2013 was another year dominated by the increase in robotic exploration of humanity’s most sought-after and elusive terrestrial neighbor. With two active rovers, a fleet of orbiting vehicles, and two new missions in 2013, Mars exploration continues to pave the way for the next generation of crewed space exploration.

ESA’s Mars Express:

For the European Space Agency (ESA), the Mars Express has been the most reliable and scientifically valuable instrument ever sent to the red planet.

Launched on 2 June 2003 from Baikonur cosmodrome in Kazakhstan aboard a Russian rocket, the ESA mission represents the only Russian-launched mission (to Mars or otherwise) to successfully make it out of Low Earth Orbit since the fall of the Soviet Union — including two of Russia’s own Mars missions.

Now, more than a decade after its launch, the Mars Express and ESA marked the 10-year anniversary of probe’s successful arrival in Mars orbit on 25 December.

For 10 years, the Mars Express has returned remarkable scientific observations and discoveries and continues to function well.

In addition to scientific observations, the Mars Express has also been used as part of a communications fleet for newly arriving Mars vehicles as they’ve made the parlous Entry, Descent, and Landing sequence to the red planet.

Most notably, Mars Express has assisted with the landing of NASA’s Phoenix polar lander in 2008 and during the 2012 world-watched arrival and landing of NASA’s Curiosity rover.

By 2013, the probe had produced a near-complete topographical map of Mars’ surface and was well into its fifth mission extension, which is slated to last until 2014.

Assuming continued good operations and funding from ESA, the Mars Express has enough fuel for up to 12 more years of additional operations.

Curiosity:

After a headline-capturing landing in August 2012, NASA’s newest Martian rover, Curiosity, began 2013 with news of the indefinite extension of its mission.

The indefinite extension of the Curiosity mission superseded the original two-year operational mission plan Curiosity had when it landed at Aeolis Palus in Gale Crater on 6 August 2012.
As the new year began for Curiosity, the rover was stationed at Yellowknife Bay and completed the first-ever delivery of scientific samples drilled out from inside a rock on Mars to its science instruments.

The first-ever such drilling and sample delivery occurred in late February, just before controllers began noticing that the rover’s primary computer was indicating symptoms of a corrupted memory location.

Built with redundant computer capacity, Curiosity’s controllers took the rover from its “A-side” computer to its “B-side” computer, which is the redundant onboard computer for the rover.

In so doing, Curiosity placed itself into an anticipated minimal activity safe mode.

Safe mode was initiated on 28 February, and by 4 March, Curiosity’s teams had made good progress in the recovery effort, and the rover was out of safe mode.

With Curiosity stable and operating on its B-side computer, the teams continued analyzing data from the rover to determine the cause of the A-side memory fault.

By 11 March, significant progress had been made.

After completing a series of tests, Jim Erickson, deputy project manager for the Mars Science Laboratory/Curiosity mission at NASA’s Jet Propulsion Laboratory, Pasadena, California said, “These tests have provided us with a great deal of information about the rover’s A-side memory.

“We have been able to store new data in many of the memory locations previously affected and believe more runs will demonstrate more memory is available.”

By 16 March, engineers had diagnosed a software issue that prompted the memory corruption issue on 28 February and were ready to upload a series of corrective software patches to prevent the issue from happening again.

Before uploading the software patches, Curiosity reentered a precautionary safe mode on 17 March as the upload was carried out.

By 19 March, the upload was complete, and Curiosity was out of precautionary safe mode.

By this point, mission engineers had recovered the A-side computer as the redundant computer to Curiosity’s now fully operational B-side computer.
On 25 March, Curiosity resumed scientific observations after nearly a month of downtime because of the computer glitch event.

Nonetheless, while engineers on Earth were working on the software issue, scientists were busy analyzing data gathered earlier by the Curiosity rover.

In an 18 March release, scientists revealed that Curiosity had discovered evidence of water-bearing minerals in rocks near where it had already found clay minerals inside a drilled rock.

Following from an 11 March announcement from Curiosity science teams that the rover’s analysis of powder from drilled mudstone had indicated that past environmental conditions were favorable for microbial life, the 18 March announcement furthered that notion and suggested that those environmental conditions extended beyond the site of the current drilling.

