MICRO-G NEXT
Neutral Buoyancy Experiment Design Teams

National Aeronautics and Space Administration

2024 Micro-g NExT CHALLENGES

1 LUNAR SURFACE OPERATIONS

HAND CARRIER FOR LUNAR EVA TOOLS

Design a hand carrier for lunar EVA tools that can be adjusted to at least two different heights: short for transport and tall for working at the sampling site.

2 LUNAR SURFACE OPERATIONS

LUNAR FLAG

Design a lunar flag, flagpole, and anchoring system that can be deployed on the lunar surface.

3 LUNAR SURFACE OPERATIONS

LUNAR MAPBOOK HOLDER

Design a mapbook and holder for lunar EVAs with adjustability in height, forward and aft tilt, and planar rotation.

4 ORION CREW SAFETY

SEARCH AND RESCUE PLATFORM FOR OPTICAL TARGET RECOGNITION (SPOTR)

Design a stationary autonomous system capable of meeting specific requirements to support open-ocean search and rescue situational awareness.

Learn more at microgravityuniversity.jsc.nasa.gov

MICRO-G NEXT 2024 DESIGN CHALLENGES

NASA's Micro-g Neutral Buoyancy Experiment Design Teams (Micro-g NExT) challenges undergraduate students to design, build, and test a tool or device that addresses an authentic, current space exploration challenge. The overall experience includes hands-on full-scale engineering design, test operations, and public outreach. Throughout Micro-g NExT, students submit a proposed design before completing a preliminary design review, test equipment data package, and test readiness review to review boards of NASA employees. Test operations are conducted in the lunar analog testing environment of the Neutral Buoyancy Laboratory (NBL). Professional NBL divers will test the tools and students will direct the divers from the Test Conductor Room of the NBL facility. Micro-g NExT provides a unique opportunity to contribute to NASA's missions as the design challenges are identified by NASA engineers as necessary in space exploration missions. The 2024 Micro-g NExT challenges focus on Orion crew safety and lunar extravehicular activities (EVA) operations during the Artemis missions.

NASA Micro-g NExT Challenge

Lunar Surface Operations

Hand Carrier for Lunar EVA Tools

Background

NASA is challenged to go forward to the Moon during the Artemis missions. Artemis III astronauts will collect geological lunar samples during extravehicular activities (EVAs) using a suite of tools such as scoops, rakes, and extension handles. To transport tools to various sampling sites on the lunar surface, the astronauts will need a hand carrier. The carrier must be short enough to comfortably carry while walking long distances without hitting the ground but be adjustable to a taller height to allow the astronaut to access the tools on the carrier without kneeling. This requires an EVA-adjustable mechanism to allow the astronaut to easily select a comfortable height to position the tools. The mechanism must be dust-tolerant to remain usable in the dusty lunar environment, and it must be secure when adjusted to each intended height (i.e. no tipping, collapsing, etc.). Find a reliable, dust-tolerant, and ergonomically friendly way to store and carry tools on a hand carrier with adjustable height.

Objective

Design a hand carrier for lunar EVA tools that can be adjusted to at least two different heights: short for transport and tall for working at the sampling site. Finer adjustment capability is permitted as long as it is easily executed by a suited astronaut during an EVA. The adjustment system must be dust-tolerant, so carefully consider the materials and motions to be used in the mechanism.

Focus Areas

Materials science, geology, ergonomics, biomechanics, mechanical engineering

Assumptions

- The subject will be weighed out to near-lunar gravity (1/6 of Earth's) and can walk on the bottom of the NBL pool floor.
- The device will be tested in two phases:
  - Underwater at the Neutral Buoyancy Laboratory (NBL)
  - Dry testing environment with lunar simulant

Hardware to Provide

- 1 full Hand Carrier with locations to mount tools and dust-tolerant height adjustment mechanism.
  - NASA will provide information about options for mounting tools to the hand carrier.
  - Do not build geology tools. NASA will provide lunar EVA geology tools when you arrive at the NBL during test week. NASA will provide information about the tools your carrier must interface with.
- 1 Mechanism-only portion of the hand carrier.
  - This will be used for dust testing (dry).

