ISR 17
International Submarine Races
Contestants' Manual
Version 2.00
December 16, 2022

ISR 17 Dates: 25 - 30 June 2023

Sponsored by the
Foundation for Underwater Research and Education (FURE)
International Submarine Races Committee

"The Foundation for Underwater Research and Education (FURE) is a 501(c)(3) nonprofit organization dedicated to advancing marine technology and ocean engineering by investing in today's youth pursuing marine related scientific and engineering research and educational opportunities."

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1. ISR 17 CONTESTANTS' MANUAL CHANGE HISTORY

Version	Date	Change
1.00	27 March 2022	First Release.
2.00	16 December 2022	Updates race dates, registration information, entrance fee, and timing gate criteria, and other grammar corrections.

2. INTRODUCTION

2.1. Background Information

Congratulations for considering building and racing a human-powered submarine! This manual has been prepared for those who are interested in participating in the 17th running of the International Submarine Races (ISR 17), to be held June 25 - 30, 2023 at the David Taylor Model Basin located at the Carderock Division of the U.S. Naval Surface Warfare Center (NSWC) in West Bethesda, Maryland.

This manual is intended to be a guideline for participating in ISR 17 and addresses submarine design, race participation, registration, schedules, rules, operations, and related subjects. It has been written and edited by members of the Foundation for Underwater Research and Education (FURE) and its International Submarine Races (ISR) Committee members. As a working document, this manual is subject to change and updated versions will be placed on FURE's website, www.internationalsubmarineraces.org as they are released.

2.2. Foundation for Underwater Research and Education (FURE) Mission

FURE is a 501(c)(3) nonprofit organization dedicated to advancing marine technology and ocean engineering by investing in today's youth who are pursuing marine related scientific and engineering research and educational opportunities. FURE partners with technology and engineering students, the general public, government leaders and activities, educators, industry, scientists, and journalists to reach our goals. FURE has organized marine science educational and outreach activities throughout its history and has sponsored the ISR since 1994.

The ISR event is FURE's premier biennial activity that contributes to accomplishment of its mission.

2.3. ISR Challenge

The ISR 17 challenge is to design, build, and race a one- or two-person, human-powered submarine for 100 meters on an underwater course at the David Taylor Model Basin, NSWC Carderock.

2.4. ISR Rationale

The skills developed in team-based system level engineering projects of this complexity are vital to our collective future. While space presents the furthest reaching frontiers, the undersea domain demands the same or higher levels of engineering skills to safely explore and harness the ocean's resources. From the FURE perspective, there is a continuing need to increase the proficiency and number of engineering students of various engineering disciplines to delve into broad areas of underwater technology advancement. The ISR provides an educational opportunity for these students that translates their theoretical knowledge into reality and fosters advancements in subsea vehicle hydrodynamic, propulsion, and life support systems. Enduring lessons will continue to be learned through the process of designing, building, and operating an "optimized design." The competition rules restrict the vehicle's power to human power, thus focusing attention on maximizing the vehicle's design and life support systems.

2.5. Organization of ISR

FURE sponsors the race and manages the volunteers from its ISR Committee who have dedicated their personal talents and abilities to maintaining the continuity of this unique technology competition.

The ISR Committee leadership team for the 17th ISR is:

Daniel Dozier – Chairman of the Board & Vice President FURE
Charlie Behrle – President, FURE
Mrs. Susan Rovner – Contestant Liaison
Jerry Rovner - Race Director
TBD – Assistant Race Director
Dave Peterson - Surface Operations Director
Vin Malkoski - Supervisor of Diving
Mike Ales - Head Judge

The ISR Committee operates under the auspices of and with funding and administrative support from FURE. FURE solicits support from corporate sponsors, academic officials, and a host of private individuals to support the races and other educational events and scholarships.

The ISR committee is not affiliated with any other human-powered submarine race.

To remain current with the activities of the ISR and FURE, please regularly access our website at www.internationalsubmarineraces.org or follow us on Facebook at

www.facebook.com/Foundation-for-Underwater-Research-and-Education-358790251332752
and
www.facebook.com/International-Submarine-Races-205535162933518

2.6. Safety and Liability

Safety is of utmost importance to all involved in the races and every effort is made to conduct this event as safely as possible. There will be emergency medical personnel on hand, and many highly qualified safety divers are prepared to intervene in the case of mishap. Because of the potentially dangerous nature of submarine racing, every participating contestant must complete and sign the applicable ISR forms discussed later in this document (available on the ISR website). Each team shall assume full responsibility for the loss or damage of their equipment and any damage to the submarine or injury to personnel.

3. FACILITY SECURITY AND RULES

We are graciously allowed use of the facilities at the Naval Surface Warfare Center (NSWC), Carderock Division, a major US Navy research center, and are guests of the facility's Commanding Officer.

NSWC Carderock is a U.S. Navy facility and requires us to follow all entry and facility access procedures prescribed by the US Navy. All persons must be properly cleared by the US Navy to access the facility. Each participant is required to complete the appropriate forms and submit them well in advance (usually two months prior to the event start date – exact date to be determined and will be posted on the website) of ISR 17 for processing, according to the deadlines posted on the website. Contestants / Visitors may be denied entry by the US Navy based on negative law enforcement reports. After receiving a visitor clearance, contestants and visitors will be issued a special badge that must be worn at all times while in the facility (except when in the water). Since there is limited parking space available, teams need to limit the number of vehicles entering the facility. Vehicles entering the base are subject to search before entry is granted.

NSWC Carderock personnel conduct industrial type activities in what will be used as the race area. As this is the case, all personnel must wear appropriate clothing for their role in the races. Flip-flops and other open toe shoes are prohibited on and around the model basin's elevator and dive station area.

Cameras (including cameras on mobile phones) are allowed into the facility by obtaining a camera pass from base authorities. Photos may only be taken in the model basin race area and only for the purpose of filming race activities. Do not attempt to use a concealed camera. NSWC Carderock will require that everyone who enters or has a cell phone, internet access device, camera and or laptop computer complete a camera and laptop form, available from the ISR website at a future date. After the camera/laptop form has been approved by government security personnel, a camera/laptop pass will be issued and must be carried in plain sight with the camera/laptop at all times.

Contestants are required to stay within the race area. Anyone found outside around the ISR 17 event area or going into restricted areas could be escorted out of the facility and asked to surrender his/her badge. Unless you are taking an official tour with NSWC Carderock personnel, visiting the cafeteria, or are with authorized personnel, please remain in the designated event area.

Each team, as well as all ISR personnel, is solely responsible for the loss, damage, or theft of their equipment. When it is unattended, make every attempt to lock or secure it. The help and support of one another through the loaning of tools and equipment is strongly encouraged. Loaned gear should be marked, so that it will be returned to its owner. Make sure that anything you offer, particularly dive gear, is intact and safe. If you need something, please ask race officials for assistance.

The possession or use of alcohol or illegal drugs (including any form of Cannabis) anywhere on the facility grounds is absolutely prohibited by NSWC Carderock. As NSWC Carderock is a federal facility, US federal laws apply.

4. OVERVIEW OF REGISTRATION AND FEES

Below is a summary of the registration process, fees and key dates for ISR 17. This information and all forms can be located on our website: www.internationalsubmarineraces.org

A $500.00 entry fee will be assessed for each participating submarine. A payment of **$500.00 is due and payable along with the Team Entry Form no later than January 20, 2023.**

There are two steps required to register your team and its members. Step One requires that the Team Leaders or Advisor complete the ***Team Entry Form*** along with required fees as described below and submit it to FURE's Treasurer no later than January 20, 2023. Step Two requires that Team Leaders or Advisors ensure that each team member and Team-associated visitors complete the **Individual Registration process** described on our website (when made available in early 2023) no later than 01 May 2023. Late individual registrations may result in delays in entry to the US Navy facility.

4.1. ISR 17 Team Registration

To register your team and submarine:

1. The Team Advisor or Team Leader shall **complete page three** of the Team Entry Form (located on www.internationalsubmarineraces.org) for each registered submarine and submit it to FURE's Treasurer along with your **$500 payment no later than January 15, 2023.**
2. Payments can be made by check or by electronic wire transfer – follow directions indicated in Section 4.3 below or on the Team Entry Form. There is an additional fee imposed for wire transfers.

3. A late fee of an additional $200 may be assessed if a Team's full payment is received after January 31, 2023. Any boat registering and paying after January 31, 2023 will be assessed the $200 late fee.
4. No new applications will be accepted after March 31, 2023.

FURE will issue a full refund for Teams withdrawing from ISR17 prior to February 20, 2023. A full refund minus a $150 penalty will be assessed for Teams withdrawing later than February 20, 2023.

The ISR reserves the right to curtail registrations in the event that the number of registered submarines that have made full payments exceeds the capacity of the race facility.

- Upon receipt of your Team Entry Form, you will be contacted by the ISR Contestant Liaison.
- It is important to register your team by referring to your submarine name. If one Team is bringing more than one submarine, a separate Team Entry Form is required for each submarine name.
- Please ensure that you and all people affiliated with your Team complete the Individual Registration process by referring to the submarine name.

4.2. ISR 17 Registration for Individual Contestants and FURE Volunteers

Since we must abide by the entry procedures defined by the US Navy, our registration process for all individuals for ISR 17 is under development, and the details will be available in early 2023 on our website. The due date for all individual registrations is expected to be 01 May 2023. Those team members who be supporting the team in the water as a pilot, copilot, support diver, or support swimmer will also be required to submit responses to the medical and dive questions in this timeframe as well.

Unfortunately, this event is NOT OPEN TO THE GENERAL PUBLIC. Visitors are welcome only if they are associated with a competing Team or as a guest of FURE. Visitors associated with a team will need to register via the same process to gain access to the facility.

4.3. Fees and Payment Instructions

For Payments Made by Check

All checks must be in US dollars only and must be made payable to:

Foundation for Underwater Research and Education

The Team Registration Form and payment must be sent via U.S. Mail to:

F.U.R.E.
P.O. Box 543
Haymarket, VA 20168
USA

For Payments Made by Domestic and International Wire Transfers
If you make payments by this method, you must also complete the Team Registration Form and send via postal service to the address above.

Bank Name:	Wells Fargo Bank, NA
City/State:	San Francisco, CA
Routing Transit # (Domestic):	121000248
Routing Transit # (International):	WFBIUS6S
Acct #:	9044450121
Acct Name:	Foundation for Underwater Research and Education

An electronic transfer option via wire transfer exists to pay entry fees. There is an additional bank fee of $15.00 for U.S. bank funds transfer and $16.00 for International bank funds transfer. You MUST add the appropriate transfer fee in the total amount paid when you submit this information to your bank. In other words, a $500.00 registration fee becomes $515.00 if done by wire transfer from a US bank or $516.00 from a foreign bank.

Please contact Ms. Pamela Corry at FURE.Treasurer@internationalsubmarineraces.org if you have any questions.

4.4. Visas and Letters of Invitation

Citizens of certain foreign countries must obtain a US Visa to attend the races. For more information, please review http://travel.state.gov/visa/

IMPORTANT! Participants who require a U.S. visa are encouraged to start the application process EARLY. Processing times vary by country and the embassy/consulate. SOME VISAS HAVE A PROCESSING TIME OF SEVERAL MONTHS.

Letter of Invitation - If your country requires you to have a Letter of Invitation from FURE, please include the following information in an email request to our Contestant Liaison (contestant.liaison@internationalsubmarineraces.org):

Full name, as shown on your passport – Indicate FAMILY NAME in ALL CAPS
School or Company
Complete Mailing Address including COUNTRY

Email address
Phone/FAX
Travel dates to/from the U.S.

Your request will be acknowledged within approximately 48 hours with an invitation letter.

4.5. ISR 17 Race Week Schedule Overview

The final detailed race week schedule will be published on the web site http://www.Internationalsubmarineraces.org in advance of race week.

25 - 30 June 2023

- Race week registration at host hotel.

25 June 2023 (Sunday)

- Teams are allowed entry to NSWC Carderock after they have received their badges at the host hotel. We will offer dry safety checks starting at noon Sunday, 18 June 2023 for those submarine teams that are on site and prepared for the safety check. Because of the substantial resources gathered for this event and the large number of teams, you should maximize your use of the time available to be in the water.
- Contestant Briefings will be held in the evening at the host hotel.

