Lunar Operations

Adjustable Tool Cart Handle (ATCH)

Background

For the upcoming Artemis III mission, astronauts will be tasked with completing numerous extravehicular activities (EVAs) on the lunar surface. Though the objectives of each EVA are different, many tools are required to accomplish tasks ranging from digging trenches to collecting regolith core samples. Astronauts will use a tool cart to transport these tools across the lunar surface. Translating along the lunar surface while pushing a loaded tool cart has proven to be difficult due to suit mobility limitations, physical interactions between the cart and the lunar surface (e.g., friction, obstacles, slope), and inefficient force application. To optimize force application, the tool cart handle must accommodate astronauts along the full anthropometric range, allowing adjustability between crew members of large size difference. Design a reliable, ergonomic, and dust-tolerant tool cart handle that can be used by all astronauts within the anthropometric range to traverse the lunar surface.

Objective

Design an adjustable tool cart handle (ATCH) that allows 1st – 99th percentile astronauts to easily traverse the lunar surface. The ATCH should allow astronauts to push, maneuver, and quickly stop. The handle adjustment mechanism must be glove-compatible to allow reliable, safe EVA actuation. The handle adjustment mechanism must also be dust-tolerant, as residual lunar regolith on the gloves is sure to make its way onto the tool cart handle. Astronauts will use the device with limited mobility in a space suit, so carefully consider the ergonomics of your device's operations. The tool will be tested with the Government Reference Design (GRD) tool cart in the Neutral Buoyancy Laboratory (NBL) for overall tool function and concept of operations, as well as in the Simulant Development Lab (SDL) at NASA's Johnson Space Center, for the ability to operate within dusty environments.

Assumptions

- The Adjustable Tool Cart Handle (ATCH) will interface with the existing Government Reference Design (GRD) Tool Cart.
  - Reference provided drawings for details on interface hardware requirements.
- In the NBL, we will weigh the test subject and cart out to near-lunar gravity (1/6 of Earth's gravity), and they will walk along the bottom of the NBL pool. Selected teams will be responsible for their own test plans. The NBL will be responsible for facility-related hazards (e.g., drowning, barotrauma).
  - To simulate being in a spacesuit, the subject will be diving with a surface supplied diving helmet and EVA gloves. The helmet reduces peripheral visibility, and the gloves reduce dexterity.
  - The NBL pool is ~86 °F and 40 ft. deep.
  - We will test the device in coarse sand on the floor of the NBL.
- In the SDL, the team will test their own device using lunar simulant. Selected teams will be responsible for their own test plans. The SDL will be responsible for facility-related hazards (e.g., inhalation, handling of simulant).
  - You will test the device in a lunar simulant bin at the SDL.

Hardware to Provide

- One Adjustable Tool Cart Handle Device, configured for NBL testing.
  - We will evaluate the device concept of operations in the NBL, where a test subject will provide feedback on overall usage of the tool.
  - Bring the fully assembled tool configured as it would be used during a lunar EVA.
- One Adjustable Tool Cart Handle Device, configured for lunar simulant testing.
  - The ability of the device to smoothly operate despite dust intrusion will be tested in the SDL, where a lunar simulant will be used.
  - Bring the portion(s) of the tool required for handle position adjustment. The mechanism(s) that allow this functionality are the focus for simulant testing.
- ***NOTE:*** *You may choose to use the same hardware for the NBL and simulant testing. However, there will be approximately 24 hours between your test in the pool and in the SDL. Teams must provide fully dry devices for simulant testing. This means you may need to disassemble and dry or replace certain components which will not fully dry in time.*

