# Space News Update – January 2018

*By Pat Williams*

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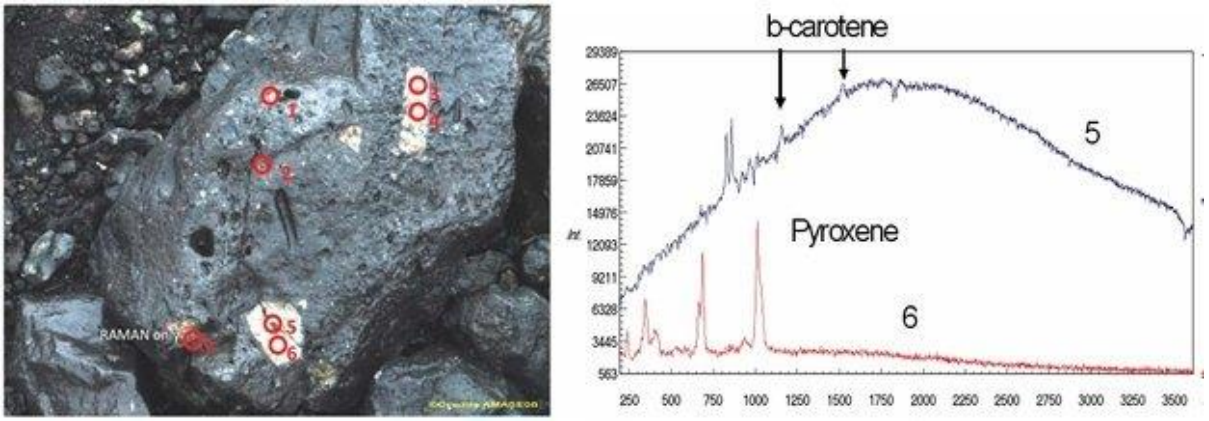
*Disclaimer - I claim no authorship for the printed material; except where noted* (PW).

## SPEND NEXT NEW YEAR'S EVE WITH NEW HORIZONS

***Artist's impression of NASA's New Horizons spacecraft encountering 2014 MU69, a Kuiper Belt object that orbits one billion miles (1.6 billion kilometers) beyond Pluto, on Jan. 1, 2019.***
***Credits: NASA/JHUAPL/SwRI/Steve Gribben***

In just under a year on Jan.1 2019 NASA's New Horizons spacecraft will buzz by the most primitive and most distant object ever explored. New Horizons' encounter with Kuiper Belt object 2014 MU69, which orbits a billion miles beyond Pluto, will offer the first close-up look at such a pristine building block of the solar system and will be performed in a region of deep space that was practically unknown just a generation ago. Observations indicate that MU69 could be two objects, perhaps accompanied by a moon. The MU69 flyby is the centrepiece of the current New Horizons extended mission that also includes observations of more than two-dozen other Kuiper Belt objects, as well as measurements of the plasma, gas and dust environment of the Kuiper Belt
(Johns Hopkins University Applied Physics Laboratory)
Spend next New Year's Eve with New Horizons (4 January 2018)

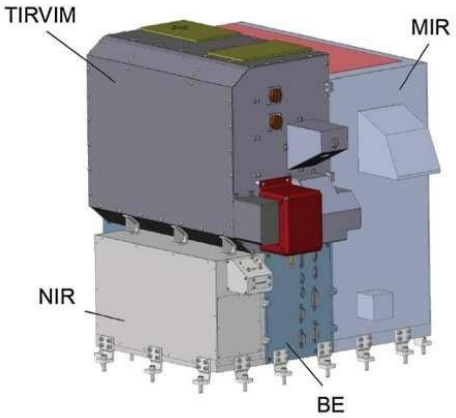
## EXPLORING ALIEN WORLDS WITH LASERS




*On-the-spot analysis of basalt rocks at the Bjockfjord volcanic complex on Spitsbergen Island, Norway, during testing for ExoMars. On the left, a high-resolution image of a basalt rock shows the spots identified for further analysis. On the right, the results of laser-based Raman spectroscopy obtained in some of these selected spots; at spots 5 and 6, Raman detected organic b-carotene and pyroxene. This testing was performed during the development of the Raman Laser Spectrometer instrument, due to fly on ESA's 2020 ExoMars rover. Credit: ESA - Raman Team, AMASE*

In everyday life we look and touch things to find out what they are made of. A powerful scientific technique does the same using lasers, and in two years' time it will fly in space for the first time. A researcher working with ESA has been investigating how lasers might be used in future space missions. We fire a laser at a material of interest and measure how much its colour is changed as it scatters off the surface, to identify the molecules responsible. This is a well-established technique terrestrially, used in all kinds of fields from security to pharmacology to art history either in labs or using hand-held devices. It requires a powerful pulsed laser, plus a sensitive synchronised camera to detect the reflected light, bearing in mind that only one in a million photons from the laser are scattered. Indian scientist Chandrasekhara Raman was awarded a Nobel Prize for discovering the effect, following his interest in understanding why the sea looks blue. ESA's ExoMars rover will carry the first such unit into space in 2020. (ESA)
Exploring alien worlds with lasers (10 January 2018)

## EUROPEAN-RUSSIAN SPACE MISSION STEPS UP THE SEARCH FOR LIFE ON MARS




*The atmospheric chemistry suite comprises four units: the NIR, MIR, and TIRVIM spectrometers and the electronic block (EB). Image courtesy of the researchers.*

In 2013, the European Space Agency and Roscosmos, the Russian governmental body responsible for space research, agreed to cooperate on ExoMars, the first joint interplanetary mission between ESA and Russia. This project now involves scientists from 29 research organizations, including MIPT and the Space Research Institute of the Russian Academy of Sciences, which is the leading contributor of hardware and equipment on the Russian side. By now, the first package of observation instruments has been delivered into Mars orbit to seek minor chemical components of the planet's atmosphere that may be traces of primitive life. (MIPT)
European-Russian space mission steps up the search for life on Mars (23 January 2018)

## FLYING OBSERVATORY MAKES OBSERVATIONS OF JUPITER PREVIOUSLY ONLY POSSIBLE FROM SPACE

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is a joint German-US space science project. Carrying a 2.7-metre telescope inside a modified Boeing 747SP, the airborne observatory performs astronomical observations in the infrared and submillimetre wavelengths, high above the disturbance of Earth's atmosphere. The scientific objective is to understand the development of galaxies and the formation and evolution of stars and planetary systems from interstellar clouds of gas and dust. Image Credit: DLR

