LIRA ASTRONAUT OPERATIONS PROTOCOL

Lunar Sample Box

Lunar Isolation and Return Assembly (LIRA)

Artemis III AxEMU Compatible Lunar Sample Container System

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Classification: EVA Field Operations
Spacesuit Compatibility: Axiom AxEMU (Axiom Extravehicular Mobility Unit)
Project: NASA HUNCH (High School Students United with NASA to Create Hardware)

PROJECT SCOPE CLARIFICATION

LIRA (NASA HUNCH Project) Deliverables:

1. **Storage Box** - 15,24 cm W × 15,24 cm D × 30,48 cm H sealed container with EPDM foam seal
2. **Collection Bag** - Portable sealed bag with bayonet lock mechanism
3. **Integration with NASA Systems** - Compatible with NASA sampling tools and AxEMU suit

NASA-Provided Components (Not LIRA Scope):

- Sampling tools (tongs, scoops, hammers, chisels)
- Sample bag dispenser
- Tool carriers and mounting systems
- Mission planning and sample tracking software

This Protocol Covers:

- LIRA box and bag operation procedures
- Interface with NASA sampling tools
- Integration points with AxEMU suit and rover systems
- Maintenance of LIRA hardware

SYSTEM OVERVIEW

The LIRA system is a two-part lunar sample containment system designed for Artemis III mission sample collection using the AxEMU spacesuit and NASA standard sampling tools.

SYSTEM COMPONENTS:

LIRA-Provided:

- **Collection Bag** - Portable sealed bag carried on AxEMU waist D-ring
- **Storage Box** - Rover-mounted sealed container (15,24 cm W × 15,24 cm D × 30,48 cm H)

NASA-Provided (Interface Components):

- **Sampling Tools** - Tongs, scoops for contamination-free sample collection
- **Sample Tracking System** - ID tags, numbering system
- **Tool Carriers** - Mounted on AxEMU suit or rover

CAPACITY:

- 1 bag = 1 sample (baseball-sized rock maximum)
- 1 box = 2 bags (stacked vertically)

KEY FEATURES:

- **Tethered bayonet lid** on bag (15 cm Kevlar lanyard prevents loss)
- **AxEMU waist D-ring attachment** (specified location, reduces swing)
- **EPDM foam compression seal** on box (semi-hermetic)
- **Multi-layer bag construction** (nylon/wool/steel mesh)
- **3D-printed hexagonal cushioning** + steel wool padding

AxEMU SPACESUIT CAPABILITIES RELEVANT TO LIRA OPERATIONS

Advanced Dexterity Features:

- **Custom gloves** - Improved finger flexibility and grip strength (15-20 lbs)
- **Enhanced tactile feedback** - Can feel bayonet lock engagement
- **Reduced hand fatigue** - Advanced joint design
- **3D-scanned fit** - Custom-fitted to each astronaut

Mobility Enhancements:

- **Kneeling capability** - Advanced hip/leg joints allow kneeling if needed
- **Greater range of motion** - Soft and hard joints in arms, legs, hips
- **Improved bending** - Can lean forward comfortably at waist

Visual & Communication Systems:

- **HD camera** - Helmet-mounted for documentation

- **Enhanced visor** - Improved visibility in low-sun conditions
- **4G/LTE communication** - Real-time voice and data transmission
- **Handheld display device** - For navigation, checklists, camera control

Tool Integration:

- **Waist D-rings** - Left and right side attachment points
- **Tool loops** - Additional attachment for sampling tools
- **8-hour EVA capability** - Extended operational time

PRE-EVA PREPARATION

FIRST-TIME USE ONLY: SEAL FILM REMOVAL

CRITICAL: Performed IN HABITAT before EVA, NOT on lunar surface.

TIMING: During pre-mission prep with BARE HANDS (not with AxEMU gloves).

BAG SEAL FILM REMOVAL:

1. Locate clear Teflon protective film on rubber O-ring seal
2. Using bare hands, carefully peel film away from O-ring groove
    - Start at one edge, peel smoothly around perimeter
    - Avoid stretching or distorting O-ring
3. Dispose of film in waste container
4. Visually confirm O-ring is clean, properly seated, undamaged
5. Test bayonet lock rotation - should move smoothly through full 25° range

BOX SEAL FILM REMOVAL:

1. Open box lid by unlatching all 4 clamps
2. Locate clear Teflon protective film on EPDM foam seal
3. Using bare hands, carefully peel film away from foam surface
4. Dispose of film in waste container
5. Inspect EPDM foam - continuous, soft, no gaps or damage
6. Close and latch box to verify clamps operate smoothly

VERIFICATION CHECKLIST:

- Bag O-ring seal film removed
- Box EPDM foam seal film removed
- Bayonet lock rotates smoothly
- Box clamps latch securely

- All protective films disposed
- Equipment ready for EVA

SECTION 1: SAMPLE COLLECTION PROCEDURE

(Astronaut + NASA Sampling Tools + LIRA Bag)

NOTE: This section describes the INTERFACE between NASA sampling tools and LIRA bag. Complete sampling procedures are defined in the NASA EVA Operations Handbook.

