UTAH STATE UNIVERSITY
SPACE DYNAMICS
LABORATORY

SpaceBot Competition Handbook

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DOCUMENT REVISION HISTORY

Revision	Date	Description of Changes	Revised By
-	09/25/2024	Original Release	-
A	10/17/2024	Updated entire document for the FY2025 competition: • Updated challenge description, list of deliverables, deliverable descriptions, timeline, judging criteria Formatting updates: • Using SDL document template rather than prior revision's template • Added Section 2: Challenge Scope • Added Section 3: Ground Demo Overview • Removed Section 3: Introduction to Satellites • Decreased indent of Sections 2.2, 2.3, 2.4, 2.6, 2.7	NP
B	04/30/2025	Updated entire document for the FY2026 competition: • Changed challenge details from pulling on plates to releasing a stuck solar panel • Added multiple stages to the competition • Updated scoring system • Updated stakeholder requirements	NP/DH/JP

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1. SPACEBOT COMPETITION INTRODUCTION

The SpaceBot Competition is a university robotics competition sponsored by Utah State University (USU) Space Dynamics Laboratory (SDL) and the USU chapter of the American Society of Mechanical Engineers (ASME).

This participant guide covers the competition scope, rules, and scoring. In addition, the guide includes:

- Target capabilities for development
- Competition cycle key milestone dates
- Milestone deliverables
- Required final demonstrations

For questions about the competition or this guide, please contact spacebot@sdl.usu.edu.

1.1 OVERVIEW

Participating university teams will be tasked with manufacturing and developing a robotic payload, or SpaceBot, to be used on a theoretical on-orbit servicing, assembly, and manufacturing (OSAM) mission.

Each team will:

- Use engineering practices to design, assemble, and test their SpaceBot system, with guidance from their faculty advisor and other SpaceBot points of contact.
- Participate in a live demonstration of their SpaceBot system functionality, which a panel of professional judges will rate and score.

1.2 OBJECTIVES

The SpaceBot Competition objectives are as follows:

1. **Outreach & Education:** The competition provides university students with hands-on project experience, connection with subject matter experts, and practice with team collaboration. The intent is to extend each participant's educational experience, providing additional options for collegiate coursework, capstone projects, or extracurricular activities.
2. **Technology Development:** Space technology is quickly evolving, requiring constant innovation to fulfill demand. The ideas behind each SpaceBot may stimulate creative solutions to aerospace challenges and lead to developing and testing new concepts that advance the state of the art in space robotics.

2. COMPETITION CHALLENGE

Space robotics engineers, SDL needs your help proving a new concept for spacecraft servicing. The challenge is to develop a new satellite payload that can deploy from, traverse around, and fix a satellite, providing new capabilities for OSAM.

The SpaceBot payloads will be hosted within a satellite and deployed to perform repairs if the host experiences an anomaly on orbit, extending mission longevity and reducing repair costs.

SDL will test this technology by performing repairs on a known malfunctioning spacecraft called Modular Earth Sensing Surveyor (MESS). The MESS spacecraft unfortunately had a deployable solar panel caught by a piece of tape during ground assembly, prohibiting the panel from deploying after launch and the spacecraft from generating power. The SpaceBot payload will be used to free the solar panel so the MESS spacecraft may resume nominal operations.

2.1 SPACEBOT TASKS

Perform the following tasks:

- Develop a stowable payload that can perform the repair activity
- Characterize the developed platform—describe the capabilities, limitations, and possible use cases of the designed SpaceBot
- Operate the integrated payload during a ground demonstration activity

Multiple ground demonstrations will be performed to sequentially test new capabilities leading up to the final repair activity. These demonstrations can be performed assuming that SDL has launched the MESS satellite with the SpaceBot payload onboard. It is now up to your team to perform the repair activities and rescue the MESS satellite. Good luck!

3. COMPETITION STRUCTURE

The SpaceBot Competition will span multiple years, with each year being referenced as a competition cycle. One cycle is defined as the period between September and the following April, aligning with university academic years.

Each cycle will consist of the key events described below:

- **Application Period:** All teams participating in the competition are required to apply to the SpaceBot Competition at the beginning of the cycle period. The application for the cycle can be found on the SpaceBot website. The SpaceBot Leadership Team will then notify teams of acceptance status via email.

- **Kick-Off Meeting (KOM):** Occurring at the beginning of each cycle, and led by the SpaceBot Leadership Team, this is an optional meeting for accepted teams to discuss project scope, the SpaceBot Handbook, and address questions.

- **Design Reviews:** Reviews are to ensure that participating teams are adequately documenting their progress and receiving feedback from subject experts. A PDR and CDR will occur throughout each competition cycle. Both reviews are required events and key components of each team's final score in the cycle.

- **Demo Day:** The final event of the SpaceBot Competition will be a live demonstration of each team's SpaceBot design during Demo Day at SDL's campus in North Logan, Utah. The purpose is to demonstrate the developed SpaceBot capabilities and functionality. Final scoring and awards will be assigned at the Demo Day event. To be considered for final placement, teams will be expected to transport team members and equipment to the SDL North Logan campus and participate in the event.

Table 1. Typical SpaceBot Competition cycle

Step #	Step Name	Date
1	Formulate team & apply	Second Friday in September
2	SpaceBot Kick-off meeting	Third Thursday in September
3	Design SpaceBot	Ongoing
4	Complete design reviews: • PDR package & review forms due • CDR package & review forms due	 Last Friday in October Last Friday in January
5	Integrate & test	In preparation for Demo Day
6	Demonstrate: • Materials due • Live Demo Day	 First Monday in April Second Friday in April

The SpaceBot Competition will feature multiple demonstration levels that progressively build on one another, ultimately leading to the final challenge. To progress to the next level, teams must complete each level, as defined in Section 3, in the specified order. Teams may only complete one level per competition cycle, meaning that teams may not attempt multiple levels in a single cycle. A level is considered complete when a score of 20% is awarded in the Completion category during demo scoring, as defined in Table 7.

As part of the competition application, teams will indicate which level they will design towards throughout the cycle and ultimately perform at the live Demo Day. Teams may not apply to participate in a level if the prerequisite level has not been completed in prior cycles. Teams applying to the SpaceBot Competition that have not participated in prior cycles will, by default, be assigned to Demo 1 for that cycle. This process is graphically shown in Figure 1.

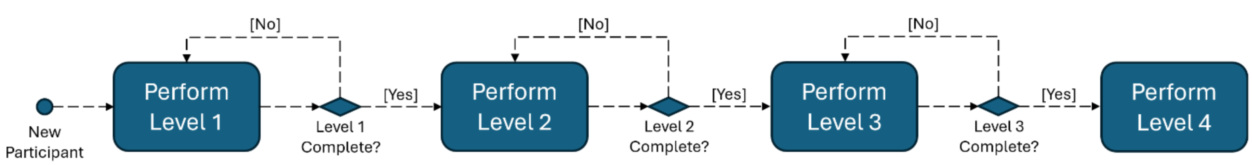

Figure 1. Flowchart of assigned demo level order across multiple years

4. DEMO DESCRIPTIONS

The SpaceBot Competition challenge is to free a satellite solar panel that has been caught by tape. Students will need to develop a robotic payload that can deploy from the malfunctioning spacecraft, maneuver to the stuck panel, and deploy the panel from its stowed position. The challenge is considered a success when the student teams confirm that the solar panel has successfully moved to the deployed position. Teams will be provided with a 3-D model of the MESS spacecraft at the cycle KOM. More details about the demo setup and required interfaces are provided in 408-0003, *SpaceBot Demo Mechanical Interface Control Document (MICD).*

4.1 DEMO LEVELS

Due to the complexity of the challenge, the repair activity has been broken out into four levels that build up to the full repair activity described above. Each level will exhibit different robotic functions needed to accomplish the final task, while building upon functions performed in prior levels. A summary of the demo levels is provided in Table 2. Details for each individual demo are described later in the handbook.

