Scenario 12.0
Preliminary Draft

Mission Operations Summaries

07/13/09

Scenario 12 Updates

Resulting from Budget Direction and LSS ConOps Meeting at JSC (5/12-5/13)

Budget Direction:

- **HLR date moved to 2022**
- **Insertion of extra sortie before first cargo mission**
- **LRS deployment in time to support Lunabago mode in 2027 (assume first LRS deployed in 2025, second in 2026)**

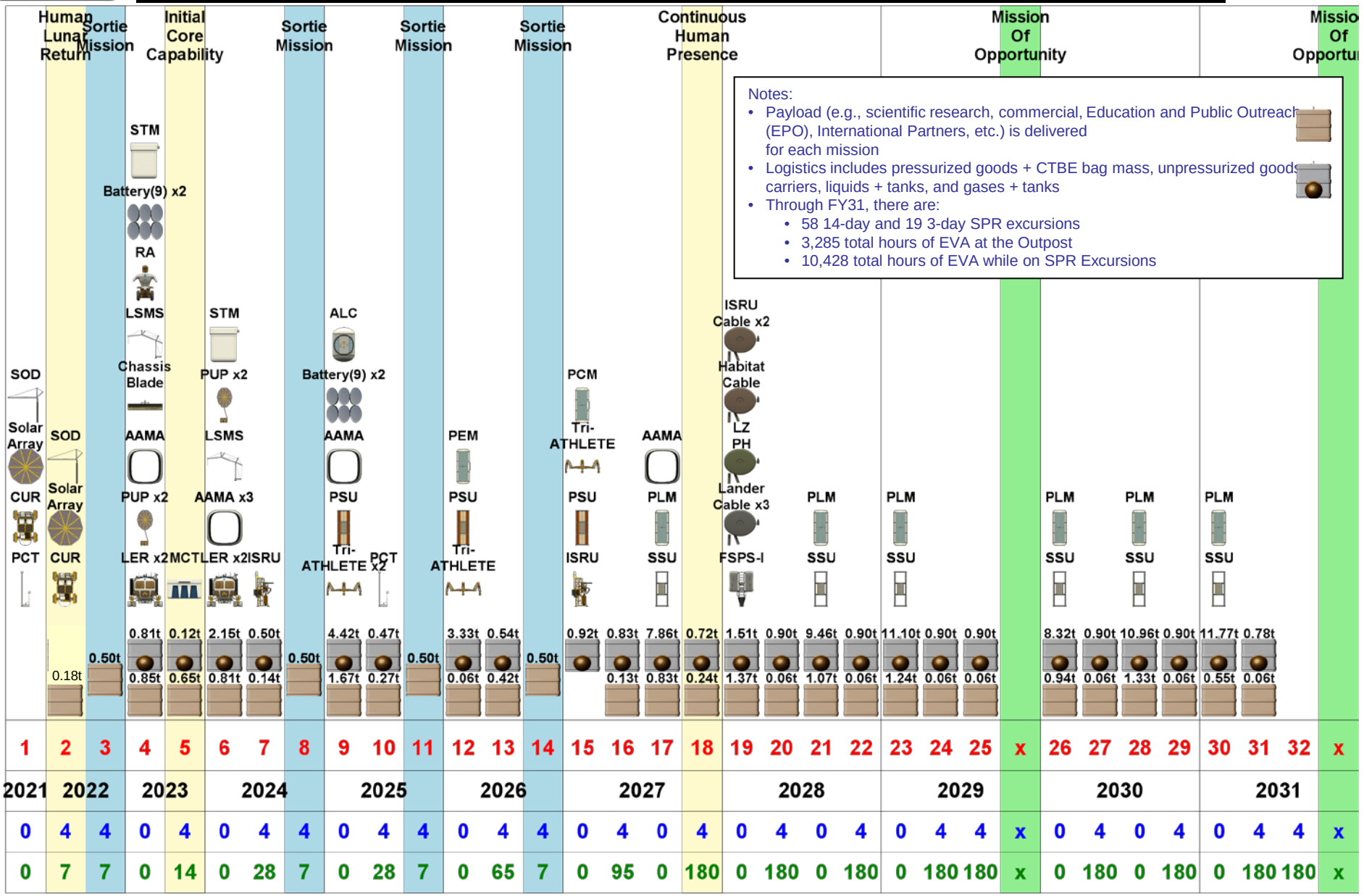
Element and Operations Changes:

- **Test mission and HLR mission land near potential outpost locations**
- **Unpressurized rover (Apollo+ class) can be ground-supervised or tele-operated (two years operational lifetime)**
- **Unpressurized rover, LER and PUP all have direct with Earth communications capability (compressed HD video minimum – "contribution quality" TBR)**
- **PUP has smaller array that can be receive half power (~1 of ~2 kW) while driving , a full set of LER batteries (~90 kW-hr) that can be swapped with LER, and the ability to be ganged together (water & power transfer)**
- **Refined ConOps for each cargo mission, crewed missions and the spans in-between**
- **Established tele-operated/monitored off-loading of cargo missions before arrival of crew**
- **Definition of 3 day LER excursion ConOps**
- **Definition of 14+ day LER ConOps (Malapert Mountain expedition)**
- **Definition of Lunabago ConOps (Schrodinger Crater – 1000 km roundtrip, 90 day excursion):**
  - 2 LERS, 4 PUPS, 2 PSUs, 2 sets of tri-ATHLETEs, PEM with suitlock/airlock and a PLM for logistics

Updates From PTR

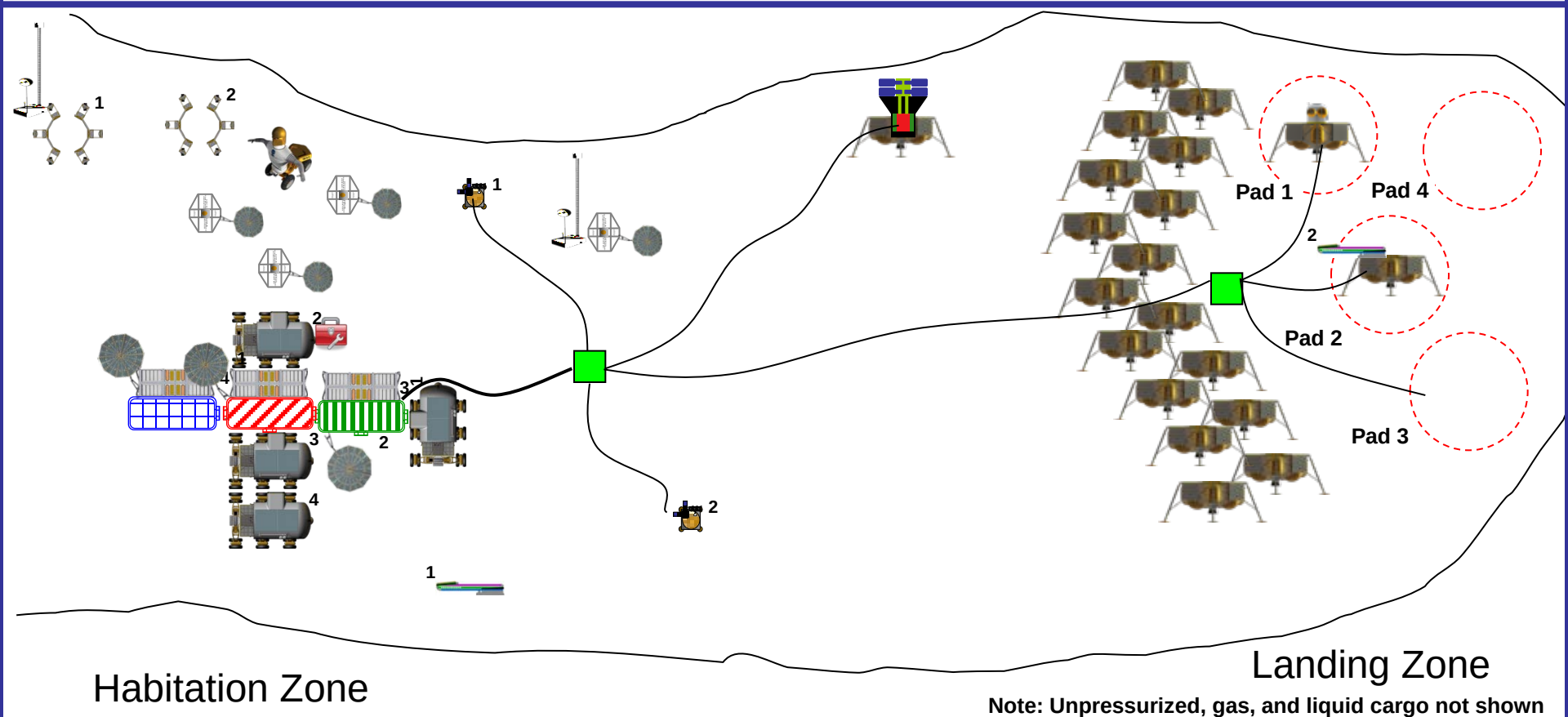
- **ACR put back on Mission 1 (test mission)**
- **1 kW modified PUP arrays and a small off-loading device (SOD) added to missions 1 and 2**
  - Combined with ACR and PCT on Mission 1, this reduces the payload capability on mission 1 to 36 kg.
- **Second STM delivered on Mission 6**
- **3 AAMAs delivered on Mission 6**
  - One LER is delivered with two AAMAs and then transfers one to the LER from Mission 4 that was not delivered with an AAMA
- **One of the AAMAs from Mission 9 was moved to Mission 17**
  - One AAMA is delivered on Mission 9 for use on the ALC and then as the connection between the PEM and PCM
  - The final AAMA is now delivered on the first PLM
- **PSU and Hab masses were updated**
- **Mission 13 surface stay was increased from 55 to 65 days**
- **Mission 16 surface stay was increased from 90 to 95 days**

