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COSMIC

CONSORTIUM FOR SPACE MOBILITY AND IN-SPACE SERVICING, ASSEMBLY AND MANUFACTURING (ISAM) CAPABILITIES

2025-26 COSMIC CAPSTONE CHALLENGE (C3) INFORMATION PACKET

The COSMIC Capstone Challenge is presented to college students who are invited to develop conceptual missions & designs for spacecraft operations in orbit or on the lunar surface. Four challenge tracks are offered in 2025-26: (1) Orbital Manufacturing and Assembly; (2) Lunar Operations; (3) Orbital Servicing; and (4) In-Space Assembly.

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REVISION AND HISTORY PAGE

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Contents

Contributors

The COSMIC Capstone Challenge (C3) has been developed over several years with contributions from dozens of students, professors, mentors, and judges. COSMIC recognizes the efforts from the track champions to formulate the challenges while providing continuing support to the COSMIC community and C3 teams. COSMIC also recognizes the efforts of the C3 leads to develop the program and create the Info Packet.

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1. Executive Summary: The 2025-26 COSMIC Capstone Challenge

The COSMIC Capstone Challenge is presented to college students who are invited to develop conceptual missions & designs for spacecraft operations in orbit or on the lunar surface. Four challenge tracks are offered in 2025-26: (1) Orbital Manufacturing and Assembly; (2) Lunar Operations; (3) Orbital Servicing; (4) In-Space Assembly.

2. Description

The Consortium for Space Mobility and ISAM Capabilities (COSMIC) was established in 2023 by NASA in response to the In-space Servicing, Assembly, and Manufacturing (ISAM) National Strategy. As an organization, COSMIC consists of members from industry, academia, and government across five different focus areas. One of these is the Workforce Development Focus Area (WDFA), which aims to inspire and prepare the next generation of engineers, artists, and visionaries to contribute to ISAM. The COSMIC Capstone Challenge (C3), led by WDFA, is a design competition taking place over the course of an academic year for students of **US-based colleges and universities** and can be adapted for a variety of in-class and out-of-class options.

Many of the entrants will be students in their senior design class, often known as capstone classes. The project can also be pursued by a group of students pursuing independent study, a team of students in a lab, or a student club. Teams can also be formed across universities. The challenge statements for the four tracks are listed below:

Track 1 Challenge: Orbital Manufacturing and Assembly (**C3-Manufacturing**)
Design a payload, to be hosted aboard Arkisys' Bosuns Locker, that would demonstrate a chain of three or more discrete operations providing a capability important for orbital manufacturing or assembly.

Track 2 Challenge: Lunar Operations (**C3-Lunar**)
Design a payload, to be delivered by the Griffin lunar lander, that can create infrastructure for a permanent lunar outpost.

Track 3 Challenge: Orbital Servicing (**C3-Servicing**)
Design a modular and maintainable spacecraft, capable of autonomously servicing multiple client satellites, to provide critical functions. The spacecraft can be designed around platforms such as ESPAStar, or other practical, existent spacecraft that can accommodate the necessary servicing features, like robotic arms, refueling ports, grappling stations, etc.

Track 4 Challenge: In-Space Assembly (**C3-Assembly**)
Design orbital or surface infrastructure element(s) and outline the mission describing its construction using autonomous robotic assembly technologies. Teams should leverage previous work in modular building blocks and "builder robots" as referenced; teams may choose NASA's Project ARMADAS or other types of building blocks and robotic systems to address their mission needs.

The goal for each challenge is to engage in **the early design work necessary for a complex ISAM mission** that could be ready for launch near the end of the decade. It is primarily a conceptual design challenge, distinguishing it from competitions that focus on building a product for demonstration or creating detailed design work sufficient to begin manufacturing. While there is a prototype required for the Lunar track, the evaluation is driven by the conceptual design. These concepts are the starting point for ambitious satellite missions. Some of these concepts may be continued post-competition, either by the entrants themselves or other entities (academic, industrial, or government). Mentors, judges, speakers, and other COSMIC members may offer guidance on how their work could be extended.

The C3 competition begins in July as the Information Packet is formally released, and when universities are encouraged to register their interest. Teams are encouraged to sign-up early as **registration closes after 100 teams have registered** and no later than October 14. After registering, teams will be assigned a mentor from industry, government, or a nonprofit research institution engaged with ISAM. Mentors will provide guidance to the students through weekly meetings, identifying problems and guiding students toward solutions. While recommended milestones are listed, there are only two interim deliverables: a statement of intent, and a midterm pitch-style briefing. The final and most important deliverable is the final presentation in mid-April at the C3 Final Showcase accompanied by a technical paper. The judge's scores will be based almost entirely on the 24-minute outbrief (followed by 4 minutes of questions), so crispness of presentation is essential. The presentations will be mostly virtual with an in-person option likely at one or more locations.

C3 was developed in response to the **ISAM National Strategy calling for the development of ISAM capabilities** across the country and promoting **workforce development.** Engineers have worked to identify and advance technologies important for servicing, assembly, orbital manufacturing and lunar operations. Many technologies have been demonstrated terrestrially and on-orbit, with more in the works. These technology advances pave the way for larger, more complex payloads which are in the various stages of development as follow-on work. Conceptually designing those payloads is one objective for C3. These projects do not stand alone; the hope is that some of these projects develop into funded missions, and the successful missions help pave the way for the future of ISAM operations. For more information, visit: https://COSMICSpace.org/C3 or contact C3-COSMIC@aero.org.

3. Track 1 Challenge: Orbital Manufacturing & Assembly (C3-Manufacturing)

Design a payload, to be hosted aboard Arkisys' Bosuns Locker, that would demonstrate a chain of three or more discrete operations providing a capability important for orbital manufacturing or assembly.

3.1 Motivation

The Bosuns Locker is a part of Arkisys' on-orbit 'Port' architecture for hosted payloads and In-space Servicing, Assembly, and Manufacturing (ISAM) activities. The Arkisys Port Module enables experiments, replacement spacecraft components, and ISAM modules to be attached and detached via physical interfaces post launch. The Port Module is a long duration spacecraft platform that supplies data, power, thermal, momentum and other services for up to 60 payloads at any one time, in various orbits. The Port Module includes robotics to enable payloads to be manipulated, moved, and even modified through physical connectable interfaces. The Bosuns Lockers are enclosures built to have physical interfaces that both "connect" to the Port Module and can be manipulated by the onboard robotic arm to move around as needed.

