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English version

Urban search and rescue - Guideline for the application of a test method for innovative technologies to detect victims in debris

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European foreword

This CEN Workshop Agreement (CWA 17947:2022) has been developed in accordance with CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements– A rapid way to standardization" and with the relevant provision of CEN/CENELEC Internal Regulations – Part 2. It was approved by a Workshop of representatives of interested parties on 2022-11-04, the constitution of which was supported by CEN following the public call for participation made on 2021-10-29. However, this CEN Workshop Agreement does not necessarily reflect the views of all stakeholders who may have an interest in its subject matter.

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Introduction

In the face of natural or man-made disasters, search and rescue teams and other first responders like police, medical units, civil protection or volunteers, race against the clock to locate survivors within the critical 72-hour timeframe (Golden Hours), facing challenges such as instable structures or hazardous environments but also insufficient situational awareness – all resulting in lengthy search and rescue processes. In order to speed up the detection of survivors trapped in collapsed buildings and to improve working conditions for the first responders, the EU-funded research project CURSOR designed an innovative Search and Rescue Kit (CURSOR USaR Kit) based on drones, miniaturized robotic equipment, advanced sensors and incident management applications. The overreaching aim of CURSOR is to develop a USaR kit that will be easy and fast to deploy, leading to a reduced time in detecting and locating trapped victims in disaster areas. To make sure that these solutions meet the needs of the first responders in the field, the system was tested by first responders of the CURSOR consortium as well as by external practitioners (e.g. INSARAG secretariat, Regione Liguria, USaR NL, Bavarian Red Cross, Japan NRIFD) throughout the whole development process. Several lab and small scale field trials were conducted. Against this background the consortium identified the standardisation potential for this CEN Workshop Agreement, which describes a field test and the associated methodology for assessing the use of innovative technologies such as the USaR kit.

In this document, the following verbal forms are used:

— “shall” indicates a requirement,

— “should” indicates a recommendation,

— “may” indicates a permission,

— “can” indicates a possibility or capability.

1 Scope

This document specifies requirements and recommendations on the set-up of a field test and a test methodology for Urban Search and Rescue (USaR) equipment for the detection of victims under debris. A realistic field test is described to gather information to test for example a Soft Miniaturized Underground Robot (SMURF) or drones equipped with specialized sensors, e.g. preparation of debris cones made of different materials. Furthermore, a performance test method for each component and the complete USaR system is described. The purpose of the test method is to specify the apparatuses, procedures and performance metrics necessary to quantitatively measure a search and rescue kit's abilities.

This document is intended to be used by Urban Search and Rescue (USaR) equipment manufacturers and developers. The document is not primary intended to be used by first responders, although the user community is benefitted by the relevant guidelines to be put in place.

The current document discusses and provides guidelines around the following questions:

— How to set up a test field for an innovative USaR kit?

— What should be tested?

— How should be tested?

— Who should conduct the testing?

— What is the minimum set of specifications for the technological tools?

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
field test
test that is performed in near real-life conditions in collaboration between solution provider and end user

3.2
use case
intended use of a technology within an application

3.3
collaborative lab test
test that is performed in a laboratory-controlled environment in collaboration between solution provider and end user

3.4
end user
person or group of persons that ultimately uses the evaluated technology, first or second responder

3.5
search and rescue
use of specialised personnel and equipment to locate people in distress or in danger and remove them from a place of actual or potential danger to a place of relative safety

Note 1 to entry: Urban search and rescue refers to scenarios in metropolitan areas.

[SOURCE: EN 17173:2020-09, definition 3.548, modified – added note]

3.6
personal protective equipment
special device or appliance designed to be worn or held by an individual for protection against one or more health and safety hazards

[SOURCE: IEC 82079-1:2012, definition 3.27]

3.7
integration test
type of testing in which the different units, modules or components of a solution/technology are tested as a combined entity

3.8
sniffer
device with inherited capability to detect and analyse a variety of chemical substances

4 Test procedures for Urban Search and Rescue (USaR) equipment

4.1 General

The fundamental question Urban Search and Rescue (USaR) operators, industry solution providers and interested stakeholders are trying to answer is: To what extent does the technology solution under consideration address capability gaps articulated by the end users?

This assessment involves an iterative exchange of information between the solution provider and end user on the instrument or device under consideration.

NOTE From the perspective of the end user, the INSARAG guidelines [1] will be a familiar way to help frame the various roles, responsibilities, detailed operating procedures, and doctrine such as the 'INSARAG marking and signalling system' during actual USaR operation.

For their part, the end users should articulate and cite any standards or other objective measures of performance that they perceive to be relevant to how their offerings may perform in the USaR environment. The testing procedures of any lab or field test is potentially complex, requiring a resource intensive planning, implementation and follow-up activities.

