EUROPEAN INTERNATIONAL SUBRACE

POWERED BY IMAREST

European International Submarine Races

Biennial Races

Contestants' Rule Book

Dated August 2023
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REVISION HISTORY

Revision No	Date of Issue	Description of Change
1.0	16 January 2022	Reformatted
1.1	21 January 2022	Amendment to Appendix B.
1.2	14 February 2022	Title changed. Correction of typo to Annex A Para 20. Clarify provided regarding the attendance of university staff - Para 84 and 85, rule V1b. Clarity to the diver's documentation requirements – Para 91, rule V5b.
2.0	16 August 2023	General overhaul of rulebook.

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1. INTRODUCTION

1.1. Applicability

(1) This document is applicable to the European International Submarine Race (eISR) event.

1.2. Purpose

(2) The purpose of the eISR Rulebook is to clearly define for all participants the rules for the eISR that must be followed by all participating teams.

1.3. Document Contents

(3) In addition to the rules, the eISR Rulebook provides the scoring used at the eISR Event, as well as details of the prizes that are awarded on conclusion of the eISR.

(4) Appendix A to the eISR Rulebook contains the procedures that must be followed during the eISR Race Event. The procedures are for the following activities:

- Wet Test,
- Racing,
- Operation,
- Safety, and
- Race Course.

(5) Annex A to the eISR Rulebook is provided as guidance. It provides best practices and information teams may find useful based on experience.

1.4. Document Updates

(6) This document is updated, as required, to include the feedback and recommendations from previous eISRs.

1.5. About The eISR

(7) The European International Submarine Races (eISR) challenges teams of university students to design, build and race human-powered submarines against the clock around a pre-defined course. The concept combines engineering design challenge with technical skill development and sets them in a unique and exciting sporting competition.

(8) 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.

(9) The resultant designs are submarines in the fullest sense of the word, minus the one constraint of watertight hull. 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 is encouraged.

(10) The eISR is 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 is not so great to prevent the teams from making their own the parts; this provides an invaluable learning experience as they see their CAD drawings come to real life.

(11) The eISR is about working as a team in a time-critical, adrenaline-charged atmosphere. During the build-up to the race, the teams learn to exploit each other's strengths, and design into their submarines what they think they will need to succeed at the races. In initial testing, the teams learn where the weaknesses are,

and make considered adjustments to their designs. Then, once the teams arrive on the racecourse, and really put their submarines to the test, the teams 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.

1.6. Race Committee and Officials

(12) The eISR is provided by the Institute for Marine Engineering, Science and Technology (IMarEST), in partnership with QinetiQ. The Race Committee consists of:

- **Race Director**: Prof William Megill.
- **Business Director:** Frank Mungo.
- **Head Judge:** Liz Whitrow.
- **QinetiQ Head of Site:** Simon Rignall.
- **QinetiQ Diving Safety Officer:** Shaun Samways.

(13) The racing is organised by the following Officials:

- **Dive Coordinator ("Control")** – responsible for all safety in the water.
- **Queue Manager ("Q")** – responsible for organising the sequence in which boats race.
- **Overhead Observer ("Overhead")** – responsible for keeping watch over the course from the overhead gantry, keeping Control informed of all events
- **Dive Master** – responsible for controlling all diver operations and maintaining the state of the diver whiteboard

1.7. Affiliations

(14) eISR is completely distinct from, and not sponsored, endorsed, nor otherwise associated with the long-running International Submarine Races held biennially in Bethesda, MD, USA, and organised by the Foundation for Underwater Research and Education.

1.8. Liability

(15) 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 on hand. 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, QinetiQ and the Race Committee assume no liability for injury to participants, nor for 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.

(16) It is the responsibility of every individual and team to secure and look after their own equipment. QinetiQ, IMarEST and the Race Committee accept no liability for loss, damage or theft. Although help and support amongst teams is encouraged, it is a team's responsibility to ensure their equipment is clearly identifiable and they know where it is located.

1.9. Location

1.9.1 Venue

(17) The eISR is held at QinetiQ's Ocean Basin testing facility at Haslar, Gosport, England. The racing is conducted in the Basin which measures 122m x 61m, 5.5m deep. The water within the Basin is swimming pool quality; however, it is not heated. Water temperatures are typically about 15C/60F. The water is lightly chlorinated, and a pH of about 8.2 is maintained. The facility is well lit, with large windows and skylights.

(18) The bottom of the Basin is clean, and the water clear. There are a number of structures along the bottom and around the edges of the Basin, so care must be taken when operating near these structures.

1.9.2 Security

(19) The Ocean Basin is within QinetiQ's Haslar Technology Park which is a secure facility. As such, all eISR participants must wear, and have visible the QinetiQ issued identification at all times. Access is only granted to the Ocean Basin, therefore participants must not wander about the site. Anyone found wandering unescorted around the facility will be removed from the grounds and will only be permitted to re-enter the site at the discretion of the QinetiQ management.

(20) The use of cameras (video or still) outside designated areas is not permitted. The designated areas will be identified at the start of the event.

(21) The possession of or use of illegal drugs is absolutely prohibited anywhere on the QinetiQ site or the campsite. Anyone found in possession of or using illegal drugs will be reported to the Police.

(22) Alcohol is not permitted anywhere on the QinetiQ site. Being found in possession of alcohol may lead to disqualification of the offender, and the offender's team from further participation in the current eISR event, and future eISR events.

1.10. Definitions

(23) The definitions defined in Table 1-1 are used within the eISR Rulebook.

