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Field Robotics Competition ERL@Rescue 2017

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Executive summary

The European Robotics League - Emergency Robots major tournament was held in Piombino, Italy, from 15-23 September 2017.

ERL Emergency Robots is a civilian, outdoor robotics competition, with a focus on realistic, multi-domain emergency response scenarios. Inspired by the 2011 Fukushima accident, the ERL Emergency Grand Challenge can only be overcome when land, underwater and flying robots successfully cooperate.

The competition itself saw 15 international teams of various disciplines and organisations surveying the scene, collecting data, searching for missing workers and identifying critical hazards, all in a race against the clock.

ERL Emergency 2017 competition was open to the public and had the visit of 1500 spectators. The event also included a general programme of talks and activities around robotics and EU-funded projects on robots for disaster response.

The event was organised by the Centre for Maritime Research and Experimentation (NATO CMRE), the University of the West of England, Bristol, the Centre for Advanced Aerospace Technologies (CATEC), the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE and the University of Oulu.
## Content

1. Introduction ....................................................................................................................................... 4  
2. The competition ................................................................................................................................ 4  
3. The teams ........................................................................................................................................ 7  
4. Two-domain Task Benchmarks ........................................................................................................ 8  
5. Three-domain Task Benchmark: The Grand Challenge .................................................................. 10  
6. Functionality Benchmarks .............................................................................................................. 13  
7. ERL Emergency 2017 ranking ........................................................................................................ 14  
8. Robotics talks and exhibitions ........................................................................................................ 16  
9. Event Staffing and VIPs .................................................................................................................. 18  
10. Conclusions ................................................................................................................................... 19
1. Introduction

On March 11, 2011, a tsunami and earthquake struck Fukushima Daiichi energy plant causing a major disaster. Since then emergency services have deployed robots to inspect the area and collect data. Some robot surveys were successful while others failed, underlining the pressing need to advance the state-of-the-art in autonomous robots for disaster response. Further research is necessary, and so is testing in realistic environments. Shinji Kawatsuma, from the Japan Atomic Energy Authority (JAEA), urged in his outstanding talk in euRathlon 2013: “Don’t build robots, build robot systems”. After the success of euRathlon 2015 Grand Challenge, the first land, sea and air robots competition, the European Robotics League (ERL) Emergency Robots Major Tournament took place again in Piombino, Italy.

Inspired by the 2011 Fukushima accident, ERL Emergency Robots is an outdoor robotics competition funded by the European Union with a focus on realistic cooperative search and rescue response scenarios for land, sea and air robots. A novelty with respect to the euRathlon 2015 was the testing of the new scoring and benchmarking methodology which was harmonised with the one of the other ERL competitions (Service and Industrial Robots). In all four Task Benchmarks, the task can only be fulfilled when the three (or two) domains of robotics are working cooperatively. Multi-disciplinary and multi-organisation teams of about 130 students and engineers met in Piombino, Italy, from September 15-23, to tackle this unique challenge. A total of fifteen teams from thirteen different countries, formed 8 multi-domain teams with ~30 robots, were required to survey the scene, collect data, search for missing workers, identify critical hazards, and more, all in a race against the clock.

2. The competition

The ERL Emergency Robots 2017 was held in Piombino, Italy, in the area surrounding the Tor del Sale building, and in the Enel-owned thermal power plant sheltered harbour.

Torre del Sale, Piombino, was the location chosen for simulating the ERL Emergency's Fukushima-like disaster. Photo Credit: European Robotics League
Scenarios took place in the harbour of the Enel power plant (left), and the Torre del Sale beach area (right).  
Photo credit: European Robotics League

The competition was designed as a 9-day event, in which teams had four days of practice before starting to compete in the scenarios.

Each scenario corresponded to a Task Benchmark (TBM) within the ERL benchmarking framework.

There were two different types of Task Benchmarks:

- **Three-domain TBM (The Grand Challenge):** a three-domain air, land and sea scenario, which comprises three missions.
- **Two-domain TBMs:** two-domain scenarios; serving as preparation to the Grand Challenge TBM.

The main goal is task fulfilment, but autonomy and cooperation between domains are also essential for completing a Task Benchmark on time.