26 - 30 June 2023 (Monday-Friday)

- (Monday) – Teams should prepare for in-water inspections as soon as their boat passes dry inspection and team divers are cleared to dive. Racing will commence when the race course and timing & video systems are ready and at least one boat is approved and ready to race.
- Continuous racing throughout the week. Racing hours will normally be from 0800 to 1530 each day except for Friday when racing will end approximately at 1130. Other schedule events may reduce racing activities.

30 June 2023 (Friday)

- Races conclude no later than midday.
- Submarine/Contestant Site breakdown. Return everything you borrowed. Prepare your submarine and related equipment for shipping.
- (ISR staff only) ISR gear break-down and removal. Organize all ISR rental gear in central location for pickup.
- Awards ceremony and picnic

5. SUMMARY OF CRITICAL DEADLINES

This section consolidates all due dates specified and described in detail in individual sections within this document as a handy guide for contestants. Please reference those specific sections within this document to understand what is required, when and by whom.

Due Date	Item	Section
TBD	• Reservations open at host hotel with ISR 17 discount	11.3
20 January 2023	• Initial Team Registration & payment due	4.1
31 January 2023	• Begin $200 late fee assessment for all registrations or payments received after this date	4.1
31 March 2023	• Last day for registration and payment (including $200 late fee) due date	4.1
15 April 2023	• 20-minute Presentation to Judging Committee sign-up schedule sheet provided to teams	10.3
15 April 2023	• Submarine Specification Sheet template provided to teams	10.1
01 May 2023	• All individual contestant registrations complete	4.2
01 May 2023	• Submarine Specification Sheet submitted to Contestant Liaison	10.1
31 May 2023	• Schedule for 20-minute Presentations to Judging Committee issued	10.3
15 May 2023	• Earliest arrival date for submarines shipped to Carderock	11.3
18 May 2023	• Final Design Report due with Copyright form	10.2
21 May 2023	• Host hotel reservations end ISR 17 discounts	11.4
03 June 2023	• 20-minute Presentation PowerPoint file and signed copyright form for the presentation submitted via email to Head Judge	10.3
24 June 2023	• Registration/badging opens at host hotel	4.5
25 June 2023	• Contestants allowed to enter Carderock with badges	4.5
26 - 29 June 2023	• 20-minute Presentations made during race week.	10.3
30 June 2023	• Race complete	

6. SUBMARINE DESIGN GUIDELINES

6.1. Definition

For the purpose of this event, a submarine shall be defined as a free flooding (liquid-filled) vehicle that **fully encapsulates the occupant(s)** and operates entirely beneath the surface of the water. The submarine may carry one or two persons. The submarine must fully encapsulate the occupant(s) for the entire race (e.g., premature release of the hatch is

reason for disqualifying a run.) Entrants designed to propel themselves by crawling on the bottom are not submarines but tractors and are prohibited.

6.2. Propulsion Systems

6.2.1. Propeller system

A propeller system is defined as a water-coupled device with radiating blades that create thrust when spinning. Blades rotating in a vertical plane driven by a rotating shaft in the flow field external to the hull generally aligned with the direction of travel will be considered a propeller system.

6.2.2. Non-Propeller system

A non-propeller system is defined as any other water-coupled device that creates a thrust when operated. A bottom crawling vehicle is not a water-coupled device.

Submarine propulsion systems shall be directly coupled to a human being and shall not employ any energy devices. All power trains shall be direct-drive without the use of any de-coupling devices.

SCUBA exhaust air from the crew may be eliminated by any method at the discretion of the team but may not be used to produce a propulsive force. You are encouraged to give this considerable thought; any exhaust air trapped in the hull will cause major changes in trim and buoyancy.

In the case of a two-person submarine, BOTH of the crew may elect to provide propulsion. However, both crew members must be directly coupled to the drive train, i.e., pilots may not have a system where they could stop providing power by de-coupling. The pilot must retain the capability to provide navigational, safety, and steering functions.

6.3. Design Categories

All submarines participating in this event shall fall into one of the following categories:

<u>One-person submarine, propeller driven</u> --
Colleges and Universities; High Schools, Corporate, and Independents

<u>One-person submarine, non-propeller driven</u> --
Colleges and Universities; High Schools, Corporate, and Independents

<u>Two-person submarine, propeller driven</u> --
Colleges and Universities; High Schools, Corporate, and Independents

<u>Two-person submarine, non-propeller driven</u> --
Colleges and Universities; High Schools, Corporate, and Independents

6.4. Life-support Systems

All diving (submarine crew, team divers, and ISR staff divers) during the ISR will be conducted using air as a breathing gas and open-circuit SCUBA equipment.

6.4.1. Authorized SCUBA cylinders for ISR Use

- All SCUBA cylinders used in the Carderock facility must be stamped with DOT and other appropriate markings as approved by the US Department of Transportation (HMR: 49 CFR Parts 171-180). As there is joint rulemaking with Canada, tanks stamped with DOT/CTC or DOT/TC (CTC = Canadian Transport Commission; TC = Transport Canada) may also be used.
- All cylinders in use must comply with appropriate DOT / CGA regulations with regards to visual inspection and hydrostatic testing periods. Required visual inspections such as those performed annually by a dive shop will not be performed by ISR staff.
- The use of aluminum cylinders manufactured from Alloy #6351-T6 (Luxfer, Walter Kidde, and others) during the period January 1972 through approximately December 1988 will not be allowed. The cylinders have an unacceptable risk of failure due to the sustained load cracking (SLC) of the tank neck (HMR; 49 CFR Parts 171-180).

6.4.2. Submarine Primary air supply

The primary air supply shall be carried onboard the submarine and have the calculated capacity to contain the air supply for a minimum of one speed run, plus 150% in reserve capacity for each crew member. Calculations shall be provided as part of the teams' design report.

At all times, all primary submarine air supplies shall have pressure gauges that must be continuously and clearly visible to the internal submarine crew. Submarine crews are required to monitor their own air supply and shall not allow their air supply to fall below 500 psi. Random checks may be performed at any time by ISR Dive Staff.

6.4.3. Submarine Secondary (Reserve) air supply

The secondary air supply for each crew member shall be self-contained and worn securely on the body or secured in an accessible location in the submarine and have sufficient capacity to enable the crew member to exit the submarine and ascend from the bottom of the model basin at a proper rate to the surface. (Note: once the submarine is on the race course (or has stopped along the course), the crew should not exit the submarine until instructed to do so by Navy divers.) This air supply can be utilized for such duties as getting into the submarine and preparing for a run.

- Teams are responsible for providing their own adaptors to permit filling of "Spare Air" or similar cylinders.

6.4.4. On-Board Pneumatic systems

Any pneumatic systems on a submarine must have their own independent air supply separate from the crew's primary and secondary air supplies.

6.4.5. Support Diver air supply

All support divers must be equipped with an alternate air source (additional second stage, AIR II, pony bottle, Spare Air, etc.) to allow support of submarine crew activities, such as ingress/egress of the submarine while submerged.

Additional information on diving equipment can be found in Section 8, Diver Information.

6.5. Submarine Safety Requirements

6.5.1. Submarine coloration

It is required for the purpose of easy monitoring that the entire submarine be painted with high-visibility coloration, using lighter colors like white, yellow, or orange. **In all cases, the entire dorsal (top) surface of the submarine (when viewed from above) must be of a light color for monitoring of the submarine while it is on the race course.** A white reflective strip at least 3 inches wide is required for the entire length of the submarine hull on both sides of the vessel. Hull numbers will not be assigned to each submarine. For the purpose of precise identification, it is required that the contestants feature the team or submarine name prominently on the hull. The listing of sponsors, affiliates, or team members is acceptable. Propeller tips and control surface tips shall be painted or marked in fluorescent green, bright yellow, or bright orange for easy visibility by divers and support personnel.

6.5.2. Rescue egress

Any and all exits that are to be used by a submarine crew for emergency egress shall be clearly marked at the location of the handle or release mechanism by a 4" square orange patch bearing the word "Rescue." If this is not possible, the handle or release mechanism must be clearly marked with highly visible fluorescent tape. The handle or release mechanism shall be easily accessible from both inside and outside the submarine. Modifications to the markings and release may be required following inspection by the judges and Navy divers.

6.5.3. Crew restraint

Any method of attachment of a crew member to the submarine, such as restraining harnesses or toe-clips, must have the release system clearly marked with orange paint or florescent tape. During both the dry and in-water safety inspections, the judges will ensure that this requirement is satisfied, and will identify to the rescue divers the specific release points for each submarine.

6.5.4. Crew visibility

Viewports, windows, canopies, etc., shall be located on the submarine so that the crew has as unrestricted a view as possible, especially forward and down in the case of the pilot. The crew's face and head areas shall also be visible to the support and safety divers at all times.

6.5.5. Strobe marking light

There shall be strobe lights on the top and bottom, and on the port and starboard sides of each submarine. Each submarine shall carry a white strobe light that is visible for 360 degrees in the horizontal plane and visible when viewed from above or below the submarine. In addition, there must be a white strobe that is visible for 360 degrees in the vertical plane on each side (port/starboard) when viewed from the side or the front of the submarine. Multiple strobe lights are acceptable if needed to meet this requirement. The strobe light shall not be part of the emergency pop-up buoy. The light shall be operating whenever the submarine is submerged. A non-functioning light is reason for disqualifying the submarine. It is recommended that batteries be changed frequently, depending on usage and that you have spare(s) light assemblies in case of light failures (e.g., flooding).

6.5.6. Emergency Pop-Up Buoy

All submarines shall carry a high visibility buoy that will release from the hull and float to the surface when an emergency occurs. The float shall be attached to the submarine by thirty feet of strong, highly visible line that must be at least 1/16" thick. Each crew member shall be able to release the float in the event of emergency or disablement. Locking devices on the release mechanisms may be employed during staging to prevent inadvertent buoy release, but the release mechanism MUST be activated and not locked whenever the submarine is actively racing or whenever occupied by crew members. Partial or full release of this buoy will initiate an emergency rescue by the Navy divers, whose primary interest will be getting the crew member out of the submarine and to the surface as quickly as possible. A partial release of a buoy is defined as any situation where there is more than six inches of cord exposed between the buoy body and the submarine's hull. If a buoy is accidentally released, the Navy divers will deploy and the run will

be considered aborted. All propulsion on the submarine must stop if the emergency buoy is released.

6.6. Other Requirements

6.6.1. Submarine Width Limitations

The only method of entry for submarines into the water is via the basin's elevator. As such, the maximum width permitted of a submarine is 84 inches (2.13 meters). It is acceptable to remove parts of the submarine or have folding components to meet this width limitation and then reattach or move such parts once the submarine is in the water.

6.6.2. Submarine Draining

The submarine must drain freely when raised out of the water using the basin's elevator. That is, the water must flow freely out of the submarine such that it can be raised out of the water and moved off the elevator without having to stop the elevator to allow the submarine to drain (this allows for quicker access to the water for racing of all boats.) No submarines will be allowed to leave the lift area while draining water.

6.6.3. Launch cradle

The launch cradle must not float off the basin elevator during submarine lowering into or recovery from the water. This may be accomplished through negative buoyancy and/or the use of straps to secure the cart to the elevator. Cradles should have a minimum of 4" diameter caster style wheels for easy movement over the elevator floor grates and be sturdy enough to withstand travel between the team's work area and the basin's elevator.

6.6.4. Team Land (Dry) Wireless Communications

During the races, the use of cell phone-based systems or US Federal Communications approved Family Radio Service radios is permitted for the teams' land-based communications. Any other method of land based wireless communication must be approved by the Race Director to avoid communications interference.

6.6.5. Team Underwater Communications

Wired submarine crew intercommunication systems are allowed but must be fully described in your basic design outline, so that they can be reviewed by the judging panel.

Team and crew underwater, wireless communications systems are prohibited due to potential interference with ISR underwater race communication systems.