Table 1-1: Definitions

eISR Event	A year long programme which includes the registration, qualification, Captains Meetings and culminates in the eISR Race Event.
eISR Race Event	The Preparation Week and the Race Week
Captains' Meetings	Meetings held between the Team Captains and the eISR Support Team
Preparation Week	The week immediately preceding the Race Week
Race Week	The week during which the racing takes place
Pilot	The diver(s) within the submarine during the racing.
Support Divers	The divers from the Team who prepare the submarine in the water
Rescue Divers	Members of the eISR Support Team who provide diving support to the divers
Team	The members from the University
Ocean Basin	QinetiQ Ocean Basin in Haslar, UK where the eISR Event is run
Submarine	A flooded underwater vehicle propelled by a fluid-coupled device (e.g., propeller, jets or wings), which fully encloses one or two pilot(s) and all of the control and propulsion mechanisms.
Safety Divers	Members of the eISR Support Team who provide surface support to the divers
Surface Liaison Officer (SLO)	Member of the Team that remains ashore and is the point of contact between the Team and the eISR Support Team. The contact within the eISR Support Team will depend upon the nature of the query/concern.

2. EISR RULES

2.1. Team Eligibility and Composition

(24) The eISR rules associated with team eligibility and composition are provided in Table 2-1.

Table 2-1: eISR Rules Team Eligibility & Composition

Rule No	Rule
G1.	The eISR Event is open to teams of university students and alumni. All members of the team must be over 18 years of age before the start of the Preparation Week.
G2.	University professors and advisors are permitted to attend the eISR Event, however, they are not permitted to enter the water during the Preparation Week or the Race Week.
G3.	All divers must be amateurs, i.e., they must not be paid to take part in the eISR Event.
G4.	All divers must have the minimum dive qualification EN 14153-2 or ISO 24801.
G5.	Teams must provide, a minimum of 4 weeks prior to the start of the eISR Race Event, the dive training organisation's rules they will be following.
G6.	All divers must be qualified to dive independently, i.e., without an instructor, by an internationally recognised dive training organisations. Examples of internationally recognised dive training organisations and their EN 14153-2 equivalent certifications include: • BSAC – Ocean Diver. • PADI – Open Water Diver. • NAUI – Scuba Diver. • CMAS – 1 Star. • NASDS/SSI – Open Water Diver. • SDI – Open Water Diver.
G7.	Each team must provide a Surface Liaison Officer (SLO).

2.2. Submarine Design

(25) The eISR rules associated with the design of the submarine are provided in Table 2-2.

Table 2-2: eISR Rule Submarine Design

Rule No	Rule
D1.	If a submarine hull is being re-used, it must have only been used in one other eISR Race Event.
D2.	If a submarine hull is being reused, it must have had a major refit, e.g., a new propulsion system.
D3.	Submarines must be designed to be operated by one or two pilots.
D4.	The submarine length, excluding appendages, must be 5.5 m or less.
D5.	The submarine width, excluding appendages, must be 1.5 m or less.
D6.	Any submarine appendage that extends beyond the maximum dimensions, as defined in D4 and D5, must be configured so that it can be attached and removed by the Support Divers when the submarine is in the water.
D7.	The submarine's centre of gravity, when out of the water (dry or draining) must be between 2.1m and 3.1m from the bow or stern extremity of the submarine.

D8.	The submarine must have a free flood hole or drain hatch opening sited on the underside of the vessel, close to the longitudinal centre of gravity position, with the following minimal dimensions: • I -pilot submarine: 117cm^2 [18in^2] • 2-pilot submarine: 233cm^2 [36in^2]
D9.	The submarine's propulsion must be water coupled.
D10.	The use of wheels or other mechanisms that generate movement of the submarine through friction along the bottom or the walls of the eISR racecourse are prohibited.
D11.	The submarine may swap between propulsion and/or control options throughout the eISR Event, unless directed otherwise by the Head Judge at the start of the eISR Event.
D12.	The submarine's propulsion system(s) must be directly coupled to the pilot(s).
D13.	The use of clutches within the submarine's propulsion system is prohibited.
D14.	Energy storage systems are permitted, only where all the energy is created, stored and dissipated during the Run itself, e.g., resonant elastic structures on oscillating biomimetic fins.
D15.	Flywheels or other energy storage devices which can be loaded before the submarine crosses the start line of the eISR racecourse are prohibited.
D16.	The use of hydraulic, pneumatic, or electric transmission systems are permitted, only if all of the energy used for propulsion is produced by the pilot(s).
D17.	The use of any fluid other than water within the submarine's hydraulic system(s) is prohibited.
D18.	The use of oil anywhere within the submarine, including within sealed watertight electronic component containers, and within the team's area in the Ocean Basin is prohibited.
D19.	The submarine must only use water-resistant grease to lubricate boxed gearing.
D20.	It is forbidden to use the pilot's onboard air supply (primary and backup) for any other purpose than life support.
D21.	The submarine electric systems must not exceed 24V DC.
D22.	If fitted with batteries, the type of battery, the battery location and how the battery can be isolated must be detailed close to where batteries are fitted.
D23.	The use of expelled air from the pilot(s) to create thrust, in any direction, is prohibited.
D24.	The tips of all moving parts and appendages extending away from the submarine hull must be high visibility orange in colour.
D25.	All internal and external handles and release mechanisms used to exit the submarine must be marked with a high visibility orange patch, a minimum of 10 cm^2.
D26.	External handles and release mechanisms used to exit the submarine must be marked in high visibility orange with the word "rescue".
D27.	All handles or release mechanism used to exit from the submarine must be readily accessible from both inside and outside the submarine.
D28.	Each pilot must have a separate exit hatch.
D29.	For 2-pilot submarines, a visual indicator must be provided for each pilot that shows that either: • both pilot exit hatches are in place and shut, or • one or both pilot exit hatches are open.
D30.	All pilot restraints within the submarine, e.g., toe clips or shoulder straps, must have the release mechanisms clearly identified with high visibility orange material.

