Mission Critical Human Factors Engineering
Comments to Productivity Commission

Public Safety Mobile Broadband

First Responder Centered & Public Safety Systems Oriented Solutions

High Velocity Human Factors "*HVHF*" Sciences LLC

http://hvhfsciences.com/

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1 Introduction

This comments in the form of a "technical brief" presents an overview of a public safety socio-technical systems and human factors oriented approach to architect, design and operationalize the Public Safety Mobile Broadband (PSMB) for Australia. The benefits resulting from this approach are as follows:

1. Enhancing the value proposition of the in terms of utility and usability delivered to Public Safety Agencies, and ultimately, first responders at the tactical edge.
2. Deliver best-in-class and an effective communication and computing solution to PSMB / Productivity Commission on budget, by taking into consideration the social, human and technical factors that make up a public safety and emergency management system.

2 Public Safety & Emergency Management

A public safety system, which brings together highly trained professionals and information & communication technology (ICT), given its charter to protect citizens, assets and enhance security, should have very high reliability and capable of high performance to realize its goals. These characteristics are integral to what makes a Public Safety Socio-Technical System (STS).

Box 1

Public Safety Socio-Technical System (STS)

A socio-technical system is one in which humans provide essential functionality related to deciding, planning, collaborating and managing. Drawing on contemporary insights from human factors & cognitive engineering, and organizational psychology specialists seek to design first responder and emergency management systems that are effective and robust.

The focus is on amplifying the human capability to reliably perform physical and cognitive work that is critical and time sensitive work by integrating human, communication & computing assets at-large in the public safety system..

The success of a technology is contingent on the utility and usability ("user friendliness") it delivers to an enterprise and its human users (end-users). Thus the success of a public safety broadband network in general, and the Operational Architecture (OA) of PSMB in particular, depend on the value (utility and usability) it delivers to the Public Safety agencies and end-users. This can be realized by taking a systematic approach to understanding and analyzing public safety operations as a complex socio-technical system (STS) that demands high reliability and high performance (high success rates).

The public safety STS is a dynamic one. This may range from normal days (e.g., traffic stops), off-nominal days (e.g., large structure fires, large planned events) to abnormal days with wide-area, large scale emergencies (e.g., hurricanes, floods, earthquakes, wildland fires and manmade disasters). (As we are US based, we share our experience and examples from our experience and vantage point, which maybe applicable to Australia as well.) FEMA[1] has developed a taxonomy to classify the emergency events by size, scope and emergency response management. For example, a Type 1 emergency (localized, large scale) is managed by a structured deployment of human, machine, radio and computing assets via the Incident Command System (ICS). This is hown in Figure 1, for illustration and discussion purposes.

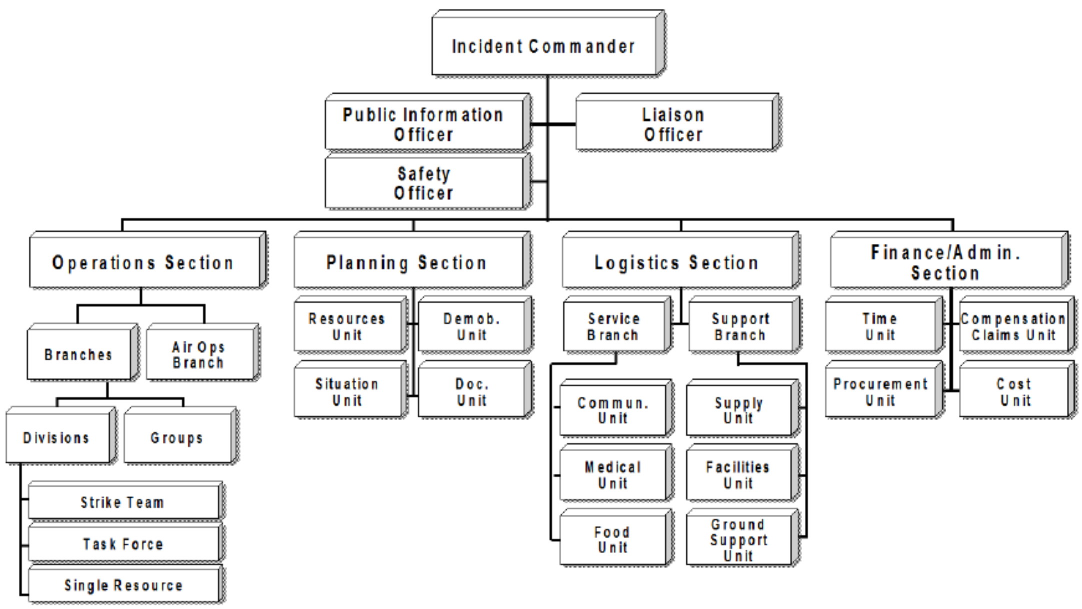


Figure 1: Incident Command System (ICS)

The successful delivery of first responder services at the tactical edge, by the strike team (left-most branch in Fig. 1), is facilitated by bidirectional flow of communication (voice, data, media) vertically up/down the chain of command and is coordinated horizontally among the four sections shown in Figures 1 & 2.

