14 AUGUST 2022

THE FINAL FRONTIER FLASH

Developments & Analysis of the Space Domain

ISR UNIVERSITY

SPACE FORCE ASSOCIATION

In This Issue

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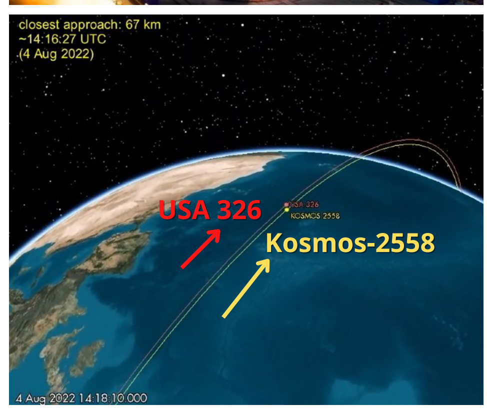
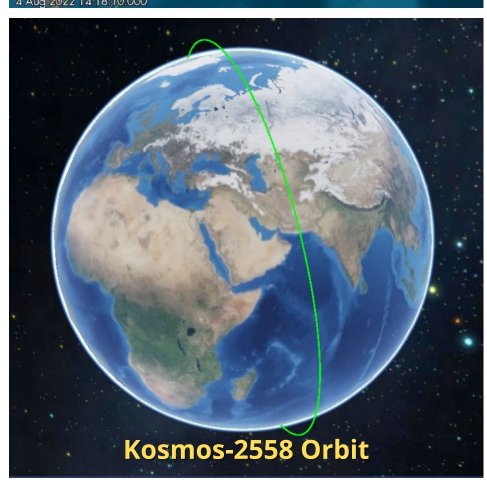
Catalog

Russia Launches Potential Inspector Satellite

1 Aug 2022: Russia launched a Soyuz-2.1v from the Plesetsk Cosmodrome with a Kosmos-2558 satellite deployed into a Sun-Synchronous Orbit (SSO). Kosmos-2558 is operated by the Russian Defense Ministry, with no stated mission. While no details about this payload are known, there is a suspicion that this payload might have been launched to match the trajectory and flight path of an American satellite, USA-326. See Kosmos-2558 fly-by USA 326 model and telescope view.

- There is speculation Kosmos-2558 will serve as an 'inspector' satellite to covertly spy on nearby spacecraft.
- USA-326 was launched by a SpaceX Falcon 9 in Feb 2022 into a 512 km altitude, 97.4° inclination orbit. It is speculated to be an experimental optical reconnaissance satellite. A new object was tracked just a week ago from the USA 326 spy satellite. It was designated object 53315 and cataloged in a 348 x 388 km orbit.
- According to Dr. Marco Langbroek, an expert in satellite tracking, the orbit difference between USA-326 and the possible Russian inspector was only 0.14 degrees in orbital inclination, 65 km in apogee, 53 km in perigee, 0.20 revolutions per day in mean motion and 0.04 degree in the Right Ascension of the Ascending Node, RAAN.
- On 4 Aug Kosmos-2558 came ~67kms from USA 326. Most of the distance was in altitude (~64 km of the ~67 km).
- The encounter took place near 42.3 N, 25.9 W, over the mid-Atlantic, with Kosmos 2558 at ~453 km altitude and USA 326 at ~518 km altitude, on a southbound trajectory.
- Loaded with an engine that allows for maneuvering its orbit, the Russian spy satellite will probably get into position to watch other satellites and then move as needed.
- This is not the first time a Russian satellite has approached a US satellite in LEO. During the Summer 2021, Kosmos-2542 maneuvered to re-synchronize its orbit with the USA-245 military satellite. The maneuvers resulted in multiple close encounters between the Russian and US spacecraft. On 2 Aug, Kosmos-2542 passed as close as 34 km from USA-245, and on 13 Aug, it was within 53 km from its purported target.

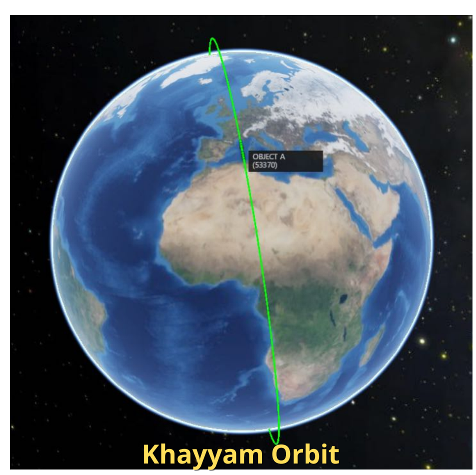




While this may sound like a provocative action, there is nothing illegal about it. In fact, as the Secure World Foundation's Brian Weeden points out, as long as Kosmos 2558 does not directly interfere with NROL-87, such an action does not violate any international laws or norms. The launch serves as a reminder that just as nations use space to spy on one another on Earth, they also use Earth to spy on space activities. And increasingly, we're seeing space-to-space observational activities.

Russia Launches Iranian Imagery Satellite

8 Aug 2022: Russia launched a Soyuz 2.1b/Fregat-M rocket from the Baikonur Cosmodrome carrying the Khayyam satellite for Iran and 16 CubeSats for various institutions and universities. The launch was originally scheduled for as early as the summer of 2021 but was delayed multiple times. Launch Video.

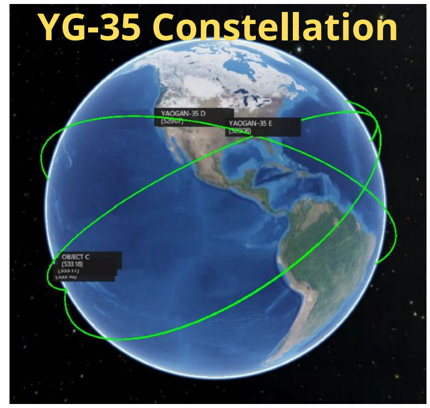


- The satellite, named "Khayyam" after a 12th-century Persian mathematician, is potentially based on the NPK Barl-designed Alpha-ES satellite.
- Alpha-ES boasts an image resolution of 0.7 m and can take panchromatic images as well as near-infrared images.
- Khayyam is in a 495x492km 97.4° sun-synchronous orbit.
- The project, referred to as Project 505, has been in the works since 2015 when Russia and Iran publicly disclosed their intent at the bi-annual MAKS aerospace show in Russia.
- Two Russian companies will work with the Iranian company Bonyan Danesh Shargh and the Iranian Space Agency to design and operate the satellite in orbit, with Bonyan Danesh Shargh being responsible for in-orbit operations.
- Iranian military officials have been heavily involved in the acquisition, and leaders of Iran's Islamic Revolutionary Guard Corps have made multiple trips to Russia since 2018 to help negotiate the terms of the agreement.
- Russian trainers have helped ground crews who would operate the satellite from a new site near the northern Iranian city of Karaj.
- The Soyuz rocket used in the Khayam mission was originally intended to launch a South Korean Earth-observation satellite. However Russia's invasion of Ukraine earlier this year made the launch impossible.
- Previously Vladimir Putin had denied the deal by saying, "It's just fake news. At the very least, I don't know anything about this kind of thing, those who are speaking about it probably will maybe know more about it. It's just nonsense, garbage."
- The Khayam satellite reached the launch pad on the heels of Putin's visit to Teheran where Russia and Iran discussed military and economic cooperation.

