Interworking Mission Critical Push-to-Talk (MCPTT) between Long Term Evolution (LTE) and Land Mobile Radio (LMR)

A Feasibility Study
Conducted for the

U.S. Department of Homeland Security (DHS)
Science and Technology Directorate (S&T)

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July 1, 2019

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Forward

This document is derived from the Final Report of a Small Business Innovative Research (SBIR) Phase I Contract with the Department of Homeland Security Science and Technology Directorate. It summarizes our conclusions from that research effort to investigate the feasibility of a standards-based Interworking solution to enable LMR to LTE communications, and also to enable LMR to LMR communications between different LMR systems. SBIR initiatives are organized around Phase I research, Phase II prototype development, and Phase III commercialization activities. The Phase I Final Report was delivered in November 2018 and in March 2019, Catalyst Communications technologies was notified it was the recipient of a Phase II Award for prototype development. A contract to proceed with this development was executed between Catalyst and DHS in April 2019. This version of the Final Report omits certain confidential information. The Phase II Award has a delivery timeframe of two years.

Beginning in April 2019, Catalyst began initial prototype development activities, including identification of 5 prototype deliverables, test equipment acquisition, initial identification of beta test candidates, assignment of internal resources, and other activities critical to the success of this Phase II project. Of the five prototype we will create, the first prototype, which will demonstrate basic Interworking between an LMR (Land Mobile Radio) talk group and an LTE (Long Term Evolution) Mission Critical Push to Talk group, is planned for March 2020 demonstration at the IWCE 2020 Exposition in Las Vegas.

Readers of this report that wish to remain current with our progress, or be considered for beta test / prototype deployment, are encouraged to contact us at interworking@catcomtec.com

- Catalyst Communications Technologies

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Abbreviations

3GPP	3rd Generation Partnership Project
DFSI	Digital Fixed Station Interface
DHS	Department of Homeland Security
DMR	Digital Mobile Radio
E2EE	End-to-End Encryption
ETSI	European Telecommunications Standards Institute
FSI	Fixed Station Interface
GSU	Generalized Subscriber Unit (P25 Subscriber Units and Consoles, MCPTT UEs)
ISSI	Inter RF Subsystem Interface
ISSI-c	Inter RF Subsystem Interface (future “compatible” version)
IWF	Interworking Function
IWF-*	Interworking Function Interfaces IWF-1, IWF-2, IWF-3
IWG	Interworking Gateway
IWGA	Interworking Gateway Adapter
KMF	Key Management Facility
LMR	Land Mobile Radio
LTE	Long Term Evolution
MC	Mission Critical
MCPTT	Mission Critical Push to Talk
NPSBN	Nationwide Public Safety Broadband Network
NPSTC	National Public Safety Telecommunications Council
NR	NPSTC Report
OTAR	Over-The-Air Rekeying (P25)
P25	Project 25
PTT	Push-to-Talk
SDS	Short Data Service
TETRA	TErrestrial Trunked Radio
TIA	Telecommunications Industry Association
UE	User Equipment

2 EXECUTIVE SUMMARY

Catalyst has proven the technical feasibility of building an Interworking Gateway (IWG) function that provides Mission Critical Push-to-Talk (MCPTT) voice interoperability between Long Term Evolution (LTE) and Land Mobile Radio (LMR) systems and between LMR systems. This analysis has included both Project 25 (P25) and non-P25 radio systems. The project culminated in specifying functionality and quantifying agency cost for a set of specific interworking configurations. The configurations include an Interworking Gateway Adapter that acts as a Bridging Gateway between systems supporting P25 Inter RF Subsystem Interface (ISSI) and P25 or non-P25 LMR systems that do not support ISSI including Digital Mobile Radio (DMR) and Terrestrial Trunked Radio (TETRA).

Catalyst has developed important inventions that will help provide LMR to LTE and LMR to LMR interworking for public safety. The IWG Adapter supports interfacing multiple LMR technologies by adapting them to be P25 ISSI compliant. For example, if the MCPTT service provider exposes an ISSI interface as their preferred interface, the IWG Adapter can provide public safety agencies an LTE to LMR Interworking solution for a variety of LMR technologies. This also includes interfacing to outdated analog interfaces, legacy trunked systems, and other deprecated LMR systems where the MCPTT service provider may not offer a compatible or affordable solution. This study demonstrates that the IWG Adapter provides significant value to public safety. There are several other inventions we are not presenting in this report for intellectual property protection that will provide to public safety highly cost-effective configurations for connecting LMR to MCPTT.

From May to October 2018, Catalyst used its extensive experience designing, manufacturing, marketing, installing, and supporting PTT dispatch and interoperability solutions to study LMR to LTE Interworking. We began with the National Public Safety Telecommunications Council's (NPSTC) January 2018 Public Safety LMR Interoperability with LTE Mission Critical Push to Talk Report as the foundation for our requirements work. Over the course of the six-month study, we produced and submitted four confidential documents to the U.S. Department of Homeland Security (DHS) Science and Technology Directorate, and had regular communication with the team overseeing our project.

In the first deliverable, Catalyst produced 56 Recommended Core Interworking Requirements from the NPSTC Report and from those Minimum Core Requirements derived Interface Requirements. Those interface requirements were used to evaluate a number of Standards-Based Interfaces using a scoring system developed for the project.

In the second deliverable, Catalyst derived System Requirements for the Interworking Gateway (IWG) from those same 56 Core Requirements, focusing on interworking between Project 25 LMR and MCPTT LTE systems. We determined the minimum requirements, functionality, and capabilities for the IWG to meet the core requirements stated in the NPSTC Report.

In the third deliverable, Catalyst derived System Requirements for the Interworking Gateway Adapter (IWGA) from the 56 Core Requirements, focusing on interworking between Non-Project 25 LMR systems and between Non-Project 25 LMR systems and MCPTT LTE systems. We determined the minimum requirements, functionality, and capabilities for the Interworking Gateway Adapter (IWGA) to meet the core requirements stated in the NPSTC Report.

In the fourth and final deliverable, we quantified functionality and agency costs for 42 unique Interworking Configurations, which represent a matrix of all combinations of subsystems and interfaces that we have analyzed for this feasibility project. We estimated agency costs and derived relative values for each unique configuration, categorizing these into nine Configuration Types. From this data, we were able to determine which configurations provided the best overall value to determine which configurations were the best candidates for Phase II prototyping and Phase III commercialization.

We conclude that not only are many of these Interworking Configurations feasible, but that certain Configurations provide significantly greater value, require less work to set up, and could be swiftly brought to market. We conclude the document with some suggested next steps for Phase II, recommendations to Standards bodies, and our perspective on the future of LTE/LMR Interworking.

3 Overview and Deliverable Roadmap

Catalyst was contracted by the U.S. Department of Homeland Security (DHS) Science and Technology Directorate(S&T) Small Business Innovative Research (SBIR) office to use our experience and expertise in LMR Interoperability to conduct a feasibility study for Interworking between LTE and LMR and between LMR and LMR. Since 1997, Catalyst has developed extensive experience designing, manufacturing, marketing, installing, and supporting PTT dispatch and interoperability solutions for Public Safety, Federal agencies, utilities, and other Critical Communications agencies. The company pioneered Radio over Internet Protocol (RoIP) and has fielded Interoperability solutions and Dispatch systems using a variety of LMR technologies, including P25 ISSI, P25 DFSI, DMR's IP-based wireline interface, as well as various legacy trunked and conventional systems. The company maintains an extensive laboratory in Forest, Virginia.

Catalyst began this Phase I project in May 2018 by analyzing the National Public Safety Telecommunications Council's (NPSTC) January 2018 Public Safety LMR Interoperability with LTE Mission Critical Push to Talk report as our requirements. We spent six months researching and for each of the four milestones, we created a confidential document, submitted it to DHS S&T, and had regular communication with the team overseeing our project. In this Final Report, we summarize and compile the work that has been presented in the four SBIR Deliverables.

Because, however, this research is so closely related to our existing Intellectual Property (IP) and new IP has also been identified as part of this project and presented in the four project Deliverables, we provide here a roadmap of where to find the major work task items for this Phase I SBIR project. Items that are considered Catalyst IP have been excluded from this report, so access to the four Deliverables is required to examine the entire project. We are therefore providing a roadmap of where to go in the Deliverables for full information, but would encourage those who have access to the Deliverables to read Deliverable Four first.

Here is a high-level summary of all of work tasks accomplished for this project.

- Requirements Analysis
    - Catalyst used the NPSTC Report as the basis for developing core interworking requirements:

        - Catalyst analyzed and augmented these requirements to derive and define 46 Core interworking requirements. See Deliverable 1, Table 1.
        - Defined a Conceptual Architecture with two different types of interfaces, two different types of subsystems, and two variants of the two subsystems. See Deliverable 4, section 2 for the final version.
        - From this Conceptual Architecture, and the Core Interworking requirements, derived:
            - LMR and LTE Interface requirements. See Deliverable 1, Table 3.
            - System requirements for the Interworking Gateway (IWG). See Deliverable 2, Table 2.
            - System requirements for the Interworking Gateway Adapter (IWGA). See Deliverable 3, Table 3.
            - System requirements for IWG and IWGA variants. See Deliverable 3, Tables 3 and 4.

- Interface Evaluation Work
    - Evaluated eight different standards-based interfaces against our derived interface requirements:
        1. LTE MCPTT as specified in 3GPP Release 15 - See Deliverable 1, sections 8.1.1 & section 8.3.1 and Deliverable 3, section 4.2.
        2. P25 LMR
            - 2.1. LMR P25 Trunked Phase II – ISSI – See Deliverable 1, section 8.1.2.
            - 2.2. LMR P25 Trunked Phase I – ISSI – See Deliverable 1, section 8.2.1.
            - 2.3. LMR P25 Conventional – DFSI – See Deliverable 1, section 8.2.2.
        3. Non-P25 LMR
            - 3.1. Analog – FSI – See Deliverable 1, section 8.2.3.
            - 3.2. DMR – DMR Application Interface Specification (AIS)– See Deliverable 1, section 8.2.4.
            - 3.3. TETRA - Inter-System Interface (ISI)– See Deliverable 1, section 8.2.5.
    - For each interface evaluation, we produced a “Conformance” factor scoring to quantify to what degree each interface meets each Core NPSTC requirements.
- Functionality/Features/Capabilities work
    - From the IWG System Requirements, derived Functional Descriptions, Feature Details and Capabilities. See Deliverable 2, section 5.2.
    - From the IWG Adapter System Requirements, derived Functional Descriptions, Feature Details and Capabilities. See Deliverable 3, section 6.2.
- Developed Feature and Cost Matrices
    - Used interface “Conformance” scoring to create and chart conformance scores for all relevant interworking combinations of evaluated interfaces and subsystems. See Deliverable 4, Figures 2, 3, 4, and 5.
    - Developed detailed cost estimates using our own internal pricing models to evaluate 42 unique Interworking Configurations for three different system sizes. See Deliverable 4, Table 4.
    - Developed a Relative Value for all 42 Interworking Configurations by combining cost estimates with Conformance scoring for three different system sizes. See Deliverable 4, Table 5.

