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NEWSLETTER

ARTEMIS I LIFTOFF!

NASA's Artemis I Mega Rocket Launches Orion to Moon

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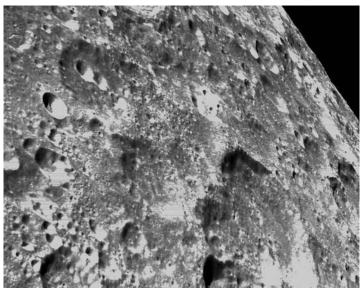
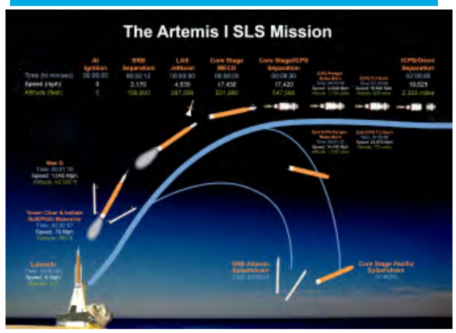




(Cover Story) Liftoff! NASA's Artemis I Mega Rocket Launches Orion to Moon (November 15)

by NASA https://www.nasa.gov/press-release/liftoff-nasa-s-artemis-i-mega-rocket-launches-orion-to-moon.

NASA's Space Launch System rocket carrying the Orion spacecraft launches on the Artemis I flight test, Wednesday, Nov. 16, 2022, from Launch Complex 39B at NASA's Kennedy Space Center in Florida. NASA's Artemis I mission is the first integrated flight test of the agency's deep space exploration systems: the Orion spacecraft, Space Launch System (SLS) rocket, and ground systems. SLS and Orion launched at 1:47am ET from Launch Pad 39B at the Kennedy Space Center.
Credits: NASA/Bill Ingalls

Following a successful launch of NASA's Space Launch System (SLS), the most powerful rocket in the world, the agency's Orion spacecraft is on its way to the Moon as part of the Artemis program. Carrying an uncrewed Orion, SLS lifted off for its flight test debut at 1:47 a.m. EST Wedanesday from Launch Pad 39B at NASA's Kennedy Space Center in Florida.

The launch is the first leg of a mission in which Orion is planned to travel approximately 40,000 miles beyond the Moon and return to Earth over the course of 25.5 days. Known as Artemis I, the mission is a critical part of NASA's Moon to Mars exploration approach, in which the agency explores for the benefit of humanity. It's an important test for the agency before flying astronauts on the Artemis II mission

"What an incredible sight to see NASA's Space Launch System rocket and Orion spacecraft launch together for the first time. This uncrewed flight test will push Orion to the limits in the rigors of deep space, helping us prepare for human exploration on the Moon and, ultimately, Mars," said NASA Administrator Bill Nelson.

(Cover Story) Liftoff! NASA's Artemis I Mega Rocket Launches Orion to Moon (November 15)

After reaching its initial orbit, Orion deployed its solar arrays and engineers began performing checkouts of the spacecraft's systems. About 1.5 hours into flight, the rocket's upper stage engine successfully fired for approximately 18 minutes to give Orion the big push needed to send it out of Earth orbit and toward the Moon.

Orion has separated from its upper stage and is on its outbound coast to the Moon powered by its service module, which is the propulsive powerhouse provided by ESA (European Space Agency) through an international collaboration.

"It's taken a lot to get here, but Orion is now on its way to the Moon," said Jim Free, NASA deputy associate administrator for the Exploration Systems Development Mission Directorate. "This successful launch means NASA and our partners are on a path to explore farther in space than ever before for the benefit of humanity."

Over the next several hours, a series of 10 small science investigations and technology demonstrations, called CubeSats, will deploy from a ring that connected the upper stage to the spacecraft. Each CubeSat has its own mission that has the potential to fill gaps in our knowledge of the solar system or demonstrate technologies that may benefit the design of future missions to explore the Moon and beyond.

NASA's Space Launch System rocket carrying the Orion spacecraft launches on the Artemis I flight test, Wednesday, Nov. 16, 2022, from Launch Complex 39B at NASA's Kennedy Space Center in Florida. NASA's Artemis I mission is the first integrated flight test of the agency's deep space exploration systems: the Orion spacecraft, Space Launch System (SLS) rocket, and ground systems. SLS and Orion launched at 1:47 a.m. EST, from Launch Pad 39B at the Kennedy Space Center. Credits: NASA/Joel Kowsky

Orion's service module will also perform the first of a series of burns to keep Orion on course toward the Moon approximately eight hours after launch. In the coming days, mission controllers at NASA's Johnson Space Center in Houston will conduct additional checkouts and course corrections as needed. Orion is expected to fly by the Moon on Nov. 21, performing a close approach of the lunar surface on its way to a distant retrograde orbit, a highly stable orbit thousands of miles beyond the Moon.

"The Space Launch System rocket delivered the power and performance to send Orion on its way to the Moon," said Mike Sarafin, Artemis I mission manager. "With the accomplishment of the first major milestone of the mission, Orion will now embark on the next phase to test its systems and prepare for future missions with astronauts."

"The Space Launch System rocket delivered the power and performance to send Orion on its way to the Moon," said Mike Sarafin, Artemis I mission manager. "With the accomplishment of the first major milestone of the mission, Orion will now embark on the next phase to test its systems and prepare for future missions with astronauts."

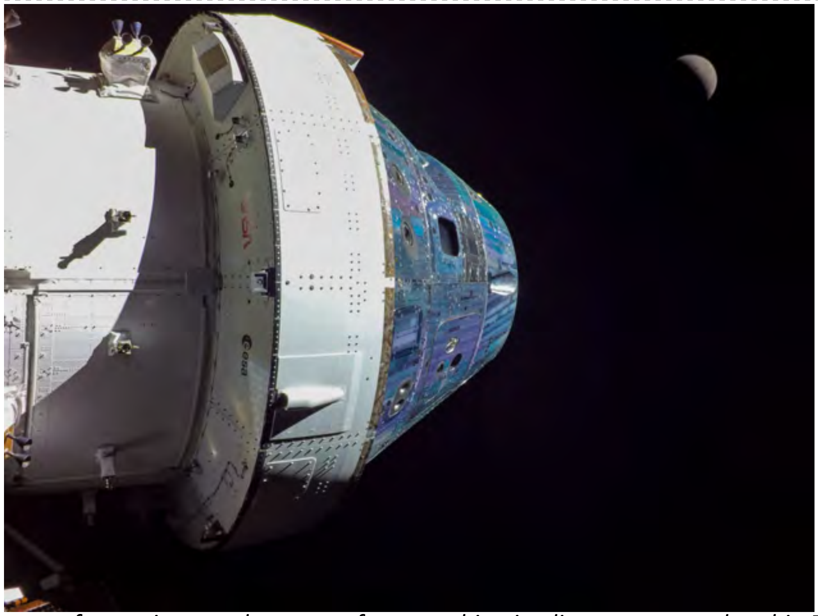
Engineers previously rolled the rocket back to the Vehicle Assembly Building (VAB) Sept. 26 ahead of Hurricane Ian and after waving off two previous launch attempts Aug. 29 due to a faulty temperature sensor, and Sept. 4 due to a liquid hydrogen leak at an interface between the rocket and mobile launcher. Prior to rolling back to the VAB, teams successfully repaired the leak and demonstrated updated tanking procedures. While in the VAB, teams performed standard maintenance to repair minor damage to the foam and cork on the thermal protection system and recharge or replace batteries throughout the system.

Artemis I is supported by thousands of people around the world, from contractors who built Orion and SLS, and the ground infrastructure needed to launch them, to international and university partners, to small businesses supplying subsystems and components.

Through Artemis missions, NASA will land the first woman and the first person of color on the surface of the Moon, paving the way for a long-term lunar presence and serving as a steppingstone for astronauts on the way to Mars.

Artemis I – Flight Day Nine: Orion One Day Away from Distant Retrograde Insertion *NASA, 2022 November 24*

https://blogs.nasa.gov/artemis/2022/11/24/artemis-i-flight-day-nine-orion-one-day-away-from-distant-retrograde-insertion/



On Flight Day 8, NASA's Orion spacecraft remains two days away from reaching its distant retrograde orbit. The Moon is in view as Orion snaps a selfie using a camera mounted on one of its solar array at 10:57 p.m. EST..

Orion is now about one day away from entering into a distant retrograde orbit around the Moon. The orbit is "distant" in the sense that it's at a high altitude approximately 50,000 miles from the surface of the Moon. Due to the distance, the orbit is so large that it will take the spacecraft six days to complete half of a revolution around the Moon before exiting the orbit for the return journey back to Earth.

During the last day in the transit to distant retrograde orbit, flight controllers performed a third in a series of planned star tracker development flight tests relative to the Sun, with a fourth planned for tomorrow. Star trackers are a navigation tool that measure the positions of stars to help the spacecraft determine its orientation. In the first three flight days, engineers evaluated initial data to understand star tracker readings correlated to thruster firings.

The spacecraft completed its sixth outbound trajectory correction burn at 3:52 p.m. CST, firing the European Service Module's auxiliary engines for 17 seconds to propel the spacecraft at 8.9 feet per second. This is the final trajectory correction before entering distant retrograde orbit. When in lunar orbit, Orion will perform three orbital maintenance burns to keep the spacecraft on course.

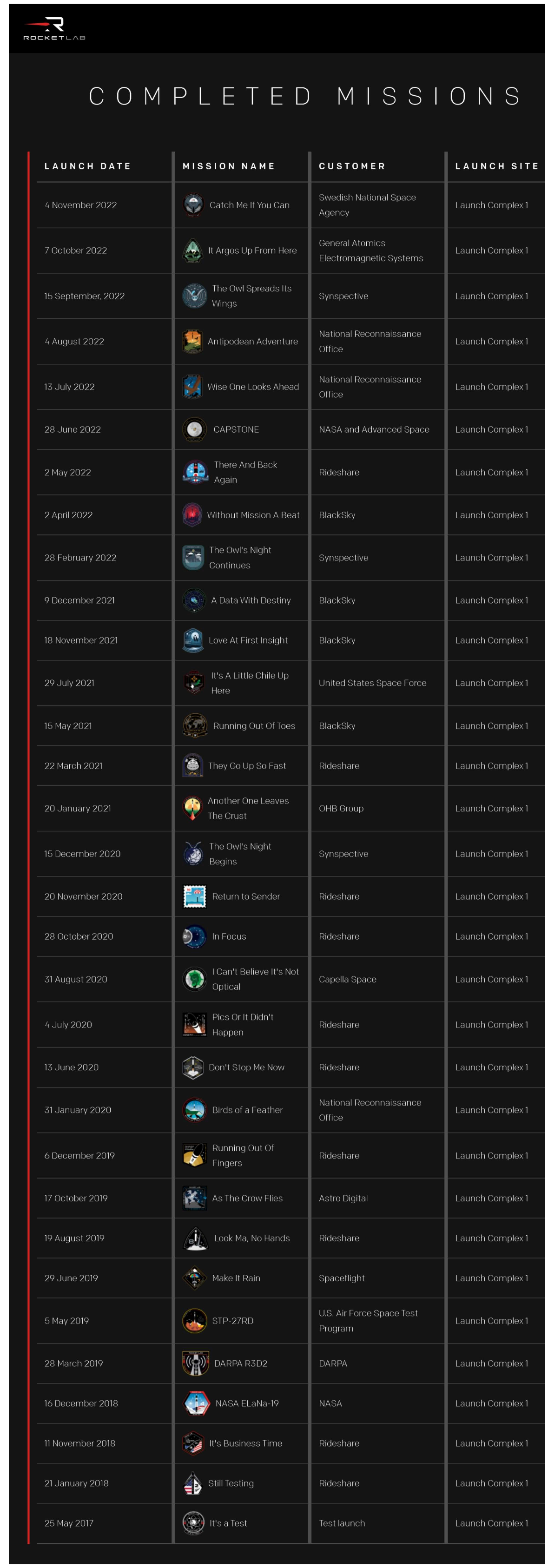
Overnight, engineers will begin a 24-hour test of the reaction control system engines to evaluate engine performance for standard and non-standard thruster configurations. This test will provide data to inform procedures and ensure that the reaction control thrusters can control Orion's orientation in an alternate configuration if there is an issue with the primary configuration.

Just after 1:42 p.m. CST on Nov. 24, Orion was traveling 222,993 miles from Earth and 55,819 miles from the Moon, cruising at 2,610 miles per hour.

NASA Television coverage of the distant retrograde orbit insertion burn, scheduled for 4:30 p.m. EST on Friday, Nov. 25. The burn is scheduled to take place at 4:52 p.m.

Rocket Lab: Launch After Launch

Rocket Lab, 2022 November 18 (with permission)


ROCKETLAB

COMPLETED MISSIONS

LAUNCH DATE	MISSION NAME	CUSTOMER	LAUNCH SITE
4 November 2022	Catch Me If You Can	Swedish National Space Agency	Launch Complex 1
7 October 2022	It Argos Up From Here	General Atomics Electromagnetic Systems	Launch Complex 1
15 September, 2022	The Owl Spreads Its Wings	Synspective	Launch Complex 1
4 August 2022	Antipodean Adventure	National Reconnaissance Office	Launch Complex 1
13 July 2022	Wise One Looks Ahead	National Reconnaissance Office	Launch Complex 1
28 June 2022	CAPSTONE	NASA and Advanced Space	Launch Complex 1
2 May 2022	There And Back Again	Rideshare	Launch Complex 1
2 April 2022	Without Mission A Beat	BlackSky	Launch Complex 1
28 February 2022	The Owl's Night Continues	Synspective	Launch Complex 1
9 December 2021	A Data With Destiny	BlackSky	Launch Complex 1
18 November 2021	Love At First Insight	BlackSky	Launch Complex 1
29 July 2021	It's A Little Chile Up Here	United States Space Force	Launch Complex 1
15 May 2021	Running Out Of Toes	BlackSky	Launch Complex 1
22 March 2021	They Go Up So Fast	Rideshare	Launch Complex 1
20 January 2021	Another One Leaves The Crust	OHB Group	Launch Complex 1
15 December 2020	The Owl's Night Begins	Synspective	Launch Complex 1
20 November 2020	Return to Sender	Rideshare	Launch Complex 1
28 October 2020	In Focus	Rideshare	Launch Complex 1
31 August 2020	I Can't Believe It's Not Optical	Capella Space	Launch Complex 1
4 July 2020	Pics Or It Didn't Happen	Rideshare	Launch Complex 1
13 June 2020	Don't Stop Me Now	Rideshare	Launch Complex 1
31 January 2020	Birds of a Feather	National Reconnaissance Office	Launch Complex 1
6 December 2019	Running Out Of Fingers	Rideshare	Launch Complex 1
17 October 2019	As The Crow Flies	Astro Digital	Launch Complex 1
19 August 2019	Look Ma, No Hands	Rideshare	Launch Complex 1
29 June 2019	Make It Rain	Spaceflight	Launch Complex 1
5 May 2019	STP-27RD	U.S. Air Force Space Test Program	Launch Complex 1
28 March 2019	DARPA R3D2	DARPA	Launch Complex 1
16 December 2018	NASA ELaNa-19	NASA	Launch Complex 1
11 November 2018	It's Business Time	Rideshare	Launch Complex 1
21 January 2018	Still Testing	Rideshare	Launch Complex 1
25 May 2017	It's a Test	Test launch	Launch Complex 1

Our Biggest Launch Year Yet!

Talk about a busy year for Electron! After maintaining a monthly launch cadence since April 2022, we've broken our previous annual launch record of seven missions. As of November, nine Electron rockets have taken to the sky this year and we're on track to hit double digits with a launch scheduled in December.

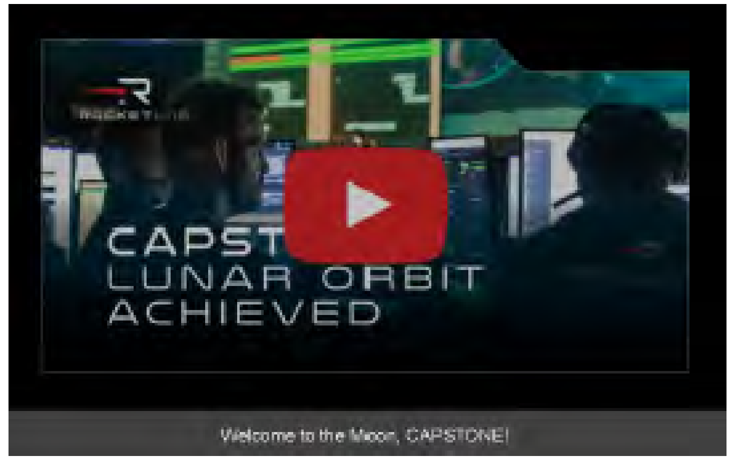
Since our last update, we've launched five missions including "Wise One Looks Ahead" and "Antipodean Adventure" for the U.S. National Reconnaissance Office; "The Owl Spreads Its Wings" for Synspective, which broke records of its own by delivering our 150th satellite to orbit and the 300th Rutherford engine flown to space; "It Argos Up From Here" for General Atomics Electromagnetics Systems; and "Catch Me If You Can," a dedicated launch for the Swedish National Space Agency, and it was also a recovery mission to boot.

If you missed any of these missions, check out the webcasts on YouTube, or learn more on our website.

Rocket Lab: Launch After Launch

CAPSTONE Enters Lunar Orbit

It seems like an age since we launched CAPSTONE as our 27th Electron mission, but time flies when you're flying to the Moon! On Nov. 13, after five months of traveling through space, the CAPSTONE spacecraft reached its lunar destination - a unique orbit around the Moon where the future Gateway space station will support NASA's Artemis missions.



Learn all about how we made the CAPSTONE mission possible here.

Inaugural U.S. Launch Announced

You read that right, our long-awaited inaugural launch from the U.S. is happening!

The "Virginia is for Launch Lovers" mission will lift-off from Launch Complex 2 in Virginia, deploying spacecraft for HawkEye 360 during a launch window that opens December 7th.

Ready to join us for this huge event? View the launch in person by visiting viewing locations on Chincoteague Island including Robert Reed Park on Main Street or Beach Road spanning the area between Chincoteague and Assateague Islands. Outside of Chincoteague, the Atlantic-facing beaches in Virginia, Maryland and Delaware provide good viewing spots, and the NASA Visitor Center at Wallops will be open for this launch.

If you can't make it in person, a live launch webcast will also be available at www.rocketlabusa.com/live-stream from around T-40 minutes..

Learn More.

Rocket Lab: Launch After Launch

Rocket Lab's VP of Launch System Shaun D'Mello, U.S. Senator for Mississippi Roger Wicker, Stennis Space Director Dr. Richard J. Gilbrech, and U.S. Senator for Mississippi Cindy Hyde-Smith cut the ribbon at the Archimedes Test Complex on Nov. 4.

Introducing the Archimedes Test Complex

Big engines need bigger testing facilities - and that's where our new engine testing site, the Archimedes Test Complex comes in!

Recently we cut the ribbon on the Archimedes Test Complex at the historic Stennis Space Center in Mississippi, officially kicking off operations at this new site. The complex will exclusively test the Archimedes engines as the Neutron launch vehicle becomes a reality.

We can't wait to breathe fire in Mississippi as we develop the rocket of the future.

Reusable Rocket Engines

For the first time, we successfully test fired a Rutherford first stage engine that was recovered from the ocean! You read that right. This is a significant technical achievement in making Electron the world's first reusable orbital small rocket.

The refurbished Rutherford engine passed all of the same rigorous acceptance tests Rocket Lab performs for every engine, including 200 seconds of engine fire and multiple restarts. Data from the test fire shows the engine performed to the same standard of a newly-built Rutherford engine, keeping us on track for reusability.

Rocket Lab: Launch After Launch

More Than Rockets...

The next generation of Rocket Lab designed and built spacecraft are taking shape in our cleanrooms. That's right, we build more than just rockets in this lab.

We're building four bespoke spacecraft for Varda Space Industries to support in-space manufacturing, enabling high-value products to be made in zero-gravity and returned to Earth in re-entry capsules.

This program is just one of many underway within our space systems teams at the moment, including our contract to design and build 17 spacecraft buses for Globalstar's new Low Earth Orbit satellites, supported by our newly expanded spacecraft production facility in Long Beach.

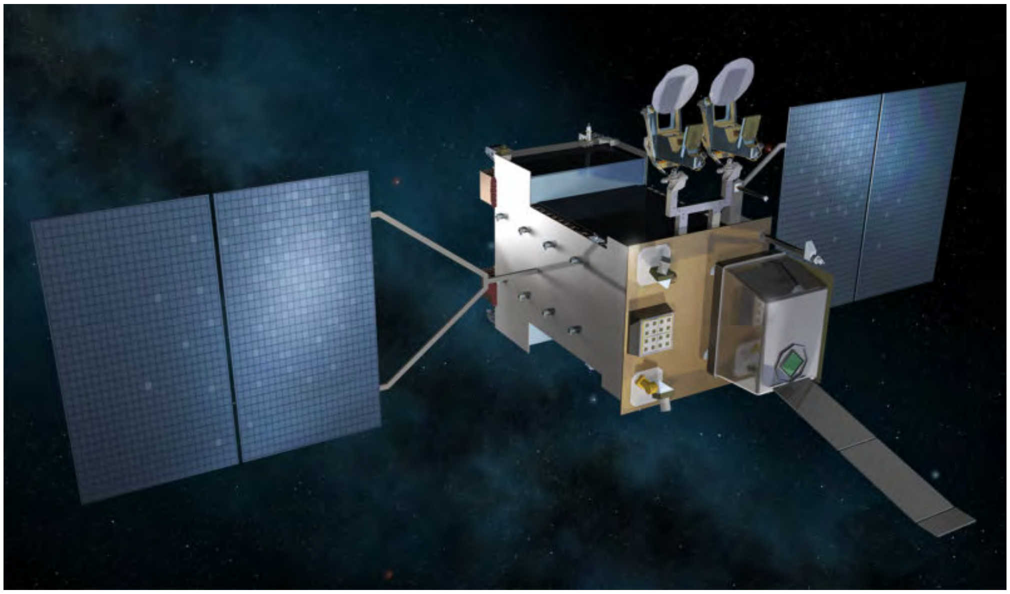
Powering the Cosmos!

Power and Propulsion Element

We recently delivered the final solar panels to Maxar that will fly on the Power and Propulsion Element (PPE) for NASA's Gateway lunar space station. The solar panels incorporate the quadruple-junction "Z4J" solar cells and utilized automated assembly methods to create high-production solar panels. The PPE is a high-power, solar electric propulsion spacecraft that will provide power, high-rate communications, altitude control, and orbital transfer capabilities.

Why does Gateway sound familiar? It is part of NASA's Artemis program that we've supported with missions like CAPSTONE and Artemis 1.

Rocket Lab: Launch After Launch



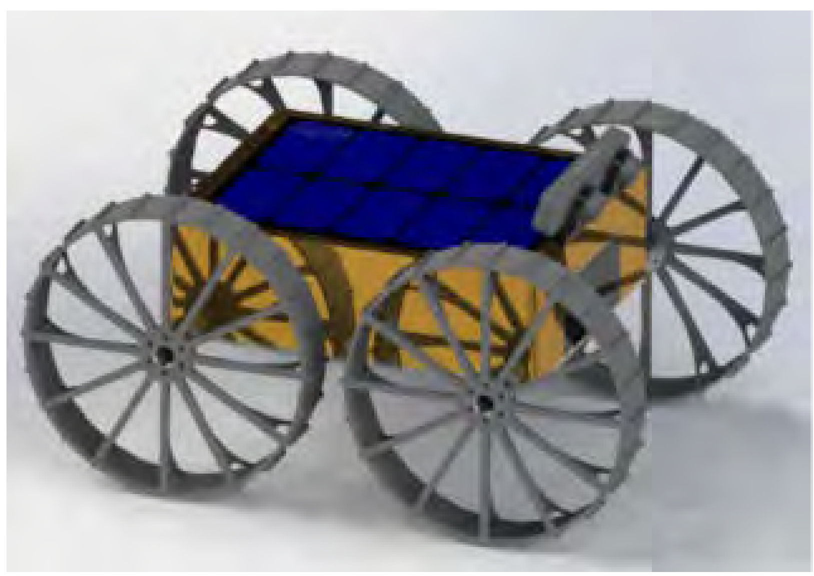
OPIR GEO Satellites

We recently announced we're providing high-efficiency, radiation-hardened Coverglass Interconnected solar Cell (CIC) assemblies to power three Lockheed Martin Next Gen OPIR GEO satellites for the U.S. Space Force that will detect missiles and counter-space threats globally.

Rocket Lab's CICs will be integrated into the solar panels and arrays on the spacecraft. The first of the three satellites is scheduled to launch in 2025.

CADRE Robots

NASA's Jet Propulsion Laboratory selected Rocket Lab to supply our IMM solar panels to power the next generation of shoe-box-sized mobile robots as part of the Cooperative Autonomous Distributed Robotic Explorers (CADRE) program. The CADRE robots will be able to explore as a group to collect data in the hardest-to-reach places on the Moon, Mars and beyond.



Constantine Papacosmas, one of Canada's foremost amateur astronomers

by Dr. David H. Levy, Comet and Asteroid Hunter, Co-Discoverer, Shoemaker-Levy 9 (2022 December article)

As I get older and older, the list of people who depart gets longer and increases with a greater frequency. But now I find myself writing, for the third month in a row, about the loss of someone who meant a lot to me and without whom I do not know how I will continue my own journey through the night sky.

Constantine Papacosmas introduced himself to me the first night I entered the old observatory of the Montreal Centre of the Royal Astronomical Society of Canada. The young observer had just completed a truly fabulous 8-inch reflector which we used once or twice. At that time he was brilliant, creative and inspiring. Within a few years we had become great friends and we spent a lot of time together. One afternoon while walking down a hill to my junior high school classes, a car passed me, then slammed on its brakes about 300 meters away. Putting the car in reverse, the driver screeched backward until it reached me. “Hello David!” It was Constantine.

You might have read a few months ago the story of how I got my own 8-inch reflector, Pegasus. It was a loaner scope. By the time David returned from college, Constantine suggested that my parents buy me the telescope. We gathered in our living room and my parents listened carefully as Constantine explained why they should make such an expensive purchase for me, and not for any of my siblings. He correctly persuaded them that I was never about to lose my passion for the night sky. By the end of that day my parents agreed to buy the telescope for $400, (which would, in 2022, amount to $3761). More important than that, that afternoon gave Dad a chance to form a genuine bond with Constantine that he never forgot.

In 1978, while resting in our home, Dad walked in and inquired how Constantine was doing. I had had a mild falling out with him, but I simply replied we hadn't been in touch for a while. Dad had something to say about that. "You can count on the fingers of one hand the number of close friends you have had since your youth. You just cannot afford to lose those precious friends." The minute he left the room I telephoned Constantine and we picked up where we had left off.

By 1984, my Dad was dying from Alzheimer's disease. He could barely recognize Mom, let alone me. But he remembered Constantine. The two began talking.

"Constantine, do you know what is happening to me?"

"Yes, I am sorry but I am afraid I do know."

"Constantine, I can't live like this. I wish…. I wish I were dead." Constantine told me that story many years later.

Those of us who knew the older Constantine may not appreciate the skill, the intelligence, the humor, and the talent of the younger amateur astronomer. But they remembered him well enough to present him the Centre's highest medal for excellence, the Charles Good award. His clock that I received shortly before his death now tells Montreal time. It is the Constaclock.

Farewell, Constantine, and thank you for enriching my nights under the stars.

Constantine Papacosmas, one of Canada's foremost amateur astronomers

(left to right) Dr. David H. Levy, Constantine Papacosmas, and Bill Strople at a Stellafane meeting

Peregrine Spacecraft On the Move

by Astrobotic, 2022 November 16 (with permission)

About Astrobotic

*Astrobotic is the Moon company and more. We develop advanced navigation, operation, power, testing, and computing systems for spacecraft. Our fleet of lunar landers and rovers deliver payloads to the Moon for companies, governments, universities, non-profits, and individuals. To date, we have two fully funded lunar lander missions on the books, and more than 60 prior and ongoing NASA and commercial technology contracts worth upwards of $350 million. Astrobotic was founded in 2007 and is headquartered in Pittsburgh, PA. www.astrobotic.*com

Pittsburgh, PA - November 16, 2022 – Astrobotic announced today the Peregrine lunar lander has left their headquarters for the last time. The spacecraft is now headed to test facilities for final acceptance testing before its first launch to the Moon in Q1 2023.

Peregrine's acceptance campaign will subject the spacecraft to a battery of industry-standard tests that will prove Peregrine can endure the launch environment aboard United Launch Alliance's (ULA) Vulcan Centaur rocket, as well as the harsh environments of space and the lunar surface. These spacecraft-level tests follow years of prototyping, engineering analyses, modeling, simulations, and sub-assembly tests that provide high confidence in the fully assembled vehicle.

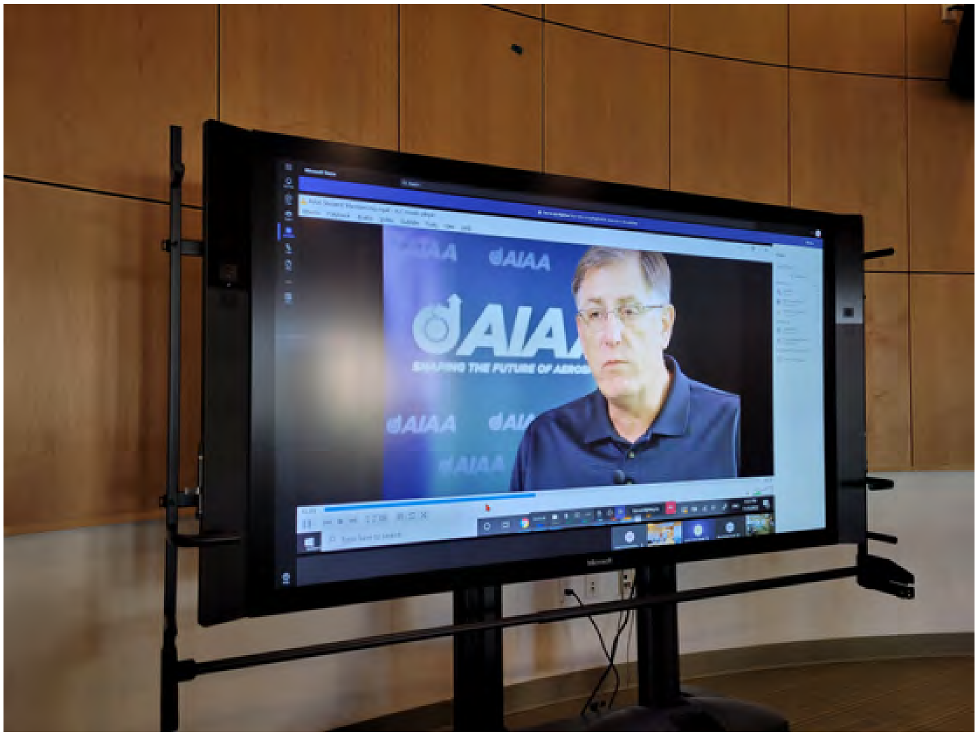
"A few years ago, we were an 18-person team with a dream. Today, Astrobotic's 200+ staff and our payload customers can celebrate as our Peregrine lander continues its historic mission to lead America back to the Moon for the first time in 50 years," says John Thornton, Astrobotic CEO.

Slated to be the first commercial lunar lander to ever soft land on the Moon, Peregrine is carrying payloads from NASA's Commercial Lunar Payload Services initiative that was awarded in 2019. Though Astrobotic had payload customers prior to NASA, that win propelled the Peregrine program forward. Despite the pandemic slowing supply chains and disrupting workflow during critical program phases, the team managed to progress quickly toward Peregrine's upcoming delivery to ULA.

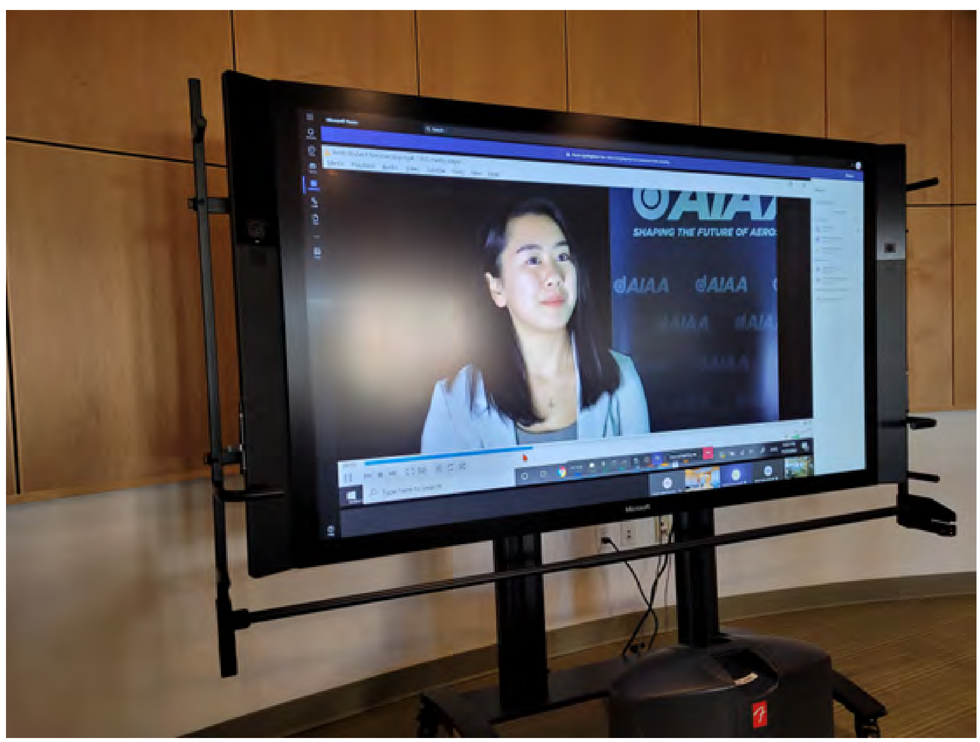
"The space industry can move slowly sometimes – but our nimble engineering team proved their dedication and worked around the clock to ensure we met our deadlines," says Sharad Bhaskaran, Astrobotic's Peregrine Mission One Director. "There are folks finishing up Peregrine that were here since its inception. We've added a dedication plaque with all of our signatures to honor that work– every person is important to achieving our mission to the Moon."

After acceptance testing, Peregrine will be shipped to Cape Canaveral, Florida for integration with Vulcan Centaur. After launch, Peregrine will separate from the rocket and Astrobotic's Mission Control Center (AMCC) will then navigate the spacecraft to the Moon for landing. The AMCC will then complete the mission by supporting lunar surface science operations.

(November 5) "AIAA LA-LV Saturday" Values and Demo *(Screenshots / photos only)*

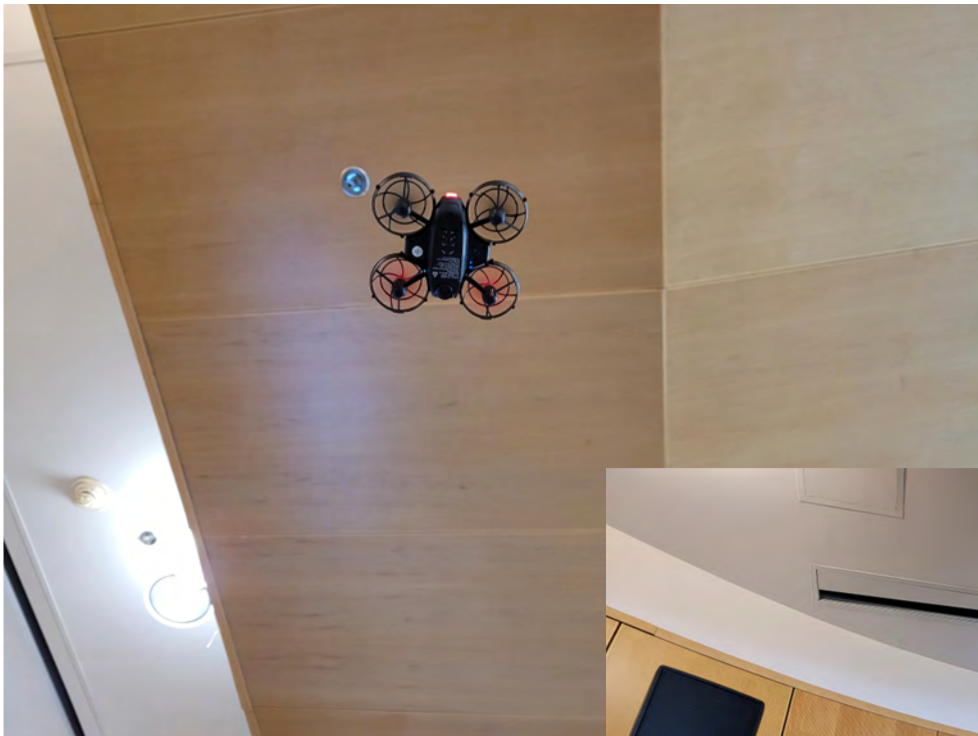


(Left) Mr. Dan Dumbacher, the AIAA Executive Director, explaining the values and benefits of the membership, in the video for the AIAA Professional Membership made by the AIAA National Office. The video was played and explained / discussed in more details.