Previously Iran used commercial satellite images to monitor Ain al-Asad Air Base in Iraq as it prepared to launch more than a dozen ballistic missiles at U.S. and coalition forces. (See VIDEO from 60 Minutes). Awareness of Iranian commercial imagery purchases allowed US forces to relocate potential targets such as aircraft. Controlling their own imaging satellite enables Iran to conduct surveillance and target development with increased operational security.

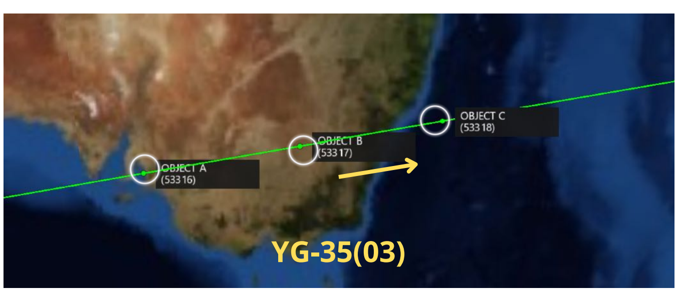
China Launches 3rd Set of Yaogan-35 Triplets

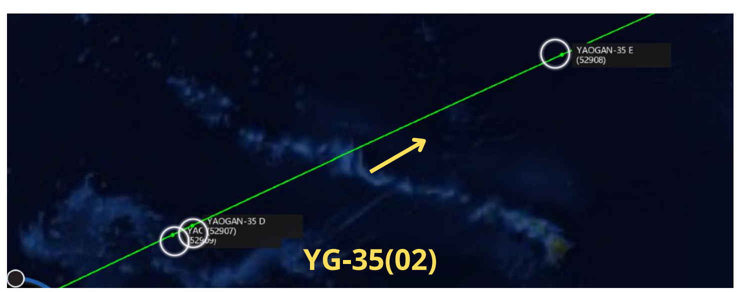
29 Jul 2022: China launched its third trio of Yaogan 35 (YG-35(03)) military reconnaissance satellites to orbit on a Long March 2D rocket from Xichang Satellite Launch Center. Details from the Chinese government regarding the individual satellites' on-orbit operations are sparse. Despite this, spacecraft analysis and comparisons to western missions and previous Chinese launches help to build a gradual understanding. Launch Video.



- The new trio join two sets of Yaogan 35 satellite triplets which were sent into orbit by two similar launches in Nov 2021 and Jun 2022. All nine satellites are now orbiting at roughly 310 miles (500 km) above the Earth, with an inclination of 35 degrees in order to provide regular, repeated passes over areas of interest.
- The China Aerospace Science and Technology Corporation (CASC), which developed both the rocket and spacecraft for the mission, stated that the satellites would be used for space scientific experiments, monitoring land usage and natural resources, and other scientific purposes.

- The European Space Policy Institute notes in its recently published yearbook on space activities that China's Yaogan series satellites are perceived by analysts to serve both civil and military users.
- As with the earlier pair of Yaogan 35 satellite launches, two of the three satellites were developed by the Aerospace Dongfanghong Satellite Co., Ltd., with the third provided by the Shanghai Academy of Spaceflight Technology (SAST), both of which operate under CASC.
- A mission patch released by SAST indicates that the payload adapter, which serves as an interface between a rocket stage and the spacecraft being sent into orbit, carries a drag sail designed to help deorbit the roughly 660-pound (300-kilogram) adapter much sooner than otherwise. SAST debuted the drag sail on the previous Long March 2D launch.
- As of 4 Aug the three YG-35(03) satellites appeared to be equally spaced, however they will likely maneuver to the 1 lead 2 trail configuration exhibited by YG-35(01) and YG-35(02).
- Yaogan-35 satellites may operate in lead-trail configuration, with the lead satellite potentially cueing the two trailing vehicles.

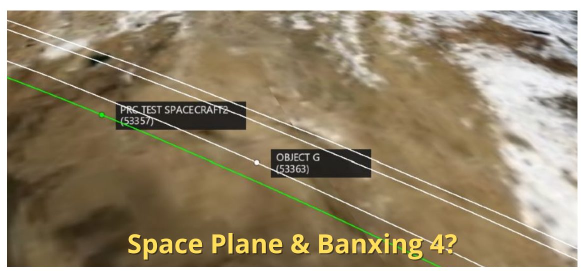


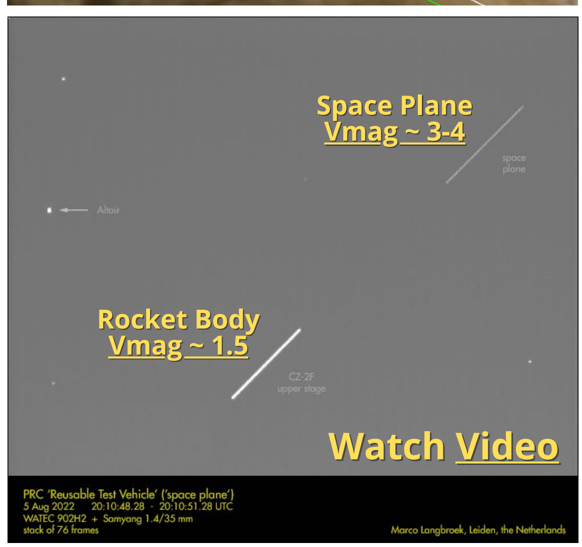


China Second Spaceplane Launch

4 Aug 2022: China launched its Reusable Experimental Spacecraft on a Long March 2F from Jiuquan. No exact T-0 or launch timing was given. The spaceplane is believed to be a similar to the design of the Boeing X-37 spaceplane launched by the United States. This is suspected to be the spaceplane's second flight, after the first flight in Sep 2020 and a longer ongoing test series out of space in the early 2010s.

- U.S. Space Force's 18th Space Defense Squadron (18 SDS) is tracking the spacecraft in 346 by 593 km orbit inclined by 50 degrees.
- While China gave no official launch time, observers estimate the LM-2F launched at 1600UTC.
- The first mission in Sep 2020 was in a 340 km circular orbit; this one in 346 x 593 km. Unclear if deliberate or if the launch vehicle made a slight overburn.
- The launch generated 8 unique trackable objects, some with apogees >800km.
- The Sepr 2020 flight had 7 unique TLEs and one of the seven was a Banxing inspector satellite released from the main payload.
- The Banxing-3 was not catalogued as separate object until the spaceplane departed from orbit 6 Sep 2020. Satellites with a similar task were deployed from Shenzhou 7 and Tiangong 2. Banxing remained in orbit 478 days, re-entering on 26 Dec 2021.
- There are signals from the 4 August 2022 suspected spaceplane test launch resembling those from the Banxing-3. The object has a rapidly and periodically fading signal.
- Official wording calls the payload a reusable spacecraft for peaceful use of space and pilot reuse and on-orbit tech validation. The plane will land at a later date in China. One of the suspected sites is Lop Nur, with recent imagery revealing that objects have appeared on the runway. As of now, it is not clear if this is in preparation for a future landing of the plane.
- The spaceplane project itself has its origins possibly in the Shenlong project, which was first spotted in 2005. Since then it is barely mentioned or shown since its original reveal in 2007. No exact weight, size, or further details about potentially loaded payloads are known for the vehicle.
- In early Sep, on-orbit lighting conditions will match those on the landing day of the previous mission. The previous mission landed on 6 Sep after 2 days in orbit.





