European International Submarine Races

Biennial Races

Contestants' Rule Book
for eISR 2018
dated 14 February 2017

[Containing changes resulting from eISR 2014, 2016 and subsequent decisions of the Race Committee]

European International Submarine Races
www.subrace.eu

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Introduction

1. The third biennial European International Submarine Race (eISR) was held from the 4th to the 15th of July 2016 in Gosport, England. Teams of University students raced their human-powered submarines against the clock around a demanding slalom course in a unique sporting and engineering challenge. The Contestants' Rule Book has been heavily amended to include the recommendations resulting from this event.

The Challenge

2. The European International Submarine Races challenges teams of university students to design, build and race human-powered submarines against the clock on an out-and-back course. The concept combines engineering design challenge with technical skill development and sets them in a unique and exciting sporting competition.
3. The basic rules of the sport are straightforward – teams must design, build and race flooded submarines piloted by either a single, or two, scuba divers, who must be fully enclosed within the hull of the machine. All propulsion power must be provided by the diver during the race (i.e. no energy storage devices such as flywheels or batteries are allowed), but otherwise the design rules are open to whatever innovation teams decide to use.
4. The resultant designs are submarines in the fullest sense of the word, minus the one constraint of watertight hull. The removal of that constraint ensures that the competition is about engineering innovation and sporting achievement, rather than just about waterproofing. Innovation comes in the design of the hulls to minimise drag and maximise thrust while optimising transmission systems to make best advantage of the pilot's limited power production. The importance of buoyancy, trim and directional control is highlighted, and innovation encouraged. One-man propeller-powered submarines achieved speeds of 7kts during the 2016 races, all on less than 600W input power.
5. The eISR is also about developing real, practical engineering skills. In the funding-constrained university environment, the practical elements of curricula have been replaced with theoretical calculation and computer modelling. A submarine big enough to contain a diver is a real, tangible machine, and the mechanisms have to produce and take real forces. At the same time, the challenge isn't so great that the students can't make the parts themselves - this provides an invaluable learning experience as they see their CAD drawings come to real life.
6. Finally, the competition is about working as a team in a time-critical, adrenaline-charged atmosphere. During the build-up to the race, the students learn to exploit each others' strengths, and design into their machines what they think they will need to succeed at the races. In initial testing, they learn where the weaknesses are, and make considered adjustments to their designs. Then, once they arrive on the racecourse, and really put their machines to the test, they invariably find new challenges, and have to bring out their engineering knowledge to find solutions on-the-fly with limited facilities. Such experience is invaluable to them later in their careers, regardless of the direction they take.

The Organisers

7. The eISR is provided by the Institute for Marine Engineering, Science and Technology (IMarEST), in partnership with QinetiQ. The Race Committee is made up of dedicated individuals and representatives of the IMarEST and QinetiQ. The current officers are:

- **Race Director**: Prof William Megill, FIMarEST
- **Business Director**: Frank Mungo, FIMarEST
- **Head Judge**: Vice Admiral Sir Robert Hill, KBE, FIMarEST
- **QinetiQ Head of Site**: Simon Rignall

- **QinetiQ Diving Safety Officer**: Gavin Anthony
- **QinetiQ Events**: Christina Harris

Affiliations

8. The European International Submarine Races are completely distinct, not sponsored, endorsed, nor otherwise associated with the long-running International Submarine Races held biennially in Bethesda, MS, USA, and organised by the Foundation for Underwater Research and Education.

Liability

9. Submarine racing is, like any other sport, an activity which encompasses a certain amount of personal risk. Every effort is taken to ensure a safe environment. Rescue divers are always present, and medical help is literally minutes away. However, the onus is on the participants to ensure their own safety and that of those around them, whether underwater, at the surface, or ashore. IMarEST and QinetiQ assume no liability for injury to participants, nor damage to or loss of their equipment. Participants are made aware of these risks, and are required to acknowledge this awareness by signing a liability waiver during the registration process.

The Venue

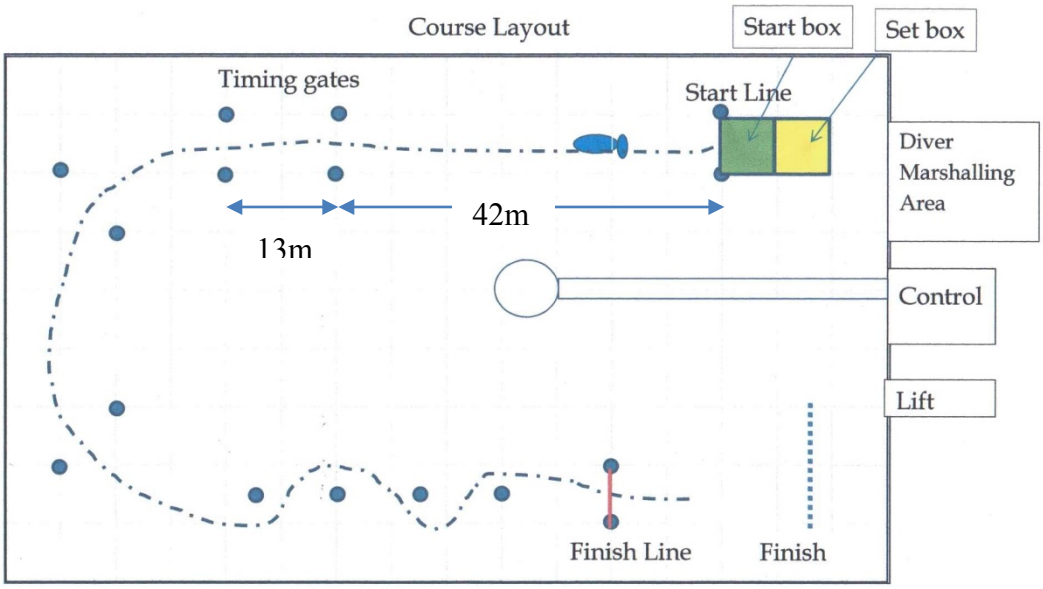
10. The races are held at QinetiQ's Ocean Basin testing facility at Haslar, Gosport, England. The basin is 122m x 61m, 5.5m deep. The water is swimming pool quality, though not heated – temperatures are typically about 15C/60F. Good wetsuits or dry suits are a must! The water is lightly chlorinated, and a pH of about 8.2 is maintained. The facility is well lit, with large windows and skylights.
11. QinetiQ's Haslar Technology Park is a secure facility. Contestants will be required to wear identification at all times, and will not be allowed to wander about the site. There will be no need to do so, as all will be provided near the main door to the Ocean Basin. Anyone found wandering unescorted around the facility will be removed from the grounds, and may not be allowed back in.
12. The use of cameras (video or still) outside designated areas will not be permitted. All cameras will require a pass. Application forms will be available on the subrace.eu website nearer to time. Camera-equipped cell phones will not be allowed on site.
13. As should be pretty obvious, the possession or use of illegal drugs is **absolutely prohibited** anywhere in the Technology Park - offenders will find themselves explaining their behaviour to the Police. Alcohol, while not illegal, is not to be consumed on site. Any abuse, either on the QinetiQ site, or at the campsite, could result in the offender's team being disqualified from further racing and/or the team being barred from future races.
14. It is the responsibility of every individual and team to secure and look after theirown equipment. Neither QinetiQ nor the Race Organisers accept any liability for loss, damage or theft. Help and support amongst teams is encouraged, but make sure your gear is readily identifiable,and that you keep track of where stuff is.

