

OKLAHOMA SPACE ALLIANCE

OUTREACH – March 2023

102 W. Linn #1, Norman, OK 73069

Oklahoma Space Alliance will meet at either the McMurray residence or at the room next to Norman Computer at 2:00 p.m. on March 11, details inside



Ganymede, the target of JUICE (Image from Galileo space probe)

OKLAHOMA SPACE ALLIANCE OUTREACH March 2023

March Meeting

Oklahoma Space Alliance will have Christmas Party II at 2:00 p.m. on Saturday, March 11, at the McMurray's house.

A lot of people weren't at the Christmas Party, so we are having a party with moderate business. We ask that everyone bring food.

Prospective members are welcome. Their house is at 2715 Aspen Circle in Norman. To get to the meeting either: (1) Take the Lindsey Street east exit from I-35, turn right at Berry, and proceed to Imhoff Road. Turn right at Imhoff, right at Poplar Lane, left at Aspen Lane, and right at Aspen Circle. or (2) Take the Highway 9 east off I-35, turn left at Imhoff Road, left at Poplar, left at Aspen Lane, and right at Aspen Circle.

Norman Computers is at 916 W Main St, opposite Norman High School. The phone number is (405) 292-9501.

We will have this meeting on Zoom for those who cannot attend in person: To join the meeting, go to <https://tinyurl.com/y2qtab28>. If the link doesn't work, call Clifford McMurray, President 405-329-4326 (H), 405-863-6173 (C) (e-mail cliffmcmurray at hotmail.com) or Syd Henderson at 405-365-8983 (C) (e-mail sydh at ou.edu) and we will send you updated information.

Saturday March 11, 2023, 2:00 p.m. (tentative)

Since this is a party, we will have minimum business.

1. Introductions and review of Space events this past month
2. What's Happening in Space, News, Pictures, and Videos approximately one hour. See <http://osa.nss.org> before the meeting for items to be discussed.
3. Break
4. Oklahoma Space Alliance Chapter Business Discussion
 - a. Review OSA treasurer's report
 - b. Minutes of November meeting
 - c. Annual Report
 - d. Presentations from ISDC
5. Video (to be announced)
6. Chat

Minutes of February 11 Oklahoma Space Alliance Meeting

Oklahoma Space Alliance met February 11, 2023, at the McMurray house in Norman, Oklahoma. Attending in person were Clifford and Claire McMurray. Adam Hemphill, John Northcutt, Tim Scott, Dave Sheely, and Syd Henderson. OSA President Clifford (Kip) McMurray presided over the meeting. He did an Update discussing links to material covered in the meeting and this is online at <https://osa.nss.org/Update2302.pdf> so I'll cover the details that aren't covered there.

Rocket Lab was delayed two years from launching in the US because it had to satisfy NASA's request for a termination system. [They've conducted many launches from New Zealand but now they can launch from Wallops Island just east of the Delmarva Peninsula.]

Starlink 2.0 is about four times as massive as previous Starlinks. This causes increased concern about how they will affect ground-based astronomy.

China had already done some joint exercises with the European Space Agency to prepare for ESA cooperation with Tiangong (which possibility is apparently defunct). There is now a new class of astronauts: reserve astronauts.

The failed Virgin Orbital flight from Cornwall, England, had nine satellites aboard. Virgin Orbital is having financial troubles and really needed this flight to succeed.

The Queqiao relay satellite is the communications relay satellite the Chinese used on the *Chang'e 4* mission to the far side of the Moon. Queqiao-2 will perform the same service for *Chang'e 6*. [It will launch in late 2024 and settle into lunar orbit before *Chang'e 6* launches in 2025.] Queqiao literally means "Magpie Bridge." [The odd name comes from the Chinese folk tale "The Cowherd and the Weaver Girl" where the cowherd is the star Altair, and the Weaver Girl was Vega. Their love was forbidden but once a year a flock of magpies forms a bridge crossing the Milky Way so they can meet each other. There is an annual celebration in China (and Korea and Japan) that celebrates the day. Sorry for the digression, but it's a lovely story and the people naming Chinese spacecraft are clearly romantics.]

We read a *Space News* article on Astroforge. Astroforge will not reveal the name of the asteroid they are going to because they consider it proprietary information. [Perhaps they fear claim jumpers.]

The NASA Innovative Advanced Concepts (NIAC) program grants include one to search for water oceans on icy worlds such as Pluto, Europa, Ganymede, Enceladus, Triton and Titan. Some of these are known, others are speculative.

Artur Davoyan's proposal uses pellet beam propulsion. It looked like the pellets are accelerated by lasers and collide with some sort of pusher plate on the spacecraft.

One article is on producing gigantic telescopes in space by using spinning fluids to make the mirrors. [The mirrors are solidified after spinning.] This has been tried on a small scale in experiments on the ISS and the fluid naturally forms a parabolic mirror shape. You also need a smaller secondary mirror to refocus the reflection to a detector. The large mirror proposed would be 2000 inches in diameter and would not need to be segmented. Since this is in space, a tube to hold the mirror would not be necessary but I think there is some sort of connection to the secondary mirror.

The James Webb Space Telescope has discovered the Chiron asteroid Chariklo is losing mass, which may be related to the discovery that it has rings (which the JWST also discovered).

All cargo flights down from the ISS are full to either mass or volume capacity.

There are 30,000 objects in orbit large enough to be tracked and an unknown number too small to be tracked.

A Canadian astronaut may be flying on one of the early Artemis flights.

We read an article on SpaceX's 31 engine burn and a video of the test. Starship actually has 33 engines, but one was turned off just before the test and one turned itself off during the test. However, 31 engines are more than enough to reach orbit.