Requirements (continued next page)

1	An adjustable-height, dust-tolerant hand carrier for lunar EVA tools shall be produced.
2	Mass of the empty, fully assembled hand carrier shall not exceed 10 lbs in 1G Earth gravity.
3	For a linear-actuating mechanism, force required to actuate shall not exceed 20 lbf (89 N). For a rotating mechanism, torque required to actuate shall not exceed 30 in-lb (3.4 Nm).
4	Hand carrier shall support 9 lbm of lunar EVA tools. Note: this is 9 lbm measured in 1G Earth gravity.
5	Loaded hand carrier shall maintain structural stability during carrying and deployment.
6	Hand carrier shall have a designated location and interface for each EVA tool (scoop, rake, extension handle, tongs).

7	At least two heights shall be available for adjustment. Additional intermediate heights may be provided if desired.
8	Carrying height: height of carrier in short configuration shall be between 16.5 and 20 in. to allow an astronaut to lift and carry the hand carrier
9	Deployed height: height of carrier in tall configuration shall be between 28 and 32 in. to allow an astronaut to easily access tools on the deployed carrier.
10	The empty, fully assembled hand carrier, when in its deployed configuration, shall fit within a volume of 32 in. height x 25 in. width x 30 in. depth.
11	The empty, fully assembled hand carrier, when in its carrying configuration, shall fit within a volume of 20 in. height x 25 in. width x 10 in. depth.
12	The proposed design shall specify all materials the provided hardware will be made from.
13	The non-mechanism portions of the hand carrier may be made from any NBL-accepted materials. A waiver may be granted on a case-by-case basis*. **(No regular PLA allowed.** Tough PLA is okay.)
14	All components of the mechanism shall be made of metal*.
15	The hand carrier, adjustment mechanism interface, and tool mounts shall be usable with EVA gloved hands (like heavy ski gloves).
16	The hand carrier should not impede the astronaut's movement while being carried.
17	The hand carrier and adjustment mechanism shall use only manual power.
18	There shall be no holes or openings which would allow/cause entrapment of fingers on the device.
19	There shall be no sharp edges on the device.

***Materials:** The mechanisms must be made from metals because plastic components will become jammed and/or damaged by lunar simulant. The remaining parts of the hand carrier may be manufactured from both metals and non-metallic materials but must adhere to the NBL Approved Materials List. Your proposal must detail your selected materials and provide rationale for any materials not included on the NBL Approved Materials List.

The NBL pool is ~86 °F and 40 ft. deep.

Additional Considerations

- A mechanism is considered dust-tolerant when it can be buried in lunar regolith simulant and remain operable when removed. Two common approaches to achieving this result are (a) designing a mechanism that is open enough to allow dust to fall through it, and (b) designing a mechanism with tight tolerances to prevent dust from entering while using hard materials to crush any dust that does penetrate the mechanism.
- The hand carrier mechanism will be buried and actuated in lunar simulant multiple times during the test.
- Consider what the astronaut will grab onto to lift and carry the hand carrier. 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.
- For requirement 16: Minimize the hand carrier bumping into the astronaut's leg during carrying and walking. It may not be possible to fully eliminate this, but the most comfortable solution for the astronaut will be one that doesn't repeatedly strike their leg or cause them to inadvertently kick the carrier while walking.

NASA Micro-g NExT Challenge

Lunar Surface Operations

Lunar Flag

Background

NASA is challenged to go forward to the Moon during the Artemis missions. Artemis III astronauts will conduct several extravehicular activities (EVAs) on the lunar surface. One important, symbolic task during EVAs will be to deploy a flag on the lunar surface.