D31.	The submarine pilot's face must be visible from outside the submarine when the pilot is in the submarine in the racing position, with the main hatch closed. In two-crew submarines, this applies to both pilots.
D32.	The submarine must be equipped with a high visibility emergency pop-up (surface marker) buoy.
D33.	The emergency pop-up buoy must have a net buoyancy (natural buoyancy minus weight) of at least 500 grams
D34.	The emergency pop-up buoy must be attached to the submarine by 10m of floating, highly visible line.
D35.	The emergency pop-up buoy (float) line must be stowed so that it cannot be a hazard to the Pilot(s).
D36.	If the emergency pop-up buoy (float) line reel is inside the hull, the line between the reel and the stowed emergency pop-up buoy must pass through a tube so that it does not snag on any fitting when the emergency pop-up buoy is released.
D37.	The emergency pop-up buoy must either form part of the hull or be contained in a fully flooded compartment inside the submarine hull.
D38.	The emergency pop-up buoy must be secured to the submarine hull to prevent it from floating to the surface unless it is intentionally deployed.
D39.	The emergency pop-up buoy must be deployed automatically should the pilot become incapacitated (e.g., "dead man's handle").
D40.	In 2-pilot submarines, each pilot must have a release mechanism that automatically releases the emergency pop-up buoy should either pilot become incapacitated.
D41.	Override mechanisms on the emergency pop-up buoy are permitted while the submarine is behind the starting line.
D42.	Use of override mechanisms on the emergency pop-up buoy once the submarine has crossed the starting line is prohibited.
D43.	All submarine hatches must be permanently attached to the submarine by means of hinges, straps, or other similar mechanisms.
D44.	The mechanism permanently attaching the hatch to the submarine must not restrict the pilot's ability to exit the submarine in any way.
D45.	Drag reducing coatings on the submarine are permitted, so long as they are not able to slough off the submarine into the Ocean Basin.
D46.	The use of drag reducing hull coatings must raised to the Head Judge during the design stage. Failure to do so may cause the team to be prohibited from entering the Ocean Basin. The Head Judge reserves the right to prohibit the use of the coating if it is considered there is a risk of contamination of the Ocean Basin

2.3. Breathing Air Supply

(26) The eISR rules associated with breathing air supply are provided in Table 2-3.

Table 2-3: eISR Rules Breathing Air Supply

Rule No	Rule
B1.	A primary air supply for each pilot must be carried aboard the submarine with sufficient capacity to complete a run at speed and not fall below the minimum pressure specified in Rule B2.
B2.	The pilot(s) must not allow the primary air supply to fall below 50bar (725 psi).
B3.	The pilot's air pressure gauge must be visible to the pilot when inside the submarine.
B4.	With the pilot(s) in the submarine and all hatches closed, the pilot(s) must be able to communicate the pressure of their primary air supply to a support diver.

B5.	Each pilot must carry a secondary independent air supply with a capacity of no less than 3 litres.
B6.	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).
B7.	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.
B8.	All divers must not let their air cylinders drop below 50bar (725psi) - Repeat low remaining pressure offences may result in the diver (pilot or support diver) being excluded from the competition. Air supply 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
B9.	All breathing air must be supplied using an open-circuit SCUBA system, and use compressed normal atmospheric air. Special gas mixtures, e.g., nitrox, are prohibited.
B10.	Re-breather systems are prohibited.
B11.	The Team must provide evidence of qualified servicing of all first and second stage regulators within one (1) year of the end of the Event.
B12.	All air cylinders must be correctly labelled in accordance with European Standard EN 1089-2, with a label displaying the green compressed-gas hazard diamond.
B13.	All air cylinders must clearly display current hydrostatic test and visual inspection dates
B14.	• All air cylinders must be CE certified to appropriate EN or BS Standards that are suitable for PPE/breathing apparatus. The current standards are: • EN 1964:2000 Transportable gas cylinders – Seamless Steel, • EN 1975:2000 Transportable gas cylinders – Seamless Aluminium, • EN 12245:2002 Transportable gas cylinders – Fully wrapped composite, • EN 12257:2002 Transportable gas cylinders – Seamless hoop-wrapped composite, • BS 5045-7:2000 Transportable gas containers – Seamless Steel, and • BS 5045-8:2000 Transportable gas containers – Seamless Aluminium.

2.4. Submarine Transport

(27) The rules associated with submarine transport are provided in Table 2-4.

Table 2-4: eISR Rules Submarine Transport

Rule No	Rule
T1.	If a crate is used to transport the submarine and support equipment to the Ocean Basin, each laden crate must have a weight no greater than one (1) metric tonne (1000 kg).
T2.	Once within the Ocean Basin facility, the submarine must use a trolley (cart) to transport the submarine between the team's working area and the launching lifts (elevators).
T3.	The trolley (cart) must be strong enough to take the weight of the submarine and any water contained within it during the process of lifting the submarine out of the water.
T4.	The draught of the submarine and the trolley (cart) must not exceed 1.2m.
T5.	The trolley (cart) must be, at max, 5kg negatively buoyant
T6.	The trolley (cart) must secure the submarine so that it does not float off the trolley (cart) in 1.2m of water.
T7.	The transverse distance between the wheels of the submarine trolley must be between 500mm and 750mm.

2.5. Operation

(28) The eISR rules association with the operation of the submarine are provided in Table 2-5.

Table 2-5: eISR Rules Operation

Rule No	Rule
O1.	Pilots must indicate an abort by releasing an emergency pop-up buoy:
O2.	Accidental release of the emergency pop-up buoy after the Start Gate will automatically abort a run.
O3.	After the emergency pop-up buoy has been deployed, whether intentionally or by accident, the pilot(s) must follow the Abort procedure.
O4.	If the command "[Submarine Name] STOP STOP STOP" is given, the Abort procedure must be followed.
O5.	On intentional release of the emergency pop-up buoy, the pilot(s) must immediately undo any restraint systems, switch to their secondary air supply, exit the submarine, remain with their submarine, and await rescue.
O6.	The pilot must retain their weight belt, keep mask on and regulator in the mouth, until secured by the rescue boat at the surface.

2.6. Race Event Pre-Requisites

(29) The eISR rules associated with the pre-requisites that must be completed prior to the Race Event are provided in Table 2-6.