The Race

15. The eISR brings a new and exciting challenge to the sport of human-powered submarine racing. Where recent races have focused on straight-line speed, the eISR introduces a slalom course. The emphasis is still on speed, but the subs score faults for all interactions with the course markers - the sub which finishes with least faults and fastest time wins!

Course layout

16. Retaining the one-boat-at-a-time, race-against-the-clock format of other human-powered submarine races, the eISR is an out-and-back race, with a set of slalom gates on the return leg. The figure below shows the layout of the racecourse. A timing gate is set up on the outbound leg, 13m long, 42m into the leg, so that speed records are reasonably compatible with those set in other races. Shortly after the timing gate, the submarines will have to make a sweeping 180° turn, on an approximately 25m radius. A set of four slalom poles are placed on the return leg.
17. Boats have to leave the first and third poles to port, and the second and fourth to starboard. The poles are placed 13m apart. On the first race day, the poles are placed wide, so that subs can run a straight line through them. As the week progresses, they are moved closer to a straight line, forcing tighter turns. The slalom section is deliberately placed on the return leg to slow the boats down before they reach the finishing area. Any boat which touches the end net will score faults. The total length of the race course is approximately 175m, but the distances travelled may be longer or shorter, depending on how tightly they take the sweeping turn and slalom gates.



Course marking & faults

18. The Ocean Basin is essentially a very large, very well lit, swimming pool. The bottom is completely clean, and the water clear. There are a lot of reinforcement structures along the bottom and around the edges of the pool, so pilots and support divers will have to take care when operating near these structures.
19. The centre line of the course is marked out along the bottom using a weighted line and a set of small orange cones. The outer edge of the curve is marked on the bottom with a string of traffic cones.
20. The starting line will be 30m from the end wall of the basin, and is marked by a pair of PVC poles placed on a tar line across the bottom of the tank.
21. Timing gates are placed at 42m and 55m from the starting line. The gates are vertical PVC pipes anchored on the floor, placed on either side of the course. The gates are solid enough to survive impact, but will give way to minimise damage during such an event. They are designed to be quickly replaced and recalibrated after a collision.
22. Two turning gates, consisting of a pair of vertical PVC pipes, are placed to mark the sweeping turn. Subs are required to leave a black & yellow pole to starboard, and a grey one to port.

23. Slalom poles consist of vertical ropes covered in swimming pool `noodles'. Subs leave red poles to port, and green ones to starboard. The poles will initially be placed such that the subs can steer a near straight-line through them. As the week progresses, the poles will be placed such that the subs will have to weave between them.
24. The finish line is marked with a pair of PVC poles and a brightly coloured tape across the floor. Pilots must stop pedaling, and engage their sub's braking system (if fitted) as soon as the bow of the submarine crosses the line. A submarine-catching safety net is placed across the arrival zone, 30m from the finish line, but eight faults will be applied to any submarine which makes contact with the net.
25. The gate marker and slalom poles are anchored with lead weights placed on 18" steel disks. Any contact with any pole will result in four faults. If the anchor is dragged off the plate, then eight faults will be applied. If a submarine passes the wrong side of any pole, eight faults will be assigned.
26. Submarines must remain dived while on the course between the starting and finishing lines. Every instance of any part of the submarine breaking the surface will result in four faults being awarded. Eight faults will be awarded for breaking the surface continuously for most of any of the three sections of the racecourse: initial straight, long bend, slalom section to finish

Race schedule

27. The Races will run over ten days. The first day (Wednesday) will be a dry day of final readying, dry judging and diver checkouts. The next two days are dedicated to ballasting and Wet Inspections. The weekend will be available for last minute adjustments. Timed runs are planned to start on the following Monday and run through to the end of Thursday. The Friday Agility Competition is a separate event which teams must qualify for over the course of the week.
28. The 2018 race will run in heats, one in the morning, and one in the afternoon. Six boats will take part in each heat, the order of racing being determined by a draw the night before. Final decisions about the order of racing, and changes to it, will be made by the Queue Manager ("Q").
29. Timing on the day will depend on many circumstances, but the aim is to launch the boats beginning at 8.30 AM, and start racing at 9.30. The morning heat will run until noon. A one-hour break at lunch is planned to allow the staff a break. Any remaining boats will be launched beginning at 1300 and the afternoon heat will start an hour later at 1330. Racing will end for the day at 1700. The goal will be to be clear of the QinetiQ site by 1800.
30. Submarines will be readied in a set of 2 boxes (Set and Start) marked out on the basin floor behind the starting line. The Queue Manager ("Q") will control the order of submarines, handing them over to the Dive Controller as and when they are ready to race. The Starting procedure is given in paragraph 82 below. The clock will start when the bow of the submarine crosses the starting line. Boats will proceed through the timing gate, around the turn, through the slalom section, and over the finish line. The pilot will then exit the submarine, and be brought to the surface by one member of the team. The other team members will return the boat to the end of the current queue, and prepare it for another run.