Review of Chinese Counterspace Activities

1 Aug 2022: Matthew Mowthorpe and Markos Trichas published an overview of Chinese counterspace development and and operations in The Space Review.

LEO Co-Orbital Testing

- SHI JIAN-12 (SJ-12) conducted a number of close approaches with the SJ-06F satellite in LEO (600 to 570 km.) These occurred between June and August 2010. In the closest approach, the two satellites were less than 300 meters apart.

- Three payloads were placed in orbit at 670 km from the same launch on 19 Jul 2013: SHIYAN-7, CHUANGXIN-3, and SHIJIAN-15. SY-7 was known to the Chinese program as TANSUO-4 and was likely fitted with a robotic arm, which interacted with a separating subsatellite, known as TANSUO-3 (CX-3), designed to provide optical surveillance in GEO and LEO. SJ-15 was known as TANSUO-5 and was designed to maneuver and conduct proximity operations.

- In 2016, the AOLONG-1 (AL-1) small satellite, known as the Advanced Debris Removal Vehicle demonstrated using a robotic arm to capture a small piece of debris for removal from orbit.

GEO Rendezvous and Proximity Operations (RPO)

- On 3 Nov 2016, China launched the SHIJIAN-17 (SJ-17) into GEO. SJ-17. SJ-17 was reportedly designed test advanced technologies, however it was also fitted with an onboard optical surveillance sensor, and a reported signals intelligence mission.

- On 23 Dec 2018, China launched another mission to GEO, the Tongxin Jishu Shiyan (TJS)-3. Two objects were catalogued from the launch, TJS-3 and a second object.

- A potential offensive use of RPO would be to install a radio frequency jammer onboard the chaser satellite, increasing its ability to interfere with the satellite's communications. Chinese academic papers recognized that reducing the distance with a small satellite platform would decrease the power requirements exponentially, identifying susceptible US assets such as the Advanced Extremely High Frequency satellites.

- On 22 Jan 2022, SJ-21 was observed to execute a large maneuver to bring itself closely next to a dead Beidou navigation satellite. SJ-21 pulled the dead satellite out of its geosynchronous orbit and placed it a few hundred miles into a graveyard orbit.

Direct Ascent ASAT

- On 11 Jan 2007, the DN-1 launched from Xichang and successfully destroyed a defunct Chinese Feng Yun-1C weather satellite at an altitude of 865 km. This ASAT test created a large amount of debris and generated a significant amount of international condemnation.

- On 13 May 2013, a likely test of a DA-ASAT that could reach higher orbits took place from Xichang. Technical analysis…indicated that the test had an apogee of 30,000 km with a flight time of 6.7 hours. This new ASAT test variant was labelled DN-2, with an estimated operational timeframe of 2020–25.

Electronic Warfare

- The PLA during exercises routinely incorporates jamming and anti-jamming techniques against multiple communication, radar systems, and GPS satellite systems in exercises. A Defense Intelligence Agency report assessed that China is developing jammers to target SATCOM over a range of frequency bands including military protected extremely high frequency communications.

Directed Energy Weapons

- China is actively pursuing directed energy weapon (DEW) development for counterspace use.

- In 2006 China used a ground-based laser to dazzle or "blind" a US optical surveillance satellite on at least one occasion. China has at least five sites that support China's DEW work.

China Launches Environmental Study Satellite

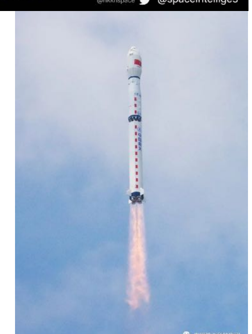
4 Aug 2022: On the same day as the LM-2F/Spaceplane launch, China also sent the Terrestrial Ecosystem Carbon Inventory Satellite (TECIS) satellite into orbit on a LM-4B. TECIS will sense solar-induced fluorescence from plant chlorophyll, forest biomass & aerosol levels in the atmosphere - key figures in determining global warming status. After China conducted a naming competition the Satellite will also go by the name Guomang. Launch Video.

- TECIS 1, approved by the China National Forestry Administration and built by the China Academy of Space Technology (CAST), will be used to evaluate major national ecological projects and monitor the atmospheric environment and the influence of aerosols on climate change.
- TECIS carries four instruments. A multi-Beam LIDAR, a polarization camera, a Hyper-spectral Monitor, and a Spectral Camera. It is designed to operate for 8 years.
- In addition to TECIS, there were two additional payloads on this launch:

1) The 40kg HEAD 2G (Jiatong) designed by the HEAD Aerospace Group in Beijing. It will be used for ship and flight monitoring in combination with their HEAD's Skywalker constellation of 48 satellites; and

2) The Minhang Youth Satellite is intended to promote middle and primary school students' participation in space-related science and engineering activities. The satellite was designed by students. This includes the logo of the satellite, the experiment's design, and the paintings on the payload. The submissions came from primary and secondary schools.

- The three payloads (Guomang, Minhang, Jiatong) are in 490 x 502 km x 97.5 deg sun-synch orbit



China: Another Successful Commercial Launch

8 Aug 2022: Chinese commercial launch service provider Galactic Energy maintained a 100 percent launch record with its third Ceres-1 solid rocket launch. The four-stage Ceres-1 rocket lifted off with three small satellites from Jiuquan. Launch Video.

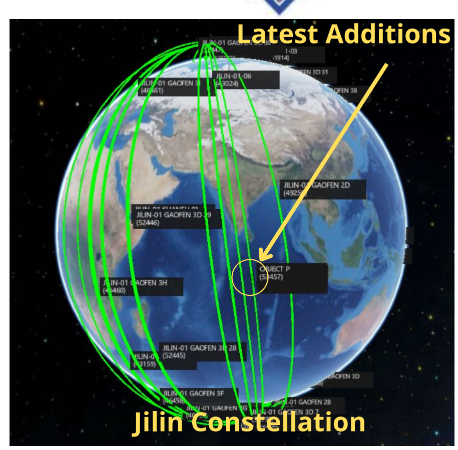
- Taijing-1 01 and 02, developed by private small satellite manufacturer Minospace using its MN50 platform, will provide commercial remote sensing services. Donghai-1, developed by Shanghai-based ASES Space, is designed to verify multi-mode remote sensing and key technologies.
- All 3 are in a 500km Sun synchronous orbit (SSO)
- This was the third launch of the Ceres-1 system, also known as Gushenxing-1. Ceres-1's first launch was in November 2020, and its second launch was in December 2021. Both launches successfully completed their missions.
- Ceres 1 is capable of launching a 350 kg payload to low Earth orbit, or up to 230 kg into a sun-synchronous orbit at an altitude of 700 km.