Scenario 12.0.1 – 062309



- Crew Size # - Surface Duration # - Mission Number

Scenario 12.0.1 Outpost Site Plan as of Mission 20 (180 days)



Note: Unpressurized, gas, and liquid cargo not shown

- Lunar Lander (LL) with Ascent Module
- Lunar Lander (LL) – Descent Module
- Tri-ATHLETE x2
- Fission Surface Power System (FSPS)
- Small Press Rover (SPR)
- Mobility Chassis Toolkit (MCT)
- Chassis Driving Kit (CDK)
- Pressurized Core Module (PCM)
- Pressurized Excursion Module (PEM)
- Pressurized Logistics Module (PLM)
- Power & Support Unit (PSU)
- Portable Utility Pallet (PUP)
- Robotic Assistant (RA)
- Off-loading Device (OD)
- ISRU Oxygen Production System (OPS)
- Portable Communications Terminal (PCT)

Mission 1: Altair 1 Test Flight (Uncrewed Test Mission)
May 2021

Objective

Perform first (and only) flight test mission of the lunar lander and the second flight test mission of the transportation system.

Pre-deploy a Capable Unpressurized Rover (CUR) and (Portable Communications Terminal) PCT to support HLR, initiate site survey, and begin surface capability validation.

Type: Altair Sortie Configuration
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew

-

Mobility

- Deliver unpressurized crew rover (two year life)
- Ground-supervised survey activities

Science

- **Science limited by lander capability**

Communications

- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- PCT location is TBD
- Rover & lander must be able to communicate with each other and with Earth. (Contribution quality)

Power

- 1 kW (TBR) keep-alive power to support comm, science, and rover recharge (power generation and energy storage split between rover and lander is TBD)

Other

- Off-loading device for rover
- There is a certain level of autonomy and operation

Concept of Operations

1-1) The test lander will touch down at a landing site near the potential outpost locations

1-2) After uncrewed touchdown, the ascent module is launched as soon as possible, within 24 hours of touchdown; nominally, ascent module launched after 4 hours on surface. Assets must be protected/survive during Ascent Module launch.

1-3) Video ascent (engine firing, plume effects, blast ejecta, etc)

1-4) Other Altair flight systems are tested as needed

1-5) Activate small solar array

1-6) Deploy/activate PCT and re-establish communications

1-7) Off-load rover with PCT and small solar array attached with the Small Off-loading Device (SOD)

1-8) Activate rover

1-9) Test rover recharge station at base of lander (maybe dummy connection)

1-10) Activate science packages on rover if needed

Span 1: Preparation for Human Lunar Return (HLR)
May 2021 to November 2021

Objective

Perform site survey, validate potential outpost locations within a 10 km range (TBR), validate lighting and terrain models, identify science opportunities

Identify HLR landing zone and emplace navigation beacons

Provide capability to capture HLR on live video

Type: Ground-supervised/robotic activities

Assumptions

Crew

•

Mobility

• Ground-supervised operations

Science

• Site survey and surface property characterization

Communications

• No LRS available until 2025
• PCT enables contribution quality (TBR) video DWE
• PCT location is TBD
• Rover and Descent Module comm capability direct with Earth splits are TBD.

Power

• 1 kW (TBR) keep-alive power to support comm, science, and rover recharge (power generation and energy storage split between rover and lander is TBD)

Other

• TBD data storage on the rover and lander

Concept of Operations

1-11) Inspect local area after ascent to validate ejecta models and get video of Altair hardware

1-12) Execute survey pattern that will encompass light and terrain data

1-13) Perform additional surveys as needed and deploy navigation beacons when acceptable HLR site is found.

1-14) Park rover during eclipses as they occur

1-15) Continue extended survey activities and perform secondary science and engineering exercises

1-16) Position for videoing HLR

Mission 2: Human Lunar Return (HLR) Crewed Sortie
November 2021

Objective

First crewed mission to the lunar surface. The sortie mission will deliver a CUR to aid crew in science, exploration, and site scouting.

Type: Sortie Mission
No. of Crew: 4
Crewed Duration : 7 Days

Assumptions

Crew
- No less than 4 days of EVA (with use of airlock)
- Ground-supervised rovers on rest days

Mobility
- Deliver unpressurized crew rover (two year life)
- Tele-operated by crew and ground

Science
- Rover is part of 500 kg EARD Payload

Communications
- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Rovers & lander must be able to communicate with each other and with Earth
- Rover and Descent Module comm capability direct with Earth splits are TBD.

Power
- 1 kW (TBR) keep-alive power to support comm, science, and rover recharge
- Rover and Descent Module power and recharge capability splits are TBD.

Other
- Off-loading device for rover
- There is a certain level of autonomy and operation

Concept of Operations

2-1) During landing, the lander is guided to the designated landing site in an automated fashion, using deployed beacons, with crew override capability as a contingency.

2-2) The crew will live in the Ascent Module and use the airlock to access the surface.

2-3) Systems Prep
- Crew checks out suits
- Crew checks out Altair systems
- Off-load the rover and PCT with the SOD and begin check out

2-4) Engineering Validation
- Crew will inspect the unpressurized rover, PCT, solar array, and Descent Module from Mission 1
- Crew comm and control of tele-ops of rovers

2-5) Prepare for Future Activity
- Crew will validate outpost locations
- Crew will validate landing zone and nav beacon locations

2-6) Science
- Crew deploys and activates science payloads
- Crew conducts geologic traverses and sampling to targets of scientific interest
- Crew preps samples for return

Span 2 & 3: Scouting of Outpost Area
November 2021 to November 2022

Objective

Extended science activities and reconnaissance

Type: Ground-supervised/robotic activities

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Site survey and surface property characterization

Communications
- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Both rover and Descent Module have comm capability with Earth
- Rover and Descent Module comm capability direct with Earth splits are TBD.

Power
- Both rover and Descent Module have power and recharge capability
- Rover and Descent Module power and recharge capability splits are TBD.

Other
- TBD data storage on the rover and lander

Concept of Operations

2-7) Park rovers during eclipses as they occur

2-8) Continue extended survey activities and perform secondary science and engineering exercises

2-9) Position for videoing for next mission

Mission 3: First Science Sortie
April 2022

Objective

Visit Aristarchus region, deploy ground-supervised unpressurized crew rover with a 1 kW solar array, perform extended science. In the absence of crew, the rover will continue to perform exploration and science under ground supervision for remaining life of the rover

Type: Sortie Mission
No. of Crew: 4 or less*
Crewed Duration : 7 or less days*
* depending on access requirements

Assumptions

Crew
- Up to 4 days of EVA (with use of airlock)
- Ground-supervise rover on rest days

Mobility
- Deliver unpressurized crew rover (two year life)
- Tele-operated by crew and ground

Science
- Rover is part of 500 kg EARD payload

Communications
- No LRS available until 2025
- Rover & lander must be able to communicate with each other and with Earth

Power
- Rover must be capable of surviving longer eclipse durations

Other
- Off-loading device for rover
- There is a certain level of autonomy and operation

Concept of Operations

3-1) Explore complex lunar volcanic/crater/plateau region, document and gather rock samples representing exposed and underlying rock formations for petrological analysis and age dating

3-2) The crew will live in the Ascent Module and use the airlock to access the surface.

3-3) Systems Prep
- Crew checks out suits
- Crew checks out Altair systems
- Rover unloaded and checked out

3-4) Prepare for Future Activity
- Crew comm and control of tele-ops of rovers

3-5) Science
- Crew deploys and activates science payloads
- Crew conducts geologic traverses and sampling to targets of scientific interest
- Crew preps samples for return

3-6) Rover operates ground-supervised for 2 year lifetime assuming sufficient energy storage and power generation is manifested. (No span operations documented)

Mission 4: Cargo for Initial Core Capability
November 2022

Objective

Two LERs, each with a Portable Utility Pallet (PUP), are delivered along with other surface support equipment including a Chassis Blade, Off-loading device (OD), Robotic Assistant (RA), an Active-Active Mating Adapter (AAMA) and a Suit-port Transfer Module (STM).