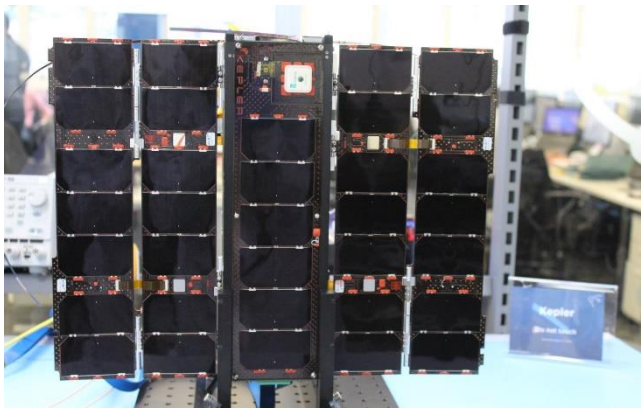
For the first time since the twin Voyager spacecraft missions in 1979, scientists have produced far-infrared maps of Jupiter using NASA's Stratospheric Observatory for Infrared Astronomy, SOFIA. These maps were created from the researchers' studies of the circulation of gases within the gas giant planet's atmosphere. Far-Infrared observations provide details not possible at other wavelengths. When gas planets like Jupiter are studied with visible light, they can only see the light reflecting from the top of the gas clouds that make up the atmosphere. Using infrared light allows scientists to see past the clouds and into the deep layers of the atmosphere, providing a three-dimensional view of the planet and the ability to study how gasses circulate within the atmosphere. Images from SOFIA reveal several interesting features. The Great Red Spot appears as a large, cold feature in the southern hemisphere indicating an upwelling of gas. The belt zone structure near the equator shows that the equator is cold and surrounded by warm belts of sinking gas. Bright, warm features near the north pole reveal heating of the planet's upper atmosphere by powerful aurora. (NASA)
Flying observatory makes observations of Jupiter previously only possible from space (5 January 2018)

## EARTH-I LAUNCHES PROTOTYPE OF WORLD'S FIRST FULL-COLOUR, FULL-MOTION VIDEO SATELLITE CONSTELLATION


British 'New Space' pioneer Earth-i has confirmed that the pre-production prototype satellite of its upcoming satellite constellation was successfully launched on 12th January 2018. The new commercial constellation, which the company announced is called Vivid-I, will be the first of its kind to provide full-colour video; and the first European-owned constellation able to provide both video and still images. The multiple satellites within the Vivid-i Constellation will significantly increase the ability of companies and institutions to monitor, track and analyse activities, patterns of life and changes at any location on earth.

Dr Graham Turnock, Chief Executive of the UK Space Agency, said: *"Today's launch is a significant moment for the UK and global space industries with Earth-i's progress being tracked across the world. Earth-i is an exciting and innovative British company and is a fine example of our thriving space sector. The Government's recently published Industrial Strategy set out a clear vision for the UK to become the world's most innovative nation and we are working with industry to capture 10% of the global space market by 2030."*
Earth-i launches prototype of world's first full-colour, full-motion video satellite constellation (12 January 2018)

## CLYDE SPACE SATELLITE LAUNCH SUCCESS



*Credit: Clyde Space.*

SCOTLAND'S pioneering spacecraft manufacturer, Clyde Space, has designed and built two advanced nanosatellites for Canadian company, Kepler Communications. The first spacecraft, KIPP, was successfully launched into Low Earth Orbit on Friday from the Jiuquan Satellite Launch Centre (JSLC) in North-western China. Kepler made contact with KIPP a

few hours later on Friday morning with all spacecraft systems performing as planned. The cutting-edge Clyde Space nanosatellites, built in the heart of Glasgow, will support Kepler Communications in deploying its in-space telecommunications network, which will relay data for devices deployed in remote regions. This pilot satellite, an advanced 3U CubeSat, carries Kepler's novel Software Defined Radio (SDR) and antenna array making the company the first commercial company to launch and operate a Low-Earth Orbiting communications satellite in Ku-band. (Clyde Space)
Clyde Space satellite launch success (22 January 2018)

## LINKS TO OTHER SPACE NEWS PUBLISHED IN JANUARY 2018

### ASTROPHYSICS

Three types of extreme-energy space particles may have unified origin (22 January 2018)
One of the biggest mysteries in astroparticle physics has been the origins of ultrahigh-energy cosmic rays, very high-energy neutrinos, and high-energy gamma rays. Now, a new theoretical model reveals that they all could be shot out into space after cosmic rays are accelerated by powerful jets from supermassive black holes and they travel inside clusters and groups of galaxies. (Penn State Eberly College of Science)

### BLACK HOLES

Researchers catch supermassive black hole burping – twice (11 January 2018)
Researchers have caught a supermassive black hole in a distant galaxy snacking on gas and then "burping"; not once, but twice. The supermassive black hole under study appears to have belched; essentially blasting out jets of bright light from the gas it inhaled, two times over the course of about 100,000 years. While astronomers have predicted such objects can flicker on and off because of gas feeding events, this is one of the few times one has been caught in the act. So why did the black hole have two separate meals? The answer lies in a companion galaxy that is linked to J1354 by streams of stars and gas, said Comerford. The team concluded that material from the companion galaxy swirled into the center of J1354 and then was eaten by the supermassive black hole. (Space Telescope Science Institute)

Black hole breakthrough: new insight into mysterious jets (9 January 2018)
Through first-of-their-kind supercomputer simulations, researchers have gained new insight into one of the most mysterious phenomena in modern astronomy: the behavior of relativistic jets that shoot from black holes, extending outward across millions of light years. Advanced simulations created with one of the world's most powerful supercomputers show the jets' streams gradually change direction in the sky, or precess, because of space-time being dragged into the rotation of the black hole. This behavior aligns with Albert Einstein's predictions about extreme gravity near rotating black holes, published in his famous theory of general relativity. (Northwestern University)

Evidence of strong winds outside black holes (22 January 2018)
What exactly causes these winds in space? For now, it remains a mystery. We think magnetic

fields play a key role. But we'll need to do a great deal of future investigation to understand these winds. (University of Alberta)

## BROWN DWARFS

Hubble finds substellar objects in the Orion Nebula (11 January 2018)
In an unprecedented deep survey for small, faint objects in the Orion Nebula, astronomers using NASA's Hubble Space Telescope have uncovered the largest known population of brown dwarfs sprinkled among newborn stars. Looking in the vicinity of the survey stars, researchers not only found several very-low-mass brown dwarf companions, but also three giant planets. They even found an example of binary planets where two planets orbit each other in the absence of a parent star. (Space Telescope Science Institute)

## CHEMISTRY

GBT detection unlocks exploration of 'aromatic' interstellar chemistry (11 January 2018)
Astronomers had a mystery on their hands. No matter where they looked, from inside the Milky Way to distant galaxies, they observed a puzzling glow of infrared light. This faint cosmic light, which presents itself as a series of spikes in the infrared spectrum, had no easily identifiable source. It seemed unrelated to any recognizable cosmic feature, like giant interstellar clouds, star-forming regions, or supernova remnants. It was ubiquitous and a bit baffling. The likely culprit, scientists eventually deduced, was the intrinsic infrared emission from a class of organic molecules known as polycyclic aromatic hydrocarbons (PAHs), which, scientists would later discover, are amazingly plentiful; nearly 10 percent of all the carbon in the universe is tied up in PAHs. (National Radio Astronomy Observatory)