Specific functionalities like object detection or mapping were evaluated through Functionalities Benchmarks (FBM). FBM data was obtained by the teams during the execution of some TBMs and will be evaluated post-competition. Only Task Benchmarks were ranked and granted awards during the competition event. Functionality Benchmarks awards will be announced in the European Robotics Forum 2018, in Tampere, Finland.

Detailed information on the scoring and benchmarking methodology can be found on [ERL Emergency Robots Rulebook](#).
The competition was arranged in increasing order of complexity, with the practice days first (4 days), followed by the two-domain Task Benchmarks (3 days) and finally the three-domain Task Benchmark (2 days).

Although competing robots faced mock scenarios, the environmental conditions and difficulties were intended to be as realistic as reasonably possible – while also safe for competitors and spectators, and the success criteria reflected straightforward end-user priorities such as task completion and minimal intervention with the robots.

Drafts of the Rulebook including competition scenarios, rules and the scoring/benchmarking schema were published in advance for teams to comment. However, detailed descriptions of the scenario setups, for instance the location of blocked doors or missing workers, were not given to teams because such details would not be known ahead of time in a real-life scenario.
3. The teams

As in previous similar competitions (e.g. euRathlon), teams were required to undertake a qualifying process to prove that their robot(s) would be able to cope with the scenarios. The teams were asked to write a Scenario Application Paper (SAP) for each of the scenarios they were planning to enter. In the SAPs they had to describe their robot(s) and explain how they planned to address the technical challenges for each specific scenario. A technical advisory board reviewed the SAPs and checked that the proposed solutions were realistic.

The 8 multi-domain teams who made it through the qualification process (out of a total of 18 individual teams who initially registered) and participated in the ERL Emergency 2017 were:

1. **Telerob (land)+ Universitat de Girona (sea) + ISEP/INESC TEC Aerial Team (air)** – The winning team of euRathlon 2015 Grand Challenge. Team Telerob is from the German-based company Telerob GmbH. The team of the University of Girona is formed by students and researchers of the Underwater Vision & Robotics Research Centre (CIRS). The team develops and operates the robot vehicle SPARUS II AUV. The team from ISEP/INESC TEC comes from Instituto Superior de Engenharia in Porto, Portugal.

2. **bebott (land) + AUV Team Tomkyle (sea) + HSR Search and Rescue (air)** – bebot comes from the University of Applied Sciences of Lucerne, Switzerland. They partnered with AUV Team Tom Kyle as in euRathlon 2015 and with a new team, HSR Search and Rescue. AUV Team Tom Kyle is from the University of Applied Sciences of Kiel, Germany. HSR Search and Rescue comes from the University of Applied Sciences of Rapperswil, Switzerland.

3. **Raptors (land + air) + OUBOT (sea)** – Raptors is a two-domain team coming from the Lodz University of Technology. OUBOT, the team from Obuda University (Hungary) participated with one SPARUS II AUV loaned by CMRE that was bought in the framework of euRathlon project with the purpose of loaning it to unexperienced teams.

4. **Robdos-IMM Team (land + sea) + IIS Piombino CVP Team (air)** – Robdos-IMM is formed by a group of students from the Technical University of Madrid (UPM) and the Institute of Mathematical Machines, Warsaw. They matched with a local team from Piombino, Italy, from the Istituto Statale di istruzione superiore “Carducci Volta Pacinotti”.

5. **ENSTA Bretagne Team (land + sea + air)** – A multi-domain team coming from the Institute of ENSTA Bretagne, France.

6. **ENSTA Team (land + sea + air)** – A multi-domain team coming from the Institute of ENSTA Bretagne, France and the Institute of ENSTA ParistTech, France.

7. **Tuscany Robotics Team (land + sea + air)** – A team comprised of two Tuscan institutions: University of Florence for sea and air and Scuola Superiore Sant’Anna di Pisa for land robots.

8. **ETH Zurich (land + air)** – A team coming from two labs of ETH Zurich, Switzerland, the Autonomous Systems Lab and the Robotic Systems Lab.
4. Two-domain Task Benchmarks

There are a total of three two-domain Task Benchmarks (TBM): land and sea (L+S), sea and air (S+A) and land and air (L+A). In these TBMs the main goal is cooperation between the two domains and preparation for the three-domain one, the Grand Challenge.

