ICE & STONE 2020

WEEK 15: APRIL 5-11, 2020

Presented by The Earthrise Institute

#15

Authored by Alan Hale

THIS WEEK IN HISTORY

APRIL 5 | 6 | 7 | 8 | 9 | 10 | 11

APRIL 5, 1861: An amateur astronomer in New York, A.E. Thatcher, discovers a 9th-magnitude comet. Comet Thatcher was found to have an approximate orbital period of 415 years and is the parent comet of the Lyrid meteor shower, which peaks around April 22 each year. The Lyrids usually put on a modest display of less than 20 meteors per hour, but on occasion have produced much stronger displays, most recently in 1982.

5 | 6 | 7 | APRIL 8 | 9 | 10 | 11

APRIL 8, 1957: Comet Arend-Roland 1956h passes through perihelion at a heliocentric distance of 0.316 AU. This was one of the brighter comets of the mid-20th Century and is a future "Comet of the Week."

APRIL 8, 2024: The path of a total solar eclipse will cross north-central Mexico and the south-central and northeastern U.S. This may be my last, best chance to see an eclipse comet; I discuss these in a future "Special Topics" presentation.

5 | 6 | 7 | 8 | APRIL 9 | 10 | 11

APRIL 9, 1994: Radar bounce experiments conducted by the joint NASA/U.S. Defense Department Clementine spacecraft suggest the presence of water ice in permanently shadowed craters near the moon's South Pole. This would be confirmed by NASA's Lunar Prospector mission in 1998. These experiments are discussed as part of a future "Special Topics" presentation.

***THERE ARE NO CALENDAR ENTRIES FOR APRIL 6 AND 7.**

COVER IMAGES CREDITS:

Front cover: This artist's concept shows the Wide-field Infrared Survey Explorer, or WISE spacecraft, in its orbit around Earth. From 2010 to 2011, the WISE mission scanned the sky twice in infrared light not just for asteroids and comets but also stars, galaxies and other objects. In 2013, engineers brought the spacecraft out of hibernation to hunt for more asteroids and comets in a project called NEOWISE. Courtesy NASA/JPL-Caltech.

Back cover: This graphic shows the orbits of all the known Potentially Hazardous Asteroids (PHAs), numbering over 1,400 as of early 2013. These are the asteroids considered hazardous because they are fairly large (at least 460 feet or 140 meters in size), and because they follow orbits that pass close to the Earth's orbit (within 4.7 million miles or 7.5 million kilometers). But being classified as a PHA does not mean that an asteroid will impact the Earth: None of these PHAs is a worrisome threat over the next hundred years. By continuing to observe and track these asteroids, their orbits can be refined and more precise predictions made of their future close approaches and impact probabilities. Courtesy NASA/JPL-Caltech.

5	6	7	8	9	APRIL 10	11

APRIL 10, 837: Comet 1P/Halley makes the closest approach it has made to Earth in recorded history, 0.033 AU. The history of Comet Halley is covered in a previous "Special Topics" presentation.

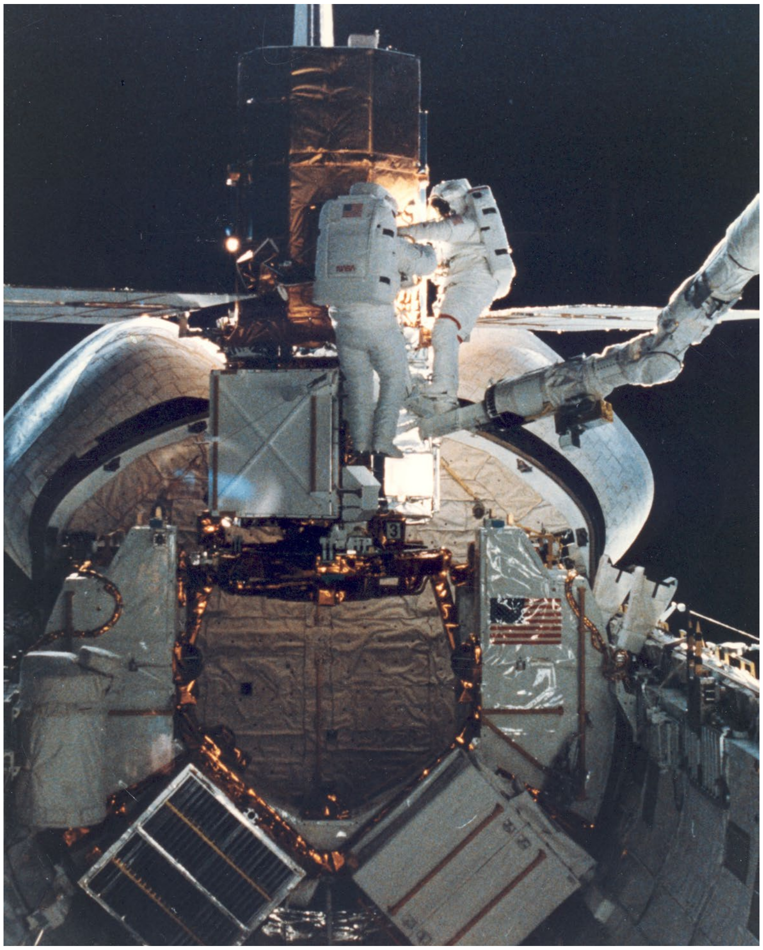
APRIL 10, 1986: Comet 1P/Halley makes its closest approach to Earth of its 1986 return, 0.417 AU. The 1986 return of Halley is a previous "Comet of the Week."