Table 2. Summary description of demo levels

Name	Description
Level 1: Repair	SpaceBots are manually mounted directly on or near the solar panel with the caught tape within reach. SpaceBots need to attach to the structure and free the panel. Teams are successful when the panel has been deployed (teams must confirm).
Level 2: Crawl & Repair	SpaceBots need to move around a single face of the spacecraft to demonstrate crawling capabilities. Bots are positioned opposite the tape side of the solar panel and must crawl to the tape. The level is complete when the bot maneuvers from the start position to the tape and frees the panel without falling off the demo setup.
Level 3: Change Faces & Repair	SpaceBots need to maneuver from a different face to the solar panel face. The bots are placed on the face of the spacecraft located opposite the solar panel and must move between a minimum of two faces. SpaceBots must then crawl to and free the solar panel.
Level 4: Deploy & Repair	SpaceBots must deploy from a garage and free the panel. The bots start in a stowed position in the garage and must crawl out of the garage onto the spacecraft exterior. The bots must then crawl, change faces on the spacecraft, and maneuver to the stuck solar panel. The challenge is completed once the solar panel is freed.

Each demo level is considered a success when the stuck solar panel has been freed and deployed to its nominal operating position. In addition, student teams must provide proof to the SpaceBot Leadership Team that the panel has deployed. Proof can take the form of images, video feed, or any other sensor feedback detecting panel deployment. If the SpaceBot unintentionally falls off the mockup satellite during any of the demo activities (i.e., onto the demo table), the SpaceBot must return to that level's starting point.

Teams must complete the demo level within a 30-minute time limit, which ends when the team provides proof of panel deployment to the leadership team. To simulate operations in a space environment, teams are required to operate their SpaceBot system without a line of sight to the robot and demo setup. During the challenge, teams will be positioned behind a barrier within close proximity to the demo setup. A top-down view of the demo setup is shown in Figure 2.

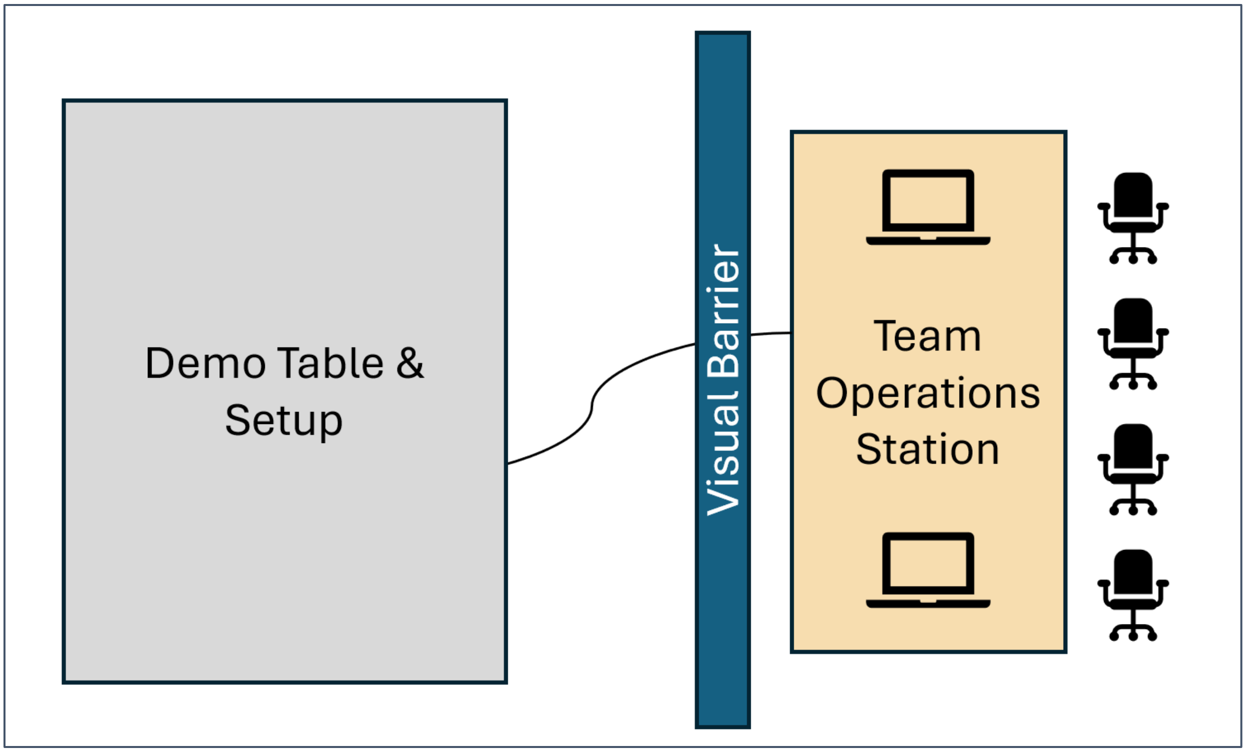

Figure 2. Model of the demo setup at Demo Day (top-down view)

Full scoring will be assigned for the Demo Completion scoring category once the team confirms that the solar panel has transitioned to the deployed position. No scoring will be assigned for the completion category if the solar panel does not fully transition to the deployed position by the end of the 30-minute period. Reversibility, a bonus category, will be rewarded if the SpaceBot can maneuver back to the current level's starting position after the solar panel is deployed. Reversibility attempts must be completed within the same 30-minute period as the nominal repair. Reversibility bonus scoring is not available for the Level 1 demo.

4.1.1 Level 1: Repair

The first level will demonstrate features for attaching to MESS and freeing the stuck solar panel. Teams will position their SpaceBot near the tape holding the solar panel down such that the tape is within operating reach. Teams will then use whichever solution they deem acceptable to free the solar panel from the caught tape.

For the demonstration, the SpaceBot and solar panel will be oriented as shown in Figure 3. Three types of materials will be positioned around the perimeter of the garage: coated aluminum, a solar panel, and aluminum covered with multi-layer insulation (MLI). The solar panel is attached to a panel of the MESS spacecraft structure via spring-loaded hinges, which automatically transition the solar panel to the deployed position once the panel is freed. The MESS panel will be oriented parallel with the demo floor, such that the SpaceBot can rest on the panel without additional support. Teams will place their SpaceBot in the location needed to free the panel.