This document positions end users to measure capabilities necessary to perform operational tasks defined by end users. Standardised test approaches encourage evaluations of the performance of USaR technologies in a realistic environment.

This clause is structured as followed:

— Select technology to be tested

— Identify test environment (lab or field)

— Identify and define evaluation criteria

— Define test scenario (e.g. earthquake, floods) and use case (detailed description of the test set-up)

— Define documentation

4.2 Select technology to be tested

The first step is determining and selecting the technologies for the evaluation test.

Who determines the technologies for testing depends on the evaluation test objective and intended audience of the results.

If the test takes place for commercialisation purposes then the solution provider determines the concrete tested technologies and functionalities.

EXAMPLE The technology to be tested is a ground robot and the functionality to be tested is its mobility.

4.3 Roles and tasks in collaborative and field tests

The following table defines roles and tasks during the test that assesses, if a technology solution under consideration addresses capability gaps articulated by end users.

Table 1 — Roles and tasks in collaborative lab tests and field tests

Role	Tasks in collaborative lab tests	Tasks in field tests
Solution provider	Provides the location and the technology. Demonstrates the solution. Explains the functionalities. Actively supports the test coordinator with test preparations.	Provides the solution. Explains the testing purpose. Provides the basic training for the end user. Actively supports the test coordinator with test preparations.
End user	Observes the technology demonstration or participates hands on if applicable. Provides feedback about the test based on the provided evaluation method. Actively supports the test coordinator with test preparations.	Hosts the test. Defines the requirements, scenario and use case. Sets up the testing site. Makes sure that the suitable end user profiles are considered when choosing the test participants (e.g. for drones test, certified pilots shall be chosen). Conducts the hands-on testing. Provides feedback about the test based on the provided evaluation method. Actively supports the test coordinator with test preparations.
Test coordinator*	Coordinates the preparations and communication between solution provider and end user. Informs the participants about the agenda, test aims. Provides all the relevant templates and forms for the test evaluation.	Coordinates the preparations and communication between solution provider and end user. Informs the participants about the agenda, test aims. Provides all the relevant templates and forms for the test evaluation. This is done

	This is done together with end user and solution provider. Coordinates the evaluation.	together with end user and solution provider. Coordinates the evaluation.
Observers	Observes the test. Provides feedback, if required.	Observes the test. Provides feedback.
* In some countries (e.g. United States or Canada) there are third party organisations who are able to take over the test organisation and implementation completely. They also have facilities that provide the necessary structures for field testing.		

Collaborative lab tests take place in the solution provider premises and serve the purpose of early feedback from the end user. Collaborative lab tests are in most cases technology demonstrations, but if the maturity of the technology allows, end users can also hands-on test them.

The solution provider demonstrates the technology and explains the development and functionalities during the collaborative lab tests. End users' feedback shall be collected and documented.

Field tests usually take place in emergency forces exercise sites, which require the usage of personal protective equipment (PPE). Every test shall have a dedicated safety officer, who instructs the participants before entering the testing site and monitors the safety conditions throughout the test. If necessary, the test shall to be stopped to make sure that the testing ground is safe for all the participants. Special attention to safety shall be given, when unmanned aerial vehicles are tested. The safety protocol shall be agreed upon between the test partners before the field test, considering the test nature and the technologies tested.

4.4 Identify and define evaluation criteria

The identification and definition of evaluation criteria is a critical task of the end users. Criteria can be categorised into:

— functional (e.g. mobility, usability, deployability etc.), and

— non-functional requirements (e.g. affordability, maintenance etc.).

Followed by identifying the operational requirements.

Each evaluation criterion has to be prioritised and weighted.

NOTE Supporting material for defining the requirements can be found on the International Forum to Advance First Responders Innovation (IFAFRI) webpage [2]. IFAFRI has defined ten first responder capability gaps and those gap descriptions also include requirements for the technology considered in the respective gap.

In addition to functional and non-functional requirements, it may be relevant to consider regulatory authorities that may have a role in approving the use of a solution in their respective jurisdictions. These authorities may be separate from the intended customers themselves. Some jurisdictions may insist that equipment's, devices, or apparatus designed for a particular part of fire-fighting domain comply with national standards.

EXAMPLE National Fire Protection Association (NFPA) standards.

These standards or codes may be voluntary or prescribed in laws, regulations or local procurement rules.

EXAMPLE A fire service or regulatory authority may make it obligatory that thermal imagers comply with NFPA 1801 Standard on *Thermal Imagers for the Fire Service*. It is then necessary to design scenarios and use cases in which the equipment will be used by the responder evaluators in the assessment.

4.5 Define test scenario and use case

Based on the technologies chosen, test aims and requirements identified, the test scenario and use cases are designed.

The test scenario shall indicate in what kind of disaster the equipment will be used (e.g. earthquake, floods, etc.).