Aborts and safety

31. While on the racecourse, the submarine will be followed by two inflatable boats at the surface, one carrying a team of rescue divers and the other a submarine recovery team. A pilot may indicate a non-emergency abort by releasing the safety buoy, opening his hatch, and swimming to the surface, where he or she will be recovered by the rescue boat. The tow boat will recover the buoy and haul the submarine to the surface, then tow it back to the starting area. If the submarine indicates an emergency abort (the safety buoy is released, but the hatch does not immediately open), or it is obvious that it is in difficulty, the rescue divers will immediately dive to the machine, extract the pilot and bring him/her to the surface. The submarine will then be removed from the racecourse by the tow boat. Once the stricken sub is clear of the racecourse, the rescue divers will return to the surface and inform the Race Controller, so that racing can resume.

Repairs and modifications

32. An important part of the Races is the on-the-fly repair, modification and improvement of the submarines during the course of the week. Experience shows that teams arrive on the first day of the competition in a variety of states of readiness. Even the boats that are ready to go first thing will benefit from inspired improvements and modifications that the teams conceive during the course of operating them on the race course. Each team will be provided with a working space (dry pit) around the edges of the Ocean Basin, where they can do minor adjustments, and any work not requiring the creation of dust

Submarine Design Rules

Note: These rules are summarised in tabular form in Annex A. References to the table are given in square brackets.

Definition

33. A submarine is defined for the purposes of this event as a flooded underwater vehicle which fully encloses a pilot and all of the control and propulsion mechanisms. It must operate entirely beneath the surface of the water, and must be propelled by a fluid-coupled device (e.g. propeller, jets or wings). For avoidance of doubt: a submarine is distinguished from a streamlined sub aqua swimmer by the fact that the external 3-D form of the vehicle remains essentially the same, with and without the pilot installed.

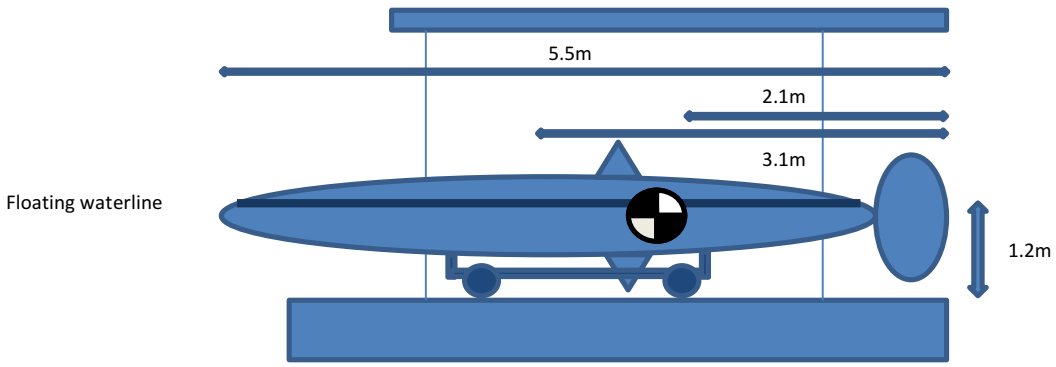
Dimensions

34. The maximum overall dimensions of a submarine are determined by those of the lift used to launch and recover them from the Ocean Basin. Submarines are therefore limited to 5.5m in length [**D1**], and to a maximum width of 1.5m [**D2**]. To fit the track on the lift, the width between the wheels must be between 500mm and 750mm [**D2**]. .

35. Subs with appendages that extend beyond this limit can be accommodated, but the appendages will have to be designed so that they can be attached or removed by divers in the water (probably easiest on the bottom) [**D3**].

36. Submarines must be designed such that their centre of gravity when out of the water (dry or draining) can be placed on the lift between 2.1m and 3.1m from the bow or stern extremity of the submarine [**D4**].

37. The draft of the submarine and its trolley may not exceed 1.2m – this is to enable the submarines to be loaded onto and off of the lift at the lower extent of its travel.[**D5**]



38. To ensure rapid draining during lifting, a free flood hole or drain hatch of at least 233cm^2 (36in^2) opening must be sited on the ventral side of the vessel, somewhere near the CofG longitudinal position (ie. near the lower triangle in the figure) [**D4a**].

Crew

39. Submarines may be crewed by one or two pilots. Additional safety rules will apply to two-man submarines. The most important of these are that each pilot must carry his/her own 3L pony bottle, and the safety buoy system must be designed so that if either pilot releases the "dead man switch", the buoy will immediately deploy.

Propulsion

40. Submarines may be propelled using either a screw (propeller), defined as a spinning device with radiating blades, or some other system. The propulsion must be water coupled. Wheels or other mechanisms which generate movement through friction along the bottom or the walls are not permitted.[**D6**]

41. Propulsion systems must be directly coupled to the pilot (or pilots – in two-man boats, both pilots must be directly coupled). No clutches are permitted [**D7**]. Energy storage systems are only permitted where all of the energy is stored and dissipated during the race itself, e.g. resonant elastic structures on oscillating biomimetic fins. Flywheels and other energy storage devices which could be loaded before the vessel crosses the starting line are prohibited [**D8**].

42. Hydraulic, pneumatic and electric transmission systems are permitted, so long as all energy used in propulsion is produced by the diver in real time - i.e. as above, no energy storage systems are permitted which could be preloaded [**D8**].

43. No oils are permitted to be used in hydraulic systems. Only water may be used as a fluid. Only water-resistant grease may be used to lubricate any gearing [**D9**].

