National Aeronautics and
Space Administration


# Commercial Low-Earth Orbit Destination (CLD)

# Concept of Operations

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## Introduction

The United States Government, through the National Aeronautics and Space Administration (NASA), intends to purchase shared use of one or more Commercial Low-Earth Orbit (LEO) Destinations (CLD), or free-flying, commercially developed, owned, and operated space station vehicles located in LEO. Government use of the CLD is envisioned to include Government personnel presence onboard the CLD as well as use of a variety of *CLD partner*[1]-provided services to support Government *mission objectives*.

The Government expects that the commercial partner will develop an appropriate governance structure over such activities to include liability framework, application of a crew code of conduct, protection of intellectual property rights, defining jurisdictional issues of crewmembers and criminal matters in accordance with US Government laws and regulations, and international law.

## Purpose

This concept of operations describes:

- High-level Government goals, objectives, and needs for the CLD program, vehicle(s), and missions,
- Strategies, policies, and processes for developing, certifying, maintaining, using, and retiring CLDs in the context of Government use, and
- Government and CLD partner roles, responsibilities, and interactions during various phases of Government CLD operations.

The intent of this document is to describe the overall high-level concept of how the end-to-end CLD service will be used to convey the nature and scope of services the Government intends to procure from the CLD partner. It will provide insight into NASA's concepts for CLD operations rather than to provide mature, explicit, or complete requirements. It addresses how the concept of operations will be used to meet NASA expectations from an operational perspective to facilitate an understanding of the end-to-end CLD service needs, goals, and objectives (NGOs). Formal CLD requirements and standards are detailed in the NASA Commercial LEO Development Program's (CLDP) various requirements, interface, process, and standards documents, as well as the contractual Statements of Work (SOW) and Data Requirement Deliverables (DRD). As such, the Concept of Operations can use terms such as "should" or "may" or "expects to" since it is not a contractual requirements document. It exists solely to convey the initial nature and type of services the Government intends to procure and is not, per se, a requirements document.

## Scope

The scope of this document addresses NASA program, institutions, elements, personnel, processes, practices, and interfaces that will be engaged with the end-to-end CLD service commercial providers and the development of the end-to-end CLD service capability. The concept of operations includes all elements of the end-to-end CLD service architecture that provides safe, reliable, and cost-effective NASA crew and cargo access, occupancy, and usage of the CLD to achieve NASA mission needs

[1] Italicized terms are defined in Appendix B.

**Applicable Documents**

a. NASA Strategic Plan 2022
b. National Aeronautics and Space Administration Authorization Act of 2022

**Reference Documents**

a. CLDP-PLN-1000 Commercial LEO Development Program Plan
b. JPR 8621.1 Johnson Space Center Mishap Response Plan
c. NPR 8621.1 NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping
d. CLDP-PLN-TBD Commercial LEO Development Program Mishap Response Plan
e. CLDP-REQ-1130 Commercial LEO Destination Service Requirements
f. NPR 7100.1 Protection of Human Research Subjects
g. NPR 8910.1 Care and Use of Animals

# Program, Services, and Destination Vehicle Concepts Overview

### Commercial LEO Development Program and Destination Objectives

The primary objective of NASA's CLDP is to enable the Government's vision of a self-sustaining, commercial, United States (US)-based industry in LEO within which the Government is one of many customers. A key industrial offering of interest to NASA is one or more orbiting space stations (or CLDs) providing for safe, reliable, and cost-effective access to LEO for Government use including:

- Continuous US and Government human presence,
- Execution of Government-sponsored scientific investigations across a variety of disciplines, particularly those that address problems related to long-duration, deep-space human exploration (e.g. crewed missions to Mars), and
- Government-sponsored advancement of spacecraft technology and systems readiness for long-duration, deep-space human exploration.

In addition to providing the above opportunities to the Government, the CLD concept supports the CLDP's primary objective by developing a US-based space economy in LEO and expanding the United States' foothold in space.

### The End-to-End Mission Service Concept

NASA intends to purchase from the commercial owner/operator of the CLD (referred to as the CLD partner throughout this document) *end-to-end mission* services such as:

- Crew pre-flight and on-orbit training,
- Pre- and post-flight payload processing,
- Crew and *cargo* transport to and from the CLD, and
- In-flight accommodation and support for Government crew, *payloads*, activities, *studies*, and *technology demonstrations* such as power and data services, provision of consumables and common use equipment and tools, mission activity planning services, activity execution services, non-Government crew time, payload integration and activity execution services.

The goals of this approach are to maximize CLD partner authority, autonomy, and control over CLD mission operations and to minimize NASA operational involvement.

**Mission Authority**

A hallmark of the CLD concept is that the CLD partner takes primary ownership of and responsibility for the majority of the end-to-end mission activities including but not limited to vehicle design, development, test and evaluation (DDT&E), crew and ground support training, crew and cargo transportation, mission planning, and mission execution. This is realized in part through a shared assurance and accountability approach to the certification and operation of the CLD. The goals of this approach are to protect *Government crewmembers*, *assets* (such as *Government-sponsored* payloads and systems), and mission objectives while encouraging CLD partner responsibility and autonomy, fostering a close working relationship between NASA and the CLD partner, and avoiding duplications of effort.

In this context, shared assurance means that the CLDP will accept evidence and testimony provided by the CLP partner's assurance functions (e.g. engineering technical authority, safety and mission assurance technical authority, health and medical technical authority) as part of the acceptance process as opposed to comprehensively performing these functions in duplication and parallel. To be successful, this approach requires that NASA have detailed insight into the CLD partner's test data, analyses methods and results, etc.

Shared accountability means that the CLD partner is responsible for DDT&E of the vehicle, as well as operations during all mission phases[2]. The CLD partner and NASA share responsibility for certifying the vehicle for Government crewmember use, and certification of flight readiness for Government-participating missions. Again, this approach requires that NASA have detailed insight into the CLD partner's test data, analyses methods and results, etc.

A risk-based assessment approach will be taken to meter NASA's level of insight required and undertaken throughout the lifetime of Government involvement with the CLD partner. The goal of this approach is efficiency while establishing a safe and reliable CLD. The depth of penetration of NASA insight activities such as audits, reviews, observations, and Product Assurance Actions (PAAs) will vary based on the recognized level of risk, derived from both partner risk (e.g. staff experience, independent review, maturity of processes) and design factors (e.g. system contribution to risk, system maturity, complexity of design, margin uncertainty).

The CLD partner and NASA also share mission authority, which is defined as joint responsibility for 1) Government mission objectives and priorities, 2) Government mission risk acceptance, and 3) Government crewmember safety.

**Mishap Response**

It is expected that the CLD partner will establish a *mishap* response plan to cope with mishaps (including mission failures) and close calls. The plan is expected to address mishap reporting, response, investigation, reporting of results, and mechanisms for instituting action to prevent recurrence. The primary purpose for mishap investigation and corrective action is to prevent similar occurrences and thus improve the safety of operations. The emphasis will be on discovering root/proximate cause-effect relationships from which remedial and corrective actions can be derived and implemented. The intent is not to place blame, but to determine how processes and responsibilities may be clarified or improved to eliminate errors. Additional purposes for investigations are to determine the nature and extent of the events and programmatic impacts; to ensure safe resumption of operations; to improve policies, standards, and regulations; to make any necessary changes in the joint risk acceptance process and to resolve any questions associated with the mishap/event.

[2] E.g. pre-flight, launch, rendezvous, docking, on-orbit, departure, landing, recovery, and post-flight.

The mishap response plan will consider the various phases of the end-to-end mission and clearly identify governing bodies and procedures for mishap response dependent on mission phase. For example, contract carriers may be responsible for mishap response during transport to and from launch and landing sites, the crew and cargo transport partners may be responsible during launch, ascent, free-space maneuvering, descent, and landing, and the CLD partner will be responsible for mishaps involving the CLD itself. Other Government entities such as the Federal Aviation Administration (FAA) and National Transportation and Safety Board (NTSB) may also maintain rights to declare and investigate mishaps associated with licensed activities.

NASA will review and approve the partner's mishap response plan as part of the CLD certification process. In parallel, NASA will maintain and execute its own mishap response plans (e.g. JPR 8621.1, NPR 8621.1, CLPD-PLN-TBD) for mishaps involving Government assets, mission objectives, or personnel.

For mishaps involving flight vehicles, equipment, systems, operations, or crew, the status and outcomes of mishap response activities may impact the CLD vehicle's continued certification status, which in turn may affect readiness for flight and/or readiness to execute critical events. Depending on the nature and severity of the mishap, an operational stand-down may be imposed while the mishap response process is undertaken and until sufficient rationale is generated or corrective action implemented to safely resume operations.

It is assumed that the CLD partner will lead CLD-related mishap response activities. Immediate, initial response to in-flight mishaps is anticipated to play out in the real-time environment via crew, FCT, and/or actions. NASA expects to be made aware of all mishaps (in-flight or otherwise) involving or affecting Government assets, personnel, or mission objectives as soon as practical. NASA additionally expects to actively participate in mishap response activities when Government assets, personnel, or mission objectives were or could be affected. NASA involvement could include, for example, serving as a member of the partner mishap investigation and findings board, providing technical expertise to the board, and/or providing Government resources to support the investigation.

It is assumed that the CLD partner will regularly status NASA regarding mishap response status and findings for all mishaps, including those that do not affect Government assets, personnel, or mission objectives. It is also assumed that there will be a mechanism that allows NASA to request activation of the CLD partner's mishap response plan.

### LEO Orbital Location

NASA defers to the CLD partner regarding the CLD's LEO orbital parameters (e.g. altitude, inclination).

### Crew Transportation

As part of the end-to-end mission services that NASA will purchase from the CLD partner, the CLD concept requires that the CLD partner directly provides or contracts with one or more third-parties for crew transportation to and from the CLD. All spacecraft transporting Government crewmembers to or from the CLD must be certified by NASA Commercial Crew Program (CCP) or another Government organization such as the FAA or other future US Government assigned agency, the process for which is beyond the scope of this document. Certification status of the crew transport vehicle, as well as mission-specific vehicle and operational readiness (e.g. deviations from the vehicle's baseline certification configuration), are assessed as part of the CLD end-to-end mission Certification of Flight Readiness (CoFR) process, jointly conducted by the CLD partner(s) and NASA. Additionally, the commercial partner is also expected to provide crew transportation to and from the launch and landing sites and recovery from an abort site.

Launch and landing date selection and vehicle traffic management are the responsibility of the CLD partner, The partner must take into consideration docking port availability, transport vehicle on-orbit life limitations,

the CLD's ability to operate autonomously, public safety and whether direct handover is desired, amongst other factors.

In addition, decades of flight experience have shown the benefits of pre-launch quarantine efforts. The CLD partner is expected to provide these pre-launch health stabilization (e.g. quarantine) services for Government and Non-Government crewmembers and their support personnel (e.g. NASA *crew surgeon* and *crew support officer*). Details for these efforts will be given to the CLD partner in the future program requirements documentation.

During launch and RPOD, NASA personnel are expecting to be present in the firing room, crew transportation partner Flight Control Room (FCR), and CLD partner FCR. Similarly, for CLD departure, landing, and recovery, NASA personnel are expecting to be present in the CLD partner FCR, crew transportation partner FCR, and at the planned landing site. It is acknowledged that this may not be possible in the event of a rapidly executed, unplanned emergency undock and landing. In this case, NASA personnel may support remotely. This presence enables NASA to provide real-time GO/NO GO status to the CLD partner Flight Director equivalent(s) as required for Government crewmembers, assets, and mission objectives. This presence also facilitates NASA insight into partner operations and polled organizations as well as NASA mission authority over Government crewmembers, assets, and mission objectives. The exact number of NASA personnel present will depend on the specific transportation provider and CLD utilized. These NASA personnel may also support from MCC-Houston and tie into the partner FCT.

The CLD partner is expected to provide or procure from a NASA-approved source post-landing recovery services for Government crewmembers including but not limited to vehicle locating, safing, and recovery, crew extraction, in-field medical care (in coordination with the NASA crew surgeon), short-turnaround science sample and data collection, and transport from the landing site to rally point at which NASA takes over care of Government crewmembers including post-flight reconditioning, human research data collection and family reunion. Government crewmembers may be made available to the CLD partner in the post-flight period for technical debriefs and science sample collection.