Table 2-6: eISR Rules Race Event Pre-Requisites

P1.	All team divers wishing to dive at the event must upload the following documents to the moodle.subrace.eu website a minimum of 4 weeks prior to the start of the eISR Race Event: • proof of their qualification, • evidence of having completed a minimum of 10 logged dives as a full qualified independent diver, i.e., the four dives completed during the PADI course do not count, • scanned copies of their divers' logbooks, and • a waiver and a medical questionnaire, similar to the ones required by the various training agencies. http://www.uksdmc.co.uk/downloads/self-cert-form-2013.pdf http://www.padi.com/english/common/courses/forms/pdf/10063-ver2-0.pdf
P2.	All team divers must attend the Ocean Basin Safety Brief before entering the water.
P3.	All team divers must have had their dive logbook checked by the identified member of the eISR Race Committee or delegate before entering the water.
P4.	On successful completion of P2 and P3, all team divers must undertake a Basin Familiarization Dive as specified in the Ocean Basin Safety Brief.
P5.	The Dry Inspection must be successfully completed before teams are permitted to commence the Wet Test procedure.
P6.	The Wet Test procedure must be successfully completed before teams are permitted to attempt Runs.
P7.	Teams must have their submarines main hatch inspected by the rescue divers before being permitted to attempt Runs.

2.7. Design Specification and Report

(30) The eISR rules associated with the design specification and report are provided in and Table 2-7.

Table 2-7: eISR Rules Design Specification and Report

Rule No	Rule
R1.	The team must produce a single page document that provides the principal parameters of their submarine in accordance with Section 3.1.
R2.	The team must produce a Design Report that follows the template provided in 3.2 .
R3.	The Design Report must include a Compliance Matrix verifying that all the Design Rules have been met.
R4.	The Design Report must include calculations that demonstrate the primary air supply carried by the pilot complies with Rule B1. It should be noted that sports diving consumption rates at depth must be used.

3. REPORTING

3.1. Single Page Submarine Parameter

(31) The single page Submarine Parameters sheets as specified in Rule R1 must contain the following details:

a. name of the submarine,
b. length overall,
c. maximum beam,
d. hull weight and contained volume,
e. positions of Centre of Gravity and Centre of Buoyancy,
f. type of propulsion,
g. method and type of propulsion,
h. propulsion rpm / cadence,
i. pedal cadence, including shaft gear ratio, and
j. type of control of hydroplanes & rudders.

3.2. Design Report

(32) The design report as specified in Rule R2 must contain the sections as detailed in Table 3-1. The maximum marks per section is also provided in Table 3-1.

Table 3-1: eISR Design Report Required Sections & Marking Scheme

Section	Description to cover	Marks
TITLE PAGE	Must contain as a minimum: a) Date. b) University Name. c) Submarine Name. d) Team Members.	/5
EXECUTIVE SUMMARY	The executive summary must be written in such a way that the reader can understand the broad aspects of report. The executive summary helps the reader understand the requirement and implication on their interest areas.	/5
ABBREVIATIONS	List all the abbreviations that are used in report.	/5
TABLE OF CONTENTS	Include Section titles, Tables, Figures, Appendices and Annexes (if included), and page numbers	/5
INTRODUCTION	Provide a clear and concise definition of the purpose of the report, who has written, and the objectives of the design. Include appropriate background on the project for the reader to be able to put the information provided in context.	/10
DESIGN PHILOSOPHY	Provide the overarching principles that guided the design process of the submarine and describe your ongoing review	/10

	and assessment testing to ensure alignment to those philosophies. Include any assumptions and/or constraints.	
DESIGN OPTIONS	Discuss other design options that were considered, and why they were discounted. Provide details about each option by mentioning advantages and disadvantages. Include all important deign decisions made during design development. Present results/ outcome graphically, in tabular format or in text as appropriate. Mention what could be achieved or not achieved through each design option. Provide commentary about how the outcome/ results match with design philosophy and criteria.	10
ENGINEERING ASPECTS & DESIGN DETAILS	Provide details of the various components used in the design in terms of their applicability, engineering logic, availability etc. Discuss how these components meet the design requirements. Discuss how the components fit the overall picture of project and how the design components are integrated with other components. Clearly state if any part of the design is being re-used from a previous eISR or ISR event. Provide details of any software used for design development including version details. The following components must be discussed.	
Hull	Hydrodynamics, shapes of hull, hatches, materials, manufacturing methods.	/10
Propulsion	Propellers, fins, type and design, materials	/10
Propulsion System	Drive train, transmission, materials	/10
Trim, Hydrostatics & Stability	Weight estimations & volume calculations , centre of gravity, centre of buoyancy, centre of lateral resistance, trim and compensation ballast/buoyancy, ballast plan, stability with and without pilot.	/10
Control Surfaces	Pitch & depth control, control surfaces, design of rudders & hydroplanes, design of fixed planes, materials	/10
Controls	Pilot controls, transmission, control surfaces actuation, automatic and manual system design and manufacture	/10
Ergonomics & Pilot Biomechanics	Pilot positions, biomechanics, visibility, instrumentation,	/5
Safety Aspects	Pop up buoy, release system/release preventer, pilot constraints, Pilot hatch/hatches	/10
TEST & TRIALS	Provide detail of tests and trials plans. Where available, provide results and achievements	/5

CONSTRUCTION, MAINTENANCE & REPAIR	Construction methods, including health and safety aspects, maintenance requirements, accessibility for repair, spare parts, tools required.	/10
ENVIRONMENTAL IMPACT	Provide details on how the submarine was designed to minimize its environmental impact throughout the submarine's lifecycle - design through to disposal	/10
GENERAL ARRANGEMENT	Provide a general arrangement of the finalized design.	/10
FUTURE DEVELOPMENT & LESSON LEARNED	Provide a description of any elements within the design, build and trials process that you would change if you did it again. Provide any additional lessons learned.	/5
SUMMARY/CONCLUSIONS	Provide conclusion of the design developed, by highlighting the fulfilment of design philosophy. Add commentary on how the design meets the original objective.	/10
REFERENCE	Include all references referred to in the report.	/5
APPENDICES		/10
Compliance Matrix	Showing how each of the rules contained with the eISR Rulebook has been satisfied.	
Supporting Calculations	As necessary.	
Other Supporting Material	As necessary.	