1.1 PRE-COLLECTION CHECKS

Before exiting habitat:

- LIRA collection bag attached to AxEMU LEFT waist D-ring via carabiner
- NASA sampling tools (tongs/scoop) attached to RIGHT waist D-ring or tool carrier
- Bayonet lock lid is tethered (15 cm Kevlar lanyard visible)
- Lid in LOCKED position (tabs engaged)
- No visible damage to bag exterior or tether
- AxEMU gloves fit properly
- Helmet HD camera operational

1.2 SAMPLE IDENTIFICATION AND WORK POSITION

Step 1: Locate Sample

- Identify geologically significant sample (per NASA mission objectives)
- Verify sample size: baseball-sized or smaller (≤3 inches diameter)
- Assess accessibility and terrain

Step 2: Choose Work Position

OPTION A: Standing (Default):

- Stand with feet shoulder-width apart
- Lean forward at waist (AxEMU allows comfortable bending)
- Stable on most terrain types

OPTION B: Kneeling (If Beneficial):

- **Use Only If:** Better sample access, unstable footing when standing, or astronaut preference
- **Safety Check:** Ensure you can stand up from kneeling position

- **Buddy Check:** Partner confirms astronaut can rise unassisted
- **Minimize Duration:** Reduces knee joint wear and regolith contamination

Sample Size Limit: Maximum 3 inches diameter (approx. width of AxEMU gloved fist)

1.3 BAG OPENING PROCEDURE

Step 3: Detach Bag from Waist D-Ring

- Press carabiner gate release with gloved fingers
- Unhook from LEFT waist D-ring
- Bag lid remains tethered (15 cm lanyard prevents loss)

Step 4: Position Bag

If Standing:

- Hold bag body in non-dominant hand at waist level
- Or rest on clean, stable surface (rock, equipment case) if available

If Kneeling:

- Rest bag on knee or place on ground in front of you
- Bag stays upright with minimal effort

Step 5: Unlock Bayonet J-Lock

1. **Grip tethered lid** with dominant hand
2. **Rotate lid CLOCKWISE** 25 degrees
    - AxEMU gloves allow feeling tab release
3. **Feel for release** - resistance decreases as tabs disengage from J-slots
4. **Lift lid straight up**
5. **Release lid** - hangs from 15 cm Kevlar tether
    - **Tether keeps lid attached to suit**
    - Lid will NOT touch lunar surface
    - One hand now FREE for NASA sampling tools

✓ **Visual Check:**

- Look into bag interior (AxEMU helmet bubble provides good downward view)
- Confirm interior clean and cushioning properly positioned

1.4 SAMPLE COLLECTION WITH NASA TOOLS

NASA SAMPLING TOOL INTERFACE:

Step 6: Deploy NASA Sampling Tool

Tool Options (NASA-Provided):

- **Long-handled tongs** (15 - 30 cm) - for individual rocks
- **Scoop** - for smaller rocks or loose material
- **Hammer and chisel** - for extracting samples from larger formations

Tool Access:

1. Reach to RIGHT waist D-ring or tool carrier
2. Remove tongs/scoop with dominant hand
3. **AxEMU glove dexterity** allows easy tool manipulation

Step 7: Collect Sample with Tool (NO GLOVE CONTACT)

CRITICAL CONTAMINATION CONTROL: Sample must NOT be touched directly with gloves. Use NASA tools ONLY.

1. **Position tool** over sample rock
2. **Grip sample** with tongs or scoop
    - AxEMU gloves provide 15-20 lbs grip strength (sufficient for tool operation)
3. **Lift sample** with tool - maintain grip
4. **Avoid glove contact** with sample surface

Step 8: Transfer Sample from Tool to LIRA Bag

1. **Hold tool with sample** over bag opening
2. **Lower sample into bag** using tool
    - Guide sample to center of bag
    - Sample should rest on steel wool/mesh cushioning
3. **Release tool grip** - sample drops gently into bag
4. **Withdraw tool** from bag - **avoid contact with bag interior or seal area**

Step 9: Stow NASA Tool

- Return tongs/scoop to RIGHT waist D-ring or tool carrier
- Secure tool for traverse to rover

Contamination Prevention:

- Tool contacted sample ONLY
- Gloves did NOT contact sample
- Tool did NOT contact bag sealing surfaces

1.5 BAG SEALING

Step 10: Close Bayonet Lock

1. **Retrieve tethered lid** - pull up via 15 cm Kevlar lanyard
2. **Align lid** with bag opening
    - Locking tabs align with J-slot channels
    - AxEMU gloves allow feeling alignment
3. **Lower lid** onto bag opening until O-ring contact
4. **Apply downward pressure** (5-10 lbs - light pressure)
5. **While pressing down, rotate COUNTERCLOCKWISE 25 degrees**
    - Feel/hear subtle "click" as tabs engage J-slots
    - AxEMU glove tactile feedback detects engagement
6. **Release downward pressure** - lid stays locked

✓ SEAL VERIFICATION (Visual Only - NO TOUCHING):

Physical Test:

- Attempt to lift lid with one hand - should NOT rotate or lift
- Attempt to rotate lid clockwise - should be mechanically stopped

Visual Inspection:

- Look around seal perimeter (helmet bubble allows good viewing angle)
- O-ring should show even compression around circumference
- No gaps visible between lid and bag body

DO NOT touch seal with gloves - contamination risk

Step 11: Document Collection

Voice Log (Hands-Free via AxEMU 4G/LTE):

- Speak naturally into helmet microphone
- "Sample [NUMBER] collected at [LOCATION], sealed in bag [ID]"
- Mission Control receives transmission via 4G/LTE
- **NOT a voice command** - this is radio communication

Optional Photo Documentation:

- Use handheld display device to trigger helmet camera
- Or request Mission Control: "Mission Control, please capture frame from my helmet feed showing sealed bag"
- Photo shows sample site and sealed bag

1.6 POST-COLLECTION ACTIONS

Step 12: Secure Bag to AxEMU Waist D-Ring

- Reattach carabiner to LEFT waist D-ring
- Press gate, hook D-ring, release gate
- Verify carabiner gate fully closed and locked
- Bag hangs at waist level, minimal swing