- Classified these Interworking Configurations into different Configuration Types to rank which configuration types provided the greatest Relative Value. See Deliverable 4, Table 6 and 7, Figures 7, 8, 9, and 10.

4 CORE INTERWORKING RECOMMENDED REQUIREMENTS

We researched and leveraged contemporary work in this area as much as possible, but the foundation of our requirements is the NPSTC Report and each of the Core Interworking Requirements in Table 1 below is either directly from requirements called out there or is derived from one of them. For derived requirements, we have cited other related requirements work. See Deliverable 1, Section 5 for a much more detailed description of our work process for deriving these core requirements and the full list of requirements, including those not included for the study because they were judged to be unrelated to Interworking. An explanation for the fields in the Core Requirement list of Table 1 are as follows:

1. **Source**
    a. **NR** - The **NPSTC Report.**
    b. NPSTC Report Appendix A2 – "NPSTC PTT over LTE Report – 2013, Public Safety Technical Requirements." Added as derived requirements with one of the **NR** requirements as parent.
    c. 3GPP TS 22.179 V16.1.0 (2018-03) Technical Specification Group Services and System Aspects; Mission Critical Push To Talk (MCPTT); Stage 1 (Release 16) – Releases 13, 14, and 15 have exactly the same requirements with the same section number.
    d. We also added derived requirements in some cases to "split" requirements that were logically multiple requirements.
2. **Core Requirement Number** - the parent **NR** requirement number followed by a "." and then an incrementing derived requirement number. By convention for the core requirement itself, the "derived" requirement number is "0".
3. **Requirement** – Text of the requirement verbatim from the source.
4. Classifications for each Core Requirement:
    - **Interworking** – judged to be relevant to interworking.
    - **P25 Specific** – the requirement calls out P25 or Project 25 explicitly.
    - Interworking Classifications – each requirement will be assigned to one of these five:
        - **Basic** – judged to be a requirement for basic interworking functionality.
        - **ID Mgmt** – needed for ID Management functionality.
        - **Encrypt** – needed for Encryption functionality.
        - **Advanced** – judged to be needed for more advanced functionality that may not be required by some agencies including private calls, text messaging, and location.
        - **Design Goal** – very broad in scope or indeterminate, (e.g. calls out undefined future functionality) but can be useful in setting open or forward-thinking design goals.

The following examples walk through how to read Table 1 for three representative requirements:

1. The **Source** for the first requirement, NR 1, is the first of 46 requirements listed in Appendix A1 (page 49) of the NPSTC Report. The exact text from that report is shown under **Requirement** and Catalyst determined that it is applicable to **Interworking**, does not call out Project 25 and so is not **P25 Specific**, and is classified as a **Basic** requirement. It is numbered **Core Requirement Number** 1.0, meaning its basis is NPSCT Report requirement "1" and it is the root requirement ("0") directly from the NPSTC report, Appendix A1.
2. Requirement 1.1 was found outside of Appendix A1. Its **Source** is from the 3rd Generation Partnership Project document 22.179, requirement [R-6.18.3.2-001]. This requirement derives from and provides additional definition to requirement number 1.0. Catalyst determined that it is applicable to **Interworking**, uses **P25 Specific** language, and is classified at the **Basic** level.
3. The **Source** of Requirement 1.9 is also found outside of Appendix A1. It comes from Appendix A2 of the NPSTC Report, Table 15 (page 58), requirement 1. The exact text from that entry is listed under **Requirement** and Catalyst determined that it is applicable to **Interworking**, does not call out Project 25 and so is not **P25 Specific**, and is classified by Catalyst as an **Advanced** requirement.

Table 1 Recommended Core Interworking Requirements Derived from NPSTC Report

Source	***Core Req #***	***Requirement***	***Interworking***	***P25 Specific***	***Basic***	***ID Mgmt***	***Encrypt***	***Advanced***	***Design Goal***
4.3.1 – Interoperability									
NR 1	1.0	First responders operating on LMR and LTE networks SHALL be able to communicate with each other including while responding to the scene of the incident as well as upon arrival.	1		1				
3GPP 22.179 - [R-6.18.3.2-001]	1.1	The MCPTT Service shall enable interworking with non-3GPP PTT Systems that are compliant with the TIA-102 (P25) standards.	1	1	1				

Note: See Deliverable 1 for the remainder of this table.

5 DERIVING INTERWORKING RECOMMENDED REQUIREMENTS

5.1 DERIVED REQUIREMENTS BASED ON CONCEPTUAL ARCHITECTURE

In the first three deliverables, we evaluated all of the following standards-based interfaces against their respective LTE Interface or LMR Interface Requirements:

1. LTE MCPTT
2. P25 LMR
    2.1. LMR P25 Trunked Phase II – ISSI
    2.2. LMR P25 Trunked Phase I – ISSI
    2.3. LMR P25 Conventional – DFSI
3. Non-P25 LMR
    3.1. Analog – FSI
    3.2. DMR – DMR Application Interface Specification (AIS)
    3.3. TETRA - Inter-System Interface (ISI) - To derive requirements, functions, features and capabilities for the different components of an Interworking solution, we derived and allocated from the Core Interworking Requirements developed in Deliverable 1, requirements for five different components of the conceptual architecture presented in Deliverable 1. Consult section 7 of Deliverable 1 for full details and background for the conceptual architecture.

In summary, we derived and allocated requirements from the Core Interworking Requirements in five logical requirement categories. Listed and described slightly out of numerical order to preserve their separate groupings as interface requirements and system requirements, the five are as follows:

- Interface Requirements:
    - LMR Interface Requirements (1) – These were presented in Deliverable 1.
    - LTE Interface Requirements (2) – These were presented in Deliverable 1.
    - LMR Console Interface Requirements (5) – To be considered for a future project, not interworking.
- Subsystem Requirements:
    - Interworking Gateway (IWG) System Requirements (3) – These were presented in Deliverable 2.
    - IWG Adapter System Requirements (4) – These were presented in Deliverable 3.

We do not reproduce all of these derived requirements in this final report. Please refer to the first three Deliverables for these requirements.

5.2 EXAMPLE OF DERIVED REQUIREMENTS IN ALL CATEGORIES

These requirement categories are shown graphically in Figure 2 below. The architectural concept shown in the figure is assumed in our allocation of requirements and is best illustrated by an example. Table 2 shows a representative Core Requirement and derived requirements in each of the five categories and the two combination categories. Note that not all Core Requirements will yield derived requirements in all categories.

Table 2 Derivation and Allocation of Requirements in all Five Categories Plus Two Combinations

Core Req #	***Core Requirement***	***LMR Interface Requirements (1)***	***LTE Interface Requirements (2)***	***Interworking Gateway System Requirements (3)***	***Interworking Gateway Adapter System Requirements (4)***	***LMR Console Interface Requirements (5)***
21.1	Interworking between the MCPTT Service and P25 shall support interoperable User IDs and P25 subscriber IDs.	The LMR Interface shall send and receive a full 56-bit unique P25 Talker ID representing the ultimate source communication device.	The LTE Interface shall send and receive a fully qualified unique MCPTT Talker ID representing the ultimate source communication device.	The IWG System shall utilize a database that maps each LMR Subscriber or Console full 56-bit unique P25 Talker ID to its corresponding fully qualified unique MCPTT Talker ID.	The IWG Adapter System shall utilize a database that maps each Adapted LMR GSU Talker ID on the adapted LMR system to its corresponding (mapped) full 56-bit unique P25 Talker ID.	The LMR Console Interface shall send and receive a full 56-bit unique P25 Talker ID representing the ultimate source communication device.

This specific example demonstrates how the interfaces are communicating IDs using their “native” formats, but the translation operation between these native formats is being done by the systems that are utilizing and “bridging” these interfaces and mapping IDs between different systems.

5.3 CONCEPTUAL ARCHITECTURE

Some existing requirements for LTE to LMR interworking, for instance, seem to imply that roles that we would relegate to the IWG or the IWG Adapter are functions required of the interface. Without a *Conceptual Architecture* that apportions functionality in enough detail to flush out system design difficulties, fundamental issues may go undetected in the system design process. In this Conceptual Architecture, the role of the interfaces is strictly to communicate with other subsystems. Operational sequencing, synchronization, validation, filtering, translation, transcoding, transcoding encryption, reconciliation, and normalization, are performed by one or both of these two subsystems. We believe this level of detail is necessary for a successful feasibility study.

Unfortunately, no single entity “owns” the intersystem design called “interworking” here, so the entities that “own” the interfaced subsystems may endeavor to perform some of these functions, inappropriately, in the systems they own, resulting in a highly coupled, difficult to maintain, design. By doing these allocations objectively and taking other relevant system components into consideration, an experienced designer can ensure a robust solution without these types of system design flaws.

The IWG Adapter System Requirements (4) may be most useful in addressing some crucial concerns regarding agencies that are not using P25 today and will not be in the near future, as well as others who may be unable to afford or elect to avoid securing a radio manufacturer ISSI for their agency:

1. As shown in Figure 2, the “adapted LMR technology” could be a legacy trunked system (e.g. SmartNet, EDACS, LTR), a conventional system (e.g., Analog, MDC1200), a standards-based non-P25 system (e.g. DMR Tier III via AIS), or even a P25 system with a low-cost interface (e.g., DFSI, P25 Control Station leveraging the P25 CAI). The overall system functionality provided by each of these interfaces varies greatly, based on the interface used as well as the capabilities of the LMR technology itself. Deliverable 4 quantifies and scores these capabilities.
2. Commercialization must answer questions regarding the relative costs of an IWG Adapter, the IWG itself, versus no-access or limited, voice-only access:
    a. Each combination of interfaces and subsystem components is called an Interworking Configuration.
    b. The IWG Adapter, because it is a separate component, may add cost to the solution, but it provides essential functionality that, if not provided by the adapter, would still need to be provided in an alternative way.
    c. On the other hand, if the P25 ISSI interface is provided as a standard MCPTT offering, the adapter being a separate component may reduce the overall cost to the agency. Further, in the event that the MCPTT interface is not made available to the agency, the adapter could still provide much needed capabilities.
    d. Conceptually, the IWF always presents the same interface (some variant of ISSI) so that it does not have to deal with the vagaries of various LMR technologies, along with providing a complex and comprehensive interface between LMR and LTE.
    e. If the LMR system already has an ISSI interface, then the Adapter is not needed and ISSI can connect directly to the IWG. That being said, for most radio manufacturers, ISSI is an expensive option, likely more expensive than the alternative IWG Adapter.
    f. The IWG Adapter may enable an agency with an aging non-P25 LMR system to avoid purchasing P25 by managing the interoperability with LTE required during its transition to a pure LTE system.
    g. In a commercial deployment, the IWG and IWG Adapter might be sold as a single appliance or service. To the public safety agency, they would be purchasing an LTE interface with a variety of available interfaces with capability and capacity commensurate with their needs and budget.