The crew transport vehicle partner is assumed to develop and deliver, as part of the CLD service contract, all crew and ground operator training associated with the transport vehicle and its operation including any additional training required for Pilot/Commander if identified as part of mission service. The CLD partner and crew transport vehicle partner are assumed to jointly develop and deliver all crew and ground operator training associated with joint partner operations such as RPOD, undocking/departure, and integrated emergency response. NASA will have reviewed training processes and products as part of the CLD and transportation vehicle certification efforts.

**Cargo Transportation**

As part of the end-to-end mission services that NASA will purchase from the CLD partner, the CLD concept requires that the CLD partner directly provides or contracts with one or more third-parties for cargo transportation to and from the CLD. It is anticipated that NASA will follow a process similar to the Commercial Resupply Services (CRS) approach ensuring adherence to a select set of safety and functional requirements to ensure safety of the NASA crew on the CLD or NASA cargo.

The approval status of all cargo transport vehicles arriving, departing, and docked/berthed to the CLD while Government crewmembers are present or carrying Government assets, as well as mission-specific vehicle and operational readiness, are assessed as part of the CLD end-to-end mission CoFR process, jointly conducted by the CLD partner and NASA.

It is expected that the Government will internally manage Government payload selection, prioritization, and pre-flight shipping to the cargo transport partner's or CLD partner's ground processing facility. NASA

will provide payload integration information to the partner such as moments of inertia, center of mass location, and environmental conditioning requirements and is currently evaluating if it may provide payload hazard information.

Launch and landing date selection and vehicle traffic management are the responsibility of the CLD partner, taking into consideration number of docking ports, cargo vehicle on-orbit life limitations, on-orbit payload need dates, equipment sparing requirements, consumable resupply requirements, and stowage management, amongst other factors. The CLD partner is additionally expected to provide facilities for Government and Principal Investigator (PI) pre-flight/post-flight equipment checkouts. Cargo packing and loading for launch, including provisions for late-load cargo, animal care, and environmentally sensitive cargo, are also the responsibility of the CLD partner.

During cargo vehicle RPOD to and departure from the CLD when Government crewmembers are present, NASA personnel are expecting to be present in the CLD partner FCR. This presence enables NASA to provide real-time GO/NO GO status to the CLD partner Flight Director equivalent(s) as required for Government crewmembers, assets, and mission objectives. This presence also facilitates NASA insight into CLD partner operations and NASA mission authority over Government crewmembers, assets, and mission objectives. Exact number of NASA personnel present will depend on the specific transportation provider and CLD utilized. These NASA personnel may also support from MCC-Houston and tie into the partner FCT.

The CLD partner is expected to provide post-landing recovery services for cargo return vehicles including but not limited to vehicle locating, safing, and recovery, payload extraction, short-turnaround science data gathering and/or sample return to PIs, maintenance of environmental conditioning, and non-time-critical return of samples and equipment to PIs.

The cargo transport partner is assumed to develop and deliver all crew and ground operator training associated with the cargo vehicle and its operation, including such activities as operation of cargo securing systems, inventory management systems, and environmental controls. The CLD partner and cargo transport partner are assumed to jointly develop and deliver all crew and ground operator training associated with joint vehicle operations such as RPOD, undocking/departure, and integrated emergency response. NASA will have reviewed training processes and products as part of the CLD certification effort.

**Vehicle Capabilities and Partner-Provided Services**

The CLD partner is expected to provide safe, reliable, and cost-effective access to LEO for Government uses including:

- Continuous US (non-Government) and Government human presence,
- Execution of Government-sponsored scientific investigations across a variety of disciplines, particularly those that address problems related to long-duration, deep-space human exploration (e.g. crewed missions to Mars),
- Government-sponsored advancement of spacecraft technology and systems readiness for long-duration, deep-space human exploration.
- Fundamental science

To meet these objectives, the CLD vehicle must serve as a laboratory, testbed, deep space analog, repair shop, fitness center, medical clinic, and temporary home to Government crewmembers. Additionally, under the end-to-end mission service concept (see The End-to-End Mission Service Concept), the CLD partner is expected provide a variety of onboard and ground-based services to support Government use of the vehicle.

Though the execution of Government-sponsored research and technology advancement (scientific utilization) is the top priority, NASA intends to utilize CLD missions for additional purposes such as public outreach, international partner collaboration, and astronaut experience building. It is expected that NASA's

engagement with the CLD partner will last several years, making it likely that NASA will identify additional CLD vehicle and service uses and needs over the course of the partnership. If newly identified Government needs cannot be met using existing vehicle capabilities and partner-provided services, it is assumed that there will be contractual options permitting NASA and the CLD partner to work together on a solution.

The CLDP will document CLD vehicle capability and partner-provided services requirements in CLDP-REQ-1130 as well as various interface, process, and standards documents, Statement Of Work (SOW), and Data Requirements Deliverables (DRD). The remainder of this section therefore describes Government expectations and needs at a high level only, with a focus on vehicle capabilities and partner-provided services related to 1) execution of Government utilization activities, 2) Government crewmember safety & wellbeing, and 3) Government insight. The intent is to convey the nature and scope of capabilities and services the Government would like to procure from the CLD partner rather than to provide mature, explicit, or complete requirements.

The commercial partner may request use of existing government furnished equipment (GFE). government furnished software (GFS) or government furnished services for CLD and/or ground operations, which may be provided at NASA's discretion.

**Government Utilization**

A primary Government interest in the CLD is its utilization to perform scientific research, particularly[3]:

- The research of NASA's Human Research Program, including research on and development of countermeasures relevant to reducing human health and performance risks, behavioral and psychological risks, and other astronaut safety risks related to long-duration human spaceflight,
- Risk reduction activities relevant to exploration technologies, including for the environmental control and life support system, extravehicular activity and space suits, environmental monitoring, safety, emergency response, and deep space communications,
- The advancement of United States (US) leadership in fundamental, basic and applied space life and physical science research, consistent with the priorities of the most recent space life and physical sciences decadal survey of the National Academies of Sciences, Engineering, and Medicine, and
- Other research and development activities identified by NASA's Administrator as essential to the Moon to Mars activities.

The following sub-sections outline NASA's CLD vehicle capability and partner-provided services needs associated with scientific and non-scientific[4] Government utilization of the CLD.

*Partner-Provided Pre-Flight Services*

It is expected that the Government will develop internal processes for soliciting, selecting, developing, and prioritizing Government-sponsored CLD utilization activities, both generally and for specific CLD missions.

Government utilization of the CLD relies on pre-flight services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Government crewmember and ground operator training
- Activity scheduling and coordination

[3] This list represents the Government's priority use of the ISS, as described in the National Aeronautics and Space Administration Authorization Act of 2022. The Government's intended scientific use of the CLD is assumed to be similar.

[4] E.g. public outreach, international partner collaboration, and astronaut experience building activities.

- Development and enforcement of requirements and standards for utilization assets launching to and operating onboard the CLD, as well as for studies and utilization activities performed onboard the CLD.
    - These will be reviewed and approved by NASA as part of the CLD certification process.
    - The CLD partner will work with NASA to approve Government assets for flight and onboard operation, and to approve Government studies and activities for on-orbit execution.
    - The CLD partner will inform NASA of deviations by any mission-participating partner or customer so that NASA can assess risk to Government crewmembers, assets, and mission objectives. NASA will review and approve all deviations that could pose a health risk to Government crew members.
    - All experiments that meet the definition of Human Subject Research must be reviewed by NASA's Institutional Review Board (IRB). NASA's IRB will review and approve all research activities involving Government crewmembers as test subjects, or that use NASA equipment or resources.
    - NASA's flight IACUC (The Institutional Animal Care and Use Committee) will review and approve all Government crewmember activities involving animals. This includes assessing potential risk to Government crewmembers as animal handlers, for example triggering of an animal allergy. Similarly, NASA expects to be informed of high-risk non-Government activities such as combustion science or radiation science.
- Access to non-Government operators of Government assets and non-Government participants in Government studies.
    - It is possible that non-Government crewmembers may participate in or execute Government studies or research, in which case it is expected that the Government PI will play a role in determining participant/operator suitability.
    - The Government PI will train non-Government crew and ground operators on operation of the Government asset or execution of the Government study.
- Access to non-Government PIs.
    - The Government crewmembers may participate in or execute non-Government studies or research, in which case it is expected that the non-Government PI will play a role in determining Government participant/operator suitability.
    - The non-Government PI will train the Government crewmember on operation of the non-Government asset or execution of the non-Government study, if Government crewmember involvement is required.
    - The non-Government PIs will provide information to NASA's IRB and CLDP upon request for the purpose of assessing risk to Government crewmembers, assets, or mission objectives.
- Pre-flight receiving and checkout facilities and services.
    - These CLD partner-provided facilities need to be secure yet accessible by Government asset owners for the purposes of post-shipping asset checkout and preparation for launch vehicle loading.
    - The CLD partner is expected to provide tools[5] and utility services[6] to support checkout and loading preparation activities and to maintain environmentally conditioned assets.
    - After arrival at the receiving and checkout facilities, and following successful checkout by the Government asset owner, ground handling responsibility for the asset transitions from the Government asset owner to the CLD partner.
- Pre-flight packing and launch vehicle loading.

[5] E.g. hand tools, power tools, multimeters, and wipes.

[6] E.g. flight-like power, data, and fluid services via flight-like interfaces, access to vacuum and hot and cold storage.

    - The CLD partner will coordinate with the Government asset owner to protectively pack the asset for loading on the cargo or crew transport vehicle.
    - To the greatest extent possible, it is expected that the CLD partner will provide protective packing material and that the Government will make use of such material[7].
    - The CLD partner will work with the transport vehicle partner to load the Government asset onboard the vehicle. In addition, the CLD partner will integrate any power or data interface tests and verifications needed with the transportation vehicle prior to flight.
    - The CLD partner is expected to provide verification in the form of photos or video when requested to verify an item is stowed appropriately
    - The CLD partner will provide late-load capabilities for time-to-launch sensitive assets[8].
- Manifesting and launch scheduling.
    - The CLD partner will provide cargo transport services including transport of Government assets from the pre-flight receiving facility to the vehicle loading location.
    - The CLD partner will provide transport of Government assets (cargo) to the CLD.
    - The CLD partner will select launch and landing dates and to coordinate the cargo manifest, taking into consideration the Government's on-orbit need dates.
- Government unpack and stowage
    - The CLD Partner is expected to develop, schedule, and support onboard execution of cargo unpacking and transfer products/procedures.
    - It is expected the CLD Partner will coordinate with the Government representative to unpack and transfer the Government asset per handling and stowage requirements as expected for on orbit usage.
    - The CLD partner is expected to provide verification in the form of photos or video when requested to verify an item is stowed appropriately.

*Vehicle Capabilities*

Vehicle systems and capabilities needed to support Government utilization of the CLD are expected to develop the operations nomenclature and labeling plan that follows the Government ISS approach. These systems and capabilities are identified in TBD and include, as a minimum:

- Microgravity environment.
    - The CLD partner is expected to consider level and duration of microgravity available to users when designing vehicle propulsion systems, attitude control systems, vibration isolation systems, and exercise countermeasure equipment. *Access to microgravity is a primary Government utilization need.*
- Physical attachment.
    - The CLD partner internal and external mounting locations are expected to consider such things as access to vehicle utilities (e.g. power, data, and thermal systems) for payload use, scientific needs (e.g. directional facing for external payloads), operator accessibility, protection from damage, and impact to surrounding systems (e.g. blocking of crew translation paths, shadowing of solar arrays, blocking of Earth-viewing instruments), and potable water).
    - The CLD partner is expected to provide mounting verification in the form of photos or video when requested to verify an item is installed appropriately
    - The Government intends to operate payloads and equipment both internal and external to the CLD.

[7] On-orbit stowage and disposal of custom packing materials is a significant challenge experienced on ISS. A best practice is to develop and employ generic, re-usable, reconfigurable, and/or collapsible materials.
[8] E.g. animals and environmentally sensitive equipment.