The American flags deployed during the Apollo missions were similar in height to the astronauts and were deployed in a method similar to a garden stake. While the Apollo design was simple and effective, Artemis III presents an opportunity to improve upon the design, including increasing height, improving stability, and making deployment easier. To fit in the flight vehicle, the flag must be collapsible to a small volume, while remaining easy to deploy.

Develop a reliable, stable, and ergonomically friendly flag that can be deployed quickly on the lunar surface.

Objective

Design a lunar flag, flagpole, and anchoring system that can be deployed on the lunar surface. The flag must remain standing vertically when subjected to axial and side loads. The flag must also be collapsible to a small volume to fit on the flight vehicle; carefully consider the materials and mechanisms used to ensure a suited astronaut can assemble the flag in dusty conditions.

Focus Areas

Materials science, geology, ergonomics, biomechanics, mechanical engineering

Assumptions

- The subject will be weighed out to near-lunar gravity (1/6 of Earth's) and can walk on the bottom of the NBL pool floor.
- The flagpole and flag will be tested underwater at the Neutral Buoyancy Laboratory (NBL)
- The flag will be tested underwater in a barrel of sand 3 ft. in diameter and 3 ft. deep.

Hardware to Provide

- 1 Lunar Flag Assembly, including flag, flagpole, and anchoring device

Requirements (continued next page)

1	A structurally stable, easily deployed flag for lunar EVA shall be developed.
2	Mass of the full flag assembly shall not exceed 10 lbs. in 1G Earth gravity.
3	For any mechanisms used: For a linear-actuating mechanism, force required to actuate shall not exceed 20 lbf (89 N). For a rotating mechanism, torque required to actuate shall not exceed 30 in-lb (3.4 Nm).
4	All mechanisms used shall be dust tolerant.
5	The flag shall remain deployed vertically and anchored without the use of an operator.
6	The flag shall be deployable from its stowed configuration in 10 minutes or less.
7	When deployed, lunar flag shall remain anchored when pulled upward with a 10 lb. force.
8	When deployed in the ground, lunar flag shall remain anchored when pulled laterally from the top of the flagpole with a 10 lb. force.
9	A 1 in. tether loop shall be included at the top of the flagpole for use in applying axial and side loads during testing.
10	The flag shall have a method of remaining unfurled in the absence of wind.
11	Height of the deployed flag shall be no less than 96 in. and no more than 120 in.
12	Flag size shall be 3 ft. x 5 ft.
13	Flag shall not touch the ground during deployment operations or once deployed.

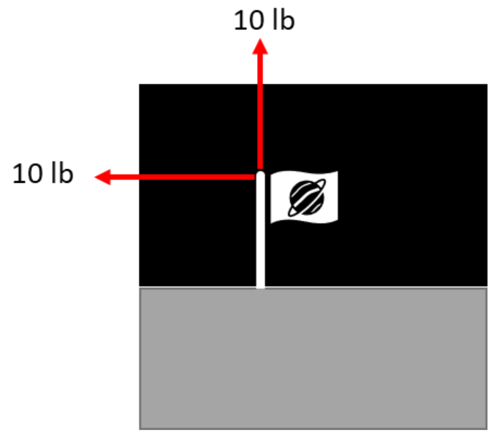
14	Flag shall be the flag of the institution the student team is from. For any multi-institution teams, please contact jsc-reducedgravity@nasa.gov for guidance.
15	Flag assembly shall be collapsible into an EVA-compatible stowed configuration* that fits within a volume of 48 in. x 12 in. x 8 in.
16	The proposed design shall specify all materials the provided hardware will be made from.
17	All materials used must be on the NBL Approved Materials List**. A waiver may be granted on a case-by-case basis. **(<u>No regular PLA allowed</u>.** Tough PLA is okay.)
18	Stress analysis and physical testing shall be conducted on the flagpole and anchoring system to ensure the materials and design are properly selected to ensure no structural damage occurs. **You are expected to show stress analysis in the proposal.** Physical testing may be done later.
19	Factor of safety of at least 1.25 shall be used in stress analysis and physical testing. Specify the factor of safety used in the proposal.
20	The flag, flagpole, and anchoring system shall be usable with EVA gloved hands (like heavy ski gloves).
21	The flag, flagpole, and anchoring system shall use only manual power.
22	There shall be no holes or openings which would allow/cause entrapment of fingers on the device.
23	There shall be no sharp edges on the device.