Step 13: Return to Rover

- Proceed to rover location with sealed bag
- NASA sampling tools remain on RIGHT waist for next sample (if collecting multiple)

SECTION 2: SAMPLE STORAGE PROCEDURE

(Rover + LIRA Storage Box)

2.1 ROVER ARRIVAL

Step 1: Approach Rover

- Navigate to rover with sealed LIRA bag on waist
- Locate LIRA storage box on rover platform
- Position for comfortable box access (stand or kneel as appropriate)

Step 2: Verify Box Security

- Box should be mounted firmly to rover platform
- No shifting or instability
- Adequate workspace around box

2.2 BOX OPENING

Step 3: Unlatch Box Clamps

4 Clamps in Opposing Pairs:

UNLATCH SEQUENCE (Prevents Seal Warping):

Standing Position (Typical):

1. **Clamp 1 (Front-Left):** Grip handle, pull outward/upward, rotate away
2. **Clamp 3 (Rear-Right - OPPOSITE):** Repeat for diagonal opposite clamp
3. **Clamp 2 (Front-Right):** Unlatch third clamp

4. **Clamp 4 (Rear-Left - OPPOSITE):** Unlatch final clamp

AxEMU gloves provide sufficient grip strength (15-20 lbs) for clamp operation.

If Kneeling:

- AxEMU mobility allows kneeling at rover if needed
- Bring clamps closer to eye level for better visibility
- Same unlatch sequence

Step 4: Remove Box Lid

1. **Grasp paracord handle** (or lid edges)
    - AxEMU gloves provide good grip on paracord
2. **Lift lid straight up** - avoid twisting
3. **Place lid INVERTED on rover platform**
    - **Seal-side UP** (EPDM foam faces upward)
    - Prevents dust contamination of seal
    - **Platform must be level or nearly level** (within 5 degrees)
    - If platform sloped: Secure lid with bungee cord or rest against rover equipment

✓ **Box Interior Inspection:**

- Look into box interior (helmet bubble provides good view)
- Hexagonal cushioning tiles on all 4 walls - check position
- Steel wool padding at bottom - evenly distributed
- No debris or damage
- **If this is SECOND bag:** Verify first bag is properly positioned

2.3 BAG PLACEMENT IN BOX

CRITICAL: Box Orientation is VERTICAL. Bags stack one on top of the other.

Step 5: Transfer Bag from Waist to Box

1. **Detach bag from LEFT waist D-ring**
    - Press carabiner gate, unhook
2. **Hold bag by bayonet lid** (not bag body - don't squeeze sample)
3. **Lower bag vertically into box**

IF THIS IS THE FIRST BAG (Box Empty):

1. **Place bag on BOTTOM of box**
    - Lower bag straight down onto steel wool padding
    - Bag should sit on base of box
    - Centered on bottom cushioning

2. **Verify bag position:**
    - Bag upright (bayonet lid at top)
    - Bag not tilted or leaning
    - Bag centered in base
3. **Place CUSHIONING SEPARATOR on top of first bag**
    - 3D-printed hexagonal tile or foam pad (provided in box)
    - Creates separation between bags
    - Prevents upper bag from crushing lower bag

IF THIS IS THE SECOND BAG (Box Has One Bag Already):

1. **Place bag on TOP of first bag**
2. **Verify stacking:**
    - Both bags upright (lids at top)
    - **Clearance check:** Top of upper bag should be at least 0.5" BELOW box rim
        - Allows lid to close without compressing bags
3. **If bags too tall:**
    - Remove upper bag
    - Reposition lower bag (compress padding slightly if needed)
    - Retry upper bag placement
    - If still doesn't fit: **One bag only** in this box, use second box for second bag

✓ **Final Position Verification:**

- Bag(s) upright and stable
- Cushioning in place
- Adequate clearance for lid closure

2.4 BOX SEALING

Step 6: Inspect and Replace Lid

1. **Retrieve lid** from rover platform
2. **Inspect EPDM foam seal** - VISUAL ONLY, NO TOUCHING
    - Look for debris on foam surface
    - **IF DUST/DEBRIS PRESENT:**
        - Gently brush away using EDGE of gloved hand
        - Use sweeping motion OUTWARD (away from seal)
        - Do NOT grind particles into foam
        - Do NOT touch seal surface directly with glove fingertips
    - **IF DEBRIS IS EMBEDDED:**
        - Note in voice log for post-EVA maintenance
        - Proceed with sealing (embedded debris is maintenance issue, not immediate failure)
3. **Position lid over box opening**

    - Hold lid level and horizontal
    - Align lid edges with 15 by 15 cm box rim
4. **Lower lid evenly onto box**
    - Keep lid level as you lower
    - EPDM foam seal contacts box rim around entire perimeter simultaneously
    - Do NOT tilt to one side

✓ Pre-Latch Check:

- Lid sits flush on rim (no obvious gaps)
- EPDM foam visibly compressing evenly

Step 7: Latch Box Clamps

LATCH SEQUENCE (CRITICAL - Opposite Pairs for Even Compression):

1. **Clamp 1 (Front-Left):**
    - Rotate clamp over lid edge
    - Align latch with catch on box body
    - Apply firm downward pressure to engage
    - Push handle fully closed
    - AxEMU gloves allow feeling "click" or solid engagement
2. **Clamp 3 (Rear-Right - OPPOSITE CORNER):**
    - Repeat latching motion
    - Diagonal pressure now balanced
3. **Clamp 2 (Front-Right):**
    - Latch third clamp
4. **Clamp 4 (Rear-Left - OPPOSITE CORNER):**
    - Latch final clamp
    - All four corners secured