APRIL 10, 1989: Karen Meech and Michael Belton make the first reported detection of a coma around the centaur (2060) Chiron. This detection allowed Chiron to be dual-designated as Comet 95P/Chiron, and it and other centaurs are discussed in a previous "Special Topics" presentation.

5	6	7	8	9	10	APRIL 11

APRIL 11, 1984: The Solar Maximum Mission (SMM) spacecraft is redeployed from the Space Shuttle Challenger following its repair by onboard astronauts. SMM would go on to discover several Kreutz sungrazing comets before entering the Earth's atmosphere in late 1989. Kreutz sungrazers are the subject of a future "Special Topics" presentation.

APRIL 11, 1996: The Spacewatch program in Arizona discovers the near-Earth asteroid now known as (68503) Didymos. A small moon – informally nicknamed "Didymoon" – accompanying Didymos was discovered in 2003, and this asteroid pair is the planned destination of NASA's Double Asteroid Redirection Test (DART) mission, currently scheduled for launch in July 2021. DART and other future "small bodies" missions are covered in this week's "Special Topics" presentation.



STS-41C astronauts George Nelson, right, and James van Hoften repair the Solar Maximum Mission (SMM) satellite captured in Challenger's cargo bay. The two mission specialists use the mobile foot restraint and the remote manipulator system (RMS) as a "cherry picker" device for moving about. Later, the RMS lifted the SMM into space once more. Courtesy of NASA.

COMET OF THE WEEK: 12P/PONS-BROOKS

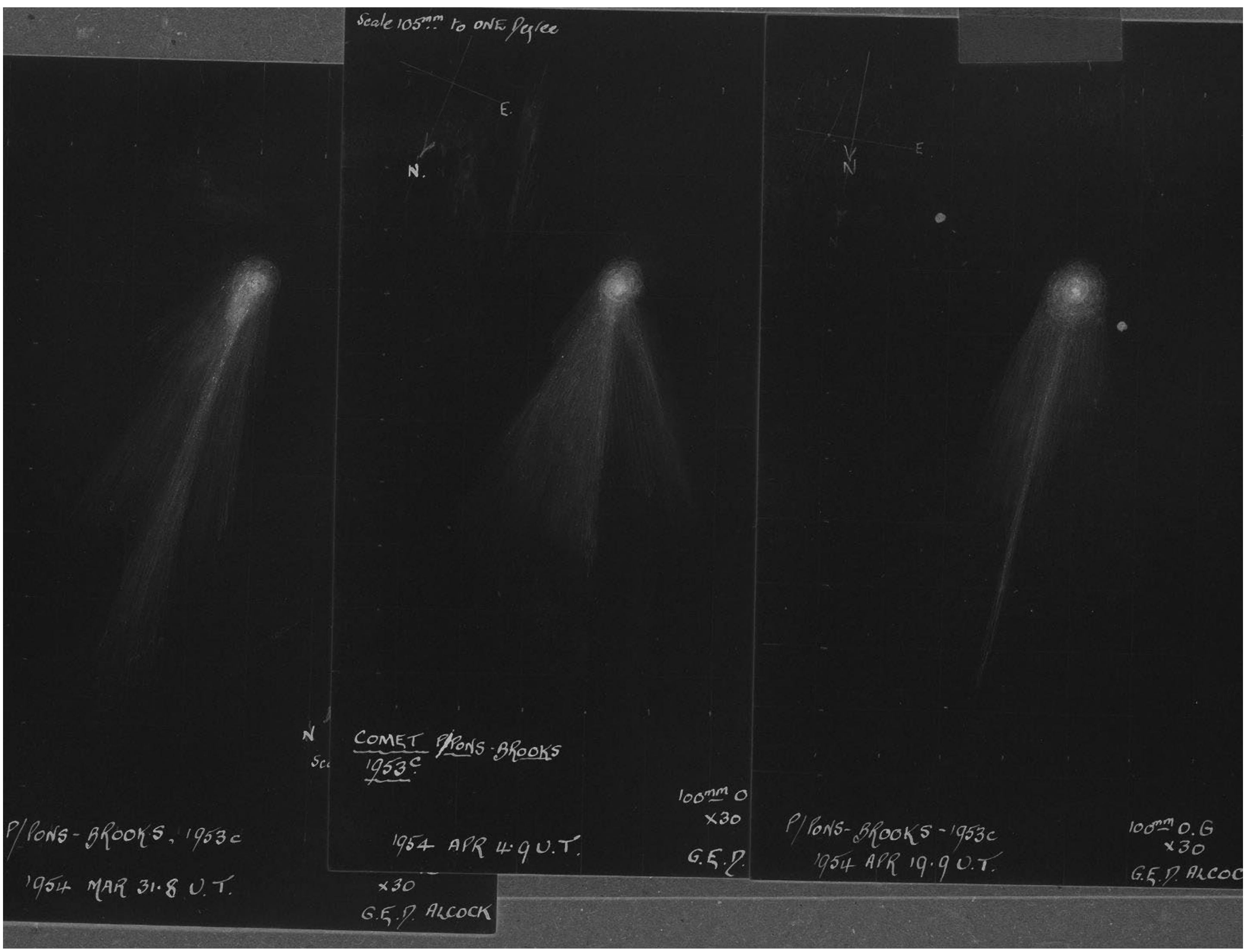
Perihelion: 2024 April 21.00, q = 0.781 AU