*** EVA-compatible stowed configuration:** This means the flag, flagpole, and anchoring system can be stowed in such a way that a suited astronaut can still deploy the flag. You cannot expect a suited astronaut to <u>build</u> the flag, i.e. do not plan to send small piece parts and have them assemble the flag from scratch. The flag should arrive on the moon (in this case, the NBL) assembled in a stowed configuration, ready for quick deployment.

**** Materials:** Select materials that are appropriate for use underwater. The NBL pool is ~86 °F and 40 ft. deep.

<u>Additional Considerations</u>

- Forces the deployed flag must withstand



- NASA will provide an EVA hammer to use in deploying the flag, if desired. Use of the hammer is not required. Note that no other tools will be available for assisting in flag deployment, and no additional tools (i.e. drills, etc.) may be provided by the student team.
    - The EVA hammer may not be used as a permanent fixture of the flag.
- A mechanism is considered dust-tolerant when it can be buried in lunar regolith simulant and remain operable when removed. Two common approaches to achieving this result are (a) designing a mechanism that is open enough to allow dust to fall through it, and (b) designing a mechanism with tight tolerances to prevent dust from entering while using hard materials to crush any dust that does penetrate the mechanism.
    - For a flagpole, careful consideration is needed in the method of deploying the flag. Some mechanism types may bind in lunar dust or NBL testing media.

NASA Micro-g NExT Challenge

Lunar Surface Operations

Lunar Mapbook and Holder

Background

NASA is challenged to go forward to the Moon during the Artemis missions. Artemis III astronauts will walk across several kilometers of the lunar surface to reach areas of scientific interest. Navigation is a crucial task during extravehicular activity (EVA). Navigation aids such as mapbooks will be utilized on the lunar surface; the astronauts must be able to quickly and easily access the mapbook as well as understand the information presented. A user friendly mapbook and an adjustable, dust-tolerant mapbook holder are needed. The mapbook holder will mount the mapbook to a wheeled tool cart pushed by the astronauts on the lunar surface. The mapbook holder must be adjustable by an astronaut during the EVA to allow astronauts of different heights to view both the map (in the astronaut's desired orientation) and the terrain ahead when pushing the tool cart.

Develop user-friendly maps of a potential Artemis III landing site using publicly available data. Design a mapbook, and find a reliable, dust-tolerant, and ergonomically friendly way to attach and display the lunar mapbook when mounted to a wheeled tool cart. The mapbook itself may be permanently fixed to the mapbook holder or removable.

Objective

Design a mapbook, maps, and mapbook holder for lunar EVAs. The mapbook should attach (permanently or removable) to the mapbook holder with adjustability in height, forward and aft tilt, and planar rotation. Additional degrees of freedom may be incorporated if desired, as long as the mechanism remains dust-tolerant and adjustable by a suited astronaut. The adjustment system must be dust-tolerant, so carefully consider the materials and motions to be used in the mechanism.

Focus Areas

Materials science, geology/planetary science, ergonomics, biomechanics, mechanical engineering

Assumptions

- The subject will be weighed out to near-lunar gravity (1/6 of Earth's) and can walk on the bottom of the NBL pool floor.
- The device will be tested in two phases:
  - Underwater at the Neutral Buoyancy Laboratory (NBL)
  - Dry testing environment with lunar simulant

Hardware to Provide

- 1 Mapbook
- 1 full Mapbook Holder capable of mounting to a tool cart
  - NASA will provide information about mounting to the tool cart.
  - NASA will provide the tool cart for NBL testing.
- 1 Mechanism-only portion of the Mapbook Holder.
  - This will be used for dust testing (dry).