Requirements

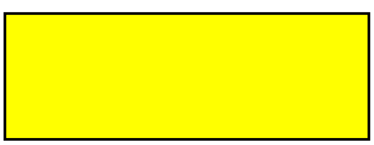
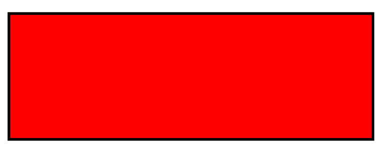
Requirement Number	Minimum Acceptable	Desired
Functional Requirements		
1	You should provide a device that allows astronauts within the full anthropometric range to maneuver the tool cart. The tool cart handle should adjust between 35-47 in. of height.	We prefer that the device enables easier, more efficient maneuverability of the tool cart along the lunar surface.
2	The device shall allow maneuverability of the tool cart despite dust intrusion or jamming.	We prefer that the device is dust-tolerant and allows actuation of adjustment despite exposure to the dusty lunar surface environment.
3	Mass of the device shall not exceed 5 lbs in Earth gravity.	We prefer that the tool or suite of tools does not exceed 2.5 lbs in Earth gravity.
4	The device shall fit within a volume of 16 in. x 16 in. x 20 in.	
5	For a linear-actuating mechanism, the force required to actuate shall not exceed 20 lbf (89 N). For a rotating mechanism, the torque required to actuate shall not exceed 30 in-lb (3.4 Nm).	
6	The tool shall require only manual power.	
7	The device shall pass stress analysis, meeting or exceeding a factor of safety of 2.0 for ultimate stress. Submit a preliminary hand-calculated stress analysis of your proposed design as part of your proposal. It is expected for your stress analysis to include free body diagrams, tracked assumptions, and equations. Finite Element Analysis (FEA) may be included but is optional. Conduct your stress analysis assuming nominal operation. The objective of the analysis is to identify the most critical component of your device(s) (i.e., the first part to fail, the part with the lowest factor of safety). Report factors of safety based on your design, materials selected, and input loads required for nominal operation. Remember to consider sub-components of mechanisms.	We prefer the following stress analyses: • The device passes stress analysis for a 99th percentile astronaut applying their full weight to the end of the handle in lunar gravity (1/6 of Earth's gravity). • The device passes stress analysis for being dropped in any orientation from 4 feet above the ground in lunar gravity (1/6 of Earth's gravity). *Note: While it is not a requirement, please consider the implications of dropping the device in Earth gravity when writing your Hazard Analysis.*

	Note: If your proposal is selected, you will be expected to provide additional stress analysis in the spring semester.	
8	The device must sink in water.	
Requirement Number	**Minimum Acceptable**	**Desired**
Material Requirements		
9	You should make the device from materials on the NBL Approved Materials List (contained in the Proposal Guidelines document). This includes metals, plastics, lubricants, coatings, foam, and adhesives. We may grant a waiver on a case-by-case basis if the team provides rationale for a material not included on the NBL Approved Materials List and receives approval. The proposed design shall specify all materials used in the provided hardware. **No regular PLA allowed.** Tough PLA is acceptable.	
10	All 3D printed components must be at least 75% infill. This is to help ensure 3D printed parts are strong enough for the application and dense enough to sink in water.	The tool cart handle is subject to significant loads during use. We prefer that all cantilevered, mechanism, and handle components are machined out of an NBL-compatible metal.
Safety Requirements		
11	There shall be no sharp edges on the device except functional sharp edges needed to meet the required challenge functionality. All functional sharp edges must be protected/inaccessible to the subject when not being used. All functional sharp edges must remain outside a "keep out zone" of at least 3 in. away from the user's hands.	We prefer that the device can meet the challenge functionality with no sharp-edged components.
12	You should present hazards inherent to the device in the proposal and, if selected, in subsequent deliverables to Micro-g NExT. See the Proposal Guidelines document for guidance on conducting a hazard analysis.	
13	There shall be no pinch points on the device. Any pinch points that cannot be eliminated shall be labeled per NBL Labeling Guidelines.	

14	Uncovered holes or gaps, other than tether points, shall be less than 0.5 in. (1.27 cm) or greater than 1.4 in. (3.56 cm) to avoid finger entrapment. Any holes or gaps which cannot be eliminated shall be labeled per NBL Labeling Guidelines.	
15	Hazards that cannot be eliminated (e.g., a functional sharp edge) shall be labeled as “Do Not Touch” zones per NBL Labeling Guidelines.	
16	Areas on the device that are intended for the user to hold shall be labeled per NBL Labeling Guidelines.	

Additional Considerations

- Consider what the astronaut(s) will grab onto to stabilize the device during operation. Handles should be suitable for use with a pressurized suit glove. *Note: smooth, round, rod-like handles tend to cause hand fatigue in a spacesuit glove.*
- Consider the ergonomics of wearing a pressurized space suit. Any operations requiring fine motor control in the hands or requiring the astronaut to get into an unnatural body position will be much harder to conduct in a space suit.
- Refer to the following NBL Labeling Guidelines below to color code your device as outlined below to ensure safe test subject handling and usage of your tool.

NBL Labeling Guidelines		
Intended Touch Zones	**Do Not Touch Zones**	**Pinch Points**
 Solid Yellow	 Solid Red	 Striped Red and White
A handle, switch, or trigger that is intended for the test subject to use.	A keep out zone around a functional sharp point.	An area to avoid placing hands when actuating a moving part.

  - Labeling may be done with marker, vinyl tape, paint, 3D-printed colored filament, waterproof label, etc. as long as it is colorfast and remains intact when exposed to chlorinated water.
  - Ensure your labeling does not interfere with your device functionality.