    - There is no requirement to confine Government assets to, or co-locate Government assets in, a dedicated onboard volume, rack, or module.
- Extravehicular robotics and external video.
    - There is no requirement for the CLD partner to provide extravehicular robotics capabilities. However, in the absence of such, the CLD partner is expected to provide concepts for the installation and removal of external Government payloads.
    - Capabilities permitting video inspections of extravehicular payloads are valuable for payload commissioning and troubleshooting activities as well as inspection and troubleshooting of external payload accommodation systems.
    - Capabilities permitting remote placement/removal of external payloads
- Extravehicular activity and airlock.
    - There is no requirement for the CLD partner to provide extravehicular (spacewalk) or airlock capabilities. However, in the absence of such, the CLD partner is expected to provide concepts for installation of external Government payloads. Additional requirements and consideration will be required to ensure crew safety. Details will be discussed in future documentation.
    - Partner capabilities permitting spacewalks are valuable for repair of external equipment and systems, including external payload attachment points and services.
    - Partner airlock capabilities are valuable for transferring failed payloads into the pressurized cabin for inflight maintenance.
    - Partner airlock capabilities are valuable for transferring external payloads from pressurized launch vehicles to external locations and vice versa (e.g. to return an external payload or component to the ground for refurbishment or for collecting material degradation coupons).
- Power.
    - The CLD partner is expected to make available power utility services for Government utilization.
    - The CLD partner is expected to provide access to high and low voltage, and in alternating and direct current.
    - Capabilities such as surge protection, filtering, and upstream inhibits are expected to be provided by the CLD partner to protect Government assets and operators
    - Government payloads and equipment should access vehicle power through power outlets as opposed to being wired directly into the vehicle's power architecture.
- Thermal regulation.
    - The CLD partner is expected to make available thermal regulation utility services for Government utilization. These include active and passive systems such as cold plates, forced air circulation, and heat exchangers.
- Data Handling.
    - The CLD partner is expected to provide the operating procedures and equipment for the user interface devices[9] and software applications for onboard command and control of Government assets and partner-provided support equipment, recording data, viewing and operating procedures, processing imagery, viewing vehicle and asset telemetry to ensure asset operating constraints are met, etc.
    - The CLD partner is expected to provide onboard data services (including WiFi at TBD rate and TBD speed) for crew operation of Government assets, including operating procedures for command and control of the asset, reading of asset telemetry, reading of vehicle telemetry (e.g. to verify asset operating pre-conditions are met), and data recording and storage.

[9] E.g. laptops, tablets, haptic devices, virtual reality devices, augmented reality devices, etc.

    - The CLD partner is expected to provide the secure data uplink services to permit ground-based operation of (commanding to) onboard Government assets, uplink of operational procedures and uplink of custom (Government-provided) software applications for asset command and control.
    - The CLD partner is expected to provide the secure data downlink services for real-time and non-real-time transmission of vehicle and Government asset and activity telemetry, video, and recorded data to Government ground operators located at NASA facilities and Government PI institutions. The ability to restrict access to secure downlink data to protect Government crewmember privacy and Government and PI proprietary information is critical.
    - The CLD partner is expected to provide secure real-time, two-way voice and videoconference communication between the Government crewmember and Government ground operators located at NASA facilities and Government PI institutions, as well as between the Government crewmember and outreach destinations such as media outlets, event facilities, and schools is required. *The ability to restrict secure communications access to protect Government crewmember privacy and Government and PI proprietary information is critical.*
    - The CLD Partner will provide labeling for crewmember interfaces and documents using common and consistent operational nomenclature and acronyms to ensure clear communication and understanding of information the crewmembers must process, manage, or take action on.
    - NASA will review the nomenclature and labeling plan to identify potential conflicts with well understood meanings.
    - NASA will seek commonality in terminology across CLDs whenever practical, or at a minimum prevent problematic overlaps in terminology (e.g. acronyms that have different meanings which cause operational risk).
- Vacuum.
    - The CLD partner is expected to provide access to vacuum for operations and/or venting of internal Government assets, research, and studies.
- Containment, life support, and exhaust systems.
    - The CLD partner is expected to provide systems such as compartments, filters, and air scrubbers for odor control, hazardous material containment, and the housing of research animals.
- Sample collection and stowage.
    - When designing body waste systems, the CLD partner is expected to consider use of these systems in the collection of urine and feces samples and in the duration and expected usage.
    - Biomedical and biological samples often require environmentally controlled stowage. The CLD is expected to provide stowage at a variety of temperatures (warm, cool, and frozen).
- Flight crew systems
    - The CLD partner needs to provide such crew equipment items as exercise countermeasures, toilet/personal hygiene equipment, equipment location and potable water.
- Systems for tracking locations of onboard items.
    - A variety of equipment, tools, and supplies are needed to perform utilization activities. Systems for tracking locations and consumption of such items are expected to be provided by the CLD partner, be available to the crew, and be maintained by the CLD partner.
- Vehicle architectures (e.g. docking/berthing ports) to support transport of Government assets to the CLD and return of samples to the ground must be provided by the CLD partner.

- NASA is still determining requirements for external cargo. If external cargo is manifested, CLDS will need the ability to perform attitude control and reboost to ensure Government payload pointing needs are maintained (TBD).

The CLD partner is additionally expected to provide utilization support onboard the vehicle and make available to the Government crewmember a variety of utilization support equipment and tools including:

- Common use laboratory equipment such as laptops, tablets, cameras (video and still), ultrasound devices, gloveboxes, biological specimen research habitats, centrifuge, and microscopes.
- Laboratory tools such as scalpels, forceps, scissors, pipettes, timers, and measuring devices.
- In-flight maintenance tools such as screwdrivers, socket drivers, soldering equipment, drills, and feeler gauges.
- Personal protective equipment such as safety glasses, disposable gloves, animal handling protection, respirators, and heat and cold resistant gloves.
- Consumable items such as slides, sharps, adhesive tapes, paper, writing utensils, and wipes.
- Voice capture and transmission equipment such as microphones and headsets.

Similarity of the CLD operating environment, vehicle services, and utility interfaces to those of the ISS is not required, though a similarity does enable continuity of research between the ISS and the CLD. An additional consideration when selecting utilization support equipment and tools is similarity to those used by ground researchers to enable continuity of measurements and improve validity of results.

To support Government activities relevant to the development of exploration technologies, the CLD vehicle is expected to operate as a testbed for technologies such as next-generation spacecraft systems. On rare occasions, this may require direct integration of the technology into CLD vehicle systems and/or impact operation of vehicle core systems[10]. Close collaboration between NASA and the CLD partner will be needed in this case with consideration given to such things as health and safety of the crew, integrity of the vehicle, system interfaces, roles and responsibilities for operation and troubleshooting, and impacts to vehicle certification status and emergency response procedures.

It is expected that the CLD partner will provide Interface Control Documents (ICDs) to vehicle system users. It is possible that the Government will contract with more than one CLD partner for access to more than one CLD. Ideally, all CLDs would use the same or sufficiently similar payload-to-vehicle interfaces (e.g. power and data sockets, physical attachment systems) such that Government payloads may be flown to any CLD interchangeably. This dictates a need for CLD partners to share information with each other.

For each CLD, some measure of interoperability between the CLD and its associated crew and cargo transport vehicles is assumed to be necessary for successful transport of powered and/or environmentally controlled payloads and for successful vehicle-to-vehicle system interaction while the visiting vehicle is in proximity of and docked to the CLD.

NASA may be interested in using CLD missions to develop specific skills and experience for NASA astronaut crewmembers[11]. In this utilization case, there may be a desire to have the NASA crewmember perform in-flight vehicle system maintenance, participate more actively in housekeeping activities, and/or take on specific crew roles such as crew commander, medical officer, robotics operator, spacewalker, etc. Crew cohesion can be negatively affected if crewmembers do not share housekeeping tasks therefore NASA and the CLD provider need to jointly determine the best collaborative crew methods based on their operations concept to mitigate this concern. No Government-unique vehicle capabilities have been identified for this utilization case; rather, NASA would engage with the CLD partner to identify, and enable NASA crewmember participation in, "target of opportunity" partner activities that meet NASA objectives

[10] For example, testing of a regenerative environmental control and life support system (ECLSS) may require direct integration into the vehicle's air circulation system and temporary disabling of the vehicle's primary ECLSS hardware.
[11] Pending resolution of concerns regarding Government liability and indemnity.

and align with the Partner business case. In all cases, the CLD partner retains responsibility for crew training, provision of operational procedures, and flight control and engineering support during activity execution.

NASA expects Government crewmembers to support public outreach events and activities while onboard the CLD. Examples of these include speaking with schoolchildren, giving opening remarks at a conference, and holding conversations with high visibility public figures. Such activities may be performed in real-time, requiring two-way secure voice and video communication routing from the CLD to the ground recipient. Public outreach events may alternately be pre-recorded and downlinked to NASA via the CLD partner for later use or dissemination to the recipient. On occasion, public outreach activities require private/restricted access communication between the crewmember and the recipient.

*Partner-Provided Onboard Operator Services*

Government utilization of the CLD may be accomplished by the Government crewmembers or, more likely, Government utilization will rely on onboard operator services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Onboard operator support of Government utilization activities are expected to be procured by the Government from the CLD partner as part of their end-to-end service support. Some examples of such support are non-Government crewmember unpacking of Government assets from cargo vehicles; non-Government crewmember installation, maintenance, and operation of Government assets; and non-Government crewmember participation in and execution of Government studies.
- The CLD Partner is expected to develop, schedule, and support onboard execution of cargo unpacking and transfer products/procedures. It is expected the CLD Partner will coordinate with the Government representative to unpack and transfer the Government asset per handling and stowage requirements and expected on orbit usage. The CLD partner is expected to provide verification in form of photos or video when requested to verify an item is stowed appropriately.
- When operating Government assets or participating in Government studies, it is expected that the Government PI or asset owner will play a role in determining suitability of the non-Government test subject or operator. In the case of a single Government crewmember onboard (see Table 1), non-Government crewmember assistance may be frequently needed, as many utilization activities require two or more crewmembers to perform[12].
- Non-Government crewmembers are expected to assist with gathering and preparing Government samples and assets for return to Earth and to perform return vehicle cargo loading.
- Non-Government crewmembers are expected to perform onboard vehicle maintenance, troubleshooting, and repair to ensure the availability of vehicle systems for Government utilization.

*Partner-Provided In-Flight Ground Services*

Government utilization of the CLD relies on in-flight ground services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Flight control and engineering services for vehicle systems and partner-provided equipment & tools.
    - The CLD partner is expected to operate the CLD vehicle and to ensure vehicle systems and partner-provided equipment and tools are available and configured for Government utilization activities.
    - The CLD partner is expected to provide real-time support to Government crewmembers when interacting with vehicle systems and using partner-provided equipment and tools.

[12] E.g. blood draws, large equipment installation, and extravehicular activity.

    - The CLD partner is expected to track locations of onboard items (including Government items) and to direct the crew regarding item locations, stowage, and disposal. The CLDS should have an onboard Inventory Management System to allow the on-orbit or ground crew to manage and find the location of items.
    - The CLD partner is expected to perform secure uplink/downlink of Government products such as operating procedures, software applications, and imagery.
    - The CLD partner is expected to integrate Government PIs and ground-based Government asset operators[13] into the partner flight control team.
- Provision of operating procedures for vehicle systems and partner-provided equipment and tools for use by Government crewmembers, PIs, and ground operators.
- Ground activity scheduling and on-orbit activity scheduling.
- Operation of Government assets.
    - Ground operator support of Government assets is expected to be procured by the Government from the CLD partner. Examples of such support are CLD partner FCT monitoring and/or operation of Government assets. In this case, it is expected that the Government asset owner will provide operating procedures and training to the CLD partner.
- Ground facilities and services.
    - The CLD partner is expected to provide NASA, Government PIs, and Government asset owners/operators with access to vehicle, crew, and asset telemetry; asset command and control capabilities; and CLD partner FCT voice loops including two-way communication with onboard operators. Remote access to these services will be made available such that Government and Government PI personnel are not required to support operations from the CLD partner's location.
    - The CLD partner is expected to provide console workspace in their flight control facility for use by NASA flight controllers, Government PIs, and Government asset owners/operators.
    - The CLD partner is expected to provide teleconference and videoconference capabilities for Government support of CLD partner meetings and discussions affecting Government utilization.
    - The CLD partner is expected to provide partner site access and on-site office space for NASA personnel.
- Government sample and asset return scheduling and coordination.
    - The CLD partner is expected to provide cargo transport services including return of Government samples and assets to Earth.
    - The CLD partner is expected to select landing dates and to coordinate the cargo manifest, taking into consideration the Government's need dates.
    - The CLD partner is expected to develop, schedule, and support onboard execution of cargo packing and vehicle loading procedures.
    - The CLD Partner is expected to develop, schedule, and support onboard execution of cargo packing and vehicle loading products/procedures. It is expected the CLD Partner will coordinate with the Government representative to pack and load the Government asset per handling and return requirements and to resolve any real-time deviations to the return manifest for Government assets. The CLD partner is expected to provide verification in the form of photos or video, when requested, to verify an item is packed appropriately.