Payload developers who do not want to build their own containment for their payload or experimental enclosure can use the Arkisys Bosuns Locker as a modular payload containment unit. The Bosuns Locker is designed to focus developers on their specific payload, which not only encapsulates their payload through electrical and structural modularity but enables in-space manipulation compatible with the Arkisys Port architecture for post launch connectivity. The Bosuns Locker design includes sensors to support monitor a payloads performance over time and can be placed on any face or surface of the Port Module as needed for experimental needs.

3.2 Definitions

- An **operation** is defined as an action or set of actions performed by a single device. Examples of operations are listed below.
  - Polymer extrusion
  - Moving a part
  - Generating or receiving a diagnostic signal
  - Cutting, bending, grabbing, or dispensing
  - Determining minimum distance between two satellites in proximity
  - Growing inorganic crystals (e.g. semiconductor applications)
  - Mixing chemical or biological agents (for biological or physical science applications)
- A **capability** is a chain of operations that, when performed together, perform a useful function. Examples of capabilities are listed below.
  - Extruding polymer, moving the nozzle on a gantry, and removing finished part from a build plate
  - Generating an ultrasound signal without contact, listening for the signal after it passes by an inspection target, and interpreting that signal to evaluate the target part
  - More broadly, capabilities could be inspection, manufacturing, assembly, or other tasks necessary for orbital manufacturing
  - Manufacturing semiconductor crystals that would be returned to earth

    - Performing a life-sciences experiment
- The **Bosuns Locker**
    - Available volume: 15.75” x 15.75” x 35.45”
    - Payload mass capability: 400 kg
    - Peak available power: 1000W
    - Sustained available power: 300W
    - CAD drawings will be available
- Autonomous means it should operate on its own with limited remote commands
    - Since the phrase “limited remote commands” is subject to interpretation, teams should describe and justify their expected level of remote interaction. Initiating a sequence, confirming alignment before operation, interrupting an operation or proceeding to the next step are clear examples of “limited remote commands.”

3.3 Elements of the Conceptual Design

- The payload should be designed for Arkisys’ Bosuns Locker.
- It needs to demonstrate three or more operations to demonstrate a capability important for orbital manufacturing.
- The payload should be designed to operate semi-autonomously with limited remote commands
- Key design elements
    - The payload design should consider the entire mission lifecycle starting from launch.
    - Consideration should be given to known loads and environmental factors; this includes operating in vacuum, operating in microgravity, how it will be operated, and designing to survive launch loads.
    - The team should describe the expected operating duration.
    - The design should be captured using CAD software that can display essential views required to explain the process and concept of operations for this design.
    - A rough bill of goods required to build and integrate the payload should be included in the C3 Final Showcase presentation.
    - Analysis is required to sufficiently determine if a design is feasible and can meet the Arkisys Bosuns Locker specifications.

3.4 Recommended Majors

For single major teams, this project works best with teams of aerospace or mechanical engineers, however interdisciplinary teams of combined engineering majors would also work very well. Other STEM majors outside of engineering are free to participate within the challenge, however they must consider how to gain or leverage others with engineering expertise to fully satisfy the requirements of this challenge.

4. Track 2 Challenge: Lunar Operations (C3-Lunar)

Design a payload, to be delivered by the Griffin lunar lander, that can create infrastructure for a permanent lunar outpost.

4.1 Motivation

NASA and industry interest and investment in developing lunar surface infrastructure is present and growing. Whether it is to support a lunar surface water economy, for the production of propellants for in-space refueling, or to provide test facilities for technology development and demonstration, basic lunar surface infrastructure is needed. Common infrastructure needs include basic utilities such as *power*, *communications*, and *navigation*, as well as constructed infrastructure such as *landing pads*, *protective shelters/ storage facilities*, and *towers*. Power, communications, and navigation technologies are currently being developed and are making good progress. The next step is the development of technologies for the autonomous robotic construction of landing pads and shelters in the near term as NASA aims to establish continuous operations on the lunar surface. The concepts and designs proposed by C3 teams could shape the future of these plans, and great ideas proposed by strong teams could be extended beyond C3.

4.2 Definitions

- An **operation** is defined as an action or set of actions performed by a single device. Examples of operations are listed below.
  - Regolith sifting
  - Moving a part
  - Generating or receiving a diagnostic signal
  - Cutting, bending, grabbing, or dispensing
- A **capability** is a chain of operations that, when performed together, perform a useful function. Examples of capabilities are listed below.
  - Collecting regolith, putting it into a sifter, and collecting different types/ sizes of material
  - Moving to a prescribed destination, collecting a component via transfer, and move it to storage
- Griffin lunar lander
  - Detailed information from Astrobotic
  - Griffin is a medium-class lander with flexible mounting options to accommodate a variety of rovers and other large payloads
  - While the maximum payload mass is 625kg, for C3 the maximum available payload mass is 200kg; the available volume is roughly half the total volume, and the final geometry is to be determined
  - For these missions, the Griffin lunar lander will act as a delivery vehicle and also as a base station. For C3, consider that the lander will have a large solar panel array (the exact size will be provided) and a large capacity battery (size is still to be determined). The lander will be the relay for communicating with Earth, with a WiFi access point available for relaying communications.
- Prototype
  - A hardware assembly that demonstrates one or more key elements of the proposed design
  - The prototype may focus on the novel elements of the design or the whole thing
  - Prototypes should be functional but do not need to be designed to survive launch or the operating environment
  - Prototypes will be evaluated based on function, scale, completeness, and degree of difficulty

4.3 Elements of the Conceptual Design

- The payload should be designed fit within the designated mass and volume available on the Griffin lunar lander; the payload may be stationary or mobile
- It needs to create infrastructure important for a permanent lunar outpost
- The payload may be designed to operate with various levels of human engagement. That could include full autonomy with limited remote commands, remote operation, local operation by an on-surface astronaut, or cooperative operation with an astronaut.
- Key design elements
    - The payload design should consider the entire mission lifecycle starting from launch.
    - Consideration should be given to known loads and environmental factors; this includes operating in vacuum, operating in lunar gravity, designing to survive launch and landing loads, operating during day or night, and ensuring it can meet the Griffin specifications
    - Description of how the payload will be operated, how long it will operate, where it will operate, how it will interact with the Griffin lander, and how operations during both lunar day and night will be managed
    - The design should be captured using CAD software that can display essential views required to explain the process and concept of operations for this design
    - A rough bill of goods required to build and integrate the payload should be included in the C3 Final Showcase presentation

4.4 Recommended Majors

It is important to consider that for this track a prototype is required, so a larger group and resources like a makerspace would be helpful for this track. For single major teams, this project works best with teams of aerospace, electrical, or mechanical engineers; interdisciplinary teams of combined engineering majors would also work very well. Other STEM majors outside of engineering are free to participate within the challenge, however they must consider how to gain or leverage others with engineering expertise to fully satisfy the requirements of this challenge.