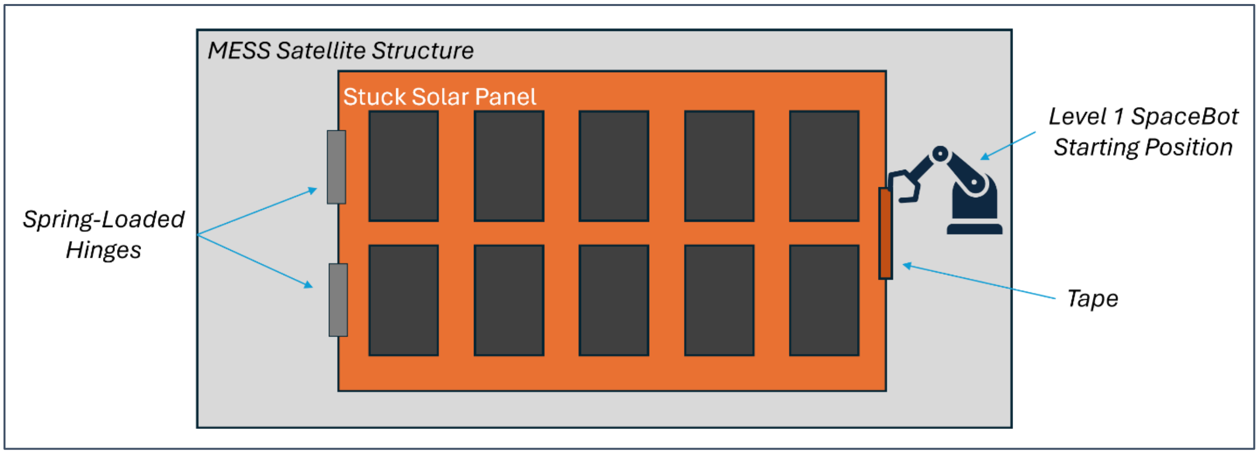

Figure 3. Level 1 demo layout (top-down view)

4.1.2 Level 2: Crawl & Repair

The second level builds upon the first by showing functionality for moving across the external spacecraft materials. The second demo will require the SpaceBot to maneuver from a different location on the solar panel face to the tape, testing the robot's ability to crawl along a flat surface. Teams will again free the panel caught by tape, like the repair performed during Level 1.

Like Level 1, the solar panel and MESS satellite structure will be oriented as shown in Figure 4, with the MESS panel and stuck solar panel parallel to the demo floor. Teams will place their SpaceBot at the location shown in Figure 4 and maneuver it to the tape on the opposite side of the panel. This level is considered a success once the team proves that the panel has successfully deployed.

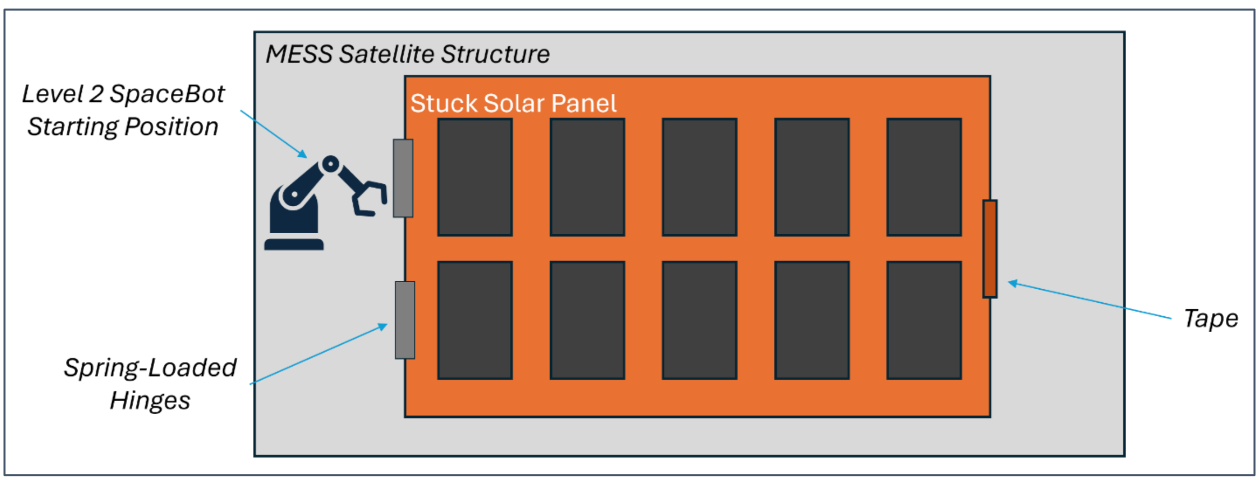

Figure 4. Level 2 demo layout (top-down view)

4.1.3 Level 3: Change Faces & Repair

The third stage will demonstrate the SpaceBot's ability to 1) traverse along vertical surfaces and 2) maneuver between different faces of the mockup satellite. The SpaceBot will be placed opposite the face with the stuck solar panel. The SpaceBot will need to traverse along multiple flat faces, transitioning between faces, to reach the solar panel and tape. This requires the

SpaceBot to traverse surfaces that are perpendicular and upside down with respect to the demo floor. By the end of this demo, the SpaceBot will need to attach to three unique faces of the mockup satellite. It can be assumed that all faces are straight (not curved) and normal to each other.

Teams will place their SpaceBots on the upward-facing MESS structure as shown in Figure 5, such that the SpaceBot traverses parallel to the demo floor. The SpaceBot will perform two transitions between spacecraft faces that are 90° from each other, traversing along different material types such as coated aluminum, MLI, and the solar panel. Once positioned on the solar panel face, the SpaceBot will maneuver to the tape and free the solar panel. This level is considered a success once the team proves that the panel has successfully deployed.