44. Pneumatic systems may not use the diver's breathing air except for charging a closed system [**D10**].

45. Electric systems of up to 24V DC are permitted. [**D11**]. If batteries are fitted there is to be a sign indicating their type, location and means of isolation **[D11a]**

46. Expelled diver air may not be used to create thrust, whether forward or sideways [**D12**].

Life Support

Primary air supply

47. The pilot's primary air supply shall be carried aboard the submarine, and have double the capacity required to complete one run at speed (i.e. it should be at least half-full after the completion of one run) [**A1**]. No pilot shall allow his/her supply to fall below 50bar (725 psi) [**A2**]. The air pressure gauge must be visible to the crew member inside the submarine, and it must be possible to communicate that pressure to a support diver once the pilot's hatch is closed [**A3**].

Secondary air supply

48. Each pilot must carry an independent air supply, which must have sufficient capacity to enable the diver to exit the submarine and reach the surface **[A4].** This capacity shall not be less than 3L. Bailout bottles (e.g. *Spare Air* brand cylinders) are not sufficient for this purpose [**A5**]. The secondary air supply must not be used for tasks such as loading and preparing for a run, and its pressure must not be allowed to fall below 50bar (725psi) **[A6].**

Support diver air supply

49. All support divers must be equipped with a spare second stage regulator (octopus), for safety and support (e.g. assisting pilots during submarine entry and egress) [**A7**]. All support divers are required to monitor their air supply, and no cylinder is to drop below 50bar (725psi) [**A8**].

Note: repeat low remaining pressure offences may result in the diver being excluded from the competition for a period of time or altogether. Pressures will be checked on entry and exit from the water, and the Dive Supervisor has the ultimate authority to decide whether a diver will be allowed into the water.

Pressure regulators

50. All breathing air must be supplied using an open-circuit SCUBA system [**A9**]. Re-breather systems are prohibited [**A10**]. Evidence of recent qualified servicing of regulators (first and second stage) may be required. This includes pony bottles [**A11**]. The Dive Supervisor will have the final say as to whether a piece of equipment will be allowed into the water.

Air cylinders

51. In the UK it is not legal to charge air cylinders supplied and approved in the USA. DOT cylinders will not be permitted **[A12]**.
52. Cylinders must be CE certified to appropriate EN or BS Standards that are suitable for PPE/breathing apparatus. The current standards are **[A13]:**
    a. EN 1964:2000 Transportable gas cylinders – Seamless Steel
    b. EN 1975:2000 Transportable gas cylinders – Seamless Aluminium
    c. EN 12245:2002 Transportable gas cylinders – Fully wrapped composite
    d. EN 12257:2002 Transportable gas cylinders – Seamless hoop-wrapped composite
    e. BS 5045-7:2000 Transportable gas containers – Seamless Steel
    f. BS 5045-8:2000 Transportable gas containers – Seamless Aluminium

53. All cylinders must clearly display current hydro and visual inspection dates. They should be correctly labelled in accordance with European Standard EN 1089-2, namely with a label displaying the green compressed-gas hazard diamond. Cylinders will be inspected at the beginning of the competition, and air-refill personnel will additionally inspect the cylinders before filling to ensure that inspections are current [**A12**].

Breathing air

54. Only compressed normal atmospheric air shall be used in divers' cylinders. Special gas mixtures (e.g. nitrox) are prohibited [**A14**].

Safety Markings & Other Items

High visibility colours

55. Any and all moving parts, plus any small parts extending away from the hull of a submarine, should have their tips painted hi-viz orange, to maximise their visibility to divers. Otherwise colour schemes are free to each team to set as they wish [**D16**].

Rescue egress

56. Handles and release mechanisms for all exits must be clearly marked on the outside of the submarine. A 10cm square hi-viz orange patch bearing the word "Rescue" is recommended as a marker [**D20**]. The handle or release mechanism must be easily accessible from both inside and outside the submarine. Its use will have to be demonstrated as part of the wet test before the submarine is allowed on the course [**D21**].
57. In the case of 2-crew submarines, an exit hatch is to be provided for each crew member. In order to ensure that the second crew is aware of the situation in the first crew's cockpit, an indicator is to be provided for each crew member which shows that either
    i. Both crew exit hatches are in place and shut, or
    ii. One or both exit hatches are open. [**D20a**]

Crew restraint

58. If the pilot is restrained in any way inside the submarine (e.g. toe clips or shoulder straps), then release mechanisms must be clearly identified with orange paint or fluorescent tape. Any such releases will be inspected by the judging team during the dry test, and their function will have to be demonstrated as part of the wet test [**D22**].

Crew visibility

59. **Each** pilot's face and head must be easily seen by support divers outside the submarine [**D23**]. It is highly recommended, even in the case of sonar (or otherwise) guided submarines,that the pilot has sufficient vision forward and sideways to see the course and where the submarine is going.

Emergency pop-up buoy

60. Each submarine shall be equipped with a **high visibility** surface marker buoy which is released by the pilot to signal that help is required. The buoy must have a net buoyancy (natural buoyancy minus weight) of 500 grams **[D24].** The buoy must be attached to the submarine by 10m of floating, highly visible line, at least 5mm in diameter. To ensure that the line runs easily when the buoy is deployed, it must be stowed on a reel. If the reel is inside the hull, the line between the reel and the stowed buoy must pass through a tube so that it does not snag on any fitting when the buoy is released. The attachment of the float line to the submarine must be sufficiently strong that the line can be used to bring the submarine from the bottom of the tank to the surface (eg in the event of an abort) **[D25].**
61. The buoy shall either form part of the hull or be contained in a fully flooded compartment inside the hull, being prevented from floating to the surface by a hatch in the top of the hull or by some other means. Using a "dead man's handle" or similar device, the buoy shall be released automatically in the event that the pilot is incapacitated and unable to continue preventing its release. Override mechanisms are permitted to ease operations while the sub is behind the starting line. [**D26, O8**].

62. The buoy is the first signal to the rescue divers that something has gone wrong, and that the pilot may require assistance. If the pilot does not immediately open the hatch, then this will be the signal to the rescue team to deploy into the water. Accidental release of the buoy beyond the starting line will automatically abort a run, and the sub will have to be returned to the end of the queue.
63. In two-crew boats, the marker buoy must be released if either crew member is incapacitated [**D26a**].

Towing points

64. – Deleted -

Hatch restraint

65. All hatches must be permanently attached to the hull of the submarine by means of hinges, straps or other similar mechanisms. The restraints must not interfere with the designed function of the hatch. Specifically, restraints on the pilot's main access hatch must not restrict his/her egress in an emergency [**D14, O4**].