- **TBM 2 (L+A): Survey the building and search for missing workers** – A minimum of one land robot and one aerial robot was required to participate in this scenario. The robots had to perform a reconnaissance mission of the building and the land surrounding it. The team had to look for damages in the building, locate an unobstructed entrance, and at the same time find a safe path to the building and to the machine room for their land robot. Additionally, the robots had to find two missing workers (represented by a mannequin), one inside and outside the building. If the worker was found during the first 30 minutes of the TBM, the team’s chances of rescuing the worker alive improved. The first-aid kits must be deployed by the aerial robot, one close to the mannequin outdoor and one close to the ground robot. The ground robot must then enter the building and leave the first-aid kit close to the mannequin.

![Team IIS Piombino CVP during the mission to deploy the first-aid kit to the worker. Photo credit: European Robotics League.](image)

- **TBM 3 (S+A): Pipe inspection and search for a worker** - A minimum of one marine robot and one aerial robot was required to participate in this scenario. Aerial robots had to inspect and map the beach area surrounding the building, and sea robots had to inspect and map the Enel-harbour area. They had to search for damage and leaks in the four pipe sections on land and the four pipe sections underwater, represented by different markers. Robots also had to look for two missing workers represented by a mannequin dressed in bright orange. One worker was on land outside the building and another at sea trapped in a debris area. The worker on land requires a first-aid kit that needs to be deployed by the aerial robot near the worker. The worker trapped underwater is...
considered a casualty, but his/her position needs to be known for emergency brigades to recover the body.

Team Raptors taking-off for surveying the Torre del Sale area.  
Photo credit: European Robotics League.

- **TBM 4 (L+S): Stem the leak** - A minimum of one land robot and one marine robot was required to participate in this scenario. In this sub-challenge, it was known that the pipes on land close to the shore were not damaged or leaking, so no inspection of them by the land robots was required. The land robot must reach the building (from a starting point given near it) while the underwater robot has to reach the pipes underwater. The main tasks were to find the leaking pipes and close the correct valves underwater and on land to stop the leak. Robots had to cooperate to map the area and discover the correct valves. The robots could not close the valves until the two correct pair was found, as the process of closing them had to be synchronised.
TBM 2 (L+A) participants:

- Cobham (land) + ISEP/INESC TEC (air)
- ENSTA Bretagne Team
- ENSTA Team
- Bebot (land) + HSR Search and Rescue Team (air)
- Raptors
- Robdos-IMM Team (land) + IIS Piombino CVP Team (air)
- ETH Zurich

TBM 3 (S+A) participants:

- Universitat de Girona (sea) + ISEP/INESC TEC (air)
- ENSTA Bretagne Team
- ENSTA Team
- AUV Team TomKyle (sea) + HSR Search and Rescue Team (air)
- Tuscany Robotics Team
- Raptors (air) + OUBOT (sea)
- Robdos (sea) + IIS Piombino CVP Team (air)

TBM 4 (L+S) participants:

- Cobham (land) + Universitat de Girona (sea)
- ENSTA Bretagne Team
- ENSTA Team
- Bebot (land) + AUV Team TomKyle (sea)
- Tuscany Robotics Team
- Raptors (land) + OUBOT (sea)
- Robdos-IMM Team (land, sea)

5. Three-domain Task Benchmark: The Grand Challenge

The five partners of the ERL Emergency Robots consortium worked together to create an unique disaster-response scenario, which comprised three realistic mission goals:

- **Mission-A: Search for missing workers** – Robots had to search for three missing workers represented by mannequins dressed in orange suits, which were inside the building, outside the building, and trapped underwater in a debris area. There was a specific achievement for finding the workers on land during the first 30 minutes of the TBM, because in a real scenario the probability of finding a missing person alive decreases rapidly with time. The worker trapped underwater was considered a casualty, but his/her position needed to be known for emergency brigades to recover the body. The missing
workers on land required immediate first-aid assistance and must be provided with a first-aid kit as soon as possible.

- **Mission-B: Reconnaissance and environmental survey of a building** – Robots had to inspect a building to evaluate damages (represented by markers) and find a safe path to a machine room where valves were located. This required robots to reconnoitre the area, create a map of the building and the outdoor area surrounding it, and locate the objects of potential interest (OPIs) in order to provide situational awareness to the team.