Low Earth Orbit Operations

Passive Capture Tool Dock

Background

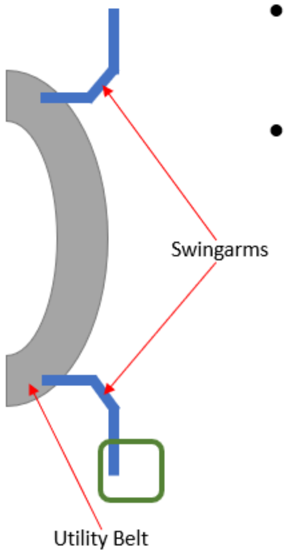
Often seen as the highlight for many astronauts during their time living aboard the international space station, extravehicular activities are critical to the health of the International Space Station (ISS). During each EVA, astronauts often translate across the outside of the ISS carrying many tools, all of which must be tethered or securely attached to the space suit. One of the main methods for EVA tool stowage is on the outside of the hip of the space suit, along the Mini Work Station (MWS) swingarms. The swingarms provide a method for stowed tools to rotate in and out of the astronaut work envelope (e.g. the volume in which methods for EVA tool stowage all require a dedicated actuation (e.g. toggling a switch, sliding a lock) to ensure that the tool is securely stowed. However, requiring a dedicated actuation action becomes cumbersome throughout an 8-hour EVA, when astronauts often find themselves in unusual body positions, unable to use both hands, or both. All tool stowage devices require single-fault tolerance, which ensures that the tool will remain secured despite any single failure of the stowage mechanism. Find a reliable, ergonomic way to allow astronauts to securely stow EVA tools without a dedicated actuation. The reliability of EVA tool stowage is critical for EVA success, as the loss of any tool may result in lost EVA objectives.

Objective

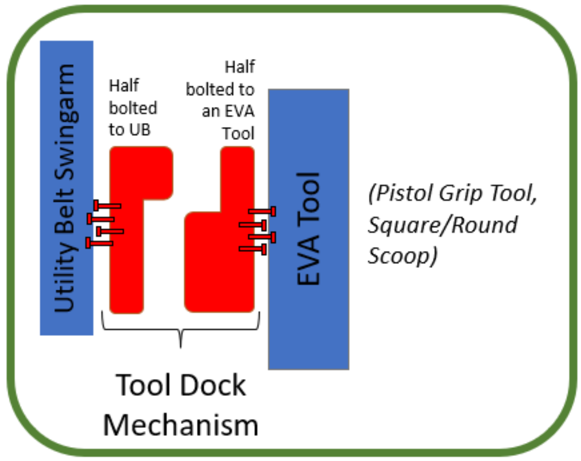
Design an EVA tool dock (e.g. receptacle and probe interface) that allows one-handed tool installation without a dedicated actuation. You should be able to install the tool without touching the tool dock receptacle or probe. Despite the lack of a dedicated stowage actuation, the tool dock should still retain the tool with single-fault tolerance (e.g. two individual buttons, switches, toggles, etc. must be actuated to detach the tool). The tool dock must be glove-compatible to allow reliable, safe EVA usage. Astronauts will use the tool dock with limited mobility in a space suit, so carefully consider the ergonomics of your device's operations. The tool will be tested in the Neutral Buoyancy Laboratory (NBL) for overall tool function and concept of operations.

Assumptions

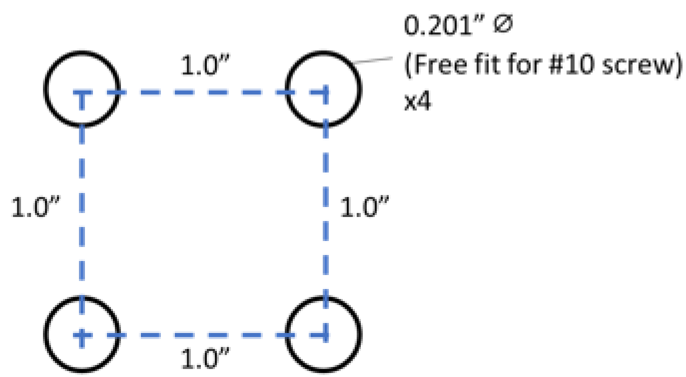
- You are to design 2 items: The interface component that will be on an existing EVA Tool and the corresponding interface piece that will be on the Utility Belt Swingarm.



- Student-provided:
  - Tool Dock Mechanism
  - **Screws
- NASA-provided:
  - Utility Belt Swingarm
  - EVA Tool(s) w/ 4-bolt hole pattern



- Use the following bolt-hole pattern for interfacing with the Utility Belt Swingarm and the existing EVA Tool.



- In the NBL, test subject will be weighed out to near-micro gravity (Zero Gravity), they will ingress a foot restraint and begin testing. Selected teams will be responsible for their own test plans. The NBL will be responsible for facility-related hazards (e.g., drowning, barotrauma).
  - To simulate being in a spacesuit, the subject will be diving with a surface supplied diving helmet and EVA gloves. The helmet reduces peripheral visibility, and the gloves reduce dexterity.
  - The subject will also don a Utility Belt with two swingarms (left and right) to simulate the ISS MWS.
  - The NBL pool is ~86 °F and 40 ft. deep.