Drag reduction

66. No materials are allowed to slough off the vessels into the basin. Other than this restriction, any drag reducing coatings are permitted. However, these will have to be cleared with the facility operator ahead of time, preferably at the design stage. Any teams considering the use of such technologies are required to contact the judges in plenty of time.

Ground transport & launching

67. A trolley or cart of some sort will be required to transport the submarine between the team's working area and the launching lifts (elevators). The trolley will need to be sufficiently strong to take the weight of the submarine and any water contained within it during the lifting process, when the sub is coming out of the water. The trolley must be negatively buoyant, and support the submarine so high off the ground that it will not float off the trolley in 1.2m of water. A tie-down system will also be required to restrain it on the lift during launch and recovery. To fit the track on the lift, the width between the wheels must be between 500mm and 750mm [**D2**].

The Teams

Eligibility

68. The eISR is open to teams of University students and alumni. All members of the team must be over 18 years of age at the time of the race [**V1**]. All divers must be amateurs, in the strictest sense of the word (i.e. they may not be paid to take part in the racing activities - **this includes professors/advisors/technicians, even if they're on holiday**! They may take part in the race, but they may not enter the water. **This is due to UK legislation governing diving at work**.) [**V2**]

Diving Operations

69. From a purely diving perspective, the eISR will operate in a manner similar to a diving lodge. The Race Committee will be providing air fills, advice on diving conditions, and rescue divers. Each team will however be operating under its own certification organisation's rules and procedures for recreational expedition diving. The minimum acceptable dive qualification is either EN 14153-12 or ISO 2480 [**V3**]. Teams will state at registration time which dive training organisation's rules they will be following [**V4**].

70. Each team will require a Surface Liaison Officer ashore who will serve as the liaison between the race staff and the team in the water [**V7**]. See para 70 below

Diver Qualifications

71. All team members must be over 18, and those wishing to dive will need to be qualified to so independently (i.e. without an instructor) by an internationally recognised dive training organisation. The following table - which is not an endorsement by the race committee of one standard over another - indicates what the Race Committee will deem acceptable. If you have a different qualification, please contact the Race Committee ahead of time so that it can be evaluated.

Organisation	**Minimum Team Member qualification**
BSAC	Ocean Diver
PADI	Open Water Diver
NAUI	Scuba Diver
CMAS	1 Star
NASDS/SSI	Open Water Diver
SDI	Open Water Diver

72. In addition to proof of their qualification, divers will have to provide, **4 weeks before the Preparation Week,** evidence of having completed **a minimum of 10 logged dives** [**V5c**] as full qualified independent divers (i.e. the four dives completed during the PADI course do not count), and they will have to complete a waiver and a medical questionnaire similar to the ones required by the various training agencies. Paperwork will need to be uploaded to the subrace.eu website before the deadline. This will include scanned copies of divers' logbooks [**V5**]. Any team member who has not provided this information by the deadline will not be allowed to dive during the race [**V6**].

Surface Liaison Officer (SLO)

73. The Team's SLO will serve as the communication channel between the team and the race staff. This person must be "competent and knowledgeable in the diving being conducted and the operation (deployment, handling and use) of the submarine," but does not need to be a qualified Dive Leader/Divemaster". He or she must be familiar enough with the team's underwater procedures to be able to explain them to the race staff [**V7**]. The SLO may be a paid member of university staff.

Air Fill Technicians

74. Cylinders will normally be filled by a member of QinetiQ staff but if one is not available, cylinders will be filled by the teams themselves from a central bank which will be located between the lifts at the busy end of the Ocean Basin. Each team will designate two of its members to receive instruction in the safe filling of cylinders from the QinetiQ staff. Thereafter it will be up to the team to ensure that they have enough air supply that they do not miss their slot in the queue.

Team and Staff Communications

75. Race Control will liaise with each team through its Surface Liaison Officer. An underwater loudspeaker will provide direct acoustic communication between the Dive Coordinator and the underwater team. In water, the use of standard international hand signals is encouraged, so that every member of every team (including the rescue divers) can understand what is meant. In particular, as in other competitions, the recommended signal to start pedalling is a single arm rotating as if turning a crank.

Pre-requisites

Diving pre-requisites to operating with submarines

76. Before operating with their submarine all divers must have
    a. Provided all the required documentation
    b. Had their log book checked
    c. Attended the Ocean Basin safety brief
    d. Undertaken a familiarisation dive in the Ocean Basin [**O9**]

Submarine pre-requisites to start racing

77. Before entering the draw for position in the queue, each submarine must have
    a. Had a Dry Inspection by the judges and corrected any rule non-compliances
    b. Successfully completed the Wet Inspection by the Dive Coordinator [**O9**]
    c. Had the main hatch inspected by the safety divers

The Wet Inspection procedure

78. The Wet Inspection procedure is as follows:
    a. Load the pilot, connect to primary air supply
    b. Demonstrate operation of the emergency safety buoy
    c. Reload the safety buoy
    d. (Reload the pilot, connect to primary air supply)
    e. Shut and secure hatches
    f. Prepare for demonstration Start
    g. At the command "GO GO GO" – follow the Start procedure (para 86 below)
    h. At the command "STOP STOP STOP"
        i. Release the safety buoy
        ii. Open the hatch, switch to secondary air supply
        iii. Exit the submarine and stand alongside
    i. Swim to the surface staying on secondary air supply until taken by the team's support divers to the pit area

    NB. Step h. must be completed within 30 seconds [O10]

Operations

Submarine Launch and Recovery

79. Submarines will be launched using the main lift on the north (creek) side of the gantry. When a sub is ready for launching, the team should bring it around to the launching area. Protective (steel toe-cap) footwear MUST be worn by people moving boats on trolleys. When directed onto the lift, the team will move the sub into place then secure their trolley to the floor of the lift. All personnel will then stand clear of the lift, and it will be lowered by QinetiQ staff into the basin. Once the submarine is floating and the lift has stopped, team divers will be told to approach it from the basin side, and guide it out into the basin. They then will swim it to its designated preparation area on the bottom.

