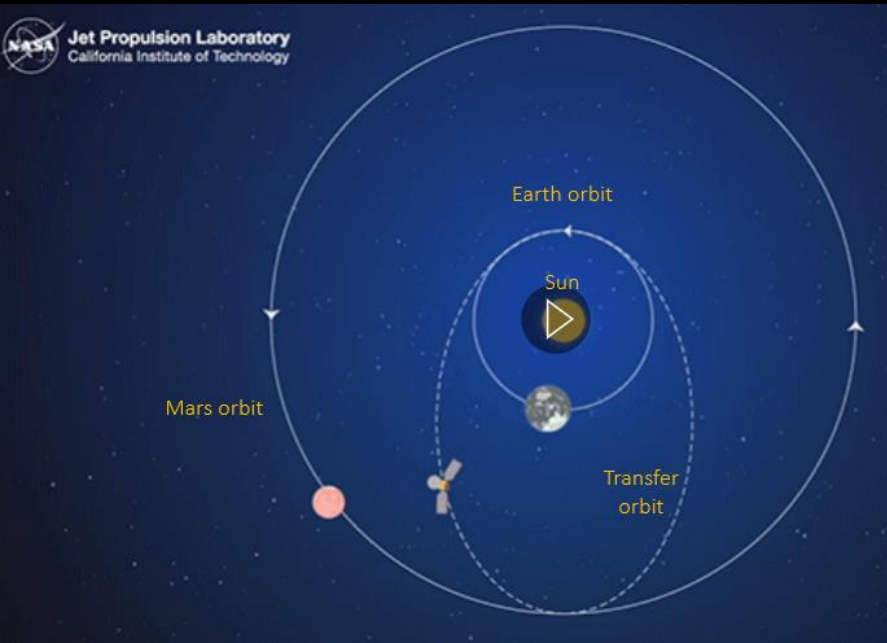
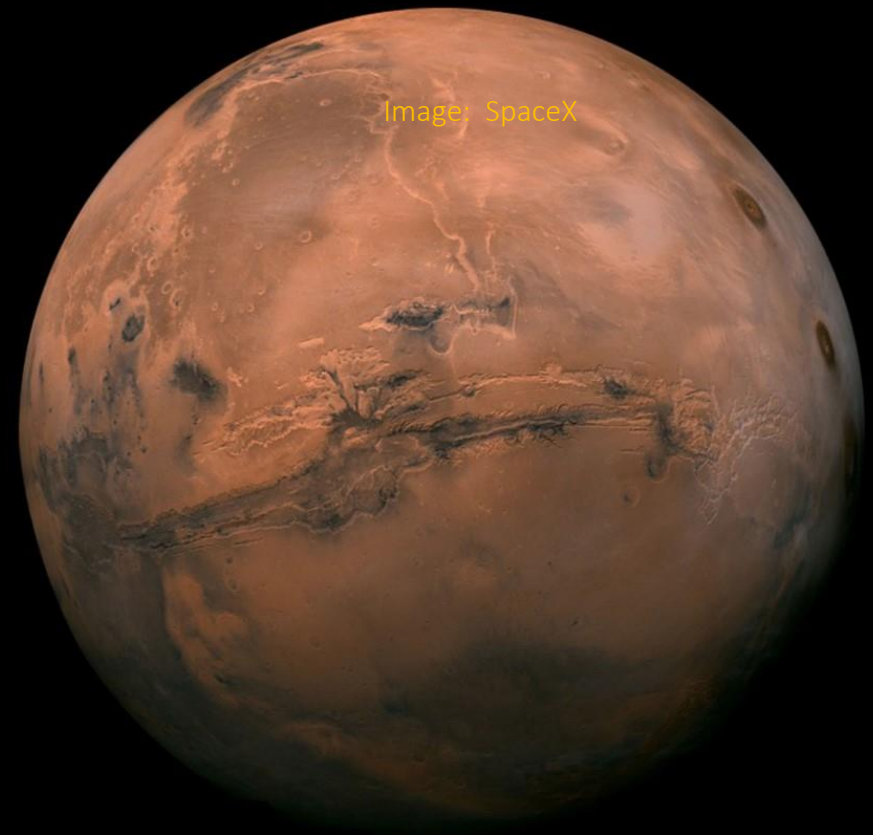


Picture from Chinese Tianwen-1: CNSA/CASC



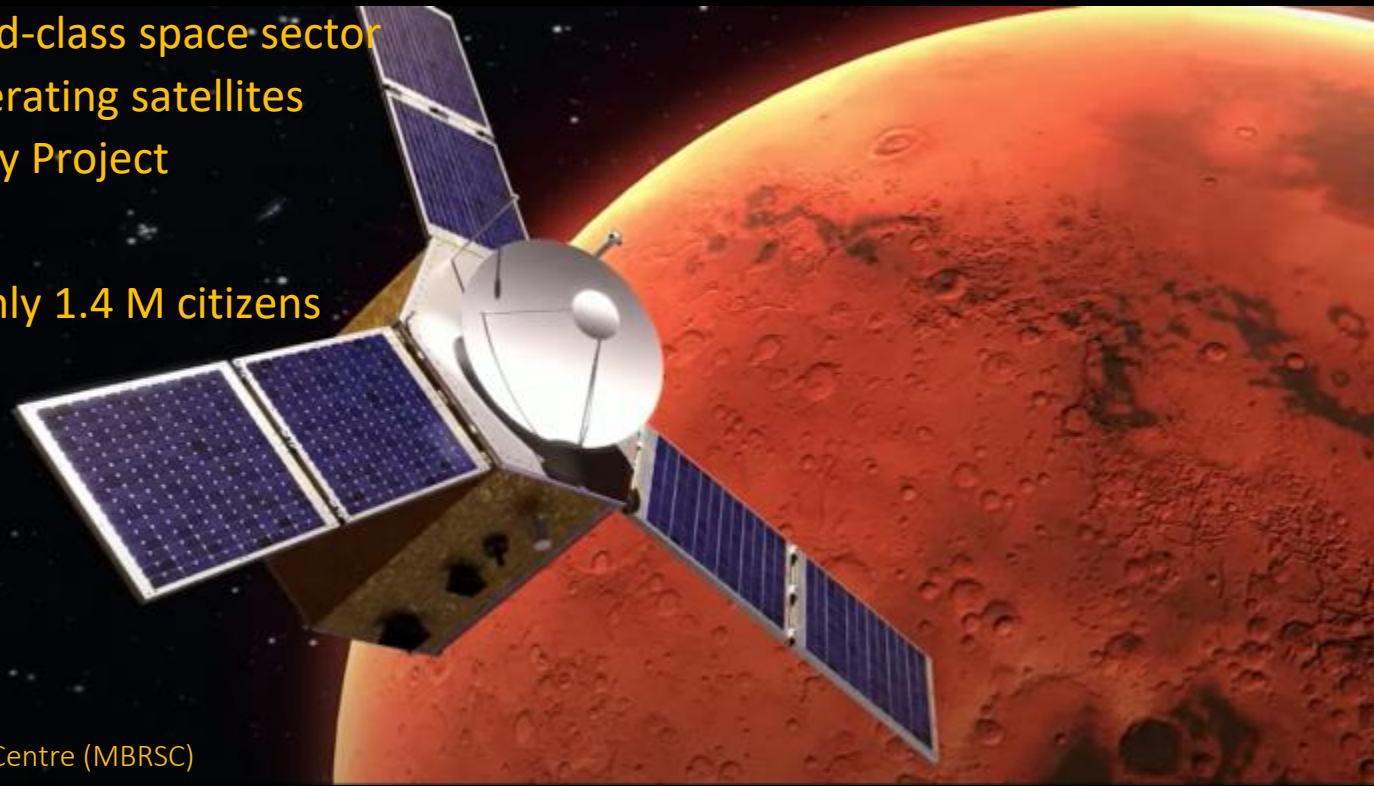
3 robotic Mars missions launched in July 2020 arrived

