P25
BEST PRACTICE

SPECIFYING YOUR P25 SYSTEM

tait
communications

Who should read these guides?

If you are a Public Safety official who is responsible for, or involved in, procuring a new communication system, this guide (and the others in the series) is written for you. You may be new to the position, or focused on other disciplines, such as IT. Or you may be new to P25. We assume that you have an understanding of Land Mobile Radio, but not necessarily in-depth knowledge.

We also assume that your interest is pragmatic; you want to make sure you procure and/or manage your radio system to meet the needs of your first responders and public service providers in a fiscally-responsible way. Becoming an expert on all related topics is not your objective.

We hope these guides will benefit you and your wider Public Safety Communications community by presenting you with a range of P25 topics so you can more effectively engage in the process.

The decision to adopt the digital open standards-based P25 platform offers Public Safety agencies many benefits, but it also raises a lot of questions. There are many common questions - and there a lot of agencies who have already tackled them, who are happy to share their experiences.

Tait is sponsoring an on-going project, to discuss these topics and put forward some answers.

Over a series of intensive round-table sessions, our participants discussed their own experiences and challenges, generously sharing their frustrations and triumphs. Together with Tait expert advice, these guides include their many valuable insights, based on their hands-on experience working through typical P25 project challenges.

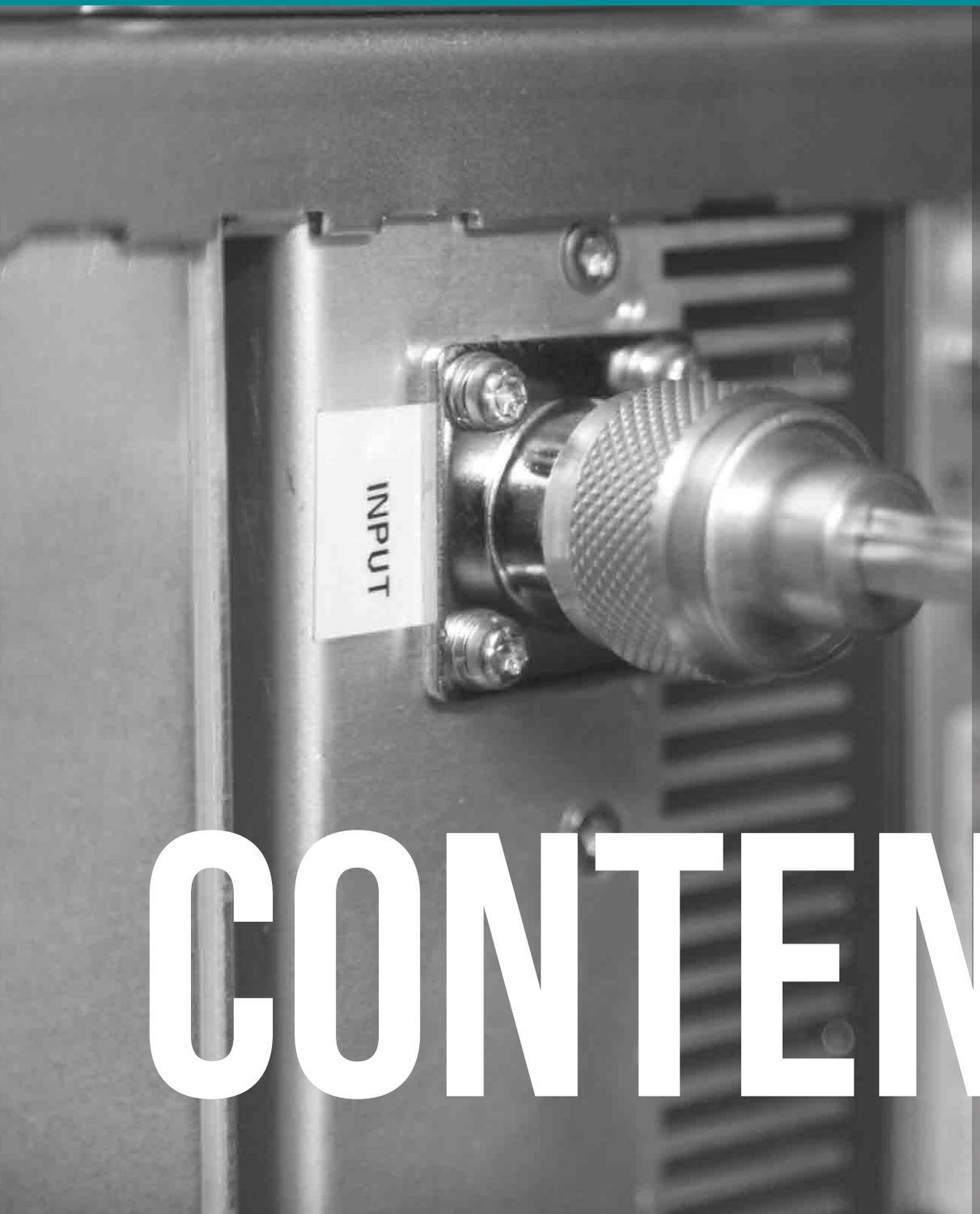
Learn more and subscribe to future guides at
www.p25bestpractice.com

SPECIFYING YOUR P25 SYSTEM

- Is P25 the right technology?
- How do I specify my coverage requirements?
- What do I need to know about ISSI?
- How can I ensure interoperability?
- What about FirstNet?

This Best Practices Guide for specifying P25 systems uses a simplified chronological approach. In reality, most of these processes are iterative and impact each other, sometimes heavily. For example, often the initial requirements are significantly scaled down after all costs are estimated and you are confronted with budgetary restrictions. We approach system architecture and functionality as two separate subjects simply to organize the contents, while in reality, they are co-dependent.

The desired system functionality will impact on its architecture and the architecture will dictate availability - or at least feasibility - of some functions.



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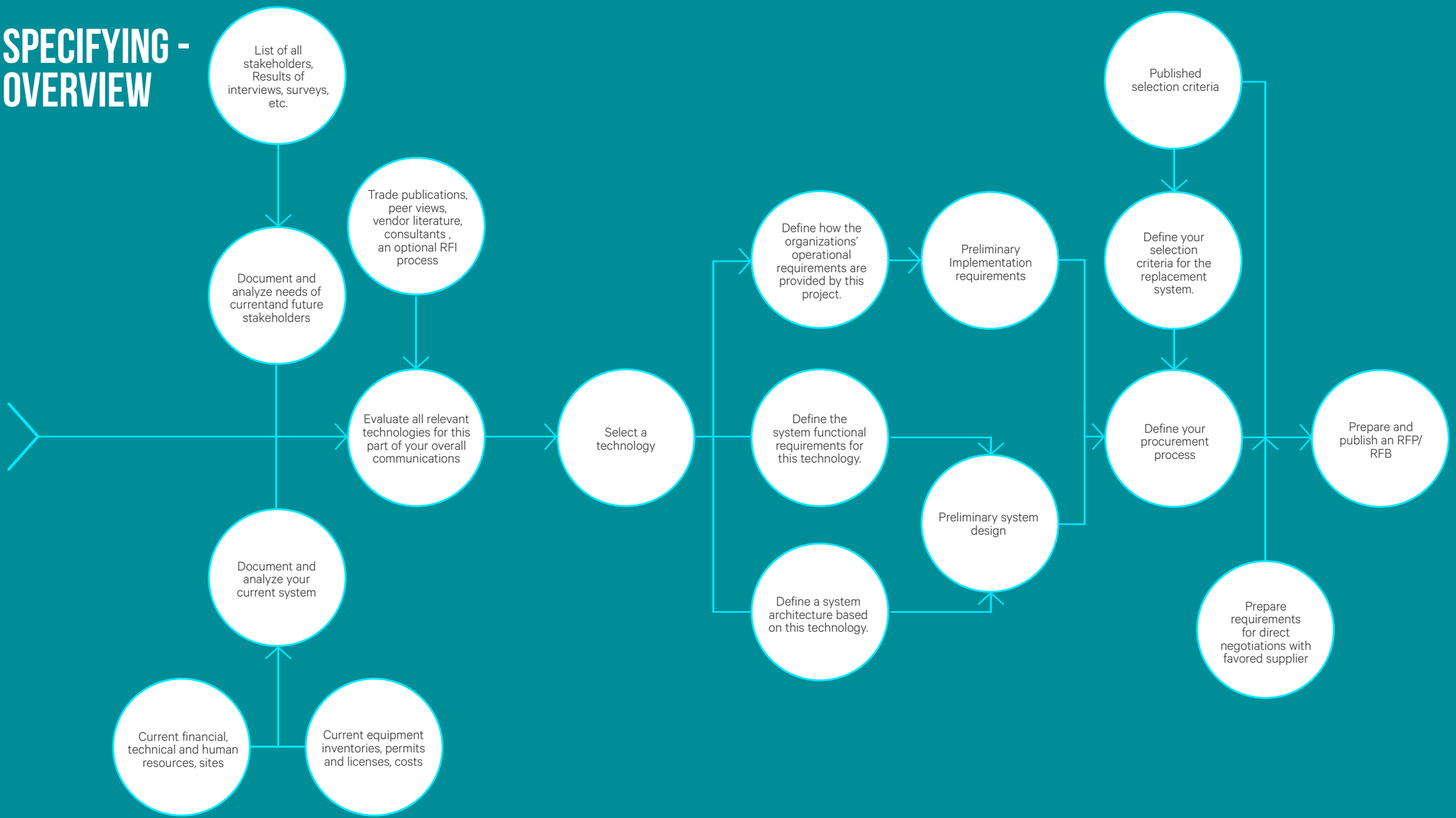