Requirements (continued next page)

1	A height-, forward/aft tilt-, and rotation-adjustable, dust-tolerant mapbook holder for mounting to a lunar EVA tool cart shall be produced.
2	A mapbook to interface with the mapbook holder shall be produced.
3	Combined mass of the mapbook and holder shall not exceed 8 lb in 1G Earth gravity.
4	For linear-actuating mechanisms, force required to actuate shall not exceed 20 lbf (89 N). For a rotating mechanism, torque required to actuate shall not exceed 30 in-lb (3.4 Nm).
5	Mapbook holder shall be capable of securing the mapbook in place at any position within its range of motion, and maintain structural stability while undergoing minor dynamic loads from the tool cart being pushed across terrain (i.e. bouncing).
6	In the shortest configuration, mapbook holder shall position the mapbook to be 3 in. or less above the mounting point.

7	In the tallest configuration, mapbook holder shall position the mapbook to be 13 in. – 16 in. above the mounting point.
8	Mapbook holder shall be adjustable to at least three distinct heights. More adjustability is allowed if desired, as long as all other requirements are met.
9	Mapbook shall be able to tilt forward and aft ±20° when mounted on the mapbook holder.
10	Mapbook shall be able to rotate in its plane ±90° when mounted on the mapbook holder.
11	The fully assembled mapbook and mapbook holder, interfaced together, shall fit within a volume of 20 in. x 16 in. 16 in. The mapbook and mapbook holder may be placed in a stowed configuration to meet this requirement.
12	Maps in the mapbook shall be a minimum of 8.5 in. x 8.5 in. and shall not exceed 16 in. x 16 in. Square or rectangular maps are acceptable.
13	Each map shall have a scale bar, feature identifiers, and a grid. Other navigational tools may be included as desired.
14	The proposed design shall specify all materials the provided hardware will be made from.
15	The non-mechanism portions of the mapbook holder may be made from any NBL-accepted materials. A waiver may be granted on a case-by-case basis*. **(No regular PLA allowed.** Tough PLA is okay.)
16	All components of the mechanism shall be made of metal*.
17	The mapbook, holder, and adjustment mechanism interface(s) shall be usable with EVA gloved hands (like heavy ski gloves).
18	The mapbook, holder, and adjustment mechanism(s) shall use only manual power.
19	The mapbook shall not use any electronic components.
20	There shall be no holes or openings which would allow/cause entrapment of fingers on the device.
21	There shall be no sharp edges on the device.

***Materials:** The mechanisms must be made from metals because plastic components will become jammed and/or damaged by lunar simulant. The remaining parts of the mapbook holder may be manufactured from both metals and non-metallic materials but must adhere to the NBL Approved Materials List. Your proposal must detail your selected materials and provide rationale for any materials not included on the NBL Approved Materials List.

The NBL pool is ~86 °F and 40 ft. deep.

Additional Considerations

- A mechanism is considered dust-tolerant when it can be buried in lunar regolith simulant and remain operable when removed. Two common approaches to achieving this result are (a) designing a mechanism that is open enough to allow dust to fall through it, and (b) designing a mechanism with tight tolerances to prevent dust from entering while using hard materials to crush any dust that does penetrate the mechanism.
- The mapbook holder mechanism will be buried and actuated in lunar simulant multiple times during the test.
- The mapbook may be permanently fixed to the mapbook holder or removable. If removable, it should be easy to hold with an EVA-gloved hand.
- Consider how maps relate to each other. Having multiple maps of one area showing different details can be highly valuable. Information you might include on maps: different terrain views, zoom levels/scale, horizon pictures, detailed views, etc. can be valuable information to include.