For this week's "Comet of the Week" I am turning my eye towards the near-term future: a comet that I hope to see within the next few years.

While there perhaps is no exact formal definition of the term, the phrase "Halley-type comet" is generally used for those comets with orbital periods between 20 and 200 years. ("Centaur" comets like 95P/Chiron and 174P/Echeclus are generally excluded from this; these objects, along with other centaurs, are discussed in a previous "Special Topics" discussion.) Unlike the shorter-period Jupiter-family comets, which tend to have small orbital inclinations, Halley-type comets have inclinations that range all over, and a significant fraction of them are in retrograde orbits. The prototype, certainly, is none other than Comet 1P/Halley itself, with an orbital period of 76 years and which travels in a retrograde orbit with an inclination of 162 degrees.

With the advent of the comprehensive survey programs two decades ago numerous Halley-type comets are being discovered quite frequently nowadays. Prior to that, only a relatively small number of them were known, and there are only a handful of what can be called "classical" Halley-type comets, which perhaps can be loosely defined as those that were known before the beginning of the 20th Century. Some of these comets, like Halley, are moderately bright.

One of these "classical" Halley-type comets was discovered in July 1812 by the champion French



Sketches of Comet 12P/Pons-Brooks during its 1954 return made by British amateur astronomer George Alcock.

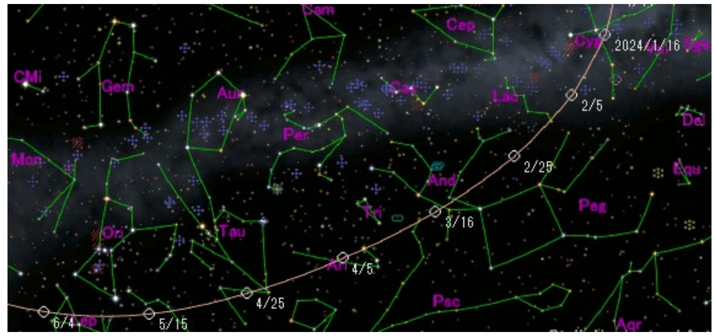
comet hunter Jean Louis Pons. The comet reached a peak brightness of approximately 4th magnitude and was followed for two months, which was long enough for the astronomers of that era to determine that it had an orbital period in the vicinity of 70 years. It was expected to return in the early 1880s but was not found despite several searches, but then in September 1883 the champion American comet hunter William R. Brooks discovered a comet which soon proved to be the long-awaited comet discovered by Pons. The viewing geometry was rather favorable during that return, with perihelion occurring in late January 1884; the comet passed 0.64 AU from Earth earlier that month and reached a peak brightness of 3rd magnitude. According to the astronomers of that time, the comet underwent a series of short-lived brightness flares as it approached perihelion, and spectroscopic studies indicated that these were apparently due to ejections of large dust clouds from the nucleus.

German amateur astronomer Maik Meyer has recently completed an examination of historical records in an effort to identify potential earlier returns of Comet Pons-Brooks. A comet observed in January 1457 by Paolo Toscanelli in Florence, Italy, and also by observers in China and Japan, appears to be such a return, as does a comet also observed from China and Japan in October and November 1385. Calculations suggest the viewing geometry would have been relatively favorable during both of these returns, and the available data (such as it is) suggests that the comet was as bright as 2nd or 3rd magnitude both times.