EVALUATE AVAILABLE TECHNOLOGIES

With a good understanding of your status quo and the future needs of your system's users, it is time to determine which technology might best fit for project. While this guide is written chiefly for Public Safety buyers of P25 systems, in some cases it is not your only feasible option. If you are not sure which way to go and cannot afford a consultant to help you, consider issuing a Request For Information (RFI). This does not carry any commercial obligation on your part and will greatly improve your understanding of the current options.

There are, of course, good reasons why P25 is the best choice for most Public Safety agencies.

- Several Federal or State grants require P25 compliance.
- P25 interoperability gives you the ability to program your radios and roam on your neighbors' networks and allow them to use your system. This is hard to overvalue, especially in times of crisis.
- After the slow start, the competition between P25 vendors is now delivering real results in the terms of project costs, user equipment pricing, quality, functionality and other areas.

When to consider non-P25 systems

When should Public Safety officials look at non-P25 systems for First Responders? It is difficult to come up with such scenarios. Agencies that procure non-P25 systems to replace their old analog systems usually cite price as the decisive factor, but that argument is now outdated, typically based on prices that are several years old. They may also be based on the false assumption that all P25 networks are high-end, complex and expensive. In reality, you can procure a highly functional, simple P25 system and user equipment at a cost rivalling proprietary digital or high end Public Safety grade analog technologies.

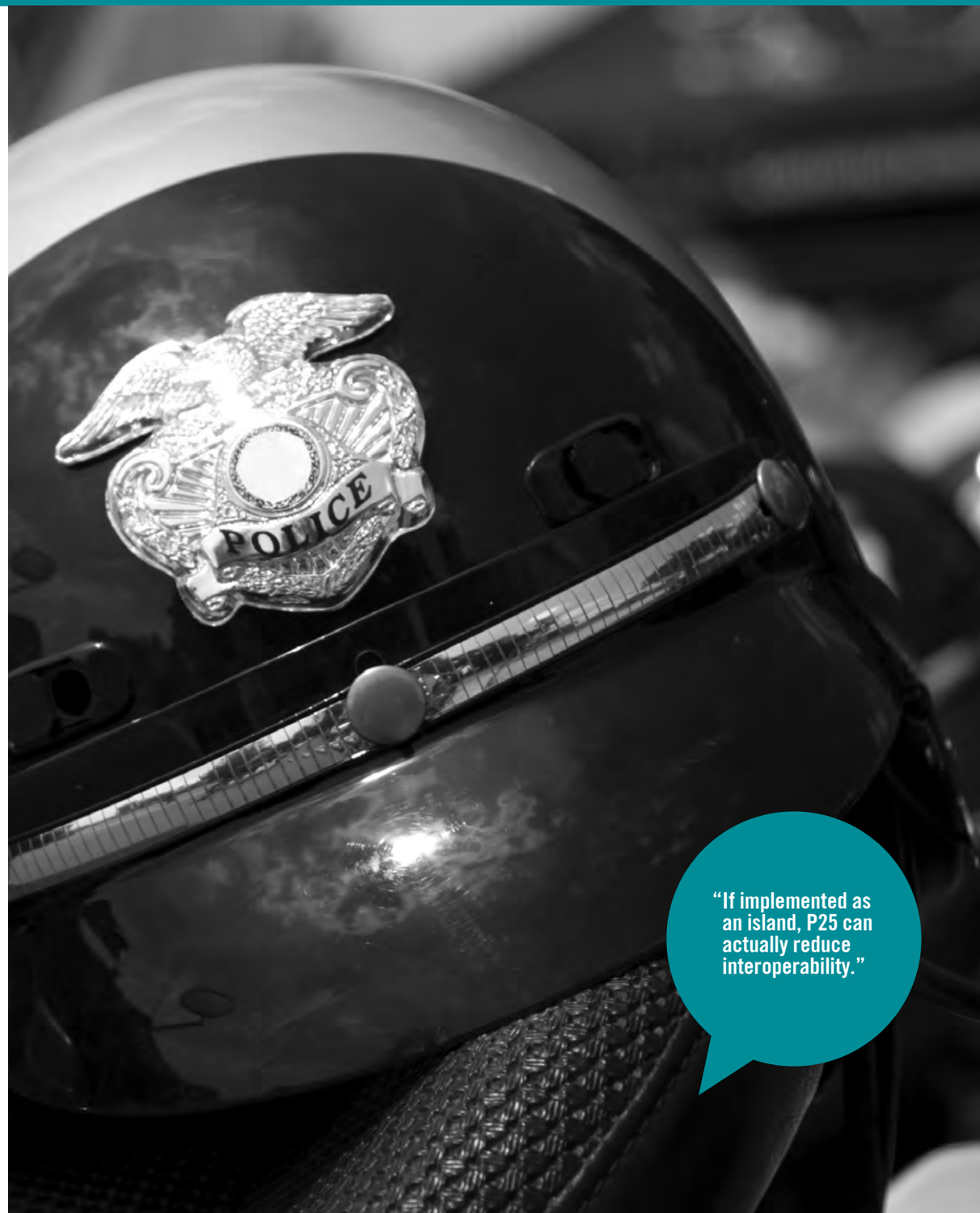
If you have a well-functioning conventional analog system that meets your needs other than capacity or coverage, you can augment it with additional channels and sites.

Otherwise, P25 is more than likely your best option.

"Budgets and requirements may vary, but the objective is always reliable communications."

ADVANTAGES OF P25

- **Proven in mission-critical use:** for nearly two decades
- **Proven interoperability:** with P25 Compliance Assessment Program (P25 CAP)
- **Multi-vendor ecosystems:** ensure competitive pricing
- **Extensive Public Safety feature set:** specific to mission-critical communications
- **Scalable:** to suit agency (conventional and trunked)
- **Backwards capable:** eases migration in mission-critical environments



PERCEIVED SHORTCOMINGS OF P25

P25 has had its share of criticism, much of which was misplaced, unfair or is no longer valid. For example, some early large systems did not have enough radio sites and the resulting coverage problems - though technology independent - were unfairly attributed to P25.

This list represents criticism that is at least partially justified.

- Despite significant progress and increasing competition, cost is still perceived as the biggest problem.
- Voice quality is perceived as a problem by some users.
- Low tolerance for interference and multipath when compared against analog.
- Limited data transmission capability (9.6Kbps).
- Full compliance and interoperability are possible, but require careful planning.
- Not all subsets of the standards are finalized or commercially implemented, as the standard is still evolving.
- The sharp drop-off in voice quality with weak RF signal is an issue, in particular for on-scene Fire communications.
- No support for paging.
- Audio delay compared with analog.