We saw an article about the discovery, using archives of the Ottoman Empire, that a man in Asia Minor was killed by a meteorite in 1888. He is the first known man to have been killed by a meteorite.

We watched a video from the Tiangong space station including sunrise on New Year's Day.

We watched the first half of an interview with Stoke Space on the web program “Everyday Astronaut” Stoke Space is a startup which is building a rocket that uses the aerospike idea on the upper stage. [Aerospike was an idea that was proposed for the shuttle replacement, but it doesn’t seem to have panned out.] They are also using an innovative heat shield design that uses excess energy from the rockets to pump coolant to refrigerate the heat shield. Thrust is generated on the perimeter of the base of the rocket so all forces are in the axial direction.

--Minutes by OSA Secretary Syd Henderson

Minutes of January 14 Oklahoma Space Alliance Meeting

Oklahoma Space Alliance met January 14, 2023, at the McMurray’s house in Norman, Oklahoma. Attending in person were Clifford and Claire McMurray. Adam Hemphill, Tim Scott, Dave Sheely, and Syd Henderson. Robin Scott attended by Zoom. OSA President Clifford (Kip) McMurray presided over the meeting He did an Update discussing links to material covered in the meeting and this is online at <https://osa.nss.org/Update2301.pdf> so I’ll cover the details that aren’t covered there.

Speculation is that the *Soyuz 22* spacecraft attached to the International Space Station was hit by space debris, not by a Geminid meteor. *Soyuz 22* will be sent back to Earth for evaluation. The Russians will send *Soyuz 22* back to the ISS as a cargo vehicle [Since the coolant system was damaged].

Adam doesn’t think Soyuzes are reusable, though this is a special case.

The cubesat deployed from the *Tiangong* space station is for amateur radio.

We watched the launch of the *Tiangong* relief crew. We also watched video of the docking and of the new astronauts boarding *Tiangong*.

The *Zhuque-2* spacecraft would have been the first commercial liquid fuel rocket to make orbit.

InSight detected a host of Marsquakes that came from a region about 1,000 kilometers from where it landed. *InSight* discovered that Mars had a much larger core that originally thought but that it still is solid. [Since the mass of Mars hasn’t changed, I think this means the core must be a bit less dense than originally thought.]

We watched a video on the landing of *InSight* and its achievements. [*InSight* was at the end of its mission due to it being covered by dust, including its solar panels.]

InSight captured the sound of a meteorite striking Mars. It was the first time the seismic waves from such an impact were detected on another planet. [I believe they have been detected on the Moon.]

We read an article on protecting rovers from dust, and before and after pictures of *InSight* as it got covered by dust.

Falcon 9 can transfer more energy to the moon craft it releases so they can use much less energy by going into orbits farther out and getting captured on their way back. There will be 60+ missions to the Moon in the next few years.

(Robin arrived by Zoom at this point.)

We watched video of the launch of *Artemis 1*. It had nine million pounds of thrust. Starship has 16 million pounds of thrust.

We watched video of the announcement of the #dearmoon crew.

SpaceX had 61 launches in 2022. 34 of these were Starlink launches.

We watched video of an asteroid impact simulator.

NEO Surveyor will be at the Earth-Sun L1 point so it will be able to see a lot more asteroids coming from the sunward direction.

Northrop Grumman’s Space Solar Power demo test from orbit will be from a spacecraft called *Arachne* scheduled to launch in 2025.

Inflatable heatshields allow an increase of mass of landers on Mars from 1-2 tons to 20-40 tons. They may be 14 -15 meters in diameter. We watched a video simulation of an inflatable heatshield undergoing reentry.

We watched a video of an egg being dropped from 100,000 ft.

Adam: Virgin Galactic hasn't launched since the Branson flight.

Business: We have \$908.91 in our checking account and \$267 in our cash box, for a total of \$1175.91.

It's annual report time! Syd needs to get the activity report to Tim by the February 11 meeting.

Bring some food for the March meeting. Kip will be out of town the week before, so we'll have more of a party.

We have a backlog of *Ad Astras*.

Mark Deaver is setting up a meeting space next to the computer store. There is a charge that would deplete our treasury, but can we work something out in trade?

We watched a video of the Moon eclipsing Earth (via *Artemis 1*) and a video of images from the James Webb Space Telescope.

--Minutes by OSA Secretary Syd Henderson

Space News

We may have a solution to the Moon dust problem. This was a problem for the Apollo moon walkers because it is very sticky though static electricity, very fine and very abrasive. The solution may turn out to be liquid nitrogen, which in a simulated moon dust experiment, removed 98% of dust. It also has the advantage of not damaging spacesuits anywhere near as much as trying to rub the stuff off. This will obviously be one of the main things tested on early Artemis Moon landings, and I have a suspicion it will also be useful on Mars. Article: <https://www.space.com/artemis-astronauts-moon-dust-removal-spray>.

The James Webb Space Telescope is starting to make discoveries that challenge cosmology. Most recently, it has discovered 100 billion stellar- mass galaxies forming only 700 million years after the Big Bang. It appears already to have as many stars as the Milky Way. This is impossible by current theories of galaxy formation since that many stars shouldn't have formed so quickly. It also appears that some of these are harboring quasars which means they already have supermassive black holes.

We mentioned in the February meeting that the James Webb Space Telescope has detected ring about the Chiron asteroid Chariklo, Well, the Cheops space telescope and some ground-based telescopes have detected that so does the Kuiper Belt dwarf planet Quaoar has a ring as well as its moon Weywot. This is unexpected because the ring is over twice the distance as Roche's limit would be. A ring that far out should have condensed to form a satellite. My guess is that it may be debris from a collision, but there may simply be something about ring formation we don't know. [Incidentally, the only other Kuiper Belt object known to have a ring is the fellow dwarf planet Haumea, which is also in the Kuiper Belt. They're hard to find, so there are probably many more.