Overall Document Format & Presentation	The report must have proper page numbering. The report must use a consistent font which is easy to read and understand and looks professional. The report must have clear and readable figures, sketches, drawings, tables etc. Each figure, sketch, drawing, and table must be labelled using an appropriate label, must be referred to in the text, and must be included in the Contents Page. The report must have page and section breaks in appropriate places. The report must have consistent Headers and Footers. If abbreviations are used, they must be listed in the abbreviation section. If abbreviations are used, they must be spelled out in full the first time they are used, and then used in the abbreviated form for the remainder of the document. The report must have been adequately checked for incorrect spelling and grammar.	/20

4. SCORING

4.1. Design Report

(33) The marking scheme for the Design Report is provided in Section 10. The maximum achievable mark for the Design Report is 210.

4.2. Dry Inspection

(34) The marking scheme as shown in Table 4-1 will be used to mark the Dry Inspection. The maximum achievable mark for the Dry Inspection is 36.

Table 4-1: Dry Inspection Marking Scheme

Area	Judges' Comments & Notable Features	Mark
DESIGN CHANGES & REASONS		/6
HULL		/6
PLANES & RUDDERS		/6
PROPULSION SYSTEM		/6
CONTROL		/6
POP-UP BUOY, HATCHES		/6

4.3. Wet Test

(35) The West Test results in a Pass or Fail. The Teams will have the opportunity to continue attempting the Wet Test, at the discretion of the Rac Committee, until a Pass is achieved.

(36) The marking scheme as shown in Table 4-2 will be used to mark the Wet Test. The maximum achievable mark for the Wet Test is 8.

Table 4-2: Wet Test Marking Scheme

Attempts to Pass	Marks
If a submarine passes the Wet Test on the first attempt	8
If a submarine passes the Wet Test on the second attempt	6
If a submarine passes the Wet Test on the third attempt	4
If a submarine passes the Wet Test on the fourth attempt	2
If a submarine takes more than four attempts to pass the Wet Test	0

4.4. Race Scoring

(37) The race scoring system operates according to the basic principle, "Fastest time with least faults". Therefore, a clear run with no faults beats all runs which have faults, whatever their overall time.

(38) The faults will be calculated in accordance with Table 4-3.

Table 4-3: Race Scoring Faults

Action	Faults
If a submarine contacts any gates or slalom poles	4
If a submarine contacts any of the underwater camera equipment	8
If a submarine fouls the racecourse marker line to the extent where it must be reset	8
If a submarine drags the anchor of any gate or slalom pole	8
If a submarine passes the wrong side of any gate or slalom pole	8
If a submarine contacts with the submarine-catching safety net	8
If any part of a submarine breaks the surface (broaches) between the start and finish gates	4
If a submarine broaches multiple times	4 (each broach)
If a submarine broaches and then remains on the surface for the majority of any of the three sections of the course	8 (each section)

(39) If a submarine has passed a marker and then veers off the course, no additional faults will be awarded for missed, dragged, or hit markers as it re-orientates and resumes the run.

(40) The Race Committee reserves the right to 'Abort' a run if it is considered that a submarine has spent too long on the course. The length of time allowed on the course is at the discretion of the Race Committee.

4.5. Points

(41) After each day's racing each submarine's best run is identified and these best runs are ranked and awarded points towards the eISR Trophy.

(42) The number of times each submarine will race each day will be at the discretion of the Race Committee, however, it is likely to be either be 3 or 4. Whether a full day's racing is held on the first scheduled racing day depends how many teams have completed all of the pre-race requirements: diver safety brief, tank familiarisation dive, Dry Inspection and Wet Test.

(43) If half or more of the teams are ready to race, the first day will be organised as a full day of racing with marks awarded as shown in Table 4-3.

(44) If less than half the teams are ready, priority will be given to getting the remaining teams qualified, and racing will start on day two; meaning there will only be three race days. The points awarded for three days of racing will be as shown in Table 4-5.

Table 4-4: Points Awarded for Four Days of Racing

If there are four full days racing planned, i.e., Monday to Thursday									
Position	1	2	3	4	5	6	7	8	9-12
Points	12	10	8	6	5	4	3	2	1

Table 4-5: Points Awarded for Three Days of Racing

If there are three full days racing planned, i.e., Tuesday to Thursday									
Position	1	2	3	4	5	6	7	8	9-12
Points	16	14	12	10	8	6	5	4	3

(45) Teams that do not complete a run during a day's racing will get nil points that day.

(46) If the Day 1 priority is getting the remaining teams qualified, the Control will provide opportunities for qualified teams to race. The results will be ranked, and bonus points will be awarded as shown in Table 4-6.

Table 4-6: Bonus Points Awarded

Bonus Points					
Position	1	2	3	4	5
Points	8	6	4	3	2

5. PRIZES

(47) The prizes awarded during the eISR as provided below.

5.1. eISR Trophy and Runner Up

(48) The overall winner of the eISR Trophy and the ranking of the remaining teams will be determined by a formula combining design (design Report), manufacture (Design Report, Dry Inspection, West Test), race performance (race results) and reliability (race results).

5.2. Week's Top Speed

(49) The winner of this award will be for the fastest transit of the Timing Gates during the timed runs throughout the Race Week. The submarine must complete the run for the speed to stand.

5.3. Agility and Endurance Award

(50) The last day of the competition is reserved for the Agility and Endurance prize. Teams will be invited by the Race Committee to participate in this prize, depending upon their performance during the Race Week teams.

(51) Invited teams will run 2 laps of the course. After passing the Finish Line for the first time, the submarines stay dived and return to, and cross the Start Line between the Start Gates for a second time. Then the submarines complete the whole course again, including the slalom section, finishing when the Finish Line is crossed for the second time.

(52) The winner will be the team with the fastest time and least faults.

(53) The Agility and Endurance race does not count towards the eISR Trophy.

5.4. Award for Innovation

(54) This prize will be presented to the team, which in the judges' opinion, has pushed the engineering innovation envelope the furthest.

5.5. Best Communication

(55) This award will go to the team which best communicates their design to the general public.