Figure 1: Tool Cart showing approximate mapbook holder mounting location.

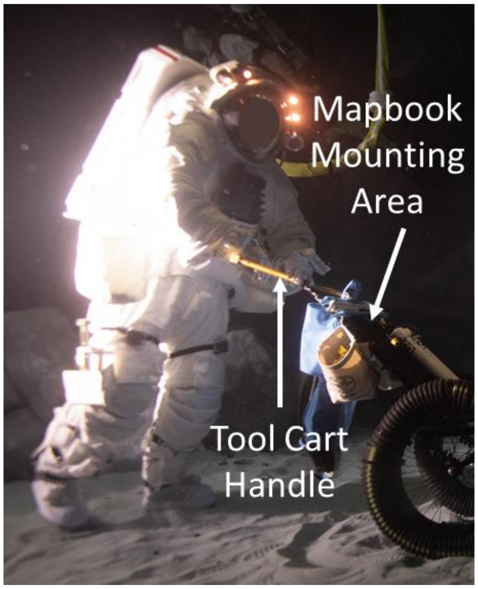
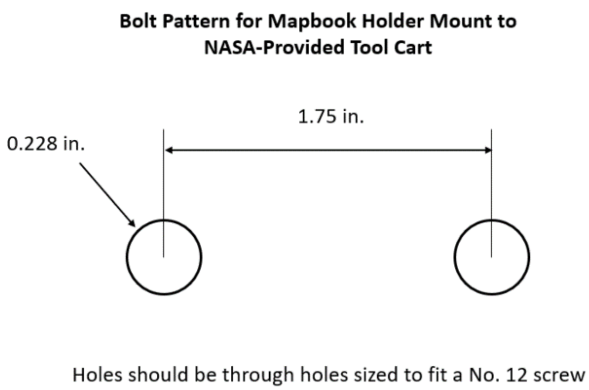


Figure 2: Suited astronaut pushing Tool Cart to show size comparison between a tall person and the Tool Cart.



Students should plan to include a mount with holes in this pattern. They do not need to provide the screws unless they want to – we will plan to provide screws to mount the holders to the Tool Cart. Description of above image: two holes, sized to fit a #12 screw (recommend free fit clearance, so hole is 0.228 in.), spaced 1.75" apart.

NASA Micro-g NExT Challenge

Orion Crew Safety

Search and Rescue Platform for Optical Target Recognition (SPOTR)

Background

NASA has been challenged to go forward to the Moon with our Artemis Program, using Orion as the spacecraft to transport crew. During the ocean capsule landing sequence, multiple items are jettisoned from the capsule, which for safety reasons, creates a large keep-out area around the capsule landing zone. An autonomous system that is capable of imaging and identifying objects of interest while the capsule is in the water will help improve the situational awareness of Search and Rescue and response personnel. Primarily, the concepts designed in this year's SPOTR challenge will be used to identify items of interest as would be present during an unassisted egress scenario from the Orion capsule (astronauts floating wearing an underarm life preserver, astronaut mulit-person life raft, etc).

Objective

Supporting open-ocean search and rescue situational awareness, design a stationary autonomous system capable of meeting the following requirements:

Functional

- Capable of autonomously identifying and tracking objects of interest including:
  - Orange colored life-ring
  - Mannequin wearing orange-colored life preserver unit (LPU)
  - Multi-person life raft
  - Orion capsule mockup (WEST) located on far end of pool
- Providing a live video stream to an operator laptop via wired ethernet or Wireless Wifi Connection
- Provide "short data burst" notification of object detection to an operator laptop
  - Text message – "<BLANK OBJECT> located" and picture of object detected

Physical

- Camera fixture mounted on tripod no greater than 36 inches in height from pool deck
- Include commercial-off-the-shelf camera (i.e. GoPro, Web Camera, etc)
- Electronics / processing elements fit on a folding table on the pool deck and accept 120V AC power input