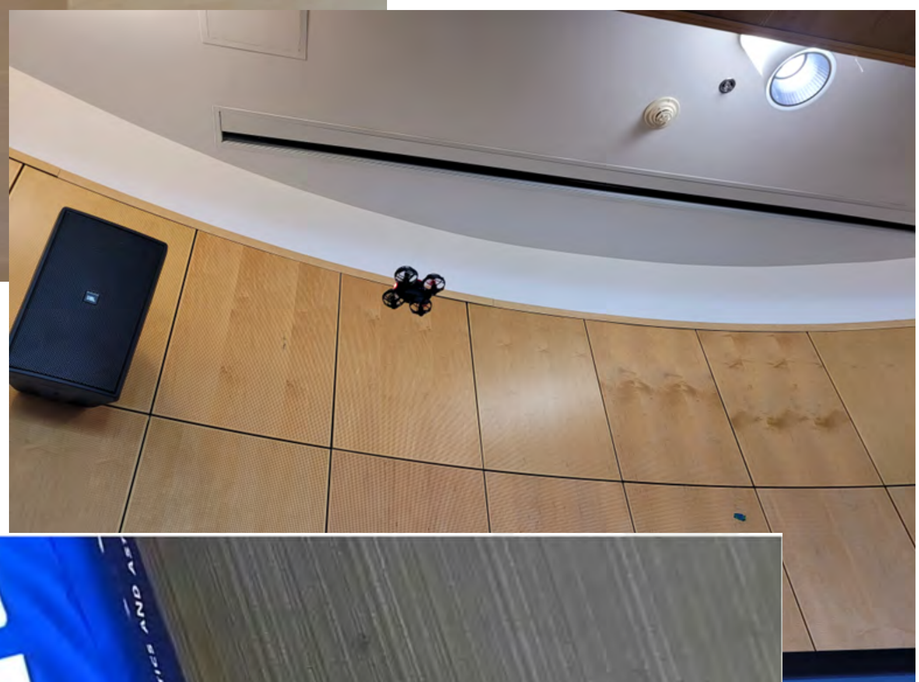


(Right) Ms. Emma Chao explaining why she joined AIAA University Student membership when she was in UNLV, and how she was excited about AIAA, in the AIAA University Student Membership video.

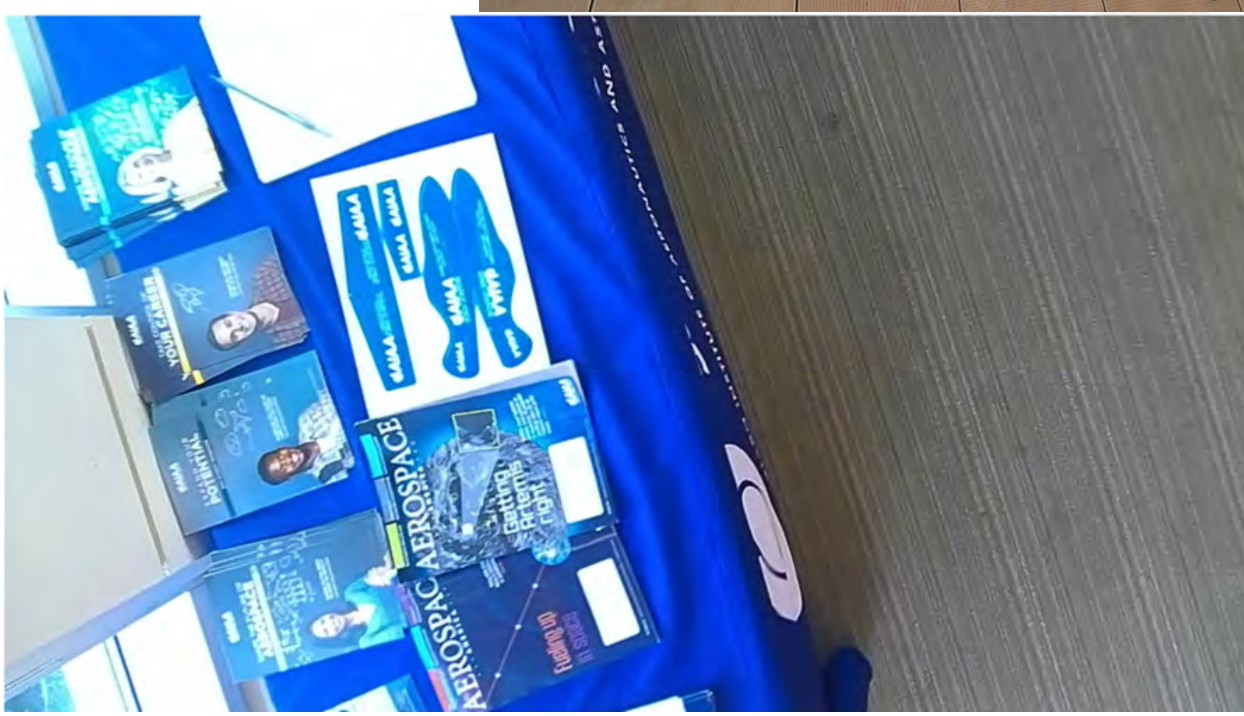
(November 5) "AIAA LA-LV Saturday" Values and Demo *(Screenshots / photos only)*



(Left) Since it's getting colder toward the winter, an indoor drone is flown as a demo first, before an outdoor drone demo in spring / summer.



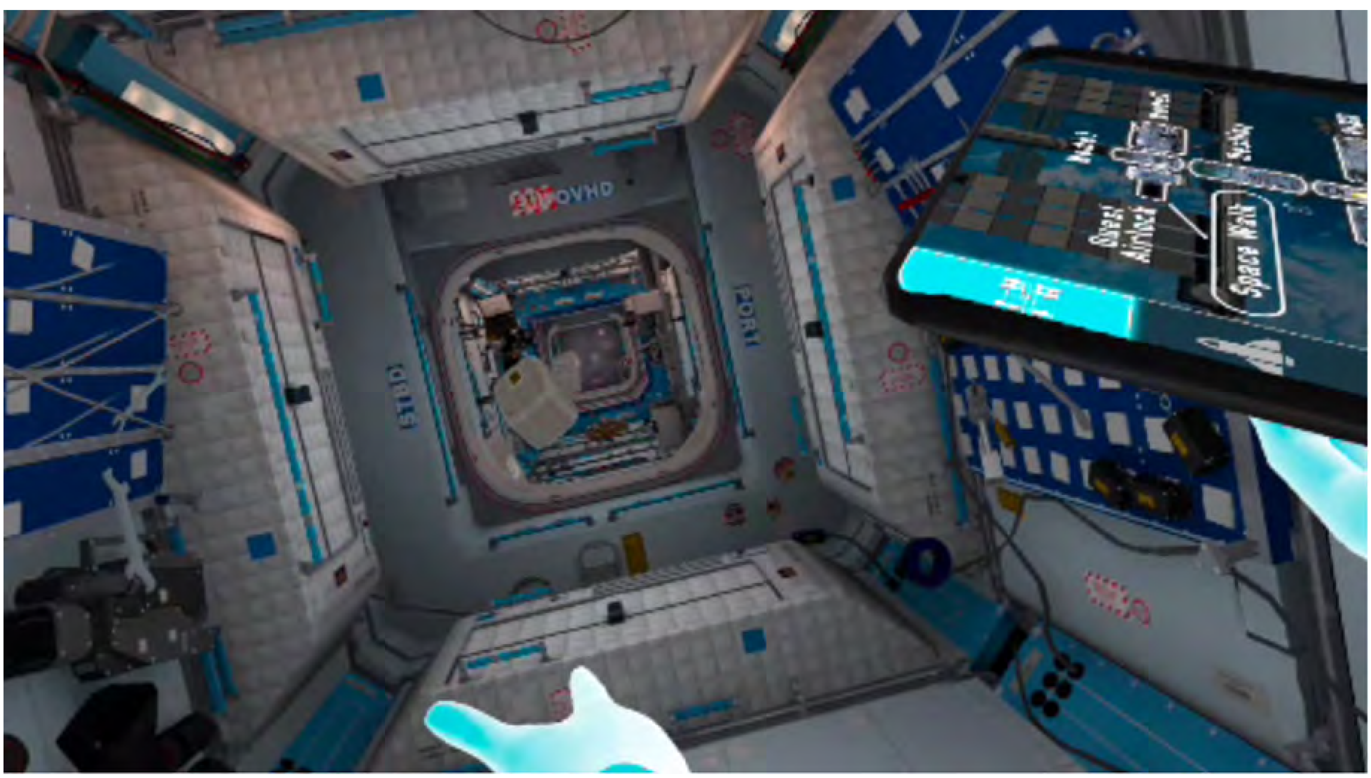
(Right) This indoor drone is safe and flying around the room, hopping from one corner of the room to another, like from one continent to another.



drone demo video with the onboard carmea for remote sensing (https://www.youtube.com/watch?v=HKG29fuXOgQ)

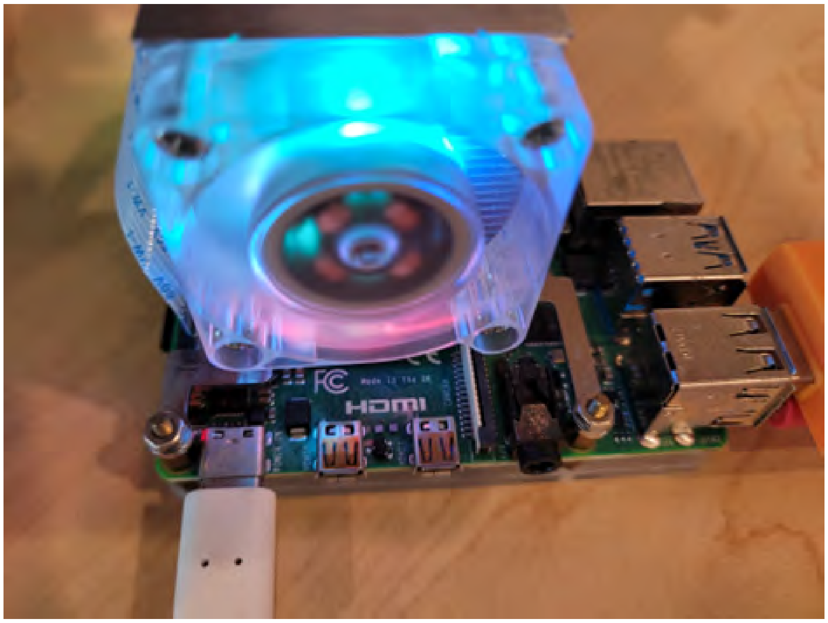
(November 5) "AIAA LA-LV Saturday" Values and Demo *(Screenshots / photos only)*

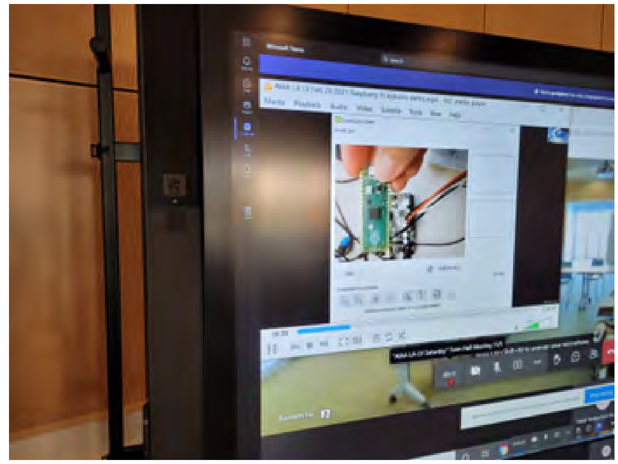
AIAA University Student Membership video, with Ms. Emma Chao (second from left), and Mr. Luis Cuevas (first from right) (AIAA LA-LV Education / Collegiate Chair) https://www.youtube.com/watch?v=FaitcKXBt-M



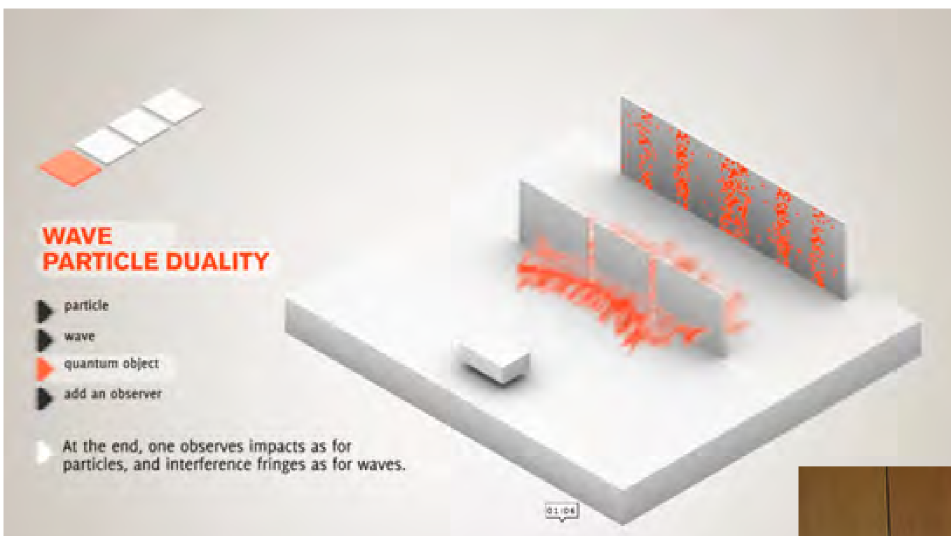
ISS in virtual reality is inspiring and can help educators and students. https://www.youtube.com/watch?v=B_J3lD12Ic8

(November 5) "AIAA LA-LV Saturday" Values and Demo *(Screenshots / photos only)*





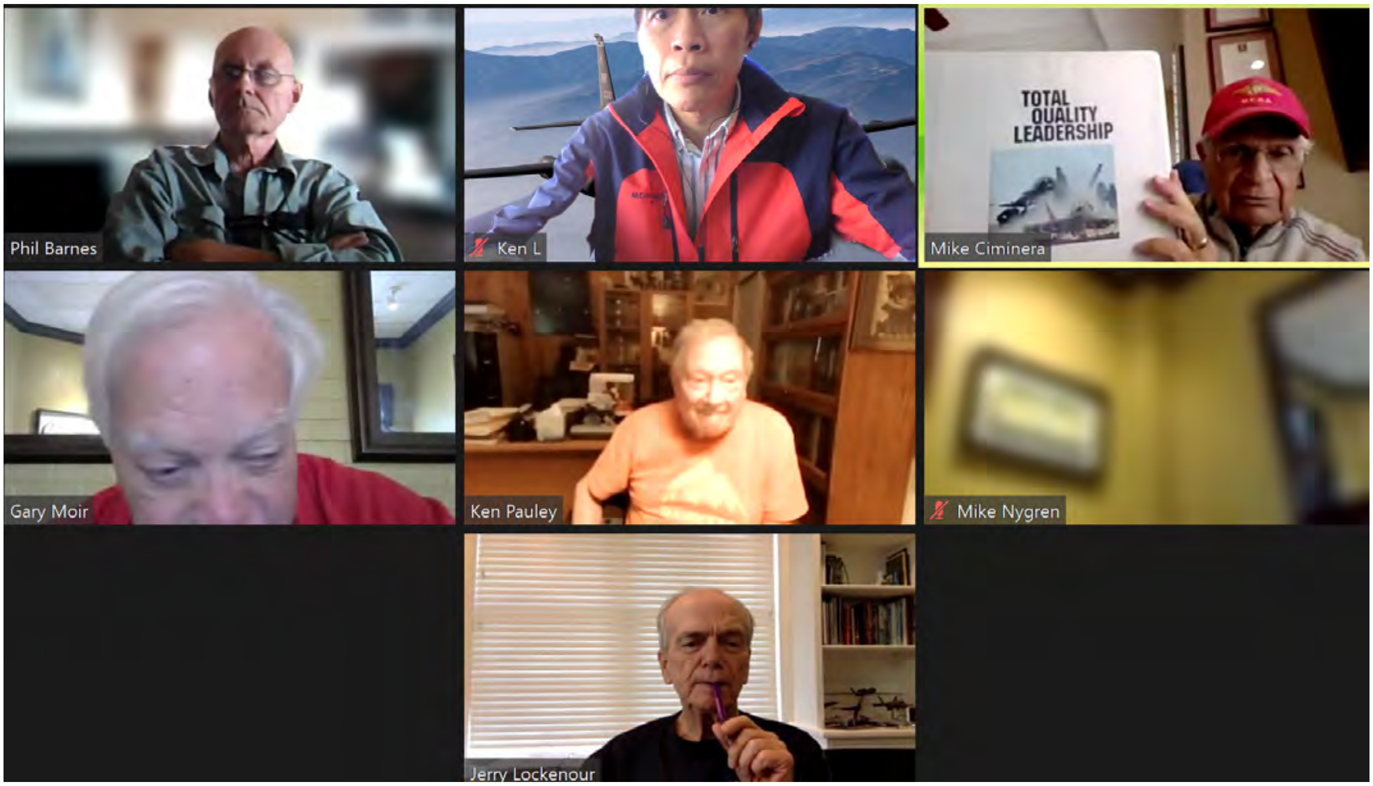
Raspberry Pi (left) and Arduino (right) demo.



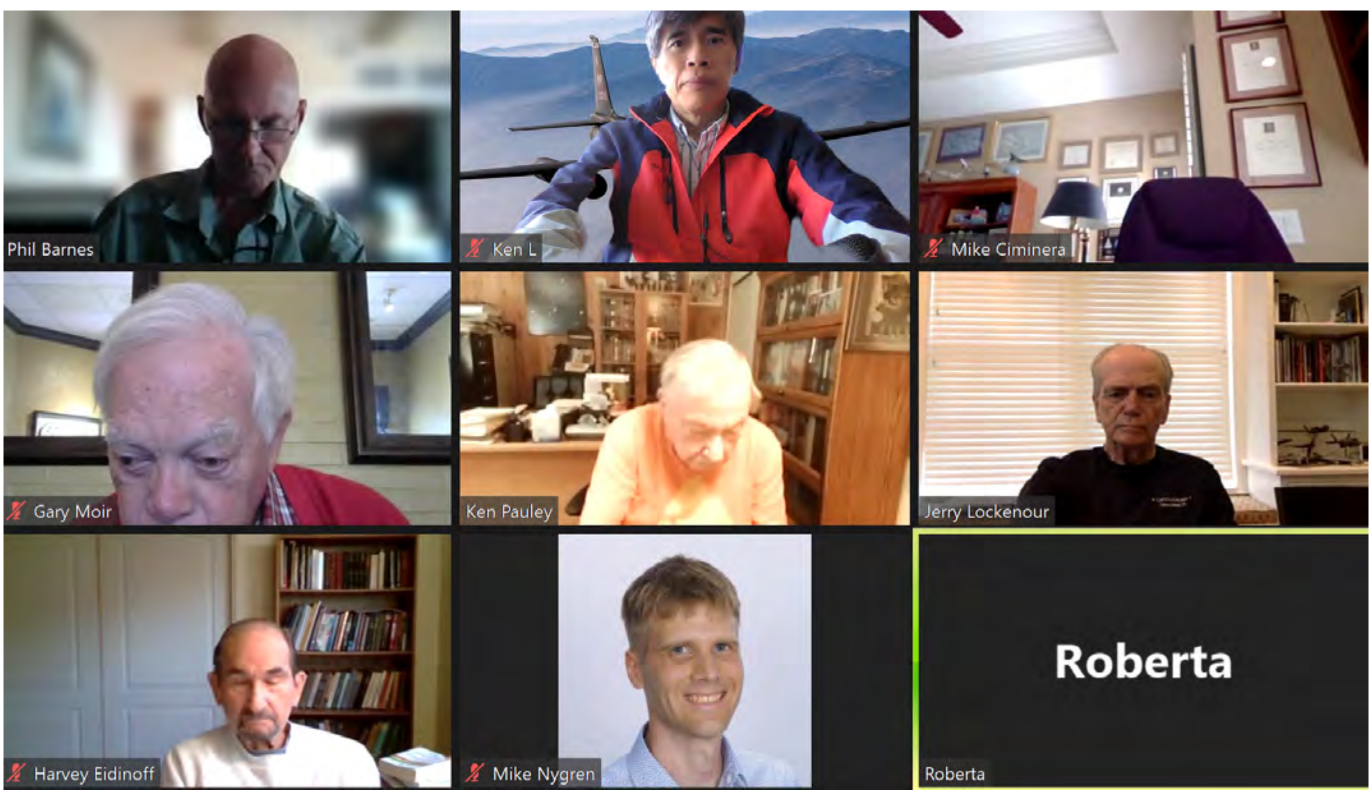
(Left) A demo on the basics of quantum computers: wave-particle duality.

(Right) A demo on the Mars driving software (courtesy of Mr. Alan Chan).

(November 9) Aero Alumni November (Hybrid) Luncheon *(Screenshots Only)*



Retirees (Aero Alumni) attending the meeting, discussing exciting topics on Mr. Gary Moir's efforts for the Apollo 17 50th Anniversary, Mr. Ken Pauley's presentation on the 1910 Los Angeles International Air Meet / Air Show, Leadership in Aerospace, F-35, Ukraine / Taiwan situations, defense, book publications etc.

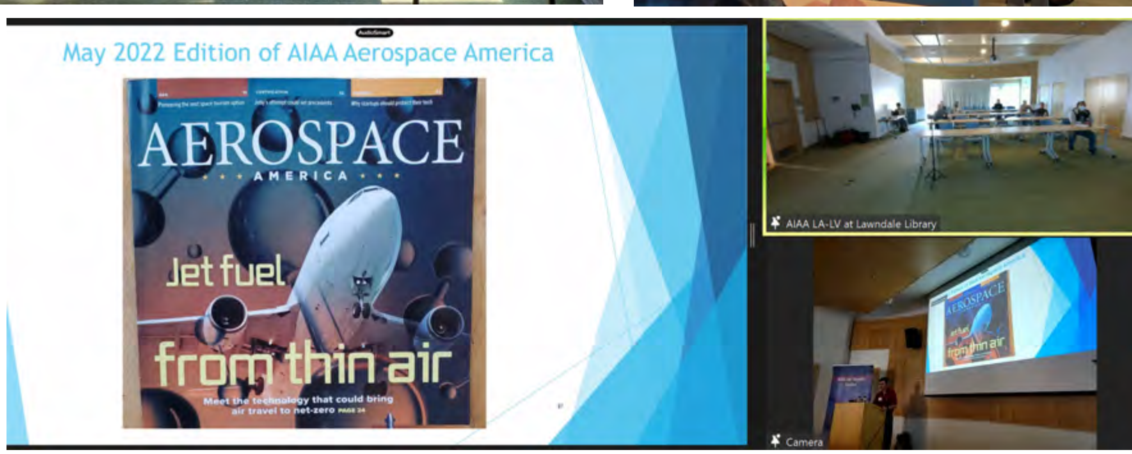


Some more attendees joined/called in, and shared thoughts about Artemis I and SpaceX efforts.

(November 12) Special Topics in Aeronautics: 1. Introduction to Sustainable Aviation; 2. Design of Electrified Propulsion Aircraft by Dr. Marty Bradley

(Screenshots only) (Video Recording on YouTube: https://youtu.be/CwZDmRsUY0)

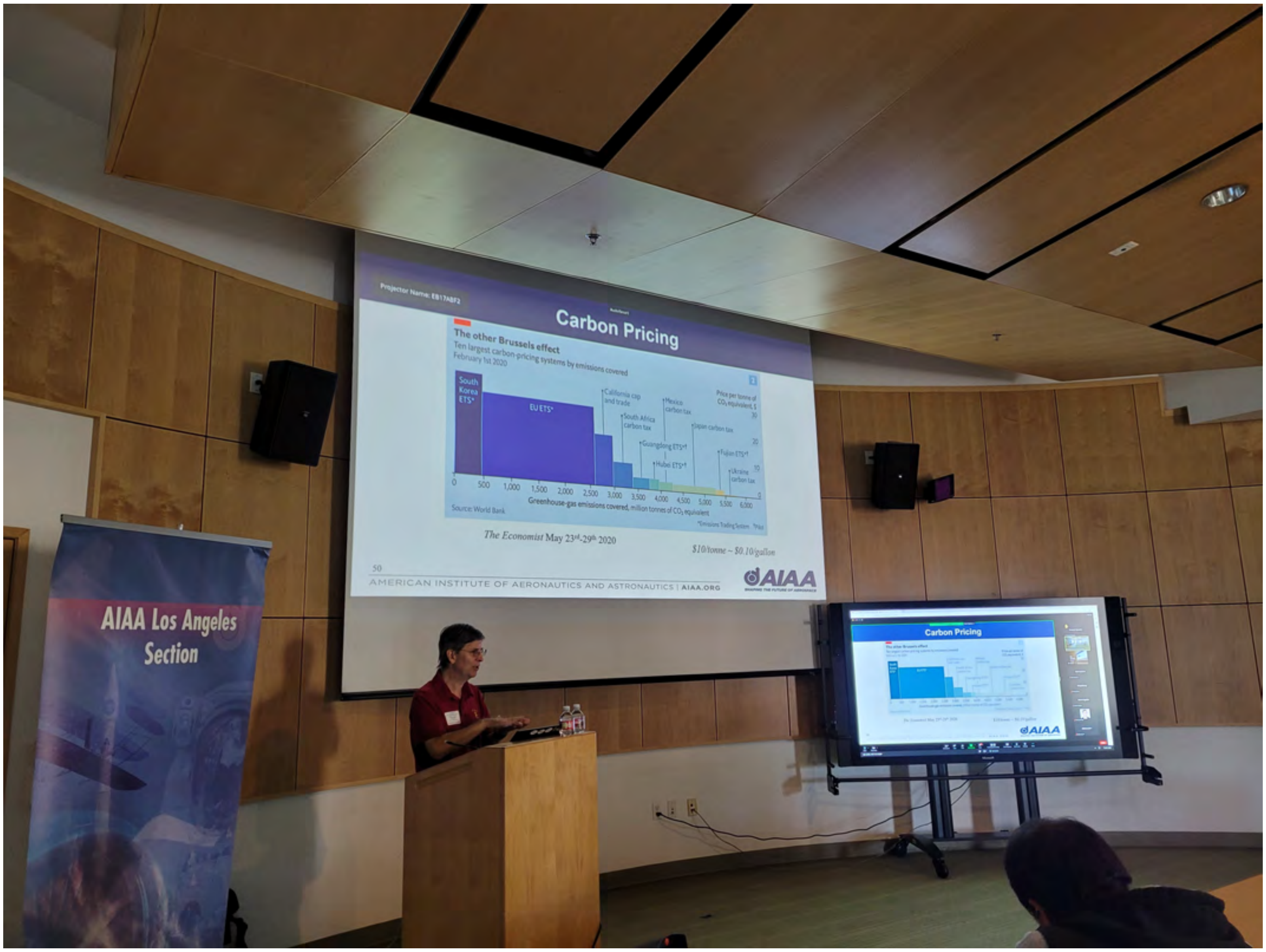
A day right after the Memorial Day, the AIAA LA-LV Section welcome the attendees for an exciting meeting with the industry leader.



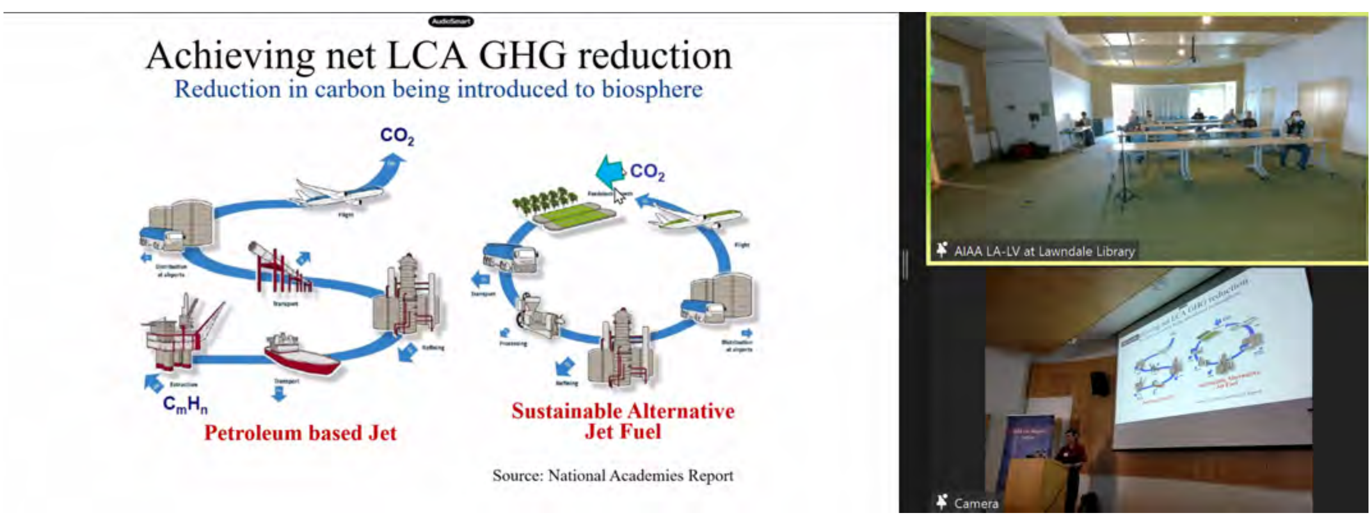
(Upper left) Check-in table, (upper right) Dr. Marty Bradley interacting with the attendees, (bottom) it's an important topic!

(November 12) Special Topics in Aeronautics: 1. Introduction to Sustainable Aviation; 2. Design of Electrified Propulsion Aircraft by Dr. Marty Bradley

(Screenshots only)



Dr. Marty Bradley speaking, explaining carbon pricing, in Part I of the talk on Sustainable Aviation.

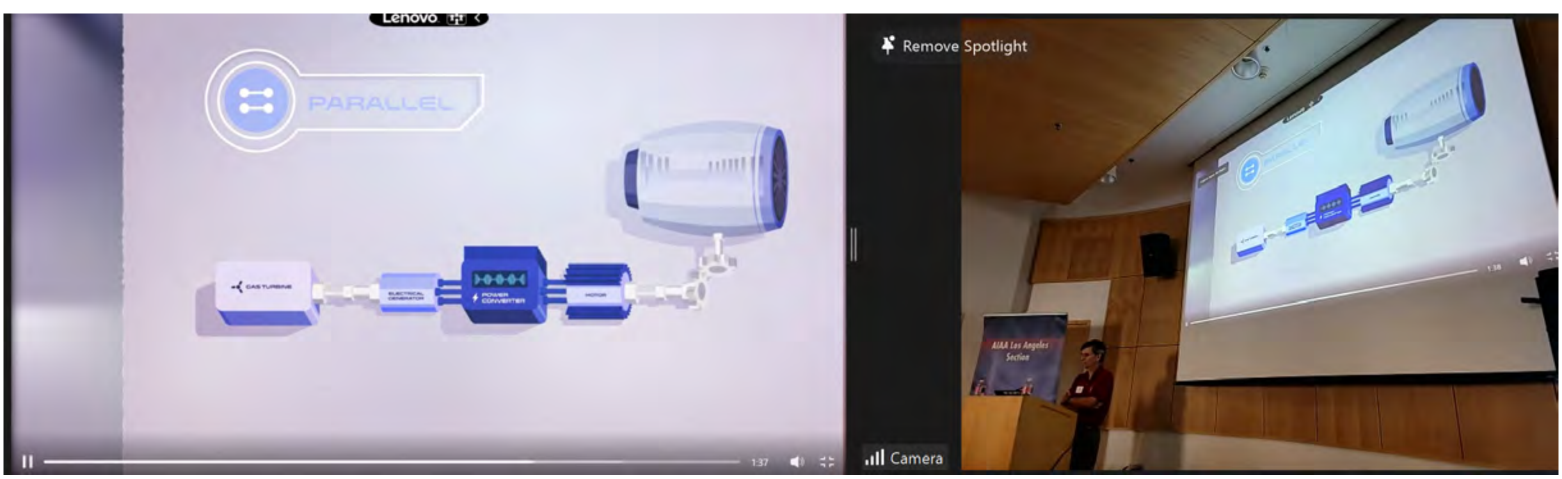


The industry trend is to reduce carbon emission into the biosphere, different from the petroleum based aviation.

(November 12) Special Topics in Aeronautics: 1. Introduction to Sustainable Aviation; 2. Design of Electrified Propulsion Aircraft by Dr. Marty Bradley

(Screenshots only)

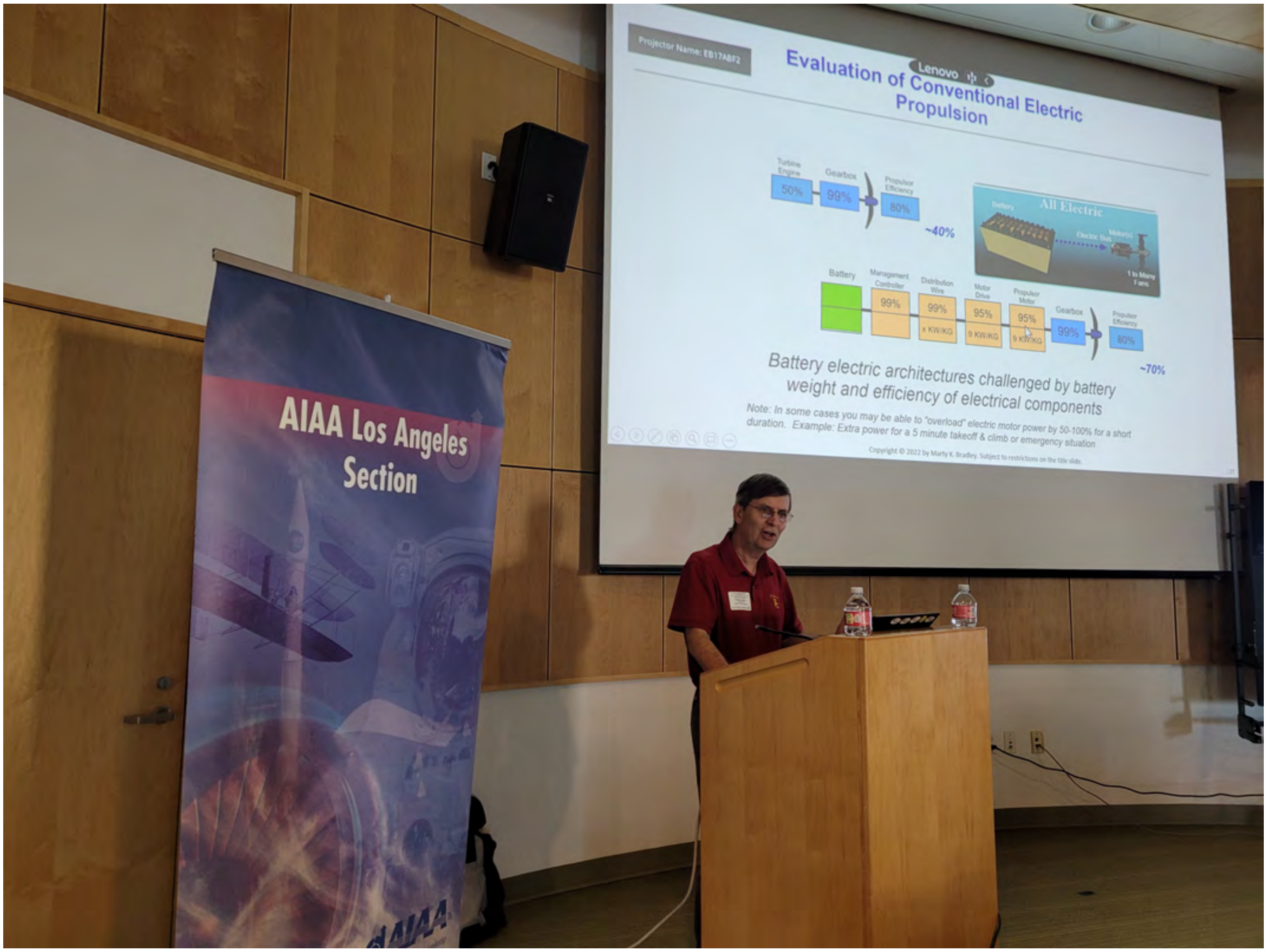
Dr. Marty Bradley speaking on the in-depth development of aircraft using electrified propulsion.



