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BuzzCraft: Evolution of A Sturdy Cislunar Cycler Architecture for Permanent Lunar Settlement Logistics

Bradley Manucha[a], Madhu Thangavelu[b]

[a] *Student, University of Southern California School of Architecture. manucha@usc.edu*
[b] *Department of Astronautical Engineering, Viterbi School of Engineering, University of Southern California, Conductor, ASTE527: Space Exploration Architectures Concept Synthesis Studio. mthangav@usc.edu*

Abstract

As part of the Artemis program, NASA intends to have boots back on the moon by 2024, with help from the Gateway station in Lunar orbit. The BuzzCraft concept architecture is an alternative to the current lunar Gateway station proposal and the NASA Artemis reference mission to the lunar south polar region. The BuzzCraft concept architecture proposes a cislunar cycler trajectory as opposed to a lunar orbiting station to build a capable and reliable Earth-Moon logistics channel ahead of a lunar orbiting Gateway station. BuzzCraft systems propose to maximize the use of certified, existing systems and hardware including those from the Apollo missions to accelerate return of humans to the Moon. The primary goal of the BuzzCraft architecture is to maximize private sector and the international community engagement, including emerging spacefaring nations, to quickly execute the Artemis mission to return humans to the Moon. Solar maximum opportunity is taken into consideration to propose deep space radiation experiments on plants and animals in geostationary orbit. Crew safety and quick abort or rescue capability are the overarching priority of the selected early mission opportunity profile. For reasons presented in the earlier Artemis Maxim concept architecture, the equatorial Apollo-11 landing region, namely mare Tranquillitatis, is recommended for early climate science and lava tube exploration. Preliminary systems and operations of the BuzzCraft architecture are presented. BuzzCraft Concept Architecture is a study in progress and several elements, systems and criteria are being evaluated to maximize commercial and international collaboration.

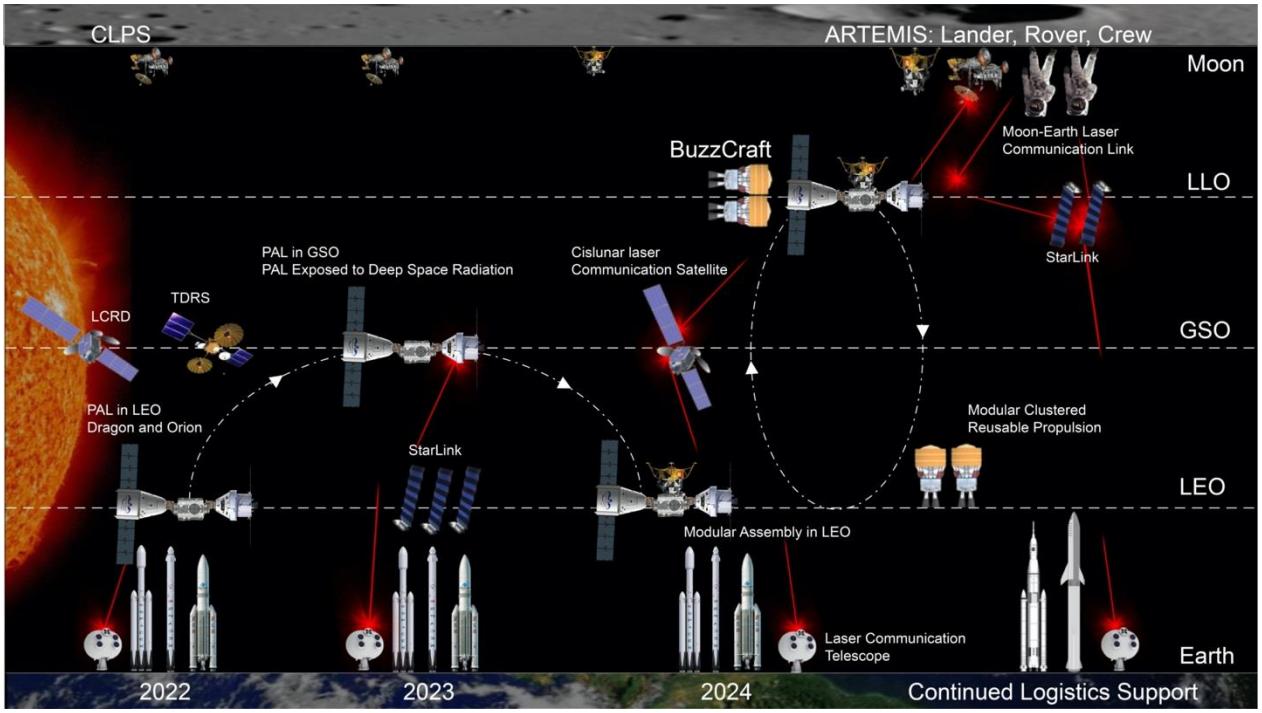


Fig. 1 shows the evolution of BuzzCraft from 2022 PAL configuration through 2024 Earth-Moon cycler and continued logistics support for Artemis beyond 2024.