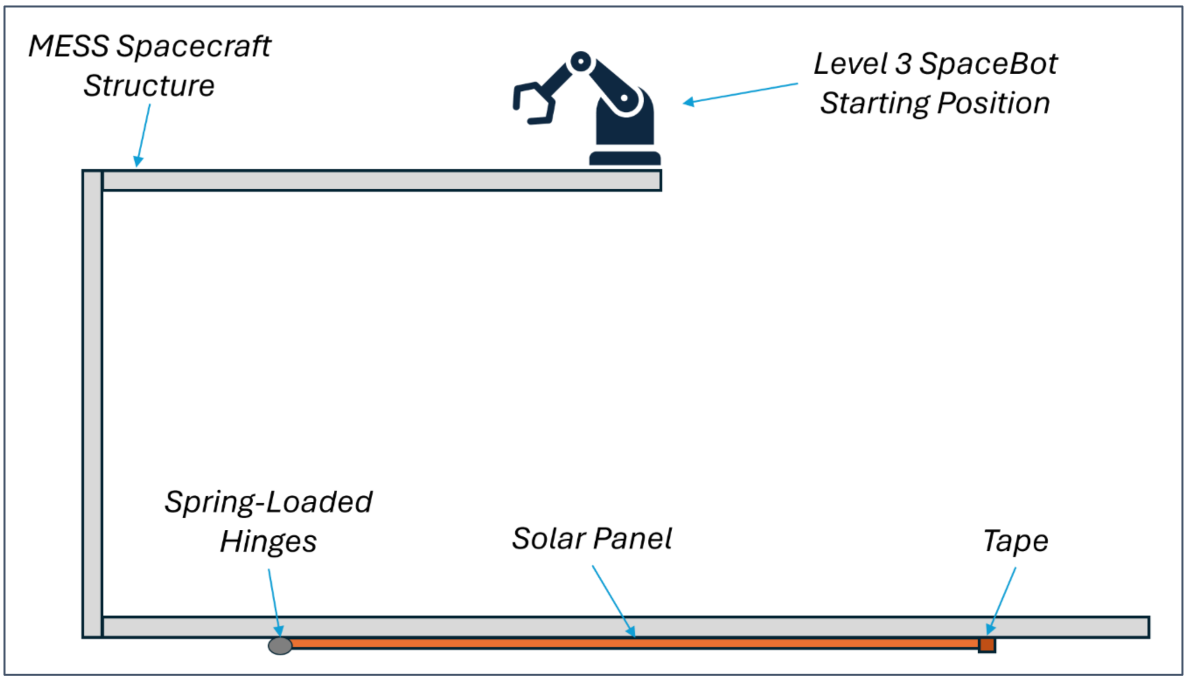

Figure 5. Level 3 demo layout (side view, with gravity vector pointing downwards)

4.1.4 Level 4: Deploy & Repair

The final level of the competition demonstrates the SpaceBot's ability to perform the solar panel repair starting from a stowed position within the spacecraft, simulating the launch phase. Level 4 is a comprehensive demonstration that will use capabilities tested in prior competition levels.

Teams will place their SpaceBot within the MESS garage, which is to be determined. The SpaceBot must be completely enclosed in this volume during the launch phase. When the timer begins, teams will maneuver their SpaceBot out of the garage and onto the exterior of the MESS structure. From here, the SpaceBot will perform all functions observed in prior demo levels to free the solar panel. This includes crawling along multiple spacecraft surfaces of different orientations (flat, vertical, upside-down) and materials (coated aluminum, MLI, solar panel); transitioning between normal faces; and freeing the solar panel caught by tape. The layout of this demo level is shown in Figure 6. Success is dictated by whether the solar panel deploys. Full scoring in the Reversibility category is awarded when the SpaceBot can fully stow itself back inside of the garage (i.e., fully enclosed by the garage envelope) after deploying the solar panel.

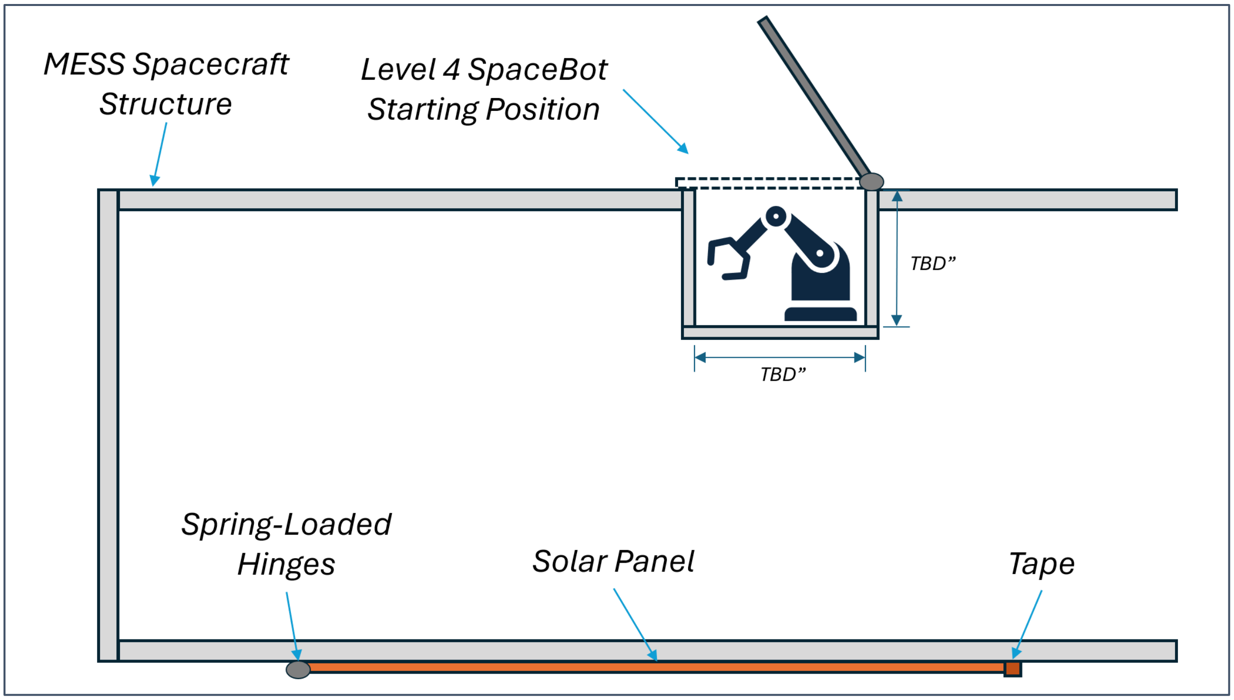

Figure 6. Level 4 demo layout (side view, with gravity vector pointing downwards)

5. MILESTONES & DELIVERABLES

Competing teams will participate in the following competition cycle milestones: PDR, CDR, and the live Demo Day. Each milestone is a key point in the program, where teams submit a deliverable package that describes the status of their project. The purpose of the milestone review is to enable teams to receive feedback from trusted reviewers pertaining to the selected SpaceBot design. Reviewers will provide feedback at multiple points throughout a challenge cycle to enable teams to improve and mature their design.

A full technical deliverable package is expected from each competing team for PDR, CDR, and Demo Day. Each deliverable package will contain full documentation and an accompanying slideshow presentation. Teams will also submit logistical documents providing details about the reviews and Demo Day participants (templates will be provided by the SpaceBot Leadership Team). All milestone documentation, including the required deliverables and completed reviewer feedback forms, must be submitted to the SpaceBot Leadership team by the dates set for the specific competition cycle.

5.1 MILESTONE DESCRIPTIONS

Each competition cycle will include milestones, each with expectations for reviews and progress in technical development.

5.1.1 Preliminary Design Review (PDR)

A successful PDR establishes the basis for proceeding with the detailed design. At this point in the development process, each SpaceBot design should have high-level details solidified. In addition, the team needs to have the system architecture defined, concept of operations

(CONOPS) completed, and a preliminary solution to the problem identified. The overall system design may be rudimentary and not necessarily final. However, a general plan to complete outstanding design tasks must be created and some design and testing documentation started. The purpose of the PDR is to convince reviewers that teams understand the capabilities they need to provide. This is the time to convince reviewers that the preliminary SpaceBot design has a high probability of meeting the competition's technical requirements.

5.1.2 Critical Design Review (CDR)

A successful CDR establishes the basis for proceeding with the construction and verification phase of the project. The purpose of a CDR is to prove to reviewers that the final design is mature enough to move into final assembly and integration efforts. The system design should be solidified, with a clear path identified for design decisions that have yet to be completed. All analyses and preliminary testing should also be complete by CDR, alongside a complete plan for assembling and testing the system. The CDR should be a continuation of the content delivered at the PDR. It should include the same content and structure and add final design information, which may have changed since the PDR.