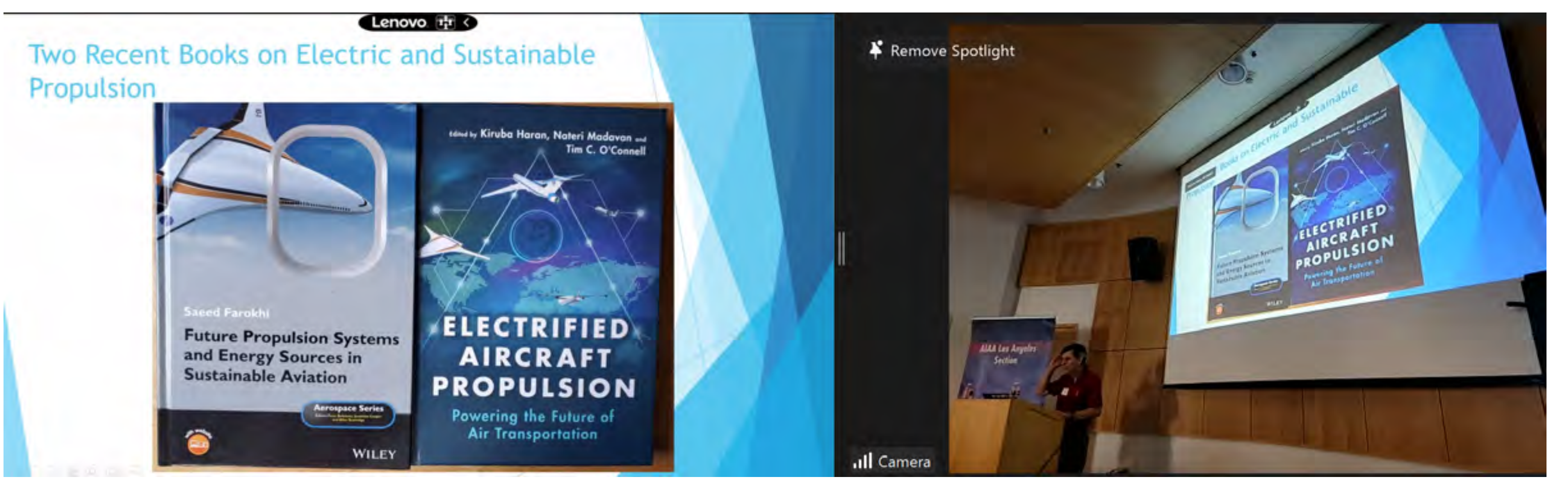
With various combinations of electrical components, the pros and cons of each propulsion architecture were discussed.

(November 12) Special Topics in Aeronautics: 1. Introduction to Sustainable Aviation; 2. Design of Electrified Propulsion Aircraft by Dr. Marty Bradley

(Screenshots only)



Dr. Marty Bradley compared several models of battery electric architectures for electrified propulsion.



Two good books on this topic were mentioned by Dr. Marty Bradley.

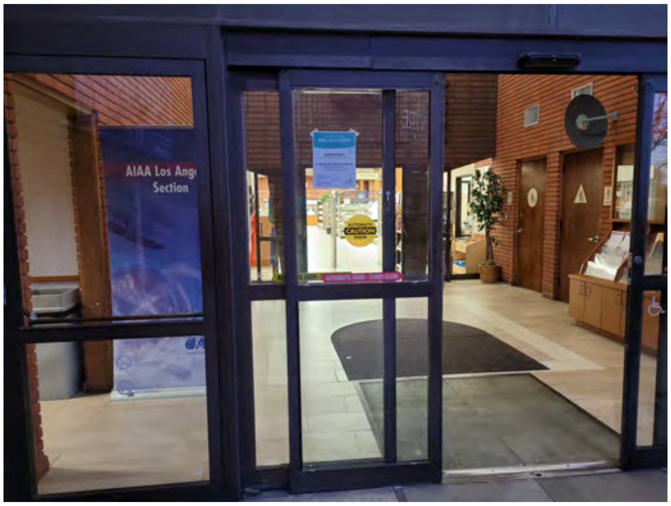
(November 12) Special Topics in Aeronautics: 1. Introduction to Sustainable Aviation; 2. Design of Electrified Propulsion Aircraft by Dr. Marty Bradley

(Screenshots only)

We are truly grateful for Dr. Marty Bradley! It's really our great pleasure and honor! People enjoyed and loved the lecture!

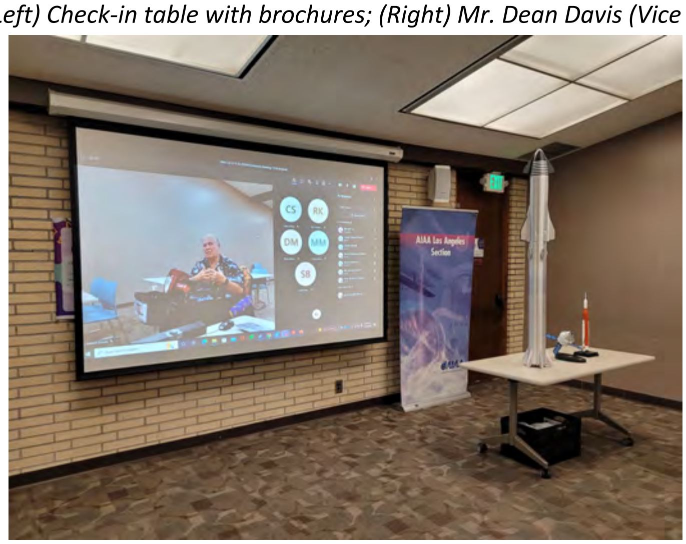
Dr. Marty Bradley engaging in interactive Q&A with the on-site and on-line attendees / audience.

(November 19) AIAA LA-LV Educators (K-12 STEAM) Meeting 11/19: Values and Demo *(Screenshots only)*



A few days before Thanksgiving, the AIAA LA-LV Section welcomed the community for an exciting meeting with the K-12 STEAM Educators.

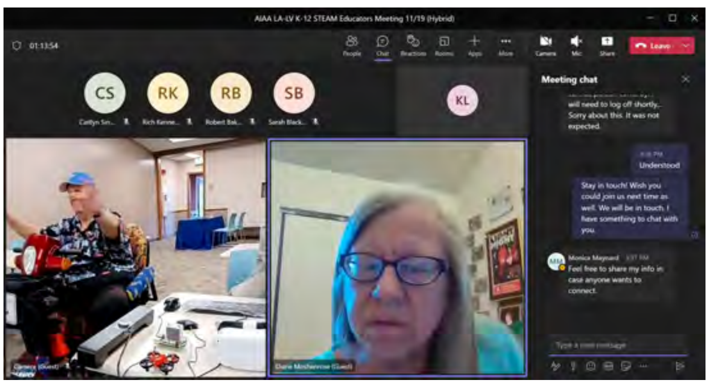
(Left) Check-in table with brochures; (Right) Mr. Dean Davis (Vice Chair, AIAA LA-LV Section) introducing himself and welcoming attendees.



(Left) Dean Davis with the nice models he brought for demo; (Right) Ms. Monica Maynard saying hello and introducing herself.

(November 19) AIAA LA-LV Educators (K-12 STEAM) Meeting 11/19: Values and Demo *(Screenshots only)*

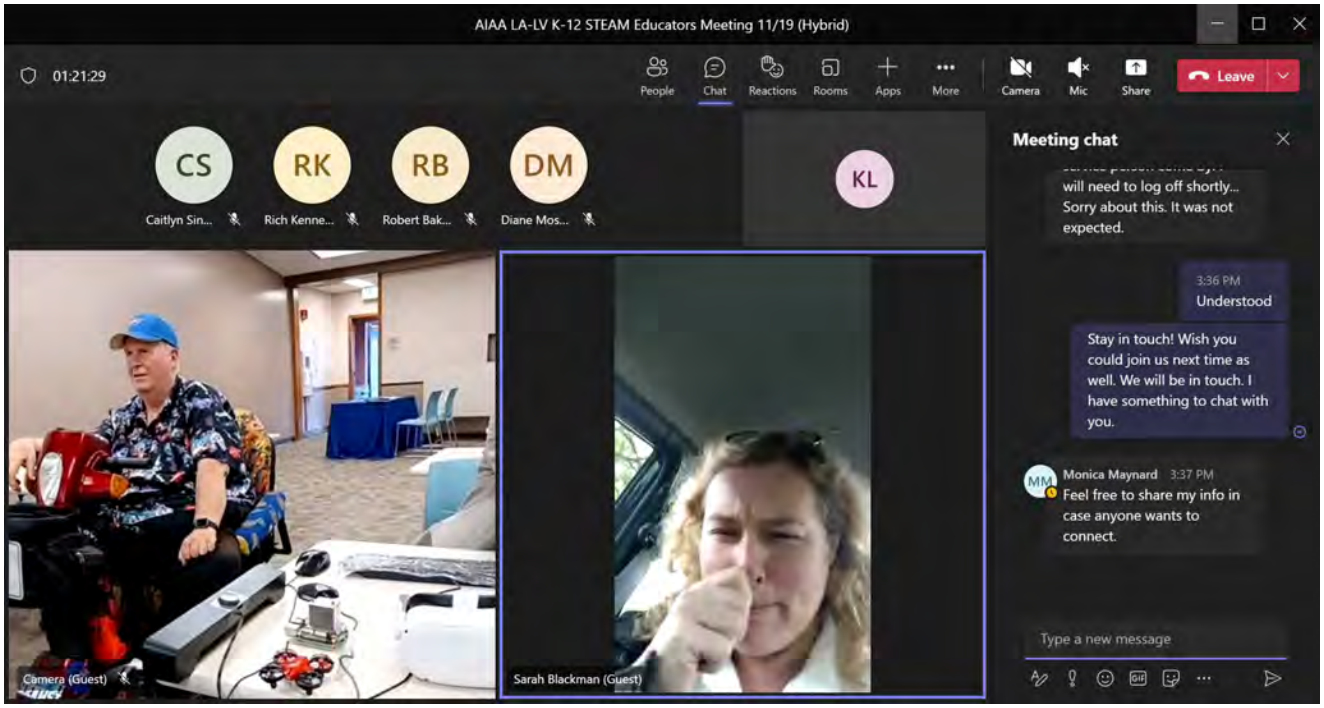
(Left) Ms. Diane Moshenrose introducing herself; (Right) Wonderful models from Dean Davis: the Starship, Orion spacecraft, SLS.



Diane expressing her interests in K-12 STEAM Outreach.

Ms. Monica Maynard, a long-term AIAA Educator Member, explaining her recent efforts in LA School District and the upcoming science fair.

(November 19) AIAA LA-LV Educators (K-12 STEAM) Meeting 11/19: Values and Demo *(Screenshots only)*

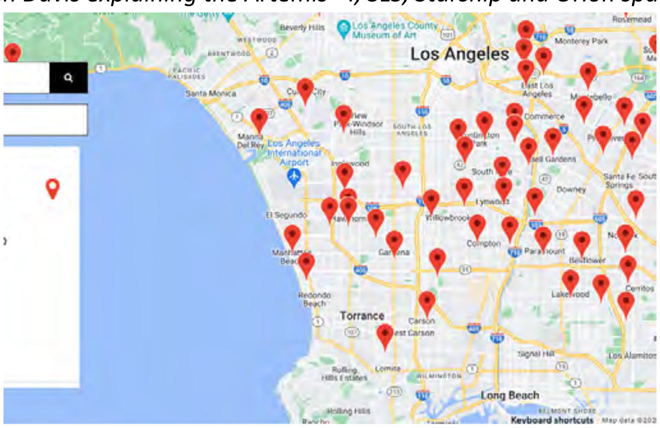


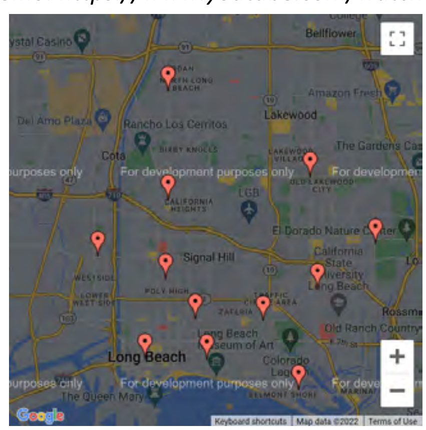
Ms. Sarah Blackman introducing herself and explaining her interests, along with her business in El Segundo, CA.

Ms. Arpie Ovsepyan, our AIAA LA-LV K-12 STEAM Chair, welcoming people with a pre-recorded video message, as she had to teach that day . https://www.youtube.com/watch?v=C08ctw_GqVg

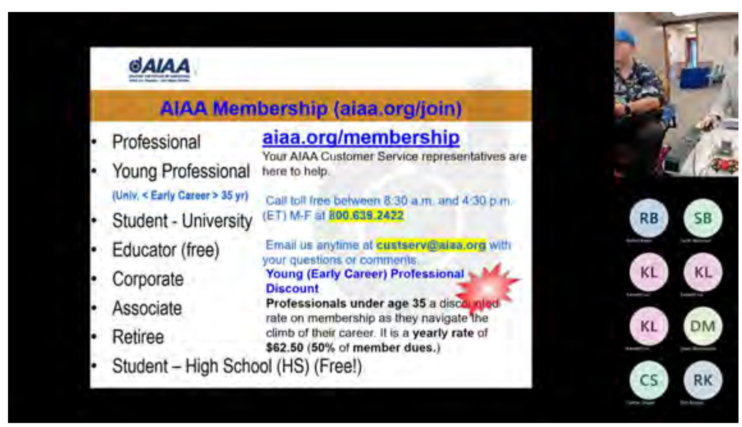
(November 19) AIAA LA-LV Educators (K-12 STEAM) Meeting 11/19: Values and Demo *(Screenshots only)*

Mr. Dean Davis explaining the Artemis - I, SLS, Starship and Orion spacecraft in his demo. https://www.youtube.com/watch?v=owxlFw2ty68



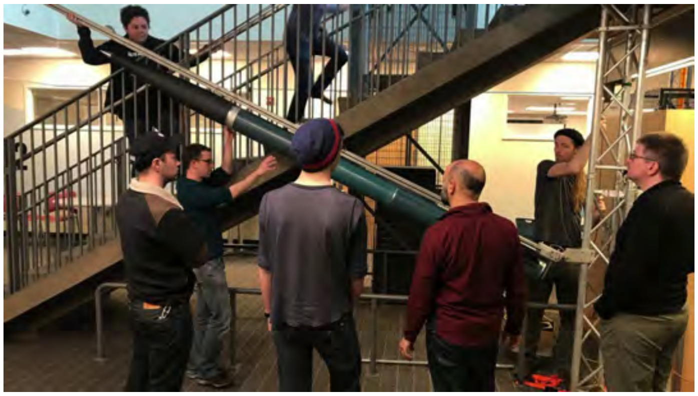


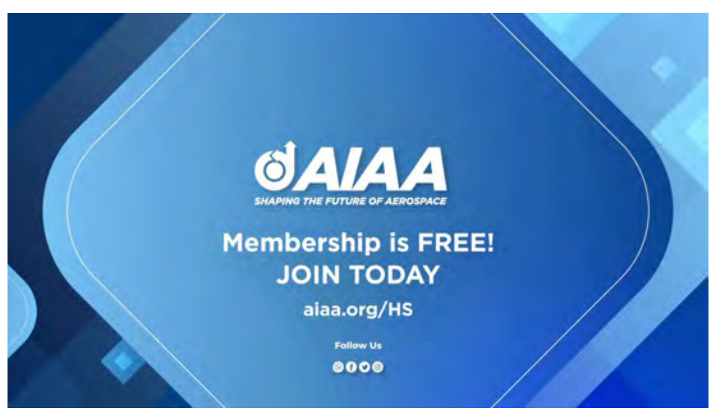
The AIAA LA-LV Section has been active in outreaching to every corner in the responsible areas in LA (SE of I-5) (left) and Long Beach (right).



(Left) AIAA Resources; (Right) AIAA Membership categories and discounts.

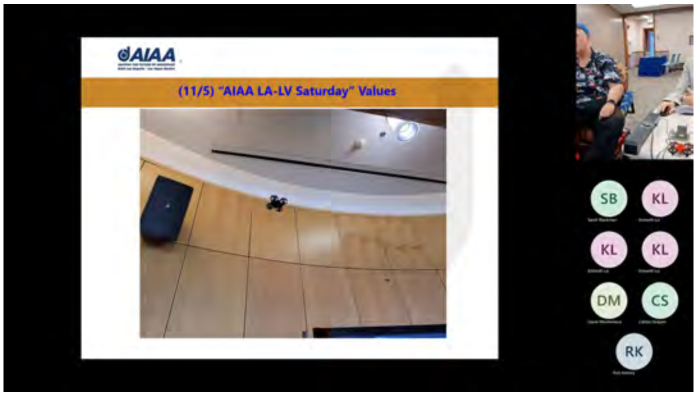
(November 19) AIAA LA-LV Educators (K-12 STEAM) Meeting 11/19: Values and Demo *(Screenshots only)*

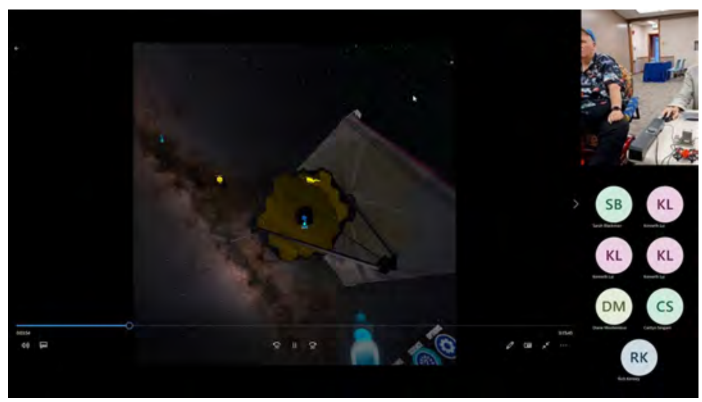


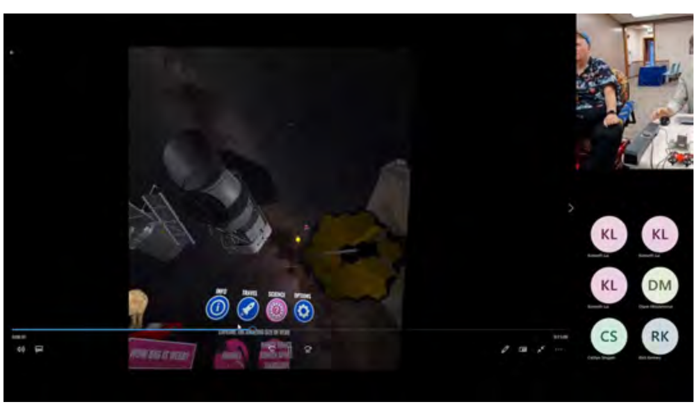


AIAA Membership explained. https://www.youtube.com/watch?v=PecxgmEVicQ;https://www.youtube.com/watch?v=QiV1az1Ov8s

(November 19) AIAA LA-LV Educators (K-12 STEAM) Meeting 11/19: Values and Demo *(Screenshots only)*

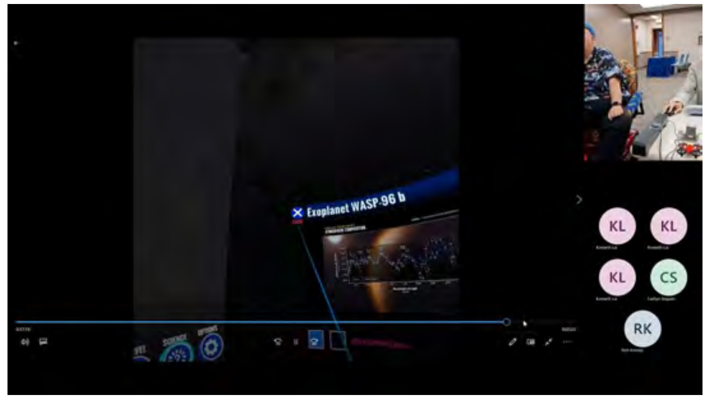


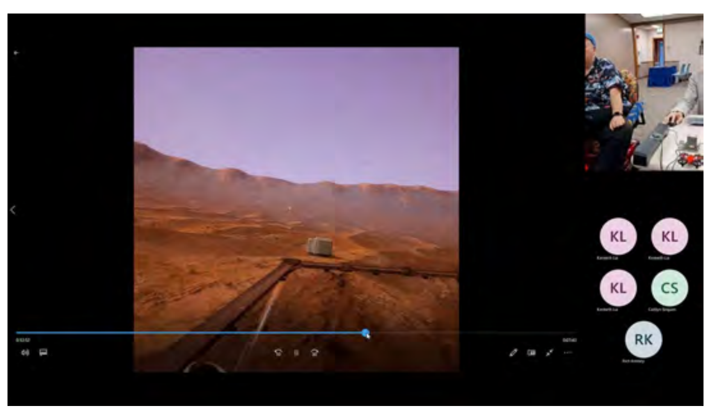




A showcase of potential demo, from drones/remote sensing, to virtual reality with ISS and James Webb Space Telescope etc.

(November 19) AIAA LA-LV Educators (K-12 STEAM) Meeting 11/19: Values and Demo *(Screenshots only)*





(Top, Middle) Demo / showcase of the JWST / astronomy in virtual reality; (Bottom) Mars Driving Software in VR (courtesy of Mr. Alan Chan)

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Reflections on early lunar base design – From sketch to the first moon landing

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ABSTRACT

This paper traces the early ideas of lunar architecture developed by the US and Soviet space programs. Starting with a historical overview of those achievements, highlighting specific engineering, architectural, and design elements; illustrated with images and drawings. Some of them will be described in more detail, showing the design and decision-making process from the first sketch to its implementation.

One example of the great engineering and management capabilities is the development and inclusion of the deployable lunar roving vehicle (LRV). Other examples include the project DLB Zvezda by Barmin's Design Bureau of General Engineering that was under development between 1962 and 1974, and a US project Horizon – a study to set up a Lunar Military outpost conducted in 1959. The paper includes personal statements from astronauts and cosmonauts, as well as people involved along design and implementation processes.

Based on a historical overview of achievements, this paper highlights particular architectural and design unique approaches that defined design strategies for creating space systems, spacecraft and habitats for decades to follow.

1. Introduction

For many years' science fiction authors, filmmakers, individual scientists and space enthusiasts have mentally worked on a 'trip to the Moon'.[1] In 1957 the first artificial satellite was launched as part of the Soviet space program and marked the beginning of the so-called 'Space Race', which actually became a race for the Moon. History books mark the end of the space race with the 1969 Apollo 11 Lunar Landing [1].

The Space Race era is a period of many achievements in a relatively short time such as pioneering launches of artificial satellites, the first animals and humans in low Earth Orbit, robotic space probes to the Moon and Mars and the first human on the lunar surface. The Soviet cosmonaut Juri Gagarin became the first human in Space on April 12 in 1961. His successful 108-min orbital flight was broadcasted worldwide with a huge media echo. "*The flight shocked the world*", as stated by the Space Center Houston [2]. A few weeks later John F. Kennedy [3] gave his 'Special Message to the Congress on Urgent National Needs' [4] on May 25, 1961. He declared that […] "*I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth.*" He further stated: "*No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.*"

President Kennedy was known for carefully choosing the 'right' words and phrases in order to communicate the 'right' message. The congress accepted his request and history has taken its course. Kennedy was right that the ideas and projects of this early phase would have a huge impact for decades to follow. Many efforts were put into reaching the set goals. According to Wernher von Braun, a German-American aerospace engineer and architect, the Apollo landing was planned and prepared by a team of almost 400,000 engineers, scientists, and supporting professions (Von Braun, 1969).

In the US, but also in the Soviet program, German rocket scientists, engineers and technicians played a vital role. It is worth noting here, that following World War II, the US and the Soviet Union intensified their national space programs. "*Between 1945 and 1955, more than 1600 German and Austrian technicians and scientists were brought to the United States through a project code-named Operation Paperclip*[2] *and a series of sister programs.*" [5] p.560). Wernher von Braun was one of them.

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[1] A Trip to the Moon (French: Le Voyage dans la Lune) is a 1902 short film directed by Georges Méliès.

[2] "Operation Paperclip was a postwar U.S. intelligence program that brought German scientists to America under secret military contracts." [11].

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Acronyms/abbreviations

LRV	Lunar Roving Vehicle
DLB	Long-term Lunar Base
RKK Energia	Rocket Space Complex Energia
ISS	International Space Station (ISS)
LDM	Long duration missions (LDMs)

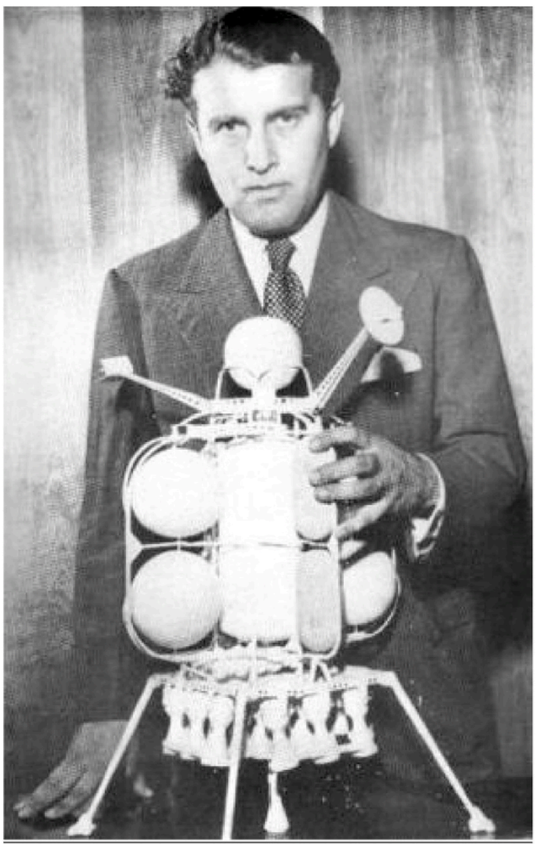

Fig. 1. Wernher von Braun with his 1952 design of a lunar lander (Source: astronautix.com; credit: US Information Agency).

Table 1
Characteristics of the project LUMAN (sources: Godwin 2019).

Project LUMAN – proposal (1958)	
Characteristics	
Space Transportation system	High-lift vehicle for Earth orbital operations and lunar reconnaissance flights, rocket "Big B" One-man lunar lander
Surface Mobility	none
Crewmembers	One (MISS)
Specifics	One lander for one person

The Soviet Union reproduced drawings of the V-2 and re-started its production in Germany. Only later, in 1946 thousands of German scientists were deported to work for the Soviet rocketry program under the lead of the German rocket scientist Helmut Gröttrup with the operation 'Osoaviakhim'.[3] In 1953 Soviet engineers took over the program and most of the Germans were allowed to return to East Germany.

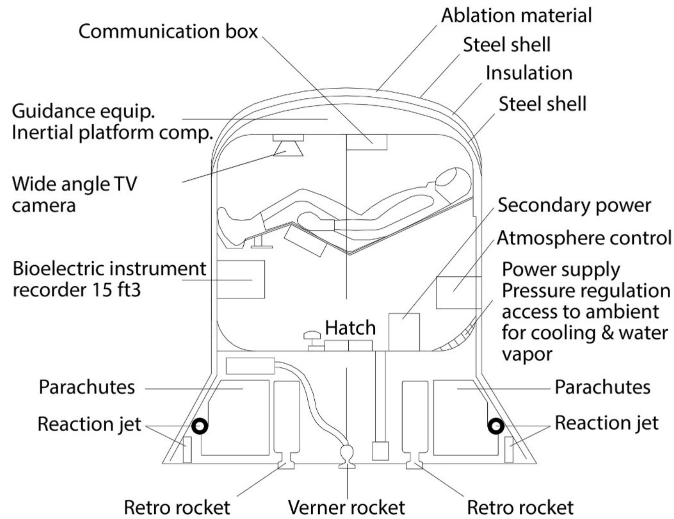

Fig. 2. Cross section of the MISS capsule concept (redrawn by the authors, based on information from USAF).

Table 2
Characteristics of the project Horizon.

Project Horizon – study (1959)	
Characteristics	
Space Transportation system	Saturn A-1 to LEO space station; Lunar landing- and-return vehicle Saturn A-2, nuclear rocket engine
Surface Mobility	Two types of surface vehicles: one for lifting, digging, and scraping; one for more extended distance trips hauling, survey and rescue.
Crewmembers	10 to 20
Mission timeframe	First manned landing in 1965; operational base by late 1966.
Construction	Cargo delivery to the Moon, first manned landing by two, Outpost manned with 12 CM
Size	Cylindrical tank with a diameter of 3 m and 6.1 m length.
Power	Two nuclear reactors
Purpose (goals and objectives)	To establish a FIRST lunar military outpost; Defense concept using unguided rockets and land mines

As it often happens, early ideas and developments influence and shape programs to follow. This paper discusses how early ideas for lunar architectures developed by engineers and scientists in the US and Soviet Union have inspired space designers around the globe. From today's viewpoint, last century lunar surface architectures can be traced back to early designs for complex and large-scale structures such as the Soviet lunar base Zvezda, sometimes called Barmingrad (section 3.2) and a US study for establishment of a Lunar Military Outpost – Project Horizon (section 2.3).

2. Early lunar programs and projects in the US

The Apollo program followed the *Mercury and Gemini Project*,[4] which defined and tested technologies and skills NASA would need for going to the moon [4]. At the beginning of the third US human spaceflight program, Project Apollo (1968–1972), the configuration for the flight to the moon was not fixed and open.

Studies examined three different strategies: (1) Direct flight to the Moon, (2) Earth Orbit Rendezvous (EOR), (3) Lunar Orbit Rendezvous

[3] http://www.russianspaceweb.com/a4_team_moscow.html#osoaviakhim.

[4] Project Mercury (1958–63) was the United States' first man-in-space-program. The Gemini Program (1961–66) was the second human spaceflight program.

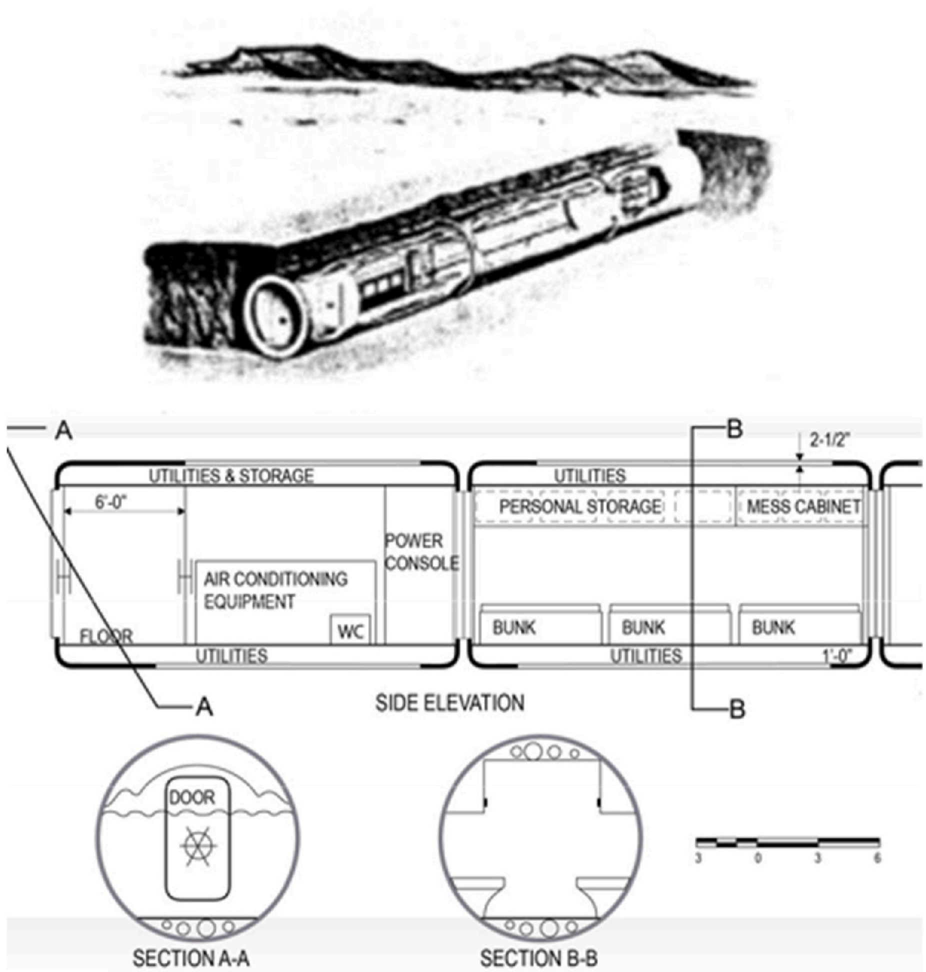

Fig. 3. a. The Project Horizon base would be made of cylindrical metal tanks with a diameter of 3 m (10 ft) and a Length of 6.1 m (20 ft). b. Cross section of a typical (military) out-post compartment. The airlock includes utilities and storage. (credits: U.S. Army Study, Project Horizon, Volume 1,1959, p.13).

Table 3
Characteristics of the project MALLAR/MALLIR.

Project MALLAR (Manned Lunar Landing and Return)/MALLIR (Manned Lunar Landing Involving Rendezvous)	
Characteristics	
Space Transportation system	Three-module system attached to a *trans*-lunar injection booster stage, plus landing module for two crewmembers
Surface Mobility	Lunar lander to lunar orbit
Crewmembers	Two
Construction	Pre-integrated capsule
Size	Entry vehicle length 3.65 m Entry vehicle L/D 0.5
Power	Solar 3.5 kW
Purpose (goals and objectives)	Manned lunar landing and return

Table 4
Characteristics of the Project LUNEX.

Project LUNEX	
Characteristics	
Space Transportation system	Direct ascent to the moon with a six-million- pound-thrust cryogenic launcher
Surface Mobility	Lunar Transport Vehicle for transporting crew and cargo
Crewmembers	Three
Construction	Pre-integrated capsule
Size	Length: 16.16 m Maximum Diameter: 7.62 m
Power	
Purpose (goals and objectives)	Military, manned lunar landing and return

(LOR) [4].

The mission should involve three astronauts, as contrary to the Mercury (with one astronaut) and Gemini capsules (two). On August 30, three feasibility study contracts were awarded to General Dynamics, General Electric and the Glenn L. Martin Company. Also, NASA, founded in 1958, performed its own design studies. In the early developments the military, private companies and newly founded space entities worked in parallel. Eventually the final decision to go to the moon using the LOR approach was announced [19].

2.1. *The designs by wernher von Braun*

Wernher von Braun is considered a key person in the development of spaceflight and space architecture activities. He had been successful in promoting his visions via the news or television. In 1952 he published the well-known concept of an orbital manned space station in Collier's weekly magazine (Collier's Weekly, 1952).

The principal idea of a rotating orbital space station ('Wohnrad') was first shown by Herman Potocnik alias Noordung in his1929[5] book. But, it

[5] Hermann Noordung „Das Problem der Befahrung des Weltraums" 1929.

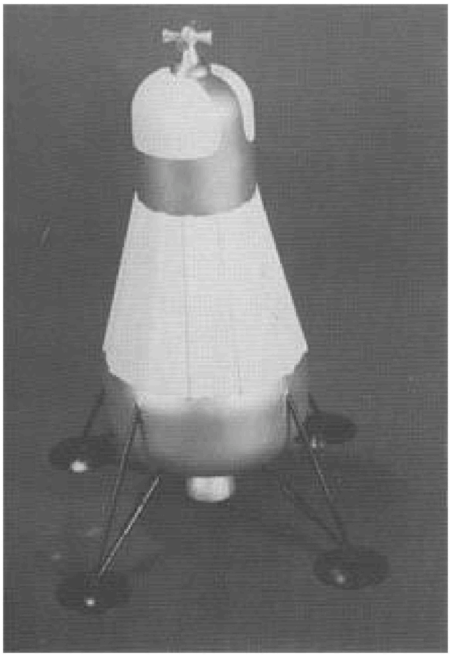

Fig. 4. An early model of the Lunar Excursion Vehicle as suggested for the project MALLIR in 1961 (NASA, John D. Bird and Ralph W. Stone, Jr., of Langley Research Center for project MALLIR).