TECHNOLOGY SELECTION

Deciding on P25 is not the end of the technology selection process: important choices need to be made. Conventional or trunked? Phase 1 or Phase 2?

Luckily, in most cases these decisions are not difficult. While you should use an experienced consultant to guide your decision, some simple rules of thumb can help you in this area.

Conventional or trunked?

First, we can dispense with the misconception that there is a large functional gap between P25 conventional and trunked systems. This is not the case. The table clearly sets out the main functional differences.

Conventional	Trunked
Radio channels selected by the user	Radio channels assigned to the user automatically
Channel access instantaneous	Channel access time varies with technology and other factors (typically measured in hundreds of milliseconds)
No control channel needed	Control channel used in all P25 trunked applications.
Suitable for smaller groups of users	Better for larger (~300+) organizations
Switching not needed	Core switching essential for operation
Digital control signaling inherent `	Digital control signaling inherent

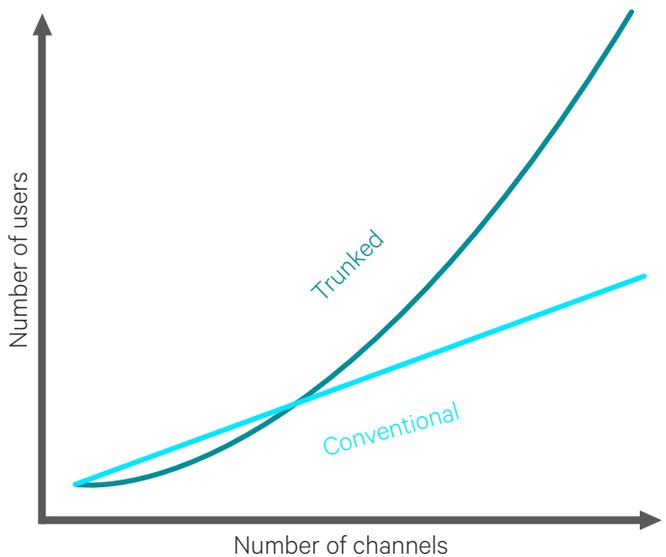
Conventional vs. trunked feature comparison

Based on this information, as long as you have sufficient channels for the number of users and the number of user groups, you will save money and effort by staying with P25 conventional architecture.

Feature	P25 Conventional	P25 Trunked
IP backbone	Available	Available
Analog and digital operation (repeaters/ subscribers)	Yes/yes	No/yes
Simplex/half-duplex/duplex (repeaters)	Yes/yes/yes	Half duplex/duplex
Access Control/subscriber registration	Yes	Yes
Supports analog and digital consoles	Yes	Yes
Dispatch console support	Analog and digital	Analog and digital
End-to-end encryption	Yes	Yes
Distributed, centralized or switched voting	Yes	Yes
Simulcast	Yes	Yes
Multisite(automatic roaming)	Yes	Yes
Self-calibration (simulcast)	Yes	Yes
Rx voting	Yes	Yes
Multi-site switching	Distributed/centralized	Centralized/distributed
Advanced remote monitoring and diagnostics	Yes	Yes
Analog line interface	Yes	Yes
MDC1200 interface support	Yes	Yes
Multiple linking options including RF	Yes	Yes (stricter requirements)
OTAR	Yes	Yes
Packet data support	Yes	Yes
Voice call types	Group, individual, announcement, broadcast, emergency	
Non-voice call types	All standardized P25 supplementary services – status, radio check, monitor, call alert, inhibit/uninhibit, short message	
Talk Group ID	Yes	Yes
Individual ID	Yes	Yes
Emergency ID	Yes	Yes
Emergency Alarm	Yes	Yes
Call addressing	Yes	Yes
Cancel P25 Unit Call (dispatcher interrupt)	Yes	Yes
Automatic working channel assignment (trunking)	No	Yes
Talk group scanning	Yes	Yes
Interfaces	ISSI, PSTN, DFSI	ISSI, PSTN, CSSI
Late entry	Yes (limited)	Yes
Call queuing	No	Yes

COMPARING TRUNKED AND CONVENTIONAL TRAFFIC HANDLING

The diagram illustrates the traffic-handling properties of trunked and conventional systems. The conventional system has the same capacity per channel regardless the number of channels. For a trunked system, the per-channel capacity grows exponentially with the number of channels at a given site. In other words, a conventional system can handle about 70 users per channel, 140 per two channels, etc. In a trunked system the more channels you have, the more users per channel your system will handle.



Some simple rules of thumb:

- ☑ If your agencies can be split into functional groups of 70 or fewer users who rarely need to speak to others, they will likely be well served by a conventional system.
- ☑ If you have three or fewer such groups, it will be sufficient to give each their own conventional channel.
- ☑ For organizations larger than this, you should consider trunking, primarily because trunking systems of four or more channels have better traffic handling capacity than a similar number of conventional channels.
- ☑ There are many conventional systems larger than this that function to the satisfaction of their users. While trunking is recommended for larger systems, it is not a must.

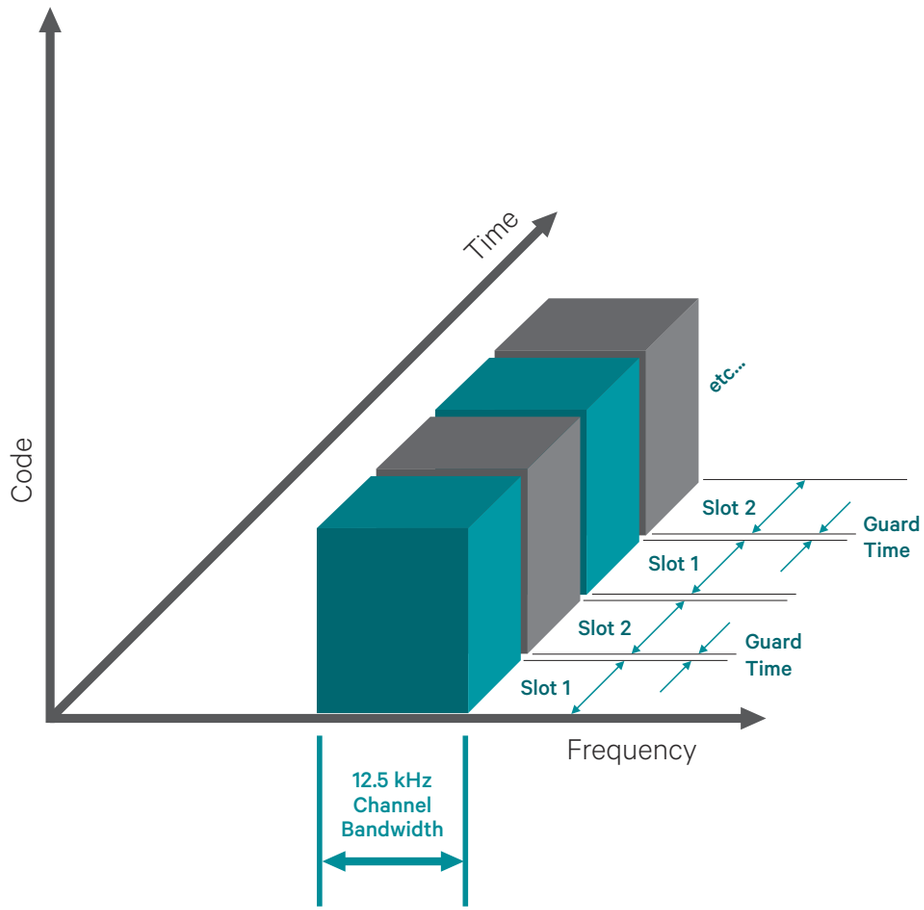
Consider your specific requirements and all available data - including current patterns of usage - before making the final decision.

PHASE 1 OR PHASE 2?