5. Track 3 Challenge: Orbital Servicing (C3-Servicing)

Design a modular and maintainable spacecraft, capable of autonomously servicing multiple client satellites, to provide critical servicing functions. The spacecraft can be designed around platforms such as ESPAStar, or other practical, existent spacecraft that can accommodate the necessary servicing features, like robotic arms, refueling ports, grappling stations, etc.

Consideration can also be given to an orbiting persistent platform as a base where a client satellite would come to be repaired, upgraded, refueled, or be attached to temporarily, with the intent to extend their operational lifespan, restore functionality, or enable mission flexibility with enhancements. The servicing platform should integrate cutting-edge automation, robotics, or repair technologies to provide hands-free servicing solutions. A successful challenge response will define the baseline spacecraft with emphasis on minimal complexity, yet maximum capability to adapt to any client servicing need.

5.1 Motivation

Satellites are expensive. The cost to replace a GEO satellite can easily reach $500M or more. Most satellites become obsolete because their sensors or components age out or fail, or their available propellent is expended. Typically, a satellite has potential residual use after its baseline mission, so extending the applications is warranted. Servicing is the means to reutilize, extend, or change that mission at a fraction of the cost of a new one, and at a fraction of the time to design, build, and put that new one on orbit.

5.2 Definitions

- A **modular** spacecraft is one that has design features that are plug & play and can be assembled with modern day advanced manufacturing techniques. This is in order to allow for ease in modifications to baseline configurations, as required for multiple missions. A spacecraft of this type could have the following features:
    - Designed for ready integration with other spacecraft via use of standard interfaces
    - Sized to easily be packaged within standard launch vehicle parameters
    - Optimized to maximize the use of off the shelf components or subsystems
- A **maintainable** spacecraft has one or more of the following characteristics:
    - Able to accept multi-missions so it can be reused many times for different clients
    - Designed for upgradable sensors and components dependent on the mission requirements
    - Designed to be refueled by servicer satellites, or can refuel client satellites
    - Robotic or other feature types to enable the replacement of parts prone to wear or failure (such as batteries or solar panels), or the upgrade of subsystems like flight computers for edge processing
    - Chemical or electric propulsion capability (or a hybrid system) to move to the client satellite in a particular orbit (LEO, MEO, HEO, GEO, cis lunar, or a combination)
- **Autonomous** servicing is a capability suite that does not rely on human-in-the-loop to complete its operation, but rather has the software sufficient to identify, diagnose, and execute a servicing function.
- **Client satellite** is one that needs a servicing function while in orbit. Note that it could be one that is already in orbit, or one that is yet to launch where the servicing requirement is built into the design and therefore will rely on the capability at some point during its mission lifetime.
- **Critical servicing functions** include but are not limited to 1) refueling via propellent transfer or swap of propulsion tanks, 2) physical interactions to “nudge” or release caught deployables such as antennas and solar arrays, 3) space situational awareness inspections via fly-by and proximity observations, 4) docking, 5) carrier vehicle for debris removal concepts requiring a controllable maneuvering base, 6) augmentation of clients via replacement of instruments/components, 7) mylar removal and replacement, 8) surgical robotics for high precision, 9) repositioning of a client to a different orbit, 10) serving as a depot for parts readily available.
- **ESPAStar** is an existing proven multi-item platform that utilizes an ESPA ring to carry a predefined set of smaller payloads and components on a single mission, that interfaces with launch fairings and fits under the constraints of the shroud.
- **Cutting-edge technologies** are those that are either state of the art, or those that are under development for adoption in the next few years. Students are encouraged to “push the limits” on what could be considered cutting edge.

5.3 Elements of the Conceptual Design

- The resulting spacecraft will include well thought out, purposefully-selected components, equipment and sensors to accurately perform the operations required in proximity of the client satellite.
- Requirements and functions of each subsystem should be clearly defined, and the size, weight and power (SWaP) estimates should be based on realistic assessment of current or future system configurations that are under development.
- The spacecraft will be designed to fit inside the shroud of the selected launch vehicle.
- Select and validate a mission area of interest, which will include the chosen orbit, class of client satellite, candidate features to be serviced, what type of devices or tools will be required for the servicing, docking or grappling operations, and other mission parameters needed to execute the mission.
- Cutting-edge technologies may include capabilities not yet demonstrated on orbit but which would be feasible with a few years of development.
- If the candidate design is a persistent platform, add the features required of the clients to rendezvous and dock with the platform and provide the unique docking requirements.
- Identify the chosen robotic features and assess needed fidelity of the system, which may include a surgical robotic capability.
- The candidate features to be serviced should include at least two of the critical servicing function shown above and should be chosen based on a systems engineering perspective of tradeoffs or via trade study. For example, for refueling, is it better to transfer propellent through a port, or just replace a tank? Is it easier to repair a damaged solar array, or attach a new ROSA (roll out solar array) over the existing one? What attachment mechanisms are optimal for a low-risk approach to connecting an orbital replacement unit (ORU) to the client?
- Key design elements
    - The concept design should consider the entire mission lifecycle starting from launch through mission success and data retrieval.
    - Consideration should be given to known loads and environmental factors including operating in vacuum and in micro gravity, temp variations in orbit, surviving micro meteorite impacts, radiation, electrostatic discharge, outgassing, thruster plume deposition, atomic oxygen effects, and designing to survive launch loads.
    - Consider manufacturability, adaptability, and accessibility for servicing.
    - Evaluate the economics of the potential missions. Is the business case feasible for servicing a particular satellite problem, or does it make more financial sense to just put up a new one?

