IMG-S Report on
Futures of First Responders Systems

This document presents thoughts and perspectives on future next generation First Responder (FR) systems as a result of new scientific breakthroughs, technological developments, trends and innovations in the field. Its purpose is to share ideas and contribute to debates towards identifying research needs for the next 5 years in FR systems.

This document was elaborated by the following IMG-S members.

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Introduction / Executive Summary

FRs operate in dangerous environments and are responsible for saving lives. As a consequence, it is critical that FRs are properly equipped and well prepared. This review summarises our vision of future capability development in this respect.

FR's **Systems and Equipment** will be more connected than ever and must support the production, storage and exchange of increasingly large amounts of data. Voice communications will continue as an essential service, but will be complemented with real-time location and status reporting, real-time situational awareness (self, team and environment), rich media (high resolution imagery and video) and rich interaction (social media like). **Next generation EU interoperable communications systems** (wireless broadband cognitive) will enable those requirements. A **robust location capability** - i.e., know the location of FRs at all times and assess proximity to risks and hazards - using and complementing the GALILEO Public Regulated Service for GNSS denial areas will exist. Location techniques based on Ultra Wideband and inertial measuring are promising. In addition, **Smart Wearable Systems** integrating distributed electronics in vests and fabrics will provide numerous possibilities for biomonitoring (e.g., body temperature, heart rate), environment monitoring (e.g., presence of dangerous chemical and biological agents), human-interface (e.g., smart watches and goggles), protection and many others.

The incorporation of advanced ICT brings improved interconnection (upstream-downstream) with tactical Command & Control systems and real-time **situational awareness**. Furthermore, new connectivity concepts, based on IPv6 and the Internet of Things, will enable exploitation of nearby sensor systems, video surveillance systems and social networks. A challenge will be to filter and share significant amounts of relevant information (**Big Data**) to the FR in an intuitive way.

Concerning **Search and Rescue** activities (including medical support), it is foreseen an improvement in determining the location of victims and empowering communication bi-directionality between FRs and victims. Medical systems' interoperability (e.g., handover ambulance to hospital and better resource management and sharing) is also foreseen.

As FR systems become more connected and more ICT dependent, **Cyber security** becomes a critical aspect. Cyber security will be ensured at all levels: communications, network, protocol and application.

Finally, FRs' capability to cope with and manage stress will be achieved through effective training. Novel techniques and methods to consider are e-Learning, Serious Games, Virtual Reality, Augmented Reality. Future **Training and Simulation** will be more immersive, realistic and data collection intensive.

This document finalises with considerations on **Emerging Technologies** and **Design Guidelines**.

First Responders' Systems and Equipment

Future FR systems will utilise digitally enabled services that will be data intensive. Voice will continue as an essential service but, enabled by broadband wireless communications, more services are emerging such as real-time location and status reporting, real-time situational awareness (self, team and environment), rich media (high resolution imagery and video) and rich interaction, e.g., using the advantages of social media for one-to-one, one-to-many and many-to-many communication and information gathering. Systems will implement smart intuitive interfaces (non-blocking), incorporating various types of wireless communications, and presenting sensors integrated on smart wearables (e.g., textiles allowing real-time assessment of FRs' health and environmental conditions) and wearable computers allowing for full interaction with the system (including Push-To-Talk or PTT communications with team members) for improved command and control and situational awareness.

We outline the following relevant development areas, described next:

- Next Generation Communications
- Location Capability
- Smart Wearable Systems
- Situation Awareness
- Protection

Next Generation Communications

The next generation (EU) radio communications system will support the exchange of large amounts of data to be analysed and used by FR systems' applications. Future FR radios will be always connected in any environmental conditions (including through barriers, inside buildings, and underground) and will meet FRs' requirements on e.g., availability, security and coverage.

Key characteristics include:

- Use of robust waveforms.
- Mobile ad hoc (multi-hop support - networking between cooperating nodes) when infrastructures are lacking.
- Delay tolerant protocols.
- Rapid deployment covering both ground and satellite communications (sat-to-ground bubble) in case of infrastructure damage (or EU external missions) supporting a large number of actors.
- Satellite communication as a global asset and/or backup for voice and broadband data transmission.
- Efficient algorithms for allocation of radio resources for broadband services.