A similar argument can be made when deciding whether to implement P25 Phase 1 or Phase 2. The main difference between the two phases is system capacity, so the primary reason for opting for Phase 2 is additional capacity.

Phase 2 TDMA (Time Division Multiple Access) doubles the number of talk paths compared with Phase 1. P25 Phase 2 TDMA creates two logical channels in one 12.5kHz physical channel. Because the Phase 2 control channel is unchanged from Phase 1 there is compatibility between the phases.

Time Division Multiple Access (TDMA)



Functionality comparison

Phase 1	Phase 2
Phase 1 can be used in trunked or conventional configurations.	Phase 2 is currently available in trunking only.
P25 Phase 1 technology is about +7dB better than 25 KHz Analog and close to +10dB better than the newly required 12.5 kHz analog for the same Delivered Audio Quality (DAQ)	There is no significant differences between Phase 1 and Phase 2 for basic RF coverage. However, for simulcast systems, Phase 2 sites may need to be spaced closer to avoid time delay interference (TDI) since the acceptable delay spread for Phase 2 is smaller than that for Phase 1.
Phase 1 equipment has been undergoing compliance testing sanctioned by the Federal Government Compliance Assessment Program (CAP), sanctioned by the Department of Homeland Security.	Phase 2 equipment has been CAP tested since 2017.
Phase 1 cannot support interactive power control or interrupt on-going transmission from SUs.	Phase 2 is capable of interactive power output control and can interrupt on-going transmission from subscriber units.

Phase 2 is appropriate for large urban areas with high user density and a requirement for more efficient use of radio spectrum.

You should specify Phase 1 that is upgradeable to Phase 2, and specify that the implementation and costs of such an upgrade are clearly identified in proposals.

If your system will use simulcast, keep in mind time delay interference when moving to Phase 2 in the future. Phase 2 sites may need to be spaced more closely than Phase 1.

True or False: Common myths and misconceptions about P25 Phase 2

Phase 2 is necessary for FCC Narrowbanding	False	Phase 1 equipment meets FCC narrowbanding requirements
Phase 2 brings added functionality to Phase 1:	False	marginal functions only - see page 8.
Everyone should upgrade to or install Phase 2:	Absolutely false!	
Phase 1 is an obsolete standard and being replaced by Phase 2	False	Phase 2 augments Phase 1, to address the infrequent situations where increased traffic capacity is needed, but does not replace Phase 1.
Phase 2 has to use 700/800 MHz spectrum.	False	Phase 2 can be offered in any frequency band

SYSTEM ARCHITECTURE

Once the basic technology choices have been made (for example, you decided that P25 trunked Phase 1 system will meet your needs) Start with the basics and get them right), it is time to begin to define your system in greater detail.

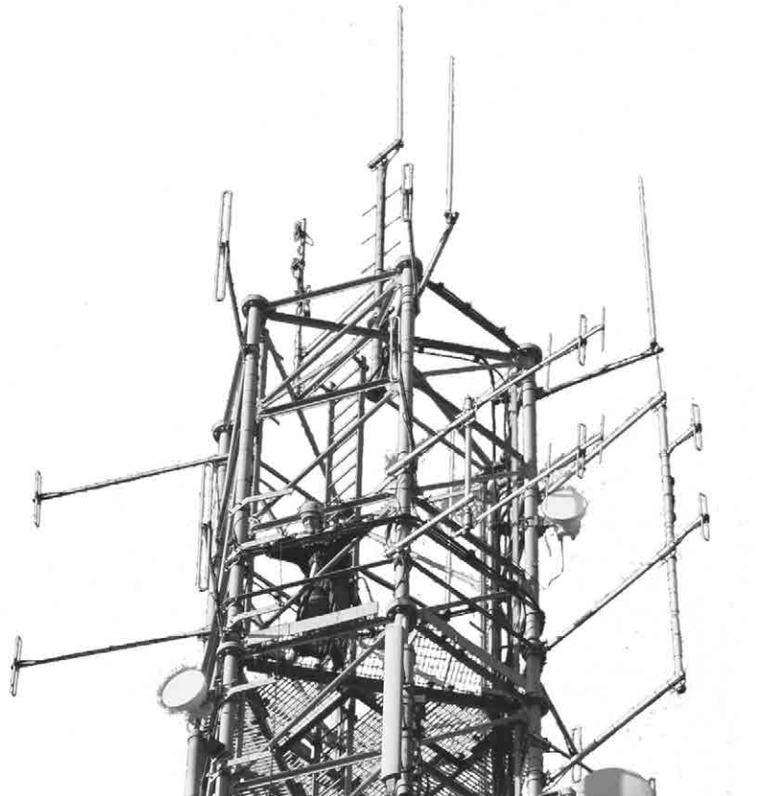
Several high level aspects of the future system are usually determined at this point. You don't need to spend millions on quadruple course switching or site controlling, but you do need to cover the basics factors as:

- ☑ coverage
- ☑ capacity
- ☑ resilience
- ☑ interoperability
- ☑ dispatch operation

COVERAGE NEEDS

Coverage considerations will dictate the number and locations of your radio sites (also referred to as towers). Together with frequency availability and traffic patterns, they will determine whether the system should be simulcast, multicast or a hybrid of the two.

Coverage engineering may be the most complex area of the radio system specification and design process and is one critical area where your investment in a competent coverage specialist will be well justified.



Measuring coverage

There are many ways to describe coverage performance. It is typically done in several different ways, which together describe what your user can reasonably expect when the new system is implemented.

Delivered Audio Quality (DAQ) is the most common signal quality measure in P25 for Public Safety.

DAQ	Definition
1	Unusable. Speech present but not understandable.
2:	Speech understandable with considerable effort. Requires frequent repetition due to noise or distortion.
3:	Speech understandable with slight effort. Requires occasional repetition due to noise or distortion.
3.4	Speech understandable without repetition. Some noise or distortion present.
4	Speech easily understandable. Little noise or distortion.
4.5	Speed easily understandable. Rare noise or distortion.
5	Perfect. No distortion or noise discernible.

For Public Safety, the accepted objective is to provide DAQ 3.4 over the service area. DAQ 3.4 is defined as "speech understandable with repetition only rarely required, and with some noise and/or distortion."

A lower DAQ (for example 3.0) may require excessive speech repetition while a higher value (for example 4.0) may require a prohibitively high level of infrastructure investment.

Predicted reliability is the other important measure of coverage performance. For Public Safety, the industry standard for coverage design is to provide 95% reliability. This is a simplified statement, which in reality means that you can expect a signal of the requested quality (for example, DAQ 3.4) 95% of the time across 95% of your coverage area.

Defining coverage needs

For most systems, it is insufficient to define uniform coverage requirements across your entire service area, for example 95/95 @3.4 DAQ. Typically, there are areas of special consideration:

- critical use - prisons, courthouses, hospitals,
- high population density - urban areas, challenging terrain – mountains, canyons,
- challenging construction – significant buildings with “dead spots”.

Map your geographical area to identify the geographical features, buildings and other locations with specific coverage level requirements.

In-building coverage

Identify where in-building coverage is needed. Include schools and colleges, hospitals, prisons, airports and any other critical areas. There are several approaches to define in-building coverage requirements.

- Some projects demand a uniform signal level in critical areas, assuming it will be sufficient in the relevant buildings. For example, general residential areas can be identified on a map and marked up for signal strength 10 dB above what is required in open spaces.

  It is advisable to characterize the most critical buildings up-front to determine the appropriate signal strength margin. Take signal strength measurements from inside the buildings, using the signal from desired existing sites or temporary reference transmitters.

- You may identify specific “must cover” buildings and place the burden of engineering on the vendors. For example, you may decide that interiors of all schools must provide 95/95@3.4DAQ and it is up to the vendors to engineer the system to provide this performance.

The first method requires more work up-front, but results in lower cost and better quality proposals as vendors can apply a more uniform approach to coverage design.

The second method shifts the burden of coverage performance to the vendors. This may be easier for the agency, but requires more time to engineer the response and is more expensive.

While this may sound straightforward and intuitive, it is only the tip of the iceberg. The coverage requirements and, above all, coverage acceptance test plans need to be approached with great care and respect.