The use case should specify the concrete application case (e.g. type of the building, which building materials, day/night time, duration etc.) of the technology.

Use cases provide a more detailed description of the test set-up. Given the risks and hazards presented in a USaR operating environment, the vantage point(s) or positioning of the end user in the response environment should be specified. For instance, some end users will be in situ, some operating from a safe stand-off vantage and other consumers of the solutions information may be located in command and control or partner vantage points.

NOTE For USaR technology tests it is useful to consider the INSARAG Guidelines, which determine the process flow during a deployment. In addition to the activities of end users during a deployment, the INSARAG Guidelines may illuminate the possible roles of logistics, information technology support, and communications personnel during a use case testing. The mission has been divided into five Assessment, Search and Rescue (ASR) levels, each level can be considered as one use case.

4.6 Documentation of the evaluation tests

Evaluation tests shall be documented so that the data collected is captured and so that it provides input for further research and development. The reports typically provide an overview of the tests conducted and present results as well as weighted scores. The test report should differentiate the results based on the test nature (verification or validation). Validation document tests are used to confirm solution provider claims, those of interest to end users making acquisition or operational decisions.

Table 2 — Example of test documentation

<table>
<tr><td colspan="6">Test procedure:</td></tr>
<tr><td colspan="6">Test ID:</td></tr>
<tr><td colspan="6">Functionality to be tested:</td></tr>
<tr><td colspan="6">Required test environment:</td></tr>
<tr><td colspan="6">Overview of the test procedure:</td></tr>
<tr><td>No.</td><td>Requirement description</td><td>Pass/Fail/Undefined</td><td>Verification</td><td>Validation</td><td>Comments</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Date of execution:</td></tr>
</table>

5 Testing evaluation methodology development

5.1 General

Designing and developing a technology involves regular testing and evaluation to make sure that the requirements and quality standards are satisfied. Test evaluation is a process that critically examines the progress of the technology development and achievements done to accomplish the set objectives. It involves collecting and analysing information and data about a characteristic of the certain technology and its performance in different development stages. This evaluation methodology targets to measure the fulfilment of the user requirements, but could be adapted also to evaluate the achievement of the technical requirements.

Evaluation can be used to create a commercial and product advantage. It is recommended to include the evaluation activities early in the technology design cycle. Identifying the system limits and capabilities early, helps to plan the resources and make informed decisions.

The following questions help to plan the test evaluation methodology:

— Will the end user choose to use (or buy) the technology (keyword: value)?

— Can the end user figure out how to use the technology (user friendliness) (keyword: usability)?

— Can the solution provider build the system (keyword: feasibility)?

— Is this solution viable for further exploitation (keyword: exploitation potential)?

5.2 Factors for choosing the evaluation methodology

The solution provider choses the test subjects and aim. The solution provider also decides, if it is a:

— platform test (e.g. ground robot with all the integrated sensors),

— sub-component test (e.g. sniffer which will be later integrated into the robot), or

— standalone technology (e.g. geophones).

These decisions are made based on the development progress depending in what stage and maturity level the technology is and what is needed to enter the next phase.

The test organiser decides what the scope and aim of the test is. This shall be clear and communicated to all the test stakeholders (technology provider, end users, test coordinator, observers). Evaluation testing in the context of this document requires (hands-on) testing conducted jointly by the end user and solution provider.

Evaluation testing is a broader term combining both processes of verification and validation.

5.2.1 Verification process

The purpose of the verification process is to provide objective evidence that a system or a system element fulfils its specified requirement and characteristics [3]. Verification results indicate whether a product, service, or system complies with a regulation, requirement, specification, or imposed condition.

EXAMPLE In the testing context, if the technology requirement is to provide a video from remote area, then through verification it has to be concluded if the video is provided or not.

Verification testing can be performed at different stages in a product life cycle and aims to show that a system or component is built according to its specifications, which are closely related to its technical requirements. Questions to be asked are for example: Are we building the system right? Does the system do what it has to do?

Verification tests usually evaluate intermediary products and are generally considered an internal process to facilitate failure analysis, accomplished by test personnel in a controlled environment.

Verification tests involve reviews, tests, simulations, calculations, and/or inspections in order to investigate, if the results given match the expected ones (investigate the reasons for deviations, decide about acceptance of deviations) and are conducted by technology providers during the development phase.

5.2.2 Validation process

The purpose of the validation process is to provide objective evidence that the system, when in use, fulfils its business or mission objectives and stakeholder requirements, achieving its intended use in its intended operational environment [3]. Validation testing checks if a product, service, or system meets the needs of the customer and other identified stakeholders.

Validation testing is conducted under realistic conditions (or simulated near real life conditions) to determine whether the system actually fulfils the purpose for which it was intended. It ensures that the system is operating as expected when placed in a realistic environment. A question to be asked is for example: Has the right system been build?