I mentioned the AstroForge asteroid mission plans in the minutes of the February meeting. More information on this is at https://skyandtelescope.org/astronomy-news/are-we-finally-on-the-cusp-of-commercial-asteroid-mining/?utm_source=cc&utm_medium=newsletter, dated February 27. There are two AstroForge missions scheduled to go up this year on SpaceX rockets, the first in April, the second in October. These are Cubesats designed to investigate M-type asteroids which are rich in platinum-group metals (platinum, palladium, rhodium, ruthenium, iridium and osmium) which are among the rarest metals in the Earth's crust since any present when the Earth formed are now in the core of the Earth. Most of them on Earth are from meteorites that hit the Earth, and they are generally obtained as a byproduct of mining other metals. They are used as catalysts, corrosion-resistant metals (including plating contacts), alloys,

precious metals, and are all very expensive. Iridium may be the rarest stable metal in the Earth's crust and only three tons are produced per year. Gold and rhenium are two other rare elements that occur in metallic asteroids.

The first CubeSat will test refining in low Earth orbit. The second one is the one that is going to the unnamed asteroid.

Kepler 444 is a triple star system in Lyra that appears to be more than 11 billion years old. It consists of a K0 type star, *i.e.*, an 'orange dwarf star' somewhat similar to Alpha Centauri B, and a red dwarf binary about twice the distance from Kepler 444A as Neptune is from our Sun. There are also five planets which are between 0.4 and 0.7 earth radii in diameter and all of them orbit with a period under ten days. This was a mystery because at first the binary was thought to approach within five astronomical units of Kepler 444A, about the distance from here to Jupiter, which would have disrupted the planetary formation and not leave enough mass to form the planets. But now it appears that the binary never comes closer than 23 astronomical units, which would have left the inner protoplanetary disk much more stable and leave an ample five hundred Earth-mass worth of dust from which to form planets. What is remarkable is that this system appears to have remained stable for more than twice the age of the Solar System.

The original paper was "The McDonald Accelerating Stars Survey: Architecture of the Ancient Five-planet Host System Kepler-444," Zhoujian Zhang et al 2023 AJ 165 73. doi:10.3847/1538-3881/aca88c" but I got it through <https://aasnova.org/2023/02/24/a-fresh-look-at-kepler-444s-ancient-planetary-system/> which was republished on <http://skyandtelescope.com>.

Space-Related Articles

"Surprises from the Jezero Crater," by Liz Kruesi, *Science News*, February 25, 2023, pp 22 – 26. Results from the *Perseverance* Mars rover mission, which is notable for having an extinct river delta entering its western side and leaving a lot of sedimentary rocks. Jezero Crater is a meteor crater about 27 miles across and the river that formed the delta broke through its wall. It's not surprising that debris from the meteor strike is still there, but it was unexpected to find igneous rock from at least two separate lava flows within the crater. Furthermore, sulfates have been found in the crater, formed by the action of water on the igneous rock, which indicates that there must have been a lake there as recently as three billion years ago.

"Mission to Jupiter's Icy Moons," by Ben Evans, *Astronomy*, April 2023, pp. 12 – 19. The JUICE (JUUpiter ICy moons Explorer, is a really strained acronym) is due to launch on April 13. After flybys of Venus and three flybys of Earth it will arrive in Jupiter orbit in October 2029. It will do only two flybys of Europa since the Europa Clipper mission will launch in October 2024 and is dedicated to that Moon. It will also make a bunch of flybys of Calisto, but most of its mission will be spent orbiting Ganymede, which is suspected to have an ocean ten times deeper than Earth's oceans but buried 200 miles deep under the ice. Ganymede also has a liquid iron core and that produces its magnetic field, The ocean affects the magnetic field which is how the ocean was detected. As usual, the possibility that this ocean may harbor life is being considered, but finding out for sure would be a huge megaproject.

Callisto may have a liquid water ocean, but its interior is so cold that it's likely the ocean would be more like a layer of slush. It doesn't have anywhere near the internal tidal heating that makes the other Galilean moons so exciting. However, Callisto is also largely outside Jupiter's magnetic field and would be the logical place to put a research colony if we ever wanted to put one near Jupiter.

"The Little Stars That Can," by Ken Crowell, *Sky and Telescope*, April 2023, pp 36 – 40. This is about the solution of a paradox in cosmogenesis: the Big Bang produced small amounts of lithium, but stars consume it during nuclear fusion so old stars have little of it. But a lot of young stars do, so where does it come from, since usual nuclear fusion bypasses it and it shouldn't come from supernovae? Apparently, most of it is produced by regular novae. These occur because matter falls onto the surface of a

white dwarf from a companion star until it spontaneously starts to fuse. But part of this process is that helium 4 and helium-3 nuclei collide to form beryllium-7, which normally absorbs a neutron to produce two helium nuclei and a lot of energy. However, the fusing material explodes before the process is complete, which spews the beryllium-7 before it has time to react. Beryllium-7 is radioactive if it has any electrons¹ and decays into lithium 7, the more common isotope of lithium. (This also means that lithium-6 comprises a smaller percentage of the element as the universe gets older). Similar processes apparently produce carbon-13, nitrogen -15 and oxygen-17, which are rare but a bit of a puzzle in that there's more than expected.