- UAE: Hope (orbiter only), arrived into orbit February 9
 - China: Tianwen-1 (orbiter/lander/rover) arrived into orbit Feb 10
 - Rover will land by May or June
 - US: Mars 2020 (landing system/Perseverance rover/Ingenuity helicopter) landed Feb 18
-
- Trips take 200 days, 300 million miles
 - Favorable alignment every 26 months



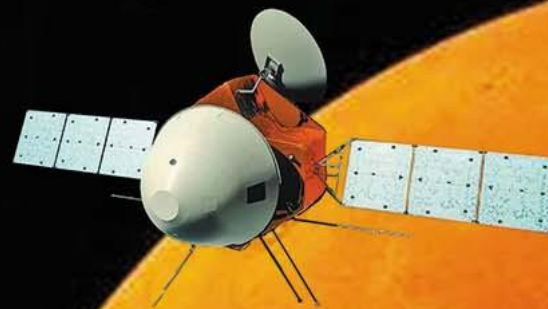
First Emirates Mars mission

- UAE Mars orbiter to study Mars weather and atmosphere
 - Launched July 19, 2020 from Japan on Mitsubishi Heavy Industries H-2A rocket
 - Reached Mars February 9, 2021
 - 2980 lbs, about the size of a small car
 - Developed by UAE, collaborating with the University of Colorado, Arizona State University, and UC Berkeley
- Step in Mars 2117 program
 - Developing world-class space sector
 - Building and operating satellites
 - Mars Science City Project
- Small kingdom!
 - 9.2 M people, only 1.4 M citizens



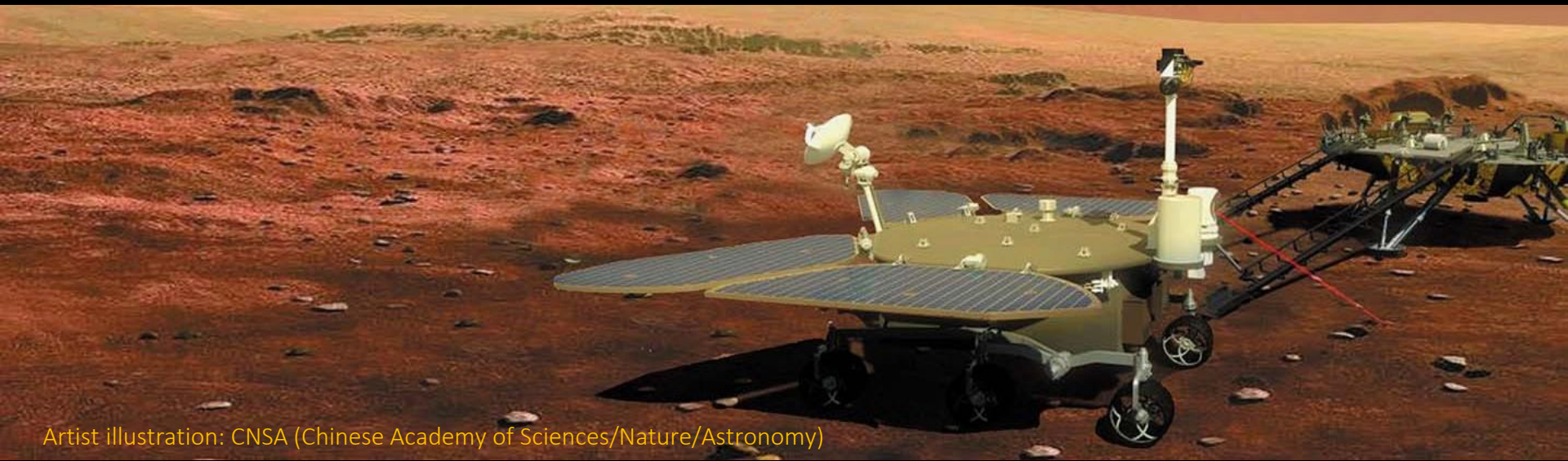
First Chinese Mars mission reached orbit Feb 10

- Launched July 23 from China on Long March 5 rocket
- 11,000 lb Mars orbiter, lander, 529 lb. rover
- Reached Mars February 10, 2021
 - Maneuvered to polar orbit, eventually will be elliptical 164 – 7,500 miles
 - Orbiter to last at least 2 years
- Will release lander/rover in May or June
 - Rover to work at least 90 days