Galactic Energy has now become the first private launch provider to succeed in its first three tries in launching to orbit. The company apparently has one other Ceres-1 launch listed on its manifest. This launch is planned for later this year and the payload currently listed is the Zengzhang-1 reusable reentry capsule demonstrator.

China: LM-6 Delivers 16 Jilin Imagery Satellites

9 Aug 2022: China launched 10 Jilin-1 electro-optical and 6 Infrared satellites on a Long March 6 from Taiyuan. The target orbit for the 16 satellites was a 535 km sun-synchronous orbit (SSO). Launch Video. See GF-03D Images (EO) & Yunyao-1 IR Image.

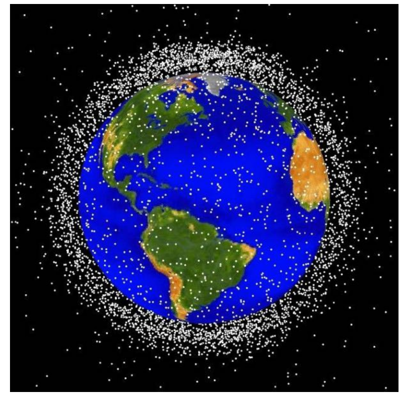
- This was the 9th successful Long March 6 launch. The LM-6 can deliver up to 1,080 kg to a 700 km SSO orbit, which has been the orbit LM-6 has flown to the most. This launch set a record for the largest number of "Jilin-1" satellites launched in a single time.
-Gaofen 03D satellites launched are optical systems that have a number different resolutions. One of these elements allows for a resolution of 0.75 meters, and the other is 3 meter resolution.
- The satellites are 1m in diameter and have a mass of 40kg.
- Six Yunyao-1 atmospheric sensing satellites were included in the payload stack for this mission. These satellites are also referred to as Jilin-1 IR satellites and are infrared satellites, and are expected to provide infrared imagery of Earth when the constellation is completed.
- Over 60 of Jilin-1 satellites have been launched on Chinese rockets, including Kuaizhou-1A, Long March 6, and Long March 11. The stated goal of the constellation is 138 satellites capable of imaging every inch of Earth's surface every 10 minutes.



The Jilin-1 constellation is China's first remote-sensing satellite constellation made by a commercial company, and the first satellites in the Jilin-1 constellation were launched in 2015. Currently, teams are planning for the 138 satellite constellation to be completed by 2030.

BBC Video: Solving the problem of dead satellites

2 Aug 2022: The British Broadcasting Company (BBC) released a 4.5 minute video discussing the hazards of increasing space debris and potential mitigation strategies. With an increasing number of governments and private companies capable of launching satellites, the space around the planet is beginning to get congested. Some estimates say that fewer than half of the satellites currently in orbit are working.

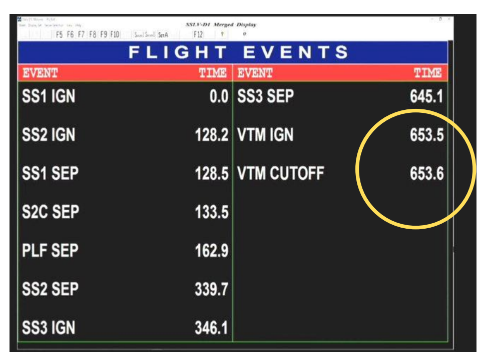


- "After 75 years of spacecraft being sent into orbit, it's a lot easier to go for launch, but a lot messier when you're up there."
- The video follows a number of small companies, space agencies, and leaders exploring space sustainability, the lack of authorities and law in space, and the threat untrackable small objects pose to the more than 5,000 satellites.
- The video closes with a plea for regulation, shared best practices, free exchange of information, and continued study and research to produce workable solutions.

So Close: India's New Launch Vehicle Fails

5 Aug 2022: India attempted to place the EOS-02 Earth observation microsatellite into orbit using a new small satellite launcher, the SSLV or Small Satellite Launch Vehicle, from Sriharikota, India. However, an issue with the fourth stage resulted in the satellites failing to reach orbit and likely re-entering over the Pacific. Launch Video.

- EOS-02, formerly known as Microsat-2A, had a 145kg mass and was equipped with mid-wavelength and long-wavelength infrared cameras...maximum resolution ~6 meters.
- The SSLV has three solid-fueled stages and a fourth stage known as the Velocity Trimming Module. The VTM provides roll control for the second and third stages as well as the ability to inject multiple payloads into different orbits.

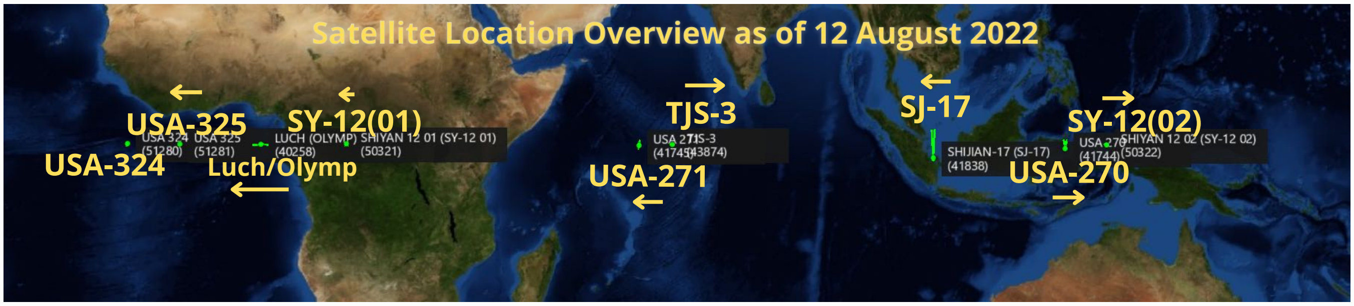


- The SSLV is designed to launch up to 500 kilograms to a 500-km altitude, 45-degree inclination low Earth orbit, or 300 kg to a 500 km altitude sun-synchronous polar orbit. In addition, the vehicle can carry various combinations of CubeSats and micro or mini-satellites.
- The SSLV is designed to use less infrastructure than earlier Indian SLVs. It is designed to take 72 hours to set up, with a team of six people to oversee launch preparations.

- The 3 solid rocket boosters appeared to operate nominally when VTM ignited its thrusters at 642 seconds, however only 0.1 seconds of burn was seen at mission command.
- The SSLV program is scheduled to fly three development launches before ISRO's commercial arm, NewSpace India Limited (NSIL), starts flights for customers. The second development launch is scheduled for late 2022 and the third launch is scheduled for the second quarter of 2023.