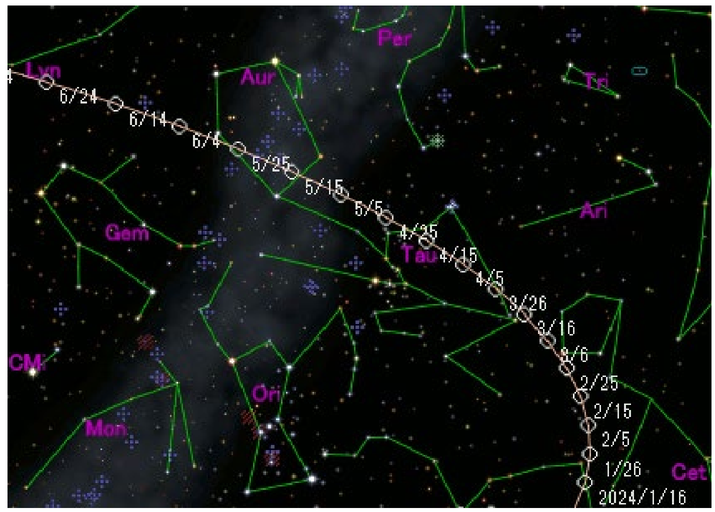
Meanwhile, Comet Pons-Brooks most recently passed through perihelion in May 1954 – four years before I was born, incidentally. The viewing geometry was not too favorable that time and the comet was never brighter than 6th magnitude, although as was the case in 1883-84 it exhibited several short-lived brightness flares while en route to perihelion.

We are now just four years away from Pons-Brooks' next perihelion passage. As of this writing it has not been recovered yet, although conceivably that could happen within the not-too-distant future. It is currently located in southeastern Hercules at a heliocentric distance of 12.3 AU, and for the next few years it passes through opposition right around the time of the June solstice.

As was the case in 1954, the viewing geometry in 2024 is relatively unfavorable. During the run up to perihelion the comet remains on the far side of the sun from Earth, although it will be located well to the north of the sun and thus observable from the northern hemisphere in the evening sky. On the final approach to perihelion the elongation remains rather small, being around 37 degrees in mid-March and shrinking to 29 degrees by the beginning of April and to 21 degrees by the time of perihelion passage. Since the comet is, intrinsically, rather bright, it may reach



Predicted paths of Comets 12P/Pons-Brooks (above) and 13P/Olbers (below) through the constellations during January through June 2024. Courtesy Seiichi Yoshida.



a peak brightness of around 5th magnitude. After perihelion it travels southward and will be visible from the southern hemisphere – albeit still at a relatively small elongation for a while – as it recedes and fades.

Comet Pons-Brooks will bring a special treat along with it when it returns. One of the other "classical" Halley-type comets is 13P/Olbers, which was discovered by the German astronomer Heinrich Olbers in March 1815 and which returned in 1887 when it was first picked up by none other than William R. Brooks. It most recently returned in 1956 – just two years before I was born – and reached a peak brightness between 6th and 7th magnitude.

Comet Olbers is next expected to pass through perihelion on June 30, 2024, just a little over two months after Pons-Brooks. As with the other comet, the viewing geometry for Comet Olbers is not especially unfavorable as it stays on the far side of the sun from Earth, with the elongation remaining between 25 and 30 degrees during the final approach to perihelion, but it will remain accessible from the northern hemisphere during this period and should reach a peak brightness between 6th and 7th magnitude. Both comets will be visible in the northern hemisphere's evening sky during the first few months of 2024, and in mid-April they will pass less than 17 degrees from each other, with Pons-Brooks being perhaps three magnitudes brighter than Olbers but lower in the sky.

SPECIAL TOPIC: UPCOMING MISSIONS TO "SMALL BODIES"

A significant part of our knowledge about the "small bodies" of our solar system has come from the various spacecraft missions that have been to – or at least by – some of them. I'll be covering these missions as a whole in a future "Special Topics" presentation, and where appropriate I am including results from specific missions in the relevant "Special Topics" and/or "Comet of the Week" presentations.

Three of these missions can be considered as "ongoing" at this time. NASA's New Horizons mission, which passed by Pluto in 2015 and by the Kuiper Belt object (486958) Arrokoth at the beginning of last year, is currently traveling through the Kuiper Belt and searches are now commencing for another Kuiper Belt object for it to fly by sometime within the next several years. JAXA's Hayabusa2 mission spent the last few months of 2018 and most of 2019 at the near-Earth asteroid (162173) Ryugu and is now en route back to Earth with its collection of samples, and NASA's OSIRIS-REx mission is presently in orbit around the near-Earth asteroid (101955) Bennu which it will depart next year to return its collected samples back to Earth.

At this writing several additional missions to some of the "small bodies" in the solar system are in development and are planned for launch within the relatively near future. I will discuss these missions here, in chronological order of their planned launch date.

It should be kept in mind that planned launch dates can slip, and that missions can be modified and/or cancelled altogether, due to budgetary and/or political reasons, or to problems with one or more of the spacecraft systems or launch vehicles. Due to the laws of celestial mechanics, which dictate when certain "launch windows" might be available, slippage in launch dates can result in delays of one or more years, or – as in the case of ESA's Rosetta mission – the selection of a different destination object.