6.6.6. Sonic and Laser emissions from submarines

Sonic Transducers: Teams will be allowed to utilize commercially available ultrasonic (>20 kHz) transducers as part of a navigating or control system, with the submission of the make and model of the transducer along with manufacturer's specifications on frequency and power output to FURE's Head Judge as soon as possible and at least 30 days prior to ISR 17. Sonar transducer heads shall be clearly marked on the outside of the submarine by clearly visible paint or other markings. Teams will specifically discuss the operation of the sonic transducer in the design report and in conjunction with the initial dry inspection by the ISR judges, including ability to switch sonar transducer on and off. Teams must receive approval from FURE's Head Judge prior to the device being operated in an ISR race.

Teams will be allowed to utilize commercially available sonar transducers operating below 20 kHz only with scientific calculations that quantify the Mechanical Index and the Thermal Index metrics in a reverberant environment submitted for review by FURE's ISR Head Judge as soon as possible and at least 30 days in advance of an ISR race.

Laser emissions from submarines will be allowed only if the laser emitter complies with American National Standards Institute ANSI Z136.1 for Class 1 or Class 1M lasers. Teams shall submit the make and model of the emitter along with manufacturer's certification to ANSI Z136.1 to FURE's Head Judge as soon as possible and at least 30 days prior to ISR 17. Teams must have approval from FURE's Head Judge prior to the device being operated in an ISR race.

6.6.7. Automatic Control Systems for Steering & Diving and Navigation

Use of automatic control systems for steering, diving, and navigation functions can add a significantly increased complexity to submarine systems, while potentially removing workload from the submarine pilot. Many automatic control systems have been used to varying degrees of success in prior races to control on-board systems. Teams must weigh the benefits of automatic control systems with the inherent complexity and increased failure rates versus more simple control systems. For automatic control systems, teams must identify in their Design Report the factors surrounding their system design, including sensor hazards to operators and safety divers, electrical shock hazards, dangerous failure modes, and fail-safe operating modes. Pilot-controlled backup control systems must be installed on submarines with automatic control systems.

6.6.8. Drag Reduction Materials and Submarine Fluids

Beyond the use of waxes on the submarine's hull and fins, the use of drag-reduction material applied to the hull and appendages is prohibited. The

submarine shall not release any type of fluid or other material other than air bubbles into the basin's waters. Designs for proposed air injection systems must include the following criteria:

- The air injection system must have an independent air source, separate from the pilot's primary or secondary air supply.

- The design must include provisions for the release of compressed air from the submarine in the event of a mechanical failure without impacting the buoyancy of the submarine. Trapped air can result in a rapid uncontrolled ascent, which may result in injury to the driver or divers outside of the submarine. This safety system must be described in the submitted design report.

- The release of bubbles by an injection system cannot obscure the pilot's vision or otherwise hinder the pilot's ability to safely maneuver the submarine. Bubble release, operational or emergency, also must not obscure the vision of safety/rescue divers.

- The air injection system must pass both the dry safety inspection and wet safety inspection (including a successful demonstration of the system that prevents uncontrolled ascents) prior to the air injection system being allowed for use during a run on the racecourse.

- The Race Director, at their discretion, may require the air injection system to be disabled should any safety concerns be identified during safety inspections or racing.

6.6.9. Reuse of Boats in ISR 17

Colleges and Universities shall only enter in ISR 17:

1. A brand new submarine hull, or an older hull that has a major design change i.e., converted from propeller to non-propeller, vice-versa or control system change. In this case the submarine's name shall be its old name with the words "Mod 1" added.

OR

2. A submarine that did not make a successful race course run during any previous International Submarine Race.

In the case of 1. or 2. above, a team's second submarine entry may be from any previous ISR .

7. AWARDS AND RECORDS

The following awards will be given to the contestants at the 17th ISR.

7.1. Overall Performance:

A trophy and $TBD award are awarded to the submarine team from any design category that displays the best overall performance. The ranking of Overall Performance is determined by quantifying a weighted seventeen parameter Figure of Merit (FOM) for each team and submarine. The FOM composition includes aspects of other award criteria and the team's attitude, persistence, and resourcefulness. The runner up team in this category will receive a plaque and $500.

7.2. Absolute Speed Award

A plaque is awarded to the submarine team with the fastest speed of the race from any of the design categories. If the speed sets a new speed record, $500 will be awarded in addition to the plaque.

7.3. Fastest speed by category

Certificates are awarded to first place and runner-up speed finishers in each design category. In the case that there are fewer than three submarine entries in a category, only first place will be awarded.

7.4. Innovation

A plaque is awarded to recognize the submarine team from any design category that incorporates the most innovative design, construction, and/or performance attribute. (Please note that this award may not be awarded if the judges determine that the level of innovation is insufficient to be recognized).

7.5. Technology

A plaque and $TBD is awarded to the team from any design category that exhibits the best and most successful use of technology to support their vessel's design, construction, and/or performance.

7.6. Most Innovative Non-Propeller Award

A plaque and $TBD is awarded to the submarine with the most innovative non-propeller propulsion system that successfully propels the submarine.

7.7. Best design outline

A plaque is awarded to the team that submits the best design outline report on their submarine.

7.8. Smooth Operator Award

A plaque is awarded to a team in recognition of their efficiency in staging for the race course, racing the course, troubleshooting as necessary, and otherwise preparing for their

next run. The winner will be selected by the Surface Operations Director and ISR Dive Staff.

7.9. Best Spirit of the Races

A plaque is awarded to the submarine team that displays the best gusto, fortitude, support for the other teams, and overall best spirit. The winner will be selected by the submarine teams themselves and is awarded in memory of the late ISR contestant, Steve Barton of team Sublime.

7.10. Participation plaques with photos

All teams will be presented photo plaques.

7.11. Current Records

The current record holders from previous races are as follows:

Category		Race	Year	Speed	Submarine	Organization
One Person	Propeller	ISR13	2015	7.42 kts	WASUB VI	Delft University of Technology
	Non-Propeller	ISR10	2009	4.92 kts	OMER 6	Ecole de Technologie Superieure
Two Person	Propeller	ISR9	2007	8.03 kts	OMER 5	Ecole de Technologie Superieure
	Non-Propeller	ISR11	2011	6.10 kts	MIGHTY MID	U.S. Naval Academy

8. DIVER INFORMATION

8.1. Diver Certification

All sub team members and in-water support crew who want to dive must have a valid Openwater certification from a nationally recognized diver certification organization such as NAUI, PADI, YMCA, etc. or be able to document equivalent experience and training (USN, USCG, etc.). The minimum age for certified divers at the races is 15. Anyone not having this certification or experience will not be allowed to dive. Questions regarding diver status and eligibility should be submitted to the Supervisor of Diving as soon as possible and no later than at least one month prior to ISR. A copy of the certification or training must be submitted to the ISR Dive Staff at the event Registration. All divers must have their certification cards with them for review at the event and the Supervisor of Diving has the authority to require a check-out dive for any diver as a condition of receiving authorization to dive at NSWC Carderock. Contestants who do not have diving credentials listed above but wish to be considered as "surface swimmers only," should submit their registration paperwork as a diver. Your skill level will be evaluated by the ISR Dive Staff, and you may or may not be allowed in the water.

The ISR Supervisor of Diving will review the medical history of all contestants requesting entry into the water. The ISR Supervisor of Diving has the sole discretion to approve any contestant to enter the water based on such review of medical history as documented on the medical history form, physical condition, and any other information intended to manage the risk and the safety of all participants. The ISR Supervisor of

Diving can review a doctor's letter approving a person to dive and either accept it or reject it.

Important Note: If you have any unusual medical history or special circumstances (including conditions not specifically delineated in the Medical History form for an Individual Registration) or any questions about your ability to dive at the ISR, please contact the ISR Supervisor of Diving well in advance of ISR at: Dive.Supervisor@internationalsubmarineraces.org

8.2. Checkout Schedule

Diver and equipment reviews, cylinder checks, and any necessary diver checkouts will primarily be conducted during the first two days of Race Week. As determined by the Supervisor of Diving, any diver may be directed to perform a check-out dive with the Supervisor of Diving's Staff. After the initial period, additional diver needs will be handled on a case-by-case basis at the discretion of the Supervisor of Diving.

8.3. Diving Equipment

All divers are responsible for the condition, function, and performance of their equipment. However, the Supervisor of Diving has the authority to inspect the condition of diving equipment and possibly forbid its use.

All divers will receive a pre-dive check from a member of the Supervisor of Diving's staff before being allowed to enter the water on every dive. It is the responsibility of every diver to ensure that their equipment is present and fully functional before entering the dive station area. Divers/teams who are not ready will be sent away to remediate problems and lose their place in the queue.

8.3.1. Regulators and Buoyancy Compensation Devices (BCDs)

- All breathing air must be delivered via an open circuit SCUBA regulator. **Re-breather units are not allowed.** All breathing air used by contestants shall be compressed normal atmospheric air. Special air mixes such as Nitrox are prohibited.
- The brand of regulators used for both primary and secondary air supplies, as well as those used by support divers, is left to the discretion of the submarine team, but it is strongly advised that the brand selected be well-known and have a good track record.
- Regulators shall be equipped with an alternate air source (octopus) and pressure gauge. BCD–mounted alternate air sources (AIR II, Air Source, etc.), diver-mounted pony bottles or Spare Air units are acceptable substitutes for an octopus.

- All regulators should be checked and/or serviced by a qualified service technician prior to the event.
- All BCDs must be in working order and be equipped with low-pressure inflators.
- All equipment - hoses, gauges, alternate air sources, etc. – must be secured to the diver in a streamlined fashion to prevent entanglement or damage.

8.3.2. Weight Systems

- Any divers using pellet weight belts or weight pockets must ensure the units exhibit no damage that may lead to pellet spillage into the Model Basin.
- All personal weights required for a diver to submerge must be carried in some form of quick-release system.
- Divers must be able to open weight belt buckles with one hand and remove the belt from their body as necessary. Excess belt material should be trimmed prior to diving.
- Weight harnesses with functioning quick-release pockets are acceptable.
- Weight-integrated BCDs may be used if the weights are contained within the quick-release pockets.
- Ankle weights may be used.

8.3.3. Cylinders

- **All SCUBA cylinders used in the Carderock facility must be stamped with DOT and other appropriate markings as approved by the US Department of Transportation (HMR: 49 CFR Parts 171-180). As there is joint rulemaking with Canada, tanks stamped with DOT/CTC or DOT/TC (CTC = Canadian Transport Commission; TC = Transport Canada) may also be used.**
- **The use of aluminum cylinders manufactured from Alloy #6351-T6 (Luxfer, Walter Kidde, and others) during the period January 1972 through approximately December 1988 will not be allowed. The cylinders have an unacceptable risk of failure due to sustained load cracking (SLC) of the tank neck (HMR; 49 CFR Parts 171-180).**
- As per DOT regulations and CGA guidelines, all cylinders must have current hydrostatic test dates stamped on the shoulder and have current visual inspection (VIP) stickers.
- All cylinders will be reviewed by the Supervisor of Diving's Staff prior to use at the ISR. Approved cylinders will receive a sticker for use during the races. No cylinder will be filled by the Navy if the sticker is missing.
- All Spare Air regulators must be in good working order and cylinders must have current hydrostatic test dates and current visual inspection (VIP) stickers as recommended by the manufacturer.
- Divers using Spare Air systems are required to have the proper equipment for filling these cylinders. The Navy personnel filling the cylinders are not

responsible for filling Spare Air cylinders and may refuse to do so if the diver does not supply the proper equipment.

- Cylinders will be filled on-site by personnel and equipment supplied by the Navy. Empty cylinders to be filled are to be left at the designated fill station. Filled cylinders will be returned to adjacent tank area. To facilitate this process, teams/divers should label their cylinders to identify ownership.

8.3.5 Crew Comfort

- The model basin water is not heated and even though **the building is fully enclosed, the temperature of the water is a chilly 60-65 degrees F.** It is strongly recommended that the crew and support divers wear dry or wet suits, gloves, hoods, and booties to **protect against possible hypothermia**.
- The contestants are also advised to leave the water, when they are not actively preparing or operating their submarine, in order to **limit exposure time**.
- Contestants are advised to bring hand-held, battery-operated underwater lights to facilitate work on their submarines when submerged.