## COMETS

Swift mission spies a comet slowdown (10 January 2018)
Observations by NASA's Swift spacecraft, now renamed the Neil Gehrels Swift Observatory after the mission's late principal investigator, have captured an unprecedented change in the rotation of a comet. Images taken in May 2017 reveal that comet 41P/Tuttle-Giacobini-Kresák, 41P for short, was spinning three times slower than it was in March, when it was observed by the Discovery Channel Telescope at Lowell Observatory in Arizona. The abrupt slowdown is the most dramatic change in a comet's rotation ever seen. The comet orbits the Sun every 5.4 years, traveling only about as far out as the planet Jupiter, whose gravitational influence is thought to have captured it into its present path. Estimated to be less than 0.9 mile (1.4 kilometers) across, 41P is among the smallest of the family of comets whose orbits are controlled by Jupiter. This small size helps explain how jets on the surface of 41P were able to produce such a dramatic spin-down. (NASA Goddard)

## DARK ENERGY

Dark Energy Survey publicly releases first three years of data (10 January 2018)
Scientists on the Dark Energy Survey (DES) announced today the public release of their first three years of data. This first major release of data from the Survey includes information on about 400 million astronomical objects, including distant galaxies billions of light years away

as well as stars in our own galaxy. DES scientists are using this data to learn more about dark energy, the mysterious force believed to be accelerating the expansion of the universe. They also announced today the discovery of eleven new stellar streams, remnants of smaller galaxies torn apart and devoured by our Milky Way. (Fermilab)

## DARK MATTER

Chasing dark matter with the oldest stars in the Milky Way (24 January 2018)
Just how quickly is the dark matter near Earth zipping around? The speed of dark matter has far-reaching consequences for modern astrophysical research, but this fundamental property has eluded researchers for years. Their big breakthrough came when they compared the velocity of dark matter to that of stars with different "metallicities," or ratios of heavy metals to lighter elements. (Princeton University)

## DWARF GALAXY

Stellar embryos in nearby dwarf galaxy contain surprisingly complex organic molecules (30 January 2018)
Astronomers using ALMA have uncovered chemical “fingerprints” of methanol, dimethyl ether, and methyl formate in the Large Magellanic Cloud. The latter two molecules are the largest organic molecules ever conclusively detected outside the Milky Way. (NRAO)

## DUST

Meteoritic stardust unlocks timing of supernova dust formation (18 January 2018)
The team focused on a rare isotope of titanium, titanium-49, because this isotope is the product of radioactive decay of vanadium-49 which is produced during supernova explosions and transmutes into titanium-49 with a half-life of 330 days. How much titanium-49 gets incorporated into a supernova dust grain thus depends on when the grain forms after the explosion. Using a state-of-the-art mass spectrometer to measure the titanium isotopes in supernova SiC grains with much better precision than could be accomplished by previous studies, the team found that the grains must have formed at least two years after their massive parent stars exploded. Because pre-solar supernova graphite grains are isotopically similar in many ways to the SiC grains, the team also argues that the delayed formation timing applies generally to carbon-rich supernova dust, in line with some recent theoretical calculations. This dust-formation process can occur continuously for years, with the dust slowly building up over time, which aligns with astronomer’s observations of varying amounts of dust surrounding the sites of stellar explosions. As we learn more about the sources for dust, we can gain additional knowledge about the history of the universe and how various stellar objects within it evolve. (Carnegie Institution for Science)

## EARTH (mainly satellite news)

Earth Networks developing enhanced GLM lightning detection (8 January 2018)
The GLM (GOES-East Geostationary Lightning Mapper) is the first lightning detector in a geostationary orbit transmitting lightning flashes in the Western Hemisphere. Earth Networks’ upcoming product adds significant value to lightning data from the GLM by

augmenting it with detection data and diagnostics from Earth Networks Total Lightning Network (ENTLN), such as classification, amplitude, polarity and location accuracy. This enhancement to GLM data will improve the GLM's native location accuracy by 20 to 40 times. With ENTLN detecting >95% of cloud-to-ground lightning seen by the GLM, this high-resolution accuracy will be crucial in situations where locating lightning strikes with greater precision is required. (Earth Networks)

Life-saving NASA communications system turns 20 (9 January 2018)
NASA's Tracking and Data Relay Satellites (TDRS) don't just enable data from spacecraft to reach Earth – they provide internet and even telemedicine to researchers at the South Pole. The South Pole TDRS Relay (SPTR) system turns 20 years old on Jan. 9, 2018.
(NASA Goddard)

NASA Alaska-launched rockets to study space X-ray emissions and create polar mesospheric cloud (9 January 2018)
NASA rockets launched during the Alaskan winter typically explore the interaction of solar winds with Earth's atmosphere and the resulting auroras that dance across the night sky. However, this winter, between January 15 - 31, 2018, NASA personnel and university researchers are traveling to the Poker Flat Research Range (PFRR) in Alaska to launch several rocket-borne investigations for other purposes. The scientists will launch four rockets to measure x-ray emissions from space and determine how large quantities of water could affect the upper atmosphere and form Polar Mesospheric clouds, or PMCs.
(NASA Goddard)

GeoCarb: a new view of carbon over the Americas (11 January 2018)
A new NASA Earth science mission in the early stages of design may achieve a transformational advance in our understanding of the global carbon cycle by mapping concentrations of key carbon gases from a new vantage point: geostationary orbit. Satellites in geostationary orbit travel at the same speed as Earth's rotation, allowing them to remain over the same place on Earth's surface at all times. The Geostationary Carbon Observatory (GeoCarb), targeted for launch in the early 2020s, will build on the success of NASA's Orbiting Carbon Observatory-2 (OCO-2) mission by placing a similar instrument on a commercial SES-Government Solutions communications satellite flying in geostationary orbit. Its longitude will allow "wall-to-wall" observations over the Americas between 55 degrees North and South latitude, from the southern tip of Hudson Bay to the southern tip of South America. Perched 22,236 miles (35,800 kilometers) above the Americas, GeoCarb will collect 10 million daily observations of the concentrations of carbon dioxide, methane, carbon monoxide and solar-induced fluorescence (SIF) at a spatial resolution of about 3 to 6 miles (5 to 10 kilometers). The abundance and distribution of carbon-bearing gases in the atmosphere are determined by both the exchange of carbon between Earth's land areas, oceans and the atmosphere, and their transport by prevailing winds. These exchanges are best understood by making frequent, densely spaced observations. While satellites in sun-synchronous, polar low-Earth orbits like OCO-2 provide global coverage, they have long revisit times, large gaps in coverage, and always look at the landscape at the same time of day. Because weather affects ecosystems on timescales of days to weeks, polar orbiting satellites may miss these changes and how they interconnect with the activities of living organisms, information that is crucial to developing better models of Earth system processes.
(JPL)