Chinese Mars lander

- Targeting Utopia Planitia, where radar indicates large ice reservoir
- Analyze soil & rock, study the atmosphere, analyze Mar's internal structure and look for buried water ice with subsurface radar
- If successful, third country to perform soft landing on Mars, second to drive a rover



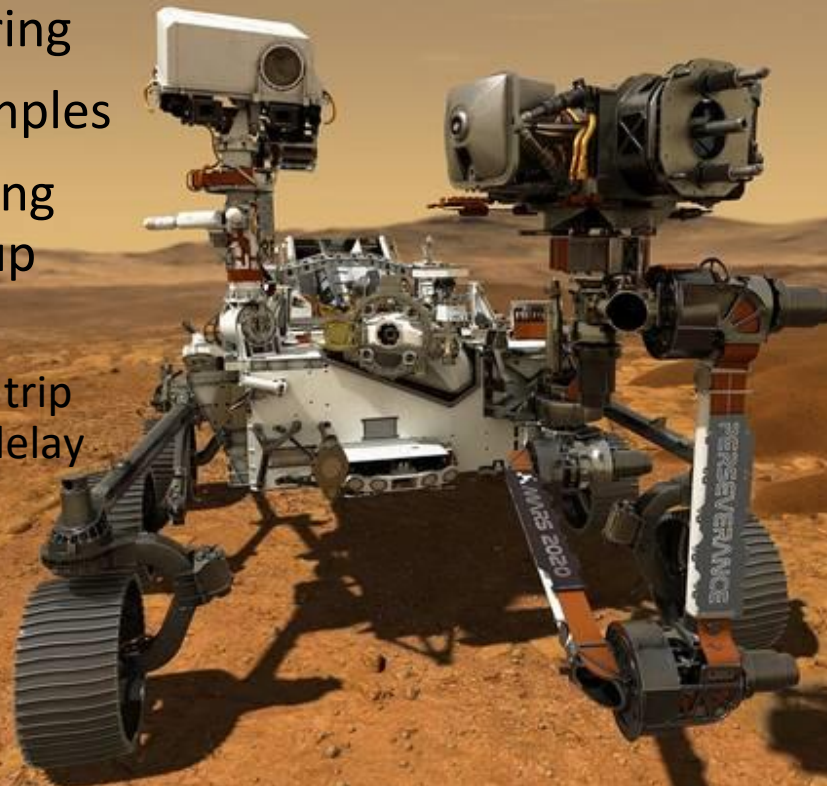
NASA Mars 2020 mission

- Launched July 30, 2020, to Jezero Crater, an ancient lakebed
 - 300 million mile, 7 month journey, directly to the surface
 - 9000 lb. payload on ULA Atlas 5 rocket with Centaur upper stage
 - Most advanced robotic explorer yet
 - 90% parts from Curiosity Rover (2012) (Curiosity still active!)
 - \$2.7 Billion over 10 years
-
- NASA landed on Mars successfully 9/10 times
 - Only other landing success: Russia landed on Mars (1971). Lasted 2 minutes

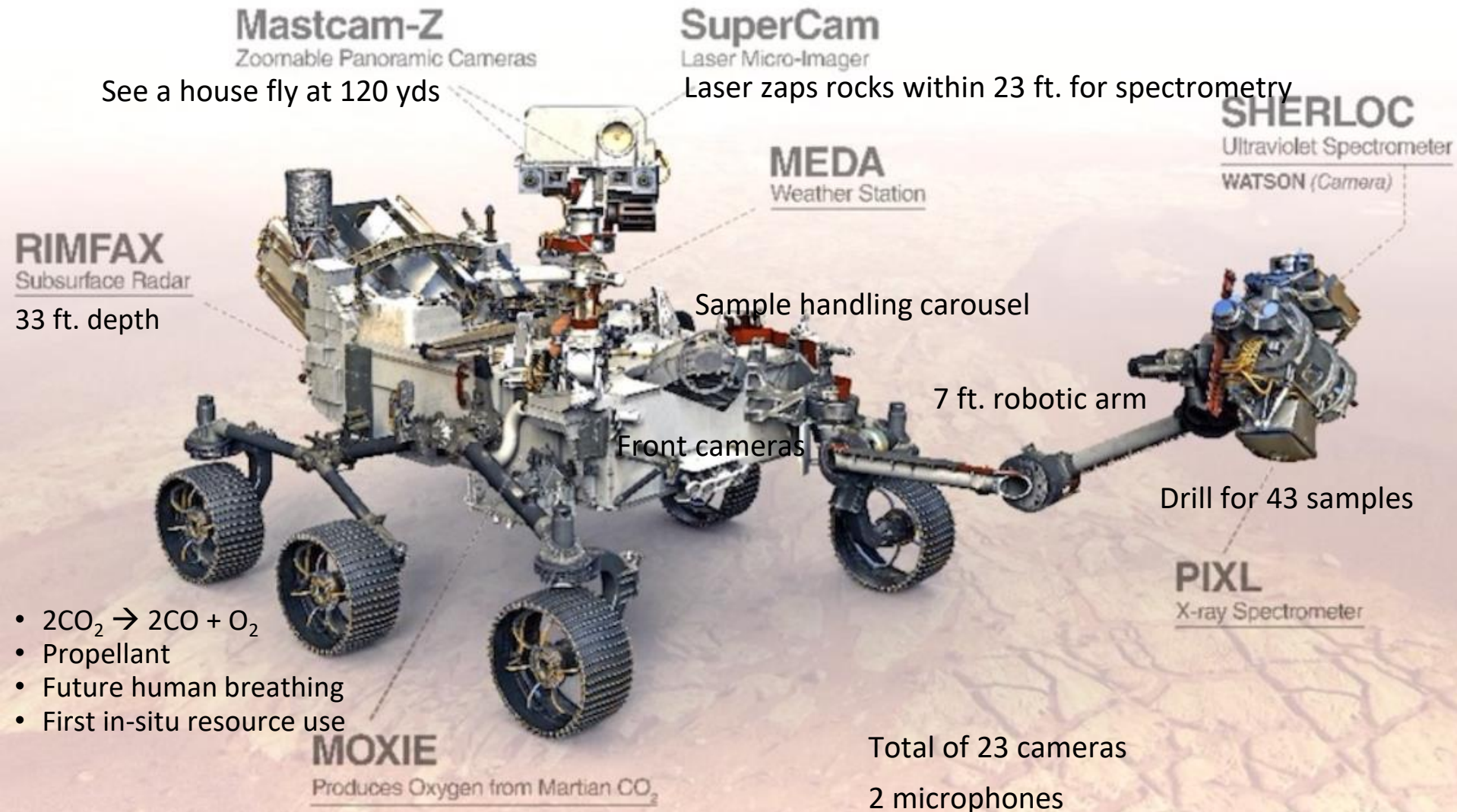
Perseverance Mars rover

- 2260 lbs., 10 feet long, 9 feet wide, 7 feet high
- Nuclear powered like Curiosity (110 Watt plutonium heat source, decays 2%/year)
- Prime mission: 3 years in Jezero crater (30 mile wide ancient lake bed and delta)