[13] E.g. NASA flight controllers operating Government technology demonstration equipment.

*Partner-Provided Post-Flight Services*

Government utilization of the CLD relies on post-flight services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Provision of landing/recovery/rally site facilities and generic equipment and tools for sample and research data collection.
- Access to Government and non-Government participants in Government studies for sample and research data collection immediately post-landing and/or during study-specified post-landing timeframe.
- Recovery and return transportation or shipping of Government samples and assets from recovery site or CLD partner post-flight receiving facility to Government-specified locations (e.g. Government post-flight receiving facilities and Government PI institutions).
    - The CLD partner is expected to provide expedited (e.g. same day) recovery and return capabilities for time-sensitive samples and assets[14].
    - The CLD partner is expected to provide equipment, facilities, and shipping options that maintain environmentally conditioned samples during recovery, partner post-flight processing, and return to Government-specified locations.

**Government Crewmember Safety and Wellbeing**

A variety of vehicle capabilities and partner-provided services are needed to safely maintain continuous US and Government human presence in LEO and to ensure a healthy crew is available to perform Government utilization activities.

*Partner-Provided Pre-Flight Services*

Government crewmember safety and wellbeing relies on pre-flight services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Crew mission selection and screening.
- Government crewmember and ground team training personnel. See Crew Training and Flight Control Team Training
- Activity scheduling and coordination.
- Development and execution of a pre-flight health stabilization program, and accommodation of NASA's medical team during pre-flight activities.
- Development and enforcement of requirements and standards for materials and items launching to and used onboard the CLD, as well as for activities performed onboard the CLD while Government crewmembers are present.
    - Government crewmembers must be protected against occupational and acute hazards such as exposure to irritants due to material off gassing or unintentional release, noxious odors, loud noises, allergens, inhalation hazards, electrical shock, radiation, vibration, release of stored energy, microbes, sharp edges, entrapment, and contact with hot and cold surfaces.
    - CLD partner requirements and standards will be reviewed and approved by NASA as part of the CLD certification process.
    - The CLD partner is expected to work with NASA to approve Government-provided materials and items for flight, and to approve Government activities for on-orbit execution. This includes approval of items such as personal clothing, medical supplies and devices, recreational supplies[15], and personal items[16].

[14] E.g. animals, environmentally conditioned samples, and samples that degrade with time.
[15] E.g. musical instruments and art supplies.
[16] E.g. jewelry, photographs, and similar items of personal significance.

    - The CLD partner is expected to inform NASA of deviations by any mission-participating partner or customer so that NASA can assess risk to Government crewmembers, assets, and mission objectives. NASA's medical operations team (see Government Crew Medical Authority and Operational Support) will review and determine acceptability of all materials, items, and activities that could pose a health risk to Government crewmembers.
- Selection of partner-provided safety and wellbeing-related items.
    - It is expected that the CLD partner will provide safety and wellbeing-related items[17] for Government crewmember use onboard the CLD. It is expected that the crewmember will have an opportunity to sample these items prior to flight and to indicate personal preference when more than one option is available. It is also expected that the CLD partner will develop and execute processes for approving and manifesting Government-provided items if the CLD partner provided options are not suitable for the Government crewmember or to augment the partner-provided items.
- Pre-flight receiving, packing, and launch vehicle loading.
    - The CLD partner is expected to develop and execute processes for receiving Government-provided safety and wellbeing-related items and packing/preparing such items for flight.
    - The CLD partner is responsible for loading Government-provided and partner-provided items onto the transport vehicle.
- Manifesting and launch scheduling.
    - The CLD partner is expected to transport Government health and wellbeing-related items to the vehicle loading location.
    - The CLD partner will transport Government items to the CLD.
    - The CLD partner will select launch dates and to coordinate the cargo manifest, taking into consideration the Government's on-orbit need dates.
- Secure uplink of Government-provided safety and wellbeing-related data.
    - The CLD partner is expected to provide a secure uplink to the CLD Government-provided software applications and data used in support of Government crewmember safety and wellbeing[18].

*Vehicle Capabilities*

Vehicle systems and capabilities needed to support Government crewmember safety and wellbeing include:

- Environmental control and life support.
    - A shirtsleeve living and working environment for the Government crewmember is expected to be provided. Pressurized living and workspaces are expected to be designed and maintained within safe and comfortable environmental limits. Variables such as breathing gas composition, air flow rates, humidity, temperature, and pressure are expected to be defined as part of the vehicle design and carefully controlled during on orbit operations, ideally with some adjustability to accommodate crew preference.
- Body waste management.
    - The capabilities to collect, store, and dispose of body waste such as urine, feces, menses, and vomitus is expected to be provided. The capabilities provided should take into account duration and frequency of use. Privacy during use of collection systems (e.g. the lavatory) is expected. Design of these systems should additionally consider use for sample collection, accommodation of contaminating substances such as expelled pharmaceuticals, odor control, location away from crew eating and sleeping areas, and duration and frequency of use.

[17] E.g. personal hygiene supplies (toothpaste, shampoo, deodorant, etc.), clothing, and food.
[18] E.g. food tracking applications, exercise prescriptions, music, movies, photographs, and digital books.

- Trash management.
    - The collection, storage, and disposal of trash items is known to be a significant challenge and impact to the crew's health and quality of life. The CLD design is expected to provide these capabilities, taking into consideration such concerns as odor control, handling, storage and labeling of hazardous materials (including feminine hygiene products), protection of areas related to sleeping/eating/etc. and considerations for protection of access to emergency equipment and crew translation paths.
- Personal hygiene and grooming.
    - Accommodations for executing personal hygiene and grooming[19] activities is needed. CLD partner design is expected to take into consideration privacy and mitigations against microbial growth. Containment of environmental contaminants (e.g. skin flakes, nail clippings, and hair strands) produced during these activities and contaminant impacts on core vehicle systems must also be considered.
- Sleep.
    - Private and quiet accommodations for Government crewmember rest and relaxation is needed. These facilities are expected to incorporate such features as sleep restraints, temperature and lighting level adjustment per crewmember preference, ventilation to prevent and sensors to monitor for CO2 buildup, storage space for personal items, and systems for viewing movies, digital books and photographs, personal email, and for previewing timelines and operating procedures, etc.
- Galley.
    - Systems for the preparation and consumption of food and beverages should be provided. Access to warm and cold potable water and the ability to warm food items are expected. Capability to refrigerate food and beverage is desired.
    - NASA recommends integrating fresh food into long duration crew diet when possible. If provided, CLDS may need to provide refrigeration.
    - Designated areas for food storage, potable water dispensing, food consumption, and shared meals, away from waste collection and trash storage locations, are desired.
- Physiological countermeasures (e.g. exercise systems).
    - Devices and equipment used to maintain Government crewmember cardiovascular fitness, bone density, muscle mass, strength, endurance, as well as for minor injury rehabilitation are expected to be provided. Their design is expected to take into consideration quality of exercise[20], user controllability, volume and layout impacts and secure ability to uplink exercise prescriptions and downlink data regarding completed workouts with enough capacity to accommodate the needs of the crew complement.
    - Exercise equipment design and use should also be considered when designing other CLD systems such as carbon dioxide, power, cooling/thermal and humidity management systems, vibration isolation systems, and precision robotics systems.
    - Acoustic noise impacts should also be considered with the countermeasures system and the potential impact to crew hearing damage. Exercise equipment should be kept separate from the other parts of CLD for comfort and privacy.
- Systems for tracking locations of onboard items
    - An inventory management system that tracks locations of onboard items must be provided. ISS experience has shown there is a significant need for such as system.
- Data handling.
    - Real-time, two-way secure voice and videoconference communication capabilities between the Government crewmember and the NASA medical team located at NASA and

[19] Such as personal cleansing/bathing, haircutting/brushing, shaving, toothbrushing, and nail cutting.
[20] E.g. by providing a variety of exercise modes, operating speeds, and levels of resistance.

CLD partner facilities, as well as between the Government crewmember and locations of personal friends and family. The ability to restrict secure communications access to protect Government crewmember privacy is therefore expected.
    - Secure data uplink services to permit uplink of Government-provided data such as exercise prescriptions, health tracking applications, and crewmember-selected entertainment media.
    - Secure data downlink services for real-time and non-real-time transmission of Government crewmember health data. The ability to restrict access to secure downlink data to protect Government crewmember privacy is therefore expected.
    - The CLD partner is expected to provide the user interface devices[21] and software applications for Government crewmember access to recreational resources, such as the internet, movies, games, and digital books and photographs as well as for Government crewmember use of safety and wellbeing-related vehicle systems.
- Vehicle architectures / other vehicle systems.
    - The CLD vehicle is expected to provide core vehicle system[22] capabilities to support the above listed crew safety and wellbeing capabilities.
    - Safety and wellbeing-related considerations when designing vehicle systems, architectures, and operations include:
        - Provision of visiting vehicle docking ports and systems to support transport of Government-provided items to the CLD and return of medical samples and Government items to the ground.
        - When establishing the number of docking/berthing ports on the vehicle, consideration should be given to whether direct crew handover is needed for safe vehicle operation, frequency of resupply missions, time critical sparing philosophy, time required to load/unload cargo vehicles, whether multiple visiting vehicle types will be accommodated (maximizes safety in the event of a fleet-grounding issue), and whether hazard analysis requires an ability to dock/berth a crew rescue vehicle in the event of an on orbit crew vehicle issue.
        - It is required that the crew always has means for rapid departure from the CLD and expedited return to Earth in the event of a medical or CLD vehicle emergency. Consideration should be given to complexity and duration of operations required to ready the CLD and crew vehicle for departure, the translation paths to the crew vehicle, and ability to navigate to the crew vehicle under emergency conditions (e.g. while wearing a respirator, in thick smoke, and/or with no electrical lighting). Consideration must also be given to accommodation of one or more incapacitated crewmembers during such activities.
        - The CLD crew are expected to have means for monitoring the approach of visiting vehicles, the ability to pause or abort the approach of uncrewed vehicles, and two-way communication with approaching crewed vehicles.
        - Vehicle systems are expected to be designed to eliminate or mitigate risks such as electrical shock, radiation, vibration, sharp edges, entrapment, microbial growth, airborne particles, and contact with hot and cold surfaces.
        - Vehicle design and equipment selection should take into consideration the impacts of radiation on the crew and vehicle systems. Mitigations against solar flares and high-radiation events should be considered, as should how loss of non-radiation hardened systems could affect safe vehicle operation.

[21] E.g. laptops, tablets, haptic devices, virtual reality devices, augmented reality devices, etc.
[22] Core vehicle systems are assumed to include environmental control and life support, thermal, electrical power, mechanical, command and data handling, and propulsion and attitude control systems.