Type: Uncrewed Mission
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Initial astrophysics package operated to characterize observational environment

Communications
- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Lander, LERs, PUPs all have DWE comm capability

Power
- Redundant power generation and energy storage is available during all stages of off-loading
- All assets are quiescent during eclipse
- PUPs are delivered with a full compliment of batteries

Other
- TBD data storage on the rover and lander
- Active-Active Mating Adapter already attached to one of the LERs
- The chassis blade may be pre-fabricated or site fabricated (currently pre-fabricated and manifested)

Concept of Operations

4-1) During landing, the cargo lander is guided to the landing zone in an automated fashion using pre-emplaced navigation aids.

4-2) One PUP solar array is deployed to provide a power source for communications and battery recharging as well as keep-alive power to all elements on the lander deck. This must occur in first seven days.

4-3) Scavenged water produced by the lander fuel cells is transferred directly into both LER waterwalls. (Assumed Altair is equipped to support water scavenging.)

4-4) Under ground supervision, the off-loading device off-loads the LER with the stowed PUP which is then deployed once on the surface.

4-5) Once power on the surface has been confirmed, the off-loading device offloads the other LER and the Robotic Assistant as well as any other cargo as needed.

4-6) Astrophysics package is deployed to test observational environment.

Span 4: Preparation for Initial Core Capability (ICC)
November 2022 to February 2023

Objective

Test and prepare assets for Mission 5

Type: Ground-supervised/robotic activities

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Robotic Assistant available to support science as needed

Communications
- No LRS available until 2025
- PCT enables contribution quality video (TBR) DWE
- Lander, LERs, PUPs all have DWE comm capability

Power
- All assets are quiescent during eclipse
- No power to lander after off-loading is completed

Other
- TBD data storage on the rover and lander

Concept of Operations

4-7) LERs go through an extended check out process, and continually report their health
- Test integrated comm infrastructure across all assets

4-8) Park rovers during eclipses as they occur

4-9) Under ground supervision, the LER fitted with the Chassis Blade begins to prepare the landing zone for the next mission and the habitation zone for the Mission 5 cargo lander, while the other LER performs further scouting.

4-10) Robotic Assistant validates maintenance techniques beginning with the unpressurized rovers

4-11) Continue extended survey activities and perform secondary science and engineering exercises

4-12) Robotic Assistant scavenges select assets from Altair Descent Modules (1 and 2)

4-13) Use robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA will also perform maintenance tasks as needed.

4-14) Position all assets to support Mission 5

Mission 5: Crewed Mission Initial Core Capability – 14 Days in LERs - February 2023

Objective

A crew of 4 performs a 14 day surface stay operating out of the LERs. The MC Toolkit is also delivered.

Type: Outpost Mission (no airlock)
No. of Crew: 4
Crewed Duration: 14 days

Assumptions

Crew

- The crew lives out of the LERs for the duration mission

Mobility

- A mix of crew-driving, tele-robotic, and ground-supervised operations
- LERs function without PUPs on 3-day excursions

Science

- Extensive preplanning of science activities occurs before the mission with identified secondary opportunities

Communications

- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Lander, LERs, PUPs all have DWE comm capability

Power

- Two PUPs are the primary power supply along with LER batteries

Other

Concept of Operations

5-1) Day 1:

- The lander touches down on a prepared pad inside the landing zone.
- The LER, under ground control, connects the PUP to the lander for water scavenging and to provide redundant keep-alive power for the Ascent Module (lander fuel cells are assumed to provide nominal keep-alive power for 14 days)
- The crew depressurizes the ascent module, climbs down the ladder and enters LERs through the suit port
- Robotic Assistant stays near a PUP

5-2) Day 2 & 3:

- .Crew does extensive checkout of LER systems
- Crew performs planned maintenance on LER, detach chassis blade from the LER and leave on the surface connected to a PUP
- Off-load the MC Toolkit & any other cargo that needs to be off-loaded
- The crew inspects ground-supervised site preparations
- As PUPs fill up with water, swap the PUPs connected to lander, perform fluid transfer.
- Drive to old landers and salvage parts

5-3) Days 4 & 5:

- The crew performs science and exploration tasks
- Science payloads are deployed and activated as required
- One day, dual-rover excursion, returning to the lander at the end of day 5.

Need detailed water, logistics, power, comm DWE availability, and crew time balance

Mission 5: Crewed Mission – 14 Days in LERs (cont)
February 2023

Concept of Operations

5-4) Day 6 (Excursion Prep):
- PUP battery swap and LER battery charging complete
- Inspect and repair the rovers
- Inspect and repair the EVA suits

5-5) Days 7 through 9:
- Three-day excursion, no further than 25 km (TBR) radial distance from the lander visiting scientific sites
- Plan path to allow continuous communications with each other and Earth as well as remaining in daylight

5-6) Day 10 (Excursion Recovery):
- Inspect the rovers and recharge/swap out batteries
- Inspect and repair the EVA suits

5-7) Day 11 through 13:
- Perform required LER maintenance and reattach chassis blade
- Pack and grade geological samples
- Follow up on local science
- Start Ascent Module checkout

5-8) Day 14:
- Move the PUPs and Robotic Assistant to safe location
- Return to the lander
- Get in suits, load any remaining items, and get in lander
- LERs move to a safe location under ground control
- Ascent Module departs

Span 5: Continue Mobility Checkout and Outpost Prep
February 2023 to October 2023

Objective

Test and prepare assets for Mission 6

Type: Ground-supervised/robotic activities

Assumptions

Crew

-

Mobility

- Ground-supervised operations

Science

- Robotic Assistant available to support science as needed

Communications

- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Lander, LERs, PUPs all have DWE comm capability

Power

- All assets are quiescent during eclipse

Other

- TBD data storage on the rover and lander

Concept of Operations

5-9) LERs go through an extended check out process, and continually report their health

5-10) Park rovers during eclipses as they occur

5-11) Under ground supervision the LER fitted with the Chassis Blade begins to prepare the 2nd landing pad for the next mission and finish the habitation zone for the Mission 6 cargo lander.

- Start recon of routes and areas of interest
- Improve path in and out of landing site for future outpost infrastructure

5-12) Continue extended survey activities and perform secondary science and engineering exercises

5-13) Robotic Assistant scavenges select assets from Altair Descent Modules (4 and 5)

5-14) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA will also perform maintenance tasks as needed.

5-15) Position all assets to support Mission 6

Mission 6: Additional Mobility Delivery
October 2023

Objective

Two LERs, each with a Portable Utility Pallet (PUP), are delivered along with other surface support equipment, Off-loading Device, and three Active-Active Mating Adapters), and an STM.

Type: Uncrewed Mission
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Initial heliophysics package operated to characterize observational and radiation environment

Communications
- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Lander, LERs, PUPs all have DWE comm capability
- PUPs placed strategically to take advantage of local terrain

Power
- Redundant power generation is available during all stages of off-loading (no additional batteries manifested on PUPs)
- All assets are quiescent during eclipse

Other
- Active-Active Mating Adapter already attached to one of the LERs

Concept of Operations

6-1) During landing, the cargo lander is guided to the landing zone in an automated fashion using pre-emplaced navigation aids.

6-2) One PUP solar array is deployed to provide a power source for communications and keep-alive and battery recharging on the lander deck. This must occur in first seven days.

6-3) Scavenged water produced by the lander fuel cells is transferred directly into both LER waterwalls. (Assumed Altair is equipped to support water scavenging.)

6-4) The OD, under ground-supervision, off-loads the LER with the stowed PUP which is then deployed once on the surface.

6-5) Once power on the surface has been confirmed, the OD off-loads the other LER as well as any other cargo as needed.

6-6) Heliophysics package is deployed to test observational and radiation environment.

Opportunities for using pre-emplaced LERs to monitor off-loading should be considered.

Span 6: Outpost Preparation
October 2023 to December 2023

Objective

Test and prepare assets for Mission 7

Type: Ground-supervised/robotic activities

Assumptions

Crew

-

Mobility

- Ground-supervised operations

Science

- Robotic Assistant available to support science as needed

Communications

- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Lander, LERs, PUPs all have DWE comm capability

Power

- All assets are quiescent during eclipse
- No power to lander after off-loading is completed

Other

- TBD data storage on the rover and lander

Concept of Operations

6-7) New LERs go through an extended check out process, and periodically report their health

- Test integrated comm infrastructure across all assets
- The LER with 2 AAMA's transfers one of them to the LER from Mission 4 that didn't have one.

6-8) Park rovers during eclipses as they occur

6-9) Under ground-supervision, the LER fitted with the Chassis Blade begins to prepare the 3rd landing pad for the next mission and finish the habitation zone for the Mission 7 cargo lander.

Start recon of routes and areas of interest

- Improve path in and out of landing site for future outpost infrastructure
- Create feed piles for ISRU OPS Plant

6-10) Continue extended survey activities and perform secondary science and engineering exercises

6-11) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

6-12) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also perform maintenance tasks.

6-13) Position all assets to support Mission 7

Mission 7: Crewed Mission – 28 Days in LERs
December 2023

Objective

A crew of 4 performs a 28 day surface stay operating out of the LERs. The first ISRU OPS Plant is delivered.