5.3.1 Embracing P25 ISSI and the MCPTT IWF Concept

Again, in an ideal world where we were doing this evaluation and feasibility study with no prejudice for particular technologies, we would have applied the same interface requirements to both subsystems. With the work already done by ATIS, TIA, and others and assumptions already made, the most efficacious means of evaluating these interfaces is to apply known differences between LTE MCPTT and LMR P25 subsystems to the requirements process. LMR and LTE interfaces are, consequently, asymmetrical and LTE and LMR interfaces are reviewed against a different set of interface requirements.

The interworking function (IWF) specified by 3GPP is a method of interfacing LMR to the 3GPP mission critical system. The mission critical standard is broken into multiple components. The Mission Critical Services Common Requirements (MCCoRe) define the overall requirements and architecture for registering and expressing interest with groups and is used across all MC services. MCPTT is defined for the PTT service itself, and MCData for short messaging, file transfer, and other public safety data transactions. The interworking function has interfaces to MCCoRe (IWF-3), MCPTT (IWF-1), and MCData (IWF-2) functions. Therefore, the Interworking Gateway in Figure 2 (what 3GPP calls the IWF) will need to act as a peer-to-peer servers for each of these three interfaces. Figure 1 expands and details the interface we refer to Figure 2 as **IWF-***, which is shorthand for IWF-1, IWF-2, and IWF-3.

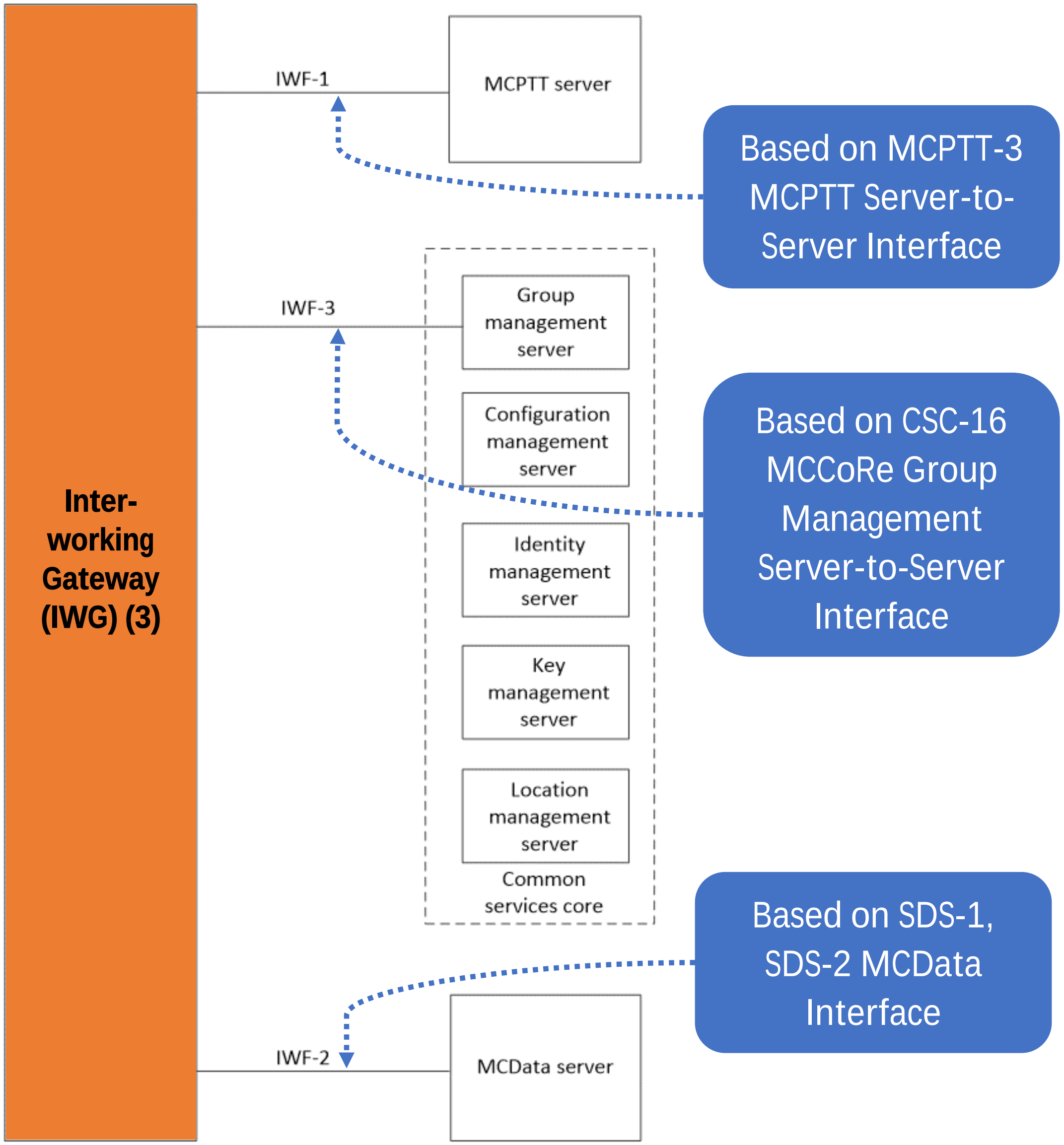

Figure 1 Expansion and Explanation of IWF- Interface*

5.3.2 The ISSI-c Concept

In Deliverable One, we coined the term and concept "ISSI-compatible" (**ISSI-c**) that we use to describe the Interworking Gateway's possible future refinement of ISSI. The concept is that ISSI-c will interoperate with another RFSS ISSI interface as if it is an ISSI connected to a P25 RFSS. However, it will have several published (i.e., not manufacturer specific) extensions that will allow it to enable and facilitate LMR to LTE and non-P25 LMR-to-non-P25 LMR interworking functionality that would not be possible with the P25-centric ISSI as it exists today. There are capabilities that would never be required when connecting a P25 RFSS to another P25 RFSS that would be of immense benefit if present when future non-P25 systems (including MCPTT) are connected using such an interface.

We understand that there would be licensing and maintenance issues with this approach and, though it would be less effort overall to enhance the ISSI standard and have a single standard, this might not be practical for, or desired by, radio manufacturers. ISSI is a logical starting point for this interface, but, like any standard, needs to be refined and adapted to changing environments.

Initially, of course, today's P25 ISSI would be the deployed interface, leveraging an installed base and general acceptance in the LMR industry. We emphasize this in Figure 2 by using the term ISSI and not ISSI-c. But as the technology and market matures and more vendors leverage the interface for more purposes, including connecting to non-P25 LMR systems, the limitations of this IP-based interface for these applications will need to be addressed.

The interface was defined with the view that it would only be used with P25 systems. So, for example, it only supports P25 codecs, enforces rules making it difficult to have an RFSS "hub" connecting multiple systems, and has messaging and configuration complexity required because a subscriber may roam between systems. There will be opportunities for improvement to the ISSI interface used on a future version IWG where we are emulating a P25 RFSS, but the connected system is not a P25 radio system.

5.3.3 ISSI Phase 2 Recommendations

There were a number of issues that were identified during Evaluation of the P25 Inter-Subsystem Interface Phase 2 during Deliverable 1. Because this interface is central to much of the work described herein and because this interface is already being used as an interface to non-P25 systems, we recommend that the following non-compliance items be addressed and put on the roadmap for a future revision:

1. Core Requirement 1.5 - **The LMR Interface shall support codec identification and/or negotiation.** - Our evaluation gave this requirement a Conformance factor of 0.5. See section 14.1 of this document for a detailed explanation of Conformance factors.
2. Core Requirement 1.13 - **The LMR Interface shall support non-P25 codecs to minimize transcoding degradation when an IWG Adapter is in use. <Future enhancement>** - Our evaluation gave this requirement a Conformance factor of 0.0.
3. Core Requirement 3.10 - **The LMR Interface shall support both talkgroup and unit to unit Texting capabilities.** - Our evaluation gave this requirement a Conformance factor of 0.2.

4. Core Requirement 45.0 - **The LMR Interface shall support full duplex talkgroup audio with both transmit and receive audio flowing concurrently.** - Our evaluation gave this requirement a Conformance factor of 0.1.

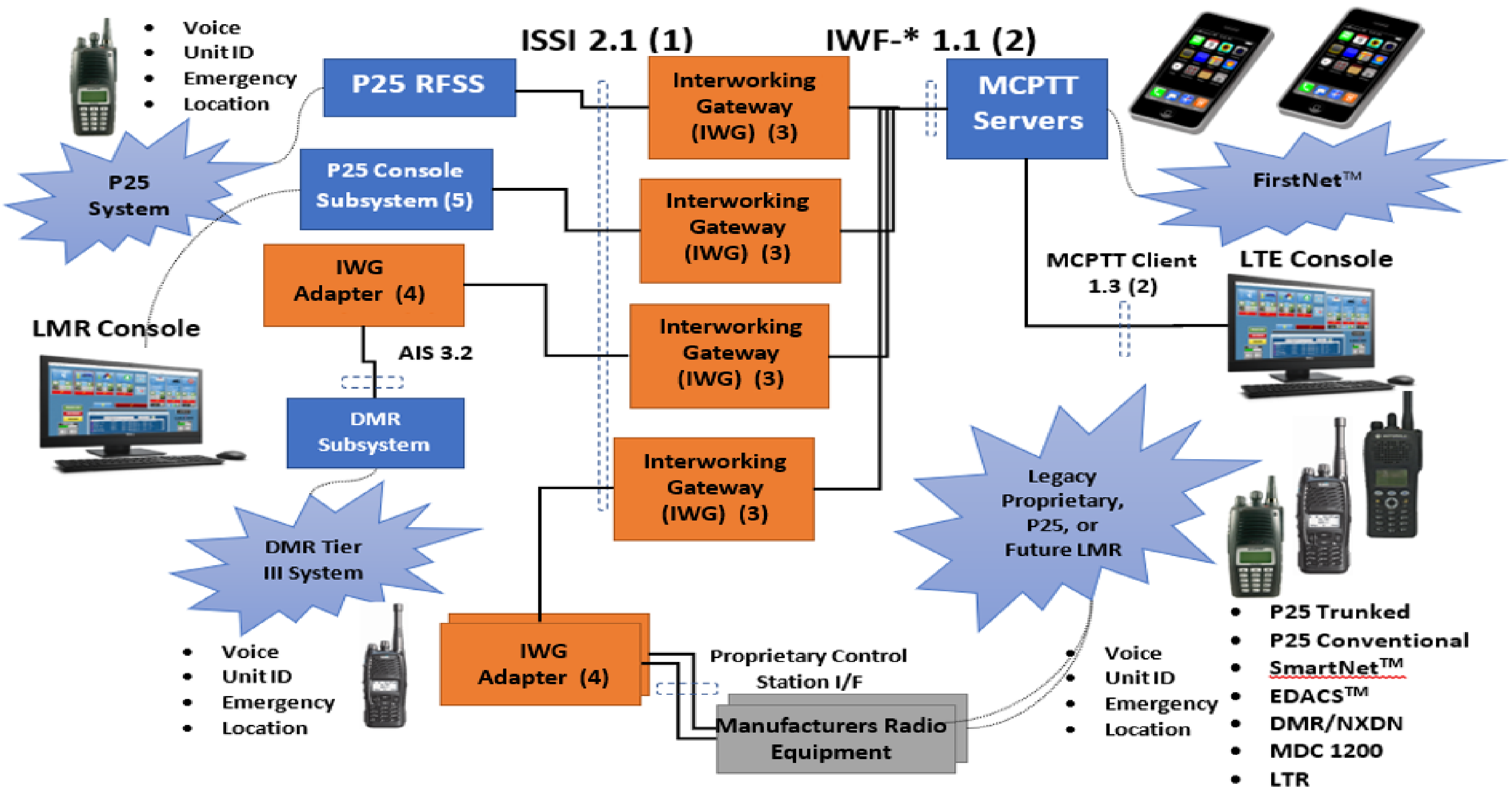

Figure 2 Relationships Between Interworking Subsystems (Requirements Category in parentheses) and Standards-based Interfaces (two-digit dotted notation Interface Number)