Abbreviations

ALSPE – Anomalously Large Solar Particle Event
CLPS – Commercial Lunar Payload Service
CNSA – Chinese National Space Agency
CONUS – Continental United States
CRRES - Combined Release Radiation Effects Satellite
CuSP – Cubesat to study Solar Particles
ESA – European Space Agency
EP – Electric Propulsion
EVA- Extra Vehicular Activity
F9 – Falcon 9
FH – Falcon Heavy
FRMCPS – Fully Reusable Modular Cluster Propulsion
GSO – Geostationary Orbit
HALO Habitat&LogisticsOutpost LunarGatewayStation
ISRO – Indian Space Research Organization
JAXA – Japan Aerospace Exploration Agency
LDSD – Low Density Supersonic Decelerator
LEO – Low Earth Orbit
LLCD – Lunar Laser Communication Demonstration
LLO – Low Lunar Orbit
LM – Lunar Module
LRCD - Laser Communications Relay Demonstration
MARE – Matroshka AstroRad Radiation Experiment
NASA – National Aeronautics & Space Administration
NRHO – Near Rectilinear Halo Orbit
O2O – Optical to Orion
PAL – Plant and Animal Lab
PICA – Phenolic Impregnated Carbon Ablator
PPE – Power and Propulsion Element
RBSP - Radiation Belt Storm Probes
ROSA – Rollout Solar Array
RSA – Russian Space Agency(RosCosmos)
SLS – Space Launch System
SPE- Solar Particle event
TDRS –Tracking and Data Relay Satellite
TLI – Translunar Injection
TLI-TP – TLI Thrust Pallet
VAB – Van Allen Belt
VAP – Van Allen Probes

1. Introduction

As part of the Artemis program, NASA intends to have boots back on the moon by 2024, with help from the Gateway station in Lunar orbit. However, questions persist about the physiological consequences of prolonged exposure to deep space radiation on the crew, especially during the current sunspot cycle 25 solar maximum period that will peak during the NASA reference Artemis mission execution. Furthermore, there is currently no cislunar infrastructure in place to aid with rescue missions in the event of an anomaly requiring crew extraction on the lunar surface, nor is there any indication of a reliable logistics channel and communications link to the Moon.

BuzzCraft concept architecture is an alternative to the current Gateway station proposal and seeks to address both of these issues [Figure 1].

2. BuzzCraft Architecture System Components

BuzzCraft Architecture Systems and Components are Existing and Certified for Human Spaceflight. Systems of the BuzzCraft for accelerated Artemis crew return to the lunar surface
include the reliable and semi reusable Falcon 9 and Falcon Heavy, Crew and Logistics Dragon, Russian Soyuz and Progress, as well as Chinese crew vehicles and Japanese and Indian launchers. Upgrading the Apollo Lunar module and EVA suits can accelerate Artemis lunar landing mission

3. Phases of the BuzzCraft Cislunar Cycler Architecture

BuzzCraft architecture could evolve over the course of four quick phases in rapid cadence between 2022 and 2024 and intends to put a woman and a man on the Moon by the end of 2024.

- Phase 1 2022 Plant and Animal Lab(PAL) assembly & integration in Low Earth Orbit
- Phase 2 2023 Plant and Animal Lab(PAL) Operations in Geostationary Orbit
- Phase 3 2024 BuzzCraft assembly, Integration and checkout in Low Earth Orbit
- Phase 4 2024 BuzzCraft Cislunar Cycler Ops and Artemis touchdown at Mare Tranquillitatis
- Follow on phases include Earth-Moon logistics and continued emergency and cislunar rescue capability