Focus Areas

This challenge is primarily an electrical engineering/ software engineering-focused effort, including the following focus areas and disciplines:

- **Software Engineering / Coding** – students should be proficient in free/open-source software tools such as Python, C++, etc.) and be able to utilize toolsets within such programming languages appropriate for image detection, processing and characterization of full-motion video (FMV) or static images taken by student camera systems
- **Single-Board Computer Programming** – students should have some basic experience with single board computers such as Raspberry Pi, Arduino, etc. for physical hosting of software scripts and image processing due to portability requirements
- **Image / video Object Recognition & Artificial Intelligence** – students will learn via this challenge basic image processing and recognition techniques such as You Only Look Once (YOLO) and other deep learning techniques
- **Basic Electronics Circuitry** – basic electrical engineering skills for prototype circuit board development may be required for overall system packaging, etc.

Team composition should include students strong in electrical engineering and software coding, as the challenge is primarily electrical engineering/software engineering focused.

Open source/free resources are available online and teams are encouraged to experiment with novel low-cost techniques for object recognition and characterization. Software Developer Kits (SDKs) and Python programming toolboxes include (but are not limited to):

- https://gopro.github.io/OpenGoPro/demos/python/sdk_wireless_camera_control
- https://www.youtube.com/watch?v=Z2Hq4jDWunk
- https://towardsdatascience.com/yolo-object-detection-with-opencv-and-python-21e50ac599e9

Assumptions

This challenge assumes that NASA will provide the following items:

- Photo library of target items for training of image recognition scripts
- Floating items in Neutral Buoyancy Laboratory (NBL) during test week

Cost/Project Management

- Utilize commercial-off-the-shelf hardware/software to largest extent possible, for example using laptops, Raspberry Pi / Arduino for on-board computing, etc.
- Teams should focus on programming and electrical engineering elements of the design challenge, requiring some undergraduate-level experience in programs such as Python and You Only Look Once (YOLO) image processing techniques.

Anticipated Costs/Supplies Needed

- Single Board Computer (Raspberry Pi, Arduino, etc) - ~$100.00 – $150.00
- Camera (GoPro, webcam) - $100.00 - $300.00
- Pelican Case - ~$60.00
- Camera Tripod - ~$40.00

Requirements

Safety	
1	Camera systems shall use commercially available tripod systems with demonstrated stability appropriate with any student-developed camera systems
2	Camera and processing hardware shall be splash proof for poolside use
3	Camera / sensing systems shall not use laser / sonar or other radiofrequency (RF) techniques for object detection
4	The SPOTR control system shall power on and begin operations via single switch throw/actuation
Operational	
1	Capable of autonomously identifying and tracking objects of interest including: • Orange colored life-ring • Mannequin wearing orange-colored life preserver unit (LPU) • Multi-person life raft Orion capsule mockup (WEST) located on far end of pool
2	Provide image detection of selectable item within 60 seconds of user selection i.e. user selects "life raft" and system should provide detection of liferaft, notice of detection, and image of selected life raft with life raft outlined in photo within 60 seconds

3	Provide "short data burst" notification of object detection to an operator laptop
	• Textual message –
	  ○ "<BLANK OBJECT> located"
	  ○ Timestamp Photo of item

4	The SPOTR control system shall not require external calibration or warmup time greater than 60 seconds from control system power-on
5	The SPOTR system shall prioritize each known object based on the prioritization table provided by NASA.
6	The SPOTR system shall visually track items of interest, based on their priority, and stream video to an operator laptop via wired ethernet cable between processing hardware and laptop.

Test Setup

Students will place camera on tripod on one end of the NBL, oriented such that the pre-placed Field of View (FOV) centerline marker is in the center of the camera's field of view. Various items such as an orange life ring and mannequin wearing an orange life preserver will be either placed or already floating in the NBL and the camera system will autonomously detect, characterize, and report on items.