Planetary Resources launches latest spacecraft in advance of space resource exploration mission (12 January 2018)
Planetary Resources today announced the successful launch of the Arkyd-6, a 6U CubeSat, containing a demonstration of technology designed to detect water resources in space. The team has already begun to receive telemetry from the spacecraft. The data obtained from the Arkyd-6 will be valuable in the development of the Arkyd-301, Planetary Resources' next spacecraft platform and the beginning of the company's space resource exploration program. (Planetary Resources)

World's first free satellite internet service, Quika, launches today (15 January 2018)
Quika launches the world's first entirely free high-speed satellite internet for consumers in developing countries. Designed to address a leading cause of economic and social inequality, Quika responds to the growing disparity between regions with high and low investment, and limited access to internet infrastructure. Quika will launch in Africa in early 2018. (Quika)

ESA to clear congested skies with Iris (17 January 2018)
ESA has signed a €41.3 million contract with Inmarsat to help get more flights in the air with fewer delays, increased safety and reduced carbon dioxide emissions. The programme will introduce a safe and secure satellite-based air traffic management data link between aircraft and air traffic control (ATC) to relieve the congested radio frequencies used today. (ESA)

Satellites paint a detailed picture of maritime activity (18 January 2018)
ESA has helped coastal authorities to track up to 70% more ships and pick up nearly three times more ship positions via satellite than was possible before. Large cargo vessels and passenger ships are required to carry Automatic Identification System equipment. It transmits the course and speed as well as identification and position information to other vessels and shore stations. Originally developed to prevent collisions, it now also tracks ships to help prevent pollution, aid in the movement of dangerous goods, and promote routine surveillance. (ESA)

NASA covers wildfires from many sources (24 January 2018)
NASA's satellite instruments are often the first to detect wildfires burning in remote regions, and the locations of new fires are sent directly to land managers worldwide within hours of the satellite overpass. Together, NASA instruments, including a number built and managed by NASA's Jet Propulsion Laboratory in Pasadena, California, detect actively burning fires, track the transport of smoke from fires, provide information for fire management, and map the extent of changes to ecosystems, based on the extent and severity of burn scars. NASA has a fleet of Earth-observing instruments, many of which contribute to our understanding of fire in the Earth system. Satellites in orbit around the poles provide observations of the entire planet several times per day, whereas satellites in a geostationary orbit provide coarse-resolution imagery of fires, smoke and clouds every five to 15 minutes. (JPL)

NASA GOLD mission to image Earth's interface to space (24 January 2018)
On Jan. 25, 2018, NASA launches Global-scale Observations of the Limb and Disk, or GOLD, a hosted payload aboard SES-14, a commercial communications satellite. GOLD will investigate the dynamic intermingling of space and Earth's uppermost atmosphere and is the first NASA science mission to fly an instrument as a commercially hosted payload. Space is not completely empty: It's teeming with fast-moving charged particles and electric and magnetic fields that guide their motion. At the boundary between Earth's atmosphere and space, the charged particles, called the ionosphere, co-exist with the upper reaches of the

neutral atmosphere, called the thermosphere. The two commingle and influence one another constantly. This interplay and the role terrestrial weather, space weather and Earth's own magnetic field each have in it is the focus of GOLD's mission. (NASA Goddard)

Recovery attempts for NASA IMAGE mission (29 January 2018)
IMAGE, a NASA mission launched into orbit around Earth on March 25, 2000, was designed to image Earth's magnetosphere and produce the first comprehensive global images of the plasma populations in this region. After successfully completing and extending its initial two-year mission in 2002, the satellite unexpectedly failed to make contact on a routine pass on Dec. 18, 2005. After a 2007 eclipse failed to induce a reboot, the mission was declared over. After an amateur astronomer recorded observations of a satellite in high Earth orbit on Jan. 20, 2018, his initial research suggested it was the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) (NASA Goddard)

NASA's small spacecraft produces first 883-Gigahertz global ice-cloud map
(30 January 2018)
A bread loaf-sized satellite has produced the world's first map of the global distribution of atmospheric ice in the 883-Gigahertz band, an important frequency in the submillimeter wavelength for studying cloud ice and its effect on Earth's climate. (NASA Goddard)

NASA IMAGE re-discovery confirmed (30 January 2018)
New data regarding IMAGE provides some additional, though not yet complete, information on how the spacecraft began to transmit signals again. On Thanksgiving Day in 2004, the IMAGE spacecraft, at that time still fully functioning, underwent an unexpected power distribution reboot, after which the power returned only on one side, labeled the B side, of the unit. (Satellites are usually built with redundant hardware, often called "A sides" and "B sides." In the event one half fails, operators can switch to the other with minimal effect to the mission.) Scientists involved in the mission concluded that the A side had failed and proceeded for the rest of the mission exclusively with the B side. However, data from today's telemetry with IMAGE indicate that the spacecraft's power unit is now operating back on its A side. The ultimate cause of the reboot is still not known, but these recent findings suggest that a reboot in some form has, in fact, occurred. (NASA Goddard)

## EXOPLANETS

Planets around other stars are like peas in a pod (9 January 2018)
In this new analysis the team focused on 909 planets belonging to 355 multi-planet systems. These planets are mostly located between 1,000 and 4,000 light-years away from Earth. Using a statistical analysis, the team found two surprising patterns. They found that exoplanets tend to be the same sizes as their neighbors. If one planet is small, the next planet around that same star is very likely to be small as well, and if one planet is big, the next is likely to be big. They also found that planets orbiting the same star tend to have a regular orbital spacing. (W M Keck Observatory)

No planets needed: NASA study shows disk patterns can self-generate (11 January 2018)
When high-energy UV starlight hits dust grains, it strips away electrons. Those electrons collide with and heat nearby gas. As the gas warms, its pressure increases, and it traps more dust, which in turn heats more gas. The resulting cycle, called the photoelectric instability (PeI), can work in tandem with other forces to create some of the features astronomers have

previously associated with planets in debris disks. (NASA Goddard)

A 'hot Jupiter' with unusual winds (22 January 2018)
The hottest point on a gaseous planet near a distant star isn't where astrophysicists expected it to be. The hottest point of all tends to be the spot closest to the star. In the mysterious case of exoplanet CoRoT-2b, however, the hot spot turns out to lie in the opposite direction: west of centre. (McGill University)