6 LTE and LMR Interface Requirements

Table 3 contains the interface requirements applicable to the LMR Interface (1) and to the LTE Interface (2) as described above. Catalyst has derived these from the Core Requirements identified in Table 1. If no corresponding interface requirement for the Core Requirement was identified, there will be no entry for it in Table 3.

Table 3 Interface Requirements Derived from the Core Requirements

Core Req #	***Core Interworking Requirement***	***LMR Interface Requirements (1)***	***LTE Interface Requirements (2)***
1.1	The MCPTT Service shall enable interworking with non-3GPP PTT Systems that are compliant with the TIA-102 (P25) standards.	The LMR Interface shall be compliant with the TIA-102 (P25) standards.	The LTE Interface shall enable interworking with PTT Systems compliant with the TIA-102 (P25) standards.
1.2	Interworking between the MCPTT Service and P25 shall be capable of interworking with a multiplicity of independently administered Project 25 Radio Frequency Subsystems (RFSS).		The LTE Interface shall be capable of interworking with a multiplicity of independently administered IWG Systems.

Note: See Deliverable 1 for the remainder of this table.

7 The Interworking Gateway

7.1 Functional Overview of the IWG

The Interworking Gateway (IWG) performs the vital function of unifying incompatible communication systems. It accomplishes this using abstraction techniques common in software applications where modules are connected using a strictly defined interface, but the internal workings of the modules on the other side of the interface are unknown. For the IWG, each communication subsystem works as if it is connected to another sister subsystem.

For both LTE and LMR systems, the concept is to use an interface that the system already uses to communicate with peer (or client) subsystems in its own universe. The LTE MCPTT server, therefore, would use the same interface it uses to communicate and coordinate with other LTE MCPTT servers, while the P25 RFSS would use the same interface that it uses to communicate to other P25 RFSSs. The advantage of this approach is that the core LTE and LMR systems do not have to change or adopt a special interface to communicate with the "foreign" system. Much of the complexity of integrating the systems is concentrated in the IWG itself.

This type of functionality is technically feasible and a common software engineering practice. There are, however, some caveats:

1. The degree of complete interoperability and unification is limited by the subsystem interface. If the interface does not fully integrate the subsystems, the IWG may be limited in the functions it can perform.
2. If the interface makes assumptions about the sibling subsystem (e.g., that it can only use the native codec on this system type), then there may be performance or capability impacts.
3. Configuration and mapping one system to the other will be complex and is a maintenance issue since a change on either side can impact IWG configuration. This includes talkgroups, users, user credentials, encryption keys, etc.
4. Some features, like end-to-end encryption, torpedo the abstraction approach since this functionality tightly couples the operation of an endpoint device in the LMR system to an endpoint device in the LTE system. Data flows from these devices can no longer be converted to impersonate devices from the other system. On the other hand, at least from the IWG perspective, end-to-end encrypted audio just requires forwarding audio packets unaltered.
5. The IWG must be "trusted" by and connected to both the LTE and LMR systems:
    a. Connects to the LMR infrastructure.
    b. Connects to LTE at the infrastructure level.
    c. Must have intimate knowledge of users, talkgroups, encryption keys, etc., in both systems.
    d. Portions must be maintained by administrators on both systems.
    e. A VPN tunnel is likely required for security when tying two infrastructures together.
    f. For physical security, should be located either at the agency's facility with its other radio equipment or offsite in "the cloud."

7.2 Interworking Gateway System Requirements

Table 4 contains the system requirements applicable to the Interworking Gateway (3) as described above. Catalyst has derived these from the **Included** Core Requirements identified in Table 1. If no corresponding IWG System Requirement for the Core Requirement was identified, then there will be no entry for it in Table 4.

The table has three headings:

1. **Derived Req. #** –the number of the Core Interworking Requirement that the system requirement was derived from.
2. **Core Interworking Requirement** –the text of the Core Requirement as it appears in Table 1.
3. **Interworking Gateway System Requirements (3) LTE to LMR** – the text of the system requirement. This requirement is allocated from the Core Requirement based on the Conceptual Architecture defined above.

Table 4 Interworking Gateway System Requirements Derived from the Core Requirements

Core Req #	*Core Interworking Requirement*	*IWG System Requirements (3)*
1.1	The MCPTT Service shall enable interworking with non-3GPP PTT Systems that are compliant with the TIA-102 (P25) standards.	The IWG System shall be capable of interworking between the MCPTT Service and non-3GPP PTT Systems compliant with TIA-102 (P25) Standards
1.2	Interworking between the MCPTT Service and P25 shall be capable of interworking with a multiplicity of independently administered Project 25 Radio Frequency Subsystems (RFSS).	The IWG System shall be capable of interworking with a multiplicity of independently administered Project 25 Radio Frequency Subsystems (RFSS)

Note: See Deliverable 2 for the remainder of this table.

8 THE INTERWORKING GATEWAY ADAPTER

8.1 FUNCTIONAL OVERVIEW OF THE IWG ADAPTER

The Interworking Gateway Adapter (IWGA) acts as an extension to the IWG for LMR systems without the P25 ISSI. It accomplishes this by using a strictly defined interface, but with the actual internal workings of the LMR system on the other side of the interface unknown. For the IWG Adapter, each communication subsystem connecting to the adapter behaves as if it is connected to a P25 trunked RFSS via ISSI.

For both LTE and LMR systems the concept is to use an interface that LMR systems already uses to communicate with peer (or client) subsystems. An IWG, connected to an LTE MCPTT system would use the LMR P25 system ISSI to communicate and coordinate with an IWG Adapter. The IWG operates as if it is connected to a P25 RFSS, but the IWG Adapter is actually communicating with an adapted LMR technology. The advantage of this approach is that the IWG does not have to change or adopt a special interface to communicate with a “foreign” LMR system. The complexity of integrating the “foreign” system with the IWG is concentrated in the IWG Adapter itself. More importantly, that integration is done with a standards-based interface so that there can be multiple, market-driven adapter solutions created by competing vendors.

This type of abstracted functionality is technically feasible; however, there are some constraints:

1. The degree of complete interoperability and unification is limited by each of the subsystem interfaces. Meaning, the solution is restricted by the interface with the least capabilities of the utilized interfaces, namely:

    a. The LTE MCPTT Interface.
    b. The P25 ISSI Phase 2 Interface.
    c. The Interface to the Adapted System.
2. If the interface makes assumptions about the sibling subsystem (e.g., that it can only use the native codec on this system type), then there may be performance or capability constraints.
3. Configuration and mapping between systems is a complex task and is a maintenance issue since a change on either side can impact both the IWG and IWG Adapter configurations. This includes talkgroups, users, user credentials, encryption keys, etc.
4. Some advanced features like end-to-end encryption will generally not be feasible because they cannot be supported by the Adapted LMR interface.
5. Both the IWG and IWG Adapter must be "trusted" by and connected to both the LTE and LMR systems:
    a. Depending on the technology, the IWG Adapter may connect to the Adapter LMR system's infrastructure.
    b. The IWG connects to LTE at the infrastructure level.
    c. Both components must have intimate knowledge of users, talkgroups, encryption keys, etc., in both systems.
    d. Configurations must be maintained by administrators on both systems.
    e. Appropriate redundant and secure backhaul (e.g. VPN) should be implemented for security and resiliency, when tying infrastructures together.
    f. For physical security, both the IWG and IWG Adapter should be located either at the agency's facility with its other radio equipment or offsite in a secure hosting facility ("the cloud").

8.2 Interworking Gateway Adapter System Requirements

Table 5 contains the system requirements applicable to the Interworking Gateway Adapter (4) as described above. Catalyst has derived these from the Core Requirements identified in Table 1. If no corresponding IWG Adapter System Requirement for the Core Requirement was identified, then there will be no entry for it in Table 5.

The table has three headings:

1. **Derived Req. #** – the number of the Core Interworking Requirement that the system requirement was derived from.
2. **Core Interworking Requirement** – text of the **Included** Core Requirement as it appeared in Table 1.
3. **Interworking Gateway Adapter System Requirements (4), ISSI to Adapted LMR** – text of the system requirement. This requirement is allocated from the Core Requirement based on the Conceptual Architecture defined above.

Table 5 Interworking Gateway Adapter System Requirements Derived from the Core Requirements

Core Req #	*Core Interworking Requirement*	*Interworking Gateway Adapter System Requirements (4)*
1.1	The MCPTT Service shall enable interworking with non-3GPP PTT Systems that are compliant with the TIA-102 (P25) standards.	The IWG Adapter System shall be capable of interworking between the Adapted LMR System and non-3GPP PTT Systems compliant with TIA-102 (P25) ISSI Standards
1.3	Interworking between the MCPTT Service and P25 shall support interoperable PTT Private Calls (with Floor control) between an MCPTT User and a P25 subscriber unit or console.	The IWG Adapter System shall forward Private Calls (with Floor control) between a GSU on the Adapted LMR System and an MCPTT User (appearing as a P25 subscriber unit or console on ISSI-c) if supported by the adapted LMR technology.

Note: See Deliverable 3 for the remainder of this table.

8.3 Interworking Gateway Adapter Functions – Issues and Special Considerations

8.3.1 Configurations and System Mapping

8.3.2 This section completely redacted to protect Catalyst confidential information. Generalized Subscriber Units (GSUs) in the Adapted System

This section completely redacted to protect Catalyst confidential information.