14 day excursion to Malapert Mountain

Type: Outpost Mission
No. of Crew: 4
Crewed Duration: 28 days

Assumptions

Crew

- The crew lives out of the LERs for the duration mission

Mobility

- A mix of crew-driving, tele-robotic and ground-supervised operations
- LERs may function without PUPs on 3-day excursions

Science

- Extensive preplanning of science activities occurs before the mission with identified secondary opportunities

Communications

- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Lander, LERs, PUPs all have DWE comm capability

Power

- Four PUPs are the primary power supply along with LER batteries and two full PUP battery packs

Other

Concept of Operations

7-1) Day 1:

- The lander touches down on a prepared pad inside the landing zone.
- An LER, under ground supervision, connects the PUP to the lander for water scavenging and to provide redundant keep-alive power for the Ascent Module
- The crew depressurizes the ascent module, climbs down the ladder and enters LERs through the suit port
- Robotic Assistant stays near a PUP

7-2) Day 2 & 3:

- .Crew does extensive checkout of all LER systems
- Crew performs planned maintenance on LER, detach chassis blade from LER and connect to PUP
- Off-load the ISRU OPS Plant & any other cargo that needs to be off-loaded
- The crew inspects ground-supervised site preparations
- Manage PUPs to extract as much water as possible before the excursion begins on day seven. Fill one PUP completely by day three, fill two more PUPs by day six
- Distribute logistics across the four LERs and four PUPs
- Start loading one LER with logistics for excursion

7-3) Day 4:

- Logistics LER with an AAMA picks up a PUP (with energy storage TBD) and is driven by ground control, begins it's trip to excursion waypoint
- Science payloads are deployed and activated as required
- Crew does one day, dual-rover excursions using new rovers, returning to the lander at the end of day
- Get ISRU OPS Plant up and running
    - Connect to PUP/lander for power using Robotic Assistant, position next to feed pile, and activate

Mission 7: Crewed Mission – 28 Days in LERs (cont)
December 2023

Concept of Operations

7-4) Day 5:

- Crew does one day, dual-rover excursions using new rovers, returning to the lander at the end of day
- Troubleshoot ISRU OPS Plant with power from Altair fuel cells
- Begin off-loading rocks for storage in rock garden

7-5) Day 6 & 7 (Excursion Prep):

- PUP swap and LER battery charging complete
- Rover inspect and repair
- Suit inspect and repair
- Finish troubleshooting and place ISRU OPS Plant in standby mode
- Off-load the rest the of rocks for storage in rock garden

7-6) Days 8 & 9:

- Two LERs with two crew, two PUPs, a PCT, and an AAMA start drive to Malapert Mountain, meet up with the logistics LER at end of day eight, transfer logistics as needed
- Plan path to allow continuous communications between LERs (not necessarily Earth) as well as remaining in daylight
- Identify science sites to explore on the return trip

7-7) Days 10 & 11 (Excursion Recovery):

- Complete drive to Malapert Mountain
- Establish camp in appropriate location
- Deploy and set up PUPs
- Identify science sites to explore on the return trip

7-8) Days 12 through 15:

- Perform science activities in Malapert region and return to PUPs as needed (no longer than 3 days away)

Need detailed water, logistics, power, comm DWE availability, and crew time balance

Mission 7: Crewed Mission – 28 Days in LERs (cont)
December 2023

Concept of Operations

7-9) Days 16 through 21:

- Drive back to lander location, doing science along the way
- Meet up with logistics LER on day 20, transfer logistics as needed
- Logistics LER follows other LERs supervised by ground control

7-10) Day 22 & 23:

- Inspect the rovers, recharge/swap out batteries
- Inspect and repair suits

7-11) Day 24 through 27:

- Perform required LER maintenance, reattach chassis blade
- Move two LERs, three PUPs, Robotic Assistant, and ISRU OPS Plant to outpost location
- Set up ISRU OPS for ground-supervised operations
- Pack and grade the samples
- Follow up on local science
- Start Ascent Module checkout
- Prepare outpost location for future missions

7-12) Day 28:

- Plug LER into PUP that is already plugged into lander
- Get in suits, load any remaining items, and get in lander
- Last two LERs move to a safe location under ground control
- Ascent Module departs

Need detailed water, logistics, power, comm DWE availability, and crew time balance

Spans 7 & 8: Preparation Habitation Systems
December 2023 to October 2024

Objective

Start ISRU OPS production
Prepare for permanent outpost elements

Type: Ground-supervised/robotic activities

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Robotic Assistant available to support science as needed

Communications
- No LRS available until 2025
- PCT enables contribution quality (TBR) video DWE
- Lander, LERs, PUPs all have DWE comm capability

Power
- All assets are quiescent during eclipse

Other
- TBD data storage on the rover and lander

Concept of Operations

7-13) Park rovers during eclipses as they occur

7-14) Under ground supervision, the LER fitted with the Chassis Blade begins to prepare the 4th landing pad for Mission 9

- Continue recon of routes and areas of interest
- Improve path in and out of landing site for future outpost infrastructure
- Prepare 4th landing pad for Mission 9

7-15) Continue extended survey activities and perform secondary science and engineering exercises

7-16) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

7-17) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

7-18) Position all assets to support Mission 9

Mission 8: Second Science Sortie
March 2024

Objective

Visit science site of interest, deploy ground-supervised unpressurized crew rover with a 1 kW solar array, perform extended science. In the absence of crew, the rover will continue to perform exploration and science under ground supervision for remaining life of the rover.

Type: Sortie Mission
No. of Crew: 4 or less*
Crewed Duration : 7 or less days*
* depending on access requirements

Assumptions

Crew
- Up to 4 days of EVA (with use of airlock)
- Tele-operates rover on rest days

Mobility
- Deliver unpressurized crew rover (two year life)
- Tele-operated by crew and ground

Science
- Rover is part of 500 kg EARD payload

Communications
- No LRS available until 2025
- Rover & lander must be able to communicate with each other and with Earth

Power
- Rover must be capable of surviving longer eclipse durations

Other
- Off-loading device for rover
- There is a certain level of autonomy and operation

Concept of Operations

8-1) Explore region performing extended science

8-2) The crew will live in the Ascent Module and use the airlock to access the surface.

8-3) Systems Prep
- Crew checks out suits
- Crew checks out Altair systems
- Unload the Rover and perform checked out

8-4) Prepare for Future Activity
- Crew comm and control of tele-ops of rovers

8-5) Science
- Crew deploys and activates science payloads
- Crew conducts geologic traverses and sampling to targets of scientific interest
- Crew preps samples for return

8-6) Rover operates ground-supervised for 2 year lifetime assuming sufficient energy storage and power generation is manifested. (No span operations documented)

Mission 9: ALC, PSU, and ATHLETE Delivery
October 2024

Objective

Delivery of an ALC and PSU provides power and logistics for future crewed missions

Deploy assets and positioned before crew arrives.

Type: Uncrewed Mission
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
-

Communications
- **One LRS is now available**
- Lander, LERs, PUPs all have DWE comm capability
- PCT enables contribution quality (TBR) video DWE

Power
- Batteries on the ATHLETES and PSU RFCs are already charged and sufficient for the tasks

Other
- Active-Active Mating Adapter is already attached to PEM

Concept of Operations

9-1) During landing, the cargo lander is guided to a prepared pad inside the landing zone in an automated fashion using pre-emplaced navigation aids.

9-2) The lander is connected to PUP elements to scavenge any remaining water and to provide redundant keep-alive power for delivered surface elements.

9-3) Under ground supervision, the Tri-ATHLETEs offload the ALC/PSU

- PSU is providing power for Tri-ATHLETEs
- Tri-ATHLETEs power up and go through static checkout
- Tri-ATHLETEs ankles are freed and limbs are tested
- Two LERs drive over and position for camera work
- Tri-ATHLETEs/PSU releases latches from lander deck
- Tri-ATHLETEs step off with ALC/PSU
- ATHLETE/ALC/PSU moves to the habitation zone
- The ATHLETE detaches from the ALC/PSU after emplacement on the surface

9-4) The PSU is deployed to provide power generation and energy storage to the habitation zone.

9-5) The Robotic Assistant pulls the PUP batteries from the PSU and places them in the PUPs.

Span 9: Initial ATHLETE Operations
October 2024 to November 2024

Objective

ALC and ATHLETE checkout
Landing Pad clearing and improvements performed by ATHLETE

Prepare for permanent outpost elements
Type: Ground-supervised/robotic activities

Assumptions

Crew

-

Mobility

- Ground-supervised operations

Science

- Robotic Assistant available to support science as needed

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCT enables contribution quality (TBR) video DWE
- One LRS available

Power

- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other

- TBD data storage on the rover and lander

Concept of Operations

9-6) Park rovers during eclipses as they occur

9-7) Perform full checkout of the ALC

9-8) The LERs will continue to assist in exploration and outpost science and maintenance tasks.

9-9) Continue extended survey activities and perform secondary science and engineering exercises

9-10) ATHLETE clears the spent Descent Modules from the landing pads completes landing zone improvements

9-11) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

9-12) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 10: Crewed Mission
November 2024

Objective

The crew will finish checkout of the ALC and transfer logistics to the LERs. The crew will also oversee the offloading and set up of the second PCT. After outpost operations are complete the crew will perform 3+ day excursions.