[1] A high level FEMA emergency classification system is presented in Appendix A (Sec. 4.1).

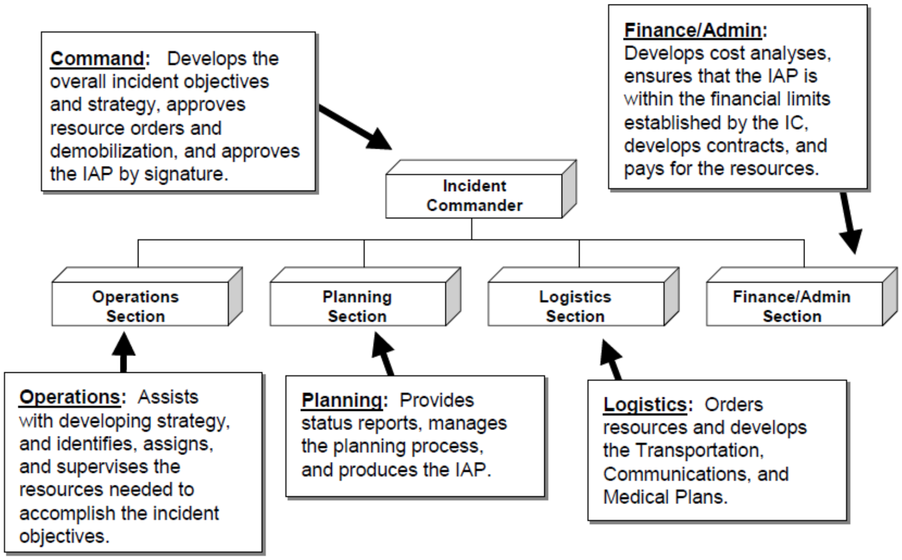


Figure 2: The top level responsibilities, tasks and functions of the ICS.

Finally, the emergency "response" itself is one of the four phases in the emergency management cycle (Figure 3).

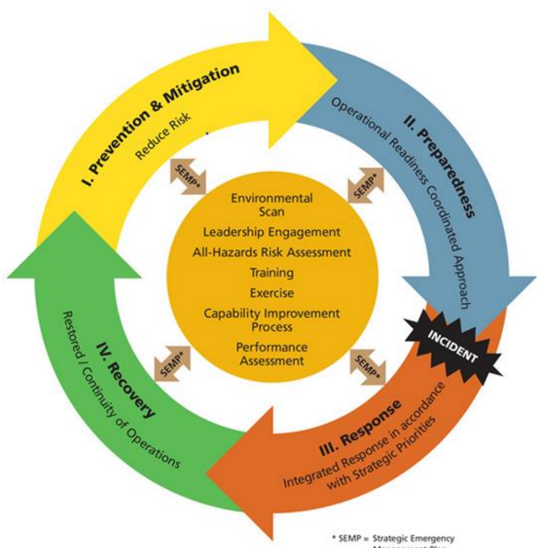


Figure 3: The Four Phases of Emergency Management (EM)

Thus the question of how to design a public safety grade broadband network to serve the needs of emergency management in general, by scaling up/down in an agile manner to match with the incident type, to provide connectivity and interoperability across agencies, personnel and databases begins with a detailed understanding of the *Use Cases* (scales, scopes, levels, terrain, predicted / unpredicted / unanticipated ("Black Swan" Event) of emergencies).

Box 2

What is Interoperability?
Interoperability is the ability of emergency responders to communicate among jurisdictions, disciplines, and levels of government, using a variety of frequency bands, as needed and as authorized.

The interoperability continuum is graphically illustrated in Appendix A (Sec. 4.2).