How big can a planet be? (23 January 2018)
The Scientist found that objects more massive than about 10 times the mass of Jupiter do not prefer stars with lots of elements that make rocks; they are, therefore, are unlikely to form like planets. Objects in excess of 10 Jupiter masses should be considered brown dwarfs, not possible planets. (Johns Hopkins University)

NASA poised to topple a planet-finding barrier (25 January 2018)
NASA optics experts are well on the way to toppling a barrier that has thwarted scientists from achieving a long-held ambition: building an ultra-stable telescope that locates and images dozens of Earth-like planets beyond the solar system and then scrutinizes their atmospheres for signs of life. Scientists at NASA's Goddard Space Flight Center in Greenbelt, Maryland, have shown for the first time that they can dynamically detect subatomic- or picometer-sized distortions, changes that are far smaller than an atom, across a five-foot segmented telescope mirror and its support structure. Collaborating with Perry Greenfield at the Space Telescope Science Institute in Baltimore, the team now plans to use a next-generation tool and thermal test chamber to further refine their measurements. (NASA Goddard)

NASA's GOLD powers on for the first time (29 January 2018)
NASA's Global-scale Observations of the Limb and Disk, or GOLD, mission powered on the GOLD instrument for the first time after launch on Jan. 28. The systems' engineers successfully established communication with the GOLD instrument and its detector doors opened when commanded. After their tests, the engineers powered off the instrument the same day. The instrument will remain powered off until its host satellite, SES-14, reaches geostationary orbit and GOLD operations commence later this year. GOLD will investigate the dynamic intermingling of space and Earth's uppermost atmosphere and seek to understand what drives change in this critical region. Resulting data will improve forecasting models of the space weather events that can impact life on Earth, as well as satellites and astronauts in space. (Aerojet Rocketdyne)

Cluster measures turbulence in Earth's magnetic environment (29 January 2018)
For the first time, scientists have estimated how much energy is transferred from large to small scales within the magnetosheath, the boundary region between the solar wind and the magnetic bubble that protects our planet. Based on data collected by ESA's Cluster and NASA's THEMIS missions over several years, the study revealed that turbulence is the key, making this process a hundred times more efficient than in the solar wind. (ESA)

## EXTRA TERRESTRIAL LIFE

A new 'atmospheric disequilibrium' could help detect life on other planets (24 January 2018)
Life that makes methane uses a simple metabolism, is ubiquitous, and has been around

through much of Earth's history. It's an easy thing to do so it's potentially more common than oxygen-producing life. This is definitely something we should be looking for as new telescopes come online. (University of Washington)

## FAST RADIO BURSTS

A repeating fast radio burst from an extreme environment (10 January 2018)
New detections of radio waves from a repeating fast radio burst have revealed an astonishingly potent magnetic field in the source's environment, indicating that it is situated near a massive black hole or within a nebula of unprecedented power. Fast Radio Bursts (FRBs) are a recently discovered class of transient astrophysical events, originating from deep in extragalactic space. Their physical nature remains a mystery. FRB 121102 is the only known repeating FRB, and this has also raised the question of whether it has a different origin compared to the apparently non-repeating FRBs. (McGill University)

## FUTURE PLANNED MISSIONS

JUICE ground control gets green light to start development of Jupiter operations
(16 January 2018)
ESA's Jupiter Icy Moons Explorer, JUICE, passed an important milestone, the ground segment requirements review, with flying colours, demonstrating that the teams are on track in the preparation of the spacecraft operations needed to achieve the mission's ambitious science goals. Planned to launch in 2022, JUICE will embark on a 7.5-year long journey through the Solar System before arriving at Jupiter in 2029. There, it will spend three and a half years examining the giant planet and its environment, in particular investigating the Galilean moons Ganymede, Europa and Callisto, which are thought to conceal oceans of liquid water beneath their icy crusts. (ESA)

Putting everyday computer parts to space radiation test (29 January 2018)
ESA's next mission, the miniature GomX-4B, includes a piggyback experiment to test how well everyday commercial computer memories perform in the radiation-soaked environment of space. Ready to be launched from China this Friday 2nd February, GomX-4B was built from six standard 10 cm CubeSat units by GomSpace in Denmark. (ESA)

## GALAXIES

Black hole research could aid understanding of how small galaxies evolve (9 January 2018)
The results are important for astronomy because they potentially impact how we understand galaxy evolution. Supermassive black holes weren't thought to influence dwarf systems, but scientists have shown that isn't the case. This may well have a big influence on future research as simulations of galaxy formation don't usually include the heating effect of supermassive black holes in low-mass galaxies, including the dwarf systems examined. (University of Portsmouth)

Astronomers detect 'whirlpool' movement in earliest galaxies (10 January 2018)
Astronomers have looked back to a time soon after the Big Bang, and have discovered swirling gas in some of the earliest galaxies to have formed in the Universe. These 'new-borns', observed as they appeared nearly 13 billion years ago, spun like a whirlpool, similar

to our own Milky Way. This is the first time that it has been possible to detect movement in galaxies at such an early point in the Universe's history. (University of Cambridge)

## INTERNATIONAL SPACE STATION

U.S. cargo spacecraft set for departure from International Space Station (8 January 2018)
After delivering more than 4,800 pounds of science and supplies to the International Space Station, a SpaceX Dragon cargo spacecraft will depart the orbiting laboratory on Saturday, Jan. 13. On Friday, Jan. 12, flight controllers will use the space station's Canadarm2 robotic arm to detach Dragon from the Earth-facing side of the station's Harmony module. After Dragon is manoeuvred into place, a ground-controlled command will release the spacecraft. Dragon's thrusters will fire to move the spacecraft a safe distance from the station before SpaceX flight controllers in Hawthorne, California, command its deorbit burn. The spacecraft will splash down about 10:36 a.m. in the Pacific Ocean, where recovery forces will retrieve Dragon and approximately 4,100 pounds of cargo, including science samples from human and animal research, biology and biotechnology studies, physical science investigations and education activities. NASA and the Center for the Advancement of Science in Space (CASIS), the non-profit organization that manages research aboard the U.S. national laboratory portion of the space station, will receive time-sensitive samples from experiments conducted aboard the station and begin working with researchers to process and distribute them within 48 hours of splashdown. Dragon, the only space station resupply spacecraft capable of returning science and cargo to Earth, launched Dec. 15 on a SpaceX Falcon 9 rocket from Space Launch Complex 40 at Cape Canaveral Air Force Station in Florida and arrived at the station Dec.17. (NASA)

See-through metals (9 January 2018)
Astronauts on the International Space Station have begun running an experiment that could shine new light on how metal alloys are formed. Succinonitrile, D-camphor and neopentyl glycol were delivered by a Dragon spacecraft inside a glass-wall cartridge together with a miniature toaster. This Bridgman furnace is like a conveyor-belt oven found in factories or fast-food restaurants. The cartridges pass through the heating element at an agonisingly slow pace: they take upwards of two days to travel 1 mm, but the experiment will run on its own for several weeks. Who knows what amazing metals might be created? The next metal age might just be something we can't imagine right now. (ESA)

## LAUNCH SERVICES

Rocket Lab to open 'Still Testing' launch window on January 20 (11 January 2018)
Rocket Lab, a US aerospace company with operations in New Zealand, will open a nine-day launch window from Saturday January 20, 2018 (NZDT) to carry out the company's second test launch of the Electron rocket. During this time a four-hour launch window will open daily from 2:30 p.m. NZDT. (Rocket Lab)

## MARS

Steep slopes on Mars reveal structure of buried ice (11 January 2018)
Researchers using NASA's Mars Reconnaissance Orbiter (MRO) have found eight sites where thick deposits of ice beneath Mars' surface are exposed in faces of eroding slopes.