Diver Entry and Exit

80. Divers will enter and exit the water only via the Diver Marshalling area. The Dive Marshall will check and collect badges from all divers entering the area, and return them as they leave. Divers will don kit ashore, then step onto the beach structure and enter the water with the "giant stride" technique.
81. As the safety responsible person, the Dive Coordinator "Control" needs to know at all times how many divers are in the water and/or the pits and how long they have been exposed to the cold. A Divers Whiteboard will be sited between Control and the diver marshalling area. Each Surface Liaison Officer will be responsible for ensuring that his/her team is all accounted for, and that all entry and exit is done responsibly. The SLO is to record on the Divers Whiteboard the number of divers (including pilots) in the team and the times the team, as a whole, entered and left the water.

The Queue

82. To maintain order in the basin, and to ensure that all teams get a fair number of chances to race, the eISR will operate a queue system. Half of the participating teams will race in the morning, and the other half in the afternoon. A draw will be held the night before to determine the Order of Racing. Submarines which need repair and can therefore not take part in the next morning's heat will be scheduled for the afternoon heat. Submarines will then follow the Order of Racing throughout the heat. If a team is not ready to race when its turn is announced, then it forfeits that round and goes to the back of the queue. The Queue will be run by the Queue Manager ("Q"), who will work with the SLOs to ensure teams are available and ready when their turn comes up.

83. Throughout each session's racing, the location of every boat will be shown on a Race Whiteboard using magnetic strips bearing each boat's name. The left hand column will show the position of every boat in the queue as these positions change as a result of events during the session.

84. The Race Whiteboard and the Divers Whiteboard will be sited between Control and the diver marshalling area.

85. **SLOs Duties:** From the above it can be seen that reliance is placed on SLOs for two important functions affecting safety and the smooth conduct of the event:
    a. To assist the Divemaster maintain the record of divers in the water on the Divers' Whiteboard
    b. To provide the communication link between their submarine and the support divers in the water, and 'Q'

*"*GET READY"*[1]

86. The first stage of the START procedure is this order from Control for a team to prepare its boat for a run. The team should have a checklist of things to be done and inspected to make it ready. [If the boat cannot be made ready, the SLO is to inform 'Q' who will order the boat to the back of the queue and order the next boat in the queue to get ready].

The Set Box

87. At the command "*MOVE TO SET" support divers move the boat to the SET box. [If the boat is not ready to do this, SLO informs 'Q' and the boat is ordered to the back of the Queue]. In the SET box the pilot is loaded, hatches are secured, the lock is taken off the safety buoy release mechanism and a final check is made of the primary and secondary air bottle pressures. The boat is allowed to remain in the Set Box for up to 10 minutes. When ready to race, the lead support **diver signals "READY"** by facing an underwater camera with arms outstretched and both thumbs up. Control responds with **"I see that"** or **"Wait"**

The Start Box

88. At the command "*MOVE TO START. REPORT WHEN READY" support divers take the boat into the START box, line it up behind the Start Line and make a final check of the pressure in the air cylinders. One support diver signals "Ready" as in 85 above. Control asks all stations on the course to report – ["ready" reports received from Timing, Overhead, Safety Boat, Tow Boat and film team]. The boat is allowed up to 5 minutes in the Start box. [If this time is exceeded, or if the boat becomes unfit to race, the SLO informs "Q" and the boat is ordered to the back of the queue]

89. At the underwater loud hailer command "***GO GO GO**"
    a. All support divers swim clear of the boat except one diver at the bow facing aft and one other diver holding the body and clear of the propeller
    b. The diver at the bow
        i. Signals the other diver to swim clear
        ii. Signals the pilot "count 5 then pedal"
        iii. Releases the bow and swims clear
    c. The pilot counts 5 seconds then
        i. starts to pedal and steers towards the START line
        ii. Crosses the START line and maintains a straight course following the bottom rope to the timing gates.

The Finish Line

90. The end of the course will be indicated by a brightly coloured tape stretched along the floor between two upright PVC poles. Pilots must stop pedalling as they cross this line, and deploy their braking system (if fitted).
91. Once the submarine has crossed the finish line and is slowing to a stop, the support divers approach and take control of the boat, returning it and the pilot to the pits.

[1] The asterix * is used to signify the name of the boat being ordered

Aborts on the Racecourse

92. Aborts will occur for a variety of reasons. Some will be due to technical malfunctions, usually transmission failures (eg chains coming off). Pilots should also feel free to indicate an abort if they get lost in the tank [**O1**]. The "dead man switch" design requirement of the safety buoy release system will ensure it also deploys in the event of the pilot being incapacitated.
93. Accidental release of the buoy beyond the starting line will automatically abort a run, and the abort procedure is then to be followed [**O2**]. The Dive Controller will signal to a pilot via the loudhailer that the run is aborted by the command "***STOP STOP STOP**"
94. When the pilot has deliberately indicated an abort, he/she should immediately open the main hatch [**O3b**]. This will be the signal to the rescue team that all is well, and no rescue is required. The pilot can then undo any restraint systems [**O3c**], switch to the secondary air supply, exit the craft, swim to the surface [**O3f**] and await the rescue boat [**O3g]** If the pilot is unable to release the hatch and leave the submarine, safety divers will enter the water and go to the submarine. The pilot is to leave himself in their care, release himself from toe straps and any other constraints and, if possible, indicate to the safety divers that he is OK.
95. The pilot must retain his/her weight belt, keep mask on and regulator in the mouth, until secured by the rescue boat at the surface [**O3g,h; O7**].
96. A team aboard the tow boat will raise the submarine using its safety buoy line. The submarine will then be returned back to the starting area, where it will be handed over to the team's support divers. They will then return the submarine to the back of the Queue.

Interval Between Runs

97. As soon as the SET box has been vacated by the preceding boat, Control will order the boat getting ready to move to SET and the next boat in the queue to Get Ready. If there is an incident on the course that Control believes will take some time to clear, he will delay the order to avoid the boat's air being used during a prolonged delay.