- Search for ancient life, with multiple instruments
- Drill & caching samples for possible return in 2031
- Weather, monitoring
- Test spacesuit samples
- Autonomous driving mode will speed up driving by 5x
 - 20-minute round trip communication delay now, more later

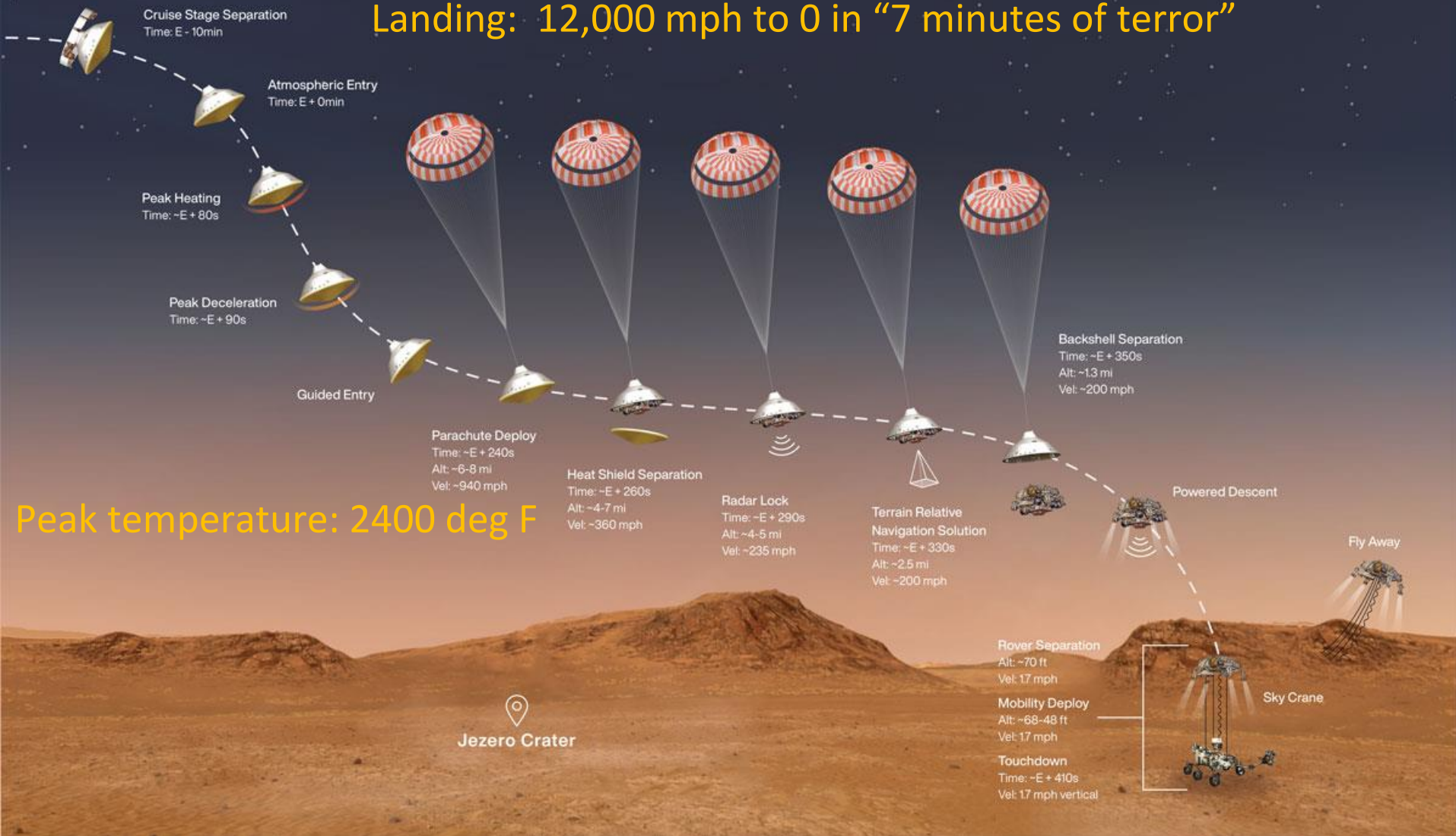


Perseverance Mars rover scientific instruments



Perseverance rover landed on Mars on Feb. 18

Landing: 12,000 mph to 0 in "7 minutes of terror"