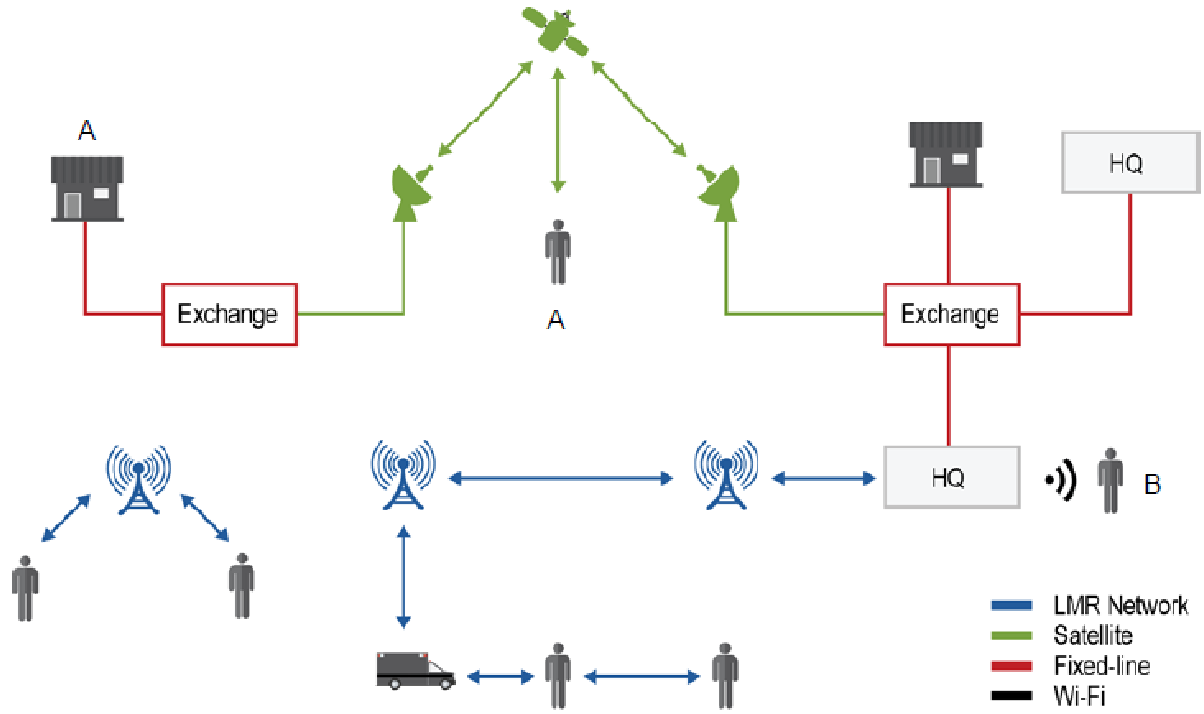
Furthermore, a LTE system should be designed to support not just the *"response"* but *all* four phases of the Emergency Management cycle (Figure 3). This socio-technical system based understanding is essential not only to provide a robust and resilient network design, but also to *innovate* with powerful differetiators, so that the public safety broadband network delivers relevant, useful and *usable* (voice to multimedia) services to the right first responder when and where needed.

2.1 Public safety Network Design and Information & Communication Technologies

2.1.1 LMR to LTE

The strengths, particularly mission critical push-to-talk (PTT) voice and reliability of the current public safety communication technology, narrowband LMR (Land Mobile Radio; APCO P25), are well known. So are the weaknesses (limited or no interoperability with non-P25 & other proprietary systems; limited data services, etc.). In addition to this, LMRs are limited in that they are not agile and mobile when agencies from different jurisdictions and emergency response platforms (aviation, marine) converge in medium-sized incidents to large scale disasters. (FEMA Type 1 – 3 incidents). Figure 4 illustrates an advanced LMR system that is typically used by a well-funded and equipped public safety agency.