These eight scarps, with slopes as steep as 55 degrees, reveal new information about the internal layered structure of previously detected underground ice sheets in Mars' middle latitudes. The ice was likely deposited as snow long ago. The deposits are exposed in cross section as relatively pure water ice, capped by a layer one to two yards (or meters) thick of ice-cemented rock and dust. They hold clues about Mars' climate history. They also may make frozen water more accessible than previously thought to future robotic or human exploration missions. (JPL)

Thales SuperCam laser prepares to follow ChemCam to Mars in 2020 (22 January 2018)
NASA has begun building the Mars 2020 rover and integrating the instruments it will carry. The Mars 2020 mission will follow in the footsteps of Curiosity, which has been exploring Gale Crater on the surface of Mars for five and a half years and will continue the search for evidence of past life. The Mars 2020 rover will look much like its predecessor, but will boast a number of innovations, including instruments never before sent to the Red Planet.
Key points
•SuperCam, a new laser with higher performance
•New functionality to search for possible signs of life
•Increased analysis capacity with form factor and dependability identical to its predecessor, ChemCam (Thales Alenia Space)

Dust storms linked to gas escape from Mars atmosphere (23 January 2018)
Rising air during global dust storms on Mars hoists water vapor high in the atmosphere, researchers using NASA's Mars Reconnaissance Orbiter report. Regional dust storms every year uplift water to a lesser extent and appear to drive a seasonal pattern in loss of hydrogen from the top of Mars' atmosphere. If Mars has a global dust storm in 2018, observations could aid understanding of its effects. (JPL)

NASA's next Mars lander spreads its solar wings (23 January 2018)
The solar arrays on NASA's InSight Mars lander were deployed as part of testing conducted Jan. 23, 2018, at Lockheed Martin Space in Littleton, Colorado. Engineers and technicians evaluated the solar arrays and performed an illumination test to confirm that the solar cells were collecting power. The launch window for InSight opens May 5, 2018 (JPL)

## METEORS

Ingredients for life revealed in meteorites that fell to Earth (10 January 2018)
Two wayward space rocks, which separately crashed to Earth in 1998 after circulating in our solar system’s asteroid belt for billions of years, share something in common: the ingredients for life. They are the first meteorites found to contain both liquid water and a mix of complex organic compounds such as hydrocarbons and amino acids. (Berkeley Lab)

## MILKY WAY

Swarm of hydrogen clouds flying away from centre of our galaxy (10 January 2018)
A team of astronomers has discovered what appears to be a grand exodus of more than 100 hydrogen clouds streaming away from the center of the Milky Way and heading into intergalactic space. This observation, made with the National Science Foundation’s Green Bank Telescope (GBT), may give astronomers a clearer picture of the so-called Fermi

Bubbles, giant balloons of superheated gas billowing out above and below the disk of our galaxy. (Green Bank Observatory)

## MOON

Possible lava tube skylights discovered near the north pole of the Moon (11 January 2018)
The SETI Institute and the Mars Institute announced today the discovery of small pits in a large crater near the North Pole of the Moon, which may be entrances to an underground network of lava tubes. The pits were identified through analysis of imaging data from NASA's Lunar Reconnaissance Orbiter (LRO). If water ice is present, these potential lava tube entrances or "skylights" might allow future explorers easier access to subsurface ice, and therefore water, than if they had to excavate the gritty ice-rich "regolith" (surface rubble) at the actual lunar poles. (SETI Institute, Mars Institute)

CubeSats for hunting secrets in lunar darkness (22 January 2018)
Imagine sending a spacecraft the size of an airline cabin bag to the Moon. What would you have it do? ESA issued that challenge to European teams last year, and two winners have now been chosen. The Lunar Meteoroid Impact Orbiter, or Lumio for short, would circle over the far side of the Moon to detect bright impact flashes during the lunar night, mapping meteoroid bombardments as they occur. The other, the Lunar Volatile and Mineralogy Mapping Orbiter, or VMMO, would focus on a permanently shadowed crater near the lunar south pole, searching out deposits of water ice and other volatiles of interest to future colonists, while also measuring lunar radiation. (ESA)

## SATURN AND MOONS

Cassini finds Saturn moon has 'sea level' like Earth (17 January 2018)
Titan's seas follow a constant elevation relative to Titan's gravitational pull -- just like Earth's oceans. Smaller lakes on Titan, it turns out, appear at elevations several hundred feet, or meters, higher than Titan's sea level. Lakes at high elevation are commonly found on Earth. The highest lake navigable by large ships, Lake Titicaca, is over 12,000 feet [3,700 meters] above sea level. The new study suggests that elevation is important because Titan's liquid bodies appear to be connected under the surface in something akin to an aquifer system at Earth. Hydrocarbons appear to be flowing underneath Titan's surface similar to the way water flows through underground porous rock or gravel on Earth, so that nearby lakes communicate with each other and share a common liquid level. (JPL)

Titan topographic map unearths cookie-cutter holes in moon's surface (17 January 2018)
The map revealed several new features on Titan, including new mountains, none higher than 700 meters. The map also provides a global view of the highs and lows of Titan's topography, which enabled the scientists to confirm that two locations in the equatorial region of Titan are in fact depressions that could be either ancient, dried seas or cryovolcanic flows. The map also revealed that Titan is a little bit flatter, more oblate, than was previously known, which suggests there is more variability in the thickness of Titan's crust than previously thought. (Cornell University)

## SPACE AND MANNED SPACE

Two heads are better than one: ICON & GOLD teaming up to explore Earth's interface to space (4 January 2018)
Like Earth, space has weather. Except instead of swirling winds and downpours of precipitation, space weather is defined by shifting electric and magnetic fields and rains of charged particles. At the very beginning of space, starting just 60 miles above Earth's surface, there's a layer of the atmosphere that shifts and changes in concert with both types of weather. Two new NASA missions are teaming up to explore this little-understood area that's close to home but historically hard to observe. The Global-scale Observations of the Limb and Disk, or GOLD, instrument launches aboard a commercial communications satellite in January 2018, and the Ionospheric Connection Explorer, or ICON, spacecraft launches later in 2018. Together, they will provide the most comprehensive observations of the ionosphere we've ever had. (NASA Goddard)