8.4. Monitoring of Air Supply

All divers are required to monitor their own air supply and shall not allow their air supply to fall below 500 psi. The Supervisor of Diving and staff have complete discretionary authority with regard to allowing divers to enter the water, especially with less than a full cylinder of air. Divers and submarine crews must have sufficient air to complete their task (sub race, support assignment, etc.) safely and return to the dive station with a minimum of 500 psi.

8.5. Safety Inspections

Prior to being certified to race for the first time, each submarine shall receive two inspections to ensure maximum crew safety and compliance with submarine design rules– a dry inspection and an in-water inspection. The inspections shall be performed by one or more judges and/or Supervisor of Diving staff, who may be accompanied by members of the Navy dive team, so that they can familiarize themselves with construction of the submarine and the location of hatch handles, crew restraint releases, etc. When you have completed assembling your submarine, notify the Surface Operations staff, so they can schedule your dry inspection. After passing the dry inspection, ensure that all your divers have been approved to dive by the Supervisor of Diving's staff, and have all of your dive equipment ready. Again, notify the Surface Operations staff, so they can schedule your in-water inspection. Teams will be expected to be on station and ready to dive at their appointed time. Teams that are unprepared will be moved to the end of the line.

The in-water inspection shall occur when the submarine has been placed on the bottom of the model basin along with a full crew. The crew shall be asked to perform an

emergency egress and demonstrate the operation of the emergency pop-up buoy (from both positions in the case of two-person subs).

Once each submarine has passed both inspections, an adhesive sticker will be placed on the hull to signify compliance and is your authorization to request to race.

8.6. Safety Precautions

Safety is everyone's responsibility. Every precaution is being taken to ensure that this event will be run as safely as possible. There will be qualified rescue divers stationed along the course, so that one is always near the racing submarine.

A qualified Supervisor of Diving will be on hand at all times to monitor and coordinate underwater activities. The sub crew and support divers are required to inform the Supervisor of Diving when entering and leaving the water so that he can be aware of their activities. The Supervisor of Diving is responsible for your safety and the smooth operation of the races. Please pay close attention to any instructions given by this individual or any member of his staff. Qualified emergency response personnel shall be on hand at all times to react to any accidents. They will be completely equipped to handle injuries and will have an emergency vehicle for transportation. Arrangements have also been made for medical evacuation if required. Emergency or urgent care may be provided by an on-site US Navy Corpsman or doctor, if warranted. In the case of minor injuries not requiring an ambulance, teams will be responsible for providing transportation to a local hospital's emergency room.

All divers will enter and leave the water through the dive station. All persons entering the water will check in with the Supervisor of Diving's staff and surrender their ID. Similarly, everyone must check in with the dive staff and retrieve their ID before leaving the dive station area.

Each submarine team shall be responsible for training crew and support divers for emergency egress. Teams should practice this exercise underwater until all involved are thoroughly familiar with the procedure. Teams are also encouraged to act responsibly and safely with regard to other submarine crews and underwater personnel. As there are several objects that protrude from the side of the basin at the surface, like the wave attenuators, and several objects that float upon the basin surface, like boats, all divers are advised to take the usual precautions when surfacing. In general, stay alert and be aware of your surroundings when underwater. Carrying a light is advisable for your own use and also to mark your presence for others. The traffic areas around the ends and sides of the basin are concrete and when wet, they may become slippery. Non-skid footwear like dive boots, reef walkers, or boat shoes are recommended. Open toed shoes and flip flops are prohibited on and around the model basin's in-water elevator area.

All persons inside the model basin carriage rails MUST wear either a United States Coast Guard Approved Type I, II, III, or Type V Personal Flotation Device (PFD) that is in good

serviceable condition and appropriately sized for the intended user. A wet suit with sufficient buoyancy to float the wearer is an acceptable substitute. The wearing of the PFD is required at any time and for any reason when inside the rails. Please have enough PFD's for all team support staff that will retrieve carts or bring in water support items.

9. OPERATIONS

9.1. Facility Description

The David Taylor Model Basin consists of a large, in-ground, freshwater basin approximately 3000 feet long, 51 feet wide, and 22 feet deep. The water is filtered and kept very clear, but because of the extremely large volume of water in the tank, the filtration cycle is very long, and suspended sediment will cloud the water all day if stirred up. To maximize visibility, all divers are requested to minimize disruption of the water near the bottom of the tank.

There are separate bathroom and showering facilities for women and men. There is a cafeteria on the facility open to all event participants.

Be advised that water in the basin is untreated for biologics. It is recommended to take hot showers and use ear drops at the end of each diving day.

Some of the model basin's main equipment consists of large platforms mounted on wheeled carriages which move up and down the model basin on rails placed upon the model basin's walls. These rails are extremely sensitive, even when covered. Care must be taken not to walk near or place anything on them. Divers shall not cross the rails and extreme care taken when passing lightweight equipment over them. Additionally, no one shall be permitted to stand on, lean on, or sit on the walls along the basin that supports the carriage rails.

We are guests in the David Taylor Model Basin and are not allowed access to areas outside of the ISR event area.

Please see the latest Race Week Schedule which will be posted on the ISR website http://www.InternationalSubmarineRaces.org for the times of the basin's opening and closings. It is important to arrive early to allow everyone time to pass through security. Vehicles and their occupants may be searched while entering or leaving the facility, at the discretion of base security personnel. At the end of the day, everyone must be prepared to leave by the published time, so start wrapping things up and cleaning beforehand.

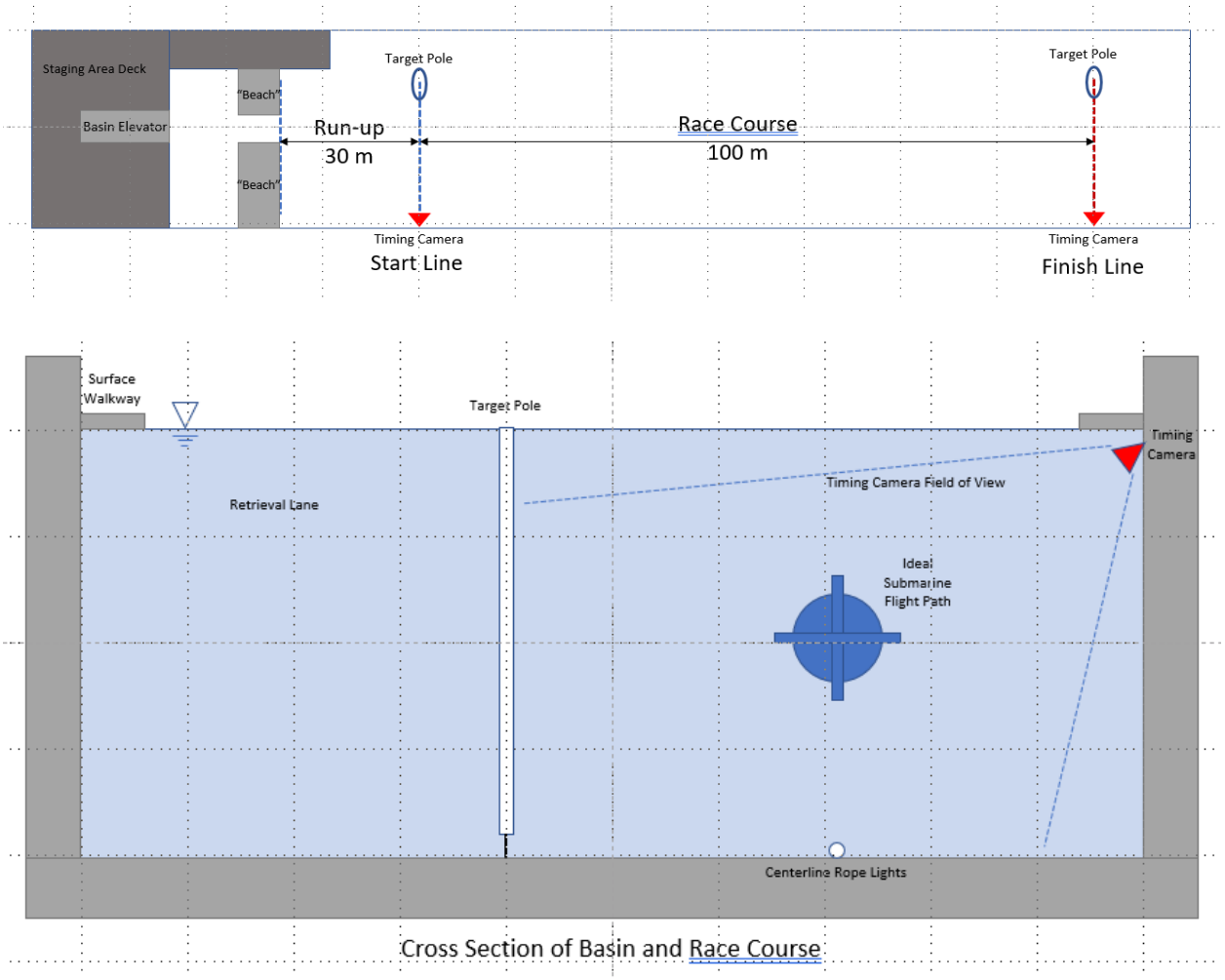
If you are competing within a time constraint during race week, you may elect to come to the ISR for just long enough to run your submarine and get a satisfactory run. Accordingly, contestants should notify the Race Director of any time constraints so appropriate arrangements can be made. However, we encourage all teams to attend the races for as

long as possible, especially in light of the fact that submarines and their teams will be judged in categories other than speed.

The generous support of NSWC Carderock personnel make this event possible. Therefore, please give them your highest respect, obey their directions, and honor their workplace.

9.2. Course Layout and Marking

The course travels the approximate center of the basin and its general layout is as follows:



Cross Section of Basin and Race Course

The center of the course will be marked along its entire length by underwater rope lights that will be weighted to stay on the bottom. There will be a 30 meter acceleration zone leading to the start line. Timing target gates will be located at the start line at 0 meters and at the finish line at 100 meters. These target poles are constructed of white PVC tubing approximately 8 meters apart and will be precisely measured and located. They will be rigid enough to support their equipment, but flexible enough to sustain a major

collision; and the measuring system used will allow them to be precisely and quickly relocated.

The cross section diagram provides the general layout of the start and finish line timing poles and cameras. Submarines can navigate low and right or high and left on the course which may prohibit observation by the timing cameras and result in a successful run but without a speed measurement. In these cases, the Race Director has the sole discretion to designate a successful run.

The start line is illuminated with lights of a particular color so as to differentiate it from the finish line. Submarine speed will be recorded for the entire 100 meter race course. A successful run for a submarine is to navigate across the start line (through the timing gate) and across the finish line (through the timing gate).

Underwater video cameras will be running continuously to record each submarine as it passes through each timing gate. The cameras will be placed on the timing gates and will have a wide-angle view so that they will see the submarine pass by at most depths. Contestants should be aware that there will be continuous white incandescent lights illuminating each timing gate area so that the timing cameras can view the submarines clearly. Every effort will be made to clean all accumulated silt from the bottom of the basin. The water itself is filtered and is completely clear. Reduced visibility produced from bottom sediments being stirred up can cause a problem with the visibility of the submarine crews and the timing cameras. Therefore, all divers are strongly discouraged from swimming close to the bottom anywhere within the race course boundaries, and the areas just before and after it, unless in an emergency situation

The 100 meter finish line is vividly marked with red lights. In addition to the red lights safety divers and Navy support divers will be present past the finish line. Submarines must cease propulsion upon reaching the 100 meter finish line. Submarines passing this point will find the tow basin quite dark and there will be no surface support in this area. A cargo net is hung to catch submarines from going too far beyond the finish line.

Teams shall not hit the timing gates. Damaged gates will close the race course for repairs causing delays in the race. Avoid hitting the manned and unmanned mobile and fixed cameras located at various places on the course. These cameras feed non-timing-related video to the surface.

9.3. Submarine Preparation

Upon arrival, each team will be assigned an outdoor area in the parking lots and grass adjacent to the working end of the basin. The exact size of the area for each sub and crew will be determined by the number of submarines that will have to be positioned there. The space should be large enough to contain a storage vehicle, the submarine, dive gear, tools, tables and sufficient working space. There will be limited power available both in

and outside of the building. In the outside area where all the submarine teams will be located, power is very limited. It is strongly suggested that contestants supply their own generators. NSWC Carderock environmental regulations require storing the gasoline for the generators in a secondary containment system such as a hard plastic concrete mixing pan or similar item to prevent spillage onto the ground.