5.1.3 Demo Day

The purpose of the Demo Day is to demonstrate that the designed SpaceBot system can perform primary functions in a live ground environment. For the Demo Day milestone, all deliverables shown in Table 3 must be finalized and submitted prior to the live demonstration at SDL. At this stage of the competition, the SpaceBot system must be completely designed, integrated, and tested in accordance with team requirements. The slideshow presentation for reviewers should demonstrate that the SpaceBot design can perform the challenge tasks while also summarizing analyses and findings gathered throughout the competition cycle. Judges will determine the final rankings for the SpaceBot Competition at the Demo Day event.

5.2 DELIVERABLE DESCRIPTIONS

The required deliverables and formatting for each milestone review are outlined in Table 3. Deliverables listed in Table 3 as Slides must be included in the milestone review presentation, using a minimum of one dedicated slide (more are allowed per team judgement). Deliverables listed in Table 3 as Document must be submitted as separate, standalone PDF document files. No other deliverable formats are required beyond what is described within this handbook.

Table 3: Technical deliverables due at each review milestone

Deliverable Name	PDR	CDR	Demo Day
Project Management Report (PMR)	Slides	Slides	N/A
Requirement Compliance Report	Slides	Slides	Slides
Concept of Operations (CONOPS)	Slides & document	Slides & document	Slides & document
Payload Block Diagrams	Slides	Slides	Slides
Safety Assessment	N/A	Slides & document	Document

Deliverable Name	PDR	CDR	Demo Day
Space Environment Readiness Assessment	N/A	Slides	Slides
SpaceBot User's Guide	N/A	Slides & document	Document
SpaceBot Design Overview	Slides	Slides	Slides & document

Deliverable packages in PDF format for each milestone must be submitted to the SpaceBot website by 8:00 a.m. (MT) on the specified due dates for the current competition cycle.

NOTE: Milestone deliverable packages must include the deliverables described in Table 3, a slide presentation, and completed reviewer forms (reviewer forms only for PDR and CDR).

5.2.1 Project Management Report (PMR)

The PMR reflects the status of SpaceBot development from a management perspective. The report conveys that the team has all the resources needed to complete the project, including staffing, funding, and scheduling.

The team must include the following:

- **Team Organization Chart:** Graphical view of the members of the project team and their allocated roles.
- **Project Budget:** Depiction of excess or deficient funding for the project, with the cost required to procure, implement, and test the entire system.
    - **Note:** Budget should include the costs needed to procure the entire SpaceBot system, regardless of equipment already owned by the teams.
      Example: If a team decides to use a university laboratory computer to control their SpaceBot, then the cost of the computer should be included in the project budget.
- **Project Schedule:** Sequential view and decomposition of all tasks needed to complete the competition, with defined task durations and personnel allocations (commonly shown in a Gannt chart).

5.2.2 Requirements Compliance Report

The compliance report communicates the expectation and status of fulfilling the imposed requirements. For each requirement listed in Appendix A: Stakeholder Requirements, the teams must report whether they expect to fully comply with the requirement by the end of the competition cycle (i.e., after completing Demo Day). Each customer requirement must be listed in a table with one of the following compliance statuses provided on each line:

- **Compliance Expected**: The student team confidently expects to fulfill the requirement by the end of the competition cycle.
- **Compliance Unknown**: The student team is uncertain if they can fulfill the requirement by the end of the cycle.

- **Noncompliance Expected**: The student team does not expect to comply with the requirement by the end of the cycle.

Note: Statuses are to convey the anticipated status of compliance by the end of the competition cycle (i.e., at the Demo Day), not compliance at the time of the milestone review.

Justification must be provided for each status assigned to a requirement, conveying why the team chose the selected compliance status. Mitigations and the path to closure must be provided for any requirements marked as Compliance Unknown or Noncompliance Expected.

5.2.3 Concept of Operations (CONOPS)

The CONOPS is a high-level, mission-focused document that describes how the system will be used for the specific mission, how the system could be utilized on other missions, and the implications that the payload design will have on the host satellite. The CONOPS helps quickly convey to stakeholders what the team plans to accomplish throughout the mission, highlighting key mission elements (spacecraft, launch vehicle, ground, etc.) and relating back to mission objectives and stakeholder needs.

Key elements that will be expected of CONOPS documents for this year's competition include the following:

1. **CONOPS Diagram/OV-1 Diagram:** This diagram shows a high-level overview of the entire mission and what the customer is trying to accomplish. The diagram is designed to quickly convey what the mission is and what its key characteristics are to someone unfamiliar with the task. The diagram should show all key elements of the mission such as the space vehicle, SpaceBot, ground control, and launch. It should also describe how each element interacts with each other to accomplish the mission.
2. **Functional Description:** Include a high-level description of how the SpaceBot system will accomplish the chosen demo. Describe the steps that must be taken (by both the payload and potential host satellite) and the key technologies that must be involved in accomplishing this task. This can be shown as a functional flow diagram, or any format determined by the participating teams.
3. **Payload Data Sheet:** This is a high-level, abstract description of the SpaceBot's capabilities and, more importantly, limitations. The overall technical capabilities of the SpaceBot system should be described including key performance and design parameters, much like the information found on common data sheets. Alongside capabilities, describe the limitations of the SpaceBot system, documenting constraints that would need to be imposed on the mission, host satellite, or spacecraft. Example questions to think about: Can the payload only be attached to a satellite with handles? Can the payload only be flown on a very large satellite? Is the attachment method repeatable? What would cause your proposed SpaceBot system to fail?
4. **Impact to the Host:** Describe how the solution will impact the performance of the host satellite after the SpaceBot completes the demo. This is primarily to address potential side-effects of the demo as opposed to potential changes in performance caused by repairs or any other OSAM activities. Provide preliminary, high-level quantitative proof as applicable. Example questions to think about: How will the host satellite's

performance change after the repair activity? Will any of the electronic components be damaged? Will it no longer be able to retain heat?

For PDR, include each of the four categories listed above in the presentation. The CDR and Demo Day presentation should only include items 1-2, as shown above, and note updates to items 3-4.

5.2.4 System Block Diagrams

Block diagrams graphically represent a system and its internals in a series of blocks. The purpose of system block diagrams is to capture the decomposition of the system into its subsystems and components, as well as the interfaces between those subsystems via lines and arrows. This diagram should convey key interface information for each subsystem, such as power and data.

SpaceBot Competition teams are required to provide block diagrams for both the system and each of the identified subsystems. Diagrams should convey the layout of the system to the stakeholder and other external parties, making it easy for them to understand how the system is internally organized. At a minimum, block diagrams must show interface connections such as power and data throughput. Blocks within the diagrams should correspond to components that physically comprise each team's SpaceBot.

For PDR, this diagram can be in draft format since the design is not expected to be finalized. For CDR, the block diagram should be finalized and accurately represent the system that the team plans to create.

5.2.5 Safety Assessment

Safety assessments document all hazards that may be present when assembling, handling, or operating the SpaceBot system. The purpose of this document is to prove that the system can be handled and operated without causing harm to the people managing it. It also proves that adequate safety controls have been implemented to mitigate each of the identified hazards. Controls can take the form of engineering, administration, process, etc. Engineering controls could include guarding/cages around the robot system, e-stop buttons, protective gear, software, etc. Key hazards, and situations in which those hazards could be brought about, must be thoroughly identified and mitigated. Emphasis should be placed on how the SpaceBot design may cause damage or harm to the demo setup, SDL facility, or audience members.