Most vendors maintain separate, specialized coverage engineering units. The processes, tests, parameters and vocabulary are well defined in the TSB 88 standards, maintained and updated by Telecommunications Industry Association (TIA). Your specifications should refer to this standard to minimize the risk of misinterpretation of either your RFP or vendors' responses.

SIMULCAST, MULTICAST OR HYBRID?

Simulcast	Multicast
One channel at each of the simulcasting sites transmits the same signal simultaneously at the same frequency	One channel at each of the participating sites transmits the same signal simultaneously at different frequency
Requires high level of signal control in any overlap area	No comparable requirement
Ease of roaming	Roaming manual or requiring advanced technology
Requires complex system failure scenarios planning	No comparable requirement
Frequency efficient	Frequency consuming
Requires identical number of repeaters at each site, even where traffic loading is low	Equipment (repeater) efficient, allows different number of repeaters at each site
Requires voting	Conventional multicast may require voting, trunked multicast does not.

Each approach has distinct advantages and disadvantages, but, in practice, in majority of Public Safety applications, the advantages of simulcast (ease of use and spectrum efficiency) will outweigh its disadvantages (typically higher costs and higher maintenance requirements). A complete and comprehensive analysis of pros and cons of simulcast vs. multicast is complex, and the outcome will depend on your particular circumstances

It is possible and indeed common to combine simulcast and multicast into a hybrid architecture. This is most advantageous where the system needs to cover both high density urban areas with a large number of users and high number of channels, as well as larger areas with low density and subsequent limited need for channels.

Network capacity engineering is relatively simple for single site systems or for pure simulcast systems, where one frequency pair = one channel. But quickly becomes very complex for multicast or hybrid systems. Your capacity needs will determine the number and location of repeaters. While network capacity engineering can be complex, you can start by applying this simple rule of thumb: about 70 users per working channel.

Keep in mind that in a trunked P25 system, one channel per site acts as a control channel so is unavailable for voice traffic.

SIZING YOUR NETWORK FOR MAJOR EVENTS

How do you size your system for “the big one”?
This is another case where precise analysis goes beyond the scope of this guide, but we can offer some helpful guidelines for major events. The guidelines are appropriate for planned events such as sports events and conventions or crime emergencies and natural disasters.

The simple rule of thumb is that, for major emergencies the capacity should be roughly three times of your normal weekly busy hour.

- Establish how much traffic is generated on your current system during the busiest hour of a typical week. For most Public Safety organizations it is Friday evening but your situation may be different.
- How can you find out? If your current system has some traffic logging features you can pull down traffic statistics from your system management terminal. Another good place to go is your logging recorder.
- If during your normal busy hour your users generate x amount of traffic on your radio system, aim for 3x capacity for major events.

This level of capacity cannot always be achieved because of lack of available frequencies or budgetary considerations. However, try to get to as close as possible to this guideline and focus your operating procedures on limiting radio traffic to essential subscribers during major events.

Why is the 3x rule just a rough guideline? A small rural department is extremely unlikely to need that much capacity regardless the circumstances – you simply may not have that many users and your emergencies may be limited in complexity, size and impact. At the other end of the spectrum, a major dense urban area in an earthquake zone, with a combination of large commercial centers, sports facilities and transportation hubs nearby may need more than the "3x busy hour" capacity.

"Understand the implications of coverage and reliability issues, during normal operation, peak loading and emergencies."

"YOU DO NOT NEED CHANNELS FOR ALL USERS IN EXTREME SITUATIONS – YOU NEED TO PLAN TO LIMIT ACCESS TO CRITICAL EVENT USERS."

BACKHAUL

System size is also a consideration when defining backhaul. While all modern P25 networks are IP based, each vendor has its own calculations to determine the capacity of the links connecting your network sites. A simple (and preliminary) rule of thumb is 64Kbps per channel (working or control).Depending on your vendor's technology implementation, that may be either excessive or insufficient.

Microwave, fiber, or...?

Beyond the important work of analyzing and selecting the best combination of backhaul solutions, it is important that the backhaul network must be "mission critical" – meet agency standard redundancy and resiliency requirements. Eliminating single points of failure, installing fail-over back-up units, and multi-path routing capability will ensure redundancy. Ensuring power requirements are available with sufficient capacity to ensure reliable power for an extended period (hours, days, weeks as your standards or local circumstances require) in case of primary power failure will guarantee power resiliency and alternate traffic routing capability.

None of the backhaul technologies is universally superior. Fiber is favored due to practically unlimited bandwidth, but many believe that operating your own microwave network provides higher level of reliability. This is because IT crews typically in charge of fiber networks are generally unaware of Public Safety radio specific network needs and sometimes nonchalant about shutting a link down for a few hours for maintenance.

Today, there are more backhaul options than ever. At the most basic level the choices are: copper, fiber and micro-wave, with multiple variants of specific technologies within each topology. Each has band-width capacity and quality of service limits which help define where it is best used.

Start by discussing backhaul requirements with your IT department addressing the following topics:

- ☑ Characteristics of the proposed new LMR network. Vendors and consultants can provide transport characteristics and requirements impacting backhaul choices.
- ☑ Review all existing backhaul networks - owned and leased.
- ☑ Discuss future network requirements at sites which may impact backhaul.
- ☑ Anticipate timeline of LMR and other network deployments at sites.

"IP/fibre combo is robust, more reliable and cheaper to maintain."

You can ask questions and solicit information and opinions from commercial carriers, backhaul infrastructure manufacturers and vendors, LMR manufacturers and vendors. At the minimum, establish working groups to research:

- which backhaul networks can we reuse or repurpose and which networks require new backhaul?
- what are the priority and latency requirements of each voice, data, and administration application requiring backhaul, and which can we group together?
- how can we converge voice and data backhaul requirements into least number of separate networks?
- which network topologies can meet our needs,
- what are their hardware/software components and requirements, what do they cost?
- own or lease - what are the total costs of ownership over next ten years?

Minimizing cost is always a worthwhile objective but the ever-multiplying growth in mobile communication capacity requirements support our recommendation to deploy a backhaul network with many times the capacity you need today.

Topology	Capex	Opex	Availability	Adaptability	Capacity	Comments
Copper	Low	High	High	Low	Medium	Carriers have much in place
Microwave	High	Low	High	Medium	Medium	Typically LoS although some NLoS available
Fiber	Medium	Medium	Medium	High	High	

Fiber is most often the preferred choice, since applications that we have not yet thought of, will be best served by backhaul that is high in technical adaptability and capacity. However, fiber is terrain-limited so doesn't work everywhere.

To decide which variant(s) of the three major platforms are most viable for you, you need to consider:

- topography,
- user group size,
- priority,
- latency,
- technical expertise needed to manage/maintain,
- budget, local availability,
- existing backbone available,
- capacity for future expansion.

For most agencies, a combination of topologies will deliver the best user experience. If you are a rural agency you will likely have access to fiber in the metro areas, but will need microwave for county-wide TX/RX locations. If you are only concerned about voice, then existing copper T circuits to the sites where you will place your LMR equipment will likely work fine with modern variants such as VDLS2.

Redundancy to ensure network resilience is probably the best argument for a mixed topology solution which would typically be fiber and microwave.

RESILIENCE

At this point you should consider some high-level failure scenarios and determine how much resilience you need to build into the design. Some common approaches are:

- ☑ Back-up power source/s – generators and batteries.
- ☑ Overprovision of sites so that no single site failure has significant impact on your coverage/capacity,
- ☑ Microwave or fiber network architecture (star, ring, hybrid, hot standby), Specify seamless switchover during failure – ring architecture for backhaul system.
- ☑ Antenna system engineering, using multiple antennas, combiners and multicouplers at large sites,
- ☑ Redundant controllers, including geographically distributed ones.

More detailed decisions are made later when writing final specifications or you can request that a solution be proposed by your vendors.

When planning for failure scenarios, do not disregard solutions seemingly-unrelated to your new system's architecture or functionality. For example, having a cache of emergency radios rigorously maintained and programmed for a mutual aid channel may be as effective - and less expensive - as a more high-tech approach. The same can be true about emergency transportable repeaters.