5.6. Sustainability

(56) This prize will be presented to the team, which in the judges' opinion, has demonstrated its understanding of the issue of sustainability, and has considered sustainability in their design.

APPENDIX A

Procedures

A1. TERMS

(1) The race rules and procedures refer to the following areas of the Ocean Basin:

- PITS: the designated area in the Basin where submarines are positioned when not on the course or preparing to race.
- SET BOX: a designated area between Pits and the Start Box where the pilot is loaded, and hatches are secured.
- START BOX: a designated area between the Set Box and the Start Line, marking the start of the course.
- START LINE: the line marked in the Basin floor that the submarines must cross to begin a timed run.
- START GATE: the two poles positioned either end of the Start Line that the submarines must pass between to begin a timed run.
- FINISH LINE: the line marked in the Basin floor that the submarines must cross to finish a timed run.
- FINISH GATE: the two poles positioned either end of the Finish Line that the submarines must pass between to end a timed run.

A2. WET TEST PROCEDURE

(1) The Wet Test procedure and commands are as follows:

a. Support divers prepare their submarine in the pits, and SLO informs Control when ready.
b. Control gives the command “Move to SET”.
c. Support divers move to Set Box, load their pilot, and SLO informs Control when ready.
d. Control gives the command “Move to START”
e. Support divers move the submarine to the Start Box, shut and secure the hatches. SLO informs Control when ready.
f. Control gives command “GO GO GO”.
g. Support divers follow the START procedure.
h. Control gives the command “STOP STOP STOP”.
i. Pilot releases the emergency pop-up buoy.
j. Pilot opens the hatch, and switches to secondary air supply.
k. Pilot exits the submarine and stands alongside.
l. Pilot waits for recovery.

A3. RACING PROCEDURE

A3.1 Start

A3.1.1 "[Submarine Name] GET READY"

(2) Control gives the command "[Submarine Name] GET READY" to inform the 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.

(3) If the submarine cannot be made ready, the SLO must inform 'Q' who will order the boat to the back of the queue and give the next boat in the queue the "[Submarine Name] GET READY" command.

A3.1.2 "[Submarine Name] MOVE TO SET"

(4) Control gives the command "[submarine Name] MOVE TO SET". The support divers move the submarine to the SET box. If the submarine is not ready to do this, SLO informs 'Q' and the submarine will return to the back of the queue.

(5) In the SET box the pilot is loaded, hatches are secured, any restraint is taken off the emergency pop-up buoy release mechanism and a final check is made of the primary and secondary air bottle pressures.

(6) When the submarine is ready to race, the lead support diver signals "READY" by facing an underwater camera with arms outstretched and both thumbs up. Control responds with "Understood" or "Wait".

(7) The submarine can only remain in the Set Box for a maximum of 10 minutes. If the submarine is not ready to race within the 10 minutes the SLO informs "Q", and the submarine must return to the back of the queue.

A3.1.3 "[Submarine Name] MOVE TO START. REPORT WHEN READY"

(8) Control gives the command "[Submarine Name] MOVE TO START. REPORT WHEN READY". The support divers take the submarine into the START box. The submarine is lined up behind the Start Gate and a final check of the pressure in the air cylinders is undertaken. One support diver signals "READY", as described in paragraph (6).

(9) Control asks all stations on the course to report their readiness by stating "READY" (Judges, Timing, Overhead, Safety Boat, Tow Boat and film team].

(10) The submarine can remain in the Start box for a maximum of 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 submarine is ordered to the back of the queue.

A3.1.4 "[Submarine Name x3] GO GO GO"

(11) Control gives the command "[Submarine Name] GO, GO, GO". All support divers swim clear of the submarine except one diver at the bow facing aft and one other diver holding the body and clear of the propeller.

(12) Support diver at the bow signals the other diver to swim clear and signals the pilot “COUNT 5 THEN PEDAL”.

(13) Support diver at the bow releases the bow and swims clear.

(14) The pilot counts 5 seconds then starts to pedal and steers towards the START Gate.

(15) The submarine crosses the START line and commences the course.

A3.2 Finish Procedure

(16) Once the submarine has crossed the finish line the pilot should steer towards the recovery area on the finish line side of the bridge.

(17) As the submarine slows, the support team will be given the order to approach their submarine and take control of it.

(18) The pilot should stop pedalling, engage any override system on the emergency pop-up buoy, undo any body restraints, switch to the secondary air supply, and open the main hatch.

(19) The pilot must keep their mask on and regulator in their mouth until secured by the support divers at the surface.

(20) Once the pilot has been secured at the surface, the support diving team should return the submarine to the pits.

A3.3 Abort Procedure

(21) The deployment of the emergency pop-up buoy is the signal to the rescue divers that something has gone wrong, and the pilot(s) may require assistance.

(22) Pilot deploys the emergency pop-up buoy and opens the main hatch to signal to the rescue divers that all is well.

(23) Pilot undoes any restraint systems, switches to the secondary air supply, exits the craft, stands by the submarine, and awaits the rescue divers.

(24) If the pilot does not immediately open the hatch, the rescue divers will assume more urgent assistance is required and implement the emergency recovery plan.

(25) The recovery team will raise the submarine to the surface, where it will be handed off to the towing vessel and returned either to the support team at the recovery area or pits, or handed off in turn to a shore based recovery team on the side of the Ocean Basin.

A3.3.1 Accidental Deployment of the Emergency Pop-Up Buoy

(26) The release of the emergency pop-up buoy after the submarine passes through the Start Gate, even accidentally, aborts the submarine’s run, and the submarine must return to the pit to await its next turn.

(27) If the emergency pop-up buoy is accidentally released after the submarine has passed through the Start Gate, Control will give the command [Submarine Name STOP STOP STOP] to initiate the ABORT procedure.

A4. OPERATIONAL PROCEDURES

A4.1 Air Cylinder Fill

(28) Cylinders will be only filled by a qualified member of QinetiQ staff.

