2013 MATE ROV Competition Manual

EXPLORER CLASS

2013 MATE ROV COMPETITION MANUAL – EXPLORER CLASS

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New for 2013! This document contains many revisions and additions from previous years. Be sure to read it over completely; do not assume carryover from previous years.

DESIGN & BUILDING SPECIFICATIONS AND COMPETITION RULES

This document contains information relevant to the **EXPLORER** class; the **RANGER** and **SCOUT** competition documents contain information specific to those classes.

COMPETITION CLASSES

The MATE Center's ROV competition is divided into three classes – **EXPLORER, RANGER, and SCOUT**. See the **General Information** document for more information about each of the competition classes.

DESIGN & BUILDING SPECIFICATIONS

SAFETY COMES FIRST

Safety is the competition's primary concern and guiding principle. Any system that is deemed unsafe by competition officials will not be allowed to compete. If a safety concern is identified during the initial inspection, teams are permitted to modify their system and have it re-inspected. Teams are permitted to have their vehicle re-inspected twice. If a team fails to pass its third and final safety inspection, it is disqualified from the underwater competition portion of the event. There are NO APPEALS once your ROV has been disqualified.

Examples of safety violations from previous ROV competitions include:

- The electrical schematic included in the technical report did not show a main fuse or circuit breaker.
- The ROV used pneumatics, but the technical report did not include a pneumatics diagram.
- The ROV used pneumatics, but the team had not passed the fluid power quiz two weeks prior to the competition.

Safety inspection protocol:

1) Before entering the water for practice or a mission run, ROVs **must** go through a safety inspection. Teams must present a SIGNED safety inspection sheet to the pool practice/mission coordinator before their vehicles are permitted to enter the water.
2) Competition staff will conduct a safety inspection of the vehicle using the safety inspection sheet (www.marinetech.org/missions--specs).
3) If the safety inspector(s) identify a safety violation, teams will have the opportunity to address it. The pool practice or mission run schedule will NOT change to allow teams more time.
4) If during the second safety review the 1) violation has not been properly addressed or 2) another violation is revealed, teams will have ONE additional opportunity to address the

issue.

5) **If during the third safety review a violation still exists, teams will not be permitted to participate in the underwater mission component of the competition.** However, teams can still participate in the engineering and communication (e.g. poster display and engineering evaluation presentation) component.
6) Reminder: All teams must present a signed safety inspection sheet to the pool practice or mission coordinator before placing their vehicles in the water. In addition, mission station judges and competition officials can pause or stop a mission run at any time if they feel that there is a potential safety concern.

International competition teams – additional safety inspection protocol details:

- Prior to the competition, safety inspectors will review your technical reports to identify potential safety violations.
- Teams with violations will be notified via e-mail. Once notified, teams must 1) respond acknowledging receipt and 2) lay out a plan to address the violation.
- Safety inspectors will compile a list of the safety violations and publish them to the competition web site. This is not done to "call out" or embarrass teams in any way. It is to emphasize the fact that EVERYONE is responsible and accountable for ensuring a safe, successful event.
- Teams must complete their initial safety inspection on the first day of the competition. Teams will be assigned to a safety inspector(s). The inspector will reference the list of violations as he/she conducts the safety inspection of the vehicle using the safety inspection sheet (www.marinetech.org/missions--specs).
- The safety inspection is worth 30 points. Each time a team fails its safety inspection it loses 10 points. After a team fails its second inspection, it must meet with the chief safety inspector to discuss a plan of action prior to returning to its workstation. THREE STRIKES and a team 1) receives 0 points for the safety inspection and 2) is disqualified from the underwater mission component.

NUMBER OF VEHICLES

MULTIPLE VEHICLES ARE NOT PERMITTED. Teams are required to design and build ONE ROV that can complete the necessary mission tasks. "Floating eyeballs" or other vehicles that are not hard connected to the frame of the main vehicle are NOT permitted. Cameras designed to provide a "birds-eye view" are permitted provided that these cameras are hard connected to the frame of the main vehicle. "Hard connection" does not include the wiring between the camera and the ROV.

POWER

Teams participating in the MATE ROV competition can utilize both **ELECTRICAL** and **NON-ELECTRICAL** power sources. These sources and the specifications for the **EXPLORER** class are described below.

ELECTRICAL POWER – GENERAL

MATE will provide the necessary power for the EXPLORER class. All power provided to your system through an external connection for any purpose during the competition must be obtained from the MATE competition power supply. This includes dedicated lines for cameras, manipulators, and any other devices. This is a singular point of connection; all power to your competition ROV must pass through the MATE-provided fuse. Laptops are permitted for command, control, and communications (C3) purposes. All other power (mechanical, chemical, or electrical) contained within the ROV system must comply with and not exceed the regulations specified here.

Exposed connections: ROVs with electrical connections that are exposed to water and not sealed are not permitted to enter the water. "Disposable motors" are also not permitted; these are exposed motors with no waterproofing.

Nominal voltage: Throughout this and other MATE competition specifications, references are made to 48V DC. Teams should plan their systems to handle fully charged lead acid batteries. For the EXPLORER class, four fully charged lead acid batteries in series can have a voltage as high as 56V due to surface charge. Any power supplies used will be set at 50.8±0.3 Volts.

Allowed voltages and currents: The following voltages and currents are allowed through your ROV's tether:

- Low voltage AC or DC control signals. Low voltage is defined as a voltage equal to or less than the maximum supply voltage per class specification.
- DC main-supply as per class specifications.

ELECTRICAL POWER

Voltage: Maximum supplied power at pool-side will be a nominal 48 Volts DC. **Teams are free to use any voltage desired up to 48 Volts, but any conversion to a lower voltage must be made on board the ROV.** Teams will not be permitted to operate an ROV that reduces the voltage on the shore-side/top-side end of the ROV tether. Voltage may not be increased above the nominal 48 volts anywhere in the ROV system.

Note: The voltage limits set by the MATE Center are for safety purposes. Voltages in excess of the class parameters set forth in the MATE competition rules are not allowed on the system at any time other than the brief moment of back electromotive forces (back EMF) from collapsing magnetic motor fields typical in any electrical motor situation.

Current: Maximum current is 40 amps. MATE's power supply includes a 40-amp fuse. In the event that your ROV blows two of MATE's fuses, your mission run will be over and you will not be able to earn any additional points.

The MATE competition does not guarantee or promise performance limits beyond the maximum specified current for your particular class. However, any ROV causing a variance of current beyond the maximum that does not “blow” the fuse will be allowed to continue competing. Competitors should keep in mind, however, that vendors as well as tolerances in manufacture may vary and fuse performance in testing may not be representative of fuse performance in the competition setting.

Connections: Power supply connections will be via terminal posts –a 1/4" bolt with a wing nut. Your ROV tether must have proper cable-lugs with 1/4" ring connectors for these posts to obtain power.

Suggestions for converting 48 Volts to lower voltages

EXPLORER class teams whose ROVs do not use 48 Volts will need to find ways to reduce the voltage for their vehicles. There are many creative ways to accomplish this task. Here are a few methods suggested by MATE competition judges:

- DC to DC converters work (but can be expensive).
- A 48-Volt H-bridge and pulse width modulation will work and can be designed to give your vehicle occasional “super boosts.”
- Circuitry design to allow a positive and negative bus, dividing 48 Volts into two 24-Volt busses.
- Teams can use a resistor rated for the current draw of their vehicle.
- Teams can step up to higher voltage motors. For example, 32-Volt bilge pump motors are available from West Marine.

CIRCUIT PROTECTION

All teams must demonstrate the presence of an appropriately-sized fuse on the positive side of their vehicle’s electrical circuitry in order to pass the safety inspection. The fuse should be located within 30 cm of the connection to the MATE power supply. The MATE power supply provided at each pool station includes an in-line fuse, but each team needs to protect their system with an additional fuse. **If your vehicle is not protected with a fuse in addition to the fuse provided on the MATE power supply, YOUR VEHICLE WILL NOT PASS THE SAFETY INSPECTION and will not be allowed to compete.** Circuit breakers may be used in place of or in addition to fuses. The type of circuit protection (fuse or circuit breaker) must be documented and included in your technical report.

POWER SOURCES

Power for the EXPLORER class will be provided by isolated power supplies. Power supplies will be a fixed output voltage and will not be “turned down” to accommodate other than the specified voltage for the class. Practice stations and/or back up replacement power may be provided by batteries.

ONBOARD ELECTRICAL POWER (i.e., power not provided by the tether)
Onboard battery powered devices are NOT allowed under any circumstance.

Water leaking into a closed battery container can result in the generation of hydrogen gas. This gas can build up inside a pressure housing and create an unsafe situation. For this reason, onboard batteries are NOT allowed under any circumstance.

Any device that needs power must obtain that power directly from the ROV tether. For devices that operate at a voltage other than the tether voltage, an onboard ROV converter may be included. The converter must be sealed and not exposed to water.

This rule includes commercial "watertight" battery containers; no battery of any type is permitted on any competition vehicle.

NEW FOR 2013!!!
LASER SAFETY RULES

- Lasers must have an on/off switch. This switch must be on the surface controller.
- All lasers must be powered by the MATE surface power supply. Batteries, including batteries for powering lasers, are not permitted on the vehicle.
- All lasers must operate in the visible range at either the 630-680 nm (red) or near the 532 nm (green) wavelength. All lasers must fall into the Class I, Class II, or Class IIIa category. Red lasers must operate at 5mW or less. Green lasers must operate at ~1mW.
- Teams using lasers cannot increase voltage to increase the power of their lasers. Lasers must use the voltage set in their specifications.
- Teams using lasers must prove (via the manufacturer specification sheet) that their laser falls within these guidelines. Teams should include detailed specifications of their laser in their technical report as well as have that information ready and available during their safety inspection and engineering evaluation presentations.
  EXPLORER teams using lasers during their demonstration at a MATE regional contest or MATE sponsored pool days must forward their laser specifications to competition coordinator (Jill Zande) **AT LEAST** 2 weeks before the event takes place. Specifications will be forwarded to the MATE Center safety inspection team for evaluation. Once the laser specifications are reviewed, a notification will be sent to both the team and the regional competition coordinator regarding the use of that specific laser system. At the event, teams **MUST** supply the MATE notification and a specification sheet to the competition coordinator or safety inspector verifying that they are allowed to use the laser. Teams failing to bring their MATE notification or their specification sheet will not be permitted to use their laser.
- When out of the water, the laser should have a shield or enclosed beam stop

attachment within 30 cm of the laser. This means that the laser beam should not travel more than 30 cm before reaching the shield. This is a requirement at all times when the laser is out of the water. The shield does not need to be attached to the ROV while it is in the water. The shield must be painted with FLAT BLACK paint.

- At no time should the laser be focused or deviate from a collimated beam.
- When testing the laser at a workstation, teams must display a sign telling others that a laser is being operated.
- Operators working with the laser while the ROV is out of the water should wear appropriate laser safety glasses at all times. This requirement is for all laser types.

Teams should observe these laser safety rules at all times, even when building their vehicles in their own workshops pre-competition.

POWER SHUTDOWN REQUIREMENT

For safety purposes, any ROV that is disconnected from the surface supply must stop functioning in less than 5 seconds. **This applies to electrical, pneumatic, and hydraulic power sources.** Any filters, capacitors or accumulators must be sized accordingly to meet this specification.

FLUID POWER – GENERAL

Hydraulic fluid: Water or biodegradable food-grade fluid, only.

- A Material Safety Data Sheet (MSDS) must be provided at the safety inspection showing the type of fluid used and its compatibility with the Biodegradable Food-Grade specification. Teams using water do not need to provide an MSDS.
- Maximum pressure allowed: 10.33 bars (150 psig)
- Hydraulic system: All lines, fittings, and hydraulic devices must be rated for a minimum pressure of two (2) times the maximum supply pressure.

The following fluids are approved for use in hydraulic systems:

1. Water
2. Mineral oil
3. Biodegradable Food-Grade Hydraulic Oil ISO Grade 32/46, SAE Grade 20, McMaster-Carr part# 3499K22

Pneumatic: Compressed air or inert gas.

- Maximum pressure allowed: 2.75 bars (40 psig)
- Pneumatic system: All lines, fittings, and pneumatic devices must be rated for a minimum pressure of two and a half (2.5) times the maximum supply pressure. For example, if an 83 bar (1200 psig) tank is regulated to 2 bars (30 psig), then all system components must have a minimum rating of 5.17 bars (75 psig).

Surface power: MATE will provide one GFI-protected outlet with a nominal 115 Volts AC (60 Hertz) and 15 amps maximum. This outlet is intended to provide power for pumps and other surface support equipment (e.g. video monitors & control boxes). This AC power source CANNOT be used to directly or indirectly power the vehicle. If hydraulic or pneumatic power is used for vehicle thrust, the power for the pump must come from the MATE supplied DC power supply for that class.

In addition to electric pumps, hydraulic, and pneumatic systems can be powered by manual pumps (e.g. bicycle tire pump) or supplied from a pre-pressurized cylinder.

Pressurized cylinders: Pressurized cylinders may be used, but must remain above the water surface and meet the following specifications:

- Approved by US DOT (Department of Transportation) or TC (Transport Canada). For regional competitions taking place outside of the US, check with your regional coordinator for approval.
- Have a current official inspection/test sticker and/or stamp.
- Stamped with the maximum allowable pressure.
- Contain a pressure relief safety device.
- May be filled up to the maximum allowable pressure of the cylinder.
- Must be regulated at its output to a maximum of 2.75 bar (40 psig).
- Must have an easily accessible shut-off valve that is clearly marked with instructions.
- May only be stationed on the surface, not on the ROV.
- Must be secured in a safe manner such that they will not fall or roll around. If the judges feel that a cylinder is unsafe, they have the discretion to prevent its use.
- SCUBA tanks are permitted. They must meet all the above specifications and have a current visual inspection sticker, or “fill permit” visible.

Pressure storage devices (pressure accumulators): Pressure storage devices are allowed on the ROV if they do not exceed 1L in total storage and do not store pressure higher than the allowed pressure for air or hydraulics. It is recognized that a team might not be able to purchase a pressure accumulator that has the proper rating and fits in the space needed. In that case, the team must show that their designed accumulator is capable of withstanding the specified pressures without rupture.

Note: In 2013, the MATE Center will NOT be providing EXPLORER teams with pneumatic power at the mission stations. If teams plan to use pneumatics on their vehicle, they must provide their own pump or source of pressurized air.

FLUID POWER QUIZ

Teams planning to use hydraulics and/or pneumatics (i.e., fluid power) are required to take and pass an online quiz. The quiz was developed by MATE Center technical support staff and competition judges and is designed to ensure that teams understand basic information on these topics and can apply that knowledge to safe practices. The intention is not to add yet another "requirement," but rather to provide a safe and successful learning experience and competition environment.

A link to the quiz will be circulated and posted to the MATE web site in mid January. The quiz can be completed by one (or more) STUDENT team members. The team's instructor or mentor can provide guidance and advice, but the questions should be answered by the students participating on the team.

The quiz will be scored and the results provided almost instantaneously. A score of 100% is considered a passing grade. Teams can take the quiz as many times as they need to achieve this score.

The quiz must be completed with a passing grade at least 4 weeks prior to the international competition and/or 2 weeks prior to a regional event. (See www.marinetech.org/events for a listing of regional contests and their respective dates.) Teams failing to complete this quiz within the given time frame will NOT be permitted to use fluid power during their competition event.

The following are sources of information on hydraulics and pneumatics. This is not intended to be an exhaustive list, but rather a starting point to encourage teams to seek out additional information and resources.

- ***Underwater Robotics: Science, Design & Fabrication***, published by the MATE Center (see www.marinetech.org/underwater_robotics)
- http://www.fxsupply.com/pneumatics/psafety.html
- http://mining.state.co.us/safety/downloads/ppoint/HydraulicPressureIntensification.ppt
- National Fluid Power Association – http://www.nfpa.com/education/mini-book.asp
- Parker Hannifin Corporation – http://www.parker.com/ (look for technical literature links)

COMMAND, CONTROL & COMMUNICATIONS (C3)

For Command, Control & Communications (C3) purposes, EXPLORER class teams are not limited to the number of display screens used for video feeds or ROV status information. Display devices may be made up of any combination of TVs, monitors, laptops, and/or computer displays. These display devices may be powered by the MATE provided GFI-protected 115-Volt AC (60-cycle) and 15-amp AC power source described in the **Surface Power** section above. In addition, teams' C3 station may include devices like video recorders. All C3 devices must be able to run on the single AC power outlet provided or on its own internal battery power. Any device plugged into this AC power outlet can only provide C3 functions and cannot provide power to the ROV.

MATE will provide ONE video monitor at each control station that may be used by teams. This monitor will be powered by the GFI-protected 115-Volt AC (60-cycle) and 15-amp AC power source described in the **Surface Power** section above. This monitor will have both RCA and RF inputs. (Teams should assume that only NSTC monitors will be available at the international competition.)

Teams must supply any additional monitors (including monitors for practice sessions*), video recorders, etc. These additional video devices and/or any repair tools (but NOT ROV payload tools) can be powered by the GFI-protected power strip described in the **Surface Power** section above. Only video monitors, video recording devices, and repair tools can use this AC power.

*MATE cannot guarantee that the practice area will have power for your video monitor.

SIZE RESTRICTIONS

The mission team must be able to personally transport the vehicle and associated equipment to the mission station and to the engineering evaluation room. In this case, your team must be able to transport the vehicle and associated equipment from the pool venue to the building.

The vehicle must be launched and recovered manually; no powered winches or portable cranes can be used. Hand-powered lifts and levers may be used to launch and recover the vehicle. The vehicle and any associated equipment must not damage any part of the pool or pool deck.

OPERATING ENVIRONMENTS

SALINITY/WATER CHEMISTRY

Your vehicle must be able to function in fresh, chlorinated water. The water should be considered conductive of electrical currents.

DEPTH/TETHER LENGTH

EXPLORER class ROVs must be capable of operating in a maximum pool depth of 6 meters (19 feet). All underwater missions will take place within 10 meters from the side of the pool. The mission station will be no more than 2 meters from the side of the pool. Tether length should be calculated accordingly.

Note: Regional competitions may be held in pools with a shallower minimum depth and/or greater maximum depth. Contact the coordinator in your area to determine the maximum mission depth at your EXPLORER class demonstration.

VISIBILITY

Visibility in the pool is unlimited. The pool will not be covered or purposefully darkened in any way, although the specific mission tasks may require that your ROV operated in low-light conditions.

CURRENT

There will be no water currents intentionally created. However, depending on the venue, pressurized pool filtration system outlets may cause unexpected currents.

OTHER ENVIRONMENTAL PARAMETERS

The international competition pool may have small bottom features. Teams should be prepared to deal with small bottom topography.

Note: Regional competitions may be held in pool venues with slopes or other bottom features. Contact the coordinator in your area to determine the bottom topography of the pool at your EXPLORER class demonstration.

COMPETITION RULES

GENERAL

- All members of the team and their supporters must follow the safety regulations of the ROV competition, pool facility, and event venue.

- All team members and their supporters are expected to conduct themselves in a professional and responsible manner during the competition. Disrespectful behavior towards the judges, officials, pool staff, audience, or other teams will lead to penalty points or disqualification.

- Sabotaging, stealing, or pilfering equipment of other teams will lead to disqualification. Teams found cheating will also be disqualified.

- The MATE ROV competition is, at its core, designed to be an educational and inspirational event for **STUDENTS**. It is designed to challenge them to apply the physics, math, electronics, and engineering skills they are learning in the classroom to solving practical problems from the marine workplace.

  It is expected that all “adults” (non-students; e.g. teachers, mentors, parents) involved in the competition limit their input to educational and inspirational roles. Actual construction of the ROV (particularly in the complex electrical and software areas) must be completed by the student team members. Adults should teach and advise students about design, electronics, software, and construction, but not complete the work for the students. Throughout the process adults are encouraged to focus on benefits to the students from the process and not simply “winning” the competition. If during the engineering judging or mission execution it becomes apparent that adults exercised more than an advisory role, judges reserve the right to deduct points or, in extreme cases, disqualify teams.

While at any MATE ROV competition (international and regional), **ALL** work done on the vehicle must be conducted by team members. Teachers, mentors, parents, and non-competing students are not permitted to work on the ROVs. They may provide advisory input, but they may not work on the ROV directly. This includes writing or editing software code. All mechanical electrical and software modifications and/or repairs to the ROV must be completed by student team members. Judges or other competition officials who observe unauthorized work by non-team members will issue two warnings before asking the individual to leave the venue. If teams choose to take their ROVs off the competition grounds for maintenance and repair, they are expected to observe this rule in the interests of the spirit of the competition.

- To encourage student participation at all levels, MATE is discouraging the use of "off-the-shelf" technology. The rationale is that engineering involves integrating existing technology into new systems. As such, students are encouraged to turn to commercially-available technology where available (and affordable). Individual discrete "components" obtained commercially are acceptable. However, as this is an educational event, students are strongly discouraged from using commercially available "plug-and-play systems" within their ROVs. These devices violate the spirit of the competition in that they remove many of the technical challenges of electrical and software engineering. Thus, they eliminate much of the educational value of the event. An extreme example would be a team that focused its efforts on fundraising and simply purchased one of the low-cost ROVs available commercially. Such an entry would not be permitted.

In summary:
Multiple commercial components are **ENCOURAGED**.

Systems designed to perform multiple, complex functions from one "black box" or a series of components designed to integrate with each other are **DISCOURAGED**.

Examples of "components" versus "systems" are provided below. If teams are uncertain about the commercially-available items that they plan to use, they should contact the MATE competition coordinator (jzande@marinetech.org) early in their design phase. All such questions (and answers) will be posted to the FAQs section of the MATE competition web site.

The engineering evaluation and technical report score sheets will reflect MATE's effort to discourage the use of off-the-shelf systems. For example, both score sheets contain sections devoted to control systems. However, teams that demonstrate control systems constructed from "scratch" versus complete control system purchased from a commercial vendor will be awarded higher scores. In addition, the originality of design and teamwork sections will be weighted more heavily.

Examples of commercially-sourced components:
- Tethers
- Thrusters
- Radio control transmitters and/or receivers
- RC servo and/or motor controllers
- Pressure housings
- Watertight connectors
- Cameras with or without watertight housings
- Structural materials

Examples of commercially-sourced systems:
- "Black box" controllers that provide for multiple power and control signal interconnections and manipulations (e.g. FIRST Robotics controller systems)
- Thrusters, motor controllers, cabling, and control box designed and sold as a "system"
- Commercially available ROVs, such as VideoRays, LBVs, or SeaMATEs

PROCEDURAL

- Teams must compete during their assigned time slots. Your team is **NOT** permitted to switch time slots with another team. Failure to show at the mission station* for your scheduled mission performance run or at the room assigned for your team's engineering evaluation interview will result in "no score" for that particular competition category. **No exceptions.** Assigned time slots will be sent out in advance so that any scheduling concerns can be addressed prior to the event.

  *Individual contests may refer to the mission station as the control "station" or "shack."

- While there is no limit to the number of students who can compete as part of a team, **the pool mission team is limited to six students**. The mission team is defined as the team of students who operate the vehicle and its associated equipment during the mission performance period. Only six students will be allowed to enter the mission control area, launch, pilot, and perform the mission. Instructors, mentors, and/or non-student members cannot participate as part of the mission team. **Teams may alternate students on the mission team for the two mission attempts.** (All members of the team should participate in the engineering presentations; see the **Engineering & Communication** document for more information.)

- Only the mission team members and judges are allowed in the mission station during the mission period, which includes the set-up and demobilization periods. Other team members, instructors, mentors, audience members, and observers (press or special invited guests) must remain outside the mission station or in designated viewing areas.

- ***NEW for 2013!!!*** Instructors, mentors, parents, and "fans" are **NOT** permitted at the safety inspection stations or repair tables. Two warnings will be issued before individuals not heeding this rule will be asked to leave the venue.

- ***NEW for 2013!!!*** In addition, instructors, mentors, parents, and fans are **NOT** permitted to work on the ROV. Individuals who are seen working on the ROV who are not student team members will be issued a warning. Two warnings will be issued before individuals not heeding this rule will be asked to leave the venue.

- Video devices may be used to record the underwater activities for entertainment and learning purposes **only**. Video will not be used as an instant replay to review judges' decisions or to challenge mission timing.

- Mission stations will be roped off and marked as the either RANGER or EXPLORER. Mission stations will contain 2-3 chairs and one 6-foot table long table for teams to use. This table will be within 2 meters of the pool edge. Mission stations will be set up to prevent the pilot(s) from looking at the ROV in or under the water except through the ROV cameras.

- Teams will compete in ONE mission that consists of four distinct mission tasks. These tasks, in turn, consist of several components. Teams will get up to **TWO** attempts to complete this single mission. The **higher** of the two scores will be added to the engineering and communication score to determine the total overall score for the competition.

- The mission time consists of a 5-minute set-up period, a 15-minute mission performance period, and a 5-minute demobilization period. If the mission team and all of their equipment are not out of the mission station at the end of the 5-minute demobilization period, the team will be **penalized 1 point for each additional minute**.

- Manipulating the tether to free it from underwater obstacles is permitted. Pulling on the tether to speed up the recovery of items or to return your vehicle more quickly to the surface is not permitted and will result in penalty points. Judges will issue one warning if tether pulling occurs. Each future infraction will result in **5** points deducted from the final mission score.

- If your vehicle is completely disabled and/or its tether tangled and unable to free itself from the underwater environment, SCUBA divers can be called in to assist. However, the mission performance period time will NOT stop and **5** points will be deducted from the final mission score**.**

  Note: Some regional events may not provide SCUBA diver support for EXPLORER class demonstrations. Contact the coordinator in your area to determine if your regional will have SCUBA diver support during your mission run.

- Pilots can only leave the mission station and move poolside to repair, adjust, or alter a vehicle if the ROV is surfaced and at the side of the pool.

- No team member shall enter the water to complete an object recovery. Only arms and hands are allowed into the pool to retrieve an object or to retrieve the vehicle. Teams will be disqualified or penalized depending on the severity of the infraction.

- Communication between mission team members at the pool edge and those in the mission station will be limited. Only tether management issues (e.g. how much tether is out, how much is remaining on the pool deck) can be discussed. Those mission team members at the pool edge cannot give any directional or mission information to the pilot. Judges will issue one warning regarding illegal communication. Each future infraction will result in **5** points deducted from the final mission score.

- Communication using cell phones, text messaging, and online social media tools such as Skype, Facebook, Twitter, instant messaging, etc. is NOT permitted during the mission period, either between mission team members at poolside or between any mission team member and anyone outside of the mission station.

- Mission judges and other competition officials will only communicate with the student team members. Judges and officials will NOT communicate with mentors, parents, or other non-student members regarding mission information, challenges, or other issues except during pre- and post-competition briefing sessions.

DESIGN & SAFETY CONSIDERATIONS

- The competition coordinators and host venues stress the importance of safety practices and procedures to all competition teams. The score sheets will reflect the MATE Center's efforts to encourage and reward teams that demonstrate exceptional safety practices and procedures.

"Safety practices and procedures" includes both how team members conduct themselves and how they design and build their vehicles.

