# Private Astronaut Mission Lessons Learned

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COMMERCIAL LEO
DEVELOPMENT
PROGRAM

# Introduction

- NASA assessed lessons learned from multiple space flight participants (SFPs) and the first Private Astronaut Mission (PAM) in 2021/2022.

- PAMs are a critical opportunity for both industry and NASA to learn lessons that will enable successful future Commercial LEO Destinations (CLDs).

- Industry benefits from utilizing the International Space Station (ISS) as an early destination by:
  - Testing future CLD processes such as crew selection, training, mission planning, integration and execution.
  - Conducting technical demonstration for services, hardware, or research targeted for CLDs.
  - Demonstrating and developing commercial markets, business models, viability to investors, and customer base.

- NASA benefits from PAMs by:
  - Maturation of concept of operations, mission integration, and mission planning for future CLD mission operations.
  - Assessing commercial industry capabilities and experience for future CLD operations.
  - Identifying concerns, risks, or differences in needs associated with non-U.S. Government (USG) crew (i.e. private citizens, sovereign astronauts, etc.) vs. NASA crew.

# Background- PAM Framework

- NASA has developed a framework for PAMs to enable commercial missions to ISS
  - Minimizes impact to NASA resources and ISS mission
  - Ensures ISS vehicle and crew safety
  - Aligns with future CLD requirements
- PAM Provider requirements and responsibility:
  - PAM Crew safety for all mission phases under the ISS safety decision authority for integrated operations
  - Provider liability with flow down to U.S. Crew Vehicle (USCV) and crew
  - Acquire USCV transportation for crew
  - Ensure compliance with ISS requirements and deliver verifications
  - Meet all applicable local, national, and international laws and regulations
  - Provide supplies and resources independently or via NASA per pricing policy
  - Providing real-time mission execution support
  - Selection, training, and medical qualification of private astronauts that meets NASA requirements
- The overall PAM philosophy is to balance requirements levied on provider to protect ISS vehicle and crew while allowing provider to manage PAM unique risks
- Framework also delineates government versus commercial responsibility/liability

# PAM Solicitation Requirement Updates

- Lessons learned were incorporated into latest PAM solicitation and include:
  - Deliverable clarifications and process changes to improve NASA-Provider communication and integration
  - Requirement for PAM Commander to be a past-flown NASA Crewmember
  - Additional PAM Commander responsibilities
  - Updates to visiting vehicle integrated operations for safety
  - Mission planning and timeline development changes to reduce impacts to ISS mission
  - Tailored training to better address PAM crew needs
  - Updates to ISS, CLDP and partner processes to improve communication and integration

# Previous Spaceflight Experience

- PAM-1 highlighted need for an experienced NASA Astronaut as the PAM Commander to reduce the impact on the ISS Resident crew
- Per NASA requirements, a PAM Commander responsibilities include:
  - PAM crew leadership for pre-flight preparation, mission execution and post-flight
  - Single crew focal point for ISS Resident crew to efficiently integrate the mission and address on-board issues
  - Providing recommendations to NASA on ways to improve the government/private partnership
- CLD parallels:  Crews with mix of past-flown or professional astronaut experience reduces overall safety and mission success risk
  - Complex spacecraft and complex dynamic operations coupled with the unfamiliar micro-gravity, spaceflight environment drives a considerable amount of vehicle/operation unique training and crew skill.
  - Though it may be possible to limit a future CLD's complexity, spaceflight in general lends itself to scenarios that require quick, real-time skilled responses and will benefit from missions with a mix of experienced or professional astronauts and first-time astronauts

# Visiting Vehicle Integrated Operations

- Rendezvous, docking, and undocking are complex activities with many autonomous vehicle responses and operational controls to mitigate collision risk
  - NASA crew is trained to manually fly the USCV for certain vehicle failures, but this requires a high level training to accomplish safely
  - In order to enable PAMs, NASA requires that all USCV operations be performed autonomously without the need for manual piloting
- CLD Parallels: Maximizing the use of autonomous operations will simplify crew training, skill, and experience requirements

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# Mission Timelines

- Mission timelines can quickly become oversubscribed with a variety of activities including commercial, media, and outreach events
- It is critical to allow for space adaptation including body control, spacecraft familiarization, and personal time
- A common practice is the use of on-orbit adjustment factors to account for new flyers or complex tasks
  - On-orbit times often require 10-50% more time than the equivalent task on the ground as a result of body control/positioning, micro-g hardware control, etc.
- CLD Parallels: Customer expectations may be unreasonable because they are based on ground (1-g) experiences/training. Years of spaceflight experience show the need for reasonable crew timelines, use of adjustment factors and sufficient personal time for crews.