9 QUANTITATIVE STANDARDS-BASED INTERFACE ASSESSMENTS

9.1 AGGREGATE RESULTS – LTE

9.1.1 Aggregate Conformance Results – LTE

The scoring demonstrates that the IWF-* server-to-server interface will support all Basic, ID Management, and Encryption requirements. It supports 99% of the Advanced requirements, but none of the Design goals. These metrics and the individual scores behind them were used in Deliverable 4 to present a more comprehensive and detailed picture of what interworking functionality can be supported.

9.1.2 Aggregate Conformance Results – LTE

See section 14.1 of this document for a detailed explanation of Conformance Factors.

Table 6 Average Conformance Factors for LTE MCPTT

MCPTT (IWF) 3GPP TS 23.283					
Basic	**ID Mgmt**	**Encrypt**	**Advanced**	**Design Goal**	**Overall**
100%	**100%**	**100%**	**99%**	**0%**	**99%**

9.1.3 Aggregate Conformance Results – LMR

Discussion of these Conformance results is presented in the following section.

Table 7 Average Conformance Factors for LMR Standards Based Interfaces – P25

LMR P25 Trunked Phase I - ISSI						LMR P25 Trunked Phase II - ISSI						LMR P25 Conventional - DFSI					
Basic	ID Mgmt	Encrypt	Advanced	Design Goal	Overall	Basic	ID Mgmt	Encrypt	Advanced	Design Goal	Overall	Basic	ID Mgmt	Encrypt	Advanced	Design Goal	Overall
89%	97%	73%	59%	59%	73%	89%	97%	73%	68%	68%	76%	55%	67%	70%	38%	38%	49%

Table 8 Average Conformance Factors for LMR Standards Based Interfaces – non-P25

LMR Analog FSI						LMR DMR – AIS						LMR TETRA - ISI					
Basic	ID Mgmt	Encrypt	Advanced	Design Goal	Overall	Basic	ID Mgmt	Encrypt	Advanced	Design Goal	Overall	Basic	ID Mgmt	Encrypt	Advanced	Design Goal	Overall
26%	0%	0%	22%	22%	20%	78%	67%	60%	61%	61%	68%	59%	80%	100%	58%	58%	64%

9.1.4 Discussion on Conformance Factors

Conformance factors are assigned for each interface requirement as an estimation of how compliant the interface is for that requirement. This is useful information for this report and pushes the evaluator to quantify what is described qualitatively for each requirement, for each interface. We have provided aggregate data in Table 6 for the LTE Interface, for P25 LMR interfaces in Table 7, and in Table 8 for non-P25 LMR interfaces. These are simply the average of the Conformance Factor scores in each of the categories the requirements have been classified into.

Refer to Section 5.1 for a listing of these interfaces. As one would intuitively expect, the MCPTT (IWF) interface scores the highest as it is the newest and most comprehensive interface, though it is still under development and has not been deployed to our knowledge.

Table 7 and Table 8 present the Average Conformance Factors for Standards Based Interfaces for P25 and non-P25 interfaces, respectively. Looking at the overall numbers for LMR interfaces, as one would intuitively expect, P25 Phase II ISSI has the highest level of Conformance. Since the core requirements and their derived interface requirements were defined around this interface, this is not at all surprising. LMR Analog FSI has the lowest overall Conformance, but, somewhat surprisingly, is low for both advanced and basic requirements. Examining this a little more closely, included in basic items is the ability to register for multiple talk groups through the ISSI interface. Normally, a single ISSI interface is required to register for multiple talkgroups, since there is generally only a single ISSI. But it is permissible and likely that you will have multiple DFSI interfaces, each able to talk to a different channel or talk group. This, in part, explains the lower score for both the P25 Conventional DFSI/CAI and the Analog FSI for basic requirements.

The TETRA results are misleadingly high. Catalyst had no previous technical experience with TETRA or the ISI standard, but the attribute that most impacts the feasibility of using this interface is the fact that it appears to normally use circuit switched technology rather than working through an IP interface. Our intent in the proposal was to use IP interfaces in all cases (including the basic analog interface) so that the IWG could be a server on an IP network and act as a gateway for any of these standards-based interfaces. TETRA ISI does not appear to currently meet that fundamental, implicit requirement.

10 The Adapter Approach for both LMR to LTE and LMR to LMR

Throughout this project, we have purposely focused heavily on LMR to LTE interworking, given that it is the primary goal of the study, but our conceptual architecture also effectively addresses the secondary goal of examining LMR to LMR interworking, and addresses both P25 and non-P25 radio systems. Since P25 LMR to P25 LMR for the purposes of this project is intentionally defined exclusively as utilizing a P25 ISSI interface, we believe that the ISSI standard should natively suffice and in general an interworking gateway should not be needed. For this reason, we have not included this in our architectural concept diagram tying two P25 RFSS together. In deliverable 3, however, we expanded on the subject of general LMR to LMR interfaces

10.1 The Adapted LMR Approach for LTE and LMR

In Deliverable 2, we described possible limitations when using ISSI in connecting P25 RFSS to P25 RFSS, but considered that connection to not be, strictly speaking, Interworking for the purposes of this project. For Deliverable 3, we addressed non-P25 LMR to LTE and general LMR to LMR, addressing LMR systems that do not natively support ISSI. Referring back to Figure 2, because of the way we have chosen to architect our proposed Interworking Gateway solution, the IWG Adapter gives the specific “adapted” LMR system an ISSI interface that can be connected to an IWG, for LMR to LTE interworking, or can be connected to another IWG Adapter for LMR to LMR interworking.

As described in Deliverable 2, the approach is to use the principal, common LMR interface (ISSI/ISSI-c) for whatever LMR radio system is to be interworked and provide a compatible ISSI interface to the Adapted LMR system. If the FirstNet™ MCPTT server-to-server infrastructure interface is only available from a few vendors, then the IWG Adapter approach creates an open-market environment where specialists in a given radio technology, having the core competencies to supply an interface to the adapted radio system, can supply an interface to LTE using P25 LMR ISSI as the common interface.

10.2 Adapted LMR to Adapted LMR

Finally, the third way of utilizing these same IWG Adapters designed to provide non-P25 LMR radio systems access to MCPTT on LTE, is to connect two of the IWG Adapters via ISSI to create interworking between two different non-P25 LMR radio systems. Because it uses a standards-based interface, this is a generalized approach where two different components from two different manufacturers could be connected to provide interworking between LMR radio systems. As has been described elsewhere in this deliverable, it does have the down side of requiring the configuration of a fictitious, virtual radio system that both radio systems communicate through.

11 Network Connection Options

For those who have an LMR background in public safety, the network connectivity options available for MCPTT LTE are unusual in that the technology can provide both wireline and wireless access to MCPTT servers while supporting a high amount of traffic. In contrast, because of its narrowband nature, infrastructure level LMR interfaces can only be practically offered in wireline form. As we explore product and deployment options for MCPTT LTE, this flexibility should be leveraged to provide the most reliable and capable products.

11.1 Wireline

Historically speaking, wireline interfaces have had the advantage of being reliable, secure, and offering the greatest bandwidth for information exchange. Many networking technologies are available for these connections such as fiber, leased lines, or terrestrial microwave. Agencies will often implement redundant backhaul between key components, leveraging multiple paths in case of an outage. For example, you may have both fiber and terrestrial microwave entering the facility where an Interworking Gateway (IWG) or IWG Adapter is housed.

Though it is possible that an IWG would be located at a large agency's location, it is likely that the MCPTT service provider will offer the IWG as part of their service. In this case, the only way to obtain full featured, wireline interworking is through the MCPTT service provider's IWG.

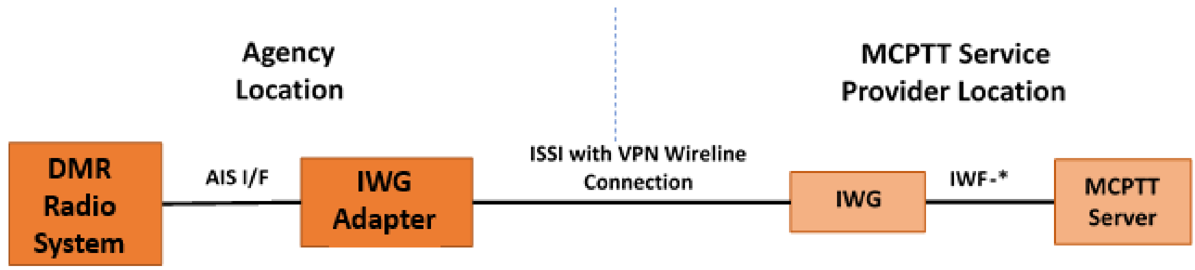

Figure 2 Wireline Interface to Carrier's IWG – Infrastructure Model

This is depicted in Figure 2 where the service provider offers access to an IWG with its external interface in the form of P25 ISSI. Interworking with a DMR system, for instance, can be implemented as shown using an IWG adapter, located at the agency's facility. Similar configurations can be used to connect to other non-P25 LMR systems.

Because these interworking solutions use Internet Protocol (IP), there is some flexibility in where equipment can be located. With this said, public safety agencies prefer to have the greatest control and autonomy of their solutions. If encryption is used, key material will likely reside on the IWG for transcoded encryption of calls. For these reasons, the agency would likely prefer to have ownership of the IWG including having it located in a controlled agency location, though this may not be practical or possible in many cases.

11.2 Wireless

Utilizing wireless interfaces for interworking offers a great deal of flexibility and economy in creating interworking between LMR and LTE. For non-P25 LMR interfaces, this may be the most efficient means of interface and one which could setup very quickly. Figure 3 shows the same LTE interworking interface to a DMR radio system, but this time connected wirelessly to the LTE.

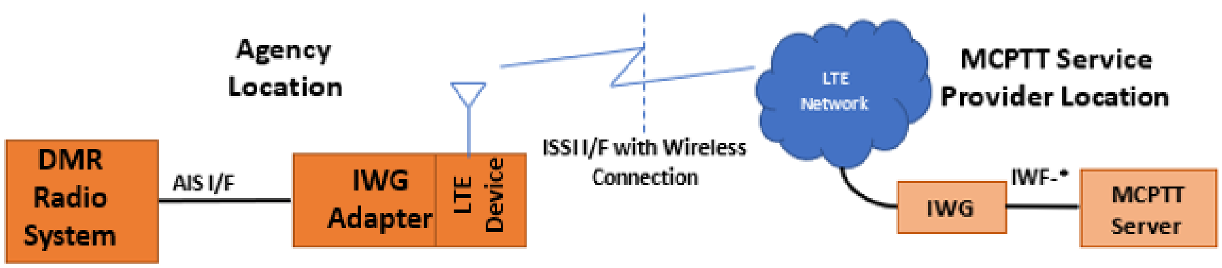

Figure 3 Wireless Interface to Carrier's MCPTT Servers - MCPTT User Model

There are many other reasons why wireless interfaces may be valuable to interworking on both the LTE and LMR side. Some of the advantages of a wireless solution is that it provides:

- A convenient interface for connecting non-P25 systems.