Type: Outpost Mission
No. of Crew: 4
Crewed Duration: 28 days

Assumptions

Crew
- The crew lives out of the LERs with logistics resupply from the ALC for the duration mission

Mobility
- A mix of crew-driving, tele-robotic, and ground-supervised operations
- LERs function without PUPs on 3-day excursions

Science
- Extensive preplanning of science activities occurs before the mission with identified secondary opportunities

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- One LRS available

Power
- PSU provides 720 kW-hr of energy storage with RFCs and 14.5 kW of power generation with solar arrays
- Four PUPs also power supply along with LER batteries

Other

Concept of Operations

10-1) The lander touches down on a prepared pad inside the landing zone. The lander is connected to a PUP for water scavenging and to provide redundant keep-alive power for the Ascent Module (lander fuel cells are assumed to provide nominal keep-alive power for 14 days).

10-2) The crew lives out of the LERs with logistics resupply from the ALC for the duration mission. The LERs are utilized for surface excursions.

10-3) The crew oversees the offloading of the PCT using the OD and deploys it. The crew offloads logistic payloads as required.

10-4) PUP elements are swapped as necessary to extract available water from the lander.

10-5) The crew oversees the ATHLETE removing any spent landers from their landing pads and their placement at a TBD location.

10-6) The crew performs science and exploration tasks. Science payloads are deployed and activated as required.

10-7) The crew also inspects and maintains all surface elements.

Span 10&11: Uncrewed Outpost Operations and Exploration – November 2024 to October 2025

Objective

Prepare for delivery of future outpost elements

Type: Ground-supervised/robotic activities

Assumptions

Crew

-

Mobility

- Ground-supervised operations

Science

- Robotic Assistant available to support science as needed

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality video (TBR) DWE
- One LRS available

Power

- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other

- TBD data storage on the rover and lander

Concept of Operations

10-8) Park rovers during eclipses as they occur

10-9) The LERs will continue to assist in exploration and outpost science and maintenance tasks.

10-10) Continue extended survey activities and perform secondary science and engineering exercises

10-11) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

10-12) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 11: Third Science Sortie
March 2025

Objective

Visit science site of interest, deploy ground-supervised unpressurized crew rover with a 1 kW solar array, perform extended science. In the absence of crew, the rover will continue to perform exploration and science under ground supervision for remaining life of the rover

Type: Sortie Mission
No. of Crew: 4*
Crewed Duration : 7 or less days*
* depending on access requirements

Assumptions

Crew
- Up to 4 days of EVA (with use of airlock)
- Tele-operates rover on rest days

Mobility
- Deliver unpressurized crew rover (two year life)
- Tele-operated by crew and ground

Science
- Rover is part of 500 kg EARD payload

Communications
- Rover & lander must be able to communicate with each other and with Earth
- One LRS available

Power
- Rover must be capable of surviving longer eclipse durations

Other
- Off-loading Device for rover
- There is a certain level of autonomy and operation

Concept of Operations

11-1) Explore region performing extended science

11-2) The crew will live in the Ascent Module and use the airlock to access the surface.

11-3) Systems Prep
- Crew checks out suits
- Crew checks out Altair systems
- Rover unloaded and checked out

11-4) Prepare for Future Activity
- Crew comm and control of tele-ops of rovers

11-5) Science
- Crew deploys and activates science payloads
- Crew conducts geologic traverses and sampling to targets of scientific interest
- Crew preps samples for return

11-6) Rover operates ground-supervised for 2 year lifetime assuming sufficient energy storage and power generation is manifested. (No span operations documented)

Mission 12: PEM/PSU and Tri-ATHLETE Delivery
October 2025

Objective

Delivery of (Pressurized Excursion Module) PEM/PSU allows for the missions to be extended beyond 28 days and excursions beyond 14 days.

Deploy assets and positioned before crew arrives.

Type: Uncrewed Mission
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew
-

Mobility
- Ground-supervised operations
- The tri-ATHLETE is preinstalled on the PEM

Science
-

Communications
- **Two LRSs are now available**
- Lander, LERs, PUPs all have DWE comm capability
- PCT enables contribution quality (TBR) video DWE

Power
- Batteries on the ATHLETES and PSU RFCs are already charged and sufficient for the tasks

Other
- Active-Active Mating Adapter is already attached to PEM

Concept of Operations

12-1) During landing, the cargo lander is guided to a prepared pad inside the landing zone in an automated fashion using pre-emplaced navigation aids.

12-2) Scavenged water produced by the lander fuel cells is transferred to the PSU scavenge tank or directly into the PEM waterwall. (Assumed Altair is equipped to support water scavenging.)

12-3) Under ground supervision, the Tri-ATHLETEs offload the PEM/PSU

- One of the previously delivered Tri-ATHLETEs docks to the unoccupied side of the PSU
- PSU is providing power for Tri-ATHLETEs
- Delivered Tri-ATHLETEs power up and go through static checkout
- Delivered Tri-ATHLETEs ankles are freed and limbs are tested
- Two LERs drive over and position for camera work
- Tri-ATHLETEs/PSU releases latches from lander deck
- Tri-ATHLETEs step off with PEM/PSU
- ATHLETE/PEM/PSU moves to the habitation zone
- The ATHLETE detaches from the PEM/PSU after emplacement on the surface
- The AAMA on the ALC is transferred to the PEM for use on excursions and docking to the PCM

12-4) The PSU is deployed to provide power generation and energy storage to the habitation zone.

Span 12: Initial PEM and ATHLETE Operations
October 2025 to November 2025

Objective

PEM and ATHLETE checkout
Landing Pad clearing and improvements performed by ATHLETE

Prepare for permanent outpost elements
Type: Ground-supervised/robotic activities

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Robotic Assistant available to support science as needed

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCT enables contribution quality (TBR) video DWE
- Two LRSs available

Power
- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other
- TBD data storage on the rover and lander

Concept of Operations

12-5) Park rovers during eclipses as they occur

12-6) Perform full checkout of the PEM

12-7) The LERs will continue to assist in exploration and outpost science and maintenance tasks.

12-8) Continue extended survey activities and perform secondary science and engineering exercises

12-9) ATHLETE clears the spent Descent Modules from the landing pads completes landing zone improvements

12-10) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

12-11) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 13: Crewed Mission
November 2025

Objective

The crew will finish checkout of the PEM and begin habitation operations. The crew will perform 3+ day excursions.

Type: Outpost Mission
No. of Crew: 4
Crewed Duration: 65 days

Assumptions

Crew
- The crew lives out of the LERs and PEM for the duration mission

Mobility
- A mix of crew-driving, tele-robotic, and ground-supervised operations
- LERs function without PUPs on 3-day excursions

Science
- Extensive preplanning of science activities occurs before the mission with identified secondary opportunities

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power
- PSUs provide 720 kW-hr of energy storage with RFCs and 14.5 kW of power generation with solar arrays
- Four PUPs also power supply along with LER batteries

Other

Concept of Operations

13-1) The lander touches down on a prepared pad inside the landing zone. The lander is connected to a PUP for water scavenging and to provide redundant keep-alive power for the Ascent Module (lander fuel cells are assumed to provide nominal keep-alive power for 14 days).

13-2) The crew lives out of the LERs and PEM for the duration mission. The LERs are utilized for surface excursions.

13-3) The crew offloads logistic payloads as required.

13-4) PUP elements are swapped as necessary to extract available water from the lander.

13-5) The crew oversees the ATHLETE removing any spent landers from their landing pads and their placement at a TBD location.

13-6) The crew performs science and exploration tasks. Science payloads are deployed and activated as required.

13-7) The crew also inspects and maintains all surface elements.

Span 13 & 14: Uncrewed Outpost Operations and Exploration – November 2025 to October 2026

Objective

Prepare for delivery of future outpost elements

Type: Ground-supervised/robotic activities

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Robotic Assistant available to support science as needed

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power
- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other
- TBD data storage on the rover and lander

Concept of Operations

13-8) Park rovers during eclipses as they occur

13-9) The LERs will continue to assist in exploration and outpost science and maintenance tasks.

13-10) Continue extended survey activities and perform secondary science and engineering exercises

13-11) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

13-12) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 14: Fourth Science Sortie
September 2026

Objective

Visit science site of interest, deploy ground-supervised unpressurized crew rover with a 1 kW solar array, perform extended science. In the absence of crew, the rover will continue to perform exploration and science under ground supervision for remaining life of the rover.

Type: Sortie Mission
No. of Crew: 4*
Crewed Duration : 7 or less days*
* depending on access requirements

Assumptions

Crew
- Up to 4 days of EVA (with use of airlock)
- Tele-operates rover on rest days

Mobility
- Deliver unpressurized crew rover (two year life)
- Tele-operated by crew and ground

Science
- Rover is part of 500 kg EARD payload

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power
- Rover must be capable of surviving longer eclipse durations

Other
- Off-loading device for rover
- There is a certain level of autonomy and operation

Concept of Operations

14-1) Explore region performing extended science

14-2) The crew will live in the Ascent Module and use the airlock to access the surface.