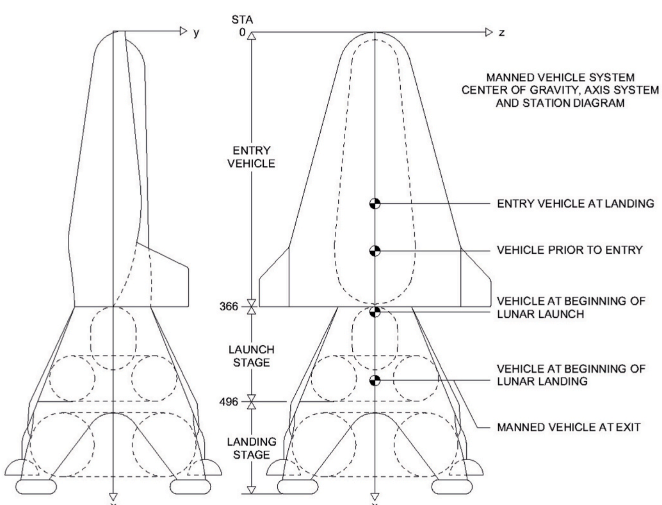

Fig. 5. Elements of the Lunex spacecraft system (redrawn by the authors, based on [8].

Fig. 6. Early 1960s Lunar Rover design by Grumman Aerospace Corporation for one astronaut.(credit: Grumman / NASA).

Fig. 7. MOLAB concept Rover design by General Motors for NASA. (credit: GM / NASA).

Fig. 8. V. P. Barmin and S. P. Korolev. (Credit and Courtesy to Barmin Design Bureau of General Engineering).

had been the magazine articles in Collier, illustrated by famous artists such as Chesley Bonestell that reached the masses. Since then similar concepts appeared as 1959 vision of an entire city in space (The Stanford Taurus), as 1968 rotating space station in Stanley Kubrick's film 'A space odyssey', up to the film 'The Martian' and many others, still influencing current architectural concepts.

At the same time, von Braun worked on a Lunar Lander that would take a 50-crew expedition for six weeks to the moon (Fig. 1). Von Braun effectively presented those ideas in the Walt Disney TV episodes, such as '*Man and the Moon*' from1955.[6] Each lunar lander would accommodate 20 astronauts and one would carry additional cargo. And although it was not yet clear how to get to the Moon, he already had the vision of astronauts "*driving a car on the Moon*" [6].

2.2. Project LUMAN

One of the earlier proposals for 'putting a man on the Moon' has been prepared by the United States Air Force (USAF). The goal of Project

[6] A Disneyland TV show episode, aired December 28, 1955, directed by Ward Kimball.

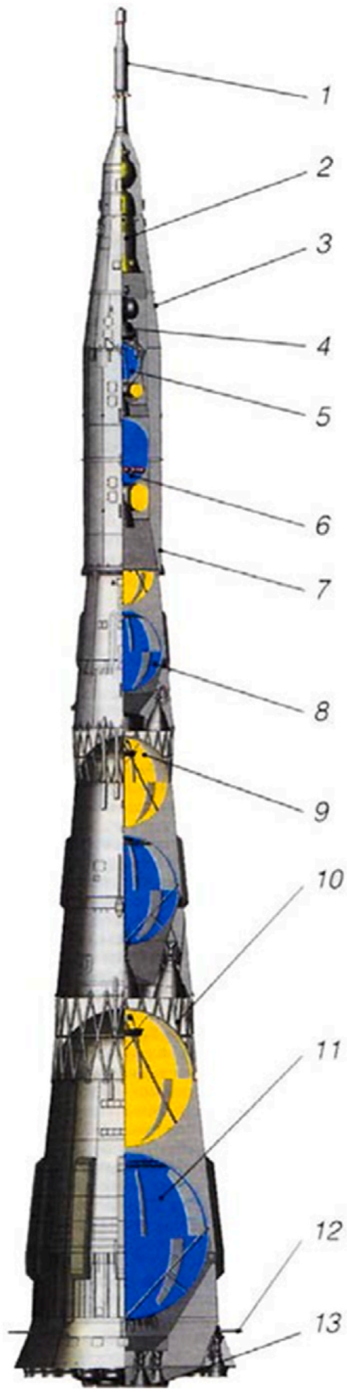

Fig. 9. Launch system N-1 [12].

Luman was to send military astronauts to the moon by 1964 (see Table 1).

The proposal was delivered in April 1958 and encompassed mainly three mission phases:

1. **Man in Space Soonest (MISS):** an initial program to put a man into outer space before the Soviet Union (Fig. 2). It was canceled in 1958 and reorganized as Project Mercury. Neil Armstrong was part of the program before he became a NASA astronaut in 1962. He was also the only one from that group that flew to space.
2. **Lunar Reconnaissance (LUREC):** this phase would include a lunar orbiter.

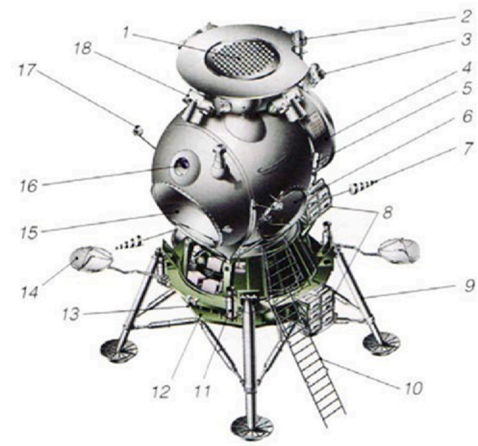

Fig. 10. L-3 lander and its components [12].

Table 5
Project N-1 – L-3 overview.

Project N-1 – L-3	
Characteristics	
Space Transportation system	Direct ascent to the moon
Surface Mobility	Lunar surface rover.
Crew	Two or three
Construction	No surface construction
Mission timeframe	11–12 days
Mission type	Exploration

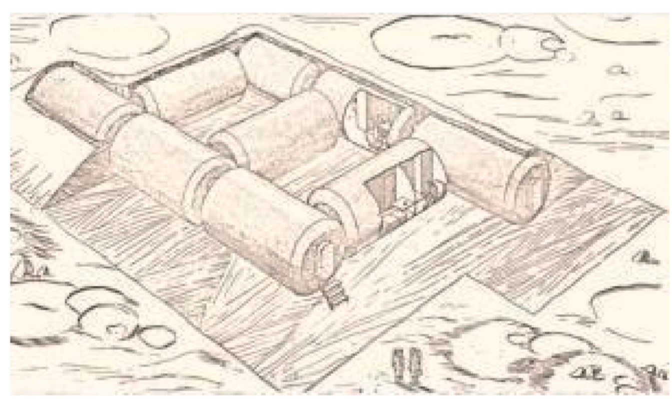

Fig. 11. Lunar base Zvezda modules in a trench on the lunar surface. (Credit and Courtesy to Barmin Design Bureau of General Engineering).

3. **Manned Lunar Landing and Return:** During the concept development, the National Aeronautics and Space Administration (NASA) was founded as an independent and civil agency in 1958. 'LUMAN' would have been the final stage of the plan with a one-man lunar lander.

2.3. Project HORIZON

Project Horizon was another ambitious feasibility plan by the US Army to set up a first Lunar Military outpost (see also Table 2). Similar to the project Luman, it had a military purpose, as reaction to the perceived 'threat' as seen in the launch of Sputnik and subsequent Soviet launches. The study was conducted in 1959 by Wernher von Braun's team in Huntsville, Alabama, with project leader Hermann Koelle. Although the project Horizon ended shortly after, the report was published as the whole team was transferred from the Army to NASA. Von Braun became

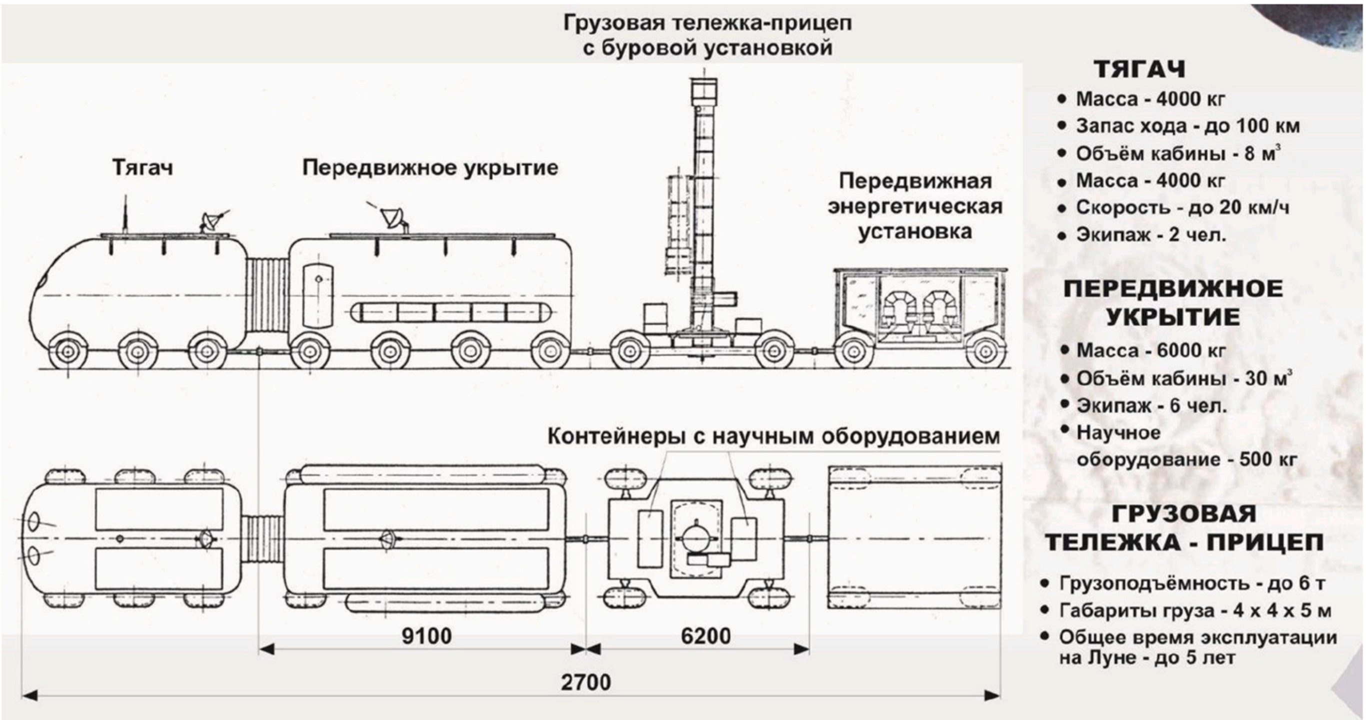

Fig. 12. Lunar manned exploration auto-train. (Credit: Barmin Design Bureau of General Engineering, redrawn by authors).

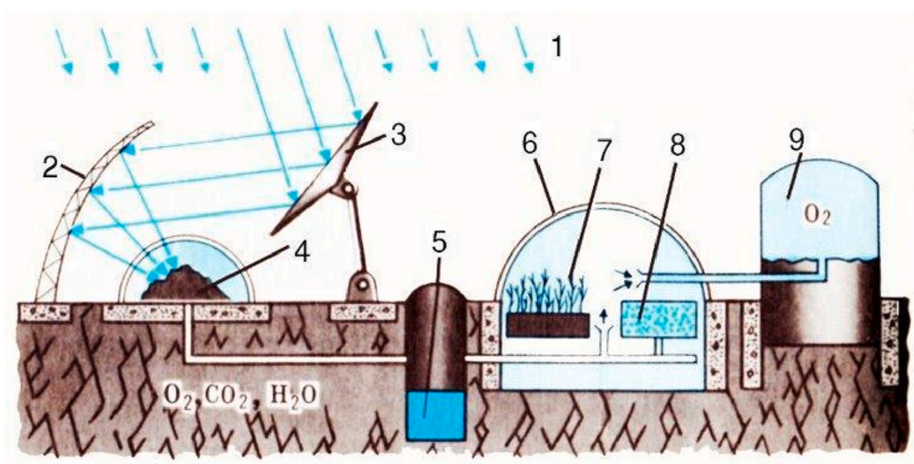

Fig. 13. Lunar ISRU plant: 1-Solar radiation; 2-Screen; 3-Rotating reflector; 4-Regolith; 5-Water container; 6-Greenhouse; 7-Plants; 8-Seaweeds; 9-Oxygen supply. (Credit and Courtesy: Barmin Design Bureau of General Engineering redrawn by authors).

NASA's first director, and this project is considered a key project for the Project Apollo. The project led to the development of the Saturn I[7] which evolved to the eventual Saturn V. In parallel with this effort, another secret project was developed by the US Air Force. The aim of the so-called Project A 119 (A Study of Lunar Research Flights) was to detonate a nuclear bomb on the moon, justified with scientific reasons. Varying sources exist on that topic, but eventually the program was canceled [7].

The objective of manned exploration of the moon with the first manned landing and return was "*to demonstrate conclusively that this nation possesses the capability to win future competition in technology*", and further "*No space achievement short of this goal will have equal technological significance, historical impact, or excite the entire world.*" (David, 2019, p.61).

The habitable modules were designed to be buried underground and covered with regolith (Fig. 3a). This approach of using in-situ Regolith for radiation and meteorite protection is still used in today's concepts. The concept also foresees extracting water and oxygen from the regolith. In-situ Resource Utilization (ISRU) is integral in current mission concepts for lunar, and also Martian human exploration. Still the most studied and advanced ISRU processing techniques are the extraction of oxygen and water from lunar soils.

Fig. 3b shows a typical cross section of the airlock and the living compartment. One living module was equipped with three bunks, space for personal storage and the mess cabinet, an area where military

[7] Saturn 1 (1961) was the first heavy-lift space launcher of the US. It was designed to launch large payloads into LEO. Saturn V supported the Apollo program and was alter used to launch the US space station Skylab.

Fig. 14. a)Bios3 greenhouse© Kirensky Institute of Physics, Krasnoyarsk, photo.kirensky.ru. b) Schematic plan of the BIOS-3 facility (credit: Häuplik-Meusburger and Bishop, as published in Space Habitats and Habitability, 2021 [9].

personnel shall socialize and eat. The concept also included an airlock to the surface.

2.4. Project MALLAR and MALLIR

Mallar – an acronym for *Manned Lunar Landing and Return* – was developed by the company Vought in Dallas, Texas under the head of an American, Asian born aerospace engineer Conrad "Connie" Albert Lau. The concept was based on a three-module system; a command module, a lunar mission module and a lunar landing module. Using the advanced rockets being proposed by von Braun's Team for the Army, the spacecraft would be positioned in lunar orbit and a landing module with two astronauts would land on the lunar surface.

Mallar featured advanced elements such as solar arrays for electrical power and included a Lunar orbit Rendezvous (three years before NASA did) (see Table 3). After 18 months following the MALLAR presentation, engineers from Langley (Dr. John C. Houbolt) presented the project MALLIR – *Manned Lunar Landing Involving Rendezvous* (Godwin, 2019). Only later, within a year, the idea evolved into Apollo. (NASA [SP-4308])

2.5. Project LUNEX

The project Lunex – Lunar Expedition Plan - was proposed by the Air Force Ballistic Missile Division in 1961. The goal was "*the first manned landing and return in late 1967*" [8].

A crew of three Air Force personnel would directly travel to the moon and land there inside a "lifting body" that would act as both lunar lander and re-entry vehicle (see Table 4). The Lunex manned spacecraft system consisted of three stages: entry vehicle, beginning of landing, and landing exit. (Fig. 4). The entry vehicle is in the configuration for lunar launch and Earth re-entry. The landing vehicle could bring either people or cargo to the lunar surface. The program also foresaw a reusable lander similar to the much later developed shuttle (see Fig. 5).

A detailed plan for a secret 'Lunar Expedition Facility' was developed, following the manned lunar landing. The underground facility would have been in service in 1968 and permanently host 21 military astronauts.

2.6. The lunar rover studies

The vision of astronauts driving on the Moon was already visible in Wernher von Braun's early plans. Lunar mobility studies had been conducted since the early 1960s by the MSFC; the Lunar Logistic System (LLS) (Fig. 6), the Mobility Laboratory (MOLAB) (Fig. 7), the Lunar Scientific Survey Module (LSSM) and the Mobility Test Article (MTA). All these studies were based on a dual-launch scenario with two Saturn Vs when one should deliver the crew and another the equipment including the rover [6].

The Lunar Logistic System (LLS) studies were produced by Grumman (Figs. 6 and 7) and Northrup as pressurized vehicles. The metal wheels became a crucial design element. They "*consumed less power, were less complex, and were not as sensitive to temperature extremes, among other advantages*" [6]. They were originally designed by a Hungarian Ferenc Pavlics, who used a wire-mesh design. He and his team received a patent in 1969.

Prototypes were also built for the Mobility Laboratory (MOLAB) that was designed for a crew of four up to two weeks. The MOLAB became one of the early ground-based chamber simulation facilities and proved that astronauts could stay in for 18 days. It also proved that the acceptability of the cabin and suit was high [9]. p.16).

Boeing and Bendex then worked on a smaller version, the Lunar Scientific Surface Module (LSSM). It was an open vehicle that could carry two astronauts with a small cargo capacity.It was later decided that due to a restricted budget only one Saturn V rocket would be launched for one mission. This had severe consequences for the weight. The rovers that were previously considered could not be included. In a famous historical anecdote by the engineer Pavlics, he was told that one instrument quadrant may be available. The upper limit on the vehicle's weight was 227 kg (500lb) [6]. Wernher von Braun told the engineers: "*if you can put the rover in the angular bay*" (Squared Pictures Production, 2015), then a rover can be included for the Apollo missions. They developed a folding and packaging concept that the rower could be stowed in one of the quadrants of the Lunar Module.

The lunar rover was integrated with the Apollo 15 mission. On the lunar surface astronauts removed the outside insulation blankets, lowered the rover from the storage quadrant and unfolded it manually by pulling straps. Astronaut H. Schmitt remembers "*and we just walked away and used our own energy to unfold it and we turned around and it was sitting on the Moon.*" [10].

3. Early soviet lunar programs and projects

Research of design principles, architectural and technical aspects of

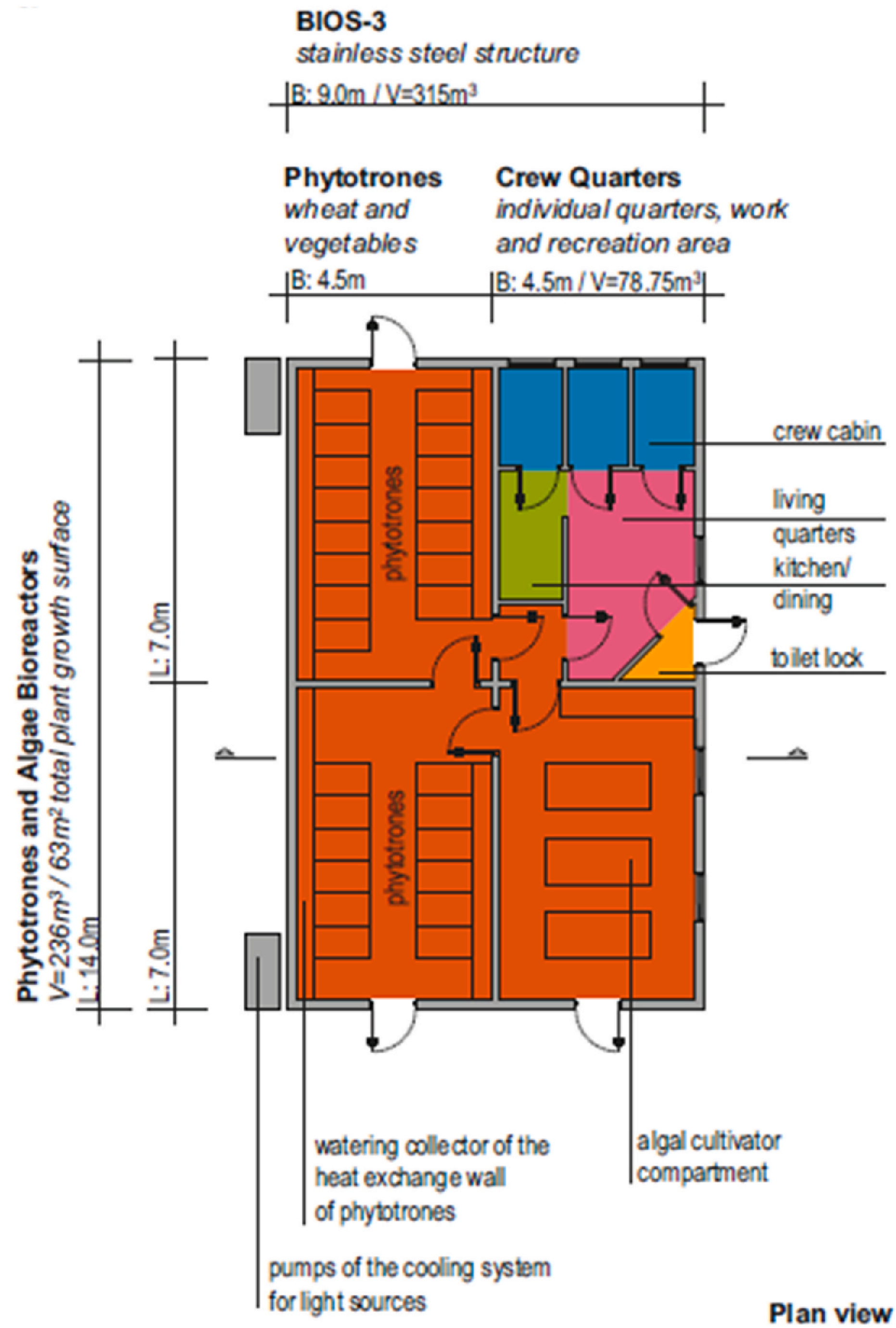

Fig. 14. (*continued*).

long-term lunar settlements initiated by Sergei Korolev (Fig. 8) in the mid-1960s and continued until the early 1980s. During that time, lunar projects were developed under several themes: Coulomb, Bolshoe Koltzo (aka Big Ring), DLB, Dal-A and Osvojenie (aka Development).

3.1. N-1 – L3 (Л3)

Sergei Korolev worked on the project N-1 lunar launch system with his close colleague and friend Mishin in 1962–1965 [11]. The systems were to support the lunar exploration program and deliver fuel, and finally a launch of a Soyuz vehicle delivered 2 or 3 crew members. First N-1 (Fig. 9) delivers a lunar module, two following launches deliver cargo to the surface and the third launch would deliver the crew and include a return vehicle. The L-3 lander (Fig. 10) was to deliver one or two crew to the surface of the Moon for a short sortie mission (Table 5) [12].

In spite of the fact that it was planned as a short sortie mission, the lander was designed with two viewports: one for docking control and another for observations that was oriented towards the surface.

3.1.1. Long-term lunar base (DLB) zvezda

DLB or Barmingrad developed by the Barmin design bureau was based on the launch system N-1, UR-500 and RLA-130A. While its major goals and objectives were focused on fundamental science, bio-medical research, and ISRU, the project also included detailed architectural and infrastructural arrangements and advanced design and planning

Fig. 15. A full-scale mockup of a Zvezda module and interior arrangements. (Credit: Barmin Design Bureau of General Engineering).

Table 6
DLB Zvezda elements and characteristics.

Project DLB Zvezda (1965–1980)	
Characteristics	
Space transportation system	Launch vehicles N-1, UR-500, rocket system RLA-130A
Surface mobility	Diverse types of vehicles: non- pressurized light robotic rover, crewed heavy exploration rover (pressurized), mobile train (tow truck, drilling system, power supply, shelter)
Crew	Max. 12 with occasionally 15–18 for 1 or 2 weeks
Construction	Cargo delivery to the selected site, assembly operations of modular structures, working with lunar regolith for DLB purposes, habitability checks
Size	Cylindrical hard-shell modules, 4 m diameter, 8 m length, max number of modules - 9
Power	Max 25 kW per 30 min
Purpose (goals & objectives)	Fundamental science, ISRU, biomedical research

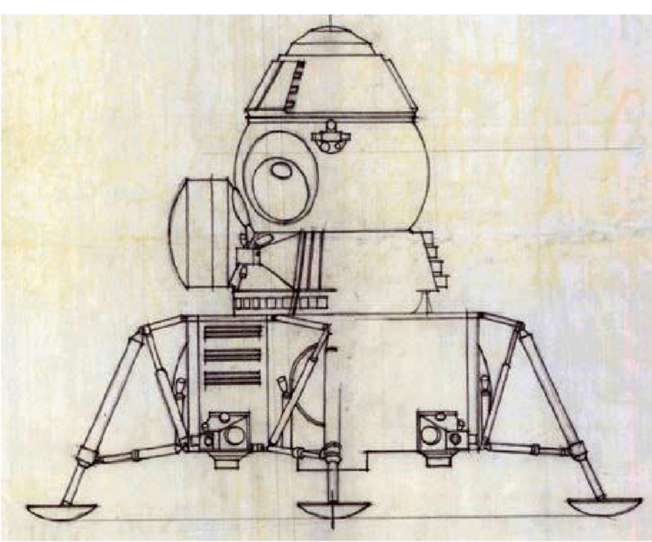

Fig. 16. Lunar orbital spacecraft (LOK). Meuser, P. "Galina Balashova, architect of soviet space program", Berlin: DOM publishers, 2018.

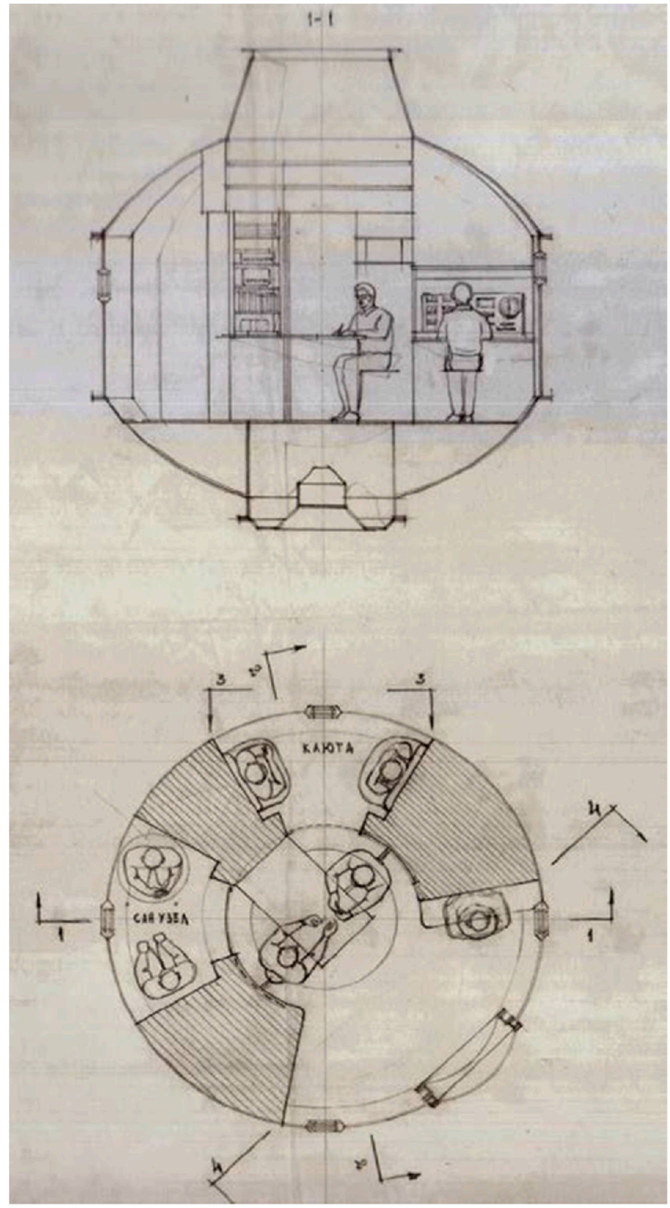

Fig. 17. Lunar orbital spacecraft (LOK), section and plan. Meuser, P. "Galina Balashova, architect of soviet space program", Berlin: DOM publishers, 2018.

Table 7
Summary of project Vulkan and LEK.

Project Vulkan and LEK	
Characteristics	
Space Transportation system	Direct delivery to the moon
Surface Mobility	Surface rovers
Crew	Three
Construction	No surface construction
Mission timeframe	11–12 days
Mission type	Military

solutions [13]. The comprehensive project addressed several stages, site selection, mobile systems, and permanent habitats [14]. The sequence of DLB development included:

- Site selection for construction of the base
- Construction of the 1st stage
- Beginning of operations

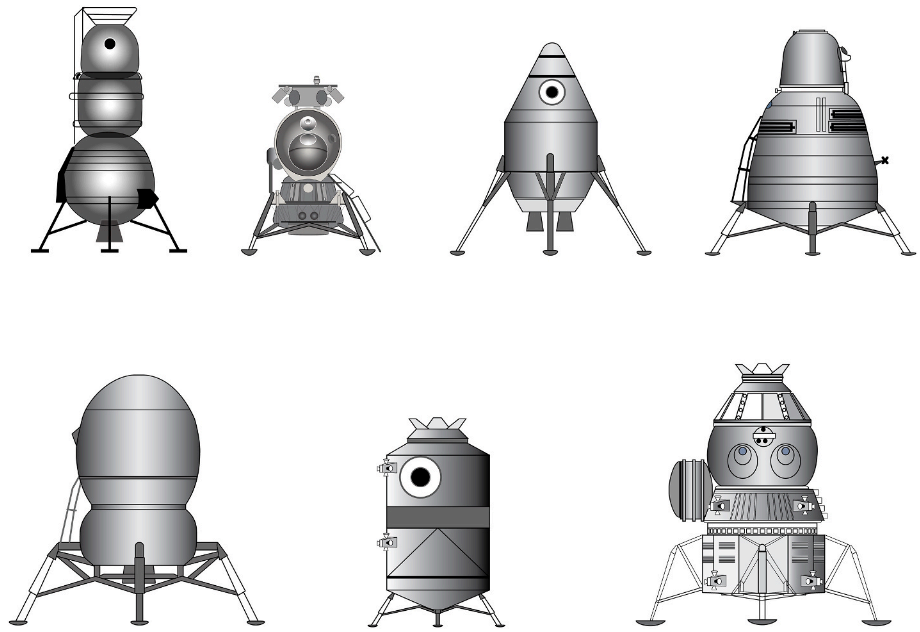

Fig. 18. Evolution of Soviet crewed lunar landers: L3 (1963); LK (1964); LK-700 (1966); L3M (1970); L3M (1972); MB (1972); LEK (1975) [17].

Table 8
Summary for influential architectural innovations from early proposals for lunar surface habitation.

Project	Innovations
Horizon	Radiation and meteorite protection provided by covering habitats with regolith, modules are fully outfitted with pre-integrated equipment and ready for use
MALLAR and MALLIR	Consisted of orbital and surface modules. Relied on solar arrays for electrical power and a lunar orbit rendezvous before Apollo missions.
LUNEX	Consisted of three stages: entry vehicle, beginning of landing, and landing exit. Crew goes directly to the moon and lands there inside a “lifting body” that would act as both lunar lander and re-entry vehicle. Integrated into a plan for a permanent facility with reusable mission elements.
Lunar Rover Studies	Proposed metal wheels consumed less power, were less complex, and not sensitive to temperature extremes. Integrated in early habitability studies. Volume and Mass restriction led to the innovation of foldable structures.
N-1 – L3	Offering direct ascent to the moon surface. The lander had two viewports: one for docking control and another oriented to the surface for observations.
Lunar base (DLB) Zvezda	Multi-phased architecture to allow increasing base habitability along with advancements in base functional operations. Mobile pressurized rovers with research capabilities for expanding exploration zones. ISRU plant construction and nuclear power production.
Ground experiment Bios3	Early closed ecosystem simulation facility. Designed for crew to plant, cultivate, and harvest the produce, managing the entire system and processing their food. Natural air and water recycling met most of the crew’s needs, and the crops produced over 50% of the food needs for the crew.
Project Vulkan and LEK	Consisted of three elements: a lander, an ascent stage and a habitat. The orbital vehicle and surface module had service and living compartments designed to offer the crew relative comfort and privacy.

- Continuing construction (2nd stage)
- Continuing operations
- Concluding construction (3rd stage)
- Ready for operations in full scale

Site selection required extensive initial exploration using autonomous operations from a lunar orbit and robotic surface rovers. The final selection was to be made using heavy moon rovers furnished with drilling equipment (Fig. 12).

Potential of using lunar regolith for on-site construction and protection was widely explored in all lunar projects. In the lunar base Zvezda, it was proposed to cover main surface habitable modules for radiation shielding and micrometeoroid protection with regolith (Fig. 11). The main structure was planned to serve as a safe haven and provide total environmental protection for the crew. The modules were planned to function for 5 years. Every pressurized module was independent from others, which provided redundancy and allowed assembly operations in stages [15].

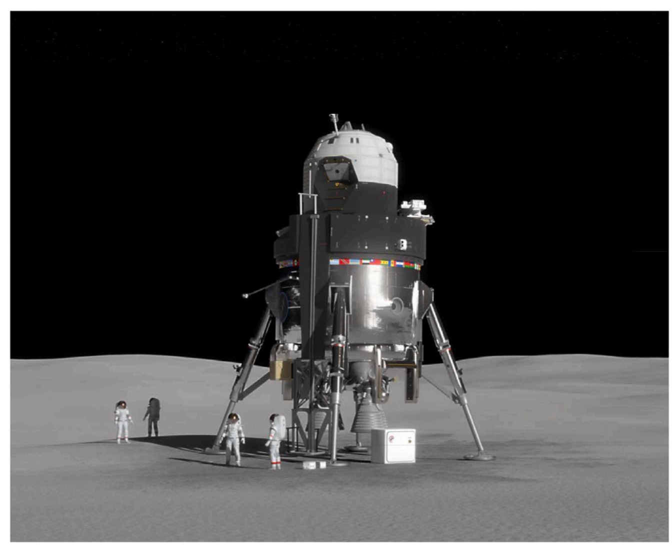

Fig. 19. Lockheed Martin lunar lander concept for crewed missions. Credit: Lockheed Martin.

Architecture and design approach of the Lunar base Zvezda offered a strategy for increasing base habitability after allowing advancements in base functional operations that are supported by mobile pressurized rovers with research capabilities for expanding options for scientific

Fig. 20. The Boeing Company lunar lander concept for crewed missions. Credit: The Boeing Company.

exploration, ISRU plant construction and nuclear power production (Fig. 12).

The ISRU plant was proposed for providing essential support for base operations (Fig. 13).

3.1.2. Ground experiments related to the lunar program

In relation to Soviet lunar projects, including DLB Zvezda, a closed ecosystem facility called "BIOS-3" was constructed by the Department of Biophysics at the Kirensky Institute of Physics in Krasnoyarsk, USSR/Russia [§] in 1972 (Fig. 14). It was a closed ecological life-support system for long-term experiments carried out in a ground complex with a human crew, higher plants, and an artificial ecological system [16]. In total, 315 cubic meters of habitat were allocated for this project.

Between 1972 and 1984, three closure experiments with CELSS (Controlled Environmental Life Support Systems) were conducted with a two to three-person crew for periods of up to six months in the Bios-3 facility. Bios-3 was divided into four equal quarters. (Fig. 14b). One quarter provided housing for the crew with three single cabins, a kitchen, hygiene area, and a control room equipped for food processing, measurements, and repairs, and additional air and water purification systems. The other three quarters of the facility were dedicated to growing wheat, vegetables, and other produce, including cultures of chlorella.

During the experiments, the crew planted, cultivated, and harvested the produce, managing the entire system and processing their food. The experiment's results demonstrated that natural air and water recycling met most of the crew's needs, and the crops produced over 50% of the food needs for the crew.

3.1.3. Mock-up development

A full-scale module mock-up was produced by the design bureau of general engineering. The mock-up was planned to investigate design aspects and finalize interior arrangements, and also for testing and evaluating design decisions (Fig. 15). The mock-up was installed in the Institute of Biomedical Problems where several isolation experiments were conducted.

All proposed DLB elements were designed with current technologies available in the USSR at that time. It demonstrated that development of a lunar base could have been achieved even sixty years ago. Table 6 summarizes DLB characteristics.