- Connection to P25 systems that are not equipped with an ISSI gateway.
- Resiliency and redundancy in setup and configuration. Antennas for donor LMR or LTE devices, for example, can be in coverage of multiple sites, providing redundancy if there is a site failure.
- Ability to engineer self-contained systems that can be easily deployed in a matter of minutes to any operational area.
- The feasibility of creating a compact physical package that can be easily fitted to first responder vehicles and relocated to be within coverage of LTE and the LMR system.
- A relay for conventional talk-around for fire-ground use to connect via MCPTT to dispatch when deployed on a fire vehicle.

Depending on the need, wireline connections could also be paired with wireless connections. For example, interfacing to a legacy proprietary LMR system via a donor radio to an MCPTT IWF wireline. This might be leveraged where an agency may have multiple needs for interworking, such as their own P25 system and a neighboring legacy LMR system.

11.3 Wireline vs Wireless Scaling Considerations

Wireline solutions generally provide the ability to support many users and many groups allowing for support of small to large interworking solutions. For agencies with the need for only a few interworking groups, however, the wireline solution may not be cost-effective. A wireless solution may be a better fit for these agencies with smaller needs. Scalability of a solution leveraging wireless interfaces can be challenging if the agency is looking for the ability to have many groups connected. It is likely this solution is most economical when just a few groups need to be connected between the systems. With that said, there are some things that can be done to scale the wireless solution to multiple groups. For the LMR side, multiple LMR and LTE devices can be used to support multiple groups. If space is limited for LMR antennas, hybrid combiners can be leveraged for connecting multiple control stations to one antenna system.

12 Security

12.1 Interworking Security

Historically, security on LMR systems has been viewed and handled based on both the technology itself and how, operationally, the technology has been used:

LMR systems have historically been closed systems, difficult for the public to access. Here are just a few examples:

1. Physical security of radio communications resources
    a. Towers
    b. Radio electronics racks
    c. Dispatch Centers
2. Over the air access
    a. Special equipment needed to access trunked systems
    b. Licensed frequency bands
    c. Encrypted channels

Because electronics and networks were generally closed, security was mostly physical. This of course has already changed with radio systems moving to IP-based computer networks. But unifying LMR with LTE systems that inherently have much greater access (both geographical and organizationally) brings concerns about LTE security to the fore. For interworking, the primary new security concerns for LMR are through connections to and interactions with the LTE side. This may sound obvious, but the point is that an LMR system's security risks are heightened through connection to LTE via interworking. Conversely, LTE is not likely going to be more vulnerable because it is connected to a closed LMR system.

12.2 LMR Security

In researching the P25 TIA documents, security concerns that are addressed are mostly confined to over the air security. There are prescribed P25 block encryption schemes for Voice Services. The kinds of encryption that are available are described and preferred encryption identified.

TETRA appears to have many documents covering security, but these are also mostly over the air.

For interworking, the LTE side will bear the brunt of keeping its side safe and, for Interworking, connections between the private, closed LMR system and the highly accessible LTE system will need to use commercial products that encrypt all data between the two system cores making them a Virtual Private Network (VPN). This is mature technology that is routinely used to tie private networks securely together and their specification is beyond the scope of this study.

12.3 LTE Security

Because of the size and accessibility of the LTE network, security is a major concern. A May 2018, TCCA White Paper, Security Considerations for Interconnection of TETRA and Mission Critical Broadband Systems, produced by TCCA's Security and Fraud Prevention Group (SFPG) presents best practices for security measures when connecting a Tetra system to an LTE MCPTT system. Although it is targeted for an interface to TETRA to/from LTE, the best practices presented are all relevant to the interface of a P25 system.

In our research, we found numerous documents addressing security concerns with LTE. The documents we believe to be relevant to the LTE Interface requirements are listed in Deliverable 1, Section 9.3.

13 Operational Interworking

This SBIR has focused almost exclusively on technological interworking between communication systems where two communication systems are connected together so that communication on talkgroups and by users on one system are forwarded to talkgroups and users on the interworked system. The ultimate interworking solution would essentially make communication between users on different systems be indistinguishable (from the user perspective) with communication between users on the same system. Depending on the technology available on the two systems, it is almost unavoidable that there will be compromises and some loss of functionality when interworking between systems. This is a phenomenon familiar to LMR users where interworking between systems, even different vintages of systems from the same manufacturer, have diminished functionality based on system differences or on differing functionality available on the end user's device.

The LMR communication model that uses Push-to-Talk and Talkgroups for communication, however, also generally depends heavily on radio dispatchers to arbitrate and manage talkgroup conversations. In a full scale LMR system, the dispatchers are:

1. Always present, monitoring talkgroup traffic.
2. Coordinating and managing incidents.
3. Separately accessing a Computer Aided Dispatch (CAD) system and passing relevant information from the 9-1-1 caller to police or firefighters on the LMR system.
4. Passing supplemental information to LMR users, knowing who does and does not have access to additional data. For instance, a policeman in a cruiser would have access to the agency's data network via a Mobile Data Terminal (MDT), while a firefighter in full gear on a portable would have very limited accessibility and need the dispatcher to relay information to him.

The LMR Dispatcher today, therefore, can be thought of as providing "Operational Interworking" (OI) to LMR users by providing them with information from other systems, whether it is CAD or the License Plate database. Just as the LMR Dispatcher who has access to these systems can today pass relevant information to LMR users, the LMR Dispatcher who has access to LTE users and databases can also provide OI to LMR and LTE users, even if there is no formal, technological interworking in place.

This approach has worked well and will likely continue to work for many LMR users for the foreseeable future. Technocrats will focus on the perspective that OI is required due to the limited capability of LMR devices, but the "group conversation" paradigm of PTT LMR and talkgroups and the way that public safety operates within this paradigm makes OI a natural fit for many agencies. When additional information is needed by an LMR Field user for an unfolding event, for example, that same information may be needed by others monitoring that talkgroup in the event that the situation quickly escalates and those monitoring LMR Field Users need to be dispatched. Since they have already been monitoring the event, they do not need to be brought up to speed on the situation when seconds count.

It may, in fact, take a long time for the "group conversation" operational model to fully transition to interworked LTE MCPTT and for public safety to discover how MCPTT's additional capabilities can best mesh with LMR's mature, well-established model. The reality that the dispatcher is the de-facto case and communications manager for public safety is deeply ingrained in LMR: from the dispatcher identifying and contacting who will be the first to respond, to the engineering of the radio system such that the dispatcher's audio always takes precedence over a field user's audio. Despite the fact that the LMR Field User is on-scene and in harm's way, the dispatcher is still technically and operationally the master of the radio system talkgroup.

The NPSTC Report dedicated the final section of requirements categories to how Dispatch Consoles might be used in an interworked LMR/LTE system, but did not take on the task of the creating specific interworking requirements for this category. In the Executive Summary section, bullet 7 says:

> "**LTE consoles play an important role in the evolution of PTT and MCPTT services**. PSAPs and first responders may begin using POC to support administrative functions. This will require tight integration with existing LMR console equipment. The

implementation of MCPTT will further require a purpose-built console device supporting a rich set of features and capabilities. Integration of LMR and LTE communications is essential, and some aspects of this function may be managed at the console level…"

We believe these statements from the NPSTC Report also supports the notion of "Operational Interworking."

14 Quantifying Functionality and Capabilities

14.1 Conformance Factors

In Deliverable 4, we utilized our prior interface evaluation work from Deliverable 1 and Deliverable 3. We utilize the conformance factors for each of the requirements as we assess the various combinations of interfaces and technologies in our Interworking Configurations.

The Conformance Factor is a number between 0.0 and 1.0 that the Catalyst evaluator has chosen to describe how well the interface meets the requirement. If 0.0 is chosen, it means that the interface can in no way meet the requirement, while 1.0 means that the interface fully meets the requirement. An intermediate score of 0.5, for example, is intended to convey that the interface only partially meets the requirement (or needs significant translation).

The purpose of this factor is to provide a meaningful metric that enables aggregation and analysis of data as well as quantitative comparison of these interfaces. In the data tables and charts below, we show these as a Conformance Percentage rather than as per-unit factors. These are the same evaluation numbers, just expressed in different units.

14.2 Strategy

For practical reasons, we have aggregated data in key categories. There is data for each individual requirement, but it did not seem practical or desirable in the context of a high-level feasibility study to provide data for each individual requirement for each combination of interfaces and each configuration. This would result in 1722 different data points. We have chosen, therefore, to provide the data in an aggregated form in several different key categorizes. We provide Conformance Factors aggregated as All, Basic, and Advanced.

14.3 Aggregate Conformance

14.3.1 Aggregate Conformance Percentage for Interface Pairs – All Requirements

The column chart of Deliverable 4, Section 2 shows aggregate Conformance for interface pairs with all interface requirements considered. Each column represents two interfaces connected to each other through either an Interworking Gateway (IWG) and an Interworking Gateway Adapter (IWGA) or two IWGAs.

The Conformance Percentage charted for an interface pair is computed as follows:

- Each individual requirement's Conformance is the minimum of the two Conformance Factors for the two interfaces. If any of the interfaces does not have a derived requirement for a given core requirement, no individual Conformance Factor is calculated for that requirement. Refer to Deliverable 1, Table 3 to see instances where there are LTE requirements with no corresponding LMR requirement and vice-versa.
- All of the applicable individual requirement's Conformance Factors are averaged and converted to a Conformance Percentage. Here is an example:
  - FSI Analog to P25 DFSI
    - Core Requirement 21.1 - Interworking between the MCPTT Service and P25 shall support interoperable User IDs and P25 subscriber IDs.
      - The configuration has the following path and has the following Conformance Factors for Requirement 21.1:
        - Interface Analog FSI - Conformance Factor = 0.0
        - System IWG Adapter
        - Interface ISSI - Conformance Factor = 0.9
        - System IWG Adapter
        - Interface P25 DFSI - Conformance Factor = 0.5
      - The Minimum Conformance Factor is 0.0 so this is used in calculating the average for the Configuration's Aggregate Conformance Factor.
    - The Aggregate Conformance calculation averages the *individual* minimum conformance for *each* requirement. The Aggregate Conformance percentage for this Configuration is 16%.

Note that there is no special significance to the order of interfaces in the chart. The order has been chosen, however, so that the taller columns are in the back and shorter ones in the front so that they can all be seen clearly. Also note that the MCPTT interfaces are shown on only one axis, since we do not evaluate interworking LTE to LTE.

14.3.2 Aggregate Conformance Percentage for Interface Pairs – Basic Requirements

The column chart of Deliverable 4, Figure 3 shows aggregate conformance for interface pairs with only those interface requirements classified as *Basic* considered. Consult Deliverable 1, Table 1 to see all of these classifications along with all of the Core Requirements. Each column represents two interfaces connected to each other through either an Interworking Gateway (IWG) and an Interworking Gateway Adapter (IWGA) or two IWGAs.