- **Mission-C: Pipe inspection and stemming a leak** – Robots had to localise four pipe sections on land, localize another four matching pipes underwater, look for damage to the land pipes and identify a contaminant leak (represented by a marker), reach the valves in the machine room and underwater, and close the correct valves in a synchronised process.

Schematic representation of the distribution of piping sections and valves and their correspondence. Credit: ERL Emergency

Example of pipe distribution. Source: Google Maps.
The TBM1: Grand Challenge was successfully met if all the three missions were accomplished within 100 minutes. Strategy was important, as teams were given significant leeway:

- Teams were free to tackle the mission goals in parallel or in sequence, and to choose the order.
- Teams were free to choose which types of robots to deploy, as well as how and when to deploy them.
- A team’s robots could communicate directly, or via their operators at the control station.

Taking place over two days, TBM1: the Grand Challenge was designed to encourage and reward cooperation between ground, marine and aerial robots, while allowing maximum flexibility in participation and innovation; testing not just the robots, but the human-robot teams. Six of the teams were multi-domain partnerships and one full multi-domain team. The partnerships were mostly built months in advance, which allowed teams to better collaborate together to tackle the challenges.

Day One participants:

- **Cobham** (land) + **Universitat de Girona** (sea) + **ISEP/INESC TEC** (air)
- **ENSTA Bretagne Team** (land, sea, air)
- **ENSTA Team** (land, sea, air)
- **Bebot** (land) + **AUV Team TomKyle** (sea) + **HSR Search and Rescue Team** (air)
- **Tuscany Robotics Team** (land, sea, air)

Day Two participants:
6. Functionality Benchmarks

In ERL Emergency 2017 competition the Functionality Benchmarks scenarios are not designed separately to evaluate individual functionalities. Instead, they are implemented in the Task Benchmarks, so the data required for the Functionality Benchmarks is collected during the task benchmark runs mentioned in each case. The Functionality Benchmarks are processed after the competition.

- **FBM 1: 2D Mapping Functionality (Land + Air)** - This functionality benchmark measures a robot’s ability to explore (cover) the 2D search and rescue area and, while doing so, visit a number of waypoints. This FBM applies to aerial and ground robots only. It is calculated from data collected in the combined air and land robot challenge, TBM2: Survey the building and search for missing workers.

- **FBM 2: Object Recognition Functionality (Land + Air)** - This functionality benchmark has the objective of assessing the capabilities of ground and aerial robots in processing sensor data in order to recognise objects. All objects presented to the robots are items that might be found in an outdoor and indoor disaster response environment. The benchmark requires that robots detect Objects of Potential Interest (OPIs) and identify the type of each object found. This FBM applies to aerial and ground robots only. It is calculated from data collected in the combined air and land robot challenge, TBM2: Survey the building and search for missing workers.

Team bebot (land) and HSR (air) during the Grand Challenge. Photo credit: European Robotics League.
• **FBM 3: Object Recognition Functionality (Sea)** - This functionality benchmark has the objective of assessing the capabilities of an underwater robot (only data from marine robots will be considered in this FBM) in processing sensor data in order to extract information about observed objects. Specifically, the objects to be recognised in this FBM are orange buoys simulating the leak of a pollutant chemical. Each buoy is identified by a black number, from 1 to 5. Each buoy is a particular instance of the buoy class. The benchmark requires that the robot detects the buoys and identifies them, based on the black number and their location. The data required for this functionality benchmark will be collected from any of the following Task Benchmarks: TBM1, TBM3 and TBM4.

• **FBM 4: Vertical Wall Mapping Functionality (Air)** - This functionality benchmark has the objective of assessing the capabilities of aerial robots in extracting specific information about the damaged building. The data will be collected during the (Land+Sea+Air) The Grand Challenge Task Benchmark. Aerial robots must inspect and map a vertical wall of the building in which interesting structures are present. The requested metric measurements are the size of the entrance door, the size of the window in the first floor, and the distance from the bottom side of the window in the first floor with respect to the ground.

7. **The Technical Committee**

The Referee Team was divided into three Referee Teams, one per domain. Each Referee Team was led by one Head Referee which managed the activity of the Referee Team.