- The vehicle design is expected to incorporate protections against micrometeoroids and orbital debris (MMOD), and automated vehicle and crew responses to both rapid and non-rapid depressurization are expected to be developed. Leak detection, isolation, and repair methods, ability to feed small leaks for some period of time, and leak response equipment, tools, supplies, and procedures are expected to be provided by the CLD partner.
- The vehicle design is expected to incorporate protections against fire and toxic atmosphere events such as fire and toxic atmosphere detection, automated response (such as disabling of air circulation), and post-event atmospheric scrubbing.
- The vehicle design is expected to consider module and/or compartment isolation capabilities to minimize the impact of and aid in troubleshooting fire, depressurization, and toxic atmosphere events.
- The vehicle design is expected to provide the ability for CLD to perform collision avoidance maneuvers and provide a Safe Haven to ensure crew safety in the event of conjunction with tracked orbital debris.
- The crew is expected to be provided with data and tools to confirm automated emergency detection, monitor automated response, and confirm successful automated recovery. The crew is additionally expected to be provided with means to interrupt or abort automated response, and to perform emergency identification, isolation, response/suppression, and recovery in the absence of automated systems. Finally, the crew is expected to be able to initiate automated emergency response independent of automated emergency detection.
- If extravehicular activity (spacewalk) or airlock capabilities are utilized by NASA, additional requirements and consideration will be required to ensure crew safety. Details will be discussed in future documentation.
- The vehicle, systems, and onboard equipment should be designed and selected taking into consideration impacts to the occupational environment such as acoustics, visible light, odors/off gassing, temperature/heat generation, touch temperature (contact with hot and cold surfaces), sharp edges, and stored energy.

The CLD partner is additionally expected to provide support onboard the vehicle and make available to the Government crewmember a variety of safety and wellbeing-related equipment, tools, and items including:

- Common use equipment and supplies for emergency medical response, non-urgent care, and routine medical surveillance. Examples include restraints, laptops, tablets, cameras (video and still), ultrasound devices, radiation dosimeters, and automated external defibrillators. This equipment must be calibrated and maintained regularly, and ideally would similar or identical to that used by the NASA medical team and/or CLD partner medical team to maximize continuity of care and validity of readings. The CLD partner is additionally expected to provide medical items such as first-aid supplies and common use pharmaceuticals.
- Common use equipment for emergency response such as fire extinguishers, breathing apparatus, manual pressure measurement devices, air quality test kits, leak detectors, leak patching kits, and biohazard material cleanup supplies.
- Personal protective equipment such as safety glasses, disposable gloves, animal handling equipment, respirators, and heat and cold resistant gloves.
- Common use housekeeping equipment and supplies such as vacuums, absorbent towels, and wipes.
- In-flight maintenance tools such as screwdrivers, socket drivers, soldering equipment, drills, and feeler gauges.
- Personal care items such as toiletries and clothing.
- Foods and beverages.

    - In addition to meeting federal/state/local laws and regulations, these are expected to meet NASA standards for nutrition and daily caloric intake and food safety.
    - Best practices are to provide varied selections and to supplement stabilized foods with fresh foods as often as possible (i.e. with every visiting vehicle arrival).
- Voice capture and transmission equipment such as microphones and headsets.
- Recreational resources such as access to the internet, personal email, a reading library, a music library, games, and a movie library; and equipment and devices[23] to access such services.
    - Crew morale and cohesion can benefit from opportunities for the integrated crew to relax together and share recreational activities. This may drive needs such as a film projector.

*Partner-Provided Onboard Operator Services*

Government crewmember safety and wellbeing relies on onboard operator services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Non-Government crewmembers are expected to perform onboard vehicle maintenance, troubleshooting, and repair to ensure vehicle systems continue to operate and provide a safe living and working environment for Government crewmembers.
- Non-Government crewmembers are expected to perform vehicle housekeeping activities to ensure the vehicle remains a clean and sanitary environment for Government crewmembers.
- Non-Government crewmembers are expected to serve in roles such as crew commander and medical officer and to protect the health and wellbeing of Government crewmembers consistent with the expectations of these roles and responsibilities defined by the CLD partner and agreed to by NASA. This includes activities such as leading integrated crew emergency response, directing Government crewmember actions during emergencies, and rendering medical care to Government crewmembers upon consultation with NASA's medical team.

*Partner-Provided In-Flight Ground Services*

Government crewmember safety and wellbeing relies on in-flight ground services provided by the CLD partner, in conjunction with NASA support, as part of the end-to-end mission services concept. These include but are not limited to:

- Flight control and engineering services for vehicle systems and partner-provided equipment and tools.
    - The CLD partner is expected to operate the CLD vehicle and to ensure vehicle systems and partner-provided equipment and tools are available and configured to protect Government crewmember safety and wellbeing.
    - The CLD must provide configuration management (CM) processes for mission operation products (i.e. procedures, flight rules and displays (crew and ground)) to assure compliance equivalent to NASA level for: version history, change control, standardization, and validation.
    - The CLD partner is expected to provide real-time support to Government crewmembers when interacting with vehicle systems and using partner-provided equipment and tools.
    - The CLD partner is expected to lead integrated crew emergency response, direct Government crewmember actions during emergencies, and render medical care to Government crewmembers upon consultation with NASA's medical team (see 0, 0).
    - The CLD partner is expected to track locations of onboard items (including Government items) and to direct the crew regarding item locations, stowage, and disposal.

[23] Such as laptops, tablets, and virtual reality headsets.

    - The CLD partner is expected to perform secure uplink/downlink of Government products such as exercise prescriptions, software applications, recreational media, and Government crewmember health data.
    - The CLD partner is expected to integrate the NASA medical team into the partner flight control team.
    - The CLD partner is expected to perform trajectory clearance analysis and, if required, plan collision avoidance maneuvers.
- Provision of operating procedures for vehicle systems and partner-provided equipment and tools for use by Government crewmembers and ground operators.
- Leading and executing mishap response.
- Ground activity scheduling and on-orbit activity scheduling.
- Ground facilities and services.
    - The CLD partner is expected to provide NASA with access to vehicle, crew, and health-related equipment telemetry as well as CLD partner FCT voice loops including two-way communication with Government crewmembers. Remote access to these services will be made available such that Government personnel are not required to support operations from the CLD partner's location.
    - The CLD partner is expected to provide console workspace in their flight control facility for use by the NASA medical team.
    - The CLD partner is expected to provide secure teleconference and videoconference capabilities for NASA support of CLD partner meetings and discussions affecting Government crewmember safety and wellbeing.
    - The CLD partner is expected to provide partner site access and on-site office space for NASA personnel.
- Government sample and asset return scheduling and coordination.
    - The CLD partner is expected to provide cargo transport services including return of Government medical samples and assets such as crewmember personal items to Earth.
    - The CLD partner is expected to select landing dates and to coordinate the cargo manifest, taking into consideration the Government's need dates.
    - The CLD partner is expected to develop, schedule, and support onboard execution of cargo packing and vehicle loading procedures.

*Partner-Provided Post-Flight Ground Services*

Government crewmember safety and wellbeing relies on post-flight services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Provision of landing/recovery/rally site medical facilities, medical care, and generic equipment and tools for medical examination and treatment.
- Secure downlink of crewmember photos and other digital media and release to NASA.
- Recovery and return transportation or shipping of Government medical samples and assets such as crewmember personal items from recovery site or CLD partner post-flight receiving facility to NASA JSC.
    - The CLD partner is expected to provide equipment, facilities, and shipping options that maintain environmentally conditioned samples during recovery, partner post-flight processing, and return to Government-specified locations.

**Government Insight**

Government crewmember presence onboard the CLD requires continued certification status. A variety of vehicle capabilities and partner-provided services are needed to enable NASA insight for continued CLD certification.

*Partner-Provided Pre-Flight Services*

Government insight and continued certification rely on pre-flight services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Leading and executing the CoFR process.
- Providing the NASA team with test data, trend data, analyses methods and results, failure root cause and recovery/mitigation information, vehicle telemetry, etc.
- Provision and manifesting/launch of spare and replacement vehicle components, equipment, and tools.

*Vehicle Capabilities*

Vehicle systems and capabilities needed to support Government insight and continued certification include:

- Vehicle health monitoring systems such as stress/strain gauges, vibration sensors, external video (e.g. to inspect for MMOD damage), acoustic sensors, and vehicle core system[24] data.
- Operating environment monitoring systems such as dosimeters, orbital maintenance data (e.g. to confirm atmospheric drag model), thermal sensors.
- Data handling.
    - Downlink of vehicle health, vehicle performance, and operating environment data.
    - Uplink and command and control capabilities for engineering-type activities such as initiation of troubleshooting scripts, changes to operating parameters to workaround failures or extend system life, and installation of software patches.
- Vehicle architectures.
    - Design of vehicle systems and component selection should consider (for example) radiation susceptibility, ability to meet performance requirements, ability to meet expected lifetime, maintainability, and design for minimum risk.
    - The CLD design is expected to provide two-fault tolerance where inadvertent operation or failure can result in a catastrophic hazard.
    - Single failure tolerance may be sufficient for hazards with a long time to effect, crew evacuation response plan, and acceptable crew survivability analysis.
    - Design for minimum risk criteria may be applied for hazards where fault tolerance does not apply (e.g. fire hazards).
    - Design of vehicle and automated systems should consider crew size for safe operation and successful emergency response. This is a particular concern in the event of an incapacitated crewmember or minimal training case (e.g. Government crewmember reliant on a single or minimal partner crew to lead and execute emergency response).

*Partner-Provided Onboard Operator Services*

Government insight and continued certification rely on onboard operator services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Crewmembers are often primary sources of vehicle performance information. Non-Government crewmembers are expected to be vigilant in monitoring and reporting vehicle condition including changes in or unusual appearance, sound, feel, smell, and taste, signs of wear and tear, and changes in performance of systems, hardware, and consumables.
- Non-Government crewmembers are expected to perform onboard vehicle maintenance, troubleshooting, and repair.

[24] Core vehicle systems are assumed to include environmental control and life support, thermal, electrical power, mechanical, command and data handling, and propulsion and attitude control systems.

*Partner-Provided In-Flight Ground Services*

Government insight and continued certification rely on in-flight ground services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Trending and analysis of vehicle performance data to identify failures and performance degradation.
- Monitoring of data to validate analysis assumptions regarding the vehicle operational environment.
- Dissemination of trend data and analysis to the NASA team.
- Leading and execution of failure, anomaly, emergency, and mishap response.
    - Immediate failure, anomaly, emergency, and mishap response actions are expected to be executed by the CLD partner consistent.
    - The CLD partner is assumed to be responsible for developing and leading execution of failure investigation, anomaly resolution, emergency, and mishap response plans.
    - The NASA team expects to participate in and/or to have insight into CLD partner-led activities such as root/proximate cause investigation and failure isolation, troubleshooting, recovery, and workaround plan formulation.
    - The nature of the failure, anomaly, emergency, or mishap and/or nature of the troubleshooting, recovery, and/or workaround actions may drive formal CLD partner and NASA risk assessments, which in turn may drive re-validation of the CLD's certification status.
- Ground facilities and services.
    - The CLD partner is expected to provide NASA with access to vehicle and operating environment telemetry as well as CLD partner FCT voice loops for the purposes of vehicle health monitoring and performance trending. Remote access to these services will be made available such that Government personnel are not required to support operations from the CLD partner's location.
    - The CLD partner is expected to provide console workspace in their flight control facility for use by the NASA team.
    - The CLD partner is expected to provide teleconference and videoconference capabilities for NASA support of CLD partner meetings and discussions affecting Government insight and continued certification.
    - The CLD partner is expected to provide partner site access and on-site office space for NASA personnel.

*Partner-Provided Post-Flight Ground Services*

Government insight and continued certification rely on post-flight services provided by the CLD partner as part of the end-to-end mission services concept. These include but are not limited to:

- Analysis of samples and failed equipment returned to Earth as part of root/proximate cause investigations.
- Participation in certification re-validation activities.
- Treatment of failures, anomalies, mishaps, and emergencies during the next mission's CoFR activities in the form of closure of all actionable work associated with such events, or, in absence of closure, risk analysis and mitigations to support proceeding with flight.

**Vehicle Commissioning and Evolution**

Prior to launch of first Government crewmembers to the CLD, it is expected that the vehicle will have successfully demonstrated the abilities to maintain orbit and sustain life. It is a best practice that the mission be nominally planned for a short duration with the option to extend upon verification that vehicle performance supports sustained human presence and that no crew safety issues exist.

It is possible that the CLD vehicle will be expanded or evolved over the course of the Government's involvement. For example, new modules or major capabilities may be added, and hardware or software systems may be upgraded. Government crewmember presence during such activities will be approved dependent upon safety and risk evaluation results presented to the NASA authority for approving high risk operations. It is expected that all such activities would be reviewed and approved by NASA as part of the CoFR and continued certification processes.