The conformance charted for an interface pair is the average of each individual basic requirement's conformance. Each individual requirement's conformance is the minimum of the two conformance factors for the two interfaces and the conformance factor of the bridging ISSI.

14.3.3 Aggregate Conformance Percentage for Interface Pairs – Advanced Requirements

The column chart of Deliverable 4, Figure 4 shows aggregate conformance for interface pairs with only those interface requirements classified as *Advanced* considered. Advanced requirements are intended to include those that are challenging for interworking and which may not be of importance to some smaller agencies. These include features such as private calls, location, override, losing audio, and talk group regrouping. See Deliverable 1, Table 1 for which core requirements are considered in each category. Each column represents two interfaces connected to each other through either an Interworking Gateway (IWG) and an Interworking Gateway Adapter (IWGA) or two IWGAs.

The conformance charted for an interface pair is the average of each individual Advanced requirement's conformance. Each individual requirement's conformance is the minimum of the two conformance factors for the two interfaces and the conformance factor of the bridging ISSI.

14.4 Conclusions from Aggregate Conformance

1. Advanced functionality in one interface is wasted and unproductive when connected to an interface that only supports basic functionality.
    a. Deliverable 4, Figure 2 shows that no matter which interface the **S-2-S MCPTT** interface is paired with, its very high Conformance Factors are essentially limited by the interface it is connected to.
2. When you look at two LMR interfaces that are the same on both axes, you are seeing the maximum Conformance that that interface offers. Comparing that with pairing with different interfaces gives an indication of the functionality that can be lost when interworking.
3. The Basic requirements include most Talkgroup features including Unit ID, late entry, and Emergency, while the Advanced requirements include many private, unit-based operations, location, and text messaging. (See Deliverable 1, Table 1 for a complete classification of Basic vs. Advanced vs. All requirements.) As has been discussed in section 6.3 of Deliverable 3, these advanced features add greatly to maintenance costs and complexity.

Overall, though those who write requirements and specify functionality for these systems want to ensure that all feasible functionality is available, cost will be one of the greatest determinants for whether MCPTT for public safety will be embraced.

15 Quantifying Agency Cost

15.1 Introduction

In order to better understand what it costs for an agency to purchase equipment and services that meet these requirements, we look at several factors that describe funding needed to provide this feature:

- Initial Cost – Buying and installing equipment that supports the requirement.
- Recurring Cost – Access/ISP/Seat costs that are incurred usually on a monthly basis.
- Indirect/Support Costs – Infrastructure, software, systems required to support or sustain the requirement. To ensure that our cost estimates only include *additional* costs associated with adding interworking, we have excluded indirect costs such as that for devices, the device's

native network access costs, and any other infrastructure required for independent (non-interworking) LTE operations or LMR operations.

- Configuration/Maintenance Cost – the cost for trained personnel to make updates and upgrades to maintain the system for interworking, such as mapping talkgroups and devices between systems.

We are predicting and estimating what we believe to be the total cost of ownership (TCO) for these solutions to agencies will be. We have included normal discounting so that pricing is reflective of actual "agency cost" with this TCO model.

15.2 Strategy and Process

The pricing estimates here are intended to provide guidelines and relative prices that can be used to assess the best value for an agency. A great deal of time has been spent to try to provide real-world numbers, but because neither MCPTT nor interworking for MCPTT is even a deployed technology in the US, we do not claim that the absolute numbers represent precisely what this technology will cost. On the other hand, we are confident that these numbers can be used to provide relative guidance for which technologies will provide the best values. Here are our processes and assumptions:

1. We used our own pricing strategies and models. Because this is company confidential data, it cannot be shared, but we felt strongly that using these seasoned models for our relative comparison would provide the most realistic results.
2. We used available information on recurring costs (such as monthly access fees) and adjusted them based on predictions of how much FirstNet™ MCPTT access would be relative to current available technologies and how much agencies might be willing to pay.
3. We applied our calculations and predictions to a number of representative configurations. This allowed us to correct and adjust calculations and verify that there were no errors in our calculations.
4. We identified three interworking system sizes with what we believe to be realistic scenarios for talkgroups and devices for a given agency. Current PTT solutions charge based primarily on the number of users and end-point devices that are enabled.

Again, the purpose of these estimates is to try to make relative predictions on what costs might be, including maintenance costs, and providing guidance for which technologies are appropriate for a given sized agency. Maintenance costs are likely underestimated and, in our opinion, are generally poorly accounted for in complex, interworked systems.

15.3 Pricing by Individual Subsystems and Interfaces

Costs are estimated for each component of the system:

1. The Interworking Gateway (IWG) or Gateways
    a. A server-to-server IWG requires access to an MCPTT server at the infrastructure level requiring a solution, technology, and manufacturer that has invested heavily in the feature and likely limited to a very short list, understandably restricted by the carrier.
2. The Interworking Gateway Adapter or Adapters

    a. The formal IWGA that we describe, uses ISSI to connect to an IWG. This is a well-defined LMR Interface, but not the most efficient access method for Legacy LMR systems, since it uses the highly optimized (for over the air transmission) AMBE codec and implements Inter-Subsystem features that most non-P25 LMR interfaces will not support.
3. Each interface
    a. There is cost associated with implementing a given interface whether to a radio system (i.e., ISSI, DFSI, AIS, etc.) or to an LTE system. The cost is on both sides of the solution and has to be funded by some entity, generally the owner of an independently maintained radio system. For LTE, the carrier may fund the establishment of an interface, but expects users to pay monthly fees for its use.
4. Access for each interface
    a. Access must be granted both physically and logically:
        i. An MCPTT LTE Interface must be provisioned and authorized to be on the system. This requires a wired/wireless connection as well.
        ii. An ISSI interface in LMR requires a wired/wireless connect, a license with sufficient capacity for the interface, and logical access by knowing key pieces of information: Wide Area Communications Network ID, system and fleet numbers, talkgroup IDs, and unit IDs.

The estimates for costs are based on Catalyst's real-world experience with setting prices for interoperability systems as well as estimates of what others would charge for items such as network access. These cost estimates are admittedly starting points and place holders for what promises to be a very dynamic environment where both the technology as well as participants in the market will be changing and pricing will correspondingly be highly dynamic.

15.4 The Cost Spreadsheet

The cost spread sheet uses estimated agency costs for each component and each interface and sums the pricing for the relevant individual components for each interworking configuration. It does this for three representative system sizes. And it does it for each considered Interworking Configuration. See section 5.3 for more information on these Interworking Configurations.

15.4.1 Considered System Sizes

Table 9 lists the system sizes used for these calculations. The chosen sizes are intended to be representative of small to medium sized systems, which work best with our pricing models. The smallest might not be particularly small for some agencies, but a single talkgroup, for instance, was judged to be characteristic of an agency that is not really interworking LTE and LMR but rather is using tactical, incident-based interoperability.

Table 9 System Sizing Used for Interworking Calculations

	Small	Medium	Large
Interworked Talkgroups	3	10	40
LMR Subscriber Units	10	50	100
LTE User Equipment Units	100	250	1000

These are Interworked Talkgroups, and do not represent all of the Talkgroups in the systems. Similarly, the LMR Subscriber Units and LTE User Equipment Units here are only those that are Interworked and available across the Interworking interface.

The number here (especially for LMR SUs) is low, but we believe that it will be expensive to provide advanced functionality across systems and therefore only a relatively small number of users would have/need this capability.

15.4.2 Estimated Pricing

Table 13 lists all of the considered interworking configurations and provides a **Raw Total** for each configuration and size. This estimate is the monthly agency cost for interworking and the calculation attempts to consider all cost factors including equipment costs, monthly access fees, and maintenance costs in order to estimate cost for a particular interworking configuration. For equipment that must be purchased up front, the calculation assumes an equipment lifetime of five years, and distributes the price of the equipment over that five-year period.

Also shown in Table 13 is the average conformance percentage for each configuration. In order to provide a more meaningful cost/pricing measure, we also calculate a **Weighted Total** that takes the **Raw Total (Monthly)** Cost and divides it by the average conformance factor. This provides an adjusted cost that takes the functionality provided by a given configuration into consideration.

15.4.3 Relative Values

In addition to the raw TCO pricing numbers shown in Table 13, we believe it is extremely instructive to provide a **Value** metric that can be used to objectively compare these different configurations, knowing that each configuration provides varying functionality at different agency costs. The **Weighted Total** calculated above that takes the Compliance factor into consideration is a step in the right direction towards that goal. But because this number is in dollars, is intended as a comparison metric, but does not represent the actual cost any agency would pay, we do not document the **Weighted Total** but use it instead to create a comparison metric that we call the **Relative Value**. The **Relative Value** is expressed as a percentage that defines the **Weighted Total** for the Full IWG configuration (using the two **Principal Interfaces**) to be 100% and then scales all other **Weighted Totals** to a percentage relative to that base-line configuration.

These **Relative Values** are shown in Table 14 and are used for a number of graphical comparisons. Both Table 13 and Table 14 identify each configuration by fully spelling out the Configuration Processing Chain, which is all of the interfaces and subsystems that the data for interworking flows through. As has been mentioned, some of these are symmetrical, i.e., effectively the same processing chain, but right to left rather than left to right.

15.4.4 Chain Elements

Because some of the terms in the processing chain have been made cryptic for brevity's sake, we define each one of them in Table 10. The columns in this table are:

- **Identifier** – the designation for the standards-based interface or applicable subsystem requirements as described in section 5.1.

- **Chain Element** – the short name shown in the **Configuration Processing Chain** Field for Table 13 and Table 14. These represent:
    - **Interfaces** – either the "left" or "right" interface
    - **Special Interface Designations** – special designations for ISSI P2 that signify how it is utilized. Required by the spreadsheet so that pricing is correctly calculated.
    - **Subsystems** – the one or two subsystems required in the processing chain.
- **Description** – a longer description of the interface or subsystem referred to by **Chain Element**.

*Table 10 Names in the **Configuration Processing Chain** Field for Table 13 and Table 14*

Identifier	Chain Element	Description
		Interfaces
1.1	**S-2-S MCPTT**	MCPTT IWF-* Server-to-Server Interface
2.2	**P25 ISSI P1**	LMR P25 Trunked Phase I – ISSI
3.2	**DMR AIS**	DMR Application Interface Specification
3.3	**TETRA ISI**	TETRA - Inter-System Interface (ISI)
2.3	**P25 DFSI**	LMR P25 Conventional – DFSI
3.1	**Analog**	Analog – FSI (DFSI in Conventional "Analog" Mode
2.1	**P25 ISSI**	LMR P25 Trunked Phase II – ISSI
		Subsystems
(3)	**IWG**	**Interworking Gateway**
(4)	**IWG Adapter**	**Interworking Gateway Adapter (IWGA)**

15.5 Cost and Value Tables

The **Estimated Pricing for All Considered Configurations and Interfaces** is listed in Table 13. The columns in this table are:

- **Configuration Processing Chain** – Fully spells out the Configuration Processing Chain for each Interworking Configuration, which is all of the interfaces and subsystems that the data for interworking flows through. Includes symmetrical Configurations which are equivalent processing chains, but right to left rather than left to right. The elements in the processing chain are explained in Table 11.
- **Raw Total (Monthly)**– estimate of the monthly agency cost for interworking. For equipment purchased up front, the calculation assumes an equipment lifetime of five years. Each Interworking Configuration has three **Raw Total** values, one for each system size.
- **Average Conformance** – the aggregate Conformance Percentage for this Interworking Configuration for All Requirements. See section 14.1 for more information.