The Technical Committee consisted of the following members:

**Chairs**
- Marta Palau Franco (University of the West of England, Bristol, UK) – Chair Referee
- Dr Gabriele Ferri (Centre for Maritime Research and Experimentation, CMRE, Italy) – Chair Referee Logistics

**Land Referees**
- Dr Bernd Brüggemann (Fraunhofer FKIE, Germany)
- Dr-Ing Michael Gustmann (Kerntechnischer Hilfsdienst GmbH, Germany)*
- Dr Hans-Arthur Marsiske (Germany) *
- Prof Juha Röning (University of Oulu, Finland)
- Dr Frank E. Schneider (Fraunhofer FKIE, Germany)
- Prof Alan Winfield (University of the West of England, Bristol, UK)

**Sea Referees**
- Dr Vladimir Djapic (SPAWAR Systems Center, San Diego, USA)*
- Dr Andrea Munafò (National Oceanography Centre, Southampton, UK)*
- Prof Yvan Petillot (Heriot-Watt University, Scotland, UK)*
- Dr Darío Sosa Cabrera (University of Las Palmas de Gran Canaria, Spain)*
- Kelly Cooper (Office of Naval Research - ONR, Washington, DC, USA)*
- Hitesh Patel (AUVSI Foundation, Washington, DC, USA)*
Air Referees
- Dr Antidio Viguria (Centre for Advanced Aerospace Technologies, CATEC, Spain)
- Francisco Javier Perez Grau (Centre for Advanced Aerospace Technologies, CATEC, Spain)
- Prof Stjepan Bogdan (University of Zagreb)*

Safety pilots
- Carlos Albo (Centre for Advanced Aerospace Technologies, CATEC, Spain)
- Jose Carlos Marquez (Centre for Advanced Aerospace Technologies, CATEC, Spain)

*External referees, not members of the European Robotics League Organising Committee.

8. ERL Emergency 2017 ranking

After each task benchmark was complete, the referees analysed the data provided by the teams and discussed with the respective team leader(s) the results. Only the Task Benchmarks were evaluated and ranked on site. The awards ceremony took place at the gardens of Giardini Pro Patria, Piombino.

![First ranked team of ERL Emergency 2017 TBM1: Team Cobham (Land)+Universitat de Girona (Sea) + INESP/INESC TEC (Air). Photo credit: European Robotics League](image)

Task Benchmark Awards

- **TBM1 (L+S+A): The Grand Challenge**
  1st: Telerob, Germany (land) + Universitat de Girona, Spain (sea) + ISEP/INESC TEC Aerial Robotics, Portugal (air)
  2nd: IIS Piombino CVP, Italy (air) + Robdos, Spain -IMM, Poland (sea and land)
  3rd: Raptors, Poland (air & land) + Oubot, Hungary (sea)
• **TBM2 (L+A): Survey the building and search for missing workers**
  1st: IMM, Poland + IIS Piombino CVP, Italy
  2nd: Raptors Team, Poland
  3rd: Telerob, Germany + INESTEC/ISEP Aerial Robotics, Portugal

• **TBM3 (S+A): Pipe inspection and search for missing workers**
  1st: Universitat de Girona, Spain + INESTEC/ISEP Aerial Robotics, Portugal
  2nd: Tuscany Robotics Team, Italy
  3rd: AUV Tomkyle, Germany + HSR Search and Rescue Team, Switzerland

• **TBM4 (L+S): Stem the leak**
  1st: Telerob, Germany + Universitat de Girona, Spain
  2nd: Raptors, Poland + Oubot, Hungary
  3rd: bebot, Switzerland + AUV Tomkyle Team, Germany

**Special Awards**

• **Mapping Award.** – AUV Team Tomkyle (Sea)
• **Navigation Award** – Oubot Team (Sea)
• **Fair Play Award** – ENSTA Team and ENSTA Bretagne (Land, Sea, Air)
• **Creativity Award** – Tuscany Robotics Team (Land, Sea, Air)
• **Multi-domain Cooperation Award** – Telerob + Universitat de Girona + ISEP/INESC TEC (Land, Sea, Air)
• **Perseverance Award** – HSR Search and Rescue Team (Air)
• **Piloting Award** – Raptors (Air)
• **Autonomy Award** – IMM (Land)
• **SAUC-E Student Award** – AUV Team Tomkyle (Sea)