Sky Viewing

There aren't any bright comets anticipated this year, but Comet C/2023 A3 is making a close pass by the Sun in fall of 2024 and, since it has already been spotted this early and has not been in the inner Solar System in 80,000 will likely be magnitude 0.7, which is very good, and possibly magnitude -5, which would be spectacular. Note this is very early, and astronomy sites have a tendency to play up the brightness of comets, but this is something to keep an eye out for,

The **Lyrid Meteor Shower** peaks on the night of April 22 – 23 and this year there will no interference from the Moon. Although the Lyrids can be active, this year about 15 meteors per hour are expected. Best time is about 2 in the morning, but you should be able to see meteors around midnight, and the Lyrids are known for producing fireballs. Oddly the radiant isn't in Lyra at all but a bit inside Hercules; however, the bright star Vega isn't that far from the radiant and is the fifth brightest star in the night sky.

The Earth has three solar eclipses in the next fourteen months. Two of them will be visible from the United States, but one this April 20 will be on the other side of the Earth. This is what is known as a "hybrid" eclipse, meaning that it is an annular eclipse from the beginning of its path in the southern Indian Ocean almost to Australia, nips the northwestern tip of Australia (by which time it is a total eclipse), achieves greatest totality—72 seconds—south of the island of Timor in the Indonesian archipelago, then across far western New Guinea, finally turning into an annular eclipse again in the Marshall Islands. This eclipse is remarkable that it has such a long path and hits no populous land area at all, though Australia, Indonesia, Malaysia, Papua New Guinea, Vietnam, the Philippines, Taiwan and a lot of small island nations will get partial eclipses. North Island of New Zealand will be on the very edge of the eclipse.

The April issue of *Astronomy* has an article on the October 14 annular eclipse, which will cross the United States from Oregon to the southeastern tip of Texas and at its closest will be about three hundred miles from Norman. That is, it will be substantially partial here. The April 8 total eclipse crosses Mexico, Texas (including Dallas-Fort Worth, Austin and San Antonio) and continue northeast, crossing the metropolitan areas of Indianapolis, Cleveland and Buffalo before moving into Canada. All these metropolitan areas have more than two million people (Dallas seven million) except Buffalo, which is 1.2 million), and Hamilton and Montreal in Canada are also in the path of totality. The path of totality crosses southeastern Oklahoma. Totality in our area will be around four minutes.

The April issue of *Sky & Telescope* has an article on the April 20, 2024 solar eclipse.

There are also two partial eclipses of Moon this year, the first a penumbral eclipse (which means you won't notice anything) and the second is centered on Australia.

Mercury is approaching its March 17 superior conjunction with the Sun, hence is not currently visible. However, it will appear again in late March. On March 27 it will be in the western sky and the ecliptic is highly inclined toward the horizon at sunset this time of year, although it still will only be a few de-

¹ Beryllium-7 decays solely by one of its protons capturing an electron and producing a neutron and a neutrino. If all the electrons are stripped from beryllium-7, the nucleus is stable—at least until it finds some electrons.

degrees above the horizon. However, this is when it has a conjunction with Jupiter, getting within 1.3 degrees of each other. Jupiter will be magnitude -2.1 and Mercury magnitude 1.5. Even though that's pretty bright, you'll need binoculars to see them. Mercury will be more visible in early April as it approaches greatest elongation on April 11. This is a very favorable elongation so if you can find a place with a clear western horizon, it's worth looking. It will still be ten degrees above the horizon 45 minutes after sunset.

Venus, meanwhile, is very conspicuous in the western sky after sunset. Venus itself had a conjunction with Jupiter on March 1 (naturally the sky here was overcast) and is still higher in the sky each night while Jupiter is approaching conjunction. At magnitude -3.9 and at a greater height, Venus is by far the brighter of the two planets, and Venus is getting brighter as it gradually approaches Earth. By April 10 it will be magnitude -4.1 and only a couple of degrees from the Pleiades.

Mars is still visible all evening but has now faded to magnitude 0.5. Still, that is noticeably brighter than Aldebaran, the first-magnitude star in Taurus. You can find Aldebaran by following the line of the Belt of Orion going west. Mars is the next bright "star" going north. The fairly bright star a bit farther north is El Nath, the second brightest star in Taurus. It marks the tip of the northern horn of the Bull. Mars, meanwhile, is fading slowly as it moves toward Gemini, where it will meet the crescent Moon on April 25. They will be three degrees apart but in a good location, right in the center of Gemini.

Jupiter is still easily visible below Venus in the west, and it won't start getting hard to see until the end of the month as it approaches its April 11 conjunction with the Sun (which will make it not visible at all in April). Incidentally, Jupiter is magnitude -2.1, which is half a magnitude less than it was at opposition, which is not surprising because it is 180 million miles farther away.

Saturn was in conjunction with the Sun on February 16 and is still lost in the sunrise. It will become visible again in late March in the east before sunrise, but it will be well into April before it's easily visible.

I don't mention asteroids that often, but **Ceres** is a dwarf planet after all, and it will be at opposition on March 21. It will be magnitude 6.9, which means binoculars at least, and is in Coma Berenices, which is north of Virgo and west of Leo. This is the closest and brightest Ceres will be until 2032. There is a location map on page 49 of the March *Sky and Telescope*.

Data on the planets come from the March and April issues of *Sky and Telescope* and *Astronomy* and from their websites.

Viewing Opportunities for Satellites (March 10 – April 11, 2023)

You can get sighting information at www.heavens-above.com, which gives you a constellation map showing the trajectory of the satellite. The Sky & Telescope web site carries ISS observation times for the next few nights at skyandtelescope.com/observing/almanac. You can also get data at <https://spotthestation.nasa.gov/sightings/>.