Timing System

98. Timing is based on video recording of the submarines moving past specific markers filmed using underwater video cameras.

Video

99. Underwater video cameras are placed throughout the tank so that the progress of the submarines can be monitored by those ashore. Timing specific cameras are placed at the starting line, at both timing gates, and at the finish line. These cameras record at 50Hz to a central digital video recorder. During a run, a member of the timing team watches the live feed and uses a stopwatch to generate a first estimate of the submarine's speed. After the run is complete, whether successful or aborted, the timing team rewind the recording and extract the video frames at which an identified marker (often the tip of the nose, but sometimes a stabiliser fin) crosses the frame directly above the tar tracks on the floor. These timings are processed by a dedicated computer programme and sent to the scoreboard.

Results Boards

100. Results will be posted to a set of electronic scoreboards placed around the basin. Times, speeds, and faults will be presented. The results will be posted as soon as they are available.
101. The scoring system is described in Appendix B.

Sensible Safety

Diving

102. Submarine racing is a lot of fun, but it does bring with it risks which need to be managed. The Race Organisers have put in place a set of procedures and rules which will manage many of the risks associated with the sport, but in the end it is the pilot and support divers who bear the major responsibility for their own safety.

103. Transport of pilots from the surface to the submarine on the bottom: The following is not a "rule", but a "recommendation", as the race does not dictate to divers how they are to dive. Every team dives according to its own certification agency's rules, regulations and recommendations.

    In order of preference:

    Option 1: The pilot should dive independently, with his/her own BCD/Cylinder/Breathing apparatus, and remove kit on arrival at the submarine. A support diver can return the kit to the surface once the submarine has left the start box. A dive rope will be provided for the pilots' use so that they can descend slowly, even without the control provided the support divers by their fins.

    Option 2: The pilot dives with a support diver, breathing off the support diver's "octopus". Such diving behaviour requires very careful coordination by the diver pair, and should be practiced regularly before attending the races. Both pilot and support diver should be in constant eye-to-eye contact during the descent. "Riding" the support diver's cylinder is discouraged but not forbidden, as long as a robust and practiced communication system between diver and pilot is in place. As the more vulnerable diver of the pair, the pilot should lead the dive and call off any further descent, and not hesitate to let go and ascend on his/her emergency air if necessary to avoid injury. Under no circumstances should either diver be "dragged down" by the other.

104. Moving the submarine: Ascents and descents must be taken SLOWLY. The support divers control the descent of the vehicle to the bottom and must make sure the crew is not experiencing ear clearing problems or any other distress during descent. Visual contact is needed with all crew members during the entire descent. The support divers have control of the vehicle prior to the start and must make sure the crew is okay at all times.

105. Pilots: Remember that ascent is controlled by the vehicle, not the diver! It may sometimes be more rapid than free diver ascent, particularly if air gets trapped in a nose or tail cone. This means that you must continue to breathe during the entire human powered submarine operation. NEVER HOLD YOUR BREATH!! It's a good idea to keep at a constant depth during the race – focus on keeping a constant distance from the bottom.

106. Further advice

a. For the safety of the pilot and anyone else in the water, it is imperative that everyone obey the commands issued by the Race Controller. Only this person is in a position to see everything that is going on, and only he or she can coordinate everyone's activities. If you are asked to do something, just do it – unreasonable requests will not be made, even though they may at times seem so.
b. DON'T PANIC. If things go wrong, focus on your air supply. Reach for your secondary supply and focus on breathing. Many eyes are watching, so just sit tight and wait for rescue.
c. Always cede control of a situation to a more experienced person. The rescue divers are highly qualified and experienced people, who have likely seen and dealt with many more situations than you have, so let them do their jobs.
d. 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!! This is also a requirement at the surface, until positive buoyancy can be established for you.
e. Do not remove your weight belt at the bottom, except in an emergency. There should be no need to shoot for the surface. Obviously in a true emergency, do as you've learned in your training.
f. Your alternative air supply is your lifeline. The rules have deliberately over-specified its size, so that in the event of an emergency where you can't get the hatch open, or can't free yourself from the pedals or other restraints, you don't have to worry about your air while you wait for the rescue team or deal with whatever the problem is.

107. Other advice which will help ensure your experience is a safe one:

a. 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.
b. Be careful of hand placement when closing the hatch, especially in the water. Always hold the sub with your hands away from the hatch opening and say "CLEAR" before closing the hatch. Also, be careful not to let SCUBA equipment get in the way of closing.
c. Never position yourself under the submarine during any operations, either in or out of the water.
d. BEWARE OF THE PROPELLOR/PROPULSION UNIT DURING OPERATION AND STAY CLEAR WHEN IT IS ROTATING.
e. The submarines may have sharp edges, bolt heads, hoses and hatches that can cut or pinch hands and snag SCUBA equipment. BE CAREFUL.

Lithium Ion and Lithium Polymer Batteries

108. Modern lithium based batteries are used in a huge variety of applications with Lithium Polymer (LiPo) becoming standard for radio controlled applications. Lithium based batteries are becoming so widely used that their infrequent failures attract a lot of adverse media coverage. Entries for Submarine Racing events are progressively adopting electrical control and automation systems and the battery of choice is emerging as the LiPO. As more systems rely on electrical power the capacity of the battery is increasing and the risk of hurt to pilot and crew increases. This note is to outline some of the safety issues arising from use of these batteries and to recommend a design approach. In future eISR events the judges will wish to be convinced that battery safety has been addressed and the risk to personnel is reasonably low.

109. Background: LiPo batteries come in a range of capacities, normally quoted in mAh, and discharge capabilities normally quoted as a C rating, A typical top end high capacity battery might be 7.4Volts, 5200mAh 30C; this battery can deliver 30 x 5.2 amps for a period of about 2 minutes with the battery exterior rising to perhaps 180^0C. The I^2R losses in all of your system carrying high currents are a significant design consideration. At high temperatures LiPo batteries can suffer a thermal run away and self-destruct. Damaged LiPo batteries charged by simple chargers are at risk of thermal runaway.