5.4 Recommended Majors

This track is very involved, and it is important that some team members have some experience and knowledge of satellite design and architectures. It is recommended to have a larger team of 7 or more to effectively pursue this challenge. For single major teams, this project works best with teams of aerospace engineering majors, however interdisciplinary teams of combined engineering majors would also work very well provided there is a core group of aerospace engineering majors. Other STEM majors outside of engineering are free to participate within the challenge, however they must consider how to gain or leverage others with engineering expertise to fully satisfy the requirements of this challenge.

6. Track 4 Challenge: In-Space Assembly (C3-Assembly)

Design orbital or surface infrastructure element(s) and outline the mission describing its construction using autonomous robotic assembly technologies. Teams should leverage previous work in modular building blocks and "builder robots" as referenced; teams may choose NASA's Project ARMADAS or other types of building blocks and robotic systems to address their mission needs.

6.1 Motivation

Robotic assembly and construction are critical capabilities needed to develop sustainable and scalable infrastructure to enable a persistent presence in space. Challenges related to developing cost effective and economical systems, demonstration of reliability in extreme environments, and mass limitations of launch vehicles have limited our ability to easily scale construction activities in space. Recent advances in autonomous robotic systems, materials, and integrated system designs have enabled development of robotic assembly systems that can (1) scale physically and economically, (2) be adaptable and reconfigure to multiple mission scenarios and needs, and (3) have performance characteristics that meet aerospace needs. NASA wants the next generation of explorers to think about how these types of missions and systems are designed and executed to enable a scalable and economical future for space exploration.

6.2 Definitions

- **Orbital Infrastructure** is any system or asset in orbit that provides capabilities or services for users. Examples include:
    - Spacecraft refueler
    - Persistent payload host platform
    - Mars transport vehicle
    - Spaceport
- **Surface infrastructure** is any system or asset on a planetary surface that provides capabilities or services for users. Examples include:
    - Tower for power or communications
    - Shelters
    - Berms and landing pads
    - Rover repair vehicle
- **Mission** is defined as the development, execution, and operation of an activity to achieve a goal.
- **Robotic construction** is the process of building an asset that is performed by robotic agents. This can include excavation, material logistics, manufacturing, assembly and more.
- **Robotic assembly** is the process of aligning and joining pre-designed elements together using robotic agents to build a functional structure.
- **Building blocks** are modular structural units that are connected together to create a larger structure. Some examples of building blocks are listed below:

    - ARMADAS voxel: a cuboctahedron shaped building block that has four reversible connections on each of the faces.
    - Tri truss: a truss building block that can be used to build curved structures.
    - Tall lunar tower: a truss assembly system for building towers.
    - Sandbags: a building block consisting of a bag filled with regolith (or other material) that can be stacked to create a structure.
- **Robotic agents** are electro-mechanical systems that are used to automate the construction process. Some examples of robot technologies are listed below:
    - Fixed robot arm: a robot arm that can manipulate materials and perform tasks using end effectors
    - Transport robot: a robotic agent that carries building blocks from a depot to the build front
    - Joining robot: a robotic agent that joins or fastens building blocks together
    - Crane robot: a robotic agent that can lift heavy payloads vertically and provide offloading capabilities
    - Inspection robot: a robotic agent that monitors the health of the structure
    - Outfitting robot: a robotic agent that can install outfitting modules onto the base structure
- **Autonomous** means it should operate on its own and resolve problems with minimal levels of input. Teams should describe and justify their expected level of autonomy.
- **Outfitting** means adding a specific capability to the base substructure to support a desired application. Some examples of outfitting are listed below:
    - Utility outfitting:
        - Power and Data Cabling: Electronics can be installed on the substructure to provide power and data transmission.
        - Pipe and ducting: fluid and air transfer systems can be installed to provide needed capability.
    - Functional outfitting:
        - Rail System: Rail modules are installed on the substructure to provide an integrated transportation system.
        - Paneling: Panel modules are installed on the substructure to provide a covered shelter.
        - Surface Interfaces: Footer modules can be installed on the bottom of the substructure to interface with the surface.
- **Material Source** means where the construction material is manufactured and coming from. This can be from materials sourced from the earth, from supply depots in orbit, on the moon, or from ISRU materials gathered from local sources.

6.3 Elements of the Conceptual Design

- Systems Engineering
    - Goals, needs, and objectives should be clearly described.
    - High level requirements should be included.
    - CONOPS should be included and describe the sequencing of construction, including transport of raw materials.
    - Risks and mitigations should be identified and described.
- Concept design and analysis
    - Include CAD model of the robotically assembled functional structure

- Description of the manufacturing sequence and which tools would be used in construction. If there are additional tools needed to enable construction, describe those.
- Describe the purpose of the structure and why it is better to assemble in space instead of fitting it within a single payload fairing and deploying directly.
- Analysis to assess relevant metrics such as mass efficiency, performance, survivability.
- Analysis for structure and process to perform in the expected environment.
- Describe the joining method you would employ and why you would choose it.
- Describe how to outfit the non-structural elements into the system (functional modules, power and data routing, fluid transport, etc.).
- Describe the sequencing of the build process in at least six steps in lieu of animating the entire process.
- Describe how your team would use in-space resources; if your requirements exceed those described above, then define what's needed to complete your mission.
- Describe how are the materials to enable the mission sourced – both long distance and local logistics.
- If other steps are required to create a functioning system, describe those steps.

6.4 Recommended Majors

Due to this track creating large structures and developing a plan to assemble them, it is important the teams consider members with structural design experience. For single major teams, this project works best with teams of aerospace engineers, civil/structural engineers, mechanical engineers, and architects. Interdisciplinary teams of combining engineering and architecture majors would also work very well. Other STEM majors outside of engineering, are free to participate within the challenge, however they must consider how to gain or leverage others with engineering expertise to fully satisfy the requirements of this challenge.

7. Evaluation Criteria

7.1 Deliverables

Top teams in each Challenge Track will be recognized. Any prizes will be announced during Spring Semester 2026.

1. Judging will be based upon a 24-minute briefing that comprises 95% of the score at the C3 Final Showcase.
2. A 10-20 page technical paper will account for 5% of the final score. The paper and briefing will be due on April 9, the Thursday before the Final Showcase begins.
3. Statement of intent: 50-150 words + 3 key references by October 24.
4. 5-minute brief for midpoint showcase in December; after this event, each team will receive feedback from one or more COSMIC members on their progress.
5. There is an optional category for the best functional prototype which does not count toward the final score, and the top prototype entry will be recognized. The prototype is required for C3-Lunar (Track 2). A video of the prototype must be submitted to complete this deliverable, as judges will review it to score the prototype. The video is due a week before the final due deadline (April 2nd) of the design competition.