With the addition of the solar panels, the International Space Station can be as bright as magnitude -4.0 making it brighter than all the stars other than the Sun and all the planets other than Venus, although magnitude -2 to -3 is more likely. The Hubble Space Telescope can get up to magnitude 1.5, which is brighter than the stars in the Big Dipper, but magnitude 2.0 – 2.5 is more likely. *Tiangong* is the Chinese Space Station. It currently gets up to magnitude -2.3 after the addition of the Wentian module in July.

The "mag." beside the date indicates the brightest magnitude the satellite gets during the pass. All the ISS passes get between -3 and -4, which is brighter than Jupiter ever gets, but not quite as bright as Venus.

Missions to and from the International Space Station and *Tiangong* can change their orbits. SpaceX launched a crew to the ISS on March 2 and there will be a crew return mission sometime in the next week or two. SpaceX will launch a resupply mission to the ISS on March 12. There will be (hopefully) the first Starliner mission to the ISS in April. There are no missions to *Tiangong* until May and none to Hubble in the near future. Also note that the ISS (and presumably *Tiangong*) sometimes have to alter orbits to avoid space debris. Hubble is high enough that this is less of a concern.

The information below is from Heavens Above. There are no good passes of the Hubble Space Telescope

| Tiangong 3/10/23 mag. -1.9 | | |
|----------------------------|----------|-----------|
| Time | Position | Elevation |
| 7:22 p.m. | 255° | 10°* |
| 7:25 | 338 | 64 |
| 7:28 | 59 | 16 |

*Passes just above Venus

| Tiangong 3/12/23 mag. -1.1 | | |
|----------------------------|----------|-----------|
| Time | Position | Elevation |
| 7:58 p.m. | 271° | 10° |
| 8:01 | 343 | 41 |
| 8:04 | 56 | 10 |

| ISS 3/15/23 mag. -3.4 | | |
|-----------------------|----------|-----------|
| Time | Position | Elevation |
| 9:01 p.m. | 237° | 10° |
| 9:04:31 | 320 | 63 |
| 9:05:42 | 27 | 27 |

Vanishes into Earth's shadow

| ISS 3/16/23 mag. -3.8 | | |
|-----------------------|----------|-----------|
| Time | Position | Elevation |
| 8:13 p.m. | 218° | 10° |
| 8:16 | 135 | 66* |
| 8:19 | 53 | 10 |

*Passes very close to Rigel

| ISS 3/18/23 mag. -2.3 | | |
|-----------------------|----------|-----------|
| Time | Position | Elevation |
| 8:12 p.m. | 253° | 10°* |
| 8:15 | 323 | 37 |
| 8:19 | 33 | 10 |

*Passes between Jupiter and Venus

| Tiangong 3/18/23 mag. -1.4 | | |
|----------------------------|----------|-----------|
| Time | Position | Elevation |
| 8:22 p.m. | 304° | 10° |
| 8:25:57 | 17 | 46 |
| 8:27:10 | 84 | 16 |

| Tiangong 3/19/23 mag. -2.1 | | |
|----------------------------|----------|-----------|
| Time | Position | Elevation |
| 8:58 p.m. | 291 | 10° |
| 9:00:56 | 208 | 70 |
| 9:27:10 | 143 | 50 |

Vanishes into Earth's shadow

| ISS 4/4/23 mag. -2.5 | | |
|----------------------|----------|-----------|
| Time | Position | Elevation |
| 8:53 p.m. | 296° | 10° |
| 8:56 | 227 | 37 |
| 8:59 | 162 | 13* |

Skims Orion's belt and passes very close to Sirius

| Tiangong 4/7/23 mag. -1.2 | | |
|---------------------------|----------|-----------|
| Time | Position | Elevation |
| 6:25 a.m. | 221° | 10° |
| 6:28 | 149 | 41 |
| 6:31 | 78 | 10 |

| Tiangong 4/9 mag. -2.2 | | |
|-----------------------------|----------|-----------|
| Time | Position | Elevation |
| Appears from Earth's shadow | | |
| 6:00:01 a.m. | 234° | 29° |
| 6:01:33 | 154 | 70 |
| 6:05:37 | 68 | 10 |

Key: Position is measured in degrees clockwise from north. That is, 0° is due north, 90° is due east, 180° is due south, and 270° is due west. Your fist held at arm's length is about ten degrees wide. "Elevation" is elevation above the horizon in degrees. So, to view the Tiangong Space Station at 9:01 p.m. on March 19, measure about three fist-widths west of due south then seven fist-widths above the horizon.

Programming Notice: NASA TV on the Web

Watch NASA TV (Public, Media and Education Channels) on your computer using Flash, Windows or QuickTime at <http://www.nasa.gov/multimedia/nasatv/index.html>.

NASA TV Schedules are available at <http://www.nasa.gov/multimedia/nasatv/schedule.html>.

The Expedition 68 Crew to the ISS will be returning sometime in March but the date isn't set yet. It's possible they may show SpaceX's orbital test flight of Starship in April since it's so relevant to the return to the Moon, but the date isn't set yet.

Calendar of Events

Sometime in 2023: [Postponed from 2022.] Launch of SLIM, the Smart Lander for Investigating Moon, a Japanese lunar lander. Another JAXA spacecraft, *XRISM*, the X-Ray Imaging Spectroscopy Mission (pronounced "krism") launches on the same flight. For more information, see https://en.wikipedia.org/wiki/Smart_Lander_for_Investigating_Moon and https://en.wikipedia.org/wiki/X-Ray_Imaging_and_Spectroscopy_Mission.