The first phase is a SpaceX Dragon and NASA Orion module docked together in Low Earth orbit containing a Plant and Animal laboratory(PAL). PAL's initial phase in LEO within Earth's magnetosphere will serve as a control for study of biological tissue taken from plants and animals in the capsule. At this stage the teleorobotic systems needed for PAL operations and maintenance between crew-assisted rack and sample changeouts are tested and certified. Optical communication links will provide secure, ultra-high bandwidth capability enabling a variety of high fidelity robot assisted activities and high resolution live imaging on PAL without the need for TDRS or other orbital relay systems.
After this initial phase, PAL will move into phase 2: Geostationary orbit where it will be beyond the protection of Earth's magnetosphere and the biological tissue will be exposed to deep space radiation for prolonged periods of time. PAL will be relatively quickly accessible by crew in short visits to GSO by the Orion or suitable craft for rack maintenance, changeouts and collecting tissue samples as needed.

4. PAL in the Van Allen Belt

Satellites like the Combined Release and Radiation Effects Satellite(CRRES) and the Van Allen probes(VAP) in the Van Allen Belt(VAB) have shown that VAB is a dynamic, pulsing radiation zone, that swells and shrinks, reacting to solar wind activity. A primary inner proton and outer electron shell are separated by a gap, absorbing and dissipating the energies directed at Earth by solar coronal mass ejections.(CME).[Fig.2]

This activity and changes in high energy particulate flux and fluence are especially evident during anomalously large solar particle events(ALSPE) that occur during peak solar maximum activity, that we are starting to experience in this current solar cycle 25.

Carefully timed and calibrated transits of the PAL through the various zones of the Van Allen Belt during solar maximum could simulate varied aspects of solar storms and provide useful data on how particulate radiation affects live biological samples and spacecraft systems.

PAL could be equipped with racks to determine best suited materials and configurations for the design of effective spacecraft solar storm shelters, a critical necessity for endurance-class crewed missions in deep space, especially during months long interplanetary transit. PAL in the Van Allen Belt can drastically reduce the time required to acquire vital deep space radiation data and pick the most effective storm shelter mitigation strategies.

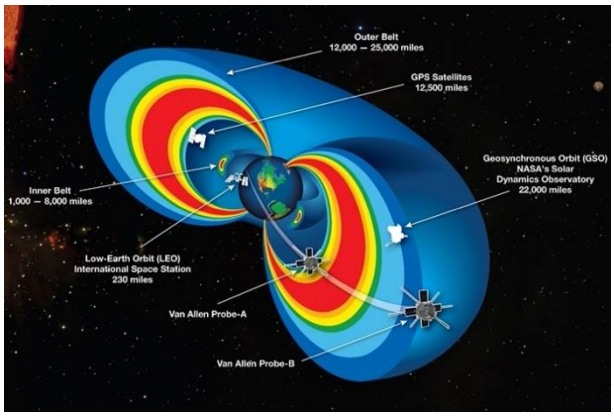


Figure 2. Plant and Animal Lab(PAL) transiting the Van Allen Belt or in geostationary orbit over CONUS or beyond can simulatethe effects of anomalously large solar particle events(ALSPE). PAL proposes to follow the Van Allen Probes profile and can also be moved to other locations over the globe, depending on needs of participating nations

In Phase 3: PAL will move back into LEO where other modules and a Fully Reusable Modular Cluster Propulsion System(FRMCPS) will be clustered with help from international partners. After the modular assembly of the constituent modules and propulsion are stacked, Buzzcraft will be injected into an Apollo-class equatorial free-return trajectory and cislunar orbit. PAL will be attached to Buzzcraft to continue the biological studies, and other modules will carry cargo, landers, and crew into cislunar orbit.

Once in this orbit, in Phase 4, BuzzCraft will be become a critical piece of the Earth-Moon logistics channel infrastructure, and will aid the Artemis mission to carry crew, landers and various payloads to the Moon as well as become the critical emergency and rescue system should anomalies arise that require quick crew extraction during any phase of Artemis operations.

5. PAL and the NASA Reference Gateway Power and Propulsion Element(PPE)

Once the Space Launch System(SLS) inserts the lunar Gateway station into a high equatorial lunar orbit, the current NASA reference for lunar Gateway deployment proposes the use of a high power electric propulsion system called the power and propulsion element(PPE) to achieve the near rectilinear halo orbit(NRHO) gradually.[Fig.3] The PPE can be used to station keep as well as move the Gateway station with its Habitat and Logistics Outpost(HALO) to other desired orbits as required.