"THE COMMON OBJECTIVE IS ALWAYS RELIABLE COMMUNICATIONS"

Back up power

During natural disasters, it is most often lack of power that brings radio systems down. Generators are prone to failure, and you need to be vigilant to maintain sufficient fuel on standby to protect you in an emergency.

Do not assume you will be able to refuel your back-up generator quickly. Invest in large enough fuel tanks, monitor evaporation and factor in how weather events might restrict access to your sites. Consider too, that if power failure is widespread, your supplier may be unable to pump fuel.

Well-maintained batteries can give reliable power in the event of both your power and your generator failing.

"The fundamental requirement of a resilient system is to guarantee power throughout foreseeable events and disasters."

INTEROPERABILITY

The range of needs and solutions, both technical and non-technical, is vast, and likely to increase with statewide networks and mutual aid agreements. Your first priority is to define the scope of your interoperability:

- Which outside entities does your system need to connect to?
- How often will these connections be required?
- Should they be permanent connections or activated manually?
- What, or who, triggers their activation?

In some cases, public safety agencies simply rely on caches of equipment for emergencies. On the other end of the spectrum, some require totally seamless, automatic roaming with their neighbors, and opt for ISSI (Inter Sub-System Interface).

Consider also your interoperability with non-LMR voice systems (e.g. LTE). This is the right time to consider your current – and future - connections to PSTN, cellular systems, private and public wireline and wireless data systems, public internet, alarm systems, etc.

"Keep it simple. Problems increase exponentially when you couple systems."

"INTEROPERABILITY DEPENDS AS MUCH ON HUMAN FACTORS AND OPERATIONS POLICIES AS TECHNOLOGY. CREATE AN OPERATIONAL SOLUTION RATHER THAN A TECHNICAL ONE."

INTEROPERABILITY WITH ISSI

The P25 Inter RF Sub-system Interface (ISSI) provides IP-based open standard system-level interoperability. Using the ISSI you can interconnect two or more P25-compliant trunked systems - even if they are from different vendors or operating in different frequency bands (e.g., UHF vs. 700 MHz); using different versions of P25 (Phase 1 or Phase 2); or all of the above. The basic requirement is that each network must install an ISSI interface.

Given the capabilities of the ISSI, it is easy to imagine some scenarios for its deployment:

- Designing a very wide-area 'system of systems' for an organization by interconnecting multiple smaller P25 networks through the ISSI.
- Agencies that wish to set up mutual-aid communications can interconnect their independent P25 systems (and consoles) through the ISSI and CSSI.
- A public-safety agency can deploy a radio system from its preferred vendor rather than joining a statewide system, while at the same time honoring its interoperability obligations by connecting to the statewide system via the ISSI.

For mobile or portable radios roaming across or between networks, the ISSI supports a variety of call and data services, including:

- P25 addressing
- Encrypted and clear voice calls (both individual and group)
- Authentication of roaming radios
- Mobility management
- Call control
- Push-to-talk management
- P25 supplementary data service (e.g., call alert)

- P25 packet data on the Data Network - Interface (including OTAR)
- ISSI support of the P25 CSSI console interface
- P25 conventional voice service (including mixed trunked/conventional voice service)

Management of P25 addressing lies at the heart of the ISSI. Radios have identities that can be tracked and controlled when they roam from one network to another. They have "home" networks that they normally belong to and "visited" networks to which they roam. Similarly, they have home consoles (also with IDs) that operate in their home network and which must communicate with consoles in visited networks, and they have a home talk group to which they belong and talk groups they wish to connect to when they visit a different network.

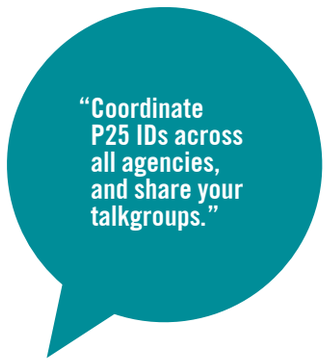
As a result, the trunking concepts of registration (for mobility management) and authentication (for security), as well as call privileges permitted to the visitor, must be carefully negotiated between the home and visited networks.

The planning effort for ISSI internetworking should not be underestimated. It is a highly complex undertaking which will be different for each group of agencies and users. Do not expect implementing ISSI to be a 'plug-and-play' technology exercise.

Useful guidance on the complexities of planning for ISSI may be found in:

Best Practices for Planning and Implementation of P25 Inter-RF Subsystem Interface (ISSI) and Console Subsystem Interface (CSSI): Volume I (2019) and Volume II (2020).

Both these documents are available for free download through the P25 Technology Interest Group (PTIG) at http://www.project25.org/index.php/compliance-assessment/p25-non-cap-issi-cssi-interoperability-testing.



DISPATCH NEEDS

Dispatch is the point where radio and other technologies merge. It is essential to involve dispatch management and personnel in preparing requirements for the new system.

- What is the total number of dispatch positions?
- Will all of them be in the same geographical location?
- Do you expect that configuration to remain unchanged in the foreseeable future or do you expect changes like dispatch consolidation or addition of new consoles/dispatch centers?
- Do you need the flexibility to add consoles on ad-hoc basis?
- What kind of auxiliary equipment will be connected to the consoles (logging recorders)?

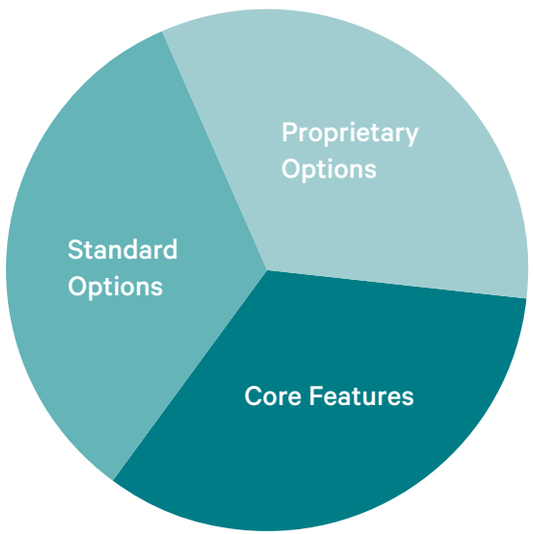
P25 supports two standards for connecting consoles to RF systems. The Digital Fixed Station Interface (DFSI) is used to connect dispatch systems to P25 Conventional systems and permits voice, data, and repeater control. The Console Sub-System Interface (CSSI) connects dispatch systems to P25 Trunked systems and supports services very similar to the ISSI. Indeed, the CSSI is essentially the same protocol as the ISSI, differing chiefly in how it is used.

It is not important to look in detail at all desired functions of the dispatch system at this time, but the number and location of dispatch consoles and some auxiliary equipment, especially logging recorders, will have to be considered in backhaul design.

P25 SYSTEM FUNCTIONALITY

System and user equipment functionality is determined in your Needs Analysis. However, you need to understand the implications of your choice of features and functions.

P25 systems and devices may have three different levels of features and functions. Their status is defined in the APCO Project 25 Statement of Requirements (SoR). For full details of the status of any specific function, see the most recent version here.



Core Features

Core Features are mandatory. All relevant P25 devices and systems must have them and they must be implemented according to the P25 Standard to assure interoperability. The most obvious example for all user equipment is Air Interface Protocol. For example, any radio claiming to be P25 conventional Phase 1 unit must be able to communicate with a P25 unit from any other manufacturer.

The core features can be taken for granted. They come with the system and user equipment regardless of the supplier or the model. CAP certification is highly recommended, however, to guarantee interoperability. Core (Mandatory) features include:

- ☑ Group calls
- ☑ Common channel operation
- ☑ Affiliation
- ☑ Unit to unit calls
- ☑ Broadcast calls

A complete list is available in the P25 SoR.