(29) It is the responsibility of the team to ensure that they have mandated air supply when it is their turn to enter the water. If it is deemed a team has insufficient air supply the team will not be allowed to enter the water and they will have to go to the end of the queue.

A4.2 Team and Staff Communications

(30) Race Control will liaise with each team through its SLO.

(31) An underwater loudspeaker will provide direct acoustic communication between Control and the underwater team.

(32) 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, the recommended signal to start pedalling is a single arm rotating as if turning a crank.

A4.3 Submarine Launch and Recovery

(33) All submarines will be launched using the main lift on the north (creek) side of the gantry. When a submarine is ready for launching, “Q” will instruct the team to bring it around to the launching area on its trolley. Protective (steel toecap) footwear should be worn by people operating the trolley.

(34) When directed to, the team will move their submarine onto the lift and secure their trolley to the floor of the lift. Once secure, the lift will be lowered by QinetiQ staff into the Basin. The team may accompany the submarine on the lift. Once the submarine is floating and the lift has stopped, team divers will guide the submarine into the Basin. The team will swim their submarine to its designated preparation area.

(35) The recovery of the submarines will be a reverse of the launch procedure.

A4.4 Diver Entry and Exit

(36) Divers will enter and exit the water only via the Diver Marshalling Area. The Divemaster 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.

(37) 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 under the control of the Divemaster will be sited between Control and the Diver Marshalling Area.

(38) Each SLO will be responsible for ensuring that their 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 exited the water.

A4.5 Race Queue

(39) 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.

(40) 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.

(41) 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.

(42) 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.

(43) The Race Whiteboard and the Divers' Whiteboard will be sited between Control and the Diver Marshalling Area.

A4.6 Interval Between Runs

(44) As soon as the SET box has been vacated by the preceding submarine, Control will order the submarine getting ready to move to SET and the next submarine in the queue to get ready. If there is an incident on the course that Control believes will take some time to clear, orders may be retracted or delayed to avoid divers air being used up.

A4.7 Safety

A4.7.1 Safety Boats

(45) While on the course, 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.

(46) Should the rescue divers or recovery team be required to assist a submarine, racing will only resume once both teams have confirmed they are ready.

A4.8 Safety within the Ocean Basin

(47) Personnel in specified areas on side of the Basin and on the overhead walkway must wear lifejackets if not dressed for diving.

(48) Unless dressed for diving with neoprene boots, leather or canvass shoes are to be worn. Bare feet, flip flops and open toe sandals are not permitted.

(49) Submarines on their trolleys must only be moved by the QinetiQ staff unless team members are wearing protective (steel toe-cap) footwear, in which case they may move the submarine themselves.

A4.9 Building Evacuation

(50) Should the building evacuation siren sound, all personnel are to leave the Ocean Basin promptly. The evacuation muster location will be advised during the Safety Brief. All team members must go straight to the evacuation muster location, where the SLO will ensure the whole team is present. All team members must remain at evacuation muster location until they are advised by QinetiQ personnel that it is safe to enter the Ocean Basin.

A5. RACE COURSE

(51) Submarines race one at a time. The course consists of three sections (Figure 1):

a. the Start Line through the Timing Gates.
b. sweeping 180° turn, on an approximately 25m radius, and
c. a set of four slalom poles on the return leg

(52) The Start Line is 30m from the end wall of the basin closest to the diver marshalling area. To start the race, the submarine must pass between the Start Gates, positioned either side of the Start Line.

(53) Two pairs of Timing Gates are positioned 42m and 55m from the Start Line. The submarine must pass between each pair of Timing Gates.

(54) Turning Gates mark the sweeping turn. Submarines must leave the black & yellow Turning Gates to starboard, and grey turning gates to port.

(55) In the slalom section, submarines must leave the first and third slalom poles to port, and the second and fourth slalom poles to starboard.

(56) The slalom poles are placed 13m apart. Initially the slalom poles are positioned to enable the pilot to navigate through them in a straight line. As the week progresses, the 2nd and 4th slalom poles are moved towards the centre of the basin forcing tighter turns.

(57) The Finish Line finishes the course. To finish the race, the submarine must pass between the Finish Gates, positioned either side of the Finish Line.

(58) A submarine-catching safety net is positioned 30m from the Finish Gate. All submarines must stop before reaching the submarine-catching safety net.

(59) The total length of the course is approximately 175m.

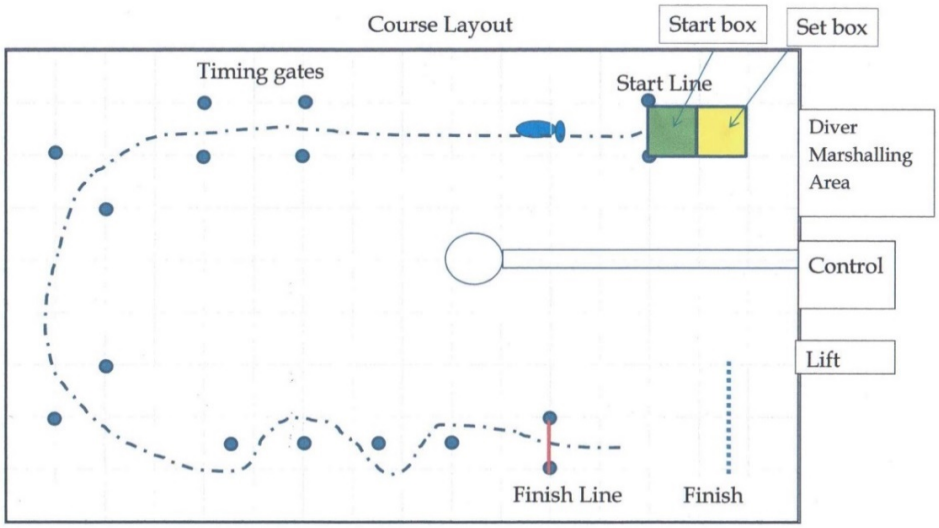

Figure 1 – eISR Course Layout

A5.1 Course Markings

(60) All gates and slalom poles are anchored with 4kg lead weights.