Teams of 8 or more students can tackle any challenge but are only eligible for prizes in Track 2: C3-Lunar or Track 3: C3-Servicing.

7.2 Guidance for Judging

The following elements requested below mimics the judging rubric that is provided in this document.

1. The presentation must describe in sufficient detail the design to understand the following about the conceptual design:
    1. Technical impact of demonstrated capability.
    2. Feasibility of proposed mission.
    3. Innovativeness of the payload design.
    4. Relate how the successful execution of the proposed mission would advance support for one or more of the high-value missions identified by COSMIC.
2. Provide an overview of the system and the program:
    1. Animate one or more key operating sequences.
    2. Create a storyboard of the complete operation.
    3. The recommended path to proceed to a Preliminary Design Review (PDR).
    4. Document achievement of key milestones.
3. Describe the engineering concepts utilized in the design in sufficient detail:
    1. Adherence to the design requirements.
    2. Identification and mitigation of risks associated with the design.
    3. Generate a high-level overview of data handling and ground communications.
    4. Summary of trade studies that help illustrate the design development.
4. List key lessons learned during the project:
    1. Three innovative ideas that were shared, even if not pursued.
    2. Three technologies most important to develop for this demo or other ISAM activities.
    3. Three biggest challenges encountered, even if avoided.
5. The work should be well defined and clearly described:
    1. Make a professional, concise, understandable presentation at the C3 Final Showcase.
    2. Write a 10–20-page technical paper that would be appropriate for at least an engineering conference, journal, engineering magazine, etc. The deadline for submitting an extended abstract to AIAA SciTech is typically in late May. While optional, it accounts for 5% of the score and builds good experience.
    3. By October 24, describe your planned concept in 50-150 words and list 3 references (not taken from this packet) relevant to your work.
    4. Give a 5-minute "pitch" to give a clear and concise idea about the status of their work during the Midpoint Showcase.
6. There is an **optional** category for the Best Functional Prototype. This is not required and will not be considered in judging the winners, except as a tool to illustrate the Conceptual Design. The team with the best functional prototype will be recognized with a distinct recognition. The prototype is required for C3-Lunar, where it is 20% of the final score.

8. Timeline

8.1 Key dates for universities & other educational institutions

- April 14, 2025: Preview of C3 information packet released and registration opened
- August 4, 2025: Preferred registration deadline (to enable C3 organizers to match mentors and teams)
- Registration will close once 100 teams have signed up.
- October 13, 2025: Late registration deadline

8.2 Key Registration and Deliverable Dates for Students

- September 9, 2025: Live on-boarding session for teams and mentors (recorded for later viewing)
- October 13, 2025: Deadline to register your team for the COSMIC Capstone Challenge
- October 24, 2025: Provide a statement of intent
- December 8-12, 2025: **Midpoint showcase** and announcement of divisions and possible prizes
- April 13-17, 2026: **Presentation and judging** at C3 Final Showcase (winners announced the following week)
- A survey will be sent the week before the Final Showcase, and teams must complete the survey to be award eligible

8.3 Key milestones & recommended completion dates for student teams

- Recommended dates based upon 2 semesters spanning 9/3/2025 – 5/2/2026, and may be adjusted for other timeframes
- September 16, 2025: Identify who on the team will serve as program manager
- October 14, 2025: Select operations to form the foundation of the target capability
- November 15, 2025: Present Systems Requirements Review (SRR) to peers, mentor & advisor
- January 13, 2026: Complete trade studies
- March 3, 2026: Present Conceptual Design Review to peers, mentor & advisor
- April 6, 2026: Develop a plan to reach Preliminary Design Review
- May 2026: Submit paper to technical conferences (such as AIAA SciTech Abstracts)

8.4 Key dates for organizers, mentors, judges, and sponsors

- April 15, 2025: Mentor registration opens
- July 2025: Socializing C3 at COSMIC meetings, at ISSRDC, and through university & high school networks
- August 5, 2025: Preferred mentor registration deadline (enable C3 organizers to match mentors & teams)
- Week of September 9, 2025: Live on-boarding session for teams and mentors
- September 30, 2025: Late mentor registration deadline
- October 1, 2025: Judge registration opens
- November 1, 2025: Deadline for sponsors to offer prizes
- Week of December 9, 2025: Midpoint showcase and announcement of categories and any prizes
- February 2026: Send Out Schedule Survey (to begin planning C3 Final Showcase agenda)
- March 2026: Judge registration closes

- March 2026: Establish agenda for presentations & judging assignments
- March-April 2026: Judge orientation/on-boarding
- April 13, 2026: Presentation and judging at C3 Final Showcase (winners announced the following week)
- April 17, 2026: Send out post-event survey to judges, mentors, and advisors
- Late April 2026: Meet with judges, mentors, and advisors to gather feedback

8.5 Recurring events

- COSMIC will host weekly office hours for ask questions & guidance beginning week of August 19
- Meet with industry mentors on weekly or biweekly basis
- COSMIC-hosted monthly ISAM seminars

9. Expectations

9.1 Expectations for students

- Contact mentor to set up weekly or biweekly meetings & act professionally in those interactions
- Read through this entire C3 Information packet at start of project
- Review reference documents
- Reach out to mentors, academic advisors, and C3 committee as appropriate with questions
- Complete all required classwork, even if it is not required for C3
- Address & document key milestones from Timeline page
- Eligibility: all members enrolled at a US-based college
- Complete survey

9.2 Expectations for professors & other academic advisors (or team lead for clubs, etc.)

- Sign up for C3 on website by August 5 (preferred) and no later than September 30
- Direct students to contact mentor
- Reach out to C3 committee with questions about the program
- Help students form teams as: part of a class, for a student club, or as independent study
- For design classes, grades based upon the school's own criteria; professors may choose to use the provided judging criteria to inform their grades, but should not use judges' scores

9.3 Expectations for mentors

- Meet 4-10 hours monthly with students (at least biweekly)
- Serve as the ISAM expert for the students, and direct them to appropriate resources
- Contact C3 committee if there are team issues and with other questions
- Treat the students as junior engineers; encourage them to be innovative
- Do not share export-controlled or proprietary information with teams
- Support, encourage and advise students
- Are not responsible for evaluating individual students or the team