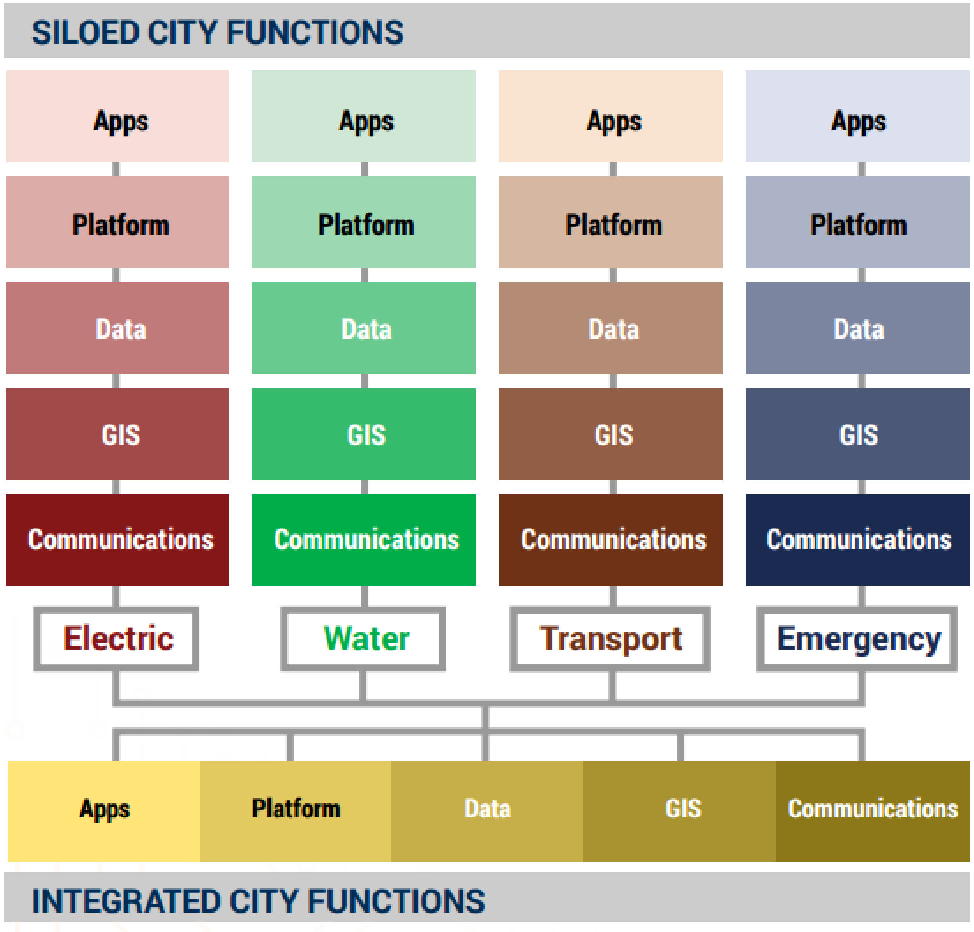
Even though vendors have developed RoIP (Radio over IP) solutions for ad hoc patching purposes, they lack both in utility and usability, as they fail to overcome the socio-technical aspects of an ICS. This problem came to fore, during Hurricane Katrina, when various public safety agencies struggled to coordinate and collaborate to deliver emergency response and recovery services.



(credits: Australian Government Productivity Commission)

Figure 4: A traditional LMR system despite its strengths and recognized weaknesses lacks agility and fluidity to configure and connect various first responder agencies from different jurisdictions. Even though vendors have developed RoIP (Radio over IP) solutions they lack both in utility and usability.

Another major problem faced by critical infrastructure services are the siloes of information impeding interoperability among databases, communication and computing systems among various agencies serious challenges for public safety and effective delivery of emergency response (Fig. 5). Thus PSMB's utility is amplified if it able to connect the silos and transform them into end-user friendly, Integrated City Functions (bottom of Fig. 5).



(courtesy: Smart Cities Council)

Figure 5: PSMB operational architecture should overcome data, informational, and computing silo's among critical infrastructure organizations and Integrate City Functions to facilitate public safety.

2.1.2 Public Safety LTE Network Socio-Technical System

PSMB is much more than providing broadband wireless connectivity and coverage footprint, as important as they are. If its potential has to be fully realized and operationalized at the tactical edge for public safety and emergency response, it needs to be seen through the important mission elements of the public safety STS, which are:

1. Mission Critical
2. Mission Essential
3. Mission Functional

Figure 6 illustrates the above, with a schema, that would directly bear on the communication and computing architecture of PSMB.