- **ALL ROVS MUST PASS A SAFETY INSPECTION CONDUCTED BY COMPETITION OFFICIALS PRIOR TO ENTERING THE POOL.** These inspections will be conducted topside to ensure that ROV systems meet the design and building specifications and do not pose a risk to the integrity of the event venue. See the SAFETY COMES FIRST section at the beginning of this document for additional information.

- Keep an eye out for tripping hazards in the mission station and at your team's work station. Make sure power cords are not laying in pools of water on the deck.

- During your mission period, be sure to secure any equipment so that it does not fall off the mission station table, damage the deck, or cause injury.

- Loose fitting clothing, jewelry, and long hair could all become safety issues. Consider securing long shirts or baggy pants, removing jewelry, and tying back long hair when working on or operating your ROV.

- ROVs may be constructed out of materials of your team's choice, provided they meet the competition rules and safety regulations. Warning labels should be posted on potentially hazardous components of your ROV system.

- All teams must wear close-toed shoes and safety glasses or goggles. **No one will be allowed into the work station area without close-toed shoes and safety glasses or goggles**. **No one will be allowed on the pool decks without close-toed shoes.** This includes team members, parents, mentors, and guests. Safety glasses/goggles are also recommended when working with your vehicle on deck.

- Personal flotation devices (PFDs) may be required when launching and recovering your vehicles. Contact your regional coordinator or the international competition coordinator to determine if this is a requirement at your event. If PFDs are required, the coordinator will provide them.

EXPLORER CLASS COMPETITION MISSIONS

Ocean Observing Systems: Launching a New Era of Ocean Science & Discovery

This document contains information about the **EXPLORER** class missions. The **RANGER Class** and **SCOUT Class Competition Mission** documents contain information specific to those classes.

COMPETITION SCORING OVERVIEW

The competition consists of underwater missions, technical reports, engineering presentations, and poster displays with the following scoring breakdown:

- Mission
    - RANGER and EXPLORER – 300 points (max), plus a time bonus
- Engineering & communication – 200 points (max)
    - Technical reports
        - RANGER and EXPLORER – 90 points (max)
    - Engineering evaluations
        - RANGER and EXPLORER – 90 points (max)
    - Poster displays
        - RANGER and EXPLORER – 50 points (max)
            - International competition teams ONLY – 5 bonus points for media outreach

Note that regional contests may not require all of these components. Contact your regional coordinator for more information.

THINK OF YOURSELVES AS ENTREPRENEURS

From deepwater oil drilling to the exploration of shipwrecks and installation of instruments on the seafloor, individuals who possess "entrepreneurial skills" are in high demand and stand out in the crowd of potential job candidates. What are entrepreneurial skills? They include the ability to understand the breadth of business operations (from finances to research and development to media outreach), work as an integral part of a team, and apply technical knowledge and skills in new and innovative ways.

To help you to better understand and develop these skills, the MATE ROV competition is asking you to think of yourself as an entrepreneur. Your first task is to create a company or organization that specializes in solutions to real-world marine technology problems. Use the following questions as a guide.

- What is your company name?
- Who are its leaders – the CEO (chief executive officer – the leader) and CFO (chief financial officer who oversees the budget and spending)?
- Who manages Government and Regulatory Affairs (i.e. who's in charge of reviewing the competition rules and making sure that they are understood and followed by everyone)?

- Who is responsible for research and development (R&D)?
- Who is responsible for system(s) engineering? Design integration? Testing? Operations?
- Who is responsible for funding-raising, marketing, and media outreach?
- What other positions might you need? (Depending on your personnel resources, more than one person may fill more than one role.)
- What products and services do you provide?
- Who are your potential clients?

In this case, the MATE Center and scientists, engineers, and technicians at the University of Washington are your "clients" who recently released a request for proposals. A request for proposals (RFP) is a document that an organization posts to solicit bids from potential companies for a product or service. The specifics of your product design and rules of operation are included within the **EXPLORER Class Design & Building Specifications and Competition Rules** document. The specifics of the mission – that is, the tasks that you must accomplish – are described below.

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MISSION OVERVIEW

EXPLORER class companies will compete in ONE mission that consists of the following four distinct tasks:

Task #1: Complete a primary node and install a secondary node on the seafloor.
Task #2: Design, construct, and install a transmissometer to measure turbidity over time.
Task #3: Replace an Acoustic Doppler Current Profiler (ADCP) on a mid-water column mooring platform.
Task #4: Remove biofouling from structures and instruments within the observatory.

Companies may choose to do the four tasks in any order they wish; however, the *steps* of task #1 and task #3 must be completed in order. (See the "Mission Notes" for each task for details.) Companies may leave a task to complete other tasks, but the steps of task #1 and task #3 must be completed in order. For example, a company could complete the first four steps of task #1, remove some nearby biofouling (task#4), then continue to complete task #1.

Your company will get up to **TWO** attempts to complete this single mission (contact your regional coordinator to confirm the number of attempts that you will receive). The higher of the two scores will be added to your engineering and communication score (see the **Engineering & Communication** document) to determine the total, overall score for the competition.

TIME

You will have 5 minutes to set up your system, 15 minutes to complete the mission tasks, and 5 minutes to demobilize your equipment and exit the control shack. During the 5-minute set-up, you may place your vehicle in the water for testing and/or trimming purposes, provided that a member of your company has a hand on the vehicle at all times and uses extreme caution. The 15-minute mission period will begin after the full 5 minutes of set-up time expires, regardless of whether you are ready to start the mission. It may begin sooner if your CEO notifies the mission judges that your company is ready to begin.

At any time during the mission, you may pilot your ROV to the surface and remove the vehicle from the water for such things as buoyancy adjustments, payload changes, and troubleshooting, but the 15-minute mission clock will only be stopped by a judge who determines it is necessary for reasons beyond your control. Otherwise, the clock will only stop after all mission tasks are successfully completed, the ROV has returned to the surface under its own power so that it touches the side of the pool, and a member of your company at the launch station has physically touched the vehicle. Your ROV is not required to return to the surface between mission tasks.

Your 5-minute demobilization will begin as soon as the 15-minute mission time ends, regardless of where your ROV is located (i.e., still at depth, on the surface, etc.).

TIME BONUS

Your company will receive a time bonus if you:

1) successfully complete the four mission tasks;
2) return your ROV to the surface under its own power so that it touches the side of the pool; and
3) physically touch your vehicle before the mission time ends.

Your company will receive 1 point for every minute and 0.01 point for every second under 15 minutes remaining.

GOOD LUCK!

The MATE Center would like to thank the John Delaney, Deborah Kelley, and Chuck McGuire of the University of Washington for their technical expertise and assistance with this year's mission scenario and tasks. We also thank the Center for Ocean Sciences Education Excellence Networked Ocean World (COSEE NOW) and Rutgers University for their contributions. We appreciate their vision and support in bringing "interactive oceans" to the 2013 competition teams and the entire ocean community!

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OCEAN OBSERVING SYSTEMS: TAKING THE PULSE OF THE OCEAN

The ocean is the planet's largest ecosystem. It drives an incredible range of natural phenomena, including our climate, and directly impacts human society (from the food we eat to the energy we use) – and we impact it. There are currently 7 billion people on planet Earth; more than half the population lives or works near the ocean. By 2030, there will be a billion more, with another billion arriving in the following two decades. Many nations rely on the economic contributions of goods and services associated with ocean activities, such as oil and gas, food, transportation, and recreation, for their overall economic health.

The pressure that we place on our ocean continues to increase – water pollution, overfishing, and ocean acidification from the use of fossil fuels are a few examples of our impact. How the ocean responds to this pressure will, in turn, put pressure on us. For example, patterns of ocean circulation and changing sea-surface temperatures correlate closely with ever-shifting patterns of drought and flooding on the continents, which consequently links directly to patterns of plentiful food and famine. It is critical that we better understand the ocean so that we can better manage this vital resource. Our future and the ocean's future depend upon it.

Technology revolutions have transformed society. Just as the Internet revolution of the 1990's provided instantaneous information transfer around the world, this last decade has ushered in the sensor revolution – the Internet connected to sensors that, in a way, are giving the planet its first electronic nervous system.

Meteorologists have used sensors and the Internet to monitor and predict weather for the past two decades. Monitoring the ocean and predicting its "weather" has been much more difficult. Historically, oceanographers have gone to sea in ships to study specific processes in small geographic areas of the ocean for limited periods of time. In the 1950's, the geographic range and duration of ocean research was extended through the use of satellite systems for surface imaging and communications. However, the data collected in this way is still only providing a piece of the ocean puzzle. Scientists crave a better way to collect data and do it continually. The next step is to develop the technology that will allow researchers to keep sensors "permanently" in place.

Ocean observing systems are collections of instruments and sensors above and below the waves that provide around-the-clock information about what is happening in the ocean (e.g. changing temperatures, currents, salinity, biological productivity). A global system of ocean observatories is now emerging that uses a suite of technologies to answer many different questions. Sensors on satellites miles above the earth look at both large and small areas of the ocean surface, providing key data about the temperature, color, and height of the water. Radar towers on land collect information about the movement of the water at the surface, including the speed and direction of the currents. Sensors and instruments attached to stationary buoys collect information at the same location over long periods of time. AUVs traveling below the surface collect information about water conditions. Instruments connected to networks of underwater hubs called "nodes" continuously collect data and send it back to land through fiber optic cables. The same cables also provide electrical power to the nodes and other equipment.

Using data collected by ocean observatories, scientists can forecast ocean conditions, much like meteorologists do for the weather, which can better inform the decisions affecting coastal and ocean resources, and, therefore, us.

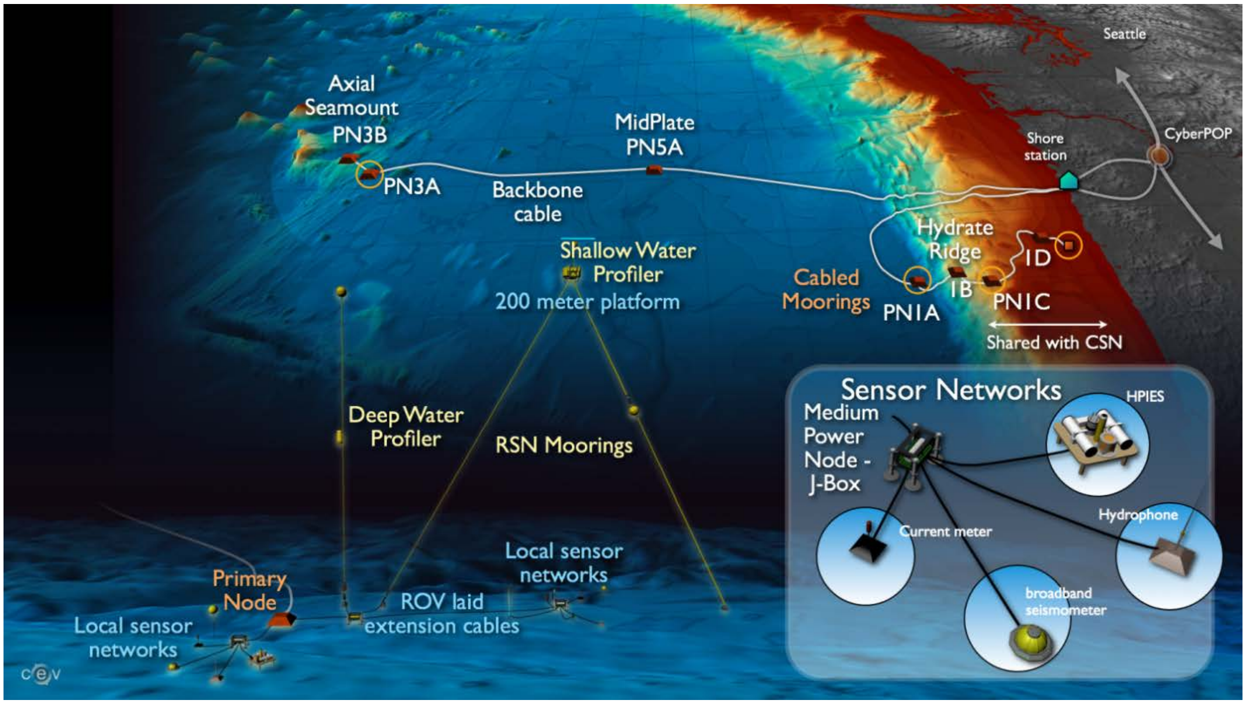
The global system of ocean observatories

The Ocean Observatories Initiative (OOI) is a project funded by the U.S. National Science Foundation (NSF). The goal of OOI is to construct a networked infrastructure of sensor systems to measure the physical, chemical, geological, and biological variables in the ocean and on the seafloor. The network will include moorings, AUVs, and cabled seafloor systems all connected by a cyberinfrastructure. Scientists, engineers, and technicians at the University of Washington led the design and are now constructing a cabled observing system called Regional Scale Nodes (RSN), which will become OOI's first cabled ocean observatory, and the largest in the U.S.

When complete, the RSN will consist of nearly 1,000 kilometers of cable capable of providing 56 kilowatts of electrical power and up to 240 Gigabits per second of telecommunication bandwidth. To date, a ship has laid 900 kilometers of cable from a shore station in Pacific City, Oregon west across the Juan de Fuca tectonic plate to the Axial Seamount, then south along the Cascadia subduction zone to Hydrate Ridge. Seven primary nodes that will serve as connection points for moorings and other instrumentation have been installed. These primary nodes will be populated with instruments and water column moorings at Hydrate Ridge, Axial Volcano, and along shallow coastal sites (collectively known as the Endurance Array) west of Newport, Oregon.

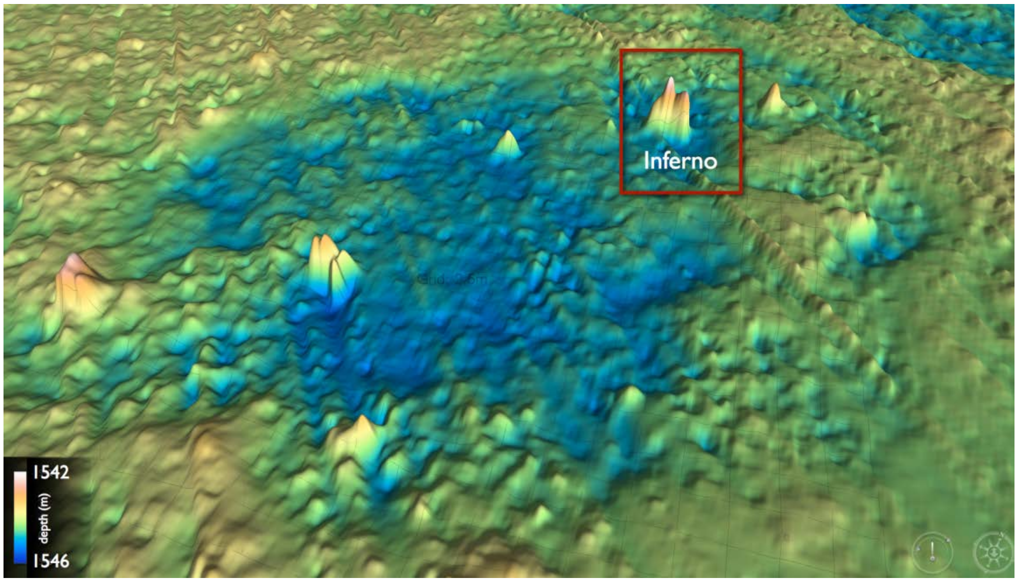
The observatory is scheduled to become operational in 2014 and designed to operate continuously for 25 years. Once operational, data and video imagery will be transmitted in real-time and will be accessible to users around the world, including scientists, educators, students, and decision-makers.

The network is designed to be expandable. The ultimate goal is to create an observatory that, when complemented by Canada's NEPTUNE cabled observatory to the north, will encompass an entire tectonic plate and all the natural phenomena that occur there – whether below the seafloor, on the seafloor, in the ocean, or at the air-sea interface.

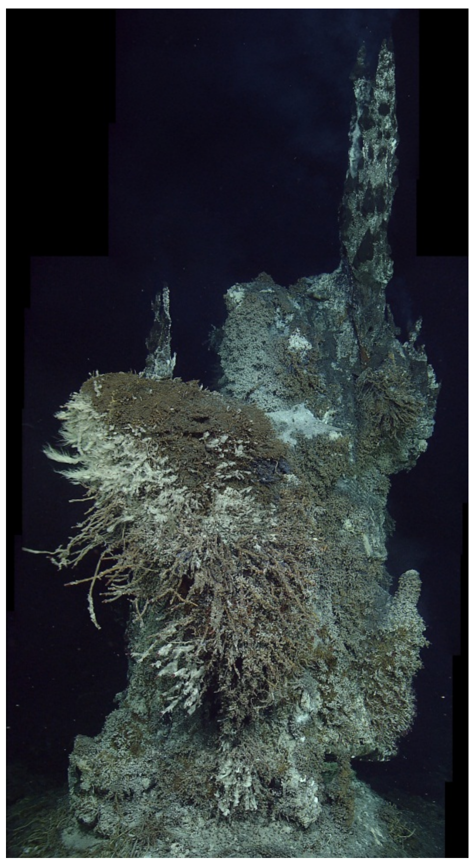


Regional Scale Nodes, OOI's first U.S. cabled observatory

And, in our scenario, expansion is already starting to take place. Scientists, engineers, and technicians at the University of Washington recently released a request for proposals (RFP) for ROV services to extend the network of cables, nodes, and instruments on the Axial Seamount. They are interested in expanding their existing Axial Seamount Hydrothermal Emissions Study (ASHES) experiments to better understand the underlying geology of a hydrothermal vent field located just north of the seamount. In addition to installing nodes and deploying instruments, the RFP includes routine maintenance work on existing water column moorings located near the seamount.



A bathymetric map of the ASHES site highlighting the Inferno vent chimney



A photo mosaic of the Inferno vent chimney

This is where your mission begins.

REQUEST FOR PROPOSALS (RFP)

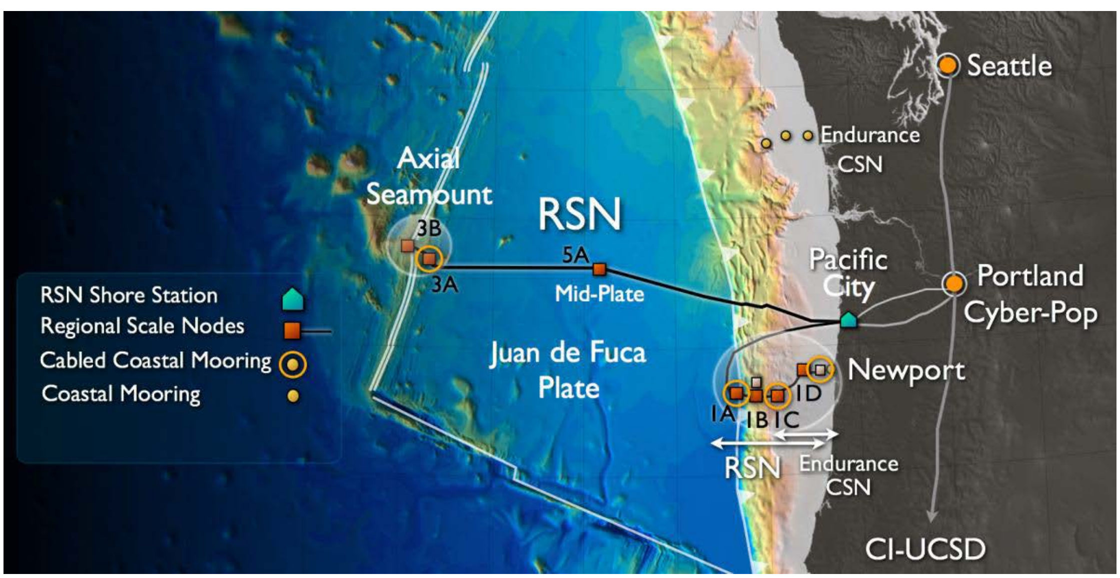
1. General

a. RSN and Study Site Overview

The Regional Scale Nodes (RSN) cabled observatory off the coast of Washington and Oregon is part of the NSF-funded Ocean Observatories Initiative (OOI). The system currently consists of seven scientific underwater terminals or "hubs" called primary nodes that are located on and around the Juan de Fuca plate. These nodes are connected by 900 kilometers of submarine fiber optic cable that terminates at a shore station in Pacific City, Oregon. The shore station provides power and allows for two-way communication to/from the nodes. The nodes and cable are the primary infrastructure, or "backbone," of the RSN.

Each node consists of two components: the Backbone Interface Assembly (BIA) and the Science Interface Assembly (SIA). The BIA is connected to the backbone cable and is the "frame" of each primary node. The SIA fits down into and is connected to the BIA. It includes ports for scientific instruments. The SIA is removable for servicing with an ROV.

The seven primary nodes were installed at the following sites: Axial Seamount (2 nodes); Mid-Plate (1 node); at the base of the slope of the Cascadia Margin (1 node); Hydrate Ridge (1 node); and at 600 and 110 meters water depth along the Endurance Array offshore of Newport, Oregon.



The RSN primary infrastructure, showing the location of the primary nodes

The primary infrastructure will provide power and communication to a secondary infrastructure that will consist of about 40 kilometers of submarine extension cables, underwater science sensors, instruments, moorings, and other nodes. The second infrastructure will be installed and routinely maintained by ROVs.

b. Document Scope and Purpose

This and accompanying competition documents contain the technical specifications and requirements for the ROV services needed to support the successful installation and maintenance of the secondary infrastructure as well as the servicing of the existing RSN structures and instrumentation. In 2013, ROV services include:

- Installing the SIA into the BIA of a primary node previously deployed at the ASHES site then connecting the BIA to the backbone cable via the Cable Termination Assembly (CTA). ASHES is located ~2 km west of the one of the primary nodes installed at the Axial Seamount.
- Installing a secondary node at ASHES and connecting it to the SIA for power and communications. The node currently rests on an elevator previously deployed at the site.
- Designing then installing a transmissometer to measure turbidity over time (turbidity in the water column can indicate the presence of a vent plume).
- Removing an Acoustic Doppler Current Profiler (ADCP) from a water column mooring platform located near the Axial Seamount for maintenance and service and replacing it with a new ADCP.
- Locating and removing biofouling from existing structures and instruments at both the Axial Seamount and the ASHES site.

2. Acronyms and Definitions

Ocean observatory work uses a number of acronyms, as do most professions. The following is a list of acronyms used within this document.

RSN: Regional Scale Node
BIA: Backbone Interface Assembly
SIA: Scientific Interface Assembly
CTA: Cable Termination Assembly

The **RSN** is the cabled observatory**.**

The **primary infrastructure** is the underwater component of the RSN that serves as the backbone of the observatory. It provides high-voltage DC power and two-way communication links from shore to the submarine network. It consists of cable and primary nodes.

The **secondary infrastructure** will receive its power and communication from the primary infrastructure and consists of **secondary nodes**, extension cabling, and instrumentation.

3. **Specifications**

   See the specific tasks described below as well as the **Design & Building Specifications and Competition Rules** document.

4. **Maintenance and Technical Support**

   The company shall warrant the ROV and associated systems and equipment for at least the duration of the competition event. Repair or replacement shall be at the company's expense, including the cost of shipping the ROV to and from the competition facility.

   During regional events, the company shall provide at least one day of technical support to resolve hardware, software, and operational issues. They shall provide at least three days of the same for the international event.

5. **Shipping and Storage**

   Refer to the **Shipping Information** document for specifics on shipping the ROV to the competition site.

   Delivery of the ROV and associated systems and equipment shall be no later than the date of the geographically closest regional contest or by June 20, 2013, which is the start date of the international competition.

6. **Evaluation Criteria**
   a. Technical report
   b. Engineering presentation
   c. Poster display
   d. Performance

References (for the scenario and the mission tasks):

An Introduction to the Integrated Ocean Observing System (IOOS),
www.cencoos.org/visual_media/classroom/IOOSintro/IOOSintro.htm

ASHES Virtual Site, http://www.pmel.noaa.gov/vents/nemo/explorer/ashes.html

Biofouling Protection for Marine Instruments, www.severnmarinetech.com

Biofouling, www.stccmop.org/blog/schillij/biofouling

COSEE NOW, http://coseenow.net/

Favali, P., De Santis, A., & Beranzoli, L. (2012). *Seafloor Observatories: A New Vision of the Earth from the Abyss.* Springer. ISBN: 3642113737, 9783642113734.

Hotaling, L., Sullivan, D., & Zande, J. (2007). The Sensor Revolution: Benefits and Challenges for the Marine Technical Workforce. *Marine Technology Society Journal, 41(3)*

Hunting for Hydrothermal Vents, http://oceanexplorer.noaa.gov/explorations/05galapagos/logs/dec10/dec10.html

Interactive Oceans, www.interactiveoceans.washington.edu

John R. Delaney and Deborah S. Kelley, University of Washington School of Oceanography. *Next-Generation Science in the Ocean Basins: Expanding the Oceanographer's Tool-Box Utilizing Submarine Electro-Optical Sensor Networks.*

Ocean Observatories Initiative: Transforming Our Understanding of How the Ocean Works, www.oceanobservatories.org

Ocean Observing Systems, http://coseenow.net/about/ocean-observing-systems/

Physical Oceanography, Hydrology, Water Quality, and Modeling, http://kinneticlabs.com/pages/oceanographic.html

United Nations Department of Economic and Social Affairs. (2004). World Population in 2300, New York, 1-254.

University of Washington OOI Team Provides Update on Secondary Nodes System, www.oceanobservatories.org/2012/university-of-washington-ooi-team-provides-update-on-secondary-nodes-system

Using Ocean Observing Systems in K-12 Education, http://marine.rutgers.edu/outreach/rtd/oos.htm

What Is a Transmissometer?, www.wisegeek.com/what-is-a-transmissometer.htm

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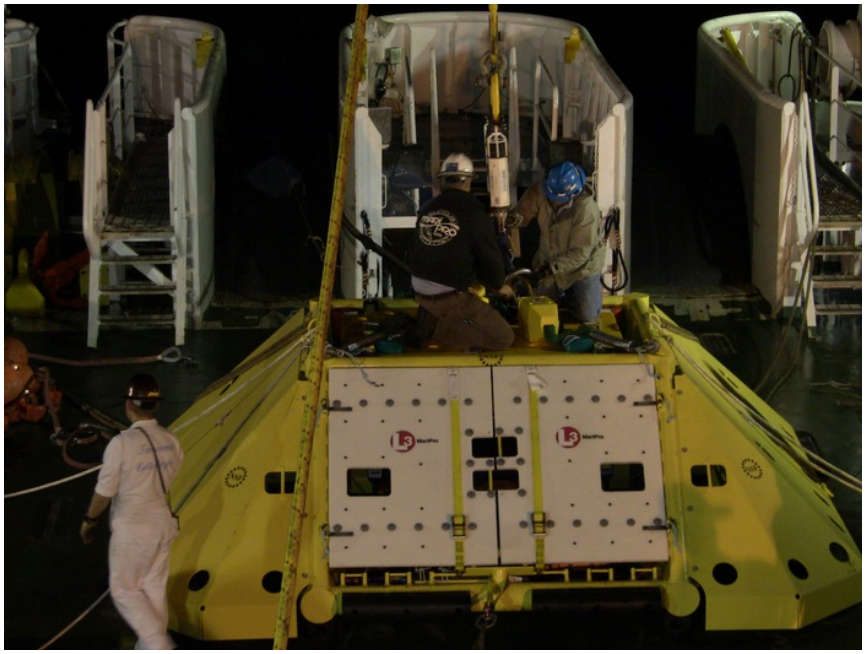
Task #1: Complete a primary node and install a secondary node on the seafloor.