Latching Force:

- AxEMU gloves provide 15-20 lbs grip (sufficient)
- Should feel solid engagement without excessive force
- Clamp should not move when pulled gently

✓ SEAL VERIFICATION:

Physical Tests:

1. **Clamp Security:** Gently pull each clamp handle - should not unlatch
2. **Lid Stability:** Attempt to lift lid at corners - should not move
3. **Even Compression:** Press gently on lid at multiple points - should feel firm resistance (EPDM compressed)

Visual Inspection (NO TOUCHING):

1. **Perimeter check:** Lid flush with box rim at all points
2. **Foam compression visible:** EPDM foam shows slight bulge at seal line (compression visible)
3. **No gaps:** No visible space between lid and box body

Voice Log:

- "Box [ID] sealed, [1 or 2] bags stored, all 4 clamps engaged"

Optional Photo:

- Use handheld display to trigger helmet camera
- Or request Mission Control frame capture

2.5 POST-STORAGE ACTIONS

Step 8: Verify Box Security

- Check box is firmly mounted to rover
- Paracord handle accessible
- No tools or equipment obstructing box

Step 9: Update Mission Log

Voice Log (AxEMU 4G/LTE Transmission):

- "Sample [NUMBER] stored in Box [ID] at [TIME]"
- "Box [ID] contains [1 or 2] bags"
- **IF BOX FULL:** "Box [ID] complete with 2 bags, ready for habitat transport"

Step 10: Determine Next Action

IF BOX NOT FULL (1 bag, capacity for 1 more):

- Continue sample collection with new bag (if available)
- Return to Section 1 for next sample

IF BOX FULL (2 bags):

- Box complete for this EVA
- Continue EVA with new box (if mission requires more samples)
- Or return to habitat

SECTION 3: EMERGENCY PROCEDURES

3.1 BAYONET LOCK FAILURE TO ENGAGE

SYMPTOM: Locking tabs won't engage in J-slots, or lid rotates freely after attempted locking.

PROCEDURE:

1. **Rotate lid fully CLOCKWISE** to open
2. **Remove lid** (stays on tether)
3. **Inspect J-slots** (visual + helmet camera if needed):
    - Regolith dust in slots?
    - Bent/damaged tabs?
    - Misaligned O-ring blocking slot?
4. **IF DEBRIS IN SLOTS:**
    - Hold bag with opening facing DOWN
    - Tap bottom gently to dislodge particles
    - Use AxEMU glove dexterity to carefully clear channels
    - Retry engagement
5. **IF TABS DAMAGED OR MECHANISM NON-FUNCTIONAL:**
    - Place lid on bag opening (even if tabs don't lock)
    - **Voice log:** "Bag [ID] bayonet lock failure"
    - Continue to rover and place in box
    - Report to Mission Control

3.2 SAMPLE TOO LARGE FOR BAG

SYMPTOM: Sample doesn't fit through 85 mm bag opening, or bag won't close with sample inside.

PROCEDURE:

1. **DO NOT FORCE** - risk of bag damage
2. **Remove sample from bag** using NASA tongs/scoop (no glove contact)
3. **Return sample to surface** at collection location
4. **Document for future collection:**
    - Voice log: "Sample at [LOCATION] oversized, approx [SIZE], [DESCRIPTION]"
    - Request Mission Control helmet camera capture
5. **Select smaller alternative sample** (≤3" diameter)
6. **Retry collection** with NASA tools

Size Reference: ≤3 inches diameter (width of AxEMU gloved fist)

3.3 BOX CLAMP MECHANICAL FAILURE

SYMPTOM: One clamp breaks, bends, or won't engage.

PROCEDURE:

1. **Identify failed clamp** (Front-Left, Front-Right, Rear-Left, Rear-Right)
2. **Voice log:** "Box [ID] Clamp [POSITION] failure"
3. **DO NOT force broken clamp**
4. **Proceed with 3 REMAINING CLAMPS** using modified sequence:

Modified Opposite-Pair Latching:

- If Front-Left failed: Latch Front-Right, then Rear-Left, then Rear-Right
- If Front-Right failed: Latch Front-Left, then Rear-Right, then Rear-Left
- If Rear-Left failed: Latch Front-Left, then Front-Right, then Rear-Right
- If Rear-Right failed: Latch Front-Right, then Front-Left, then Rear-Left

Principle: Maintain best diagonal balance possible with 3 clamps

5. **Verify seal integrity:**
    - Check EPDM compression at failed clamp corner
    - Gently press lid at failed corner - should still show resistance
    - If gap visible or lid lifts: See Section 3.5 (Seal Compromise)
6. **If seal adequate:**
    - Mark box exterior (scratch, chalk, tape) at failed clamp
    - Voice log: "Box [ID] operating with 3 clamps, seal integrity acceptable"
    - Continue mission
7. **Post-EVA:** Flag box for clamp repair before next use

3.4 SEAL CONTAMINATION OR DAMAGE

SYMPTOM: EPDM foam or O-ring shows visible damage or contamination.