Currently, there is a strong trend towards adopting LTE/LTE-A and WiMAX to achieve a FR broadband capability for data exchange, while continuing with voice services over current networks (e.g., TETRA and TETRAPOL). There is uncertainty still whether the implementation model will evolve towards resource sharing (infrastructure and spectrum) with civilian networks (less costly, risk of lack of availability, security risk) or as a dedicated resource for security users (more costly, ensured availability, lack of spectrum). Notwithstanding, ensuring support to FR key services over commercial technology (e.g., PTT) still requires development taking into account efforts done by 3GPP and TCCA.

Initiatives towards universal radio (software defined radio, cognitive radio) and the dynamic use of the spectrum will offer an unprecedented level of flexibility and universality. For example, the dynamic use of the spectrum will allow releasing and allocating FR spectrum according to needs. However, barriers such as high cost and lack of regulation will have to be overcome.

Commercial mobile terminals (including smartphones) already supporting various forms of communications (WiFi, Bluetooth, cellular), rich multimedia and application deployment and offer unlimited potential. Support to operate in security specific networks (dual-band civil-security terminals) will be available at an affordable cost. Moreover, properties like PTT, device-to-device (D2D), multi-hop routing and disruption tolerance will be supported. Optional use of satellite communications will be included to the toolbox as well.

Given the slow upgrading cycles of FR systems, roll-out of next generation (FR) networks will ensure interoperability with existing networks. In this regard, data exchange from broadband to (current) narrowband networks will deal with data prioritisation and network disruptions and latencies. However, even with present technology, standards and mature solutions to ensure interoperability at national and cross-border levels are still lacking.

Location Capability

A key future service for the safety of FRs will be the development of a location capability to provide the location of FRs at all times and assess in real time proximity to risks and hazards (e.g., entering dangerous/contaminated area).

The European GNSS system Galileo will offer a reliable high-quality location capability. Destined for government authorised users, the Galileo Public Regulated Service will provide position and timing with a high level of accuracy and availability (99.5%).

Dealing with situations where GNSS is not available (e.g., dense urban environment, indoor or underground), location mechanisms complementing GNSS (EU-GALILEO) will be provided: ultra wideband (UWB) devices for precise ranging info, integration with 4G/LTE devices and short-range communications (based on Short Range Devices standards), inertial measuring units (3 axis gyroscopes and accelerometers), auxiliary navigation sensors like pressure sensors and magnetometers, RFID readers, and 3D mapping sensors, correlated with building schematics.

Standards on novel location mechanisms will accompany these new developments.

Smart Wearable Systems

Wearables will be incorporated into FR equipment and systems as "hands-free systems". These will include distributed electronics in smart vests and electronic circuits embedded in fabrics, bringing numerous possibilities:

- self: biomonitoring (health parameters: body temperature, heart rate, cardiac arrhythmia, blood intoxication), GNSS and inertial (see location), fall detection / man-down.
- environment: body-worn camera, temperature, CBRN sensors (sense and alert).
- visualisation and interaction: watches, goggles with augmented reality (e.g., intuitive way-out directions). speech-to-text and text-to-speech technologies, as well as online real-time translations.
- protection (see Protection).

Other technological advances will be wearable antennas, embedded electronics, FRs Alarm/SOS button and led/light-emitting clothes.

Reference architectures, interfaces (for wearable technology (on power and data), standards and human factors (considering FRs operational stress) will accompany technological developments.

Situation Awareness

ICT upstream technologies are required for providing enhanced situation awareness and closer link with team members as well as with tactical command and control centres.

Real-time team level location and status information, combining each FR's location data, will allow assessing risk, managing resources and supported decision making. In case of dynamic course of action, knowledge on the surrounding environment and easy-to-understand information supporting time critical decisions will be delivered to the FR. Multiple sources of data will be exploited for the purpose of building a better understanding of the area, including threats and hazards:

- Sensor systems in the FRs' area of operation (e.g. detectors of smoke, fire in the building) will provide data to be analysed online (e.g., fire or gas detected).
- Video cameras will provide visual access to the scene.
- Useful (multimedia) posts will be shared in social networks.

These tools will contribute to a better situational awareness and common operational picture, through enhanced data fusion, leveraging big data technologies taking advantage of multiple information sources and scalable/predictive analytics to anticipate scenario evolution and cascading effects in FR operations.