The **Relative Values for All Considered Interworking Configurations and Interfaces** are listed in Table 14. The columns in this table are:

- **Configuration Processing Chain** – Fully spells out the Configuration Processing Chain for each Interworking Configuration, which is all of the interfaces and subsystems that the data for interworking flows through. The elements in the processing chain are explained in Table 11.

- **Relative Value** – a comparison metric expressed as a percentage that defines the **Weighted Total** for the IWG configuration (using the two **Principal Interfaces**) to be 100% and then scales all other **Weighted Totals** to a percentage relative to that configuration. Each Interworking Configuration has three percentages, one for each system size. So, for each size:
  - **Relative Value % = IWG Weighted Total / This Config Weighted Total * 100** Therefore, 200% means that This Config's Weighted Total is Half That of the IWG.
- **Configuration Type** – a classification of each Interworking Configuration that is used to more efficiently analyze which types offer the greater cost or value advantages. See Table 11 for a full description of all configuration types.

Table 11 Configuration Types Categorizing Interworking Configurations

Configuration Type	***Description***
Interworking Gateway – LTE to P25 ISSI	
IWG	Interworking Gateway – uses Server-to-Server Interface
LMR to P25 ISSI Adapter	
Adapter	Adapts a non-P25 LMR interface to P25 ISSI
LTE to LMR	
IWG + Adapter	Interworking Gateway plus an Adapter
LMR to LMR	
Adapter to Adapter	Adapter connected to another Adapter via ISSI

Table 12 Estimated Pricing for All Considered Configurations and Interfaces

Configuration Processing Chain	Raw Total (Monthly)			Average Conformance
	Small	Medium	Large	
P25 ISSI Phase 2 Configurations				
P25 ISSI IWG + IWG + S-2-S MCPTT	$1,491	$4,437	$15,697	79%
P25 ISSI + IWG Adapter + P25 ISSI P1	$663	$1,191	$3,418	72%

Note: See Deliverable 4 for the remainder of this table

Table 13 Relative Values for All Considered Interworking Configurations and Interfaces

Configuration Processing Chain	Relative Value			Configuration Type
	Small	Medium	Large	
P25 ISSI Phase 2 Configurations				
P25 ISSI IWG + IWG + S-2-S MCPTT	100%	100%	100%	**IWG**
P25 ISSI + IWG Adapter + P25 ISSI P1	206%	342%	421%	**Adapter**

Note: See Deliverable 4 for the remainder of this table

16 Additional Analysis of Solution Cost and Functionality

For Deliverable Four, we built a very extensive pricing spreadsheet to help determine our best estimate of what solutions are feasible and practical. We are also studying, as a precursor to both prototype building and product commercialization, which solutions will provide the greatest value to the public safety community and therefore be the highest priority products for development. With our pricing analysis, we have spent a considerable amount of time:

1. Verifying and validating the pricing calculations using various configurations and scenarios.
2. Using these scenarios for "what if" comparisons that would be applicable for various agencies of various sizes and technologies.
3. Applying the "what if" comparisons to various pricing scenarios that believe are reasonable for this market, based on our own experience at selling competitive commercial products.

16.1 Pricing Conclusions

In Table 14, we show in table form the **Relative Values** for basic Interworking Configurations. The use of the ISSI as an interworking interface between both P25 and non-P25 radio systems provides a general way of solving general LTE/LMR and LMR/LMR interworking. It allows customers to buy each component from a different vendor, providing the greatest flexibility, but it does add cost and complexity. Finally, those configurations that require P25 ISSI as an Interface Endpoint will only work for a restricted set of applications.

Table 14 Summary of Cost and Functionality Data

Configuration Type	Interface Endpoints	Small	Medium	Large	Comment
IWG	MCPTT - P25 ISSI	100%	100%	100%	Only works with P25 systems with existing ISSI
Adapter	P25 ISSI - LMR	162%	254%	302%	Only works with ISSI
IWG + Adapter	MCPTT - LMR	45%	50%	52%	Required ISSI bridge costly
Adapter to Adapter	LMR - LMR	51%	80%	94%	Required ISSI bridge costly

Other pricing conclusions have been excluded from this report, so access to the four Deliverables is required to examine the full conclusions from the entire project. We would encourage those who have access to the Deliverables to read Deliverable four first.

17 RECOMMENDATIONS TO STANDARDS BODIES

The 3GPP specifications for MCPTT are detailed and well-articulated. The IWF as currently defined is clearly feature rich and seems to meet most LMR/LTE interworking needs. It is also greatly appreciated that these 3GPP specifications are available to the public, driving open discussion and the ability for vendors to understand without having to purchase something or sign non-disclosure agreements. Because many of the other evaluated standards are not available publicly, we are not including any of the standards-based interface evaluations in this final report.

In our evaluations, there were several requirements that the ISSI Phase II interface did not fully meet. As this interface is used for non-P25 communication systems (the Kodiak EPTT ISSI interface is just one prominent example), adding these issues to TIA's roadmap would speed ISSI's adoption as a more versatile and often adopted inter-system interface. See section 5.3.3 for these recommendations.

As the ATIS/TIA working group is working to define the Interworking Interface for P25 to MCPTT, there are a number of items that this study has revealed:

1. Private calls from LMR to LTE are possible and defined by the interface. But our study indicates that this capability, while desirable, may be expensive and difficult to maintain. This may be especially problematic for small agencies that only have a few interworked talkgroups.
2. Regarding Talker IDs, it is our recommendation that the interface support the passing of IDs for Talkgroup calls, whether or not there are actual Talker IDs registered on either system but especially on the LTE side.

18 RESULTING INSIGHTS

For this Phase I feasibility study we have focused on an assessment of interface options for LMR to LTE as well as LMR to LMR, with the goal of defining and meeting a recommended set of requirements from the NPSTC Report. Because work for this task that is already being done in the industry has focused heavily on interfacing MCPTT over LTE with the P25 LMR standard interface ISSI, this study is consistent with that approach. The minimum requirements for LMR and LTE interfaces have been presented as well as for the Interworking Gateway System. Further, we identify the Interworking Gateway Adapter System, an approach for general LMR to LMR and LMR to LTE Interworking, reinforcing and detailing our plan to accomplish interworking using ISSI as the principal interface, while providing accessibility to non-P25 LMR systems using the LMR Adapter concept.

In addition to meeting all of the Deliverables, Catalyst has developed other important inventions that will help provide LMR to LTE and LMR to LMR interworking for public safety. These proprietary inventions are not described in this report, but are available to those who have access to the four Deliverables associated with the project; contact Catalyst for additional information.

Items found and discussed in the four Deliverables that present challenges to meeting the full intent of the NPSTC requirements are:

1. Transcoded encryption (encoding/decoding and encrypting/decrypting at the IWG), will be a complex function for the IWG, and will be even more challenging if communicating with non-P25 LMR systems through an IWG Adapter.

2. The establishment and maintenance of mapping information for interworking talkgroups between LMR and LTE appears workable, but when extended to an IWG Adapter the amount of mapping work is essentially doubled.
3. The establishment and maintenance of mapping information for interworking individual GSUs between LMR and LTE will be laborious and maintenance intensive without a comprehensive plan for keeping them updated programmatically with little or no human interaction.

Deliverable four provides a matrix of functionality and costs for all of the Interworking Configurations that have been analyzed for this project. Some summary information on this data is provided in this final report, but many of the innovative and pivotal items from this study are only available in the deliverables themselves. It is our judgment that the overall cost, business case, speed of adoption, and critical mass of deployments will have greater impact on public safety's access to this technology and the success of FirstNet™, than the features and capabilities that are technically feasible.

19 CONCLUSION

In this final report, we discuss how we quantified functionality and agency costs for 42 Interworking Configurations. We describe the derivation of Relative Values based on the estimated Agency Costs and available functionality for each configuration. By ranking each configuration's compliance with the Core Public Safety requirements as documented by NPSTC, the Relative Value provides a metric that includes the expected performance, security features and other capabilities. By including in our Agency Cost estimates the product maintenance costs, we account for the impact of user setup and configuration.

We conclude that not only are these Interworking Configurations feasible, but that certain Configurations provide significantly greater value including less initial and ongoing work by practitioners than other configurations. **This project demonstrates the relative value of each of the configurations presented and allows us to make some key conclusions that will result in products that will present greater value to public safety and a greater commercialization potential.**

Catalyst has developed important inventions and a set of building blocks that will help provide LMR to LTE and LMR to LMR interworking for Public Safety as well as other Critical Communications agencies. Our proposed framework uses standards where available so that different manufacturers can provide each component.

The IWG Adapter, one of the Catalyst SBIR inventions that is described in this report, supports interfacing multiple LMR technologies by adapting them to be P25 ISSI compliant. For example, if the MCPTT service provider exposes an ISSI interface as their preferred interface for full featured MCPTT, the IWG Adapter can provide Public Safety with an LTE to LMR Interworking solution for a variety of LMR technologies. It supports interfacing to widely used analog interfaces, legacy trunked systems and other deprecated LMR systems for which MCPTT service providers are unlikely to offer solutions. The deliverables validate that the IWG Adapter provides high value not only when used with the MCPTT Interface but also when connecting LMR to LMR.

The highly cost-effective configurations that have been defined through this feasibility project can be expedited to market, especially during the early stages of FirstNet™ deployment while the formal IWG solution is still being developed. The pivotal Interworking Configurations identified in Deliverable Four, along with a Console, are recommended for prototyping for Phase II and would be excellent starting points for efficient and valuable commercial products that could be fielded well before the conclusion of the Phase II project.

Catalyst is well positioned to execute Phase II. Through our work on Phase I, we have expanded our knowledge of the 3GPP, P25, DMR, and ISI standards and protocols. Our research and development laboratory is equipped with P25 trunked, P25 conventional, DMR trunked, DMR conventional, legacy trunked, and various analog LMR equipment. We have quotes for the LTE components required to complete our research and build the prototypes. And we have lined up several customers to advise us and assist with the prototype evaluations. Our plans for Phase III commercialization are already underway including a program to educate the Public Safety community and promotion of these solutions at the upcoming IWCE trade show.

REFERENCES

National Public Safety Telecommunications Council (NPSTC) Public Safety LMR Interoperability with LTE Mission Critical Push to Talk report, January 8, 2018

See References in Final Report