3.2. Project Vulkan and LEK

A new launch system Vulkan was proposed by Sergei Korolev's opponent of many years, Valentin Glushko. A Lunar Expedition Spacecraft (LEK) was planned to become the main transportation system to deliver cosmonauts and cargo to the Moon. The spacecraft would be launched with an enormous rocket Vulkan. Vulkan's characteristics were very impressive: mass of 3810 tons, height of 88 m, and a diameter of 7.8 m. The rocket was supposed to be capable of delivering 200 metric tons to LEO, 65 to the Moon, 54 to Venus and 52 to Mars [17].

The orbital vehicle and surface module had service and living compartments designed to offer the crew relative comfort and privacy (Figs. 16 and 17) [18].

The spacecraft was created for a direct mission and consisted of three elements: a lander, an ascent stage and a habitat (Fig. 17 and Table 7). The craft was 9.7 m long, with a maximum diameter of 5.5 m, and total mass of 31 tons. The maximum operation time was set for 365 days.

A habitable module and an ascent stage were similar to the same elements designed for the N-1-L3M project (Fig. 18).

Evolution of crewed lunar landers with an ascent stage attached shows that there were no dramatic changes in the design although the crew number was not always the same. All approaches were considering direct flights to the Moon that were too expensive and risky. The Soviet lunar program faced multiple challenges due to N-1 failures, competition between two design bureau proposals (Korolev/Mishin and

Fig. 21. Illustration of setting up the Artemis Base Camp on the lunar South Pole. Credit: NASA.

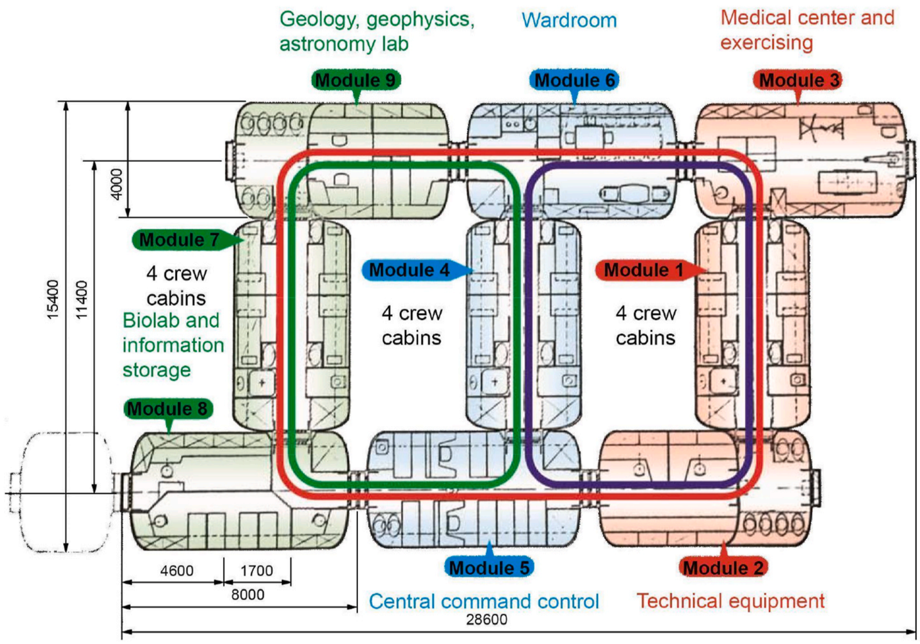

Fig. 22. Zvezda base layout. (Credit: Barmin Design Bureau of General Engineering, redrawn by authors).

Glushko/Chelomei), funding cut-outs and changes in political agendas.

Finally, the USSR leadership lost its interest in the lunar program and lunar exploration became strictly robotic with less launches and was finally completely canceled for a reason that the Moon has been fully investigated and does not represent any appeal for scientific research anymore [12]!

4. Discussion and summary

Fifty years have passed since "*The Eagle has landed*" and Neil Armstrong set foot on the moon for the first time. It was the beginning of a new era of lunar exploration or "lunar renaissance" and in the next decade new proposals for lunar missions emerged around the world.

Currently another generation of engineers, scientists and architects explore orbital and surface mission scenarios [12]. Architectural conceptualization of future lunar settlement varies in shapes, size, construction methods and materials. Still, there is some continuation of thoughts and lessons learned from previously developed concepts. Table 8 highlights some of the early innovative architectural and design ideas.

Similar to LOK spacecraft and LEK lander, designs for first human missions of the Artemis program propose combining landers with habitats and living off the lander during first short surface missions (Figs. 19 and 20).

History taught us that space mission scenarios and objectives often may change with time. Therefore, designers and architects looking for adaptable interior arrangements in order to meet various crew needs while complying with launch and landing restrictions. Developing a sustainable human exploration on the moon proposes living off the lander during first surface missions and transferring to a larger habitat with a larger crew when it becomes feasible for the mission success. A lot of effort goes into the development of innovative concepts and technologies to use in-situ-resources (ISRU).

Multi-staged approaches to establishing surface settlements on the surface of the Moon were suggested since first long-term missions were proposed. After successful but expensive Apollo sortie missions, it became clear that sustainable lunar habitation and operations will require reusable systems and elements, where every surface element is designed for continuous operations and capable of modifications for diverse missions' needs (Fig. 21).

Current initial base proposals employ a modular and dual egress approach for the habitable areas. This approach is similar to the strategy used in Lunar base Zvezda design (Fig. 22). It addresses the important safety consideration with dual egress from all habitable modules to an airlock or a module equipped with one [15].

Common considerations derived from the lessons learned in previous activities for habitable elements include:

- Combination of different module types including hard shell modules with plug-n-play capabilities Maximizing plug-n-play capabilities
- Decisions on selecting a close or open loop life support depend on the duration of the mission.
- Providing only strictly necessary surface transportation, possibly non-pressurized (e.g., 1 km between a habitat and landing site)
- Closed loop life support where needed and where possible, including a life-cycle strategy
- Adjustable mission goals (e.g., science exploration operations, establishing initial ISRU support infrastructure etc.) lead to adjustable architectural concepts

After almost 65 years since Sputnik 1 was launched, it became apparent that Sputnik was not a threat but an opportunity. The space race was born and space exploration began. It has proved that competition can be a driver for innovation. Nevertheless, allow us to think of what would have happened, if those two space nations would have cooperated and what could have been achieved. In view of future sustainable developments in space as well as on Earth, the authors encourage learning from history to push collaboration in order to achieve sustainable lunar operations and a permanent surface settlement.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Object WE0913A, When A Translunar Rocket Disposal Is Left To Chance

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(Ed. note: this 42-page paper is being published in three installments. This is Part II.)

4.0 Following WE0913A Through Its Closest Lunar Encounters

The consistency of Project Pluto's WE0913A ephemeris chain is documented in Table 7's comparisons using parameters akin to Table 4's. These comparisons are enabled by a WeavEncke coast initialized with the ending state vector of a predecessor ephemeris in the chain at epoch t_E and extending forward in time past the beginning state vector of a successor ephemeris in the chain at epoch t_B. The actual comparison is made at t_B with the following parametric definitions.

$\Delta a \equiv$ signed geocentric semi-major axis deviation in the sense "successor ephemeris minus WeavEncke coast"

$\Delta x \equiv$ signed along-track curvilinear geocentric position deviation of the WeavEncke coast with respect to the successor ephemeris (positive values indicate WeavEncke coasted motion is ahead of successor ephemeris motion)

$\Delta w \equiv$ unsigned wedge angle between the WeavEncke coast's geocentric orbit plane and that of the successor ephemeris

Table 7. As each predecessor ephemeris gives way to its successor in the Project Pluto WE0913A chain, the following comparisons are made to quantify the chain's consistency.

Pred./Succ.	t_E (UTC)	t_B (UTC)	Δa (km)	Δx (km)	Δw (deg)
2014-15/2015	14.9 Feb 2015	15.2 Feb 2015	+94.8	+48.7	0.00579
2015/2016	04.9 Dec 2015	05.2 Dec 2015	+41.5	-3.0	0.00172
2016/2017	27.9 Dec 2016	28.2 Dec 2016	-36.4	-559.5	0.00365
2017/2018	22.9 Nov 2017	23.2 Nov 2017	+0.2	-11.6	0.00338
2018/2019	03.9 Jan 2019	04.2 Jan 2019	+1.5	+65.1	0.00756
2019/2020	05.9 Jan 2020	06.2 Jan 2020	+3.3	-43.3	0.00135
2020/2021	17.9 Jan 2021	18.2 Jan 2021	-12.1	+19.6	0.00350
2021/2022	12.9 Jan 2022	13.2 Jan 2022	-989.1	+310.9	0.13261

Considering the translunar context for Project Pluto's WE0913A ephemeris chain, Table 7 comparison magnitudes are remarkably small. This consistency bestows high confidence in the following close lunar encounter trajectory plots as suggested by Table 2. The first of these encounters on 27 October 2014 has already been addressed by Figures 3 and 4. Similar geocentric and selenocentric graphics in the following Subsections 4.1 through 4.10 illustrate subsequent WE0913A trajectory evolution until lunar impact.

To summarize evolution of WE0913A's trajectory history, its geocentric semi-major axis and ecliptic inclination are plotted over the Project Pluto ephemeris chain time span in Figure 7. Variations in these orbit elements are attributable to lunar encounters (those at distances greater than 100,000 km are not annotated) and to solar gravity perturbations. The Sun's influence on WE0913A geocentric motion is particularly notable when semi-major axis is greatest between Orbit 8 and Orbit 17.

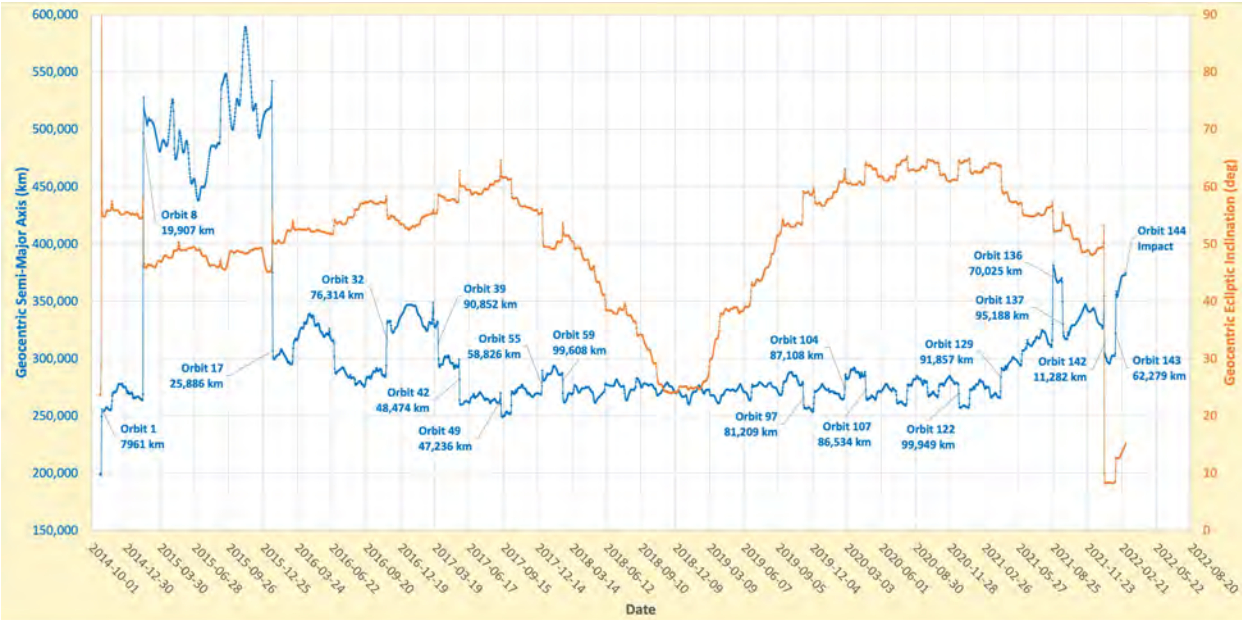

Figure 7. Geocentric WE0913A semi-major axis (blue) and ecliptic inclination (orange) are plotted as functions of time during the Project Pluto ephemeris chain's duration. The semi-major axis locus is annotated with orbit count and pericynthion distance for each lunar encounter appearing in Table 2.

4.1 Orbit 8 Lunar Encounter @ 13.858 February 2015 UTC: 19,907 km

Figures 7 and 8 illustrate the dramatic WE0913A geocentric semi-major axis increase from Orbit 8's close lunar encounter. This increase is imparted from the Moon's position ahead of WE0913A as the rocket body passes through its descending node on the ecliptic. From the minute shaded area on Earth in Figure 8, the Sun's location slightly clockwise of the direction to ♈ is evident. This geometry indicates WE0913A is considerably more observable from Earth after the lunar encounter than before it. Note Figure 8's WE0913A plot ends at the same time Figure 1's begins. As annotated in Figure 1, WE0913A is discovered less than two weeks later.

As documented in Table 7, the Project Pluto ephemeris chain has an interpolation "gap" as its 2014-15 segment transitions to its 2015 segment barely a day after the encounter. Rather than concatenating the two segments into one ephemeris, both Figures 8 and 9 are plotted using a WeavEncke coast bridging the gap.

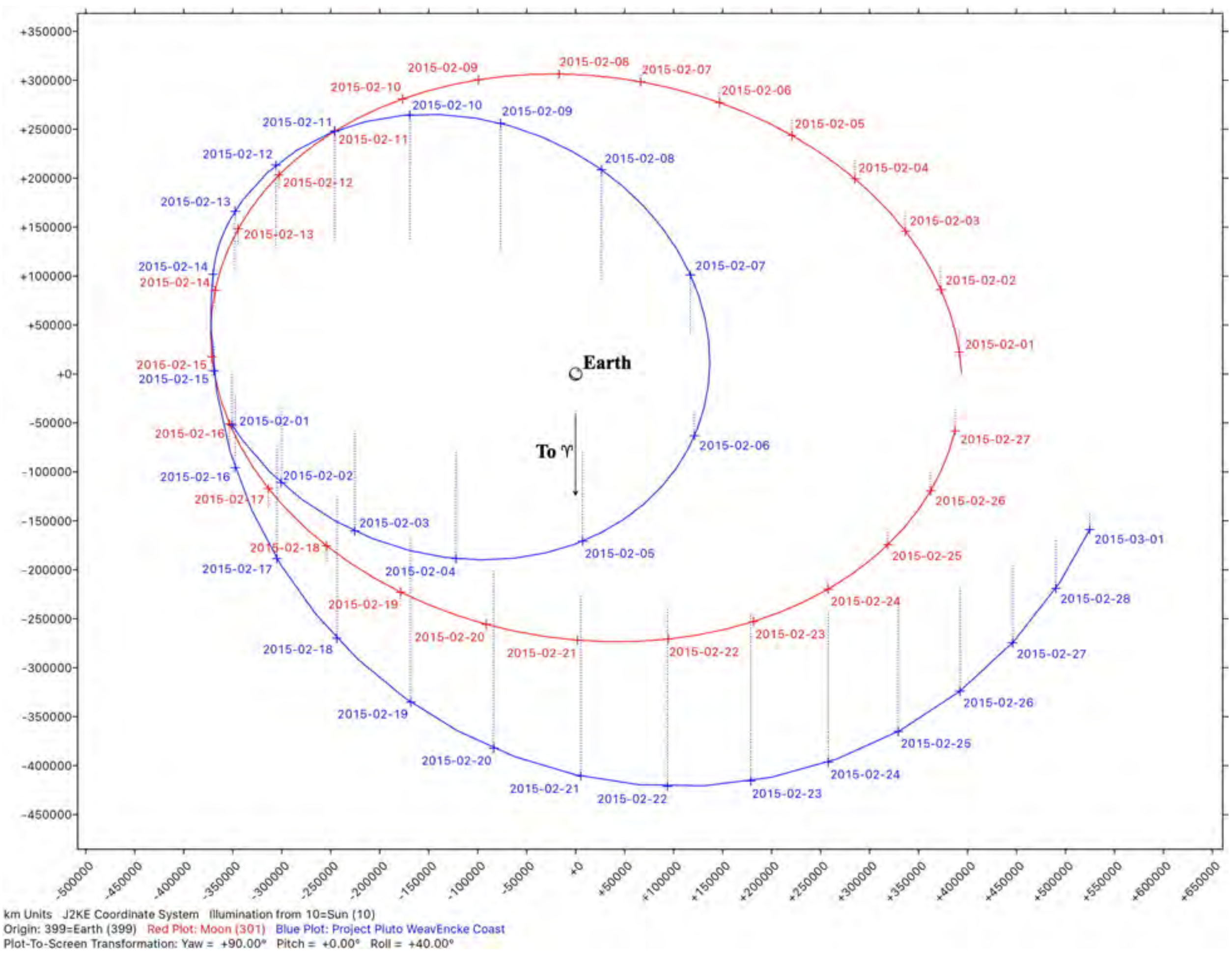

Figure 8. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted through most of February 2015, including the close lunar encounter at 13.858 February UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

Figure 9 shows the Moon clearly leads WE0913A in their geocentric orbits during the 13 February 2015 encounter at selenocentric inclination 93.5°. Thus, lunar gravity exerts a prograde acceleration on WE0913A during the encounter to increase the rocket body orbit's geocentric semi-major axis. Note the perspective in Figure 9 and other selenocentric WE0913A trajectory plots is motivated by a desire to show the Moon's nearside to the greatest extent possible. Except where noted otherwise, this permits the Moon's geocentric motion to be easily visualized, conveying an understanding of how WE0913A's geocentric orbit is altered by each lunar encounter. The "price" of this understanding is a somewhat foreshortened WE0913A trajectory such that annotated geometric pericynthion distance is generally larger than associated plot scales would suggest.

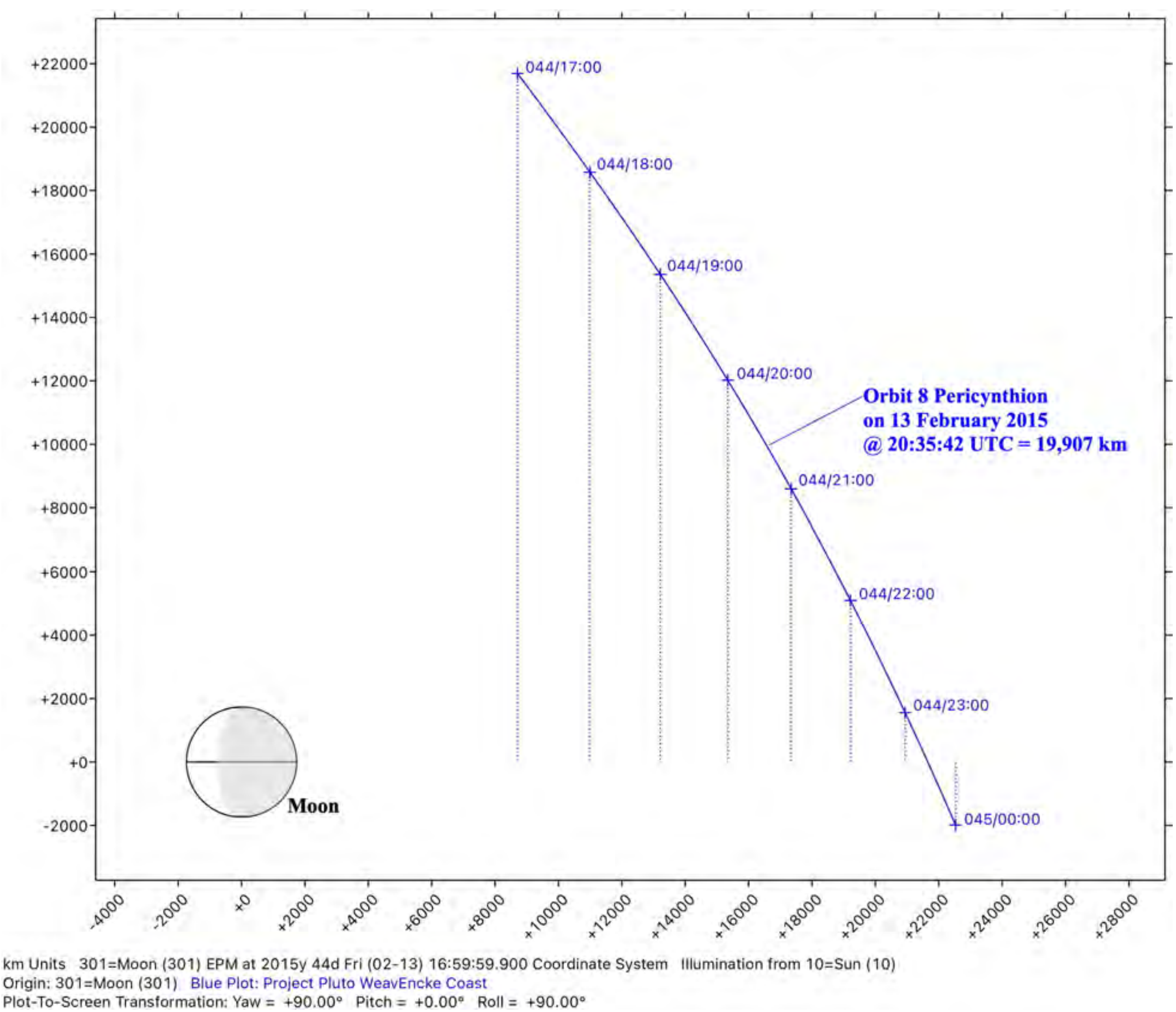

Figure 9. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.2 Orbit 17 Lunar Encounter @ 17.832 January 2016 UTC: 25,886 km

Figures 10 and 11 illustrate the close lunar encounter of 17 January 2016 at selenocentric inclination 78.0°. By chance, this encounter is virtually a mirror-image of that on 13 February 2015. It occurs near WE0913A's *ascending* node on the ecliptic and, because WE0913A *leads* the Moon at pericynthion, the rocket body's geocentric motion is *retarded*, appreciably *reducing* its semi-major axis.

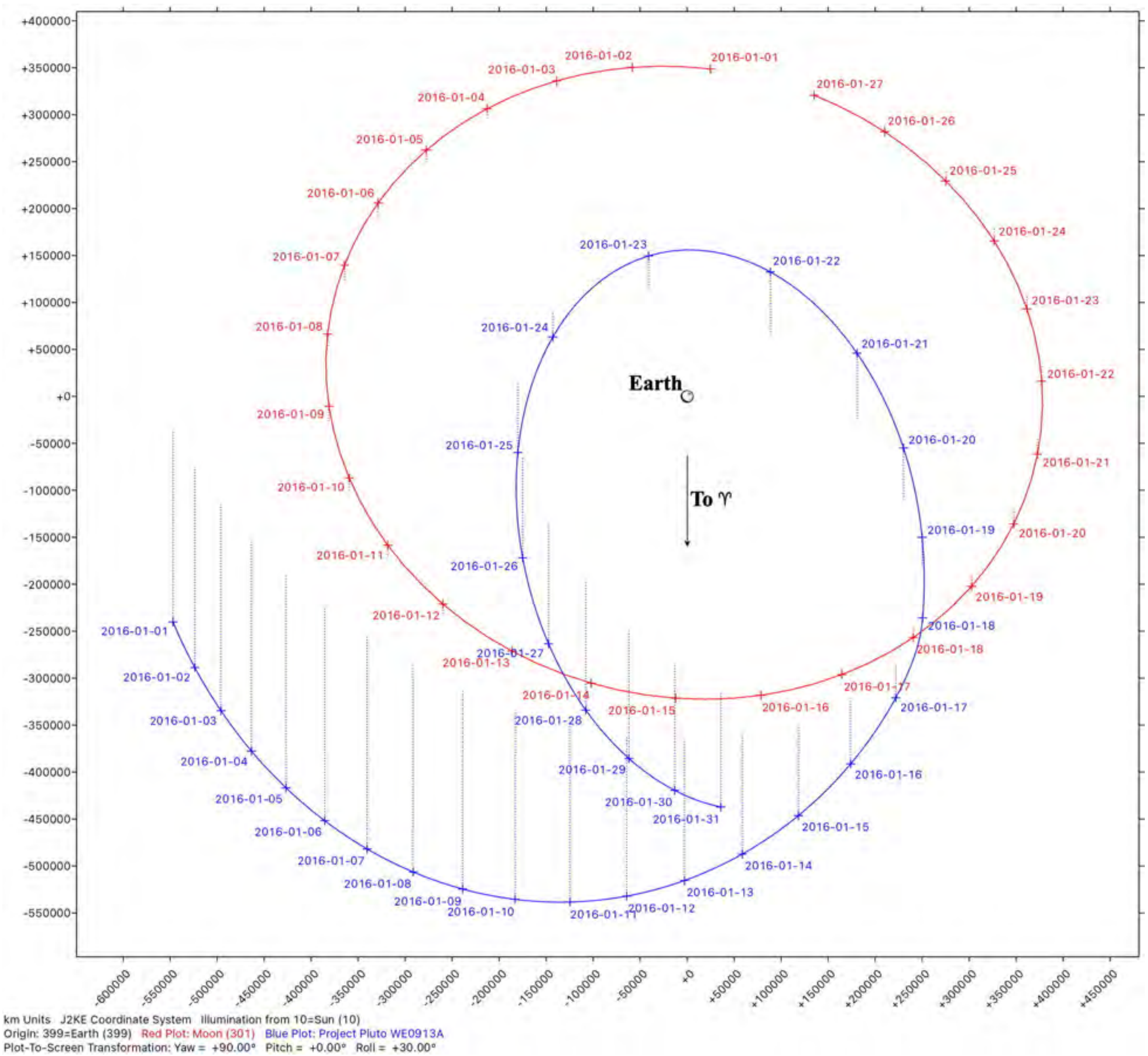

Figure 10. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted through most of January 2016, including the close lunar encounter at 17.832 January UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

Object WE0913A, When A Translunar Rocket Disposal Is Left To Chance

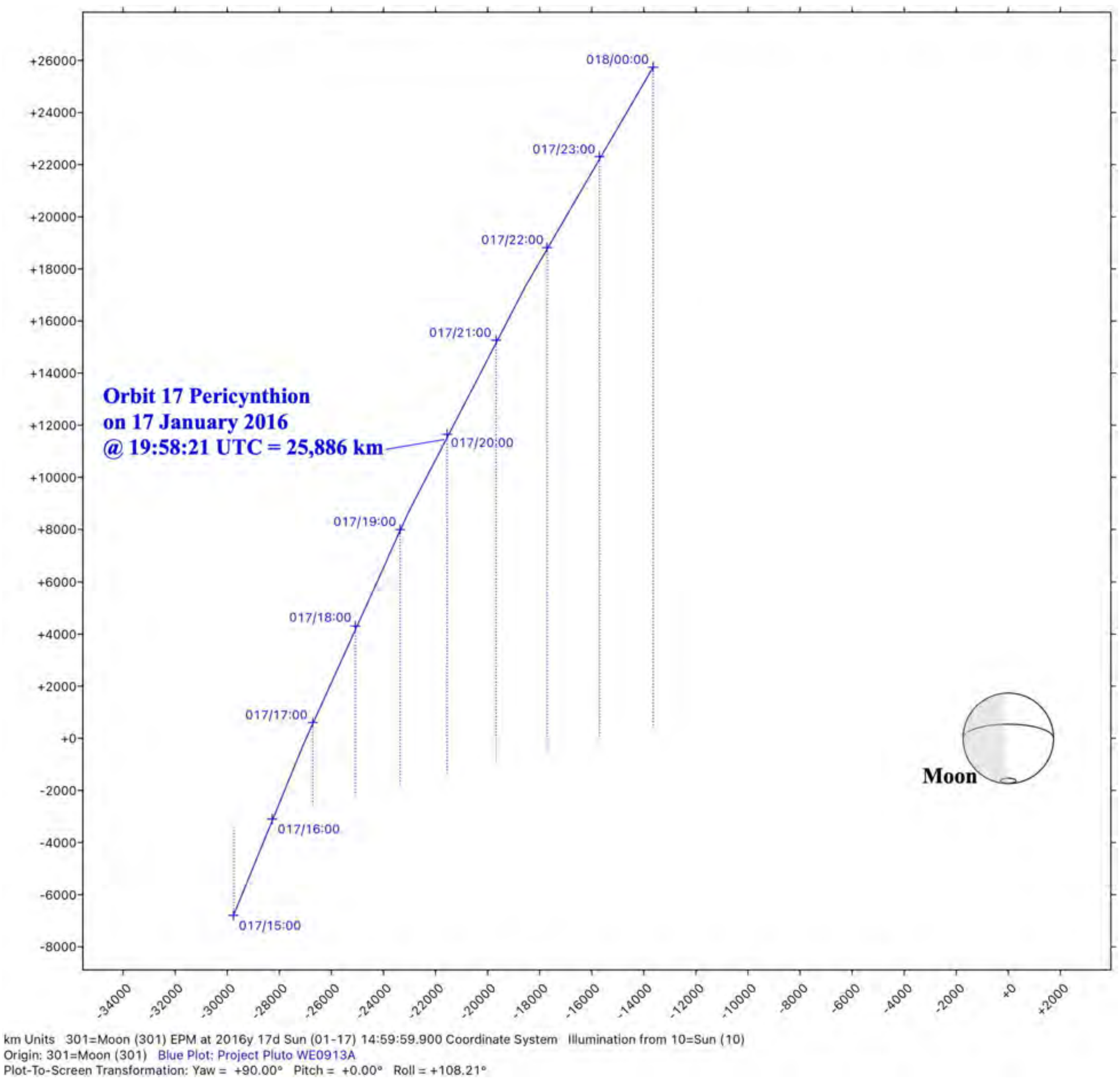

Figure 11. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside predominantly visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.3 Orbit 42 Lunar Encounter @ 21.751 May 2017 UTC: 48,474 km

By May 2017, continued perturbations to WE0913A's geocentric orbit have brought it inside the Moon's. This geometry is evident from dotted blue projection lines onto the ecliptic plane in Figure 12. At this point in WE0913A orbit evolution, the trajectory can no longer be considered strictly "translunar".

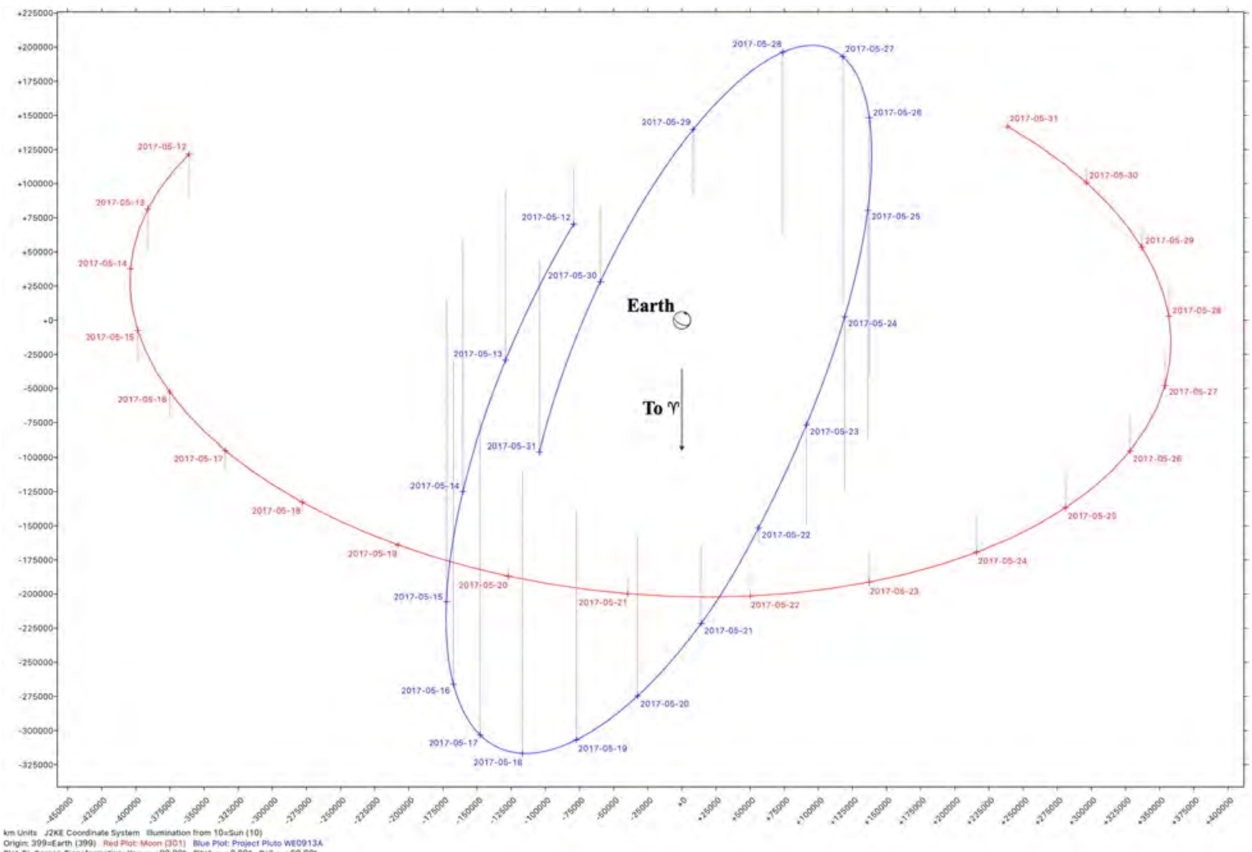

Figure 12. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted through late May 2017, including the close lunar encounter at 21.751 May UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

At slightly less than 50,000 km pericynthion and selenocentric inclination 65.3°, as illustrated in Figure 13, perturbations from the Moon cannot substantially alter WE0913A's geocentric orbit. In this case, pericynthion on 21 May 2017 is ahead of the Moon in its geocentric orbit, further reducing WE0913A's geocentric semi-major axis and increasing this orbit's separation from the Moon's.

Object WE0913A, When A Translunar Rocket Disposal Is Left To Chance

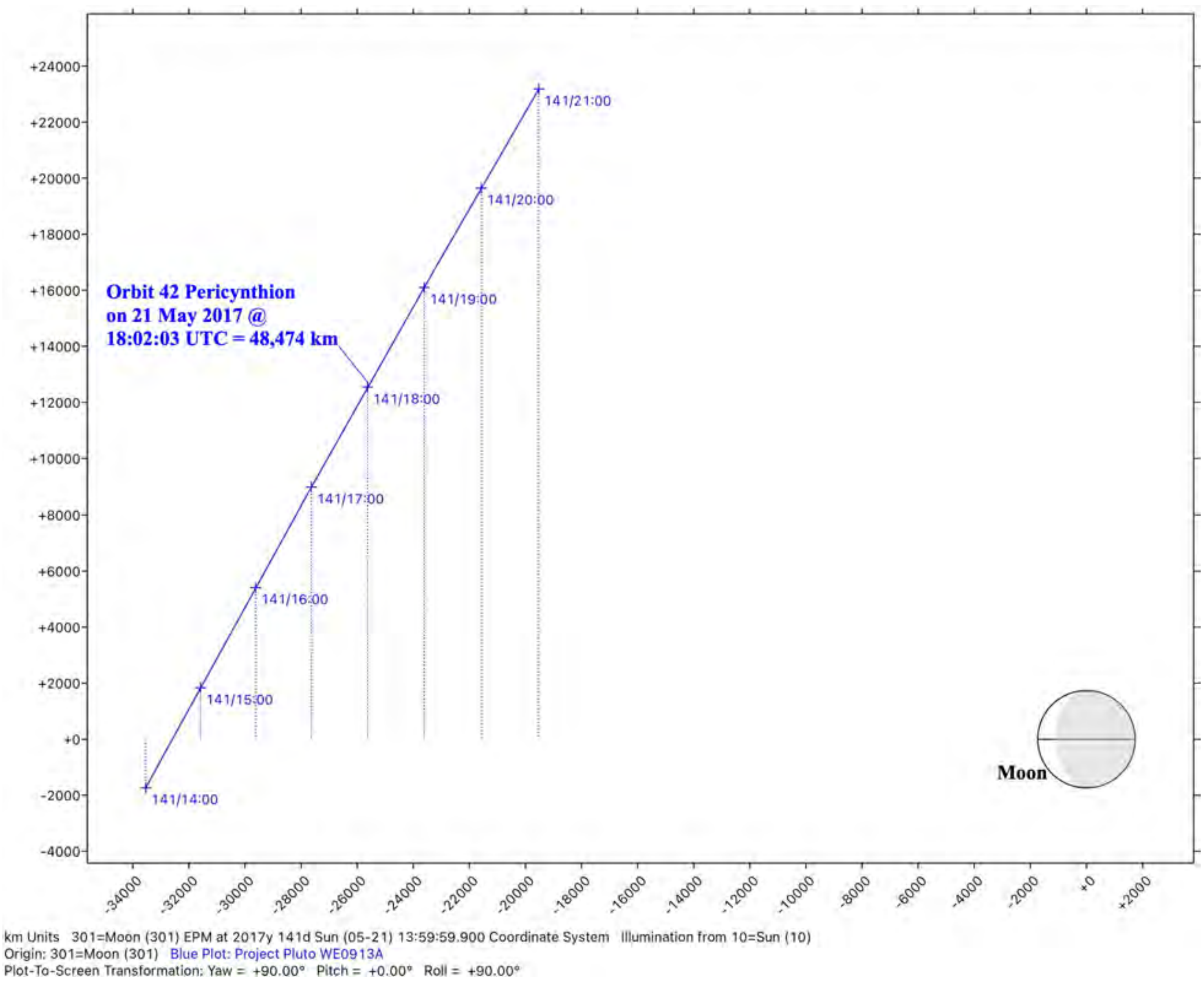

Figure 13. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.4 Orbit 49 Lunar Encounter @ 07.544 September 2017 UTC: 47,236 km

Less than 4 months after the 21 May lunar encounter, WE0913A undergoes a nearly identical flyby as illustrated in Figures 14 and 15. Geocentric semi-major axis is further reduced, and the geocentric orbit remains well inside the Moon's. Figure 15 selenocentric inclination during Orbit 49's pericynthion is 62.4°.