It gets very hot during June and July in Washington, DC. Shade cover, sunscreen, and constant hydration are strongly recommended.

It may be helpful if teams come with a van or large truck in which to store nonessential gear and work on their submarine. The use of power tools, epoxies, paint, etc. is permitted, but please be aware that teams are responsible for completely cleaning up any debris or stains resulting from the process. Any chemical which is considered to be hazardous to health or environment must be accompanied by a Material Safety Data Sheet (MSDS). Be considerate to the other teams and the people who work at the basin. The disposal of any epoxy, paint, solvent, or petroleum-based product is expressly forbidden unless supervised by NSWC Carderock personnel.

When the work on a submarine is complete and the crew is ready to deploy, a crew representative will notify the Surface Operations Director. The ISR committee will send Judges and safety divers to your area to perform the dry safety inspection. Submarine entry to the building is coordinated by the Surface Operations Director. However, space inside the building is somewhat limited and priority will be given to those in their final stages of preparation or already in the queue. Once passed, you will join the queue awaiting entrance into the basin. It is likely that additional racing time will be available for those who are prepared when others are not. There will be a big advantage in coming to the races as early and staying as long as possible.

9.4. Submarine Launching

For ease of transportation around the facility and for launching, it is recommended that your submarine have a cradle with wheels or some sort of cart to move it around on. If you launch your submarine using this device, it must be negatively buoyant or secured to the dry dock elevator so that it does not float during launch and recovery. The working end of the basin has a platform with an in-water elevator. Submarines will be moved into position on the elevator at the direction of the Supervisor of Diving's Staff. The elevator will then be lowered and the sub eased off by the crew and support divers. Team crew members with personal floatation devices (PFDs) must remove the cradle from the elevator and the building after the submarine is launched. Cradles should have a minimum of 4" diameter caster style wheels for easy movement over the elevator floor grating.

9.5. Removing the Submarine from the water

Upon determining that the submarine is ready to be removed from the water, request permission from the Supervisor of Diving who will coordinate with the Surface Operations Director. Cradles are not to be brought into the basin area until given permission. Recovery will be by the reverse process of launching. Team crew members with PFDs move the cradle onto the elevator and secure it. After the submarine drains all water, the crew can move the submarine and cradle off the dry dock elevator. The submarine should immediately be removed from the building.

9.6. Submarine Staging for Racing

In the working end of the basin beyond the lowering elevator the 'beaches' will be staging areas. After the Supervisor of Diving has cleared your team to launch, you will be directed to one of these spots. This will give your crew time to ballast and balance the submarine and check out all of the systems. Your submarine will still receive a visual safety inspection by the Dive Staff every time it is launched. When you are prepared to race, one of your support divers will surface and notify the Racing Starter that you are ready to race. In the event of a long delay, it may be wise to get out of the water and stay warm; but be ready to go as soon as you are called.

9.7. Course Operations

When your submarine is called, prepare to move it into the course starting area. Try to keep your support diving crew small to avoid excessive traffic in the starting area. If there is a submarine already poised to launch in that position, avoid it and allow it to launch unhindered, and then move into the start position. From this time on, you will have a maximum of ten minutes for final preparation for launching your submarine. If you exceed this time without launching, you may have to move out of position and be placed at the back of the queue if other submarines are ready. There is 30 meters between the staging area (at the beach) and the start line. All submarines have the option of starting anywhere along this acceleration area. You can use the whole 30 meters for your run-up, start at the start line timing gate, or anywhere in between. Since every submarine will be allowed as many runs as possible, you may wish to experiment with this factor. Similarly, the crew can elect to start the run at any depth at least 6 ft below the water surface to the bottom. Bear in mind that by definition, a submarine travels completely submerged, so a run down the course where any part of the submarine breaches the surface will be considered as a "did not finish" attempt. The same also applies if the submarine fails to pass between the vertical markers marking each gate. The submarine is allowed to wander off course a little during the run but must pass through all four gates properly. Striking the gate uprights and disturbing the cameras or targets may cause the run to be declared unofficial.

When your submarine is straight and level, is pointing down the course properly, and is far enough off the bottom so that nothing will hit, the support diver shall check to see

that everyone else is out of the way, both fore and aft of the submarine. The support diver will then surface and notify the Racing Starter that the sub is "ready to race". The Race Starter, through an underwater loudspeaker, will give permission to race. The support diver will signal to the crew to commence propelling in case they could not hear the race command. This sign will be to rotate one arm as though cranking and shall be universal so that any diver in the area will be aware of what is going on and can avoid the submarine. The Racing Starter will notify all subsea personnel by underwater loudspeaker that the submarine is under way and on course. **The topside support crew will then walk down the course on the concrete aisle on the left side of the race course to assist divers at the other end in retrieving your submarine. All team members providing surface support within the basin walls must wear PFDs or wet suits, provided by each team.**

Subsurface support crew shall not follow the submarine onto the course, nor can your topside support personnel follow on the surface by boat or swimming. This is to minimize traffic on the active race course.

Once the submarine has traversed the course (or has stopped along the course), the crew should not exit the submarine until instructed to do so by Navy divers. The submarine is then towed to the left-side basin wall by the Navy divers. The submarine's support crew is then responsible for towing the submarine back to the beach area of the basin. Care should be taken to hug the basin wall to avoid obstructing the race course. When the submarine gets back to the beginning of the start line, you may be vectored right back onto the start line, or be put in the queue, or waved back to the underwater staging area, depending on the traffic at that moment.

Check all crew and support diver air supplies; if any are low, request positioning into the staging area immediately. The goal will be to have each submarine run several times during each immersion. If for any reason your crew cannot repeat runs, you should request positioning back to the staging area for removal of your submarine from the water. Do not move submarines to the lift or carts into the building before checking with the Supervisor of Diving and Surface Operations Coordinator. The submarines will be allowed to make as many runs as time will allow. Every team needs to be as fully prepared as possible before entering the race queue. Be considerate of other teams; if you come up with a problem that takes a little time to fix, allow other teams to pass by to keep everything moving.

9.8. Submarine Braking

Submarine braking at the end of the marked course will not be a major problem at the NSWC Carderock facility because of its great length, but crews are encouraged to stop their submarines in as short a distance as practical. Speed brakes, flaps, and propeller reversals are acceptable methods, but drogue chutes or sea anchors are prohibited because of their tendency to snag on other objects. Braking by rapid ascent or breaching

is prohibited as there is a potential for embolism in even a few feet of water. **Once the submarine has stopped, the team's topside support crew must be ready at the end of the race course to assist in disembarking the crew and returning the sub to the staging area**. Suggestions will be made by the Operations staff for the return process.

9.9. Cautions in and around the indoor facility

DANGER: Access to the center right narrow aisle (on the right hand side of the race course as you enter the basin is limited to ISR Operations Staff and ISR volunteers only. The timing and video control station is located in this aisle. There is a major hazard in the ceiling of this area: unshielded high voltage power cables that power the carriages which the model basin uses. Contact with these cables can kill you. Do not handle long poles, pipes, etc. in this area.

The beach structure is not solid; it is an inclined slotted structure to attenuate wave action. Do **not enter or swim under the beach structure**. Be careful not to catch toes or equipment between the slats of the beach structure. Divers or support staff wearing fins are not allowed to climb or walk across the beaches if in water less than knee deep. This is to prevent falls.

There are slatted steel walkways along both sides of the basin. To avoid injury, always look up prior to ascent, especially near the walls. There is a carriage-arresting gear structure that hangs over the water at about the 60 meter mark. There are also Navy Zodiacs on the surface with spinning propellers. Again, always look up prior to ascent, particularly near the walls.

Lighting may be limited depending upon an individual's location in the model basin. Also, summer electrical storms can cause power failures. The basin can get very dark, very quickly. Dive lights are recommended. Dive lights also work well as signaling devices and enhance the ability of others to see you.

All contestants inside the model basin carriage rails MUST wear either a United States Coast Guard Approved Type I, II, III, or Type V Personal Flotation Device (PFD) that is in good serviceable condition and appropriately sized for the intended user. A wet suit with sufficient buoyancy to float the wearer is an acceptable substitute.

9.10. Safety Concerns During Submarine Operations

DON'T PANIC! If you remain calm, keep breathing from the regulator, and stay in/with the sub until the Navy divers arrive and instruct you what to do, almost any situation can be controlled.

Air supply can be lost by simply dropping your regulator from your mouth, or by running out of SCUBA air, or other equipment malfunction. KEEP YOUR REGULATOR IN YOUR

MOUTH AT ALL TIMES!! If there is an air supply problem, reach for your alternative air source first, and then open the hatch. If at all possible, remain inside your submarine until Navy Divers come to you for rescue.

Descent is controlled by the submarine team's support divers prior to the start and they must make sure the crew is safe at all times. Of particular importance is for the support divers to actively monitor the crew for ear clearing problems or any other distress during descent. Visual contact is needed with all crew members during the entire descent.

Ascent is controlled by the vehicle and may be more rapid than a free diver ascent. This means that crewmembers must continue breathing during the entire human powered submarine operation. NEVER HOLD YOUR BREATH!! The vehicle should always operate near the bottom unless there is a control problem or emergency.

Some submarines may have buoyant hatches. If the hatch is opened on the surface, the loss of buoyancy may cause the submarine to descend. Ensure crew members have access to SCUBA regulators and that support personnel are not trapped underneath.

BEWARE OF THE PROPELLOR/PROPULSION UNIT DURING OPERATION AND STAY CLEAR WHEN IT IS ROTATING. The submarines may have sharp edges, bolt heads, hoses, and hatches that can cut or pinch hands and snag SCUBA equipment. BE CAREFUL.

A moving submarine has a lot of inertia. Never be between a moving sub and the basin walls.

The water is cold and can cause cramps. Be sure to stretch prior to diving, eat appropriate foods, and drink plenty of fluids to help reduce the risk of cramps. The crewmembers are more susceptible to cold because they are moving only during the run. It is wise to get out of the water to get warm.

It gets very hot outside during June and July in Washington, DC. Shade cover, sunscreen, and hydration is strongly recommended.

If you have a diving or equipment problem, stop diving. You will become a liability at that point and will not help anyone, including yourself. Make sure the Supervisor of Diving is aware that you are getting out of the water.

9.11. Timing System

The timing system uses two fixed underwater video cameras that look across the course at target poles placed on the opposite side of the course. The camera/target pairs are located at the start of the measurement course (0 meters) and at the finish of the course (100 meters). The video from these two cameras are combined to make a 2-part split screen video signal. This video is recorded along with television time code. The time code

generator counts each 1/30 of a second television frame as well as seconds, minutes and hours. Even though individual frames are 1/30 second apart, a time resolution of 1/60 second is possible by interpolation, that is, by the position change of the submarine in adjacent frames.

After each run, the recorded video is examined to find the exact television field where some identifiable marking or component of the submarine passes through each of the four targets. The time the submarine takes to travel between each target is determined by the difference in time and frame number. A spread sheet program calculates the time difference and then the submarine's average speed over the 10 meter and 100 meter sections of the course. A contestant speed form will be generated for every run of each submarine and will be authenticated by the timing officials.

FURE is continuously updating the timing and video system and reserves the right to make changes to the system described and will notify Teams of any changes when available.

9.12. Speed Measurement Accuracy

The three primary factors that determine the accuracy of the speed measurement are: 1. the frame rate of the television system; 2. the time uncertainty of the submarine crossing the target, because the cameras are not synchronized; and 3. the accuracy of the distance between the camera/target pairs.

1. The frame rate of the television system is measured using a universal counter/timer with a high stability temperature controlled crystal oscillator reference. The required correction for the television system frame rate is embedded in the formula of the spread sheet program.