Protection

FRs will have effective smart protective clothing and equipment against multiple hazards.

New smart materials and wearable technology will bring improved levels of protection:

- Flexible smart textiles for knifes and bullets protection: 2D/3D weaving; non-Newtonian fluids / shear thickening fluids and nanotechnology (e.g., carbon nanotubes).
- Lightweight (covert/discrete): undergarment vests, helms/caps.
- Reliability against local damage (durability, distributed electronics, smart textiles).
- Comfortable: breathable, moisture management, heat/cold, temperature management and regulation.

Big Data and Decision Support

Intelligent decision support and situational awareness will benefit from analysis of Big Data containing substantial volumes of information from multiple sources (video sources, sensors, structured and unstructured data), including non-conventional ones (social media),

Processing significant amounts of geo-spatial data in particular will be improved by the design of new systems and geospatial services for NoSQL databases, allowing the insertion of data without a predefined schema. Efficient mapping and area assessment (e.g., damage) will be generated.

Advanced data analytics comprising data fusion, correlation and mining will be used to identify trends and patterns for particular contexts and missions. Prediction tools will also be developed.

Main challenges for the future will encompass effective visualisation tools for humans, effective information filtering and attain real-time results to assist *in-situ* FRs.

Social Media

Encompassing the World Wide Web, online services and online technology (including mobile), social media is a ubiquitous platform to produce and consume information in various forms at all times and enabling rich interaction (one-to-one, one-to-many, many-to-many), namely in emergencies and crises.

By nature, social media allow a whole new level of bi-directionality between citizens and FRs: total conversation (voice+text+video+data, including location) and asynchronous interaction (social media posts and tweets contain longitude and latitude coordinates).

Next Generation 112 Apps will be developed with efficient emergency incident report enriched with imagery, video and location information (see location of victims - Search and Rescue). 112 Apps will also include total conversation and multi-language support.

The use of crowd sourcing, initiated by user contributed geo-tagged information, will support the visualisation of local conditions, especially when combined with enhanced cognition technologies over the crisis area (e.g., based on 3D models reconstruction).

IT tools for social media monitoring and the analysis of big amount of data will assist information processing (see Big Data).

A complex challenge that will be tackled consists in the evaluation of the reliability of the information gathered from different sources, the identification of misinformation and the correction of false information. Such will require combining the study of both technical and social data. Therefore, a cyber-social mechanism will surely be adopted. This mechanism will be able to evaluate and rank information on real-time events, conversations and, even, users, through machine learning based information security detection techniques to incorporate reports from active users. The results will, then, be used in conjunction with the traditionally used results in real-time threat detection.

Search and Rescue / Medical Support

Situations of large-scale emergencies or disasters will exhibit an effective and efficient use of resources for search and rescue operations and subsequent victim handling and treatment. All these steps involve FRs in activities that will benefit from:

- <u>Location of victims in need</u>: RF sensing (sense smartphone held by victims), infrastructure-based location (via e.g., WiFi access points); SMS SOS message with location information.
- <u>Better information of victims' needs</u>: smart App incorporating medical history; improved scanning and triage.
- <u>Assessment of victims on-site</u>: body sensors (blood pressure, heart beat rate) to automatically upload health data to handheld devices; Patient status assessment form (incorporating sensor data and risk assessment for better triage).
- <u>Automated handover:</u> victims data transferred from ambulance to hospital.
- <u>Resource Availability:</u> Information on hospitals' resources (location, available beds, staff); transportation resources (e.g., ambulances and helicopters); Route planning (special privileges for ambulances; e.g., adaptive traffic lights).

Cyber security

Cyber security is an important aspect to take into account as FR systems become more connected and more ICT dependent.

One on hand, cyber security and resilience of the communication channels, networks and services will be assured. This will mean that systems will be resilient to attacks on lower layers (e.g. protection from DDoS attacks and jamming).

On the other hand, ICT systems belonging to FR organisations will be protected from application layer attacks, namely SQL Injection or Cross Site Scripting. Such attacks on web applications and database-related ICT systems may lead to malicious operations on the data belonging to FRs and stored in these systems (e.g. information on resources and capabilities).

To better cope with cyber security, FRs will have periodic actions on training and awareness creation – i.e. in order to understand threats and learn best practices.