Your company is required to complete a primary node, install a secondary node, and connect that node to the primary node for power and communications.

Completing the primary node involves installing the Science Interface Assembly (SIA) into the Backbone Interface Assembly (BIA) and inserting the Cable Termination Assembly (CTA) into the BIA. Then companies will install a secondary node. Installing the secondary node will require pulling a pin to release it from an elevator, installing it in a designated location, and inserting its cable connector into the SIA for power and communications.



The backbone interface assembly of an RSN

This task involves the following steps:

- **Transferring the SIA to the seafloor – 5 points**
- **Installing the SIA so that it rests completely within the BIA – 15 points**
- **Removing the CTA from the seafloor – 5 points**
- **Inserting the CTA into the bulkhead connector on the BIA – 10 points**
- **Pulling the pin to release the secondary node from the elevator – 10 points**
- **Removing the secondary node from the elevator – 5 points**
- **Measuring distance to find the designated location – 15 points**
- **Installing the secondary node in the designated location on the seafloor – 10 points**
- **Adjusting the legs to level the secondary node – 25 points**
- **Opening the door of the BIA – 5 points**
- **Removing the secondary node cable connector from the elevator – 5 points**
- **Inserting the secondary node cable connector into the bulkhead connector on the SIA – 10 points**

Total points = 120

Mission notes:

Companies may alternate between task #1 and other tasks, but the steps of task #1 must be completed in order, with the following two exceptions: 1) companies may measure the distance to determine the designated location before or after pulling the pin and removing the secondary node from the elevator and 2) companies may remove the secondary node cable connector from the elevator at any point after pulling the pin to release the secondary node and opening the door of the BIA. Companies may skip any step of task #1, but will not receive points if they complete that step at a later time. All steps of task #1 must be completed to receive a time bonus.

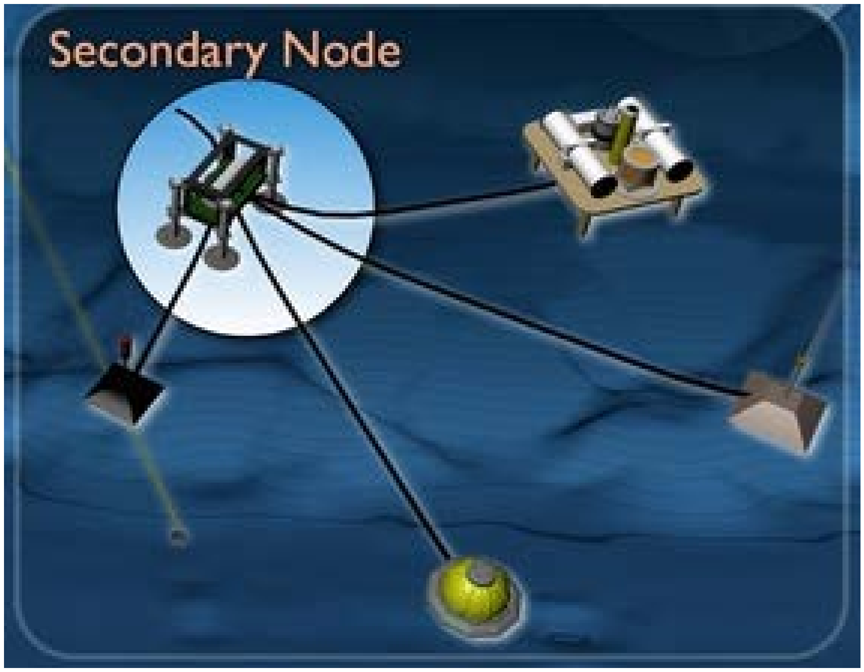
Companies will install the SIA into the opening on top of the BIA. The BIA is constructed of ½-inch PVC with corrugated plastic walls and will be located on the seafloor. The SIA is constructed from a milk crate. A U-bolt is attached in the center of one side of the milk crate as a lift point. The SIA will be located on the surface, at the mission station. Companies may attach the SIA to their vehicle during the 5-minute set-up period. Companies will receive 5 points when any part of the SIA touches any part of the BIA. Companies will receive 15 points when the SIA is completely installed and resting flat within the BIA. (Note that the SIA will extend several centimeters above the top of the BIA when properly installed.) Companies will only receive one SIA. If it is dropped, your company must retrieve it to complete the mission.

The SIA weighs less than 4 Newtons in water.

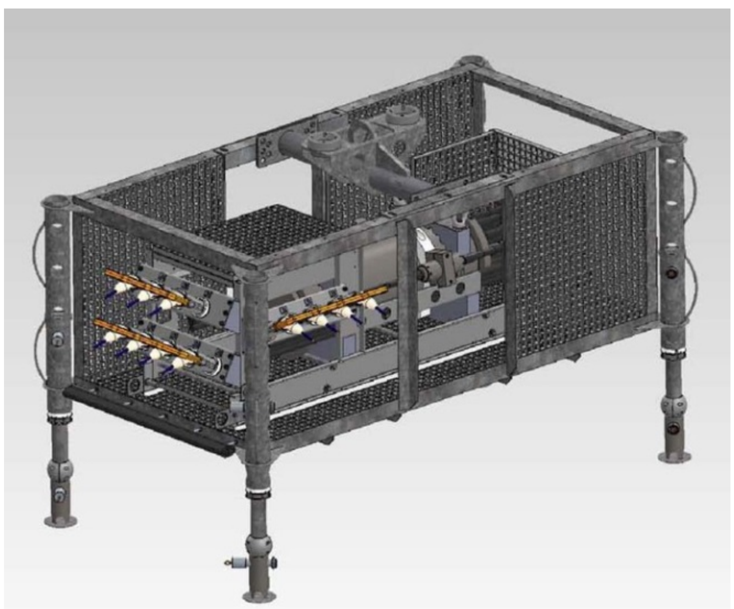
Once the SIA is installed into the BIA, companies must connect the main power cable (or CTA) to the node. The CTA is constructed from a 1-inch PVC coupling. A screw hook and screw eye will act as lift points for the CTA. The CTA will be resting upright on the pool bottom within 2 meters of the BIA. Companies will receive 5 points when the ROV is in possession of the CTA, and the CTA is no longer in contact with the seafloor. Once removed from the seafloor, the CTA must be inserted into the bulkhead connector on the node. The bulkhead connector is constructed from 2-inch PVC pipe and is located on a bottom corner of the BIA, opposite the BIA door. Companies will receive 10 points when the CTA is installed into the bulkhead connector and the two bolts protrude through the 2-inch end cap. Velcro will secure the CTA into the bulkhead connector. If the CTA is knocked over during retrieval, or dropped during transport, your company must retrieve it to complete the mission.

The CTA weighs less than 2 Newtons in water.

The secondary node will be located on an elevator previously deployed to the seafloor. The elevator is constructed of ½-inch PVC. The secondary node, the secondary node cable connector, and the cable will be resting on plastic net meshing covering the top of the elevator. The elevator will be located within 3 meters of the BIA. Companies will receive 10 points for pulling a pin to release the secondary node from the elevator. The pin is a 6-inch metal J-bolt and will penetrate through holes drilled into the elevator and through matching holes drilled into the secondary node framework. The pin must be completely removed from holes in the secondary node and the holes in the elevator. Once removed, the pin may be left on the seafloor without penalty.



A secondary node with scientific instruments installed



A diagram of a secondary node

The secondary node is constructed from a length of 3-inch PVC pipe set inside a ½-inch PVC pipe framework. A U-bolt is set in the top center of the secondary node as a lift point. Once released from the elevator by pulling the pin, companies will receive 5 points for removing the secondary node from the elevator. The ROV must be in possession of the secondary node and no part of the node may be touching the elevator or seafloor.

The secondary node weighs less than 10 Newtons in water.

Once the secondary node is removed from the elevator, companies must install it in a designated location. The designated location is a set distance from the BIA. During the 5-minute set-up period, the mission station judge will inform companies of this distance (in meters). The underwater mission area will have four potential locations adjacent to each other, each at a set distance from the BIA. These locations will be represented by a 60 cm x 60 cm, ½-inch PVC square. Companies must measure the distance from the base of the BIA to the center of each location to determine which is the one designated for the secondary node. A 12 cm length of PVC with a ½-inch coupling will mark the base of the BIA. The length of pipe and coupling will be painted red. Companies will receive 15 points when they show the mission station judge their measurement from the base of the BIA to the center of the designated location. The center of the designated location is defined as the point where the two corners of the paving bricks (see below) join together 30 cm from each edge. The measurement must be within 10 cm of the distance reported by the mission station judge.

Measuring the distance to find the designated location is one step of this task that may be completed out of order. Companies will receive points for measuring the distance at any time after the CTA has been installed into the BIA and before deploying the secondary node. For example, companies can measure the distance to the designated location then return to remove the secondary node from the elevator, or companies may retrieve the secondary node from the platform and hold it on their ROV while measuring the distance.

Companies will receive 10 points for installing the secondary node in the designated location. The secondary node must be placed completely within the designated location. No part of the secondary node may be touching any of the PVC pipe that denotes the perimeter of the designated location.

Once the secondary node has been placed in the designated location it must be leveled. The designated location will not be level; portions of it may be up to 5 cm above the floor of the pool. Companies must adjust as many as four handles, constructed from ½-inch PVC tees, to raise or lower the legs of secondary node to level it. A circular bubble level is secured to the top of the node and is used to determine when the secondary node is level. Companies MUST show the mission station judge through a video camera that the bubble is completely within the outer circle of the bubble level. When displaying whether the secondary node is level, the ROV should not be touching or holding any part of the node. Companies will receive 25 points when the secondary node is level within the designated location.

Once the secondary node is deployed and leveled, companies must connect the secondary node to the SIA bulkhead connector. The secondary node cable connector is constructed of ½-inch PVC pipe, with a screw hook and screw eye that will act as lift points. The front end of the cable connector is covered with Velcro loops. A 7 meter length of rope connects the secondary node to the cable connector. This rope will be coiled on the elevator. Companies will receive 5 points for removing the secondary node cable connector from the elevator. The ROV must be in possession of the secondary node cable and no part of the connector may be touching the elevator or the seafloor.

The secondary node cable connector weighs less than 2 Newtons in water.

Removing the secondary node cable connector from the elevator is another step of this task that may be completed out of order. Companies will receive points for picking up the cable connector at any time after they remove the pin from the secondary node and elevator. Alternatively, companies may leave the cable connector on the elevator until after opening the door on the BIA. At that point they may return to the elevator, remove the cable connector, and install the connector into the SIA bulkhead connector.

Once the secondary node is placed into the designated location, companies must open the door on the BIA to expose the SIA bulkhead connector inside. The door of the BIA is constructed from a corrugated plastic sheet. Two hinges allow the door to open. A handle is located on the right side of the door and is constructed from ½-inch PVC pipe. Companies will receive 5 points for opening the door on the BIA. If the door subsequently closes due to ROV and/or water movement, points will not be taken away from your company. However, the door must be opened again to complete this step of the task.

Companies will receive 10 points for installing the secondary node cable into the bulkhead connector on the SIA. If the SIA was not installed correctly, companies will need to reinstall the SIA in the proper orientation. To do so, companies must first unplug the CTA from the BIA. Only when the CTA is unplugged can the SIA be removed and reinstalled in the proper orientation. The CTA must be inserted again before the secondary node cable can be installed into the bulkhead connector on the SIA. Companies that need to remove and reinstall the SIA within the BIA will not lose points they have received for task #1. For example, if a company finds that they have installed the SIA backwards in the BIA, and subsequently detaches the CTA from the BIA, they will not lose points for detaching the BIA or removing the SIA from the BIA.

Mission prop specifications

See the **EXPLORER Construction Photos, Mission Prop Photos, and SolidWorks Assemblies and Drawings** documents for visuals.

All PVC used in construction is DURA brand PVC. If items are unavailable or built to different specifications in your area, check online at www.duraplastics.com to purchase specific PVC pieces. Alternatively, certain dimensions may need to be extended or shortened to match DURA brand products.

<u>Backbone Interface Assembly (BIA)</u>:

The backbone interface assembly (BIA) is constructed from a framework of ½-inch PVC pipe. Corrugated plastic form the walls of the BIA over the ½-inch PVC pipe framework. The BIA is designed so that a 33 cm x 33 cm x 28 cm milk crate (see SIA specifications below) fits into it. If your company is using a milk crate of different dimension than listed in the SIA specifications below, you may need to alter the specifications of the BIA to accommodate your milk crate.

To construct the BIA:

1. Start with constructing the top portion of the BIA, which is a rectangle approximately 42 cm long by 37 cm long. The corners of the rectangle are built with ½-inch PVC side outs (corner pieces) with a short arm pointing down. PVC tees are also incorporated, with their middle openings also pointing down.
2. Cut a 9 cm length of ½-inch PVC pipe and insert it into the long end of a ½-inch PVC side out. Attach the side opening of a ½-inch PVC tee to the other end of the 9cm length of PVC pipe. Cut another 9 cm length of ½-inch PVC pipe and insert it into the other side opening of the PVC tee. Attach the long end of a ½-inch PVC side out to the other end of the 9 cm length of pipe.
3. Cut a 15 cm length of ½-inch PVC pipe. Insert the pipe into a short opening of the PVC side out. Attach the side opening of a ½-inch PVC tee to other end of this length of pipe. Cut another 15 cm length of ½-inch PVC pipe and insert it into the other side opening of the PVC tee. Attach the short opening of a ½-inch PVC side out to the other end of this 15 cm length of pipe.
4. Cut a 9 cm length of ½-inch PVC pipe and insert it into the long end of the ½-inch PVC side out. Attach the side opening of a ½-inch PVC tee to the other end of the 9 cm length of pipe. Cut another 9 cm length of ½-inch PVC pipe and insert it into the other side opening of the PVC tee. Attach the long end of a ½-inch PVC side out to the other end of the 9 cm length of pipe.
5. Cut a 3 cm length of PVC pipe. Insert it into the short opening of the PVC side out. Attach the side opening of a ½-inch PVC tee to other end of this length of pipe. Cut a 20.5 cm length of ½-inch PVC pipe and insert it into the other side opening of the PVC tee. Attach the side opening of a ½-inch PVC tee to other end of this length of pipe. Cut a 3 cm length of PVC pipe. Insert this length of pipe into the other side opening of the PVC tee. Insert the other end of this 3 cm length of pipe into the short opening of the ½-inch PVC side out from step #2.

At this point you should have a rectangle approximately 42 cm long by 37 cm long. Each corner should be a ½-inch PVC side out with short ends pointing down. Twist all five PVC tees so their empty middle openings are facing down as well.

See EXPLORER mission photo #1.

6. Cut nine 3 cm lengths of ½-inch PVC pipe. Insert these 3 cm lengths of PVC pipe into the four openings of the short ends of the PVC side outs and the five middle openings of the PVC tees. Attach nine ½-inch PVC 45^{o} elbows to the other end of each 3 cm length of PVC pipe. Twist each 45^{o} elbow so it faces outwards, away from the center of the BIA.

7. Cut four 47 cm lengths of ½-inch PVC pipe. Insert these lengths of pipe into the 45^o elbows at the four corners of the BIA (the elbows coming down from the PVC side outs). Attach the middle opening of a ½-inch PVC tee to the other end of each length of pipe.
8. Cut eight 7 cm lengths of ½-inch PVC pipe. Insert the 7 cm length of pipe into the side openings of each PVC tee at the bottom of each "leg" (47 cm length of pipe). Attach a ½-inch 45^o elbow to the end of each 7 cm length of pipe.
9. Cut two 34.5 cm lengths of PVC pipe. Insert them into the 45^o elbows that are on the same side of the rectangle. Attach the middle opening of a ½-inch PVC tee to the other end of each length of pipe.
10. Cut a 20.5 cm length of pipe and two 20 cm lengths of pipe. Connect the two ½-inch PVC tees at the bottom of the "legs" with the 20.5 cm length of pipe. Insert the 20 cm lengths of pipe into the other side openings of the PVC tees. Insert the other ends of these 20 cm lengths of pipes into the 45^o elbows on the ends of the corner legs (step 8).
11. Cut three 21 cm lengths of PVC pipe. Insert these pipes into the three remaining 45^o elbows on the BIA. Attach the side opening of a PVC tee to the other end of each length of pipe. Cut three 10 cm lengths of ½-inch PVC pipe. Insert these lengths of pipe into the other side openings of each PVC tee. Attach the middle opening of ½-inch PVC tee to the other ends of these 10 cm lengths of ½-inch PVC pipe.
12. Cut five 25 cm lengths, one 17.5 cm length and one 3 cm length of ½-inch PVC pipe. Insert the 17.5 cm length of pipe and 3 cm length of pipe into the side openings of a ½-inch PVC tee. The length of this combination piece should be 25 cm.
13. Insert the 25 cm lengths of pipe into the other side openings of the PVC tees at the bottom of the BIA. Insert the other ends of these 25 cm lengths of pipes into the 45^o elbows on the ends of the corner 'legs' (step 8). The front of the BIA is defined as the side that that has two 34.5 cm lengths of pipe. The combination 25 cm length of pipe (17.5 cm pipe, tee, 3 cm pipe) needs to be placed on the back right corner of the BIA.

Design note: You may need to slightly alter the lengths of some PVC pipe to achieve the best fit for constructing the BIA.

14. Cut three 3 cm lengths of PVC pipe. Insert these lengths of pipe into the middle opening of the ½-inch PVC tees on the three legs of the BIA. Attach a 45^o elbow to the other end of each 3 cm length of pipe.
15. Cut a 26 cm length and two 18 cm lengths of ½-inch PVC pipe. Insert the 26 cm length of pipe into the middle opening of a PVC tee and insert the two 18 cm lengths of PVC pipe into the side openings of the PVC tee. Attach the side opening of a PVC tee to the other end of each 18 cm length of PVC pipe. Cut two 10 cm lengths of PVC pipe. Insert them into the side openings of each PVC tee. Twist the PVC tees so the middle opening is flat and facing in the opposite direction of the middle opening of the PVC tee in the middle of this construction (step 13).
16. Cut two 5 cm lengths and one 40 cm length of ½-inch PVC pipe. Insert the 5 cm lengths of PVC pipe into the middle openings of the two PVC tees. Attach a 90^o elbow to the other end of each

5 cm length of pipe. Insert the 40 cm length of PVC pipe between the two 90° elbows.

At this point you should have a flat topped, octagonal bottomed pyramid structure approximately 1 meter across at the bottom. The side of the BIA with the two ½-inch PVC struts is the front of the BIA and will have a door that the ROV must open. The opposite side of the BIA is the back and will have the bulkhead connector where the CTA must be inserted.

See EXPLORER mission photo #2, #3 and #4.

The back and the sides of the BIA will be covered with corrugated plastic sheets. The front of the BIA will have a small corrugated sheet covering part of it, and a larger corrugated sheet that will act as a door to reveal the SIA within. The front of the BIA is designated as the side with two legs on one side, separated by the 20.5 cm length of PVC pipe.

To construct the walls:

1. Use three sheets of 60 cm x 38 cm corrugated plastic. Fit the corrugated plastic over the two side walls and back wall of the BIA. Cut the top corners of the corrugated plastic down to fit the shape of the BIA.
2. The corrugated plastic should cover from the 45° elbows near the top of the BIA to the bottom edge of the BIA. Bottom corners do not need to be covered.
3. Use cable/zip ties and screws to hold the corrugated plastic onto the BIA framework.
4. Cut a 19 cm x 38 cm sheet of corrugated plastic. Fit the corrugated plastic over the left side front of the BIA, from the left PVC pipe to the left corner of the BIA. Use screws and cable/zip ties to secure it to the PVC pipe. Cut the top left corner of the corrugated plastic down to fit the shape of the BIA.
5. Cut a 42 cm x 38 cm length of corrugated plastic. Fit this adjacent to the 19 cm x 38 cm sheet of corrugated plastic, covering the rest of the front side of the BIA. Do NOT secure it to the PVC framework of the BIA. Cut the top right corner of the corrugated plastic down to fit the shape of the BIA.
6. Use two 3 ½-inch brass hinges (Home Depot part **#237-070**) to attach the 42 cm x 38 cm corrugated plastic to the 19 cm x 38 cm corrugated plastic. Use #10 1-inch bolts instead of the screws that come with the hinges. This will eliminate the sharp points of the screws and allow for tighter connections with the plastic. Use a 10-24 nut to secure the bolts through the hinges. When attaching the bolts through the corrugated plastic, use a 1 ¼-inch x ¼-inch Fender washer on the two outside bolts of each hinge. This will increase the surface area against the corrugated plastic and prevent damage.
7. Cut a 10 cm length of ½-inch PVC pipe. Attach a ½-inch 90° PVC elbow to each end. Drill two 5/32-inch holes into the open end of each 90° PVC elbow. This is the handle to open the corrugated plastic door of the BIA.
8. Place the handle on the side of the corrugated plastic opposite the hinges, 3 cm from the far edge of the plastic. The handle should be positioned so the open ends of the 90° PVC elbow are

flat against the corrugate plastic and the handle.

9. Drill four holes into the corrugated plastic, each one adjacent to the holes drilled into the open end of the 90° PVC elbow. Insert cable/zip ties through the holes of each 90° PVC elbow, through the holes in the corrugated plastic. Tighten the ties to secure the handle to the corrugated plastic.

See EXPLORER mission photo #5, #6 and #7.

Design note: Check sign-making/printing stores for corrugated plastic. Corrugated plastic can also be reused from the 2012 competition props. Use the same corrugate plastic sheet that covered the sides of the shipwreck.

<u>Science Interface Assembly (SIA)</u>:
The science interface assembly (SIA) fits into the top opening of the BIA. The SIA is constructed from a milk crate. These specifications use a milk crate 33 cm x 33 cm x 28 cm. If your company is using a milk crate of different dimensions, you may need to alter the specifications of the BIA above to accommodate your milk crate. A flat ABS plastic sheet covers the 33 cm x 33 cm opening of the milk crate. A 2-inch hole in the ABS sheet is the bulkhead connector for the secondary node cable to be inserted into. A #310 1 ½-inch pipe U-bolt (Home Depot part **#117-996**) is placed in the center of the top wall of the SIA.

To construct the SIA:

1. Cut a 33 cm x 30 rectangle of 1/8-inch flat ABS plastic sheeting.
2. Use a 2-inch hole saw to drill a hole through the ABS plastic sheeting. Alternatively use a smaller drill bit to drill multiple holes in a 2-inch circle and cut the ABS plastic to complete the hole. The center point of the hole should be located on the midline on the 33 cm dimension, 16.5 cm from each edge. The center point of the hole should be off center on the 30 cm dimension, 12 cm from one edge, 18 cm from the other edge.
3. Cut an 8 cm length of 2-inch PVC pipe. Attach two 1 ½-inch corner braces (Home Depot part #163-518) to opposite sides of one end of the 8 cm length of pipe. Use round headed #10 ½-inch bolts instead of the screws that come with the corner braces. The bolts should be fitted from inside the 2-inch pipe to the outside. Use a 10-24 nut to secure the braces to the 2-inch PVC pipe. If you cannot find #10 ½-inch bolts, use #10 1-inch bolts and use a hacksaw to cut them off AFTER tightening on the 10-24 nut.
4. Align the 8 cm length of 2-inch PVC pipe over the hole cut into the ABS sheet. Secure the other ends of the corner braces to the ABS sheet. Use #10 bolts from the ABS through the corner braces.
5. Cut a 5 cm x 5 cm square of industrial strength Velcro hooks (Home Depot part #**90593**). Cut the corners off of the Velcro square to make it octagonal. Attach the Velcro hooks to the inside of a 2-inch PVC end cap.
6. Attach the 2-inch end cap to the end of the 8 cm length of 2-inch PVC pipe.

See EXPLORER mission photo #8.

7. Attach a 1 ½-inch pipe U-bolt in the center of a side wall (33 cm x 28 cm wall) of the milk crate. The U-bolt should stick up 5.5 cm above the outer wall of the milk crate. Use 1 ¼-inch x ¼-inch Fender washers to secure the U-bolt. This wall will be defined as the 'top' of the SIA.
8. Use cable/zip ties to secure the ABS plastic sheet over the open side of the milk crate. Place the ABS sheet at the very top of the milk crate (the side with the U-bolt). This may leave a small 2 cm opening along the bottom. Orient the plastic sheet so that the opening of the bulkhead connector is closer to the top of the milk crate.

Add flotation/ballast as necessary to the SIA to achieve the desired weight in water.

See EXPLORER mission photo #9 and #10.

__**Cable Termination Assembly**__:
The cable termination assembly (CTA) is constructed from a 1-inch PVC coupling with a 1-inch end cap attached to each end. Two #10, 1-inch bolts act as the plugs. A #6 screw hook (Home Depot part **#14672**) and a #6 Screw eye (Home Depot part **#14092**) act as grab points on the assembly. 10 meters of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**14068**, Home Depot SKU #**140287**, ACE Hardware part #**75851**) attach the assembly to surface, side of the pool. Velcro will help to secure the CTA into BIA bulkhead connector.

To construct the CTA:

1. Drill two 5/32-inch holes into the 1-inch PVC end cap. The holes should be along a centerline and be drilled 2.5 cm apart. Screw a #10 1-inch bolt through each hole, from the inside of the end cap to the outside.
2. Cut an 8 cm x 1 cm strip of industrial strength Velcro hooks. Attach this Velcro strip over the top of a 1-inch PVC end cap. The strip should be positioned equidistance between the two #10 bolts, with 2 cm of the strip over each side of the 1-inch end cap.
3. Drill a 5/32-inch hole in the exact center of another 1-inch PVC end cap. Drill a 3/16-inch hole 1 cm out from the hole in the center. Screw a #6 Screw eye into the center hole. The Screw eye should be completely screwed into the end cap. Insert one end of the 1/8-inch rope into the off-center hole. Tie an overhand knot into the rope so that it is secured inside the end cap.
4. Cut two 4 cm lengths of 1-inch PVC pipe. Insert a 4 cm length into both ends of a 1-inch PVC coupling. Attach the two 1-inch PVC end caps to each end of the 1-inch coupling.
5. Drill a 5/32-inch hole into the center 1-inch PVC coupling, 3 cm from either end. Screw a #6 Screw hook into this hole. The Screw hook should be screwed in until only 2 mm of the thread remains outside of the 1-inch coupling.
6. On the opposite side of the coupling from the screw hook, drill four 3/32-inch holes. Two holes should be placed 1 cm from each end of the coupling. Each set of holes should be 2 cm apart

from each other, 1 cm to either side of the bottom of the connector. The bottom is defined as the line directly opposite the #6 Screw hook.