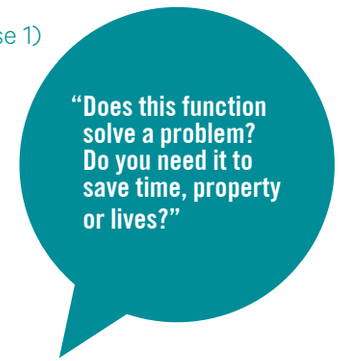
Standard Options

Standard Options do not have to be included in the systems or radios, but, if they are, they must be implemented in the prescribed way, assuring compliance between vendors. An example is AES or DES encryption. P25 radios may not have encryption included, but, if they have either AES or DES encryption (not any other type), they must be implemented according to the standard, assuring compliance between vendors.

Standard options should be selected with care. For example, one of the most common features is Over The Air Rekeying (OTAR). While the idea is great and it has some die-hard enthusiasts, in practice it is seldom used. Is it necessary in your new network? The broad experience of a good consultant may be invaluable to help you decide. Standard Options features include:

- ☑ Over The Air Rekeying
- ☑ Group calls on a conventional system (Phase 1)
- ☑ Voice encryption on a trunked system
- ☑ Text messaging
- ☑ Unit de-authorization (stun)

A complete list is available in the **P25 SoR**.



Vendor Proprietary Options

Vendor Proprietary Options do not need to be included and vendors are free to implement them any way they want. An example is Over The Air Programming (OTAP). Not all manufacturers provide this feature and the ones that implement it do it in a proprietary manner. These features are typically not compatible between different vendors.

Vendor proprietary options should be selected with utmost care. On one hand, they may provide very valuable functionality, on the other hand they can practically lock system owners into a proprietary relationship with one vendor, with all the known risks, such as higher prices and lower level of service. Vendor Proprietary features include:

- ☑ Over The Air Programming
- ☑ Patch Calls
- ☑ Dynamic Regrouping
- ☑ Failsoft
- ☑ Free-form text messaging

COMPLIANCE AND INTEROPERABILITY

There are several traps when considering mandatory features, standard options and vendor proprietary options.

First, the desire to include too many features may result in prohibitive price tag. In organizations that are conscious of budgetary restrictions, functional needs should be prioritized so that the final wish-list reflects the actual needs of your agency, rather than personalities or bargaining power of stakeholders. A consultant can play an invaluable role here too, as an external objective expert.

It is critical that you consider interoperability when selecting features and functions. Fortunately, the P25 Compliance Assessment Program provides some standardized testing between different manufacturers' products. Products that offer Suppler Declaration of Compliance have been tested and proven to interoperate with competitor products listed.

P25 Compliance Assessment Program (CAP)

- US Government-sponsored program (see https://www.dhs.gov/science-and-technology/p25-cap)
- Process for ensuring equipment complies
- Series of controlled tests
- Vendors test each other's equipment
- CAP testing results are published on https://www.dhs.gov/science-and-technology/approved-grant-eligible-equipment
- Supplier Declaration of Compliance (SDoC) issued to complying products.
- SSI/CSSI Equipment CAP Testing is in progress

"Don't include specifications that pre-select vendors, such as proprietary or trademark terms."

"SPECIFY PRODUCTS THAT MEET P25 CAP REQUIREMENTS TO GUARANTEE INTEROPERABILITY AND SUPPORT."

WHAT ABOUT DATA?

The data capabilities inherent in the P25 standard have been largely surpassed by commercial broadband developments and FirstNet expectations. However, there are some useful applications which operators should consider.

Plan for the future of P25 data

From the outset, P25 has been data-capable, with Public Safety data applications still being identified and developed by vendors.

While P25 data is not robust enough for some applications promised with the standard, other, less bandwidth-demanding applications, such as status messages and workforce management tools, are working well.

AVL is sufficiently accurate to locate first responders outdoors. Anecdotally, this has already proven to save lives. Location data can easily be retrieved, via the CAD (Computer Aided Dispatch) and referred to in the event of an enquiry.

While waiting for full FirstNet deployment, agencies should prepare for, and take advantage of, a rapid increase in Public-Safety-specific data applications in the near future. The majority of these applications require broadband wireless technologies, but the inherent data capabilities of P25 should not be ignored.

Balance your voice and data needs

P25 combined voice and data networks bring many efficiencies and safety benefits, and communicating via data may help reduce voice traffic on your network.

Data is generally more of a management tool, with messages usually sent from dispatch rather than incoming. So most systems do not see the decrease in voice traffic they may have expected, once data is implemented. You also need to be aware that voiceless dispatch is not permitted in some jurisdictions.

Consider a dedicated data channel, with priority-based voice override for efficient channel use.

Over the air programming/rekeying

OTAP and OTAR are among the most often discussed P25 data applications. Purchasers should understand the limitations of any offering. OTAP is not yet defined in the P25 standard, so every OTAP solution that is currently available is proprietary. This will create problems when programming radios from multiple vendors.

OTAR is defined in the P25 standard, but is rarely used. (this issue will be discussed in a later best practice guide).

Paging on P25 digital radios

Paging is widely used by Fire agencies as an effective and inexpensive communication with their volunteers. Vendors promise a P25 paging solution but this has not eventuated to date. The lack of a robust paging solution on P25 remains an issue, as Fire agencies are forced to maintain analog channels to support paging, within the P25 network.

The future of FirstNet

Conceived in response to the 9/11 commission’s findings, this extensive new network will provide access to applications and coverage for public safety first responders. Users will have fast access to information they need.

Initially FirstNet will be used to send data, video, images and text and make cellular-quality voice calls. FirstNet will allow for priority access among public safety users.

It is important that you discuss the potential impact of FirstNet on your communications with your consultant and/or vendor to future-proof your contract and the decisions you make now.

What to do?

Even if you are not sure if you want to use any data capabilities of your future P25 networks, make sure that the vendors explain capabilities of their solutions as well as the cost and effort needed to implement some basic applications such as AVL, text messaging, status messaging, workforce management tools, productivity tools, OTAP and OTAR. Similarly, request the information on your vendors' broadband data activities and capabilities. While it is too early to ask for specific solutions, you want to make sure that your future partners are up to speed and planning interoperability with the future broadband technologies.

If you are interested in specific data applications and tools, include them in your specifications - even if you plan to implement them at a later date - to obtain accurate, binding and competitive cost information.

"THE REALITY IS THAT FIRSTNET WILL INITIALLY BE URBAN BECAUSE THAT IS WHERE THE CARRIERS ARE."

PROJECT IMPLEMENTATION

We now move our focus from the technology, and look at the logistics of your upgrade or replacement process. There are some big questions to tackle here.

Forklift or migration?

The answer is almost always “migration”, so you need to factor the migration process into your decision making and planning. This opens up additional questions such as:

- availability of space for two systems co-existing side by side,
- the method of migration, the impact of migration on the everyday and potential emergency operations,
- the desired level of functionality between the old and new systems.

The migration process is often over-complicated and unnecessarily costly, even though some simple logistical measures and inexpensive technical solutions are perfectly sufficient. Employing experienced system designers and installers will minimize the potential risk to critical communication during the system changeover.

“You can’t have enough lead time. Allow three years to engineer your migration before your decision to change.”

Defining the migration process – what, who, when?

What internal resources can be delegated to the project? What roles could they play? For example, you may have someone on your team who can act as your internal Project Manager. Alternatively, you can hire an external resource who will oversee the project on your behalf?

Who should carry out the work? This may be assigned to one vendor (“prime contractor”) or you may have management resources to save money by contracting the civil work, licensing and other sub-projects to third parties.

When should the implementation/migration take place? Weather impacts on potential construction work and site access, but also needs to be considered for other reasons. For example, coverage testing should be conducted between late Spring and early Fall under full foliage conditions - the presence of leaves on trees impacts coverage performance.

At this stage, you should also consider your post- implementation needs, in terms of system maintenance and administration.

“Good planning will minimize potential loss of critical communication for your users during the system changeover.”

TRAINING

Define your education and training needs early. Build a business case for a training budget and plan education and training for users at every level. You need to consider what kind of training is needed, where and when should it take place and who needs to be trained?