From mid-April to early May, Curiosity was placed into autonomous operation mode during the 25 day Earth-Mars solar conjunction.

The conjunction placed Earth and Mars at opposite sides of the sun from one another in their respective orbits and prevented communication between the two planets.

During the solar conjunction, Curiosity remained stationary on the Martian surface but continued to monitor atmospheric and radiation data during that period.

On 19 May, following reestablishment of communication, Curiosity was directed to drill into another rock at Yellowknife Bay.

The drill site measured 0.6 inches in diameter and 2.6 inches in depth and was the second such sample drilling event into a rock on Mars.

The drilling and delivery of samples was commanded by the science team in order to use the findings to check the analysis of the previous rock drill in February – the drilling event that revealed that favorable conditions including the key elements of ingredients for life and energy and water were once present at the location.

By the end of May, attention was quickly turning away from Curiosity’s current science operations to measurements taken during the rover’s cruise to Mars in 2012.
Readings from Curiosity’s Radiation Assessment Detector (RAD), which was the first instrument to measure the radiation environment during a Mars cruise mission from inside a spacecraft that is similar to potential human exploration craft, helped to reduce uncertainty about the effectiveness of radiation shielding and provided vital information to space mission designers who will build the protection for spacecraft occupants in the future.

In particular, the findings from the RAD instrument indicated that radiation exposure for humans could exceed NASA’s career limit for astronauts if current propulsion systems are used for the Mars Transfer Vehicle.

During inter-planetary travel, two forms of radiation pose potential health risks to astronauts in deep space. One is Galactic Cosmic Rays (GCRs), particles caused by supernova explosions and other high-energy events outside the solar system, that are highly energetic and highly penetrative.

The other is Solar Energetic Particles (SEPs) associated with solar flares and coronal mass ejections from the sun.

Radiation exposure is measured in units of Sievert (Sv) or milliSievert (one one-thousandth Sv). Long-term studies have shown that exposure to radiation increases a person’s lifetime cancer risk, and that exposure to a dose of 1 Sv, accumulated over time, is associated with a five percent increase in risk for developing fatal cancer.

NASA has established a three percent increased risk of fatal cancer as an acceptable career limit for its astronauts currently working in low-Earth orbit.

The RAD data from Curiosity showed that the rover was exposed to an average of 1.8 milliSieverts of GCR per day on its journey to Mars.

Multiplied out to include a long duration stay on Mars and the return trip to Earth, the measurements give some concern to human Mars exploration mission planners and give vital data on new spacecraft shielding requirements for human voyages to Mars.
Meanwhile, back on Mars, Curiosity was ready to begin a bold new step in its exploration: the beginning of its drive toward its primary research target of Mount Sharp.

Curiosity began its trek toward Mount Sharp on 4 July, 7 July, and 9 July with three test-drives of 59 feet, 131 feet, and 135 feet, respectively.

From Curiosity’s then location, Mount Sharp was 8 km (5 miles) away.

By 17 July, Curiosity had driven a total of one kilometer.

On 1 August, Curiosity trained its two camera Mast Camera skyward to record an interesting event: the eclipse of one of Mars’ moons by the other of Mars’ moons.

The 55-second event saw Phobos eclipse Deimos, temporarily blocking it from view of Curiosity’s cameras.

The event marked the first time that cameras located on the surface of Mars had captured one of Mars’ moons eclipsing the other.

Scientifically, the event helped scientists refine their knowledge of the moons’ orbits.

“The ultimate goal is to improve orbit knowledge enough that we can improve the measurement of the tides Phobos raises on the Martian solid surface, giving knowledge of the Martian interior,” said Mark Lemmon of Texas A&M University, College Station. "We may also get data good enough to detect density variations within Phobos and to determine if Deimos’ orbit is systematically changing."

As early August approached, Curiosity’s operations team wrapped up planning for a very special event for the rover.

6 August marked the one-year anniversary of Curiosity’s successful landing on the red planet, and to celebrate the milestone, the rover audibly played “Happy Birthday To You” to itself in honor of the anniversary.

The event marked the first time that a song was played on a foreign planet, making “Happy Birthday To You” the first song and Curiosity the first device used to play music on a foreign planet.

It also marked the first time that music was transmitted between two planets.