- Complete post-event survey

9.4 Expectations for C3 committee

- Provide clear guidelines to all stakeholders
- Be available on a daily basis for email & weekly basis for verbal communications from July 1 onward
- Maintain a compelling program throughout the academic year & incorporate feedback from stakeholders

9.5 Expectations for judges

- Attend judging onboarding brief, which includes overview of ISAM and objective of C3
- Spend 1 or more days listening to presentations & scoring entries
- Do not act as a judge for any team you have advised, with an allowed exception for providing feedback regarding the Midpoint Showcase
- Review the C3 Information Packet & score sheets before the C3 Final Showcase

10. Reference Documents

These references are mostly a carryover from 2024-25. This will be updated and expanded for the Final Release in July 2025, and will include many more references specific to each track

10.1 General References

About ISAM & related technologies

- COSMIC ISAM 101
- NASA ISAM overview
- COSMIC released products
    - ISAM Resources & References database
    - ISAM Education Advocates database (add public link)
    - COSMIC Lexicon
    - ISAM Technology Taxonomy

Technology assessment and development roadmaps – required reading

- "In-Space Servicing, Assembly and Manufacturing Strategy," National Science & Technology Council. April 2022
- "In-space Servicing, Assembly, and Manufacturing (ISAM) State of Play," Dr. Dale Arney, John Mulvaney, Christina Williams, Wilbert Andres Ruperto Hernandez, Jessica Friz (NASA Langley Research Center), Christopher Stockdale (Analytical Mechanics Associates, Inc.) , John Nelson (US DoD), Rafael Rivera Vargas (University of Puerto Rico-Mayaguez)
- "Technology Roadmap for the Development of an Orbital Smallsat Factory," Matthew B. Obenchain, Jacob Rome, Chris Hartney, Kelvin Chen, Alejandro Trujillo, Arianna Villegas, Vinay Goyal, Jon Strizzi and Deneen Taylor. AIAA 2024-1274. AIAA SCITECH 2024 Forum. January 2024. https://doi.org/10.2514/6.2024-1274
- "In-Space Servicing, Assembly, and Manufacturing for the New Space Economy," Alec Cavaciuti, Joseph Heying, Joshua Davis
- "Toward a Fully Capable In-Space Manufacturing Ecosystem," Matthew B. Obenchain, Alex Trujillo, Jacob Rome, Joseph H. Heying, Arianna Villegas, Vinay K. Goyal and Deneen Taylor. AIAA SCITECH 2024 Forum. January 2025. https://doi.org/10.2514/6.2025-1781

Exemplar ISAM missions

- NASA OSAM-1
- DARPA Orbital Express
- Northrop Grumman Mission Extension Vehicle
- Astroscale Refueler

About the COSMIC Capstone Challenge

- "Overview of the ISAM Design Challenge and Competition," Jacob Rome and Vinay Goyal. AIAA 2024-0628. AIAA SCITECH 2024 Forum. January 2024. https://doi.org/10.2514/6.2024-0628

- "Orbital Manufacturing Initiative," Rome (SSDM)
- LinkedIn Group.
- "COSMIC Capstone Challenge," Joey Heying and Jacob Rome, AIAA SCITECH 2025 Forum, January 2025. https://doi.org/10.2514/6.2025-0803

Example projects

- University of California San Diego: Autonomous Rail Transportation Network for Spacecraft Servicing and Inspection, Lovekin, E., Kattee, A., D'Souza, R., Khan, E., AIAA SCITECH 2025 Forum. January 2025.
- Kennesaw St.: "Conceptual Development Design Challenge of On-Orbit Autonomous Manufacturing Payloads," Goyal, Vijay, AIAA SCITECH 2025 Forum. January 2025.
- California State University Northridge, "Concept Development for Autonomous In-Space Additive Manufacturing, Inspection Using Thermography, and Robotic Manipulation," William A. Sulprizio, Rogelio Reynoso, Erek Flores, Noah Liu and Joshua Santiago. AIAA SCITECH 2025 Forum. January 2025.

Design review templates

The first reference listed is **required reading**. The others are provided for students as guidelines for conducting reviews and planning the work. They are meant to be descriptive not prescriptive.

- "Introduction to Conceptual Design," Lee
- "NASA System Requirements Review Template," Benedict
- "NASA System Concept Review Template," Benedict
- "EML2322L – Design Report Template," University of Florida

Program Management

- NASA Research and Technology Program and Project Management Requirements (Revalidated w/change 5) NPR 7120.8A
- NASA Systems Engineering Processes and Requirements Updated w/Change 2. NPR 7123.1D
- Project Planning for Beginners: https://youtu.be/ZWmXi3TW1yA?si=toydKiVnwEZH572Z
- Project Management Fundamentals from Coursera

Other Design Competitions

Links are provided to other competitions to spark ideas amongst students as they pursue their design projects. While most of the competitions focus on building prototypes, many have solid university-appropriate guidelines on how to progress through the design process.

- AIAA Design/ Build/ Fly
- Formula SAE
- 3D Printed Aircraft Competition
- American Solar Challenge
- Revolutionary Aerospace Systems Concept Academic Linkage (RASC-AL)
- Intelligent Ground Vehicle Competition
- NASA Student Launch Initiative

10.2 References for C3-Manufacturing

Partial selection of technologies that would benefit on-orbit demonstration

- "No More Lost in Space: Low-SWAP ID and Tracking Aids," Barbara M. Braun, The Aerospace Corporation (OTR 2021-00372)
- "Methods of Non-Destructive Evaluation of Composites," NASA (LAR-TOPS-120)
- "ISS Interface Mechanisms and Their Heritage," John Cook, Valery Aksamentov, Thomas Hoffman, and Wes Bruner, The Boeing Company (NASA 20110010964)
- "Applications of Permanent Magnet in Outer Space," Stanford Magnets
- "Technology Roadmap for the Development of an Orbital Smallsat Factory," Matthew Obenchain et al., The Aerospace Corporation/United States Space Force Space Systems Command/NASA Langley Research Center (NASA 20230015444)

Host Vehicle

This vehicle was chosen to provide all teams with a common starting point. Other companies offer similar host capabilities, either as a satellite bus or a persistent platform.