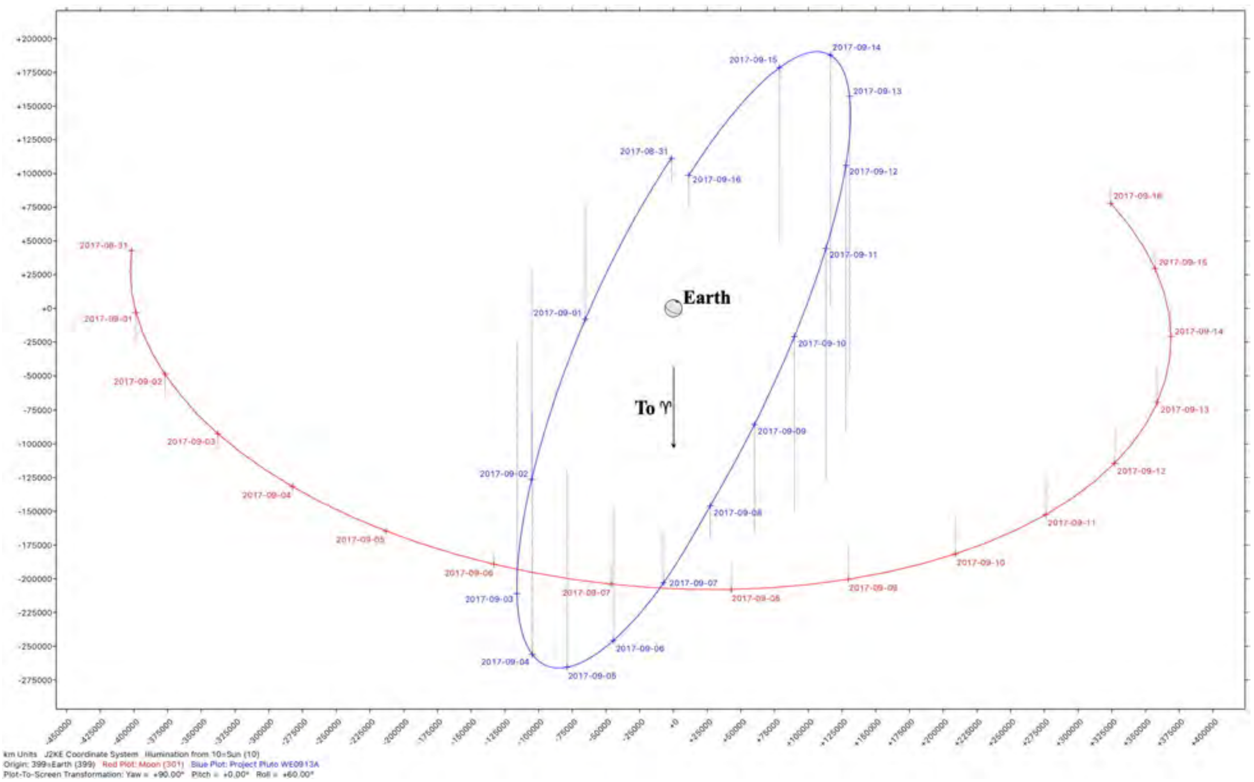

Figure 14. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted through early September 2017, including the close lunar encounter at 07.544 September UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

Object WE0913A, When A Translunar Rocket Disposal Is Left To Chance

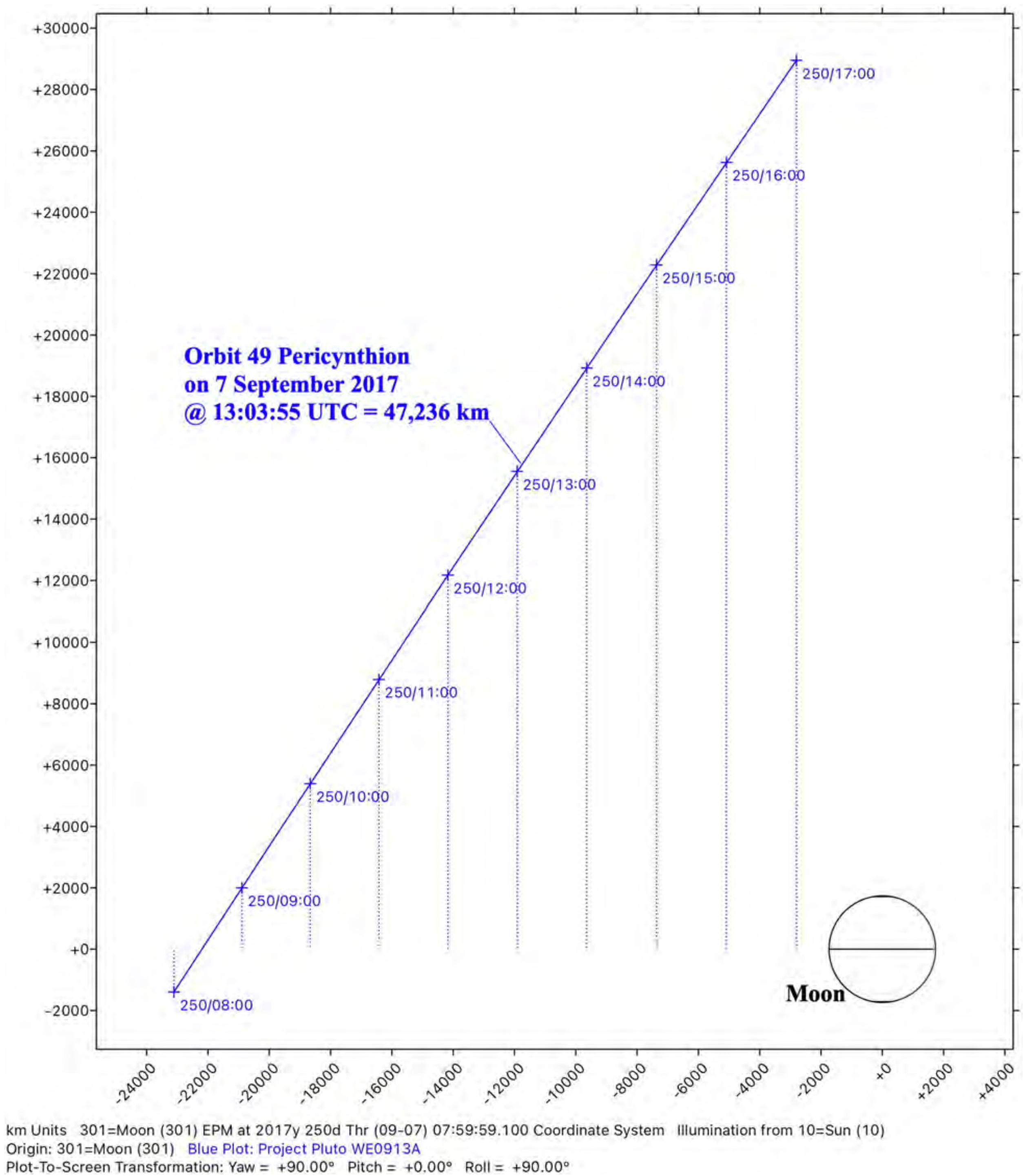

Figure 15. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.5 Orbit 55 Lunar Encounter @ 25.861 December 2017 UTC: 58,826 km

Despite a nearly in-phase lunar encounter near ascending node in Figure 16, WE0913A barely approaches within 60,000 km and experiences relatively minor geocentric orbit perturbations attributable to the Moon. Consequently, WE0913A's geocentric orbit remains well-separated from and everywhere interior to the Moon's. The Figure 17 flyby trajectory has selenocentric inclination 60.6°.

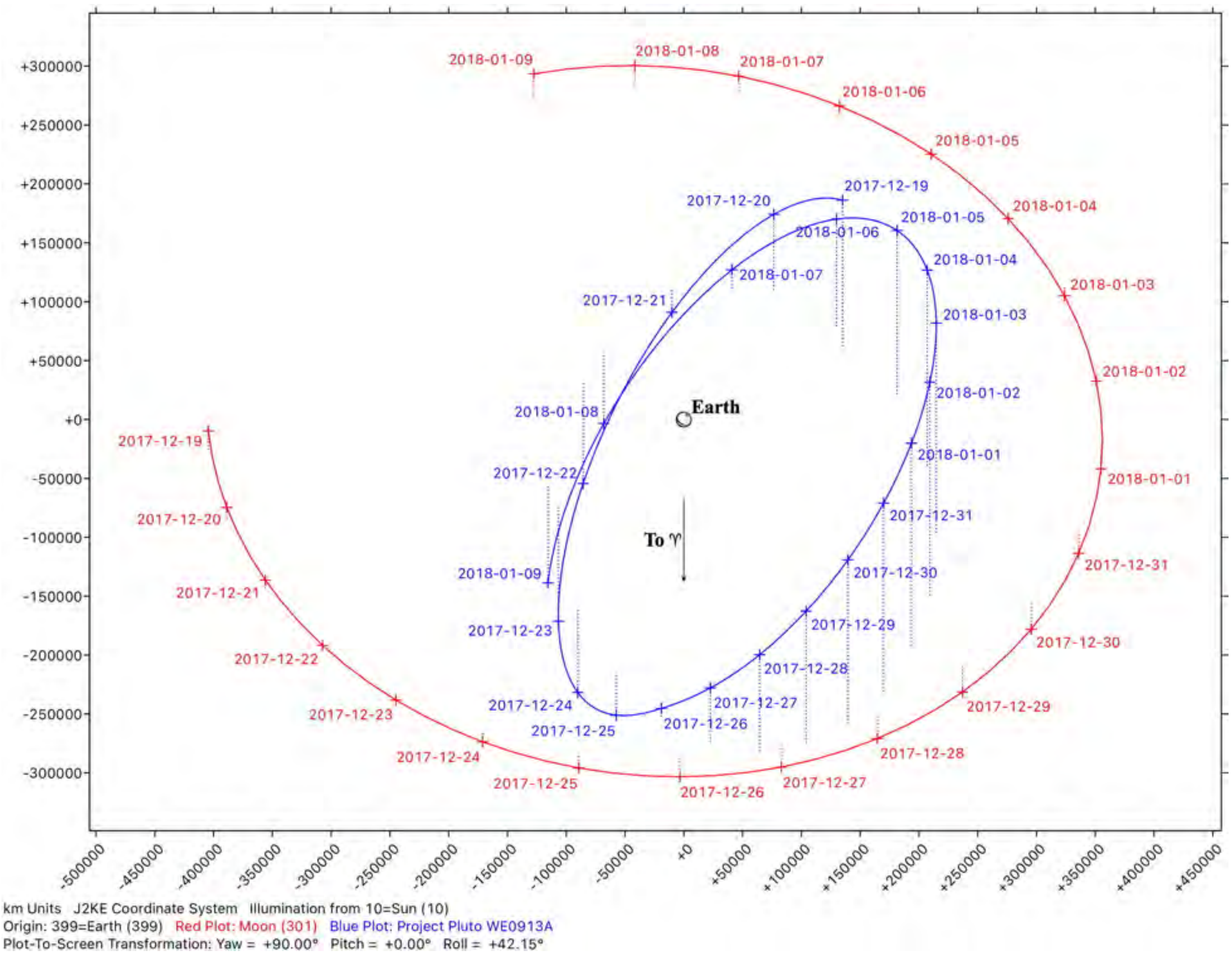

Figure 16. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted through late December 2017, including the close lunar encounter at 25.861 December UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

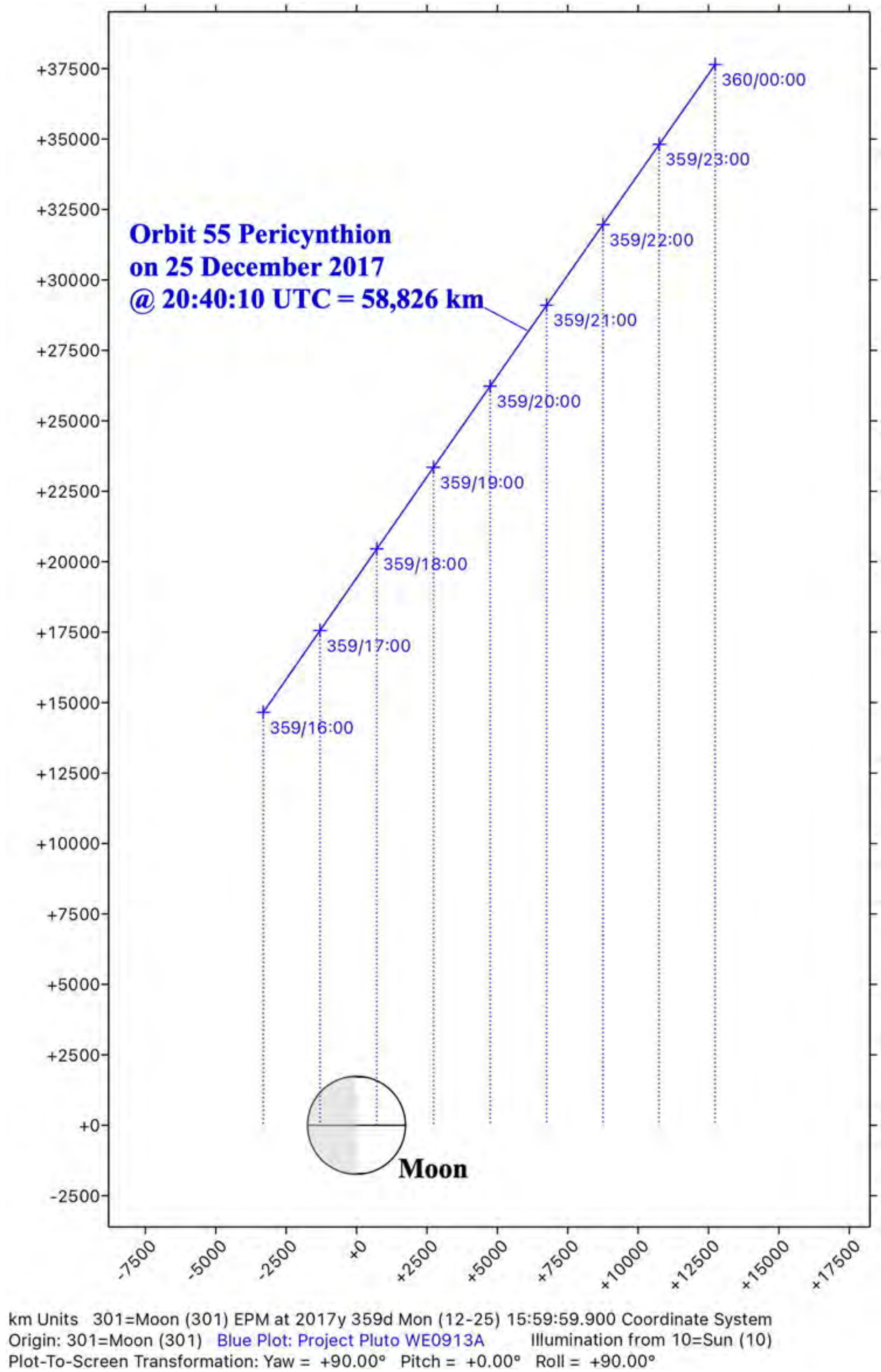

Figure 17. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.6 Orbit 107 Lunar Encounter @ 20.026 April 2020 UTC: 86,534 km

Following late December 2017's lunar encounter, WE0913A does not again approach the Moon so closely until 2022. Therefore, the distant lunar encounter in late April 2020 plotted in Figures 18 and 19 is provided as a midway status check. It finds WE0913A's geocentric orbit still completely interior to the Moon's. Figure 18 illustrates the midway flyby is near WE0913A's descending node on the ecliptic, and Figure 19's selenocentric inclination is 47.7°.

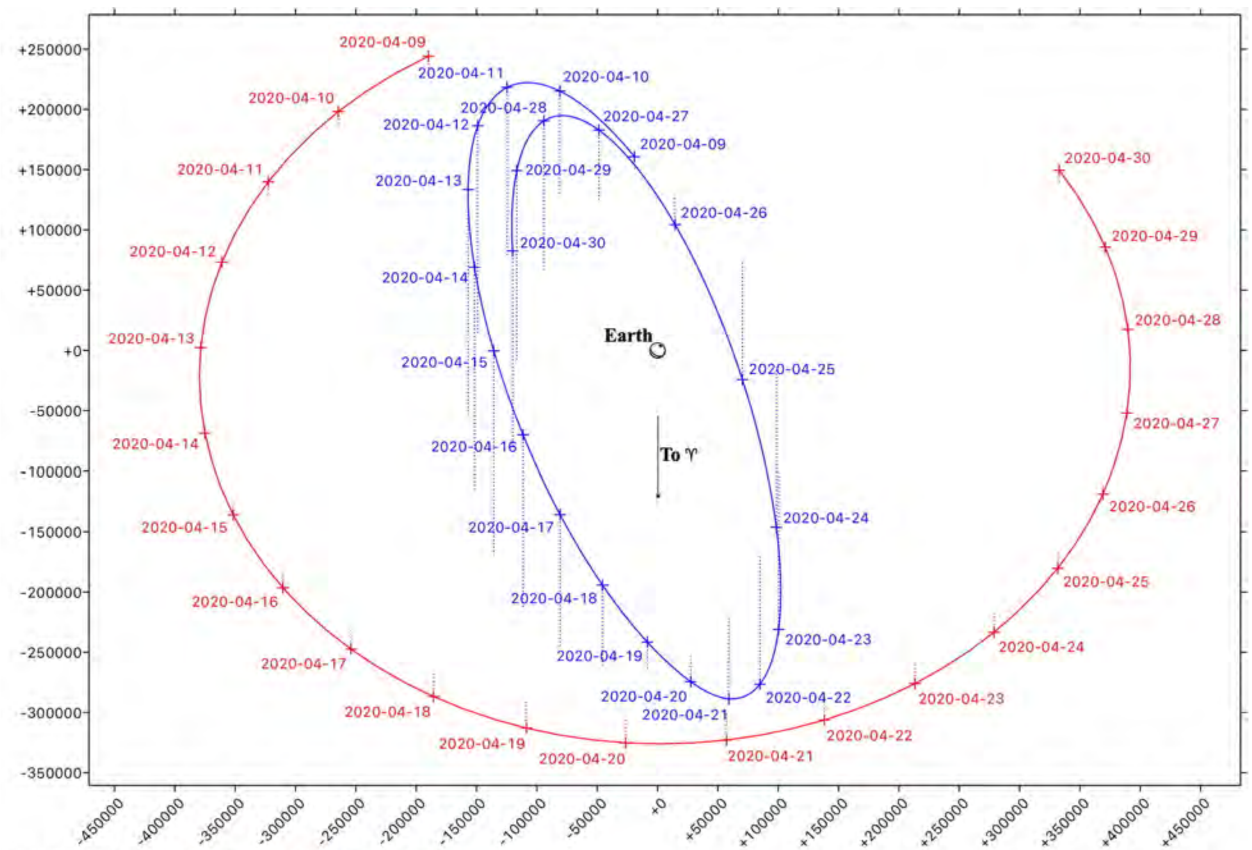

Figure 18. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted during April 2020, including the more distant lunar encounter at 20.026 April UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

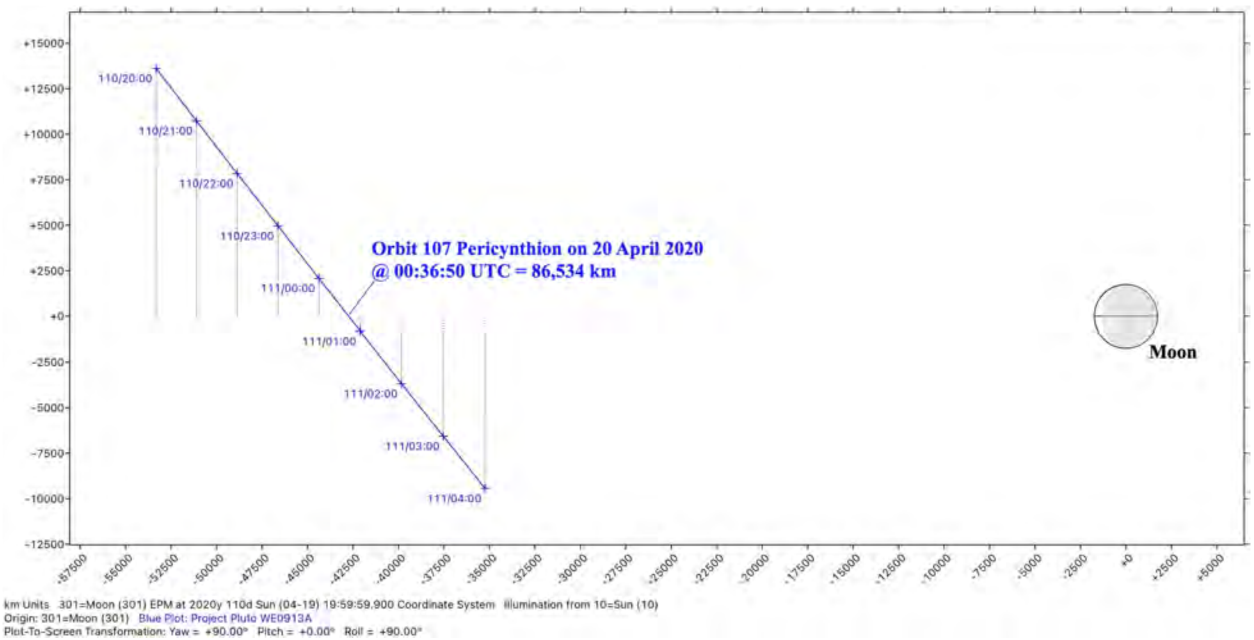

Figure 19. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.7 Orbit 136 Lunar Encounter @ 23.710 August 2021 UTC: 70,025 km

Another distant lunar encounter by WE0913A is illustrated in Figures 20 and 21 during August 2021. Prior to this encounter, WE0913A has become a marginally translunar object, as is apparent from dotted blue projection lines onto the ecliptic in Figure 20. From Figure 21, the encounter is seen to occur near WE0913A's descending ecliptic node with the rocket body trailing the Moon in its geocentric orbit at selenocentric inclination 56.7°. Lunar gravity thereby increases the WE0913A geocentric semi-major axis, rendering it more clearly translunar.

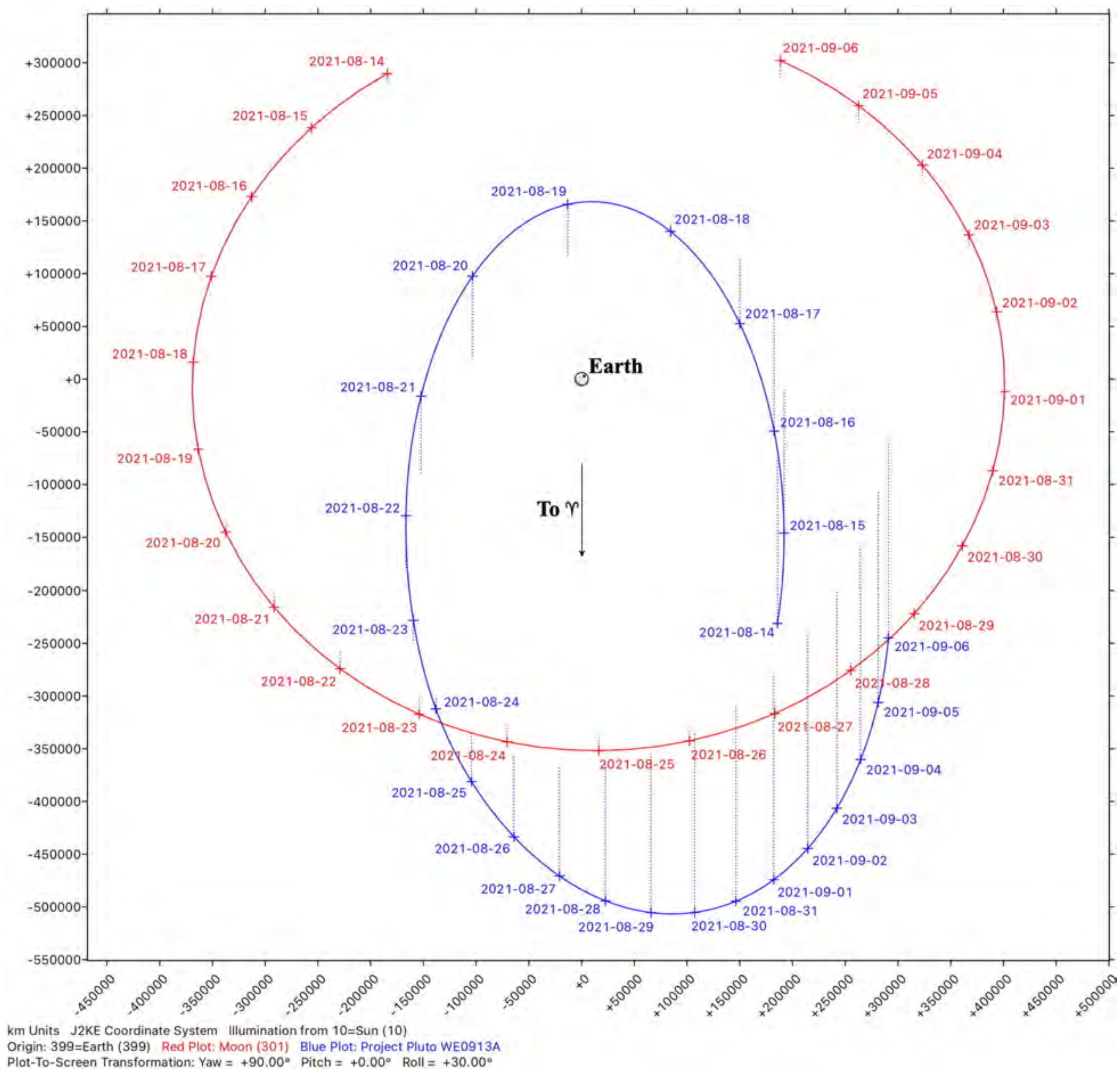

Figure 20. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted during August-September 2021, including the distant lunar encounter at 23.710 August UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

Object WE0913A, When A Translunar Rocket Disposal Is Left To Chance

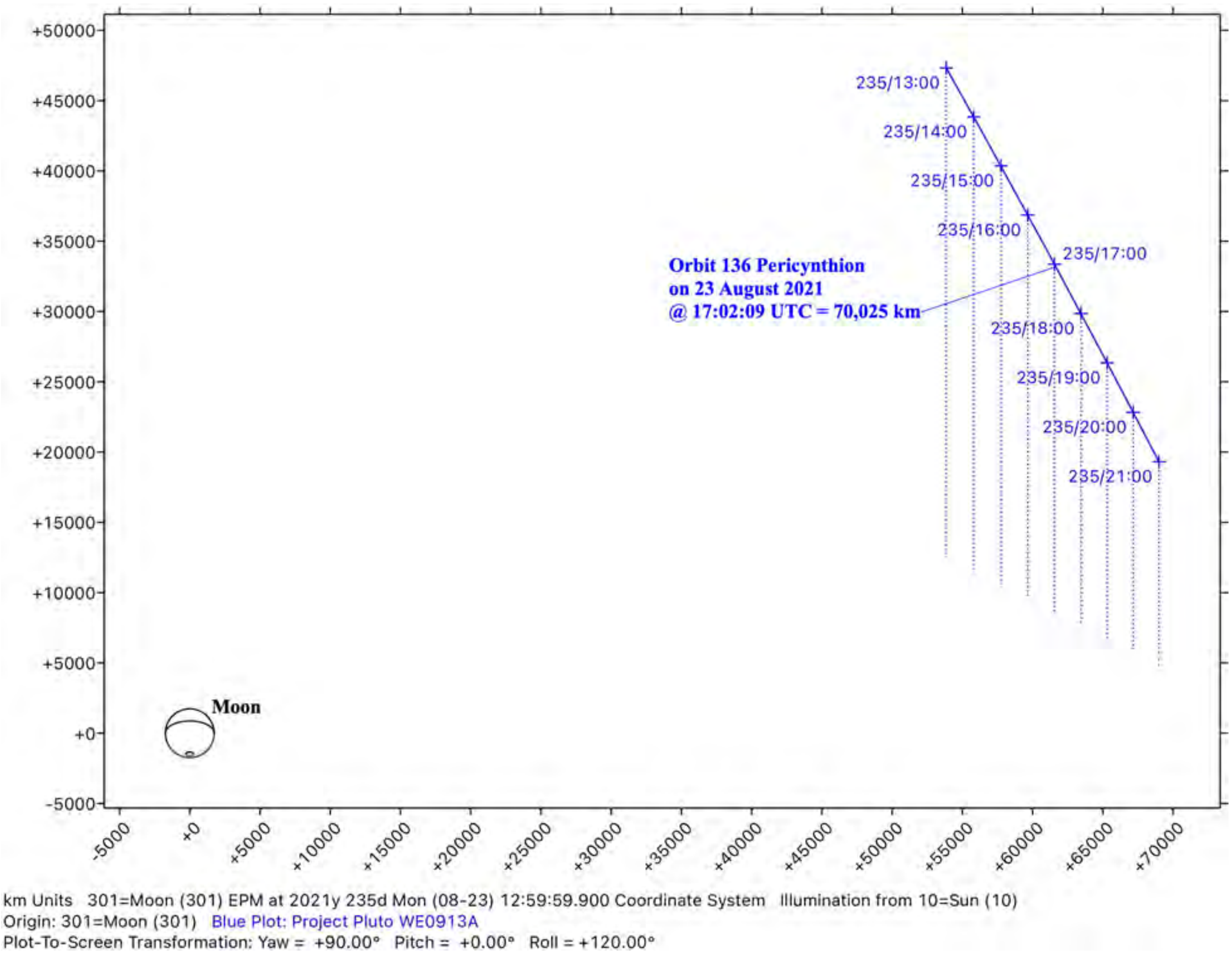

Figure 21. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside predominantly visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.8 Orbit 142 Lunar Encounter @ 05.514 January 2022 UTC: 11,282 km

The lunar encounter by WE0913A in early January 2022 at selenocentric inclination 77.9° is the closest since the hypothesized flyby 4 days after Chang'e 5-T1 launch in October 2014. Strong lunar gravity perturbations reduce WE0913A's inclination to the Moon's orbit plane and further enhance its translunar character, making future lunar encounters more likely than after these attributes were lost in 2017.

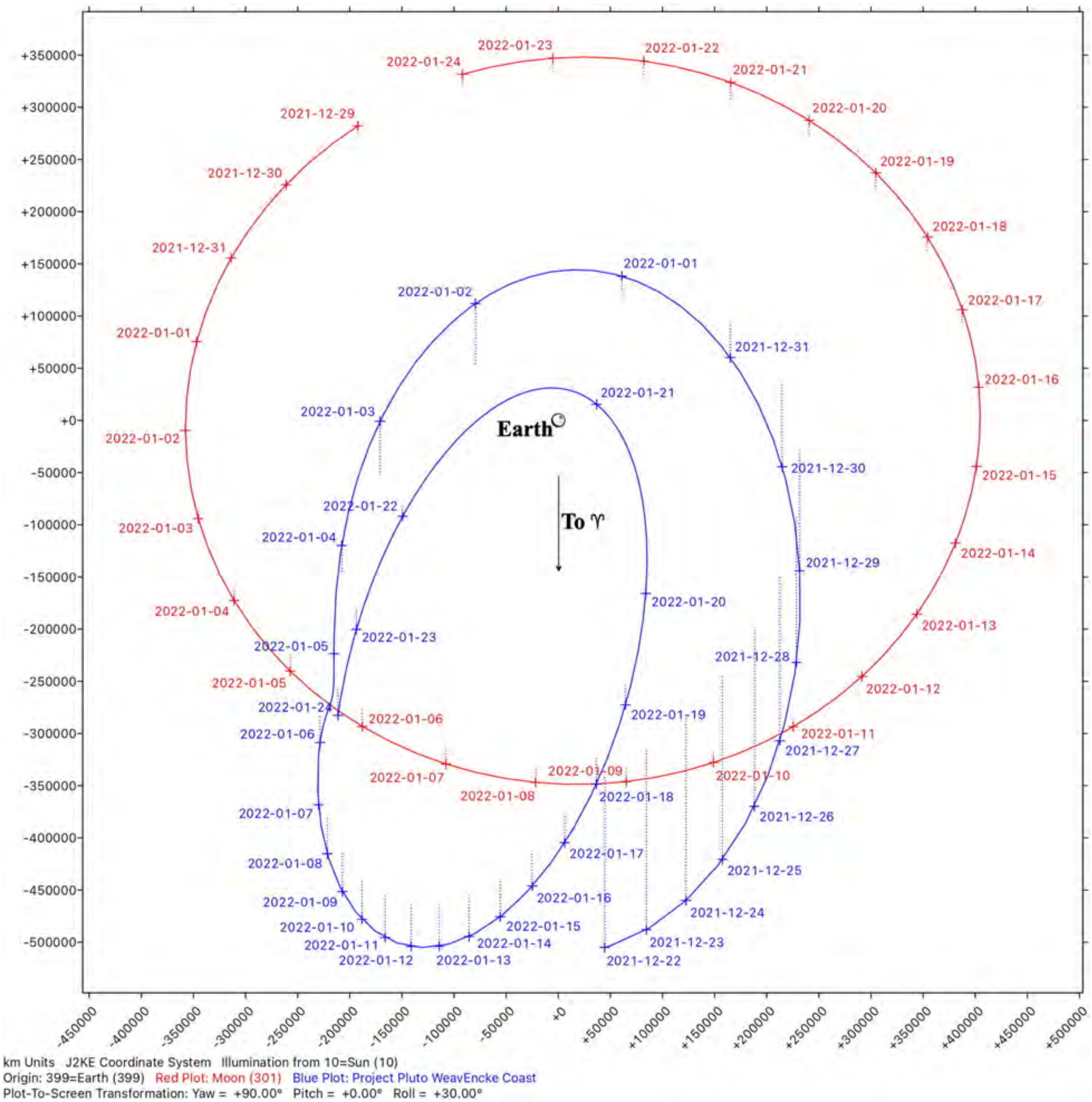

Figure 22. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted during December-January 2021-22, including the lunar encounter at 05.514 January UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

As documented in Table 7, the Project Pluto ephemeris chain has an interpolation "gap" as its 2021 segment transitions to its 2022 segment barely a week after the encounter. Rather than concatenating the two segments into one ephemeris, both Figures 22 and 23 are plotted using a WeavEncke coast bridging the gap.