Fourteen days later, Curiosity once again turned its cameras skyward and aimed them directly at the sun to witness an annular solar eclipse by Phobos.

The eclipse occurred near local solar noon at Curiosity’s location, which put

Phobos at its closest point to the rover.

“This is the closest to a total eclipse of the sun that you can have from Mars,” said Mark Lemmon of Texas A&M University, College Station, a co-investigator for use of Curiosity’s Mastcam.

“This one is by far the most detailed image of any Martian lunar transit ever taken, and it is especially useful because it is annular. It was even closer to the sun’s center than predicted, so we learned something.”

During the 20 August eclipse observation, the position of Phobos crossing the sun was approximately 2-3 kilometers closer to the center of the sun’s position than researchers anticipated.
These eclipse observations by Curiosity and its older, still-active cousin Opportunity help researchers refine their knowledge of the moons' orbits and thus the Martian system.

By mid-September, Curiosity had returned data points indicating a lack of methane in the Martian environment, seemingly contradicting earlier observations by orbiting spacecraft of methane pockets near the surface of Mars.

By the end of September came an exciting find: the presence of water in soil samples analyzed by Curiosity's SAM (Sample Analysis at Mars) instrument.

"One of the most exciting results from this very first solid sample ingested by Curiosity is the high percentage of water in the soil," said Laurie Leshin, dean of the School Science at Rensselaer Polytechnic Institute.

"About 2 percent of the soil on the surface of Mars is made up of water, which is a great resource, and interesting scientifically."

The same SAM analysis also revealed a compound containing chlorine and oxygen, likely chlorate or perchlorate, that had previously been discovered near the north pole on Mars.

The find of a similar compound at Curiosity's equatorial site would seem to suggest that the compound is distributed more globally than initially thought and also suggests the presence of carbonate materials, which form in the presence of water.

By mid-October, Curiosity's examination of the Martian atmosphere had confirmed that some meteorites that have fallen to Earth really have originated on the red planet.

The long-held theory of some meteorite origin on Mars was confirmed via a key new measurement of the inert gas argon in Mars' atmosphere.

"We really nailed it," said Sushil Atreya of the University of Michigan, Ann Arbor. "This direct reading from Mars settles the case with all Martian meteorites."

By early November, Curiosity was back in safe mode after an unexpected software reboot occurred during a communications pass with the Mars Reconnaissance Orbiter.

By 12 November, Curiosity was out of safe mode and had successfully transitioned back into operational mode.

Then, on 17 November, all science observations for Curiosity were suspended after a voltage change was detected in the rover.
Full science operations resumed on 23 November after engineering teams resolved the voltage change indication and traced its likely caused to an internal short in Curiosity’s power source.

Due to the resiliency in the power source’s design, the short did not affect operation of the power source on the rover and is not expected to be an issue.

By 5 December, Curiosity’s laser instrument had made over 100,000 zaps of investigative targets on the red planet.

Click here for more Mars News Articles: http://www.nasaspaceflight.com/tag/mars/

As 2013 drew to a close, Curiosity’s team reveled in the amount of information the rover has returned on the red planet in its one short year on the surface.

In a little more than a year, the mobile Mars Science Laboratory has determined the age of a Martian rock (3.86-4.56 billion years old – which holds consistent to Earth’s and the inner solar system’s formation timeframe), found evidence that the planet could have sustained microbial life, taken the first readings of radiation on the surface, and shown how natural erosion could reveal the building blocks of life.

With Curiosity’s mission handed an indefinite lifetime, the discoveries are still new for the Mars rover that has captivated the attention of the general public – after all, what other spacecraft has a sarcastic version of itself on Twitter?

**Opportunity – the farthest-traveling NASA mobile vehicle:**

As 2013 began for the Opportunity rover on Mars, the rover was stationed at the edge of Endeavour Crater’s Cape York prominence.

Furthermore, mission managers were reveling in the fact that the rover had traveled a cumulative distance of 35 km (22 miles) since its landing.

On 25 January 2013, the rover marked its ninth year on Mars, an unprecedented operational time for a vehicle on a world other than Earth.

By this point, mission planners where well into executing their winter ride-out plan for Opportunity.

Being in the southern hemisphere of Mars, mission planners needed to ensure that Opportunity arrived at a northward facing slope terrain prior to the start of the southern hemisphere Martian winter in late calendar year 2013.