Sometime in 2023: launch of *#dearMoon*, which will carry Japanese billionaire, Yusaku Maezawa, two crew members, and eight artists on a lunar free-return mission. For more information, visit https://en.wikipedia.org/wiki/DearMoon_project

Sometime in 2023 [postponed from 2022]: Launch of *Eris*, the first Australian rocket to launch an Australian payload. *Eris* is the launch vehicle for Gilmour Space. For more information, visit en.wikipedia.org/wiki/Gilmour_Space_Technologies#Eris.

Sometime in 2023: First flight of Blue Origin's *New Glenn* orbital rocket. For more information, see https://en.wikipedia.org/wiki/New_Glenn.

Sometime in 2023: *Axiom 3* and *Axiom 4* space tourist missions to the ISS. Presumably these will launch after *Axiom 2* in May.

Sometime in 2023: Launch of ADRAS-J, a space debris removal demonstration.

March: UK Pathfinder Launch, from SaxaVord Spaceport on Unst in the Shetland Islands to low Earth orbit. This, amazingly, will be the first orbital launch from the ground in the history of the United Kingdom.

March [moved from January]: First orbital velocity test flight of SpaceX's *Starship*. It will travel three quarters of an orbit, landing northwest of Kauai in Hawaii.

March 15: Neptune is in conjunction with the Sun.

March 17: Mercury is in superior conjunction with the Sun.

April [Moved from December 2022]: First crewed launch of *Boeing Starliner-1* to the ISS.

April 11: Jupiter is in conjunction with the Sun/

April 11: Mercury is at greatest eastern elongation, 19.5° from the Sun (so can be seen after sunset).

April 13: Launch of *JUICE*, the Jupiter Icy Moons Explorer, by the European Space Agency. The *JUICE* web site is sci.esa.int/web/juice. This will also mark the final launch of *Ariane 5*.

April 20: Hybrid solar eclipse. This goes from the south-central Indian Ocean north of Antarctica, touches northwestern Australia, crosses central Indonesia, and western New Guinea before crossing the territory of small island nations in the western Pacific Ocean. This is total in the parts of Australia and Indonesia that it crosses, and annular along the rest of its path.

April 22: Peak of Lyrid meteor shower.

May: Launch of *Axiom-2* mission to the ISS, via Falcon 9. This carries one professional astronaut and three private astronauts. [Axioms 3 and 4 should also launch this year.]

May: Launch of Venus Life Finder atmospheric probe as well as the *Photon* relay satellite by RocketLab.

May: Fifth crewed flight to the *Tiangong* space station.

May 4: Launch of the *Peregrine* lunar lander by ULA's Vulcan Centaur for Astrobotic Technology. This is the maiden flight for Vulcan Centaur.

May 5: Peak of Eta Aquarid meteor shower.

May 9: Uranus is in conjunction with the Sun.

May 28: Mercury is at greatest western elongation, 24.9° from the Sun (so can be seen before sunrise).

June: India launches Chandrayaan-3, which will include a lander and a long-lived rover which will explore craters around the Moon's South Pole in search of ice. See <https://en.wikipedia.org/wiki/Chandrayaan-3>.

June [Moved from March]: Launch via Falcon 9 of the *Nova-C* lander and other cargos to the Lunar South Pole.

June 4: Venus is at greatest elongation, 45.4 degrees east of the Sun (so can be seen after sunset).

July: Launch of the European Space Agency's *Euclid* space telescope. This will map the distribution of dark matter and search for evidence of dark energy. The Euclid website is <https://sci.esa.int/web/euclid>. This is one of the missions that had to find a new ride after the Russian invasion of Ukraine.

July: Launch of *Luna 25*, the first mission of Russia's Luna-Glob program, landing near Bogul'skyy crater. For more information, see https://en.wikipedia.org/wiki/Luna_25.

July [Moved from March]: Launch of *Polaris Dawn* flight carrying Jared Isaacman and four other civilians into space.

July 30-31: Peak of Southern Delta Aquariid meteor shower. Moon, alas, will be almost full.

August: First ISS Cargo Resupply mission for Dream Chaser.

August: Seventh operational Crew Dragon flight to the ISS.

August 12 – 13: Peak of Perseid meteor shower. This may be good since the Moon is a thin crescent.

August 13: Venus is in inferior conjunction with the Sun.

September 24: *OSIRIS-REx* returns samples from Asteroid Bennu.

Fourth quarter of 2023: Second Nova C mission carrying the *Trailblazer* lunar orbiter, the Micro-Nova lunar hopper, and two lunar rovers for various companies. In addition, PRIME-1, the Polar Resources Ice Mining Experiment 1, flied on this flight.

Fourth quarter of 2023 [moved from June]: India launches Chandrayaan-3, which will include a lander and a long-lived rover which will explore craters around the Moon's South Pole in search of ice. See <https://en.wikipedia.org/wiki/Chandrayaan-3>.

Fourth quarter of 2023 [Moved from April]: April Maiden flight of Ariane 6.

Fourth quarter of 2023: First (uncrewed) *Gaganyaan* flight test.

Fourth quarter of 2023: China launches its *Xuntian* space telescope, which will orbit close to orbit close to *Tiangong* for easy servicing.

October: Launch of the IM-2 South Pole Mission, including the Polar Resources Ice Mining Experiment 1 (PRIME-1), the IM-2 Lunar Lander, the Lunar Trailblazer orbiter, the Micronova Lunar Hopper, and the M1-MAPP demo lunar rover. The last is a joint US/Finnish mission. Also on this flight is Tanker-002, an in-space refueling satellite from Orbit Fab. This is the second NOVA-C mission.

October 10]: Launch of *Psyche*, which will orbit a large metallic asteroid also named Psyche. See [en.wikipedia.org/wiki/Psyche_\(spacecraft\)](https://en.wikipedia.org/wiki/Psyche_(spacecraft)). The *Janus* mission, which will send twin probes *Serenity* and *Mayhem* to separate asteroids (yet to be determined), will launch on the same flight. For more information, see [en.wikipedia.org/wiki/Janus_\(spacecraft\)](https://en.wikipedia.org/wiki/Janus_(spacecraft)).