This Fortnight in GEO

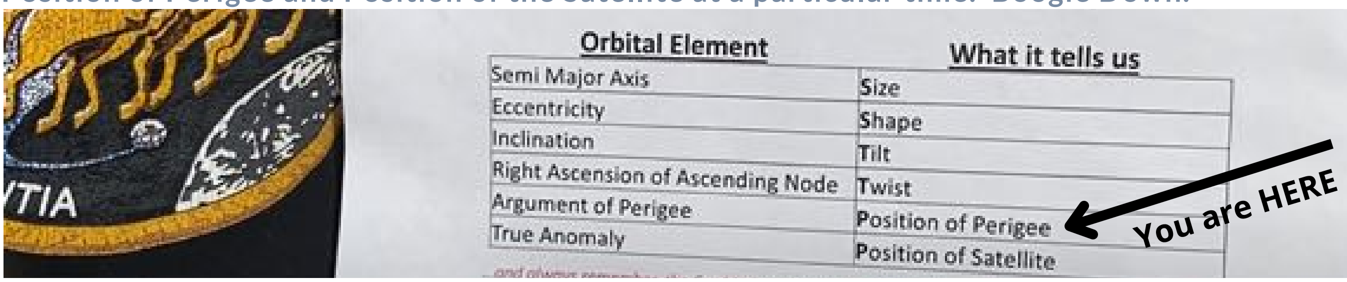
- There were no new maneuvers from high interest objects in GEO reported in the past 2 weeks.
- TJS-3 continues to drift eastward towards its early-July position. Briefly in vicinity of TJS-2.
- Russian Luch/Olymp Satellite continues 2° per day westward drift.
- SJ-17 continues westward drift. Briefly in vicinity of Gaofen-4.
- SY-12(01) and SY12(02) continue their westward and eastward drifts, respectively, and were not in the vicinity of other satellites during this period.



Editor's Note: Thanks to weekly reporting from Palski & Associates Inc, we're going to try to keep track of maneuvers of select spacecraft in GEO. For this week, orbital information is courtesy of the 2022-07-22 & 2022-07-29, Space Domain Awareness Reports from Palski & Associates Inc. Send a request to david.pierce@palski.com to get added to their distro list!

Jack's Astro Corner: Argument of Perigee – Let's get close with our orbit (Part V)

Over the summer, Jack Anthony will break down each of the six orbital elements required to uniquely identify a specific orbit and satellite in that orbit. This week we examine Argument of Perigee. For those who can't wait the entire summer, please visit Jack's "Orbit Element Dance" on YouTube" and you'll find a 1:02 video featuring Jack in his driveway demonstrating this highly effective way to learn about the 6 classical orbital elements (COE). Each movement ties to an important astrodynamics principle. Below is a screen grab from this video. As you can see, Jack uses the STP method of remembering the 6 COEs. Size, Shape, Tilt, Twist, Position of Perigee and Position of the Satellite at a particular time. Boogie Down.

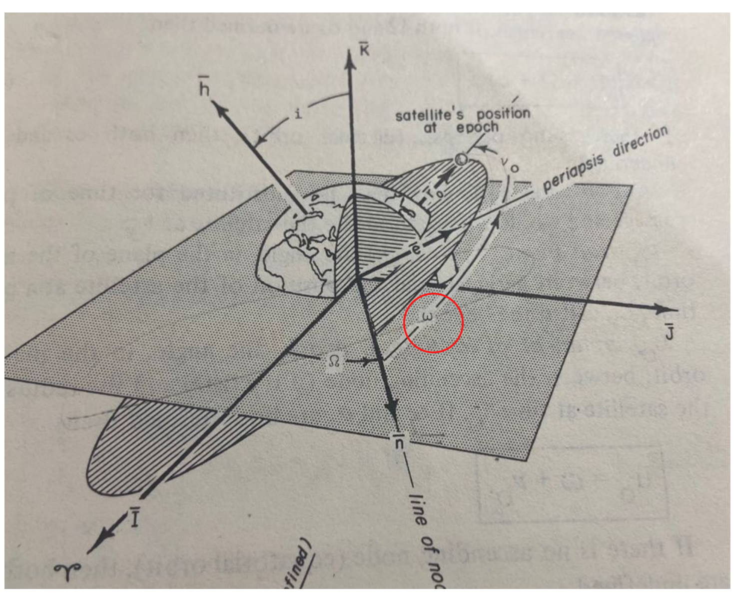


Orbital Element	What it tells us
Semi Major Axis	Size
Eccentricity	Shape
Inclination	Tilt
Right Ascension of Ascending Node	Twist
Argument of Perigee	Position of Perigee
True Anomaly	Position of Satellite

We now move into the P's of my STP method of learning and remembering the Classical Orbital Elements. Let's review: Size-Semi Major Axis, Shape-Eccentricity, Tilt-Inclination, and Twist-Right Ascension of the Ascending Node. So, by now you should be most awesome doing the Orbit Element Dance....hope so. They even show my 1-minute dance performance in the USAF Academy core Astro classes...I wonder what they think?

We are now going to learn about the orbital element called the Argument of Perigee. Hey wait a minute, we got an "argument" in the orbital elements? What's with that? Well, we owe that term as used in astronomy to Geoffrey Chaucer (1340-1400) who wrote The Canterbury Tales. Not many folks know this, but he also wrote The Treatise on the Astrolabe, in which he introduces ways to describe where the planets are. He also used "argument" as an astronomical reference in his poetry. So, the early astronomers used the term "argument" to mean angle or arc in astronomy. Way to go Astro smartie Geoffrey Chaucer!

Once again I am going to use the superb illustration in BMW. Here it is below:



Jack's Astro Corner: Argument of Perigee (Cont)

You see the RAAN angle depicted using Ω. That orbital element is the angle between the I-axis of the ECI frame and the Ascending Node vector. Well, we shall now measure an angle NOT in the fundamental plane of the ECI frame but in the orbit plane. You'll see the Argument of Perigee is denoted using ω, which is "small omega." It is the angle between the Node vector and a vector pointing to where perigee is. Perigee is the closest point to the Earth of the orbit. You'll see the vector is denoted "e". What's that you ask? It's called the "eccentricity vector" and it points from the center of the Earth toward perigee and has the magnitude of the orbit's eccentricity. If you really want to dive into the "where did they get that?" math, find a copy of Fundamental of Astrodynamics by Bate, Mueller and White (published first in 1971) Section 2.4-1 (page 62) and check out equation 2.4-5.

OK, so let's see what the Argument of Perigee can tell us about the orbit. As you can see, it starts with the Node vector and the angle is measured in the orbit motion direction to perigee direction. So, if ω is zero degrees, that means perigee is at the ascending node. What if ω is 180 degrees? "Let's ask Ferris Bueller…Bueller, Bueller, Bueller?" "It's at the descending node" says Ferris. Right you are Bueller. OK, so what if it's 90 degrees? That puts perigee at the northern most point of the orbit. Finally, if it's 270 degrees, that places perigee at the southern most point of the orbit. Argument of Perigee helps us locate where perigee is in the orbit plane.