That point was identified in 2012 as Solander Point, a northward facing slope with geologic formations that Opportunity could explore during winter.

For mission scientists and managers, Solander Point would provide a good sun-solar angle to allow Opportunity to not only survive the Martian winter, but also to continue performing scientific experiments and hopefully continue roving during the lower sun-angle period.

The Martian winter is a particularly dangerous time from a power standpoint for Opportunity as the energy it needs to function is gathered by its solar arrays.

As the arrays are already covered in dust from the Martian atmosphere, and the reduced sun angle during winter time further drops the available energy supply, Opportunity’s team must take precautions to ensure adequate power supply during this period.

By the end of January, Opportunity was on its way to Solander Point. By May, the rover had passed through the three-week communications black out caused by the solar conjunction as Earth and Mars reached opposite sides of the sun from one another in their respective orbits.

During the communications blackout, Opportunity’s arm was extended into position on a nearby rock so that the rover could continue to collect scientific data on the geologic formation during the solar conjunction.

By 16 May 2013, Opportunity reached a major milestone in its exploration of Mars when it surpassed the total driving distance of the Apollo 17 lunar roving vehicle to become the farthest-traveling NASA vehicle on a celestial body other than Earth.

Opportunity reached this milestone when its total odometry surpassed 35.744 km (22.210 miles) – the distance traveled by the Apollo 17 lunar roving vehicle.

With its place in NASA history secure, Opportunity now stands as the second farthest-traveling vehicle on another world, with only the Soviet Union’s Lunokhod 2 lunar rover having driven a greater distance.

Based on the wheel rotation data from Lunokhod 2, its originally estimated travel distance was 37 km (23 miles).

However, Russian scientists have since revised that estimate based on images from NASA’s Lunar Reconnaissance Orbiter to a distance of 42 km (26 miles).

If the 37 km travel distance for Lunokhod 2 is the correct distance, then Opportunity surpassed this record on 23 June 2013.

If the 42 km travel distance is correct, Opportunity could, assuming it drives the same distance it did in 2013 and survives the depth of the coming Martian winter, break Lunokhod 2’s record before the end of 2014 to become humanity’s farthest-travelling vehicle on another world.

The following day, 17 May, NASA released preliminary scientific information regarding rock outcroppings that Opportunity surveyed during its stay at Endeavour Crater.

The results indicated a neutral pH water on the surface of Mars in the past, a result that further advanced the notion that ancient Mars was a water-rich world with conditions amenable for life.
On 21 June, Opportunity marked the beginning of its fifth Martian year on the red planet – a date which roughly coincided with the 9.5 Earth-year mark in its operational history on Mars.

At the time of this milestone, Opportunity’s total odometry reading was 36.84 km (22.89 miles).

After nearly eight Earth-months of travel, Opportunity arrived at its winter home on Solander Point in early August.

On 6 August, energy intake was 385 watt-hours, which was a decrease from 395 watt-hours just six days prior.

In August and September, Opportunity continued to rover around Solander Point to explore numerous surface targets and rock formations.

Meanwhile, the rover’s controllers continued to monitor the power level drop as the Martian winter began to set it.

By 9 October, total power intake was down to 325 watt-hours.

While that was a significant drop from the 546 watt-hours collected at the beginning of May, it was still a significant ways off from the minimum reported watt-hour intake registered by Opportunity’s twin rover Spirit prior to the cessation of its operations in 2010.

For Spirit, the rover continued to communicate up to a minimum power intake of 134 watt-hours and an air temperature of negative 41.5 degrees C.

By 5 November, or solar day 3,478 on Mars, Opportunity had traveled 38.53 km (23.94 miles). Total power being received from the sun was 311 watt-hours.

On 20 November, Opportunity transferred its 186,246th photograph to Earth.

In late November and early December, the Opportunity team was hit with an unexpected communications slow down as the Odyssey orbiter at Mars went into safe mode.

Odyssey’s team was able to successfully fix the issue and return the satellite to normal operations by 10 December.

The final publicly released information status update on Opportunity for 2013 indicated a healthy rover as of 7 December.

On that day, Opportunity was receiving 268 watt-hours of solar array energy and had driven a total of 38.7 km (24.05 miles) since landing on Mars.