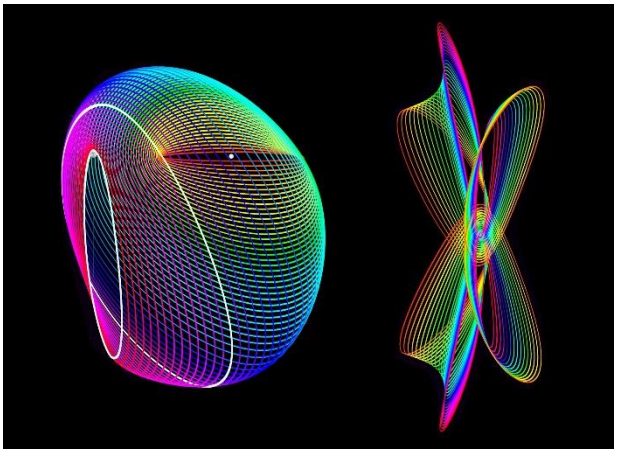


Figure 3. Propagation of the NASA reference NRHO for the lunar Gateway station

The PAL architecture does not prescribe the current high power electric version proposal of the PPE for operations in the VAB because the 50kW large rollout solar arrays(ROSA) and electric propulsion components will experience undesirable interactions with the intense radiation fields of the VAB. [Fig.4]

The PPE could be deployed in Phase 4 of the BuzzCraft cislunar cycler operations, as an alternative to chemical propulsion stages. Several Earth-Moon cycler orbits are possible.[Fig 5,6] The BuzzCraft could be a

two-week Earth-Moon supersynchronous orbit and is currently being investigated.[Fig.7]

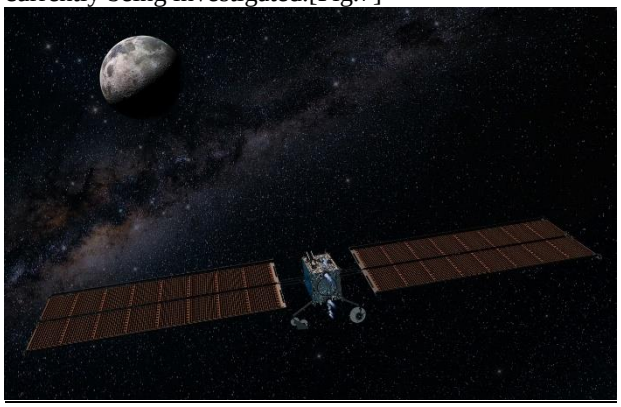
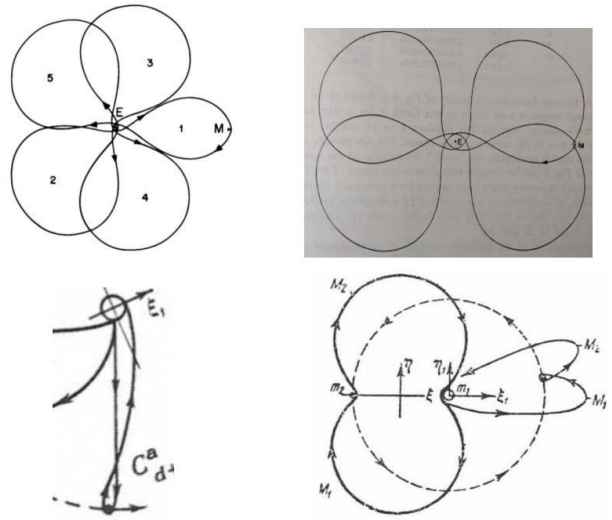


Figure 4. The MAXAR electric PPE proposed for the Gateway is not suited for the early BuzzCraft trajectory profile due to the extended mission duration in the Van Allen Belt for the PAL experiments.[credit Maxar]



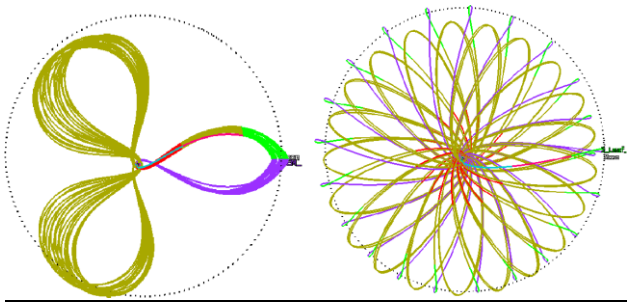


Figure 5, 6. Several periodic cycler orbits are possible in the Earth-Moon system[credit Genova, Aldrin]