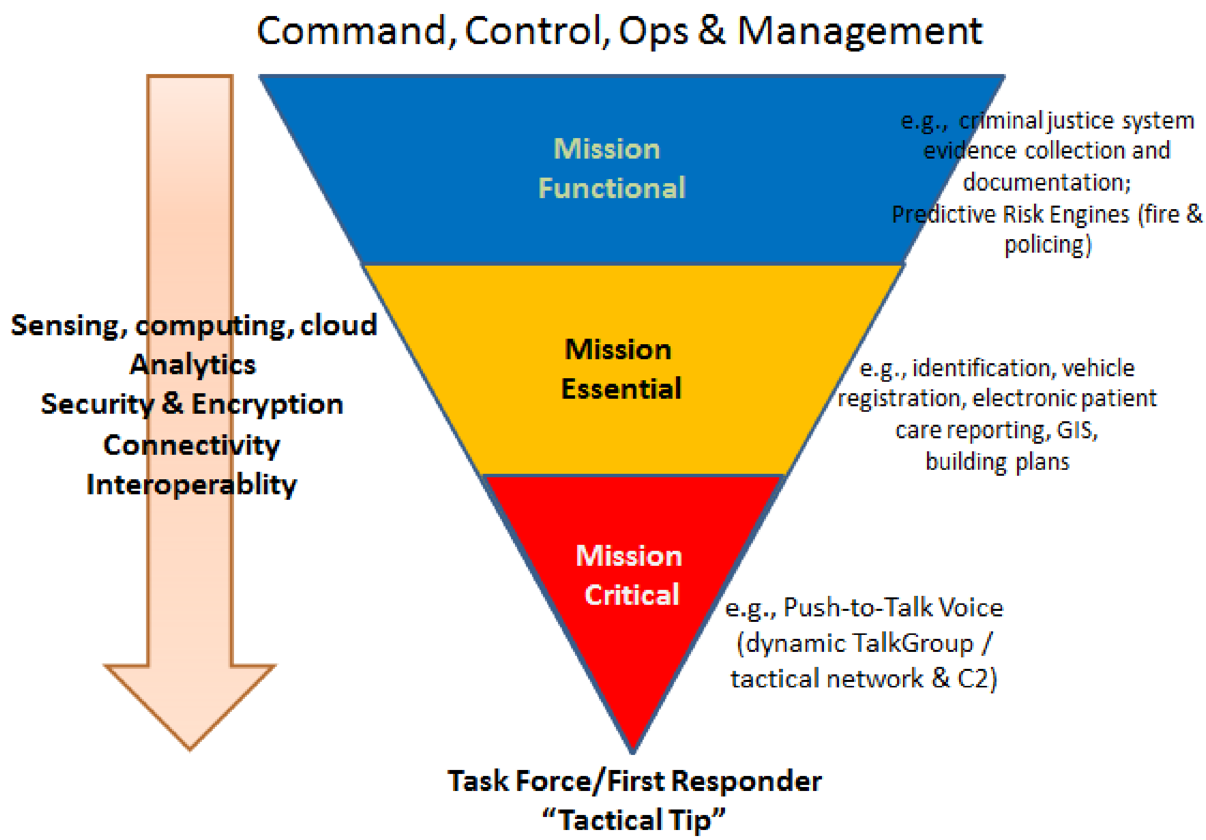


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Figure 6: Mission Elements of a Public Safety Socio-Technical System that must be operationalized by a LTE communication (PSMB) and computing networks.

Given that this document is a Technical Brief, Figure 6 just provides an overview of how the Operational Architecture for PSMB must be ideated and conceived by taking a socio-technical systems perspective. Furthermore, the operational architecture for PSMB must also consider various types and critical aspects of emergency response to be successful. Below are sample cases:

- Providing incident situation awareness ("ground truth") to first responders. For example, school shootings, commercial or public transportation (rail, aviation) accidents, hurricanes, physical and cyber-attacks to infrastructure, etc.
- Interlinking networks (any-to-any connectivity; e.g., public safety to commercial networks or ad hoc patching of a RoIP to a PA system) during impending or currently unfolding disasters in real time.

The above – and additional cases -- are beyond the scope of this Technical Brief. For a quick review of potential and possibilities, please follow the links below to HVHF Sciences' post-incident analyses, case studies and models of emergency response delivery with broadband connectivity:

SITUATION AWARENESS" - Say what? by @mrahman4 on @LinkedIn https://www.linkedin.com/pulse/situation-awareness-say-what-moin-rahman

PSMB: Reaping the Benefits of the Broadband by Aligning it with Social and Human Factors by @mrahman4 on @LinkedIn https://www.linkedin.com/pulse/PSMB-reaping-benefits-broadband-aligning-social-human-moin-rahman

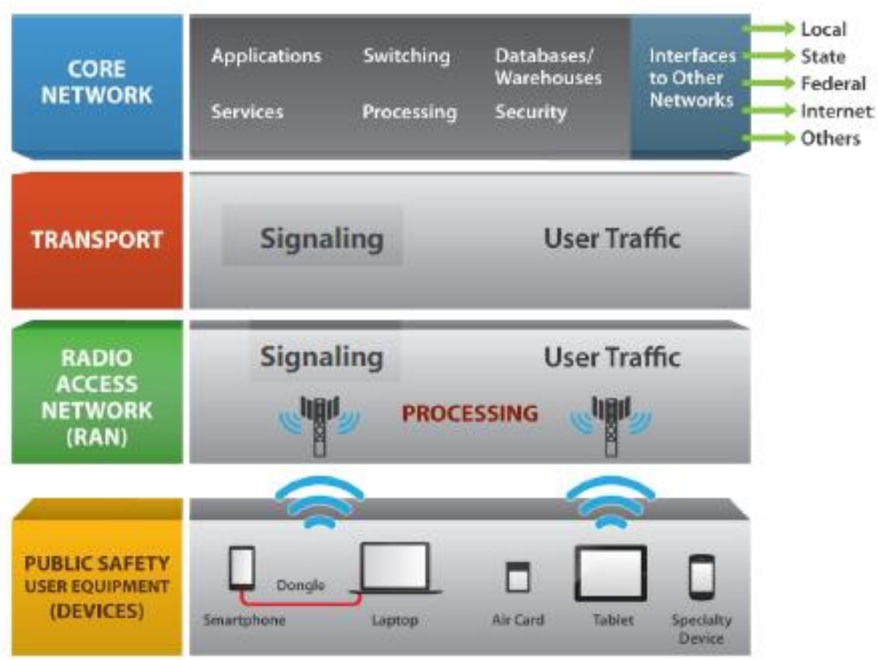
The Future of First Responder Comms/Computing & Emergency Management: New Technology Considerations by @mrahman4 on @LinkedIn https://www.linkedin.com/pulse/future-first-responder-commscomputing-emergency-new-moin-rahman