**Typical Government Crewed Mission**

Upon identification of a flight opportunity for Government personnel, NASA performs Government crewmember selection and coordinates the integrated crew complement with participating partners.

Flight specific crew training is expected to be developed and delivered by the CLD partner, as outlined. Following completion of training, the Government crewmember launches to the CLD onboard a CLD partner provided, or CLD partner-contracted, crew transport vehicle (see Crew Transportation).

The typical on-orbit duration for Government crewmembers is assumed to be several continuous months, though the Government is interested in both shorter and longer duration expeditions, potentially up to two years, as an analog for long-duration, deep-space exploration. During the Government crew member's on-orbit period, cargo vehicles may arrive and depart, as may other crews. While onboard the CLD, the Government crewmember is expected to devote the majority of their time to the execution of Government activities, with a focus on the execution of Government-sponsored scientific research and technology development. Vehicle operation, maintenance, outfitting, and housekeeping is assumed to be primarily performed by non-Government (e.g. commercial professional) crewmembers.

After the prescribed time onboard the CLD, the Government crewmember departs via a CLD partner provided, or CLD partner contracted, crew transport vehicle. After crew handover, NASA is expecting to manage post-flight activities for Government crewmembers including physical reconditioning, human research data collection and post-flight debriefs.

**Crew Complement and Crew Attributes**

The integrated crew complement for flights involving Government crewmembers is assumed to include one or more *commercial professional crewmembers*. The crew may be augmented with *NASA international partner* crewmembers, additional commercial professional crewmembers, and/or non-professional crewmembers representing foreign or domestic private, public, or governmental interests.

Government crewmembers will typically be assigned to a specific CLD mission from NASA's astronaut corps, though they may alternately be selected from other NASA organizations or other Government organizations.

The decision whether to assign backup Government crewmember(s) to a specific mission is primarily risk-based and depends on considerations such as vehicle minimum crew size for safe operations, Government mission objectives, and contractual obligations between NASA and the commercial partner. A best practice is to make the decision as early as possible and, once made, to fully support the decision so that backup

crewmember training, suit fabrication, processing of personal preference items, etc. are not rushed should the backup crewmember need to fly.

All Government crewmembers are assumed to meet NASA's physical and psychological mission selection standards. In the interests of mission success, crew safety and cohesion, it is expected that the CLD partner will develop and adhere to similar standards and requirements for all personnel visiting the CLD while Government crewmembers are present or flying with Government crewmembers onboard a crew transport vehicle. NASA will have reviewed and agreed to the partner's medical standards as part of the CLD certification effort. If any crewmember deviates from the CLD partner standards and is assigned to fly with a Government crewmember on a crew transport vehicle or be present at the CLD at the same time as a Government crewmember, it is expected that NASA will be informed of the nature of the deviation, associated risks, and planned mitigations. NASA will then assess risks to Government crewmembers, assets, and mission objectives, the outcome of which assessment may impact NASA's CoFR endorsement for the mission. NASA will similarly inform the CLD partner of any Government crew standards deviations.

Crew cohesion is an extremely important factor in crew safety, performance, and mental wellbeing. It is therefore recommended that the CLD partner provide opportunities for the Government crewmember to bond and build trust with the non-Government crewmembers cohabitating the CLD during the Government crewmember's stay. Examples of this include Government crew member's participation in maintenance. If system maintenance capabilities are utilized by NASA, additional requirements and consideration will be required to ensure crew safety. Details will be discussed in future documentation.

**Crew Training**

All Government crewmembers are assumed to have completed NASA's generic, pre-assignment training program[25] prior to being eligible for assignment to a CLD mission. Individual Government crewmembers' past operational experience and training should be considered by the CLD partner when developing individualized training plans, with the goal of making CLD and transport vehicle flight-specific training as efficient as possible.

The crewmember's assigned role(s), responsibilities, and tasks for the mission are assumed to dictate the amount of training the crewmember will receive. For example, not all crewmembers may be trained to operate all systems or to operate systems with the same level of expertise. It is expected that NASA will be involved in decisions regarding role, responsibilities, and task assignments for Government crewmembers as NASA may desire development of specific skills or exposure to specific experiences for the individual Government crewmember or across the NASA astronaut corps. It is recognized that some specialist roles (e.g. robot operator, spacewalker, commander) require a significant amount of training. Crewmember assignment to these roles should occur as early as possible in the training template to avoid compressed training schedules and heavy training load.

The CLD partner is expected to develop and deliver all CLD vehicle-related training for Government crewmembers. NASA will review and approve the CLD partner's crew training plans and products per the vehicle certification process. Vehicle-related training is assumed to include, but is not limited to:

- Operation, maintenance, and repair of vehicle systems and specialist systems[26] at a level appropriate to the crewmember's assigned role and anticipated use,

[25] Currently labeled "ASCAN" or Astronaut Candidate training, this program includes instruction in such topics as fundamental aerospace science concepts, technical photography techniques, and physical geography for Earth observation.

[26] E.g. EVA and robotic systems, if the CLD provides these capabilities.

- Operation, maintenance, and repair of partner-provided general payload and science support equipment[27],
- Use of crew support equipment, applications, and tools[28], and
- Execution of emergency response procedures, use of emergency equipment and tools, and use of personal protective equipment.

The crew and cargo transportation partners are expected to develop and deliver all transport vehicle-related crew training. The transportation partners and CLD partner are expected to develop and deliver integrated crew training for joint activities such as RPOD, undocking, and emergency response. NASA will review and approve these training plans and products per the vehicle certification processes.

It is expected that the CLD partner and/or PIs for non-Government payloads and studies develop and deliver crew training required for execution of tasks associated with non-Government payloads and studies. NASA will review these training plans and products if Government crewmembers are assigned to complete this training or to perform non-Government payload-related tasks or studies.

With NASA support, PIs for Government-sponsored payloads and studies are expected to develop and deliver training required for operation of the payload or execution of the study, regardless of whether on orbit tasks will be performed by Government or non-Government crewmembers. The Government PI is assumed to have a role in determining whether the crewmember is qualified (sufficiently skilled) to perform tasks related to operation of the payload or performance of the study. Similarly, the Government is assumed to be responsible for developing and delivering training required for operation of Government-sponsored or owned technology demonstration systems.

It is assumed that Government crewmembers will train for several months in advance of a typical multi-month month CLD mission. The integrated training plan is assumed to include all CLD vehicle- and mission-related training, transport vehicle-related training, and science-related training. The CLD partner is expected to coordinate with all training organizations[29] to develop the integrated training plan (schedule and content).

It is recognized that crew training will likely use a variety of delivery methods and tools such as classroom, simulators of varying fidelity, self-study materials, and/or interactive computer-based applications. Use of next-generation training tools and approaches (e.g. virtual reality, artificial intelligence-guided, remote, just-in-time, and/or on-demand training technologies) is of interest to NASA as these are expected to be useful in support of deep space exploration. To the greatest extent practical, training should make use of flight-like equipment and simulate flight-like conditions.

Crew training is assumed to primarily occur at partner training facilities, though consideration should be given to enabling some training to occur at the crewmember's home location (typically Houston for Government crewmembers). Quality of life should be considered when scheduling training events and related travel.

Because the CLD partner is responsible for crew training, it is assumed that the CLD partner will also be responsible for assessing training outcomes and formally qualifying individual crewmembers for flight based on their performance during training. Flight crew qualifications may limit the Government crewmember to operation of specific systems, execution of specific roles, and/or performance of specific activities, consistent with training received and performance during evaluations. It is expected that a crew commander be designated, appropriately trained, and capable of executing the various aspects of the role. It is expected that NASA will be involved in decisions regarding role assignments for Government crewmembers (e.g. pilot, spacewalker, maintenance expert, crew medical officer, robot operator) as NASA

[27] Such as ultrasound equipment, glovebox, animal enclosures, etc.
[28] Such as laptops, cameras, timeline and procedure viewing applications, entertainment systems, etc.
[29] E.g. CLD partner, crew transport partner, cargo transport partner, Government PIs, and partner PIs.

may desire development of specific skills or exposure to specific experiences for the individual Government crewmember or across the NASA astronaut corps.

To promote crew cohesion, safety, and task efficiency, it is a best practice to provide opportunities for all members of the crew to train together in a variety of situations and to rehearse together highly integrated and choreographed crew activities such as emergency response. If this is not possible, it is expected that Government crewmembers will participate in emergency response simulations with alternate personnel playing the roles of missing crewmembers. In the absence of opportunities to train together, the CLD partner is expected to provide other means for crewmembers to build rapport prior to flight. Training on subjects such as crew resource management is also considered critical. Backup crewmembers, if assigned, should ideally be given opportunities to train with the prime crew.

It is expected that the CLD partner will accommodate requests for personnel other than Government crewmembers to attend Government crew training activities. Such personnel could include NASA crew surgeons, crew support officers, members of the media, etc.

It is expected that there will be a mechanism for requesting additional training if the Government crewmember or NASA feels that the crew has not been adequately prepared for the mission. Additionally, it is expected that there will be a mechanism for incorporating lessons learned from past missions into training processes and products.

Because the CLD partner is responsible for crew training, it is assumed that the CLD partner will also be responsible for assessing training outcomes and formally qualifying individual crewmembers for flight based on their performance during training. It is expected that there will be a mechanism for appeal and/or remedial training if a Government crewmember's performance is not deemed satisfactory, and that NASA will be a participant in such process.

In the interests of safety and crew cohesion, it is expected that the CLD partner will develop and adhere to minimum training and qualification standards for all personnel visiting the CLD while Government crewmembers are present or flying with Government crewmembers onboard a crew transport vehicle. NASA will have reviewed these standards as part of the CLD certification effort. If any crewmember deviates from the CLD partner standards and is assigned to fly with a Government crewmember on a crew transport vehicle or be present at the CLD at the same time as a Government crewmember, it is expected that NASA will be informed of the nature of the deviation, associated risks, and planned mitigations. NASA will then assess risk to Government crewmembers, assets, and mission objectives, the outcome of which assessment may impact NASA's CoFR endorsement for the mission.

The CLD partner is expected to ensure perishable crew skills and knowledge are maintained throughout the pre-flight training period and mission. This is particularly important in the event of launch delays or mission extensions. Ground-based and on-orbit proficiency training is expected to be developed and provided by the CLD and transportation partners.

On-orbit training in support of just-in-time activities (such as EVA and system maintenance) is also expected to be developed and delivered by the commercial partners. If extravehicular activity (spacewalk)/airlock and system maintenance capabilities are utilized by NASA, additional requirements and consideration will be required to ensure crew safety. Details will be discussed in future documentation.

~~Government crewmembers are currently bound to Government policy associated with federal employees.~~ The Government expects that the CLD partner will develop and enforce a crew code of conduct applicable to all crewmembers, which NASA will have reviewed and approved as part of the CLD certification process. NASA expects that this CLD crew code of conduct include contingencies and repercussions for non-compliance.

**Flight Control Team Training**

The CLD partner is expected to develop and deliver training for members of their FCT, to assess training outcomes, and to formally qualify individuals to perform flight control duties. NASA will review and approve the CLD partner's training plans and products per the vehicle certification processes. Additionally, it is expected that there will be a mechanism for incorporating lessons learned from past missions into training processes and products.

The CLD partner is expected to develop and deliver flight control training for Government personnel embedding in the CLD partner flight control team such as NASA crew surgeon, NASA ground operators of Government assets, and Government PIs. Government PIs and NASA personnel participating in CLD flight control activities may or may not have previous flight control experience.

Flight controller training provided by the CLD partner to Government PIs and NASA flight controllers is assumed to include, but is not limited to:

- Foundational flight controller skills including crew resource management and integrated CLD flight control team coordination,
- Operation of CLD partner ground systems including telemetry, voice, and command & control applications,
- Use of CLD partner ground support tools such as mission planning applications and procedure and flight rule viewers,
- Knowledge of vehicle systems in the context of their interaction with Government assets being operated by the Government PI or NASA flight controller,
- Knowledge of crew support and common use equipment, applications, and tools[30] in the context of their use in support of Government on-orbit activities, and
- Execution of emergency response procedures in the context of actions to be undertaken by the Government PI or NASA flight controller during an emergency.