## STARS AND STAR CLUSTERS

Supermassive black holes control star formation in large galaxies (1 January 2018)
Comparing the star formation histories of galaxies with black holes of different masses, there are striking differences. These differences only correlate with black hole mass and not with galactic morphology, size, or other properties. For galaxies with the same mass of stars but different black hole mass in the centre, those galaxies with bigger black holes were quenched earlier and faster than those with smaller black holes. Star formation occurs over hundreds of millions of years, while outbursts from active galactic nuclei occur over shorter periods of time. The precise nature of the feedback from the black hole that quenches star formation remains uncertain. (University of California Santa Cruz)

Alien megastructure not the cause of dimming of the 'most mysterious star in the universe' (3 January 2018)
A team of more than 200 researchers led by Louisiana State University's Tabetha Boyajian, is one step closer to solving the mystery behind the "most mysterious star in the universe." KIC 8462852, or "Tabby's Star," nicknamed after Boyajian, is otherwise an ordinary star, about 50 percent bigger and 1,000 degrees hotter than the Sun, and about 1,000 light years away. However, it has been inexplicably dimming and brightening sporadically like no other. Several theories abound to explain the star's unusual light patterns, including that an alien megastructure is orbiting the star. The team found that the star got much dimmer at some wavelengths than at others. Dust is most likely the reason why the star's light appears to dim and brighten. The new data shows that different colours of light are being blocked at different intensities. Therefore, whatever is passing between us and the star is not opaque, as would be expected from a planet or alien megastructure
(Pennsylvania State University)

Weighing massive stars in nearby galaxy reveals excess of heavyweights (5 January 2018)
Massive stars are particularly important for astronomers because of their enormous influence on their surroundings They can explode in spectacular supernovae at the end of their lives, forming some of the most exotic objects in the Universe, neutron stars and black holes. Scientists have not only been surprised by the sheer number of massive stars, but also that their IMF is densely sampled up to 200 solar masses. Until recently, the existence of stars up to 200 solar masses was highly disputed, and the study shows that a maximum birth mass of stars of 200-300 solar masses appears likely.(University of Oxford)

Iron-rich stars host shorter-period planets (9 January 2018)
Using SDSS data, they found that stars with higher concentrations of iron tend to host planets that orbit quite close to their host star, often with orbital periods of less than about eight days; while stars with less iron tend to host planets with longer periods that are more distant from their host star. Further investigation of this effect may help us understand the full variety of extrasolar planetary systems in our Galaxy, and shed light on why planets are found where they are.

ASU astronomers to build space telescope to explore nearby stars (10 January 2018)
Scientists are going to study the habitability and high-energy environment around stars M dwarf stars, aiming to show that small space telescopes like SPARCS can answer big science questions. The stars that SPARCS will focus on are small, dim, and cool by comparison to the sun. Having less than half the sun's size and temperature, they shine with barely one percent its brightness. The choice of target stars for SPARCS might seem counterintuitive. If astronomers are looking for exoplanets in habitable environments, why bother with stars that are so different from the sun? An answer lies in the numbers. M dwarfs are exceedingly common. They make up three-quarters of all the stars in our Milky Way galaxy, outnumbering sun-like stars 20 to 1. Astronomers have discovered that essentially every M dwarf star has at least one planet orbiting it, and about one system in four has a rocky planet located in the star's habitable zone. This is the potentially life-friendly region where temperatures are neither too hot nor too cold for life as we know it, and liquid water could exist on the planet's surface. (Arizona State University)

How massive can neutron stars be? (15 January 2018)
With an accuracy of a few percent, the maximum mass of non-rotating neutron stars cannot exceed 2.16 solar masses. (Goethe University Frankfurt)

Neutron-star merger yields new puzzle for astrophysicists (18 January 2018)
The afterglow from the distant neutron-star merger detected last August has continued to brighten, much to the surprise of astrophysicists studying the aftermath of the massive collision that took place about 138 million light years away and sent gravitational waves rippling through the universe. New observations from NASA's orbiting Chandra X-ray Observatory indicate that the gamma ray burst unleashed by the collision is more complex than scientists initially imagined. (McGill University)

Astronomers create first detailed images of surface of giant star (22 January 2018)
An international team of astronomers has produced the first detailed images of the surface of a giant star outside our solar system, revealing a nearly circular, dust-free atmosphere with complex areas of moving material, known as convection cells or granules, according to a recent study. The giant star, named $\pi^1$Gruis, is one of the stars in the constellation Grus (Latin for the crane, a type of bird), which can be observed in the southern hemisphere. An evolved star in the last major phase of life, $\pi^1$Gruis is 350 times larger than the Sun and resembles what our Sun will become at the end of its life in five billion years. Studying this star gives scientists insight about the future activity, characteristics and appearance of the Sun. Convection, the transfer of heat due to the bulk movement of molecules within gases and liquids, plays a major role in astrophysical processes, such as energy transport, pulsation and winds. The Sun has about two million convective cells that are typically 2,000 kilometers across, but theorists believe giant and supergiant stars should only have a few large convective cells because of their low surface gravity. Determining the convection properties of most evolved and supergiant stars, such as the size of granules, has been challenging

because their surfaces are frequently obscured by dust. In this study, the researchers discovered the surface of the giant star π1Gruis had a complex convective pattern and the typical granule measured 1.2 x 1011 meters horizontally or 27 percent of the diameter of the star. (Georgia State University)

Stellar magnetism: What's behind the most brilliant lights in the sky? (30 January 201)

Space physicists at University of Wisconsin–Madison have just released unprecedented detail on a bizarre phenomenon that powers the northern lights, solar flares and coronal mass ejections (the biggest explosions in our solar system). The data on so-called "magnetic reconnection" came from a quartet of new spacecraft that measure radiation and magnetic fields in high Earth orbit. Magnetic reconnection is difficult to describe, but it can be loosely defined as the merger of magnetic fields that releases an astonishing amount of energy. Magnetic reconnection remains mysterious, especially since it "breaks the standard law" governing charged particles, or plasma. The scientists used the Magnetosphere Multiscale satellite when it passed through the point where the solar wind meets Earth's magnetic field. The data clearly show that electrons suddenly cease to follow magnetic fields and zoom off in another direction, corkscrewing and turning. The activity confirmed the theoretical descriptions of magnetic reconnection. But it violated the standard law governing the behaviour of plasmas, clouds of charged particles that comprise, for example, the solar wind. The 'plasma frozen-in law' says electrons and magnetic fields have to move together always, and suddenly that does not apply. (University of Wisconsin-Madison)