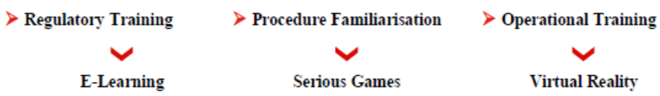
Training and Simulation

The capability of FRs to cope with and manage stress resulting from deployment in dangerous scenarios (emergency, hazardous areas, life-threatening risk) is an essential aspect that can be achieved only through effective training.

Also mission performance is significantly improved by resorting to training, in particular when it refers to the whole decision chain, comprising personnel from different organisations, with asymmetric levels of responsibility and specific procedures to follow, cooperating for the benefit of the global situation management.

In the future, specific training methods and technologies will be incorporated:

- **e-Learning**: learning environment joining multimedia and interaction, involving users and complementing traditional learning methods.
- **Serious Games**: interactive virtual simulations based on videogame technology, including decision games that allow crisis managers and responders to analyse and memorise potential consequences of their choices and decisions in simulated situations.
- **Virtual Reality**: highly immersive training environment, with realistic visual representation of scenarios and enabling characters’ interaction.
- **Augmented Reality**: corresponding to a real environment expanded with computer generated elements, both graphical, textual, or audio, in order to enhance the environment’s informational content.
- **Virtual World**: persistent simulated environment allowing the interaction among a large number of users (avatars) in real time and over the network.
- **Training Management Information System**: allowing the management of teaching and learning of procedures inside or outside training centres.



Training systems will exploit the use of new and innovative technologies:

- Body tracking, able to monitor in real time the human posture, correlating it with biometric data in order to have a complete picture of the human status.
- Monitoring of the physiological and biometric status and parameters influencing human behaviour.
- Hand tracking, able to monitor all the information on hand positions across three axis, including vibration and flicker, fingers folding and related pressure on the arm trigger.
- High-fidelity simulation tools and 3D realistic visualisation (virtual reality) for a high degree of immersion.
- Physical replica of particular conditions (e.g. bumpy road, space constraints) in order to reproduce real difficulties.
- Sounds and smell projectors, in order to recreate critical situations for emotional stress, and acoustic signature database for proper effect-making.
- Conduct of biometric data evaluation for stress assessment.

Lessons Learned Systems

FR organisations learn from previous experiences and apply knowledge management mechanisms. However, this process is difficult to implement, due to a number of reasons: e.g. lessons are very specific and difficult to generalise, lessons applied only to operational echelons, limited knowledge on mechanisms and processes related to the identification of relevant lessons and their transformation into learned lessons.

Thus, new methodologies, frameworks and tools will enable the process of knowledge management in FR and crisis management organisations. These solutions will bring more efficiency to complex endeavours, where critical events affect a broad range of sectors, infrastructures and actors, within and across Member States’ borders.

Emerging Technologies

New scientific breakthroughs and technological developments represent novel opportunities and unthought-of applications:

- Augmented reality techniques and advanced human-machine interfaces will be incorporated into gear to provide FRs more situational information (e.g. way out of the building).
- Cooperative semi-autonomous "pocket-size" unmanned platforms (e.g. marsupial UGVs and snake robots) equipped with electronic devices such as cameras and sensors to enter hazardous areas of interest (e.g., debris) and perform rapid assessment and victim localisation, allowing more

targeted and prioritised FR operations; perform on-the-fly area 3D mapping (to feed augmented reality FR goggles): Flood Modelling, Pollution Modelling, Urban Planning, Coastline Management , Cellular Network Planning, Scene of Accident/Crime, Fire and Smoke Modelling, Mapping and Cartography.
- New body worn sensors (radar, hyper spectral) and data processing on visible and infrared sensors.
- Advanced clothing/wearable systems: exoskeleton, cooling clothes, sensors-on-fabric.
- Energy management and harvesting: ambient energy harvesting (self: RF, COTS: Peltier, solar, physical movement, vibration) (see Wearables).

Design Guidelines

The future FR systems' design will comply with the following guidelines:

- Modular architecture to allow easy updating and change of response.
- Seamless interoperability – with other responders, systems and sensors.
- Low-power/Ultra-low-power operation, maximum battery life.
- Standardised interfaces and modularity for seamless extendibility.
- Interoperability: development of standards to support the design of PPDR modules and applications.
- Security by design.
- Privacy by design.