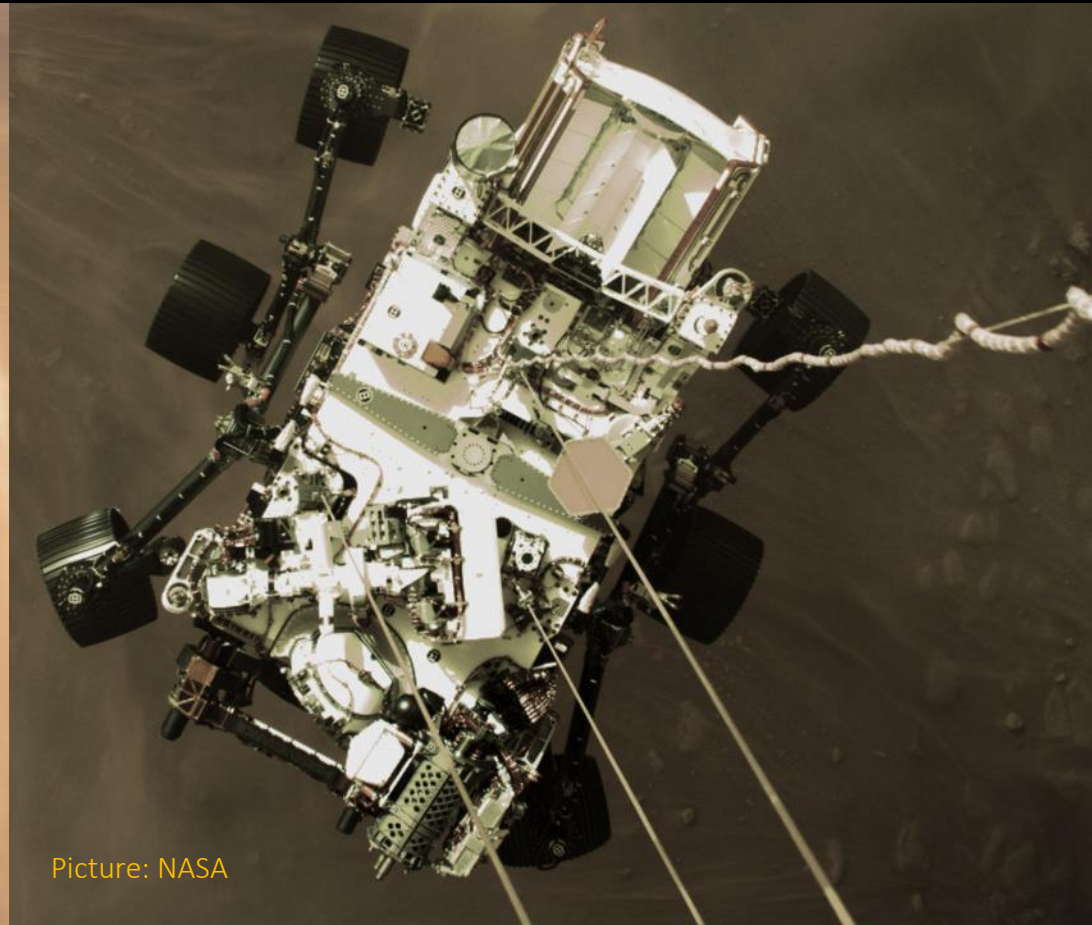


Perseverance Mars rover automated landing

- Automated parachute and thrusters in search for exact landing site in rugged terrain
 - 70 foot parachute deployed at altitude of 7 miles, discarded at 1.3 miles altitude, 200mph
 - Thrusters on, searched for exact landing site, hovered at 66 feet, lowered rover
 - After rover landing, “Sky crane” flew to crash a safe distance away
 - 11 minute transmission delay each way



Image: NASA



Picture: NASA

Perseverance Mars rover automated landing

- Found flat spot (1.2 degree tilt) near rough terrain: 35 meters to boulders
- 1.1 miles from center of the 4-mile wide landing zone



Perseverance Mars 360° panorama Jezero crater rim



Perseverance Mars rover status

- Landed in a flat spot, sent back images & sound recordings
- Activating equipment and testing for several weeks is ongoing
 - Software update from cruise to roving takes 4 days!
 - Establishing communications, starting instruments, flexing robot arm, etc.
 - Took 21 foot test drive March 4