SpaceBot Competition teams are required to provide a thorough safety assessment to ensure that all potential hazards are identified and addressed. Inherently, the SpaceBot Competition requires teams to interact with hardware that could potentially cause harm if not properly handled, such as physical collisions or contact with active electrical connections. Team safety assessments must identify the hazards associated with each SpaceBot system and list strategies for how those hazards will be mitigated.

Note*:* Teams are required to maintain a safe perimeter from their SpaceBot systems while it is powered on at SDL's campus. Teams are allowed to interact with their robots when the systems have been fully deenergized and powered off. Teams not following these policies will receive penalties to their demo scores, as defined in Table 8.

Note*:* Teams are responsible for providing personal protective equipment (PPE) for both team members and observing audience members, as required by the safety assessment.

5.2.6 Space Environment Readiness Assessment

This assessment determines the design's space environment operational readiness and how the design may need to be adjusted to accommodate the space environment. Teams should prove that the newly developed SpaceBot system can be operated on the ground and in space. The assessment must describe how the team has designed for the mission space environment and describe what changes must be made to ensure that the payload can be flown on orbit. Supporting analyses proving space readiness are highly encouraged to provide sufficient customer confidence but not required.

Teams will use their judgement to determine the depth and content of the assessment, although some example topics are included below:

- Launch: Shocks, vibrations, launch vehicle compatibility, vehicle safety, electrical inhibits
- Environmental Radiation: Impacts on SpaceBot electronics
- On-Orbit Thermals: Impacts on performance in both sunlight and Earth's shadow
- Commanding & Control: How would you command your payload from the ground?
- Vacuum Tolerance: Ability to operate in a vacuum
- Microgravity Effects: Variations in how the payload performs in zero-gravity versus Earth surface gravity
- Material Integrity: Material degradation, outgassing, corrosion
- Stowage & Transport: Effects on performance after being stored inside a satellite for extended periods of time (months to years)

5.2.7 SpaceBot User's Manual

The SpaceBot User's Manual documents and conveys how the SpaceBot would be controlled by a human operator, detailing exactly how to control the SpaceBot and perform key demo activities. The User's Manual should include step-by-step instructions on how to use the SpaceBot, with less focus on the demo/competition activities and more focus on general control instructions for the system. The manual should be written in a way that can be clearly understood by anyone regardless of prior experience with the robot or space operations. It should also include both a high-level overview of the SpaceBot payload design and key troubleshooting steps for resolving anomalies commonly encountered with the payload design.

5.2.8 SpaceBot Design Overview

The SpaceBot Design Overview is a detailed description of the SpaceBot design. The purpose of the overview is to mitigate student team turnover by recording all designs decisions such that subsequent competition participants can understand how each choice was made. The design overview will be delivered in both presentation format for each of the milestone reviews and in a comprehensive final document at Demo Day.

For presentations, the design overview should be a high-level overview of the proposed SpaceBot solution and key design decisions, specifically highlighting the driving (or most influential) design decisions made. The presentation should not go into the same depth of information as the final document but should still deliver enough information for the customer to understand the developments made. The amount of content presented at each of the milestones should correspond with the maturity of the content within the cycle, with the PDR being the least mature design and Demo Day being the as-built SpaceBot design. The Demo Day SpaceBot design presentation should be a brief, high-level overview of key aspects of the robot rather than a deep dive into design details.

The final document will record all key design decisions made throughout the design process clearly, with rationale and justification for those decisions. The document should include a detailed description of the final SpaceBot design and all analyses, trades, reports/results, and other pertinent information used to inform the SpaceBot design. The document should also include design recommendations for future instantiations of the SpaceBot design, including high-level plans for how the design may change in the future to accomplish other parts of the competition.

The depth of content provided should only be to the extent of documenting how key system design decisions were made. For example, rationale for the type of computer used to control the robot (such as a microcontroller or laptop) may be worth documenting, but the specific model of the computer (such as Dell vs. MacBook) may not need to be documented if irrelevant to overall system design. Each team should use their best judgement in determining the most pertinent information to include.

In summary, the key elements expected in the SpaceBot Design Overview final document include the following:

- Detailed description of the SpaceBot solution showing content
- Rationale for key design decisions made with supporting analyses and research, where applicable
- Recommendations for future team participants for how the design could be changed to accomplish other aspects of the competition

5.2.9 Review Presentation Slides

Review slides will be presented during each design review. The slides must be submitted in PDF format with all milestone deliverable packages prior to presentation delivery. Minor changes to the slides may be made between the deliverable submission and presentation.

The review presentation content should achieve the purposes and convey the messages for each of the design reviews as outlined in Section 4.2. For PDR and CDR, the presentation must address the topics shown in Table 3, at a minimum. The focus of these presentations should be more on the specifics of the SpaceBot design and implementation of the planned design.

Demo Day presentations need to emphasize the final design capabilities as seen in the CONOPS, conveying readiness for the demonstration activity, and concluding the competition efforts. At a minimum, the Demo Day presentations must include the items shown in Table 3, alongside the following:

- Key challenges faced by the team throughout the competition (technical, programmatic, etc.)

- Technical recommendations: Changes to design, CONOPS, implementation
- Lessons learned from the competition

5.3 MILESTONE LOGISTICS

Deliverable packages in PDF format for each milestone must be submitted to the SpaceBot website by 8:00 a.m. (MT) on the specified due dates for the current competition cycle. Demo Day deliverable packages do not require submitting reviewer forms.

5.3.1 Design Review Logistics

For each design review (PDR and CDR), teams are responsible for selecting reviewers, coordinating presentation times, and ensuring that review forms are completed. Teams are expected to choose their own reviewers, which may be peers, professors, subject matter experts, or anyone who may provide useful feedback on their progress. It is recommended that the faculty advisor serve as a reviewer (the faculty advisor may not be a presenter). It is not required that the panel includes the same reviewers for each review. There is no limit to the number of reviewers nor a requirement concerning their qualifications. Teams should solicit reviewers who will help teams prepare for the live demonstration in a productive manner.

Design reviews (PDR and CDR) will be delivered by each university team to their selected panel of reviewers. A copy of the final presentation must be delivered to each reviewer by 8:00 a.m. (MT) on the day prior to the presentation. Completed Review Feedback forms (Appendix D) on all design reviews should be collected following the review presentations and should be included in the deliverable package.

5.3.2 Demo Day Logistics

SpaceBot Competition teams will travel to SDL's headquarters in North Logan, Utah, to present their final design and demonstrate the capability of their SpaceBot to a panel of judges.

Note: All team members and faculty advisors attending the Demo Day must be US citizens.

Each team must submit the Demo Day Attendance Form one week prior to the scheduled demo day. A preliminary agenda for the Demo Day is shown in Table 4.