It is expected that there will be a mechanism for requesting additional training if the Government PI or NASA flight controller feels that they have not been adequately prepared for the mission.

With NASA support, PIs for Government-sponsored payloads and studies are expected to develop and deliver training to the CLD partner as required for partner ground operation or support of the payload or execution of the study. Similarly, the Government is assumed to be responsible for developing and delivering training required for CLD partner ground operation or support of Government-sponsored or -owned technology demonstration systems or assets.

It is recognized that flight controller training will likely use a variety of delivery methods and tools such as classroom, simulators of varying fidelity, self-study materials, and/or interactive computer-based applications. Use of next-generation training tools and approaches (e.g. virtual reality, artificial intelligence-guided, remote, just-in-time, and/or on-demand training technologies) is of interest to NASA as these are expected to be useful in support of deep space exploration. To the greatest extent practical, training should make use of flight-like equipment and simulate flight-like conditions.

Flight controller training may occur at partner training facilities, though it is expected that some training events (e.g. integrated flight control team simulations) will be supported from the Government PI or NASA flight controller's operating location (e.g. Marshall Space Flight Center, Johnson Space Center, or academic institution). Quality of life should be considered when scheduling training events and related travel.

[30] Such as laptops, cameras, glovebox, ultrasound, etc.

To promote team cohesion, safety, and task efficiency, it is important that opportunities are provided for all members of the CLD flight control team (Government PIs, NASA flight controllers, and CLD partner flight controllers) to train together in a variety of situations.

### Other Team Training

The CLD partner is expected to provide a subset of the training to NASA personnel for the purposes of certification compliance and mission and vehicle situation awareness.

The CLD partner is additionally expected to provide training to NASA program and management personnel as required to enable effective support of the real time management decision processes.

### On-orbit Government Crew and Government Activity Scheduling

A Government crewmember's on-orbit workday is spent performing activities from one or more of the following broad categories:

1. Government activities
2. Self-care activities
3. Commercial utilization activities
4. Vehicle support activities

Government activities are defined as activities that directly support Government mission objectives. These may include but are not limited to:

- Performance of Government-sponsored science and participation in Government-sponsored studies,
- Installation, maintenance, or operation of Government-owned or -sponsored systems (e.g. payloads, hardware, and software), and
- Performance of Government-sponsored outreach events.

Self-care activities are defined as activities that directly support the Government crewmember's health and wellbeing. These may include but are not limited to:

- Exercise,
- Personal hygiene,
- Meal preparation and consumption,
- Private medical and family conferences, and
- Recreation/relaxation.

Government activities and self-care activities (category 1 and 2 activities) are assumed to be performed on Government crewmember time allocated to the Government.

It is possible that there will be contractual mechanisms that permit or require Government crewmembers to perform activities on behalf of or in support of the CLD partner or other commercial partner(s)[31]. These are assumed to be performed on time bartered or purchased by the benefitting partner and are categorized as commercial utilization and vehicle support activities (categories 3 and 4).

Example commercial utilization activities are:

- Performance of partner-sponsored science and participation in partner-sponsored studies,
- Installation, maintenance, or operation of partner-sponsored payloads or systems, and

[31] Pending resolution of concerns regarding Government liability and indemnity.

- Performance of partner-sponsored outreach events.

Example vehicle support activities are:

- Housekeeping tasks,
- Vehicle outfitting, operations, and maintenance tasks,
- Cargo vehicle loading and unloading, and
- Onboard training for and execution of vehicle control tasks (e.g. RPOD, emergency response).

Having all crewmembers share in housekeeping and light maintenance tasks is a best practice that promotes crew cohesion and provides Government crewmembers with valuable, well-rounded spaceflight experience. However, the CLDP's intent is that most vehicle support activities will be performed by CLD partner crewmembers, allowing the majority of the Government crewmember's workday to be allocated to performance of Government activities and self-care activities (categories 1 and 2). Actual distribution of the Government crewmember's time across all four activity categories will depend on a variety of factors such as mission duration, crewmember role, number of crewmembers onboard, vehicle design, and contractual agreements between NASA, the CLD partner and other commercial partners.

It is assumed that the division of the Government crewmember's time between Government and partner activities (i.e. percentage or number of hours per week spent on activities from categories 1 and 2 vs. 3 and 4) will be determined and agreed between NASA and the CLD partner well in advance of the mission. This allows each party to identify and prioritize the various payloads, studies, and mission objectives the Government crewmember will support during their time onboard the CLD and ensures appropriate processes (such as NASA Institutional Review Board approval and payload manifesting) are completed in time for execution.

Similarly, it is possible that there will be contractual mechanisms that permit or require non-Government crewmembers to perform activities on behalf of or in support of the Government. These are assumed to be performed on time bartered or purchased by NASA and fall under the Government activities category (category 1). It is assumed that the percentage or number of hours per week spent on activities from category 1 by non-Government crewmembers is determined and agreed between NASA and the CLD partner well in advance of the mission. Additional crew time can be required for a number of reasons so the overall services agreement is expected to cover a certain amount of changes without requirement for contract update.

It is assumed that the CLD partner will provide software application(s) and processes for planning, coordinating, and scheduling crewmember activities. The CLD partner is assumed to lead integrated activity planning, including resolution of spatial, system, and equipment use conflicts and provision of operational procedures for CLD partner-provided systems and equipment such as exercise devices, galley systems, and common use science equipment. The CLD partner is also assumed to provide inventory management and stowage services for all onboard activities.

NASA will provide planning inputs (including all information and constraints) for Government activities (category 1 activities), regardless of whether the activity is being performed by a Government or non-Government crewmember. NASA will provide planning inputs (including all information, resources and constraints) for self-care activities (category 2) when these are being performed by a Government crewmember.

The CLD partner is expected to lead planning of all activities in all categories (see notional approaches, below). It is expected that NASA will have insight into all activities planned for execution onboard the CLD while Government crewmembers are present or when Government assets are being operated, for example by being involved in weekly planning meetings, timeline reviews, and/or having access to the mission timeline for all crewmembers. It is assumed that NASA will perform any activity planning support from a NASA location(s).

A notional approach to Government crewmember activity planning:

1. NASA communicates Government activity requirements[32] and Government crewmember self-care activity preferences[33] to the CLD partner well in advance of the mission.
    - This ensures Government and partner-provided assets and supplies are approved for flight, manifested, launched, and deployed onboard in time for Government activity execution.
    - This allows the CLD partner to identify and resolve resource conflicts and to develop advanced planning windows (e.g. target week) for the execution of each Government activity. Target activity execution windows are communicated to and negotiated with the NASA planning team and Government PIs.
2. NASA and the CLD partner identify commercial utilization and vehicle support activities to be performed by the Government crewmember and Government activities to be performed by non-Government crewmembers. This occurs well in advance of the mission to ensure activities such as operator training, study participant screening, and resolution of liability concerns can be completed.
3. In the tactical timeframe, the Government crewmember's activities are assumed to be planned on a weekly basis, several weeks in advance of execution. Deviations from pre-planned activity execution windows established in Step 1. are identified, negotiated, and resolved at this time.
4. The number of Government crewmember hours reserved for partner use (execution of activities from categories 3 and 4) for the week are refined and confirmed.
5. The CLD partner team assigns activities from categories 1 and 2 to the remaining hours of the Government crewmember's work week, consistent with the pre-planned activity execution windows and negotiated deviations. The NASA planning team provides final activity details (e.g. operational procedure references, work location, supplies and resources needed, activity duration) for category 1 activities and acts as a resource for category 1 and 2 planning questions. CLD partner-provided templates are used to populate this information for category 2 activities since these are assumed to use CLD partner-provided systems.
6. The NASA planning team's inputs are provided to the CLD partner planning team. The CLD partner planning team looks across the integrated crew timeline, identifying and working to resolve workspace and resource conflicts coordinating with the NASA planning team as required in a timely manner per the agreed-to planning cycle. The CLD partner planning team adds category 3 and 4 activities to the Government crewmember's work week, filling in the hours reserved for partner use.
7. The CLD partner planning team adds such information as equipment stowage notes and procedures for partner-provided equipment use to all Government crewmember activities.
8. NASA reviews the integrated timeline for the purposes of verification, insight, situation awareness, and identification of activities that may pose a risk to Government crewmembers, assets, or mission objectives.
9. The CLD partner planning team uplinks the crewmember activity schedules to the vehicle; the crewmembers access timeline and activity information using CLD partner-provided systems and applications.

A notional approach to Government activity planning (Government activities performed by commercial crewmember):

[32] E.g. studies, research, and utilization activities to be performed and payloads to be operated during the mission, along with vehicle system resources and constraints and partner-provided and common use equipment, tools, and supplies needed to perform each activity.

[33] E.g. preferences to exercise at a particular time of day, preference to perform exercise in a single session or to break it into separate sections, and meal scheduling preferences.

1. NASA communicates Government activity requirements[34] to the CLD partner well in advance of the mission.
    a. This ensures Government and partner-provided assets and supplies are approved for flight, manifested, launched, and deployed onboard in time for Government activity execution.
    b. This allows the CLD partner to identify and resolve resource conflicts and to develop advanced planning windows (e.g. target week) for the execution of each Government activity. Target activity execution windows are communicated to and negotiated with the NASA planning team and Government PIs.
    c. This ensures activities such as operator training, study participant screening, and resolution of liability concerns can be completed.
2. In the tactical timeframe, the commercial crewmember's activities are assumed to be planned on a weekly basis, several weeks in advance of execution. Deviations from pre-planned activity execution windows established in Step 1. are identified, negotiated, and resolved at this time.
3. The number of commercial crewmember hours reserved for Government use (execution of activities from category 1) for the week are refined and confirmed.
4. The NASA planning team provides activity details (e.g. operational procedure references, work location, supplies & resources needed, activity duration) for category 1 activities.
5. The CLD partner planning team looks across the integrated crew timeline, identifying and working with the NASA planning team to resolve workspace and resource conflicts.
6. The CLD partner planning team populates the commercial crewmember's work week.
7. The CLD partner planning team adds such information as equipment stowage notes and procedures for partner-provided equipment use to all Government activities.
8. NASA reviews the integrated timeline for the purposes of verification, insight, situation awareness, and identification of activities that may pose a risk to Government crewmembers, assets, or mission objectives.
9. The CLD partner planning team uplinks the crewmember activity schedules to the vehicle; the crewmembers access timeline and activity information using CLD partner-provided systems and applications.

*Integrated Crew On-orbit Activity Scheduling Best Practices*

It is recommended that the following best practices be considered when planning integrated (Government and non-Government) crew on-orbit activities:

- Time should be allocated at the start of the mission for adaptation to the weightless environment.
- Activity durations should be extended early in the mission while the crew becomes familiar with the vehicle, systems, and equipment.
- Crew cohesion can be negatively affected if crewmembers do not work a similar number of hours or are not similarly task loaded.
- Crew efficiency, health, and cohesion can be negatively affected by frequent or significant sleep-shifting or shift work.
- Crew cohesion can be negatively affected if crewmembers do not share housekeeping tasks.
- Crew cohesion can be positively affected by providing opportunities for shared meals, days off, and relaxation time.
- Morale and efficiency can be positively affected by providing maximum autonomy and flexibility to the crew, such as allowing them to self-schedule activities, re-order activities, or select activities from a "job jar."

[34] E.g. studies, research, and utilization activities to be performed and payloads to be operated during the mission, along with vehicle system resources and constraints and partner-provided and common use equipment, tools, and supplies needed to perform each activity.

**Government Crew Medical Authority and Operational Support**

NASA's intent to exercise medical authority for Government crewmembers participating in CLD missions is driven by the need for crew safety, continuity of care, NASA duty of care requirements for NASA astronauts, the safeguarding of private medical information, and the importance of biomedical data in informing NASA science around long duration, deep space exploration.