EXAMPLE If a video is provided from a remote area, then during the validation testing it is checked if the video meets the required qualities (resolution, time spent for receiving the video, does it help to make decisions etc.).

Validation testing is a continuous iterative activity, where the results from one test feed into the next test. The results are evaluated to assess the progress of design, performance, supportability, etc.

5.2.3 Collaboration lab test or field test

In addition to the aim of the test (verifying or validating), it has to be decided, if it is a collaboration lab test or field test. These differ from their evaluation methods as well as from implementation.

Collaborative lab tests are part of the verification process and take place in the early stages of the technology development. In this testing phase, it is acceptable, if the technology is demonstrated and hands on testing is not yet provided but it depends highly on the maturity of the respective solution. Collaborative lab tests should increase the understanding of the complexity of the technology and provide the end users opportunities to suggest design and functionality changes (again based on the maturity of the technology).

The concept of field testing means hands-on testing conducted by end users (with the support by solution providers, if necessary). These are mandatory components of a field test:

- Realistic, near real deployment testing conditions
- Hands-on testing is conducted by end users
- Training has to be provided
- Key performance indicators (KPIs) are defined and tracked

Depending on the nature of the technology, integration tests can be considered. In the simulated environment, the integration of different platforms, sensors or solutions can be performed and tested. The conditions for planning and realising the integration test are the same as for field test.

5.3 Evaluation methodology

Evaluation methodology is depending on the aims and nature of the test. The test organiser has to state, if it is a collaborative lab or field test, if it is verification test or validation test or both. This determines the test procedures and indicates the framework for the test evaluation.

It is suggested to start simpler tests with the addition of complexity based on successful technology evaluations. It is also recommended to start with collaborative lab tests and, after achieving the collaborative lab test results, move on to the field tests.

5.3.1 Collaborative lab test evaluation

Evaluation during the collaborative lab tests consists of collecting both qualitative and quantitative data related to the observations of testing participants and any characterisation of the solution in a laboratory setting.

Qualitative data is collected for the usability of the technology through, for example, a survey.

EXAMPLE The System Usability Scale Survey from John Brooke could be used to collect usability data [4]. Every end user gets the online survey link and is encouraged to fill it out directly after the test. The results are collected and the average value for every question is calculated. The survey results are an integral part of the test report, and the results help to collect findings by means of a statistical procedure.

The qualitative evaluation can consist of two parts. After the technology demonstration there is a questions-answers session where solution providers can discuss with end users. This exchange is about collecting information about the value of the technology. Solution providers get feedback about the technology, the value to end users, and suggestions for changes. This discussion is documented and used as the basis for the second part of the qualitative evaluation. This exchange provides benefits for further development of the technologies, since it takes place during the early stages of the development.

The second part of the qualitative data collection are so called traceability reports. These reports will be done based on the single end users requirements to the solution. End users have to choose between Pass/Fail/Undefined/Not tested. These reports are conducted throughout the testing phase and help the solution provider to follow the end user orientation.

The table below summarises the evaluation methodology during the collaborative lab test phase.

Table 3 — Collaborative lab test evaluation principles

<table>
<tr><th colspan="2">Characteristics</th><th colspan="2">Status</th><th>Notes</th></tr>
<tr><td colspan="2">Test nature</td><td colspan="2">Lab test with end user involvement</td><td>Demonstration of the technology</td></tr>
<tr><td colspan="2">End user role</td><td colspan="2">Observers, if the maturity allows it then hands-on testing</td><td>If the maturity allows it then hands-on testing</td></tr>
<tr><td rowspan="5">Data collection methodology</td><td>Online survey</td><td>Yes</td><td></td><td>Quantitative data</td></tr>
<tr><td>Exchange</td><td>Yes</td><td></td><td>Qualitative data</td></tr>
<tr><td>Requirements tracing</td><td>Yes</td><td></td><td>Qualitative data</td></tr>
<tr><td>KPIs</td><td>No</td><td></td><td>Qualitative data, quantitative data</td></tr>
<tr><td>Report</td><td>Yes</td><td></td><td>Data synthesis and dissemination</td></tr>
<tr><td colspan="2">Performance assessment</td><td colspan="2">Yes</td><td>Considering the early stages of the technology</td></tr>
<tr><td colspan="2">Ethical considerations</td><td colspan="2">Yes</td><td>Consent forms for research participations and data collection are mandatory</td></tr>
</table>

5.3.2 Field test evaluation

The best opportunity to set up the realistic testing field is usually in the end user's premises. Here one important aspect is to understand how challenging these conditions should be and what functionalities are tested. This also plays a role later on, when assessing the test results. The test organiser has to involve the end user in the early stages to ensure that the right testing conditions can be provided.