14-3) Systems Prep
- Crew checks out suits
- Crew checks out Altair systems
- Rover unloaded and checked out

14-4) Prepare for Future Activity
- Crew comm and control of tele-ops of rovers

14-5) Science
- Crew deploys and activates science payloads
- Crew conducts geologic traverses and sampling to targets of scientific interest
- Crew preps samples for return

14-6) Rover operates ground-supervised for 2 year lifetime assuming sufficient energy storage and power generation is manifested. (No span operations documented)

Mission 15: PCM/PSU, Tri-ATHLETE and ISRU OPS Delivery - October 2026

Objective

Delivery of (Pressurized Core Module) PCM/PSU allows for the missions to be extended 180 days at the outpost location.

Type: Uncrewed Mission
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew

-

Mobility

- Ground-supervised operations
- One tri-ATHLETES land preinstalled on the PCM

Science

-

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- Batteries on the ATHLETEs and PSU RFCs are already charged and sufficient for the tasks

Other

Concept of Operations

15-1) During landing, the cargo lander is guided to a prepared pad inside the landing zone in an automated fashion using pre-emplaced navigation aids.

15-2) Scavenged water produced by the lander fuel cells is transferred to the PSU scavenge tank or directly into the PCM waterwall. (Assumed Altair is equipped to support water scavenging.)

15-3) Under ground supervision, the Tri-ATHLETEs offload the PCM/PSU

- One of the previously delivered Tri-ATHLETEs docks to the unoccupied side of the PSU
- PSU is providing power for Tri-ATHLETEs
- Delivered Tri-ATHLETE powers up and go through static checkout
- Delivered Tri-ATHLETE ankles are freed and limbs are tested
- Two LERs drive over and position for camera work
- Tri-ATHLETEs/PSU releases latches from lander deck
- Tri-ATHLETEs step off with PCM/PSU
- ATHLETE/PCM/PSU moves to the habitation zone
- The ATHLETE detaches from the PCM/PSU after emplacement on the surface, docked to the PEM with the AAMA delivered with the ALC

15-4) The PSU is deployed to provide power generation and energy storage to the habitation zone.

15-5) The ISRU OPS is off-loaded and is checked out under ground supervision.

Span 15: Initial PCM Operations
October 2026 to December 2026

Objective

PCM and second ISRU OPS Checkout

Prepare for continuous human presence

Type: Ground-supervised/robotic activities

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Robotic Assistant available to support science as needed

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs are now available

Power
- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other
- TBD data storage on the rover and lander

Concept of Operations

15-6) Park rovers during eclipses as they occur

15-7) Perform full checkout of the PCM

15-8) The LERs will continue to assist in exploration and outpost science and maintenance tasks.

15-9) Continue extended survey activities and perform secondary science and engineering exercises

15-10) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

15-11) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 16: Crewed Mission
December 2026

Objective

The crew conducts exploration and science objectives. The crew will oversee the setup and initial operation of the new OPS.

Type: Outpost Mission
No. of Crew: 4
Crewed Duration: 95 days

Assumptions

Crew
- The crew lives out of the LERs, PEM, and PCM for the duration mission

Mobility
- A mix of crew-driving, tele-robotic, and ground-supervised operations
- LERs function without PUPs on 3-day excursions

Science
- Extensive preplanning of science activities occurs before the mission with identified opportunities

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power
- PSUs provide 720 kW-hr of energy storage with RFCs and 14.5 kW of power generation with solar arrays
- Four PUPs also power supply along with LER batteries

Other

Concept of Operations

16-1) The lander touches down on a prepared pad inside the landing zone. The lander is connected to a PUP for water scavenging and to provide redundant keep-alive power for the Ascent Module (lander fuel cells are assumed to provide nominal keep-alive power for 14 days).

16-2) The crew lives out of the LERs and PEM and PCM for the duration mission. The LERs are utilized for surface excursions.

16-3) The crew offloads logistic payloads as required.

16-4) The crew will oversee the setup and initial operations of the new ISRU OPS and trouble shoot any issues.

16-5) PUP elements are swapped as necessary to extract available water from the lander.

16-6) The crew oversees the ATHLETE removing any spent landers from their landing pads and their placement at a TBD location.

16-7) The crew performs science and exploration tasks. Science payloads are deployed and activated as required.

16-8) The crew also inspects and maintains all surface elements.

Span 16: Uncrewed Outpost Operations and Exploration – December 2026 to February 2027

Objective

Prepare for the delivery of future outpost elements

Type: Ground-supervised/robotic activities

Assumptions

Crew

-

Mobility

- Ground-supervised operations

Science

- Robotic Assistant available to support science as needed

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other

- TBD data storage on the rover and lander

Concept of Operations

16-9) Park rovers during eclipses as they occur

16-10) The LERs create feed piles for ISRU OPS Plan

16-11) Continue extended survey activities and perform secondary science and engineering exercises

16-12) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

16-13) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 17: PLM/SSU Delivery
February 2027

Objective

Delivery of the first (Pressurized Logistics Module) PLM with an SSU and AAMA, providing logistics resupply at the outpost.

Type: Uncrewed Mission
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew

-

Mobility

- Ground-supervised operations
- The two tri-ATHLETES land preinstalled on the PLM

Science

-

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- Batteries on the ATHLETES and PSU FCs are already charged and sufficient for the tasks

Other

-

Concept of Operations

17-1) During landing, the cargo lander is guided to a prepared pad inside the landing zone in an automated fashion using pre-emplaced navigation aids.

17-2) The lander is connected to PUP elements to scavenge any remaining water and to provide redundant keep-alive power for delivered surface elements.

17-3) Under ground supervision, An ATHLETE offloads the PLM/SSU

- One of the previously delivered ATHLETEs docks to the SSU
- The ATHLETE's solar array is providing power
- Two LERs drive over and position for camera work
- ATHLETE/SSU releases latches from lander deck
- ATHLETE step off with PLM/SSU
- ATHLETE/PLM/SSU moves to the habitation zone
- The ATHLETE sets down the PLM/SSU
- In preparation for the Lunabago, the initial PLM will need to be placed on the PSU delivered on flight 9 prior to docking to the habitation cluster

Span 17: Initial PLM Operations
February 2027 to July 2027

Objective

PLM checkout

Type: Ground-supervised/robotic activities

Assumptions

Crew
-

Mobility
- Ground-supervised operations

Science
- Robotic Assistant available to support science as needed

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power
- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other
- TBD data storage on the rover and lander

Concept of Operations

17-4) Park rovers during eclipses as they occur

17-5) Perform full checkout of the PLM

17-6) The LERs will continue to assist in exploration and outpost science and maintenance tasks.

17-7) Continue extended survey activities and perform secondary science and engineering exercises

17-8) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

17-9) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 18: Crewed Mission – Continuous Human Presence
July 2027

Objective

The crew will prepare for the FSPS delivery on Mission 19. 14 day excursions can be completed as time allows.

Type: Outpost Mission
No. of Crew: 4
Crewed Duration: 180 days

Assumptions

Crew

- The crew lives out of the LERs, PEM, PCM, and PLM for the duration mission

Mobility

- A mix of crew-driving, tele-robotic, and ground-supervised operations
- LERs function without PUPs on 3-day excursions

Science

- Extensive preplanning of science activities occurs before the mission with identified opportunities

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- PSUs provides 720 kW-hr of energy storage with RFCs and 14.5 kW of power generation with solar arrays
- Four PUPs also power supply along with LER batteries

Other

Concept of Operations

18-1) The lander touches down on a prepared pad inside the landing zone. The lander is connected to PUP elements to scavenge water from the lander fuel cells and to provide keep-alive power for the Ascent Module.

18-2) The crew lives out of the PCM and PEM. The LERs are utilized for surface excursions.

18-3) The crew assists in any remaining setup of the PLM/SSU. The crew offloads science and logistic payloads as required.

18-4) The crew will validate the FSPS zone, cable runs, and Mission 19 landing zone.

18-5) The crew oversees the ATHLETE removing any spent landers from their landing pads and their placement at a TBD location.

18-6) The crew performs science and exploration tasks. Science payloads are deployed and activated as required.

18-7) The crew also inspects and maintains all surface elements.

Span 18: Crewed Outpost Operations and Exploration
July 2027 to October 2027

Objective

Prepare for delivery of FSPS
Crew is on the surface, however these operations are designed to be ground-supervised.

Type: Ground-supervised/robotic activities

Assumptions

Crew
- Crew from Mission 18 are still on surface

Mobility
- Ground-supervised operations

Science
- Robotic Assistant available to support science as needed

Communications
- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power
- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other
- TBD data storage on the rover and lander

Concept of Operations

18-18) Park rovers during eclipses as they occur

18-19) The LERs will:

- Continue to assist in exploration and outpost science
- Continue outpost maintenance tasks
- Finish final preparation of FSPS zone and Mission 19 landing zone
- Perform test runs of cable deployment paths

18-20) Continue extended survey activities and perform secondary science and engineering exercises

18-21) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

18-22) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 19: FSPS Delivery
October 2027

Objective

The FSPS will be delivered and autonomously set up with the assistance of an LER and off-loading device. A Landing Zone Power Hub and three Lander cables are also delivered. All functions are assumed to be ground-supervised with crew oversight if needed.