Table 4. Preliminary Demo Day agenda (Subject to change)

Time (MT)	Event
0800–0900	Teams check in and unpack
0900–1030	Team presentations
1030–1045	Break
1045–1245	Demo session 1
1215–1315	Lunch (provided)
1315–1445	Demo session 2
1445–1630	Tour of SDL facilities; judges confer
1630–1700	Awards ceremony

For the live event, each team will:

- Receive a staging area with a table (approximately 6' long) where hardware can be unpacked
- Give a presentation in front of the judges and other competitors
  - The presentation should be no longer than 30 minutes (25 minutes for slides, 5 minutes for questions)
  - The presentation content is described in further detail in Section 5.2
- Perform the live ground demonstration activity in accordance with team CONOPS

Teams are expected to bring all equipment needed to perform assembly activities to complete the competition. This includes, but is not limited to, tooling, controllers, displays (i.e., monitors or televisions), lighting equipment, etc.

6. COMPETITION SCORING

Competition mission success requires full completion of the ground demo activity using a unique solution, as described in Section 3, and submission of all deliverables, as described in Section 5.2. The Success Criteria featured in Table 5 describes the metrics in which participating teams will be measured.

Table 5. Success criteria for participant judging

Category	Description	Score
Preliminary Design Review (PDR)	**Emphasis on CONOPS development and preliminary system design**	**15%**
PDR Presentation	Presentation includes all PDR content defined in Table 6	10.0%
PDR Documentation	Documents include all PDR content defined in Table 6	5.0%
Critical Design Review (CDR)	**Final SpaceBot design and path to Demo Day**	**20%**
CDR Presentation	Presentation includes all CDR content defined in Table 6	12.0%
CDR Documentation	Documents include all CDR content defined in Table 6	8.0%
Demo Day	**Design summary, performance, recommendations, and competition reflection**	**20%**
Final Presentation	Presentation includes all Demo Day content defined in Table 6	12.0%
Final Documentation	Documents include all Demo Day content defined in Table 6	8.0%
Demo Score	**Demo score calculated, see Table 7**	**45%**
FINAL SCORE		**100%**

Final scoring will occur by ranking teams in terms of the total score calculated from the success criteria. The highest scoring team will be ranked in first place, the second-highest scoring team will be ranked at second, etc. Teams will only be ranked against other teams participating in the same demo level for that cycle. For example, teams competing in Level 2 for that cycle will be ranked against each other in final scoring, but a team participating in Level 2 will not be ranked against a team participating in Level 3. Each level will have an individual list of final placements.

Note: Teams will only be considered for final scoring placement if they attend and participate in the live Demo Day event. Teams may still attend and participate in the Demo Day even if their SpaceBot cannot perform the ground demonstration. In such cases, it will be scored using the Success Criteria category of Demo Score accordingly.

6.1 MILESTONE SCORING

The scoring shown in Table 6 represents how each of the milestones will be scored with decomposition into deliverable categories. Sum percentages in the DELIVERABLES SCORE row of Table 6 represents the allocated deliverable percentages, as shown in Table 5. Individual deliverable percentages shown within Table 6 depict the value of said deliverable in the final score for each SpaceBot team. Each of the deliverables listed in Table 6 will be scored in accordance with their descriptions in Section 5.2.

Table 6. Milestone scoring categories

Deliverable Name	PDR		CDR		Demo Day	
	Slides	Document	Slides	Document	Slides	Document
Project Management Report (PMR)	2%	-	1%	-	-	-
Requirement Compliance Report	2%	-	1%	-	1%	-
Concept of Operations (CONOPS)	2%	5%	1%	2%	1%	1%
Payload Block Diagrams	1%	-	1%	-	1%	-
Safety Assessment	-	-	2%	4%	-	2%
Space Environment Readiness Assessment	-	-	2%	-	3%	-
SpaceBot User's Guide	-	-	1%	2%	-	1%
SpaceBot Design Overview	3%	-	3%	-	6%	4%
DELIVERABLES SCORE	**10%**	**5%**	**12%**	**8%**	**12%**	**8%**

6.2 DEMO SCORING

Scoring used for all demos is shown in Table 7, which are assigned based on the SpaceBot's performance at Demo Day. Some scoring categories are *binary*, meaning that success criteria were or were not met, as opposed to *curve* scoring in which teams may be ranked against each other and scored proportionally to their category ranking.

Table 7. Demo scoring categories

Category	Description	Max Score
Demo Completion	Selected level completion, as described in Section 3. Binary scoring: • Fully Complete = Full Score • Not Complete = No Score *Note: Full Score in this category enables application to the next demo level.*	20%
Completion Time	Time to complete the selected main demo activity (not including reversibility). Scored on a curve: • Lowest time = Full Score • Highest time = Half Score • Demo Incomplete = No Score	10%
Host Spacecraft Damage	Host spacecraft performance degradation due to repair activity. Scored on a curve: • Left No Trace = Full Score • Some Demo Maintenance Needed = Half Score • Demo Needs Replacement = No Score	5%
SWaP	Volume (stowed) and final payload mass. Scored on a curve: • Lowest = Full Score • Highest = No Score	10%
Bonus Points	**Can be added to the final score above to make up lost points**	**12%**
Automation	How much does the system operate by itself? Scored on a curve: • Real-time controls = No extra score • One command for the entire demo = Full extra score	7%
Innovation	The challenge was completed using either a highly unique payload design or using a unique method. Scoring is binary, subjective, and per judge discretion: • No innovation = No extra score • Innovation = Full extra score	2%
Reversibility	Completely reversing the demo and fully returning to the starting position once the primary task is complete. All attempts at reversibility must be completed after the main task is complete and within the time limit. Additional time will not be allocated for reversibility attempts. Binary scoring: • Not returned to the starting position = No extra score • Returned to starting position = Full extra score *Note: Not applicable for Level 1*	3%
DEMO SCORE	**Final score, sum of the above categories**	**45%**

Core scoring categories are shown at the top of Table 7, while the bottom shows bonus categories that teams can use to earn lost points. Teams can earn back up to 12% of their final score if they accomplish the tasks outlined in the bonus categories.

6.3 SCORING PENALTIES

Penalties to final scoring will be imposed on teams for the items shown in Table 8.

Table 8. Scoring penalties

Description	Impact to Score
Milestone deliverables are not submitted by the specified deadlines. This includes deliverable documents, slides, and completed reviewer forms/attendance forms, where applicable.	-10% to final score for each full 24 hr. period not submitted: • Submitted between 0–24 hours after deadline: -10% total deduction • Submitted between 24–48 hours after deadline: -20% total deduction
The team did not respond to the SpaceBot Leadership's correspondences by three weeks from the initial contact.	Full disqualification
Student approaches an energized SpaceBot system within an unsafe distance during the live Demo Day event.	-15% to demo score per incident
Permanent damage caused to the demo equipment as described in requirement SB-12. *Note: This excludes the entire mockup satellite.*	Full disqualification

7. COMPETITION EXPECTATIONS

Expectations for the SpaceBot leadership and university teams are outlined in the following sections.