7. Insert a #6, ½-inch screw into each hole. The two screws placed near the end cap that contains the Screw eye and 1/8-inch rope should not be screwed all the way in. The head of the screw should be approximately 2 to 3 mm from the PVC coupling. These screws will act as small legs to hold the CTA upright.
8. Twist the end caps into proper alignment. The end cap containing the two #10 1-inch bolts should be twisted so that the two bolts are flat; a line between the two bolts should be parallel with the ground. Twist the other 1-inch end cap so that 1/8-inch rope is directly below the #6 Screw eye.
9. Twist the #6 Screw eye and #6 Screw hook into proper alignment. The Screw eye should be twisted so that the eye is parallel with the pool bottom. Turn the Screw hook so that the open end of the hook faces the screw eye.

Use PVC glue to secure the end caps onto the 1-inch PVC pipe once the alignment of your CTA is correct. Drill small holes into the top and bottom of each end to allow water to fill connector.

Add flotation/ballast as necessary to the CTA to achieve the desired weight in water.

See EXPLORER mission photo #11.

<u>CTA bulkhead connector</u>:
A bulkhead connector for the CTA must be attached to the back of the BIA. The bulkhead connector is constructed from 2-inch PVC pipe and a 2-inch end cap.

To construct the CTA bulkhead connector:

1. Cut a 5 cm x 5 cm square of industrial strength Velcro loops. Cut the corners off of the Velcro square to make it octagonal. Attach the Velcro loops to the inside of a 2-inch PVC end cap.
2. Use a spade bit to drill two 5/8-inch holes into the 2-inch PVC end cap. The center points of the two holes should be approximately 2.5 cm apart from each other and approximately 0.75 cm below the centerline of the end cap.

Design note: The two 5/8-inch holes should accommodate the ends of the two #10 bolts on the front of the CTA bulkhead connector. Measure and drill accordingly to fit of the connector. There should be 2-inch PVC pipe inside the end cap when calculating locations to drill your holes.

3. Cut a 10 cm length of 2-inch PVC. Insert the 10 cm length of PVC into a 2-inch end cap.
4. Cut the top half of the 2-inch PVC away. The two holes drilled in the 2-inch end cap should be just below the centerline. The bottom of the bulkhead connector is the side with the two holes. The top of the bulkhead connector is the opposite side of the centerline from those two holes. At the edge of the end cap, use a saw to cut halfway through the 2-inch PVC pipe. Then cut the

PVC lengthwise to remove half the 2-inch PVC pipe.

5. Using the open PVC pipe as the top, use screws to secure the CTA bulkhead connector to the back right side (door is front) of the BIA. Countersink screws in the 2-inch PVC pipe so the heads of the screws do not interfere with the CTA connection.

See EXPLORER mission photo #12, #13, and #14.

Elevator:

The elevator is constructed out of a ½-inch PVC framework. The top of the elevator is covered with a plastic mesh. The mesh can be plastic square mesh (Home Depot part #**889250A**) or plastic hexagonal mesh (Home Depot part #**090786**). A pin will hold a secondary node onto the elevator. The pin is a 6-inch J-bolt with ¼-inch threads (ACE Hardware part #**57933**).

To construct the elevator:

1. Cut six 22 cm lengths and six 17 cm lengths of ½-inch PVC pipe. Insert two of the 22 cm lengths of pipe into the side openings of a ½-inch PVC tee. Insert a 17 cm length into the middle opening of the same PVC tee. Repeat this process with another PVC tee, two 22 cm lengths into the side openings, a 17 cm length of pipe into the middle opening.
2. Attach the other ends of the 17 cm lengths of pipe into opposite openings on a ½-inch PVC cross. Twist the pipe so all pieces lay flat.
3. Insert the remaining two lengths of 22 cm ½-inch PVC pipe into the other two openings on the PVC cross. Attach the middle opening of ½-inch PVC tee to the ends of both 22 cm lengths of pipe.
4. Insert the remaining four lengths of 17 cm pipe into the side openings of both PVC tees (four openings total). Twist so all pipe lays flat.
5. Use four ½-inch side outs to complete the rectangle. The short ends of the side out should attach to the open ends of eight lengths of PVC pipe. The long openings of the four side outs should all face the same way.

See EXPLORER mission photo #15 (top left).

6. Cut four 22 cm lengths, six 17 cm lengths, two 15 cm lengths and two 3 cm lengths of ½-inch PVC pipe. Insert one 15 cm length and one 3 cm length of pipe into the side openings of a PVC tee. Repeat this with the other 15 cm length and 3 cm length of pipe. Combined with the PVC tee, these should be 22 cm long.
7. Repeat the above steps 1 through 5, using the combination 22 cm lengths of pipe (15 cm, tee, 3 cm) into the side openings of the same PVC tee.
8. Cut four lengths of 5 cm ½-inch PVC pipe. Insert these lengths of pipe into the long openings of the four PVC side outs. Attach the long openings of the four PVC side outs from the other construction to the other end of the four 5 cm lengths of pipe.
9. The side of the elevator with the two extra PVC tees is the top. Twist the middle openings of

those two PVC tees so they are facing upwards.

10. Cut two 8.5 cm lengths of PVC pipe and insert them into the middle openings of the two PVC tees. Attach a 90^{o} elbow to the other end of each 8.5 cm length of pipe. Twist the elbows so their openings face each other.
11. Cut a 34.5 cm length of ½-inch PVC pipe. Insert it between the openings of both 90^{o} PVC elbows.
12. Drill a 3/8-inch hole completely through both sides of the left most 90^{o} PVC elbow. Make sure the edges of the drill holes are smooth.

The 3/8-inch holes in the 90^{o} elbow will match up with similar holes in the legs of the secondary node. The 6-inch J bolt will fit through both holes, securing the secondary node onto the elevator until the pin is removed. The height of the holes may need to be slightly altered to accommodate easy removal of the pin. Vary the length of the 8.5 cm pipe as needed.

See EXPLORER mission photo #15 and #16.

<u>Secondary node</u>:

The secondary node is constructed of a 3-inch PVC housing capped on each end by a 3-inch knock out cap (Home Depot part# **39102**, SKU #**508260**, Home Depot online #**39102**). A ½-inch PVC framework surrounds the 3-inch PVC housing. 7 meters of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**140-287**, ACE Hardware part #**75851**) connect the secondary node to the secondary node cable connector. A Johnson's bull's eye level (Home Depot online part #**100194712**) is used to determine when the secondary node is leveled.

To construct the secondary node:

1. Cut an 8.5 cm length of ½-inch PVC pipe. Attach the side opening of a PVC tee to each end of the 8.5 cm length of pipe.
2. Cut two 12 cm lengths of PVC pipe. Insert these 12 cm lengths of pipe into the middle opening of the PVC tee. Attach a ½-inch 90^{o} elbow to the other end of each 12 cm length of PVC pipe.
3. Cut two 3 cm lengths of ½-inch PVC pipe. Insert two of the 3 cm lengths into the two remaining side openings of both PVC tees. Attach the side opening of a ½-inch PVC tee to each end of the 3 cm length of pipe.
4. Cut two 3 cm lengths of ½-inch PVC pipe. Insert these 3 cm lengths of pipe into the other side openings of the PVC tee.
5. Repeat steps 1 through 4 for the other side of the ½-inch framework.
6. Cut four 25 cm lengths of PVC pipe. Use two 25 cm lengths of pipe to connect the 90^{o} elbows from one half of the framework to the 90^{o} elbows on the other half of the framework. Use the other two 25 cm lengths of pipe to connect the middle openings of the two PVC tees from one half of the framework to the middle openings of the PVC tees on the other half of the framework.
7. Cut a 25 cm x 16 cm rectangle of black ABS plastic sheeting. Screw the ABS sheet to the 90^{o}

elbows at the top of the PVC framework.

8. Cut a 25 cm length of 3-inch PVC pipe. Position the 3-inch pipe into the middle of the ½-inch framework underneath the ABS sheet. Secure the 3-inch pipe to the ABS sheet with screws.
9. Drill two ¼-inch holes 5.6 cm apart in the middle of the ABS sheet and through the 3-inch PVC pipe. Attach a #310 1 ½-inch pipe U-bolt (Home Depot part **#163518**) through these two holes. The U-bolt should stick up 5 cm above the wall of the 3-inch pipe.
10. Drill a 3/16-inch hole 2 cm from one edge of one knock out cap. Insert one end of the 5 meter length of rope through this hole, from the outside of the knock out cap through to the inside. Tie an overhand knot to secure the rope inside the cap. Insert 3-inch knock out caps into both sides of the 3-inch PVC pipe. Position the knockout cap with the rope so that the rope is closest to the bottom side of the canister (opposite the U-bolt).
11. Drill small holes into the 3-inch PVC pipe so that it will fill with water when submerged.
12. Use epoxy or glue to secure a circular bubble level to the top of the ABS sheet. The bubble level should be located halfway between one fork of the U-bolt and the 16 cm edge of the ABS sheet.

Four adjustable legs are positioned at each corner of the secondary node. The legs are constructed of a 3/8-inch x 6-inch threaded hex bolt. The 3/8-inch hex bolt should be threaded the entire length. This bolt screws into a 3/8-inch nut that is secured within a ½-inch length of PVC pipe set inside a ½-inch PVC tee. A 1 ½-inch knock out cap (Home Depot part **#39100**, Home Depot SKU **#508226**, Home Depot online part **#39100**) is used as a platform at the bottom of each leg.

To construct a leg:

1. Cut a 1.5 cm length of ½-inch PVC pipe. A 3/8-inch nut should be just larger than the ½-inch opening of the PVC pipe. Use a hammer to pound the 3/8-inch nut into the ½-inch PVC pipe. Insert this 1.5 cm length of pipe into the side opening of a PVC tee.
2. Align the nut within the ½-inch PVC pipe. Use the 6-inch bolt to straighten the nut within the PVC pipe and tee. The 6-inch bolt should travel through the center of the long axis of the PVC tee. Once the nut is aligned, remove the 6-inch bolt and use 5-minute epoxy or other glue to secure the nut in place. Make sure no glue gets on the threads of the nut.
3. Drill a 3/8-inch hole into the center of the top of a ½-inch PVC end cap. Insert the 6-inch bolt completely through the 3/8-inch hole in the end cap. The top hex end of the bolt should be inside the end cap. Twist a 3/8-inch nut completely down the 6-inch bolt. Use pliers to tightly secure the end cap between the top of the bolt and the 3/8-inch nut.
4. Cut a 3 cm length of ½-inch PVC pipe. Insert the 3 cm length of pipe into the ½-inch end cap. Attach the middle opening of a red-painted PVC tee to the other end of the 3 cm length of pipe.
5. Repeat steps 1 through 4 to complete three additional times to create all four legs of the secondary node.
6. Attach the middle opening of the PVC tee on the legs to the3 cm lengths of ½-inch pipe at each corner of the secondary node. Position the side opening of the PVC tee with the 3/8-inch nut at the bottom of the secondary node (farthest away from the 3-inch pipe and U-bolt). Once the PVC tee of the leg is positioned exactly vertical, use small set screws to keep it from twisting.

7. Using the red painted PVC tees as the handle, screw all four 6-inch bolts completely through 3/8-inch nut.
8. Position each leg in the exact center of a 1 ½-inch knock out cap. Fill the knockout cap with epoxy.

See EXPLORER mission photo #17, #18, and #19.

Secondary node cable connector:
The secondary node cable connector is constructed from ½-inch PVC. 7 meters of 1/8-inch braided nylon and polypropylene rope connect it to the secondary node. Two grab points on the connector are constructed from a #6 screw hook (Home Depot part **#14672**) and a #6 screw eye (Home Depot part **#14092**).

To construct the secondary node cable connector:

1. Drill two 5/32-inch holes into a ½-inch PVC end cap. One hole should be in the center of the end cap, the other hole should be 0.5 cm away from the center point. Insert the end of the 5 meter rope through the hole that is not in the center of the end cap. Tie an overhand knot in the rope to secure it inside the end cap.
2. Cut four 3 cm lengths of ½-inch PVC pipe. Insert two 3 cm lengths of pipe into opposite openings on a ½-inch PVC cross. Attach the end cap with the rope to one 3 cm length of pipe. Attach a ½-inch PVC coupling to the other 3 cm length of pipe.
3. Insert another 3 cm length of pipe into the other end of the ½-inch coupling. Attach a second ½-inch coupling to the 3 cm length of pipe.
4. Insert the fourth 3 cm length of pipe into the other end of the ½-inch coupling. Attach a ½-inch end cap to the 3 cm length of pipe.
5. Cut a 3.5 cm x 3.5 cm square of industrial strength Velcro loops (Home Depot Part #**90593**). Cover the front of the ½-inch end cap with the Velcro.
6. Drill a 5/32-inch hole in the coupling nearest the ½-inch cross. The hole should be 0.5 cm from the border of the coupling and the cross.
7. Insert a #6 screw hook into this hole. Continue to twist the hook into the hole until it screws into the other wall of the PVC coupling. Orient the end of the screw hook so it faces the PVC cross.
8. Insert a #6 screw eye into the center hole on the PVC end cap. Screw the eye all the way into the end cap.
9. Twist the PVC coupling containing the screw hook so it is perpendicular to the PVC cross. Twist the screw eye so it is parallel with the PVC cross and the rope emerges below the eye.

Add flotation/ballast as necessary to the secondary node cable connector to achieve the desired weight in water.

See EXPLORER mission photo #20, #21, #22, and #23.

<u>Designated locations</u>:
The four designated locations are constructed from ½-inch PVC pipe.

To construct the designated locations:

1. Cut twelve 60 cm lengths and two 28 cm lengths of PVC pipe. Insert the two 28 cm lengths into the two side openings of a ½-inch PVC tee. Attach a ½-inch 90^{o} elbow to the other end of each 28 cm length of pipe. Insert a 60 cm length of pipe into each 90^{o} elbow. Attach the side opening of a PVC tee to the end of each 60 cm length of pipe. Twist the middle openings so they are facing each other. Connect the two middle openings with another 60 cm length of PVC pipe.
2. Insert two 60 cm lengths of PVC pipe into the side openings of the PVC tees. Attach the side opening of a PVC tee to the end of each 60 cm length of pipe. Twist the middle openings so they are facing each other. Connect the two middle openings with another 60 cm length of PVC pipe.
3. Insert two 60 cm lengths of PVC pipe into the side openings of the PVC tees. Attach the side opening of a PVC tee to the end of each 60 cm length of pipe. Twist the middle openings so they are facing each other. Connect the two middle openings with another 60 cm length of PVC pipe.
4. Insert two 60 cm lengths of PVC pipe into the side openings of the PVC tees. Attach a ½-inch 90^{o} elbow to the end of each 60 cm length of pipe. Twist the other opening of the 90^{o} elbow so they face each other. Use the final 60 cm length of PVC pipe to connect the two openings of the elbow.
5. Use a variable length of ½-inch PVC pipe to connect the middle opening of the PVC tee on the designated location to the middle opening of the PVC tee on the back of the BIA.

The 60 cm x 60 cm squares will not be level. Two square paving bricks (30 cm x 30 cm) will be placed within each square to make the seafloor uneven. The center of the designated location is where the two corners of the paving bricks join together 30 cm from each edge.

See EXPLORER construction photo #24, #25, #26, and #27.

Task #2: Design, construct, and install a transmissometer to measure turbidity over time.

Prior to the competition, your company is required to design and construct an optical beam transmissometer. This is a device that measures the attenuation of light as it travels through water, or any medium. Oceanographers use transmissometers to measure the concentration and attenuation effects of particles in the water, often called turbidity. (Visit www.wisegeek.com/what-is-a-transmissometer.htm to learn more about how transmissometers work.)

Hydrothermal vents often exude plumes of seawater filled with particles that form as the water coming from below the seafloor meets the surrounding seawater above the vent. These vent plumes are sometimes called black or white “smokers,” with the color coming from the particles that precipitate rapidly within the plume as the hydrothermal fluids mix with the cold seawater at and above the vent opening. The particles in the plume make it opaque; oceanographers studying vents use optical beam transmissometers to measure this opacity. From the data, they can determine the likelihood of a recently active hydrothermal vent nearby.

During the competition, your company will be required to install your beam transmissometer near a hydrothermal vent within the ASHES site and obtain real-time optical transmission data over an extended time period. Companies will be required to record and graph relative beam transmission readings every second over a 5-minute time period. Accuracy of the optical transmission measurement will not be judged, but relative data will be, i.e., the percentage changes of the measured medium (pool water with a special disk simulating a plume).

This task involves the following steps:

- **Designing and constructing an optical beam transmissometer prior to the competition – 15 points**
- **Installing the transmissometer in the vent field to monitor the opacity through the medium – 10 points**
- **Detecting the relative changes in opacity – 10 points**
- **Detecting the relative changes in opacity over five minutes – 20 points**
- **Graphing the relative optical transmission (aka opacity) versus time on a video display – 20 points**

Total points = 75

Mission Notes:

Your company is responsible for designing and constructing its own optical beam transmissometer. The MATE Center will NOT provide one to your company at the competition. Your company is responsible for installing your transmissometer so it can measure the relative opacity of a plastic disk that is being used to simulate particles in the water column. Your transmissometer should be independent of your ROV. Once installed on the seafloor, the ROV can disengage and complete other tasks. The instrument may NOT have any thrusters or video capabilities; it must be completely deployed by the ROV. Companies will receive 15 points for having a transmissometer available at the start of the mission run.

Your transmissometer must be powered from the surface; no onboard batteries of any type are allowed. Companies may use USB to connect their sensor to a computer. Companies may also use surface battery packs (limited to 12 volts maximum) or the MATE supply to provide power for their transmissometer. MATE will also supply each mission station with a 12 volt battery as an alternative power source for the transmissometer. This 12 volt battery may only be used to power the transmissometer; it may not be used in any way to power the ROV, devices on the ROV, or any device other than the transmissometer. If companies are using the MATE supplied 12 volt battery or their own battery pack, they must provide a 3 amp fast blow fuse on the positive side of their connection. If companies are using the 48 volt MATE supply to power their transmissometer, both the ROV and transmissometer must run through the single 40 amp fuse before splitting off to the 3 amp sensor fuse.

Companies must install their transmissometer onto a small platform that is being used to simulate the seafloor. A round plastic sheet with varying optical density (hereafter the "medium") protrudes that represents the particle matter in the water column protrudes from the platform.

The platform is 41 cm long, 34 cm wide and 25 cm tall. It is constructed from a framework of ½-inch PVC pipe with black plastic ABS sheets covering the top and corrugated plastic sheets covering the side. The ABS top sheets are a working surface upon which companies can install their transmissometer. The side walls will provide a darkened environment; light will not be reflecting up from underneath the seafloor. Four guideposts are available for companies to center their transmissometer if they choose to do so. The four guideposts are constructed from ½-inch PVC and stick up 5 cm. They are 38.7 cm apart by 16.7 cm apart (from the midpoint of the 1.2-inch PVC pipe). Companies are not required to use these guideposts. Companies will receive 10 points when their transmissometer is installed on the platform so that their meter is monitoring the plastic absorbing medium. The medium will be a round, 21 cm diameter disk of varying opacity. This disk will protrude approximately 5 cm above the ABS sheets. Companies should attempt to avoid measuring at the very edge of the disk. A motor will slowly turn the disk during the mission run, thus varying the opacity at any given point.

Once installed, the transmissometer must continuously monitor the opacity of the disk over a 5-minute time period. As the disk turns, the opacity of the medium will change over time. Companies will receive 10 points for detecting any significant change in relative opacity. A significant change in relative opacity is a change greater than the natural variance of the transmissometer.

Companies will need to measure the relative opacity and display the differences over a 5-minute time period. The relative opacity will be changing during the entire mission run. Companies will receive 20 points when they show the mission station judge relative changes in opacity over a 5-minute time period.

Companies must graph, on a video display, the relative opacity of the medium over time. Companies are not allowed to graph this data by hand. Companies will receive 20 points when their video display begins to receive and graph data from the transmissometer. Companies should inform the mission station judge when data is received from their transmissometer. It is not up to the mission station judge to recognize or interpret that data is being visually displayed on a video screen.

To accurately detect changes in relative opacity, it is recommended that the transmissometer produces a data point each second, and that the company graph every data point. This graph should compare relative opacity (Y-axis) versus time (X-axis).

The entire five minutes of data should be graphed and shown to the mission station judge. Companies can scroll their display back and forth if necessary to display the entire 5-minute time period. The mission station judge must be informed when the 5-minute period is up and the video display is ready to be evaluated. Companies may only have their graph evaluated once. If the judge determines the graph is incorrect, companies may not attempt to acquire a new, 5-minute data set. The mission station judge may defer the evaluation of the graph until the demobilization period. Companies will not be penalized if a mission station judge takes excessive time in evaluating the graph during the demobilization period. If a company runs out of time and cannot measure and display the entire 5-minute time period, they cannot receive full mission points and therefore cannot receive a time bonus.

Mission prop specifications

See the **EXPLORER Construction Photos, Mission Prop Photos, and SolidWorks Assemblies and Drawings** documents for visuals.

All PVC used in construction is DURA brand PVC. If items are unavailable or built to different specifications in your area, check online at www.duraplastics.com to purchase specific PVC pieces. Alternatively, certain dimensions may need to be extended or shortened to match DURA brand products.

Seafloor platform:

For this mission, the seafloor is simulated by a small platform that allows the simulated plume medium (rotating plastic disk) to turn and thus vary over time. The platform is constructed from a PVC framework with 1/8-inch ABS plastic sheeting and corrugated plastic sheeting surrounding it. The platform allows the MATE Center to mount a motor that will slowly turn the disk.

To construct the seafloor platform:

1. Cut a 12.5 cm length of ½-inch PVC. Attach the side opening of a PVC tee to each end of the 12.5 cm length of pipe. Cut two 3 cm lengths of ½-inch PVC pipe and insert them into the other side openings of each PVC tee. Attach the short end of a ½-inch side out to the other side opening of each tee.
2. Twist the two PVC side outs so they are mirror images of each other. Cut two 3 cm length of PVC pipe and insert them into the other short end of the two PVC side outs. Attach the side opening of a PVC tee to the other end of each 3 cm length of pipe. Turn the middle opening of these two PVC tees to face each other. Cut a 27 cm length of PVC pipe and connect the two middle openings of the PVC tees.
3. Cut two 3 cm lengths of PVC pipe. Insert the 3 cm pipe into the side openings of the two PVC tees. Attach a side opening of a PVC tee to the end of each length of pipe. Cut two 7 cm lengths of ½-inch PVC pipe. Insert them into the middle opening of each PVC tee. Attach a ½-inch 45^{o} elbow to the other end of each 7 cm length of pipe. Twist the tees so the exposed ends of the 45^{o} elbows face each other. Cut a 13 cm length of PVC pipe and connect the open ends of each

45^{o} elbow.

4. Cut two 20 cm lengths of ½-inch PVC pipe. Insert these lengths of pipe into the side openings of the two PVC tees. Attach the short end of a PVC side out to the end of each 20 cm length of pipe. Turn the two side outs so their remaining short arms are facing each other. The four side outs used should all have their long ends facing in the same direction.
5. Cut two 3 cm length of PVC pipe. Insert these lengths of pipe into the two short ends of each side out. Attach the side opening of a ½-inch PVC tee to the other end of each 3 cm length of pipe. Cut a 12.5 cm length of pipe and connect the two side openings of a PVC tees.

This is the top of the seafloor platform. The side outs should all have the long ends facing down. Twist the four PVC tees so that their middle openings all face up.

6. Cut two 8 cm lengths of 1.2-inch PVC pipe. Insert these 8 cm lengths into the side openings of a PVC tee. Attach the long end of a PVC side out to the other end of each 8 cm length of pipe. Cut two 9.5 cm lengths of PVC pipe. Insert them into one of the short ends of the two PVC side outs. Twist the side outs with the 9.5 cm lengths of pipe so they are mirror images of each other. Attach a side opening of a PVC tee to the other end of each 9.5 cm length of pipe.
7. Cut two 22 cm lengths of ½-inch PVC pipe. Insert the 22 cm lengths of pipe into the side openings of the two PVC tees. Attach a ½-inch 90^{o} elbow to the other end of each 22 cm length of pipe.
8. Twist the three PVC tees so that the middle openings all three point in the same direction as the open short arm of the two side outs. Cut three 10 cm lengths of ½-inch PVC pipe and insert these lengths into the middle openings of the three PVC tees. Attach a ½-inch 90^{o} elbow to the other end of each 10 cm length of pipe.
9. Cut two 11 cm lengths, a 9 cm length and a 3 cm length of ½-inch PVC pipe. Insert the two 11 cm lengths of pipe into opposite sides of a ½-inch PVC cross. Insert the 9 cm length and the 3 cm length into the other two opposite openings of the cross.
10. Twist all 90^{o} elbows to face towards the center of the construction. Attach the two 11 cm lengths and the 9 cm length of PVC pipe into the openings of the three 90^{o} elbows. Attach a ½-inch PVC coupling to the other end of the 3 cm length of pipe.
11. Cut four 15 cm lengths of ½-inch PVC pipe. Use these to connect the four corners from the top of the construction to the four corners on the bottom of the construction.
12. Cut four 5 cm lengths of PVC pipe. Twist the middle openings of the four tees on the top of the construction to point upwards. Insert a 5 cm length of pipe into the middle opening of each PVC tee.

This is the framework for the seafloor platform. The top of the framework will be covered with 1/8-inch black ABS sheeting. The four sides of the seafloor framework will be colored with dark corrugated plastic. Use black or dark blue corrugated plastic if possible. Alternatively, companies may paint corrugated plastic in a dark color.

1. Cut a 33 cm x 21 cm rectangle and a 33 cm x 10 cm rectangle of 1/8-inch ABS plastic. Screw the 33 cm x 21 cm sheet of ABS over the 20 cm lengths of PVC pipe on the framework. Screw the 33 cm x 10 cm sheet of ABS over the 27 cm length of PVC pipe. Note: Companies may need to notch one side their ABS sheet to fit around the PVC tees.
2. Cut two 40 cm x 25 cm rectangles and two 31 cm x 25 cm rectangles of corrugated plastic sheeting. Screw the corrugated plastic sheets over the four sides of the seafloor framework.