Hardware to Provide

- Two tool dock devices (4 components), configured for NBL testing.
    - We will evaluate the device concept of operations in the NBL, where a test subject will provide feedback on overall usage of the tool.
    - Two tool dock devices will be used during testing, both of which will be installed on the test subjects Utility Belt, one on each Swingarm (left and right).
    - Bring the fully assembled tool configured as it would be used during an ISS EVA.

Requirements

Requirement Number	Minimum Acceptable	Desired
Functional Requirements		
1	The device shall allow one-handed tool installation.	We prefer that the device enables one-handed, blind installation. (i.e. Tool installation can be done without looking)
2	The device shall retain the tool with single fault-tolerance. In other words, the device requires two independent actuations to detach the tool.	
3	Mass of the device shall not exceed 2 lbs in Earth gravity.	We prefer that device does not exceed 1 lbs in Earth gravity.
4	The device shall fit within a volume of 5 in. x 5 in. x 5 in.	We prefer that the device fit within a volume of 3.5 in. x 3.5 in. x 3.5 in. The smaller the better.
5	For a linear-actuating mechanism, the force required to actuate shall not exceed 10 lbf (44.5 N). For a rotating mechanism, the torque required to actuate shall not exceed 1.5 in-lb (1.7 Nm).	
6	The device shall support at least 15 lbs of weight in Earth gravity. In other words, the device must support a tool that weighs 15 lbs.	
7	The tool shall require only manual power.	
8	The device shall pass stress analysis, meeting or exceeding a factor of safety of 2.0 for ultimate stress. Submit a preliminary hand-calculated stress analysis of your proposed design as part of your proposal. It is expected for your stress analysis to include free body diagrams, tracked assumptions, and equations. Finite Element Analysis (FEA) may be included but is optional. Conduct your stress analysis assuming nominal operation. The objective of the analysis is to identify the most critical component of your device(s) (i.e., the first part to fail, the part with the lowest factor of safety). Report factors of safety based on your design, materials selected, and input loads required for nominal operation.	*Note: While it is not a requirement, please consider the implications of dropping the device in Earth gravity when writing your Hazard Analysis.*

	Remember to consider sub-components of mechanisms. *Note: If your proposal is selected, you will be expected to provide additional stress analysis in the spring semester.*	
9	The device must sink in water.	
Requirement Number	**Minimum Acceptable**	**Desired**
Material Requirements		
9	You should make the device from materials on the NBL Approved Materials List (contained in the Proposal Guidelines document). This includes metals, plastics, lubricants, coatings, foam, and adhesives. We may grant a waiver on a case-by-case basis if the team provides rationale for a material not included on the NBL Approved Materials List and receives approval. The proposed design shall specify all materials used in the provided hardware. **<u>No regular PLA allowed</u>.** Tough PLA is acceptable.	
10	All 3D printed components must be at least 75% infill. This is to help ensure 3D printed parts are strong enough for the application and dense enough to sink in water.	We prefer that Tool Dock components are machined out of an NBL-compatible metal.
Safety Requirements		
11	There shall be no sharp edges on the device except functional sharp edges needed to meet the required challenge functionality. All functional sharp edges must be protected/inaccessible to the subject when not being used. All functional sharp edges must remain outside a “keep out zone” of at least 3 in. away from the user’s hands.	We prefer that the device can meet the challenge functionality with no sharp-edged components.
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13	There shall be no pinch points on the device. Any pinch points that cannot be eliminated shall be labeled per NBL Labeling Guidelines.	

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16	Areas on the device that are intended for the user to hold shall be labeled per NBL Labeling Guidelines.	

Additional Considerations

- Consider the ergonomics of wearing a pressurized space suit. Any operations requiring fine motor control in the hands or requiring the astronaut to get into an unnatural body position will be much harder to conduct in a space suit. Additionally, consider the line-of-sight limitations imposed by the space suit.
- Refer to the following NBL Labeling Guidelines below to color code your device as outlined below to ensure safe test subject handling and usage of your tool.

NBL Labeling Guidelines		
Intended Touch Zones	**No Touch Zones**	**Pinch Points**
Solid Yellow	Solid Red	Striped Red and White
A handle, switch, or trigger that is intended for the test subject to use.	A keep out zone around a functional sharp point.	An area to avoid placing hands when actuating a moving part.

  - Labeling may be done with marker, vinyl tape, paint, 3D-printed colored filament, waterproof label, etc. as long as it is colorfast and remains intact when exposed to chlorinated water.
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