7.1 EXPECTATIONS FROM UNIVERSITY TEAMS

- Teams must provide their own funding for the competition.
- Team expenditures should not exceed $15,000. This includes equipment for SpaceBot hardware, software, and mentoring and consultation from subject experts. Expenditures should not include travel costs.
- Team members and faculty advisors attending the live Demo Day event must be US citizens.
- Teams should provide all the equipment needed to perform the ground demonstration apart from equipment provided by SDL. This includes any equipment needed for assembling, operating, and troubleshooting SpaceBots at the demonstration facilities.
- Teams must maintain active communication with the SpaceBot Leadership team.
- Teams should be aided by at least one faculty advisor from their own university.
- Teams will be responsible for all personnel and equipment transportation to and from the demo site at SDL. Equipment delivery must be coordinated with SpaceBot leadership if delivery is needed.
- If teams would like to communicate with the SpaceBot Leadership Team, send inquiries to spacebot@sdl.usu.edu.

7.2 EXPECTATIONS FROM SPACEBOT LEADERSHIP

- The SpaceBot Leadership team will provide clarifying information regarding competition details, requirement interpretation, deliverable expectations, etc.
- The SpaceBot Leadership team will provide high-level technical support/advice upon request, although they will not directly solve technical problems encountered by participating teams.
- For each milestone review, the SpaceBot Leadership team will provide deliverable feedback to participating teams within one week of the listed deliverable date.
- The SpaceBot Leadership team will reply to communication inquiries via email within 72 hours of the team receiving the email.

8. ADDITIONAL RESOURCES

8.1 REFERENCE LINKS

Use the following reference links when developing your SpaceBot system or writing the required deliverables:

- University Nanosatellite Program (UNP)
    - Additional documents, lectures, and resources on space systems engineering from Air Force Research Lab's 20+ year outreach program
- NASA Systems Engineering Handbook
    - NASA's guide to systems engineering
- SE Book of Knowledge (SEBoK)
    - Wiki-based database on systems engineering concepts and topics

8.2 ACRONYMS

ASME	American Society of Mechanical Engineering
CDR	Critical Design Review
CONOPS	Concept of Operations
KOM	Kick-off Meeting
MESS	Modular Earth Sensing Surveyor
N/A	Not Applicable
OSAM	On-orbit Servicing, Assembly, and Manufacturing
PDR	Preliminary Design Review
SDL	Space Dynamics Laboratory
TBD	To Be Determined
USU	Utah State University

APPENDIX A: STAKEHOLDER REQUIREMENTS

The stakeholder requirements being levied on each participating student team. The imposed requirements are to ensure compatibility with the provided demo equipment and ensure the safety of demo observers. Teams are expected to comply with the requirements in accordance with the statement definitions shown below.

Table 9. Definitions

Statement Type	Key Word	Meaning
Requirement	Should/will/must	Mandatory action where 100% compliance is expected. Deviations require communication with the SpaceBot Leadership Team.
Policy/Guidance	Should	Good practice; recommended but not required for compliance. It is expected that these practices have been read and understood and that an informed decision about whether to follow has been made.
Discretionary Actions	May, Can	Terms used to show areas where discretion is used to determine the action, means, or approach.

Table 10. Requirement ID definitions

ID	Name	Text	Rationale
SB-01	Mission Environment	The SpaceBot should operate in the geostationary orbit (GEO) space environment. Note: GEO is defined as an altitude of 35,786 km (±250 km).	It wouldn't be a SpaceBot without the Space! This requirement encourages certain design decisions to be space ready.
SB-02	Repair Activities	The SpaceBot should perform repair activities as defined in SDL/23-3169, *SpaceBot Handbook*, Section 3.	This refers to the demo level activities, which are required to complete to receive competition scoring.
SB-03	Maximum Repair Time	The SpaceBot should perform the repairs activities defined in SB-02 within a maximum timeframe of 30 minutes.	This is to ensure that all teams are able to participate in the demo.
SB-04	Remote Operation	The SpaceBot should function without an operator line of sight. Note: "Line of sight" means that operators use their eyes to observe the SpaceBot's functionality.	This is to simulate operating the payload in outer space from the ground. Teams should rehearse remote operations prior to the live Demo Day event.
SB-05	Emergency Stop Availability	The SpaceBot should include emergency stop (e-Stop) buttons that immediately inhibit all system power upon button actuation.	These are safety features to be used during the demo.

ID	Name	Text	Rationale
SB-06	Exposed Wires	The SpaceBot should refrain from using exposed surfaces with electrical continuity of 50V or greater while the SpaceBot system is powered on. Note: This refers to live wires, connector contacts, or any other exposed electrical surfaces that could cause harm to human operators.	This is a safety requirement to prevent electrical shocks during the live Demo Day event.
SB-07	Mass	The SpaceBot should have a maximum total mass of TBD kg.	If the SpaceBot payload is too heavy, then the satellite may not be able to launch in the desired launch envelope.
SB-08	Size/Stowing	The SpaceBot should have a maximum stowed volume of TBD size. Note: Stowed refers to the payload being stored and completely enclosed within the host spacecraft garage.	The size of the SpaceBot must be compatible with the host satellite for it to be launched.
SB-09	Mechanical Interface	The SpaceBot should mechanically interface with the host bus in accordance with 408-0003, *SpaceBot Demo MICD*.	This ensures that the SpaceBot design can successfully interact with the demo setup to accomplish the live demo.
SB-10	Power Type	The SpaceBot may use 120 V wall power during operations.	If using wired power, teams will only be provided with typical office building wall outlets as power sources for their payloads. Otherwise, bots may either generate or carry their own power.
SB-11	Transportation	The SpaceBot should be transportable to SDL North Logan facilities. Note: Student teams are fully responsible for SpaceBot transportation costs and logistics.	The designed robot will need to be transported to SDL facilities for the competition demonstrations.
SB-12	Equipment Damage	The SpaceBot should refrain from causing permanent damage to demo equipment.	This is to prevent causing damage to SDL-provided equipment. Teams are allowed to permanently damage the mockup satellite but are not allowed to permanently damage the demo table, facility, facility power circuits, or any other equipment provided by SDL.

APPENDIX B: COMPETITION CYCLE GIVER/RECEIVER LIST

Table 11. Giver/receiver list

Item	Giver	Receiver	Due	Delivery Method
SpaceBot Handbook	SDL	Teams	April	Download from the SpaceBot Website
Team Application Form	Teams	SDL	Registration deadline	Submit through the SpaceBot Website
Accompanying Challenge Documents & Files (e.g. CAD models, ICDs, etc.)	SDL	Teams	Team registration confirmation	Email to the team point of contact
Cycle-Specific Information (e.g. due dates, rule updates, etc.)	SDL	Teams	Kick-off meeting	Email to the team point of contact
PDR Deliverable Package *Note: See Section 4.2*	Teams	SDL	PDR deadline	Submit through the SpaceBot Website
PDR Deliverable Score	SDL	Teams	1 Week after PDR deadline	Email to the team point of contact
CDR Deliverable Package *Note: See Section 4.2*	Teams	SDL	CDR deadline	Submit through the SpaceBot Website
CDR Deliverable Score	SDL	Teams	1 Week after CDR deadline	Email to the team point of contact
Demo Day Attendance Form	Teams	SDL	1 Week before the Demo Day event	Send to the SpaceBot Email
Demo Day Deliverable Package *Note: See Section 4.2*	Teams	SDL	1 Week before the Demo Day event	Submit through the SpaceBot Website