**SUN.**

NASA team studies middle-aged Sun by tracking motion of Mercury (18 January 2018)
Like the waistband of a couch potato in midlife, the orbits of planets in our solar system are expanding. It happens because the Sun's gravitational grip gradually weakens as our star ages and loses mass. Now, a team of NASA and MIT scientists has indirectly measured this mass loss and other solar parameters by looking at changes in Mercury's orbit. The new values improve upon earlier predictions by reducing the amount of uncertainty. That's especially important for the rate of solar mass loss, because it's related to the stability of G, the gravitational constant. Although G is considered a fixed number, whether it's really constant is still a fundamental question in physics. (NASA Goddard)

**TECHNOLOGY**

Sierra Nevada Corporation's Dream Chaser spacecraft passes major NASA milestone after free-flight test (5 January 2018)

Sierra Nevada Corporation's (SNC) Dream Chaser program passed a major NASA milestone for its Commercial Crew Integrated Capability (CCiCAP) contract with the completion of a successful Free-Flight test, which produced subsonic flight and landing performance data. Milestone 4B validated the spacecraft's design for a safe and reliable return of cargo services to Earth through a gentle runway landing, signaling the program is one step closer to orbital operations. The Dream Chaser will go to the space station for at least six cargo resupply

missions starting in 2020 under a separate contract, NASA's Commercial Resupply Services 2 (CRS2). (Sierra Nevada Corporation)

W. M. Keck Observatory achieves first light with NIRES (5 January 2018)
NIRES (Near-Infrared Echellette Spectrometer) is expected to be one of the most efficient single-object, near-infrared spectrographs on an eight to ten-meter telescope, designed to study explosive, deep sky phenomena such as supernovae and gamma ray bursts, a capability that is in high demand. The power of NIRES is that it can cover a whole spectral range simultaneously with one observation. It's a cross-dispersed spectrograph that works in the infrared from where the visual cuts off out to 2.4 microns where the background from the thermal emission gets severe. Because NIRES will be on the telescope at all times, its specialty will be capturing Targets of Opportunity (ToO) – astronomical objects that unexpectedly go 'boom.' This capability is now more important than ever, especially with the recent discovery, announced October 16, of gravitational waves caused by the collision of two neutron stars. For the first time in history, astronomers around the world detected both light and gravitational waves of this event, triggering a new era in astronomy. With its high-sensitivity, NIRES will also allow astronomers to observe extremely faint objects found with the Spitzer and WISE infrared space telescopes. Such ancient objects, like high-redshift galaxies and quasars, can give clues about what happened just after the Big Bang. NIRES arrived at Keck Observatory in April. It will be available to the Keck Observatory science community in February. (W. M. Keck Observatory)

First ELT main mirror segments successfully cast (9 January 2018)
The first six hexagonal segments for the main mirror of ESO's Extremely Large Telescope (ELT) have been successfully cast by the German company SCHOTT at their facility in Mainz. These segments will form parts of the ELT's 39-metre main mirror, which will have 798 segments in total when completed. The ELT will be the largest optical telescope in the world when it sees first light in 2024. (ESO)

Arianespace and ArianeGroup kick off production for the final Ariane 5 launchers (9 January 2018)
ArianeGroup and its Arianespace subsidiary have announced an order for 10 Ariane 5 ECA launchers. The 10 launch vehicles covered by this will be deployed from the Guiana Space Center beginning in 2020, coming after the launches of 18 Ariane 5s ordered in 2013. This production order represents a total value of more than one billion euros for the European space industry, involving more than 600 companies in 12 European countries**,** including 350 small and medium-sized enterprises. The order's size is aligned with the ramp-up for the next-generation Ariane 6, which is scheduled to make its first flight in mid-2020, reaching full capacity in 2023. (ArianeGroup)

NASA team first to demonstrate X-ray navigation in space (11 January 2018)
In a technology first, a team of NASA engineers has demonstrated fully autonomous X-ray navigation in space, a capability that could revolutionize NASA's ability in the future to pilot robotic spacecraft to the far reaches of the solar system and beyond. The demonstration, which the team carried out with an experiment called Station Explorer for X-ray Timing and Navigation Technology, or SEXTANT, showed that millisecond pulsars could be used to accurately determine the location of an object moving at thousands of miles per hour in space, similar to how the Global Positioning System, widely known as GPS, provides positioning, navigation, and timing services to users on Earth with its constellation of 24 operating satellites. (NASA Goddard)

ICEYE launches world's first SAR microsatellite (12 January 2018)
ICEYE, the leader in synthetic-aperture radar (SAR) technology for microsatellites providing expanded access to reliable and timely earth observation data, today announced the successful launch of its proof-of-concept satellite mission, ICEYE-X1, on ISRO's PSLV-C40 rocket. The success of the launch, from Satish Dhawan Space Center in India, distinguishes ICEYE-X1 as the world's first microsatellite equipped with synthetic-aperture radar (SAR) to ever be deployed in space and as Finland's very first commercial satellite. Making further history, ICEYE has also successfully established communications with the 70 kg satellite at 5:20 AM GMT now in orbit, signalling the next step in the mission's success. (ICEYE)

ESA and China team up on typhoon-targeting imager (17 January 2018)
ESA has teamed up with the Chinese Academy of Sciences to test an instrument capable of peering down from orbit through dense clouds and rain to sound the depths of typhoons and storms. (ESA)

First ICEYE-X1 radar image released (17 January 2018)
A synthetic-aperture radar (SAR) instrument sends its own radio waves to the ground, creating an image from the energy that scatters back to the instrument. Given this, SAR sensors can provide imaging of the Earth during both day and night, regardless of cloud cover and weather condition. Conventional SAR satellites typically weigh in excess of 1000 kg due to the amount of instrumentation on board. ICEYE-X1 is ICEYE's first satellite mission. Both the satellite bus and the SAR instrument were developed and integrated by ICEYE. ICEYE-X1 is a significant shift in size from traditional SAR satellites, allowing the technology to be condensed into a satellite weighing under 100 kg. This in turn enables launching a constellation of many satellites rather than only a few. (ICEYE)

First ignition for Europe's most powerful rocket engine, the Vulcain 2.1 (23 January 2018)
The new Vulcain 2.1 engine, which is set to carry the new European launcher Ariane 6 into space in 2020, is intended to achieve greater efficiency at lower costs (DLR)

Microbes may help astronauts transform human waste into food (25 January 2018)
Human waste may one day be a valuable resource for astronauts on deep-space missions. Now, a Penn State research team has shown that it is possible to rapidly break down solid and liquid waste to grow food with a series of microbial reactors, while simultaneously minimizing pathogen growth. (Penn State)

*Pat Williams January 2018*