ASSESSMENT:

MINOR (Proceed with Caution):

- Surface dust (loose, not embedded)
- Small particles <2mm on seal

MAJOR (Seal Compromised):

- Cuts/tears in seal >5mm
- Large debris >2mm embedded
- Permanent deformation (foam doesn't recover)
- Chunks missing from seal

PROCEDURE:

FOR MINOR CONTAMINATION:

1. **Clean seal (EDGE of glove only):**
    - Use sweeping motion OUTWARD
    - Do NOT grind particles in
    - Do NOT touch seal with glove fingertips
2. **Verify debris removed** (visual inspection)
3. **Proceed with sealing**
4. **Extra verification recommended**

FOR MAJOR DAMAGE:

1. **Document damage:**
    - Voice description of damage
    - Request Mission Control helmet camera capture
2. **Proceed to Section 3.5 (Seal Compromise Protocol)**

3.5 SEAL COMPROMISE PROTOCOL

APPLIES WHEN: Sealing mechanism damaged, non-functional, or integrity uncertain.

PHILOSOPHY: Partial containment better than no containment.

PROCEDURE:

1. **Complete sealing to best of ability:**
    - Even compromised seal provides some barrier
    - Prevents bulk regolith entry
    - Sample retains scientific value
2. **Mark container:**
    - **Bag:** Attach marker to carabiner if available
    - **Box:** Mark lid with "SEAL COMPROMISED"
3. **Document thoroughly:**
    - Voice log:
        - Container ID
        - Nature of compromise
        - Time/location
        - Actions taken
        - Severity assessment
    - Request helmet camera documentation
4. **DO NOT discard sample** - preserve for analysis
5. **Continue to habitat**
6. **Report to Mission Control** via 4G/LTE

    - Await guidance on processing priority
7. **At habitat:**
    - Isolate compromised container from other samples
    - Process compromised samples first (minimize exposure time)

3.6 TETHER FAILURE

SYMPTOM: Lid tether breaks or detaches.

FOR BAG LID TETHER:

1. **If lid is CLOSED when tether fails:**
    - No immediate problem (lid mechanically locked)
    - Note in voice log
    - Continue normally
2. **If lid is OPEN when tether fails:**
    - **CRITICAL: Hold lid, don't let it contact lunar surface**
    - **Temporary solution:**
        - Use NASA sampling tool (tongs) to pick up sample
        - Hold lid in non-dominant hand while using tongs
        - Place sample in bag
        - Transfer lid to dominant hand
        - Seal bag
    - **OR if kneeling:** Rest bag on knee, hold lid, use one hand for tongs
    - Voice log tether failure
    - Continue to rover

FOR BOX LID TETHER:

1. **Grab lid before it drifts** in low gravity
2. **Place lid on rover platform** (inverted, seal-up)
3. **Secure lid:**
    - Brace against rover equipment
    - Or have buddy astronaut hold lid
4. **Complete sealing procedure** with extra care (lid not tethered)
5. **Voice log tether failure**

POST-EVA: Inspect all tethers for fraying, replace as needed

3.7 BOX OVERFILLED - SECOND BAG WON'T FIT

SYMPTOM: Second bag makes stacked height >25,4 cm, lid won't close without crushing bags.

PROCEDURE:

1. **Remove second (upper) bag from box**
2. **Verify first (lower) bag position:**
    - Properly seated on bottom
    - Cushioning compressed appropriately
3. **Attempt second bag again:**
    - Lower bag carefully
4. **If still doesn't fit:**
    - **Accept 1 bag per box for this EVA**
    - Seal box with 1 bag only
    - Use second box for second bag
    - Voice log: "Box [ID] capacity limited to 1 bag due to fit"
5. **Post-EVA analysis:**
    - Verify bag dimensions
    - Check if bags larger than spec
    - Adjust cushioning thickness if needed

SECTION 4: POST-EVA PROCEDURES

4.1 HABITAT ARRIVAL

EVA Termination Sequence:

1. **Preliminary Decontamination (Airlock):**
    - Standard AxEMU dust removal procedures
    - LIRA boxes may have regolith on exterior (expected)
    - Avoid disturbing sealed containers
    - Soft brush on exteriors if very dusty
2. **AxEMU Suit Doffing:**
    - Remove suit per rear-entry procedure
    - **Before doffing:** Remove any bags from waist D-rings
    - Place bags in sample staging area
3. **Box Transfer from Rover:**
    - Move boxes from rover to habitat staging area
    - Use paracord handles for carrying
    - **Maintain VERTICAL orientation** (15,24 cm W × 15,24 cm D × 30,48 cm H)
    - **DO NOT tilt or invert** - bags stacked inside

4.2 SAMPLE INVENTORY AND DOCUMENTATION

In Habitat Sample Processing Area:

1. **Inventory:**

    - Count boxes collected
    - Note box IDs
    - Cross-reference with EVA mission log
    - Voice log: "EVA [NUMBER] return: [X] boxes, [Y] total samples"
2. **Visual Inspection (DO NOT OPEN BOXES):**
    - Examine exteriors
    - Check clamps still latched
    - Look for "SEAL COMPROMISED" markings
    - Photo documentation (each box, multiple angles)
3. **External Seal Verification:**
    - Gently attempt to lift each lid (should not move)
    - Check all clamps engaged
    - Look for gaps around lid perimeter (visual only)
    - **If seal appears compromised:** Mark clearly, process first
4. **Temperature Stabilization:**
    - Allow boxes to reach habitat temperature gradually
    - Typical wait: 30-60 minutes
    - Prevents thermal shock to seals

4.3 STORAGE PENDING EARTH RETURN

Box Stacking Configuration:

LIRA boxes designed for efficient stacking.