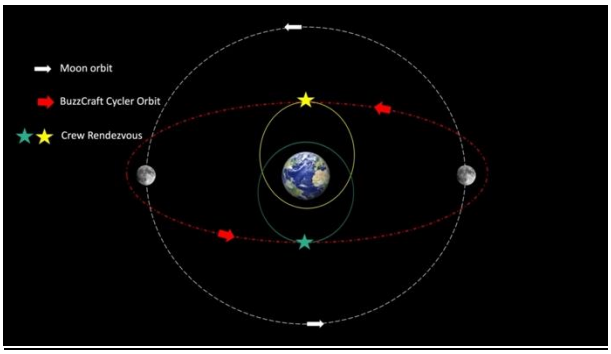


Figure 7. Schematic of BuzzCraft 2-week Earth-Moon Cycler Orbit.[not to scale]

6. Fully Reusable Modular Cluster Propulsion System(FRMCPS)

In the BuzzCraft concept architecture, the translunar and transearth injection is accomplished using a fully reusable modular cluster propulsion system. In this way the technology development testing and certification associated with orbital refueling is eliminated.

The FRMCPS consists of strong, lightweight space structure based aerobrake thrust pallet(TP) that is attached to the BuzzCraft. It uses phenolic impregnated carbon ablator (PICA) technology. The TP Fully fueled modular propulsion and tankage units flown into orbit are integrated with the thrust pallet to form a symmetrical propulsion cluster. The size and number of units depend on the deltaV needed for the BuzzCraft stack for translunar injection (TLI), midcourse corrections and for return transearth injection (TEI). Since the propulsion units are fully reusable, they would return to Earth using aerobrakes or decelerator technologies. No stages are jettisoned. Work is underway to optimize the design of this system.

7. BuzzCraft Abort and Rescue Capability

This BuzzCraft cislunar Cycler would serve as a crew emergency and rescue system and also initiate the evolution of a cislunar logistics channel adding vital value to the Artemis effort. Eventually, BuzzCraft could also evolve into Gateway in different orbits including the near rectilinear halo lunar polar orbit (NRHO-HALO) that is proposed currently in the NASA Gateway reference mission.

The architecture of BuzzCraft is composed of already existing commercial space technology, both human rated and non-human rated, including SpaceX's Dragon capsule, the Falcon 9 and Falcon Heavy launchers, as well as Boeing's *Unity* connection module. Tried and tested Apollo hardware including the Lunar Module(LM) and the Apollo lunar surface EVA suit can be quickly upgraded for the Artemis lll mission.