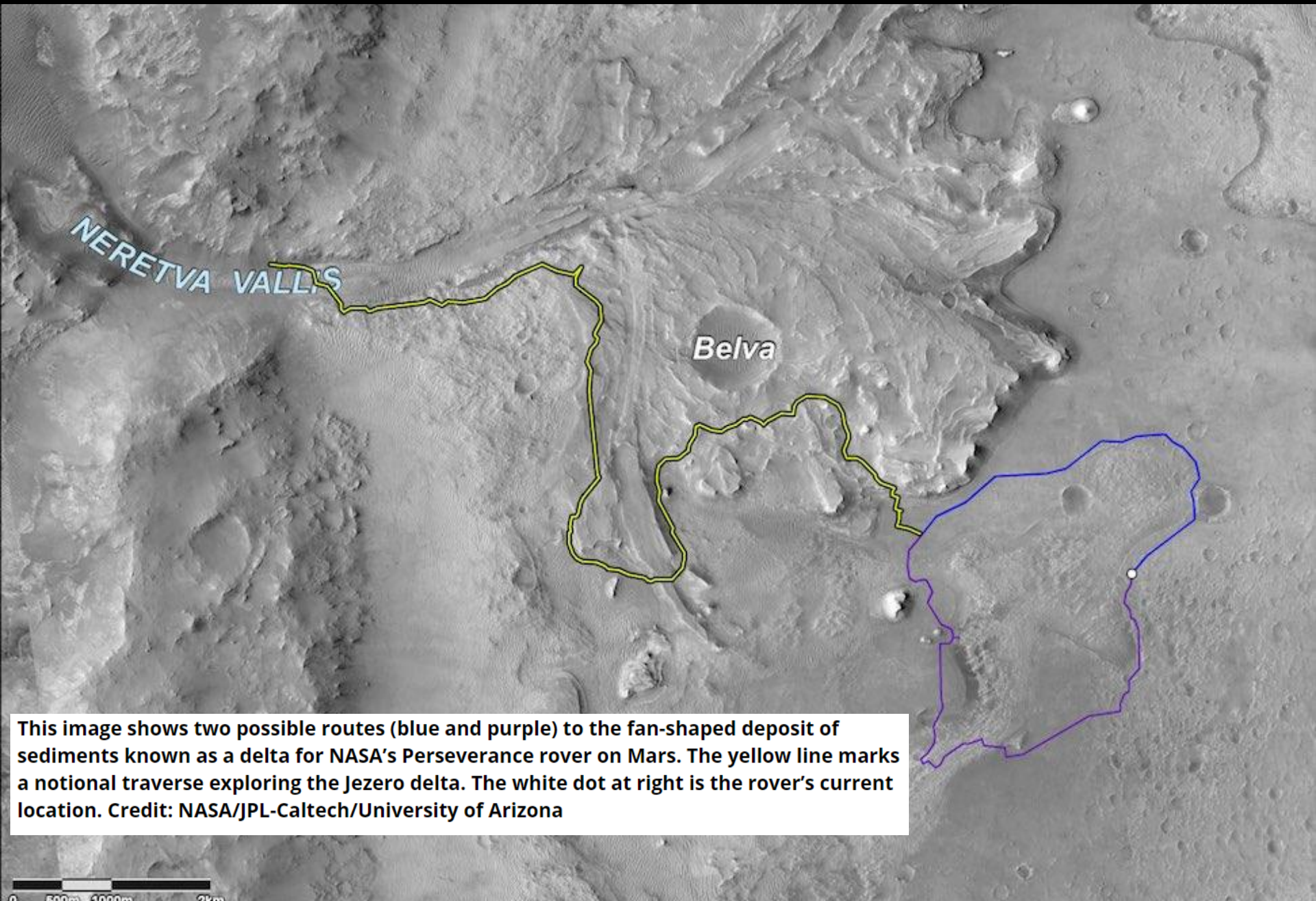


The 21-foot Perseverance test drive, March 4



Picture: NASA/JPL

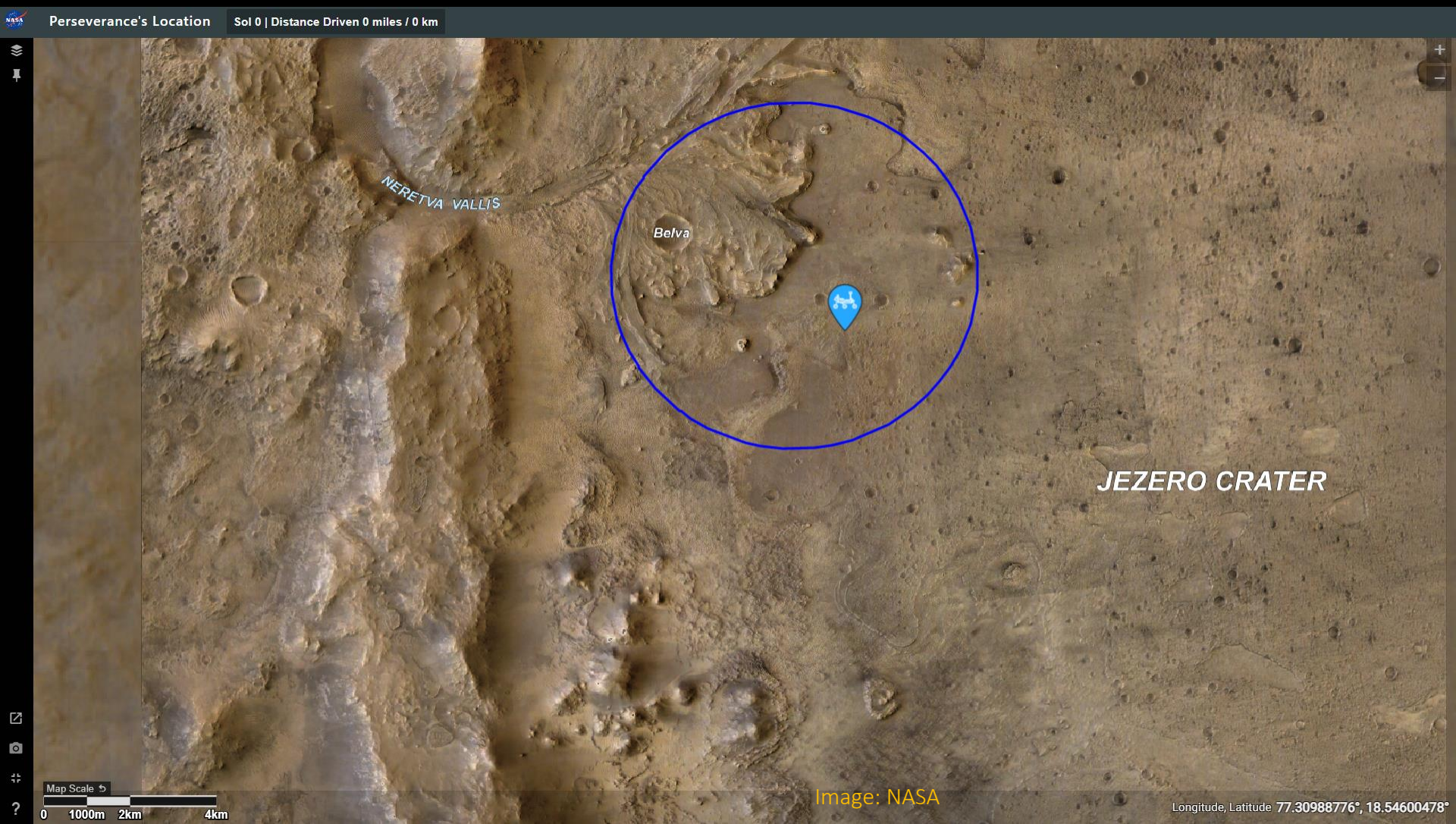
Perseverance route to an ancient river delta



This image shows two possible routes (blue and purple) to the fan-shaped deposit of sediments known as a delta for NASA's Perseverance rover on Mars. The yellow line marks a notional traverse exploring the Jezero delta. The white dot at right is the rover's current location. Credit: NASA/JPL-Caltech/University of Arizona