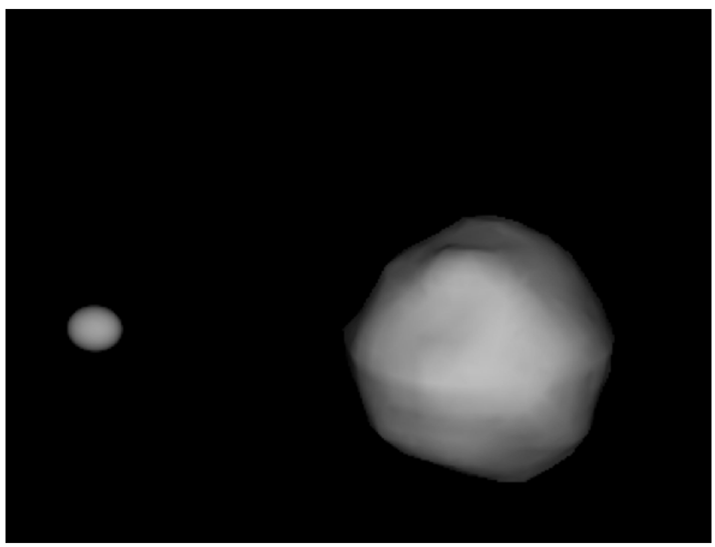
The nature of spaceflight being what it is, the possibility of a mission failure, either at launch or sometime afterwards, is always present. One dramatic example is NASA's COmet Nucleus TOUR (CONTOUR) mission that was launched in July 2002 with the ambitious goal of visiting two short-period comets with the possibility of either a third short-period comet or an at-that-time-undiscovered long-period comet. Although the launch was successful and CONTOUR was safely placed into its initial geocentric orbit, contact was lost and it broke into at least three pieces once it was injected into its first destination orbit, probably as a result of a failure of the solid-rocket booster that performed that injection.

With the above caveats in mind, the following missions are presently in development, with launch planned for the relatively near-term future:

ASTER

This space mission by the Brazilian Space Agency – which would be its first interplanetary probe – is presently scheduled for launch in February 2021. It will be utilizing solar electric propulsion for its travels, and in addition to scientific investigations one of its primary missions is to promote and enhance STEM education in Brazilian universities.

ASTER's planned destination is the near-Earth asteroid (153591) 2001 SN263, a carbonaceous asteroid accompanied by two smaller moons. With the currently planned launch date, arrival at (153591) would be in April 2022, with orbital insertion to follow.



Simulated image of (65803) Didymos and "Didymoon," based upon radar images and photometric data. Courtesy Shantanu Naidu et al./AIDA Workshop 2016.

DOUBLE ASTEROID REDIRECTION TEST (DART)

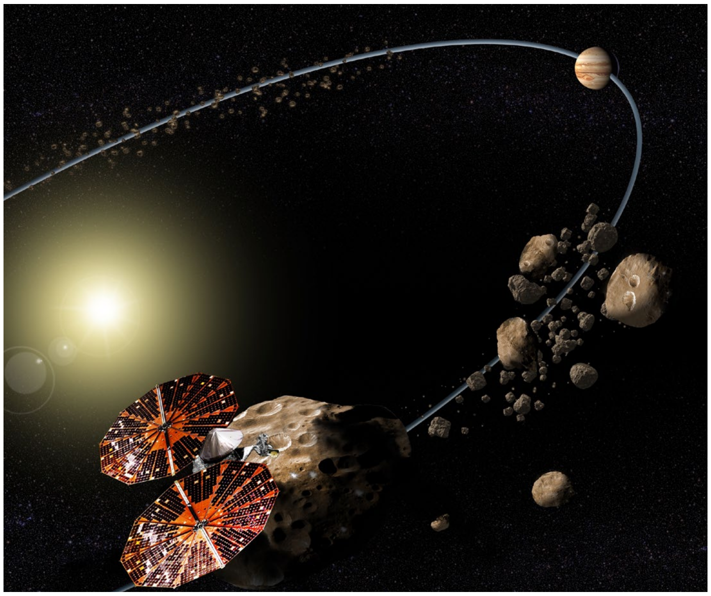
NASA's DART mission was originally part of a NASA-ESA collaboration under the name of AIDA (Asteroid

Impact and Deflection Assessment) with ESA supplying a component called Asteroid Impact Mission (AIM), however the development of AIM was cancelled in 2016. ESA is presently developing a smaller and scaled down mission called Hera, to be discussed below.

DART is currently scheduled for launch in July 2021. Utilizing a xenon ion thrust engine, DART is planned to make a flyby of the near-Earth asteroid (3361) Orpheus, with its ultimate destination being the near-Earth (Amor-type) asteroid (65803) Didymos with arrival scheduled in October 2022.