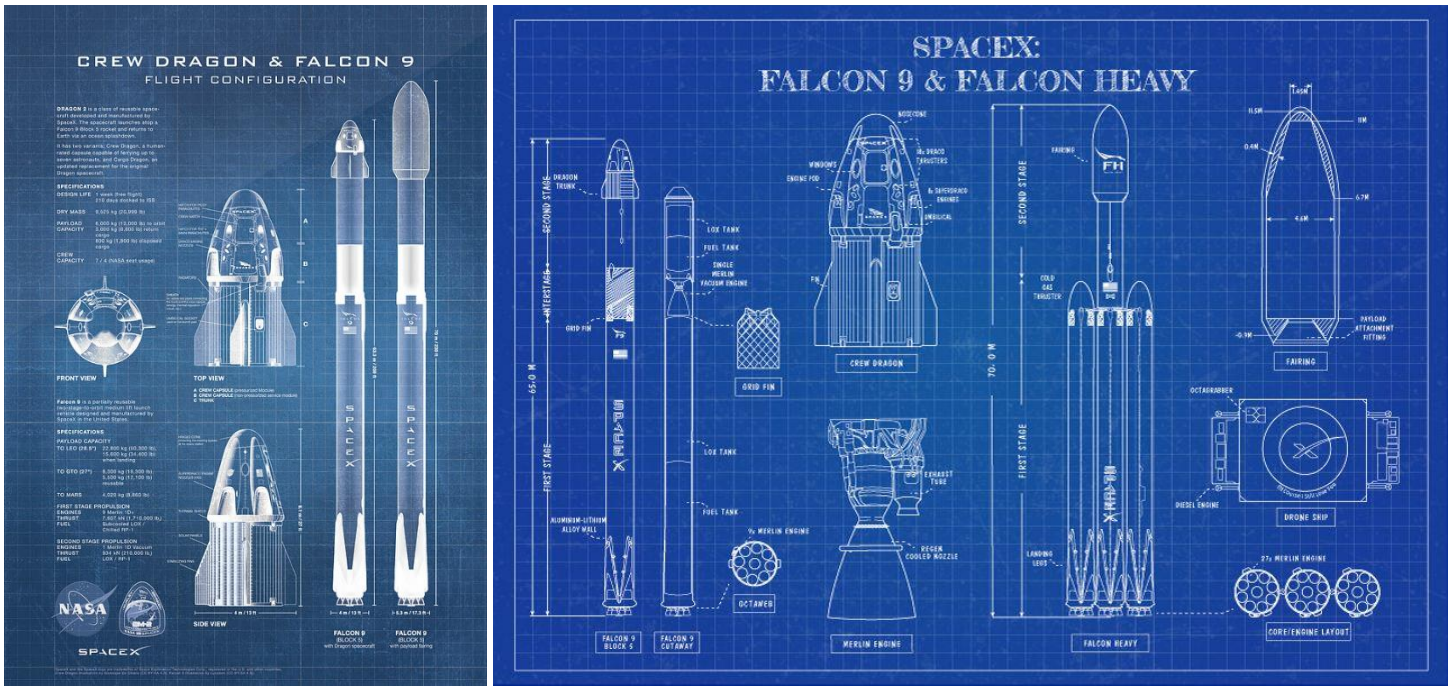


Figure 8. The SpaceX Falcon 9 and the Falcon Heavy along with the Boeing Starliner and the Orion can be used for deploying and evolving the BuzzCraft Architecture, starting with operations in LEO and GSO in short order.

Figure 9. Many nations around the globe now operate space launch facilities that could support the establishment of a sturdy cislunar logistics channel, using the BuzzCraft cycler as it transits the Earth periodically to send payloads the Moon and back.

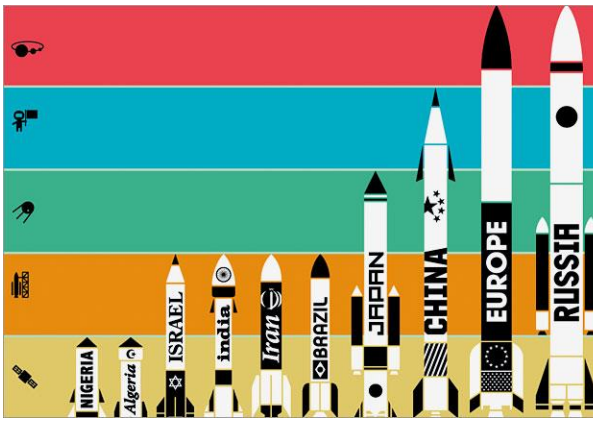


Figure 10. Established space faring nations as well as those emerging nations capable of lofting payloads to Earth orbit can participate effectively in evolving the BuzzCraft architecture, aiding peaceful global cooperation and collaboration.

As a result, the first phase of BuzzCraft could be launched as soon as 2022.

Operations in low Earth orbit enable both commercial and international partners to engage in quickly evolving BuzzCraft cislunar architecture. Furthermore, modules and payloads can be supplied by international partners such as the ESA, RosCosmos, CNSA, JAXA, and ISRO as well as emerging nations with spacefaring ambitions.

8. Cislunar Optical Communications and Artemis Accords

Free space optical communications have been tested at data rates far exceeding radio communications between the Earth and the Moon.[Fig.11] Advanced Starlink optical communication satellites and ground stations will provide secure link and total ultra-wideband connectivity for BuzzCraft operations, commencing with PAL and extending to cislunar missions. Companies are already providing ultra-wideband laser communication systems for inter-satellite links and orbit- to-ground stations around the world.[Fig.12]

Optical communications form the backbone of global terrestrial networks and could be used to patch, build redundancy and strengthen communication networks around the world, while attracting many more nations to join the Artemis Accords.