The heart of the Martian winter for Opportunity is expected in February 2014.

All evidence would suggest at this point that Opportunity will survive the Martian winter with more than enough power to continue life critical system operations.
With a successful 2013 behind it, the next major milestone, and a major one it will be, for Opportunity will come on 25 January 2014, when the rover, its teams, and NASA celebrate an unheard of and unpredictable 10 years of mobile operations on the surface of Mars.

Ten years… for a rover that was only supposed to last for 90 days.

New Mars missions -MAVEN launches and India joins an elite club:

For Martian exploration, 2013 wasn’t just about the rovers and orbiters that are already there. It was also about the beginning of two very important missions to the red planet.

For NASA, 2013 saw the beginning of the MAVEN (Mars Atmosphere and Volatile EvolutioN) mission, a scientific research flight designed to study Mars’ atmosphere and determine the mechanisms behind why Mars is losing its atmosphere to the solar wind of the sun.

While much of 2013 was spent preparing MAVEN for launch, it was the 1-17 October shutdown of the United States federal government that provided the biggest drama for the MAVEN mission this year.

With the suspension of all government funding at the stroke of midnight on 1 October, NASA’s MAVEN mission was put in jeopardy of missing its precisely short three-week long launch window.

But in what many considered to be a surprising and shocking move, the federal government determined that MAVEN’s mission was essential to the operation of the government, therefore allowing the mission to continue processing for the targeted 18 November opening of the launch window.

Sadly, the reason MAVEN’s mission was deemed essential was not for the scientific observations it would perform but instead for its role as a replacement in the communications network at Mars between NASA’s Curiosity rover and the agency’s other planned rover for 2020.

With the turmoil of government spending behind it, MAVEN completed all prelaunch processing and was mounted atop its Atlas V launch vehicle.

Without any delay, the Atlas V rocket lifted off with the MAVEN spacecraft at the beginning of the very first launch window on 18 November 2013 at 1828 UTC from the Cape Canaveral Air Force Station’s SLC-41 launch pad in Florida.

MAVEN was successfully placed into a heliocentric Mars Transfer Orbit shortly after attaining Low Earth Orbit.

MAVEN is currently in cruise configuration en route to Mars for a 22 September 2014 orbital insertion maneuver at the red planet.

And on 22 September 2014, MAVEN will be joined in orbital insertion maneuvers by a spacecraft from a nation making its first attempt to fly a craft to Mars.

On 5 November 2013, the Indian Space Research Organization (ISRO) successfully launched the Mars Orbiter Mission (MOM) spacecraft into Earth orbit.

Launch of India’s first mission to Mars and first interplanetary mission lifted-off from the First Launch Pad at Satish Dhawan Space Centre SHAR, Sriharikota, Andhra Pradesh aboard a Polar Satellite Launch Vehicle at 0908 UTC.

The probe spent 25 days in Earth orbit performing a series of seven altitude raising orbital maneuvers before successfully performing a trans-Mars injection burn on 30 November, which placed the spacecraft in a heliocentric Mars Transfer Orbit.

With the successful completion of the trans-Mars instruction burn, India became only the fifth space agency (after the Soviet Union’s space agency, NASA, European Space Agency, and Japan’s space agency) to successfully send a probe on its way to Mars.

Assuming a successful orbital insertion on 22 September 2014, India’s MOM probe will place the country into a list of only three other nations/space agencies: the list of those who have successfully sent a probe to the red planet.

If successful, India will join only the United States, the now-defunct Soviet Union, and the European Space Agency as only the fourth space agency/nation to succeed in getting a probe to Mars.

Russia, Japan, and China have all attempted Mars missions, but the two Russian missions suffered mission-ending launch failures, Japan’s mission ran out of fuel before it reached the red planet, and the Chinese mission was lost with Russia’s Fobos-Grunt probe in the November 2011 launch failure.

In all, though, 2013 greatly expanded our knowledge of our most sought after terrestrial neighbor and set the stage for impressive new discoveries in 2014.

(Part IV of NASASpaceflight’s 2013 Year In Review series will be published on Tuesday and will focus on exoplanet discoveries.)

*Click here for Part I*
*Click here for Part II*

(Images via NASA, JPL, Boeing, ISRO and L2).

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