EXAMPLE A ground robot mobility test should not be conducted on even grounds only, the test site should allow climbing tasks over a certain height and different materials. This is the matter of test planning, creating the appropriate use cases.

In addition, it may be worth considering the extent to which the end user premises or testing site is representative of the operating environments of a broader constituency of USaR response agencies.

Hands on testing is a mandatory part a field test. End users have to use the technology, otherwise they are not able to provide meaningful feedback. Since the technology might be new to them, the preliminary training and support from the solution provider is needed.

It is recommended to organise the field tests in several iterations (starting with simpler set ups and moving towards more complex tests), but this depends on the resources available for testing. Iterations allow monitoring and evaluation of the development process and the improvements done after the previous field test. The evaluation results from the previous field test have to be considered and improvements demonstrated, therefore the evaluation documentation plays a crucial role.

The table below summarises the field test evaluation methodology.

Table 4 — Field test evaluation principles

Characteristics		Status		Notes
Test nature		Field test with end users involvement		Testing of the technology in the realistic field conditions
End Users Role		Hands-on testing		Technology providers support if necessary
Data collection methodology	Online survey	Yes		Quantitative data
	Exchange	Yes		Qualitative data
	Requirements tracing	Yes		Qualitative data
	KPIs	Yes		Qualitative data, quantitative data
	Report	Yes		Data synthesis and dissemination
Performance assessment		Yes		Based on the use cases and test set up
Training		Yes		Training is required in order to allow first responders to use the technologies
Ethical considerations		Yes		Consent forms for research participations and data collection are mandatory

5.3.3 Integration test evaluation

For integration tests, both collaborative lab tests as well as field tests can be used. Before the integration test, all the integrated sub-components shall be tested as single components. It is reasonable to start with collaborative lab tests and to go into the field after the collaborative lab tests have been completed successfully. The evaluation method does not differ from the field test method. Integration tests are, by their nature, more complex and evaluation is not that straightforward.

Evaluation planning and the logical workflow:

1) Purpose

2) Use case

3) Task

4) Functionality

5) Requirement

6) Required test environment

7) Materials used

8) Overview of the test procedure

The examples below show the close connection between test objectives and requirements for the evaluation activities. This approach can also be applied to other tests.

Example – Test evaluation process during an integration test

— Topic: Ground robot field integration test.

— Purpose: Testing the detection and localisation of a disaster victim in the collapsed building. Testing the integration of the robot hardware, software and sensors.

— Conditions/use case: Collapsed building with underground spaces, reinforced concrete material, no infrastructure available. The distance between robots and the workstation is about 150 m.

— Task: Detect and locate live victims under the rubble.

— Functionalities to be tested:

  — Mobility: the robot has to find the way inside the rubble and move there

  — Navigation: end user has to be able to navigate the robot

  — Detection of the person: using sniffer and audio-video sensors

  — Localisation: the robot has to provide its location data

  — Safety: obstacle detection and avoidance, modes of operations (autonomous and manual)

  — Communications: the robot has to be able to communicate with the workstation

  — Command & Control Unit: visualisation of the sensor data in real life and understandably to the end user

— Requirements:

Table 5 — Example requirements

Functionality	**Example Requirement 1**	**Example Requirement 2**
Mobility	Climbing obstacles 20 cm high	Structures of varied construction materials (e.g., steel, concrete, etc.)

Navigation	Highly manoeuvrable	Controllable from the workstation
Detection	Voice and video communication	Indicating human presence at least 3 m from the location of the victim
Localisation	Real time GPS coordinate information	Video recording capability
Safety	Switching between manual and autonomous mode	Doesn’t create harm for the disaster victims
Communications	The data transmission is in real-life	Secure, digital encrypted communications
Command and Control Unit	User-defined graphical interface	Intuitive navigation

— Required test environment: Pile of rubble or other overburden that is characteristic of the jurisdiction within which the solution is being offered – reasonably expected to hide victims in the underground space.

— Materials used: Concrete walls, wooden or brick stone obstacles at the height of 20 cm on the floor. Possibility to set up the robot command and control about 150 m from the pile of rubble.

— Overview of the test procedure: Testing use case describes the situation wherein, after an earthquake, three persons are trapped under the collapsed building. There is no visual or audio contact with them, it is unknown if they are dead or alive. With other tools, the possible location has been narrowed down to this building. The end users employing the tested device do not know the location of the trapped victims. The end user starts the deployment of the robot. The robot is manually navigated through the pile of rubble and over different obstacles. After entering the building, the operator switches to the autonomous navigation. Three additional robots are deployed to search for the victims. Simultaneously, the sensors of robots are used (sniffer as well as audio and video tools). The received data is analysed and next steps are decided based on the information received.