Type: Uncrewed Mission
No. of Crew: 0
Crewed Duration: 0 days

Assumptions

Crew

- Crew from Mission 18 is still on the surface

Mobility

- Ground-supervised operations

Science

-

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- Batteries on the ATHLETES and PSU FCs are already charged and sufficient for the tasks

Other

-

Concept of Operations

19-1) Prior to landing the crew will move to a safe location in the LERs. After landing in the designated FSP zone, the FSPS will deploy its solar array to provide keep-alive power to the FSPS.

19-2) The off-loading device will offload the FSPS PMAD system on to an LER which will transport it to the PMAD site, deploying the cable at the same time, with the help of a Robotic Assistant.

19-3) The off-loading device will offload the Landing Zone Power Hub on to an LER which will transport it to the Landing Zone, deploying the cable at the same time, with the help of a Robotic Assistant.

19-4) An ATHLETE system will work to fill the cavity around the FSP reactor with regolith.

19-5) During the setup, the lander is connected to PUP elements to scavenge any remaining water and to provide redundant keep-alive power for delivered surface elements. The PUPs will be disconnected prior to FSPS start-up

19-6) FSPS radiators are deployed and the FSPS begins its start-up procedures.

19-7) An LER and Robotic Assistant deploy cables from the PMAD site to the habitation cluster and the two ISRU OPSs enabling full operation throughout the lunar day.

Span 19: Initial FSPS Operations
October 2027 to January 2028

Objective

FSPS Checkout with crew oversight if needed.

Type: Ground-supervised/robotic activities

Assumptions

Crew

- Crew from Mission 18 still on the surface

Mobility

- Ground-supervised operations

Science

- Robotic Assistant available to support science as needed

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- All assets are quiescent during eclipse
- No power to lander after unloading is completed

Other

- TBD data storage on the rover and lander

Concept of Operations

19-8) Park rovers during eclipses as they occur

19-9) Perform full checkout of the FSPS

19-10) The LERs will continue to assist in exploration and outpost science and maintenance tasks.

19-11) ISRU OPS can now operate through eclipses with power from FSPS.

19-12) Continue extended survey activities and perform secondary science and engineering exercises

19-13) Robotic Assistant scavenges select assets from Altair Descent Modules (all previous Descent Modules)

19-14) Use Robotic Assistant to recover science assets, exposure samples, and other science instruments. The RA can also support ISRU activities and perform maintenance tasks.

Mission 20: Crewed Mission and Initial Lunabago Excursion - January 2028

Objective

The crew conducts exploration and science objectives.

Extended excursion away from the outpost with mobile assets.

1,000 km (Round-trip) excursion

Type: Crewed Mission
No. of Crew: 4
Crewed Duration: 180 days

Assumptions

Crew

-

Mobility

- A mix of crew-driving, tele-robotic, and ground-supervised operations
- Take two LERs and drop two PUPs off at strategic staging points (one each)

Science

-

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- FSPS + 3 PSUs + 4 PUPs
- Full Eclipse Capability

Other

-

Concept of Operations

20-1) The lander touches down on a prepared pad inside the landing zone. The lander is connected to PUP elements to scavenge water from the lander fuel cells to the LZPH to provide keep-alive power for the Ascent Module.

20-2) The crew lives out of the PCM, PEM, and PLM. The LERs are utilized for surface excursions.

20-3) The crew assists in any remaining setup of the FSPS. The crew off-loads science and logistic payloads as required.

20-4) The crew oversees the ATHLETE removing any spent landers from their landing pads and their placement at a TBD location.

20-5) Science payloads are deployed and activated as required.

20-6) The crew performs science and exploration tasks.

Mission 20: Lunabago Portion of Mission

Objective

The crew conducts exploration and science objectives.

Extended excursion away from the outpost with mobile assets.

1,000 km (roundtrip) excursion (60-90 days total)

Type: Crewed Mission
No. of Crew: 4
Crewed Duration: 180 days

Assumptions

Crew

- All crew go on excursion

Mobility

- Multiple mobility assets are going on excursion to cover contingency scenarios
- Driving during eclipses (requires two PSUs)
- Allows for 28 days contingency of logistics

Science

-

Communications

- Lander, LERs, PUPs all have DWE comm capability
- PCTs enable contribution quality (TBR) video DWE
- Two LRSs available

Power

- 2 PSUs – 14.5 kW generation and 720 kW-hr storage on each
- 4 PUPs (2 at final location) – 2-3 kW (TBR) generation on a “drivable” array and a full set of batteries for swap out (100 kW-hr storage in 10 batteries) on each

Other

- Leaving one habitable volume and ISRU OPS, FSP, 2xLERs, and unrelated science
- Ascent module remains

Concept of Operations

20-7) The convoy consisting of two LERs (with PUPs), a PCT, two ATHLETEs each carrying a PUP and a PSU, the PEM, and either a PLM or ALC (depending on pressurized/unpressurized logistics needs pending CAT analysis) traverses to waypoint #1 (1/3 of distance)

- Leave one contingency-PUP at waypoint #1
- Two LERs are driven by crew, two ATHLETEs are supervised by ground control or crew

20-8) Remaining convoy goes to waypoint #2 (2/3 of total distance)

- Leave second contingency-PUP at waypoint #2

20-9) Remaining convoy arrives at Schrodinger Basin. Up to this point, convoy stops every three days to recharge batteries with either the PUPs or PSUs. Total trip out, roughly 25 days.

20-10) Establish a base camp in a sunlit location (PLM or ALC/PEM and PUPs). Two LERs start series of one to three day excursions from base camp. Recharge every three days.

20-11) Science payloads are deployed and activated as required.

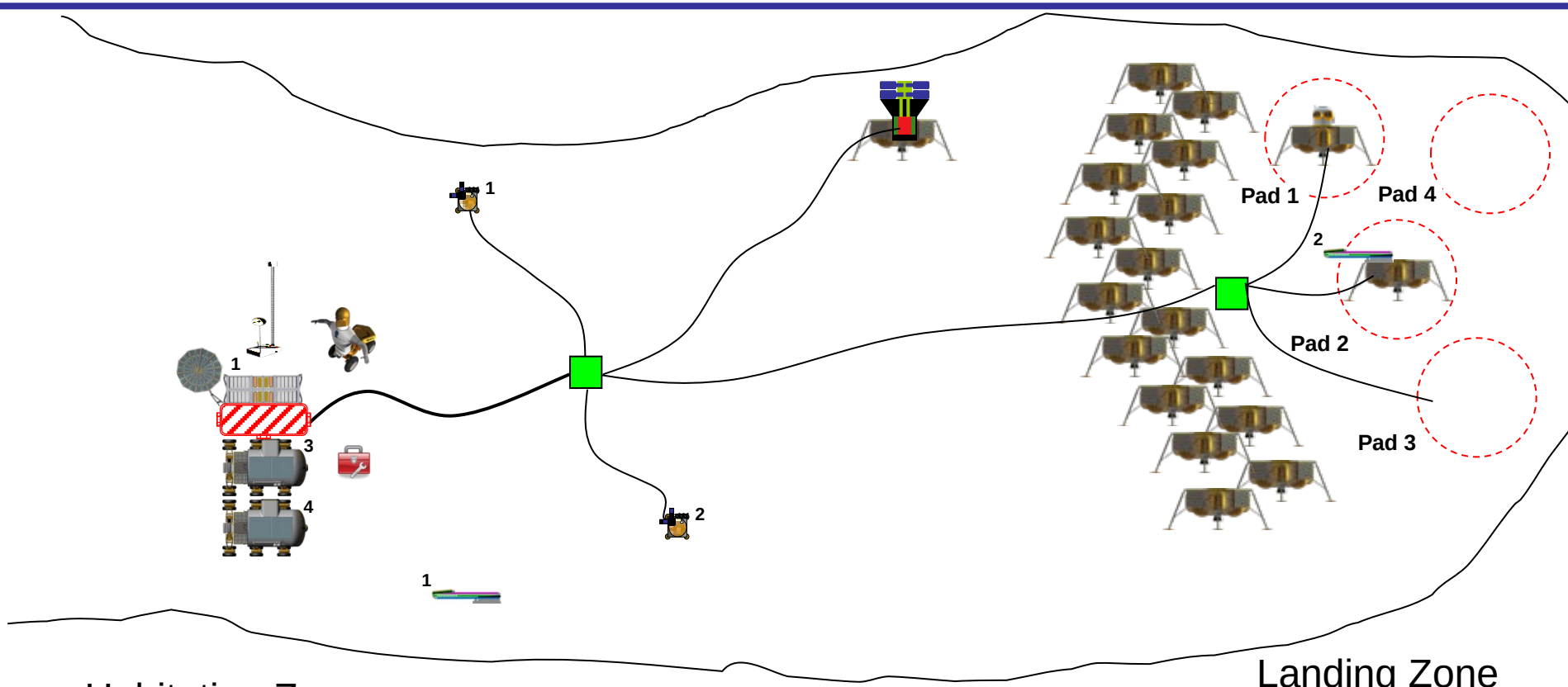
20-12) The crew performs science and exploration tasks.