Stacking Procedure:

1. **Base Layer:**
    - Place 4 boxes on flat surface (2x2 arrangement)
    - Orient VERTICALLY (15,24 cm W × 15,24 cm D × 30,48 cm H)
    - Handles facing outward for access
2. **Intermediate Lid (Optional for Multi-Layer):**
    - Place flat transport lid on top of base layer
    - Provides stable platform for next layer
    - Distributes weight evenly
3. **Additional Layers:**
    - Stack next layer on transport lid

Storage Environment:

- Temperature: 65-75°F (18-24°C) - habitat controlled
- Orientation: VERTICAL (15,24 cm W × 15,24 cm D base down)
- Humidity: Dry environment (prevent steel corrosion)
- Security: Braced/restrained against spacecraft movement
- Labeling: Clear ID tags, chain-of-custody

4.4 EARTH RETURN - LRL PROCESSING

Pre-Flight:

1. Verify all boxes accounted for
2. Final seal check (visual, no opening)
3. Secure in spacecraft cargo (approved restraints)
4. Chain-of-custody documentation

Upon Earth Landing:

1. **Rapid transport to LRL**
2. **Process "SEAL COMPROMISED" boxes first**
3. **For intact boxes:**

LRL Opening Procedure:

1. **Open in Controlled Atmosphere:**
    - Nitrogen environment or vacuum chamber preferred
    - Unlatch 4 clamps (opposite-pair sequence)
    - Lift lid carefully
2. **Document seal condition:**
    - Photograph EPDM foam (document wear for design improvement)
    - Note compression set or damage
3. **Remove bags from box:**
    - Lift upper bag first
    - Remove cushioning separator
    - Lift lower bag
    - Photograph box interior
4. **Open bags in controlled environment:**
    - Rotate bayonet lock counterclockwise
    - Remove lid (tether stays attached)
    - Extract sample using sterile tools
    - Document bag interior condition
5. **Sample curation:**
    - Standard lunar sample procedures
    - Note any contamination concerns from compromised seals
    - Adjust analysis protocols based on documented handling

SECTION 5: MAINTENANCE AND INSPECTION

5.1 PRE-EVA INSPECTION (IN HABITAT)

COLLECTION BAG (Bare Hands):

- **Bayonet lock:** Rotates smoothly, tabs straight, J-slots clear
- **Tether (15 cm Kevlar lanyard):**
  - Securely attached to lid AND bag body
  - No fraying or cuts
  - Extends and retracts smoothly
  - Breaking strength: >50 lbs (test by pulling firmly)
- **O-ring seal:** Seated properly, no cracks, supple
- **Bag fabric:** No rips, tears, seams intact
- **Interior cushioning:** Steel mesh and wool properly positioned
- **Carabiner:** Gate operates, locking mechanism functional

STORAGE BOX:

- **All 4 clamps (test with AxEMU gloves ON):**
  - Operate smoothly
  - Springs provide firm resistance
  - Latches engage securely
- **EPDM foam seal:**
  - Continuous around perimeter
  - Soft and compressible (not hardened)
  - No tears or missing sections
- **Interior cushioning:**
  - Hexagonal tiles on 4 walls
  - Steel wool on bottom
  - Cushioning separator available for stacking
- **Paracord handle:** Secure, no fraying, supports loaded box weight
- **Box structure:** No dents, cracks, or corrosion

Corrective Actions:

- Any failed component → Flag for repair/replacement
- DO NOT use damaged equipment for EVA

5.2 POST-EVA INSPECTION AND MAINTENANCE

After Each EVA:

1. **Visual Damage Inspection:**
   - Check all surfaces for new EVA damage
   - Regolith abrasion on fabrics
   - Seal contamination or wear
2. **Seal Integrity:**
   - **EPDM foam:** Press with finger - should spring back

        - If remains compressed (compression set), approaching end-of-life
    - **O-ring:** Check for permanent flattening
        - If deformed, replace O-ring
3. **Mechanical Function:**
    - Bayonet lock: Smooth rotation test
    - Clamps: Open/close resistance test
    - Tethers: Inspect for stretch or fraying
    - Carabiner: Gate snap test
4. **Cleaning (EXTERIORS ONLY):**
    - **Clean:** Bag exterior, box exterior, carabiner, clamp handles
    - **DO NOT CLEAN:** Seal surfaces, interiors, bayonet mechanism
    - **Method:** Soft brush, dry only, brush OUTWARD direction
5. **Documentation:**
    - Record in maintenance log:
        - Component ID
        - EVA date
        - Cycle count (number of uses)
        - Condition assessment
        - Repairs performed

5.3 COMPONENT REPLACEMENT SCHEDULE

COLLECTION BAG:

Component	Lifespan (Cycles)	Replacement Indicators	Inspection Frequency
O-ring seal	200-500	Permanent deformation, cracks, hardening	Every 50 cycles
Bayonet mechanism	200-500	Bent tabs, worn J-slots, difficult rotation	Every 50 cycles
Bag fabric	Indefinite	Tears, punctures, seam separation	Each use

Tether(15cm lanyard)	500+	Fraying, stretching, attachment loosening	Every 25 cycles

STORAGE BOX:

Component	Lifespan (Cycles)	Replacement Indicators	Inspection Frequency
EPDM foam seal	**50-75**	Compression set >25%, tears, hardening	**Every 10 cycles**
Clamps	200+	Spring weakness, bent handles	Every 50 cycles
Tether(15cm lanyard)	500+	Fraying, damage	Every 25 cycles
3D cushioning tiles	200-500	Cracks, detachment	Every 25 cycles
Box structure	Indefinite	Dents affecting fit, cracks, corrosion	Each use

CRITICAL: EPDM foam seal has SHORTEST lifespan (50-75 cycles)

- This is the wear-limiting component
- **Monitor closely after 40 cycles**
- **Replace <u>proactively, not reactively</u>**