October 14: Annular eclipse of the Sun. The path where it is annular extends from the coast of Oregon, northern Nevada, Utah, central New Mexico, and southwestern Texas (including Austin and San Antonio), thence lengthwise through Yucatan and Central America, then Colombia and northern Brazil. This will be partial from Oklahoma with 80% of the Sun covered. This makes a good prelude to the total eclipse the following April.

October 20: Peak of Orionid meteor shower.

November 2023: Launch of Masten Mission One lander and Moon Ranger rover on the Moon via Falcon 9. They will land at Haworth Crater near the South Pole of the Moon. For more information, see https://en.wikipedia.org/wiki/Masten_Space_Systems#Masten_Mission_One. Note: Masten recently went bankrupt and was acquired by Astrobotic (see osa.nss.org/Update2208.pdf). The mission is still on, but the launch date is less certain.

November 11 – 12: Peak of Northern Taurid meteor shower.

November 17 – 18: Peak of Leonid meteor shower.

December 13 – 14: Peak of the Geminid meteor shower. Often the best shower, the Geminids will be even better since the Moon is practically New.

December 21 – 22: Peak of the Ursid meteor shower.

Sometime in 2024: Launch of *Hakuto-R* mission 2, Japan's lunar lander and rover. For more information, see <https://en.wikipedia.org/wiki/Hakuto>. Sometime in 2024: First launch of Firefly's *Blue Ghost* lunar lander. For more information, see https://en.wikipedia.org/wiki/Firefly_Aero-space#Blue_Ghost_lunar_lander.

Sometime in 2024: JAXA launches *DESTINY+*, an asteroid flyby mission to Phaethon, the parent of the Geminid meteor shower. It will arrive there in 2028. For more information, see en.wikipedia.org/wiki/DESTINY%2B.

Sometime in 2024: India launches Mars Orbiter Mission 2.

Second quarter of 2024: A SpaceX Nova-C mission to the moon takes Intuitive Machines' IM-3 lander, NASA's Lunar Vertex rover, Lunar Outpost's M2 MAPP rover, and several NASA Cadre rovers.

Second quarter of 2024: Launch of the Mission Robotic Vehicle (MRV) which carries the RSGS (Robotic Servicing of Geosynchronous Satellites) to attach jet packs to remove dying satellites from orbit.

April 8, 2024: Next total eclipse of the Sun visible in the United States. This one will be visible on a path through northern Mexico (making landfall opposite the tip of Baja California), passes through Texas (including Dallas, Arlington, and Waco), touches the southeastern corner of Oklahoma, then crosses Arkansas, eastern Missouri, Illinois, western Kentucky, Indiana, Ohio (including Cleveland), Erie in Pennsylvania, upper New York (including Buffalo and Niagara Falls), Burlington in Vermont, New Hampshire, and Maine, then into Canada.

May 2024: *Artemis 2*, the first crewed test flight of SLS and Orion. This will be a free-return mission: that is, it will loop around the Moon without landing.

September 2024: Launch of Japan's *Martian Moons Exploration* (MMX) which includes a Phobos lander and sample return. For more information, see [https://en.wikipedia.org/wiki/Martian_Moons_exploration_\(MMX\)](https://en.wikipedia.org/wiki/Martian_Moons_exploration_(MMX)).

Fourth quarter of 2024: India launches its first crewed orbital flight *Gaganyaan-3*

Fourth quarter of 2024: Impulse Space sends the Terran R lander to Mars. For more information, see https://en.wikipedia.org/wiki/Terran_R.

Fourth quarter of 2024: *ESCAPADE Blue* and *Gold* Mars Orbiters launches.

October 2024: Launch of the *Hera* asteroid orbiter by the ESA, which contains the *Juventas* and *Milani* asteroid probes. Destination is the binary asteroid Didymos/Dimorphos to evaluate the results of the DART asteroid impact mission.

October 2024: Launch of *Europa Clipper* orbiter. For more information, https://en.wikipedia.org/wiki/Europa_Clipper,

November 2024: Launch of the first two modules of the Lunar Orbiter Platform- Gateway. These were originally going to be launched on separate spacecraft but are now bunked together.

November 2024: Launch of NASA's *VIPER* lunar rover, which will hunt for ice near the at Nobile Crater at Moon's South Pole. VIPER is landing aboard Astrobotic's *Griffin* lunar lander. They leave Earth aboard a Falcon 9.

December 2024: Launch of India's *Shukrayaan-1* Venus orbiter. For more information, see <https://en.wikipedia.org/wiki/Shukrayaan-1>.

December 2024: Launch of the Space Entertainment Enterprise's SEE-1 inflatable space habitat docked to the Axiom segment of the ISS.

December 24, 2024: Parker Solar Probe (formerly Solar Probe Plus) makes its first pass through the outer corona of the Sun. For more information, see <http://parkersolarprobe.jhuapl.edu>.

Sometime in 2025: first uncrewed test launch of *Orel*, Russia's new crewed spacecraft, with first crewed launch later in the year. For information, [https://en.wikipedia.org/wiki/Orel_\(spacecraft\)](https://en.wikipedia.org/wiki/Orel_(spacecraft)). This is the first flight for Russia's Angara A5P spacecraft.

Sometime in 2025: Launch of *Artemis 3*, which will be the first crewed lunar landing since 1972.

Sometime in 2025: China launches the *Chang'e 6* lunar sample return mission.