I mentioned the USAF Academy Astro course earlier. All cadets take the course their junior year. The Astro majors tackle it as early as their doolie year. Did you know they have a YouTube site with many, many Astro educational videos? They created most of them early in 2020 when the health crisis was ramping up…ugh. These helped all the cadets virtually take part in a class and keep up with their learning. They have a super 16-second video that shows the Argument of Perigee,

On YouTube.com you can find all their videos at "USAFA Astronautics & Space Ops"

Well, the Position of Perigee is the first "P" and is an angle measured from the Node Vector to the Perigee Vector, which we all know is denoted the Eccentricity Vector. The angle is measured in the Orbit Plane in the direction of orbit motion. It tells us where the satellite is closest to the Earth. Next time we'll meet the second "P", that is the True Anomaly. What? There's an "anomaly" in the Orbit Elements? "Anomalies" are never good in the space business. Well, this is a good and informative "anomaly." It is NOT a glitch or something gone wrong. The use of the term "anomaly" has an explanation that goes way back Egyptian astronomer Ptolemy. More next time!

Jack's Astro Corner: Argument of Perigee (Cont)

We are almost to the last classical orbital element, that's means you need a confidence building quiz....a True/False one, let's see how sharp you are:

Jack's Quiz (These are all T or F)

1. T/F? Semi-major axis, Mean Motion and Orbit Period are related to each other
2. T/F? Inclination alone does not fully describes an orbit's plane
3. T/F? In the Orbit Element Dance, the move after "Twist" is a John Travolta class designation of the Node Vector
4. T/F? The eccentricity of a HEO orbit is always .5
5. T/F? RAAN is measured from the Greenwich meridian to the Ascending Node
6. T/F? If argument of perigee is 270 degrees, the perigee is located at the descending node
7. T/F? The eccentricity vector points to perigee from the center of the Earth and has the magnitude of the Perigee Altitude
8. T/F? For a LEO, inclination of 63.4 degrees is good if you want to avoid perigee drift
9. T/F? STP is an oil treatment and the way Jack remembers the Classical Orbit Elements
10. T/F? Argument of perigee is a confrontational discussion on how low perigee can go

Answers: 1)T; 2)T; 3)T; 4)F; 5)F; 6)F; 7)F; 8)T; 9)T; 10)F

Bonus Jack's Astro Corner: How To Rendezvous With Another Satellite

This essay will introduce the process of a “chaser” spacecraft (maybe a refueler servicing vehicle) goes through to arrive at the “target” spacecraft (the one who ordered the refueling). The terms chaser and target have been used by NASA way back as they planned and executed rendezvous, then loitered around the other spacecraft, that’s called proximity operations, and then they would dock. Some call this ZPO, zero prox ops. This process involves maneuvering the chaser and hopefully the target is cooperative and not maneuvering without telling you.

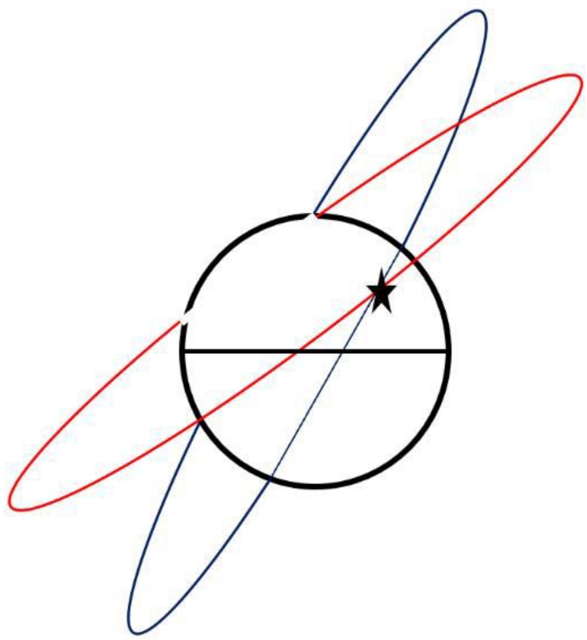
The chaser’s orbital elements provide information into how the rendezvous mission progressing If you are not aware of the target, following this trend will help resolve that. It’s the change and matching of the chaser’s elements to the target’s elements that give insight into how the process is moving along. In the end, if the chaser is to dock with the target, then the orbital elements must match. There are three phases to completing a RPO and then ZPO. While the chaser’s maneuvers may not always follow the expected flow of these phases, they provide a framework to follow along. Here below is a table that summarizes the 3 phases. Give it a review and study before reading on, it will be helpful.

Phase	Orbit Elements to be Matched	Cool things to know
Orbit Plane Match	Inclination & RAAN	Unless launching directly into the target's orbit plane, this phase can involve some large Delta-V maneuvers to "get into the plane." Plane matching is key to getting on course to complete an RPO and remain in a persistent position or pattern of positions with the target
Orbit Shape & Alignment	Eccentricity & Argument of Perigee	This phase is very subtle, but matching the shape enables efficient maneuvering and aligning the orbit's line of apsides supports effective phasing maneuvering in the final phase.
Orbit Phasing & Position Match	Semi-Major Axis & True Anomaly	Matching semi-major axis enables station keeping and matching true anomaly or having it be darn close establishes the persistent presence to observe, dock or do whatever you are there to do

Bonus Jack's Astro Corner: How To Rendezvous With Another Satellite (Cont)

Let's look at each phase and go a little deeper to give you insight into what's going on.

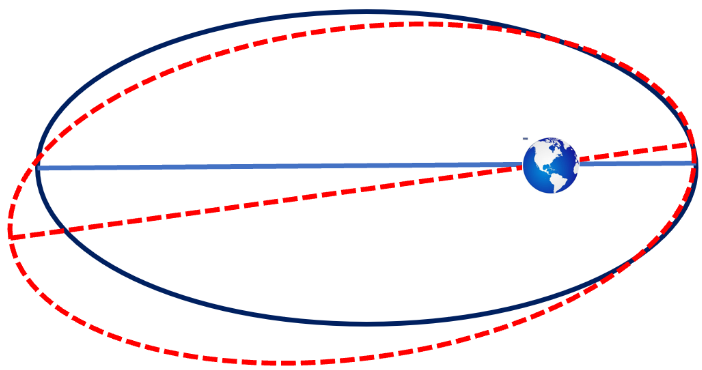
Orbit Plane Matching: Plane matching usually occurs early in planning and executing a mission. The launch vehicle usually does it all, you launch right into the orbit plane of the target (see Russia's recent launch of Kosmos 2558). But there can be errors in that insertion and thus orbit plane matching maneuvers are needed. Below is a simple illustration (all my drawings are simple😁) that shows the red and blue orbits have different inclinations and RAANs. So, the task at hand to match orbit planes would be to execute a Delta V where that star is and get the orbit planes matched to have same inclination and RAAN. A really important step to ensure when you get close for proximity operations you are not zig zagging back and forth.