- "The Bosuns Locker," Noah Gladden, Rahul Rughani, Dave Barnhart, Arkisys
- CAD for the Bosuns Locker, courtesy Arkisys
- Interface Control Drawing for the Bosuns Locker, courtesy Arkisys

10.3 References for C3-Lunar

Partial selection of technologies that would benefit lunar surface infrastructure demonstration

- "Ten NASA Science, Tech Instruments Flying to the Moon on Firefly Lander," NASA
- "NASA Enables Construction Technology for Moon and Mars Exploration," NASA
- "Lunar Landing Pads," NASA (KSC-TOPS-89)
- "Design Analysis for Lunar Safe Haven Concepts," Iok Wong et al., NASA Langley Research Center/NASA Marshall Space Flight Center (NASA 20210024725)
- "Lunar Surface Power Systems," John Scott, NASA Space Technology Mission Directorate (NASA 20230005406)

Host Vehicle

This vehicle was chosen to provide all teams with a common starting point. Other companies offer similar host capabilities, either as a satellite bus or a persistent platform.

- "Griffin Lunar Lander," Astrobotic

10.4 References for C3-Servicing

Partial selection of technologies that would benefit lunar surface infrastructure demonstration

- "A New Design Approach: Modular Spacecraft," Matthew Kohut, NASA
- "Autonomous Robot Swarms for Lunar Orbit Servicing and Space Asset Assembly," NASA Space Technology Mission Directorate
- "Technologies for Refueling Spacecraft On-Orbit," David Chato, NASA Glenn Research Center, (NASA 20000121212)
- "Space Situational Awareness," Space Safety Institute, The Aerospace Corporation
- "Robotic Servicing Arm," NASA NEXIS

Host Vehicle

This vehicle was chosen to provide all teams with a common starting point. Other companies offer similar host capabilities, either as a satellite bus or a persistent platform.

- "ESPAStar," Northrop Grumman

10.5 References for C3-Assembly

Partial selection of technologies that would benefit in-space assembly demonstration

- "SpaceFrame: Modular Spacecraft Building Blocks for Plug and Play Spacecraft," Miller et al., AeroAstro Inc./Air Force Research Laboratory
- "Robotic Technologies for In-Space Assembly Operations," Roa et al., German Aerospace Center (DLR)
- "Robotic Assembly and Outfitting for NASA Space Missions," NASA
- "NASA Enables Construction Technology for Moon and Mars Exploration," Loura Hall, NASA

Reference systems

This vehicle was chosen to provide all teams with a common starting point. Other companies offer similar host capabilities, either as a satellite bus or a persistent platform.

- "ARMADAS," Sanders et al., NASA Ames Research Center
- "TriTruss: New and Novel Structural Concept Enabling Modular Space Telescopes and Space Platforms," Doggett et al., NASA Langley Research Center/National Institute of Aerospace
- "Tall Lunar Tower," Matthew Mahlin, NASA Langley Research Center
- "Lunar Sandbags," Du et al., Space Exploration Initiative, Massachusetts Institute of Technology

11. Vision For the Future of the COSMIC Capstone Challenge

The genesis of C3 was the ISAM Design Challenge starting in Fall 2022, a senior design project developed by Aerospace to harness the creativity of college students while introducing them to the emerging ISAM field. It evolved during the past two years, and with the creation of C3, the structure has become better defined and formalized. The design challenge has been crafted with input from industry mentors, government customers, capstone professors, competition organizers, competition judges and student participants. During the second year of C3, the focus is expanding the program successfully and maintaining the high level of mentor-team engagement. With the expansion to 4 tracks, each with its own champion, C3 is being developed to sustain and grow in the future.

To that end, C3 has been developed to ease its adoption within the construct of a **2-semester senior engineering design class**, often referred to as a Capstone project. However, **it is not restricted to that category**. Instead, it is being opened wider, so that student clubs could enter the challenge, as could groups of students, either undergraduate or graduate, pursuing independent or directed study. The best outcome of these projects will be an excited core of students that want to continue the project past the conceptual design phase to detailed design work or even prototyping.

There is a strategic component to casting it as a judged competition with mentoring. To be precise, the judges and mentors will often be drawn from elements of the government and industry that are interested in pursuing these projects. **The successful version of this program would connect student teams with funding sources to continue the work towards an eventual mission,** executed either by a successor team at the university or by contractor capable of executing the designated mission. This is an element that could play well with student clubs, which typically have carryover from year-to-year. It is possible that a future iteration of C3 will be to bring a promising Conceptual Designs to the Preliminary Design phase, in which case student clubs would be able to leverage that continuity to continue.

For the coming academic year, the competition remains focused on the engineering part of the problem. In future iterations, the **scope may be widened to encourage non-engineering students with an interest in ISAM to participate**. This could be done through the problem statement, through the judging rubric, or via additional categories. For example, up to 10 points could be awarded for developing a business plan to identify how the project would go from Conceptual Design through launch by identifying funding sources, launch opportunities, and long-term project management. A similar approach could take place for artwork. Or there could be a separate award for the team that creates the best 1-page marketing pitch to potential sponsors.

C3 is very much a work in progress. The development of the program in the future will be guided by mentors, judges, other members of the COSMIC community, students, professors, and supporters. The community will develop Future C3 Information Packets, and it is the intent of COSMIC to appeal to a broad swath of students as we work to advance ISAM while exposing students to the possibilities of ISAM.

12. Administrative Items

- COSMIC has no rights to any intellectual property (IP) generated during this project, with a limited permission to share the final products as described in the next bullet.
- Entrants grant the COSMIC Capstone Challenge (C3) organizers a non-exclusive right to:
  - Post online the outbriefs from the competition online to share them with the COSMIC membership and (past, current, and future) participants in the COSMIC Capstone Challenge
  - To allow C3 organizers to incorporate elements into written publications, briefings and marketing materials that would be available to the public.
- There is no guarantee of monetary prizes being awarded. If there are any prizes awarded by C3 sponsors, the prize is the sole responsibility of the sponsors.
- All C3 judges and mentors must be authorized participants from a COSMIC member organization; COSMIC is no cost to join, and open to any US organization.
- Any authorized participants from a COSMIC member organization may serve as a mentor or a judge. Mentors may serve that role for multiple teams. C3 organizers may fulfill either judge or mentor roles. Mentors, advisors and organizers may not act as judges for teams they have advised
- If C3 is used as a Capstone, scoring criteria used in this solicitation is not required to grade students. It is up to the discretion of the professor to select class grading material. Likewise, mentor feedback should not have direct impact on student grades.
- There is a strict no-harassment policy.
- All participants (entrants, judges, and mentors) must abide by ITAR rules. Mentors must not provide any information to any team that is ITAR controlled, and student entries must not include any ITAR restricted materials.
- While entrants must be enrolled at a US-based educational institution, there is no citizenship requirement for any student members of participating teams or their advisors.
- COSMIC membership is not required for teams or their associated educational institutions to enter.