Didymos is approximately 750 meters in diameter, and is accompanied by a moon – nicknamed "Didymoon" – roughly 170 meters across. DART is essentially a projectile with the mission of impacting Didymoon, to determine how such an impact might affect its orbital motion. In keeping with its mission name, DART's ultimate objective is a test of a deflection technique that might be necessary if a future asteroid were to pose an impact threat. (Deflection techniques are discussed in a future "Special Topics" presentation.)

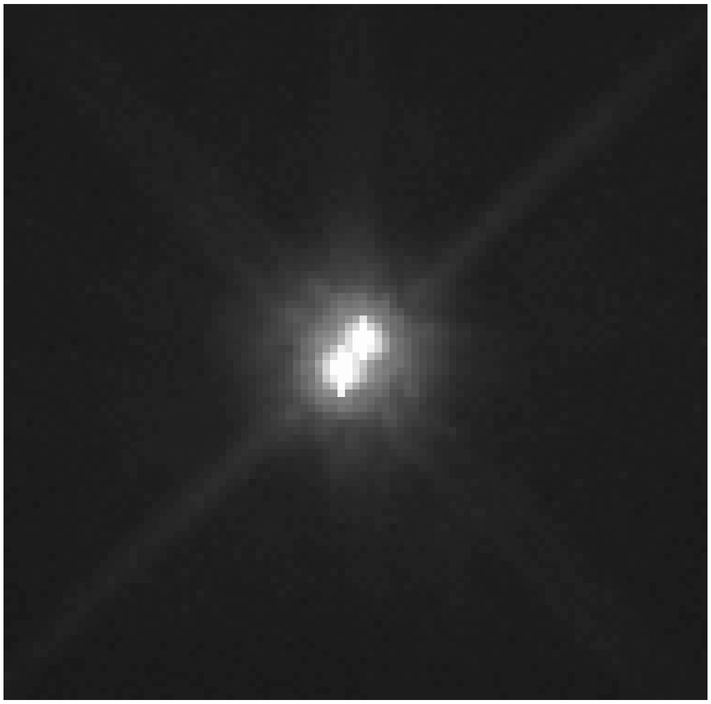
The Italian Space Agency is developing a small spacecraft, the Light Italian Cubesat Imaging of Asteroids (LICIA) that would be piggybacked aboard DART but would separate shortly before impact. LICIA would then be in a position to transmit images of the DART impact and its effects back to Earth.



In this artist's concept (not to scale), the Lucy spacecraft is flying by Eurybates, one of the six Trojans to be studied. Courtesy of Southwest Research Institute.

LUCY

This ambitious NASA mission, named after the "Lucy" hominid skeleton discovered in Ethiopia in 1974, is currently scheduled for launch in October



Hubble Space Telescope image of the Jupiter Trojan asteroid (617) Patroclus (lower left) and its moon Menoetius, taken February 13, 2018. Courtesy NASA.

2021. After a flyby of the main-belt asteroid (52246) Donaldjohanson – named in honor of one of the discoverers of the "Lucy" skeleton – Lucy will travel to the Jupiter-sun L4 Lagrangian point and visit several of the Trojan asteroids there: the current schedule of encounters include (3548) Eurybates in August 2027, (15094) Polymele in September 2027, (11351) Leucus in April 2028, and (21900) Orus in November 2028. (Trojan asteroids are the subject of a future "Special Topics" presentation.) Afterwards Lucy returns to Earth's vicinity for a gravity-assist, then journeys out to the Jupiter-sun L5 Lagrangian point for a rendezvous with the Trojan asteroid (617) Patroclus and its moon Menoetius in March 2033.

Like other asteroids, Jupiter Trojans are believed to be "leftovers" from the planetary formation process, and due to their larger distances from the sun they may be less processed due to solar heating than their siblings in the main asteroid belt. Thus, in keeping with its name, Lucy is an investigation into our solar system's origins. The asteroids that are on Lucy's itinerary are of various taxonomic classifications and thus should offer a fairly wide range of asteroidal phenomena to examine.

NEAR-EARTH ASTEROID SCOUT (NEA SCOUT)