(61) The centre line of the course is marked out along the bottom of the Basin using a weighted line.

(62) The Start Gate is marked by a pair of PVC poles placed either end of the Start Line.

(63) The Start Line is marked by a tar line on the bottom of the Basin, between the State Gate.

(64) The slalom poles consist of vertical ropes covered in pipe cladding.

(65) The timing gates are vertical PVC pipes anchored on the floor of the Basin, placed on either side of the course centre line.

(66) Turning Gates consisting of vertical PVC pipes anchored on the floor of the Basin.

(67) The Finish Gate is marked with a pair of vertical PVC pipes anchored on the floor of the Basin.

(68) The Finish Line is marked with bright coloured tape across the bottom of the Basin between the Finish Gates.

A5.2 Timing, Faults and Results

(69) The eISR combines straight-line speed, with the manoeuvre ability element of a slalom course. The submarine which finishes in the fastest time with least faults wins.

A5.2.1 Timing

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

(71) Underwater video cameras are placed throughout the Basin so that the progress of the submarines can be monitored by those ashore.

(72) Timing specific cameras are placed at the Start Gate, at both timing gates, and at the finish line.

(73) 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. A judge, situated on the overhead gantry, uses a stopwatch to record the time through the timing gate and the total run.

(74) 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 (e.g., the tip of the nose, or stabiliser fin) crosses the frame directly above the markings on the floor of the Basin. These timings are processed by a dedicated computer programme and sent to the scoreboard.

A5.2.2 Faults

(75) A judge, situated in the overhead gantry, records the track of the submarine as it does its run, marking down any faults.

(76) The faults are as defined in Section 4 of the eISR Rulebook.

A5.2.3 Results Boards

(77) 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.

(78) The scoring system is described in Section 4 of the eISR Rulebook.

ANNEX A

Best Practice & Useful Information

A1. BEST PRACTICES AND USEFUL INFORMATION

(1) Although submarine racing is fun, it does bring with it risks that need to be managed. The Race Organisers have put in place a set of rules (eISR Rulebook Section 2) and procedures (eISR Rulebook Appendix A) which will manage many of the risks associated with the event, however, in the end it is the team who bear the major responsibility for their own safety.

(2) The following sections are provided as recommendations based upon best practice and experience of the Race Committee and previous competing teams.

A1.1 General

(3) It is imperative that everyone obey the commands issued by Control. This is for the safety of the pilot, anyone else in the water, and the smooth running of the event. Only Control is in a position to see everything that is going on, and only they can coordinate everyone's activities. Unreasonable requests will not be made, therefore if you are asked to do something, it is being asked for a reason.

(4) If you are a diver, 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.

(5) In all cases, 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.

(6) Air supply can be lost by simply dropping your regulator from your mouth, by running out of breathing 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.

(7) Do not remove your weight belt at the bottom, except in an emergency.

(8) Your alternative air supply is your lifeline. The rules have deliberately over-specified its size, so that in the event of an emergency where the pilot can't open the hatch open or can't free themselves from the pedals or other restraints, there is sufficient air while they wait for the rescue team or deal with whatever the problem is.

(9) Some submarines may have buoyant hatches. If the hatch is opened on the surface, the loss of buoyancy may cause the submarine to descend, therefore, care needs to be taken to ensure support divers are not trapped underneath.

(10) 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.

(11) Never position yourself under the submarine during any operations, either in or out of the water.

(12) Beware of the propellor/propulsion unit during operation and stay clear when it is rotating.

(13) The submarines may have sharp edges, bolt heads, hoses and hatches that can cut or pinch hands and snag SCUBA equipment, therefore, be careful.

A1.2 Diver Descent

(14) The following options are provided as methods the pilots could transfer from the surface to their submarine when it is on the bottom of the Basin. The following options are recommendations only, the Race Committee do not dictate to divers how they should dive. Every team should dive in accordance with their own certification agency's rules, regulations and recommendations.

(15) Option 1 - The pilot should dive independently, with their 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.

(16) 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 need to be in constant eye-to-eye contact during the descent. "Riding" the support diver's cylinder is discouraged but not forbidden, if a robust and practiced communication system between support diver and pilot is in place.

(17) Whichever method is taken, 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 their emergency air if necessary to avoid injury. Under no circumstances should either diver be "dragged down" by the other.

A1.3 Ascending and Descending the Submarine

(18) Ascending and descending the submarine must be taken slowly.

(19) The support divers control the descent of the submarine to the bottom of the Basin and must make sure the pilots are 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 pilots are okay at all times.

(20) Pilots must remember that the ascent of the submarine is controlled by the vehicle, not the diver. It may be more rapid than free diver ascent, particularly if air gets trapped in a nose or tail cone. The pilot must continue to breathe the entire time they are submerged, and never hold their breath. Ideally keep at a constant depth during the race, focusing on keeping a constant distance from the bottom.

A1.4 Lithium Ion and Lithium Polymer Batteries

(21) 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.

A1.4.1 Background

(22) 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 1800C. The I2R 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.

A1.4.2 Safety Features

(23) 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.

A1.4.3 Advice

(24) Buy batteries and chargers from quality suppliers and understand the inherent protection.

(25) Keep the batteries dry in a well-sealed pressure vessel.

(26) Protect the battery by adjacent disconnection if your system imposes a fault (typically a fuse).

(27) Design your pressure vessel to manage the gas release from a battery thermal runaway (contain or safely vent).

(28) Only charge the batteries outside the submarine and consider using a fire retardant bag.

(29) Undertake a risk assessment (identify the hazards, evaluate the risk and implement mitigation).

(30) A different technology battery will also be hazardous.

A1.5 In-Water Testing

(31) Past events have demonstrated that submarines entering eISR for the first time often experience issues causing them to compete ineffectively because they have had insufficient in-water testing before coming to the event.

(32) Teams should ensure there is sufficient time after they have completed the construction of their submarine for in-water testing to ballast and trim the boat with pilot in place and to test the controls and propulsion.

(33) A course is not needed, for example, 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.