CYCLE COUNT TRACKING:

Maintain log:

ID	Type	Cycle Count	Last Inspection	Condition	Next Replacement
BAG-001	Bag	23	2026-02-10	Good	50 cycles
BOX-A	Box	47	2026-02-12	Fair (foam compression)	**50 cycles (SOON)**

Replacement Philosophy:

- Replace BEFORE failure, not after
- Cost of replacement << cost of mission failure

SECTION 6: TECHNICAL SPECIFICATIONS

6.1 COLLECTION BAG SPECIFICATIONS

Dimensions:

- **Diameter:** 11 cm
- **Height:** ~16 cm

Materials:

- **Outer layer:** Nylon fabric (⚠️ NOT fire-resistant)
- **Middle layer:** Merino wool (puncture resistance, thermal insulation)
- **Inner layer:** Stainless steel mesh (laceration protection)
- **Seal:** Standard rubber O-ring
- **Lid:** 3D-printed bayonet mechanism (PLA)
- **Tether:** 15 cm Kevlar lanyard (>50 lbs breaking strength)

Sealing Mechanism:

- **Primary:** Bayonet J-lock (25° rotation, 3 locking tabs)
- **Seal type:** O-ring compression seal (semi-hermetic)

AxEMU Compatibility:

- Bayonet lock sized for gloved operation
- Grip surfaces optimized for 15-20 lbs grip strength
- Visual inspection compatible with helmet bubble field-of-view

Temperature Tolerance:

- **Operational:** -40°F to 180°F (-40°C to 82°C) - O-ring limit
- **Nylon melting point:** 420°F (215°C) - keep away from heat

Limitations:

- NOT flame-resistant (nylon is flammable)
- Wool absorbs moisture (30% max) - dry environment only
- Poor petroleum chemical resistance

6.2 STORAGE BOX SPECIFICATIONS

Dimensions:

- **External:** 15,24 cm W × 15,24 cm D × 30,48 cm
- **Wall thickness:** 0,1905 cm (14 gauge steel)

Capacity:

- **2 bags stacked VERTICALLY** (one on top of other)

Materials:

- **Structure:** A569/A1011 Carbon Steel, ASTM A36
    - Requires corrosion protection (powder coating/galvanizing/paint)
    - Will rust in 6-12 months if unprotected in humid environment
- **Seal:** EPDM foam (compression seal, semi-hermetic)
- **Cushioning:**
    - 3D-printed hexagonal tiles on 4 walls and bottom (PLA)
    - Steel wool padding on 4 walls and bottom
- **Handle:** Kevlar-core paracord, welded stainless steel eyelets

Latching System:

- **4 clamps** (stainless steel or corrosion-resistant alloy)
- Configuration: 4 corners (Front-Left, Front-Right, Rear-Left, Rear-Right)
- Force required: ~5-10 lbs per clamp (within AxEMU 15-20 lbs grip)

Temperature Tolerance:

- **EPDM seal limit:** -40°F to 250°F (-40°C to 121°C)

- **Steel structure limit:** -40°F to 540°F (-40°C to 282°C)
- **Operational range:** Limited by EPDM = -40°F to 250°F

AxEMU Compatibility:

- Clamp handles sized for gloved operation (15-20 lbs grip)
- Box height (12") allows easy access with AxEMU bending
- Paracord handle compatible with AxEMU glove grip

Limitations:

- **Heavy:** 2.9× heavier than aluminum alternatives
- **Corrosion-prone:** Requires protective coating maintenance
- **EPDM seal lifespan:** 50-75 cycles (shortest-lived component)
- **Single-mission suitable:** Best for 1-2 Artemis missions, not sustained base ops

6.3 OPERATIONAL PARAMETERS

Sample Constraints:

- **Maximum size:** Baseball-sized (7.5 cm diameter)
- **Weight:** No limit specified, but consider:
    - AxEMU waist attachment comfort
    - Astronaut fatigue during traverse
    - Typical lunar rock: 2-6 lbs for baseball-sized

Sealing Effectiveness:

- **Bag:** Semi-hermetic (O-ring compression)
    - Contamination **reduction**, not absolute isolation
    - Prevents bulk regolith entry
    - Allows slow gas permeation over time
- **Box:** Semi-hermetic (EPDM foam compression + pressure valve)
    - Secondary containment layer
    - With valve closed: maintains vacuum or pressurized environment
    - **Two-layer containment** (bag + box = better than single seal)

Environmental Exposure:

- Lunar surface vacuum compatible
- Temperature extremes (within limits specified)
- Regolith dust-resistant (minimized, not eliminated)

EVA Duration:

- AxEMU: 8-hour capability

- Compatible with multiple samples per EVA

Planetary Protection:

- Partial contamination barrier (semi-hermetic)
- Suitable for **lunar samples** (low biological risk)

Chain of Containment:

1. Sample collected with NASA tools (no glove contact)
2. Placed in LIRA bag → sealed (1st barrier)
3. Bag in LIRA box → sealed (2nd barrier)
4. Box in pressurized habitat
5. Box in spacecraft
6. Opened in LRL controlled environment

APPENDIX A: QUICK REFERENCE CHECKLIST

SAMPLE COLLECTION (BAG + NASA TOOLS)