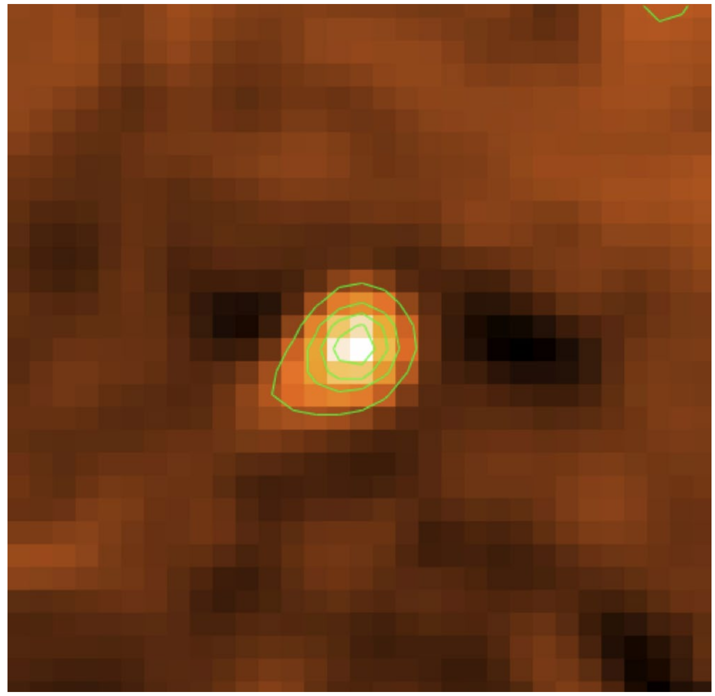
This is one of 13 small CubeSats planned as secondary payloads to be deployed during NASA's Artemis 1 mission that will be an unmanned spacecraft sent into lunar orbit and that will feature the maiden flight of the under-development Space Launch System. The launch date for Artemis 1 has been slipping, but at this writing is planned for sometime in late 2021. NEA Scout's destination has not been firmly determined at this time, but the most likely destination is the small near-Earth asteroid 1991 VG – subject, certainly, to the eventual launch date and available launch windows. 1991 VG is a very tiny asteroid no more than 10 to 12 meters in diameter, and travels in a near-circular, low-inclination orbit with a period of just barely over one year. It is one of the "easily retrievable objects" identified in 2013 as a site for potential future mining operations; these are discussed in the "Special Topics" presentation on "Resources in 'Small Bodies.'"

PSYCHE

The currently scheduled launch date for this NASA mission is July 2022. Its destination is the large main-belt asteroid (16) Psyche, which is primarily metallic in composition (over 90% iron and nickel, with various assorted other metals) and which may be the remnant metallic core of a former protoplanet. After a gravity-assist flyby of Mars in May 2023, the Psyche mission is scheduled for arrival at its destination asteroid in January 2026, after which it will go into orbit around it where it is expected to remain for at least the next 21 months.

Psyche's primary mission involves a detailed compositional and structural analysis of its namesake asteroid, including the strength and structure of any magnetic field. Ultimately, the Psyche mission could begin laying the foundation for future resource extraction activities on metallic asteroids like its namesake, a topic covered in the earlier "Special Topics" presentation on "Resources in 'Small Bodies.'"

Artist's conception of the Psyche mission approaching its namesake asteroid. Courtesy NASA.



Composite image of a coma and dust tail on (3200) Phaethon, obtained by the STEREO-A spacecraft on June 21, 2009. Courtesy NASA/Jing Li and David Jewitt (UCLA)

(16) Psyche, incidentally, will be at opposition this coming December, and should be an easily observable object near 9th magnitude around that time.

DESTINY+

JAXA's Demonstration and Experiment of Space Technology for INterplanetary voYage Phaethon fLyby dUSt science (DESTINY+) mission is primarily a technology test and demonstration mission, with a planned launch timeframe of 2022. After launch, the mission plan calls for it to spend approximately 1 ½ years in Earth orbit that is gradually rising via the usage of ion propulsion engines. Once the orbit is high enough it can then use a lunar gravity assist to send it elsewhere in the solar system.

DESTINY+'s primary destination is the enigmatic object (3200) Phaethon, a near-Earth "asteroid" that appears to be the parent object of the Geminid meteor shower and that has exhibited weak cometary activity (surface dust emissions due to intense solar heating) when near perihelion; it may well be an extinct cometary nucleus. DESTINY+ may go on to examine other objects afterwards.