2. The split screen combiner can accept video from sources that are not synchronized. In order to assemble the videos into a single split screen image, the individual videos must be brought into proper time alignment. The combiner does this by adding delay as needed to each camera's video. The model of combiner used in this system adds delay of 0 to 1/60 second to each camera's video to bring it into time alignment with the other cameras. Thus, there is an uncertainty of the time of occurrence of an event seen by any one camera relative to an event seen by the other cameras of up to 1/60 second. A test of the timing system has been performed to determine the maximum uncertainty of the time of occurrence of an event seen by the cameras. During the test, both cameras were pointed toward a strobe that flashed approximately once per second. A test recording was made and examined field by field. The strobe flash appeared either in the same or an adjacent field of the split screen image of the two cameras. This test proved that the uncertainty of the time of occurrence of an event seen by the cameras in this system is no more than 1/60 second.

3. Course layout alignment targets on the north and south walls of the basin were positioned by the staff of Naval Surface Warfare Center, NSWC Carderock Division using a calibrated, and computer controlled laser measurement system. The distance between these targets was measured then averaged to determine the course centerline distance. The accuracy of these measurements is tied directly to a 60-inch calibration bar that has been calibrated using a coordinate measurement machine (CMM) which has traceability to a NIST standard. The television cameras and their targets are positioned using plumb lines suspended from horizontal lines running across the course between the alignment targets.

The dominant speed error component is the 1/60 second time measurement uncertainty. For a submarine traveling 8 knots through the 100-meter course, the 1/60 second timing uncertainty could cause an error up to 0.0055 knots or 0.069%. Note that for slower speeds, the error decreases because the 1/60 second uncertainty is a smaller fraction of the travel time. Note also that these possible errors are worst-case maximums, using the assumption that the cameras are as far out of synchronization as possible. Statistically, the average errors are likely half these values.

9.13. Timing Results

Submarine speeds will be displayed on television monitors and posted on a status board as soon as they are available. A section of the status board will show the highest speed in each category. As each speed is bettered, a new higher speed will replace the previous maximum. When races are in rapid succession, speed determination may be delayed, but the speed will be posted as soon as it is available. Please do not ask the timing officials for speed data during active racing. **REMEMBER: access to the center aisle is limited to race officials and ISR volunteers.**

10. FORMAL DOCUMENTATION REQUIRED

10.1. Submarine Specification Sheet for Race Program

The ISR Race Program presents overall information about the race, the race teams, and the specifications of each submarine entered. The form requesting required information will be issued no later than 15 April 2023 and must be returned to the Contestant Liaison no later than 1 May 2023. Accurate information is needed on this form as it is the basis for the printed Race Program and Award letters and plaques.

15 April 2023	Each team receives Microsoft Office Template for required information
1 May 2023	Completed MS Office templates due to Contestant Liaison via e-mail) contestant.liaison@internationalsubmarineraces.org

10.2. Submarine Design Report

Each submarine team will be required to submit a design report to the ISR judging panel. This report shall completely document the team's efforts in the conception, design, construction, and testing of its submarine. Entry to the races will not be allowed if this document is not presented by the assigned date. There are three reasons for this requirement. The judges will use the design report to determine if the submarine conforms to the design guidelines and rules set forth in this contestant's manual. In addition, they reserve the right to reject from competition any contestant or team whose design or intentions are not in keeping with the honor and tradition of the races. Deficiency in design from the standpoint of crew safety is also cause for rejection.

The report for each submarine will be compiled and a journal produced to provide educational benefit to those interested in human-powered submarine engineering. An award shall be given to the submarine crew that develops the most complete and informative report for their project. ISR organizers firmly believe that one of the most important aspects of the races is the educational benefit that these reports will offer. At a minimum, the design report must cover the following topics:

1. Executive Summary
    a. Design Philosophy & Goals
    b. Design and Fabrication
2. Hull
3. Propulsion System
4. Control Systems
5. Life Support System
6. Safety Systems
    a. Submarine Testing
    b. Crew Training
    c. Lessons Learned
    d. Budget

All reports are to be copyrighted to FURE and will become the property of FURE. It is the intention of FURE to make these reports available on the ISR website at a later date. Copyright forms will be supplied no later than the 20 February 2023 registration deadline. The reports should preferably be sent via email as an attachment to Head.judge@internationalsubmarineraces.org. A completed, signed copyright form for the design report shall be scanned into a PDF file and submitted with the report. If the report file is too large to be sent by email the team shall contact the Head Judge to determine another mutually acceptable submission method (such as Google Docs or Dropbox).

18 May 2023 Final Design Report submission due to Head Judge along with completed Copyright form.

If you have questions, you can e-mail the head judge at: Head.judge@internationalsubmarineraces.org

10.3. 20-Minute Presentations

Each team must make a 20-minute presentation to the Judging Committee for each submarine entered. At a minimum, the presentation should be in Microsoft PowerPoint and include the following elements:

1. Team introduction
2. Sponsoring organization
3. Team Members
    a. Overview and Goals
    b. Design Philosophy
    c. Design and Fabrication
4. Hull
5. Propulsion System
6. Control Systems
7. Life Support System
8. Safety Systems
    a. Submarine Testing
    b. Crew Training
    c. Lessons Learned
    d. Functionality of Systems Described in the Design Report
9. Update on what is working at the race and what is not.
10. Budget
11. Closing

The schedule of the presentations will be supplied to each team by the contestant liaison after team inputs / requests are received. The critical dates for this process are:

15 May2023	20-minute Presentation: Sign-up Sheet sent out to teams
31 May 2023	20-minute Presentation: Schedule Issued
03 June 2023	20-minute Presentation PowerPoint file and signed copyright form for the presentation submitted via email to Head Judge at: Head.judge@internationalsubmarineraces.org .
19-22 June 2023	20-minute Presentations during race week

10.4. Copyright Forms

The Final Design Report and the 20-Minute Presentations are to be copyrighted to FURE. Each team will be supplied the required format and information requested by the

Contestant Liaison no later than 1 April 2023, as described above. The due dates for the forms are as follows:

18 May 2023	Final Design Report Copyright form submitted with Final Design Report
10 June 2023	20-Minute Presentation Copyright form submitted with 20-minute Presentation PowerPoint file.

11. Miscellaneous

11.1. Directions to David Taylor Model Basin/NSWC Carderock Facility and Parking

The website will contain the latest set of directions and maps. Building Number 4 will house the races, and parking will not be allowed at the east end of the building and along the side of the building.

Limited parking will be available at the David Taylor Model Basin - NSWC Carderock Facility, including space for large vehicles. People will not be allowed to stay overnight in motor homes or otherwise and must be off the facility by the times posted in the final race week schedule posted on the website. Teams are encouraged to bring as few vehicles as reasonable, since the facility needs to keep the traffic flow to a minimum.

Please do not park in any parking spaces that are marked as reserved and drive carefully around the facility. US Navy police may issue citations for traffic violations.

11.2. International Shipments and Customs

All teams are responsible for shipping their submarines and equipment to the race location and must ensure all required paperwork for customs declarations for importation and exportation is completed. If needed, FURE will provide contacts to other teams who have successfully navigated these challenges. FURE nor NSWC Carderock can act as the importer of any Team's gear.

11.3. Submarine Shipping and Delivery Instructions

The shipping address is:
Naval Surface Warfare Center
NSWC Carderock Division
Receiving Code 3341 Bldg 143
9500 MacArthur Blvd
West Bethesda, MD 20817-5700

The contact person at NSWC Carderock :

Charlotte Crowley
(301) 227-8869

Mark containers **INTERNATIONAL SUBMARINE RACES** in very large letters. Allow sufficient transport time, so that your gear will get there before you do. **Do not however plan for the submarine to arrive at Carderock before 15 May 2023**. Please call & email Mrs. Crowley one week prior to shipping date to confirm expected arrival date. (The crate's dimensions and weight(s) would also help determine forklift requirements ahead of time). NSWC Carderock does not provide recommended shipping companies or deal with customs. Teams must verify with your foreign shipping company that arrangements have been made in the United States for customs processing and final delivery to NSWC Carderock in time to support your participation. NSWC Carderock should only be contacted for final delivery and delivery signature.

Non-US citizen truck drivers are not allowed on NSWC Carderock property. If trucking companies do not heed this, their drivers will be prohibited from entering the property. This will lead to delays and possibly increased shipping costs for the contestants.

Deliveries must be made during the week (M-F) between the hours of 6:30 am and 2:00 pm. Please ensure your trucking company knows the hours of operation and the special driving directions. **TELL THE SHIPPING COMPANIES TO ARRIVE BEFORE 2:00 PM WITH ONLY US CITIZEN DRIVERS/HELPERS, OR THEY WILL BE PROHIBITED FROM ENTERING THE PROPERTY.** The facility will unload the containers from the transport trucks and **store them outside** near the model basin. Calling one hour prior to arrival will minimize unloading delays if a forklift is required for offload which is almost always required.

All submarines must be shipped out of NSWC Carderock by contestants within two weeks after the end of the races. **If not, the submarine will become property of FURE.** Return shipping arrangements should be made prior to the end of the race week and communicated to Mrs. Crowley. All other submarines must be removed from NSWC Carderock by the end of the award ceremonies on Friday, 23 June 2023.

11.4. Host Hotel

The Host Hotel for ISR 17 is:

TBD. THIS SECTION IS UNDER REVISION

The ISR room rates are:

Single King Bed: $TBD plus applicable taxes
Two Double Beds: $TBD plus applicable taxes

These room rates are available from TBD and include a hot, full American breakfast for all overnight guests. Breakfast will start at 6 am from Monday, 26 June, through Friday, 30 June 2023. (Note that the hotel cannot place rollaway beds in king bed rooms or rooms with two double beds due to safety concerns and fire code restrictions.)

Reservations can be made by contacting hotel reservations at TBD. When making reservations, be sure to identify yourself as part of the "ISR 17" room block. Individuals must cancel more than 24 hours prior to arrival or will be subject to a first night's room and tax fee. **Reservations are due to the hotel by 4pm eastern time on TBD**. Any unused rooms will be released after this time to the hotel for general sale.

11.5. Publicity and Reporter Clearance

Any media personnel interested in attending the ISR should contact the ISR Media contacts identified below. All media entering NSWC Carderock property must obtain prior clearance and be escorted by NSWC Carderock Public Affairs Office personnel. Names of foreign media contacts must be submitted one month prior to ISR 17. FURE will provide all media requests to NSWC Carderock Public Affairs Office for final approval while on NSWC Carderock property.

11.6. ISR Contestant Contact Information

At this time your points of contact regarding the ISR 17 are listed below. If they cannot answer your questions, they will direct you to someone who can.

ISR Contact List

Contestant Liaison
TBD contestant.liaison@internationalsubmarineraces.org

Supervisor of Diving
Vin Malkoski dive.supervisor@internationalsubmarineraces.org

Head Judge
Mike Ales head.judge@internationalsubmarineraces.org
203-556-1570

Media Relations
Charlie Behrle FURE.President@internationalsubmarineraces.org
571 334-3776

Foundation for Underwater Research and Education (FURE)
Charlie Behrle FURE.President@internationalsubmarineraces.org
Daniel Dozier FURE.VicePresident@internationalsubmarineraces.org

ISR Mailing Address:

International Submarine Races
Foundation for Underwater Research and Education
PO Box 543
Haymarket, VA 20168-0543

All relevant information can be found on our web site:
http://www.Internationalsubmarineraces.org

Also, follow us on Facebook at
www.facebook.com/International-Submarine-Races-205535162933518

12. APPENDIX 1 – INTERNATIONAL SUBMARINE RACES (ISR) HISTORY

THIS SECTION IS UNDER REVISION

Human-powered submarine racing has come a long way since its inception in 1988. In that year, the concept was brought forth and developed by the H.A. Perry Foundation and Florida Atlantic University's Department of Ocean Engineering. **The first ISR** was held in June 1989 at Riviera Beach, Florida. Nineteen entrants from academic institutions, corporations, and independent groups gathered to race their submarines and test their designs. The weeklong event was extremely educational for all involved, who learned just how complicated submarine racing can be. Many different factors had to be taken into consideration; not the least of which was weather, which forced the cancellation of these races prematurely. The U.S. Naval Academy's submarine 'Squid' garnered the overall performance prize for this first race.

In 1991, **ISR 2** was held at the same location. It was decided that the competition should be biennial to allow time for new submarine development and construction. Because the first event had received much media attention, there were many more entrants, attendees, and spectators. The ISR organization of the event had improved and grew considerably to meet the requirements. The original entry list consisted of thirty-six racing teams and was truly an international event with one team coming from as far away as Germany. Many excellent lessons were learned, good weather prevailed, and the competition was fast-paced and fierce. The 'Subasaurus', an entry from the oceanographic corporation Benthos, carried away the prize for best overall performance.