2.1.3 PSMB: First Responder Centered & Public Safety Systems Oriented Design and Innovations for the PSBN

As discussed in the previous sections, the design and innovations for the Public Safety Broadband communication and computing Network (Figure 6) can't be purely seen in technological terms – a "*Cyber-Physical System*" -- without taking into consideration the socio-technical and human factors of a public safety system.

Box 3

What are Cyber-Physical Systems?
Massive integration of wireless networks, advanced sensors, 3D simulations, and cloud services that are enabling a new generation of Smart Systems.



(credit: FirstNet - USA)

Figure 6: Basic LTE Network Components: High Level Architecture in Pure Technological Terms

To maximize the utility delivered by public safety LTE network, including usability, efficiency and costs, it is imperative that the public safety STS be adopted to inform the design and architecting of PSMB. This ranges from getting a detailed understanding of organizational structures and operational protocols of public safety agencies, emergency management practices, data/information/knowledge needs of personnel in real time, to a variety of use cases in the field. Additionally, one also needs to take into consideration the evolution of LTE over the next decade (VoLTE, IMT-Advanced, etc.) – how it may influence public safety operational protocols and structure – and the acceptance and use of new services and offerings by first responders and other end-users.

The comprehensive knowledge of the public safety STS and first responder human factors should be obtained and made intrinsic into PSMB's (LTE network's) operational architecture. This, in turn, will enable LTE network engineers, technologists, and policy makers to develop valid specifications, standards, and set realistic goals that can be attained when PSMB is operationalized. and operationalize the network. This is listed below by using a LTE network rubric that consists of *coverage*, *capacity*, and *radio access network.*

Coverage required for a given geotype (urban, rural, tribal areas) and type of anticipated public safety STS operations to support various use cases: citizen services to emergency response scenarios:

- Type of LTE & LMR networks, ad hoc Incident Area Networks & scalability and interlinking (fixed infrastructure; Cellular on Wheel or Light Truck/CoWs & CoLTs; 802.11x Wi-Fi; DSRC; RoIP; LTE-D/Proximity Services, etc.).
- Spectrum utilization, loaning, leasing, and authorized opportunistic appropriation strategies; and bandwidth requirements from center to edges of network.
- COML (comms. Leader/operator) and/or smart machine driven real time network configurations to make knowledgeable and informed optimizations for QoS (Quality of Service), Prioritizing and Preempting (QPP).
- Types of communication and computing devices supported (e.g., LMRs, Cognitive Radios, Hybrid LMR/LTE radios, Vehicular Modems, Smartphones, Tablets, etc.).

Capacity required for a given size and type of Public Safety STS and available RF spectrum:
- Normal & Off-Nominal Days: Support X number of (intra- & inter) agencies and users
- Non-normal & Abnormal Days: The above + the anticipated user and organizational configurations (inter-connectivity, linking, interoperability)
- Downlink/Uplink rates to support communications & applications (voice, data, video, multimedia)

Radio Access Network (RAN) for a given geotype (urban, rural, tribal areas) and type of anticipated public safety STS operations to support various use cases: citizen services to emergency response scenarios:
- Determine the locations and Sites: RAN sites access points (towers, antennas, power equipment) and size of LTE cells (macro, micro, pico)
- Site hardening solutions based on anticipated criticality to deliver the desired QoS and QPP (including security & reliability): physical, augmented back-up power, dual path backhaul transmission.
- Core network hardware and software: network monitoring tools, operations support system, business support system, LMR network gateways.

3 HVHF Sciences' Recommenations

This technical brief provided an overview on the importance of understanding public safety socio-technical systems and mission critical human factors and applying it to effectively design PSMB at cost; meet and exceed the service and quality goals set by PSMB; and provide the foundations to innovate in the design of the RAN, network hardware and software, and deliver an outstanding utility and usability to public safety agencies, personnel and first responders from the back-end (dispatch & command)to the tactical edge.