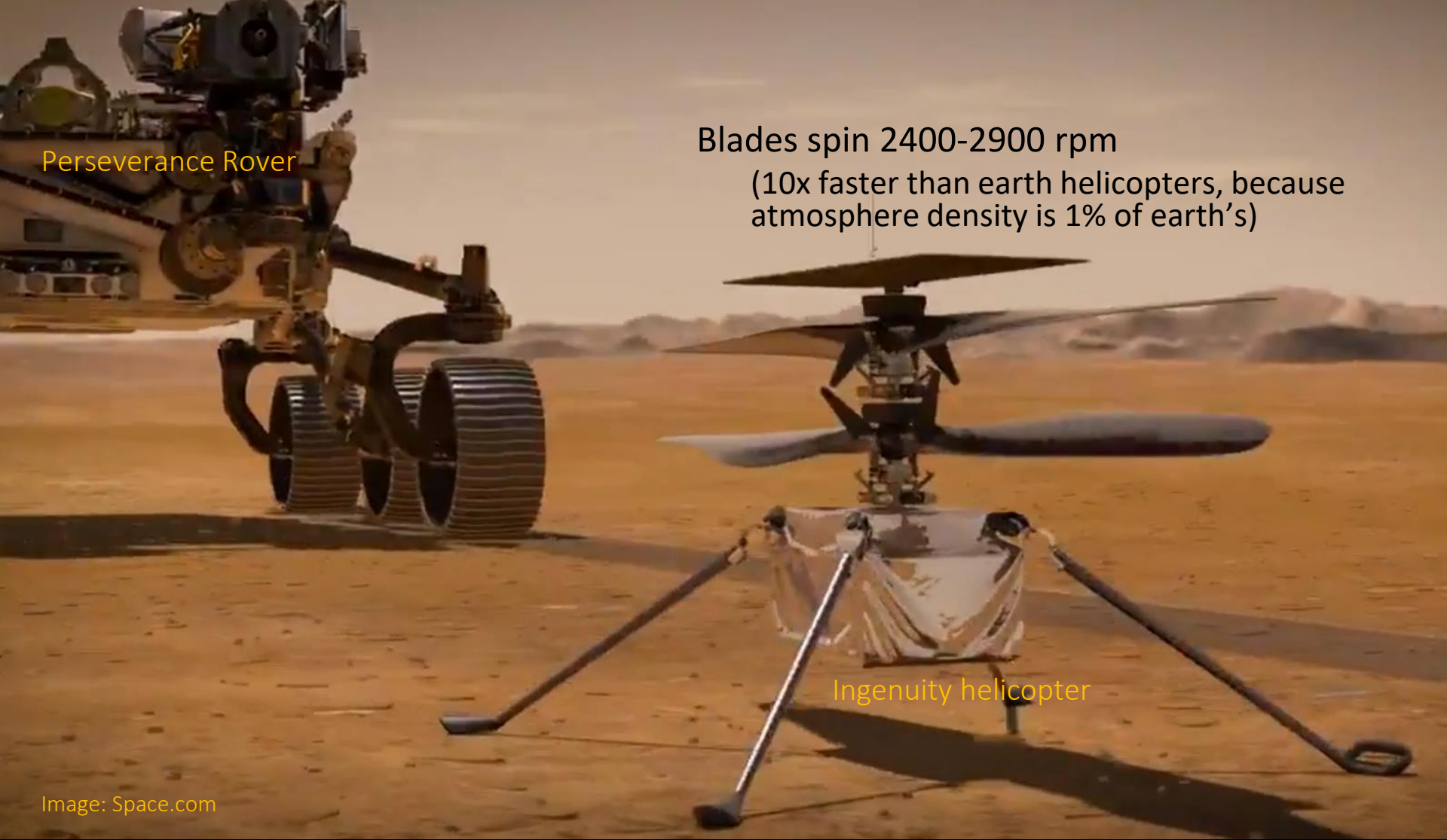
Where is Perseverance now?

- Live, interactive (zoomable) map at <https://mars.nasa.gov/mars2020/mission/where-is-the-rover/>



Helicopter on Mars: Ingenuity

- 4 lbs, 1.6 feet tall, 4 foot diameter blades
- Solar cell powered, recharging Lithium-ion batteries
- 30 day design life, 5 3-minute autonomous flights



Perseverance Rover

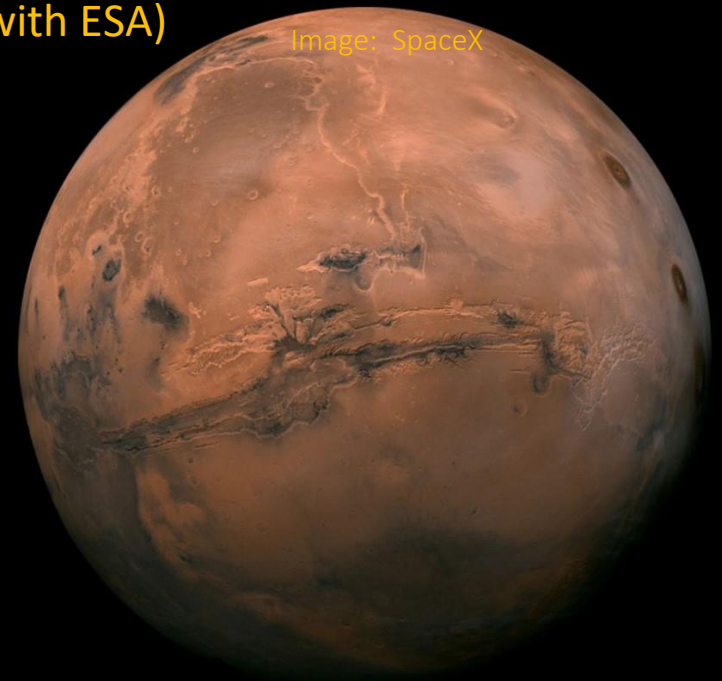
Blades spin 2400-2900 rpm

(10x faster than earth helicopters, because atmosphere density is 1% of earth's)

Ingenuity helicopter

There are now 11 active missions at Mars

- NASA (6)
 - Rovers or Lander: Perseverance (2021), Curiosity (2012), Insight (2018)
 - Orbiters: 2001 Mars Odyssey, Mars Reconnaissance Orbiter (2006), MAVEN (2014)
- ESA (2)
 - Mars Express (2003), ExoMars Trace Gas Orbiter (2016)
- Roscosmos (Russia) (1 shared with ESA)
 - (ExoMars Trace Gas Orbiter is in collaboration with ESA)
- ISRO (India) (1)
 - Mars Orbiter Mission (2014)
- UAE (1)
 - Hope (2021)
- China (1)
 - Tianwen-1 orbiter and lander (2021)