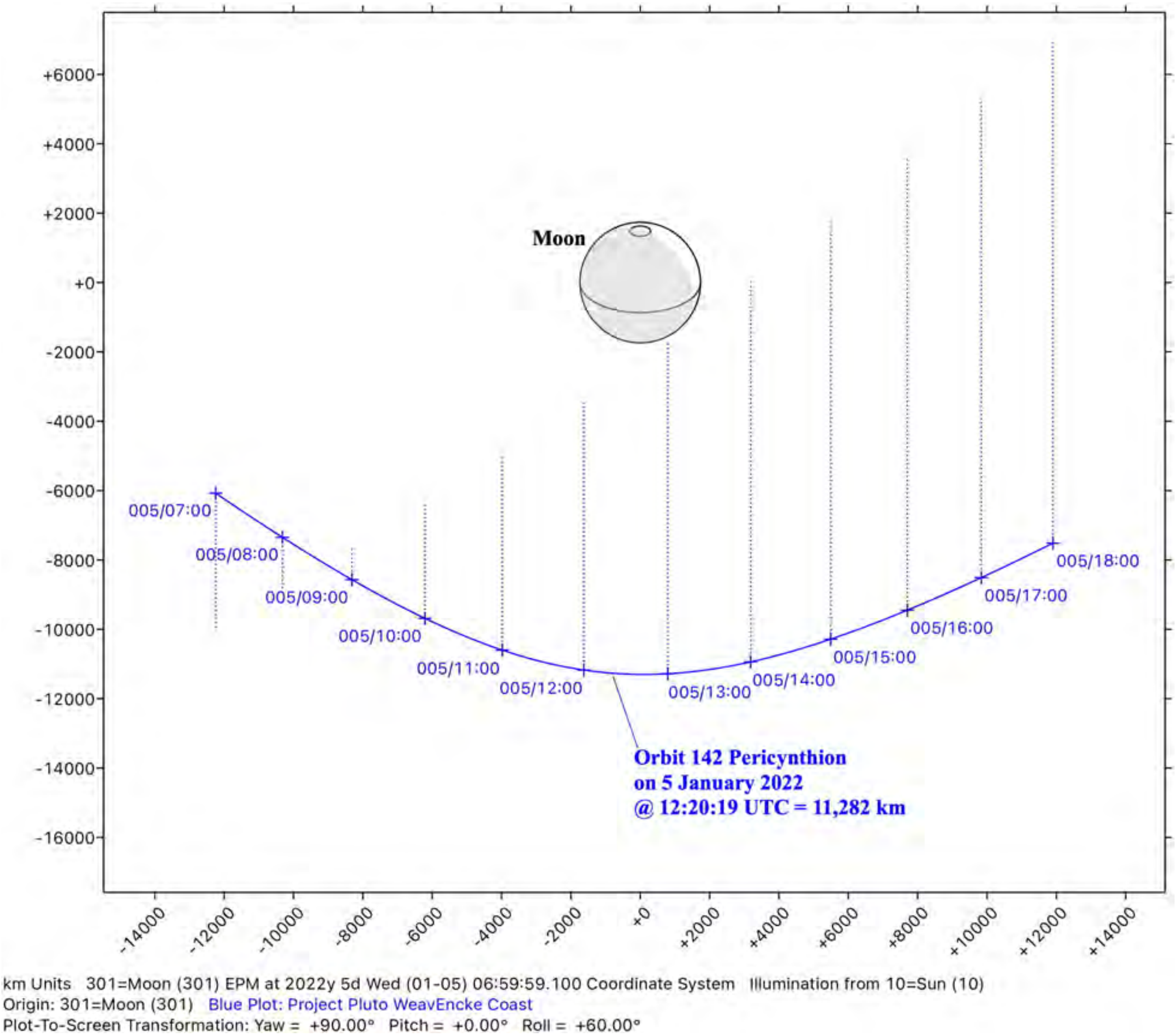

Figure 23. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted with the Moon's nearside predominantly visible. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. Dotted lines are projections onto the lunar equator. The area shaded gray is the Moon's nightside.

4.9 Orbit 143 Lunar Encounter @ 05.249 February 2022 UTC: 62,279 km

The more distant lunar encounter by WE0913A in early February 2022 is illustrated by Figures 24 and 25. Although the previous encounter is outbound from perigee, this event occurs inbound from apogee. With Figure 25 pericynthion at selenocentric inclination 151.7° positioned behind the Moon in its geocentric orbit, an increase in WE0913A geocentric semi-major axis is imparted by the encounter.

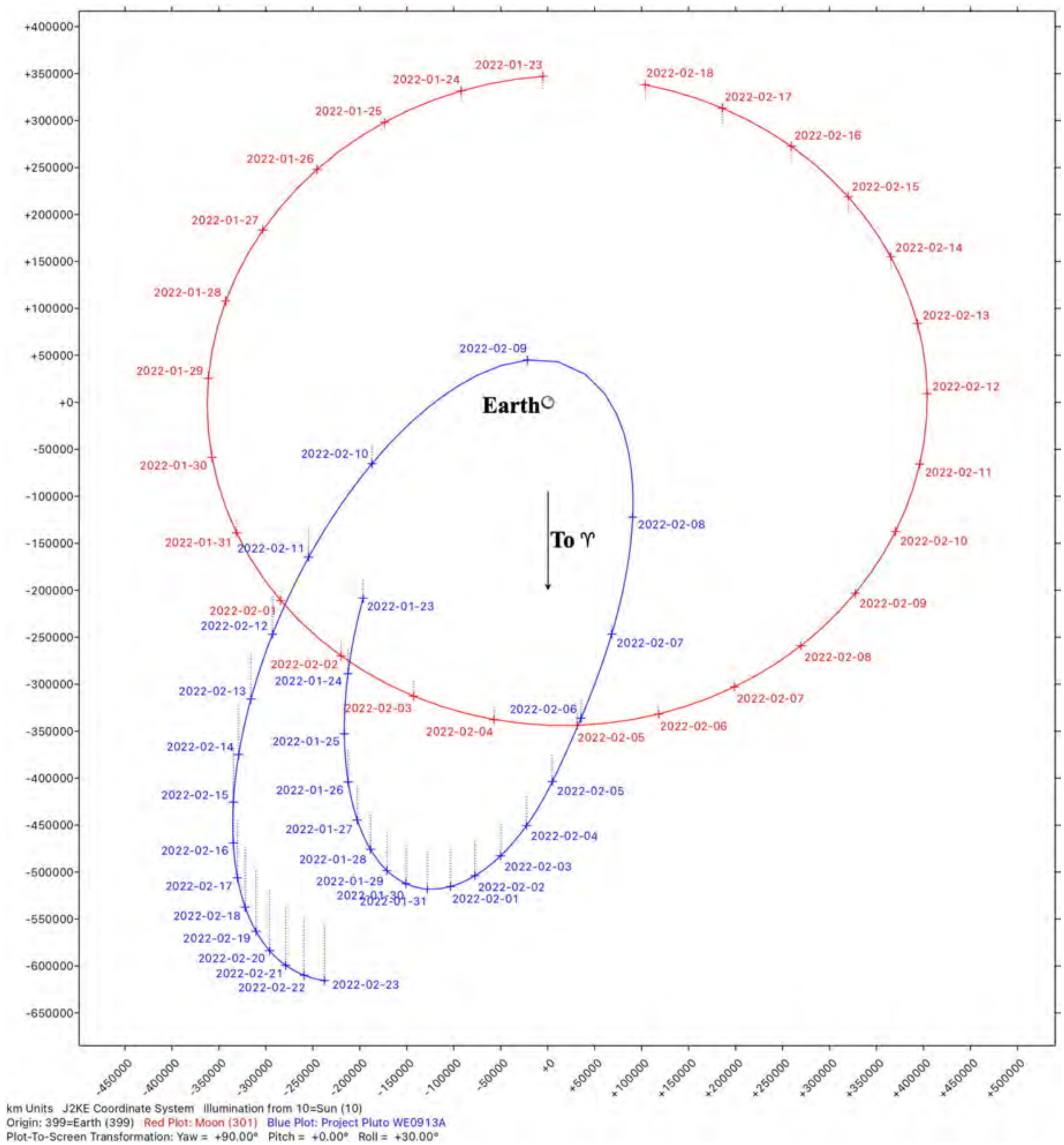

Figure 24. Geocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) and the Moon (red) is plotted during January-February 2022, including the lunar encounter at 05.249 February UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

Object WE0913A, When A Translunar Rocket Disposal Is Left To Chance

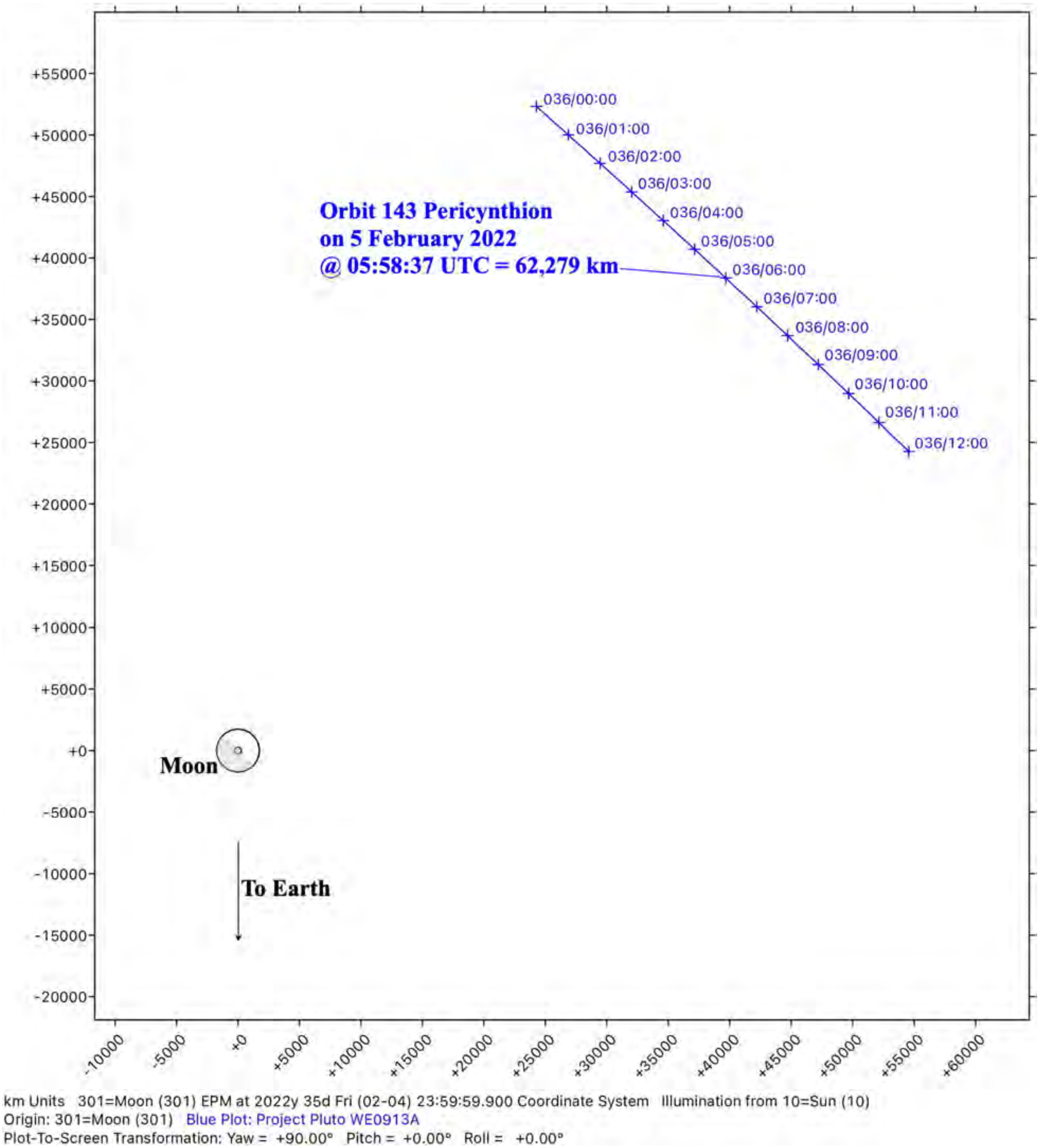

Figure 25. Selenocentric inertial motion of the Project Pluto WE0913A ephemeris chain (blue) is plotted in the ecliptic plane. From this perspective, the Moon's geocentric motion is leftward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. The area shaded gray is the Moon's nightside.

4.10 Orbit 144 Lunar Encounter @ 04.518 March 2022 UTC: 1737 km

The geocentric semi-major axis increase from early February's lunar encounter places WE0913A in a 1 : 1 orbit period resonance with the Moon. An early March inbound lunar encounter is therefore expected, and it ends with impact on the Moon's farside. Figures 26, 27, and 28 illustrate this event with WE0913A at a 35.9° selenocentric inclination.

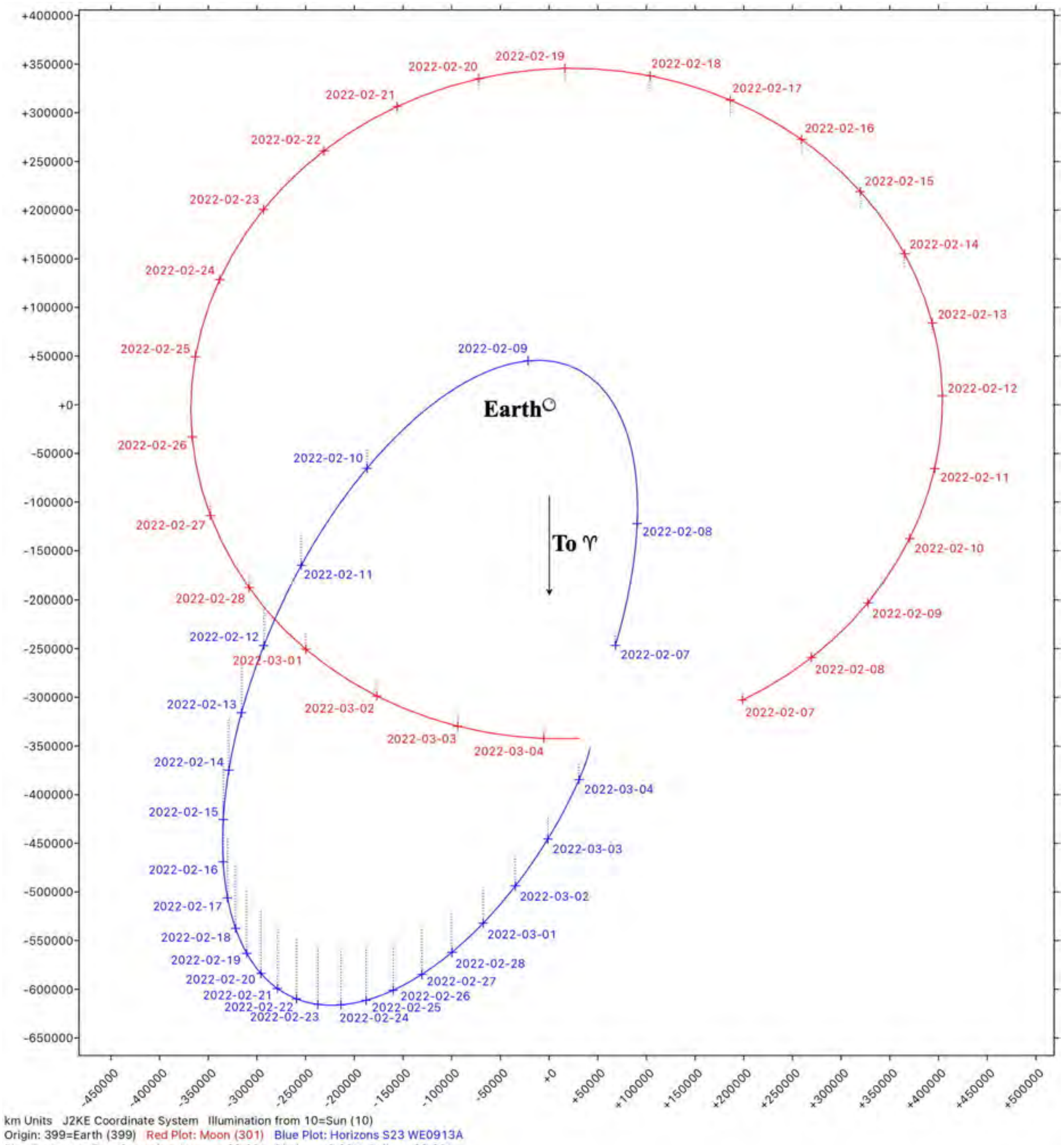

Figure 26. Geocentric inertial motion of the *Horizons* S23 WE0913A ephemeris (blue) and the Moon (red) is plotted during February until a few hours before lunar impact on 04.518 March 2022 UTC. Time tick "+" markers are annotated in YYYY-MM-DD format at 00:00 UTC every day. Dotted lines are projections onto the ecliptic plane. The area shaded gray is Earth's nightside.

Object WE0913A, When A Translunar Rocket Disposal Is Left To Chance

The final lunar encounter for WE0913A is reconstructed using the *Horizons* S23 ephemeris because it can be interpolated through the time of impact. With the Project Pluto ephemeris chain ending about 14.8 hours before impact, using S23 avoids another WeavEncke coasted extrapolation.

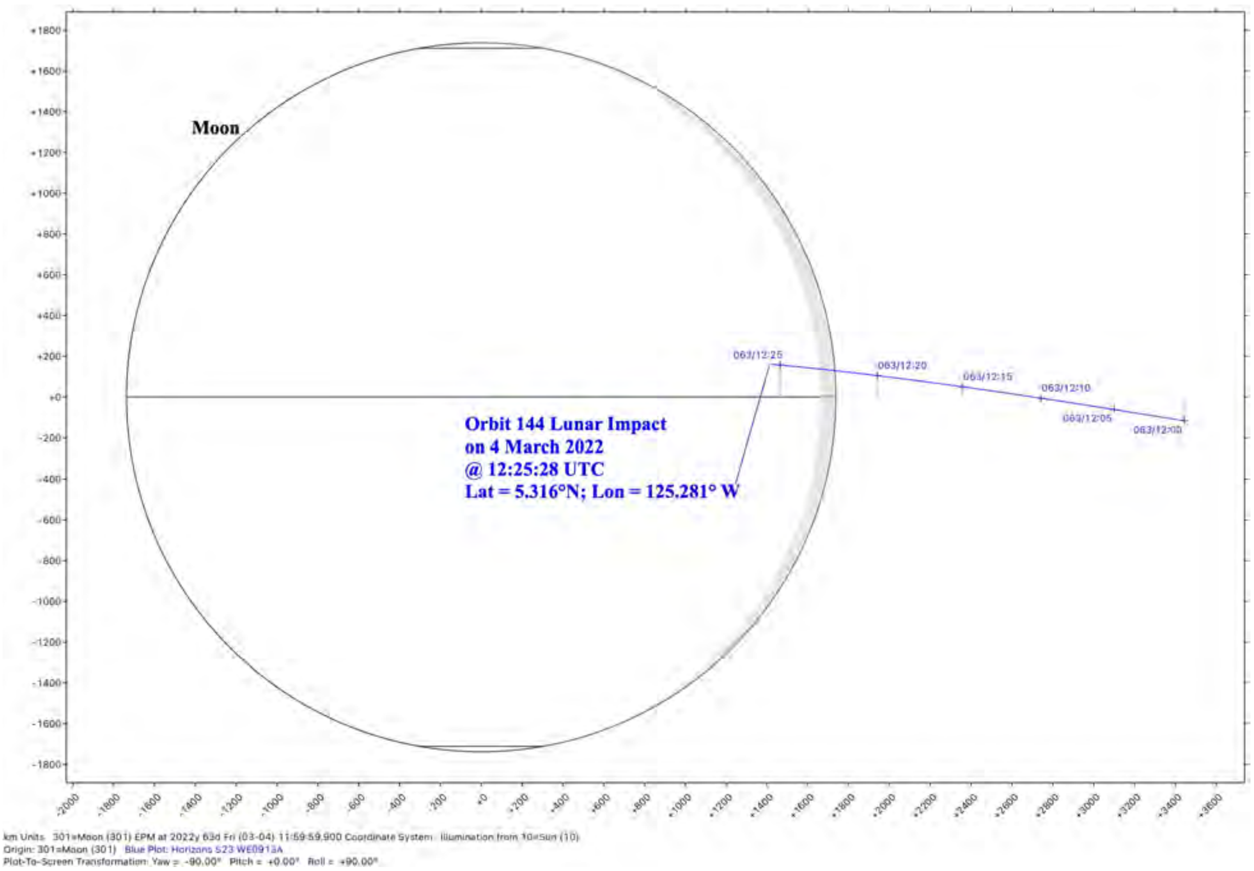

Figure 27. Selenocentric inertial motion of the *Horizons* S23 WE0913A ephemeris (blue) is plotted with the Moon's farside visible. From this perspective, the Moon's geocentric motion is rightward. Time tick "+" markers appear every hour and are annotated in DOY/HH:MM UTC. The area shaded gray is the Moon's nightside.

Figure 28. In this Moon-centered *Celestia*[23] rendering, the diagonal red line beginning at lower left is WE0913A's trajectory leading to lunar impact near the center of the Moon's disc. Earth is visible at upper right. *(To be Continued)*

EXPANDING THE SCOPE OF ASTROSOCIOLOGY IN ORDER TO SETTLE MARS: AN ESSAY (Part 4)[1]

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REPLICATING TERRESTRIAL SOCIETIES ON MARS

The successful functioning of any social group depends upon a shared culture and interacting parts – that is, in this case, students contributing from different backgrounds – that create a stable and largely cohesive social structure. As students cooperate to solve problems associated with making the settlement on Mars possible, they must do so in the context of the fact that they would be living in human-based ecosystem, or space society, as the population expands.

> An example of existing knowledge applicable to space involves society's institutions in the context of replicating a society in space (i.e., a space society) ... In order to place a population of human beings in an isolated and dangerous space environment, planners must construct these institutions (e.g., government, family, economy, and criminal justice) to regulate social life just as they function to do so on Earth. Though social groups will adapt to space the best they can manage, the basic organizational patterns have been tested over thousands of years. They are unlikely to change on a fundamental level. Thus, data available from the study of space analogs is especially relevant to early settlements as well as the early history of all new ones.[i]

Replicating a social system on Mars is a complicated process. It becomes increasingly difficult as the population increases. This requires an increasing level of formalization in turn, which means that the replication of groups and institutions familiar in terrestrial societies becomes progressively important. Sustainability ultimately requires stability in terms of how societies function, which necessitates that they must avoid undue conflict and deviance.

An important aspect of the Tiger Team's efforts, then, must include solving aspects of settlement life that deals with behavioral and interactive complexities. It is important to take into account historical lessons associated with negative impacts on societies as well. Constructing a settlement, both physically and socially, requires attempting to take advantage of the good and eliminate the bad. This is important for both the Tiger Teams and the construction of the actual Martian settlement. Working through both physical and social matters now is extremely important for the success of space societies into the future. A comprehensive understanding of these types of issues

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[1] This paper is an added item from this author for the 24th Annual International Mars Society Convention (2021) that expands the contents of the slide presentation.

by younger students will ultimately result in their chipping away at the status quo by infusing the space sector with a renewed emphasis on astrosocial phenomena.

Social problems will inevitably occur. Thus, students need to be wary about simply solving a physics problem, for example, without taking into account the impact on the human dimension. Another example relates to another focus of the Tiger Team, namely working on cybersecurity issues without taking into account how possible solutions affect others in the settlement. There is a larger human dimension that necessitates the need to integrate the physical and social elements into every procedure undertaken. The advantage of the Tiger Team program is the fact that it combines astrosociology with otherwise non-socially-related problem solving. The real world of human behavior, wherever it exists, is a complex combination of physical and social domains. Taking this into account for students at an undergraduate and even earlier time frame is essential to making a future Martian settlement sustainable and livable.

Space Architecture and Astrosociology

The mere physical construction of a space habitat that supports human life is another example of a necessary although insufficient condition. A human can technically survive in an enclosed and isolated physical structure, but that does not necessarily mean that the social conditions in that structure are conducive to a thriving community, and conditions could worsen as a space society on Mars becomes more complex organizationally.

Photos Credit:
https://www.yankodesign.com/2020/08/04/space-architecture-designed-to-be-a-home-to-the-future-humans-living-on-mars/

Figure 12: Outside Architecture / Inside Garden

Architectural decisions have implications for both practical recreational and working conditions *and* how the settlement is intended to operate. For example, a corporate or government sponsored settlement will differ from a penal colony in terms of how the physical elements are constructed. "Leaving Earth will require a re-evaluation of our societal values, cultural practices and preferred governance systems."[ii] This type of re-evaluation is intimately related to how the modules are designed, as it informs how the residents will interreact on a daily basis. If punishment is not the motivation for design, then it is important to avoid architectural elements that are conducive to negative experiences in everyday social life. Social structures are also affected. Quasi-military governmental structures that were appropriate for small groups of astronauts in the past may not be the best solution in large settlements, especially when their orientation is a focus on scientific objectives such as the search for Martian life, for example.

Decisions about what types of architectural designs are beneficial versus detrimental to settlers involve a series of compromises. One area of architectural decision making involves the overall design itself. Should modules be separate physical structures, which would require settlers to don spacesuits to move around the settlement or should they be linked together as shown in Photo #1 in Figure 12? Another example is whether farming should be designed as a strictly functional matter such as an unemotionally pleasing hydroponic room or should it be more esthetically pleasing such as part of a garden (see photo #2 in Figure 12, for example). Function will not always result in a positive outcome while form can become the best solution for various situations. Human needs may even compromise the best functional architectural resolution.

Thus, upscaling solutions derived in the classroom requires imaginative thinking for students. Space architecture is important even when working on solutions to a scientific problem. Solutions derived must fit well into how the overall, or a specific, social structure functions. How these resolutions are designed may not fit well into a human ecosystem. Interestingly, not all settlements will require the same types of implementations as they relate to their physical and/or social requirements. The need for aesthetic surroundings and other architectural matters may seem of secondary importance, but long-term or permanent residence on Mars is not a trifle area of concern and must be thoroughly investigated.

CONCLUSIONS

The development of astrosociology is important because it continues building a community of individuals focused on outer space from social and behavioral science, humanities, and arts perspectives. Such voices have been relatively quiet throughout the space age. Beyond this, the development of space exploration has historically taken place with a singularly strong commitment to focus mostly on the STEM-based disciplines and academic fields to the detriment of the social sciences. The objective for this pilot high school program is to eventually get more social scientists involved in the study of astrosocial phenomena while convincing those in the traditional space community to accept them and work with them.

Thus, a few interrelated facts cannot be overly emphasized. Based on the history of space exploration and visions of settlements beyond Earth, it has long been painfully clear for many social scientists that sociology and the other social sciences have failed to be influential in the space sector.[iii] [iv] [v] [vi] [vii] Concurrently, too many of those outside of the STEM disciplines have demonstrated relatively little interest in space issues. Abundantly clear is the fact that this cannot continue, especially as humankind contemplates migrating beyond Earth, which is fraught with dangerous environments that challenge human survival. It is essential to provide spacefarers with all the knowledge available, including that related to the human dimension, so that they can potentially solve problems related to physics as well as social problems whenever they arise. It cannot be predicted which types will reveal themselves.

There is a growing need for social and physical elements to converge much more formally in order to produce an unprecedented holistic understanding about what it will take to settle Mars on a sustainable basis.[viii]. Such a convergence between the social and physical branches of science is a great step forward that must involve students becoming aware of this overwhelmingly growing necessity. A holistic approach that integrates all levels of education and research among students, educators, and professionals is the best path forward.

Therefore, "Expanding Astrosociology in Order to Settle Mars" presumes that social science is largely missing and there is the need to get astrosociology into the classroom so that a pipeline from the high school level, and even lower, allows social science students studying astrosociology to move into postsecondary schools and eventually into the space sector. It refers to the need to bring the non-STEM academic fields and disciplines to a point of at least near equal footing in the planning of the mission and to a much better understanding about human behavior in transit to, and living in, Martian settlements. The social and behavioral sciences, humanities, and arts all have their roles to play along with the STEM disciplines and fields. While the problem in the past has been the overwhelming focus on the latter, the need can be addressed successfully if the mindset changes on an unprecedented basis, which is increasingly necessary as plans for sending humans to Mars are accelerating.

At the outset, in contrast, the Astrosociology in the Classroom program alone focused almost exclusively on postsecondary students, which was a limiting approach. Together, however, the First Classroom on Mars that includes Tiger Teams and the Astrosociology in the Classroom pieces exist to engage educators, professionals, and students in increasing the status of the human dimension of space exploration and settlements. That is, this hybrid program is aimed at providing students with opportunities to pursue space education that includes a social scientific perspective. By placing the astrosociologist in the leadership position of each Tiger Team, high school students are introduced to astrosociology, which has never existed before. Moreover, they flip the normal script by informing students that the social sciences are just as important as the STEM disciplines. This pilot program is limited, but it lays the foundation for a new approach. Mentorships from the university level downward will also become much more possible once astrosociologists enter academia and the space sector in adequate numbers.

At this moment, settling Mars is not practical because the social sciences are not ready. It is vital to expand astrosociology in order to settle Mars successfully and sustainably. Thus, settling Mars without inclusion of the social sciences will be difficult, and perhaps impossible. This is a conundrum! How do you educate and train enough social scientists? How can those in the STEM disciplines attract social scientists? Answers to such questions boil down to the fact that progress must occur within and between both the social sciences and physical sciences. If the pace can be accelerated and the participants expanded, then a sustainable Martian settlement is much more probable and closer to reality in the relatively near future. This will require greater funding for astrosociology's development directly as well as new and existing programs that support it. The case here demonstrates that it is possible is to integrate astrosociology into previously existing programs with adequate funding.

The types of programs such as those described herein are aimed at modifying the status quo that devalues social science input, as many have argued has been the necessary case since the Mercury program, which was based on a practical need to rely on physical science, mathematics, and engineering, as the first astronauts entered into the unknown, NASA wanted to select astronaut candidates with outstanding physical, psychological, and biological attributes. In contrast, the great majority of Martian settlers will not embody "The Right Stuff" [ix] characteristics of that era, nor should we expect them to live up to such an archaic standard.

For astrosociologists, the high diversity characteristic of the settlement population will necessitate a high number of social-scientific investigations in the actual settlement, as settlers will exhibit a variety of statuses and associated roles. This lesson is important for the members of the Tiger Teams as they continue to work in their analog settlement simulations long before humankind actually sets foot on the Martian surface. Integrating the social and physical sciences early for students will provide them with well-rounded backgrounds as they advance to their next educational level.

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[i] Pass, Jim (2008). "Astrosociology and Space Exploration: Taking Advantage of the Other Branch of Science." *Space Technology and Applications International Forum (STAIF) Conference Proceedings*, 969(1), pp. 879-887. [Paper published in Proceedings and presented at 2008 STAIF Conference in Albuquerque, NM]. URL: http://www.astrosociology.org/Library/PDF/STAIF2008_OtherBranch.pdf.

[ii] Edwards, Erin (2020). "Will Our Cultural Baggage Permeate Our New Homes in Space?" *Astrosociological Insights,* 8(1), p. 14.

[iii] Bluth, B.J. (1988). "Lunar Settlements: A Socio-Economic Outlook." *Acta Astronautica*, 17(7): 659-667.

[iv] Harrison, Albert A., Yvonne Clearwater, and Christopher McKay (1991). *From Antarctica to Outer Space: Life in Isolation and Confinement*. New York: Springer Verlag.

[v] Rudoff, Alvin (1996). *Societies in Space (American University Studies, Series XI, Anthropology & Sociology, Volume 69).* New York: Peter Lang Publishing.

[vi] Tough, Allen (1998). "Positive Consequences of SETI Before Detection." *Acta Astronautica*, 42(10-12): 745-748.

[vii] Harrison, Albert A. (2001). *Spacefaring: The Human Dimension*. Berkeley, CA: University of California Press.

[viii] Pass, Jim, and Harrison, Albert A., (2016). "Astrosociology (Social Science of Space Exploration)." Chapter 38 in Bainbridge, William S., and Roco,Mihail C. (eds.), *Handbook of Science and Technology Convergence*. New York: Springer, pp. 545-558. Prepublication Version (2014). URL: http://www.astrosociology.org/Library/PDF/PassHarrisonConvergence.pdf.

[ix] Wolfe, Tom (1979). *The Right Stuff*. New York: Farrar, Straus and Giroux

SAVE THE SHUTTLE:

The Life and Times of the Space Shuttle and the Secret Attempt to Save it (Sample Chapter excerpts)

by Dr. Lawrence Kuznetz, Former NASA Senior Scientist and Aerospace Engineer

L H KUZNETZ

OVERVIEW.

This is a painful story you're about to hear but it's not all doom and gloom. For like a Phoenix rising from the ashes, the space shuttles rose from 2 horrendous disasters to redeem themselves. The frantic attempt I began to save and re-fly them after their retirement was a fool's errand if ever there was one. The program had been running $5 billion a year in the red for over 30 years, and the notion that anyone could save much less fly them at a profit at this end stage was ridiculous. The notion it could be me and my little band of bottom crawlers was patently absurd.

Yet that's what nearly happened.

Their last flight had been a PR stunt, a cross country jaunt atop a 747 carrier plane to museums. I couldn't watch and vowed to never enter those museums. The Shuttles belonged in space, not in 3 museums and the $20 million they'd each paid NASA for *Atlantis*, *Discovery* and *Endeavour* was as good a steal as the Dutch foisting Manhattan Island from the natives for 24 bucks.

It took years to get over the emotional hit of losing them and I did it by writing this book. Only then did I come to understand the legacy left by the Shuttles. It can be summed up in a single word—REUSABILITY. That word is what drove Elon Musk to start SpaceX, drastically cut the cost of space flight and propel him on a mission to make humanity a multi-planet species before we lose our only home to disasters of our own or cosmic making. For their part, NASA forgot about that word. Their SLS Space Launch System, the biggest rocket built, will drop it's jewel-like Shuttle-derived main engines into the Atlantic Ocean never to see the light of day again. But I'm getting ahead of myself. So let's start at the beginning:

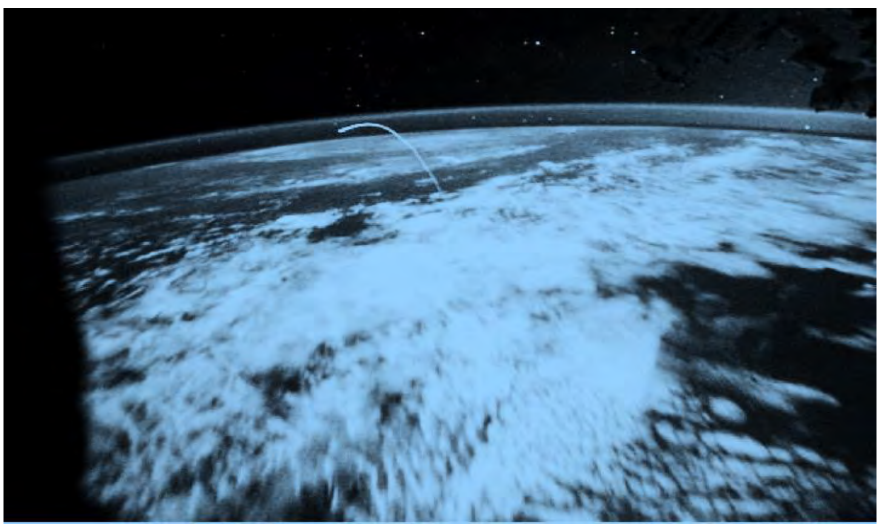
On April 5th. 1979 I walked through a tightly guarded set of yellow-rimmed double doors into the biggest jigsaw puzzle in human history. It had 31,763 pieces, no two alike, each of a different size, shape and thickness. What made this puzzle so mind blowing, was that a single mistake, like inadvertently swapping 2 pieces that looked alike, grabbing one piece too hard or not placing one precisely in its intended spot—and I mean PRECISELY—could obliterate 5 billion dollars and multiple human lives in a heartbeat.

Avoiding this catastrophe fell upon the shoulders of 1200 select people. People who worked around the clock wearing secret badges sequestered in a secret building for an interminable period of time fighting against an externally imposed critical deadline. They had left family, friends and normal lives to solve this puzzle and saw births, deaths, joy and sorrow as their ritual continued. They were known as The Puzzle People and success in their struggle wouldn't be measured like in a conventional jig-saw puzzle with pieces fitting neatly together in an eye-catching graphic. It would be measured by a massive explosion with no one getting killed.

Decades later in 2011, long after all 31,763 tiles had been bonded to Space Shuttle *Columbia* and the Shuttles had flown 135 times, they were retired. This was their epitaph:

Carried 700+ astronauts safely to space from 16 nations
Delivered over 3 million pounds to orbit
Flew 850 critical payloads for communication, crop and weather management
Launched, saved and maintained the amazing Hubble Space Telescope
Launched, assembled and completed the International Space Station
Launched the Galileo probe to Jupiter and Cassini to Saturn
Exploded during launch (Challenger) and reentry (Columbia) killing 14

In August of that year, I found myself in the IMPOSSIBLE position of trying unretire, save and privatize them while they waited to be shipped off to museums. The caper began with a photograph.



Taken from ISS, the International Space Station, it shows Shuttle *Atlantis* plunging to Earth on its very last flight. I showed this picture to a friend and gawking at it, he asked: “Why is NASA retiring them?” When I answered, “to put them in museums,” he said, “That’s insanity. Let’s rescue them. They belong to the people, not NASA or museums.”