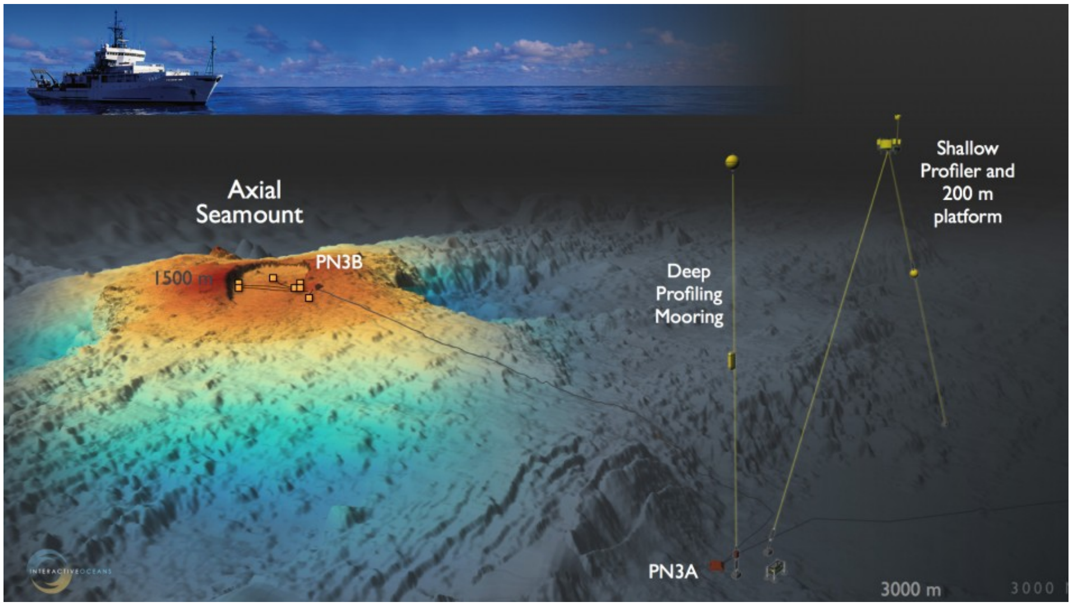
Design note: Check sign-making/printing stores for ABS sheeting and corrugated plastic. ABS sheeting and corrugated plastic can also be reused from the 2012 competition props

Motor mount and opaque disk:
A motor will slowly turn the opaque disk during the competition. The motor will be mounted horizontally above the ½-inch PVC coupling inside the seafloor framework. The opaque disk will be mounted to the motor's axis such that it rotates and is perpendicular to the platform above it. It will protrude through the platform and the top will be 5 cm above the black ABS sheets of the platform. The MATE Center will use a small waterproofed electric motor and a gear reduction system to reduce the rpm. (See www.pololu.com/catalog/product/70.) The disk will be a 21 cm diameter disk of 1/8-inch Plexiglass, attached to the motor shaft with a propeller adapter. Companies constructing this device may use any slow turning motor. Alternatively, during testing, companies may use other methods to change the varying opacity medium being monitored by the transmissometer.

See EXPLORER mission photo #28, #29, and #30.

Task #3: Replace an Acoustic Doppler Current Profiler (ADCP) on a water column mooring platform.

Your company is required to remove and replace an ADCP that is located on a mooring platform suspended in the water column at the Axial Seamount site. Companies must first disconnect power to the platform, unlock the hatch, open the hatch to expose the ADCP, remove the ADCP, and replace it with a new ADCP. Once the new ADCP is installed, companies must close the hatch, lock the hatch, and reconnect power.



Moorings deployed along the Axial Seamount

This task involves the following steps:

- **Disconnecting power to the platform – 10 points**
- **Turning the handle to unlock the hatch – 10 points**
- **Opening the hatch – 10 points**
- **Removing the ADCP from the mooring platform – 10 points**
- **Installing the new ADCP into the mooring platform – 10 points**
- **Closing the hatch – 10 points**
- **Turning the handle to lock the hatch – 10 points**
- **Reconnecting power to the platform – 10 points**

Total points = 80

Mission Notes:

Task #2 must be completed in order. Companies may alternate between task #2 and other tasks, but the steps of task #2 must be completed in the order listed above. Companies may skip any step of task #2, but will not receive points if they complete that step at a later time, i.e., after steps later in the list. All steps of task #2 must be completed to receive a time bonus.

The mooring platform containing the ADCP is constructed from a milk crate. The mooring platform will be positively buoyant, but will be anchored in mid-water by four ropes attached to dive weights. Six manipulator/ROV attachment points (a.k.a., "grab" points) are located around the mooring platform – two screw hooks, two screw eyes and two U-bolts. Companies may use these grab points to stabilize the ROV relative to the platform as desired.

Companies must first disconnect power to the mooring platform. The connector is constructed from a 1-inch PVC coupling and two 1-inch end caps. A screw hook and screw eye will act as lift points for this connector. The bulkhead connector is constructed of 2-inch PVC and a 2-inch end cap. A small square of Velcro will secure the mooring platform connector into the bulkhead connector. Companies will receive 10 points for disconnecting power to the platform. A successful disconnect is when the platform connector is no longer in physical contact with any part of the bulkhead connector.

It will take less than 2 Newtons to remove the platform connector from the bulkhead connector.

To reach the ADCP, companies must unlock then open the hatch on the top of the platform. Unlocking the hatch requires turning a handle located on the side of the platform. The handle is constructed from ½-inch PVC pipe and must be turned 90^{o} to unlock the hatch. Companies will receive 10 points for turning the handle and unlocking the hatch. Once the hatch is unlocked, companies will receive 10 points for opening the hatch. The hatch is located on the top surface of the platform and is constructed from a sheet of corrugated plastic. A handle is constructed of ½-inch PVC pipe. Opening this hatch will reveal the ADCP inside the platform.

It will take less than 2 Newtons to turn the handle to lock/unlock the hatch.
It will take less than 2 Newtons to open/close the hatch.

An ADCP ready for deployment

After the old ADCP is removed, a new ADCP must be installed into the mooring platform. Both the old ADCP and the new ADCP are identical in construction. The ADCP is constructed from a 3-inch pipe topped by an end cap. A U-bolt mounted in the end cap serves as a lift point. The old and new ADCP will be painted differently to distinguish one from the other. An ADCP cradle, constructed of ½-inch

PVC, is mounted inside the platform. The new ADCP must be placed inside this cradle. Companies will receive 10 points for removing the old ADCP from the cradle. The ROV must be in possession of the old ADCP and no part of the ADCP may be touching the platform. The old ADCP must be returned to the surface. If the old ADCP is left on the seafloor when the mission time ends, companies will be assessed a 5-point penalty and will not receive a time bonus. If the old ADCP is in possession of the ROV when the mission time ends, companies will not incur a penalty.

The new ADCP will be located on the surface in the mission station area. Companies may attach the new ADCP to their vehicle during the 5-minute set-up period. Companies will only get one ADCP. If it is dropped, your company must retrieve it to complete the mission. Companies will receive 10 points for installing the upgraded ADCP into the platform. The new ADCP must sit completely flat against the inside bottom of the platform, within the ½-inch PVC pipe ADCP cradle.

Both ADCPs will weigh less than 2 Newtons in water, though they may not be of exactly the same mass.

Once the new ADCP is installed into the platform, the hatch must be closed and locked. Companies will receive 10 points for closing the hatch on the platform. The hatch on top of the platform must sit flush with the side walls of the milk crate. If the hatch cannot be shut due to improper installation of the new ADCP (e.g. the ADCP is not all the way down into the cradle), companies must adjust the ADCP until is rests completely within the platform and the hatch is flush with the side-walls of the milk crate.

Companies will receive 10 points for relocking the closed hatch. Relocking the hatch requires turning the handle located on the side of the platform. The handle must be turned approximately 120^{o}, until the PVC elbows of the locking mechanism prevent the hatch from opening.

Power must be reconnected once the hatch is closed and locked. Companies will receive 10 points for reconnecting power to the platform. To reconnect power, companies must insert the platform connector into the bulkhead connector. The power has been successfully reconnected when the bolts of the platform connector protrude through the holes in the bulkhead connector. The platform connector must remain in bulkhead connector as the ROV moves away from the mooring platform. If the platform connector comes out of the bulkhead connector at any time during the mission run, companies will lose the points they received for reconnecting power to the ADCP and must attempt to reconnect the power to regain these points.

Mission prop specifications

See the **EXPLORER Construction Photos, Mission Prop Photos, and SolidWorks Assemblies and Drawings** documents for visuals.

All PVC used in construction is DURA brand PVC. If items are unavailable or built to different specifications in your area, check online at www.duraplastics.com to purchase specific PVC pieces.

Alternatively, certain dimensions may need to be extended or shortened to match DURA brand products.

Mooring platform:
The mooring platform is constructed from a milk crate. These specifications use a *Dean Foods* milk crate with a diamond pattern of holes on the sides. If your milk crate has different specifications, you may need to modify your design to some degree. Contact the Competition Coordinator, Jill Zande, if you need assistance in making modifications.

To construct the mooring platform:

1. Cut a 34 cm by 32 cm sheet of corrugated plastic.

Design note: Check sign-making/printing stores for corrugated plastic. Corrugated plastic can also be reused from the 2012 competition props. Use the same corrugate plastic sheet that covered the front of the calibration tank (milk crate).

2. Draw a line 4.5 cm in from one edge of the plastic sheeting. Draw another line 19.5 cm in from the same edge. Draw a line 3.5 cm in and 7.5 cm in from each adjacent edge of the corrugated plastic. There should be lines marking two 4 cm by 15 cm rectangular areas. Use a box cutter to cut out these two 4 cm by 15 cm rectangular holes into the corrugated plastic.
3. Use two 3-inch brass hinges (Home Depot part **#237-067**) to secure the corrugated plastic sheet over the open side of the milk crate. These hinges should be placed on the edge furthest away from the holes.
4. Position the hinges along the edge of the milk crate and drill holes into the plastic of the milk crate and into the corrugated plastic.
5. Use #10-24 1-inch long bolts instead of the screws that come with the hinges. This will eliminate the sharp points of the screws and allow for tighter connections with the plastic. Use a 10-24 nut to secure the bolts through the hinges. When attaching the bolts through the corrugated plastic, use a 1 ¼-inch x ¼-inch fender washer on the two outside bolts of each hinge. This will increase the surface area against the corrugated plastic and prevent damage.
6. Cut a 9 cm length of ½-inch PVC pipe. Attach a ½-inch 90^o PVC elbow to each end. Drill two 5/32-inch holes into the open end of each 90^o PVC elbow. This is the handle to open the corrugated plastic top to the mooring platform.
7. Place the handle on the side of the corrugated plastic opposite the hinges, 3 cm from the edge of the plastic. The handle should be positioned so the open ends of the 90^o PVC elbow are flat against the corrugated plastic and the handle is located centrally between the two holes cut into the corrugate plastic.
8. Drill four holes into the corrugated plastic, each one adjacent to the holes drilled into the open end of the 90^o PVC elbow. Insert cable/zip ties through the holes of each 90^o PVC elbow, through the holes in the corrugated plastic. Tighten the ties to secure the handle to the corrugated plastic.

See EXPLORER mission photo #31.

Handle and locking mechanism:
The handle and locking mechanism is constructed from ½-inch PVC pipe. The handle must be turned to remove the locking mechanism before the top hatch can be opened.

To construct the locking mechanism and handle:

1. Cut a 19.5 cm length of ½-inch PVC pipe. Attach the side opening of a ½-inch PVC tee to each end of the 19.5 cm length of pipe. Align the PVC tees so their middle openings face the same direction.
2. Cut two 10.5 cm lengths of PVC pipe. Insert these 10 cm lengths of pipe into the middle openings of each PVC tee. Attach a ½-inch 90^{o} PVC elbow to the end of each 10.5 cm length of PVC. Insert a 5.5 cm length of ½-inch PVC into the open end of each elbow. Align the 90^{o} PVC elbows so that as the PVC tees lay flat on the ground, the 5.5 cm lengths of PVC stick straight up into the air.
3. Cut two lengths of 4 cm length of ½-inch PVC pipe and insert them into the side openings of the two PVC tees. As the locking mechanism lies flat on the ground, with the 5.5 cm lengths of pipe sticking straight up, a middle opening of a PVC tee will attach to the 4 cm length of PVC pipe on the right hand side of the locking mechanism. A ½-inch PVC coupling will attach to the 4 cm length of PVC pipe on the left hand side of the locking mechanism.
4. Before attaching the tee and coupling, fit the locking mechanism inside the milk crate. The 4 cm lengths of PVC pipe should fit into a diamond shaped hole on the sides of the *Dean Foods* milk crate. The PVC pipe should fit into the top most full diamond hole under the handle of the top hatch of the mooring.
5. Attach the middle opening of the PVC tee to the 4 cm length of pipe on the right side of the locking mechanism. Attach the ½-inch coupling to the 4 cm length of pipe on the left side of the locking mechanism.
6. Cut a 3 cm length of ½-inch PVC pipe and insert it into the open end of the ½-inch coupling. Attach a ½-inch 90^{o} PVC elbow to the other end of the 3 cm length of pipe.
7. Cut an 11 cm length of ½-inch PVC pipe. Insert this 11 cm length of pipe into the open end of the 90^{o} PVC elbow.
8. Twist the 90^{o} PVC elbow until the 11 cm length of pipe is parallel two 5.5 cm length of pipes.

As an ROV turns the handle, the locking mechanism should rotate into or out of the holes cut into the corrugated plastic sheeting. If the corrugated plastic hinders the PVC locking mechanism, readjust the position or widen the holes. The locking mechanism should engage and disengage freely without brushing against the corrugated plastic top.

The handle will take less than 2 Newtons to turn.

See EXPLORER mission photo #32 and #33.

Six manipulator attachments, or grab points, will be located around the mooring platform. Two grab points will be #310 1 ½-inch U-bolts (Home Depot part **#117-996**). One U-bolt will be mounted to the front-side of the platform (side opposite the hinges), while the other U-bolt will be mounted to the back-side of the platform (side with the hinges attached). U-bolts will be positioned horizontally along the centerline of the milk crate, 14 cm from the top of the milk crate and 13 cm from the bottom of the milk crate. Two #6 Screw eyes (Home Depot part **#14092**) will be located on the sides of the platform. Screw eyes will be located at the top, front side of both the left and right wall of the platform. Screw eyes will be positioned 2.5 cm from the top of the milk crate and 2.5 cm from the front edge of the milk crate. Two #6 Screw hooks (Home Depot part **#14672**) will be located on the sides of the platform as well. Screw hooks will be located at the bottom, front side of both the left and right wall of the platform. Screw hooks will be positioned 5 cm from the bottom of the milk crate and 2.5 cm from the front edge of the milk crate.

1. Attach a U-bolt to the front side center and back side center wall. Use 1 ¼-inch x ¼-inch fender washers to secure the U-bolt to the milk crate.
2. Drill four 5/32-inch holes into the top front (2.5 cm down, 2.5 cm in) and bottom front (5 cm up, 2.5 cm in) of the left and right side milk crate walls. Screw a #6 Screw eye into the holes at the top of the milk crate. Screw them in so that no threading shows outside the milk crate wall. Twist them so they are parallel to the ground. Screw a #6 Screw hook into the holes at the bottom of the milk crate. Screw them in so that approximately 0.5 cm to 1 cm of thread is showing outside the milk crate wall. Twist them so that the open end of the hook is facing upwards.

See EXPLORER mission photo #34.

ADCP:
The ADCP that is removed from the platform will be identical to the new ADCP that is installed into the platform. Only color will be different. The ADCP is constructed from 3-inch ABS pipe, (companies that cannot find ABS pipe may substitute PVC pipe), a 3-inch PVC end cap, a 3-inch knock out cap (Home Depot part# **39102**, SKU#**508260**, Home Depot online# **39102**), and a 1 3/8-inch, long U-bolt (ACE Hardware, 5/16 x 1 3/8, long U-bolt, part #**51613**). The U-bolt rises 6 cm above the top of the end cap.

Design Note: The scientific instrument is a shortened version of the ELSS pod used in the 2009 ROV competition.

To construct the ADCP:

1. Cut a 16 cm length of 3-inch ABS pipe. Insert a 3-inch knockout cap into one end of the ABS pipe. Drill small holes into the pipe so that it fills with water.
2. Drill two holes into the top of a 3-inch PVC end cap. The center points of the holes should be

placed 4.3 cm apart, 2.15 cm on opposite sides of the center of the end cap. Insert the forks of the U-bolt through the holes. Use 5/16-inch nuts to tighten the U-bolt on both sides of the end cap.
3. Attach the end cap to the other end of the ABS pipe.

Insert foam into the inside of the end cap to provide positive buoyancy. Use weights inside the body of the scientific instrument to provide ballast. The balance of positive buoyancy and ballast should be less than 2 N when submerged in water.

The 3-inch end cap will be painted either red or yellow.

When the ADCP is complete, it should sit inside the milk crate, with the top of the U-bolt just below the top hatch of the platform.

See EXPLORER mission photo #35.

<u>**ADCP cradle**</u>:
Once the top hatch of the platform is open, the ADCP will need to be removed from its cradle and the new ADCP installed into the cradle. The cradle is constructed from a framework of ½-inch PVC pipe.

To construct the ADCP cradle:
1. Cut four 15 cm lengths of ½-inch PVC pipe. Attach the middle opening of a ½-inch PVC tee on both sides of each 15 cm length of pipe (8 tees total).
2. Cut sixteen 3 cm lengths of ½-inch PVC pipe. Insert these 3 cm lengths of pipe into both side openings of all eight PVC tees.
3. Attach a ½-inch 90^{o} PVC elbow to the end of the 3 cm PVC pipes to make a square.
4. Use cable/zip ties to secure the ½-inch PVC pipe assembly to the bottom center of the milk crate. Make sure that the placement of the PVC pipe does not interfere with the handle and locking mechanism on the platform.

See EXPLORER mission photo #35 and #36.

<u>**Connector**</u>:
Design note: The connector is the exact same design as the CTA from mission #1, but without the Velcro connection.

The connector is constructed from a 1-inch PVC coupling with a 1-inch end cap attached to each end. Two #10, 1-inch bolts act as the plugs. A #6 screw hook (Home Depot part **#14672**) and a #6 Screw eye (Home Depot part **#14092**) act as grab points on the connector. Two meters of 1/8-inch braided nylon and polypropylene rope (Home Depot part #**14068**, Home Depot SKU #**140287**, ACE Hardware part #**75851**) attach the connector to a rope that holds the mooring platform in place.

To construct the connector:

1. Drill two 5/32-inch holes into the 1-inch PVC end cap covered with Velcro. The holes should be along a centerline and be drilled 2.5 cm apart. Screw a #10 1-inch bolt through each hole, from the inside of the end cap to the outside.
2. Drill a 5/32-inch hole in the exact center of another 1-inch PVC end cap. Drill a 3/16-inch hole 1 cm out from the hole in the center. Screw a #6 Screw eye into the center hole. The Screw eye should be completely screwed into the end cap. Insert one end of the 1/8-inch rope into the off-center hole. Tie an overhand knot into the rope so that it is secured inside the end cap.
3. Cut two 4 cm lengths of 1-inch PVC pipe. Insert a 4 cm length into both ends of a 1-inch PVC coupling. Attach the two 1-inch PVC end caps to each end of the 1-inch coupling.
4. Drill a 5/32-inch hole into the center 1-inch PVC coupling, 3 cm from either end. Screw a #6 screw hook into this hole. The screw hook should be screwed in until only 2 mm of the thread remains outside of the 1-inch coupling.
5. On the opposite side of the coupling from the screw hook, drill four 3/32-inch holes. Two holes should be placed 1 cm from each end of the coupling. Each set of holes should be 2 cm apart from each other, 1 cm to either side of the bottom of the connector. The bottom is defined as the line directly opposite the #6 Screw hook.
6. Insert a #6, ½-inch screw into each hole. The two screws placed near the end cap that contains the Screw eye and 1/8-inch rope should not be screwed all the way in. The head of the screw should be approximately 2 to 3 mm from the PVC coupling. These screws will act as small legs to hold the connector upright.
7. Twist the end caps into proper alignment. The end cap containing the two #10 1-inch bolts should be twisted so that the two bolts are flat; a line between the two bolts should be parallel with the ground. Twist the other 1-inch end cap so that 1/8-inch rope is directly below the #6 Screw eye.
8. Twist the #6 Screw eye and #6 Screw hook into proper alignment. The Screw eye should be twisted so that the eye is parallel with the pool bottom. Turn the Screw hook so that the open end of the hook faces the screw eye.
9. Cut four length of rope and tie one to each bottom corner of the mooring platform. The four ropes should be similar in length, but the overall length will be dependent on the depth of the pool. Attach dive weights to the other end of each length of rope.
10. Tie the 2 meter length of rope attached to the connector to one of the ropes holding the mooring platform to the seafloor.

Use PVC glue to secure the end caps onto the 1-inch PVC pipe once the alignment of your connector is correct. Drill small holes into the top and bottom of each end to allow water to fill connector.

See EXPLORER mission photo #37.

<u>Bulkhead connector</u>:
The bulkhead connector is constructed from 2-inch PVC pipe and a 2-inch end cap.

To construct the bulkhead connector:

1. Use a spade bit to drill two 5/8-inch holes into the 2-inch PVC end cap. The center points of the two holes should be approximately 2.5 cm apart from each other and approximately 0.75 cm below the centerline of the end cap.

Design note: The two 5/8-inch holes should accommodate the ends of the two #10 bolts on the front of the connector. Measure and drill accordingly to fit of the connector. There should be 2-inch PVC pipe inside the end cap when calculating locations to drill your holes.

2. Cut a 10 cm length of 2-inch PVC. Insert the 10 cm length of PVC into a 2-inch end cap.
3. Cut the top half of the 2-inch PVC away. The two holes drilled in the 2-inch end cap should be just below the centerline. The bottom of the bulkhead connector is the side with the two holes. The top of the bulkhead connector is the opposite side of the centerline from those two holes. At the edge of the end cap, use a saw to cut halfway through the 2-inch PVC pipe. Then cut the PVC lengthwise to remove half the 2-inch PVC pipe.
4. Using the open PVC pipe as the top, use screws to secure the connector to the top, right hand corner of the front of the mooring platform (hinges are the back side). The top of the cut portion of 2-inch PVC pipe should be 4 cm from the top of the milk crate. The front of the 2-inch PVC pipe should be flush with the right side of the milk crate. Use screws or bolts to secure the bulkhead connector to the milk crate.

See EXPLORER mission photo #38 and #39.

<u>Flotation and Ballast</u>:
The mooring platform will be situated in the mid-water; it will not be secured to the bottom by four anchors. Companies will not know the exact depth of the mooring platform. The platform itself will be positively buoyant and will be attached to its anchor weights on the bottom by 1/8-inch braided nylon and polypropylene rope (Home Depot part #**14068**, Home Depot SKU#**140287**, ACE Hardware part #**75851**).

To position the mooring platform in mid-water:

1. Secure pipe insulation foam or other flotation inside the platform or secure flotation to the bottom of the platform until it is positively buoyant. Any flotation inside the milk crate platform should not interfere with the locking mechanism or the insertion of the scientific instrument.
2. Cut 4 similar lengths of rope. Tie one end of each rope to each bottom corner of the milk crate. Tie a heavy weight to the other end of each rope. Adjust the lengths of each rope so the platform sits evenly in the water.

Position the dive weights so the mooring platform is level in the water column. Lengthen or shorten the ropes as needed to achieve this.

See EXPLORER mission photo #40.

Task #4: Locate and remove biofouling from structures and instruments within the observatory.

Your company is required to remove biofouling from various structures and instruments.

This task involves the following steps:

- Locate five areas of biofouling and removing all biofouling organisms **– 5 points each**

Total points = 25

An ADCP before and covered with biofouling six months after deployment

Mission Notes:

Companies are responsible for locating and removing all areas of biofouling from the various structures and instruments of the regional cabled observatory. The exact structures and instruments with biofouling will not be revealed; your company must locate them. Each area of biofouling will have multiple organisms that must be removed. Once removed, the organisms do not need to be returned to the surface. Companies may leave the organisms on the seafloor.

Mission prop specifications

See the **EXPLORER Construction Photos, Mission Prop Photos, and SolidWorks Assemblies and Drawings** documents for visuals.

Biofouling organisms:

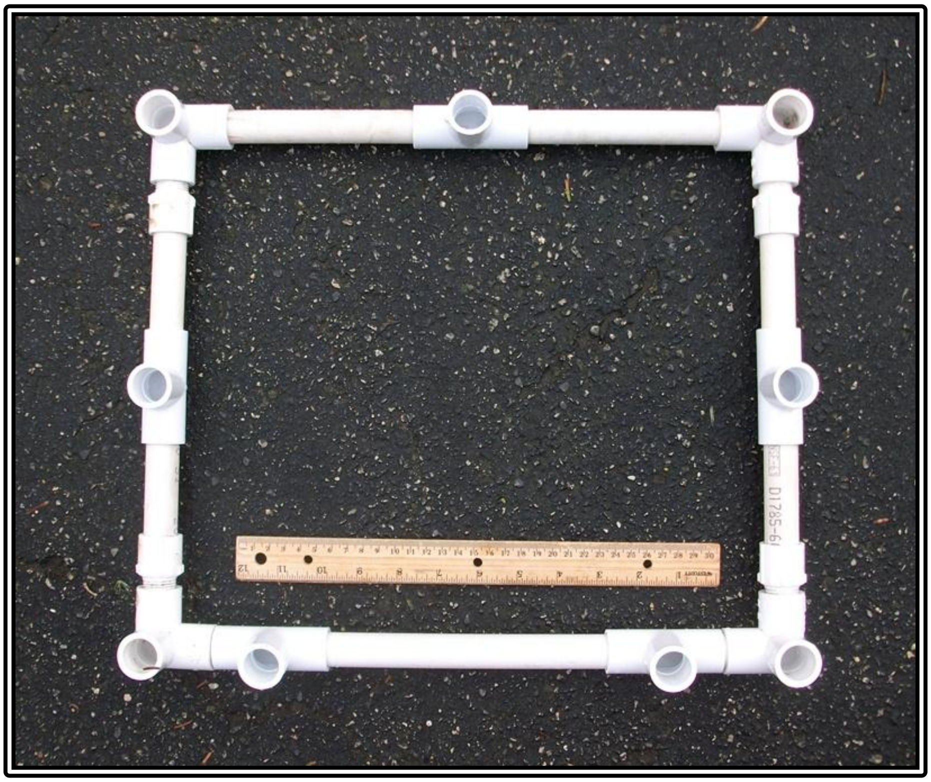
Biofouling organisms will be constructed of 30 cm (12-inch) chenille pipe cleaners. The ends of the chenille pipe cleaners will be inserted into small 3/32-inch holes drilled into the ½-inch PVC pipe.