- 1. Locate sample at site
- 2. Choose work position (standing default, kneeling if beneficial)
- 3. Detach bag from LEFT waist D-ring
- 4. Position bag (hold, or rest on surface/knee)
- 5. Unlock bayonet (rotate CW) - lid hangs on 15 cm tether
- 6. Deploy NASA sampling tool (tongs/scoop) from RIGHT waist
- 7. Collect sample with tool
- 8. Transfer sample from tool into bag
- 9. Stow NASA tool
- 10. Retrieve tethered lid, align, lower onto bag
- 11. Push down, rotate CCW to lock bayonet (feel click)
- 12. Verify seal (visual - no touching)
- 13. Voice log: "Sample [#] sealed in bag [ID]"
- 14. Reattach bag to LEFT waist D-ring
- 15. Return to rover

SAMPLE STORAGE (BOX)

- 1. Arrive at rover
- 2. Unlatch clamps: 1 → 3 → 2 → 4 (opposite pairs)
- 3. Lift lid, place inverted on rover platform
- 4. Visually inspect box interior

- 5. Detach bag from waist
- 6. Lower bag VERTICALLY into box:
    - **First bag:** Bottom of box
    - **Second bag:** On top of separator (stacked vertically)
- 7. Verify bag position (upright, centered, clearance for lid)
- 8. Inspect EPDM seal (visual only - no touching, brush if dusty)
- 9. Replace lid on box (level, even contact)
- 10. Latch clamps: 1 → 3 → 2 → 4 (opposite pairs)
- 11. Verify seal (visual + gentle pull test)
- 12. Voice log: "Box [ID] sealed, [1 or 2] bags stored"

APPENDIX B: NASA SAMPLING TOOLS INTERFACE

NASA-Provided Tools (Not LIRA Scope):

Long-Handled Tongs (30 - 45 cm):

- For individual rock collection
- Prevents glove-to-sample contact
- Stored on AxEMU RIGHT waist D-ring or tool carrier

Scoop:

- For smaller rocks or regolith collection
- Stainless steel or aluminum construction
- Stored on AxEMU RIGHT waist or rover tool rack

Hammer and Chisel:

- For extracting samples from larger formations
- Stored on rover tool rack

Sample Bag Dispenser:

- Holds multiple LIRA bags for multi-sample EVAs
- Mounted on rover or AxEMU suit
- Astronaut retrieves fresh bag for each sample

LIRA Integration Points:

1. **Tool → Sample:** NASA tools collect sample (no glove contact)
2. **Sample → LIRA Bag:** Transfer from tool into open LIRA bag
3. **LIRA Bag → Storage:** Sealed bag placed in LIRA box

Sample Contamination Control:

- NASA tools contact sample ONLY
- Gloves do NOT contact sample
- Tools do NOT contact LIRA bag sealing surfaces
- LIRA provides sealed containment after collection

APPENDIX C: BUDDY SYSTEM PROCEDURES (OPTIONAL)

Artemis III EVAs typically have **2 astronauts**. Buddy can assist with LIRA operations:

During Sample Collection:

- **Buddy holds LIRA bag** while primary astronaut uses NASA tools
- **Buddy verifies seal closure** (visual check from different angle)
- **Buddy photo-documents** collection site with helmet camera
- **Buddy provides stability** if primary astronaut kneeling

During Box Storage:

- **Buddy holds box lid** while primary astronaut places bag
- **Buddy inspects seal** from different viewing angle
- **Buddy confirms all 4 clamps latched**

Emergency Situations:

- **Buddy assists astronaut** to rise from kneeling if difficulty
- **Buddy retrieves dropped equipment** in low gravity
- **Buddy provides second set of hands** if tether fails

Communication:

- Coordinate via AxEMU 4G/LTE voice
- "I'll hold the bag, you work the tongs"
- "Seal looks good from my angle"
- "All four clamps confirmed latched"

Buddy system is OPTIONAL but RECOMMENDED for increased efficiency and safety.

APPENDIX D: SAMPLE TRACKING INTEGRATION

NASA Sample Numbering System (Not LIRA Scope):

NASA provides:

- Pre-assigned sample numbers (mission planning)
- Physical tags or labels for bags/boxes
- Digital tracking system

LIRA Integration:

Sample ID Assignment:

- NASA Mission Control assigns: "Sample 001, Sample 002," etc.
- Astronaut voice logs sample number when collected
- LIRA bag ID (BAG-001, BAG-002) linked to sample number in database

Physical Labeling:

- NASA may provide labels/tags to attach to LIRA bags
- Astronaut applies label before or after sealing
- Label survives EVA, transport, LRL processing

Voice Log Format:

- "Sample 003 collected at [LOCATION], sealed in LIRA bag BAG-005"
- Mission Control records in database: Sample 003 = Bag BAG-005
- Later: "Bag BAG-005 stored in Box BOX-B"
- Chain established: Sample 003 → Bag BAG-005 → Box BOX-B

Digital Tracking:

- AxEMU 4G/LTE transmits voice logs to Mission Control
- Mission Control updates database in real-time
- Chain-of-custody maintained digitally

LIRA Role:

- Provide containment and transport
- Interface with NASA tracking system
- Voice log integration points defined in protocol

APPENDIX E: TROUBLESHOOTING GUIDE

Problem	Possible Cause	Solution	Reference
Bayonet lock won't engage	Debris in J-slots	Clear slots carefully, retry	Section 3.1
Sample won't fit	Too large (>3")	Use NASA tools to remove, select smaller sample	Section 3.2
Box clamp broken	Mechanical failure	Use 3 remaining clamps in modified sequence	Section 3.3
EPDM seal contaminated	Regolith dust	Brush gently with glove edge, visual only	Section 3.4
Lid tether breaks	Lanyard failure	Hold lid carefully, complete procedure, voice log	Section 3.6
Second bag won't fit box	Bags too tall stacked	Use 1 bag per box, use second box	Section 3.8

END OF DOCUMENT