The chaser can do a series of small orbit plane adjust maneuvers to incrementally get the orbit planes aligned. As you all remember from the Orbital Element Series of articles I wrote, the orbit plane is characterized by the inclination and RAAN. The amount of Delta-V to align inclination only gives us some basic rules of thumb. In GEO, 53 m/s of Delta-V is needed to change or correct 1 degrees of inclination, for LEO it's about 115 m/s. But remember, you got to also get the RAAN lined up. That can be costly in propellant. Here's an example: You launched into a 97.4 degrees incline LEO orbit. Nailed the inclination. But, the RAAN is not aligned, it's off by 1.5 degrees. How much Delta-V do you think is needed to fix that? Hummmm? Well, its 197.5 m/s, wow! Now, get ready for some learning, what if the inclination was 28 degrees. Is there a difference in what's needed to fix the 1.5-degree error in RAAN? Yup, it's only 97 m/s. Still, a lot. So, orbit plane matching usually is the launch vehicles chore, but if you need to tweak thinks to get the orbit planes aligned, that can cost you fuel (and time making PowerPoints to explain what's going on... LOL).

Bonus Jack's Astro Corner: How To Rendezvous With Another Satellite (Cont)

Orbit Shaping & Alignment: Normally mission planners like to have the long axis of the orbits matched, this is called the line of apsides. It enables efficient maneuvering. This can be a very subtle stage, usually the orbits are so near circular this phase may not occur. Orbit shaping is reflected in the eccentricity and argument of perigee matching. Hopefully the launch vehicle did its job getting things properly inserted into orbit. Of course, if the target starts playing games and maneuvering, then this problem gets tougher. The illustration on the next page shows that the red dashed orbit and the blue orbit do not have their lines of apsides lined up. Some planners would want to execute a maneuver to get them aligned to support more efficient maneuvering.



Orbit Phasing: This is my favorite phase. This is where you get to close in on the target and hang out with them or better yet, dock and refuel them. This phase is usually seen as where the chaser orbit is being adjusted and we see changes in its orbit's apogee and perigee. They are fiddling with the semi-major axis and getting the approach going, perhaps slowing down the relative closer rate. As semi-major axis getting close to a match, chances are the true anomaly is also closing it. Match them up and you can reach out and shake hands or get set for the dock and refueling. Here's a cool rule of thumb I think you'll enjoy knowing and sort of relates to phasing. For LEO Earth orbits, there is a 10:1 rule, my friend James Oberg at NASA/JSC came up with it. Here's what it means. If you are 1 Km below your target orbit and you are plane matched and circularized, then you will advance 10Km forward each orbit period. Thus 10:1. So, let's say you are 5 Km below and 150 Km behind. Let's say your orbit periods are really close and 90 minutes. OK, so when will you be right underneath the target? Well, use the 10:1 rule. Each orbit you scoot ahead relative to the target 50 Km (5 Km times 10). So, we are 150 Km behind, and guess what? In 3 orbit or 4.5 hours we can look "up" and see the target. Pretty cool, the 1- to 1 rule of thumb by James Oberg. Yay for him!

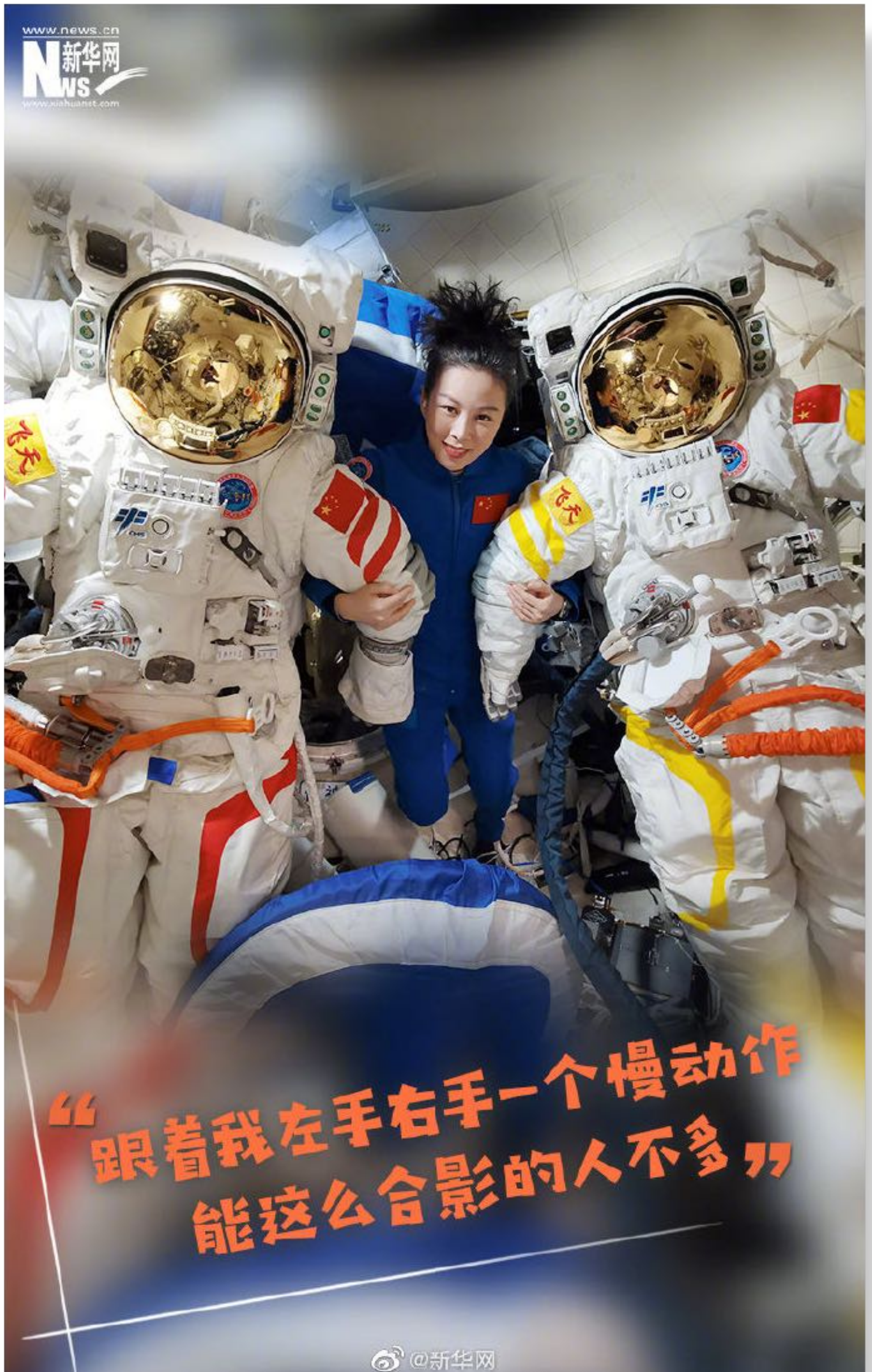
Well, there you have it. The 3 phases of RPO and some details as to what's going on. You may ask, how does Jack know this stuff? Well, two folks play a BIG role in helping me understand and get all enthusiastic about RPO. Dr Chirold Epp helped me in the early 1980's. While at Johnson Space Center I'd meet with Dr Epp and he'd tell me all the cool things Shuttle would be doing with regard to RPO. He helped me understand the math and art to all this. Then Mr. A. Clark Keith III came along in 1989 as my Aerospace Corporation advisor for the famous TAOS space mission that flew 1994-2000. I got to know Clark and one of his finest hours (or years) was the XSS-11 RPO test