1. Annex – About IMG-S

The Integrated Mission Group for Security (IMG-S) is a wide European Network bringing together technology experts from Industry, SMEs, Research and Technology Organisations (RTOs) and Academia.

IMG-S aims to support the European Commission and its Member States to build world-class European technological capabilities. By defining research priorities for the security domain at all levels, from fundamental research to mission capabilities and system integration, IMG-S contributes to ensure that short, medium and long-term security needs are addressed.

With more than one hundred entities from 24 European countries, IMG-S covers the entire security RTD domain and is able to bring an answer to European and global security needs. Its members are well experienced in identifying the needs and requirements of security stakeholders and end-users and effectively transfer knowledge and R&D into innovations and market applications in the security sector.

The IMG-S organisation comprises seven vertical **Technical Areas** (TAs), each addressing a specific security challenge, the **Aerospace Security and Defence Strategic Research and Technology** (ASD-SRT) that provides strategic orientation and advise on security and R&T priorities, including dual-use technologies, and a **Synthesis and Coordination Group** (SCG) to orient, steer and produce integrated reports and holistic research priorities.

SCG Coordination: Marco Manso (Rinicom, UK), Brenda Wiederhold (Virtual Reality Medical Institute, BE), Andrew Proudlove (αBXL, BE).

ASD-SRT Members: Clive Goodchild (BAE Systems, UK), Cristina Leone (Finmeccanica, IT), Laila Gide (Thales, FR), Nicolas Renard (Dassault, FR), Brigitte Serreault (Airbus, FR).

TA1 (Surveillance and Identification) is focused on surveillance for citizens, infrastructure protection, urban security, crisis management and identification management of people and assets. TA1 topics span across many domains in the Security missions and technologies, thus representing a high priority for Europe.

Coordination: Alberto Bianchi (Selex ES, IT), Vincenzo Cuomo (CNR, IT), Andre Samberg (SEC-Control, FI)

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TA2 (Communications Systems) focuses on identifying innovative technologies and applicable cross-platform solutions for secure and critical communications. Its scope includes analysis of communications media, hardware, protocols, services and data efficiency meeting stringent requirements on security, privacy, reliability, availability and maintainability.

Coordination: Krzysztof Samp iTTi (PL), Artur Krukowski (Intracom, GR), Marco Manso (Rinicom, UK), Andre Samberg (SEC-Control, FI)

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TA3 (Ethics, Human Factors, Societal Impact) is a cross-cutting area devoted to new concepts recently emerged - such as societal security and the notion of human security - that are integral to the European security philosophy. TA3 aims to inject into the technological and industrial matrix the main ethical, human rights, privacy and societal implications of security.

Coordination: Brenda Wiederhold (Virtual Reality Medical Institute, BE), François Prenot-Guinard (Airbus, FR), Robert Gianni (University of Namur, BE)

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TA4 (Resilience) focuses on delivering innovative and adaptive technology and societal solutions to strengthen recovery to man-made and natural disasters, addressing all 'systems' employed in Prevention, Preparedness Response and Recovery.

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TA5 (Information Processing and Management) is at the core of human sense-making, dialogue, analysis, decision-making, design, government and any organised human activity today. TA5 aims at identifying, exploring and developing concepts, architectures, technologies and support for information infrastructures that will enhance information processing and management for security applications.

Coordination: Hakan Enquist (Chalmers University, SE), Rainer Koch (Universität Paderborn, GE), Stefano Pasquariello (SELEX ES, IT)

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TA6 (CBRNE) a group of European experts working in the Chemical Biological Radiological Nuclear Explosive (CBRNE) field. The group addresses the complete range of technologies, methods and procedures taken to provide effective Prevention, Resilience, Resistance, Reaction and Recovery concerning the CBRNE environment.

Coordination: Jean-Claude de Miscault (Miscault Ingénierie, FR), Maarten Nieuwenhuizen (TNO, NL), Alexandre Custaud (ISA, FR), Andrew Proudlove (αBXL, BE)

Contact: ta6@imgs-eu.org

TA7 (Cyber Security) focuses on studying innovative technologies and applicable solutions for cyber security domain, cyber crime fighting and cyber crime prevention.
Coordination: Andre Samberg (SEC-Control, FI), Michal Choras (iTTi, PL), Bartosz Jasiul (WIL - Military Communication Institute)

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