# Crew Code of Conduct

- Crews must understand and adhere to a set of rules and regulations to ensure safety, mission success and compliance with NASA/ISS policies
  - NASA requires all crewmembers flying to ISS to sign the ISS Crew Code of Conduct
  - PAM crews sign a version tailored to private astronauts
  - PAM crews receive additional training for "do's and don'ts" including vehicle systems, behaviors, and policies
- CLD Parallels: To maintain safety, efficiency, and crew well-being, a crew code of conduct and associated rules/policies will be required on a CLD. How these will be implemented and enforced will be defined jointly between NASA and the CLD.

# Liability Framework

- Though NASA maintains overall mission authority for integrated operations (close to and on-board ISS), the PAM provider is responsible for their mission and crew at all times.
  - The PAM Provider bears liability flow down responsibility to USCV and PAM crew
- NASA requires:
  - Purchase of insurance for PAMs for property damage, injury/death for PAs and resident ISS crew
  - PAM Provider certification of PA informed consent, assumption of risk, and waiver of claims including from the estates of PA
- CLD Parallels: Future CLDs will need to develop a liability framework unique to their business model. Future discussions will be needed for cross-waiver of liability, potential property insurance for NASA assets, and other liability aspects. NASA HQ is kicking off a liability and insurance assessment and reaching out to partners Summer 2023.

# External Support & Vendors

- PAM Provider is responsible for launch, free flight, and return operations, including splashdown recovery
- PAM Provider is required to provide supplies and resources which can be procured independently or via NASA per pricing policy
  - E.g. food, quarantine facilities, recovery capability
- Commercial industry has stepped in and has provided support that was previously provided by the government in many areas but NASA still provides some support for PAMs.
- CLD Parallels: As the number and types of missions increase, NASA may be limited or decide not to continue to provide government furnished equipment or services. CLDs will need to develop vendor networks to provide support and services previously performed by NASA and other government agencies.

# Science and Outreach

- For research during PAMs, its advantageous to use the ISS National Lab as a sponsor given their working relationship with NASA.
- SFPs, PAMs and other non-governmental missions have opened up LEO to non-traditional international, commercial, and research partners
  - Increased interest in LEO and space exploration has been noted with the entry of new space participants (e.g. I4, Polaris, Dear Moon, Ax-1).
  - Provides NASA and CLDs the opportunity to utilize additional spaceflight data gathered from non-traditional sources
  - Enables evaluation and utilization of improved and emerging technologies
  - Increases awareness that low Earth orbit is available more broadly
- CLD Parallels: CLDs can build upon this increased interest and can be a laboratory for LEO ecosystem.  NASA will have continued research needs in LEO.

# Additional Considerations

- Early crew selection is critical in order to stay on ISS required mission integration templates
  - Private Astronauts must be identified NLT L-12 months to allow time for training integration and medical assessment
- Understanding of the requirements in the Basic Ordering Agreement and Mission Order prior to finalizing a contract with USCV provider to ensure all deliverables and requirements are met
- Mission definition should be identified prior to integration kickoff to ensure adequate review
- NASAs policy on commercial activities on the ISS is continually evolving. Although CLDs will not have the same limitations, there may be similar concerns.
  - Commercial Activities – Types of activities that can be conducted on a government platform vs. a commercial platform
    - Marketing/Advertising
    - Entertainment
  - Political Platform – A government platform cannot be used for political objectives. With NASA procuring CLD services and flying crews to CLDs, this must be assessed for CLDs.
  - Charity – A government platform cannot be used for charitable activities. Charities are of high interest to many PAM customers. NASA is assessing policy options.

# In Closing

- As NASA continues to develop public-private partnerships to enable LEO commercialization, we expect we will continue to learn and modify our approach.
- This continuous improvement process will benefit future PAMs and the development of commercial destination(s) with government and non-government objectives
- We value feedback from the CLD and PAM providers to make this transition an effective and successful one