— After the test the end user are asked to evaluate the requirements:

Table 6 — Requirement evaluation

Requirement	Pass	Fail	Undefined	Comments
The robot is climbing obstacles 20 cm high		X		
The robot is able to move over structures of varied construction materials (e.g. steel, concrete, etc.)			X	
The robot is highly manoeuvrable	X			
The robot is controllable from the workstation	X			

The evaluation continues with a discussion round to learn about end user experience, the usability and the value of the technology. The information gathered in the tests (and discussions), is compiled into a test report, to track whether the requirements have been met.

5.4 Key Performance Indicators

Key performance indicator (KPI) is a type of performance measurement. KPIs evaluate the success of a particular activity. For the evaluation testing purposes, KPIs can be derived from the user requirements. In this step, the evaluation of the technology goes deeper than the single end user requirements for a single technology. End users have to define relevant indicators, which help them and solution providers to understand the current performance of the technology. The challenge of developing KPIs is to, on one hand, have few, easy to understand, measurable, realistic, achievable and meaningful KPIs, and, on the other hand, to be able to cover the broad variety of requirements of a complex technical solution. The end user requirements, which form one of the fundamental bases of the technology development, are the input to derive the KPIs, which ensures that we concentrate on the important indicators and success factors.

KPIs specify what is measured and assessment techniques detail how and when it will be measured. The assessment of the KPIs with pass/fail estimation does not work. Here indicators have to be defined which help to track and assess the KPIs. One option is to use percentage intervals to track the status.

Table 7 — Example KPIs for a ground robots performance evaluation

KPIs definition	0 % – 24 %	25 % – 49 %	50 % – 74%	75 % – 100 %
Ground robot provides information, if the victim detected is alive or dead	The distinction is not provided			The robot differentiates between alive and dead persons
Robot is able to use all the sensors simultaneously	Only one sensor at a time can be used	Some sensors can be used simultaneously		Robot is able to use all the sensors simultaneously

6 Tools and technologies

6.1 General

This clause provides a categorisation of tools and technologies used in USaR. The primary users of such tools are the various USaR teams participating in USaR missions. This clause further supports technology providers to determine the type and scope of tools and technologies that are tested by end users. Furthermore, this clause categorises the identified tools and technologies categories into the Assessment, Search and Rescue Level of the typical USaR operations.

This clause answers to the following questions:

— What are the current capacities of USaR teams?

— What are the current tools and technologies used in field testing and how these have been selected?

— What are the different tools' categories that nominate for candidates under USaR field testing?

— What need do these serve?

— Which operational context and USaR phases of operations these fit in?

6.2 Levels of USaR team capacities

The purpose of INSARAG accredited field tests and exercises are to define and exercise the operational minimum standard for international USaR and as such classify and reclassify the relevant teams whilst being trained for a multitude of conditions. The USaR teams are required to consist of Management, Search, Rescue, Logistics and Medical components, and they abide to three levels of capacity, i.e., Light, Medium and Heavy.

Typically, a Light USaR team can conduct search and rescue operations in collapsed or failed structures of wood and/or unreinforced masonry constructions, including structures reinforced with steel mesh. They have the capacity to work at a single worksite for at least 12 hours.

A Medium USaR team shall have the capacity to operate in the same environment as the Light USaR teams but for at least of 24 hours.

Last, a Heavy USaR team has the operational capability for complex technical search and rescue operations in collapsed or failed structures that require the ability to cut, break and breach steel reinforced concrete structures, as well as delayer these structures using lifting and rigging techniques. Moreover, a Heavy USaR team should be able to work on two worksites in parallel for more than 24 hours.

At present, the above mentioned USaR teams are equipped with a typical toolbox that allows them to conduct tasks depending on their type. Even though the level of technological advancement of operational equipment varies from country to country, it's rare that novel, beyond state-of-the-art technological components are being used.

6.3 Checklist for selecting technical solutions

The tools and technologies currently selected by USaR teams answer to the following checklist:

— Is there an effective communication system between the USaR team and its sponsor to ensure timely decision making with regards to deployment?

— Does the USaR team have the ability to access the Virtual On-Site Operations Coordination Centre while in-transit and while on mission in the affected country?

— Does the USaR team appropriately interact with other USaR teams when deployed?

— Does the USaR team have the ability to communicate internally, externally or internationally?

— Does the USaR team use GPS technology?

— Does the USaR team use information and communication equipment?

— Does the USaR team management have a process to gather information pertaining to the emergency and brief USaR team members on the current situation, including structural characteristics, weather and emergency evacuation?

— Does the USaR team have sufficient equipment to be able to operate a Reception and Departure Centre (RDC), a USaR Coordination Cell (UCC) and a Sector Coordination Cell (SCC)?

— Does the USaR team have the ability to submit data to a situational awareness dashboard?

— Does the USaR team take the appropriate search equipment to the site of operations, based on the available information?

— Does the USaR team take the appropriate rescue equipment to the site of operations, based on the available information?