ISR 3 was conducted in 1993. The races were staged off Ft. Lauderdale, Florida. Almost fifty teams participated in the competition. For two weeks, these teams dealt with mechanical difficulties and unpredictable weather in the form of high winds and seas. The final race was terminated early by the failure of mechanical course components. Tennessee Tech University's 'Tech Torpedo II' was selected as overall performance winner.

In 1994, a group of west-coast submariners looking to test the performance level of their vehicles in a controlled environment began laying plans for a new and different submarine event. Out of this was borne the 1994 West Coast Submarine Invitational (WCSI). This new event was held in March 1994 at the Offshore Model Basin in Escondido, California, the largest privately-owned model basin in the United States. Touted as an event, not a design competition, WCSI '94 placed emphasis on the fact that the conditions would be controlled and would place minimal impact on the submarine teams, which would maximize their efficiency. Speed was the ultimate goal, and the Guinness Book of World Records was asked to authenticate the timing system and publish the results. The event was a success with fourteen entrants participating. The official, ultimate speed record was set by the Florida Atlantic University entrant at 5.9 knots.

The escalation of growth in ISR led to increasing demands for funding and personnel. A restructured ISR emerged, led by several individuals who had been involved in ISR 1 – 3 and

whose main concern and interest was for furthering the educational experience and technology of submarine design, construction and operation.

ISR 4 was held during December 1995. The David Taylor Model Basin in Bethesda, Maryland was selected as the location, and from all aspects the race was a complete success. The controlled environment facility turned out to be ideal for this event. Eleven submarines from three countries competed. All design categories were covered; one and two person, propeller and non-propeller driven, corporate, academic, and private. Though the world speed record for a two-person submarine set at WCSI '94 was not matched, the record for single-person was set, by William Nicoloff's 'Substandard' at 5.0 knots. Another 'first' at this event were in-submarine female competitors. In four days, over 260 dives were made with a total of 544 hours underwater, and dozens of runs were made by the submarines without accident or major mishap. Many lessons were learned by all, and everyone had a lot of fun.

ISR 5 was held at the NSWC Carderock model basin in June 1997. The one-person sub "OMER 3" from the University of Quebec's École de Technologie Supérieure, achieved a speed of 6.97 knots. The Canadian team swept the sub race prize categories. The team's two-person sub "OMER 2" won its class with a performance of 6.36 knots. In the history of human powered submarine racing, two-person teams have been the norm. However, three teams came to the 1997 races with brand new one-person designs in addition to their previously raced two-person subs. The 1997 ISR saw a number of other important "firsts." Winston Churchill High School of Potomac, MD, brought the world's youngest female submarine pilot to race. The first all-female crew in ISR history piloted and powered "Mermaid" for the Annapolis, MD Human-Powered Sub Club, and became the first team of women ever to finish the regulation course. True to the spirit of the races, many teams worked through the nights, replacing damaged equipment and engineering performance improvements on the spot, ready to race again the next day. The sharing of tools, techniques, and solutions was common throughout the five-day event.

ISR 6 was held in 2001 again at the NSWC Carderock David Taylor Model Basin. The award for Overall Performance, sponsored by the IEEE Oceanic Engineering Society, went to Virginia Polytechnic University, Blacksburg, VA. Judging was for speed and maneuverability in the water as well as high-tech design of composite materials, computerized advanced power-to-propulsion conversion, and the team's response to challenging and changing circumstances during race week.

In other awards: Absolute Speed, Omer 4; Best Use of Composites, Omer 4; Innovation, 1st place Reef Cruiser, Robert Golobic, 2nd place Jonah, Merchant Marine Academy, 3rd place Neptune, University of Michigan; Spirit of the Races, Merchant Marine Academy and Lawrence Technical University, a tie. Best Design Guideline, Lawrence Technical University, Southfield, MI.

ISR 7 was held at the NSWC Carderock David Taylor Model Basin in June 2003. The OMER 5 team from the Ecole de Technologie Superieure, Montreal, Canada won the Absolute Speed Award with a sprint of 6.814 knots, and the Best Use of Composites Award for their unique

use of sandwich-hull construction, comprised of carbon fiber, Kevlar, and closed cell nautical foam and the Overall Performance Award. Judges awarded the Best Design Outline and Report Award to Sussex County Technical High School of Sparta, N.J., whose first-time entry, Umptysquatch-1, was completely designed, built, and operated by high school students. The Spirit of the Races Award went to the team from Florida Institute of Technology, whose submarine, Miss FIT, was a bright red 16-foot-long six-sided torpedo. This award recognizes overall spirit, gusto, fortitude and support of other teams, and is given to honor the late ISR high school contestant, Steve Barton of Florida. A new award, the Smooth Operator Award, went to Sirius, from the University of Washington. This award recognizes team efficiency.

The top speed awards for ISR 7 were: One-person, propeller, academic category - RSR Fournier, University of Maryland, 4.916 knots; One-person, propeller, independent category - Scuba Doo, Wheaton Submarine Works, Wheaton, MD, 4.875 knots; One-person, non-propeller, academic category - Specter 1, Virginia Tech, 3.520 knots; Two-person, propeller, academic category - Omer 5, Ecole de Technologie Superieure, 6.814 knots; Two-person, non-propeller, academic category - Miss FIT, Florida Institute of Technology, 3.417 knots. The design competition drew 19 teams from throughout the U.S., Canada, and Mexico, including two high school teams.

ISR 8, held at the NSWC Carderock David Taylor Model Basin in June 2005, continued the trend of speeds increasing steadily over the history of the event. In the early days, speeds rarely exceeded three knots. In 2005, Omer 5, a sleek two-person submarine from the University of Quebec's Ecole de Technologie Superieure (ETS) in Montreal, Canada, set a new two-person speed record of 7.061 knots. The Canadian women's team also set a record of 5.885 knots. Some of the hottest competition occurred in the first-ever, side-by-side race between the fastest submarines. Event organizers also held the first ever race over a slalom course to judge maneuverability, however this category has not been continued due to increasing numbers of teams entering the basic competition.

ISR 8 top speed awards: Two-Person, Propeller Category - OMER 5 of the University of Quebec, ETS with a speed of 7.061 knots. One-Person, Propeller Category - WASUB from the Technical University Delft, Netherlands with a speed of 6.903 knots. Independent One-Person, Non-Propeller - Bruce Plazyk's FAUX FISH with a speed of 1.676 knots. Best Use of Composites: UMPTYSQUATCH II, a second time this team from Sussex County Technical High School, New Jersey participated. Innovation: First Place: PHANTOM 5, Virginia Poly-technic Institute and State University. Second Place: SPARKY'S SUB, designed and piloted by independent Don Burton. Third Place: FAUX FISH designed and piloted by independent Bruce Plazyk.

Best Design Outline: sponsored by Compass Publications, parent company of Sea Technology magazine and given to the Technical University of Delft's submarine team WASUB. The Overall Performance Award: T U Delft, the Netherlands' WASUB who also won the Spirit of the Races award, which is selected by the submarine teams themselves. Smooth Operator: FA-U BOAT, Florida Atlantic University.

ISR 8 held the first-ever slalom competition with eight teams showing the maneuvering skills to complete the course in the basin. Technical University Delft, Netherlands led the way with WASUB completing all three of its slalom-course runs with a top speed of 5.736 knots.

During **ISR 9** in 2007, the consistently winning Canadian team set a new world speed record of 8.035 knots. The competition hosted 22 experimental human-powered submarine teams with 24 subs from the U.S., Canada, Mexico and England. The new speed mark, which won the Absolute Speed Award, was set by the OMER 5 submarine crewed by Sebastien Brisebois and Joel Brunet from the Ecole de Technologie Superieure at the University of Quebec, Montreal, Canada. The previous world record was 7.192 knots set by OMER 4 in June, 2001. OMER team members had predicted that they might finally break the eight-knot mark, a speed most enthusiasts previously deemed unachievable by human-powered submarines.

ISR 10 in June of 2009 marked the 20th Anniversary of the ISR. Eighteen teams competed the event featured a first-ever sweep of overall prize categories by a high school team. The Overall Performance Award went to team "Sublime" from Hernando County Schools, Florida. The high school team from Hernando County also beat out arch-rival Florida Atlantic University's "FAU Boat" in a special head-to-head Florida team's race. New international speed records were also set in a non-propeller-powered vehicle designed by the Ecole de Technologie Superieure, Montreal, Canada. A submarine team from Universidad Simon Bolivar, Caracas, Venezuela joined the other international contestants from Canada and England.

ISR 11 had 24 teams, competing with 28 submarines. The U.S. Naval Academy entered after an 18-year absence with the SSH-11 Mighty Mid, which earned the Overall Performance, Fastest two-person non-propeller submarine, and the Spirit of the Races Awards. Florida Atlantic University's sub Talon-1 also won several awards: Fastest Overall Speed of 6.814 knots and Fastest Speed in the one-person, propeller category. An all-female FAU crew raced the submarine in successful runs, capturing record breaking speeds in that category, entering the record book.

ISR 12 had a total of 19 teams participating, entering 21 submarines, from the U.S., Canada, Mexico, the United Kingdom, Germany, the Netherlands and the Sultanate of Oman. The fastest submarine was from the University of Quebec's École de Technologie Supérieur in Montreal, Canada. This submarine, Omer 8, turned in the winning speed in the one-person propeller-driven category, 7.28 knots. Team Omer's current world record, set during ISR™ 9, stands at 8.03. Team Omer also won the Overall Performance award that included a cash prize of $2000, sponsored by the Platinum Sponsors, the Ocean Engineering Society of the Institute of Electrical and Electronic Engineers and Intelligent Decisions Inc. of Ashburn, VA. Omer took home the third-place prize for Innovation with had a single bladed propeller with a counterweight for balance. The second-place award for fastest speed, in the one-person, propeller-driven colleges and universities went to the University of Washington's WASUB-3 and third place was awarded to Florida Atlantic University's Talon 1. FAU also took home the Absolute Speed Award in the Women's subcategory, in Talon 1,

In the one-person non-propeller driven, colleges and universities category, the First-place award went to El Pez Gordo, built by students at Carnegie Mellon University. In the One-person submarine - propeller driven; high school category, First-place was awarded to Springstead High School of Brooksville, FL SUBLIME Race Team. This same team raced their second submarine, SubZero, to win First place in the Two-person propeller-driven; high school category. First place for One-person, non-propeller driven; Independents went to Carts Independent, a team consisting of seven home-schooled youngsters ranging in age from 6 to 16, from Accokeek, MD. This team also won the Best Spirit of the Races Award, chosen by all of the teams competing, for showing the best gusto, fortitude, support for other teams and overall best spirit. This award is given in memory of a late ISR contestant, Steve Barton, from team Sublime. In the Women's subcategory, one-person submarine - propeller driven; high school first place was won by Springstead High School of Brooksville, FL, racing in SUBLIME. Also, in the Women's subcategory, for two-person submarine - propeller driven; high school first place was won by Springstead High School of Brooksville, FL, racing in SUBLIME.

Prizes also were awarded for the most successful examples of design and construction. First place for the Innovation Award went to Virginia Tech for Phantom 6, which had the pilot and co-pilot seated in tandem, with a single transmission to power two propellers equally. Virginia Tech received a trophy and a $1500 cash prize, contributed by Intelligent Decisions. Second place went to the University of Washington's Laurie Belle, which had a modular system with all components mounted on a single structural member secured to the submarine with two bolts at each end. Third place for Innovation, as previously mentioned, was presented to Omer 8. FAU also won the $300 prize, and a trophy for the Best Use of Composite Materials for their second submarine, FAU-BOAT II. The award was given for a new material consisting of basalt that was combined with fiberglass, and the resultant material has a higher strength-to-weight ratio compared to standard fiberglass and is significantly easier to lay up. A $300 award was given to the team from the Sussex Technical School of Engineering, Sparta, New Jersey who built UMPTYSQUATCH VI, for the Best Design Outline.