To construct a biofouling organism:

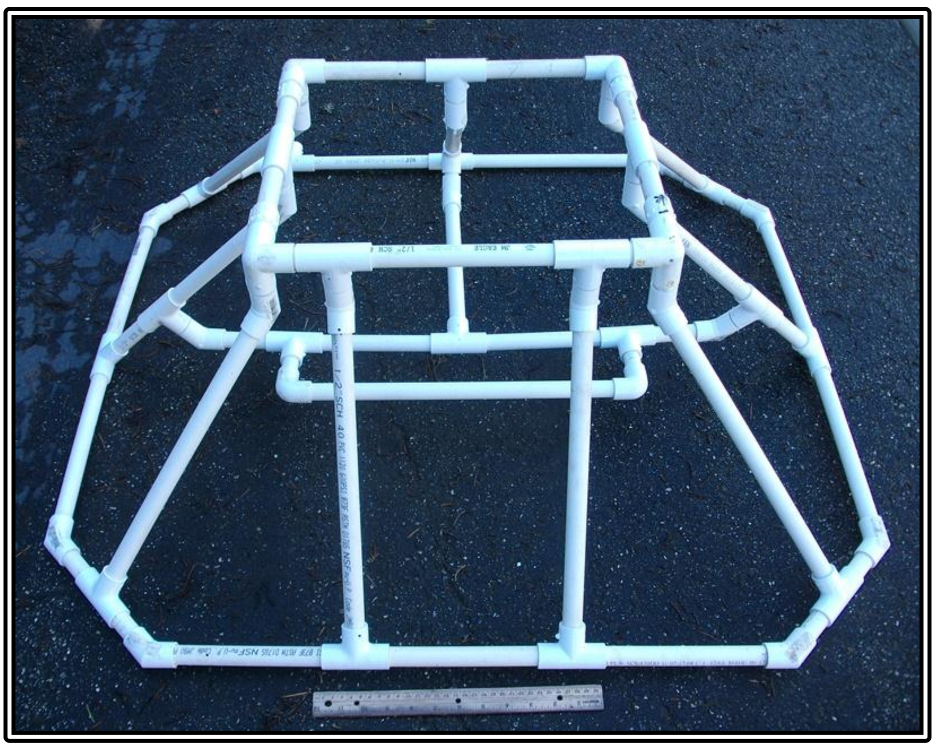
1. Bring the two ends of a 30 cm length of chenille pipe cleaner together. Tightly twist 5 cm of the ends of the pipe cleaner together. Spread out the folded end of the pipe cleaner into an oval approximately 8 cm long and 5 cm wide.
2. Use wire cutters to snip 0.3 cm from the twisted end of the pipe cleaners.
3. Using a 3/32-inch drill bit, drill a hole into the ½-inch PVC pipe of another mission task prop. Insert the twisted end of the pipe cleaner approximately 1 cm into the hole.

See EXPLORER mission photo #41.

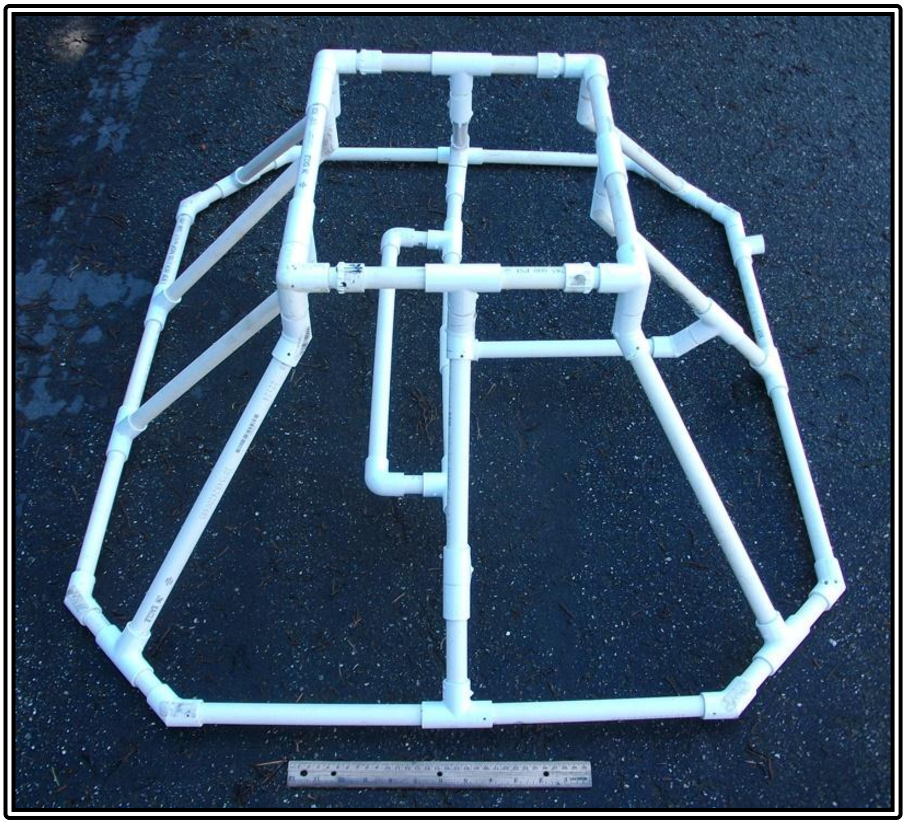
EXPLORER CLASS



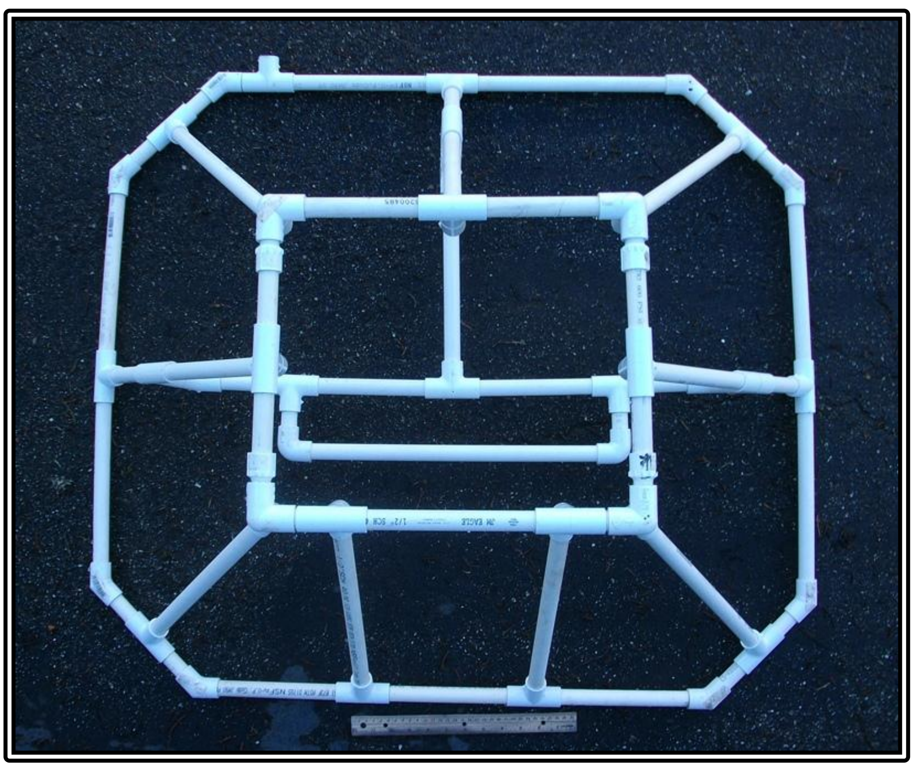
EXPLORER mission photo #1: Partial construction of top of BIA.



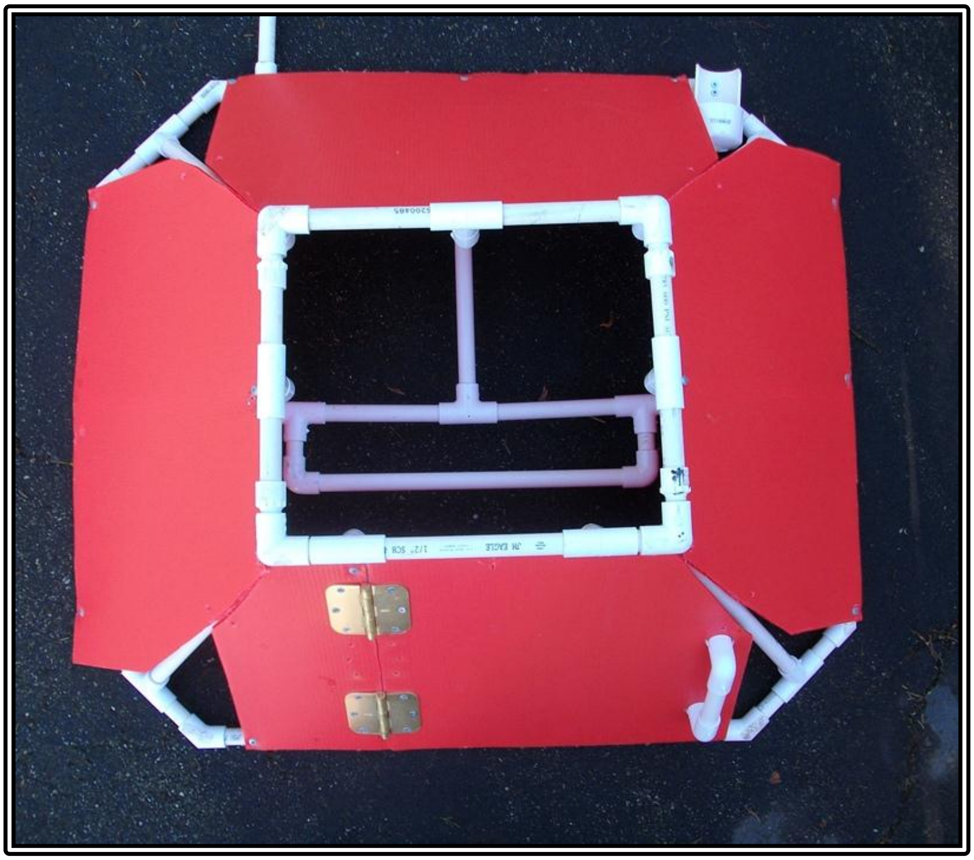
EXPLORER mission photo #2: Front view of BIA framework.



EXPLORER mission photo #3: Side view of BIA framework.

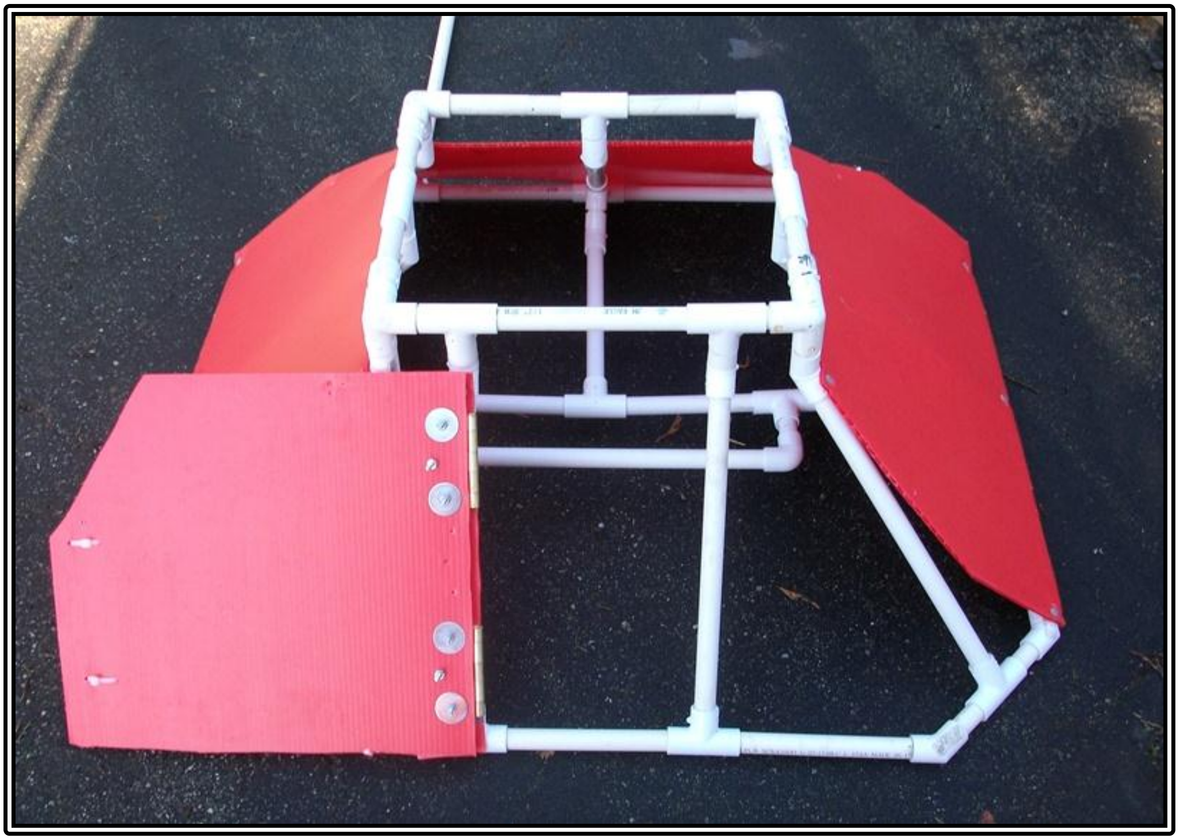


EXPLORER mission photo #4: Top view of BIA framework.

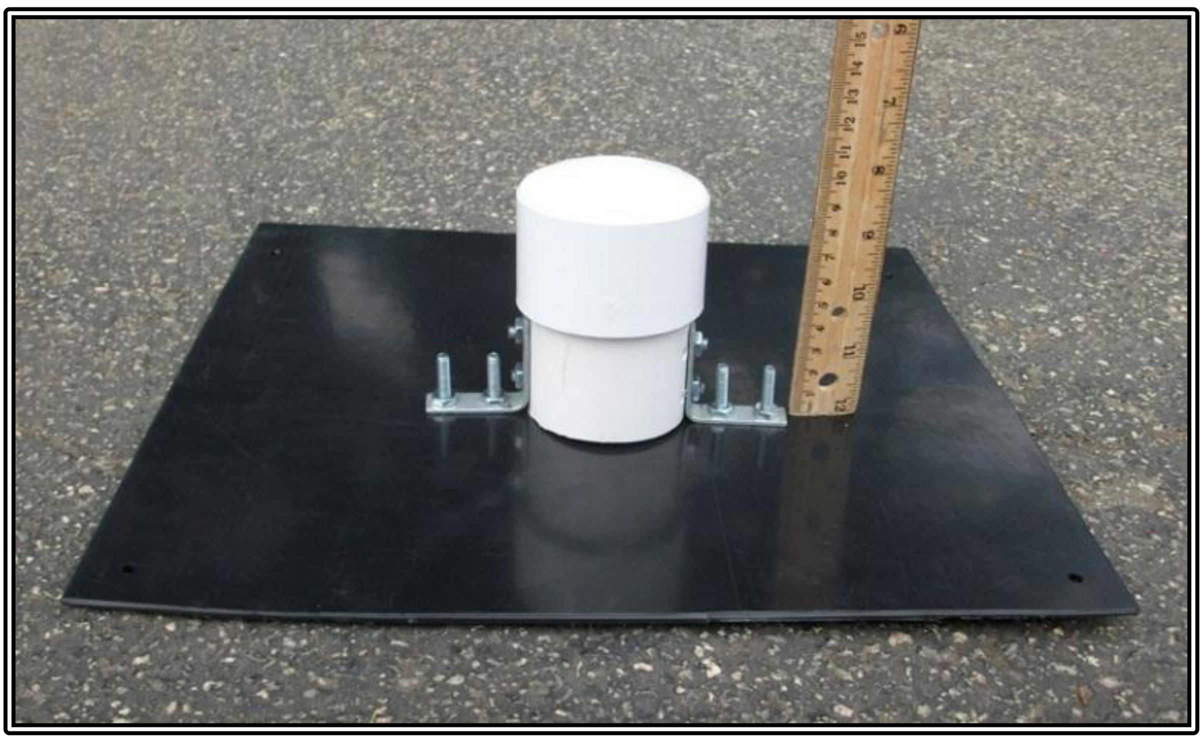


EXPLORER mission photo #5: Top view of BIA. Door closed.

EXPLORER mission photo #6: Isometric view of BIA. Door closed.



EXPLORER mission photo #7: Front view of BIA. Door open.



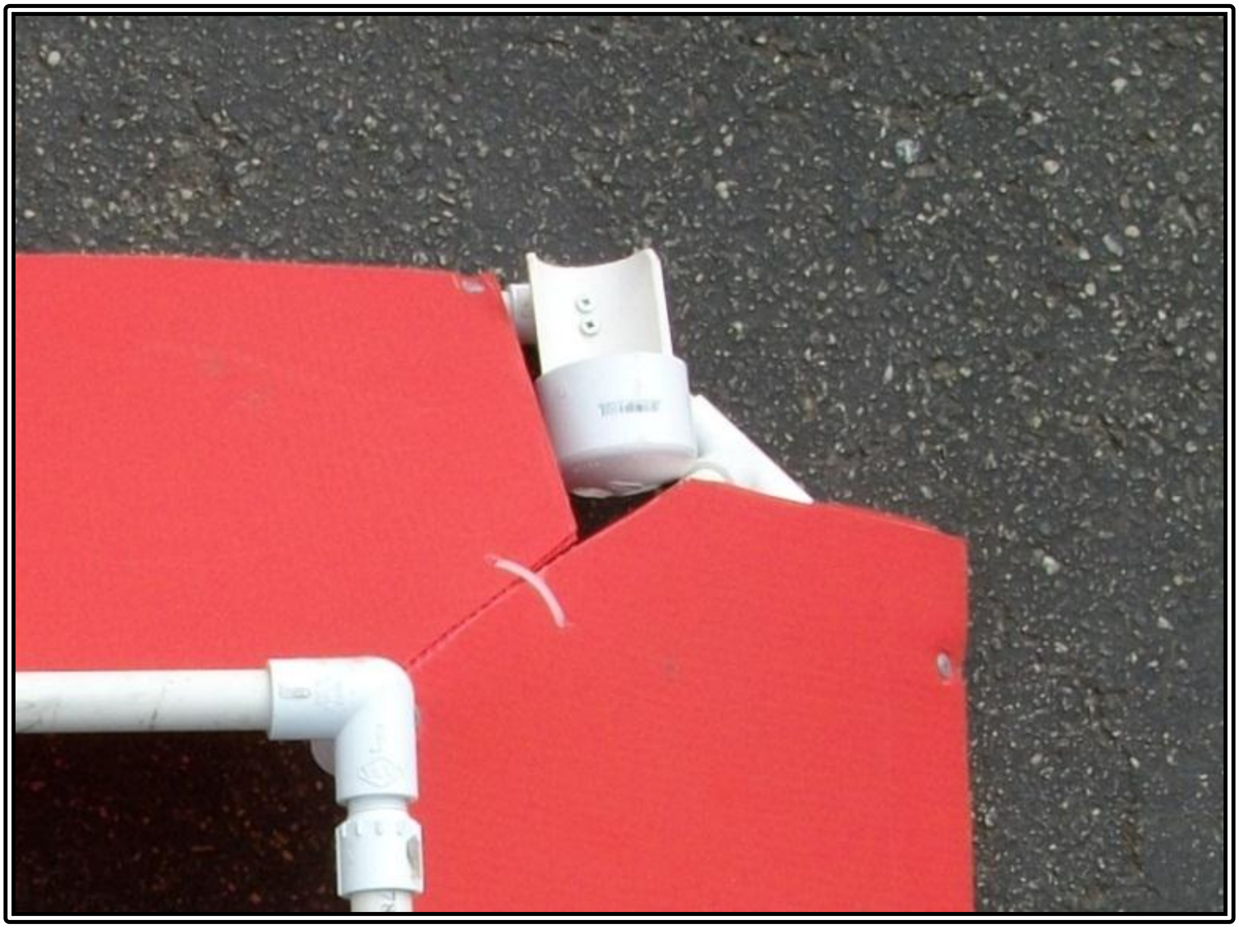
EXPLORER mission photo #8: Partial construction of SIA bulkhead connector (inner side).

EXPLORER mission photo #9: SIA.

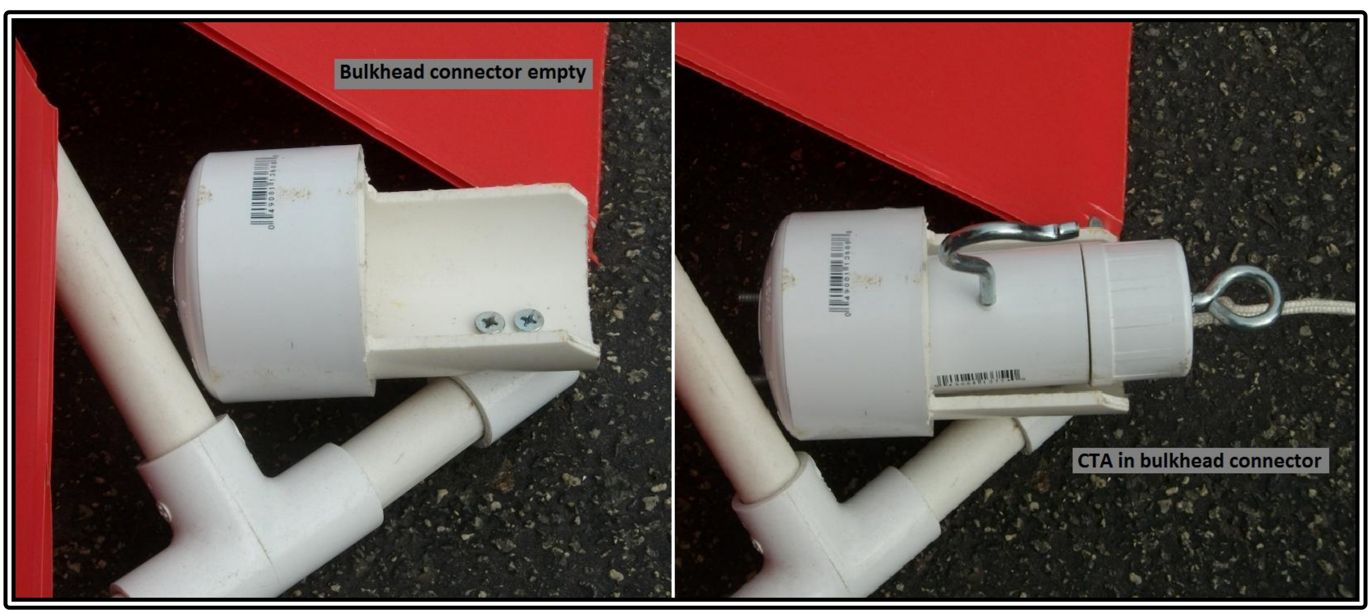
EXPLORER mission photo #10: SIA inside of BIA. Door open.

EXPLORER mission photo #11: CTA side view and front view.

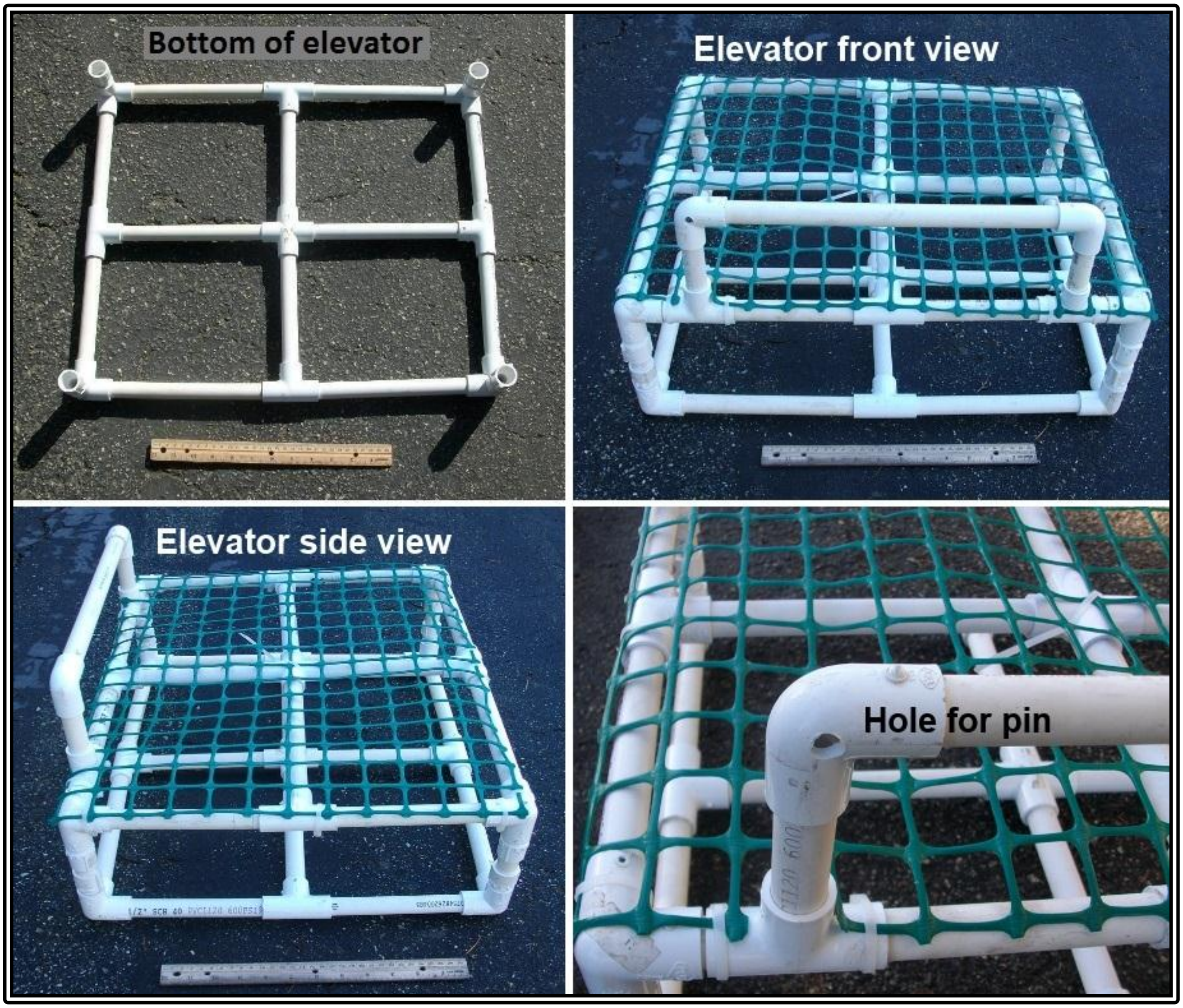
EXPLORER mission photo #12: Front view, rear view, side view, and top view of CTA bulkhead connector.



EXPLORER mission photo #13: CTA bulkhead connector on BIA.