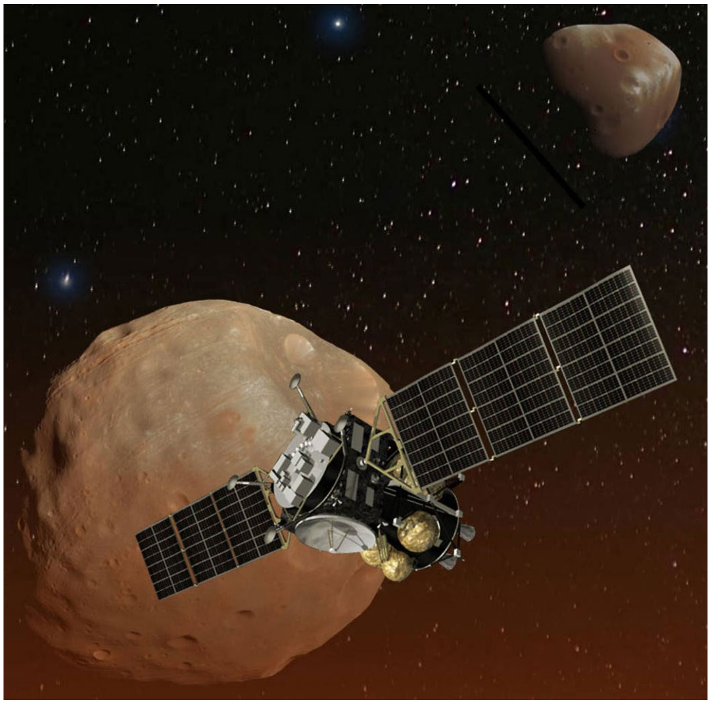
HERA

This is ESA's contribution to the joint NASA-ESA Asteroid Impact and Deflection Assessment (AIDA) mission, of which DART (see above) is the NASA contribution.

The ESA contribution was originally planned to be a large spacecraft called Asteroid Impact Mission (AIM) but funding issues have forced a delayed and scaled-down replacement. Hera, which was formally approved a few months ago, is planned for launch in 2024 with a subsequent plan of arriving at (65803) Didymos and going into orbit around it to study the effects of the earlier DART impact into "Didymoon."

MMX

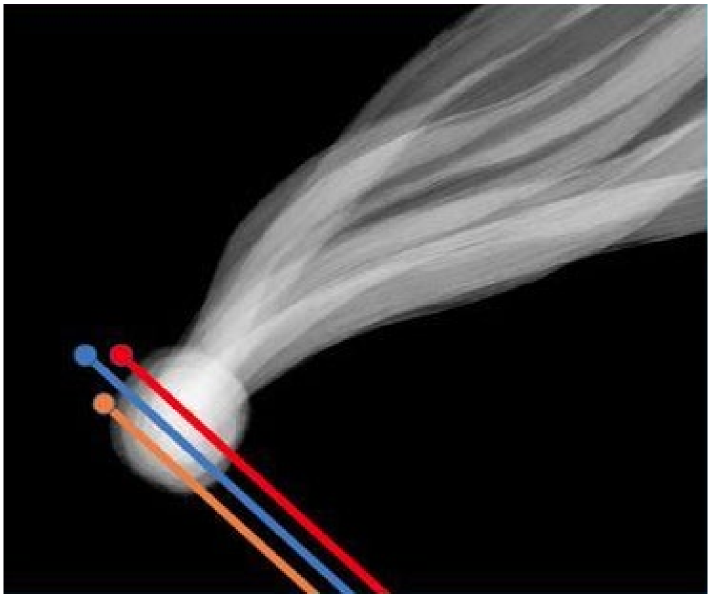
The Martian Moons eXploration (MMX) mission is under development by JAXA as a detailed examination of the Martian moons Phobos and Deimos. As currently planned MMX would be launched in September 2024, and after arrival at Mars the following year would touch down once or twice upon Phobos in order to collect up to 10 grams of surface materials. After leaving Phobos MMX would perform several flybys of Deimos before leaving Mars orbit in August 2028 for return to Earth, with the collected samples, in July 2029.



Artist's concept of Japan's Mars Moons eXploration (MMX) spacecraft, carrying a NASA instrument to study the Martian moons Phobos and Deimos. Courtesy of NASA.

COMET INTERCEPTOR

One important type of "small body" that has not yet been investigated by a spacecraft mission is a long-period comet. Since the existence of any particular such object is usually not known until, at most, a couple of years before its visit to the inner solar system, the preparation of any mission to such an object is problematical.



Current logo of ESA's Comet Interceptor mission, showing stylized representations of the three component spacecraft. Courtesy ESA.

ESA is getting around these difficulties with its planned Comet Interceptor mission, which was approved for development just a year ago. According to the mission plan, after launch – currently scheduled for 2028 – Comet Interceptor would be "parked" at the Earth-sun L2 Lagrangian point (1.5 million km directly anti-sunward of Earth) until a suitable long-period comet is discovered, at which time it would be placed on an intercept trajectory for a flyby encounter. (If after a certain period of time, about three years, a suitable long-period comet has not been discovered, Comet Interceptor would be sent towards an already-known short-period comet.)

In addition to the main spacecraft, Comet Interceptor would carry two smaller spacecraft that would be deployed separately to fly even closer to the comet's nucleus. These would, among other activities, collect samples of cometary material from the coma, and together with the main spacecraft help put together a 3-D picture of the comet's environment.

In addition to the above missions, which are being developed and flown by various governmental space agencies, some private entities are also in the process of developing space missions to the solar system's "small bodies." One of these is the MILO Institute, formed at the University of Arizona and which is building a coalition of University and business partners to build and fly a series of low-cost CubeSat space missions. The inaugural mission, dubbed NEOshare, is a proof-of-concept mission currently planned for launch in February 2023 which will place several CubeSats into heliocentric orbit where they can then be independently directed towards various near-Earth asteroids (to be determined at a later time).

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