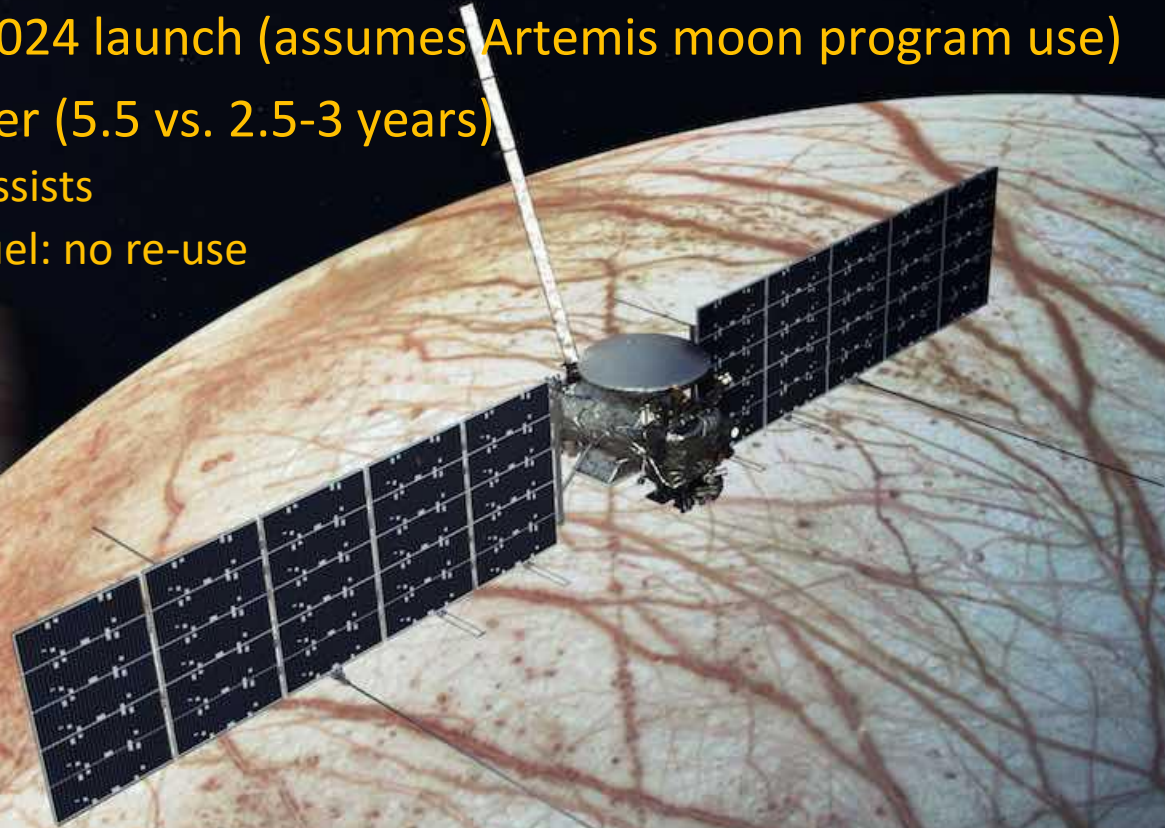
Asteroid Apophis flew close to Earth Mar. 5

- 1000-1500 feet across
 - Hitting earth would be equivalent to 1000 megatons of TNT
 - Asteroid that killed the dinosaurs and 70% of Earth's species was 6-10 miles wide
- Approaches Earth roughly every decade, not expected to collide in future
 - Passed at 44 times Earth-Moon distance
- BUT: it will pass within 19,000 miles in April, 2029
 - Could damage satellites – that's within range of geosynchronous orbits
 - Astronomers are interested in getting close observation in 2029



SLS dropped from 2024 Europa Clipper mission

- Mission to Europa will now be on a proven “commercial heavy lift rocket”, not the government’s Space Launch System (SLS)
- SLS would delay 2024 launch (assumes Artemis moon program use)
- Trip will take longer (5.5 vs. 2.5-3 years)
 - Require gravity assists
 - Use all booster fuel: no re-use



Charles Bolden, NASA Administrator, 2014:
*"Falcon 9 Heavy may someday come about. It's
on the drawing board right now. SLS is real."*

Image: NASA/JPL

A luxury space hotel in 2027?

- Orbital Assembly Corporation announces ambitious plan for a luxury space hotel starting in 2026, available in 2027
 - 650 foot diameter wheel rotates for moon-level artificial gravity (1/6 Earth)
 - Outfitted like an expensive cruise ship, up to 400 guests
 - 24 habitation modules, each 65 ft x 40 ft, with private airlocks
 - Big push to get investment, build 200 ft prototype in LEO, build in stages



Another convert to re-usable rockets

- Rocket Lab CEO Peter Beck once said he would eat his hat if Rocket Lab ever moved toward making its boosters reusable.
- Peter Beck, Feb. 2021: *“This hat is not tasty”*



Image from Rocket Lab video announcing new, larger Neutron rocket capable of launching 8 tons to LEO in 2024 (vs 500 lbs in Electron)

How many launches since the last meeting (Feb 6)?

*This includes failed launches only if they lift off the launch pad
and only includes launches that attempt going into orbit*

“Third time’s a charm...We’ve had a successful soft touchdown on the landing pad that’s capping a beautiful test flight of Starship 10.”

(John Insprucker, SpaceX principal integration engineer)

*“So.... congrats and also RIP 🙏😭 bye bye SN10,
congrats on making history!!!!*

(Elon Musk)



Starship prototype SN10 test didn't count: it was sub-orbital (10 km/6.2 miles)
(The explosion 8 minutes after successful landing didn't disqualify it)

Launches since last meeting (Feb 6, 2021)

 Feb 14 – Soyuz – 2.7 ton cargo to International Space Station (ISS)

 Feb 15 – Falcon 9– 19th batch of 60 comm. satellites for Starlink

- Failed to recover booster rocket on it's 6th mission
- SpaceX currently has 6 Falcon 9 boosters

 Feb 20 – Antares/Cygnus (Northrop Grumman) – 4.2 ton cargo to ISS

 Feb 23 – Long March 4C – 3 military reconnaissance satellites

 Feb 27 – PSLV (India) – Brazilian earth observation sat., misc. rideshares

 Feb 28 – Soyuz – arctic weather & comm. satellite

 Mar 04 – Falcon 9 – 20th batch of 60 Starlink (internet service) satellites

Discussion & questions?



Featured Speaker: Hugh Blair-Smith

- Topic (and book): Left Brains for the Right Stuff: Computers, Space, and History



- Engineering & Applied Math degree at Harvard
- Worked at what is now MIT Draper Labs
- Programmed the Apollo guidance computer, space shuttle control software, space station
- Involved in startups
- Returned to NASA, including Lunar Reconnaissance Orbiter
- Working on a science fiction book