It is expected a set of medical selection standards and requirements will be developed and implemented by the Partner for all CLD astronauts and reviewed and approved by NASA as part of CLD certification. The partner is expected to develop processes to identify, communicate and mitigate risks to crew safety and mission success based upon the crew's ability to meet such standards. This process will enable the Partner to make final assessment on fitness of crews and the related risk to their station and commercial operations, and for NASA to assess risk to its crews and its mission from all crews resident on a CDFF while USG astronauts are inhabitants. In addition, the commercial partner must keep NASA informed on the other non-NASA crew members health status and stabilization efforts. For each CLD mission involving Government crewmembers, a NASA medical operations team comprised of NASA crew surgeons, behavioral health and performance (BHP) specialists and other clinical staff will be assigned and responsible for managing routine and contingency Government crewmember medical and behavioral care. A single team will likely support all Government crewmembers assigned to the same CLD mission. The medical operations team will be staffed from NASA's Human Health and Performance Directorate.

The NASA medical operation team's responsibility is expected to begin upon Government crewmember assignment to the CLD mission and to continue through crewmember post-flight reconditioning. The NASA crew surgeon is expected to have authority and responsibility to intervene during all phases of the mission in any situation that may affect Government crewmember health. While medical authority for Government crew members rests with the NASA crew surgeon, medical decision making with impacts to non-Government crewmembers or non-Government mission aspects is expected to be performed cooperatively between the NASA crew surgeon and the CLD partner's medical team.

The NASA crew surgeon expects to be familiar with all medical- and health-related systems and operational products used by the CLD partner and all training on such provided to the Government crewmember. This may require that the NASA crew surgeon has insight and training on select CLD partner systems and operational products. The NASA crew surgeon also expects to observe the Government crewmember's training events and to be provided with crew training materials for review. Further, the NASA crew surgeon is responsible for providing medical support to Government crewmembers during pre-flight hazardous training events.

The NASA crew surgeon expects to be physically present with the Government crewmember and has direct oversight of his/her health during pre-flight activities such as health stabilization (quarantine) and suit-up. The CLD partner is responsible for executing a health stabilization program (HSP) that meets the intent of NASA's HSP plan. This plan is expected to be applied for all crew that flies to the CLD and that will cohabitate with Government crew at any point during the mission. This includes but is not limited to selecting, outfitting, and maintaining HSP facilities and supplies, providing and training personnel to lead and manage the HSP, and developing infectious disease control processes and policies. The NASA crew surgeon expects to have insight into and support decision making regarding the management of infectious disease events during HSP that pose propagated risks to current or future Government crew on the CLD.

While the Government crewmember is on-orbit, the NASA crew surgeon maintains awareness of Government crewmember health and well-being through CLD partner-provided insight into vehicle and crew systems. In addition, the NASA crew surgeons and BHP specialists are expected to have direct and private communication with the Government crewmember. The crew may also need to regularly conference with strength, conditioning, and rehabilitation specialists (ASCR) to help manage plans and issues with their onboard exercise countermeasures, the prescriptions for which are developed by NASA specialists.

The NASA crew surgeon is assumed to work within the CLD partner's medical infrastructure, actively participating in all data reporting and real-time decisions affecting or regarding Government crewmember health. The NASA crew surgeon team may support flight operations from the CLD partner's flight control facility or from a remote location. The CLD partner's medical infrastructure must allow for regular exchange of health status information for all crew for the assessment of risk to crew and mission.

The CLD partner is expected to provide nominal, launch abort and contingency crew recovery and post-landing medical services including identifying facilities in case of a medical contingency. The NASA crew surgeon also expects to be physically present at the planned landing site and to attend to the Government crewmember following extraction from the crew transport vehicle. This presence is maintained during ground or air transport from the landing site to the post-mission rally point. NASA crew surgeon expects to perform medical examinations of the Government crewmember immediately upon recovery, with the assistance of CLD partner-provided field medical staff (e.g. flight nurses and field nurses) and using CLD partner-provided field medical facilities, equipment, and resources. In the event of an off-nominal landing where contingency medical needs exceed NASA crew surgeon's capabilities, or where it is not possible to deploy the NASA crew surgeon to the off-nominal landing site, it is assumed that the partner medical team will provide care for the Government crewmember.

The CLD partner is responsible for direct return of the Government crewmember to a NASA location for post-flight reconditioning. Government crewmember post-flight reconditioning is expected to be performed using NASA facilities by NASA medical personnel.

The CLD partner is expected to provide, maintain, and perform in-flight medical and behavioral support for the Government crewmember that is capable of addressing anticipated conditions and enables required occupational surveillance and health monitoring activities. This includes but is not limited to:

- Provision, flight control, and engineering support of onboard medical devices, equipment, and tools
- Provision, flight control, and engineering support of countermeasure devices, equipment, and tools (e.g. exercise equipment, nutritional supplements, health-related software applications)
- Monitoring, control, and reporting of onboard environmental conditions (e.g. noise levels, atmospheric constituent levels)
- Provision and maintenance of an onboard shared medical supplies and consumables (e.g. oxygen and water for medical use) for performing emergency, non-urgent, routine, and surveillance medical care
- Provision of, flight control, and engineering support of systems and capabilities that promote psychological well-being (e.g. recreational resources, contact with family and friends)

NASA is responsible for providing crew-specific medical resources and operations unique to its crewmembers or its mission.

**Decommissioning**

NASA does not intend to levy any CLD decommissioning requirements beyond those specified by the FAA and Federal Communications Commission (FCC). Decommissioning review entrance and exit criteria documented in NASA Procedural Requirements (NPR) 7123.1 may serve as a reference. It is NASA's expectation that the FAA, FCC or other government regulatory organization will be responsible for the decommissioning and disposal of the CLD.

Should the CLD partner choose to operate the CLD after cessation of Government crew involvement, continued NASA certification of the CLD would no longer be appropriate or necessary. Similarly, the CLD partner will be released from all contractual obligations following cessation of Government use of the CLD. Government involvement will cease after release of all contractual obligations.

# Appendix A: Acronyms

| | |
|---|---|
| ASCAN | Astronaut Candidate |
| BHP | Behavioral Health and Performance |
| CLD | Commercial Low-Earth Orbit Destination |
| CLDP | Commercial Low-Earth Orbit Development Program |
| CoFR | Certification of Flight Readiness |
| CRS | Commercial Resupply Services |
| DDT&E | Design, Development, Test and Evaluation |
| DRD | Data Requirement Deliverables |
| ECLSS | Environmental Control and Life Support System |
| EVA | Extravehicular Activity |
| FAA | Federal Aviation Administration |
| FCC | Federal Communications Commission |
| FCR | Flight Control Room |
| FCT | Flight Control Team |
| GFE | Government Furnished Equipment |
| GFW | Government Furnished Software |
| HSP | Health Stabilization Program |
| ICD | Interface Control Document |
| IRB | Institutional Review Board |
| ISS | International Space Station |
| JSC | Lyndon B. Johnson Space Center |
| LEO | Low-Earth Orbit |
| MMOD | Micrometeoroids and Orbital Debris |
| NASA | National Aeronautics and Space Administration |
| NPR | NASA Procedural Requirements |
| NTSB | National Transportation and Safety Board |
| PAA | Product Assurance Action |
| PAM | Private Astronaut Mission |
| PI | Principal Investigator |
| PL | Payload |
| RPOD | Rendezvous, Proximity Operations, and Docking |
| SOW | Statement(s) of Work |
| TA | Technical Authority |
| US | United States |
| VV | Visiting Vehicle |

# Appendix B: Definitions

| Term | Definition |
|---|---|
| (Government) Activity | Activities in direct support of Government mission objectives and performed on time allocated to the Government. These activities may be performed by Government or non-Government crewmembers Includes activities performed by Government-sponsored PIs. |
| (Government) Asset | Government-owned or Government-sponsored hardware, equipment, applications, and items. Examples include payloads (science equipment), logistics supplies, computer systems, software applications, technology demonstration systems (which may operate in a stand-alone capacity similar to a science payload, or may be integrated into the CLD vehicle system), etc. Government assets may be spaceborne or ground-based (e.g. training facilities, tools, etc.) |
| Cargo | Tangible goods transported to, from, or stored onboard a spaceflight vehicle. Examples include science payloads, live animals, consumable supplies (e.g. foodstuffs, clothing), tools, replacement parts, vehicle components and systems being transported but not yet actively operating as part of the vehicle, etc. |
| CLD Partner | Commercial owner/operator of the CLD and end-to-end mission. Responsible for designing, constructing, maintaining, and operating the CLD. Additionally responsible for providing various pre-flight, on-orbit, and post-flight services to the Government customer. The CLD partner may contract with third parties and/or utilize government furnished equipment, Government services, and/or Government expertise to fulfill their obligations. |
| Commercial Professional Crewmember | Crewmember employed by a commercial organization for the purpose of performing technical flight support duties such as serving as crew commander and performing vehicle maintenance & repair. |
| Crew Surgeon | Member of NASA's medical team, charged with medical authority over Government crewmembers. The crew surgeon position is typically staffed by a physician from NASA's Human Health and Performance Directorate, though responsibilities may be delegated. |
| Crew Support Officer | NASA person assigned to support the Government crewmember throughout pre-mission training, the on-orbit mission, and landing/recovery. The crew support officer position is typically staffed by a member of NASA's Flight Operations Directorate. Example duties include tracking and working to resolve crewmember questions and concerns, representing the crew at meetings and in discussions, and coordination with the crewmember's family. |
| Critical Events | Major milestone activities and high risk, technically complex, and/or tightly choreographed on-orbit operations such as RPOD, spacewalks, undocking, etc. for which programmatic confirmation of readiness and approval to proceed are required. |
| End-to-End Mission | The series of activities required to complete a mission, starting from identification of a flight opportunity, including pre-flight training, mission planning, transport vehicle launch, RPOD, on-orbit increment execution, transport vehicle landing and recovery, and concluding with post-flight activities such as crew debriefs. |
| Government | The United States Federal Government, Agency(ies), and organizations of the United States Federal Government. |
| Government Crewmember | Crewmember selected from NASA's astronaut corps, another NASA organization, or another US Government organization. |

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|---|---|
| Government-Sponsored | Payloads, studies, assets, crewmembers, etc. sponsored for flight by the US Government. |
| Mission | The period of time from launch through landing for a Government crewmember. Also referred to as an increment or flight. |
| Mishap | An unplanned event that results in at least one of the following:<br>1. Injury or illness to personnel caused by CLD operations<br>2. Damage to or destruction of public or private property caused by CLD operations<br>3. Mission failure before the scheduled completion of the planned primary mission. |
| (Government) Mission Objective | A mission activity sponsored by the Government and/or of importance to the Government. It defines the primary purpose and approach and is the focus of the mission. Successful completion of mission objectives is the primary factor in declaring mission success. Government utilization activities are considered mission objectives. |
| NASA International Partner | A foreign Government NASA partner, typically coordinated with through the foreign Government's federal space agency. |
| Non-Government Crewmember | All crewmembers other than Government crewmembers. May include CLD professional crewmembers, other commercial professional crewmembers, private crewmembers, or crewmembers from International Partner countries. |
| Outreach Activity | Utilization activities designed to promote (for example) goodwill, education, and public awareness. |
| Payload | is any equipment or material carried by the visiting vehicle or installed on the CLD that is not considered part of the basic visiting vehicle or CLD configuration |
| (Government) Principal Investigator | is the individual(s) a research organization designates as having an appropriate level of authority and responsibility for the proper conduct of the research, including the appropriate use of funds and administrative requirements such as the submission of scientific progress reports to the agency. |
| Private Crewmember | Crewmember other than Government crewmember or professional crewmember, typically participating in a single mission. |
| Study(ies) | Are scientific investigations using the scientific method to research a specific topic |
| Technical Authority | Is a part of NASA's system of checks and balances to provide independent oversight of programs and projects in support of safety and mission success through the selection of specific individuals with delegated levels of authority. |
| Technology Demonstration | A Government-owned or Government-sponsored payload that demonstrates, tests, or advances a technology's capability to operate in the spaceflight environment. The technology demonstration payload may be more complex than a typical, self-contained science payload and may require more complex services, operator support, or on rare occasions be integrated into the CLD vehicle's core system(s). An example is a regenerative environmental control and life support system. |
| Utilization | is the use of the destination platform and/or mission to conduct any use activity including science, research, development, test and evaluation, public outreach, education, and private commercialization efforts (e.g., Private Astronaut Mission [PAM]). Utilization is distinct and different from the carriers designed to sustain the mission and health of the crew (which include launch vehicles, transportation vehicles, orbital modules, and space suits). |