Bonus Jack's Astro Corner: How To Rendezvous With Another Satellite (Cont)

mission that flew 2005-2007. Clark was the Flight Director and he wrote up notes that comprised a “how to” handbook for RPO. Just before his battle with cancer took him from us in 2013, Clark wrote up his notes and gave them to his colleague Jim Baker to publish. I met with Clark just before he passed and he said “Jack’s I’m writing everything down, make sure you read and live it.” Clark’s experience, insight, and ability to explain things was awesome and helped all of us know the ways to achieve RPO. He is the Father of Military RPO. He played a huge role in planning the ANGELS mission and many more space test missions. I miss Clark and thank him. DO YOU HAVE A MENTOR HELPING YOU UNDERSTAND YOUR AREA OF RESPONSIBILITY? I BET YOU DO.

Here’s a photo of Clark and I in 2011 at the USAF Academy FalconSAT Operations Center. He loved coming to meet with the cadet’s and talk spaceflight!

Pics o' the week!



Preparing for the next spacewalk on Tiangong

Mengtian module at Wenchang -
note the experiment airlock on the right side

Satellite imagery of an air base near Lop Nor in China that has been associated with the development of a secretive spaceplane

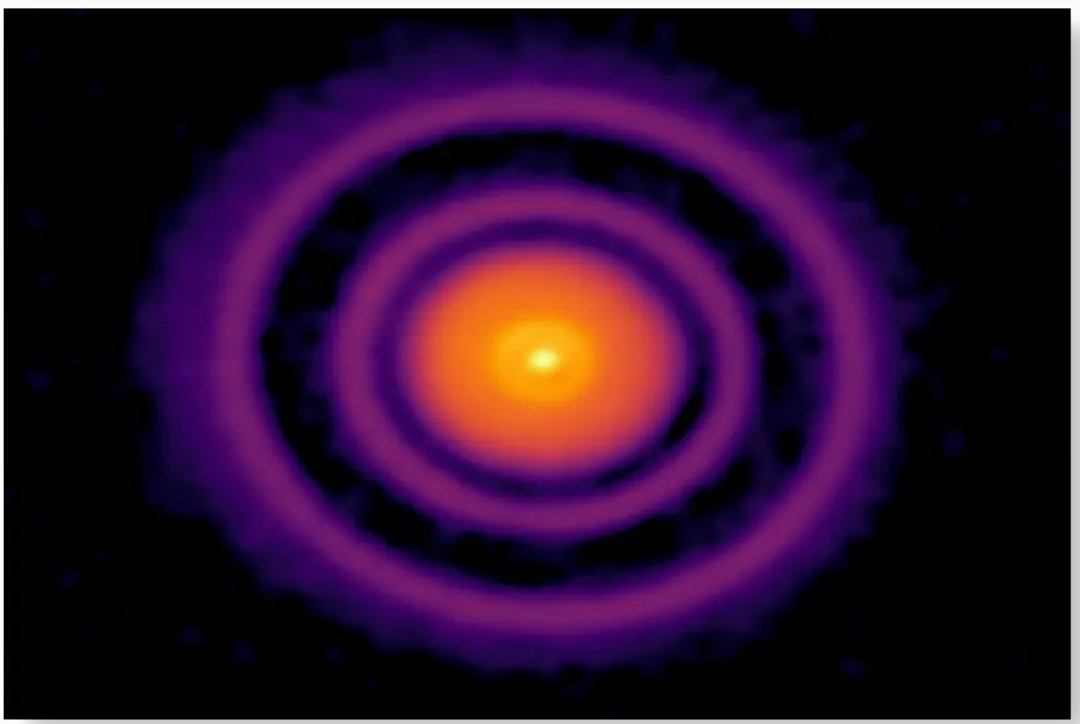
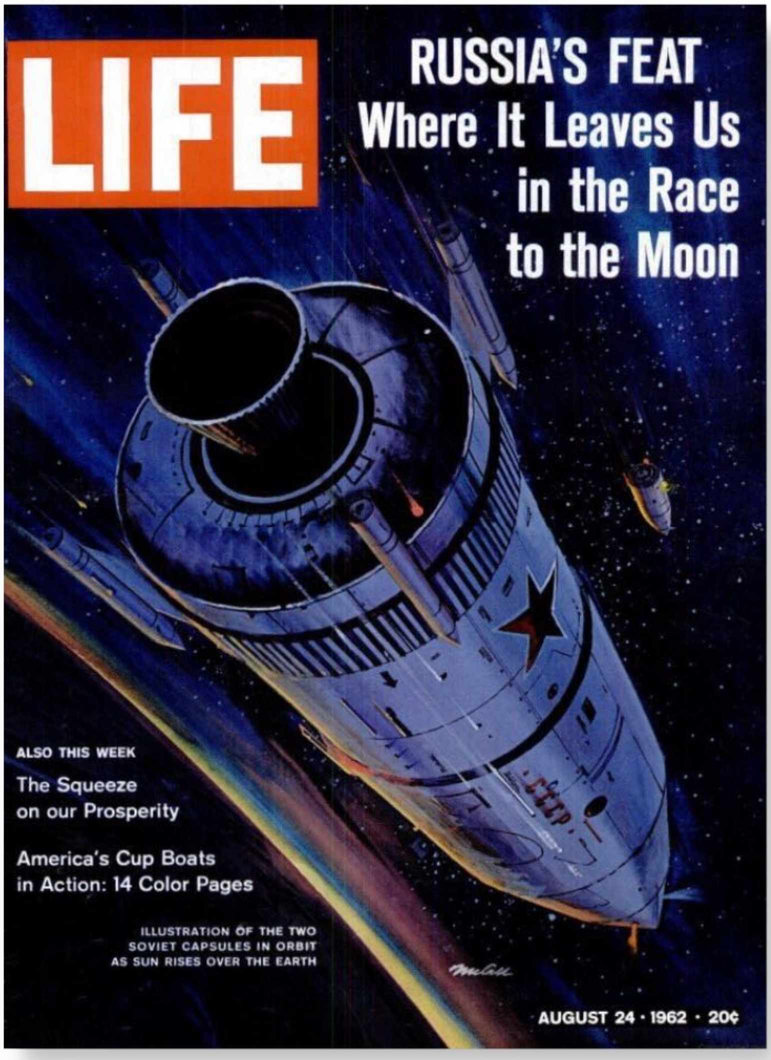


Image of the Galaxy’s Youngest Planet (potentially)
AS 209, a star that is only 1.5 million years old.



11 Aug 1962: The Soviet Union launches Vostok 3 piloted by Andriyan Nikolayev who spends four days in space. The next day, cosmonaut Pavel Popovich is launched in Vostok 4, making this the first time two crewed spacecraft are in orbit simultaneously.

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