- Cutting and Breaking: Does the USaR team demonstrate the ability to cut, break and breach through steel reinforced concrete walls, floors, columns and beams, structural steel, reinforcing bars, timber and building contents, according to the dimensions below:
  - Penetrate 200 mm of reinforced concrete vertically overhead to avoid space.
  - Penetrate 200 mm of steel reinforced concrete laterally into a void space.
  - Penetrate 200 mm of steel reinforced concrete vertically below to a void space using a "dirty" technique.
  - Penetrate 200 mm of reinforced concrete vertically below to a void space using a "clean" technique.
  - Cut a steel reinforced concrete column or beam
    - Heavy team: 450 mm with 18 mm reinforcing rod
    - Medium team: 300 mm with 12 mm reinforcing rod
  - Cut solid timber
    - Heavy and Medium team: 300 mm

    NOTE To be seen as a wooden column or beam.
  - Cut metal Plate
    - Heavy team: 20 mm thick; 1 m x 1 m
    - Medium team: 10 mm thick; 0.7 m x 0.7 m
  - Cut Structural Steel
    - Heavy Team: depth: 260 mm; width: 102 mm; web: 6.5 mm; flange: 10 mm
    - Medium team: depth: 127 mm; width: 76 mm; web: 4 mm; flange: 7.6 mm
- Lifting and Towing: Demonstrate rigging, lifting and moving of steel reinforced structural concrete columns and beams as part of a de-layering operation. USaR teams are required to lift and move the load with the purpose of gaining access to a victim.
  - Pneumatic equipment
  - Hydraulic equipment
  - Winches
  - Crane operations
    - Heavy or Medium team: 5.0 m
- Shoring and Stabilisation: Does the USaR team demonstrate the ability to analyse and conduct stabilisation operations of structural elements as follows:

- — Cribbing
- — Wedges
- — Window/door stabilisation
- — Vertical stabilisation
- — Diagonal stabilisation
- — Horizontal stabilisation

— Rope-Work: Does the USaR team demonstrate technical rope capability to:

- — Construct and utilise a vertical raising and lowering system
- — Construct a system that allows for the movement of a victim from a high point laterally to a safe point below.

— Medical Care: Does the USaR team have the ability to provide emergency medical care in collapsed structures including confined spaces from the time of access, during extrication, to the time of hand over, including emergency surgical expertise that may be required in confined space medical rescue?

— Do the USaR team members wear personal protective equipment (PPE) as required by the situation?

— Does the USaR team demonstrate a system to track personnel at all times?

6.4 Categorisation of a typical USaR toolkit at present

The table below categorises the equipment typically used by USaR teams at present including indicative examples.

Table 8 — Categories of a typical toolkit of USaR teams

Protective equipment	ICT	Cutting and breaking	Shoring and stabilisation	Rope-Work	Medical
Industrial grade gloves, uniform, helmet, boots	Satellite and mobile communication devices (Ultra High Frequency/ Very High Frequency, Global System for Mobile Communications), laptops, smartphones, 2,500 watts portable electric generator, megaphone, portable radio for point-to-point communication	Heavy duty saw, reversible electric drill, gasoline and/or electric chainsaw, electric fan for confined spaces	Structural signalling equipment, hydraulic jack, 12-ton hydraulic jack	1/2” sisal rope, 1/2" nylon rope, portable lighting equipment	Rescue stretcher for horizontal and vertical rescue operations with collection ring, advanced first aid kit, equipment for portable oxygen administration

6.5 Categories of novel tools and technologies candidates eligible for the USaR toolkit

The advancements in various technological domains and the rise of disastrous events around the globe have led to an increase of offered technologies and tools, either from other verticals or tailored to USaR operations, at the service of USaR teams. To facilitate integration to USaR procedures an elaborated categorisation of such capacities is deemed necessary towards better comprehending the offered functionalities and the support to the various Assessment, Search and Rescue level (ASR Level) that each technology belongs.

Such categorisation to be followed can be seen below.

Sensors

The sensor category supports tasks related to:

— Victim detection

EXAMPLE Geophones, ultra-wideband sensors, thermal/visual cameras, sniffers, radio frequency scanners.

— Environmental and structural monitoring and hazards and threat detection

EXAMPLE Gas sensors, visual/thermal/hyperspectral imaging.

— Physiological parameters/vitals monitoring

EXAMPLE Monitoring of physiological parameters (e.g. heart rate, respiratory rate, skin conductivity, etc.).

— Track and tracing

EXAMPLE Inertial measurement units, global navigation satellite system denied trackers, GPS trackers, visual tracking.

Communication

The communication category supports task related to:

— Ad-hoc/quickly deployed networks in a large area (radius 3 km < area < 10 km)

EXAMPLE ISM band ad hoc networks.