Sometime in 2025 (most likely September): End of *JUNO* mission to Jupiter.

Sometime in 2025 [moved from 2024]: Israel launches its *Beresheet 2* lander and orbiter on the Moon. For more information, see en.wikipedia.org/wiki/Beresheet_2.

Sometime in 2025: Launch of NEM-1, the core module of the Russian Orbital Service Station. For more information, see https://en.wikipedia.org/wiki/Russian_Orbital_Service_Station.

September 2025: First crewed flight of Russia's Orel (formerly called Federatsiya), destined for the ISS.

December 2025: *BepiColombo* arrives at Mercury orbit.

Sometime in 2026: Launch test of China's Long March 5DY, which will eventually carry Chinese astronauts to the Moon.

Sometime in 2026: China launches the lunar mission *Chang'e 7*, which include an orbiter, a rover and a hopping probe.

First half of 2026: Launch of the *NEO Surveyor* which will be able to detect more than 90% of near-earth objects greater than 460 feet in diameter. For more information, see https://en.wikipedia.org/wiki/NEO_Surveyor.

July 2026: *Hayabusa 2* flies by asteroid 2001 CC₂₁.

October 2026 [Maybe]: Launch of the *Nancy Grace Roman Space Telescope* [formerly known as WFIRST]. For more information, see https://en.wikipedia.org/wiki/Nancy_Grace_Roman_Space_Telescope.

Sometime in 2027 [moved from 2026]: Launch of *Artemis 4*, a Lunar Gateway expedition.

Sometime in 2027: Launch of the ESA's *Earth Return Orbiter* to Mars. This is the vehicle that will bring the *Perseverance* Mars samples to Earth.

Sometime in 2027: First flight of the ESA's HERACLES lunar Transport System. This is uncrewed and will carry cargo both to and from the Moon (including sample returns and lunar landers). For more information, see [https://en.wikipedia.org/wiki/HERACLES_\(spacecraft\)](https://en.wikipedia.org/wiki/HERACLES_(spacecraft)).

June 2027: Launch of *Dragonfly*, the Titan helicopter mission.

August 12; 2027: *Lucy* flies by asteroid 3548 Eurybates in its first encounter with a Trojan asteroid. It will fly by at least 3 more Trojans in 2027 and 2028.

Sometime in 2028: [tentative, postponed from 2022]: ESA launches the *ExoMars Mars Rover*, which has been christened *Rosalind Franklin*. For more information, visit <https://en.wikipedia.org/wiki/ExoMars>. Note: this is the mission most affected by Russia's invasion of Ukraine, since they were supposed to supply the landing platform.

Sometime in 2028: Launch of *VERITAS* orbiter to Venus.

Sometime in 2028: First flight of the Long March 9 super-heavy launch vehicle. This looks like it will be able to carry 53,000 kg to the Moon and 44,000 kg to Mars and will probably carry Chinese astronauts to the Moon.

Sometime in 2028: Launch of the *Sample Retrieval Lander* to.

First quarter of 2028: Launch of the *Emirates Asteroid Mission*.

November 2028: Launch of China's *Tianwen-3* Mars sample return mission.

Sometime in 2029: Launch of the *ARIEL Space Telescope* and the *ESA/JAXA Comet Interceptor* mission via Ariane 62.

Sometime in 2029: The *Psyche* asteroid probe arrives at the asteroid 16 Psyche. [This is assuming a 2023 launch.] For more information, visit [https://en.wikipedia.org/wiki/Psyche_\(spacecraft\)](https://en.wikipedia.org/wiki/Psyche_(spacecraft)).

Sometime in 2029 [tentative]: Launch of the *Yenisei* lunar flyby mission. This will be the first Russian manned mission to the Moon (though it's not a landing).

April 21, 2029: *OSIRIS-APEX* rendezvous with the asteroid Apophis. Note: *OSIRIS-APEX* is the same spacecraft as *OSIRIS-REx*; it gets renamed "Apophis Explorer" for this part of its mission.

June 2029: Launch of *DAVINCI+* to Venus.

October 2029: *JUICE* achieves Jupiter orbit. [See 2023.]

Sometime in 2033: *JUICE* achieves Ganymede orbit. [See 2023.]

December 2034: *Dragonfly* arrives at Titan.

August 12, 2045: The next total solar eclipse visible in Oklahoma City. This one is also visible in Salt Lake City, Denver, Little Rock (again), Tampa Bay and New Orleans.

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Other Information

Oklahoma Space Industrial Development Authority (OSIDA), 401 Sooner Drive/PO Box 689, Burns Flat, OK 73624, 580-562-3500. Website is <http://airspaceportok.com/#home>,

Science Museum Oklahoma (former Omniplex) website is www.sciencemuseumok.org. Main number is 602-6664.

Tulsa Air and Space Museum, 7130 E. Apache, Tulsa, OK 74115.
Web Site is www.tulsaairandspacemuseum.com. Phone (918) 834-9900.

The Mars Society address is The Mars Society, 11111 West 8th Avenue, Unit A, Lakewood, CO 80215. Phone: (303) 980-0890 Their web address is www.marsociety.org.

The National Space Society's Headquarters Executive Director e-mail nsshq@nss.org. The Chapters Coordinator is Bennett Rutledge 720-641-7987, rutledges@chapters.nss.org. The address is: National Space Society, 1300 I Street NW, Suite 400E, Washington, DC 20005. Phone (321)452-2448. Web page is space.nss.org.

The Planetary Society phone 626-793-5100. The address is 60 South Los Robles Avenue, Pasadena, California, 91101, and the website is www.planetary.org. E-mail is tps@planetary.org.

NASA Spacelink BBS 205-895-0028. Or try www.nasa.gov .

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