- ☑ Consider a “Train the Trainer” program which educates some of your personnel to train others.
- ☑ Request training for technical and administrative personnel early so that their participation in the implementation can reinforce their understanding of the system.
- ☑ Request training for system users as close to their respective cut-over so that the knowledge is fresh in their minds.

“You don’t know what you don’t know. Implementing a system is an ideal learning opportunity.”

PRELIMINARY SYSTEM DESIGN

System architecture, functional requirements and some of the implementation requirements can now be integrated into preliminary system design. By now you should be able to define:

- ☑ technology (P25 conventional or trunked, Phase 1 or Phase 2),
- ☑ system architecture (single site, Simulcast, Multicast, hybrid),
- ☑ RF sites; existing or new (green), number and locations,
- ☑ channels per site - approximate number,
- ☑ consoles and auxiliary equipment (logging recorders) - numbers and location,
- ☑ dispatch equipment functionality,
- ☑ backhaul network architecture, approximate capacity and functionality,
- ☑ interoperability needs - participating organizations, their technologies and your desired level of integration,
- ☑ subscriber equipment - approximate quantities and functionalities,
- ☑ administrative (system management) desired features and functionality,
- ☑ security requirements and equipment
- ☑ diagnostic and maintenance features.

TALKGROUP DESIGN

Now is the time to rationalize your talkgroups. Reducing the number of talk groups can also reduce the management overhead This can not only save management and administration time, but create simpler communications.

Rethink and justify your talk group structure, based on your current network experience. If your current group structure is working well, do not change it.

- Assess and justify each group and restructure according to what you need.
- Think about local, regional and global (911 and interoperability) talkgroups.
- Consider mutual aid talk groups on specific channels, permanently set up to provide aid instantly.

Live with what you specify. It may be only 98% accurate, but the cost of perfection is high!

"Trade conventional channels and talkgroups with your interoperability partners, to avoid P25 complexity. Another option: just share talkgroups."

INSIGHTS

All quote bubbles are direct insights from the industry participants at the Tait P25 round table discussions. To find out who the participants were, visit **www.p25bestpractice.com**

"To prepare for likely events, look at local history."

"If you have to manually flick a switch, that's redundancy not resilience."

"Agencies can have their own operations channels plus a shared one for interoperability."

"Everyone must understand what each channel is for, and how/when to use it."

"Just because everyone can hear, doesn't mean they know what is going on."

"Pay careful attention to failure modes – redundancy and resilience – how the system responds to different failure types."

"Don't over purchase. Will you use all the features you are paying for?"

"Invest enough to stay on air through critical events."

"P25 is not better, not worse than what you have now, but it is absolutely different. And you need to understand how different it is."

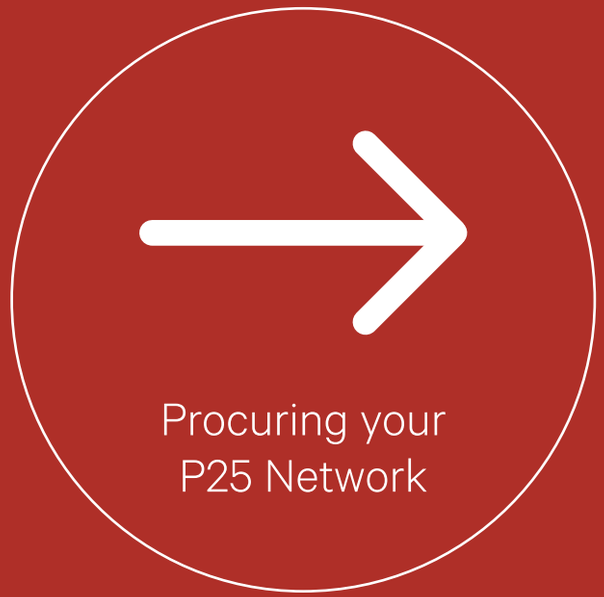
"Consider a dedicated event channel for sports events and emergencies."

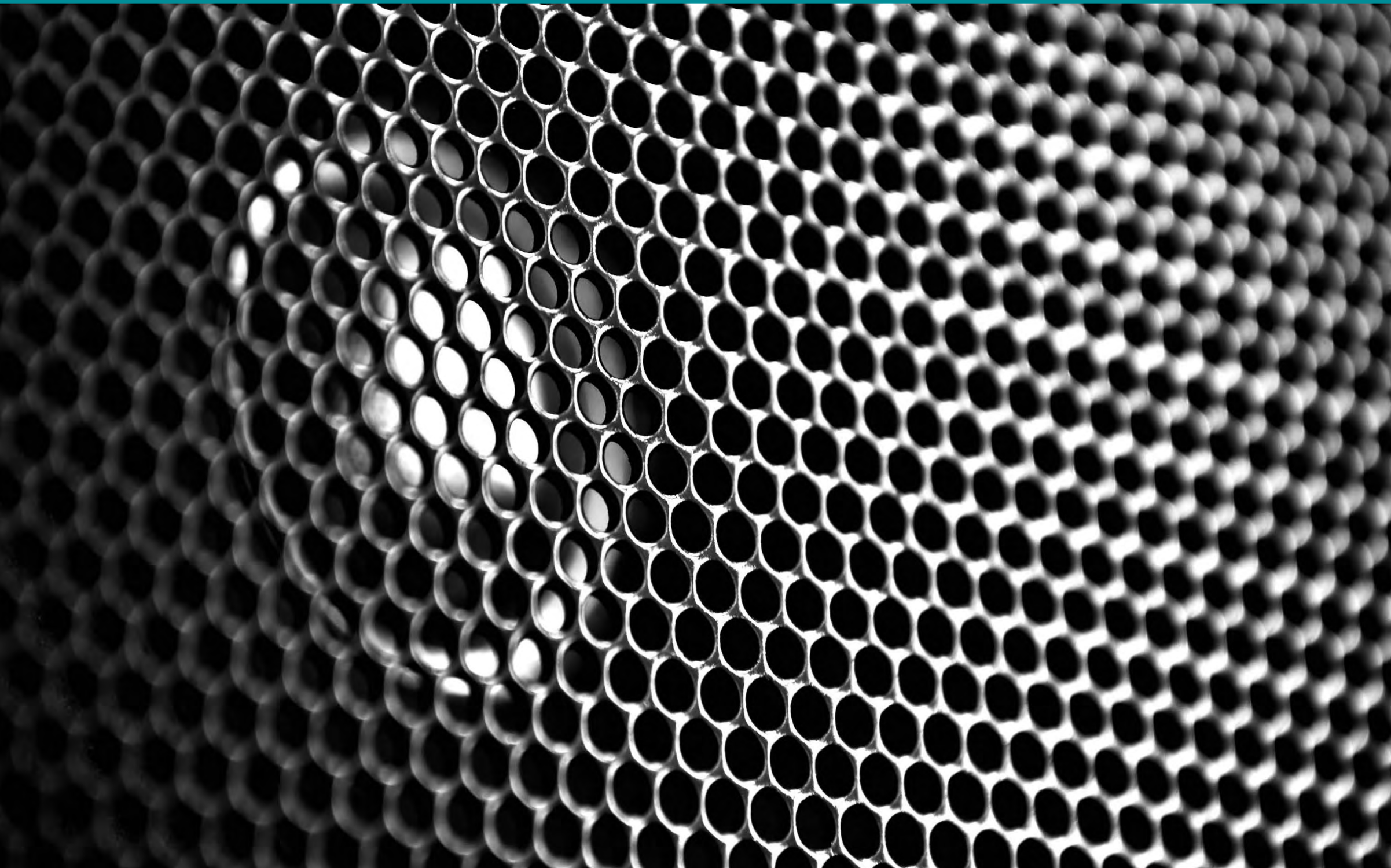
"Identify risks and define your priorities – what fails most often? People!"

With the specifications drafted for your new system, and your project stakeholders on board, you can begin to work through the process of procurement. At this phase of your project, you will need to determine your financing model, evaluate and select a vendor, then negotiate the contract.

For information and best-practice about the procurement phase of your project, see “Procuring your P25 system” available now at...

www.p25bestpractice.com





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