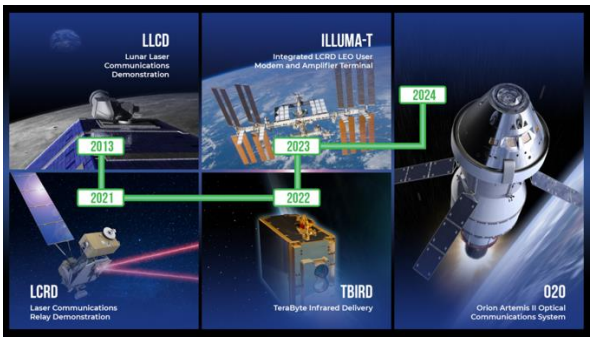


Figure 11. Earth-Moon free space communications was demonstrated using the Lunar Laser Communication Demonstration(LLCD) payload that flew on NASA's Lunar Atmosphere Dust Environment Explorer(LADEE) spacecraft. The Laser Communications Relay Satellite is in orbit and the Orion Optical System is set to fly on Artemis ll.[credit NASA]

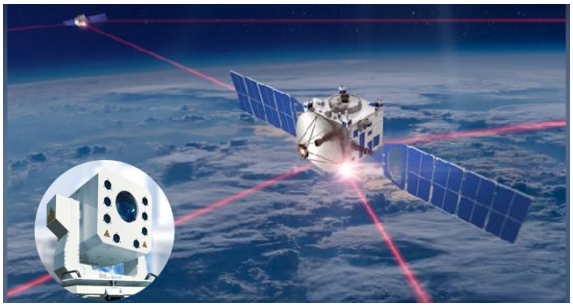


Figure 12. Commercial companies are providing free space laser communication equipment that allow reliable ultra-wideband communication inter-satellite links as well as compact ground terminals.[credit Mynaric Inc.,}

Established, mature spacefaring nations of the world with human spaceflight capability, capacity and experience can collaborate with agile and innovative commercial space sector to help build, integrate and service the core BuzzCraft crew components. Emerging and aspiring nations of the world can support the buildup of a sturdy and reliable cislunar logistics and crew support and emergency rescue capability in low Earth orbit that is vital to anomaly resolution and timely intervention, as human spaceflight missions prepare to take on more complex missions beyond Earth orbit to the Moon and planets in the 21st century.

9. Conclusion

The BuzzCraft concept architecture is an alternative to the current lunar Gateway station proposal and the NASA Artemis reference mission to the lunar south polar region. Establishing a sturdy and reliable Earth-Moon crew rescue and logistics channel that can provide timely support is seen as primary, overriding priority for human activity in cislunar space and on the lunar surface.

The BuzzCraft concept architecture proposes a cislunar cycler trajectory as opposed to a lunar orbiting station to build a capable and reliable Earth-Moon logistics channel ahead of a lunar orbiting Gateway station. BuzzCraft systems propose to maximize the use of certified, existing systems and hardware including those of from the Apollo to accelerate return of humans to the Moon. The Apollo free-return type trajectory is considered safest during early Artemis missions while new cislunar transportation systems like the Space Launch System are being tested, certified and commissioned. The BuzzCraft stack is proposed to be integrated in Low Earth Orbit and fully reusable.

The architecture of BuzzCraft is composed mostly of already existing commercial space technology, both human rated and non-human rated, including SpaceX's Dragon capsule, the Falcon 9 and Falcon Heavy launchers, as well as Boeing's Unity connection module. Tried and tested Apollo hardware including the Lunar Module(LM) and the Apollo lunar surface EVA suit(A7L) can be quickly upgraded for the Artemis lll mission.

As a result, the first phase of BuzzCraft could be launched as soon as 2022. Operations in low Earth orbit enable both commercial and international partners to engage in quickly evolving BuzzCraft cislunar architecture.

Furthermore, modules and payloads can be supplied by international partners such as the ESA, RosCosmos, CNSA, JAXA, and ISRO as well as emerging nations with space faring ambitions, aiding global cooperation and peaceful collaboration that is a hallmark of human space activity that binds our species together in the pursuit of freedom and technological excellence. BuzzCraft Concept Architecture is a study in progress and several elements, systems and criteria are being evaluated to maximize commercial and international collaboration.

Acknowledgements

This concept architecture was created in the fall 2021 ASTE527 Graduate Space Concept Studio "Commercial Human Spaceflight Expeditions (CHASE)" team project in the Department of Astronautical Engineering within the Viterbi School of Engineering at the University of Southern California. The slide presentation and proceedings of first iteration of the topic BuzzCraft may be found in Section 11 of the CHASE 2021 project in the archives : ASTE 527 Home (google.com)

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