**9. Robotics talks and exhibitions**

As part of ERL Emergency 2017, a series of robotics talks took place in the evening at Piombino Castle. On Monday, Dr Anne Bajart (EU Commission Project Officer), Prof. Maria Chiara Carrozza (Scuola Superiore di Sant’Anna Pisa) and Riccardo Oldani (science journalist) discussed the future of robotics. Tuesday’s talks were focused on current service robotics applications: Dr. Andrea Munafo’ (NOC, UK) presented underwater vehicles applications, Dr. Giancarlo Teti (RoboTech srl) gave an industry perspective on service robotics and Dr. Angelo Odetti presented a collaborative robotic system composed by aerial and marine vehicles deployed in the Arctic.

**TRADR project exhibition and opening ceremony** - A big crowd of people attended the robotics exhibition of TRADR EC Project exhibition (led by DFKI in collaboration with
University La Sapienza, Roma and Firefighters) at Piazza Bovio, in the main square of Piombino city. TRADR is an EU-funded project that focuses on human-robot teams for robot assisted disaster response. This followed a public opening ceremony introduced by Dr Anne Bajart (EU Commission Project Officer), Mary Delvaux (Member of European Parliament), Dr. Reinhard Lafrenz (euRobotics Secretary General), Dr. Gabriele Ferri (ERL Emergency Director) and Stefano Ferrini (Deputy Mayor of Piombino). Teams were presented during this ceremony and awarded with a welcome gift from the local authorities. The opening ceremony included also robotics talks from different EU projects in search and rescue robotics: TRADR, SHERPA, WALK-MAN. TRADR project was presented by Dr. Ivana Kruijff-Korbayova (DFKI), Emanuele Gissi (Italian Firefighters) and Dr. Luigi Freda (University La Sapienza Roma). The WALK-MAN EC project focuses on a robotic anthropomorphic platform to operate in disaster areas. It was presented by Dr. Manolo Garabini from University of Pisa and Enrico Mingo Hoffman from Italian Institute of Technology (IIT). Finally, SHERPA EC project was presented by Prof. Lorenzo Marconi (University of Bologna). As the previous projects, SHERPA relates to search and rescue robotics, in particular, it developed a mixed ground-aerial robotic system for search and rescue in alpine scenarios. Both TRADR and WALK-MAN teams intervened in Amatrice, Italy after the earthquake in the Summer 2016 and showed those results to the Italian public which contributes to raise the awareness of the need for search and rescue robots.
**School of Robotics workshops** - A large audience of children of different ages came to Piazza Bovio and Tor del Sale to participate in robotics workshops provided by School of Robotics at no cost for participants. This was part of the effort in involving the local community as in euRathlon 2015. This year this was extended and not only local schools and associations were part of the staff but also children could attend these workshops and a local school was part of a team.

![Young children using LEGO WeDo kit during the Robotics workshops.](https://www.robotics-league.eu)

A total of ~1500 people attended the parallel public programme, from all ages.

**10. Event Staffing and VIPs**

The event was staffed by ~80 people, including the organising staff, referee team, technical and safety team (including divers and safety pilots), media and film crew, stewards and volunteers. The international referee team comprised ~20 judges from Europe and the US.

VIPs who attended the event included Dr. William Kirkwood, from IEEE Oceanic Engineering Society, Platinum sponsor of ERL Emergency 2017, whom presented a plaque to the local organising committee for the outstanding competition; and Kris Kydd from TOTAL, organiser of the ARGO Challenge.

[www.robotics-league.eu](http://www.robotics-league.eu)

YouTube videos at:

- [https://www.youtube.com/watch?v=YEzD1OTCLGI](https://www.youtube.com/watch?v=YEzD1OTCLGI)
- [https://www.youtube.com/watch?v=wiRxoKxQld4](https://www.youtube.com/watch?v=wiRxoKxQld4)
- [https://www.youtube.com/watch?v=6l9gg7YhYfA](https://www.youtube.com/watch?v=6l9gg7YhYfA)
11. Conclusions

ERL Emergency Robots Major Tournament has been successfully delivered. This is supported by the very good comments received from teams, external referees, observers, VIPs, local authorities and the general public.