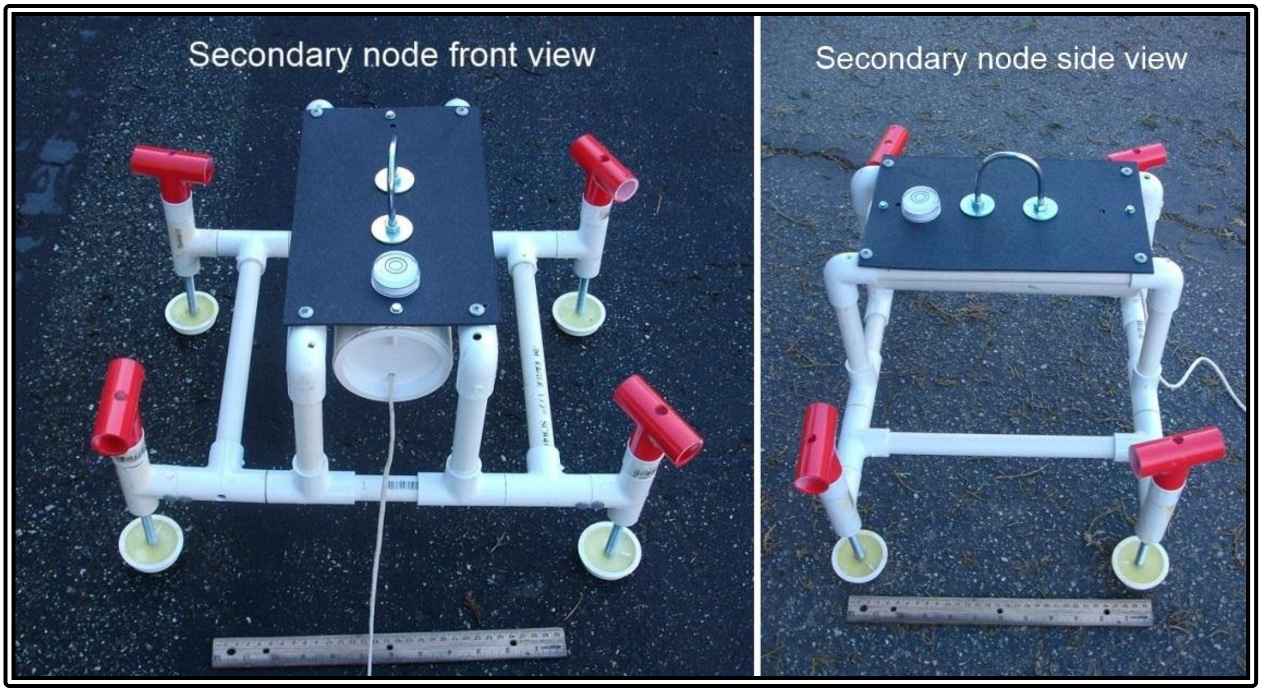


EXPLORER mission photo #14: CTA bulkhead connector on BIA without and with CTA connector installed.

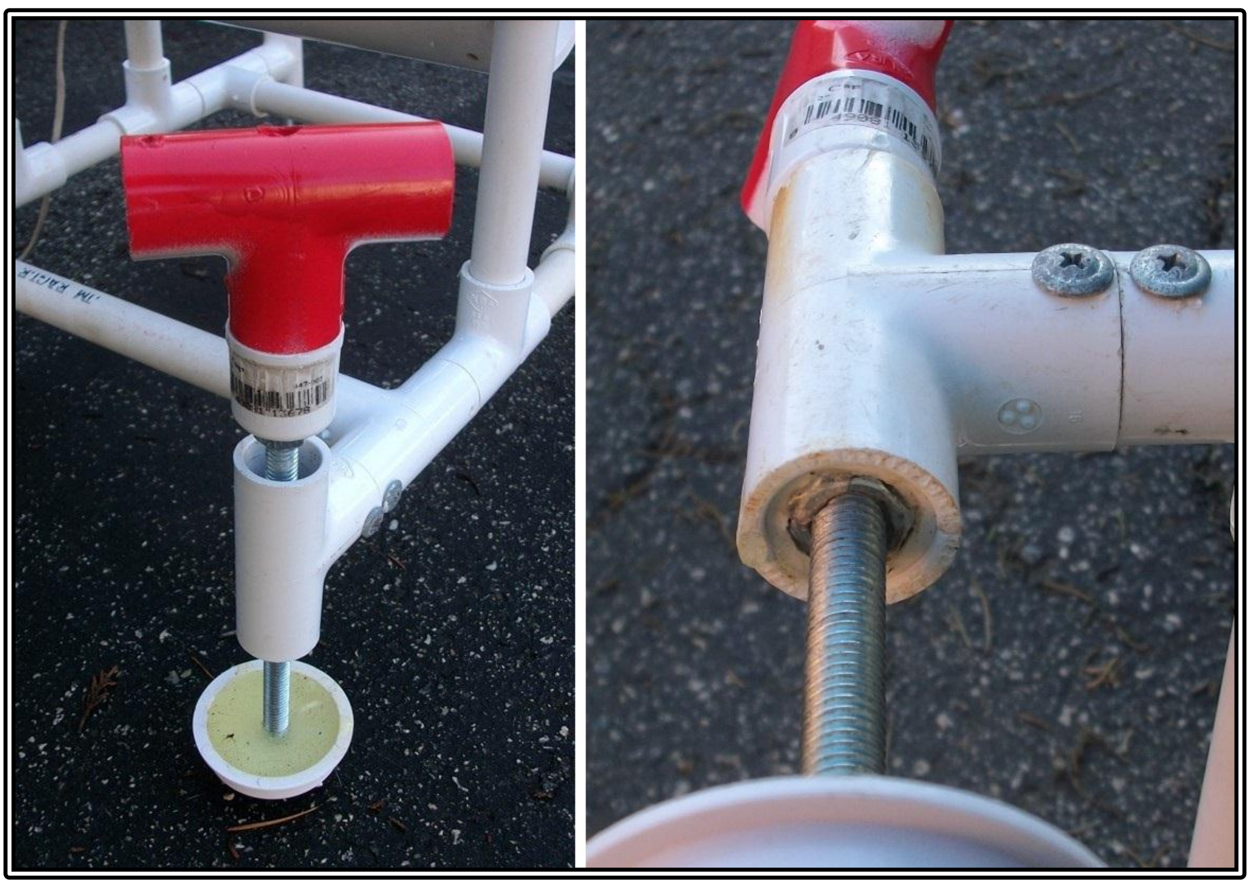


EXPLORER mission photo #15: Partial construction of elevator bottom, elevator front view, elevator side view, and view of hole for the pin.

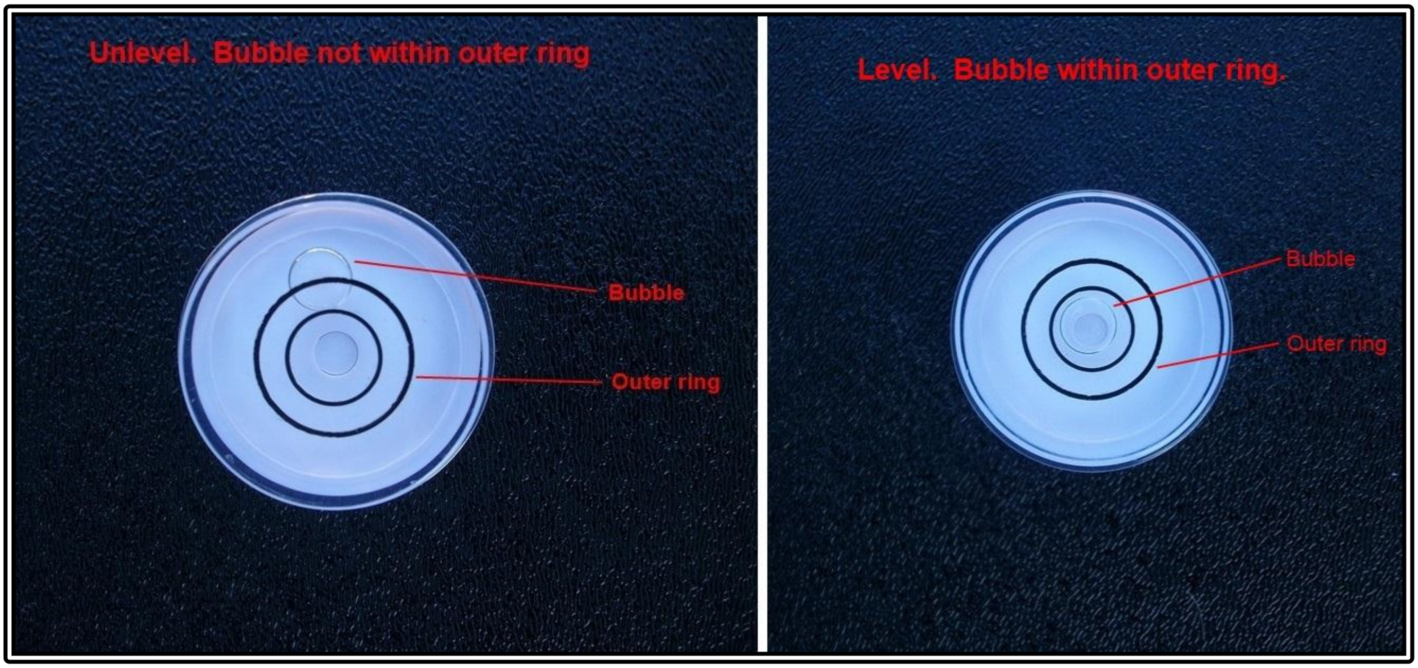
EXPLORER mission photo #16: Pin to hold secondary node on elevator.



EXPLORER mission photo #17: Secondary node front view and secondary node side view.

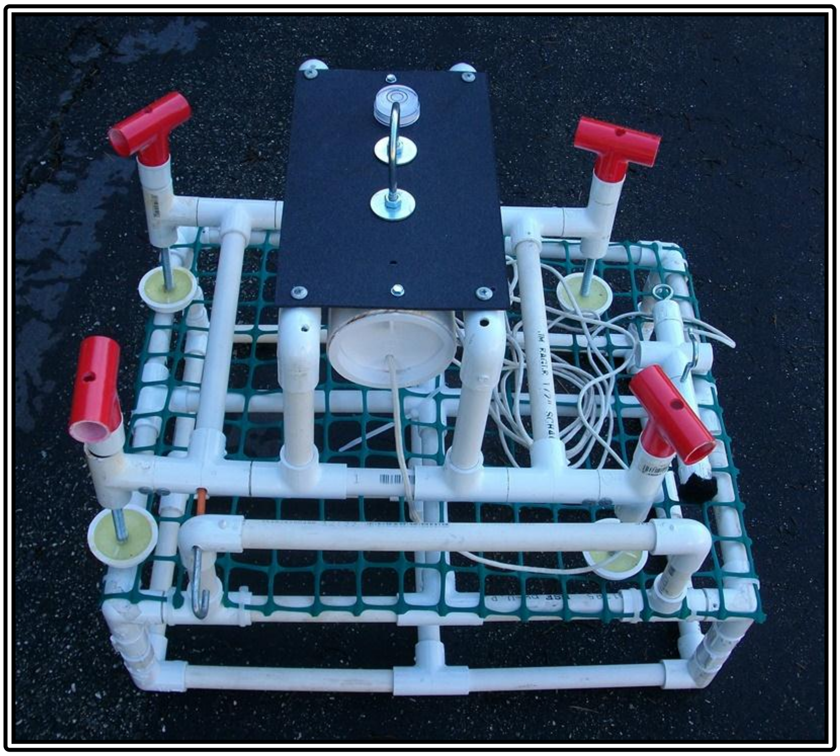


EXPLORER mission photo #18: Leg of secondary node.

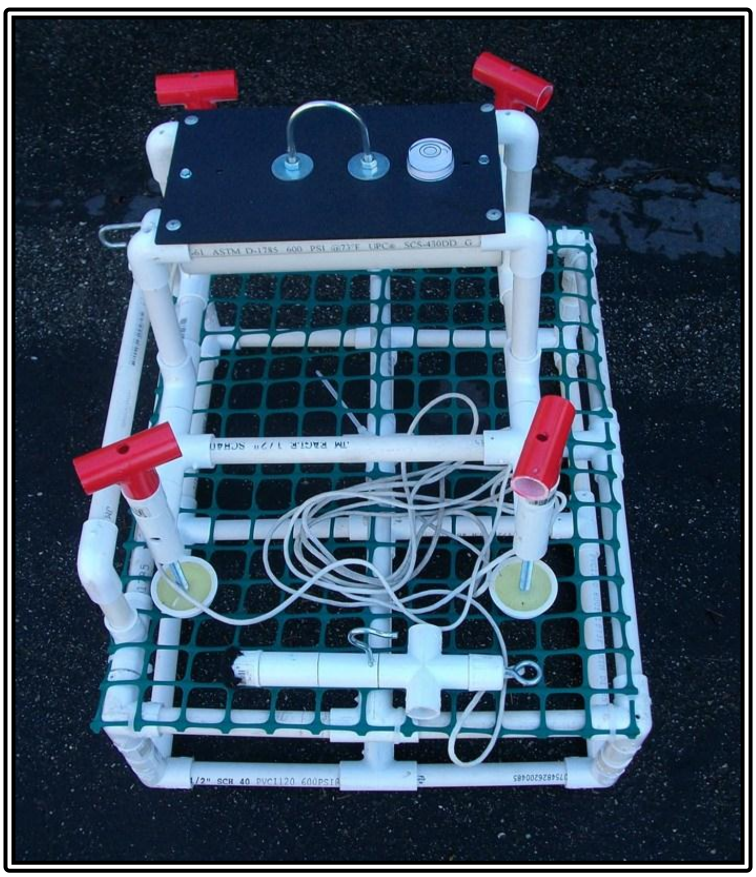


EXPLORER mission photo #19: Bubble level on top of secondary node. In the first photo (left), the secondary node is not level; the bubble is outside of the outer ring. In the second photo (right), the secondary node is level; the bubble is inside the outer ring.

EXPLORER mission photo #20: Secondary node cable connector.

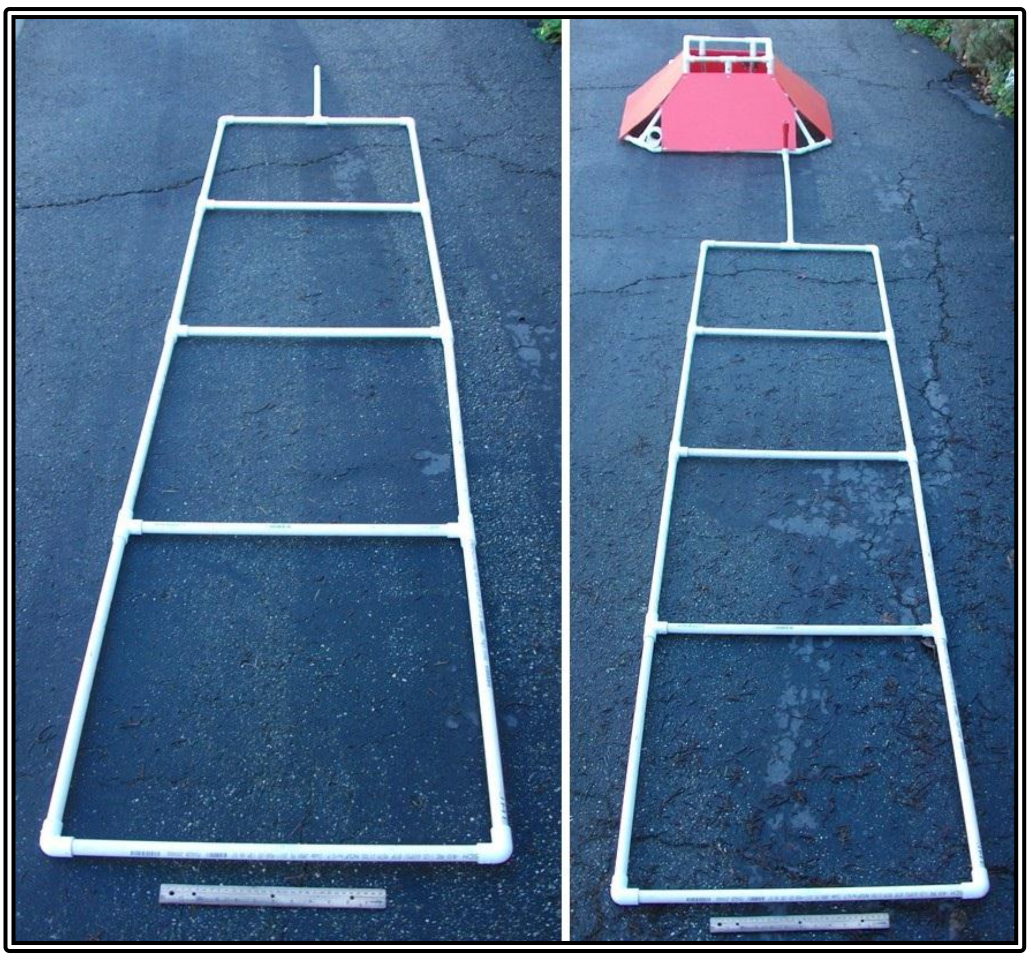


EXPLORER mission photo #21: Front view of elevator with secondary node, secondary node cable connector, and cable.

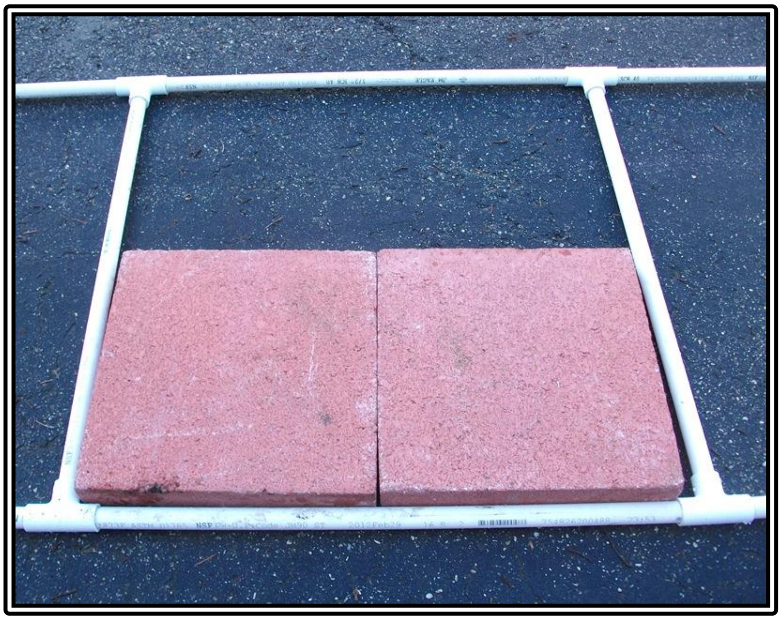


EXPLORER mission photo #22: Side view of elevator with secondary node, secondary node cable connector, and cable.

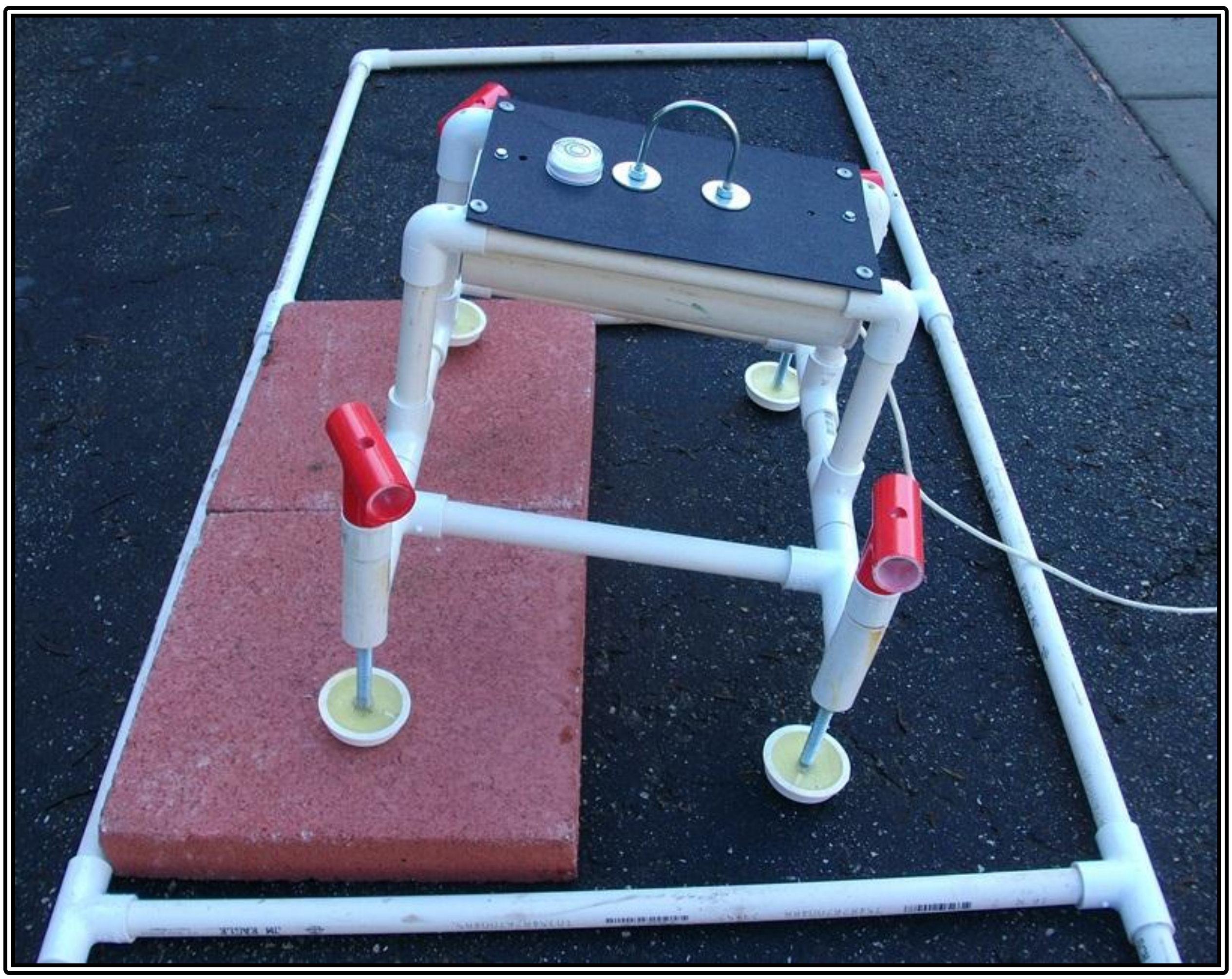
EXPLORER mission photo #23: Pin through elevator and secondary node.



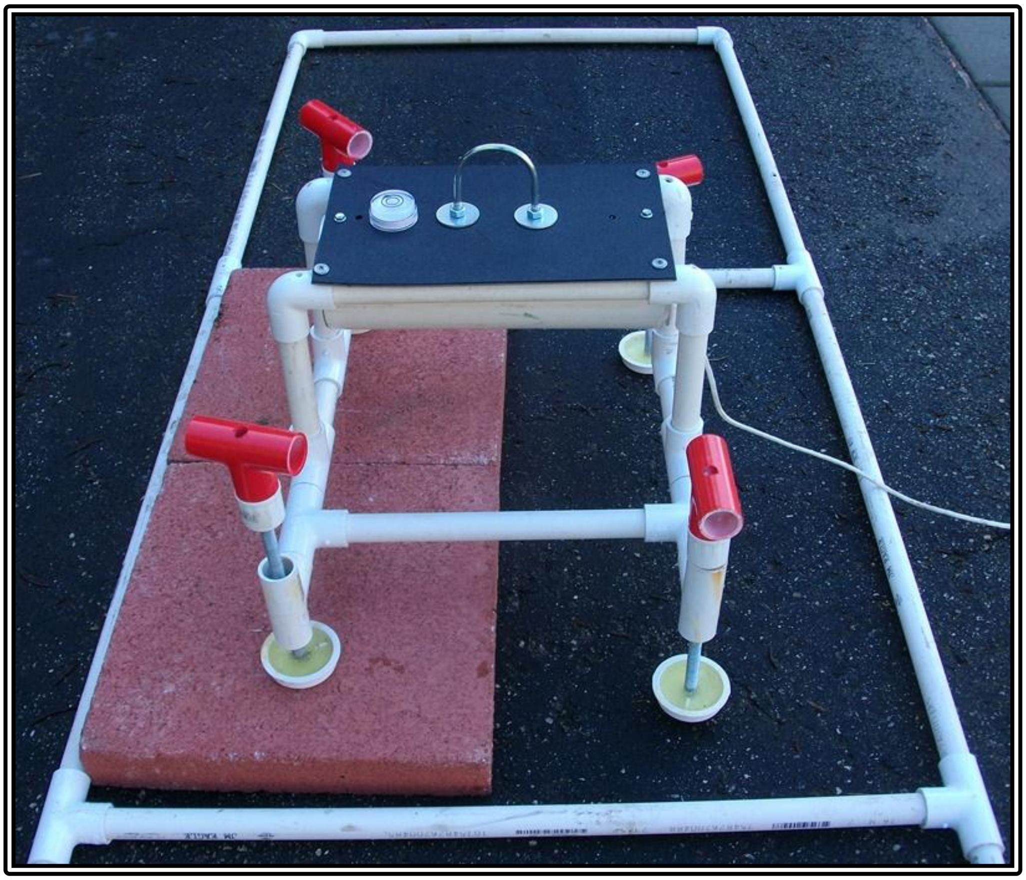
EXPLORER mission photo #24: Designated location without and with BIA.



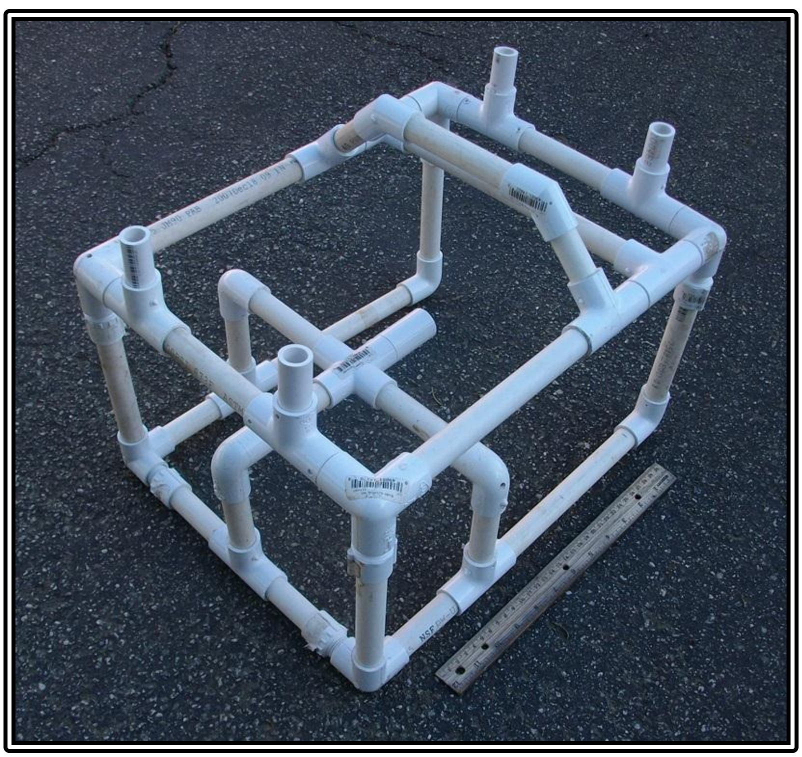
EXPLORER mission photo #25: Designated location, not level.