1. PSMB should provide both a rationale and pathway to take include public safety socio-technical system and human factors considerations, to design, operationalize and realize a public safety broadband network that is powerful, innovative and delivers high value proposition to PSMB.
2. Involve experts in mission critical human factors & communications and emergency management socio-technical systems to develop criteria and evaluate proposals from vendors. Utilize a vendor with the ability of delivering the following; or engage a teaming partner to ensure the following:
    a. Collaborate with vendor's engineers and program managers to integrate public safety STS and Human Factors
    b. Identify ways and means to enhance utility, usability and efficiencies for public safety agencies and first responders.
    c. Perform technical reviews of design and engineering and provide inputs as required.
3. Engage and utilize subject matter experts to provide PSMB deep pubic safety domain knowledge from actual practioners and first responder professionals (police officers, firefighters, paramedics, public safety communication experts, mission critical telecommunication human factors experts)

4 Appendix A

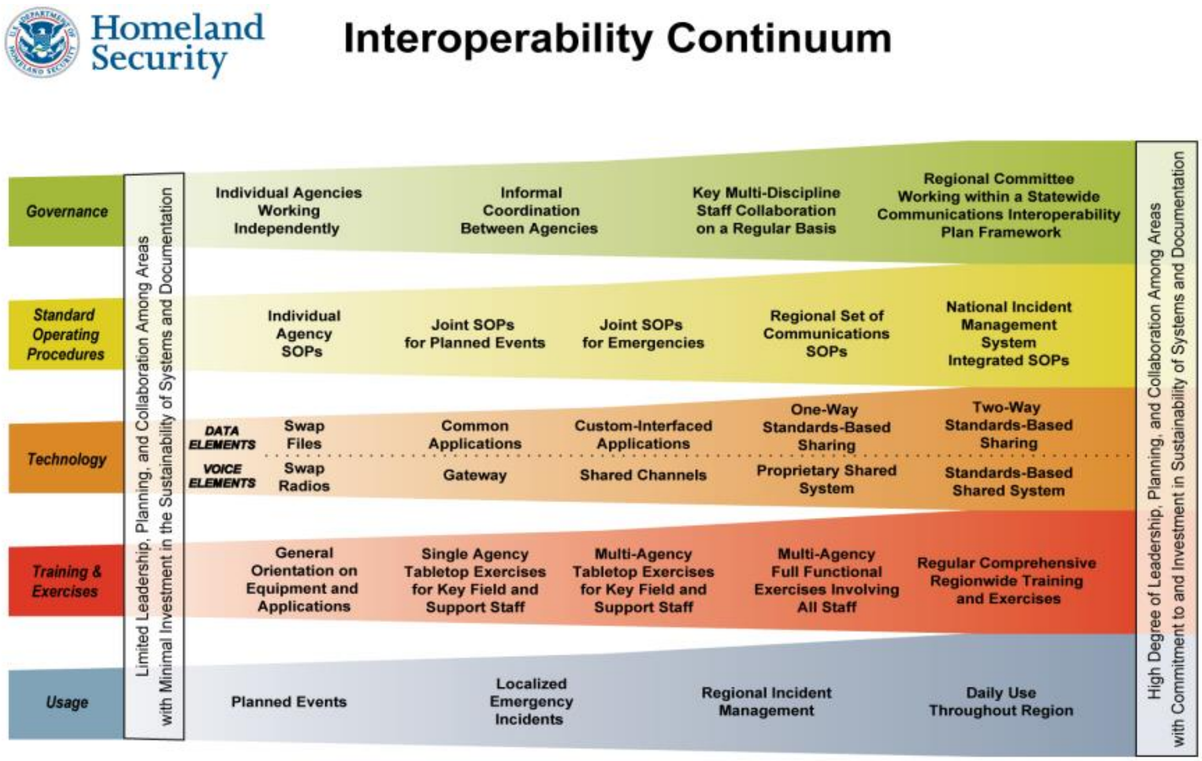
4.1 FEMA's Classification System for Incident Complexity

Incident Complexity

Incident and/or event complexity determines emergency and incident response personnel responsibilities as well as recommended audience for NIMS curriculum coursework delivery. The *NIMS Training Program* training recommendations reflect the following five levels of complexity:

Type 1	• This type of incident is the most complex, requiring national resources for safe and effective management and operation. • All command and general staff positions are filled. • Operations personnel often exceed 500 per operational period and total personnel will usually exceed 1,000. • Branches need to be established. • A written incident action plan (IAP) is required for each operational period. • The agency administrator will have briefings, and ensure that the complexity analysis and delegation of authority are updated. • Use of resource advisors at the incident base is recommended. • There is a high impact on the local jurisdiction, requiring additional staff for office administrative and support functions.
Type 2	• This type of incident extends beyond the capabilities for local control and is expected to go into multiple operational periods. A Type 2 incident may require the response of resources out of area, including regional and/or national resources, to effectively manage the operations, command, and general staffing. • Most or all of the command and general staff positions are filled. • A written IAP is required for each operational period. • Many of the functional units are needed and staffed. • Operations personnel normally do not exceed 200 per operational period and total incident personnel do not exceed 500 (guidelines only). • The agency administrator is responsible for the incident complexity analysis, agency administration briefings, and the written delegation of authority.
Type 3	• When incident needs exceed capabilities, the appropriate ICS positions should be added to match the complexity of the incident. • Some or all of the command and general staff positions may be activated, as well as division/group supervisor and/or unit leader level positions. • A Type 3 IMT or incident command organization manages initial action incidents with a significant number of resources, an extended attack incident until containment/control is achieved, or an expanding incident until transition to a Type 1 or 2 IMT. • The incident may extend into multiple operational periods. • A written IAP may be required for each operational period.
Type 4	• Command staff and general staff functions are activated only if needed. • Several resources are required to mitigate the incident, including a task force or strike team. • The incident is usually limited to one operational period in the control phase. • The agency administrator may have briefings, and ensure the complexity analysis and delegation of authority is updated. • No written IAP is required but a documented operational briefing will be completed for all incoming resources. • The role of the agency administrator includes operational plans including objectives and priorities.
Type 5	• The incident can be handled with one or two single resources with up to six personnel. • Command and general staff positions (other than the incident commander) are not activated. • No written IAP is required. • The incident is contained within the first operational period and often within an hour to a few hours after resources arrive on scene. • Examples include a vehicle fire, an injured person, or a police traffic stop.

4.2 *Interoperability Continuum: Public Safety & Emergency Management Socio-Technical System*



5 About *HVHF Sciences, LLC*

HVHF Sciences specializes in the research and design of first responder socio-technical systems and mission critical human factors engineering. HVHF's core expertise and practice areas include joint cognitive systems that bring together human and computing assets & communication networks in critical infrastructure organizations such as public safety, transportation, hospitals, utilities and other safety critical enterprises.

HVHF performs RD&E for human-systems integration and user-interface design & cognitive engineering of technology used by first responders, surgeons, and operators such as portable communication & computing devices, in-vehicle human-machine interfaces (HMIs), control rooms, among others.

HVHF's has designed human-technology interfaces (graphical & physical user-interfaces, decision aids) from in-vehicle technologies and their human-machine interfaces (HMIs), wearables to dispatch, command & control computers; joint cognitive systems engineering of partly automated systems and autonomous vehicles.

Box 4

HVHF's principal scientist, Moin Rahman, has over 15-years of experience in the telecommunications and public safety industry – including 12 years at Motorola Solutions as Principal Human Factors Scientist to the CTO – and academia. He has conducted extensive research and design of technology for public safety radio communication technologies (APCO P25, TETRA, iDEN, 3GPP); first responder cognition and decision making under normal to stressful (high stakes and time compressed) situations.

Moin has performed extensive R&D work on human-system network integration and interaction design for first responder / public safety domains; Human-Machine Interface (HMI) / user-interface (UI) design and usability testing on s/w and h/w for portable, wearable, and in-vehicle communication and computing devices used by first responders.

Moin is a member of NPSTC committees (interoperability & EMS) and his work has been cited by PSAC (public safety advisory committee) when it was tasked by PSMB to develop Human Factors guidelines and specifications for the Public Safety Broadband Network.

Moin Rahman's LinkedIn Profile: http://www.linkedin.com/in/moinrahman

HVHF staff comprise of human factors specialists & cognitive engineers, public safety subject matter experts (law enforcement officers, paramedics and fire fighters), user-interaction designer, and experts in public safety radio communications and automotive technologies (autonomous & connected vehicles).

HVHF Sciences serves the following domains (organizations, industries and product categories): Public safety & homeland security, emergency/first responders, transportation, power generation & process industries, warfighting, healthcare, and safety-critical consumer products.

HVHF Sciences has been awarded contracts by Federal Government and Private Sector Clients and has successfully delivered services that have met and exceeded client expectations.

Most recently (2014-15), HVHF Sciences as a teaming partner to Mercer Engineering Research Center performed research and analysis of RF interference (Radios and First Responder PANs) and its human factors and public safety systems impact on delivering the emergency response. This study was done in simulated, live exercise settings where first responders performed search & extrication in a collapsed building, delivered emergency response on an aircraft that was disabled in flight and landed and to a bomb threat in a subway (underground simulations). The findings and engineering design recommendations were delivered to the sponsoring client:
Department of Homeland Security (DHS), Science & Technology Directorate (First Responder Group): Contract Number: BAA DHS-ST-14-065-FR01.

HVHF Sciences LLC is a minority owned small business. HVHF is SAM certified to perform work on Federal Contracts and its registration is valid until 6/3/2016.

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