13. COSMIC Capstone Challenge 2025-26 Score Sheet

Judges may score each subcategory, or may score the entire category as a whole, depending upon their preference.

Track Number: ____

Team Name: ____

Team Organization: ____

Team Members: ____

____

____

Judge’s Name: ____________________________________

Date: ____________________________________

(Note that categories 5.3, 5.4 and 6, will be scored by the organizers before the Final Showcase.)

Category 1: Conceptual Design			
Subcategory	Description	Score Range	Score (½ OK)
1.1 Technical Impact of Demonstrated Capability	If the mission is successfully executed, how much impact would those capabilities have for future space missions? Consider the following 3 questions: Would it enable new or improved types of spacecrafts? Could it be used to augment or repair existing satellites? Would other technology developments be required for this capability to be useful?	0-8	
1.2 Feasibility of Proposed Mission	How likely is it that this mission (if funded) could be designed & built within 5 years? Evaluation of these items should be considered when scoring this category: the bill of materials, current CAD drawings, plans to develop technology as needed, approach for manufacturing & testing.	0-8	
1.3 Innovation	Is the design original in a pertinent way? Considerations for this category: Has this been demonstrated in space before? Has it ever been proposed? Has it been executed in a similar fashion? Is it uniquely suited for its proposed function?	0-7	
1.4 Advancing High-Value Missions	Do the students connect their proposed demonstration mission to the high-value missions identified by COSMIC? How much confidence would a successful demo mission advance the enterprise towards executing those high-value missions?	0-5	
Category Total	Conceptual Design	0-28	

Category 2: Systems and Program Overview			
Subcategory	Description	Score Range	Score (½ OK)
2.1 Animate key operating sequence	Utilizing CAD designs, a prototype, or other tools, develop an animation or video to show step by step processes required to execute concept design.	0-7	
2.2 Storyboard of complete operation	At each phase of a mission (from launch until deorbit), illustrate and describe the varying configurations and operations the concept will progress through over the mission's duration.	0-7	
2.3 Path to PDR	Has team identified next steps for design process & outlined a sequenced to advance to Preliminary Design Review?	0-4	
2.4 Program Management Milestones	Did the team provide evidence that they hit the key milestones: Selecting a program manager, selecting operations, presenting SRR, completing trade studies, presenting CoDR, develop path to PDR?	0-4	
Category Total	Concept of Operations	0-22	

Category 3: Project Engineering			
Subcategory	Description	Score Range	Score (½ OK)
3.1 Completion of Required Elements	Is there analysis to show that the design conforms to requirements & perform per requirements? **Five elements to consider for Tracks 1-3**: Will it fit within the assigned volume, staying within mass and power requirements? Will the proposed bus support the operations; if not has the team identified potential solutions? Does the design consider the launch/ descent environment? Does the design demonstrate a useful capability by combining/ sequencing multiple technologies? Is the appropriate type of analysis performed? **For Track 4, elements to consider include**: Does it specify the existing robotics systems it would use and how it would use them? How does it leverage the referenced supply chain & logistics? Has the team evaluated how the assembled structure would perform in its environment?	0-15	
3.2 Identify & mitigate risks	Has the team identified likely points of failure and identified potential solutions?	0-4	
3.3 Data handling & comms	Develop a high-level overview/flowchart of data management and ground communications needs	0-3	
3.4 Trade Studies	Has the team highlighted trade studies to illustrate the design development & selection process?	0-4	
Category Total	Concept of Operations	0-26	

Category 4: Lessons Learned			
Subcategory	Description	Score Range	Score (½ OK)
4.1 Innovative concepts	What are the three most innovative ideas you had? Even if they weren't pursued.	0-3	
4.2 Tech. gap assessment	Identify 3 technologies as most important to develop for this effort.	0-3	
4.3 Biggest challenges	The three biggest challenges with the design process, even if you avoided them.	0-3	
Category Total	Lessons Learned	0-9	

Category 5: Deliverables			
Subcategory	Description	Score Range	Score (½ OK)
5.1 Presentation	Clarity, professionalism, and persuasiveness of the presentation, including visual aids and verbal communication. Consider these 5 key elements: Chart construction, verbal explanations, cohesiveness, proper use of white space, handling of questions.	0-8	
5.2 Paper	A paper ten-to-twenty pages long which would be suitable for inclusion in a technical conference. Consider elements such as length, organization, technical content, writing, and bibliography	0-4	
5.3 Statement of Intent	Describe your planned concept in 50-150 words and list 3 references (not taken from this packet) relevant to your work	0-1	
5.4 "Pitch" Presentation	During the Midpoint Showcase, teams will give a 5-minute "pitch" to give a clear and concise idea about the status of their work	0-2	
Category Total	Presentation and Paper	0-15	

Category 6: Prototype (Optional/ Required for Track 2)			
Subcategory	Description	Score Range	Score (½ OK)
6.1 Includes key elements	Does the prototype include the elements that are essential to the mission? It is more important to include the elements which are novel than those which have flight heritage.	0-7	
6.2 Function	Does the prototype function? If there is a mechanism, does that work? If there is an operational step in the demo mission, is that included?	0-6	
6.3 Completeness	How much of the design is included? The more elements that are included the more useful the prototype is	0-6	
6.4 Utility	How can the prototype be used in the next stages of design? Does it serve as a communications tool? A mass/ volume simulator? Could it be used for developmental testing?	0-6	
Category Total	Prototype	0-25	

Summary			
Category	Description	Score Range	Score (½ OK)
1.	Conceptual Design	0-28	
2.	Systems and Program Overview	0-22	
3.	Project Engineering	0-26	
4.	Lessons Learned	0-9	
5.	Deliverables	0-15	
Grand Total	COSMIC Capstone Challenge	0-100	
Opt. Prototype	If the team opted to create a functional prototype, provide a score based upon its function and performance	0-25	

Team Name: ____________________________________

Judge's Name: ____________________________________

Total Score: _______________________________

14. Frequently Asked Questions & Updates