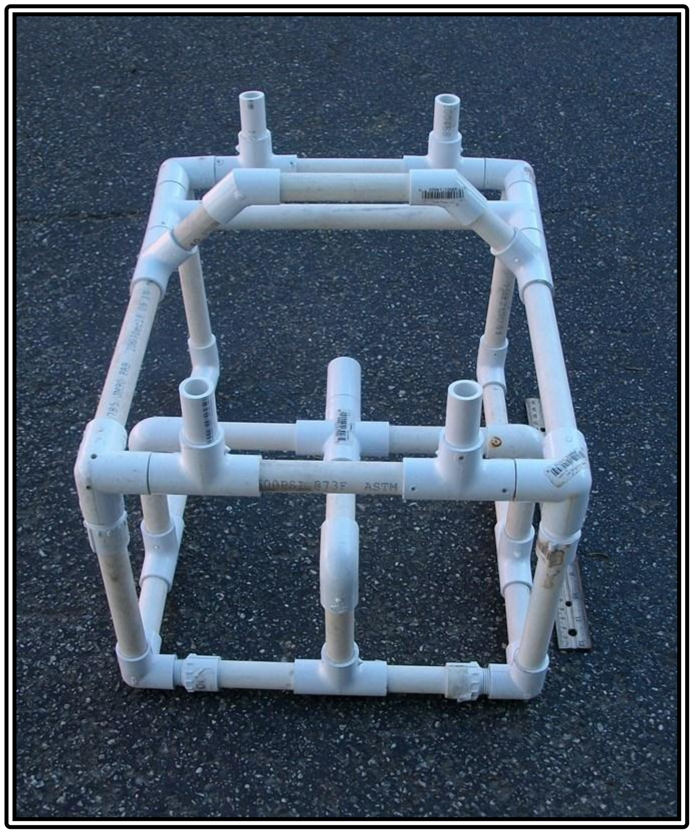
EXPLORER mission photo #26: Unleveled secondary node in designated location.



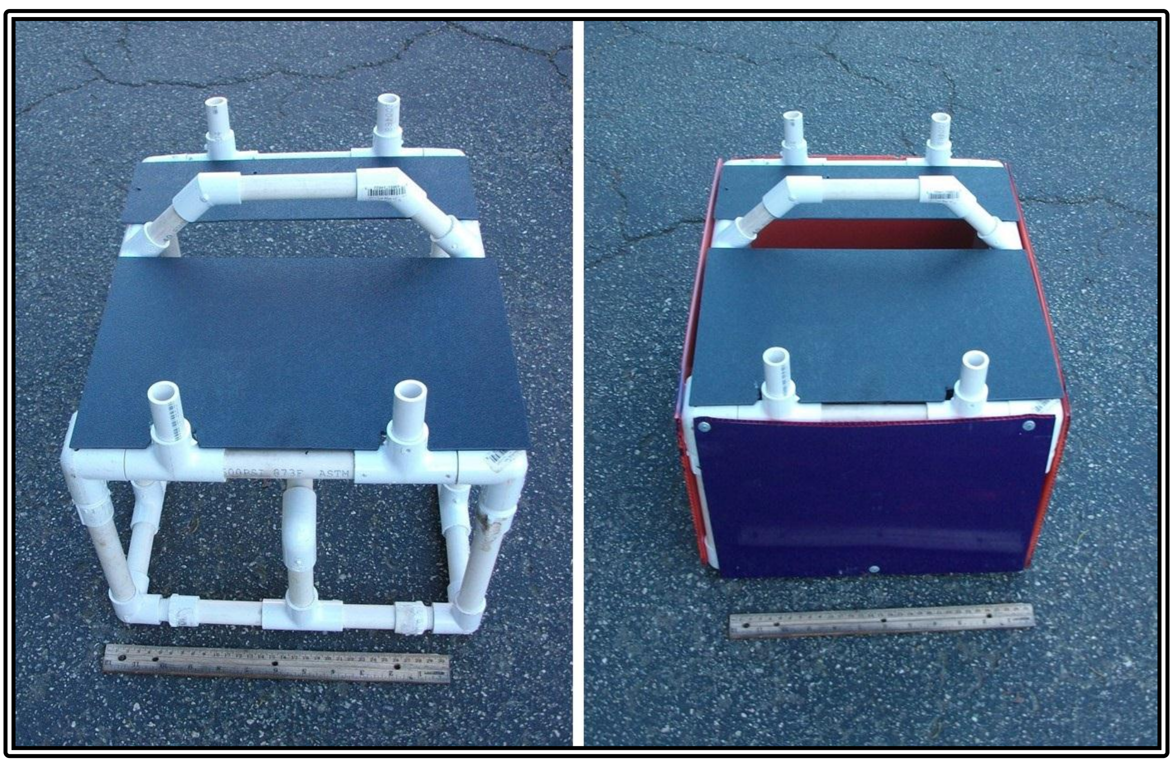
EXPLORER mission photo #27: Leveled secondary node in designated location.



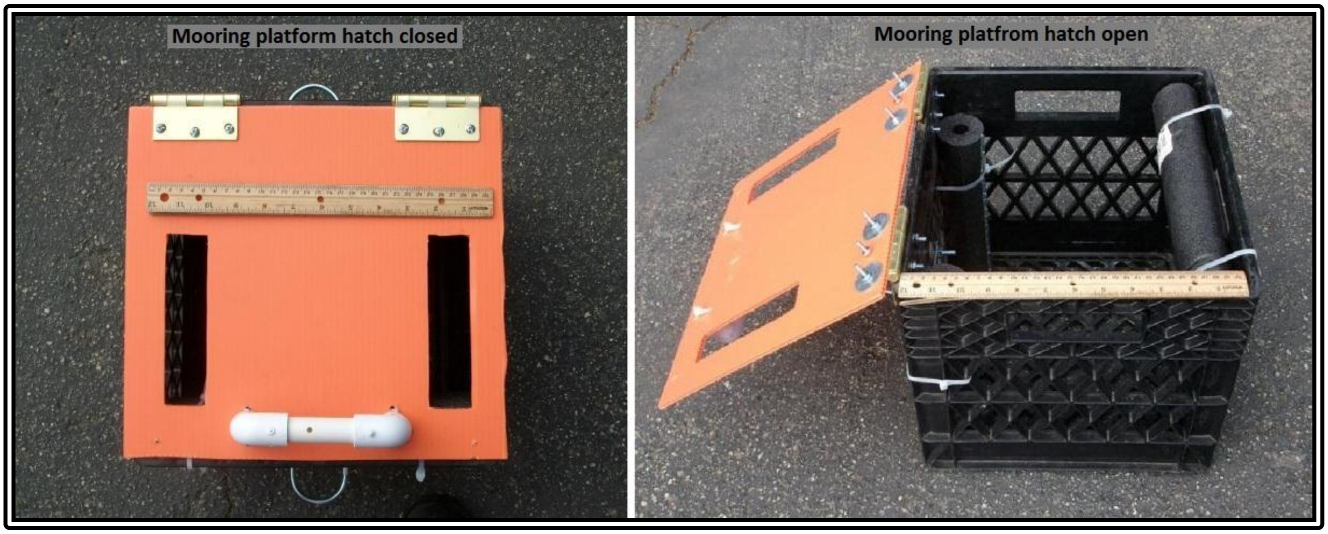
EXPLORER mission photo #28: Isometric view of the framework of the seafloor platform.



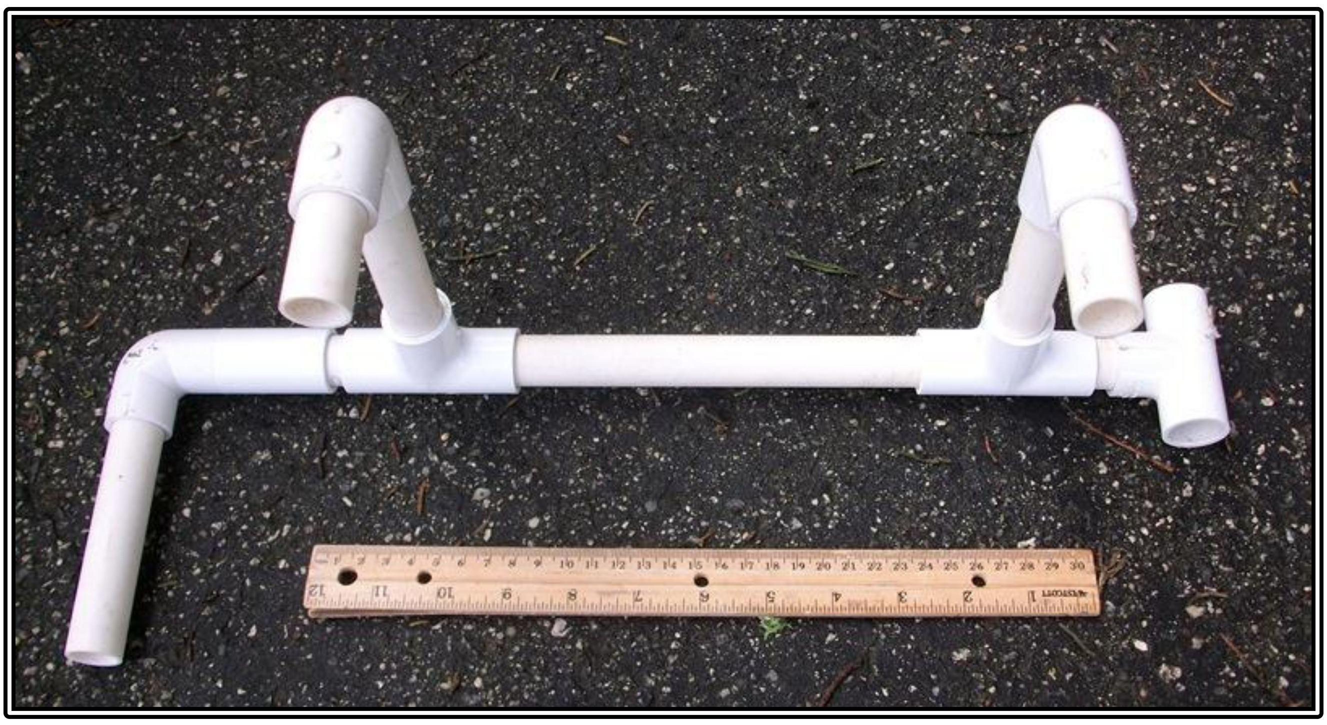
EXPLORER mission photo #29: Front view of the platform of the seafloor framework.



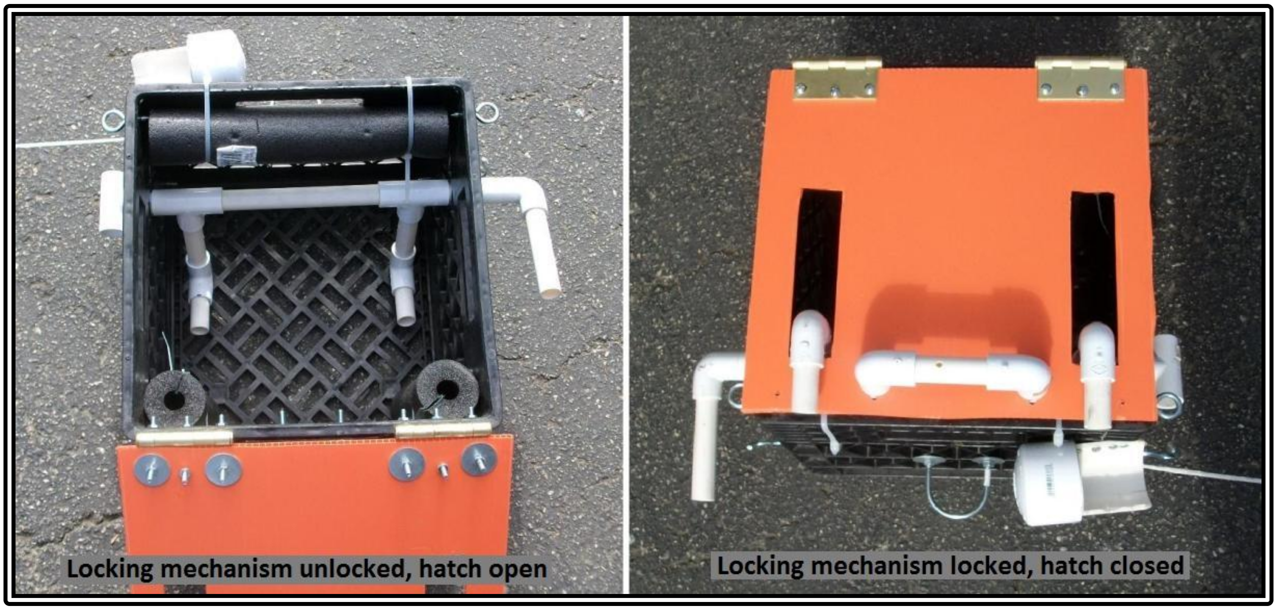
EXPLORER mission photo #30: Seafloor platform with ABS top sheets attached (left). Seafloor platform with ABS top sheets and corrugated plastic walls attached (right).



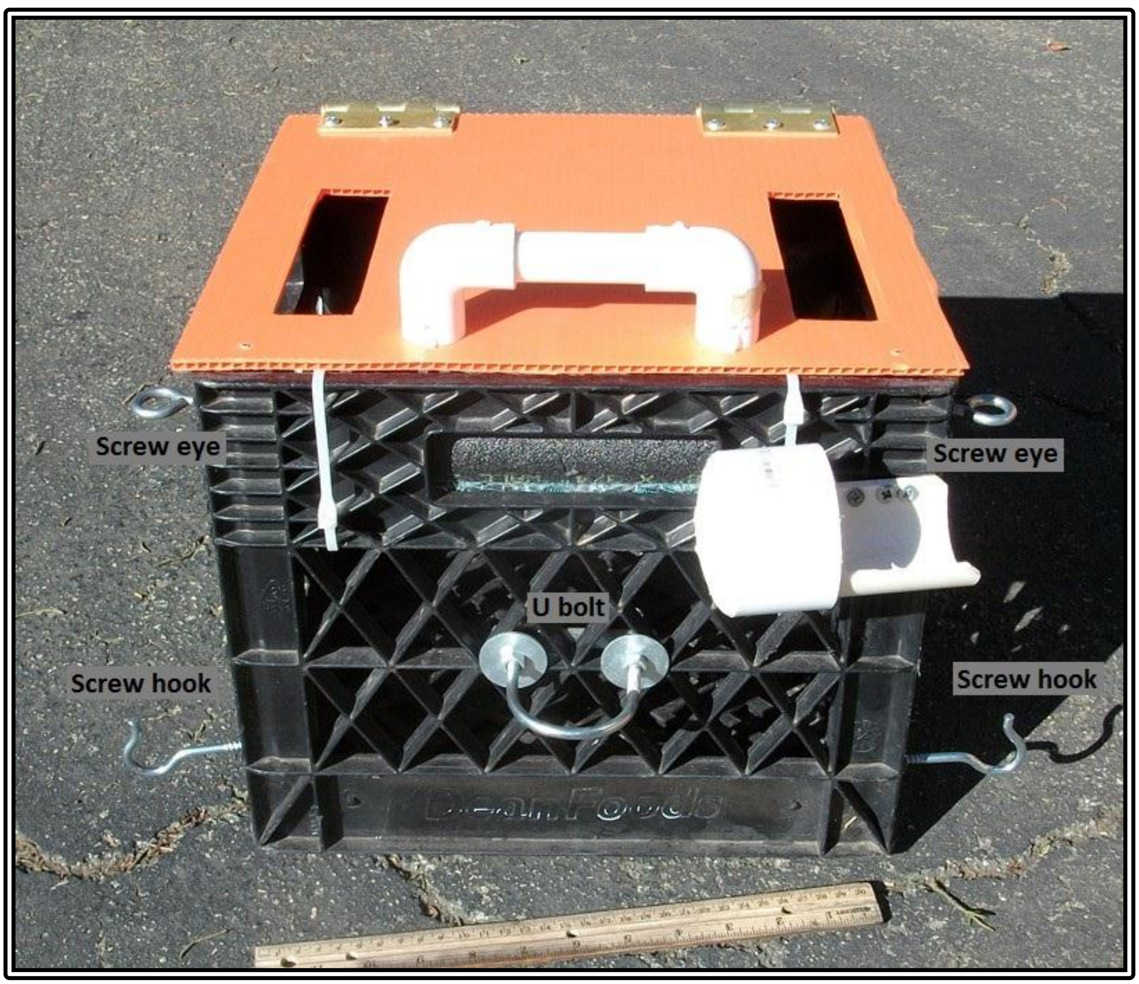
EXPLORER mission photo #31: Mooring platform with hatch closed and open. Mooring will be held in mid-water with four lengths of rope connected to weights.



EXPLORER mission photo #32: Locking mechanism for mooring platform hatch.

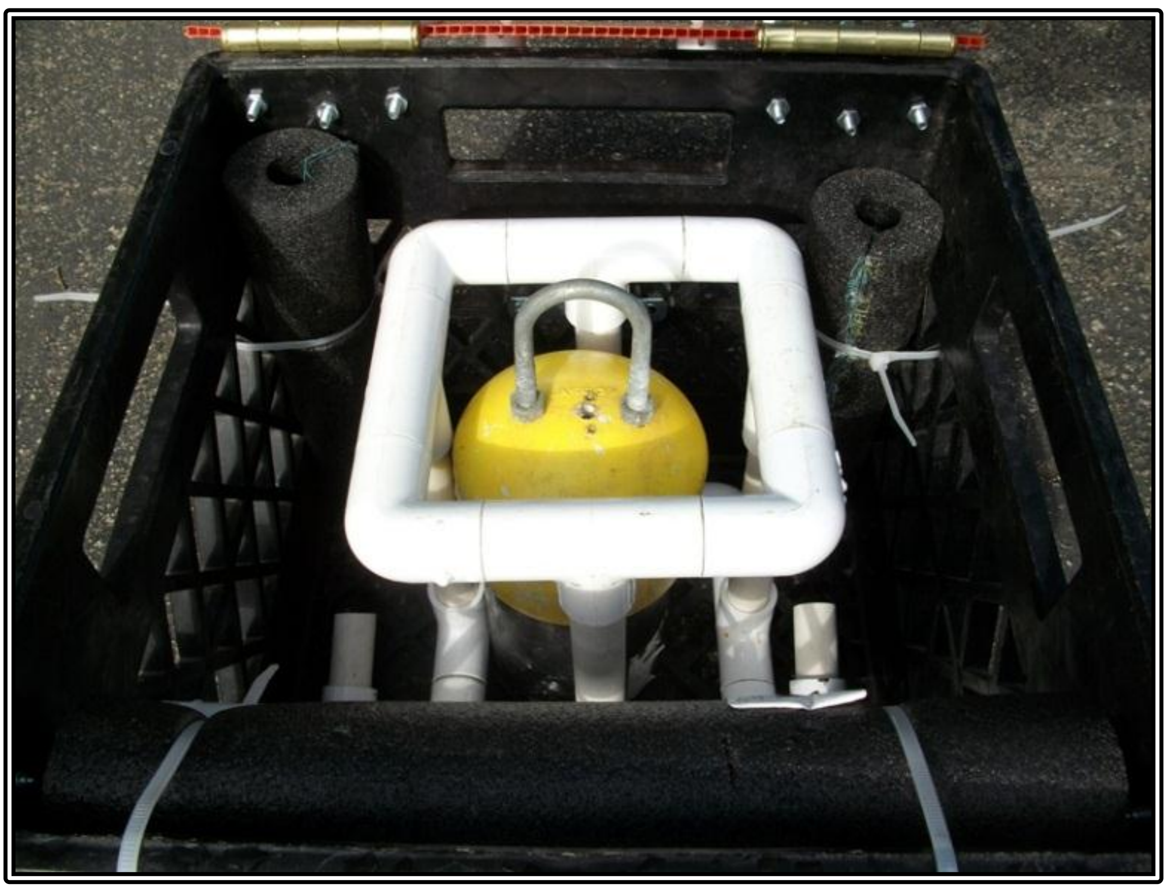


EXPLORER mission photo #33: Locking mechanism unlocked, hatch open and locking mechanism locked, hatch closed.



EXPLORER mission photo #34: Grab points on mooring platform.

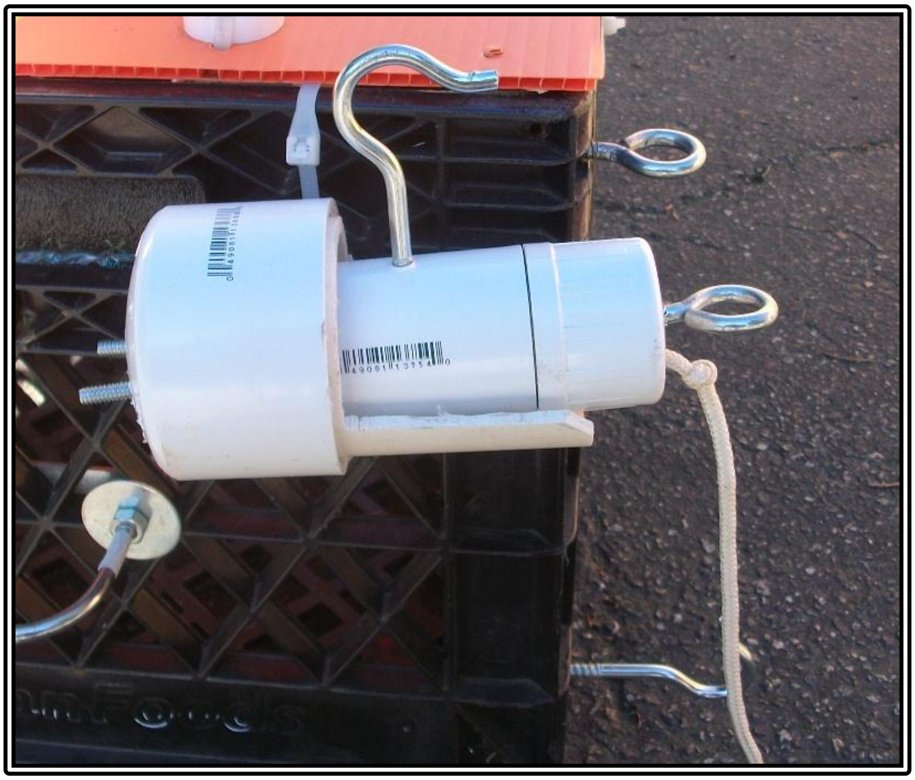
EXPLORER mission photo #35: ADCP cradle and ADCP.



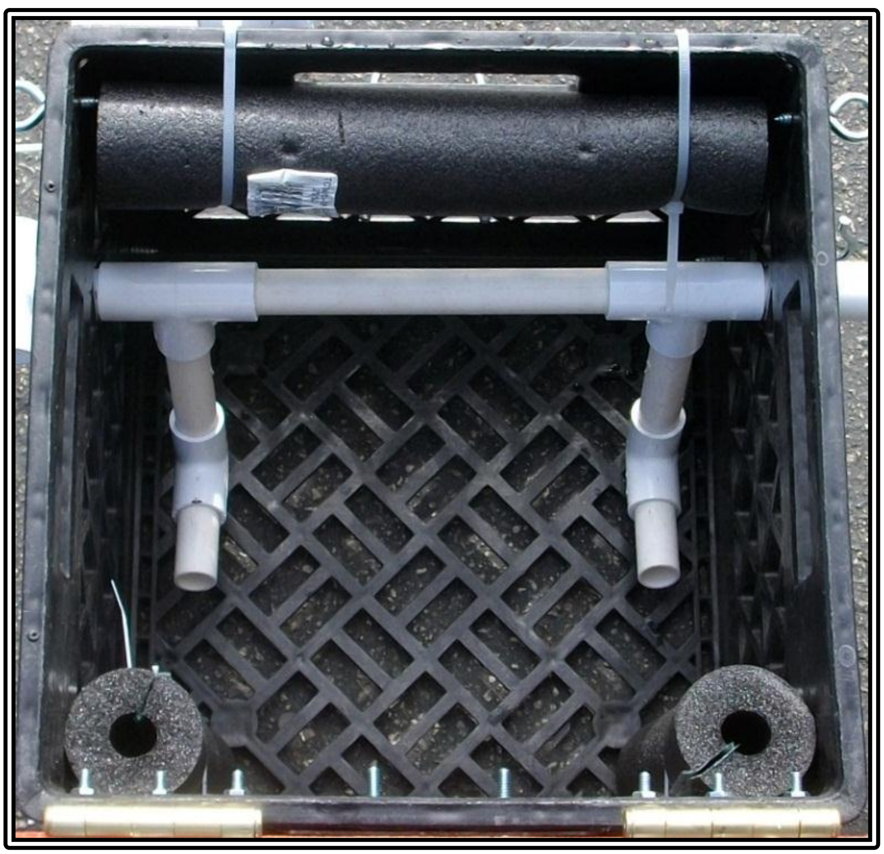
EXPLORER mission photo #36: ADCP inside cradle inside mooring platform.

EXPLORER mission photo #37: Connector side view and front view.

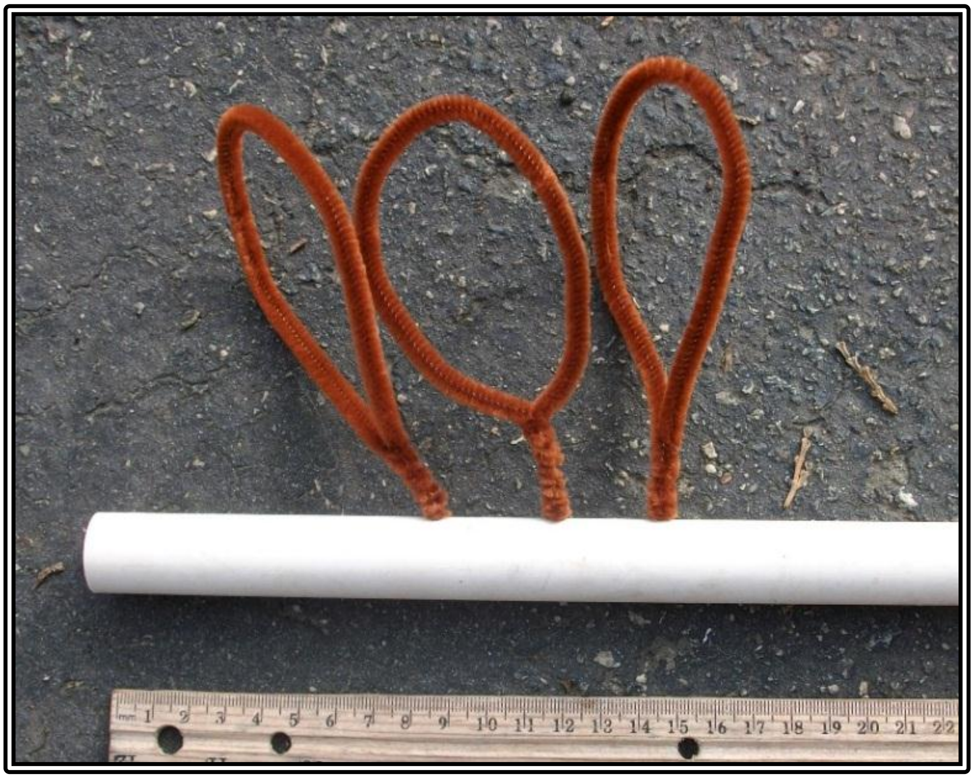
EXPLORER mission photo #38: Bulkhead connector front view and side view.



EXPLORER mission photo #39: Connector installed in bulkhead connector.



EXPLORER mission photo #40: Flotation for mooring platform.



EXPLORER mission photo #41: Biofouling on PVC pipe.