20-13) After 2- 3 weeks of science activities, prepare for trip back to outpost.

20-14) After operations base camp are completed, convoy begins traverse to outpost. Prior to mission and while at base camp, a route back to the outpost is identified that allows for more science/ explortation objectives to be satisfied.

20-15) The route back to the outpost can take up to ~45 days. When the convoy reaches the waypoints, the ATHLETES will pick up the PUPs and continue towards the outpost.

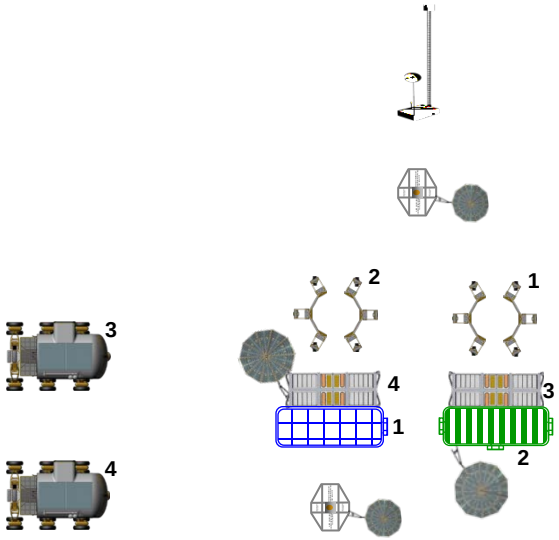
Scenario 12.0.1 Outpost Site Plan during first Lunabago excursion on Mission 20 (180 days)



Note: Unpressurized, gas, and liquid cargo not shown

- Lunar Lander (LL) with Ascent Module
- Lunar Lander (LL) – Descent Module
- Tri-ATHLETE x2
- Fission Surface Power System (FSPS)
- Small Press Rover (SPR)
- Mobility Chassis Toolkit (MCT)
- Chassis Driving Kit (CDK)
- Pressurized Core Module (PCM)
- Pressurized Excursion Module (PEM)
- Pressurized Logistics Module (PLM)
- Power & Support Unit (PSU)
- Portable Utility Pallet (PUP)
- Robotic Assistant (RA)
- Off-loading Device (OD)
- ISRU Oxygen Production System (OPS)
- Portable Communications Terminal (PCT)

Scenario 12.0.1 Lunabago Site Plan



Note: Unpressurized, gas, and liquid cargo not shown

Lunar Lander (LL) with Ascent Module

Lunar Lander (LL) – Descent Module

Tri-ATHLETE x2

Fission Surface Power System (FSPS)

Small Press Rover (SPR)

Mobility Chassis Toolkit (MCT)

Chassis Driving Kit (CDK)

Pressurized Core Module (PCM)

Pressurized Excursion Module (PEM)

Pressurized Logistics Module (PLM)

Power & Support Unit (PSU)

Portable Utility Pallet (PUP)

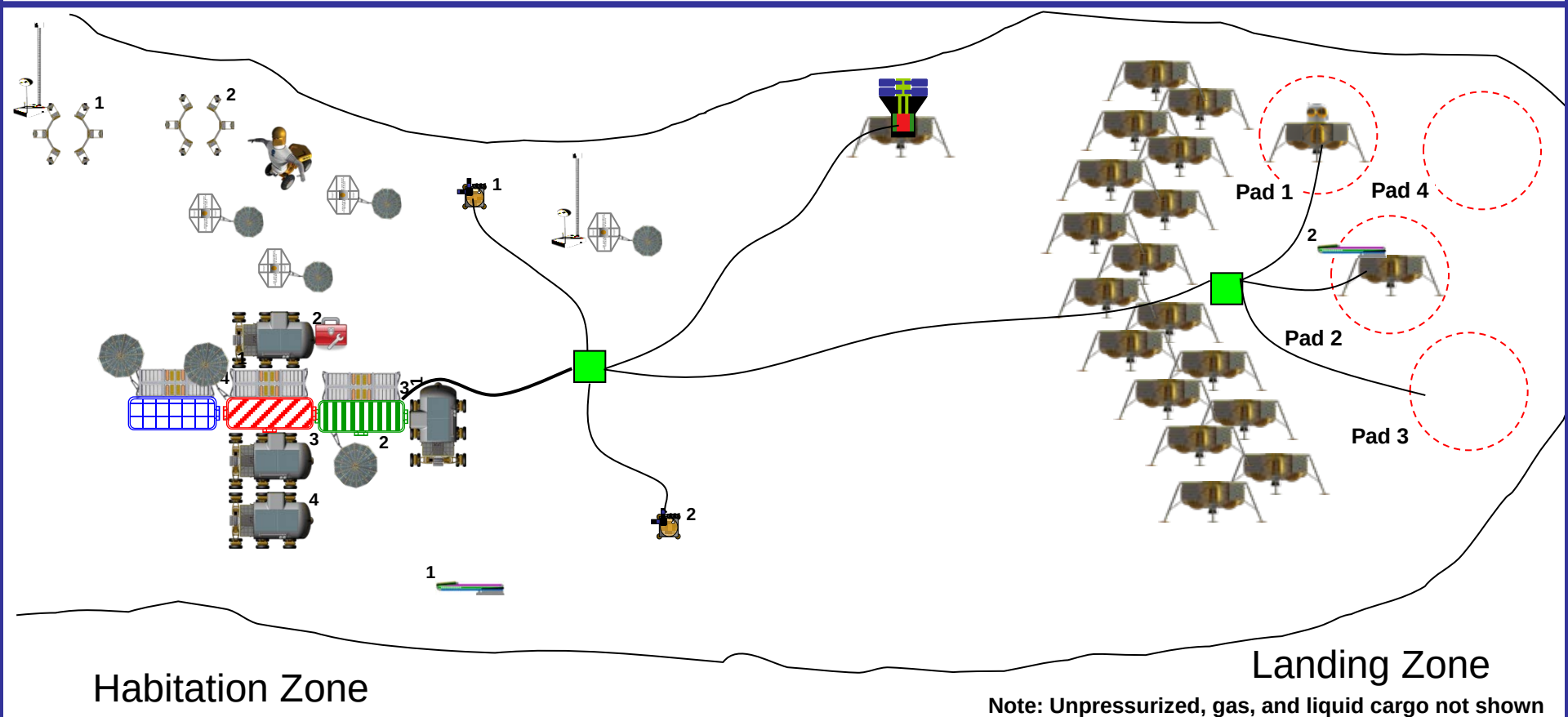
Robotic Assistant (RA)

Off-loading Device (OD)

ISRU Oxygen Production System (OPS)

Portable Communications Terminal (PCT)

Scenario 12.0.1 Outpost Site Plan as of Mission 20 (180 days)



Note: Unpressurized, gas, and liquid cargo not shown

- Lunar Lander (LL) with Ascent Module
- Lunar Lander (LL) – Descent Module
- Tri-ATHLETE x2
- Fission Surface Power System (FSPS)
- Small Press Rover (SPR)
- Mobility Chassis Toolkit (MCT)
- Chassis Driving Kit (CDK)
- Pressurized Core Module (PCM)
- Pressurized Excursion Module (PEM)
- Pressurized Logistics Module (PLM)
- Power & Support Unit (PSU)
- Portable Utility Pallet (PUP)
- Robotic Assistant (RA)
- Off-loading Device (OD)
- ISRU Oxygen Production System (OPS)
- Portable Communications Terminal (PCT)

Other Missions

- The rest of the missions consist of 180 day crewed missions and additional PLM deliveries when needed.
- Lunabago modes are performed as resources allow to targeted destinations as determined by the science community.
- Missions of opportunity are used to augment the outpost and other lunar exploration activities beyond our current scope leveraging the power rich environment provided by the FSPS.

Acronym List

- AAMA – Active-Active Mating Adapter
- ALC – Airlock-derived Logistic Carrier
- ATHLETE – All-Terrain Hex-Legged Extraterrestrial Explorer
- DWE – Direct With Earth
- EARD – Exploration Architecture Requirements Document
- EVA – Extra Vehicular Activity
- FSPS – Fission Surface Power System
- HLR – Human Lunar Return
- ICC – Initial Core Capability
- ISRU – In-Situ Resource Utilization
- LER – Lunar Electric Rover
- LRS – Lunar Relay Satellite
- LZPH – Landing Zone Power Hub
- MCT – Mobile Chassis Toolkit
- OD – Off-loading Device
- OPS – Oxygen Production System
- PCM – Pressurized Core Module
- PCT – Portable Communications Terminal
- PLM – Pressurized Logistics Module
- PMAD – Power Management and Distribution
- PSU – Power and Support Unit
- PUP – Portable Utility Pallet
- RA – Robotic Assistant
- RFC – Regenerative Fuel Cell
- SSU – Structural Support Unit
- STM – Suitport Transfer Module