ISR 13 had a total of 21 teams participating, entering 24 submarines, from the U.S., Canada, Mexico, the United Kingdom, Germany, the Netherlands, New Zealand and the Sultanate of Oman. This line-up represented 17 Universities, 3 High Schools, and 1 Independent team. Collectively, the teams had 206 starts which resulted in 83 completed runs which included a speed record of 7.42 kts (1 person, propeller) by WASUB 5 of Delft University of Technology, Delft, Netherlands. Contestants registered 3064 hours in the water with 1260 "dives." Volunteers performing diver checkouts, wet safety inspections and camera operators spent 270 wet hours in 103 dives. The US Navy filled 1,052 Tanks.

The Overall Performance award was won by Omer 9, École de Technologie Supérieure of Montréal, Québec, CANADA with a speed of 7.19 knots. The best absolute speed and new record for 1 person, propeller was by WASUB 5, 7.42 kts, Delft University of Technology of Delft, Netherlands. The Smooth Operator Award, for being prepared and ready to enter the

water and race, chosen by ISR staff was awarded to Jesse IV, Old Saybrook High School of Old Saybrook, CT, USA. The Best Spirit of the races, chosen by the teams, was awarded to Nautilus, K.I.D.S. (Kids Into Discovering Science), of southern Maryland, USA,

The Innovation Award was presented to Godiva, University of Warwick,-United Kingdom, Biodegradable hull and fold-away design. Honorable mentions were presented to:

- Taniwha, University of Auckland, Auckland, New Zealand, for the water trim system
- Umptysquatch VII, Sussex County Technical School, Sussex County, New Jersey, USA for the Squid drive
- Archimede, École Polytechnique de Montréal, Montreal, Canada, for the use of virtual reality-based training methodology
- Nautilus, K.I.D.S. (Kids Into Discovering Science), southern Maryland, USA, for the use of a Fibonacci screw in the propulsion design

The Best Design Outline was awarded to WASUB 5, Delft University of Technology, of the Netherlands

ISR 14 had a total of 24 teams participating, entering 25 submarines, from the U.S., Canada, Mexico, the United Kingdom, Germany, the Netherlands and the Sultanate of Oman. ISR 14 contestants registered 1838 hours in the water. Volunteers performing diver checkouts, wet safety inspections, and camera operators spent 210 wet hours in 209 dives.

The winner of ISR 14 Overall Performance Award was from OMER X of Ecole de Technologie Superior. OMER X received a trophy and $1000 award. It is given to the submarine team from any design category that displays the best overall performance. The ranking of Overall Performance is determined by quantifying the Figure of Merit (FOM) for each team and submarine. Seventeen weighted parameters are ranked to determine the FOM. The analysis includes aspects of other awards and the team's attitude, persistence, and resourcefulness. This award was sponsored by Booz Allen Hamilton.

The winner of the Smooth Operator Award was Umptysquatch 8 from Sussex County Technical School. A plaque is given to a team in recognition of their efficiency in staging for the race course, racing the course, troubleshooting as necessary, and otherwise preparing for their next run.

Speed Awards by Category

One Person, Propeller, College

1st place	HPS Atlantic	Florida Atlantic University	4.90 kts
2nd place	Archimede VII	Polytechnique Montreal	4.05 kts
3rd place	Godiva 3	University of Warwick	2.52 kts

One Person, Propeller, High School

1st place	SUBLIME	Hernando County Schools	5.77 kts

2nd place	Jesse V	Old Saybrook High School	3.27 kts
3rd place	Trigonus AC	Mosley High School	1.28 kts

One Person, Propeller, Independent

1st place	Rubber Ducky	Kids Into Discovering Science	1.24 kts

Two Person, Propeller, College

1st place	Knotty Dawg	University of Washington	3.27 kts
2nd place	Tijuana Taxi	University of Veracruz	1.03 kts

One Person, Non-Propeller, College

1st place	OMER X	Ecole De Technologie Superieure	4.59 kts
2nd place	WASUB VII	Delft University of Technology	2.09 kts
3rd place	Rivershark Mod 1	Rhein-Waal University of Applied Sciences	1.49 kts

ISR 15 marked 30 years of racing human-powered submarines. It was a milestone not lost upon participants and support volunteers. Many wondered if the original race enthusiasts from Florida Atlantic University's Department of Ocean Engineering and the H.A. Perry Foundation ever thought their dream and creation would survive 30 years. Not only has it survived—it has thrived.

Twenty-one human powered submarines and more than 400 team members gathered on June 23, 2019. A strong field of participants represented 20 teams from around the world and across the academic spectrum. Canada, Netherlands, United Kingdom and the United States were represented by teams from 15 universities, four high schools and one independent group.

Participating universities included: the Polytechnique Montréal from Montreal, Canada, with Archemede VIII; Florida Atlantic University with Atlantic II; University of Michigan with Bluefin; University of Victoria from British Columbia, Canada, with Chinook II; University of Waterloo from Ontario, Canada, with Claire; Gulf Coast State College from Panama City, Florida, with Commodore; University of Warwick from Coventry, U.K., with Godiva III Mod I; École de Technologie Supérieure from Montreal, Canada, with Omer 11; Virginia Polytechnic Institute and State University with Phantom 8 and Trident; University of California San Diego with Santiana; University of British Columbia from Vancouver, Canada, with Skookumchuck MK V; University of Southampton from Hampshire, U.K., with Tempest; Texas A&M University with the 12th Manatee; University of Washington with the Underdawg; and Delft University of Technology from Delft, Netherlands, with Wasub IX.

High-school teams included Frederick County Career and Technology Center from Frederick, Maryland, with CLS Mako; Dover Area High School of Dover, Pennsylvania, with Cormorant; Son of Trigonus, sponsored by the Gulf Coast State College; and Sussex County Technical School from Sparta, New Jersey, with Umptysquatch 9.

One independent team also participated: Kids Into Discovering Science (KIDS) from Accokeek, Maryland, with Maryland Mako.
A very successful week was had by all. The contestants departed satisfied and tired and, most importantly, with a feeling of success, positive memories, new knowledge and experiences, and new friends.
Awards included:

The Booz Allen Hamilton Overall Performance Award. A trophy and $1000 award are given to the submarine team from any design category that displays the best overall performance. The ranking of Overall Performance is determined by quantifying the Figure of Merit (FOM) for each team and submarine. Seventeen weighted parameters are ranked to determine the FOM. The analysis includes aspects of other awards and the team's attitude, persistence, and resourcefulness. This award is sponsored by Booz Allen Hamilton. The runner up team in this category will receive a plaque and $500.

Winner	*OMER 11 / École de Technologie Supérieure (ÉTS)*
Runner-up	*WASUB IX / Delft University of Technology*

Innovation Award. A plaque is given to recognize the submarine team from any design category that incorporates the most innovative design, construction and/or performance attribute. (Please note: This award may not be awarded if the judges determine that the level of innovation is insufficient to be recognized).

Winner: OMER 11 / École de Technologie Supérieure (ÉTS) - OMER 11 had three modes of propulsion: mirage drive, conventional two-bladed propeller, and mono-blade propeller. In addition, the mirage drive has springs added to even out the power impulses provided by the fins. The propeller pitch could also be adjusted during operation.

This year the Woods Hole Center of Marine Robotics has provided an award of free attendance to two team members of the Innovation Award winning team to attend the 6th annual Entrepreneurs Showcase and Leadership Forum in July 2020 in Woods Hole, Massachusetts. Woods Hole Oceanographic Institute created the Center for Marine Robotics to speed development of marine robotic technologies. The goal of the center is to collaborate with industry academia, and government agencies to change the way people and machines work together in the marine environment.

First Honorable Mention: UMPTYSQUATCH 9 / Sussex County Technical School - UMPTYSQUATCH 9 designed and installed an integrated ballast and trim system with integral structural tanks, pumps, and vents that maintained neutral buoyancy and trim during runs down the tank.

Second Honorable Mention: TRIDENT / Virginia Tech - Virginia Tech completely changed their management systems, resulting in a great improvement in race performance. Their testing plans included a bollard pull test, which was a submarine race first.

The American Systems Best Use of Technology Award. A plaque and $1000 award are given to the team in any design category that exhibits the best and most successful use of technology to support their vessel's design, construction, and/or performance. This award is sponsored by American Systems.

Winner: CHINOOK II / University of Victoria - CHINOOK II won this award based on their use of existing technology to implement an autonomous depth control system, as well as their use of a four-piece modular hull design which facilitated shipping the submarine to the race. They also used tubercles on their fin leading edges to delay flow separation and reduce the associated wing drag.

Absolute Speed Award. A plaque is given to the submarine team with the fastest speed of the race from any of the design categories. If the speed sets a new speed record, $500 will be awarded in addition to the plaque.

Winner OMER 11 / École de Technologie Supérieure (ÉTS) - 6.85 knots

Best Design Outline. A plaque is given to the team that submits the best design outline report on their submarine.

Winner: WASUB IX / Delft University of Technology - The report was well-organized and logically presented. The use and quality of graphics was superb. The coverage of each topic was thorough and of professional quality, with the report content thoroughly documented.

Smooth Operator Award. A plaque is given to a team in recognition of their efficiency in staging for the race course, racing the course, troubleshooting as necessary, and preparing for their next run.

Winner: GODIVA III MOD I / University of Warwick

Best Spirit of the Races. A plaque is given to the submarine team that displays the best gusto, fortitude, support for the other teams, and overall best spirit. The winner is selected by the submarine teams themselves. The Best Spirit of the Races is awarded in memory of the late ISR contestant, Steve Barton of team Sublime.

Winners (tie): MARYLAND MAKO / KIDS and OMER 11 / École de Technologie Supérieure (ÉTS)

Fastest Speed by Category. Certificates are given to first place and runner up speed finishers in each design category. The categories for speed awards include the combinations of the following characteristics - one or two person boats, propeller or non-propeller boats and Independent, High School and College level teams.

One Person, Non-Propeller, College

Winner – OMER 11 / École de Technologie Supérieure (ÉTS) - 4.78 knots

One Person, Propeller, Independent

Winner – MARYLAND MAKO / Kids Into Discovering Science (KIDS) – 2.34 knots

One Person, Propeller, High School

Winner - CLS MAKO / Frederick County Career & Technology Center – 3.29 knots

Runner-up - CORMORANT / Dover Area High School – 0.92 knots

One Person, Propeller, College

Winner - OMER 11 / École de Technologie Supérieure (ÉTS) – 6.85 knots

Runner-up - WASUB IX / Delft University of Technology – 6.54 knot

2019 FURE Scholarship Winner. An award of $2000 was made to Mr. Andrew Prater who graduated from Crawford Mosley High School and is a member of the Gulf Coast State College submarine team.

2020 FURE Scholarship Winners. Two scholarship awards were made in 2020. A $2,000 USD award was made to Mr. Itai Savage from Sussex County Technical School. Mr. Savage was headed to Princeton University's School of Engineering and Applied Science and is a veteran of ISR15 in 2019. A $1,500 USD award was made to Mr. Guillaume St-Yves from Ecole de Technologie Superieure. Mr. St-Yves was entering his fourth year at ETS and participated in eISR 2018 and ISR15.

ISR 16 was a unique virtual design competition driven by the restrictions of the COVID-19 pandemic. Since school attendance was severely restricted across the globe, a design competition was created for those Teams who could participate. The elements included judged written design submissions to include overall design as well as submarine sub-systems. A virtual Team Problem Solving interview was held with participating teams. While not the in-person event that we all wanted, the Teams who were able to participate enjoyed the outlet for their creativity.

2021 FURE Scholarship Winner. An award of $2,000 USD was made to Ms. Hannah J. Douglas, graduating from Sussex County Technical School. Ms. Douglas was headed to Stevens Institute of Technology to study mechanical engineering.

2022 FURE Scholarship Winner. An award of $2000 was made to Mr. Garrett Kemper of Portsmouth Rhode Island with an award of $2000. He is a rising freshman at the University of Rhode Island.

For **ISR 17**, FURE and its ISR Committee are devoted to continuing to embrace the original event objectives as set forth in 1988. We hope our efforts will enhance the development of scientists and engineers in the field of marine technology and ocean engineering. FURE is dedicated to making human-powered submarine racing as safe and effective as possible in this capstone event.