110. Safety features: European and North American industry sourced LiPo batteries can be expected to have internal protections to prevent damage in extreme conditions by limiting current surges, disconnecting the battery if cell pressure rises, venting gases out from the battery at high cell pressures and inhibiting ion flow in the cell by melting some material at limiting temperatures. The quality of the individual cells and their assembly into a reliable and safe battery is well regulated in European and North American industries but sometimes less well so from Asian industries.

111. Advice

- Buy batteries and chargers from quality suppliers and understand the inherent protection.
- Keep the batteries dry in a well-sealed pressure vessel.
- Protect the battery by adjacent disconnection if your system imposes a fault (typically a fuse).
- Design your pressure vessel to manage the gas release from a battery thermal runaway (contain or safely vent).
- Only charge the batteries outside the submarine and consider using a fire retardant bag.
- Undertake a risk assessment (identify the hazards, evaluate the risk and implement mitigation).
- A different technology battery will also be hazardous.

Design Reports

112. The eISR is as much an engineering design competition as it is a sporting event. The design aspect of the competition will be evaluated by means of two written documents and a presentation.

113. The first document is a single page giving the principal parameters, namely:

Name of the submarine
Length overall
max beam
hull weight & contained volume
positions of C of G and Centre of Buoyancy
type of propulsion
type of propeller /fins
propeller rpm /fin cadence
pedal cadence : propeller shaft gear ratio
type of control of hydroplanes & rudders

114. The second document is a design report which fully describes the vessel. The report is to use the sequence of subjects given in **Annex B2: The Design Report Marking Scheme**. The report should provide a concise account of each topic. The Design Report should also provide a Compliance Matrix verifying that the Design Rules have been met. [**D15**].

115. An award will be presented to the team which produces the best design report. After the event, the reports may be compiled and made available on the subrace.eu website as an educational resource for future teams and others interested in human-powered submarine racing.

116. The final academic aspect of the judging will be a public display by the team to the judges, other contestants and the general public. Teams will be required to prepare a static (poster, revolving Powerpoint presentation, or something similar) presentation to explain their concept to the general public during the Open Day. Because these presentations will be open to the public, attending VIPs and the media, teams are encouraged to put some thought into the presentation format! This is your opportunity to sell your design and show off the work that went into making it into a functioning whole. There will be an award for best presentation.

In-Water Testing

117. Experience shows that submarines entering eISR for the first time are often unable to take advantage of the unique experience of operating in Qinetiq's Ocean Basin and fail to be able to compete effectively because they have had insufficient in-water testing before coming to the event. Project plans should include plenty of time after completion of submarine construction for in-water testing in order to ballast and trim the boat with pilot in place and to test the controls and propulsion. A long course is not needed. The propulsion can be tested by tethering the boat and measuring "bollard pull". If this is not done, the team risks being severely disappointed by not experiencing the reward of all their hard work.

Judging

Judges

118. The judges are:

- Vice Admiral Sir Robert Hill KBE FREng Hon FIMarEST (Head Judge)
- Gan Jenkins RCNC CEng FIMarEST
- David Mattick CEng FIMarEST
- John Clayden CEng FIMarEST
- Liz Whitrow CEng MRINA
- Claire Machin CEng MIMarEST

Prizes

119. Awards are given for speed and agility. The top prize combines the two, and includes a significant element of design and manufacture, to encourage creativity and innovation.

a. **eISR Trophy and Runner Up**
   a. The overall winner of the eISR Trophy will be determined by a formula combining design, manufacture, race performance, reliability and poster display as shown in Annexes B and C below:

b. **Week's Top Speed**
   a. The winner of this award will be for the fastest transit of the timing gates during the week. The sub must complete the run for the speed to stand.

c. **Agility Award**
   a. On the last day of the competition, qualifying teams will run a double-length course, twice through the timing gates and slalom course to provide an agility challenge. Teams will have to qualify to compete during the course of the week:

d. **Award for Innovation**
   a. This prize will be presented to the team, which in the judges' combined opinion, has pushed the engineering innovation envelope the furthest. By its very nature, innovation is hard to categorise, but the eISR's experienced panel of submarine engineers will recognise it when they see it!

e. **Best Presentation**
   a. This award will go to the team which best presents its submarine design visually and verbally during the poster display on the Wednesday Open Day

120. The previous winners are:

	eISR Trophy	
2012	***Omer 8*** - Ecole de Technologie Superieure, Quebec, Canada	
2014	***Omer 9*** - Ecole de Technologie Superieure, Quebec, Canada	
2016	***Taniwha 2*** – University of Auckland, New Zealand	
2018		
	Runner up	
2012	***Talon 1*** - Florida Atlantic University, USA	
2014	***Archimede V*** - Ecole Polytechnique de Montreal, Canada	
2016	***WASUB VI*** – Delft University, Netherlands	
2018		
	Third Place	
2012	***Minerva*** - University of Bath	
2014	***Mayflower*** – University of Plymouth	
2016	***What Sub Dawg*** – University of Washington, USA	
2018		
	Top Speed	
2012	***Omer 8*** - Ecole de Technologie Superieure, Quebec, Canada	
2014	***Omer 9*** - Ecole de Technologie Superieure, Quebec, Canada	
2016	***WASUB VI*** – Delft University, Netherlands	
2018		
	Agility Award	
2012	***Omer 8*** - Ecole de Technologie Superieure, Quebec, Canada	
2014	***Omer 9*** - Ecole de Technologie Superieure, Quebec, Canada	
2016	***WASUB VI*** – Delft University, Netherlands	
2018		
	Innovation	
2012	***Wolverine the Submarine*** - University of Michigan, USA	
2014	***Inia*** - Rhine Waal University of Applied Sciences, Germany	
2016	***Omer 10*** - Ecole de Technologie Superieure, Quebec, Canada	
2018		
	Best non-propeller biomimetic	
2012		
2014	***Taniwha*** – University of Auckland, New Zealand	
2016	***Taniwha 2*** – University of Auckland, New Zealand	
2018		
	Best Presentation	
2012	***Minerva*** - University of Bath	
2014	***Omer 9*** - Ecole de Technologie Superieure, Quebec, Canada	
2016	***Skookumchuck II*** – University of British Columbia	
2018		