— Indoor/fixed base stations-denied communication

EXAMPLE Beacons and nodes.

— Internet of Things/sensors networking

EXAMPLE Long Range Wide Area Network (LoRA WAN), Radio Access Network Edge (RAN Edge).

— High speed mobile and satellite communication

EXAMPLE 5G and high speed satcom links.

Information System

The information system category supports tasks related to:

— Aggregation, analysis and fusion of information from multiple sources

EXAMPLE Analysis and fusion of tracking, sensory, vitals and environmental data.

— Incident and resources management

EXAMPLE Status of the incident, categorisation of sectors and worksites and management of the teams.

— Hazard/threat and behaviour modelling and simulations

EXAMPLE Plume modelling, evacuation modelling, building collapse modelling.

— Map based visualisation of information and dashboard

EXAMPLE Insertion of all necessary information georeferenced onto a map or in a situational awareness dashboard dashboard.

Robotics

The robotic category supports tasks related to:

— (Semi-) Autonomous robotic systems for exploration, mapping and tasking

EXAMPLE Unmanned aerial or ground vehicles.

Immersive technology

The immersive technology category supports tasks related to:

— Augmented reality

EXAMPLE Augmented reality glasses or augmented reality services into smartphones for extending field of view and adding layers of information.

Technical interoperability

The technical interoperability aspect is also uniquely categorised since it allows seamless integration of novel tools and technologies within the USaR toolkit. The technical interoperability aspect is related to:

— Syntactic interoperability

EXAMPLE When two different tools or technologies can communicate to each other by using common data formats or communication protocols.

— Semantic interoperability

EXAMPLE When two different tools or technologies can automatically interpret the information exchanged meaningfully and accurately.

6.6 Mapping of ASR levels with novel tools and technologies

USaR operations are split into the five levels below:

— Level 1: Wide Area Assessment

— Level 2: Worksite Triage Assessment

— Level 3: Rapid Search and Rescue

— Level 4: Full Search and Rescue

— Level 5: Total Coverage Search and Recovery

For all tools and technologies of the previous clause, the solution providers, alongside the end users, should map the offered functionality to the purpose and task of each Assessment, Search and Rescue Level (ASR Levels) and the intended users. This process should allow the testing of a novel tool or technology against the operational need. The following table presents such mapping in relation to novel tools and technologies, supported tasks and ASR Levels.

Table 9 — Mapping novel tools and technologies with ASR Levels and Users

Categorisation	Level 1		Level 2		Level 3		Level 4		Level 5	
	Field	UCC	Field	UCC	Field	UCC	Field	UCC	Field	UCC
Sensors		Environmental and structural monitoring and hazards and threat detection	Victim detection		Victim detection, environmental and structural monitoring and hazards and threat detection, physiological parameters/vitals monitoring, track, and tracing	Victim detection, environmental and structural monitoring and hazards and threat detection, physiological parameters/vitals monitoring, track, and tracing			Victim detection	
Communication		Ad-hoc/quickly deployed networks in a large area (radius 3 km< area < 10 km)	Ad-hoc/quickly deployed networks in a large area (radius 3 km < area < 10 km), high speed mobile and satellite communication		Indoor/fixed Base stations-denied communications, Internet of Things/ sensors networking		Indoor/fixed Base stations-denied communications, Internet of Things/ sensors networking		Ad-hoc/quickly deployed networks in a large area (radius 3 km< area < 10 km), high speed mobile and satellite communications	
					Ad-hoc/Quickly deployed networks in a large area (radius 3 km < area < 10 km), High speed mobile and satellite communications		Ad-hoc/quickly deployed networks in a large area (radius 3 km < area < 10 km), high speed mobile and satellite communications			
Information System		All tasks belonging to information systems	All tasks belonging to information systems		All tasks belonging to information systems		All tasks belonging to information systems		All tasks belonging to information systems	
Robotic		–			(Semi-) Autonomous robotic systems for exploration, mapping and tasking		(Semi-) Autonomous robotic systems for exploration, mapping and tasking			
Immersive technology		–	Augmented reality		Augmented reality		Augmented reality		Augmented reality	
Technical Interoperability		Syntactic and semantic	Syntactic and semantic		Syntactic and semantic		Syntactic and semantic		Syntactic and semantic	

The following questions should be answered and assessed before a certain tool is nominated to be incorporated in an operation USaR toolkit:

— By which member of the USaR team or of the coordinating cells is the tool operated?

— Does it meet its purpose advancing the mode that similar tasks were performed before using it?

— Does it offer backwards compatibility?

— Is it interoperable with current tools used and current operational tasks/procedures?

— Does it satisfy transportation requirements?

— Does it satisfy minimum times of USaR operations?

— Does it satisfy minimum training requirements and associated material of its intended operator?

— Does it adequately address the USaR evaluation methodology presented in clause 5?

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