While that nudged the caper out of the starting gate, it didn’t get serious until a month later when I was on the Queen Victoria cruise ship to give a talk. That’s when the kingpin of the one-armed bandit machines in pubs across the UK approached and asked, “You mean those shuttles are for sale? How much? Can anybody buy one?

If you told me then that we’d soon raise $3.5 Billion, have bipartisan support from Congress with Neil Armstrong behind us and help set the stage for Elon Musk’s commercial space business and drive to Mars, I’d have said you were nuts.

But truth can be stranger than fiction.

12/20/2011

Last Ditch Effort to Save the Space Shuttle Program

By keltrustsnoone

NASA's Space Shuttle could have flown again as early as 2014 if a secret effort to repurposethem for commercial flight had succeeded.

Two reports this week reveal frantic efforts to save one or two Shuttles from full-scale dismantling and relaunch them as a commercial operation—without government funding. Part of this incredible story comes from someone who ought to know, Mary Lynne Dittmar, PhD. Though she now runs a consulting firm in Houston, TX., Dittmar previously managed International Space Station Mission Operations and Spaceflight Training for the Boeing Company. In a fresh post on her blog, Dittmar tells the tale of an English millionaire who thought there might be a chance that the Space Shuttle Atlantis and Endeavor could be used for commercial operations.

Dittmar writes that she was initially "disinterested" in the idea: The space community had "moved on" from the Shuttle program and commercial shuttle program efforts were nothing new and generally financially unsustainable. The millionaire persisted and eventually Dittmar listened. Dittmar, though, did outline four prerequisites for a viable commercial space shuttle project:

1) No government money for development or operations
2) A real business without NASA as a customer
3) An ability to reimburse the government for any infrastructure costs involved
4) She would only support a serious effort and a team she trusted.

According to a lengthy report on NASA Spacelight.com, Dittmar not only became a revival supporter and a key liaison in the Shuttle revival plan, but also saw real benefits in the switch to commercial operations.

"One of the advantages of our purely commercial approach is that it allowed our engineers to consider alternative suppliers and advances in manufacturing, materials, processing, and production across the globe and across several industries," Dittmar told http://www.nasaspaceflight.com

Though secret, the plan quickly gained support and Dittmar described how funding and interest grew dramatically. "Initially skeptical," she wrote, "people became caught up in the vision of a Commercial Space Shuttle funded entirely by private and institutional investors and put back into service to shape new markets."

Over a 10-week period, all the pieces seemed to be falling into place. According to NASA Spaceflight.com, "Based on 'available demand' – details of which are proprietary – it was anticipated one flight would have taken place at the end of 2014, then two in 2015, three in 2016, and four a year beginning in 2017." That was just a little more than two years away.

So why aren't we gearing up for the return of the Space Shuttle program?

Sample Chapter excerpts

Prologue

What if there was an machine that could take you to the coolest place, a place where you could lose all your wrinkles, float free as a bird, peer out at the cosmos, do amazing experiments, and finish with a breathtaking roller coaster ride through a 3000 degree plasma before gliding to a silent stop on a runway? Once upon a time there was such a machine and nearly 700 people boarded it, many repeat passengers. It was called the Space Shuttle and on July 21 2011, 42 years and 1 day after Neil Armstrong took his historic first step on the Moon, it was officially retired. While many people came out to salute it and cheer when it flew through their cities atop its iconic 747 on the way to museums, I was filled with sadness. I knew it didn't belong in museums.

Chapter 1. Words from The Moon

The space shuttle program began with a BANG—the launch of *Columbia* in April 1981, and ended with a whimper—*Atlantis* rolling to an eerie stop on July 21, 2011. A highlight reel of its 30-year life might include: 135 flights; launching and saving the incredible Hubble Space telescope; building ISS, the International Space Station; flying hundreds of people into space, including men, women, congressmen, teachers, even an Arab sheik, and lest we forget, 2 catastrophic accidents. During my career, I had the privilege of being there from beginning to end. I didn't design nor fly in them but I did help build them, standing with many others, on the shoulders of giants to do so. And in an unlikely twist of fate I spent nearly half my life with them.

The adventure began in April 1967 on a stormy day in League City, Texas, a suburb of Houston at the doorsteps of NASA. I was staying at the home of a family friend until I could find an apartment of my own after moving from New York. It was my first time in Texas and I was nervous. I was also excited. Only a super-magnet could have drawn me away from the center of my universe in the Big Apple. Project Apollo and the race to the Moon was that super-magnet. It was 7:30 that morning when my new boss, Reese Reumont, beeped his horn to pick me up. One of the fiercest thunderstorms I'd ever seen greeted me as I left the house. You couldn't see your fingers in front of your face. Carrying a flimsy umbrella that the wind promptly destroyed, I tiptoed across a driveway full of potholes until I got to the biggest one of all by the beckoning door of Reumont's Ford. He was motioning for me to jump over it. I pondered the size of it, using everything I 'd learned at Columbia University's School of Engineering to precisely calculate the strength and duration of the required leap. Only when my foot slipped off the back edge and I tumbled ass-first into the pothole did I realize the calculation hadn't been precise enough. And that the only suit I owned was now covered in mud. Reumont, already late to a meeting, refused to let me go back and change. Hiding a smile, he grabbed a towel from his trunk and motioned for me to sit on it. I spent my first day washing and drying that suit under a hair dryer instead of building and testing spacesuits, the job I would soon be tasked to do.

Chapter 2. Piled Higher and Deeper

The days that followed were filled with wonder. Everything was brand spanking new to me, especially Texas. It was like a different country. The women were different--they wore hot pants and cowboy boots topped with platinum blonde bouffant hairdos and said y'all with a drawl. The weather was different. If you didn't like it, wait 5 minutes was the mantra. The music was different, the food was different, the dances were different, and most of all, the Manned Spacecraft Center (MSC), which would later become the Johnson Space Center (JSC) was different. I was a kid in a candy store there. Everywhere I looked on the palm tree covered campus with its manicured lawns and duck ponds, the pulse of Apollo could be felt. Dangerous things were being done to expensive people (astronauts) and gigantic rocket pieces were being moved around like tinker toys.

The scale of things was mind-boggling. The biggest centrifuge in the world adjoined my office; the neutral buoyancy training pool could hold a space station; Lunar and Command Modules were being tested in the largest thermal vacuum chamber in the world that had the biggest door in the world that slammed on the biggest O-ring in the world. And the Saturn 5 at 36 storeys tall would be the biggest rocket ever built.

At the other end of the scale in both size and absurdity, high-fidelity male and female lower torso dummies with immaculately reproduced gynaecological structures were being made to test UCD's (urine containment devices) for the spacesuits of the astronauts.

It was Wonderland and I felt like Alice. We were all young, educated and tireless, most of us in our early 20s and proud to wear one of the 3 kinds of badges that heralded us: Confidential badges with our photo surrounded by a blue background: Secret badges with our photo surrounded by a red background and Top-Secret badges with our photo surrounded by a yellow background. I wore a red badge but never saw a single secret document in all my years at NASA. Maybe the yellow badges did but there weren't many of those for they were reserved for the astronauts or their bosses. The astronauts stood out in other ways too. They wore royal blue flight suits adorned with the fancy NASA meatball logo, elaborate pockets, zippers and other cool appendages. I practically peed in my pants when I first saw those guys walking across the campus.

It didn't take long for them to come down to earth, as long as it took for one of them to screech to a stop in front of 1 Portofino Strip where I was living and ask for directions to apartment 516. After I pointed, he leapt over the door of his white Corvette convertible towards the residence of a well known lady of the night. That's when I understood the all American hero who'd been on the cover of Life Magazine put on his pants like the rest of us—one leg at a time—even if those pants were royal blue with fancy pockets.

Chapter 3: The Spy

An ocean of visceral sensations assaulted me when I passed through a heavily guarded set of double doors into the OPF (Orbiter Processing Facility)——artificial wind buffeted my snow-white clean room suit; the rat-a-tat-tat of pneumatic hammers, and the seething mass of humanity buzzing around a tangled maze scaffolding like worker bees. Unseen in the midst of their hive was their queen--the very first space shuttle, *Columbia*.

Astronaut Bob Overmyer clued me in: I was to go through Rockwell International's tile school, be assigned to a Bond team on the OPF floor wearing Rockwell blues and then snoop around to try and find out why things were going so badly. I listened knowing that NASA guys were contractually forbidden from even touching *Columbia*, much less working on her until she was finished.

“You want me to be a spy?” I asked in disbelief. “But I’m a civil servant, what if I get caught?”

“The Rockwell floor managers know. HQ told them. You’ll be okay.”

Moving through the maze of scaffolds the second day, I noticed the green-primed metal surface of what appeared to be a wing above me (I say appeared because everything in the OPF was enveloped in jigs). Pasted on the green metal was a red matrix of inch-wide strips, thousands of them, each shaped into a raised square. Each square formed a shallow cavity into which a tile was soon to be affixed, a tile made of 90% air and 10% pure silicon and light as Styrofoam yet able to withstand 2300 degrees Fahrenheit temperatures. Tens of thousands of these tiles were to be affixed to *Columbia*, covering every square inch of her—big ones, small ones, thick ones, thin ones, flat ones and curved ones, each unique and destined for only one spot on her body in the biggest jigsaw puzzle ever conceived. Imagine trying to cover every millimetre of a 1959 Cadillac with tile and you get the idea. Think of the swooping fenders, mirrors, door handles, wheel covers, hood ornaments and those outrageous tail fins. Then think of the Shuttle’s tail, delta wings, engines, pods and size and you realize the magnitude of the job.

Not only would every tile have to be installed and epoxied, but the paper chase would be murderous. Each one would have to be checked, double-checked, triple- checked and pull-tested. The records would likely fill the Pentagon. The sheer scope of the job was staggering.

After the tour, I reported to Dan Brown and Jim Berry, the Rockwell floor managers. "Welcome to the Build Team, Fuzzynuts," Brown the prankster greeted me, reprising a notorious nickname from my grammar school. He and Berry then gave me the lay of the land. There were six different organizations managing *Columbia’s* assembly -- Rockwell Palmdale, CA; Rockwell Downey, CA; Rockwell KSC, Florida; NASA KSC, Florida; NASA JSC, Houston, and NASA Headquarters, Washington, DC. None of the six trusted the other 5, Brown added from a couch in his office with the stuffing hanging out, in the trailer that would become my second home.

That was just a prelude to the tale of woe they described—launch and reentry pressures higher than predicted, not enough tooling and testing equipment, inadequate manpower, poor RTV epoxy strength, poor quality control and so on.

When Bob Overmeyer asked how it went with Dan and Jim later, I told him I thought they resented my presence. He laughed. “If it was up to them they’d like everyone from NASA to ‘crawl back into the hole we came from.’ But don’t let it get to you. They’re alright, they just take some getting used to.”

“Okay but about this spy thing. How am I supposed to do it?”

“Carry a little black book with you. Write down everything you see that looks funny.”

“Yeah...but how, where? There’s 1200 people in there, they’ll get suspicious.”

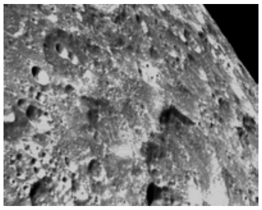
“You gotta take a dump don’t you? Do it in the john.”

More available on request

Lawrence H Kuznetz

Dr. Lawrence H Kuznetz is a 50-year veteran of the space program with advanced degrees from Columbia University and the University of California, Berkeley. His projects for NASA ranged from the construction of the Space Shuttles to water and life on Mars to Life Science Experiment Manager for the International Space Station to intelligent spacesuit designs that talk. His publication list includes one of the first papers to show that water could stay liquid on the surface of Mars; a spacesuit user's manual for kids; and an environmental thriller about the first human mission to Mars. He has also developed new paradigms in math and science education for middle schools, high schools and universities. Dr. Kuznetz holds 8 US patents, is a consultant to private industry and has appeared on the “Tonight Show”, Good Morning America and CNN, among others.

AIAA LA-LV Aerospace News Digests *by Dr. Ken Lui, AIAA LA-LV Section*



(Nov. 25) NASA spaceship beams back really eerie images of the moon

(Nov. 24) NASA lost contact with its Orion spaceship for 47 minutes

(Nov. 15) Op-ed | SpaceX fans should stand behind NASA and support Artemis

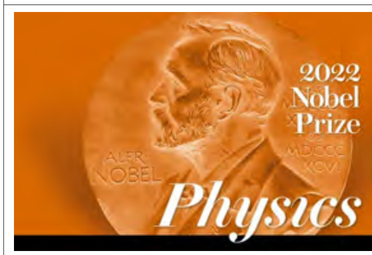
(Nov. 18) NASA's daring Artemis 1 'Red Crew' saved the day for the launch to the moon. Here's how.

(Nov. 18) See The International Space Station Flying Like A Jet In The Sky

(Nov. 6) 100 Times Longer Than Previous Benchmarks – A Quantum Breakthrough

(Nov. 15) The unimon, a new qubit to boost quantum computers for useful applications

(Nov. 14) Nuclear Fusion Experiment Reveals Unexpected Physics Inside 'Burning Plasma'



(Oct. 4) Explorers of Quantum Entanglement Win 2022 Nobel Prize in Physics

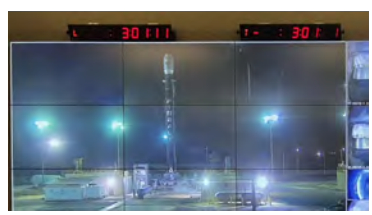
(Nov. 23) Artemis 1 cubesat fails to fire engine as planned during moon flyby

(Nov. 20) USAF U-2 Avionics Technician explains why S-300 and S-400 missile systems would not be able to shoot down the SR-71 Blackbird

(Nov. 16) Artemis I releases 10 cubesats, including a Moon lander, for technology and research

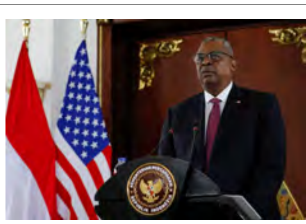
(Nov. 10) The story of the USAF B-52 Stratofortress Strategic Bomber that did a fly-by below the flight deck of USS Ranger Aircraft Carrier

(Nov. 18) Five NATO aircraft carriers hold drills in major naval deployment



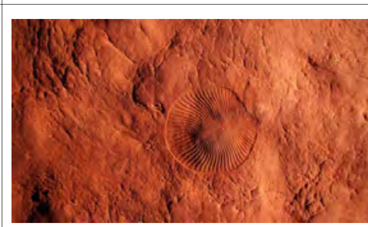
(Nov. 6) Space Force lays out timeline for 2023 rapid-response launch experiment

(Nov. 14) NASA's Hubble Captures Magnificent Image of Intergalactic Bridge



(Nov. 22) Pentagon chief raises concern about Beijing's 'dangerous' behavior with Chinese counterpart

(Nov. 7) Israeli scientists make breakthrough on producing 'green' hydrogen fuel



(Nov. 15) Scientists just found a hidden 6th mass extinction in Earth's ancient past

(Oct. 24) USAF F-16 Viper pilot explains why the F-15E Strike Eagle can't hold a candle to an F-22 Raptor in an up close and personal engagement

RSVP and Information: (https://conta.cc/3GZwKFX)

50th Anniversary
Apollo 17 – THE LAST FOOTSTEPS ON THE MOON

Launched: December 7, 1972 – Splashdown December 17, 1972

Apollo 17 Mission Patch

Astronaut LMP Geologist Harrison Schmitt with Lunar Rover (NASA)

Mission In Progress
Artemis 1 – PRELUDE TO THE NEXT FOOTSTEPS

Launched: November 22, 2022 – Splashdown December 11, 2022

Who?
Engineers that worked on the projects
Presented by:
American Institute of Aeronautics & Astronautics
LA/LV Section Technical Meeting

When?

6:30-8:00 PM, December 7, 2022 – 50th Anniversary!

Where?
Palos Verdes Peninsula Center Library
701 Silver Spur Road, Rolling Hills Estates, CA, US, 90274

Contact: Mr. Gary Moir (technical-chair@aiaa-lalv.org, gary.moir@ingenuir.com)

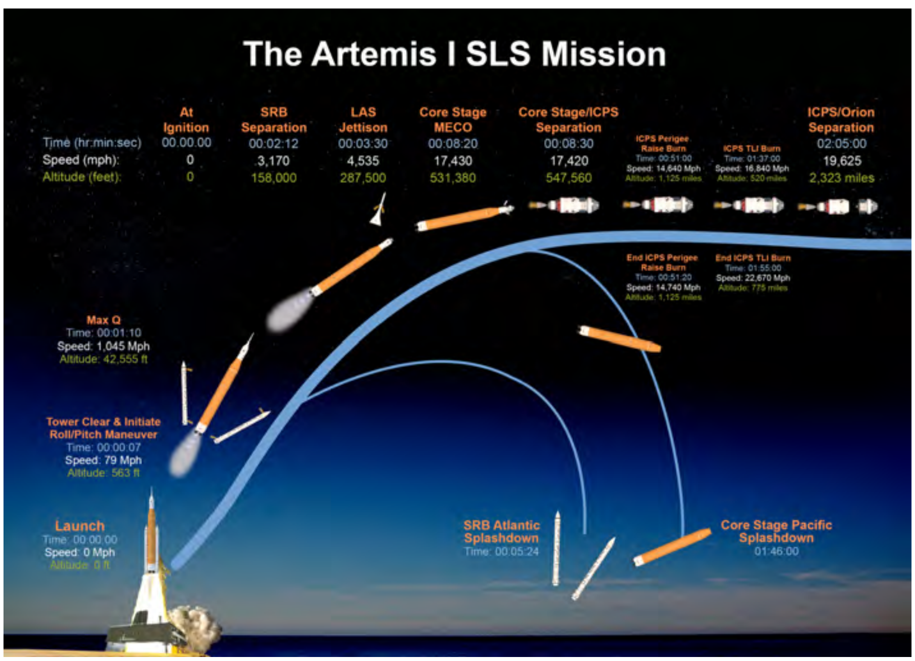
RSVP and Information: (https://conta.cc/3F5cDVh)

AIAA LA-LV 12/11 Section Online Meeting

Sunday, 2022 December 11, *9:00 AM - 11:00 AM PST* (US and Canada) (GMT -0800)

Witness the great moment together - NASA Artemis-I Mission Splashdown/Return: Watch the online coverage with AIAA LA-LV Section

(Online for now. If a suitable meeting room is located, it will be changed to a hybrid meeting.)



Artemis-I Mission Timeline on NASA Artemis Website:
https://www.nasa.gov/specials/artemis-i-press-kit/

Times below are based on a launch at Nov. 16 at 1:04 a.m. Eastern. The timing of events may change if launch occurs at a time other than the opening of the launch window. All times Eastern.

Flight Day 20-26 - Return transit

Flight Day 20 (12/5): Return Flyby (burn 11:43 a.m.), Lunar close approach (~79 miles, 128 km)

Flight Day 26 - Earth Return

Flight Day 26 (12/11): Splashdown (1:06 p.m. EST)

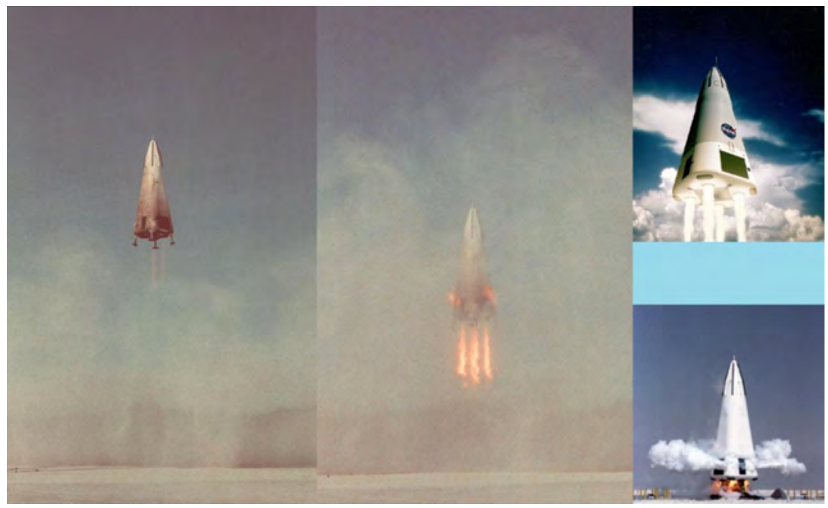
Contact: events.aiaalalv@gmail.com, k-12_steam_outreach_chair@aiaa-lalv.org

RSVP and Information: (https://conta.cc/3RwGLvH)

AIAA LA-LV 12/12 Section (Hybrid) Meeting

Monday, 2022 December 12, 3 PM PST/6 PM EST (US and Canada) (GMT -0800)

DC-X/XA – The Genesis of Fully Reusable Access to Space



speakers/panelists:

Dan Dumbacher
(Keynote speaker / Moderator)
(NASA interest in DC-X/XA and their linkage to SpaceX)
Executive Director
American Institute of Aeronautics and Astronautics (AIAA)
(Online/remote participation)

Jess Sponable
(Speaker / Panelist)
(DC-X Firsts)
President and Chief Technology Officer
New Frontier Aerospace (NFA), Inc.
(Online/remote participation)

Joaquin H. Castro
(Speaker / Panelist)
(Propulsion)
Aerojet Rocketdyne
Space Advanced Programs
(Online/remote participation)

James R. French
(Speaker / Panelist)
(Systems engineering and schedule)
AIAA Fellow (60+ year member of AIAA !)
President, JRF Aerospace Consulting LLC
(In-person participation)

Jeff Laube
(Speaker / Panelist)
Senior Project Leader
The Aerospace Corporation
Associate Fellow, AIAA
Chief Emeritus, Integration and Outreach Division, AIAA
Council of Directors
(In-person participation)

Physical Location
Manhattan Beach Library
1320 Highland Avenue
Manhattan Beach, CA 90266
(South of 105 Hwy and West of 405 Hwy/Pacific Coast Hwy (1))
(also online for a hybrid event)
(This event is not sponsored by the Lawndale Library)
Online on Zoom (Please register /RSVP and you will receive the ticket with the Zoom link.
Please check Spam or Junk folder shortly after registration to make sure. If not, please try using an alternative email address.)

Tentative Agenda: (All Time PST (GMT -0800))
02:00 PM PST / 5:00 PM EST: Check-in, Networking
03:00 PM PST / 6:00 PM EST: Dan Dumbacher (Opening Remarks and Keynote Speech)
03:20 PM PST / 6:20 PM EST: Jess Sponable (DC-X Firsts)
03:35 PM PST / 6:35 PM EST: Joaquin H. Castro (Propulsion)
03:50 PM PST / 6:50 PM EST: James R. French (Systems engineering and schedule)
04:05 PM PST / 7:05 PM EST: Jeff Laube (TBD)
04:20 PM PST / 7:20 PM EST: Panel Discussion
05:10 PM PST / 8:10 PM EST: Bonus Presentation (Joaquin H. Castro and Jess Sponable)
06:00 PM PST / 9:00 PM EST: End of Program; Dinner for in-person participants and attendees
07:15 PM PST / 9:15 PM EST: Adjourn (Library Meeting Room closes at 7:30 PM PST)

Disclaimer: The views of the speakers do not represent the views of AIAA or the AIAA Los Angeles-Las Vegas Section.

Contact: events.aiaalalv@gmail.com

AIAA LA-LV 12/14 Section Aero Alumni (hybrid) Meeting

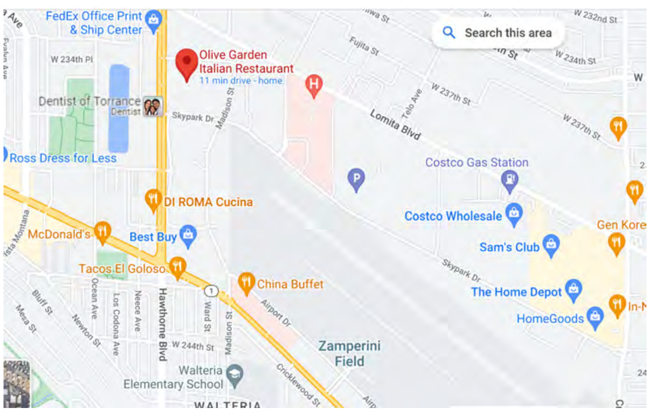
Wednesday, December 14, *11:00 AM - 1 PM PST* (GMT -0800) (US and Canada)

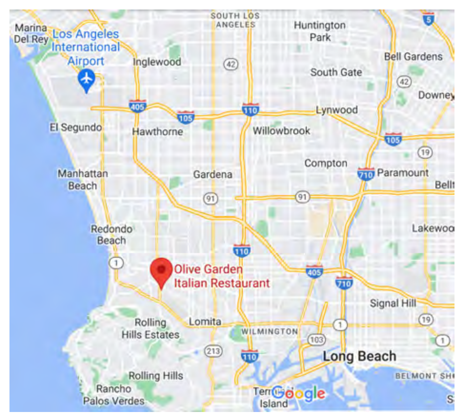
Aero Alumni Meeting

Hybrid in-person luncheon and Zoom on-line meeting

Our monthly Aero Alumni Zoom meeting is at 11 am PST on December 14. (The 2nd Wednesday of November) It will be a hybrid meeting (both in-person there and on-line) at the *Olive Garden in Torrance, 23442 Hawthorne Blvd., Torrance, CA 90505*. COVID is again allowing a hybrid meeting. If you can, please join me at the Olive Garden. I'll meet you there. If you can't, you can use the Zoom link below. It will take a few minutes to set up the link. You can chat among yourselves until it's ready.

In-Person in:
Olive Garden in Torrance
23442 Hawthorne Blvd., Torrance, CA 90505
(South of 105/405 Hwy, West of 101 Hwy, North of Pacific Coast Hwy (1))





Online on Zoom:

Join Zoom Meeting: *https://aiaa.zoom.us/j/87083738692?pwd=Vm01ZnV2clgxWWZEb3JISTRZV0tiZz0*

Meeting ID: 870 8373 8692 ***Passcode: 398677***

One tap mobile +16694449171,,87083738692# US +17193594580,,87083738692# US
Dial by your location +1 669 444 9171 US

+1 346 248 7799 US (Houston)
+1 719 359 4580 US
+1 720 707 2699 US (Denver)
+1 253 215 8782 US (Tacoma)
+1 646 558 8656 US (New York)
+1 646 931 3860 US
877 853 5257 US Toll-free
Meeting ID: 871 5345 6123
Find your local number: https://aiaa.zoom.us/u/k1j73qu8Q

+1 689 278 1000 US
+1 301 715 8592 US (Washington DC)
+1 309 205 3325 US
+1 312 626 6799 US (Chicago)
+1 360 209 5623 US
+1 386 347 5053 US
+1 507 473 4847 US
+1 564 217 2000 US
888 475 4499 US Toll-free

Please contact Mr. Gary Moir (gary.moir@ingenuir.com)

RSVP and Information: (https://conta.cc/3GP08P8)

AIAA LA-LV 12/17 Section Hybrid-Meeting

Saturday, 2022 December 17 10:30 AM - 1:00 PM PST (US and Canada) (GMT -0800)

AIAA LA-LV Educators (K-12 STEAM) Meeting 12/17 (Hybrid)

Tentative Agenda: (All Time PST (GMT-0800))

10:00pm: Check-in (In-person), Quick-Setup
10:30pm: Welcome, Introduction
10:40pm: AIAA Membership (Free for Educators and High School Students. Annual renewal required.)
11:00pm: Values and benefits for Engagement
11:30pm: Self-introduction, Sharing, Needs / demands from Educators/Students
12:00pm: Inputs and Suggestions, Demo
01:00pm: Adjourn
02:00pm: (Meeting Room Closes)

(In-person check-in starts 10:00 PM PST)
Physical Location (Also online on Microsoft Teams)
Angelo M. Iacoboni Library (Meeting Room)
4990 Clark Ave.,
Lakewood, CA 90712
South of 105/91 Hwy, North of 405 Hwy, East of 710 Hwy, and West of 605 Hwy.
(No food or water will be provided.)
(This event is not sponsored by the Angelo M. Iacoboni Library)

Contact: events.aiaalalv@gmail.com, k-12_steam_outreach_chair@aiaa-lalv.org

RSVP and Information: (https://conta.cc/3EIW0gU)

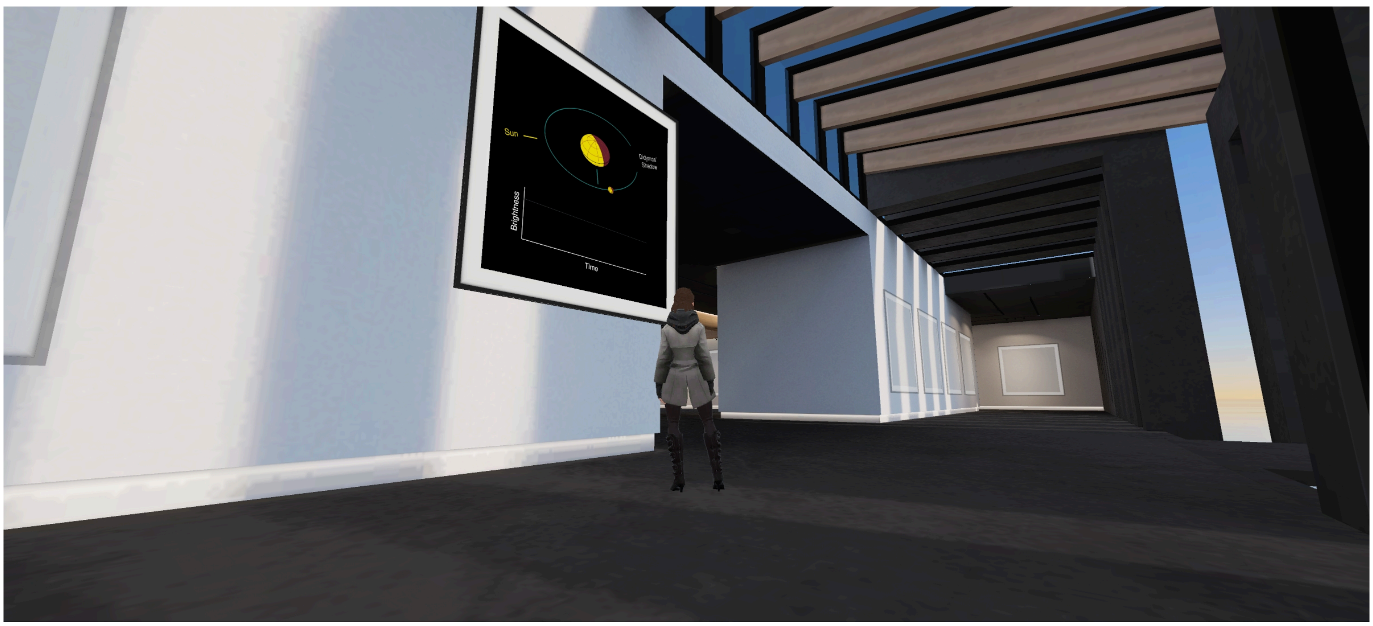
AIAA LA-LV 12/20 Section Meeting

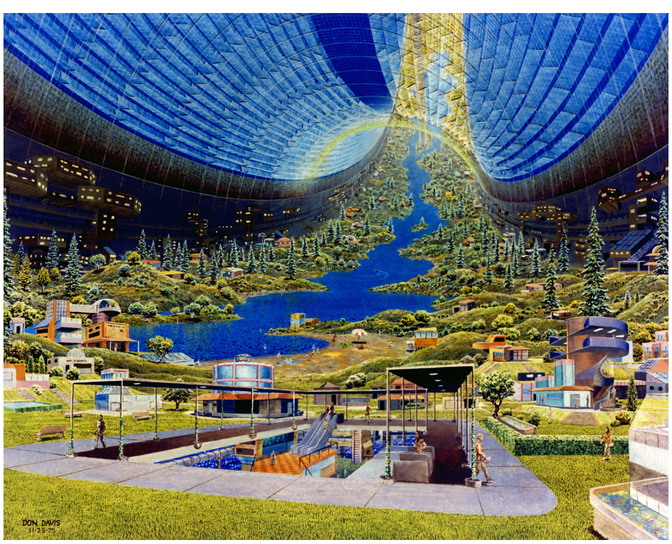
Tuesday, 2022 December 20, *5:30 PM - 7:30 PM PST* (US and Canada) (GMT -0800)

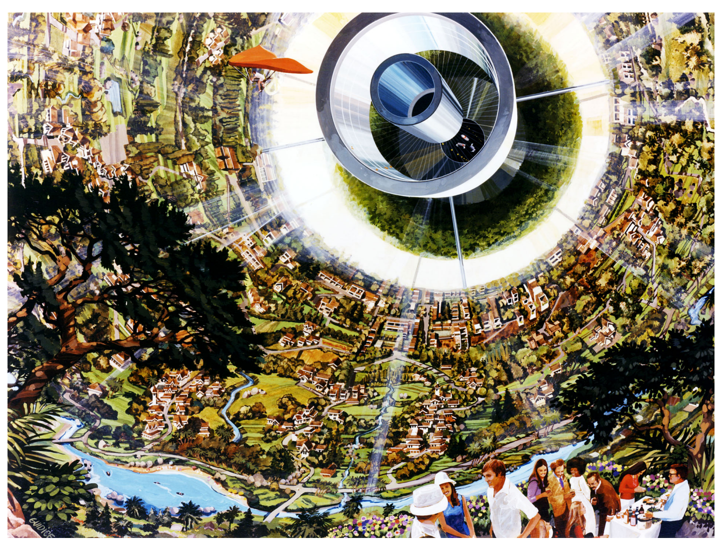
AIAA LA-LV Virtual Reality Happy Hour, Space Settlement / Aerospace Art Gallery

Tentatively, this is on-line only, with possible hybrid setting if a suitable location is identified.

Please RSVP / register following the RSVP and Information link above, and the meeting link/URL will be emailed to you a few days prior to December 20.







RSVP and Information: (https://conta.cc/3GyXc94)

AIAA LA-LV 1/21 Section (Online) Meeting

Saturday, 2023 January 21, *10:30 AM PST* (US and Canada) (GMT -0800)

NASA's Digital Information Platform (DIP) to Accelerate NAS Transformation

by

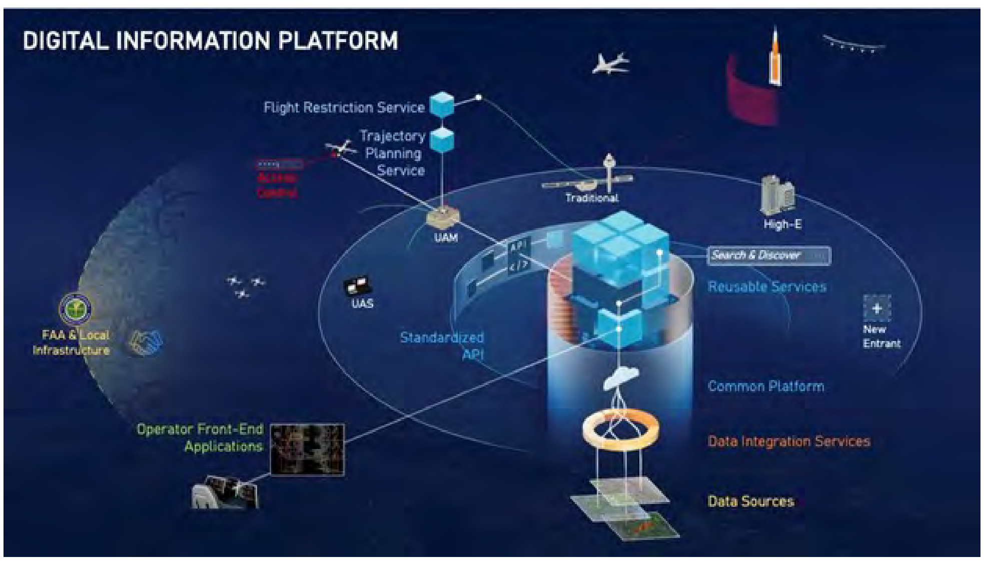
Dr. Swati Saxena

Technical Lead at NASA Ames Research Center

(The speaker will present online remotely.)

(Attendees can attend online or in n a physical location for a hybrid event)

Tentatively, this is on-line only for now, with possible hybrid setting if a suitable location is identified.



Tentative Agenda: (All Time PST (GMT -0800))

10:00 am - 10:30 am: Check-in, Networking
10:30 am - 12:00 pm: Presentation and Q&A
12:00 pm: Adjourn

Disclaimer: The views of the speakers do not represent the views of AIAA or the AIAA Los Angeles-Las Vegas Section.

Contact: events.aiaalalv@gmail.com